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RADC-TR-80-206
Final Technical Report
June 1980

BASEBAND EYE MONITOR SIGNAL DISCRIMINATION AND IDENTIFICATION STUDY PROGRAM

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(19) **REPORT DOCUMENTATION PAGE** — READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: RADC-TR-80-206 2. GOVT ACCESSION NO.: AD-A090 319	3. RECIPIENT'S CATALOG NUMBER: 9
4. TITLE (and Subtitle): 6 BASEBAND EYE MONITOR SIGNAL DISCRIMINATION AND IDENTIFICATION STUDY PROGRAM.	5. TYPE OF REPORT & PERIOD COVERED: Final Technical Report, 2 Jan 79 - 2 Feb 80,
	6. PERFORMING ORG. REPORT NUMBER: 280-16392
7. AUTHOR(s): Mr. T. J. Campbell, [redacted] L. F. Doty, Mr. B. M. Kearns, [redacted] S. G. Hurst	8. CONTRACT OR GRANT NUMBER(s): 15 F30602-79-C-0056
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Honeywell Inc./Avionics Division, 13350 U.S. Highway 19, St. Petersburg FL 33733	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 61101F, 16 LD91109C1 17 09
11. CONTROLLING OFFICE NAME AND ADDRESS: Rome Air Development Center (DCLD), Griffiss AFB NY 13441	12. REPORT DATE: Jun[redacted]980 (12) 262
	13. NUMBER OF PAGES: 265
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Same	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Same

18. SUPPLEMENTARY NOTES

RADC Project Engineer: Arnold E. Argenzia (DCLD)

This effort was funded totally by the Laboratory Directors' Fund.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Pattern Analysis & Recognition
Signal Processing
Baseband Eye Monitor

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Baseband Eye Monitor Signal Discrimination and Identification Study Program sought to determine techniques to characterize interference signal types using the present Baseband Eye Monitor Unit; to develop a statistical mathematical analysis that could be used to discriminate and identify interference signal types using the present "Dispersion Voltage Output; to temporarily adapt the present BEM unit to provide additional information to supp rt the analytical approach; to develop

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Item 20 (Cont'd)

a demonstrative computer program allowing laboratory signal discrimination and identification to be performed; to recommend future analytical approaches and equipment modifications that could be used to further enhance the present BEM hardware/software discrimination and identification capability.

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EVALUATION

Evolution of the Defense Communications System from an analog system through a hybrid (analog/digital) configuration to an all digital posture is a transitional process which will span the next two decades. In order to properly design future computer controlled, adaptive, digital communications systems, with associated system control capabilities, additional technique development is required in the area of Electronic Counter Measures signal detection, discrimination, and identification. The principal aim of this study was to assess the capability of the Baseband Eye Monitor (BEM), developed under another RADC contract, to discriminate and identify various types of jamming signals. Extensive laboratory tests were conducted and distribution curves were developed from the BEM measurements. Test runs accomplished for the different signal types show that, in general, discrimination from a graphical viewpoint is possible for the signal types considered.

Based on detailed analysis of all the study results, it is concluded that the BEM can indeed discriminate signals which have different probability distributions, independent of associated power levels. However, although the BEM is quite effective even when the signal distributions are quite close, signals whose distributions are essentially the same cannot be differentiated.

In conclusion, the work accomplished under this effort clearly establishes that the BEM is capable of discriminating and identifying a variety of jamming type signals and as such has potential utility in future ECM signal monitoring systems. However, in view of observed BEM difficulties in handling interfering signals which are (1) pulsing rapidly compared to the measurement time, (2) not stable and repeatable over the measurement time, and (3) of essentially the same distribution (except for repeatable noise), the BEM approach must be viewed as a complimentary rather than an independent discrimination/identification capability.

The study results will be used as inputs to on-going efforts in projects 2155 and 2157.

Arnold E Argenzia

ARNOLD E. ARGENZIA
Project Engineer

Section 1

BACKGROUND DISCUSSION AND SUMMARY

1.1 PRIOR WORK ON THE BASEBAND EYE MONITOR (BEM)

An extensive description of the BEM equipment, its design, laboratory tests, and field test are summarized in RADC-TR-77-431, Final Technical Report, January 1978, Reference 1. The report was part of and summarized work done by Honeywell under the ATEC Digital Adaptation Study, Development and Field Evaluation - Digital Automated Technical Control.

1.1.1 Baseband Eye Pattern Monitor Functional Description

The Phase I ATEC Digital Adaptation Study recommended that a device be developed for monitoring those properties of a digital baseband which directly relate to signal quality. It was further indicated that the existing ATEC Baseband Monitor was a viable candidate for the adaptation for several reasons. First, it provides selectable inputs as would be required in a digital system. Second, the frequency range is correct, except for a possible downward extension of the low frequency range. Lastly, the output circuitry is suitable for providing a performance related voltage for measurement by the existing Measurement Acquisition Controller, of such parameters as eye pattern dispersion, eye hits, and eye amplitude.

Typically, the output from the degradation monitor is either an analog voltage proportional to the degree of eye pattern closure, or a derived bit error rate which is a gross extension of the basic error rate. In either case, the applique unit, of which the degradation monitor is a part, will perform the necessary signal measurement to achieve compatibility with the MTS option interface. The analog voltage output from the first mentioned type should be measured with a resolution on the order of 1 percent, which is possible even with very simple A/D conversion techniques. The pseudo error output from the second type must be counted to give events per unit time, and buffered.

The eye pattern monitors, in general, reflect a "smoothed" measure of system performance. The output of the device itself contains a significant amount of information. It can be easily trended to identify deteriorating system operation. In order to maximize the value of its use, however, the eye pattern data must be correlated with other monitored parameters such as other estimates of bit error rate and radio alarms.

In an all digital network, such as the FKV system, the Bit Error Rate (BER) is to the end user the ultimate measure of communication quality.

The most powerful indirect technique for BIR estimation is the use of the eye pattern monitor. The output of the baseband monitor is designed to be compatible with the ATEC MTS option interface. An important feature of this form of BER measurement is that it provides a good estimate even in extremely low ($<10^{-9}$) BER environments.

This section provides the study and design rationale and mathematical proofs involved in the conception, design, construction and testing of the Baseband Eye Monitor (BEM).

1.1.2 Inadequacy of Output Error Counting for Degradation Measuring

Digital communication links are intentionally designed to have as large a tolerance to noise and other signal degradations as practicable. A system can have such a large built-in tolerance that it will still run error free even with one or more elements severely degraded. A primary objective of performance monitoring is to detect such degradations so that they may be corrected before the digital link begins to make errors. It is obvious that the desired information for meeting this objective cannot be obtained by examining the digital output because the objective is to detect degradations while this output is still error free. Presumptive tests which remove digital links from service long enough to run test sequences through them for measuring error rate, as well as error detecting and correcting codes, have valid applications in performance monitoring; however, they are not adequate for measuring performance margin under error free conditions because they give no indication of degradations until they have become bad enough to cause errors in the received data. An ideal degradation monitoring technique should be capable of detecting degradations before they become large enough to cause errors in the received data.

The ability to detect signal degradations before they become large enough to cause errors in the received messages is vitally important for both analog and digital channels; however, the channel user's ability to detect gradually increasing degradations and anticipate loss of the channel is far better for analog voice channels than digital communication links. In analog communication links, such as voice channels, the channel induced noise and distortion are delivered to the user along with the desired signal; hence, these degradations can be detected by the user. These degradations are detectable by the user at power levels several decades lower than the level at which they make the channel unusable by lowering the intelligibility index of the voice signal below an acceptable level. Thus, in analog communication channels there is typically a large margin between the level at which noise and distortion is detectable and that at which it becomes intolerable. Furthermore, the user of a voice channel can readily estimate the degree of channel degradation by a qualitative estimate of signal intelligibility. The user of a digital channel is presented with a very different situation because each digital receiver in the communication chain reshapes the digital pulses so that the symptoms of channel noise and distortion are removed before the signal is forwarded.

The primary effect of pulse reshaping between the links of the digital communication chain is to reduce the message error rate by stripping off noise and distortion at each link interface so that these individual link induced distortions are not allowed to accumulate as they would in an analog system. Thus, even if the sum of the noises and distortions for the total number of links is so large as to produce an intolerable error rate for an end-to-end digital system using no intermediate pulse reshaping, it is often possible to reduce the end-to-end error rate to approximately zero by stripping off the noise and distortion and regenerating the digital signal at selected locations in the chain. As long as the cumulative degradation in each individual link is kept below the critical level for that link, each link will run error free, and hence, the end-to-end channel will run error free. On the other hand, if the degradation in one, several, or all of these links is just slightly below the critical level at which it begins to produce errors, there will be no indication of this impending problem in the error-free data stream delivered to the user. Thus, the pulse reshaping in digital systems is advantageous in that it can help reduce the error rate of the system; however, it removes symptoms of channel degradation from the output data signal. Since the digital output signal gives no indication of degradation until errors actually occur in the output, the user who has nothing but the receiver digital signal to work with has no means of estimating how close the channel degradations are to the critical levels until after one or more of those levels has been exceeded.

The inability of the user to detect gradual channel degradations until they are large enough to produce errors in the received digital data stream would be less objectionable if there were a greater separation between the degradation level at which the error rate becomes just barely measurable and that at which it becomes intolerable. Assuming that the degrading factor is additive uncorrelated Gaussian noise, then the amplitude of the noise will be distributed in accordance with the cumulative Normal probability function plotted in Figure 1-1. Observe that the probability, $P(z<t)$, of the normally distributed noise amplitude, z, exceeding an arbitrary threshold, t, decreases so rapidly with increasing t that even when using a seven decade semi-log scale, the probability function crosses the plot vertically more than seven times (indicating more than 49 decades) as the amplitude of t is changed less than 24 db (1.2 decades). As a consequence of this extremely rapid change of $P(z>t)$ with respect to t, the bit error rate of a digital receiver can change very rapidly with respect to small changes in the amplitude of the additive Gaussian noise. For an ordinary PAM (pulse amplitude modulated) signaling, it can be shown that the BER (Baud error rate; that is, probability of receiving one or more bits incorrectly in one Baud) for additive uncorrelated Gaussian noise can be computed from the following relations.

$$\text{BER} = 2\left(1 - \frac{1}{L}\right) P\left(z > \sqrt{\frac{3}{(L^2 - 1)}\,\frac{S^2}{N^2}}\right) \qquad (1\text{-}1)$$

where

$L \equiv$ number of levels per Baud

$z \equiv$ normally distributed random variable with mean = 0 and variance =1.

$S^2 \equiv$ signal power at decision circuit.

$N^2 \equiv$ noise power at decision circuit.

$P(z>\ldots) \equiv$ the probability plotted in Figure 1-1.

For the most common types of partial response signaling (Class I with n=2 and Class IV with n=3), the BER can be computed using the similar relationship shown below:

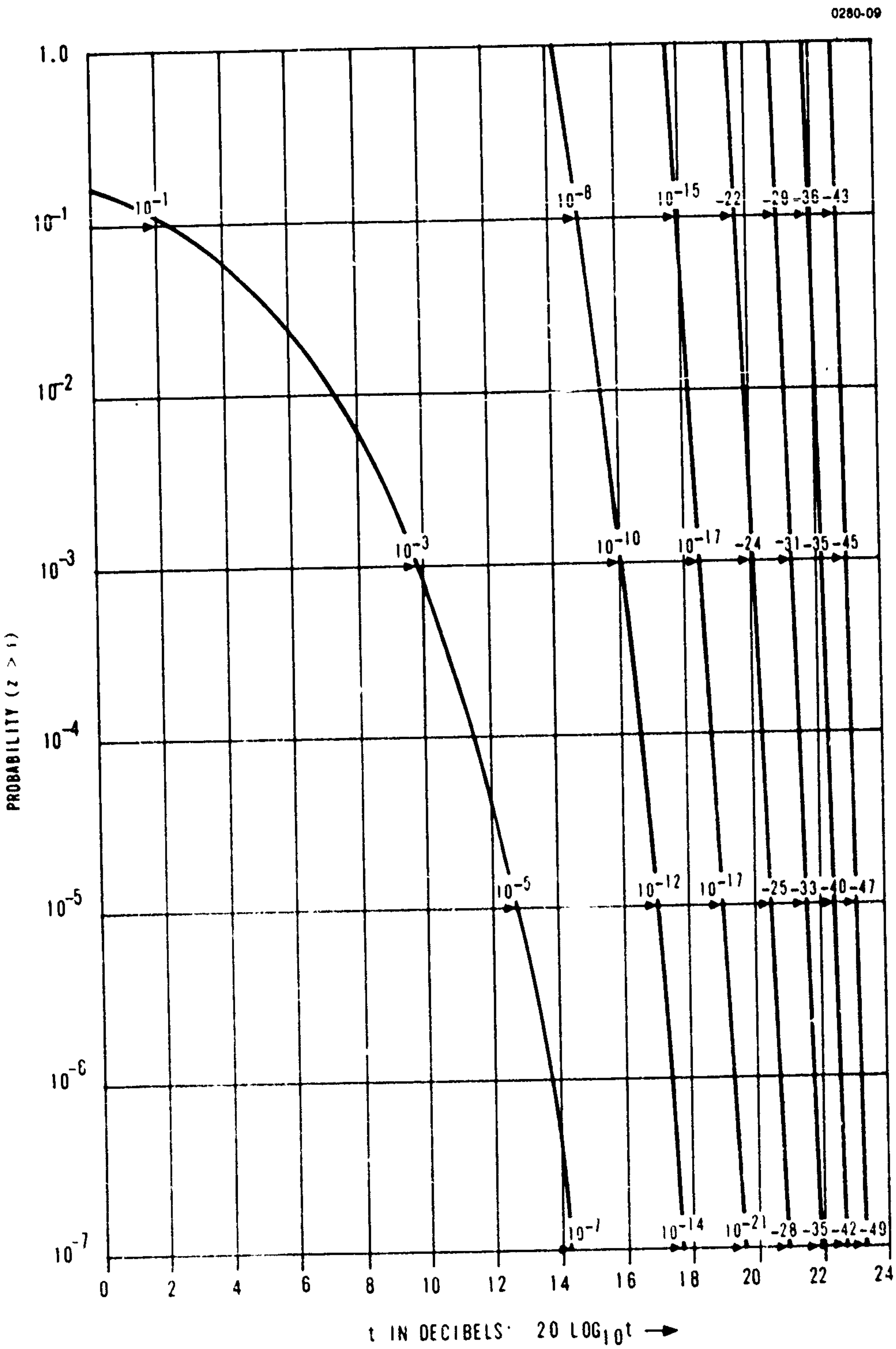


FIGURE 1-1. PROBABILITY THAT z>t GIVEN THAT z IS NORMALLY DISTRIBUTED WITH MEAN = 0 AND VARIANCE = 1

$$\mathrm{BER}^* = 2\left(1 - \frac{1}{M^2}\right) \; P \; \left(z \; > \; \sqrt{\frac{3}{2(M^2 - 1)} \; \frac{S^2}{N^2}}\right) \tag{1-2}$$

where

$$M \equiv \frac{L + 1}{2} \tag{1-3}$$

*The reason that the above equation for BER requires a 0.91210 db higher signal to noise ratio than that given on page 89 of Reference 10 is that Lucky, Salz and Weldon's equation was derived for measuring SNR at the receiver input with half of the partial response shaping in the transmitter and half in the receiver, whereas the above equation is for SNR measured at the decision circuit regardless of how the partial response filtering is partitioned.

To clearly illustrate how the BER can change from a value essentially equal to zero to a value so large as to be intolerable for a relatively small change in signal to noise ratio, the BER for a three-level 12.5 meg bit/sec partial response signal has been computed and the results are presented in Table 1-1.

TABLE 1-1. BER COMPUTATION

Errors/Time	BER	Signal/(Noise) db
10,000 errors/second	8×10^{-4}	13.31
100 errors/second	8×10^{-6}	15.89
1 error/second	8×10^{-8}	17.52
1 error/minute	1.33×10^{-9}	18.60
1 error/hour	2.22×10^{-11}	19.46
1 error/day	9.26×10^{-13}	20.04
1 error/year	2.54×10^{-15}	20.94
1 error/century	2.54×10^{-17}	21.53

Table 1-1 shows that the difference in signal to noise ratio (SNR) for 100 errors per second and for one error per century is only 5.64 db. For a reasonably accurate performance measurement it is necessary to observe a significatnt number of errors because the standard deviation of the number of errors measured per sample is essentially equal to the square root of the average number of errors measured per sample. For example, if the average number of errors per sample is 100, then the standard deviation is computed as $\sqrt{100} = 10$, which means that the BER is being measured with error of about 10 percent, one sigma. For measurement periods of one hour, the computed error rate will be based on error observations which on the average are half an hour old at the time the computation is made. Also, for one hour long measurements, the percentage error in the measurement will increase rapidly as the error rate drops below 1 error per minute. The signal to noise ratio producing one error per minute is only 2.71 db lower than that producing 100 errors per second which is not considered to be a very good margin for a performance degradation detector that is intended to predict rather than confirm system failure. If larger error sample is taken to increase the margin (measured in db) of the monitor, the measurement will take longer causing an even longer delay in the monitoring process. The conclusion is that counting errors in the output data stream as a means of predicting the failure of a digital system suffering gradual degradation leaves a lot to be desired. Fortunately, more powerful degradation detection techniques are available as will be described in the next section.

1.1.3 Eye Pattern Measurements for Degradation Monitoring

The eye pattern shown in Figure 1-2 was obtained by taking a time exposure of an oscilloscope presentation of the voltage at the input to the decision circuit of a VICOM T1-4000 multiplexer. At the sampling times the voltage ideally would be at one of three distinct levels; hence, this is called a three-level eye. Ideally, the decision circuit will sample the eye pattern voltage at each of the sampling times and decide whether an upper, center, or lower level signal was intended to be received at that sampling time. Additive noise will cause the voltages to deviate from their ideal values, thus widening the lines on the oscilloscope picture in the vertical direction. As the noise increases, the images corresponding to the upper, middle, and lower levels widen. When the images of the levels become so wide that there is no longer a clear separation between levels, the decision circuit will begin to misinterpret the intended message which causes errors. The spaces separating the images of the various levels at the sampling points are called the "eyes". When signal degradations become so bad that these spaces shrink to zero, the "eyes" are said to "close". When the eyes are closed, the receiver will be making errors.

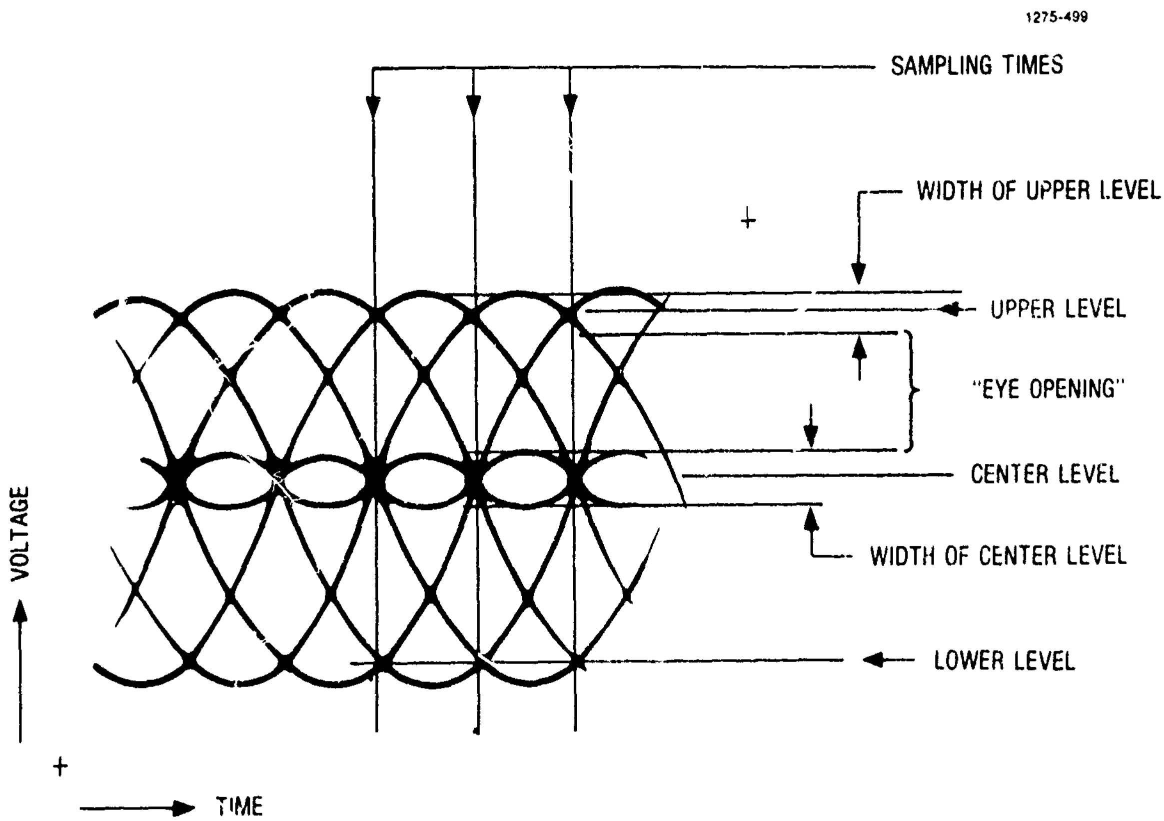


FIGURE 1-2. EYE PATTERN FOR THREE LEVEL PARTIAL SIGNAL RESPONSE

The size of the eye openings relative to the distances between the centers of adjacent levels expressed as a "percentage of eye opening" has long been used as a figure of merit for performance measurement and it is a good one if its limitations are understood. First, if the decision voltage levels of the decision circuit are not located in the center of the eye vertically and, second, if the sampling times are not centered in the eyes horizontally, then the receiver will begin to make errors before the eye is totally closed. Third, since the noise typically has a Gaussian amplitude distribution, the width of the levels (and hence the percentage of eye opening) is not sharply defined because the level width image on the oscilloscope can be varied from about ±1 sigma depending upon the intensity setting of the oscilloscope and the length of the time exposure for averaging time).

These three limitations may be overcome by proper system design as will be discussed in the following paragraphs. The techniques to be discussed apply to eye patterns with any number of levels; however, the discussions will be concentrated primarily on the three-level case because the two-level case is too simple to display generality while examples involving more than three levels would make the explanation more cumbersome without adding any significant degree of insight.

Conceptually, what the eye pattern monitor should do is to measure the probability density function of the signal perturbations from the ideal levels so that the desired error rates and performance margins can be computed. In actual practice, point by point determination of the probability density function is too expensive. A practical alternative is to assume that the distribution of the perturbation amplitudes is Gaussian and make some measurement from which the rms amplitude of the distribution may be inferred. Since there are several common conditions such as additive tones, highly correlated intersymbol interference, and impulse noise for which the distribution of the perturbations deviates significantly from Gaussian, it is desirable to augment the first amplitude measurement with a second measurement which can either indicate that the distribution is Gaussian or indicate the nature of its deviation from Gaussian.

To measure the signal perturbations from the nominal levels, it is first necessary to determine the exact amplitude of the nominal levels so that when we measure the distances from the nominal reference levels to the observed signals we will be measuring signal perturbations only -- not perturbations plus or minus the error in measuring the nominals. Automatic gain control systems based on measurement of signals biased by noise (References 4,6, and 8) have been used for this purpose but the nominal level of the signal which they control will necessarily change as the amount of noise changes. Another example of how the signal level may become dependent upon noise amplitude is the BICOM T1-4000 multiplexer which uses a peak clipping circuit for its amplitude sensing signal so that the larger the noise the smaller the signal will be. The system concept proposed here for measuring the nominal levels in the eye pattern degradation monitor is to adjust the reference level of a comparator with a feedback loop such that 50 percent of the samples associated with that level fall above that level and the other 50 percent fall below that level. The hardware needed to implement this concept is reasonably simple.

Conceptually, it would be possible to subtract the nominal levels from the observed levels to obtain the perturbation amplitudes, compute the rms value of these amplitudes, and assume that the perturbations are normally distributed with a mean of zero and a standard deviation equal to the measured rms value. In actual practice it would be difficult to mechanize the above system for a 12.5 megabaud/sec receiver. Also, it would be desirable to make some additional measurement (such as rectified average versus rms) to test the distribution for deviation from Gaussian. For building a device which will measure eye quality at 12.5 megabaud/sec, a system which uses one or more additional comparators offset from the nominal levels to sense the amount of signal perturbation from nominal seems to be a practical compromise between complexity and performance.

The offset threshold monitors described in References 5 and 6 use comparators with offset thresholds as described above to measure signal quality and, therefore, they have been carefully analyzed to determine their capabilities and limitations. From an operational viewpoint, one of the biggest disadvantages of this mechanization is that its quality output signal has no absolute scale such that a specific output voltage would have a specific meaning. The calibration of the device is accomplished after it is attached to the specific multiplexer which it is to monitor. In accordance with the calibration procedure, all monitors on all multiplexers are adjusted to indicate a signal quality of 0.10 volt at the end of calibration regardless of individual variations in the operating conditions of the various multiplexers at time of calibration. To take an absurd example, if a signal quality monitor indicated a problem with a multiplexer, the first troubleshooting step might be to check the calibration of the degradation monitor by repeating the calibration procedure; in which case the symptom of trouble would automatically disappear regardless of the condition of the multiplexer. Assuming that a calibration technique could be developed for circumventing the above problem, the existing offset threshold monitor is still not recommended because it uses a fixed (adjusted by a potentiometer during calibration) offset from the nominal reference level as a reference voltage for the comparator used to measure "pseudo error rate". With the aid of Figure 1-3, the measured "pseudo error rate" may be defined as equal to the number of samples observed between upper data decision threshold at +d volts and the upper offset threshold at

+(2d-a) volts plus the number of samples observed between corresponding pair of lower thresholds -d, and -(2d-a) divided by the number of sampling periods over which the count was made. When a fixed threshold offset, a, is used, "pseudo error rate" measurements suffer from the same rapid changes for small changes in signal to noise ratio as previously described for counting actual errors. If the offset, voltage, a, is made too large, the pseudo error rate will be too small to make accurate measurements of low level degradations. If the offset voltage, a, is made too small the error rate will change rapidly for small degradations but tend to remain nearly constant at nearly 25 percent (assuming that the outer signaling levels are used 50 percent of the time) for large noise levels in the amplitude range of greatest interest where the system just begins to make actual errors. In either case, the error rate variation versus noise level is a highly nonlinear function which is not readily interpreted.

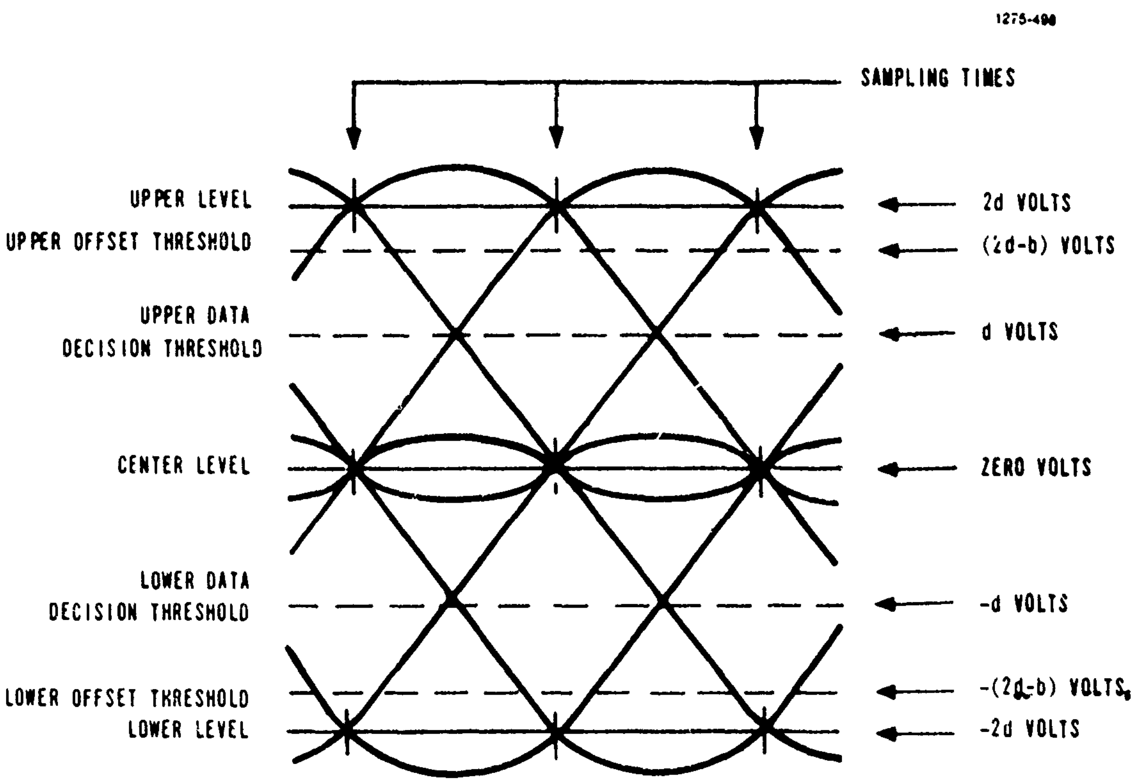


FIGURE 1-3. DEFINITION OF LEVELS FOR OFFSET THRESHOLD MONITORING OF THREE LEVEL EYE

The recommended solution to the dilemma as to how large to make the voltage offset, a, for measuring "pseudo error rate" is to design a closed loop system which adjusts the voltage offset, a, as required to keep the pseudo error rate constant. From Figure 1-3 it may be seen that the thresholds for the upper pair of pseudo error comparators at 2d-a and d volts are a volts and d volts, respectively, below the nominal upper signal level. If, at a point where the signal is supposed to be at its upper level, it suffers a perturbation in the negative direction larger than a and less than d, the level of the perturbed signal will fall between the limits defined by the upper pair of pseudo error comparators and, thus, be counted as a pseudo error. The exact probability of counting a pseudo error is not determined here, but for the present discussion an approximate analysis will be meaningful. Assuming that perturbations larger than d volts are so rare compared with those larger than a as to be negligible, the probability of counting a pseudo error when the signal is nominally at the upper level is equal to the probability that the amplitude perturbation, ε, is more negative than a. To maintain the same pseudo error rate when the rms amplitude of ε is doubled, the amplitude of a must be doubled. Thus, within the limits of our approximation, it is obvious that when a is adjusted to keep the pseudo error rate constant that a is directly proportional to the rms amplitude of the perturbations ε.

1.1.4 Derivation of Voltage Offset Versus Noise for Constant Pseudo Error Rates

We now derive the relationship shown in Figure 1-3 which indicates how the voltage offset a (normalized by dividing it by d) must be adjusted to keep the pseudo error rate constant as the rms noise level N (normalized by dividing it by a) changes. This relationship is derived for the three level partial response signal. It is assumed that noise at the sample points is normally distributed with a mean equal to zero and a standard deviation equal to N.

It is further assumed that two pairs of comparators are used. One pair measures the number of samples between d and (2d-a) volts; the other measures the number of samples between -d and -(2d-a) volts. In actual practice, the pseudo error rate measured by the upper pair of comparators may differ from that measured by the lower pair because the signal waveform may be distorted by clipping or saturation in such a manner that only one side is distorted. For this reason, it is considered necessary to use two sets of comparators so as to test both the top and bottom levels of the signal.

In the idealized case which we are considering here, the upper and lower comparator sets would both obtain the same average number of pseudo errors; hence, in this derivation, we shall derive the average rate for the top pair alone and then multiply by two to obtain the total pseudo error rate.

The magnitude of each received voltage sample is equal to its nominal intended magnitude +2d, 0, -2d volts plus the magnitude of the signal perturbation, ε. In accordance with our previous assumption, ε must be a normally distributed random variable with mean equal to zero and a standard deviation equal to N. The probability of a particular sampled voltage amplitude falling between d and 2d-a volts, assuming that the nominal intended level was 2d, is equal to the probability that ε is of the proper size to cause the sampled voltage to fall within the specified range.

P (upper pair detects pseudo error | intended level = 2d)

$$= P\,(d \le 2d + \varepsilon < 2d-a)$$

$$= P\,(-d \le \varepsilon < -a)$$

$$= P\,[-d/N \le \varepsilon/N < -a/N \mid \varepsilon/N \sim N(0,1)]$$

$$= P\,[d/N < z \le a/N \mid z \sim N(0,1)]$$

$$= Q(a/N) - Q\,(d/N) \qquad (1\text{-}4)$$

where

$$Q\,(t) \triangleq P\,[z > t \mid z \sim N(0,1)]$$

$= P\,(z > t)$ given z is normally distributed witn mean = 0 and variance =1.

The conditional probability of the upper pair of comparators detecting a pseudo error given that the intended level was zero may be computed simularly.

P (upper pair detects pseudo error | intended level = 0)

$$= P\,(d < 0+\varepsilon \le 2d-a)$$

$$= P\,[d/N < \varepsilon/N \le (2d-a)/N \mid \varepsilon/N \sim N(0,1)]$$

$$= Q\,(d/N) - Q\,(2d-a)/N \qquad (1\text{-}5)$$

Likewise,

P (upper pair detects pseudo error | intended level = -2d)

$$= P\ (d < -2d+\varepsilon \leq 2d-a)$$

$$= P\ (3d < \varepsilon \leq 4d-a)$$

$$= P\ [3d/N < \varepsilon/N \leq (4d-a)/N \mid \varepsilon/N \sim N(0,1)]$$

$$= Q\ (3d/N) - Q\ (4d-a)/N \qquad (1\text{-}6)$$

For the three-level partial response signal considered here, the probability of level +2d, 0, or -2d being intended is 1/4, 1/2, or 1/4, respectively. Therefore, the probability of the upper pair of comparators detecting a pseudo error is as follows.

P (upper pair detects pseudo error)

$$= 1/4\ \{Q(a/N) - Q(d/N)\}$$

$$+ 1/2\ \{Q(d/N) - Q[(2d-a)/N]\}$$

$$+ 1/4\ \{Q(3d/N - Q[(4d-a/N]\}$$

$$= 1/4\ \{Q(a/N) + Q(d/N) - 2Q[(2d-a)/N] + Q(3d/N) - Q[(4d-a)/N]\} \qquad (1\text{-}7)$$

Given that both an upper pair (2d-a and d) and a lower pair (-2d+a and -d) of pseudo error comparators ar to be used, and assuming that both pairs detect the same average number of errors, the total pseudo error rate will be twice that derived above.

P (pseudo error)

$$= 1/2\ (Q(a/N) - (Q\ [(4d-a)\ \ N]\ ) \qquad (1\text{-}8)$$

1.1.5 BEM Analyses Assuming a Three-Level Partial Response Eye Definitions

The classical partial response three-level eye pattern has been shown in Figure 1-3. This figure represents the pattern which would be obtained on the face of an oscilloscope if the analog eye pattern voltage were connected to the vertical inputs and the horizontal time base were synchronized with Baud timing so that each sweep would start with the same Baud timing phase.

If the sweep time were adjusted to cover several Baud periods, then the proper sampling times would become apparent as they are in the figure. At the proper sampling times, the analog voltage is equal to one of three values: 2d, 0 or -2d volts. These three voltage levels, and five additional levels, making eight voltage levels in all, are shown in Figure 1-3. By using eight voltage comparators, with these eight voltage levels as references, it is possible to determine whether the voltage was above or below each of these eight levels at each sampling time. Two of these levels, the upper and lower offset thresholds, are adjustable by changing the value of the offset voltage, a. The level Kd is determined by selecting the constant K. For the purposes of the present discussions, the level Kd can be ignored. The other five levels are constant.

Several detailed analyses for this eye pattern have been reported in Appendix A of the ATEC Digital Adaptation Study, RADC-TR-76-302. It was assumed that two zones would be used for counting pseudo errors. The upper pseudo error zone extends from d to (2d-a) volts, and the lower pseudo error zone extends from -d to -(2d-a) volts. For the math models used in the mathematical analyses, the pseudo error rates for the upper and lower zones are equal; therefore, the total error rate for the two zones is equal to twice the pseudo error rate for either of the single zones. The VICOM eye pattern used during laboratory testing was found to be so asymmetrical that it was necessary either to use a single pseudo error zone on one side of the signal, ignoring the other side, or to provide the hardware with additional degrees of freedom and control loops so that both sides of the signal could be tracked separately. Because of power, size, and schedule constraints, it was decided to use only a single pseudo error zone. Most of the mathematical analyses and computer programs had been finished at the time that the asymmetry was discovered; therefore, all pseudo error rates in these documents are expressed as two zone or "two sided" pseudo error rates unless otherwise specified. Interpreting results stated in terms of the two-zone pseudo error rate definition will cause no hardship as long as it is remembered that the single-sided pseudo error rate is equal to half of the two-sided pseudo error rate. In this report, the number 1 or 2 will follow the letters PER may appear without the number 1 or 2 following, in which case, it is the two-sided error rate which is being referred to. These and some other useful definitions are listed below:

PER1 the one-sided pseudo error rate.

PER2 the two-sided pseudo error rate = 2 x PER1.

PER $\equiv$ PER2 unless specifically stated to the contrary.

BER $\equiv$ the Baud error rate = the bit error rate for this one-bit-per-Baud eye pattern.

$P[A] \equiv$ the probability that A is true.

$P[A \mid B] \equiv$ conditional probaibility of A given that B is true.

$P[A,B]$ joint probability that A and B are both true.

$S^2 \equiv$ signal power in eye pattern.

$N^2 \equiv$ noise power in eye pattern.

$\varepsilon \equiv$ a normally distributed random variable with mean = 0 and variance = N^2.

$z \equiv$ a normally distributed random variable with mean = 0 and variance = 1.

$Q(x) \equiv P[z>x \mid z \sim N(0,1)]$ which is to be read as "the probability z is greater than x, given that z is a normally distributed random variable with mean equal to zero and variance equal to one."

$Q^{-1}(p) \equiv [x \mid Q(x)=p]$ which is read as "Q inverse of p is defined as equal to the value of x for which Q of x equal to p."

$Q'(x) \equiv \frac{d}{dx} Q(x)$ which is equal to minus the density function of the N(0,1) distribution at point where the random variable is equal to x.

1.1.6 Pseudo Error Rate Equation

The pseudo error rate for the three-level eye was derived in Paragraph 1.1.4 with the results for the one-sided and two-sided solutions. The one-sided solution is:

$$PER1 = (1/4) \{Q(a/N)+Q(d/N)-2Q[(2d-a)/N] +Q(3d/N)-Q[(4d-a)/N]\} \quad (1\text{-}9)$$

1.1.7 Computation of Dispersion Amplitude

Using the equations just developed, it is possible to compute the dispersion, a/d, for a fixed pseudo error rate, PER1, for a given noise level, N/d, or a given bit error rate, BER. When solving these equations it is convenient to express the equation in terms of three variables: pseudo error rate, PER1; dispersion, a/d; and decision level to noise ratio, d/N.

$$PER1 = (1/4)\ \{Q[(a/d)(d/N)] + Q(d/N) - 2Q[2(d/N) - (a/d)(d/N)] + Q[3(d/N) - Q[4(d/N) - (a/d)(d/N)]\} \qquad (1\text{-}10)$$

1.1.8 Pseudo Error Rate Loop Analysis

A block diagram of the control loop for holding the pseudo error rate constant is shown in Figure 1-4. The three parameters which affect the loop are shown entering at the left hand side of Figure 1-4. These three parameters are the Baud rate, B, the rms noise level, N, and the signal level, d. For the system presently under study, the Baud rate, B, is equal to 12,552,600 Baud/sec. The signal level, d, is held constant by an AGC system. Thus, the only variable entering the pseudo error rate control loop is the rms level of the noise, N.

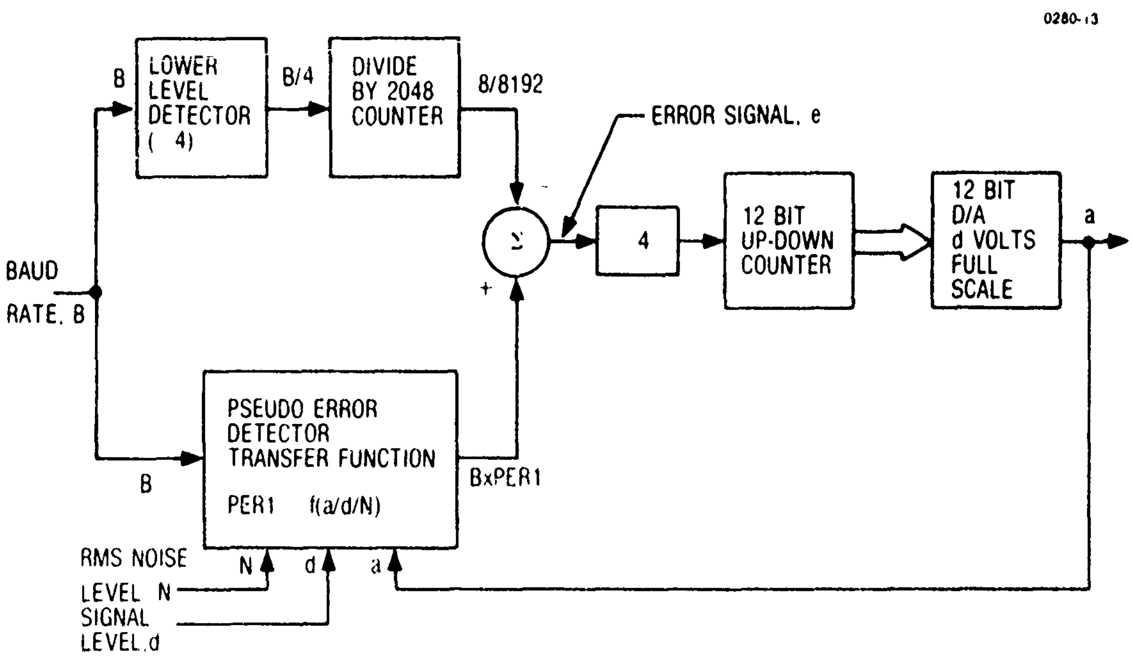


FIGURE 1-4. PSEUDO ERROR RATE CONTROL LOOP

In order to keep the amplitude of the output, a, dependent upon only one variable, N, the control loop in Figure 1-4 must keep the pseudo error rate, PER1, constant. The summing device is an up-down counter in which pulses into the lower input cause it to count up, pulses into the upper input cause it to count down, and simultaneous pulses into both inputs cause it to do nothing. The lower input into the summing device is the output of the pseudo error detector which transmits one pulse for each pseudo error. The average number of pseudo error pulses transmitted per second is equal to the Baud rate, B, times the pseudo error probability per Baud, PER1. The upper input to the summing device is obtained by dividing the output of a lower level detector by 2048. The reason for using the lower level detector is that the pseudo error detector in this system looks for pseudo errors only around the lower level. When the probability of receive bauds being at the lower level is 1/4, the lower level detector can be replaced by a divide-by-4 counter. Normal data patterns are sufficiently random that a lower level probability will be 1/4; however, the lower level detector is used in preference to a divide-by-4 counter in order to keep the ratio of pseudo errors made per Baud tested constant even in the presence of special test patterns. For normal data patterns, the average rate out of the lower level detector is equal to 1/4 the Baud rate, B/4, so that the average rate out of the divide by 2048 counter is B/8192. The average rate of the error signal, e, out of the summing device is equal to the difference between the rates of the lower and upper inputs.

$$e = B \times PER1 - B/8192 \tag{1-11}$$

Assuming that the control loop drives the error signal, e, to zero, and that the baud rate, B, is not equal to zero, the pseudo error rate can be determined from Equation 1-11.

$$PER1 = 1/8192 \text{ given } e=0,\ B\neq 0 \tag{1-12}$$

The pseudo error rate can be readily adjusted by changing the count down ratio in the 2048 counter.

For computation of the dynamics of the pseudo error rate control loop, the equations will be simplified by defining two new variables, A and D, to replace the three variables, a, d, and N.

$$\text{Define } A = a/d \tag{1-13}$$

$$\text{and } D = d/N \tag{1-14}$$

$$\text{where } d = \text{a system constant} \tag{1-15}$$

$$\text{PER1} = (1/4) \quad Q(AD)+Q(D)-2Q\ (2-A)D$$
$$+Q(3D)-Q\ (4-A)D \qquad (1\text{-}16)$$

1.2 MOTIVATION FOR THE PRESENT STUDY

Based on the results and analysis of Reference 1, quoted in part in Subsection 1.1, it was concluded that if different countdown ratios were used in the BEM measurement, then a unique dispersion would be observed for each countdown ratio. Accordingly, in the basic error rate equation,

$$4(\text{PER1})=Q(AD)+Q(D)-2Q((2-A)D)+Q(3D)-Q((4-A)D), \qquad (1\text{-}17)$$

where the terms have all been defined in Subsection 1.1. It is seen that if PER1(=1/(count down ratio))is changed and if the corresponding value of A is measured, then the only unknown is D for each measured pair (count down ration and A). If the noise type were known, then the form of the Q function would be known and Equation 1-17 would yield the same value of D for each measured pair (count down ratio and A), except for measurement and modeling errors. In Reference 1, the measurements were assumed to be taken in the presence of Gaussian noise, and it was found, indeed, that the value of D was essentially the same for different testing conditions.

This suggested that BEM measurements, using different count down ratios with the corresponding measured dispersions, could be used to detect the type of signal being used to corrupt the measurement. This hypothesis was based on the following observations:

a. The error rate Equation 1-17 was shown to be valid to a close approximation for Gaussian noise in Reference 1.

b. The derivation of Equation 1-17 is equally valid for any corrupting signal, provided that it is of a random nature (so that it may be described by a distribution function).

c. If the value A was measured and the value D was determined, then the value A.D would be known. The expression Q (A.D) in Equation 1-17 then represents a value of the distribution Q for a known value of its argument (A.D); that is, each different value of A.D represents a different point for which Q is determined. A sequence of such measurements then determines the shape of the Q distribution curve for the corrupting random signal, with the use of equation 1-17.

d. If the Q distribution curve were sufficiently different for different random test signals, then the generation of the Q curve from BEM measurements on an unknown signal could be used to classify that signal within the set of test signals.

The present study was undertaken to examine the ability to discriminate between corrupting signals using BEM measurements as described above and to develop methods for performing the discrimination.

1.3 SUMMARY OF PRESENT STUDY

Based on the discussion of the above sections, the present study was initiated.

The basic question which was to be answered in the study was to determine if Q distribution curves generated from BEM measurements were adequate for the discrimination and identification of interfering signal types, assuming that the BEM equipment was modified only to the extent of using a set of count down ratios, as contrasted to one ratio in the original equipment.

BEM measurements for a set of test signals, at different count down ratios and different power levels, were taken as described in Section 2. It was found from measurements, and from the analysis of Section 3, that pulsed signals could not be distinguished from from their parent nonpulsed signals from a Q distribution viewpoint because of the inherent averaging process used in the BEM measurements. It was found, however, that the effect of power level could be removed as a factor in discrimination because of a simple normalizing technique developed in Sections 5 and 6.

The methods for generating the Q distribution are developed in Sections 5,6,7,8, and a motivation for the methods is given in Section 4.

The signals used as test signals for constructing the reference data base are discussed in Sections 8, 10, 11, and the results of the discrimination capability are given in Sections 10 and 11. The basic analytical method used for discrimination, as opposed to the visual observation of the Q distribution curve, was the method of linear discriminates. This method is described in some detail in Section 9. Results are shown to be good if the signal type have, indeed, a different Q distribution curve.

The general conclusions and recommendations are given in Section 12.

Section 2

DESCRIPTION OF EXPERIMENTAL TECHNIQUE

2.1 GENERAL DISCUSSION

Laboratory experiments were conducted for the Baseband Eye Monitor (BEM) Signal Discrimination and Identification Study Program, in order to provide Bit Error Data versus BEM Dispersion Voltage when various signal interference types are introduced into the BEM system.

The components utilized in the experiments are listed in Table 2-1

TABLE 2-1. LABORATORY EQUIPMENT

Description	Manufacturer	Model
Digital Multiplex Switch	Vicom	T1-4000
Baseband Eye Monitor	Honeywell	
Active Coupler	Honeywell	
True RMS Voltmeter	H-P	3403C
Event/Internal Counter	H-P	5330B
DC Voltmeter	Fluke	8200A
Noise Generator	Marconi	TF2091
Signal Generator	H-P	8640B
Signal Generator	H-P	3330B
Signal Generator	IEC	F34
Summing Amplifier	Honeywell	N/A
Impedance Matching Pads	Honeywell	N/A

2.2 LABORATORY TEST SET-UP

A block diagram of the test set-up used for the BEM study program is shown in Figure 2-1. The "gain" of the BEM active coupler was modified to provide the proper signal level to the BEM using the laboratory test configuration.

2.3 BEM TEST MODIFICATIONS

To provide correlation between BEM "Dispersion" data (as a function of signal interference) and the analytical results, it was necessary to incorporate a means of varying the "pseudo error

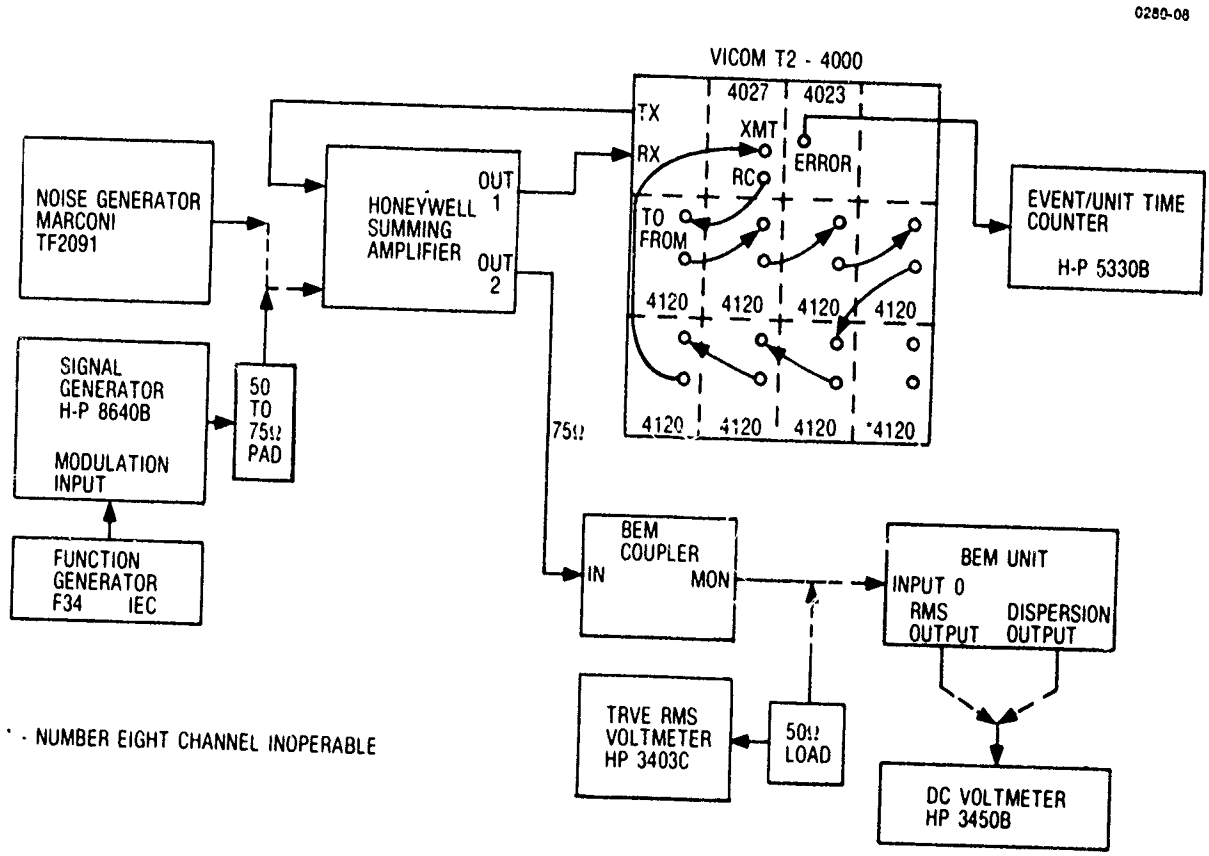
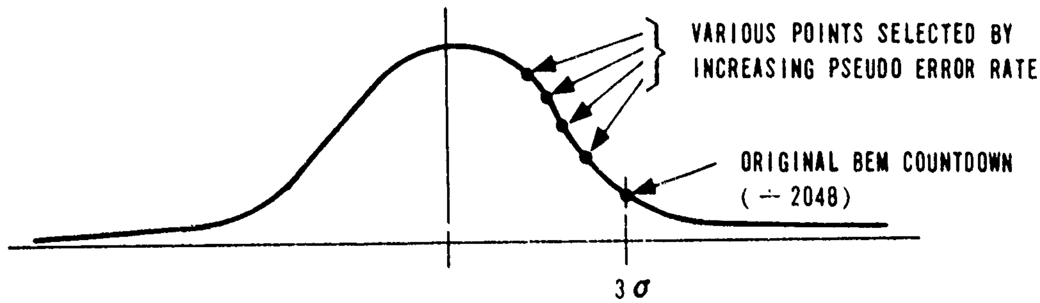


FIGURE 2-1. TEST SET-UP BLOCK DIAGRAM

rate" of the Baseband Eye Monitor. This was accomplished using a series of thumbwheel switches to provide a selectable countdown ratio for the "a" control board (A8). A block diagram of this function is shown in Figure 2-2. The pseudo error rate was changed by altering the countdown ratio in the high speed up/down counter section of the A8 card. A partial schematic of the A8 card is shown in Figure 2-3.

As the countdown ratio is reduced the pseudo error rate increases and provides a value of dispersion voltage which represents a point higher on the gaussian distribution, as illustrated below.



GAUSSIAN DISTRIBUTION CURVE

The countdown ratios selected for the first experiments were as shown below:

:9216 (original BEM)
:4608
:2304
:1152

After taking a number of sets of data using various interference types, the results were cross-checked against initial analytical predictions. The comparison between empirical and analytical results showed that there was a need to decrease the countdown ratio further. This was needed to both refine the analytical approach and to provide a basis for selecting countdown ratios that would provide the best signal discrimination capability with the fewest number of countdown ratios. As a result the number of countdown ratios was increased to include: :288, :72, :36, and :20.

2.4 TYPE OF DATA COLLECTION

Since most laboratory study programs are based upon repeatable empirical data, the primary objective at the start of the

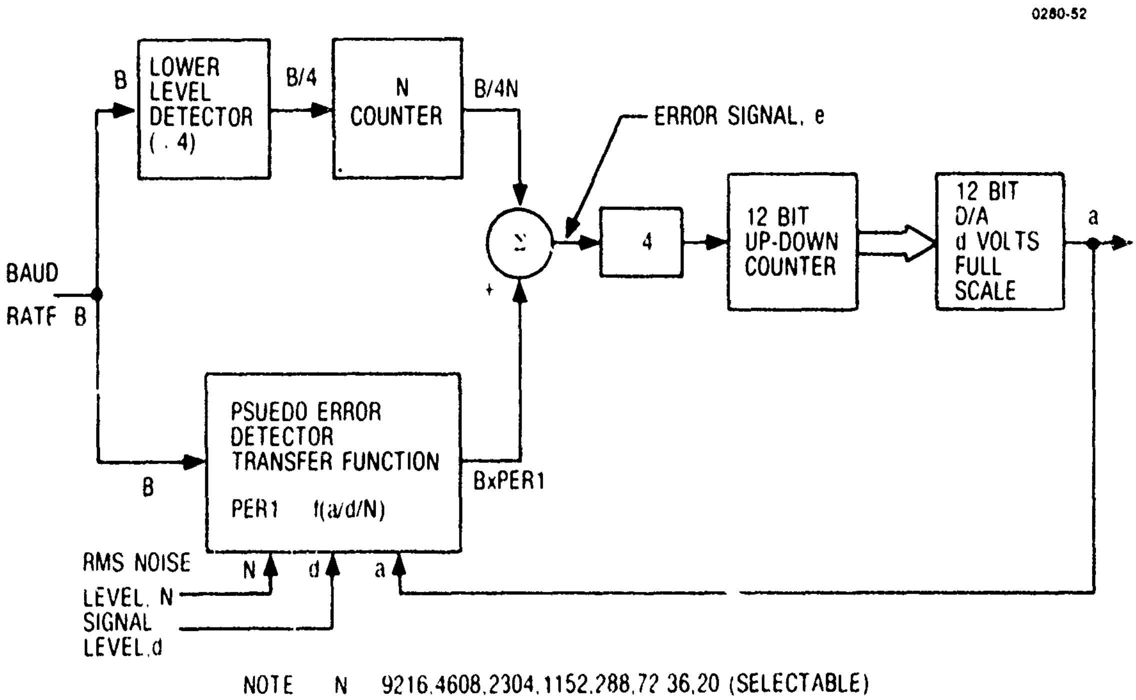
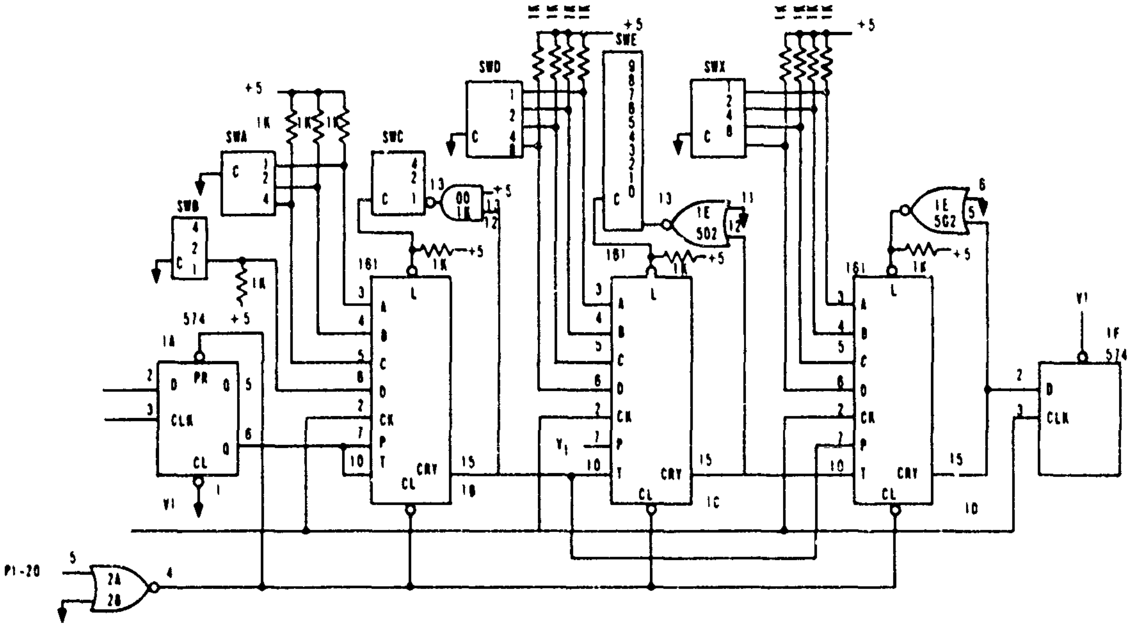


FIGURE 2-2. PSEUDO ERROR RATE CONTROL LOOP

0280-146B



NOTE SWA, SWB, SWC, SWD AND SWX ARE BCD THUMBWHEEL SWITCHES
SWE IS A TEN LINE TO ONE LINE THUMBWHEEL SWITCH
REFERENCE DWG NO 34027542

FIGURE 2-3. MODIFIED BEM A8 CARD
(PARTIAL SCHEMATIC)

program was to verify the results obtained when the BEM equipment was originally delivered to Rome Air Development Center.

The tests conducted during the initial program when the BEM equipment was developed, were based upon usage as a bit error rate measurement device in a system where white noise (Gaussian distribution) was the only contributor to system performance degradation. To verify that the equipment was operating within the original design concepts, extensive tests were conducted to correlate results of the original design tests to results obtained for the equipments received after use in the field. During the initial phase of the program, effort was concentrated on obtaining good correlation between the original and current empirical data, using white noise as the interference source. Due to the highly sophisticated nature of this equipment, it was extremely important to establish a reliable baseline between past and present performance characteristics.

This baseline was established by recording the value of dispersion voltage and true rms outputs (dc voltage outputs) from the BEM under specified carrier to interference ratios. In addition to the dispersion and true rms data, the bit error rate was measured at the Vicom T1-4000 unit. The "error output" test jack of the "RCV input module" was used for the bit error counted for specified time intervals. The bit error rate (BER) was then calculated using the equation shown below:

$$\text{BER} = \frac{\text{Bit Errors Counted}}{\text{Bit Rate x Time}}$$

The bit rate used was 12.5526 MHz, and the time was the time interval over which the bit errors were collected. The time interval was selected between one second and 100 seconds depending on the expected BER value. For low values of carrier to interference ratios the BER values would be high ($\approx N \times 10^{-3}$), and the time selected would be one to two seconds. For low BER values ($\approx N \times 10^{-6}$ and lower), a time interval of 100 seconds would be used.

2.5 TYPES OF INTERFERENCE CONSIDERED

During the initial phase of the study program, the following signal types were considered: White noise (Gaussian Distribution), Swept CW, Pulsed CW, Single Frequency with FM Noise Modulation and Single Frequency with AM Noise Modulation.

However, due to limitations of the signal generating test equipment, the list of signal types was changed to permit accurate correlation between analytical and empirical test results. When attempts were made to generate a single frequency sinusoid with AM or FM noise modulation, the spectral output showed characteristics that could not be described using a basic mathematical equation. The alternative was to select a single frequency sinusoid with AM or FM sine wave modulation. Another signal type that could not be provided was pulsed noise. Since there was no alternate signal type that could be related to this complex wave form, it was eliminated from the list of signal types where empirical data was to be obtained.

A detailed definition of each of the signal types tested is given below. In each case, the baseband "eye" signal is denoted as the carrier, "C", and the interference signal as "I". In all cases the "C" and "I" signals were applied to a summing amplifier. The output of the summing amplifier contained both signals, and was fed back to the input of the Vicom T1-4000. The signal to noise or carrier to interference ratio (C/I) was the ratio of power contained in the output between the carrier and interference signal.

a. <u>White Noise (Gaussian Distribution)</u>

Band Limited - 12 kHz to 552 kHz

$C = 12.5526 \times 10^6$ bits/second

I = Band limited white noise interference level.

b. <u>Swept CW</u>

Single frequency sinusoid, slowly swept from 1 MHz to 12.5526 MHz.

$C = 12.5526 \times 10^6$ bits/second

$I = P \text{ Sin } wt$

Where P is the selected value of interference level, and w varies from 6.283×10^6 to 7.5398×10^7 radians/second.

c. <u>Single Frequency CW</u>

Single frequency sinusoid, set at one fourth the bit rate of the Vicom T1-4000

$C = 12.5526 \times 10^6$ bits/second

$I = P \text{ Sin } wt$

Where P is the selected value of interference level, and W = 2.002×10^7 radians/second.

d. <u>Single Frequency with FM Sine Wave Modulation</u>

$C = 12.5526 \times 10^6$ bits/second

The FM carrier frequency is described by the equation

$e_i = E_i \text{ Cos } \omega_i t$

Where Ei is the selected value of interference level and ωi is the FM carrier frequency select at one fourth of the bit rate of the "Baseband Eye".

$\omega i = 2.002 \times 10^7$ radians/second.

The modulating signal is described by $e_m\ (t) = Em \text{ Cos } \omega mt$.

Where Em represents the peak value of the modulating wave form and ωm is the radian/second equivalent of the modulating frequency.

Three modulating frequencies were used, 100 Hz, 1 kHz and 5 kHz. The final equation for the FM modulation signal is

$$I = e_s(t) = Ei \text{ Cos } (\omega i\ t + KEm/\omega m \text{ Sin } \omega mt)$$

Where KEm represents the maximum frequency deviation of the FM carrier. The maximum frequency deviation was ±20 kHz in all cases, due to limitations of the signal generator. The total summed signal applied to the system is then described as $C + I = C + e_s\ (t)$.

e. <u>Single Frequency with AM Sine Wave Modulation</u>

$C = 12.5526 \times 10^7$ bits/second.

The AM modulated signal (double sideband) is described by the equation

$$I = e_i(t) = [K + e_m(t)] \cos \omega i\ t$$

Where Cm (t) is the basic modulating frequency shown by the equation below:

$$e_m(t) = E \text{ Cos } \omega mt$$

The term $\text{COS}\omega ct$ is the AM carrier frequency. The value of ωi was 2.002×10^7 for all AM tests. Two values of ωm were used, 628 and 6.28×10^3 radians/second.

2.6 DATA ACCURACY AND CONSISTENCY

During the course of testing on the BEM Study Program, three types of measurements were performed: True rms ac voltage, dc voltage, and counts per unit time. The accuracy of each of these measurements is discussed separately below.

2.6.1 AC Voltage - True RMS

The true rms voltage measurements were made on the output of the baseband coupler, and consisted of the baseband eye voltage or the Interference Level. The measurements were made independently by disconnecting the undesired signal at the input to the summing amplifier. The accuracy of the true rms voltmeter is ±2 percent over the frequency range used.

2.6.2 DC Voltage Measurements

The dc voltage measurements consisted of the dispersion voltage output and the true rms output of the BEM. The accuracy of the meter used was 0.01 percent.

2.6.3 Bit Error Per Unit Time (BER)

The bit errors were obtained from a dc pulse output from the RCV input module (type 4023) error output on the Vicom T1-4000. The counter accuracy was plus or minus one count. For BER values greater than 10^7, the number of counts collected was always greater than 100 in any counting interval, therefore the accuracy was a maximum of ±1.0 percent at 10^7 and decreased as the BER value increased above 10^7. For BER values less than 10^7, the number of counts was less than 100. Therefore the accuracy tolerance would increase accordingly, i.e., for a bit error count of 50 ±1, the tolerance would be basically ±2 percent.

Repetitive counts measurements were made in all cases, regardless of the BER value, which provides a higher degree of confidence in most cases regarding the consistency of the data obtained. However, this factor only provides an intuitive feel for the accuracy of the data. At a BER value of 10^9, the count accuracy could not be firmly quoted as anything less than ±10 percent.

The accuracy of the time interval used for any of the error counts collected was 10^6, and is well below the ±1 percent value at a BER of 10^7. Therefore, the accuracy tolerance of the time interval is not considered a factor in this measurement.

2.6.4 Data Consistency

The data consistency was considered excellent during the laboratory test period. This is primarily a judgment factor based on review and comparison of data during the entire course of the laboratory test series.

Prior to restarting any test series or changing interference types, the test set-up for Gaussian noise was reconnected and data was measured for selected levels and countdown ratios (for the A8 card in the BEM unit). The data was then compared to verify the consistency and operational integrity of the BEM/Vicom equipment.

2.7 DATA PRESENTATION

The raw data collected during the test program is presented in this section. Explanation of raw data will be brief, since the primary purpose of the BEM Study Program was to determine the feasibility of discriminating various signal types using the BEM equipment. The raw data was used as a tool to verify and refine analytical concepts developed during the program.

The initial data is contained in Tables 2-2 through 2-7, and was used as a foothold in the early stages of the analysis and development of equations used for signal discrimination. Each table shows the interference level used, BEM dispersion voltage, count interval, number of error, BEM rms output dc voltage, calculated BER and the carrier to interference ratio. Tables 2-2 through 2-7 show the results of Gaussian and sine wave interference, as a function of interference level and countdown ratio.

Table 2-8 shows the results of a constant sine wave interference level as a function of frequency and countdown ratio.

Tables 2-9 through 2-11 show the results of FM interference as a function of interference level, for three different countdown ratios.

After collecting the previous data, the results of the analysis showed that it was necessary to collect data for a wider range of countdown ratios. Tables 2-12 through 2-19 show the results of tests performed with eight countdown ratios ranging from 9216 to 20, as a function of interference level.

TABLE 2-2. BAND LIMITED GAUSSIAN NOISE - 12 kHz TO 552 kHz

Interference Level MVRMS	BEM Dispersion DC Output (-VDC)		Time Sec	Bit Error Count		BEM RMS DC Voltage Monitor		Bit Error Rate		C/I Rate (db)
	1 CH	7 CH		1 CH	7 CH	1 CH	7 CH	1 CH	7 CH	
				BEM Coupler Input = 0.306 VRMS						
None Added	2.320	2.660	100	0	0	2.4810	2.482	$< 8 \times 10^{10}$		N/A
54.9	9.400	9.401	10	871831 867644 861814 860710	769372 771813 771185 773112			6.9×10^{-3}	6.15×10^{-3}	5.57 (14.9 db)
50.2	9.230	9.298	10	544166 537933 541327 539705	482628 480412 477244 476491			4.3×10^{-3}	3.82×10^{-3}	6.09 (15.7)
44.4	8.480	8.950	10	257011 259562 257165	220320 221271 219685			2.05×10^{-3}	1.75×10^{-3}	6.89 (16.76)
38.8	6.597	7.395	10	94554 96384 94445 94139	77013 77365 77675 77297			7.57×10^{-4}	6.2×10^{-4}	7.88 (17.94)
34.0	5.700	6.522	10	25723 25751 25883	22593 22485 22714			2.05×10^{-4}	1.8×10^{-4}	9.0 (19.08)
28.3	4.876	5.700	60	14074 14133 14024	17685 17475 17304			1.87×10^{-5}	2.32×10^{-5}	10.8 (20.68)
23.7	4.267	5.054	100	1255 1247 1307	2209 2226 2177			1.01×10^{-6}	1.75×10^{-6}	12.9 (22.2)
20.0	3.866	4.576	100	44 42 52	89 102 105			3.74×10^{-8}	7.56×10^{-8}	15.3 (23.7)
18.0	3.623	4.299	100	4 4 4	7 6 8 7 7			3.7×10^{-9}	5.58×10^{-9}	17 (24.6)

ORIGINAL BEM CONFIGURATION

TABLE 2-3. BAND LIMITED GAUSSIAN NOISE - 12 kHz TO 552 kHz

Inter-ference Level	BEM Dispersion DC Output (-VDC)		Time	Bit Error Count		BEM RMS DC Voltage Monitor		Bit Error Rate		C/I Rate
MVRMS	1 CH	7 CH	Sec	1 CH	7 CH	1 CH	7 CH	1 CH	7 CH	(db)
				BEM Coupler Input = 0.305 VRMS						
None Added	2.318	2.662	100	0	0	2.4811	2.4820	$<8 \times 10^{10}$		N/A
55.0	9.218	9.330	2	160873 161149 161134	148382 148078 148198	2.5220	2.5225	6.412×10^{-3}	5.903×10^{-3}	5.5 (15.9)
49.6	8.836	9.047	4	185372 185540 186900	159582 160892 160649	2.5085	2.5168	3.704×10^{-3}	3.186×10^{-3}	6.15 (15.8)
43.7	7.249	8.016	8	186190 182417 182392	153839 156765 153659	2.5038	2.5050	1.832×10^{-3}	1.543×10^{-3}	6.98 (16.9)
39.1	6.255	7.012	20	183276 183734 183534	163175 161831 162412	2.5000	2.5004	7.309×10^{-4}	6.472×10^{-4}	7.8 (17.8)
34.4	5.322	6.139	60	117151 117154 117115	114531 114442 114733	2.494[illegible]	2.4980	1.555×10^{-4}	1.52×10^{-4}	8.86 (18.9)
23.2	3.931	4.770	60	349 411 396	752 785 771	2.4825	2.4880	5.178×10^{-7}	1.022×10^{-6}	13.1 (22.4)
20.3	3.669	4.392	90	50 67 51	136 117 131	2.4835		5.13×10^{-8}	1.75×10^{-7}	15.0 (23.5)
18.1	3.458	4.155	90	8 4 8	12 10 11	2.4799	2.4822	7.08×10^{-9}	9.74×10^{-9}	16.8 (24.5

DATA RUN WITH CHANGE TO A8 (÷4608)

TABLE 2-4. SINE WAVE 3.1864 MHz

Interference Level MVRMS	BEM Dispersion DC Output (-VDC) 1 CH	7 CH	Time Sec	Bit Error Count 1 CH	7 CH	BEM RMS DC Voltage Monitor 1 CH	7 CH	Bit Error Rate 1 CH	7 CH	C/I Rate (db)
				BEM Coupler Input = 0.305 VRMS						
None Added										.
80.6	6.119	6.500	1	172638 169914 169076	140529 134647 138717	2.5660	2.5666	1.36×10^{-2}	1.1×10^{-3}	3.78 (11.5)
77.2	59.2	6.312	2	170708 180081 179977	153008 149026 149848	2.5575	2.5564	7.05×10^{-3}	6×10^{-3}	3.95 (11.9)
70.2	5.518	5.957	10	124384 126842 125155	137583 137200 135139	2.5479	2.5518	1.0×10^{-3}	1.08×10^{-3}	4.34 (12.76)
64.9	5.238	5.666	100	157973 152836 152450	141863 139984 140906	2.5379	2.5443	1.22×10^{-4}	1.12×10^{-4}	4.7 (13.4)
62.8	5.148	5.598	100	67450 66792 67767	46270 46960 47234	2.5290	2.5318	5.37×10^{-5}	3.74×10^{-5}	4.85 (13.7)
59.0	4.979	5.430	100	7040 7200 6496	2581 2718 2736	2.525	2.529	5.61×10^{-6}	2.15×10^{-6}	5.2 (14.3)
58.4	4.901	5.375	100	1496 1500 1423	446 420 403	2.5278	2.5276	1.19×10^{-6}	3.35×10^{-7}	5.22 (14.3)
55.5	4.772	5.204	100	573 549 468	120 99 106	2.5215	2.5238	4.374×10^{-7}	8.44×10^{-8}	5.49 (14.8)

ORIGINAL BEM CONFIGURATION

TABLE 2-5. SINE WAVE 3.1864 MHz

Interference Level MVRMS	BEM Dispersion DC Output (-VDC) 1 CH	7 CH	Time Sec	Bit Error Count 1 CH	7 CH	BEM RMS DC Voltage Monitor 1 CH	7 CH	Bit Error Rate 1 CH	7 CH	C/I Rate (db)
				BEM Coupler Input = 0.305 VRMS						
None Added	2.267	2.662					2.4761			
77.2	5.740	6.255	2	150178 148572 148408	135423 134844 133091	2.5515	2.5525	5.935×10^{-3}	5.337×10^{-3}	3.95 (11.9)
80.6	5.060	6.389	1	155807 156615 154393	129329 128703 124553 127010	2.5649	2.5560	1.235×10^{-2}	1.012×10^{-2}	3.78 (11.5)
70.2	5.363	5.847	10	107971 103947 105010	135154 136794 134900	2.5375	2.5382	8.365×10^{-4}	1.075×10^{-3}	4.34 (12.76)
64.7	5.094	5.636	60	72438 73746 75139	78916 79[illegible]48 7[illegible]430	2.5310	2.5380	9.759×10^{-5}	1.05×10^{-4}	4.7 (13.5)
60.4	4.866	5.354	60	8432 7742 7546	5016 4753 4999	2.5182	2.5208	1.035×10^{-5}	6.506×10^{-6}	5.05 (14.0)
56.8	4.680	5.161	60	574 600 521	152 174 146	2.5170	2.5137	7.966×10^{-7}	2.124×10^{-7}	(14.6)
58.9	4.780	5.271	60	3308 3019 3183	1384 1300 1297	2.5185	2.5194	4.249×10^{-6}	1.76×10^{-6}	5.2 (14.3)
62.8	4.958	5.454	60	26480 25913 26121	22127 21478 21761	2.5266	2.5273	3.478×10^{-5}	2.894×10^{-5}	4.65 (13.7

DATA RUN WITH CHANGE TO A8 (:4608)

TABLE 2-6. SINE WAVE 3.1864 MHz

Interference Level MVRMS	BEM Dispersion DC Output (-VDC) 1 CH	7 CH	Time Sec	Bit Error Count 1 CH	7 CH	BEM RMS DC Voltage Monitor 1 CH	7 CH	Bit Error Rate 1 CH	7 CH	C/I Rate (db)
			BEM Coupler Input = 0.305 VRMS							
None Added	2.125	2.550				2.4760	2.4780			
80.2	5.813	6.262	1	177857 176865 178045	136619 141910 135475	2.5595	2.5620	1.416×10^{-2}	1.09×10^{-2}	3.8 (11.6)
76.8	5.562	6.054	2	177744 174899 178766	154561 151877 153722	2.5520	2.5585	7.08×10^{-3}	6.12×10^{-3}	3.79 (12)
70.1	5.164	5.716	10	133065 132715 129708	145131 145679 141919	2.5435	2.5450	1.06×10^{-3}	1.157×10^{-3}	4.35 (12.8)
64.6	4.895	5.437	60	95939 93310 94801	89911 87127 88057	2.5315	2.5378	1.26×10^{-4}	1.175×10^{-4}	4.72 (13.5)
62.4	4.792	5.321	60	31178 31611 31773	26174 25545 25463	2.5300	2.5325	4.182×10^{-5}	3.42×10^{-5}	4.89 (13.8)
60.7	4.730	5.262	60	11586 11185 10759	5900 5861 5817	2.5163		1.47×10^{-5}	7.78×10^{-6}	5.0 (14.0)
58.9	4.644	5.185	60	4913 4945 5037	2140 2089 2142			6.58×10^{-6}	2.84×10^{-6}	5.[illegible] (14.3)
56.8	4.485	5.047	100	678 691 655	250 291 227		2.5162	5.4×10^{-7}	1.99×10^{-7}	5.37 (14.6)

DATA RUN WITH CHANGE TO A8 (#2304)

TABLE 2-7. SINE WAVE 3.1864 MHz

Interference Level MVRMS	BEM Dispersion DC Output (-VDC) 1 CH	BEM Dispersion DC Output (-VDC) 7 CH	Time Sec	Bit Error Count 1 CH	Bit Error Count 7 CH	BEM RMS DC Voltage Monitor 1 CH	BEM RMS DC Voltage Monitor 7 CH	Bit Error Rate 1 CH	Bit Error Rate 7 CH	C/I Rate (db)
			BEM Coupler Input = 0.305 VRMS							
None Added	1.980	2.480	0			2.4825	2.4820			
80.4	5.627	6.178	1	165453 169978 168904	137844 133524 133514	2.5640	2.5630	1.34×10^{-2}	1.06×10^{-2}	3.8 (11.6)
77.2	5.324	5.915	2	164225 169561 168058	140899 143484 141682	2.5545	2.5535	6.7×10^{-3}	5.616×10^{-3}	3.95 (11.9)
70.2	4.912	5.576	10	114844 116240 115003	132711 133359 131299	2.5415	2.5440	9.16×10^{-4}	1.06×10^{-3}	4.34 (12.7)
64.9	4.650	5.288	60	78884 78638 78761	78773 79838 79526	2.5345	2.5360	1.045×10^{-4}	1.055×10^{-4}	4.7 (13.4)
62.8	4.548	5.180	60	25458 25518 24861	23074 22434 22529	2.5305	2.5325	3.37×10^{-5}	2.987×10^{-5}	4.86 (13.7)
60.7	4.439	5.077	60	8264 8013 8009	4584 4269 4447	2.5295	2.5276	1.07×10^{-5}	5.84×10^{-6}	5.02 (14.0)
58.9	4.361	4.990	60	2982 3360 2675	1578 1488 1464	2.5245	2.5235	3.98×10^{-6}	1.99×10^{-6}	5.18 (14.3)
56.8	4.240	4.255	60	711 768 926	825 786 688	2.5235	2.5225	6.37×10^{-7}	5.9748×10^{-7}	5.4 (14.6)

DATA RUN WITH CHANGE TO A8 (÷1152)

TABLE 2-8. SINE WAVE INPUT - CONSTANT AMPLITUDE
(C/I = 4.34 = 12.74 db)

Frequency MHz	Time Sec	Error Count / BER - 1 CH	Error Count / BER - 7 CH	Dispersion (-VDC) ÷2304 1 CH / 7 CH	÷1152 1 CH / 7 CH	÷288 1 CH / 7 CH	÷72 1 CH / 7 CH	÷36 1 CH / 7 CH	÷20 1 CH / 7 CH	Comments
1.0	0.2	74463 74438 75000 2.97×10^{-2}	83636 84071 83796 3.33×10^{-2}	7.4[illegible]1 7.318	7.278 7.211	6.826 6.910	5.758 5.981	4.680 4.954	3.562 3.516	C/I = 4.34 (12.74 db)
2.0	0.5	126926 125337 128727 $2.02 \times 10^{-[illegible]}$	204440 19951[illegible] 122688 2.[illegible]$\times 10^{-2}$	6.712 6.640	6.110 6.467	5.420 5.947	4.238 4.666	3.805 3.951	3.206 3.717	C/I = 4.34 (12.74 db)
3.1864	10	139173 137520 140380 1×10^{-3}	155913 152716 150477 1.22×10^{-3}	5.296 5.840	5.043 5.682	4.028 5.260	3.461 4.069	3.160 3.160	2.674 2.688	C/I = 4.34 (12.74 db)
4.0	10	20125 20089 20573 1.6×10^{-4}	23197 22315 22661 1.8×10^{-4}	4.947 5.486	4.707 5.341	3.656 4.917	3.071 3.768	2.787 3.019	2.366 2.380	C/I = 4.34 (12.74 db)
5.0	100	42 45 45 3.505×10^{-8}	1-2 1.2×10^{-9}	4.277 4.800	4.051 4.646	3.065 4.254	2.423 3.280	2.138 2.453	1.795 1.885	C/I = 4.34 (12.74 db)
6.3728	100	0 0 0 $<8 \times 10^{-8}$	0 0 0 $<8 \times 10^{-10}$	3.331 3.840	3.130 3.720	2.275 3.348	1.507 2.611	1.306 1.760	1.100 1.273	C/I = 4.34 (12.74 db)
7.0	100	0 0 0 $<8 \times 10^{-10}$	0 0 0 $<8 \times 10^{-10}$	3.025 3.525	2.840 3.397	2.118 3.044	1.267 2.404	1.075 1.636	0.897 1.146	C/I = 434 (12.74 db)

TABLE 2-9. CARRIER FREQUENCY 3.1864 MHz
FM MODULATION FREQUENCY 1 kHz, FREQUENCY DEVIATION ±20 kHZ

Interference Level MVRMS	BEM Dispersion DC Output (-VDC)		Time Sec	Bit Error Count		BEM RMS DC Voltage Monitor		Bit Error Rate		C/I Rate (db)
	1 CH	7 CH		1 CH	7 CH	1 CH	7 CH	1 CH	7 CH	
			BEM Coupler Input = 0.306 VRMS							
None Added	2.259	2.612				2.4710	2.4720			
80.6	5.950	6.359	1.0	156041 153518 158996	126722 126723 126577	2.5537	2.5580	1.242×10^{-2}	1.0×10^{-2}	3.78 11.5
89.9	7.002	6.914	1.0	234339 235884 237741	247865 242917 244240	2.5771	2.5770	1.872×10^{-6}	1.944×10^{-2}	2.4 (10.6)
None Added	2.246	2.604				2.4780	2.4794			
85.5	6.268	6.617	1.0	185061 178141 184967	131405 131043 132159	2.5710	2.5690	1.465×10^{-2}	1.05×10^{-2}	3.56 (11.0)
75.5	5.606	6.074	2	106646 106052 103184	94948 94323 95733	2.5490	2.5520	4.22×10^{-3}	3.78×10^{-3}	4.04 (12.1)
70.0	5.309	5.799	10	87713 92454 89159	115456 113870 112517	2.5410	2.5435	7.09×10^{-4}	9.08×10^{-5}	4.36 (12.8)
68.1	5.231	5.718	10	47424 46288 45697	55946 56902 56171	2.5396	2.5408	3.66×10^{-4}	4.54×10^{-4}	4.48 (13.0)
64.9	5.055	5.541	10	10499 10654 10846	11719 11789 11286	2.5342	2.5340	8.44×10^{-5}	9.32×10^{-5}	4.7 (13.4)
60.5	[illegible]	5.317	10	1094 1002 967 948	607 554 492 563	2.5252	2.5267	7.966×10^{-6}	4.38×10^{-6}	5.04 (14.0)
58.2	4.744	5.227	10	156 186 171	78 69 74	2.5193	2.5190	1.36×10^{-6}	5.86×10^{-7}	5.2 (14.4)

THIS DATA RUN WITH CHANGE TO A8 (2304)

TABLE 2-10. CARRIER FREQUENCY 3.1864 MHz
FM MODULATION FREQUENCY 1 kHz, FREQUENCY DEVIATION ±20 kHZ

Inter-ference Level MVRMS	BEM Dispersion DC Output (-VDC)		Time Sec	Bit Error Count		BEM RMS DC Voltage Monitor		Bit Error Rate		C/I Rate (db)
	1 CH	7 CH		1 CH	7 CH	1 CH	7 CH	1 CH	7 CH	
			BEM Coupler Input = 0.305 VRMS							
None Added	2.259	2.612				2.4710	2.4720			
80.4	5.951	6.380	1.0	159427 159311 156884	127339 125313 126377	2.5530	2.5546	1.266×10^{-2}	1.0×10^{-2}	3.8 (11.6)
89.9	7.036	6.891	1.0	238422 238770 233373	240820 244732 243358	2.5774	2.5795	1.9×10^{-2}	1.944×10^{-2}	2.4 (10.6)
85.5	6.267	6.620	1.0	185588 179202 180828	133568 132477 135496	2.5710	2.5694	1.43×10^{-2}	1.07×10^{-2}	3.56 (11.0)
75.5	5.594	6.740	2	96742 90930 93374	93629 95201 91814	2.5510	2.5530	3.7×10^{-3}	3.72×10^{-3}	4.04 (12.1)
70.0	5.324	5.807	10	94658 92938 93785	116920 116336 113969	2.5425	2.5438	7.488×10^{-4}	9.24×10^{-4}	4.36 (12.8)
68.1	5.227	5.704	10	41298 41059 40141	55005 55178 55098	2.5401	2.5406	3.266×10^{-4}	4.39×10^{-4}	4.48 (13.0)
64.9	5.057	5.550	10	9522 9387 8831	11473 11817 11824	2.5352	2.5356	7.33×10^{-5}	9.4×10^{-5}	4.7 (13.4)
60.5	4.847	5.326	10	1076 1111 1200	566 588 512	2.5240	2.5260	8.76×10^{-6}	4.38×10^{-6}	5.04 (14.0)
58.2	4.737	5.220	10	216 215 190	70 78 84	2.5186	2.5210	1.65×10^{-6}	6.16×10^{-7}	5.2 (14.4)

DATA RUN WITH CHANGE TO A8 (4608)

TABLE 2-11. CARRIER FREQUENCY 3.1864 MHz
FM MODULATION FREQUENCY 1 kHz, DEVIATION ±20 kHZ

Interference Level MVRMS	BEM Dispersion DC Output (-VDC)		Time Sec	Bit Error Count		BEM RMS DC Voltage Monitor		Bit Error Rate		C/I Rate (db)
	1 CH	7 CH		1 CH	7 CH	1 CH	7 CH	1 CH	7 CH	
			BEM Coupler Input = 0.305 VRMS							
None Added	2.111	2.532	.			2.4840	2.4835			
89.5	6.844	6.770	1.0	223560 219936 225365	230791 228693 226443	2.5844	2.5826	1.776×10^{-2}	1.816×10^{-2}	
85.6		6.461	1.0		161299 158777 158108		2.5705		1.266×10^{-2}	
85.6	6.154	6.444	1.0	201293 198393 203904	161384 160399 159896	2.5718	2.5700	1.601×10^{-2}	1.275×10^{-2}	
80.5	5.776	6.213	1.0	175810 170949 170627	140222 139816 141378	2.5612	2.5650	1.358×10^{-2}	1.115×10^{-2}	
77.2	5.530	6.043	2	176829 175127 170765	147933 146543 146271	2.5549	2.5540	7.01×10^{-3}	5.815×10^{-3}	
70.2	5.149	5.695	10	105254 98963 101681	134882 137466 134111	2.5435	2.5462	8.05×10^{-4}	1.08×10^{-3}	
64.8	4.864	5.411	60	63330 62330 60715	70525 68922 69774	2.5373	2.5355	8.23×10^{-5}	9.23×10^{-5}	
62.8	4.827	5.305	60	21140 23554 20436	17625 17770 17365	2.5195	2.5311	2.85×10^{-5}	2.323×10^{-5}	
58.9	4.594	5.117	60	2267 2453 2566	972 965 1038	2.5250	2.5272	3.25×10^{-6}	1.3×10^{-6}	
56.8	4.458	5.000	60	326 238 308	113 102 98	2.5207	2.5200	3.65×10^{-7}	1.39×10^{-7}	

DATA RUN WITH CHANGE TO A8 (2304)

TABLE 2-12. BAND LIMITED GAUSSIAN NOISE (12 kHz to 552 kHz)

Interference Level MVRS	Time Sec	Error Count Vicom T1-4000 4023-B Card 1 CH	Error Count Vicom T1-4000 4023-B Card 7 CH	BER 1 CH	BER 7 CH	Dispersion (-VDC) ÷9216 1 CH 7 CH	÷4608 1 CH 7 CH	÷2304 1 CH 7 CH	÷1152 1 CH 7 CH	÷288 1 CH 7 CH	÷72 1 CH 7 CH	÷36 1 CH 7 CH	÷20 1 CH 7 CH	RMS (-VDC) 1 CH	RMS (-VDC) 7 CH	C/I (db)
54.9	2	171785 161940 163671	137829 134460 133572	6.987×10^{-3}	6.378×10^{-3}	9.400	9.218	8.965	8.220	6.420	4.310	3.201	2.117	2.5229	2.5227	5.55 (14.9)
						9.401	9.330	9.188	8.853	6.930	4.550	3.538	2.300			
50.3	2	111942 113628 112121	97012 96792 97479	4.643×10^{-3}	4.091×10^{-3}	9.230	8.836	8.211	7.211	5.544	3.868	2.979	1.902	2.5130	2.5138	6.06 (15.65)
						9.298	9.047	8.723	7.813	5.995	4.180	3.145	2.107			
44.4	5	151083 149763 149431	119583 118939 118832	2.42×10^{-3}	1.86×10^{-3}	8.480	7.249	6.761	6.107	4.820	3.384	2.506	1.662			6.87 (16.74)
						8.950	8.016	7.470	6.730	5.330	3.776	2.848	1.914			
38.9	10	84446 84521 83650	82050 81720 81877	8.1×10^{-4}	6.5×10^{-4}	6.597	6.255	5.781	5.259	4.186	2.941	2.153	1.461			7.84 (17.9)
						7.395	7.012	6.492	5.928	4.764	3.388	2.552	1.718			
34.8	10	26541 26880 27045	26215 26324 26493	2.14×10^{-4}	2.2×10^{-4}	5.700	5.322	5.103	4.662	3.708	2.606	1.957	1.324	2.4940	2.4969	8.76 (18.8)
						6.522	6.139	5.831	5.368	4.339	3.090	2.331	1.580			
28.1	60	14865 14654 14788	19420 19261 19653	1.96×10^{-5}	2.58×10^{-5}	4.876	4.573	4.284	3.918	3.106	2.175	1.627	1.147	2.4910	2.4909	10.85 (20.7)
						5.700	5.332	5.068	4.681	3.795	2.721	2.040	1.386			
21.7	100	93 108 112	259 211 216	8.3×10^{-8}	1.82×10^{-7}	3.998	3.733	3.452	3.128	2.413	1.680	1.280	0.949			14.05) (22.95)
						4.728	4.456	4.196	3.893	3.221	2.395	1.817	1.211			
None Added	100	0	0	$<8 \times 10^{-10}$	$<8 \times 10^{-10}$	2.380	2.281	2.144	2.005	1.683	0.783	0.590	0.351			N/A
						2.706	2.641	2.575	2.496	2.268	1.875	1.596	0.915			

BASEBAND EYE VOLTAGE RMS = 0.305 VRMS

TABLE 2-13. SINE WAVE INPUT - 3.1864 x 10^{-6} Hz

Interference Level MVRS	Time Sec	Error Count Vicom T1-4000 4023-B Card 1 CH	Error Count 7 CH	BER 1 CH	BER 7 CH	Dispersion (-VDC) ÷9216 1 CH / 7 CH	÷4608 1 CH / 7 CH	÷2304 1 CH / 7 CH	÷1152 1 CH / 7 CH	÷288 1 CH / 7 CH	÷72 1 CH / 7 CH	÷36 1 CH / 7 CH	÷20 1 CH / 7 CH	RMS (-VDC) 1 CH	RMS (-VDC) 7 CH	C/I (db)
85.7	1	192305 200843 210208	189047 183420 186226	1.602×10^{-2}	1.48×10^{-2}	6.720 6.736	6.529 6.688	6.484 6.648	6.260 6.441	5.570 5.953	4.425 4.638	3.975 4.042	3.290 3.290	2.5520	2.5518	3.55 (10.99)
77.2	2	196607 196013 198110	160712 163511 166865	7.64×10^{-3}	6.52×10^{-3}	5.912 6.312	5.740 6.255	5.694 6.210	5.455 6.045	4.470 5.609	3.832 4.364	3.514 3.675	2.986 2.946	2.5370	2.5377	3.94 (11.9)
70.1	10	139173 137520 140380	155913 152716 150477	1.1×10^{-3}	1.22×10^{-3}	5.518 5.957	5.363 5.847	5.296 5.840	5.043 5.682	4.028 5.260	3.461 4.069	3.160 3.160	2.674 2.688			4.34 (12.74)
64.8	60	95627 93599 96540	84741 81860 84299	1.26×10^{-4}	1.11×10^{-4}	5.238 5.666	5.094 5.636	5.021 5.568	4.755 5.412	3.767 4.990	3.185 3.845	2.905 3.129	2.454 2.477	2.5162	2.5162	4.69 (13.42)
62.7	60	38965 40829 40536	21928 21585 20147	5.32×10^{-5}	2.82×10^{-5}	5.148 5.598	4.958 5.454	4.920 5.446	4.684 5.316	3.690 4.900	3.111 3.769	2.832 3.051	2.383 2.410	2.5114	2.5126	4.85 (13.7)
58.8	100	4181 4123 4370	1835 1832 1682	3.36×10^{-6}	1.42×10^{-6}	4.951 5.842	4.761 5.243	4.680 5.231	4.496 5.121	3.493 4.708	2.917 3.614	2.641 2.880	2.225 2.264	2.5036	2.5057	5.17 (14.27)
56.8	100	1018 1087 1027	267 336 284	8.13×10^{-7}	2.35×10^{-7}	4.8[illegible]1 5.724	4.664 5.140	4.623 5.164	4.397 5.010	3.409 4.603	2.833 3.530	2.558 2.795	2.148 2.193			5.35 (14.57)

BASEBAND EYE VOLTAGE RMS = 0.304 VRMS

TABLE 2-14. FM MOD - ±20 kHz DEVIATION, 100 Hz TONE, 3.1864 MHz CARRIER

Interference Level MVRS	Time Sec	Error Count Vicom T1-4000 4023-B Card 1 CH	Error Count Vicom T1-4000 4023-B Card 7 CH	BER 1 CH	BER 7 CH	Dispersion (-VDC)	÷9216	÷4608	÷2304	÷1152	÷288	÷72	÷36	÷20	RMS (-VDC) 1 CH	RMS (-VDC) 7 CH	C/I (db)
79.0	1	197672 194696 198269	195413 196755 199689	1.57×10^{-2}	1.57×10^{-2}	1 CH			5.986	5.780	4.805	3.989	3.658	3.103	2.5240	2.5254	3.86 (11.7)
						7 CH	6.658	6.538	6.436	6.273	5.818	4.530	3.793	3.048			
70.1	10	220191 21811[illegible] 222742	214415 216156 214987	1.75×10^{-3}	1.71×10^{-3}	1 CH			5.398	5.146	4.100	3.490	3.187	2.692	2.5135	2.5150	4.35 (12.8)
						7 CH	6.203	6.088	5.959	5.801	5.365	4.150	3.396	2.694			
64.1	60	111216 108885 106705	145058 147721 143420	1.44×10^{-4}	1.93×10^{-4}	1 CH	5.410		5.086	4.830	3.786	3.189	2.897	2.450		2.5036	4.75 (13.5)
						7 CH	5.884	5.777	5.654	5.480	5.047	3.896	3.135	2.479			
58.1	100		5048 5142 4825		3.99×10^{-6}	1 CH										2.4932	5.25 (14.4)
						7 CH	5.579	5.471	5.341	5.187	4.764	3.662	2.876	2.262			
54.0	100		98 90 99		7.6×10^{-8}	1 CH										2.4878	5.65 (15.0)
						7 CH	5.371	5.266	5.136	4.980	4.564	3.513	2.713	2.114			

BASEBAND EYE VOLTAGE RMS = 0.305 VRMS

TABLE 2-15. FM MOD - ±20 kHz DEVIATION, 1 kHz TONE, 3.1864 MHz CARRIER

Interference Level MVRS	Time Sec	Error Count Vicom T1-4000 4023-B Card		BER		Dispersion (-VDC)								RMS (-VDC)		C/I (db)
						÷9216	÷4608	÷2304	÷1152	÷288	÷72	÷36	÷20			
						1 CH	1 CH	1 CH	1 CH	1 CH	1 CH	1 CH	1 CH			
		1 CH	7 CH	1 CH	7 CH	7 CH	7 CH	7 CH	7 CH	7 CH	7 CH	7 CH	7 CH	1 CH	7 CH	
79.6	1		148300 148076 147570		1.18×10^{-2}	6.680	6.559	6.423	6.260	5.806	4.523	3.788	3.024		2.5310	3.86 (11.7)
74.1	2		124512 122665 124697		4.94×10^{-3}	6.411	6.288	6.151	5.991	5.555	4.306	3.565	2.846		2.5236	4.12 (12.3)
70.0	10		218937 216460 216971		1.73×10^{-3}	6.190	6.080	5.941	5.776	5.341	4.126	3.378	2.691		2.5033	4.36 (12.8)
64.1	60		158780 156079 152199		2.06×10^{-4}	5.891	5.778	5.641	5.477	5.058	3.888	3.126	2.474		2.5058	4.76 (13.5)
60.1	100		21406 21942 22609		1.75×10^{-4}	5.675	5.564	5.426	5.270	4.853	3.720	2.941	2.323		2.4970	5.08 (14.1)
58.1	100		5924 5986 5895		4.73×10^{-6}	5.584	5.475	5.340	5.176	4.761	3.660	2.869	2.255		2.4950	5.23 (14.4)
54.0	100		92 83 79		6.74×10^{-8}	5.439	5.319	5.201	5.064	4.701	3.625	2.722	2.125	2.4720	(15.0)	5.62

BASEBAND EYE VOLTAGE RMS - 0.304 VRMS

TABLE 2-16. FM MOD - ±20 kHz DEVIATION, 5 kHz TONE, 3.1864 MHz CARRIER

Interference Level MVRS	Time Sec	Error Count Vicom T1-4000 4023-B Card		BER		Dispersion (-VDC)								RMS (-VDC)		C/I (db)
						÷9216	÷4608	÷2304	÷1152	÷288	÷72	÷36	÷20			
						1 CH / 7 CH	1 CH / 7 CH	1 CH / 7 CH	1 CH / 7 CH	1 CH / 7 CH	1 CH / 7 CH	1 CH / 7 CH	1 CH / 7 CH			
		1 CH	7 CH	1 CH	7 CH									1 CH	7 CH	
79	1		136104 135990 135246		1.08×10^{-2}	6.714	6.589	6.442	6.281	5.832	4.539	3.790	3.036		2.5179	3.84 (11.7)
74.1	2		107174 108564 107787		4.3×10^{-3}	6.489	6.305	6.233	6.082	5.692	4.391	3.592	2.876		2.312	4.1 (12.26)
70.1	10		169925 171945 170651		1.4×10^{-3}	6.207	6.085	5.950	5.779	5.344	4.137	3.404	2.707		2.5121	4.33 (12.74)
64.1	60		103620 104434 104582		1.4×10^{-4}	5.946	5.829	5.694	5.555	5.163	3.994	3.149	2.500		2.4945	4.74 (13.52)
60.1	100		16736 16663 16691		1.33×10^{-5}	5.685	5.575	5.443	5.238	4.864	3.740	2.968	2.341		2.4930	5.06 (14.08)
58.0	100		3991 3815 3851		3.1×10^{-6}	5.581	5.472	5.337	5.180	4.764	3.660	2.876	2.259		2.4924	5.24 (14.4)
54.1	100		74 80 98 71 79		6.4×10^{-8}	5.384	5.270	5.140	5.133	4.575	3.518	2.720	2.112		2.4878	5.62 (15)

BASEBAND EYE VOLTAGE RMS - 0.305 VRMS

TABLE 2-17. AM MODULATION - 50 PERCENT, 1 kHz MODULATING TONE - 3.1864 MHz CARRIER

Interference Level MVRS	Time Sec	Error Count Vicom T1-4000 4023-B Card 1 CH	Error Count Vicom T1-4000 4023-B Card 7 CH	BER 1 CH	BER 7 CH	Dispersion (-VDC) ÷9216 1 CH	Dispersion (-VDC) ÷9216 7 CH	÷4608 1 CH	÷4608 7 CH	÷2304 1 CH	÷2304 7 CH	÷1152 1 CH	÷1152 7 CH	÷288 1 CH	÷288 7 CH	÷72 1 CH	÷72 7 CH	÷36 1 CH	÷36 7 CH	÷20 1 CH	÷20 7 CH	RMS (-VDC) 1 CH	RMS (-VDC) 7 CH	C/I (db)
65.2	2.0		205662 200857 201891		8.1×10^{-3}		9.272		9.183		7.127		6.715		5.725		4.191		3.350		2.291		2.4858	4.66 (13.4)
60.5	2.0		96607 96148 95246		3.82×10^{-3}		6.940		6.631		6.388		6.123		5.244		3.890		3.100		2.124			5.03 (14.02)
56.7	10		233888 234953 234299		1.87×10^{-3}		6.580		6.385		6.192		5.969		5.147		3.745		2.996		2.033			5.36 (14.6)
52.3	10		66974 65620 66415		5.3×10^{-4}		6.166		6.012		5.841		5.513		4.752		3.478		2.766		1.880			5.81 (15.3)
48.4	60		62987 63669 63574		8.4×10^{-5}		5.785		5.637		5.454		5.228		4.513		3.280		2.614		1.763		2.4832	6.3 (16.0)
43.9	100		1963 3281 3301		2.27×10^{-6}		5.470		5.328		5.157		4.942		4.266		3.075		2.423		1.638			6.9 (16.8)
42.4	100		293 324 301		2.43×10^{-7}		5.362		5.216		5.050		4.842		4.190		3.011		2.370		1.594			7.17 (17.1)

BASEBAND EYE VOLTAGE RMS - 0.304 VRMS

TABLE 2-18. AM MODULATION - 100 PERCENT, 100 Hz MODULATING TONE - 3.1864 MHz CARRIER

Interference Level MVRS	Time Sec	Error Count Vicom T1-4000 4023-B Card 1 CH	Error Count Vicom T1-4000 4023-B Card 7 CH	BER 1 CH	BER 7 CH	Dispersion (-VDC) ÷9216 1 CH / 7 CH	÷4608 1 CH / 7 CH	÷2304 1 CH / 7 CH	÷1152 1 CH / 7 CH	÷288 1 CH / 7 CH	÷72 1 CH / 7 CH	÷36 1 CH / 7 CH	÷20 1 CH / 7 CH	RMS (-VDC) 1 CH	RMS (-VDC) 7 CH	C/I (db)
60.7	2.0		243418 240721 243093		9.65×10^{-3}	9.366	9.222	7.62	6.895	5.618	4.052	3.001	2.06		2.4980	5.01 (13.99)
55.9	2.0		145436 147246 142617		5.8×10^{-3}	9.16	7.102	6.715	6.372	6.306	3.80	2.828	1.952		2.49	5.44 (14.7)
50.0	2.0		45718 46675 42845		1.8×10^{-3}	6.47	6.287	6.076	5.81	4.862	3.44	2.602	1.82		2.48	2.08 (15.7)
46.5	2.0		15001 15351 14754		5.98×10^{-4}	6.134	5.968	5.768	5.512	4.622	3.24	2.479	1.741		2.48	6.54 (16.3)
41.1	2.0		891 1009 1012		3.86×10^{-5}	5.760	5.62	5.442	5.217	4.410	3.005	2.364	1.691		2.46	7.4 (17.4)
38.3	10.0		328 313 344		2.6×10^{-6}	5.455	5.302	5.113	4.886	4.116	2.621	2.212	1.566		2.47	7.94 (17.99)

BASEBAND EYE VOLTAGE RMS - 0.304 VRMS

TABLE 2-19. AM MODULATION - 100 PERCENT, 1 kHz MODULATING TONE - 3.1864 MHz CARRIER

Inter-ference Level	Time	Error Count Vicom T1-4000 4023-B Card			BER	Dispersion (-VDC)								RMS (-VDC)		C/I (db)
						÷9216	÷4608	÷2304	÷1152	÷288	÷72	÷36	÷20			
						1 CH	1 CH	1 CH	1 CH	1 CH	1 CH	1 CH	1 CH			
MVRS	Sec	1 CH	7 CH	1 CH	7 CH	7 CH	7 CH	7 CH	7 CH	7 CH	7 CH	7 CH	7 CH	1 CH	7 CH	
64.0	2.0		234489 233646 232552		9.3×10^{-3}	9.418	9.34	9.197	8.504	6.125	4.370	3.213	2.088		2.5038	4.75 (13.5)
60.1	3.0		167731 167863 169025		6.7×10^{-3}	9.388	9.277	8.997	7.1	5.753	4.119	3.037	1.999		2.499	5.06 (14.08)
54.7	2.0		82222 80304 82152		3.24×10^{-3}	9.255	8.701	6.671	6.289	5.240	3.769	2.795	1.887		2.488	4.56 (14.9)
50.1	2.0		33304 31847 33376		1.31×10^{-3}	6.553	6.327	6.089	5.820	4.885	3.418	2.62	1.719		2.485	6.07 (15.66)
46.1	2.0		10467 10030 9465		3.98×10^{-4}	6.096	5.937	5.73	5.477	4.606	3.257	2.469	1.701		2.481	6.59 (16.4)
43.6	10		17251 16871 17046		1.36×10^{-4}	5.878	5.72	5.528	5.284	4.449	3.123	2.391	1.654		2.476	6.97 (16.9)
41.6	60		24651 24075 23773		3.21×10^{-5}	5.708	5.55	5.358	5.121	4.317	3.015	2.320	1.617		2.475	7.31 (17.3)
38.0	100		812 749 880		6.48×10^{-7}	5.415	5.263	5.08	4.857	4.105	2.841	2.211	1.55		2.474	8.00 (18.06)

BASEBAND EYE VOLTAGE RMS - 0.304 VRMS

Section 3

ANALYTICAL DISCUSSION OF PROBABILITY DISTRIBUTIONS

3.1 METHODS FOR COMPUTING DISTRIBUTIONS OF FUNCTIONS

There are several methods for computing the probability distribution of a random variable y defined by a known deterministic function of a random variable x whose distribution is know. The functional relation may be expressed

$$y = g(x), \tag{3-1}$$

where,

$g(\cdot)$ is a known functional form.

x is a a random variable whose probability density function is $f_x(x)$. Here, the subscript x on f denotes the x density functional from $f_x(\cdot)$, and the x in the argument $(\cdot)$ denotes the random variable x.

y is a random variable whose probability density function, as yet unknown, is denoted by $f_y(y)$, the notation being the same as above, noting that f_x and f_y are different functional forms.

The desired result is to find the probability density function $f_y(\cdot)$ from a knowledge of $g(\cdot)$ and $f_x(\cdot)$.

3.1.1 Probability Density Function Method

To illustrate this method, consider the deterministic curves $y = g(x)$ defined by Equation 3.1, as shown on Figures 3.1a and 3.1b.

Figure 3.1a denotes a monotone curve which has a single value y for single value x, and inversely. Whenever the random variable y occurs in the domain dy, the random variable x will lie in the domain dy, the random variable x will lie in the domain dx and the probabilities are equal. Using the definition of probability density functions, this equality requires that

$$f_y(y)dy = f_x(x)dx \tag{3-2}$$

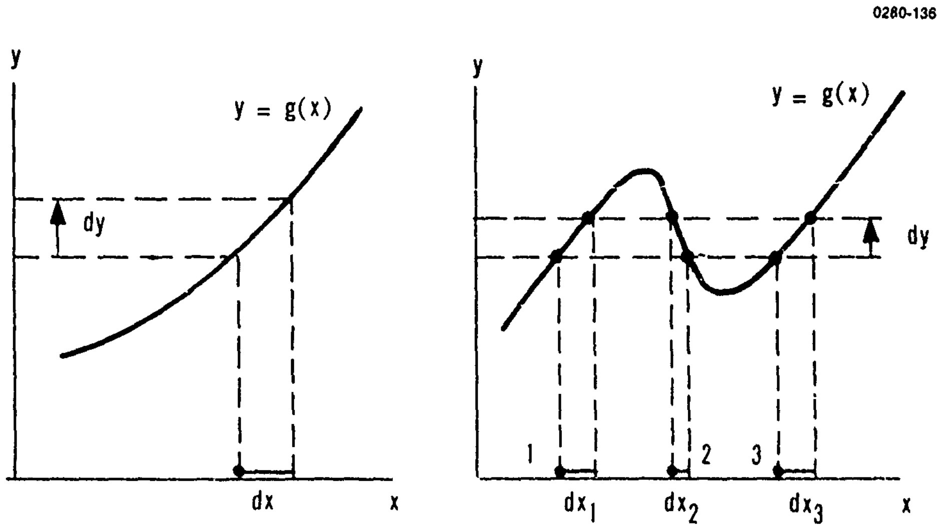


FIGURE 3-1. PROBABILITY DENSITY FUNCTION

From the functional relation of Equation 3-1,

$$dy = g'(x)dx \tag{3-3}$$

where $g'(\cdot)$ is the derivative. The desired result, using Equation 3-2 is given by

$$f_y(y) \cdot g'(x)dx = f_x(x)dx$$

or

$$f_y(y) = \frac{f_x(x)}{|g'(x)|} \tag{3-4}$$

where the absolute value has been used to account for the situation in which $g'(x)$ is negative. This follows from the requirement that the density functions are positive and that the projection of the segment of the curve on the axis x is the same whether the curve is rising or falling.

The results in a more general case may be established by observation of Figure 3-1b. Here, for a given y and its domain dy, there are three corresponding domains, dx_1, dx_2, and dx_3.

Then, a random y in dy will occur only if x is in dx_1, or dx_2, or dx_3. Since these are independent events, the probability that y is in dy is equal to the sum of the probabilities that x is in dx_1, or dx_2, or dx_3. This equality of probabilities requires that

$$f_y(y)dy = f_x(x_1)dx_1 + f_x(x_2)dx_2 + f_x(x_3)dx_3$$

But

$$dy = g'(x)dx \text{ and } dy_1 = dy_2 = dy_3 = dy_1$$

so that

$$dy = g'(x_i)dx_i \text{ for all } x_i \quad .$$

The results is then

$$f_y(y) = \frac{f_x(x_1)}{|g'(x_1)|} + \frac{f_x(x_2)}{|g'(x_2)|} + \frac{f_x(x_3)}{|g'(x_3)|} \tag{3-5}$$

which clearly holds for any number of roots x_i of the Equation 3-1, for a given value of y. Generally, the original Equation 3-1 is used to express x in terms of y.

As an example, consider the random variable y defined by

$$y = a\ x + b$$

where a and b are deterministic and x is a random variable whose density is known and denoted by $f_x(x)$. The, using the above formulas

$$y = g(x) = a\ x + b$$

$$g'(x) = a$$

$$f_y(y) = \frac{f_x(x)}{|\ a\ |}$$

But from the defining relation

$$x = (y-b)/a$$

and

$$f_y(y) = \frac{1}{|a|} f_x\left(\frac{y-b}{a}\right)$$

3.1.2 Random Cosine Wave

A second example is given by the concept of a random cosine wave. Let I_p be a random variable defined by

$$I_p = P \cos(\omega pt + \phi)$$

for fixed ωp and ϕ, the random wave is introduced by sampling the time t at random. Then, the argument represents a random variable, let this be denoted by x, and then if t, is selected at random any value of x is equally likely. This corresponds to a uniform distribution on x, and the problem becomes one of determining the density function of I_p given by

$$I_p = P \cos(x),$$

when x is a uniformly distributed random variable, with a constant function in $0 < x < 2\pi$. Hence,

$$f_x(x) = \frac{1}{2\pi} \qquad \begin{array}{l} 0 < x < 2\pi, \\ x = 0 \text{ elsewhere} \end{array}$$

then, assuming P is a constant, the above formulas give

$$f_{I_p} = \frac{1}{\pi}\left(P^2 - I_p\right)^{-1/2} \qquad |I_p| < P$$

$$= 0 , \quad |I_p| > 0$$

3.1.3 Distribution Function Method

With reference to Figure 3-1a, it is seen that whenever the random variable Y is less than a selected value of Y, the random variable X is less than the value of X corresponding to the selected value of Y. That is, in terms of probability,

$$P(Y < Y(\text{selected})) = P(X < X(\text{corresponding}))$$

These expressions are the distribution functions defined by

$$F_y(y) = \int_{-\infty}^{y} f_y(y)dy, \quad F_x(x) = \int_{-\infty}^{x} f_x(x)dx \tag{3-6}$$

from which, by definition of the derivative,

$$F_y'(y) = f_y(y), \quad F_x'(x) = f_x(x) \tag{3-7}$$

the resulting formula is

$$F_y(y) = P(x < (\text{corresponding } x)) = F_x\begin{pmatrix}\text{value of } x\\ \text{in terms of } y\end{pmatrix} \tag{3-8}$$

Example. Consider again the problem to find the density $F_y(y)$, given

$$y = a\,x + b$$

From Equation 3-8, for $a > o$

$$F_y(y) = F_x(x) = F_x\left(\frac{y-b}{a}\right)$$

Using Equation 3-7,

$$f_y(y) = F_x'\left(\frac{y-b}{a}\right)\frac{d}{dy}\left(\frac{y-b}{a}\right)$$

$$= f_x\left(\frac{y-b}{a}\right) \cdot \frac{1}{a} \quad \text{, as before}$$

Extensions of this method to multidimensional cases follow the same principles as shown in Reference 4. In particular, an important case is when a product of two random variables is involved. Let the random variable Z be defined by Z = X,Y. The resulting density function of Z is, in general,

$$f_Z(z) = \int_{-\infty}^{\infty} \frac{1}{|x|} f_{x,y}\left(x, \frac{z}{x}\right) \cdot dx$$

where F_{xy} is the joint density function of X and Y. If X and Y are products, as is here the case,

$$f_{xy} = f_x \cdot f_y$$

when X and Y are independent.

For the case of amplitude modulated cosine waves, the amplitude P is random in the sense of random sampling as mentioned Paragraph 3.1.1. For that case with random P,

$$Y = \cos X$$

$$I_p = P \cdot Y,$$

and the density function is given by

$$f_{I_p}(I_p) = \int_{-\infty}^{\infty} \frac{1}{|P|} f_p(p) \cdot f_y(I_p/p) \cdot dP$$

As expected, the distribution of the cosine wave and AM modulation are quite different, as shown by the curves in Section 6.

In the same way, the distribution for the FM modulated cosine wave can be determined by noting that the FM tone shifts the results of uniform sampling mentioned in Paragraph 3.1.1, and the resulting distribution may be computed by ovserving that the distribution of the variable called X is no longer uniform. Clearly if the cosine signal is tone modulated, the differences would be less than if random wave caused the modulation. Also, it is clear that if the FM frequency shift caused by a tone is small compared with the carrier frequency, then the distribution would be nearly the same as a pure cosine wave. This is confirmed by the results of Section 6.

Section 4

BASIC ERROR EQUATION ANALYSIS

The error equation derived in Section 1 may be written

$$P = Q(AD) + Q(D) \tag{4-1}$$

where the other terms of Equation 1-1 are dropped because of their small relative size, and where,

P = 4 (pseudo error rate) = 4 (count down ratio)

Q = complementar distribution function, unknown

A = normalized dispersion, measured

D = normalized noise, unknown

In the use of Equation 4-1 in Reference 1 and in Section 1, the noise which generated the distribution function Q was assumed to be Gaussian. Accordingly, in Equation 4-1 for that case, Q is a known functional form and P and A are known values. A value of P is selected for use as BEM input and A is measured as the resulting BEM output. Then, for each pair of known values (P, A) Equation 4-1 may be uniquely solved for D, the only unknown value in the equation. A measure of the closeness of Q to a true Gaussian distribution is provided by the values of D computed for each pair (P, A).

In a real problem of unknown wave forms, the selected pseudo error rate and a measured A = (A/D) ratio are the only known quantities. However, to solve the equation, it is necessary to know the distribution function of the unknown wave form. This identification problem of unknown Q has been studied, and methods of solution have been investigated. The method of Gram-Charlier for representing density functions is one approach, now described. This procedure, applied to the present problem, expands the density function of the distribution in a series whose terms are the normal density function and its derivatives. To illustrate this, the following notatioms are used:

f(u) = any general density function

$$f(t) = \text{distribution function}$$

$$= \int_{-\infty}^{t} f(u)du = P(u<t)$$

$$Q(t) = \text{complementary distribution function}$$

$$= 1 - F(t) = P(u>t)$$

The present application represents $f(y)$ in a series of terms given by the normal density,

$$g(y) = \frac{1}{\sqrt{2\pi}} e^{-y^2/2}$$

and its derivatives. Thus,

$$f(y) = C_0 g(y) + C_1 g'(y) + C_2 g''(y) + \ldots,$$

which C_1 are coefficients to be determined from the measured data, as now discussed from the definition of $g(y)$, it follows that

$$g'(y) \quad - \frac{1}{\sqrt{2\pi}} e^{-y^2/2} \cdot y,$$

and other terms of the series are found by sequential differentiation.

From the derivation of the error equations in Section 4, the relation between the pseudo error rate, the measured A = (A/D) ratio, and the unknown D = (D/N) ratio is (to a two term approximation)

$$P = Q(A \cdot D) + Q(d)$$

where

P = 4 x psuedo error rate, known

Q = the unknown complementary distribution function

A = (A/D) ratio, unknown

D = (D/N) ratio, unknown

Sequential differentiation of g(y) shown that the expansion for f(y) may be written

$$f(y) = b_0 e^{-y^2/2} + b_1 y\, e^{-y^2/2} + b_2 y^2 e^{-y^2/2} + \ldots$$

by absorbing constants into the undetermined coefficients b_1. Integration of f(y) gives

$$Q(y) = b_0 \int_y^\infty e^{u^2/2}\, du + b_1 \int_y^\infty u e^{-u^2/2}\, du + b_2 \int_y^\infty u^2 e^{-u^2/2}\, du + \ldots$$

for as many terms as used in the representation, and it is seen that the expression is related to the moments of the distribution. In order that f(y) be a density function, it is necessary that

$$f(y) \to 0 \text{ as } y \to \pm\, \infty$$

$$Q(-\infty) = 1$$

The form of f(y) assures that the first condition is met, and the second condition imposes the requirement on the coefficients,

$$1 = b_0 \int_{-\infty}^\infty e^{-u^2/2}\, du + b_1 \int_{-\infty}^\infty u e^{-u^2/2}\, du + b_2 \int_{-\infty}^\infty u^2 e^{-u^2/2}\, du + \ldots.$$

which is easily evaluated in terms of normal density functions.

The other conditions for determining the coefficients are given by the pseudo error rate equation,

$$P = Q(A \cdot D) + Q(D)$$

given above, with only D as the unknown, and Q is expressed by the Gram-Charlier series.

For selected values of the pseudo error rate, P is known, A is measured, and the form of Q is given by the above series expression. The unknown coefficients may be determined in the following way, using only three coefficients, b_0, b_1, b_2 for illustration.

For three selected pseudo error rates, and three measured values of A, called P_1, P_2, P_3, and A_1, A_2, A_3, these values are known.

The above equation evaluated at these points then becomes the set of equations,

$$P_1 = Q(A_1D) + Q(D)$$

$$P_2 = Q(A_2D) + O(D)$$

$$P_3 = Q(A_3D) + Q(D)$$

$$Q(-\infty) = 1$$

where for example

$$Q(A_iD) = b_0 \int_{A_1D}^{\infty} e^{-u^{2/2}}\, du + b_1 \int_{A_1D}^{\infty} ue^{-u^{2/2}}\, dy + b_2 \int_{A_1D}^{\infty} u^2 e^{-u^{2/2}}\, dy$$

with similar expressions for $Q(A_2D)$ and $Q(A_3D)$ $Q(-\infty) = 1$ given in expanded form above.

The above four equations in their expanded form provide for th. explicit determination of the unknowns, D, b_0, b_1, b_2, by numerical techniques. With the coefficients known, the ditribution is known. This distribution may then be compared with the distribution of specific, known, interfering wave forms to match the observed results with a standard form. Methods for making the comparison are discussed in Sections 9, 10 and 11.

Practical numerical methods for approximating the above analysis are given in Sections 5, 6, 7, and 8.

Section 5

BASIC RELATIONS DETERMINED BY EXPERIMENTAL BEM MEASUREMENTS

5.1 INTRODUCTION

As discussed in Section 4 and in Reference 1, the basic equation which relates the measured pseudo error rate to the probability of detecting a pseudo error is

$$P = Q(AD) + Q(D) \tag{5-1}$$

where,

P = 4x (measured pseudo error rate)

= 4/C

C = countdown factor

A = (a/d), a known value

D = (d/n), an unknown value

n = standard deviation of the error signal

d = known constant = 0.9 volt for BEM tests

a = (measured dispersion)/11.05

11.05 volts = reference for BEM tests

Q = complementary distribution function.

The countdown factors chosen for the BEM test were C = (9216, 4608, 2304, 1152, 288, 72, 36, 20). For each chosen value of C, P = C/4 is a known constant, and from BEM measurements for a given signal type, a dispersion value is measured. The variables a and A defined above are then given by

a = (measured dispersion)/11.05

A = (measured dispersion/(9 x 11.05)

A = (measured dispersion)/(9.945)

Since the dispersion is measured and C is measured, P and A are known quantities in Equation 5-1. If the form of the distribution Q is assumed known, as was the case in Reference 1, then D is the only unknown and the equation may be solved for D.

However, if the distribution of the error signal is not necessarily Gaussian, but unknown, then a sequence of BEM measurements (to provide a set of values A for a set of selected values C) could then be used to construct the form of the distribution Q for different selected error signals.

If the measurements produced a sufficiently different Q distribution for each of the error signal types selected, then the Q distribution (constructed from the BEM measurements) of an unknown signal could possibly be used for its identification. This would be done by selecting the known distribution which most nearly corresponds to the unknown distribution. To accomplish the task of signal identification using the BEM measurements described above, a sequence of steps is required:

1. Select signals to be used for reference.

2. Using BEM measurements, determine the dispersion value corresponding to each selected countdown ratio for each signal type.

3. Repeat Step 2 for each of several selected signal power levels.

4. Develop a method for determining the form of the Q distribution for each selected reference signal.

5. Analyze the results graphically to determine if the resulting Q distributions are sufficiently different to offer the possibility for identification of an unknown signal.

6. Assuming a positive result in Step 5, develop a method for the analytical discrimination of signals, the method to be computer based and more powerful than the graphical analysis of Step 5.

7. Develop computer programs as required in the above sequence to support the analysis and perform numerical calculations.

8. Formalize the computer programs so that BEM measurements of an unknown signal are input to a computer program, resulting in the identification of the unknown signal.

Steps 1, 2, and 3 have been discussed in Section 2. The remaining steps will be described in the sections following.

5.2 DETERMINATION OF THE COMPLEMENTARY DISTRIBUTION FUNCTION

A general discussion of the probability distributions associated with the fundamental Equation 5-1 has been given in Section 4. Here a method for the practical determination of the Q distribution is presented.

Repeating Equation 5-1 for convenience,

$$P = Q(AD) + Q(D)$$

where the terms are defined in Subsection 5.1, it is again recalled that the solution for D is a known function, for D is the only unknown in a single equation. In the present case, however, Q is unknown and it is necessary to determine its functional form. This can be done in an approximate way, as outlined in Section 4 by evaluating the equation for a sequence of known countdown ratios and their corresponding dispersions, as provided by BEM measurements. The procedure given, however, is computationally quite involved.

In order to approach the present problem from a practical, computational viewpoint, approximations to Q which are linear in the coefficients were investigated. This was carried out computationally for a variety of different distributions. Two of these which are significantly different in shape, the Gaussian and the CW wave, were investigated and it was found that approximations within an error of less than 5 percent were possible when using equations which are linear in the coefficients.

Using the approximation,

$$Q = 0.5 + az + bz^2 + cz^3 + dz^4,$$

in the pseudo error rate equation, for illustration, gives

$$\begin{aligned} P - 1 = {} & a\,(A \cdot D) + b\,(AD)^2 + c\,(AD)^3 + d\,(AD)^4 + \\ & a\,(D) + b\,(D)^2 + c\,(D)^3 + d\,(D)^4 \end{aligned}$$

This represents one equation and 5 unknowns a, b, c, d, D. By selecting 4 different values of P, and 4 measured values of A, the equation is evaluated at each of these points. Let P - 1 = G, and the equations are (evaluated at the subscript point i),

$$G1 = a\,(A1 \cdot D) + b\,(A1 \cdot D)^2 + C\,(A1 \cdot D)^3 + d\,(A1 \cdot D)^4 + a\,(D) + b\,(D)^2 + C\,(D^3) + d\,(D)^4,$$

plus three other similar equations evaluated at other selected points, A2, A33, A4, and G2, G3, G4.

These four equations are augmented by conditions on the distribution function, as shown below, to provide the required number of equations.

The resulting equations define the problem, and their solution provides the desired result; that is, a determination of the unknown noise factor D, and the complementary distribution function Q.

The particular form of the equation chosen for illustration is linear in the coefficients and is, therefore, particularly easy to solve.

It is noted from the above G1 equation that the unknowns a, b, c, d, D are not linearly related because of product terms, aD, bD^2, cD^3, dD^4. However, as now shown, these equations are easily solved. To accomplish this, recall that the values of G1, G2, G3, G4; A1, A2, A3, A4 are known. Then let the new unknowns t, u, v, w be introduced by the relations,

$$\begin{aligned} aD &= t \\ bD^2 &= u \\ cD^3 &= v \\ dD^4 &= w \end{aligned}$$

Then, substitution into the G equations gives

$$\begin{aligned} G1 &= (A1+1)\,t + (A1^2+1)\,u + (A1^3+1)\,v + (A1^4+1)\,w \\ G2 &= (A2+1)\,t + (A2^2+1)\,u + (A2^3+1)\,v + (A2^4+1)\,w \\ G3 &= (A3+1)\,t + (A3^2+1)\,u + (A3^3+1)\,v + (A3^4+1)\,w \\ G4 &= (A4+1)\,t + (A4^2+1)\,u + (A4^3+1)\,v + (A4^4+1)\,w \end{aligned}$$

which are four linear equations for the four unknowns t, u, v, w determined by the known values G1, G2, G3, G4; A1, A1, A3, A4.

so that

$$Q = 1-F = 0.5 + \int_0^z f\,(z)\,dz$$

from this, the derivative of Q (z) is

$$Q\ (z) = -F\ (z)$$

and the variance of z may be written, (see Equation 5-1a, next page)

$$\sigma_z^2 = 1 = 2 \int_0^K z^2\ f\ (z)\ dz$$

$$= -2 \int_0^K z^2\ Q'\ (z)\ dz$$

where zero mean is assumed, and K is the value of z for which the distribution is essentially zero. (Since Q is a distribution, such a point K must exist). Another unknown, K, has been introduced into the problem, but the Q approximation yields additional information. Using the expression for Q and integration the z^2 equation above by parts gives,

$$Q(K) = 0 = 0.5 + aK + bK^2 + cK^3 + dK^4 \tag{5-2}$$

$$\frac{1}{4} = \int_0^K z\ Q\ (z)\ dz = \int_0^K (0.5z + az^2 + bz^3 + cz^4 + dz^5)\ dz,$$

$$\frac{1}{4} = \frac{0.5}{2} K^2 + \frac{a}{3} K^3 + \frac{b}{4} K^4 + \frac{c}{5} K^5 + \frac{d}{6} K^6 \tag{5-3}$$

The solution of these equations gives specific known values for t, u, v, w. Let these be denoted t, u, v, w. Then, from the above definitions for $\bar{t}$, $\bar{u}$, $\bar{v}$, $\bar{w}$,

$$a = \bar{t}/D$$

$$b = \bar{u}/D^2$$

$$c = \bar{v}/D^3$$

$$d = \bar{w}/D^4$$

The remaining equations required to complete the solution are provided by the following relations.

For a random interfering wave, represented by the random variable X, its variance may be denoted by σ_X^2. This random variable may then be normalized by introducing the random variable z defined by $z = x/\sigma_X$.

Then, by the definition of a variance,

$$\sigma_z^2 = \frac{1}{\sigma_x^2} \cdot \sigma_x^2 = 1. \qquad (5\text{-}1a)$$

The normalized complementary distribution may be approximated, as indicated above, by

$$Q = 0.5 + az + bz^2 + cz^3 + dz^4,$$

with density function f(z) and $\sigma_z = 1$.

The distribution function F may be written

$$F = 0.5 + \int_0^z f(z)\, dz,$$

From the solution of the simultaneous equations, recall that t, u, v, w are now known, and that

$$a = t/D,\ b = u/D^2,\ c = v/D^3,\ d = w/D^4$$

Substitution in the two previous Equations 5.2 and 5.3 gives

$$0 = 0.5 + t\left(\frac{K}{D}\right) + u\left(\frac{K}{D}\right)^2 + v\left(\frac{K}{D}\right)^3 + w\left(\frac{K}{D}\right)^4 \qquad (5\text{-}4)$$

$$K = \left[\frac{1}{4}\left(\frac{0.5}{2} + \frac{t}{3}\left(\frac{K}{D}\right) + \frac{u}{4}\left(\frac{K}{D}\right)^2 + \frac{v}{5}\left(\frac{K}{D}\right)^3 + \frac{w}{6}\left(\frac{K}{D}\right)^4\right)^{-1}\right] \qquad (5\text{-}5$$

$$D = \frac{1}{(K/D)} \cdot K$$

$D = do/\sigma_x$; therefore,

$\sigma_x = do/D$, where do is the voltage offset.

The sequence of solution is this:

a. Measure dispersion values using BEM for each selected countdown ratio.

b. Solve the simultaneous system for t, u, v, w.

c. Solve Equation 5.4 for (K/D), knowing t, u, v, w.

d. Solve Equation 5.5 for K, knowing t, u, v, w, (K/D).

Compute $D = (1/(K/D) \cdot K$, knowing (K/D) and K

Compute $\sigma_x = d_o/D$, knowing d_o and D

Compute $a = t/D$, $b= u/D^2$, $c = v/D^3$, $d = w/D^4$,
knowing t, u, v, w, D

Evaluate $Q = 0.5 + az + bz^2 + cz^3 + dz^4$
knowing a, b, c, d. This is the desired distribution.

The above procedure has been carried out and exercised for numerous cases of measured data. The above illustration was for a curve fit involving four unknowns, which leads to an approximating equation of degree four. This required the use of four countdown ratios and four measured dispersion from BEM. Similar analyses have been carried out with polynomial equations of higher degree, requiring more count ratios and dispersion measurements. Results of all these analyses are discussed in Section 6 and 7.

Since BEM measurements (see Section 2) were taken for eight countdown ratios, it is possible to fit a curve of a given degree with an excess of data, rather than fit the curve with the minimum required number of points The use of an excess of data suggests a least squares procedure for fitting the data to the curve. Least squares results are discussed in Sections 6 and 7.

Section 6

CURVE FITTING METHODS FOR BEM DATA

6.1 FITTING AT SELECTED POINTS

In Section 5, the basic error rate equation,

$$P = Q(AD) + Q(D) .$$

was solved by assuming a polynomial form for Q and evaluating the equation at selected values of countdown ratios and the corresponding measured values of the dispersion. Thus, the function Q was forced to pass through selected points. The illustration used in Section 5 was based on assuming a polynomial of degree four, evaluated at four corresponding pairs of countdown ratios and dispersions. Alternatively, equations of degree three to eight were considered during the analysis. As is well known, this type of curve fitting, called collocation, leads to considerable error between the fitting points if the degree of the fitting equation is too high. After considerable experimentation, an equation of degree four and the four countdown ratios 9216, 2304, 288, 36, were used. Figure 6-1 shows the results for several different signal types, each signal type being averaged over the first four experimental power levels. Results from other power levels are similar. Observation of Figure 6-1 shows that the Q curves for the signals represented are significantly different.

6.2 LEAST SQUARES FITTING

As mentioned in Subsection 6.1, collocation methods lead to unwanted oscillations between fitting points for polynomials of high degree. To produce a smoother Q curve, the method of least squares was used. Following is a brief derivation of the method applied to the present problems.

6.2.1 Derivation of Least Squares Algorithm for the Present Application

Using a polynomial of degree four, for example, the Q function is represented by,

$$Q = 0.5 + az + bz^2 + cz^3 + dz^4$$

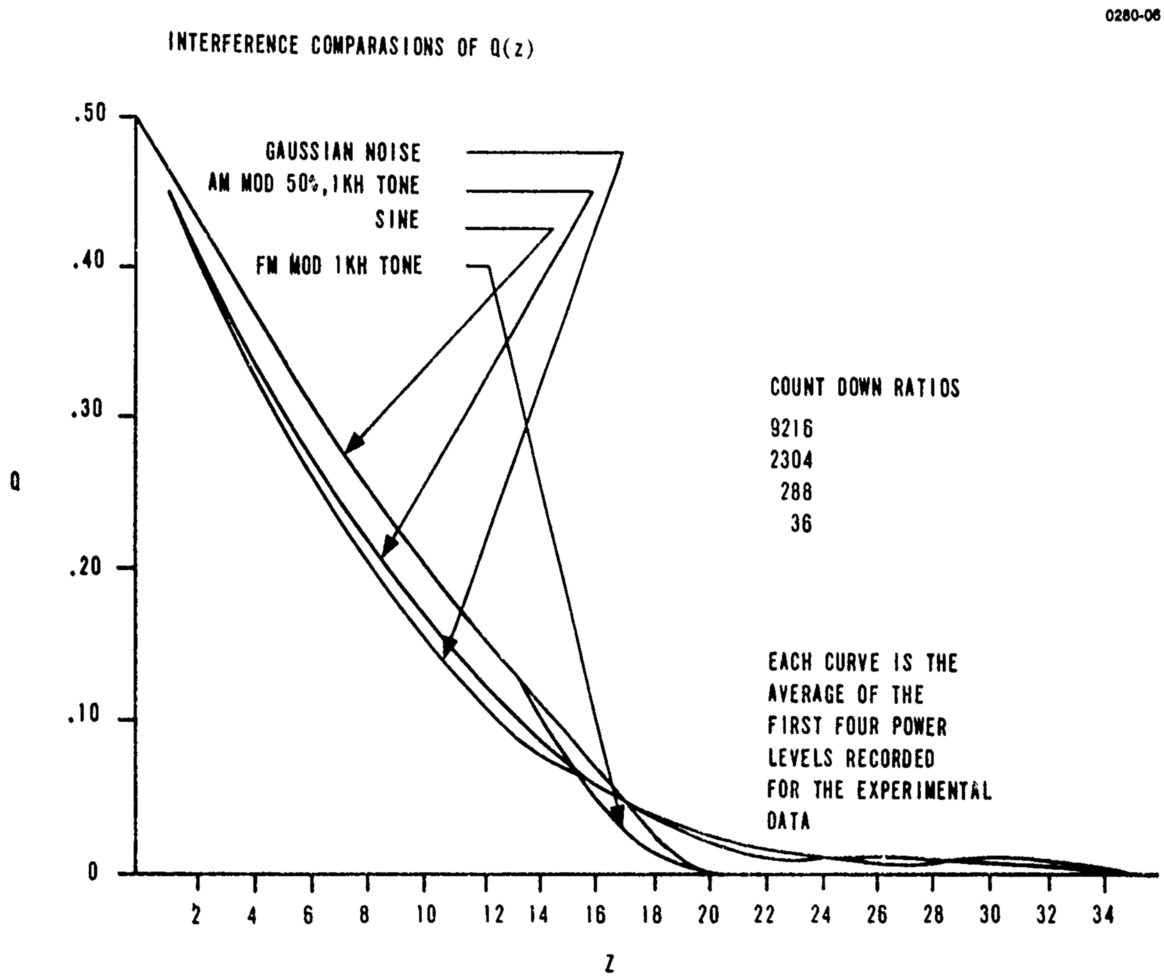


FIGURE 6-1. INTERFERENCE COMPARISONS OF Q(z)

Substitution of this form into the fundamental error rate equation,

$$P = Q(AD) + Q(D),$$

and letting G = P-1 gives

$$G = aD(1+A) + bD^2(1+A^2) + cD^3(1+A^3) = dD^4(1+A^4) \qquad (6\text{-}1)$$

Since the Q curve is to be determined from experimental data, the Equation 6-1 will not be satisfied exactly. Instead, for each measured value A an error exists between G and the right side of the equation. Let

$$\varepsilon = G - [aD(1+A) + bD^2(1+A^2) + cD^3(A+A^3) + dD^4(1+A^4)] , \qquad (6\text{-}2)$$

be the error at each point of the equation. The least squares solution then seeks to determine the coefficients (aD), (bD^2), (cD^3) so that the total error, $\Sigma\varepsilon^2$ is a minimum where summed over all input values A. As in Section 5, write the unknown coefficients in the form,

$$t = AD,\ u = bD^2,\ v = cD^3,\ w = dD^4, \qquad (6\text{-}3)$$

and insert these in Equation 6-2. The conditions on t, u, v, w, for minimizing

$$E = \Sigma\varepsilon^2$$

are,

$$\partial E/\partial t = 0,\ \partial E/\partial u = 0,\ \partial E/\partial v = 0,\ \partial E/\partial w = 0$$

Then, using the right side of Equation 6-2 to define E, the resulting equations are

$$\frac{\partial E}{\partial t} = \Sigma\varepsilon \frac{\partial \varepsilon}{\partial t} = -\Sigma\varepsilon(1+A) = 0$$

$$\frac{\partial E}{\partial u} = \Sigma\varepsilon \frac{\partial \varepsilon}{\partial u} = -\Sigma\varepsilon(1+A^2) = 0$$

$$\frac{\partial E}{\partial v} = \Sigma\varepsilon \frac{\partial \varepsilon}{\partial v} = -\Sigma\varepsilon(1+A^3) = 0$$

$$\frac{\partial E}{\partial w} = \Sigma\varepsilon \frac{\partial \varepsilon}{\partial w} = -\Sigma\varepsilon(1+A^4) = 0$$

The substitution of expression for E given by Equation 6-2 into the above relations, using the expressions in Equation 6-3, provide four linear equations for the determination of the unknowns (t,u,v,w). The first equation is,

$$t\Sigma(1+A)^2 + u\Sigma(1+A^2)(1+A) + v\Sigma(1+A^3)(1+A) + w\Sigma(1+a^4)(1+A) = \Sigma G(1+A),$$

and the remaining three equations are similarly derived. From this point onward, the procedure for determining the complementary distribution function Q as a function of the nondimensional random variable z is identical to that given in Section 5. For the two procedures, collocation or least squares, exactly the same computer programs are used, except for the two different programs which compute the coefficients. Details of all these are discussed in Section 7.

As in Section 5, the use of a fourth degree equation was typical, not required. The set of computer programs will accept, by simple input declarations, polynomials as large as degree eight, and as many as eight countdown ratios. These limit values may be easily extended in the set of computer programs if desired.

For the present application, after extensive experimentation, it was found that the smoothest and most consistent curves for Q were generated by using a polynomial of degree four and the five countdown ratios (9216, 2304, 1152, 288, 36) processed by the least squares program.

Section 7

COMPUTER PROGRAMS FOR DETERMINING DISTRIBUTION FUNCTIONS FROM MEASURED BEM DATA

7.1 DISCUSSION

In Sections 5 and 6, the algorithms selected for computing the complementary Q distribution function were derived and discussed. Given in Section 7.2 are the names of the BASIC computer programs which were developed to compute the Q distributon as a function of the normalized random variable z. These have been converted to FORTRAN and are listed and documented in Appendix D, using the same names except for prefix. That is, LFLSQ1 becomes SGHSQ1.

The reason for the introduction of a normalized random variable is to minimize the effect of different power levels on the distribution function. The present approach accomplishes this quite well.

Results of a number of sample runs for different signal types are given in Section 8. These show that, in general, discrimination from a graphical viewpoint is possible for the signal types considered for a variety of different power levels.

The visual observations of the plotted Q curves can be made more accurate, and also automatic, by using discrimination algorithms which output an estimate, with a specified confidence, of the type of signal which is causing the interference. This is accomplished by a sequence of computer programs which are described in Section 10. This section deals only with the generation of Q distribution curves.

7.2 COMPUTER PROGRAMS

The programs which accept BEM experimental data input, and output the Q distribution as a function of the normalized random variable z are implementations of the algorithms developed in Section 5. These programs perform the following functions (see Figure 7-1), with reference to Section 5.

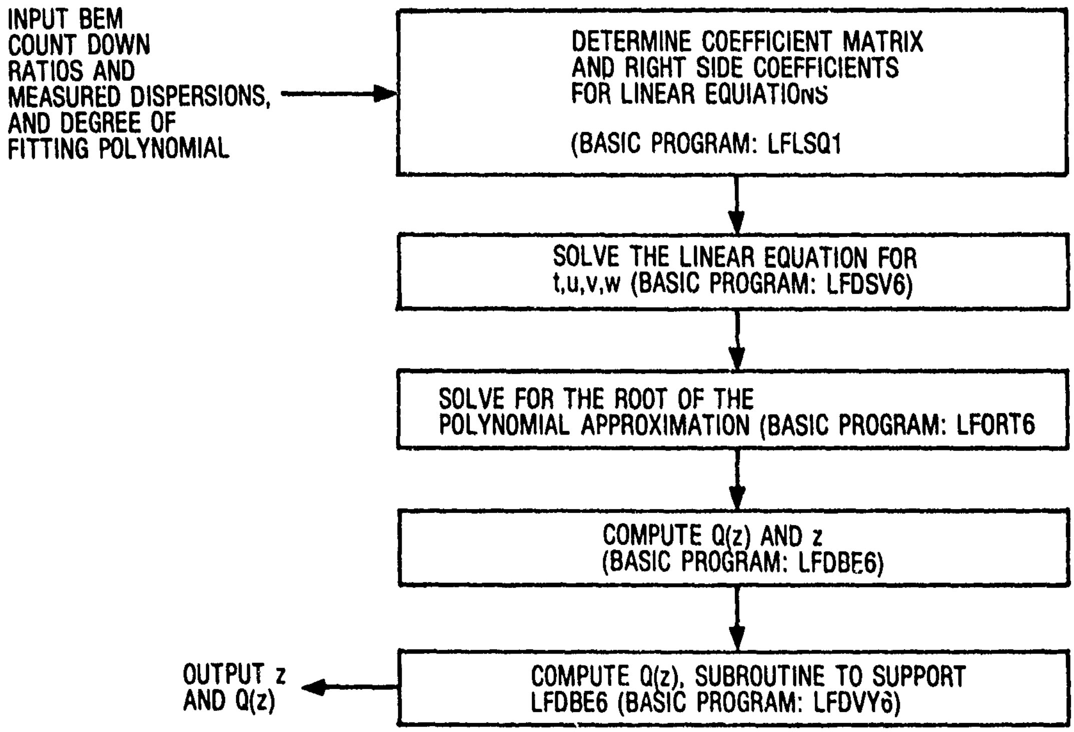


FIGURE 7-1. SOFTWARE PROGRAM SEQUENCE

The sequence of programs given in Figure 7-1 are for the case of curve fitting by least squares. Fitting by collocation may be accomplished by substituting the program listed on page D-26 for program SQHSQ1, all other programs remaining the same.

Section 8

RESULTS OF COMPUTER PROGRAMS APPLIED TO BEM DATA

8.1 DISCUSSION

During the development of the computer program algorithms, runs were made for various combinations of countdown ratios and measured dispersions for different assumed degrees of the fitting polynomials. This was repeated for each of the signal types considered and for a variety of power levels.

Of particular interest is the fact that the normalization procedure described in Section 5 served to a large extent to suppress the dependence of the Q curve on the power level of the data. This permitted the possibility of signal identification without regard to externally measuring the power level with additional equipment.

The results of some of the development runs are shown on the following figures which give plots of the Q function for conditions indicated thereon.

Figure 8-1 gives a summary of 25 runs for the signal AM MOD 100 percent using collocation, curve of degree four, and all measured power levels. The curves shown the extremes and average values. The curves show the normalizing effect of the selected algorithms. In this figure, four countdown ratios were used as shown; in each run the corresponding dispersion value was selected from the BEM measured data.

Figure 8-2 shows several different runs for different signal types as indicated. This figure shows the beneficial effects of normalization and the good visual discrimination between the signal types.

Figures 8-3 and 8-4 again show the indicated signal types at different power levels and the effect of normalization. The two curves show the FM modulating tone differences are not detectable in terms of the distribution function. This was to be

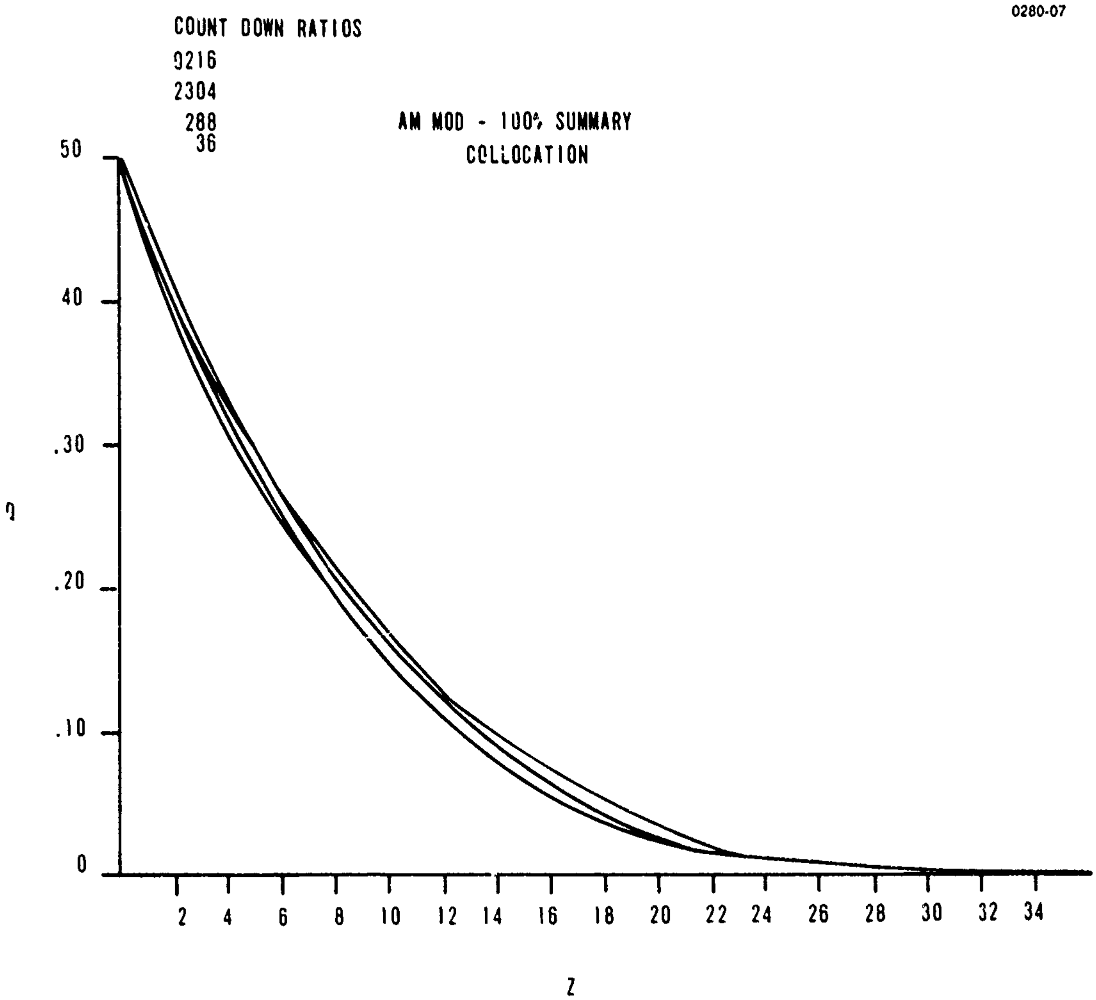


FIGURE 8-1. AM MOD - 100% SUMMARY COLLOCATION

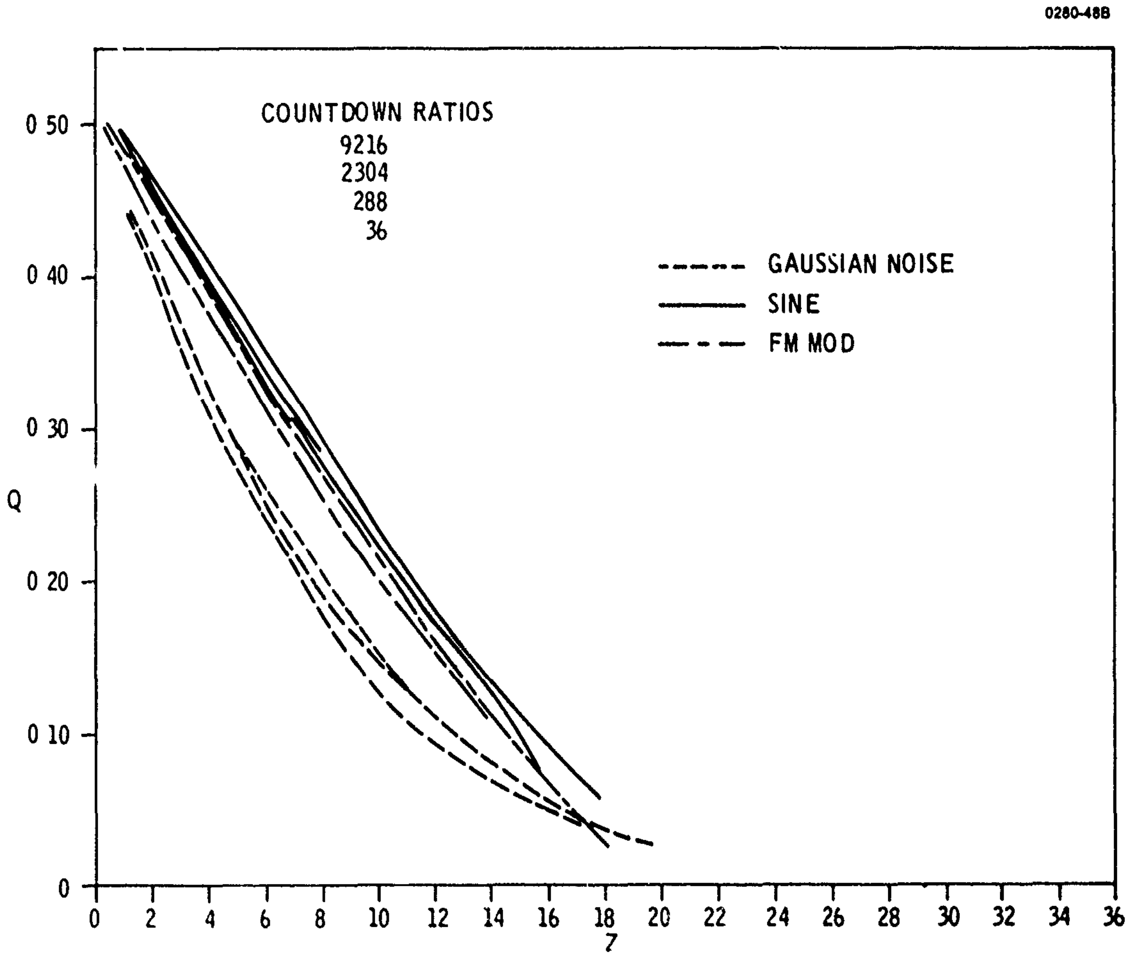


FIGURE 8-2. GAUSSIAN NOISE SINE MOD FM MOD

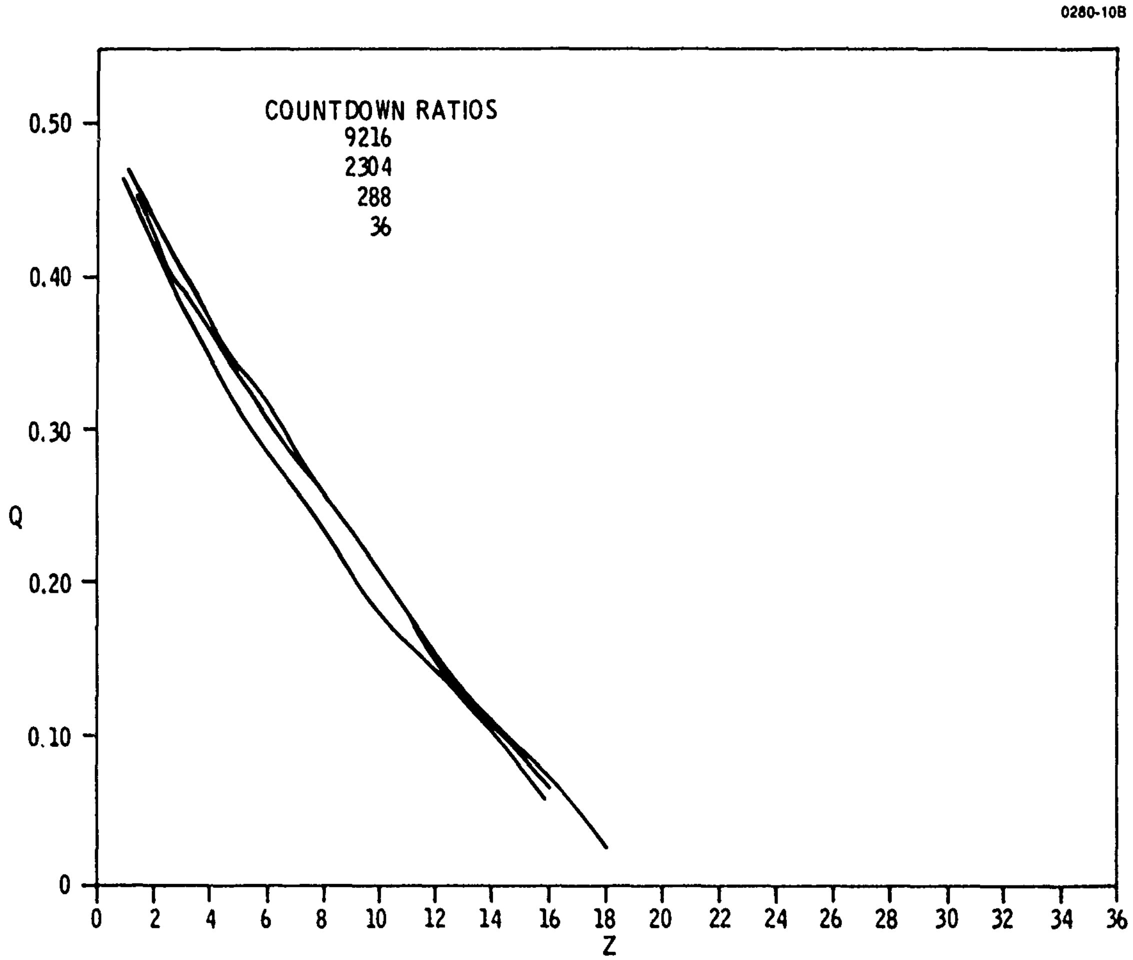


FIGURE 8-3. FM MOD 100 HZ TONE SUMMARY COLLOCATION
3.1864 MHZ CARRIER

0280-11B

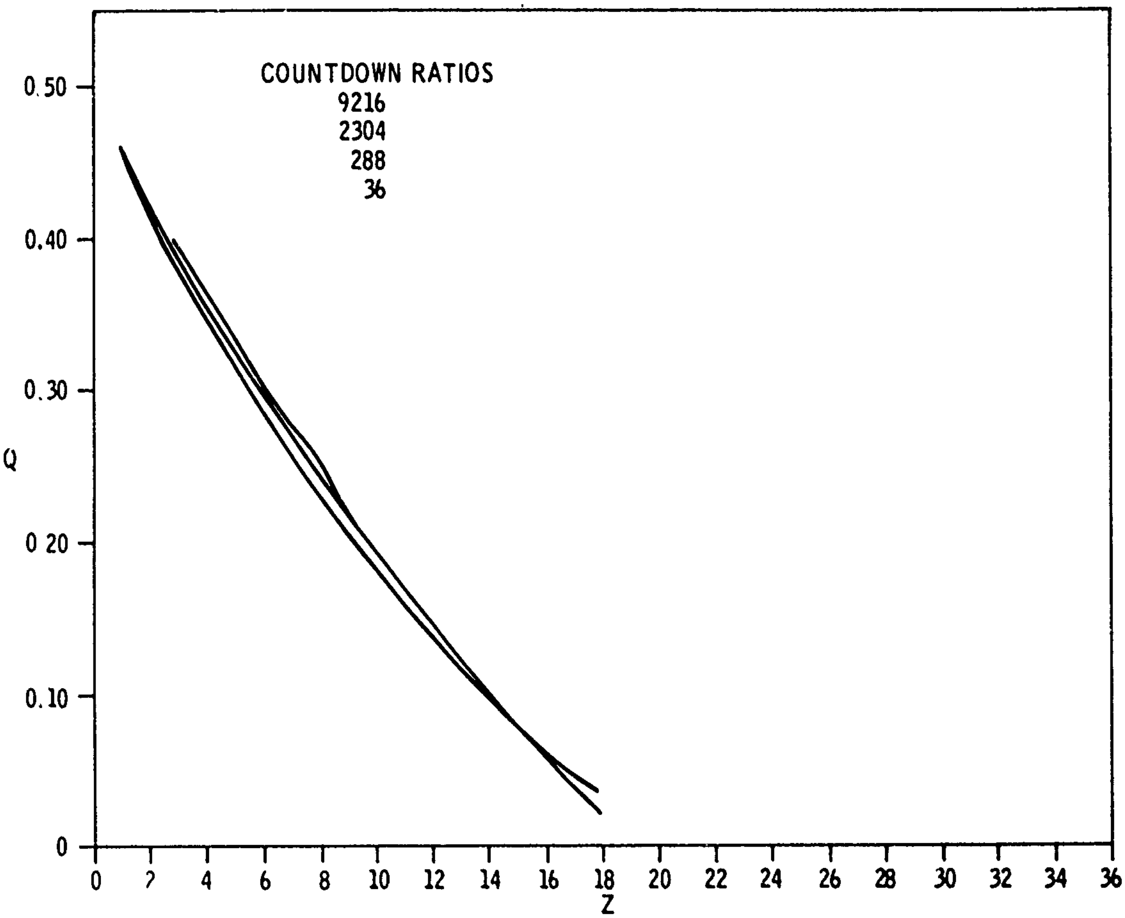


FIGURE 8-4. FM MOD 5 KHZ TONE SUMMARY COLLOCATION
3.1864 MHZ CARRIER

expected since, to the first order, a probability distribution for a random sine wave was added, as shown in Section 3. A difference would have been detected if the FM modulation had involved random noise.

Figure 8-5 shows a summary of different signal types of the types indicated.

These curves represent only a few of the runs completed during development. Runs for least squares using five countdown ratios and polynomials of different degrees were also used during development. The least square method using five countdown ratios and a polynomial of degree four was found to be, on the average, most suitable as the standard format because of the smoothness and consistency of the results. After initial testing and development, this combination was selected as the standard for building up the data base for later comparison with unknown signals. The construction of this data base is discussed in Section 9.

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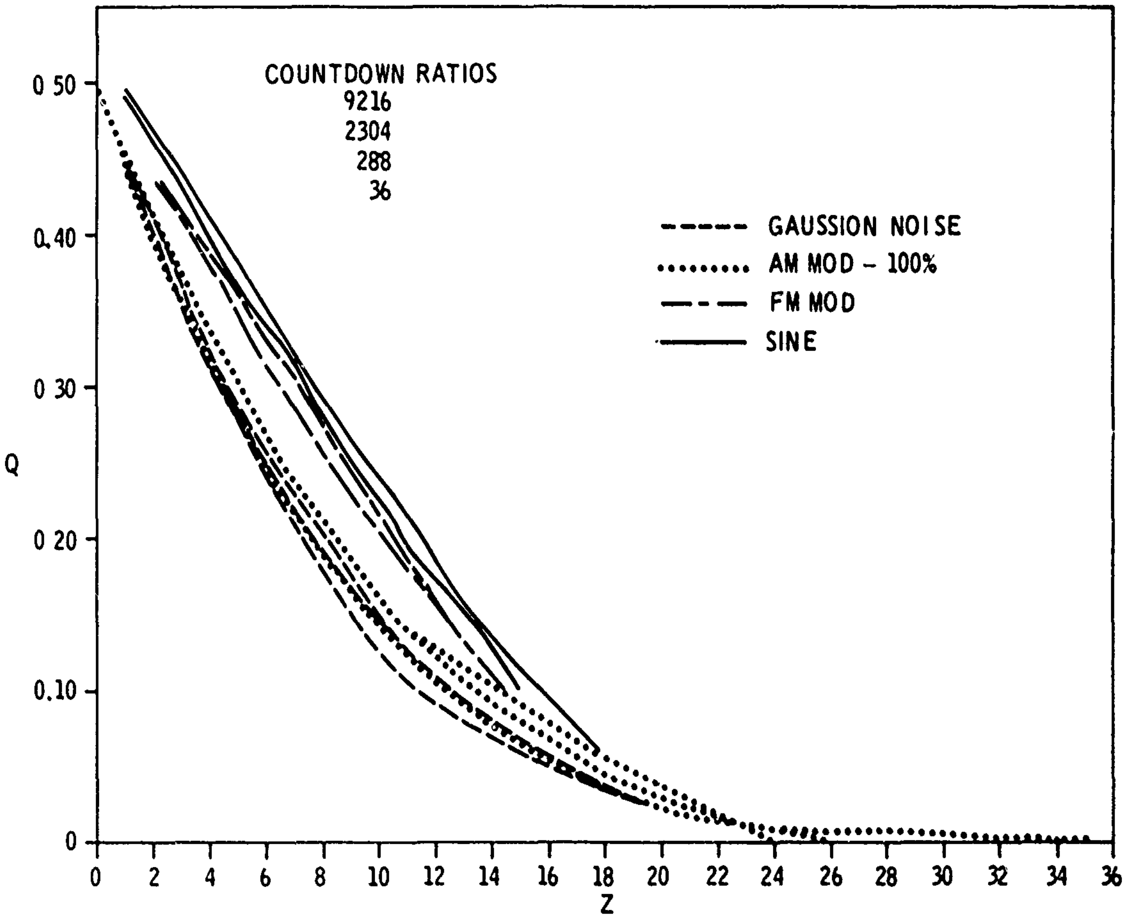

FIGURE 8-5. GAUSSIAN NOISE AM MOD - 100% FM MOD SINE

Section 9

ANALYTICAL METHODS FOR DISCRIMINATING BETWEEN SIGNAL TYPES

9.1 PATTERN RECOGNITION METHODS

Pattern recognition, References 2, 3 and many others, has become a well organized procedure in recent years for classifying objects as belonging to certain known groups. Following is a brief discussion of some of the basic ideas involved which are pertinent to the present application. Since a significant amount of computation is involved, even in simple cases, the discipline is strongly oriented to computer usage for applied problems. After a brief orientation, a particular method for the present application is selected and discussed.

9.2 SOME GENERAL COMMENTS

Consider a set of classes and a set of features for each member of a class. It is assumed that all classes have similar features but that the numerical values of the similar features for different members of the classes are (or may be) different. For example, consider a collection of round wooden rods which have the two features of diameter D and length L. Then, separate the rods into two classes: the first class contains all rods which weigh less than W pound each; the second class contains all rods which weigh greater than W pounds each. Each class may have many members, but each member of either class has only two measurable features: diameter D and length L.

The problem is to develop a rule so that an arbitrarily chosen rod of measured D and measured L can be assigned to its proper class. If this can be done, discrimination (or pattern recognition) has been accomplished.

This simple example illutrates a number of important aspects of discrimination:

1. Each class is well defined.

2. Each class contains items which have measurable features. These features are well defined and the same for each class.

3. The numerical values of the measured features are (or may be) different for each item.

4. Prior to application of the discrimination rule, any arbitrarily selected item may belong to any of the classes.

5. A proper discrimination rule will place an arbitrary item in its proper class, or at least in a class with a certain probability of success.

From the simple example and the above observations, some conclusions may be inferred:

1. The features chosen for measurement are not unique.

2. The features chosen for measurement may not be sufficient for discrimination.

3. The algorithm which defines functional relations between measured features to produce a discrimination rule is not unique and may not be adequate for discrimination.

4. In general, the best features and the best algorithm using those features for discrimination are not known in advance. Instead, they are chosen from various standardized forms, and then tested against experimental data for verification.

In the simple example of the wooden rods, a discriminate may be calculated from geometry if the wooden material is assumed to be of the same density. Then, the weight of a single rod is proportional to

$$z = K\,D^2 \cdot L$$

which will determine the proper class. However, simple geometric relations like this, in general, do not exist; or if they do, the complexity of the problem makes the relations not obvious. Also, in general, it is not obvious in advance if the measured features are sufficient for discrimination. In simple cases, however, the inadequacy is obvious. In the present case, if the rods were made of varying buy unknown material, then measurements of D and L alone would certainly not determine the weight of the rod. Based on the above and other more advanced considerations, a discrimination problem requires, at least:

1. A definition of the classes to be considered.

2. An assumption of the number and kind of features to be measured.

3. An assumption of the general form of the functional relation to be used for constructing the discrimination algorithm. This will contain a set of initially unknown parameters, to be determined by:

   - A set of items from which measured values of the selected features may be obtained to construct the parameters of the discrimination algorithm.

4. Verification of the discrimination algorithm, so that it determines the proper class for a measured item.

When the classes and the features are selected, and the measured data is tabulated for each item, it is generally not possible to properly assign each item to a class because of the scatter of the data and the complexity of the problem. In the discriminate approach to pattern recognition, it is assumed that a discriminate of the form

$$Z = f(a,x)$$

can be found which will separate the set of items into classes. This means that if the scalar Z is computed for an arbitrary item, then the value of the scalar determines the proper class. In the formula, f is a selected functional form, a is a vector,

$$a = [a_1, a_2, a_3, --a_n]$$

of parameters to be determined from measured data, and X is a vector

$$X = [X_1, X_2, X_3, --X_m]$$

of selected features to be measured. The idea is that, although the raw measurement data will not classify the item, a combination of its features will classify the item when the discriminate Z is properly chosen. This is similar in principle to choosing a polynomial form and a least squares criteria for an estimation problem.

As in many areas of applied analysis, discriminates are divided into two braod classes: linear and nonlinear. The latter offers better possibilities for discrimination, but at the expense of simplicity. For a linear assumption, the discriminate may be written:

$$Z = A \cdot X + W_o$$

when A is the above vector of parameters and X is the above vector of features. W_o is a scalar selected to set the base level of the discriminate Z.

First, suppose there are only two classes and for all data items $Z_1 > K > Z_2$. Then, an arbitrary item with Z greater than K belongs to class 1; otherwise to class 2.

Next, suppose there are three classes and for all data items $Z_1 > K_1 > Z_2 > K_2 > Z_3$. Then, an arbitrary item with $Z > K_2$, for example, will be compared with both Z_1 and Z_2 to determine its class. A similar argument holds for a greater number of classes.

In making the binary comparisons, it is noted that all the data from classes i,j is used to compute the Z discriminate for those classes.

An alternative approach is to consider all classes at the same time. The derivations for both approaches is well known in the literature. See, for example, References 2 and 3.

9.3 APPLICATION TO PRESENT APPLICATION

1. Selection of classes for consideration.

2. Selection of features to be measured.

3. Selection of experimental data from which numerical values of the features are computed for each individual of a class.

4. Selection of a method for placing an unknown individual in its proper class.

5. Selection of a computational method for establishing a data base to define each class.

During the development of this study, a variety of procedures were considered for meeting the above requirements. the following were selected:

1. The classes are the signal types selected.

2. The features are the second, third, and fourth moment of the normalized Q curve, together with the value K (see the algorithms of section 5) which is the value of z where Q first satisfies the relation $Q < 0.001$. These provide measurable differences in signal types.

3. The individuals of a class are each of the above moments and K, computed for selected power levels.

4. The linear discrimination method was used because of its classifying success in preliminary study and because of its simplicity.

9.3.1 Linear Discriminate Methods

To describe this discrimination procedure, assume first that there are two well defined classes 1 and 2, and that each class contains a number of individuals with two features which can be measured. Note that a vital assumption is that a data base can be constructed from the measured features of the individuals, each of which is known to be in a particular class.

Let the two measurable features of each individual be called X_1 and X_2 in each class, 1 and 2. The arrangement of the data may be visualized as shown in Figure 9-1.

EIGHT SUCH TABLES 0280-141

		1	2	3	4	5	6	7	8	9	10	
CLASS 1	X_1	–	–	–	a	–	–	–	–	–	–	$\bar{X}_{11}$
	X_2	–	–	–	–	–	–	–	–	–	–	$\bar{X}_{21}$
CLASS 2	X_1	–	–	–	–	–	–	–	–	–	–	$\bar{X}_{12}$
	X_2	–	–	–	–	–	–	a	–	–	–	$\bar{X}_{22}$

FIGURE 9-1. SAMPLE LINEAR DISCRIMINATE TABLE

In the above figure, numerical values may be assigned to each to indicate individuals. For example, the fourth individual in class 1 has the numerical value a for the measurement of its feature X; the seventh individual in class 2 has the numerical value b for the measurement of its feature X_2. The average of the numerical values for a given feature in a given class is shown at the right end of the figure. For example, $\bar{X}_{21}$ is the average for the second feature of all individuals in class 1.

In general, let the numerical values of Figure 9-1 be denoted by the following notation.

X_{pij} = the value of the pth feature for the jth individual in the ith class. In this notation, the value a of the figure is $a=x_{114}$, and the value b of the figure is $b=x_{227}$.

$\bar{X}pi$ = The value of the average of the pth feature in the ith class. Specific values of $\bar{X}pi$ are shown on the figure.

Suppose first that each value Xpij in class 1 is greater than the corresponding value of Xpij in class 2. Then the discrimination problem is easy. If a new unclassified individual is considered and both of its X and X_2 values are less than any of the X and X_2 values of class 1, then the individual is considered to be closer to class 2.

In general, however, the classification is not obvious because the individuals in the date base have Xpij values, which vary throughout the figure. In this event, it may be possible to transform the data base numbers to those in which the separation is obvious. The linear discriminant method assumes that a new parameter z can be computed from a linear combination of the features X, and X_2 such that classes 1 and 2 are separated in numerical value. Whether or not this separation is possible can only be answered by trial. That is, the z values are computed from the linear relation

$$z = \lambda_1 X_1 + \lambda_2 X_2$$

for each individual in the data base, where

z = the new parameter

X_1 = the numerical value of X_{1ig}

X_2 = the numerical value of X_{2ig}

λ_1, λ_2 - selected numerical values

Then, if the value of z for each individual in class 1 is greater than the value of z for each individual in class 2, the separation is complete. To identify an unclassified individual, use its X, and X_2 values used in the data base. The individual is then considered in the class having the z value closest to the z value of the new individual. However, if the z values in the data base are not separated, than the assumed form for the linear discrimination will not serve for classification. The linear assumption may fail for several reasons:

1. The features have not been wisely selected.

2. The number of features is too few.

3. The fundamental problem being studied is strongly nonlinear, and cannot be separated by linear combinations.

In the above Equation 9-1, the coefficients X_1 and X_2 were considered known constants, selected according to some criteria. The linear discriminate procedure provides an algorithm for choosing these coefficients so that the separation, by the parameter z, between the two classes is as great as possible.

9.3.2 Linear Discriminate Algorithm

Again, consider the example problem in which the individuals of class 1 and class 2 have specific values of X_1 and X_2. These, and their corresponding z values are shown in Figure 9-2. From a geometric view, it is desired to rotate the plane so that the resulting z values are as great as possible between classes and as small as possible within classes.

Linear discrimination selects the expression

$$(\bar{z}_1 - \bar{z}_2)^2 \qquad (9\text{-}2)$$

as a measure of separation between the classes, where $\bar{z}i$ is the average value of z in the ith class, and L = 1 or 2. The selected measure of separation within classes is chosen as:

$$\sum_{L=1}^{z} \sum_{j=1}^{ni} (zij - \bar{z}i)^2 \qquad (9\text{-}3)$$

where ni is the number of individuals in the ith class, $-\bar{z}i$ has been defined above, and zij is z value for the jth individual in the ith class. Note that the squares are chosen to eliminate cancellation by signs, and that the summation extends over both classes in Equation 9-3.

To accomplish the above definition of the separation criteria, the function G, defined by

$$G = \frac{(z_1 - z_2)^2}{\sum_{L=1}^{2} \sum_{j=1}^{ni} (zij - \bar{z}i)^2} \qquad (9\text{-}4)$$

is to be made a maximum.

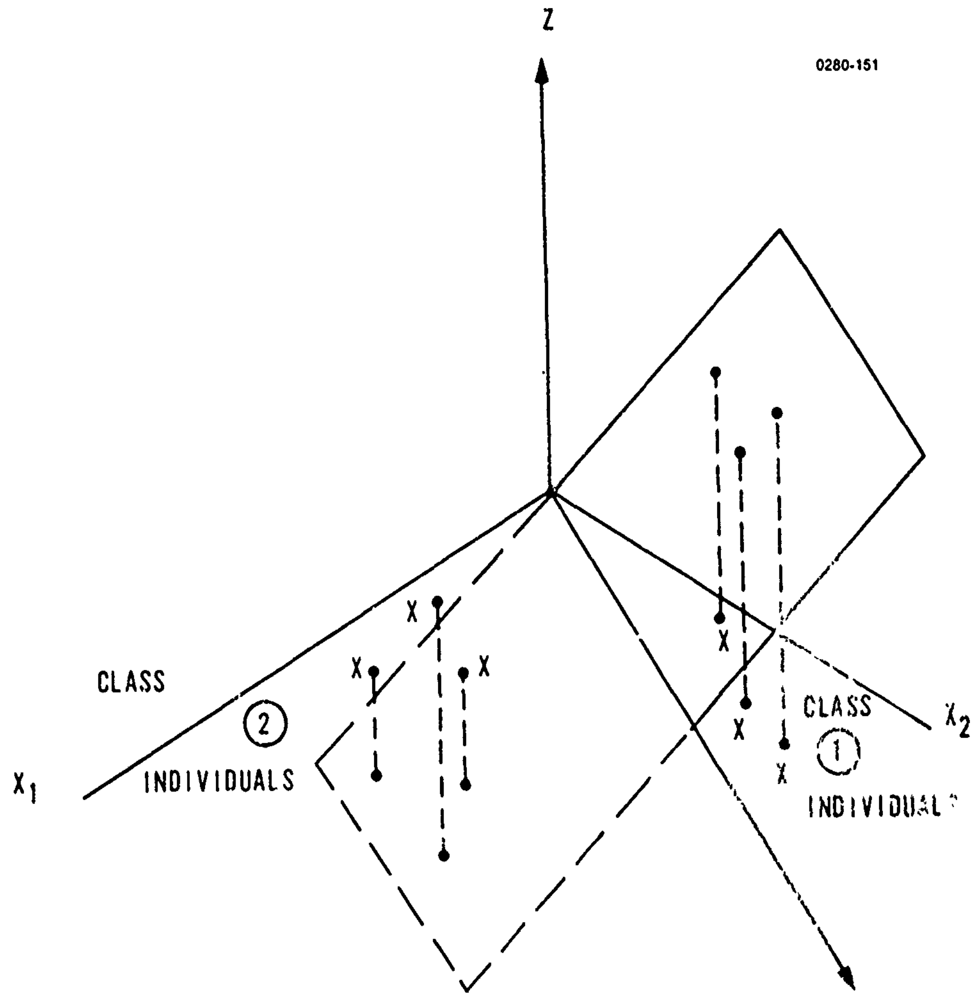

FIGURE 9-2. ABSTRACT Z VALUE MODEL

Reference to discussion of Paragraph 9.3.1 shows that each Xpij is known, and that each z is expressed in terms of Equation 9-1. Hence, in the G function of Equation 9-4 the only unknowns are the values of λ_1 and λ_2. The necessary conditions for a maximum are:

$$\partial G/\partial\lambda_1 = 0 \quad , \quad \partial G/\partial\lambda_2 = 0$$

which provide two equations and two unknowns for the determination of λ_1 and λ_2.

In the general case, the number of classes (for binary comparison) is still two, and the number of individuals may be any number. The number of features, however, may be any number. Since the basic Equation 9-4 is expressed in terms of z, and the general z value may be written, for k different features,

$$z = \lambda_1 X_1 + \lambda_2 X_2 + \ldots \lambda_K X_{K1}$$

The derivation may be carried out in general terms. To do this, the z values of Equation 9-4 are expressed in terms of the X_p features and the z values.

$$\bar{z}_1 - \bar{z}_2 = \lambda_1(\bar{X}_{11} - \bar{X}_{12}) + \text{---} + \lambda_K(\bar{X}_{K1} - \bar{X}_{K2})$$

Let

$$z_{ij} - \bar{z}_i = \lambda_1(X_{1ij} - \bar{X}_{1i}) + \text{---} + \lambda_K(X_{Kij} - X_{Ki})$$

$$S_{pq} = \sum_{i=1}^{2} \sum_{j=1}^{ni} (X_{pij} - \bar{X}_{pi})(X_{qij} - \bar{X}_{qi}) \tag{9-5}$$

$$d_p = \bar{X}_{p1} - \bar{X}_{p2} \quad , \quad d_q = \bar{X}_{q1} - \bar{X}_{q2} \tag{9-6}$$

Then, after some manipulation

$$(\bar{z}_1 - \bar{z}_2)^2 = \sum_{p=1}^{K} \sum_{q=1}^{K} \lambda_p \lambda_q \, d_p d_q \tag{9-7}$$

$$\sum_{i=1}^{2} \sum_{j=1}^{ni} (z_{ij} - \bar{z}_i)^2 = \sum_{p=1}^{K} \sum_{q=1}^{K} \lambda_p \lambda_q \, S_{pq}$$

Substitution of these expressions in Equation 9-4 uniquely gives G in terms of the known constants d_p, d_q, and S_{pq}. Differentiations of G with regard to the λ values provides the equations for the λ values. Because of the linear assumption of Equation 9-1 and the quadratic assumptions of the Equations 9-2 and 9-3, the resulting equations for the λ values are linear. The equations are:

$$\lambda_1 S_{p1} + \lambda_2 S + \text{---} \ \lambda_K S_{rK} = d_r \tag{9-8}$$

for the index r-1,---,k, where k is the number of features selected, and Equation 9-8 represents k equations.

After the Equations 9-8 are solved for the λ values, the expression

$$z = \lambda_1 X_1 + \lambda_2 X_2 + \text{---} + \lambda_K X_K$$

is evaluated for each individual in the classes, where in this notation, each value of an X is the corresponding value, $X_p = X_{pij}$ for the jth individual in the ith class.

This results in the construction of a z_{ij} table corresponding to the original X_{pij} table, Figure 9-1. For example, Z_{23} is shown by the letter a in Figure 9-3.

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		1	2	3	4	5	6	7	8	9	10
CLASS 1	Z_1	•	•	•	•	•	•	•	•	•	•
CLASS 2	Z_2	•	•	b	[illegible]	•	•	•	•	•	•

FIGURE 9-3. z_{ij} TABLE

9.4 SIGNAL DISCRIMINATION FOR PRESENT APPLICATION

For the present application, it is desired to first establish a data base from the measured BEM data given in Section 2. For each selected signal type and each selected power level the Q distribution curve as a function of the normalized random variable z (not the discriminate value z above) may be computed by using the programs described in Section 7. With these curves, a set of moments and a k value (see Section 5) may be computed for each selected signal type and each selected power level. (The computation of the moment is described in Paragraph 9.4.1). With these values, a correspondence with the abstract model described in Subsection 9.3 may be established.

Each signal type may be considered a separate class, and each moment is a different feature of that class. Different power levels represent different individuals of the class. The data base, according to the above definitions may be represented as in Figure 9-4.

0280-49

		1	2	3	4
		POWER LEVEL			
CLASS 1	K	—	—	—	—
		—	—	—	—
	M_2	—	—	—	—
	M_3	—	—	—	—
	M_4	—	—	—	—
CLASS 2	K	—	—	—	—
	M_2	—	—	—	—
	M_3	—	—	—	—
	M_4	—	—	—	—

FIGURE 9-4. MOMENT CLASSIFICATION TABLE

The corresponding z discrimination values are computed from the values of Figure 9-4 and the values computed from the Equation 9-7 as shown in Figure 9-5. For actual numerical values, see Figures (11-2) in Section 11.

0280-50

		1	2	3	4	POWER LEVEL
CLASS 1	Z_1	—	—	—	—	Z_1
CLASS 2	Z_2	—	—	—	—	Z_2

FIGURE 9-5. Z DISCRIMINATION TABLE

In Figure 9-4 the normalization procedure insures that the values of the moments for different power levels are nearly the same. The differences are caused by random noise on the overall BEM system and by inaccuracies in the basic mathematical model of the BEM measurements given by Equation 5-1, as discussed in Reference 1. Both of these errors, however, have a random character, and resulting differences in a given moment feature for different power levels may be considered random.

After the z values in Figure 9-5 have been computed for each signal pair, the z value for an unidentified signal may be compared with each signal pair. The z value from the data base which most nearly equals that of the unidentified signal determines the best estimate of the signal type. Detailed discussion of the algorithms implemented and the results obtained by using the actual BEM data are given in Sections 10 and 11.

9.4.1 Features Used For Discrimination

As stated in Subsection 9.3, the features chosen for discrimination are the K value (see Section 5) and the moments of the Q distribution curve. All four of these values are related to the normalized curves and thus vary little with power level. Also, these were chosen as discriminates because small variations in the Q curves are magnified by higher moments.

The derivation of the moment features is given by the following equations for a polynomial of degree four. All notation has been defined in Section 5. The first moment,

$$M = \int z\ Q(z)dz$$

is not used as a discriminate for, as shown in Section 5, its value is invariant with the coefficients. The K value is given by the equations of Section 5.

$$Q(z) = 0.5 + az + bz^2 + cz^3 + dz^4$$

$$M = \int_o^\infty z\ Q(z)dz = \int_o^K 0.5z + az^2 + bz^3 + cz^4 + dz^5\ dz$$

$$M = \frac{0.5}{2} K^2 + \frac{a}{3} K^3 + \frac{b}{4} K^4 + \frac{c}{5} K^4 + \frac{d}{6} K^6$$

$$\overline{M} = K^2(0.25 + a/3\ K + b/4\ K^2 + c/5\ K^3 + d/6\ K^4)$$

$$M(2) = \int_o^K (z-M)^2\ Q(z)dz \int_o^K (z^2-2Mz+M^2)(0.5+az+bz^2+cz^3+dz^4)dz$$

$$= \int_o^K (0.5z^2+az^3+bz^4+cz^5+dz^6)dz$$

$$-2M \int_o^K (0.5z+az^2+bz^3+cz^4z+dz^5)dz$$

$$+M^2 \int_o^K (0.5+az+bz^2+cz^3+dz^4)dz$$

$$M(2) = \frac{0.5}{3} K^3 + \frac{a}{4} K^4 + \frac{b}{5} K^5 + \frac{c}{6} K^6 + \frac{d}{7} K^7$$

$$-2M \left(\frac{0.5}{2} K^2 + \frac{a}{3} K^3 + \frac{b}{4} K^4 + \frac{c}{5} K^5 + \frac{d}{6} K^6\right)$$

$$+M^2 \left(0.5\ K + \frac{a}{2} K^2 + \frac{b}{3} K^3 + \frac{c}{4} K^4 + \frac{d}{5} K^5\right)$$

$$M(3) = \int_0^K (z-M)^3 \, Q(z)dz$$

$$= \int_0^K (z^2-2Mz+M^2)(z-M) \, Q(z)dz$$

$$= \int_0^K (z^3-2Mz^2+M^2z-Mz^2+2M^2z-M^3) \, Q(z)dz$$

$$= \int_0^K (z^3-3Mz^2+3M^2z-M^3)(0.5+az+bz^2+cz^3+dz^4)dz$$

$$M(3) = \int_0^K (0.5z^3+az^4+bz^5+cz^6+dz^7)dz$$

$$-3M \int_0^K (0.5z^2+az^3+bz^4+cz^5+dz^6)dz$$

$$+3M^2 \int_0^K (0.5z+az^2+bz^3+cz^4+dz^5)dz$$

$$-M^3 \int_0^K (0.5+az+bz^2+cz^3+dz^4)dz$$

$$M(3) = \frac{0.5}{4} K^4 + \frac{a}{5} K^5 + \frac{b}{6} K^6 + \frac{c}{7} K^7 + \frac{d}{8} K^8$$

$$-3M \left(\frac{0.5}{3} K^3 + \frac{a}{4} K^4 + \frac{b}{5} K^5 + \frac{c}{6} K^6 + \frac{d}{7} K^7\right)$$

$$+3M^2\left(0.25 \, K^2 + \frac{a}{3} K^3 + \frac{b}{4} K^4 + \frac{c}{5} K^5 + \frac{d}{6} K^6\right)$$

$$-M^3 \left(0.5 \, K + \frac{a}{2} K^2 + \frac{b}{3} K^3 + \frac{c}{4} K^4 + \frac{d}{5} K^5\right)$$

$$M(4) = \int_0^K (z-M)^4 \; Q(z)dz = \int_0^K (z^3-3Mz^2+3^2z-M^3)(z-M)Q(z)dz$$

$$= \int_0^K (z^4-3Mz^3+3M^3z^2-M^3z-Mz^3+3M^2z^2-3M^3z+M^4)Q(z)dz$$

$$= \int_0^K (z^4-4Mz^3+6M^2z^2-4M^3z+M^4)(0.5+az+bz^2+cz^3+dz^4)dz$$

$$M(4) = \int_0^K (0.5z^4+az^5+bz^6+dz^7)-4M\int_0^K (0.5z^3+az^4+bz^5+cz^6+dz^7)dz$$

$$+6M^2\int_0^K (0.5z^2+az^3+bz^4+cz^5+dz^6)dz$$

$$-4M^3\int_0^K (0.5z+az^2+bz^3+cz^4+dz^5)dz$$

$$+M^4\int_0^K (0.5+az+bz^2+cz^3+dz^4)dz$$

$$M(4) = 0.1\;K^5 + \frac{a}{6}\,K^6 + \frac{b}{7}\,K^7 + \frac{c}{8}\,K^8 + \frac{d}{9}\,K^9$$

$$-4M\left(0.125\;K^4 + \frac{a}{5}\,K^5 + \frac{b}{6}\,K^6 + \frac{c}{7}\,K^7 + \frac{d}{8}\,K^8\right)$$

$$+6M^2\left(\frac{0.5}{3}\,K^3 + \frac{a}{4}\,K^4 + \frac{b}{5}\,K^5 + \frac{c}{6}\,K^6 + \frac{d}{7}\,K^7\right)$$

$$-4M^3\left(0.25\;K^2 + \frac{a}{3}\,K^3 + \frac{b}{4}\,K^4 + \frac{c}{5}\,K^5 + \frac{d}{6}\,K^6\right)$$

$$+M^4\left(0.5\;K + \frac{a}{2}\,K^2 + \frac{b}{3}\,K^3 + \frac{c}{4}\,K^4 + \frac{d}{5}\,K^5\right)$$

Section 10

COMPUTER PROGRAM FOR DISCRIMINATION OF SIGNAL TYPES

10.1 INTRODUCTION

As discussed in Section 9, implementation of the selected discrimination technique requires two distinct stages. These are summarized here by giving the program flow in the required sequential order: Stage 1, Computation of the data base, and Stage 2, Current Time Discriminations.

10.1.1 Stage 1: Computation of the Data Base

1. Select the signal types to be used for reference.

2. Perform BEM experimental runs and record the measured dispersions for each of the selected signal types at each count down ratio. Repeat the measurements for each of a selection of power levels. The process is discussed in Section 2.

3. Using the measured data, implement the computer programs discussed in Section 7 to compute, for each signal type and each power level, the A distribution function as a function of the normalized variable z. Additional discussion and documentation of the required programs is given in Appendix A.

4. Select the features of the Q distribution to be used as discriminates. The ones used are K (see Section 5), and the second, third, and fourth moments of the Q distribution. The moments are defined and analytically expressed in terms of the known polynomial chosen to represent the Q distribution.

5. The moments are evaluated numerically for each selected Q distribution. The program which accomplishes this is a direct evaluation of the moment formulas given in Section 9. The program is given in Appendix A under the file name of SGHMON. It is written in Honeywell Level 6 FORTRAN and linked to all prior programs. With this linkage, Items 3, 4, and 5 may be directly computed with the inputs of Item 2. The outputs of this sequence of programs are the Q distribution as a function of the normalized random variable z, and each of the selected discriminates, K, M(2), M(3), and

M(4). This results in the table shown in Figure 10-1, with one such table for each selected signal types. In the table, note that K/10 is used instead of K to keep all discriminates in the same order of magnitude.

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		1	2	3	4	- POWER LEVEL
	K/10	–	–	–	–	
DISCRIMINATES	M(2)	–	–	–	–	
	M(3)	–	–	–	–	SIGNAL TYPE
	M(4)	–	–	–	–	

FIGURE 10-1. MOMENT DISCRIMINATION TABLE

6. With the numerical values of the discriminates available, one for each signal type, two signal types may be considered together to generate a z discriminate table using the algorithms developed in Section 9. One such z discriminate table is then generated for each combination of signal pairs. The computer program to accomplish this is under the file name LFMAIN, supported by the subroutines LFDFLL, SGHLV, and SGHZ. The object program for these subroutines are, respectively, FILLA, SOLVE, and ZFORM. The single run program to link together all these programs has the file name Z5RUN. These programs are listed (except the object programs which are in assembler language) and documented in Appendix A. Here is a brief description of their usage

   Since discrimination depends on the comparison of two signal types at a time, it is convenient to assign numbers to each reference signal type selected. For the present application, as discussed in Section 1, the signals selected for discrimination together with their numerical designations are:

   1 Gaussian noise

   2 Sine Wave, 3.1864 MHz carrier

   3 FM MOD 100 Hz Tone, 3.1864 MHz carrier

   4 FM MOD 5 kHz Tone, 3.1864 MHz carrier

   5 AM MOD 50 percent 1 kHz Tone, 3.1864 MHz, carrier

6 AM MOD 100 percent 100 Hz Tone, 3.1864 MHz carrier

7 FM MOD 1 kHz Tone, 3.1864 MHz carrier

8 AM MOD 100 percent 1 kHz Tone 3.1864 carrier

A z discriminate table is computed for each combination of signal parts. The combinations are C(8,2) = 28 pairs. Explicitly, the pairs are:

(1,2) (1,3) (1,4) (1,5) (1,6) (1,7) (1,8)

(2,3) (2,4) (2,5) (2,6) (2,7) (2,8)

(3,4) (3,5) (3,6) (3,7) (3,8)

(4,5) (4,6) (4,7) (4,8)

(5,6) (5,7) (5,8)

(6,7) (6,8)

(7,8)

Each z table is computed from pairs of arrays of the fundamental discriminate values as shown in Figure 10-1. The sequence of programs being considered has all the discriminate values stored, and upon designation of the selected pair the two M tables are filled. The run version of the sequence, (Z5RUN) operates in the following way:

> Upon execution, a prompt asking for card number 15 is asked twice. The response is above number designation in integer from (1 to 8). The proper M tables are automatically loaded and printed out for verification with the code (P,I,J) also printed to designate the individual M value. Here, as in Section 9, P = moment (1 to 4); I = class (1 or 2), meaning the first or second card of the input M tables, and J = designation of individual. Next the means and 5 (P,Q) calculated values, using the algorithms of Section 9 are printed out. This sets up simultaneous equations which are solved by 5GHSLV, and the λ values are printed out.

These values of λ are used with the algorithm in Section 9 to compute and print of the z table and the average z value for each class being compared. These two classes are the initial inputs to (Z5RUN), called RACE A and RACE B on the output. A sample run is included here in the text. Repeated running of this program with each pair of the 28 signal combinations generates the required reference z tables. This concludes the generation of the reference data base. Note that all this is done off-line, and recomputation of the reference data base is not required for the identification of an unknown signal.

7. The next program is not a final result, but is used for testing and development. It is written in FORTRAN and is designed to identify an unknown signal. It is not a part of the data base, but is discussed in this section because it is not part of the complete discrimination program, to be discussed in the next subsection.

   This test program is designated .GHDD and is not supported by any subroutines. It has stored (in DATA statements) a complete table of the λ values and a complete table of the z values for all 28 combinations of reference signals. They were computed off-line by the Z5RUN) program just discussed. The test discrimination program has a run version called (PCENT). It operates in the following way:

   > Upon execution, the moments of a test signal are input to the program, these moments having been computed off line. With these moments, the test z value is computed for each pair of data base combinations, using the proper set of λ values for each pair (recall that each signal pair in the data base has a set of z values and a set of λ values which are unique to that pair). This gives a complete set of 28 z test values. In each data base pair there are two signals. The corresponding z test value is compared with each of these 56 z data base values, and the smallest absolute difference, ABS (Z_{test} - Z_{base}) determines the z data base signal closest to the test value. The result, called XMIN is printed out together with the numerical designation of the signal nearest the z test value. Next a confidence number is input upon being prompted. The confidence number, which must be input in decimal form, has the form IXX, where XX, is a percent. The program then again searches and selects all those base signals whose z values are within XX percent of the signal which was designated or being the best match to the test signal. All signals which qualify, including the closest signal are output by number and name. The number here referred to is the sequential number assigned in each number pair. For example, in the pair designation (1,2) (1,3) (1,4) ----- (1,7), the first signal in each is gaussian noise.

The sequential number designation is 1,2,3,4,5,6---. That is, comparing the two strings, the number 3 in the pair (1,3) has the designation 4, by direct left to right counting.

In the program a prompt is also asked, "select column for specific z". This refers to the level from which the z values were taken. Recall that the z table has four values plus an average z for each signal. Each of the four values corresponds to a power level in the original, experimentally determined table of measured dispersions. The M tables are constructed with 4 moments and 4 power levels. The designators 1,2,3,4 refer to the column number of each z, 1 being the highest power level, 4 the lowest. The designator 5 refers to the average z. In this test program, 5GHDD, only the average z values were stored. Hence, the proper response to the prompt is the integer number 5. In the final version, to be discussed in the next subsection, all numbers, 1 to 5 may be used. The program SGHDD listing and a sample runn are included here.

10.1.2 Stage 2: Current Time Discrimination

1. This sequence of programs makes use of the data base which has been computed off-line. The programs are written in Honeywell Level 6 FORTRAN and are conversions of the already described programs used to generate the data base. The only exception is the last program (5GHDD) discussed in Paragraph 10.1.1. In the Level 6 sequence, the discrimination program (5GHDD) has been modified so that the input of moment data is not required. Instead, all data base material including complete z tables and λ values are stored in the sequence of programs.

   The Level 6 sequence accepts as input countdown ratios and measured dispersions from BEM measurements on an unknown signal. The output is the best estimate of the signal type (chosen from the moved data base signal types), and a listing of all other data base signal types which are within a prescribed (as an input) percentage of the best estimate signal.

   The sequence of these programs are contained in Appendix A. They are documented and follow the same program flow as the data base programs described in Paragraph 10.1.1, except as noted above.

10.2 COMMENTS ON DISCRIMINATION PROGRAMS AND BIT ERROR RATE (BER)

It is again emphasized that the generation of the data base depends on off-line computation which is completed prior to using the current time programs. The data base described here, consisting of the eight reference signal types listed in Paragraph 10.1.1, Item 6, is used as a proof-of-principal set, and may be expanded to different signals and different numbers of signals by minor modification to the programs. The modifications require only the proper dimensioning of arrays to account for the number of signals in the data base. Of course, the data base would be recomputed as an off-line effort.

In application of the current time discrimination, it is required, upon prompting, to supply an input column number to select the power level of reference signals as discussed in Paragraph 10.1.1. Loosely, the power level of the BEM measurements performed for the construction of the data base can be correlated with the bit error rate (BER) of the reference signal. For current time applications, the BER of the unknown signal may, or may not be known. It it is not, the average value of the reference z is used, and the column designator selected for response to the prompt, "Select Column for Specific z", is the integer 5, as discussed in Paragraph 10.1.1. If the BER is approximately known, then the column of z values may be selected by an integer number (1 to 4) to designate a range of BER. Number 1 indicates the highest BER, number 4 the lowest. Following is a selection criteria which may be used as a rough guide:

Order of BER	Column Selection
Unknown	5
10^{-2}	1
10^{-2}, 10^{-3}	2
10^{-3}	3
$<10^{-3}$	4

In this way, the effect of BER may be investigated. The effectiveness of this procedure can only be determined by observing results obtained with differenc and expanded data bases. The entire subject of how best to incorporate BER data, if at all, is an important consideration which should be pursued in future study.

Section 11

RESULTS OF DISCRIMINATION PROGRAMS

11.1 DISCUSSION

The programs were used to generate a data base from the measured BEM data, and to perform a number of trial runs using the current time discrimination programs. The results of both of these efforts are included here. In particular, the following tables give the form of the data which were used to generate the present data base and the corresponding values. The data of Section 2 and the corresponding moments of Section 9 were used in Figure 11.1. Results are shown in Figure 11.2.

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COUNT DOWN RATIOS | COMPUTED DISCRIMINATES

.9216	—	—	—	—		MEASURED BER	K/10	M(2)	M(3)	M(4)
MEASURED DISPERSIONS	X	X	X	X		X	X	X	X	X

4 ROWS

FIGURE 11-1. COMPUTED DISCRIMINATE TABULATION

The following data base z table was computed using the Z5RUN program described in Section 10 using the moments as indicated by number pairs, each pair representing a combination of signal types. The numbers in the pair are those of the eight signal types described in Section 10 and repeated here for convenience:

1 Gaussian noise

2 Sine Wave, 3.1864 MHz carrier

3 FM MOD 100 Hz tone, 3.1864 MHz carrier

4 FM MOD 5 kHz tone, 3.1864 MHz carrier

5 AM MOD 50 percent 1 kHz Tone, 3.1864 MHz carrier

6 AM MOD 100 percent 100 Hz Tone, 3.1864 MHz carrier

7 FM MOD 1 kHz Tone, 3.1864 MHz carrier

8 AM MOD 100 percent 1 kHz Tone 3.1864 MHz carrier

Figure 11-2 lists the four data base z values and the average z for each signal type in combination, as described in Section 10.

The meaning of the symbols is given on run one (1) of Figure 11.2, along with references to prior sections.

```
INPUT FIRST CARD NUMBER
1 1

 1   1   1      0.321450E 00
 1   1   2      0.364090E 00
 1   1   3      0.392810E 00
 1   1   4      0.335060E 00
 2   1   1      0.186890E 00
 2   1   2      0.188960E 00
 2   1   3      0.196590E 00
 2   1   4      0.242110E 00
 3   1   1      0.270640E 00
 3   1   2      0.283190E 00
 3   1   3      0.317340E 00
 3   1   4      0.445450E 00
 4   1   1      0.477040E 00
 4   1   2      0.530740E 00
 4   1   3      0.659010E 00
 4   1   4      0.963290E 00
INPUT SECOND CARD NUMBER
1 2

 1   2   1      0.197390E 00
 1   2   2      0.181680E 00
 1   2   3      0.179550E 00
 1   2   4      0.176420E 00
 2   2   1      0.134710E 00
 2   2   2      0.124350E 00
 2   2   3      0.122920E 00
 2   2   4      0.120790E 00
 3   2   1      0.132120E 00
 3   2   2      0.112790E 00
 3   2   3      0.110260E 00
 3   2   4      0.106540E 00
 4   2   1      0.149150E 00
 4   2   2      0.117450E 00
 4   2   3      0.113510E 00
 4   2   4      0.107800E 00
```

First column is power level, second column is signal type (see list on page 106), third column is discriminate designator (K/10, M2, M3, M4; see Sections 9 and 10), fourth column is value of the discriminator.

```
1
                          MEAN(I,J)
 I =  1  J =  1  MEAN =     0.353352E 00
 I =  2  J =  1  MEAN =     0.203635E 00
 I =  3  J =  1  MEAN =     0.329155E 00
 I =  4  J =  1  MEAN =     0.657520E 00
 I =  1  J =  2  MEAN =     0.183760E 00
 I =  2  J =  2  MEAN =     0.125692E 00
 I =  3  J =  2  MEAN =     0.115427E 00
 I =  4  J =  2  MEAN =     0.121978E 00
                          S(P,Q)
 P =  1   Q =  1          0.328628E-02
 P =  1   Q =  2         -0.431473E-03
 P =  1   Q =  3         -0.900302E-03
 P =  1   Q =  4         -0.613569E-03
 P =  2   Q =  1         -0.431473E-03
 P =  2   Q =  2          0.214088E-02
 P =  2   Q =  3          0.642460E-02
 P =  2   Q =  4          0.169825E-01
 P =  3   Q =  1         -0.900302E-03
 P =  3   Q =  2          0.642460E-02
 P =  3   Q =  3          0.195922E-01
 P =  3   Q =  4          0.525654E-01
 P =  4   Q =  1         -0.618569E-03
 P =  4   Q =  2          0.169825E-01
 P =  4   Q =  3          0.525654E-01
 P =  4   Q =  4          0.143175E 00

 D1 =      0.169592E 00  D2 =      0.779425E-01
   D3 =      0.213727E 00  D4 =      0.535542E 00


1                         LAMBDA VALUES
  0.66053186035E 03           1
 -0.1216515625E 05            2
  0.94276777344E 04           3
 -0.20139462891E 04           4
```

See Sections 9 and 10 for definition of symbols: I, J, MEAN (I, J), S(P, Q) D1, D2, D3, D4, Lambda values.

```
 C =  4  N =  4


                          LINEAR DISCRIMINATE FUNCTIONS


 RACE A = 1 = GAUSSIAN NOISE
   -0.466839E 03
   -0.453770E 03
   -0.463852E 03
   -0.459930E 03
 AVERAGE =  -0.461098E 03


 RACE B = 2 = SINE WAVE, 3.1864 MHZ CARRIER
   -0.560670E 03
   -0.563604E 03
   -0.563559E 03
   -0.563325E 03
 AVERAGE =  -0.562789E 03
```

C = 4, N = 4 designate that a fourth degree equation was solved correctly. The values under Race A and Race B are the final z values used for discrimination between Race A and Race B. The word "Race" is used to indicate signal type. Average is average z value.

FIGURE 11-2. COMBINATIONAL Z5 RUN 1

```
 INPUT FIRST CARD NUMBER
1 1

  1   1   1      0.321450E 00
  1   1   2      0.364090E 00
  1   1   3      0.392810E 00
  1   1   4      0.353060E 00
  2   1   1      0.186880E 00
  2   1   2      0.188960E 00
  2   1   3      0.196590E 00
  2   1   4      0.242110E 00
  3   1   1      0.270640E 00
  3   1   2      0.283190E 00
  3   1   3      0.317340E 00
  3   1   4      0.445450E 00
  4   1   1      0.477040E 00
  4   1   2      0.530740E 00
  4   1   3      0.659010E 00
  4   1   4      0.963290E 00
 INPUT SECOND CARD NUMBER
1 3

  1   2   1      0.202250E 00
  1   2   2      0.187800E 00
  1   2   3      0.181170E 00
  1   2   4      0.174660E 00
  2   2   1      0.137030E 00
  2   2   2      0.128390E 00
  2   2   3      0.124010E 00
  2   2   4      0.119440E 00
  3   2   1      0.138440E 00
  3   2   2      0.120150E 00
  3   2   3      0.112190E 00
  3   2   4      0.104220E 00
  4   2   1      0.160060E 00
  4   2   2      0.129200E 00
  4   2   3      0.116500E 00
  4   2   4      0.104290E 00
1
                         MEAN(I,J)
 I =  1  J =  1  MEAN =     0.353352E 00
 I =  2  J =  1  MEAN =     0.203635E 00
 I =  3  J =  1  MEAN =     0.329155E 00
 I =  4  J =  1  MEAN =     0.657520E 00
 I =  1  J =  2  MEAN =     0.186420E 00
 I =  2  J =  2  MEAN =     0.127443E 00
 I =  3  J =  2  MEAN =     0.118750E 00
 I =  4  J =  2  MEAN =     0.127512E 00
                         S(P,Q)
 P =  1   Q =  1          0.344767E-02
 P =  1   Q =  2         -0.323776E-03
 P =  1   Q =  3         -0.698453E-03
 P =  1   Q =  4         -0.284947E-03
 P =  2   Q =  1         -0.323776E-03
 P =  2   Q =  2          0.221275E-02
 P =  2   Q =  3          0.655926E-02
 P =  2   Q =  4          0.172050E-01
 P =  3   Q =  1         -0.698453E-03
 P =  3   Q =  2          0.655926E-02
 P =  3   Q =  3          0.198447E-01
 P =  3   Q =  4          0.529830E-01
 P =  4   Q =  1         -0.284947E-03
 P =  4   Q =  2          0.172050E-01
 P =  4   Q =  3          0.529830E-01
 P =  4   Q =  4          0.143866E 00

 D1 =      0.166932E 00  D2 =      0.761925E-01
   D3 =      0.210405E 00  D4 =      0.520007E 00


1                        LAMBDA VALUES
  0.63532507324E 03          1
 -0.12145625000E 05          2
  0.93353105469E 04          3
 -0.19805603027E 04          4



 C =  4  N =  4



                         LINEAR DISCRIMINATE FUNCTIONS
 =1= GAUSSIAN NOISE

 RACE A = GAUSSIAN NOISE
   -0.483848E 03
   -0.471218E 03
   -0.480888E 0.
   -0.477145E 03
 AVERAGE =  -0.478275E 03



 RACE B  = 3 = FM MOD 100 HZ TONE, 3.1864 MHZ CARRIER
   -0.571380E 03
   -0.574314E 03
   -0.574484E 03
   -0.573461E 03
 AVERAGE =  -0.573410E 03
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 2

```
INPUT FIRST CARD NUMBER
! 1

 1   1   1      0.321450E 00
 1   1   2      0.364090E 00
 1   1   3      0.392810E 00
 1   1   4      0.335060E 00
 2   1   1      0.186880E 00
 2   1   2      0.188960E 00
 2   1   3      0.196590E 00
 2   1   4      0.242110E 00
 3   1   1      0.270640E 00
 3   1   2      0.283190E 00
 3   1   3      0.317340E 00
 3   1   4      0.445450E 00
 4   1   1      0.477040E 00
 4   1   2      0.530740E 00
 4   1   3      0.659010E 00
 4   1   4      0.963290E 00
INPUT SECOND CARD NUMBER
! 4

 1   2   1      0.201940E 00
 1   2   2      0.187680E 00
 1   2   3      0.188670E 00
 1   2   4      0.178830E 00
 2   2   1      0.137670E 00
 2   2   2      0.128301E 00
 2   2   3      0.128970E 00
 2   2   4      0.122430E 00
 3   2   1      0.137930E 00
 3   2   2      0.119990E 00
 3   2   3      0.121220E 00
 3   2   4      0.109390E 00
 4   2   1      0.159210E 00
 4   2   2      0.128950E 00
 4   2   3      0.130950E 00
 4   2   4      0.112170E 00
1
                         MEAN(I,J)
I = 1  J = 1  MEAN =    0.353352E 00
I = 2  J = 1  MEAN =    0.203635E 00
I = 3  J = 1  MEAN =    0.329155E 00
I = 4  J = 1  MEAN =    0.657520E 00
I = 1  J = 2  MEAN =    0.189280E 00
I = 2  J = 2  MEAN =    0.129343E 00
I = 3  J = 2  MEAN =    0.122132E 00
I = 4  J = 2  MEAN =    0.138220E 00
                         S(P,Q)
P = 1   Q = 1        0.329698E-02
P = 1   Q = 2       -0.425275E-03
P = 1   Q = 3       -0.883156E-03
P = 1   Q = 4       -0.580836E-03
P = 2   Q = 1       -0.425275E-03
P = 2   Q = 2        0.214440E-02
P = 2   Q = 3        0.643485E-02
P = 2   Q = 4        0.170057E-01
P = 3   Q = 1       -0.883156E-03
P = 3   Q = 2        0.643485E-02
P = 3   Q = 3        0.196183E-01
P = 3   Q = 4        0.526202E-01
P = 4   Q = 1       -0.580836E-03
P = 4   Q = 2        0.170057E-01
P = 4   Q = 3        0.526202E-01
P = 4   Q = 4     .  0.143285E 00

D1 =      0.164072E 00  D2 =      0.742922E-01
  D3 =      0.207022E 00  D4 =      0.524700E 00

1                         LAMBDA VALUES
  0.64446264648E 03          1
 -0.12401605469E 05          2
  0.95189316406E 04          3
 -0.20175954590E 04          4



L =  4  N =  4



                         LINEAR DISCRIMINATE FUNCTIONS


RACE A   =1= GAUSSIAN NOISE
   -0.496720E 03
   -0.483917E 03
   -0.493788E 03
   -0.489941E 03
AVERAGE =  -0.491024E 03


RACE B  = 2 = FM MOD 4 KHZ TONE, 3 1864 MHZ CARRIER
   -0.585461E 03
   -0.588178E 03
   -0.586164E 03
   -0.588117E 03
AVERAGE =  -0.587460E 03
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 3

```
 INPUT FIRST CARD NUMBER
! 1

  1   1   1       0.321450E 00
  1   1   2       0.364090E 00
  1   1   3       0.392810E 00
  1   1   4       0.335060E 00
  2   1   1       0.186880E 00
  2   1   2       0.188960E 00
  2   1   3       0.196590E 00
  2   1   4       0.242110E 00
  3   1   1       0.270640E 00
  3   1   2       0.283190E 00
  3   1   3       0.317340E 00
  3   1   4       0.445450E 00
  4   1   1       0.477040E 00
  4   1   2       0.530740E 00
  4   1   3       0.659010E 00
  4   1   4       0.963290E 00
 INPUT SECOND CARD NUMBER
! 5

  1   2   1       0.346740E 00
  1   2   2       0.249430E 00
  1   2   3       0.255410E 00
  1   2   4       0.145900E 00
  2   2   1       0.178800E 00
  2   2   2       0.194960E 00
  2   2   3       0.200320E 00
  2   2   4       0.113240E 00
  3   2   1       0.261830E 00
  3   2   2       0.275180E 00
  3   2   3       0.289650E 00
  3   2   4       0.904590E 00
  4   2   1       0.491370E 00
  4   2   2       0.443920E 00
  4   2   3       0.478670E 00
  4   2   4       0.808890E 00
1
                        MEAN(I,J)
 I =  1  J =  1  MEAN =     0.353352E 00
 I =  2  J =  1  MEAN =     0.203635E 00
 I =  3  J =  1  MEAN =     0.329155E 00
 I =  4  J =  1  MEAN =     0.657520E 00
 I =  1  J =  2  MEAN =     0.249370E 00
 I =  2  J =  2  MEAN =     0.171830E 00
 I =  3  J =  2  MEAN =     0.432812E 00
 I =  4  J =  2  MEAN =     0.555712E 00
                        S(P,Q)
 P =  1   Q =  1          0.232480E-01
 P =  1   Q =  2          0.630961E-02
 P =  1   Q =  3         -0.675578E-01
 P =  1   Q =  4         -0.340714E-01
 P =  2   Q =  1          0.630961E-02
 P =  2   Q =  2          0.685409E-02
 P =  2   Q =  3         -0.303453E-01
 P =  2   Q =  4         -0.342440E-02
 P =  3   Q =  1         -0.675578E-01
 P =  3   Q =  2         -0.303453E-01
 P =  3   Q =  3          0.316353E 00
 P =  3   Q =  4          0.211027E 00
 P =  4   Q =  1         -0.340714E-01
 P =  4   Q =  2         -0.342440E-02
 P =  4   Q =  3          0.211027E 00
 P =  4   Q =  4          0.228816E 00

 D1 =      0.103983E 00  D2 =      0.318050E-01
   D3 =    -0.103657E 00  D4 =      0.101807E 00

1                       LAMBDA VALUES
  0.68177474976E 02          1
  0.19700067139E 03          2
  0.62612197876E 02          3
 -0.44199870149E 02          4


 C =  4  M =  4


                        LINEAR DISCRIMINATE FUNCTIONS


 RACE A  =1= GAUSSIAN NOISE
    0.545916E 02
    0.563207E 02
    0.562506E 02
    0.558531E 02
 AVERAGE =   0.557540E 02


 RACE B  = 5 = AM MOD 50%, 1KHZ TONE, 3.1864 MHZ CARRIER
    0.535398E 02
    0.530214E 02
    0.530550E 02
    0.531413E 02
 AVERAGE =   0.532092E 02
```

FIGURE 11-2. COMBINATIONAL 25
RUN 4

```
INPUT FIRST CARD NUMBER
! 1

  1   1   1      0.321450E 00
  1   1   2      0.364090E 00
  1   1   3      0.392810E 00
  1   1   4      0.335060E 00
  2   1   1      0.186880E 00
  2   1   2      0.188960E 00
  2   1   3      0.196590E 00
  2   1   4      0.242110E 00
  3   1   1      0.270640E 00
  3   1   2      0.283190E 00
  3   1   3      0.317340E 00
  3   1   4      0.445450E 00
  4   1   1      0.477040E 00
  4   1   2      0.530740E 00
  4   1   3      0.659010E 00
  4   1   4      0.963290E 00
 INPUT SECOND CARD NUMBER
! 6

  1   2   1      0.390490E 00
  1   2   2      0.272540E 00
  1   2   3      0.346650E 00
  1   2   4      0.292500E 00
  2   2   1      0.183840E 00
  2   2   2      0.184780E 00
  2   2   3      0.228610E 00
  2   2   4      0.234000E 00
  3   2   1     -0.268840E 00
  3   2   2      0.249540E 00
  3   2   3      0.408360E 00
  3   2   4      0.390600E 00
  4   2   1      0.498520E 00
  4   2   2      0.393430E 00
  4   2   3      0.876980E 00
  4   2   4      0.744350E 00
!
                         MEAN(I,J)
 I =  1  J =  1  MEAN =    0.353352E 00
 I =  2  J =  1  MEAN =    0.203635E 00
 I =  3  J =  1  MEAN =    0.329155E 00
 I =  4  J =  1  MEAN =    0.657520E 00
 I =  1  J =  2  MEAN =    0.325545E 00
 I =  2  J =  2  MEAN =    0.207807E 00
 I =  3  J =  2  MEAN =    0.329335E 00
 I =  4  J =  2  MEAN =    0.628320E 00
                         S(P,Q)
 P =  1   Q =  1         0.115894E-01
 P =  1   Q =  2        -0.136732E-02
 P =  1   Q =  3        -0.127629E-02
 P =  1   Q =  4         0.429617E-02
 P =  2   Q =  1        -0.136732E-02
 P =  2   Q =  2         0.424954E-02
 P =  2   Q =  3         0.127486E-01
 P =  2   Q =  4         0.333702E-01
 P =  3   Q =  1        -0.127629E-02
 P =  3   Q =  2         0.127486E-01
 P =  3   Q =  3         0.392261E-01
 P =  3   Q =  4         0.105284E 00
 P =  4   Q =  1         0.429617E-02
 P =  4   Q =  2         0.333702E-01
 P =  4   Q =  3         0.105284E 00
 P =  4   Q =  4         0.269460E 00

 D1 =     0.278075E-01  D2 =    -0.417247E-02
   D3 =    -0.180006E-03  D4 =     0.292000E-01


!                          LAMBDA VALUES
 -0.19534559250E 01          1
 -0.27308825684E 03          2
  0.16159857178E 03          3
 -0.27165084639E 02          4



 L =  4  M =  4



                          LINEAR DISCRIMINATE FUNCTIONS


 PAGE A   =1= GAUSSIAN NOISE
   -0.208625E 02
   -0.209685E 02
   -0.210741E 02
   -0.209557E 02
 AVERAGE =  -0.209712E 02


 PAGE B  = 6 = AM MOD 100%, 100HZ TONE, 3 1864MHZ CARRIER
   -0.210655E 02
   -0.213559E 02
   -0.209407E 02
   -0.215740E 02
 AVERAGE =  -0.212340E 02
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 5

```
 INPUT FIRST CARD NUMBER
! 1

  1   1   1      0.321450E 00
  1   1   2      0.364090E 00
  1   1   3      0.[illegible]92810E 00
  1   1   4      0.335060E 00
  2   1   1      0.186880E 00
  2   1   2      0.188960E 00
  2   1   3      0.196590E 00
  2   1   4      0.242110E 00
  3   1   1      0.270640E 00
  3   1   2      0.283180E 00
  3   1   3      0.317340E 00
  3   1   4      0.445450E 00
  4   1   1      0.477040E 00
  4   1   2      0.530740E 00
  4   1   3      0.659010E 00
  4   1   4      0.963290E 00
 INPUT SECOND CARD NUMBER
! 7

  1   2   1      0.202080E 00
  1   2   2      0.192750E 00
  1   2   3      0.187600E 00
  1   2   4      0.179440E 00
  2   2   1      0.137830E 00
  2   2   2      0.131630E 00
  2   2   3      0.128260E 00
  2   2   4      0.123180E 00
  3   2   1      0.138230E 00
  3   2   2      0.126210E 00
  3   2   3      0.119900E 00
  3   2   4      0.110720E 00
  4   2   1      0.159700E 00
  4   2   2      0.139190E 00
  4   2   3      0.128800E 00
  4   2   4      0.114220E 00
1
                    MEAN(I,J)
 I =  1  J =  1  MEAN =     0.353352E 00
 I =  2  J =  1  MEAN =     0.203635E 00
 I =  3  J =  1  MEAN =     0.329155E 00
 I =  4  J =  1  MEAN =     0.657520E 00
 I =  1  J =  2  MEAN =     0.190592E 00
 I =  2  J =  2  MEAN =     0.130225E 00
 I =  3  J =  2  MEAN =     0.123765E 00
 I =  4  J =  2  MEAN =     0.135477E 00
                   .(P,Q)
 P =  1   Q =  1          0.328362E-02
 P =  1   Q =  2         -0.433510E-03
 P =  1   Q =  3         -0.898326E-03
 P =  1   Q =  4         -0.605365E-03
 P =  2   Q =  1         -0.433510E-03
 P =  2   Q =  2          0.213935E-02
 P =  2   Q =  3          0.642558E-02
 P =  2   Q =  4          0.169908E-01
 P =  3   Q =  1         -0.898326E-03
 P =  3   Q =  2          0.642558E-02
 P =  3   Q =  3          0.196012E-01
 P =  3   Q =  4          0.525927E-01
 P =  4   Q =  1         -0.605365E-03
 P =  4   Q =  2          0.169908E-01
 P =  4   Q =  3          0.525927E-01
 P =  4   Q =  4          0.143241E 00

 D1 =      0.162760E 00  D2 =      0.734100E-01
   D3 =      0.205390E 00  D4 =      0.522043E 00

1                       LAMBDA VALUES
  0.64593078613E 03          1
 -0.12437205078E 05          2
  0.95449628906E 04          3
 -0.20229248047E 04          4


 L =  4  N =  4

        .

                       LINEAR DISCRIMINATE FUNCTIONS


 RACE A   =1= GAUSSIAN NOISE
   -0.498398E 03
   -0.485567E 03
   -0.495431E 03
   -0.491605E 03
 AVERAGE =  -0.492750E 03


 RACE B  = 7 = FM MOD 1KHZ TONE, 3.1864MHZ CARRIER
   -0.587351E 03
   -0.589507E 03
   -0.590131E 03
   -0.590026E 03
 AVERAGE =  -0.589254E 03
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 6

```
 INPUT FIRST CARD NUMBER
! 1

  1   1   1     0.321450E 00
  1   1   2     0.364090E 00
  1   1   3     0.392810E 00
  1   1   4     0.335060E 00
  2   1   1     0.186880E 00
  2   1   2     0.188960E 00
  2   1   3     0.196590E 00
  2   1   4     0.242110E 00
  3   1   1     0.270640E 00
  3   1   2     0.283190E 00
  3   1   3     0.317340E 00
  3   1   4     0.445450E 00
  4   1   1     0.477040E 00
  4   1   2     0.530740E 00
  4   1   3     0.659010E 00
  4   1   4     0.963290E 00
 INPUT SECOND CARD NUMBER
! 8

  1   2   1     0.355530E 00
  1   2   2     0.385000E 00
  1   2   3     0.400000E 00
  1   2   4     0.427440E 00
      2   1     0.191750E 00
      2   2     0.186630E 00
  2   2   3     0.180060E 00
  2   2   4     0.177420E 00
  3   2   1     0.293430E 00
  3   2   2     0.278020E 00
  3   2   3     0.260000E 00
  3   2   4     0.244460E 00
  4   2   1     0.561320E 00
  4   2   2     0.524640E 00
  4   2   3     0.470000E 00
  4   2   4     0.420480E 00
1
                          MEAN(I,J)
  I =  1  J =  1  MEAN =     0.353352E 00
  I =  2  J =  1  MEAN =     0.203635E 00
  I =  3  J =  1  MEAN =     0.329155E 00
  I =  4  J =  1  MEAN =     0.657520E 00
  I =  1  J =  2  MEAN =     0.391993E 00
  I =  2  J =  2  MEAN =     0.183950E 00
  I =  3  J =  2  MEAN =     0.268978E 00
  I =  4  J =  2  MEAN =     0.494110E 00
                         S(P,Q)
  P =  1   Q =  1          0.572363E-02
  P =  1   Q =  2         -0.117108E-02
  P =  1   Q =  3         -0.311610E-02
  P =  1   Q =  4         -0.660525E-02
  P =  2   Q =  1         -0.117108E-02
  P =  2   Q =  2          0.215231E-02
  P =  2   Q =  3          0.662317E-02
  P =  2   Q =  4          0.178205E-01
  P =  3   Q =  1         -0.311610E-02
  P =  3   Q =  2          0.662317E-02
  P =  3   Q =  3          0.205623E-01
  P =  3   Q =  4          0.558713E-01
  P =  4   Q =  1         -0.660525E-02
  P =  4   Q =  2          0.178205E-01
  P =  4   Q =  3          0.558713E-01
  P =  4   Q =  4          0.153596E 00

  D1 =     -0.384400E-01  D2 =      0.196850E-01
    D3 =      0.601774E-01  D4 =      0.163410E 00


 1                        LAMBDA VALUES
 -0.10233568192E 02          1
  0.27602362061E 03          2
 -0.19030990601E 03          3
  0.37825256348E 02          4


  C =  4  N =  4


                          LINEAR DISCRIMINATE FUNCTIONS


  RACE A  = 1 = GAUSSIAN NOISE
     0.148314E 02
     0.146130E 02
     0.147779E 02
     0.150624E 02
  AVERAGE =   0.148214E 02


  RACE B  = 2 = AM MOD 100%, 1KHZ TONE, 3.1864MHZ CARRIER
     0.14[illegible]E 02
     0.145090E 02
     0.1308[illegible] 02
     0.139795E 02
  AVERAGE =   0.14[illegible]38E 02
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 7

```
 INPUT FIRST CARD NUMBER
1 2

  1   1   1      0.197390E 00
  1   1   2      0.181680E 00
  1   1   3      0.179550E 00
  1   1   4      0.176420E 00
  2   1   1      0.134710E 00
  2   1   2      0.124350E 00
  2   1   3      0.122920E 00
  2   1   4      0.120790E 00
  3   1   1      0.132120E 00
  3   1   2      0.112790E 00
  3   1   3      0.110260E 00
  3   1   4      0.106540E 00
  4   1   1      0.149150E 00
  4   1   2      0.117450E 00
  4   1   3      0.113510E 00
  4   1   4      0.107600E 00
 INPUT SECOND CARD NUMBER
1 3

  1   2   1      0.202250E 00
  1   2   2      0.187800E 00
  1   2   3      0.181170E 00
  1   2   4      0.174460E 00
  2   2   1      0.137930E 00
  2   2   2      0.128390E 00
  2   2   3      0.124010E 00
  2   2   4      0.119440E 00
  3   2   1      0.138440E 00
  3   2   2      0.120150E 00
  3   2   3      0.112190E 00
  3   2   4      0.104220E 00
  4   2   1      0.160060E 00
  4   2   2      0.129200E 00
  4   2   3      0.116500E 00
  4   2   4      0.104290E 00
1
                       MEAN(I,J)
 I =  1  J =  1  MEAN =    0.183760E 00
 I =  2  J =  1  MEAN =    0.125692E 00
 I =  3  J =  1  MEAN =     0.115427E 00
 I =  4  J =  1  MEAN =    0.121978E 00
 I =  1  J =  2  MEAN =    0.186420E 00
 I =  2  J =  2  MEAN =    0.127443E 00
 I =  3  J =  2  MEAN =    0.118756E 00
 I =  4  J =  2  MEAN =    0.127512E 00
                       S(P,Q)
 P =  1   Q =  1          0.684800E-03
 P =  1   Q =  2          0.454412E-03
 P =  1   Q =  3          0.841837E-03
 P =  1   Q =  4          0.137260E-02
 P =  2   Q =  1          0.454412E-03
 P =  2   Q =  2          0.301546E-03
 P =  2   Q =  3          0.558582E-03
 P =  2   Q =  4          0.910666E-03
 P =  3   Q =  1          0.841837E-03
 P =  3   Q =  2          0.558582E-03
 P =  3   Q =  3          0.103510E-02
 P =  3   Q =  4          0.168816E-02
 P =  4   Q =  1          0.137260E-02
 P =  4   Q =  2          0.910666E-03
 P =  4   Q =  3          0.168816E-02
 P =  4   Q =  4          0.275429E-02

 D1 =    -0.266004E-02  D2 =    -0.175002E-02
   D3 =    -0.332250E-02  D4 =    -0.553498E-02


1                         LAMBDA VALUES
 -0.60294960469E 04          1
 -0.24669523437E 05          2
  0.35255351562E 05          3
 -0.10419353516E 05          4



 L =  4  N =  4


                     LINEAR DISCRIMINATE FUNCTIONS


 RACE A   =2= SINE WAVE, 3.1864 MHZ CARRIER
   -0.141398E 04
   -0.141392E 04
   -0.141382E 04
   -0.141389E 04
 AVERAGE =  -0.141390E 04


 RACE B  = 3 = FM MOD 100HHZ TONE, 3 1864 CARRIER
   -0.141391E 04
   -0.141378E 04
   -0.141368E 04
   -0.141368E 04
 AVERAGE =  -0.141381E 04
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 8

```
INPUT FIRST CARD NUMBER
! 2

  1       1      0.197390E 00
  1   1   2      0.181680E 00
  1   1   3      0.179550E 00
  1   1   4      0.176420E 00
  2   1   1      0.134710E 00
  2   1   2      0.124350E 00
  2   1   3      0.122920E 00
  2   1   4      0.120790E 00
  3   1   1      0.132120E 00
  3   1   2      0.112790E 00
  3   1   3      0.110260E 00
  3   1   4      0.106540E 00
  4   1   1      0.149150E 00
  4   1   2      0.117450E 00
  4   1   3      0.113510E 00
  4   1   4      0.107800E 00
INPUT SECOND CARD NUMBER
! 4

  1   2   1      0.201940E 00
  1   2   2      0.187680E 00
  1   2   3      0.168670E 00
  1   2   4      0.178830E 00
  2   2   1      0.137670E 00
  2   2   2      0.128301E 00
  2   2   3      0.128470E 00
  2   2   4      0.122430E 00
  3   2   1      0.137930E 00
  3   2   2      0.119990E 00
  3   2   3      0.121220E 00
  3   2   4      0.109390E 00
  4   2   1      0.159210E 00
  4   2   2      0.128450E 00
  4   2   3      0.130950E 00
  4   2   4      0.112170E 00
1
                        MEAN(I,J)
 I =  1  J =  1  MEAN =    0.183760E 00
 I =  2  J =  1  MEAN =    0.125692E 00
 I =  3  J =  1  MEAN =    0.115427E 00
 I =  4  J =  1  MEAN =    0.121978E 00
 I =  1  J =  2  MEAN =    0.189280E 00
 I =  2  J =  2  MEAN =    0.129343E 00
 I =  3  J =  2  MEAN =    0.122132E 00
 I =  4  J =  2  MEAN =    0.132820E 00
                        S(P,Q)
 P =  1   Q =  1           0.534113E-03
 P =  1   Q =  2           0.352912E-03
 P =  1   Q =  3           0.657134E-03
 P =  1   Q =  4           0.107671E-02
 P =  2   Q =  1           0.352912E-03
 P =  2   Q =  2           0.233192E-03
 P =  2   Q =  3           0.434170E-03
 P =  2   Q =  4           0.711320E-03
 P =  3   Q =  1           0.657134E-03
 P =  3   Q =  2           0.434170E-03
 P =  3   Q =              0.806641E-03
 P =  3   Q =  4           0.132530E-02
 P =  4   Q =  1           0.107671E-02
 P =  4   Q =  2           0.711320E-03
 P =  4   Q =  3           0.132530E-02
 P =  4   Q =  4           0.21.287E-02

 D1 =    -0.552002E-02  D2 =    -0.365028E-02
   D3 =    -0.670500E-02  D4 =    -0.108425E-01


1                       LAMBDA VALUES
 -0.34520867187E 05        1
 -0.52604515625E 05        2
  0.10312535937E 06        3
 -0.28577605469E 05        4



 L =  4   M =  4



                        LINEAR DISCRIMINATE FUNCTIONS


 FACE M  = 2 = SINE WAVE, 3 1864MHZ CARRIER
    -0.453786E 04
    -0.453809E 04
    -0.453761E 04
    -0.453796E 04
 AVERAGE =  -0.45378.E 04


 FACE B  = 4 = FM MOD 5KHZ TONE, 3.1864MHZ CARRIER
    0.453847E 04
     .45 416E 04
    -0.453834E 04
    -0.453840E 04
 AVERAGE =  -0.45 384E 04
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 9

```
 INPUT FIRST CARD NUMBER
! 2

  1   1   1      0.197390E 00
  1   1   2      0.181680E 00
  1   1   3      0.179550E 00
  1   1   4      0.176420E 00
  2   1   1      0.134710E 00
  2   1   2      0.124350E 00
  2   1   3      0.122920E 00
  2   1   4      0.120790E 00
  3   1   1       .132120E 00
  3   1   2      0.112790E 00
  3   1   3      0.110260E 00
  3   1   4      0.106540E 00
  4   1   1      0.149150E 00
  4   1   2      0.117450E 00
  4   1   3      0.113510E 00
  4   1   4      0.10[illegible]800E 00
 INPUT SECOND CARD NUMBER
! 5

  1   2   1      0.346740E 00
  1   2   2      0.249430E 00
  1   2   3      0.255410E 00
  1   2   4      0.145900E 00
  2   2   1      0.178800E 00
  2   2   2      0.194460E 00
  2   2   3      0.[illegible]003[illegible]0E 00
  2   2   4      0.11[illegible]240E 00
  3   2   1      0.261830E 00
  3   2   2      0.275180E 00
  3   2   3      0.284650E 00
  3   2   4      0.904590E 00
  4   2   1      0.491370E 00
  4   2   2      0.443920E 00
  4   2   3      0.478670E 00
  4   2   4      0.608690E 00
1
                          MEAN(I,J)
 I =  1  J =  1  MEAN =     0.183760E 00
 I =  2  J =  1  MEAN =     0.125692E 00
 I =  3  J =  1  MEAN =     0.115427E 00
 I =  4  J =  1  MEAN =     0.121978E 00
 I =  1  J =  2  MEAN =     0.249370E 00
 I =  2  J =  2  MEAN =     0.171830E 00
 I =  3  J =  2  MEAN =     0.432812E 00
 I =  4  J =  2  MEAN =     0.555712E 00
                        S(P,Q)
 P =  1   Q =  1          0.204651E-01
 P =  1   Q =  2          0.708780E-02
 P =  1   Q =  3         -0.660175E-01
 P =  1   Q =  4         -0.324139E-01
 P =  2   Q =  1          0.708780E-02
 P =  2   Q =  2          0.494268E-02
 P =  2   Q =  3         -0.363460E-01
 P =  2   Q =  4         -0.197186E-01
 P =  3   Q =  1         -0.660175E-01
 P =  3   Q =  2         -0.363460E-01
 P =  3   Q =  3          0 297544E 0 0
 P =  3   Q =  4          0.159732E 00
 P =  4   Q =  1         -0.324139E-01
 P =  4   Q =  2         -0.197186E-01
 P =  4   Q =  3          0.159732E 00
 P =  4   Q =  4          0.677035E-01

 D1 =     -0.656100E-01   D2 =     -0.461[illegible]5E-01
   D3 =     -0.317365E 00   D4 =     -0.43[illegible]775E 00


1                         LAMBDA VALUES
  0.46346252441E 03          1
  0.39725988769E 03          2
  0.58548046875E 03          3
 -0.81065844726E 03          4


 L =  4  N =  4


                          LINEAR DISCRIMINATE FUNCTION


 CASE N  = 2 = SINE WAVE, 3.1864MHZ CARRIER
     0.101442E 03
     0.104426E 03
     0.104583E 0[illegible]
     0.104737E 0[illegible]
 AVERAGE =    0.10[illegible]47E [illegible]


 CASE 5  = S = AM MOD 50%, 1KHZ TONE, 3.1864MHZ CARRIER
   -0.133058E 02
   -0.570374E 01
   -0.205014E 02
   -0.135064E 02
 AVERAGE =  -0.132550E 02
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 10

```
 INPUT FIRST CARD NUMBER
! 2

  1   1   1      0.197390E 00
  1   1   2      0.181680E 00
  1   1   3      0.179550E 00
  1   1   4      0.176420E 00
  2   1   1      0.134710E 00
  2   1   2      0.124350E 00
  2   1   3      0.122920E 00
  2   1   4      0.120790E 00
  3   1   1      0.132180E 00
  3   1   2      0.112790E 00
  3   1   3      0.110260E 00
  3   1   4      0.106540E 00
  4   1   1      0.149150E 00
  4   1   2      0.117450E 00
  4   1   3      0.113510E 00
  4   1   4      0.107800E 00
 INPUT SECOND CARD NUMBER
! 6

  1   2   1      0.390490E 00
  1   2   2      0.272540E 00
  1   2   3      0.346650E 00
  1   2   4      0.292500E 00
  2   2   1      0.183840E 00
  2   2   2      0.184780E 00
  2   2   3      0.228610E 00
  2   2   4      0.234000E 00
  3   2   1      0.268840E 00
  3   2   2      0.249540E 00
  3   2   3      0.408360E 00
  3   2   4      0.390600E 00
  4   2   1      0.498520E 00
  4   2   2      0.393430E 00
  4   2   3      0.876980E 00
  4   2   4      0.744350E 00
1
                       MEAN(I,J)
 I =  1   J =  1  MEAN =     0.183760E 00
 I =  2   J =  1  MEAN =     0.125692E 00
 I =  3   J =  1  MEAN =     0.115427E 00
 I =  4   J =  1  MEAN =     0.121978E 00
 I =  1   J =  2  MEAN =     0.325545E 00
 I =  2   J =  2  MEAN =     0.207807E 00
 I =  3   J =  2  MEAN =     0.329335E 00
 I =  4   J =  2  MEAN =     0.628320E 00
                     S(P,Q)
P =  1   Q =  1          0.882648E-02
P =  1   Q =  2         -0.589135E-03
P =  1   Q =  3          0.263995E-03
P =  1   Q =  4          0.595372E-02
P =  2   Q =  1         -0.589135E-03
P =  2   Q =  2          0.233834E-02
P =  2   Q =  3          0.674796E-02
P =  2   Q =  4          0.170759E-01
P =  3   Q =  1          0.263995E-03
P =  3   Q =  2          0.674796E-02
P =  3   Q =  3          0.204165E-01
P =  3   Q =  4          0.539895E-01
P =  4   Q =  1          0.595372E-02
P =  4   Q =  2          0.170759E-01
P =  4   Q =  3          0.539895E-01
P =  4   Q =  4          0.148348E 00

D1 =    -0.141785E 00  D2 =    -0.821150E-01
  D3 =    -0.213907E 00  D4 =    -0.506342E 00

1                     LAMBDA VALUES
-0.43775588489E 02        1
-0.53371691894E 03        2
 0.22374165181E 03        3
-0.21650146464E 02        4


L =   4   N =   4


                      LINEAR DISCRIMINATE FUNCTIONS


RACE A   = 2 = SINE WAVE, 3.1864MHZ CARRIER
   -0.542062E 02
   -0.516278E 02
   -0.512521E 02
   -0.506870E 02
AVERAGE =  -0.519453E 02


RACE B   = 6 = AM MOD 100%, 100HZ TONE, 3 1864 CARRIER
   -0.658547E 02
    0.6[illegible]1E 02
    0.6480[illegible]E 02
   -0.664158E 02
AVERAGE =  -0.650785E 02
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 11

```
 INPUT FIRST CARD NUMBER
1 2

  1   1   1     0.197390E 00
  1   1   2     0.181680E 00
  1   1   3     0.179550E 00
  1   1   4     0.176420E 00
  2   1   1     0.134710E 00
  2   1   2     0.124350E 00
  2   1   3     0.122920E 00
  2   1   4     0.120790E 00
  3   1   1     0.132120E 00
  3   1   2     0.112790E 00*
  3   1   3     0.110260E 00
  3   1   4     0.106540E 00
  4   1   1     0.149150E 00
  4   1   2     0.117450E 00
  4   1   3     0.113510E 00
  4   1   4     0.107800E 00
 INPUT SECOND CARD NUMBER
1 7

  1   2   1     0.202080E 00
  1   2   2     0.192750E 00
  1   2   3     0.187600E 00
  1   2   4     0.179940E 00
  2   2   1     0.137830E 00
  2   2   2     0.131630E 00
  2   2   3     0.128260E 00
  2   2   4     0.123180E 00
  3   2   1     0.138230E 00
  3   2   2     0.126210E 00
  3   2   3     0.119900E 00
  3   2   4     0.110720E 00
  4   2   1     0.159700E 00
  4   2   2     0.139190E 00
  4   2   3     0.128800E 00
  4   2   4     0.114220E 00
1
                        MEAN(I,J)
 I =  1  J =  1  MEAN =     0.183760E 00
 I =  2  J =  1  MEAN =     0.125692E 00
 I =  3  J =  1  MEAN =     0.115427E 00
 I =  4  J =  1  MEAN =     0.121978E 00
 I =  1  J =  2  MEAN =     0.190592E 00
 I =  2  J =  2  MEAN =     0.130225E 00
 I =  3  J =  2  MEAN =     0.123765E 00
 I =  4  J =  2  MEAN =     0.135477E 00
                        S(P,Q)
 P =  1   Q =  1           0.520751E-03
 P =  1   Q =  2           0.344678E-03
 P =  1   Q =  3           0.641964E-03
 P =  1   Q =  4           0.105218E-02
 P =  2   Q =  1           0.344678E-03
 P =  2   Q =  2           0.228142E-03
 P =  2   Q =  3           0.424901E-03
 P =  2   Q =  4           0.696396E-03
 P =  3   Q =  1           0.641964E-03
 P =  3   Q =  2           0.424901E-03
 P =  3   Q =  3           0.791611E-03
 P =  3   Q =  4           0.129784E-02
 P =  4   Q =  1           0.105218E-02
 P =  4   Q =  2           0.696396E-03
 P =  4   Q =  3           0.129784E-02
 P =  4   Q =  4           0.212852E-02

 D1 =     -0.683251E-02  D2 =     -0.453252E-02
   D3 =     -0.833750E-02  D4 =     -0.135000E-01


1                        LAMBDA VALUES
 -0.18037109375E 05          1
 -0.15791006250E 06          2
  0.19541193750E 06          3
 -0.58576507812E 05          4



 L =  4  N =  4



                        LINEAR DISCRIMINATE FUNCTIONS


 RACE H  = 2 = SINE WAVE, 3.1864MHZ CARRIER
   -0.775127E 04
   -0.775240E 04
   -0.775177E 04
   -0.775142E 04
 AVERAGE =  -0.775171E 04



 RACE E  = 7 = FM MOD 1 KHZ TONE, 3.1864MHZ CARRIER
   -0.775255E 04
   -0.775268E 04
   -0.775207E 04
   -0.775156E 04
 AVERAGE =  -0.775221E 04
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 12

```
 INPUT FIRST CARD NUMBER
1 2

  1   1   1      0.197390E 00
  1   1   2      0.181680E 00
  1   1   3      0.179550E 00
  1   1   4      0.176420E 00
  2   1   1      0.134710E 00
  2   1   2      0.124350E 00
  2   1   3      0.122920E 00
  2   1   4      0.120790E 00
  3   1   1      0.132120E 00
  3   1   2      0.112790E 00
  3   1   3      0.110260E 00
  3   1   4      0.106540E 00
  4   1   1      0.149150E 00
  4   1   2      0.117450E 00
  4   1   3      0.113510E 00
  4   1   4      0.107800E 00
 INPUT SECOND CARD NUMBER
1 8

  1   2   1      0.355530E 00
  1   2   2      0.385000E 00
  1   2   3      0.400000E 00
  1   2   4      0.427440E 00
  2   2   1      0.191750E 00
  2   2   2      0.186630E 00
  2   2   3      0.180000E 00
  2   2   4      0.177420E 00
  3   2   1      0.293430E 00
  3   2   2      0.278020E 00
  3   2   3      0.260000E 00
  3   2   4      0.244460E 00
  4   2   1      0.561320E 00
  4   2   2      0.524640E 00
  4   2   3      0.470000E 00
  4   2   4      0.420480E 00
1
                      MEAN(I,J)
 I =  1  J =  1  MEAN =     0.183760E 00
 I =  2  J =  1  MEAN =     0.125692E 00
 I =  3  J =  1  MEAN =     0.115427E 00
 I =  4  J =  1  MEAN =     0.121970E 00
 I =  1  J =  2  MEAN =     0.391993E 00
 I =  2  J =  2  MEAN =     0.183950E 00
 I =  3  J =  2  MEAN =     0.268970E 00
 I =  4  J =  2  MEAN =     0.494110E 00
                      S(P,Q)
 P =  1   Q =  1          0.296076E-02
 P =  1   Q =  2         -0.392892E-03
 P =  1   Q =  3         -0.157581E-02
 P =  1   Q =  4         -0.494770E-02
 P =  2   Q =  1         -0.392892E-03
 P =  2   Q =  2          0.241105E-03
 P =  2   Q =  3          0.622487E-03
 P =  2   Q =  4          0.152618E-02
 P =  3   Q =  1         -0.157581E-02
 P =  3   Q =  2          0.622487E-03
 P =  3   Q =  3          0.175268E-02
 P =  3   Q =  4          0.457647E-02
 P =  4   Q =  1         -0.494770E-02
 P =  4   Q =  2          0.152618E-02
 P =  4   Q =  3          0.457647E-02
 P =  4   Q =  4          0.124835E-01

 D1 =     -0.208233E 00  D2 =     -0.582575E-01
   D3 =     -0.153550E 00  D4 =     -0.372132E 00

1                    LAMBDA VALUES
 -0.20413874023E 04        1
  0.16437613281E 05        2
 -0.75600634766E 04        3
 -0.76942062378E 02        4


 L =  4  N =  4


                  LINEAR DISCRIMINATE FUNCTIONS

 RALE A   = 2 = SINE WAVE, 3.1864MHZ CARRIER
    0.801060E 03
    0.811411E 03
    0.811683E 03
    0.811623E 03
 AVERAGE =    0.808944E 03


 RALE B   = 8 = AM MOD 100%, 1KHZ TONE, 3.1864MHZ CARRIER
    0.164618E 03
    0.139621E 03
    0.140456E 03
    0.163327E 03
 AVERAGE =    0.152005E 03
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 13

```
 INPUT FIRST CARD NUMBER
! 3

  1   1   1      0.202250E 00
  1   1   2      0.167600E 00
  1   1   3      0.161170E 00
  1   1   4      0.174460E 00
  2   1   1      0.1379[illegible]0E 00
  2   1   2      0.128390E 00
  2   1   3      0.124010E 00
  2   1   4      0.119440E 00
  3   1   1      0.138440E 00
  [illegible]   1   2      0.120150E 00
  3   1   [illegible]      0.1121[illegible]0E 00
  3   1   4      0.104220E 00
  4   1   1      0.160060E 00
  4   1   2      0.129200E 00
  4   1   3      0.116500E 00
  4   1   4      0.104290E 00
 INPUT SECOND CARD NUMBER
! 4

  1   2   1      0.201940E 00
  1   2   2      0.187680E 00
  1   2   3      0.188670E 00
  1   2   4      0.179630E 00
  2   2   1      0.137670E 00
  [illegible]   2   2      0.128301E 00
  [illegible]   2   3      0.128970E 00
  2   2   4      0.122430E 00
  3   2   1      0.1[illegible]7[illegible] [illegible]0E 00
  3   2   2      0.119990E 00
  [illegible]   2   3      0.121220E 00
  [illegible]   2   4      0.109390E 00
  4   2   1      0.159210E 00
  4   2   2      0.128950E 00
  4   2   [illegible]      0.120950E 00
  4   2   4      0.112170E 00
 1
                        MEAN(I,J)
 I =  1   J =  1   MEAN =      0.186420E 00
 I =  2   J =  1   MEAN =      0.127447E 00
 I =  3   J =  1   MEAN =      0.118750E 00
 I =  4   J =  1   MEAN =      0.127512E 00
 I =  1   J =  2   MEAN =      0.189280E 00
 I =  2   J =  2   MEAN =      0.129343E 00
 I =  3   J =  2   MEAN =      0.122132E 00
 I =  4   J =  2   MEAN =      0.132820E 00
                         (F,U)
 F =  1    U =  1          0.249550E-03
 F =  1    U =  2          0.460210E-0[illegible]
 F =  1    U =  [illegible]          0.[illegible]28983E-0[illegible]
 F =  1    U =  4          0.141033E-02
 F =  2    U =  1          0.460610E-0[illegible]
 F =  2    U =  2          0.[illegible]050[illegible]0E-03
 F =  2    U =  [illegible]          0.566826E-0[illegible]
 F =  2    U =  4          0.433811E-03
 F =  3    U =  1          0.358983E-03
 F =  3    U =  2          0.568826E-03
 F =  3    U =  3          0.166117E-02
 F =  3    U =  4          0.171291E-02
 F =  4    U =  1          0.1410[illegible]3E-02
 F =  4    U =  2          0.4[illegible]3811E-0[illegible]
 F =  4    U =  3          0.174291E-02
 F =  4    U =  4          0.[illegible]2640EE-02

 D1 =     -0.[illegible]2599[illegible]E-0[illegible]   D[illegible] =     -0.1[illegible]00[illegible]2E-0[illegible]
   D[illegible] =     -0.[illegible]3625UE-0[illegible]   D4 =     -0.[illegible] [illegible] [illegible]E-0[illegible]

 1                     LAMBDA VALUES
 -0.692108[illegible]053[illegible]2E 04          1
 -0.166620565594E 05          [illegible]
  0.[illegible]70[illegible]4[illegible]492[illegible]19E 0[illegible]
 -0.[illegible]6[illegible][illegible]1201172E 04          4

 L =  4   N =  4

                        LINEAR DISCRIMINATE FUNCTION.

 PAGE H   = 3 = FM MOD 100HZ TONE, 3 1864 MHZ CARRIER
    -0.11[illegible]220E 04
    -0.117282E 04
    -0.117248E 04
    -0.11724[illegible]E 04
 AVERAGE =  -0.117250E 04

 PAGE I   = 4 = FM MOD 4KHZ TONE, 3.1864MHZ CARRIER
    -0.117312E 04
    -0.117293E 04
    -0.117291E 04
    -0.117270E 04
 AVERAGE =  -0.11[illegible]291E 04
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 14

```
 INPUT FIRST CARD NUMBER
 1

  1   1   1      0.202250E 00
  1   1   2      0.187800E 00
  1   1   3      0.161170E 00
  1   1   4      0.174460E 00
  2   1   1      0.137930E 00
  2   1   2      0.128390E 00
  2   1   3      0.124010E 00
  2   1   4      0.119440E 00
  3   1   1      0.138440E 00
  3   1   2      0.120150E 00
  3   1   3      0.112190E 00
  3   1   4      0.104220E 00
  4   1   1      0.160020E 00
  4   1   2      0.129200E 00
  4   1   3      0.116500E 00
  4   1   4      0.104290E 00
 INPUT SECOND CARD NUMBER
 15

  1   2   1      0.346740E 00
  1   2   2      0.249430E 00
  1   2   3      0.255410E 00
  1   2   4      0.145440E 00
  2   2   1      0.178600E 00
  2   2   2      0.194960E 00
  2   2   3      0.200320E 00
  2   2   4      0.113240E 00
  3   2   1      0.22[illegible]30E 00
  3   2   2      0.275180E 00
  3   2   3      0.25[illegible]650E 00
  3   2   4      0.404590E 00
  4   2   1      0.441370E 00
  4   2   2      0.443920E 00
  4   2   3      0.426670E 00
  4   2   4      0.308840E 00
1
                        MEAN(I,J)
 I =  1  J =  1  MEAN =     0.186420E 00
 I =  2  J =  1  MEAN =     0.127443E 00
 I =  3  J =  1  MEAN =     0.118750E 00
 I =  4  J =  1  MEAN =     0.127512E 00
 I =  1  J =  2  MEAN =     0.249370E 00
 I =  2  J =  2  MEAN =     0.171830E 00
 I =  3  J =  2  MEAN =     0.432812E 00
 I =  4  J =  2  MEAN =     0.555712E 00
                        S(P,Q)
 P =  1   Q =  1        0.206465E-01
 P =  1   Q =  2        0.719550E-02
 P =  1   Q =  3       -0.658157E-01
 P =  1   Q =  4       -0.320602E-01
 P =  2   Q =  1        0.719550E-02
 P =  2   Q =  2        0.501475E-02
 P =  2   Q =  3       -0.362113E-01
 P =  2   Q =  4       -0.194963E-01
 P =  3   Q =  1       -0.658157E-01
 P =  3   Q =  2       -0.362113E-01
 P =  3   Q =  3        0.297796E 00
 P =  3   Q =  4        0.160150E 00
 P =  4   Q =  1       -0.320802E-01
 P =  4   Q =  2       -0.194963E-01
 P =  4   Q =  3        0.160150E 00
 P =  4   Q =  4        0.863947E-01

 D1 =    -0.629500E-01  D2 =    -0.443375E-01
   D3 =    -0.314062E 00  D4 =    -0.428200E 00


1                    LAMBDA VALUES
  0.4478095703[illegible]E 03       1
  0.4915580200[illegible]E 0[illegible]       2
  0.6105931346[illegible]5E 0[illegible]
 -0.8364457275[illegible]4E 03       4



 L =  4  N =  4



                    LINEAR DISCRIMINATE FUNCTIONS


 RACE H  = 3 = FM MOD 100HZ TONE, 3 1864MHZ CARRIER
     0.120234E 0[illegible]
     0.122851E 0[illegible]
     0.123097E 0[illegible]
     0.122794E 0[illegible]
 AVERAGE =    0.122244E 0[illegible]


 RACE I   = 5 = AM MOD 50%, 1KHZ TONE, 3 1864MHZ CARRIER
     0.114424E 02
     0.166444E 02
     0.4[illegible]3904E 01
     0.112[illegible]1E 02
 AVERAGE =    0.[illegible]1490[illegible]E 02
```

FIGURE 11-2. COMBINATIONAL Z5 RUN 15

```
 INPUT FIRST CARD NUMBER
! 3

  1   1   1     0.202250E 00
  1   1   2     0.187800E 00
  1   1   3     0.181170E 00
  1   1   4     0.174460E 00
  2   1   1     0.137930E 00
  2   1   2     0.128390E 00
  2   1   3     0.124010E 00
  2   1   4     0.119440E 00
  3   1   1     0.138440E 00
  3   1   2     0.120150E 00
  3   1   3     0.112190E 00
  3   1   4     0.104220E 00
  4   1   1     0.160060E 00
  4   1   2     0.129200E 00
  4   1   3     0.116500E 00
  4   1   4     0.104290E 00
 INPUT SECOND CARD NUMBER
! 6

  1   2   1     0.390490E 00
  1   2   2     0.272540E 00
  1   2   3     0.346650E 00
  1   2   4     0.292500E 00
  2   2   1     0.183840E 00
  2   2   2     0.184780E 00
  2   2   3     0.228610E 00
  2   2   4     0.234000E 00
  3   2   1     0.268840E 00
  3   2   2     0.249540E 00
  3   2   3     0.408360E 00
  3   2   4     0.390600E 00
  4   2   1     0.498520E 00
  4   2   2     0.393430E 00
  4   2   3     0.876980E 00
  4   2   4     0.744350E 00
1
                         MEAN(I,J)
 I =  1  J =  1  MEAN =     0.186420E 00
 I =  2  J =  1  MEAN =     0.127443E 00
 I =  3  J =  1  MEAN =     0.118750E 00
 I =  4  J =  1  MEAN =     0.127512E 00
 I =  1  J =  2  MEAN =     0.325545E 00
 I =  2  J =  2  MEAN =     0.207807E 00
 I =  3  J =  2  MEAN =     0.329335E 00
 I =  4  J =  2  MEAN =     0.628320E 00
                         S(P,Q)
 P =  1   Q =  1          0.298788E-02
 P =  1   Q =  2         -0.481438E-03
 P =  1   Q =  3          0.465845E-03
 P =  1   Q =  4          0.628734E-02
 P =  2   Q =  1         -0.481438E-03
 P =  2   Q =  2          0.241021E-02
 P =  2   Q =  3          0.688261E-02
 P =  2   Q =  4          0.172984E-01
 P =  3   Q =  1          0.465845E-03
 P =  3   Q =  2          0.688261E-02
 P =  3   Q =  3          0.206690E-01
 P =  3   Q =  4          0.544071E-01
 P =  4   Q =  1          0.628734E-02
 P =  4   Q =  2          0.172984E-01
 P =  4   Q =  3          0.544071E-01
 P =  4   Q =  4          0.149039E 00

 D1 =    -0.139125E 00  D2 =    -0.603650E-01
   D3 =    -0.210585E 00  D4 =    -0.500808E 00

1                        LAMBDA VALUES
 -0.41528834520 1E 02        1
  0.12320733643E 03          2
 -0.21508276367E 03          3
  0.62608123779E 02          4


 L =  4  N =  4


                         LINEAR DISCRIMINANTE FUNCTIONS


 RACE A   = 3 = FM MOD 100HZ TONE, 3.1864MHZ CARRIER
   -0.111601E 02
   -0.973266E 01
   -0.908104E 01
   -0.641567E 01
 AVERAGE =  -0.954762E 01


 RACE B   = 6 = AM MOD 100%, 100HZ TONE, 3.1864MHZ CARRIER
   -0.201774E 02
   -0.175417E 02
   -0.191645E 02
   -0.207255E 02
 AVERAGE =  -0.144123E 02
```

FIGURE 11-2. COMBINATIONAL 35
RUN 16

```
 INPUT FIRST CARD NUMBER
1 3

  1   1   1      0.202250E 00
  1   1   2      0.187800E 00
  1   1   3      0.181170E 00
  1   1   4      0.174460E 00
  2   1   1      0.137930E 00
  2   1   2      0.128390E 00
  2   1   3      0.124010E 00
  2   1   4      0.119440E 00
  3   1   1      0.138440E 00
  3   1   2      0.120150E 00
  3   1   3      0.112190E 00
  3   1   4      0.104220E 00
  4   1   1      0.160060E 00
  4   1   2      0.129200E 00
  4   1   3      0.116500E 00
  4   1   4      0.104290E 00
 INPUT SECOND CARD NUMBER
1 7

  1   2   1      0.202080E 00
  1   2   2      0.192750E 00
  1   2   3      0.187600E 00
  1   2   4      0.179940E 00
  2   2   1      0.137830E 00
  2   2   2      0.131630E 00
  2   2   3      0.128260E 00
  2   2   4      0.123180E 00
  3   2   1      0.138230E 00
  3   2   2      0.126210E 00
  3   2   3      0.119900E 00
  3   2   4      0.110720E 00
  4   2   1      0.159700E 00
  4   2   2      0.139190E 00
  4   2   3      0.128800E 00
  4   2   4      0.114220E 00
1
                          MEAN(I,J)
 I =  1  J =  1  MEAN =     0.166420E 00
 I =  2  J =  1  MEAN =     0.127443E 00
 I =  3  J =  1  MEAN =     0.118750E 00
 I =  4  J =  1  MEAN =     0.127512E 00
 I =  1  J =  2  MEAN =     0.190592E 00
 I =  2  J =  2  MEAN =     0.130225E 00
 I =  3  J =  2  MEAN =     0.123765E 00
 I =  4  J =  2  MEAN =     0.135477E 00
                         S(P,Q)
 P =  1   Q =  1           0.682145E-03
 P =  1   Q =  2           0.452376E-03
 P =  1   Q =  3           0.843813E-03
 P =  1   Q =  4           0.138580E-02
 P =  2   Q =  1           0.452376E-03
 P =  2   Q =  2           0.300010E-03
 P =  2   Q =  3           0.559557E-03
 P =  2   Q =  4           0.918887E-03
 P =  3   Q =  1           0.843813E-03
 P =  3   Q =  2           0.559557E-03
 P =  3   Q =  3           0.104414E-02
 P =  3   Q =  4           0.171546E-02
 P =  4   Q =  1           0.138580E-02
 P =  4   Q =  2           0.918887E-03
 P =  4   Q =  3           0.171546E-02
 P =  4   Q =  4           0.281973E-02

 D1 =    -0.417247E-02  D2 =    -0.278249E-02
   D3 =    -0.501500E-02  D4 =    -0.796500E-02


1                         LAMBDA VALUES
 -0.27266772461E 04         1
 -0.2212549218.E 05         2
  0.27335058594E 05
 -0.80815468281E 04



 L =  4  M =  4



                         LINEAR DISCRIMINATE FUNCTIONS


 RACE M = 3 = FM MOD 100HZ TONE, 3 1864MHZ CARRIER
     0.111291E 04
     0.111297E 04
     0.111292E 04
    -0.111266E 04
 AVERAGE =  -0.111287E 04


 RACE E  = 7 = FM MOD 1KHZ TONE, 3 1864MHZ CARRIER
    -0.11130 E 04
      .111 24E 04
      .111 15E 04
     0.111249E 04
 AVERAGE =     0.111210E 04
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 17

```
 INPUT FIRST CARD NUMBER
! 3

  1   1   1      0.202250E 00
  1   1   2      0.187800E 00
  1   1   3      0.181170E 00
  1   1   4      0.174460E 00
  2   1   1      0.137930E 00
  2   1   2      0.128390E 00
  2   1   3      0.124010E 00
  2   1   4      0.119440E 00
  3   1   1      0.138440E 00
  3   1   2      0.120150E 00
  3   1   3      0.112190E 00
  3   1   4      0.104220E 00
  4   1   1      0.160060E 00
  4   1   2      0.129200E 00
  4   1   3      0.116500E 00
  4   1   4      0.104290E 00
 INPUT SECOND CARD NUMBER
! 8

  1   2   1      0.355530E 00
  1   2   2      0.385000E 00
  1   2   3      0.400000E 00
  1   2   4      0.427440E 00
  2   2   1      0.191750E 00
  2   2   2      0.186630E 00
  2   2   3      0.180000E 00
  2   2   4      0.177420E 00
  3   2   1      0.293430E 00
  3   2   2      0.278020E 00
  3   2   3      0.260000E 00
  3   2   4      0.244460E 00
  4   2   1      0.561320E 00
  4   2   2      0.524640E 00
  4   2   3      0.470000E 00
  4   2   4      0.420480E 00
1
                          MEAN(I,J)
 I = 1  J = 1  MEAN =     0.186420E 00
 I = 2  J = 1  MEAN =     0.127443E 00
 I = 3  J = 1  MEAN =     0.118750E 00
 I = 4  J = 1  MEAN =     0.127512E 00
 I = 1  J = 2  MEAN =     0.391993E 00
 I = 2  J = 2  MEAN =     0.183950E 00
 I = 3  J = 2  MEAN =     0.268978E 00
 I = 4  J = 2  MEAN =     0.494110E 00
                          S(P,Q)
 P = 1   Q = 1           0.312215E-02
 P = 1   Q = 2          -0.285195E-03
 P = 1   Q = 3          -0.137396E-02
 P = 1   Q = 4          -0.461407E-02
 P = 2   Q = 1          -0.285195E-03
 P = 2   Q = 2           0.312973E-03
 P = 2   Q = 3           0.757142E-03
 P = 2   Q = 4           0.174866E-02
 P = 3   Q = 1          -0.137396E-02
 P = 3   Q = 2           0.757142E-03
 P = 3   Q = 3           0.200520E-02
 P = 3   Q = 4           0.499406E-02
 P = 4   Q = 1          -0.461407E-02
 P = 4   Q = 2           0.174866E-02
 P = 4   Q = 3           0.499406E-02
 P = 4   Q = 4           0.131747E-01

 D1 =    -0.205572E 00  D2 =    -0.565075E-01
    D3 =    -0.150226E 00  D4 =    -0.366597E 00

1                      LAMBDA VALUES
 -0.18846376953E 04        1
  0.15002929687E 05        2
 -0.64112636719E 04        3
 -0.24691406250E 03        4


 L =  4  M =  4


                      LINEAR DISCRIMINATE FUNCTIONS


RACE A  = 3 = FM MOD 100HZ TONE, 3.1864MHZ CARRIER
    0.760765E 03
    0.769816E 03
    0.770795E 03
    0.769015E 03
AVERAGE =    0.767599E 03


RACE B  = 8 = AM MOD 100%, 1KHZ TONE, 3.1864MHZ CARRIER
    0.165789E 03
    0.161362E 0[illegible]
    0.162754E 03
    0.164290E 0[illegible]
AVERAGE =    0.17[illegible]549E 0[illegible]
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 18

```
 INPUT FIRST CARD NUMBER
! 4

  1   1   1      0.201940E 00
  1   1   2      0.187680E 00
  1   1   3      0.188670E 00
  1   1   4      0.178830E 00
  2   1   1      0.137670E 00
  2   1   2      0.128301E 00
  2   1   3      0.128970E 00
  2   1   4      0.122430E 00
  3   1   1      0.137930E 00
  3   1   2      0.119990E 00
  3   1   3      0.121220E 00
  3   1   4      0.109340E 00
  4   1   1      0.159210E 00
  4   1   2      0.128950E 00
  4   1   3      0.130950E 00
  4   1   4      0.112170E 00
 INPUT SECOND CARD NUMBER
! 5

  1   2   1      0.346740E 00
  1   2   2      0.249430E 00
  1   2   3      0.255410E 00
  1   2   4      0.145900E 00
  2   2   1      0.178800E 00
  2   2   2      0.194960E 00
  2   2   3      0.200320E 00
  2   2   4      0.113240E 00
  3   2   1      0.261830E 00
  3   2   2      0.275180E 00
  3   2   3      0.289650E 00
  3   2   4      0.904590E 00
  4   2   1      0.441370E 00
  4   2   2      0.443920E 00
  4   2   3      0.478670E 00
  4   2   4      0.808890E 00
1
                          MEAN(I,J)
 I =  1  J =  1  MEAN =    0.189280E 00
 I =  2  J =  1  MEAN =    0.129343E 00
 I =  3  J =  1  MEAN =    0.122132E 00
 I =  4  J =  1  MEAN =    0.132820E 00
 I =  1  J =  2  MEAN =    0.249370E 00
 I =  2  J =  2  MEAN =    0.171830E 00
 I =  3  J =  2  MEAN =    0.432812E 00
 I =  4  J =  2  MEAN =    0.355712E 00
                          S(P,Q)
 P =  1   Q =  1          0.204958E-01
 P =  1   Q =  2          0.709400E-02
 P =  1   Q =  3         -0.660004E-01
 P =  1   Q =  4         -0.323761E-01
 P =  2   Q =  1          0.709400E-02
 P =  2   Q =  2          0.494640E-02
 P =  2   Q =  3         -0.363357E-01
 P =  2   Q =  4         -0.196956E-01
 P =  3   Q =  1         -0.660004E-01
 P =  3   Q =  2         -0.363357E-01
 P =  3   Q =  3          0.297570E 00
 P =  3   Q =  4          0.159787E 00
 P =  4   Q =  1         -0.323761E-01
 P =  4   Q =  2         -0.196956E-01
 P =  4   Q =  3          0.159787E 00
 P =  4   Q =  4          0.878133E-01

 D1 =    -0.600900E-01  D2 =     -0.424872E-01
   D3 =    -0.310660E 00  D4 =     -0.422892E 00


1                         LAMBDA VALUES
  0.465745605547E 03         1
  0.464064819334E 03         2
  0.606037719 73E 03         3
 -0.824397094 73E 03         4



 Q =  4  N =  4



                          LINEAR DISCRIMINATE FUNCTIONS



 RACE N  = 4 = FM MOD [illegible] CARRIER
    0.114318E 03
    0.117117E 03
    0.117005E 03
    0.11 503E 03
 AVERAGE =    0.116466E 03



 RACE 5  = 5 = AM MOD 50%, 1KHZ TONE, 3 1864MHZ CARRIER
    0.449707E 01
    0.124362E 02
   -0.204956E 01
    0.479004E 01
 AVERAGE =    0 504358E 01
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 19

```
INPUT FIRST CARD NUMBER
 4

  1   1   1      0.201940E 00
  1   1   2      0.187680E 00
  1   1   3      0.188670E 00
  1   1   4      0.178830E 00
  2   1   1      0.137670E 00
  2   1   2      0.128301E 00
  2   1   3      0.128970E 00
  2   1   4      0.122430E 00
  3   1   1      0.137930E 00
  3   1   2      0.119990E 00
  3   1   3      0.121220E 00
  3   1   4      0.109390E 00
  4   1   1      0.159210E 00
  4   1   2      0.128950E 00
  4   1   3      0.130950E 00
  4   1   4      0.112170E 00
INPUT SECOND CARD NUMBER
! 6

  1   2   1      0.390490E 00
  1   2   2      0.272540E 00
  1   2   3      0.346650E 00
  1   2   4      0.292500E 00
  2   2   1      0.183840E 00
  2   2   2      0.184780E 00
  2   2   3      0.228610E 00
  2   2   4      0.234000E 00
  3   2   1      0.268840E 00
  3   2   2      0.249540E 00
  3   2   3      0.408360E 00
  3   2   4      0.390600E 00
  4   2   1      0.498520E 00
  4   2   2      0.393430E 00
  4   2   3      0.876980E 00
  4   2   4      0.744350E 00
1
                         MEAN(I,J)
 I =  1  J =  1  MEAN =     0.189280E 00
 I =  2  J =  1  MEAN =     0.129343E 00
 I =  3  J =  1  MEAN =     0.122132E 00
 I =  4  J =  1  MEAN =     0.132820E 00
 I =  1  J =  2  MEAN =     0.325545E 00
 I =  2  J =  2  MEAN =     0.207807E 00
 I =  3  J =  2  MEAN =     0.329335E 00
 I =  4  J =  2  MEAN =     0.628320E 00
                         S(P,Q)
 P =  1   Q =  1          0.883719E-02
 P =  1   Q =  2         -0.582938E-03
 P =  1   Q =  3          0.281141E-03
 P =  1   Q =  4          0.599145E-02
 P =  2   Q =  1         -0.582938E-03
 P =  2   Q =  2          0.234185E-02
 P =  2   Q =  3          0.675820E-02
 P =  2   Q =  4          0.170990E-01
 P =  3   Q =  1          0.281141E-03
 P =  3   Q =  2          0.675820E-02
 P =  3   Q =  3          0.204446E-01
 P =  3   Q =  4          0.540443E-01
 P =  4   Q =  1          0.599145E-02
 P =  4   Q =  2          0.170990E-01
 P =  4   Q =  3          0.540443E-01
 P =  4   Q =  4          0.148457E 00

 D1 =    -0.136265E 00  D2 =     -0.784647E-01
   D3 =     -0.207202E 00  D4 =     -0.495500E 00


1                        LAMBDA VALUES
 -0.4191 .59778E 02          1
 -0.41670330566E 03          2
  0.15081930542E 03          3
 -0.85482692718E 01          4


 L =  4  N =  4


                         LINEAR DISCRIMINATE FUNCTIONS


 RACE H   = 4 = FM MOD 5KHZ TONE, 3.1864MHZ CARRIER
   -0.463983E 02
   -0.443430E 02
   -0.444949E 02
   -0.429805E 02
 AVERAGE =  -0.445541E 02


 RACE B   = 6 = AM MOD 100%, 100HZ TONE, 3.1864MHZ CARRIER
   -0.566998E 02
   -0.541603E 02
   -0.557136E 02
   -0.572352E 02
 AVERAGE =  -0.559522E 02
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 20

```
 INPUT FIRST CARD NUMBER
! 4

  1   1   1      0.201940E 00
  1   1   2      0.187680E 00
  1   1   3      0.188670E 00
  1   1   4      0.178830E 00
  2   1   1      0.137670E 00
  2   1   2      0.128301E 00
  2   1   3      0.128970E 00
  2   1   4      0.122430E 00
  3   1   1      0.137930E 00
  3   1   2      0.119940E 00
  3   1   3      0.1[illegible]E 00
  3   1   4      0.109390E 00
  4   1   1      0.159210E 00
  4   1   2      0.128950E 00
  4   1   3      0.130950E 00
  4   1   4      0.112170E 00
 INPUT SECOND CARD NUMBER
!

  1   2   1      0.202080E 00
  1   2   2      0.192750E 00
  1   2   3      0.187600E 00
  1   2   4      0.179940F 00
  2   2   1      0.137830E 00
  2   2   2      0.131630E 00
  2   2   3      0.128260E 00
  2   2   4      0.123160E 00
  3   2   1      0.138230E 00
  3   2   2      0.126210E 00
  3   2   3      0.119900E 00
  3   2   4      0.110720E 00
  4   2   1      0.159700E 00
  4   2   2      0.139190E 00
  4   2   3      0.128800E 00
  4   2   4      0.114220E 00
1
                          MEAN(I,J)
 I =  1  J =  1  MEAN =     0.189286E 00
 I =  2  J =  1  MEAN =     0.129343E 00
 I =  3  J =  1  MEAN =     0.122132E 00
 I =  4  J =  1  MEAN =     0.132820E 00
 I =  1  J =  2  MEAN =     0.190592E 00
 I =  2  J =  2  MEAN =     0.130225E 00
 I =  3  J =  2  MEAN =     0.123765E 00
 I =  4  J =  2  MEAN =     0.135477E 00
                          D(P,Q)
 P =  1   Q =  1        0.531458E-03
 P =  1   Q =  2        0.350876E-03
 P =  1   Q =  3        0.659109E-03
 P =  1   Q =  4        0.108992E-02
 P =  2   Q =  1        0.350876E-03
 P =  2   Q =  2        0.231656E-03
 P =  2   Q =  3        0.435146E-03
 P =  2   Q =  4        0.719541E-03
 P =  3   Q =  1        0.659109E-03
 P =  3   Q =  2        0.435146E-03
 P =  3   Q =  3        0.817679E-03
 P =  3   Q =  4        0.135259E-02
 P =  4   Q =  1        0.108992E-02
 P =  4   Q =  2        0.719541E-03
 P =  4   Q =  3        0.135259E-02,
 P =  4   Q =  4        0.223831E-02

 D1 =    -0.131249E-02  D2 =     0.882238E-03
   D3 =    -0.163250E-02  D4 =    -0.265747E-02


1                          LAMBDA VALUE.
  0.3.270966797E 04          1
 -0.833541015062E 04         2
  0.2489[illegible]41E 04          3
 -0.94313647461E 03          4


 L =  4  M =  4


                      LINEAR DISCRIMINATE FUNCTIONS


 VALUE M   = 4 = FM MOD 5KHZ TONE, 3 1864MHZ CARRIER
   -0.13[illegible]E 03
   -0.1[illegible]E 0[illegible]
   -0.1[illegible]921E 0[illegible]
   -0.13[illegible]36E 0[illegible]
 AVERAGE =  -0.1[illegible]40E 03


 VALUE I   = 7 = FM MOD 1KHZ TONE, 3.1864MHZ CARRIER
   -0.13[illegible]E [illegible]
   -0.1[illegible]740E [illegible]
   -0.1[illegible]910E [illegible]
   -0.1[illegible]810E [illegible]
 AVERAGE =  -0.1[illegible]78E 03
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 21

```
 INPUT FIRST CARD NUMBER
! 4

  1   1   1      0.201940E 00
  1   1   2      0.187680E 00
  1   1   3      0.188670E 00
  1   1   4      0.178830E 00
  2   1   1      0.137670E 00
  2   1   2      0.128301E 00
  2   1   3      0.128970E 00
  2   1   4      0.122430E 00
  3   1   1      0.137930E 00
  3   1   2      0.119990E 00
  3   1   3      0.121220E 00
  3   1   4      0.109390E 00
  4   1   1      0.159210E 00
  4   1   2      0.128950E 00
  4   1   3      0.130950E 00
  4   1   4      0.112170E 00
 INPUT SECOND CARD NUMBER
! 8

  1   2   1      0.355530E 00
  1   2   2      0.385000E 00
  1   2   3      0.400000E 00
  1   2   4      0.427440E 00
  2   2   1      0.191750E 00
  2   2   2      0.186630E 00
  2   2   3      0.180000E 00
  2   2   4      0.177420E 00
  3   2   1      0.293430E 00
  3   2   2      0.278020E 00
  3   2   3      0.260000E 00
  3   2   4      0.244460E 00
  4   2   1      0.561320E 00
  4   2   2      0.524640E 00
  4   2   3      0.470000E 00
  4   2   4      0.420480E 00
1
                     MEAN(I,J)
 I =  1  J =  1  MEAN =     0.189280E 00
 I =  2  J =  1  MEAN =     0.129343E 00
 I =  3  J =  1  MEAN =     0.122132E 00
 I =  4  J =  1  MEAN =     0.132820E 00
 I =  1  J =  2  MEAN =     0.391993E 00
 I =  2  J =  2  MEAN =     0.183950E 00
 I =  3  J =  2  MEAN =     0.268978E 00
 I =  4  J =  2  MEAN =     0.494110E 00
                     S(P,Q)
 P =  1   Q =  1          0.297147E-02
 P =  1   Q =  2         -0.386694E-03
 P =  1   Q =  3         -0.155866E-02
 P =  1   Q =  4         -0.490996E-02
 P =  2   Q =  1         -0.386694E-03
 P =  2   Q =  2          0.244619E-03
 P =  2   Q =  3          0.632731E-03
 P =  2   Q =  4          0.154933E-02
 P =  3   Q =  1         -0.155866E-02
 P =  3   Q =  2          0.632731E-03
 P =  3   Q =  3          0.177875E-02
 P =  3   Q =  4          0.463122E-02
 P =  4   Q =  1         -0.490996E-02
 P =  4   Q =  2          0.154933E-02
 P =  4   Q =  3          0.463122E-02
 P =  4   Q =  4          0.125933E-01

 D1 =    -0.202713E 00  D2 =    -0.546072E-01
   D3 =    -0.146845E 00  D4 =    -0.361290E 00


1                        LAMBDA VALUES
 -0.18874152832E 04          1
  0.14921716797E 05          2
 -0.64449746094E 04          3
 -0.23020407101E 03    .     4


 C =  4  M =  4


                     LINEAR DISCRIMINATE FUNCTIONS


 RACE A   = 4 = FM MOD 5KHZ TONE, 3.1864MHZ CARRIER
    0.747522E 03
    0.757224E 03
    0.756950E 03
    0.758502E 03
 AVERAGE =   0.755049E 03


 RACE B    = 8 = AM MOD 100%, 1KHZ TONE, 3.1864MHZ CARRIER
  * 0.169840E 03
    0.145579E 03
    0.147053E 03
    0.168320E 03
 AVERAGE =   0.157698E 03
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 22

```
 INPUT FIRST CARD NUMBER
 ! 3
 INPUT FIRST CARD NUMBER
! 5

  1    1    1       0.346740E 00
  1    1    2       0.249430E 00
  1    1    3       0.255410E 00
  1    1    4       0.145900E 00
  2    1    1       0.178800E 00
  2    1    2       0.134960E 00
  2    1    3       0.200320E 00
  2    1    4       0.113240E 00
  3    1    1       0.261830E 00
  3    1    2       0.275180E 00
  3    1    3       0.289650E 00
  3    1    4       0.904590E 00
  4    1    1       0.491370E 00
  4    1    2       0.443920E 00
  4    1    3       0.478670E 00
  4    1    4       0.808890E 00
 INPUT SECOND CARD NUMBER
! 6

  1    2    1       0.390490E 00
  1    2    2       0.272540E 00
  1    2    3       0.346650E 00
  1    2    4       0.292500E 00
  2    2    1       0.183840E 00
  2    2    2       0.184780E 00
  2    2    3       0.228610E 00
  2    2    4       0.234000E 00
  3    2    1       0.268840E 00
  3    2    2       0.249540E 00
  3    2    3       0.408360E 00
  3    2    4       0.390600E 00
  4    2    1       0.498520E 00
  4    2    2       0.343430E 00
  4    2    3       0.876980E 00
  4    2    4       0.744350E 00
1
                          MEAN(I,J)
 I =  1   J =  1   MEAN =      0.249370E 00
 I =  2   J =  1   MEAN =      0.171830E 00
 I =  3   J =  1   MEAN =      0.432812E 00
 I =  4   J =  1   MEAN =      0.555712E 00
 I =  1   J =  2   MEAN =      0.325545E 00
 I =  2   J =  2   MEAN =      0.207807E 00
 I =  3   J =  2   MEAN =      0.329335E 00
 I =  4   J =  2   MEAN =      0.628320E 00
                         S(P,Q)
 P =  1    Q =  1          0.287882E-01
 P =  1    Q =  2          0.615195E-02
 P =  1    Q =  3         -0.663935E-01
 P =  1    Q =  4         -0.274991E-01
 P =  2    Q =  1          0.615195E-02
 P =  2    Q =  2          0.705155E-02
 P =  2    Q =  3         -0.300219E-01
 P =  2    Q =  4         -0.333106E-02
 P =  3    Q =  1          0.663935E-01
 P =  3    Q =  2         -0.300219E-01
 P =  3    Q =  3          0.317178E 00
 P =  3    Q =  4          0.212451E 00
 P =  4    Q =  1         -0.274991E-01
 P =  4    Q =  2         -0.333106E-02
 P =  4    Q =  3          0.212451E 00
 P =  4    Q =  4          0.233988E 00

 D1 =      -0.261750E-01   D2 =      -0.359775E-01
   D3 =      0.103477E 00   D4 =      -0.726075E-01


1                     LAMBDA VALUES
 -0.11351172943E 02          1
 -0.32387550354E 02          2
 -0.94495350983E 01          3
  0.64765253067E 01          4



 L =  4  N =  4


                      LINEAR DISCRIMINATE FUNCTIONS


 RACE A   = 5 = AM MOD 50%, 1KHZ TONE, 3.1864MHZ CARRIER
   -0.901161E 01
   -0.886582E 01
   -0.901885E 01
   -0.862976E 01
 AVERAGE =  -0.888151E 01


 RACE B   = 6 = AM MOD 100%, 100HZ TONE, 3.1864MHZ CARRIER
   -0.924052E 01
   -0.880269E 01
   -0.951101E 01
   -0.976316E 01
 AVERAGE =   [illegible]
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 23

```
 INPUT FIRST CARD NUMBER
! 5

  1   1   1      0.346740E 00
  1   1   2      0.249430E 00
  1   1   3      0.255410E 00
  1   1   4      0.145900E 00
  2   1   1      0.178800E 00
  2   1   2      0.194960E 00
  2   1   3      0.200320E 00
  2   1   4      0.113240E 00
  3   1   1      0.261830E 00
  3   1   2      0.275180E 00
  3   1   3      0.289650E 00
  3   1   4      0.904590E 00
  4   1   1      0.491370E 00
  4   1   2      0.443920E 00
  4   1   3      0.478670E 00
  4   1   4      0.808890E 00
 INPUT SECOND CARD NUMBER
! 7

  1   2   1      0.202080E 00
  1   2   2      0.192750E 00
  1   2   3      0.187600E 00
  1   2   4      0.179940E 00
  2   2   1      0.137830E 00
  2   2   2      0.131630E 00
  2   2   3      0.120260E 00
  2   2   4      0.123180E 00
  3   2   1      0.130230E 00
  3   2   2      0.126210E 00
  3   2   3      0.119900E 00
  3   2   4      0.110720E 00
  4   2   1      0.159700E 00
  4   2   2      0.139190E 00
  4   2   3      0.128800E 00
  4   2   4      0.114220E 00
1
                       MEAN(I,J)
 I =  1  J =  1  MEAN =     0.249370E 00
 I =  2  J =  1  MEAN =     0.171830E 00
 I =  3  J =  1  MEAN =     0.402812E 00
 I =  4  J =  1  MEAN =     0.555712E 00
 I =  1  J =  2  MEAN =     0.190592E 00
 I =  2  J =  2  MEAN =     0.130225E 00
 I =  3  J =  2  MEAN =     0.123765E 00
 I =  4  J =  2  MEAN =     0.135477E 00
                       S(P,Q)
 P =  1   Q =  1         0.204825E-01
 P =  1   Q =  2         0.708576E-02
 P =  1   Q =  3        -0.660156E-01
 P =  1   Q =  4        -0.324007E-01
 P =  2   Q =  1         0.708576E-02
 P =  2   Q =  2         0.494135E-02
 P =  2   Q =  3        -0.363450E-01
 P =  2   Q =  4        -0.197105E-01
 P =  3   Q =  1        -0.660156E-01
 P =  3   Q =  2        -0.363450E-01
 P =  3   Q =  3         0.297553E 00
 P =  3   Q =  4         0.159759E 00
 P =  4   Q =  1        -0.324007E-01
 P =  4   Q =  2        -0.197105E-01
 P =  4   Q =  3         0.159759E 00
 P =  4   Q =  4         0.877689E-01

 D1 =      0.587775E-01  D2 =      0.416050E-01
   D3 =      0.309047E 00  D4 =      0.420235E 00


1                       LAMBDA VALUES
 -0.48732928467E 03        1
 -0.46786047363E 03        2
 -0.60768603516E 03        3
  0.82594299316E 03        4



 C =  4  N =  4


                     LINEAR DISCRIMINATE FUNCTIONS


 RACE A  = 5 = AM MOD 50%, 1KHZ TONE, 3.1864MHZ CARRIER
   -0.589679E 01
   -0.133391E 02
    0.114728E 01
   -0.569141E 01
 AVERAGE =  -0.594499E 01


 RACE B  = 7 = FM MOD 1KHZ TONE, 3.1864MHZ CARRIER
   -0.115062E 03
   -0.112250E 03
   -0.117911E 03
   -0.118265E 03
 AVERAGE =  -0.117122E 03
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 24

```
 INPUT FIRST CARD NUMBER
! 5

  1    1    1      0.346740E 00
  1    1    2      0.249430E 00
  1    1    3      0.255410E 00
  1    1    4      0.145900E 00
  2    1    1      0.178800E 00
  2    1    2      0.194960E 00
  2    1    3      0.200320E 00
  2    1    4      0.113240E 00
  3    1    1      0.261830E 00
  3    1    2      0.275180E 00
  3    1    3      0.289650E 00
  3    1    4      0.904590E 00
  4    1    1      0.491370E 00
  4    1    2      0.443920E 00
  4    1    3      0.478670E 00
  4    1    4      0.808890E 00
 INPUT SECOND CARD NUMBER
! 8

  1    2    1      0.355530E 00
  1    2    2      0.385000E 00
  1    2    3      0.400000E 00
  1    2    4      0.427440E 00
  2    2    1      0.191750E 00
  2    2    2      0.186630E 00
  2    2    3      0.180000E 00
  2    2    4      0.177420E 00
  3    2    1      0.293430E 00
  3    2    2      0.278020E 00
  3    2    3      0.260000E 00
  3    2    4      0.244460E 00
  4    2    1      0.561320E 00
  4    2    2      0.524640E 00
  4    2    3      0.470000E 00
  4    2    4      0.420480E 00
1
                         MEAN(I,J)
 I =  1  J =  1  MEAN =    0.249370E 00
 I =  2  J =  1  MEAN =    0.171830E 00
 I =  3  J =  1  MEAN =    0.432812E 00
 I =  4  J =  1  MEAN =    0.555712E 00
 I =  1  J =  2  MEAN =    0.391993E 00
 I =  2  J =  2  MEAN =    0.183950E 00
 I =  3  J =  2  MEAN =    0.268978E 00
 I =  4  J =  2  MEAN =    0.494110E 00
                         S(P,Q)
 P =  1   Q =  1          0.229225E-01
 P =  1   Q =  2          0.634819E-02
 P =  1   Q =  3         -0.682333E-01
 P =  1   Q =  4         -0.384005E-01
 P =  2   Q =  1          0.634819E-02
 P =  2   Q =  2          0.495431E-02
 P =  2   Q =  3         -0.361474E-01
 P =  2   Q =  4         -0.188807E-01
 P =  3   Q =  1         -0.682333E-01
 P =  3   Q =  2         -0.361474E-01
 P =  3   Q =  3          0.298514E 00
 P =  3   Q =  4          0.163038E 00
 P =  4   Q =  1         -0.384005E-01
 P =  4   Q =  2         -0.188807E-01
 P =  4   Q =  3          0.163038E 00
 P =  4   Q =  4          0.981239E-01

 D1 =     -0.142623E 00  D2 =     -0.121200E-01
   D3 =     0.163835E 00  D4 =      0.216025E-01


1                          LAMBDA VALUES
 -0.11894390869E 03          1
 -0.41285437012E 03          2
 -0.88243774414E 02          3
  0.212605438823E 02         4



 L =  4  N =  4



                         LINEAR DISCRIMINATE FUNCTIONS


 FACE M   = 5 = AM MOD 50%, 1KHZ TONE, 3.1864MHZ CARRIER
    -0.127719E 03
    -0.125003E 03
    -0.128465E 03
    -0.126733E 03
 AVERAGE =  -0.126980E 03



 FACE E   = 8 = AM MOD 100%, 1KHZ TONE, 3 1864MHZ CARRIER
    -0.135412E 03
    -0.136224E 03
    -0.134842E 03
    -0.136722E 0
 AVERAGE =  -0.1 800E 0
```

FIGURE 11-2. COMBINATIONAL 25
RUN 25

```
 INPUT FIRST CARD    [illegible]ER
! 6

  1   1   1     0.390490E 00
  1   1   2     0.272540E 00
  1   1   3     0.346650E 00
  1   1   4     0.292500E 00
  2   1   1     0.183840E 00
  2   1   2     0.184780E 00
  2   1   3     0.228610E 00
  2   1   4     0.234000F 00
  3   1   1     0.268840E 00
  3   1   2     0.24[illegible]540E 00
  3   1   3     0.408360E 00
  3   1   4     0.390600E 00
  4   1   1     0.498520E 00
  4   1   2     0.393430E 00
  4   1   3     0.676980E 00
  4   1   4     0.744350E 00
 INPUT SECOND CARD NUMBER
! 7

  1   2   1     0.202080E 00
  1   2   2     0.192750E 00
  1   2   3     0.187600E 00
  1   2   4     0.179940E 00
  2   2   1     0.137830E 00
  2   2   2     0.131630E 00
  2   2   3     0.128260E 00
  2   2   4     0.123180E 00
  3   2   1     0.138230E 00
  3   2   2     0.126210E 00
  3   2   3     0.119900E 00
  3   2   4     0.110720E 00
  4   2   1     0.159700E 00
  4   2   2     0.139190E 00
  4   2   3     0.128800E 00
  4   2   4     0.114220E 00
1
                         MEAN(I,J)
 I =  1  J =  1  MEAN =    0.325545E 00
 I =  2  J =  1  MEAN =    0.207807E 00
 I =  3  J =  1  MEAN =    0.329335E 00
 I =  4  J =  1  MEAN =    0.628320E 00
 I =  1  J =  2  MEAN =    0.190592E 00
 I =  2  J =  2  MEAN =    0.130225E 00
 I =  3  J =  2  MEAN =    0.123765E 00
 I =  4  J =  2  MEAN =    0.135477E 00
                         S(P,Q)
 P =  1   Q =  1          0.882383E-02
 P =  1   Q =  2         -0.591172E-03
 P =  1   Q =  3          0.265971E-03
 P =  1   Q =  4          0.596692E-02
 P =  2   Q =  1         -0.591172E-03
 P =  2   Q =  2          0.233680E-02
 P =  2   Q =  3          0.674893E-02
 P =  2   Q =  4          0.170841E-01
 P =  3   Q =  1          0.265971E-03
 P =  3   Q =  2          0.674893E-02
 P =  3   Q =  3          0.204256E-01
 P =  3   Q =  4          0.540168E-01
 P =  4   Q =  1          0.596692E-02
 P =  4   Q =  2          0.170841E-01
 P =  4   Q =  3          0.540168E-01
 P =  4   Q =  4          0.148413E 00

 D1 =      0.134953E 00  D2 =      0.775825E-01
   D3 =      0.205570E 00  D4 =      0.492842E 00


1                        LAMBDA VALUES
  0.41965923767E 02          1
  0.43651293945E 03          2
 -0.16403518677E 03          3
  0.11087591171E 02          4



 L =  4  N =  4



                         LINEAR DISCRIMINATE FUNCTIONS


 FACE H   = 6 = AM MOD 100%, 100HZ TONE, 3.1864MHZ CARRIER
     0.580718E 02
     0.555305E 02
     0.570838E 02
     0.566058E 02
 AVERAGE =    0.57[illegible]230E 02


 FACE J   = 7 = FM MOD 1KHZ TONE, 3.1864MHZ CARRIER
     0.477452E 02
     0.463914E 02
     0.456240E 02
     0.444291E 02
 AVERAGE =    0.4604[illegible]5 02
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 26

INPUT FIRST CARD NUMBER

```
 INPUT FIRST CARD NUMBER
! 6

  1   1   1      0.390490E 00
  1   1   2      0.272540E 00
  1   1   3      0.346650E 00
  1   1   4      0.292500E 00
  2   1   1      0.183840E 00
  2   1   2      0.184780E 00
  2   1   3      0.228610E 00
  2   1   4      0.234000E 00
  3   1   1      0.268840E 00
  3   1   2      0.249540E 00
  3   1   3      0.408360E 00
  3   1   4      0.390600E 00
  4   1   1      0.498520E 00
  4   1   2      0.393430E 00
  4   1   3      0.876980E 00
  4   1   4      0.744350E 00
 INPUT SECOND CARD NUMBER
! 8

  1   2   1      0.355530E 00
  1   2   2      0.385000E 00
  1   2   3      0.400000E 00
  1   2   4      0.427440E 00
  2   2   1      0.191750E 00
  2   2   2      0.186630E 00
  2   2   3      0.180000E 00
  2   2   4      0.177420E 00
  3   2   1      0.293430E 00
  3   2   2      0.278020E 00
  3   2   3      0.260000E 00
  3   2   4      0.244460E 00
  4   2   1      0.561320E 00
  4   2   2      0.524640E 00
  4   2   3      0.470000E 00
  4   2   4      0.420480E 00
1
                        MEAN(I,J)
 I =  1  J =  1  MEAN =     0.325545E 00
 I =  2  J =  1  MEAN =     0.207807E 00
 I =  3  J =  1  MEAN =     0.329335E 00
 I =  4  J =  1  MEAN =     0.628320E 00
 I =  1  J =  2  MEAN =     0.391993E 00
 I =  2  J =  2  MEAN =     0.183950E 00
 I =  3  J =  2  MEAN =     0.268978E 00
 I =  4  J =  2  MEAN =     0.494110E 00
                        S(P,Q)
 P =  1   Q =  1          0.112638E-01
 P =  1   Q =  2         -0.132874E-02
 P =  1   Q =  3         -0.195180E-02
 P =  1   Q =  4         -0.329600E-04
 P =  2   Q =  1         -0.132874E-02
 P =  2   Q =  2          0.234977E-02
 P =  2   Q =  3          0.694652E-02
 P =  2   Q =  4          0.179139E-01
 P =  3   Q =  1         -0.195180E-02
 P =  3   Q =  2          0.694652E-02
 P =  3   Q =  3          0.213866E-01
 P =  3   Q =  4          0.572954E-01
 P =  4   Q =  1         -0.329600E-04
 P =  4   Q =  2          0.179139E-01
 P =  4   Q =  3          0.572954E-01
 P =  4   Q =  4          0.159768E 00

 D1 =     -0.664475E-01  D2 =      0.238575E-01
   D3 =      0.603575E-01  D4 =      0.134210E 00

1                          LAMBDA VALUES
 -0.51395349503E 01           1
  0.36429125977E 03           2
 -0.24442739866E 03           3
  0.47946622021E 02           4


 L =  4  N =  4


                           LINEAR DISCRIMINATE FUNCTIONS


 RACE M   = 6 = AM MOD 100%, 100HZ TONE, 3.1864MHZ CARRIER
     0.231559E 02
     0.237831E 02
     0.237348E 02
     0.239582E 02
 AVERAGE =    0.236580E 02


 RACE B   = 8 = AM MOD 100%, 1KHZ TONE, 3.1864MHZ CARRIER
     0.232179E 02
     0.232091E 02
     0.225014E 02
     0.228445E 02
 AVERAGE =    0.229432E 02
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 27

```
 INPUT FIRST CARD NUMBER
! 7

  1   1   1      0.202080E 00
  1   1   2      0.192750E 00
  1   1   3      0.187600E 00
  1   1   4      0.179940E 00
  2   1   1      0.107830E 00
  2   1   2      0.131630E 00
  2   1   3      0.128260E 00
  2   1   4      0.123180E 00
  3   1   1      0.138230E 00
  3   1   2      0.126210E 00
  3   1   3      0.119900E 00
  3   1   4      0.110720E 00
  4   1   1      0.159700E 00
  4   1   2      0.139190E 00
  4   1   3      0.120800E 00
  4   1   4      0.114220E 00
 INPUT SECOND CARD NUMBER
! 8

  1   2   1      0.355530E 00
  1   2   2      0.385000E 00
  1   2   3      0.400000E 00
  1   2   4      0.127440E 00
  2   2   1      0.191750E 00
  2   2   2      0.186630E 00
  2   2   3      0.180000E 00
  2   2   4      0.177420E 00
  3   2   1      0.293430E 00
  3   2   2      0.278020E 00
  3   2   3      0.260000E 00
  3   2   4      0.244460E 00
  4   2   1      0.561320E 00
  4   2   2      0.524640E 00
  4   2   3      0.470000E 00
  4   2   4      0.420480E 00
1
                        MEAN(I,J)
 I =  1  J =  1  MEAN =     0.190592E 00
 I =  2  J =  1  MEAN =     0.130225E 00
 I =  3  J =  1  MEAN =     0.123765E 00
 I =  4  J =  1  MEAN =     0.135477E 00
 I =  1  J =  2  MEAN =     0.391993E 00
 I =  2  J =  2  MEAN =     0.183950E 00
 I =  3  J =  2  MEAN =     0.268970E 00
 I =  4  J =  2  MEAN =     0.494110E 00
                        S(P,Q)
 P =  1   Q =  1          0.295810E-02
 P =  1   Q =  2         -0.394929E-03
 P =  1   Q =  3         -0.157383E-02
 P =  1   Q =  4         -0.493449E-02
 P =  2   Q =  1         -0.394829E-03
 P =  2   Q =  2          0.239569E-03
 P =  2   Q =  3          0.623462E-03
 P =  2   Q =  4          0.153441E-02
 P =  3   Q =  1         -0.157383E-02
 P =  3   Q =  2          0.623462E-03
 P =  3   Q =  3          0.176172E-02
 P =  3   Q =  4          0.460376E-02
 P =  4   Q =  1         -0.493449E-02
 P =  4   Q =  2          0.153441E-02
 P =  4   Q =  3          0.460376E-02
 P =  4   Q =  4          0.125489E-01

 D1 =    -0.201400E 00  D2 =    -0.537250E-01
   D3 =    -0.145213E 00  D4 =    -0.358633E 00

1                        LAMBDA VALUES
 -0.18900259277E 04        1
  0.15009888672E 05        2
 -0.65059218750E 04        3
 -0.22375946045E 03        4


 C =  4  N =  4


                        LINEAR DISCRIMINATE FUNCTIONS


 RACE A  = 7 = FM MOD 1KHZ TONE, 3.1864MHZ CARRIER
     0.750050E 03
     0.757495E 03
     0.760068E 03
     0.761350E 03
 AVERAGE =   0.757241E 03


 RACE B  = 8 = AM MOD 100%, 1KHZ TONE, 3.1864MHZ CARRIER
     0.168424E 03
     0.144078E 03
     0.145543E 03
     0.166896E 03
 AVERAGE =   0.156235E 03
 AVERAGE =   0.000000E 00
```

FIGURE 1J-2. COMBINATIONAL 25
RUN 28

```
 INPUT FIRST CARD NUMBER
! 1

  1   1   1      0.321450E 00
  1   1   2      0.364090E 00
  1   1   3      0.392810E 00
  1   1   4      0.335060E 00
  2   1   1      0.186880E 00
  2   1   2      0.188960E 00
  2   1   3      0.196590E 00
  2   1   4      0.242110E 00
  3   1   1      0.270640E 00
  3   1   2      0.283190E 0
  3   1   3      0.317340E 00
  3   1   4      0.445450E 00
  4   1   1      0.477040E 00
  4   1   2      0.530740E 00
  4   1   3      0.659010E 00
  4   1   4      0.963290E 00
 INPUT SECOND CARD NUMBER
: 1

  1   2   1      0.321450E 00
  1   2   2      0.364090E 00
  1   2   3      0.392810E 00
  1   2   4      0.335060E 00
  2   2   1      0.186880E 00
  2   2   2      0.18896UE 0
  2   2   3      0.196590E 0
  2   2   4      0.242110E 00
  3   2   1      0.270640E 00
  3   2   2      0.283190E 0
  3   2   3      0.317340E 00
  3   2   4      0.445450E 00
  4   2   1      0.477040E 00
  4   2   2      0.530740E 00
  4   2   3      0.659010E 00
  4   2   4      0.963290E 00
1
                         MEAN(I,J)
 I =  1  J =  1  MEAN =     0.353352E 00
 I =  2  J =  1  MEAN =     0.203635E 00
 I =  3  J =  1  MEAN =     0.329155E 00
 I =  4  J =  1  MEAN =     0.657520E 00
 I =  1  J =  2  MEAN =     0.353352E 00
 I =  2  J =  2  MEAN =     0.203635E 00
 I =  3  J =  2  MEAN =     0.329155E 00
 I =  4  J =  2  MEAN =     0.657520E 00
                         S(P,Q)
 P =  1   Q =  1          0.604915E-02
 P =  1   Q =  2         -0.120966E-02
 P =  1   Q =  3         -0.244059E-02
 P =  1   Q =  4         -0.227612E-02
 P =  2   Q =  1         -0.120966E-02
 P =  2   Q =  2          0.405209E-02
 P =  2   Q =  3          0.124253E-01
 P =  2   Q =  4          0.332769E-01
 P =  3   Q =  1         -0.244059E-02
 P =  3   Q =  2          0.124253E-01
 P =  3   Q =  3          0.384018E-01
 P =  3   Q =  4          0.103860E 00
 P =  4   Q =  1         -0.227612E-02
 P =  4   Q =  2          0.332769E-01
 P =  4   Q =  3          0.103860E 00
 P =  4   Q =  4          0.284287E 00

 D1 =      0.000000E 00  D2 =      0.000000E 00
   D3 =      0.000000E 00  D4 =      0.000000E 00

1                        LAMBDA VALUES
  0.00000000000E 00        1
  0.00000000000E 00        2
  0.00000000000E 00        3
  0.00000000000E 00        4


 C =  4  N =  4


                         LINEAR DISCRIMINATE FUNCTIONS


 RACE A   = 1 = GAUSSIAN NOISE
    0.000000E 00
    0.000000E 00
    0.000000E 00
    0.000000E 00
 AVERAGE =   0.000000E 00


 RACE B   = 1 = GAUSSIAN NOISE
    0.000000E 00
    0.000000E 00
    0.000000E 00
    0.000000E 00
 AVERAGE =   0.000000E 00
```

FIGURE 11-2. COMBINATIONAL Z5
RUN 29

Section 12

CONCLUSIONS AND RECOMMENDATIONS

12.1 CONCLUSIONS

The basic question to be answered in the study was: to determine if Q distribution curves generated from BEM measurements were adequate for the discrimination and identification of interfering signal types, assuming that the BEM equipment was modified only to the extent of using a set of countdown ratios, as contrasted to one ratio in the original equipment.

Based on the analysis and results of the present study, it is concluded that the method is indeed a usable procedure for those signals which truely have a different probability distribution, and the method is essentially independent of power level. The results given in Sections 10 and 11 show this to be true even in signals whose ditributions are quite close together. Although signals with noise AM and noise FM were not tested, preliminary analysis has shown that signals of that type could be distinguished from each other and from those tested.

The question of the number of countdown ratios required for discrimination was studied and extensive runs were made. It was found that 5 ratios were adequate for achieving the present results, and that additional countdown ratios did not add to the accuracy of representation of the Q distribution junction.

Both collocation and least squares methods were investigated for curve fitting purposes as approximations to the general Charlier procedure. It was concluded that discrimination capability would not be improved by the general approach, but that the least squares was significantly better than collocation with respect to smoothing capability, as documented by a number of runs. In addition, least squares permitted the use of additional measured data without increasing the order of the equation. Many runs with the data taken determined that a polynomial of degree four, using five measured data values gave the best overall fit. This met the criteria to keep the number of data points required as small as possible, consistent with discrimination capability.

The approach of considering inequality bounds on the slope of the curve using spline methods would be useful in further development work.

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Numerous trials showed that linear discriminates were adequate for discrimination by the Q distribution curves considered which were repeatably different. Additional investigation into the use of nonlinear procedures would be useful in further development work which involved additional, more complex signal types.

It is concluded that a proof of principle has been clearly established and that the method of approach developed in the present study is adequate for the solution of the proposed problem, with the following exceptions. The Q distribution alone, based on averaging type measurements will not discriminate those signals which are:

1. Pulsed rapidly, compared with the measurement time when compared with the parent signals.

2. Essentially the same distribution as another signal, except for nonrepeatable noise.

3. Not stable and repeatable over the measurement time.

It is concluded that, although proof of principle has been established, the methods developed in the present report could be profitably supplemented by additional study. Topics of interest would be:

1. Detailed analysis of the basic error rate equations to determine needed corrections, sensitivity, and effect of signal correlations.

2. Analysis of more powerful curve fitting methods, such as Chebyshev and spline functions with inequality limits.

3. Additional analysis of methods for incorporating BER data into the solution, in addition to those of Sections 10 and 11 of this report.

4. Sensitivity analysis of analytical expressions for a set of practical signal types to determine the theoretical capability of the discrimination methods developed in this study.

5. Detailed study of nonlinear discriminations methods, should the results of Item 4 above indicate such an approach would be profitable.

12.2 RECOMMENDATIONS

12.2.1 Simultaneous Measurements

During the course of interference testing on the Baseband Eye Monitor, it was found that the amount of time required for the dispersion voltage to change and settle to a final value was quite long. This was particularly true when going from a state of no interference to a state of relatively high interference. For example, consider a system operating normally with a bit error rate of 10^{-12} or less, then suddenly adding an interference level that would introduce a bit error rate of 10^{-6}. The time required for the dispersion voltage to settle at its new final value would be in the order of one minute when the countdown ratio is 9216. As the countdown ratio is decreased, the time required is less due to the change in the time constant of the pseudo error rate loop.

If a single BEM unit were used to make dispersion measurements by changing the countdown ratio (say 5 times), the interference signal may well be gone before a valid set of dispersion data could be obtained.

For this reason it is recommended that five separate measurements be made simultaneously from a single BEM unit. Naturally, this means incorporating much more electronics than exists in the present BEM unit. However, for practical application in the field, the use of simultaneous measurements is the only method to accurately discriminate and identify interference types.

12.2.2 Hits Counter

The use of dispersion voltage to detect the presence of pulsed interference types is not practical due to the long time constant associated with the pseudo error rate loop. However, the hits counter adds another dimension of detection and discrimination capability. The scope of this study program did not permit sufficient time and effort necessary to evaluate the use of the hit counter as a pulsed interference detection mechanism. However, it is recommended that follow-on study of this capability be explored in order to take full advantage of the detection capability of the BEM.

12.2.3 Future Study

The analysis performed during this study program provided a much better understanding of the statistical tools needed to discriminate and identify interference signal types other than Gaussian distribution, upon which the original BEM equipment was BASED. While the basic proof of principle has been established in this report, the study effort also provided an insight to further methods that should be explored for future studies to further enhance the work already performed in signal discrimination and identification. A list of recommended future study objectives is shown below:

1. The analysis of more powerful curve fitting methods, such as Chebyshev and SPLINE functions with inequality limits.

2. Detailed analysis of the basic error rate equations to determine needed corrections, sensitivity, and effect of signal correlations.

3. Additional analysis of methods for incorporating BER data into the solution, in addition to those of Sections 10 and 11 of this report.

4. Sensitivity analysis of analytical expression for a set of practical signal types to determine the theoretical capability of the discrimination methods developed in this study.

5. The use of nonlinear procedures for more complex signal types, should the results of item 4 above indicate that such an approach would be profitable.

12.2.4 Optimum Countdown Ratios

Based on the analytical results and raw data obtained during this study program, five countdown ratios were selected to provide the optimal signal discrimination and identification capability. The countdown ratios are 9216, 2304, 1192, 288 and 36. Further studies may prove that the above countdown ratios should be changed to further optimize discrimination results, however, this is the best information available at this time.

REFERENCES

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2. Duda, Hart, Pattern Classification, Wiley, 1973.

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APPENDIX A

STRUCTURED PROGRAM DOCUMENTATION FOR THE GENERATION OF THE DATA BASE

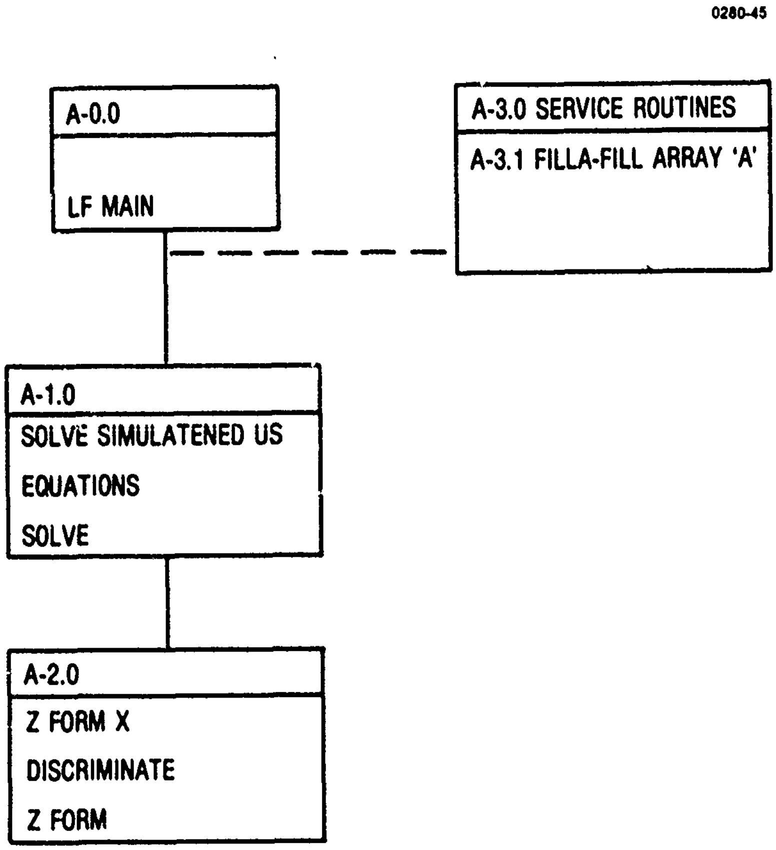


FIGURE A-1. HEIRARCHY CHART FOR THE GENERATION OF THE DATA BASE

A-0.0 LFMAIN

A-0.0-a Program Description

The main program compares the K, M(2), M(3), and M(4), from two selected signal types and calculates the Z values and the Z average for each selected combination. In doing so it first calculates the mean for each set of moments, writes the means to the terminal, calculates the S coefficients for each simultaneous equation, calculates the D values, (The right hand side of the equations), solves the simultaneous equations for the corresponding Lamba values, and computes the Z values for each item in the sample. These Z values and the average Z will be used as comparison data to discriminate between known interference signals and unknown data. The Z information is derived as follows:

$$Z_1 = \lambda_{11}\, K/10 + \lambda_{12}\, M(2) + \lambda_{13}\, M(3) + \lambda_{14}\, M(4)$$

$$\vdots$$

$$Z_4 = \lambda_{41}\, K/10 + \lambda_{42}\, M(2) + \lambda_{43}\, M(3) + \lambda_{44}\, M(4)$$

A-0.0-b. HIPO for Main Program LFMAIN

Input	Process	Output
	1. Call FILLA to fill array 'A' with moments for the two cases to be examined	Array 'A' filled with data
	2. Calculate the mean by rows	
	3. Output the Means to terminal	Listing
	4. Calculate the S coefficients	
	5. Output the S coefficients to the terminal	Listing
	6. Fill the 'AS' array with the S coefficient	
	7. Calculate D1 through D4 values	
	8. Output the D1 thru D4 values to the terminal	Listing
	9. Call SOLVE to solve the N simultaneous equations	
	10. STOP	
	11. END	

NOTES:

COMMON

A - MOMENTS FOR TWO RACES

S - Calculated S coefficients

NUM - Number of items per trial

AZ - Calculated Z Discriminate

MEAN - calculated MEAN by row

N - Number of trials per race

AS - calculated D values

H I P O NO: A-0.0-a

TITLE: MAIN PROGRAM LFMAIN

SERVICES REQUIRED

1. Provide the selected discriminate data values

A-1.0-c PDL FDR Subroutine LFMAIN

```
FILL ARRAY 'A' WITH THE MOMENTS FOR THE TWO CASES TO BE EXAMINED

L = 1

DO UNTIL L = 2

   M1 = 1

   DO UNTIL M1 = N

      X = 0.0

      N3 = 1

      DO UNTIL N3 = NUM

         SUM THE ELEMENTS ON A ROW

      ENDOO

      FILL ARRAY 'MEAN' WITH THE ACCUMULATED SUM

      DIVIDE EACH ELEMENT OF 'MEAN' WITH NUM TO OBTAIN THE MEAN
      OF THE ROW

   ENDOO

ENDOO

J = 1

DO UNTIL J = 2

   I = 1

   DO UNTIL I = NUM

         OUTPUT THE MEAN TO THE TERMINAL

   ENDDO

ENDDO

P = 1

DO UNTIL P = N

   Q = 1
```

```
DO UNTIL Q = N
   X = 0.0
   I = 1
   DO UNTIL I = 2
   J = 1
   DO UNTIL J = NUM
      COMPUTE X EQUAL TO THE S COEFFICIENT OF THE
      SIMULTANEOUS EQUATION.
   ENDOO
ENDDO
FILL THE 'S' ARRAY WITH THE COMPUTED S COEFFICIENTS
ENDOO
ENDOO
P = 1
DO UNTIL P = N
   Q = 1
   DO UNTIL Q = N
      FILL THE 'AS' ARRAY WITH THE DOUBLE S COEFFICIENTS
   ENDOO
ENDOO
COMPUTE D1 AND D2
IF N = 4
   COMPUTE D3 AND D4
ENDIF
FILL THE 'AS' ARRAY WITH D1 THROUGH D4
OUTPUT D1 THROUGH D4 TO THE TERMINAL
```

```
   CALL SOLVE TO SOLVE THE SIMULTANEOUS EQUATIONS

   STOP

   END
```

A.1-1.0

A.1-1.0.a Program Description for Program SGHDD

This program runs off-line on the Honeywell Computer Network, (HCN) and is written in Fortran to establish the required data base from the measured BEM data given in Section 2. Reference should be made to paragraph 9.3.2 for a discussion of the algorithms used. With the programs of Section 7, a set of moments and a K value (see Section 5) the Z value may be computed for each selected signal type and each power level. The data base may be represented as in Figure 9-4. With these inputs to this program, a data base of constants can be established for each of the 28 possible signal combinations by exersizing this program. The output yield 4 lambda value, 4 Z values and an average Z value for each signal. These constants will be used in the operational program to make comparisons to an unknown signal BEM data. The operation of the off-line program is discussed in Section 10, paragraphs 10.1.1 and 10.1.2.

A.1-1.0-c PDL for Program SGHDD

```
I = 1

DO UNTIL I = 4

   INPUT VALUE INTO ARRAY 'IN

ENDDO

I = 1
```

A-2.0-a Program Description

Subroutine ZFORM computes the table of Z values and the average Z from the Lambda Array and the K/10, 2ND, 3RD, and 4th moments as follows:

$$Z_1 = \lambda_{11} \frac{K}{10} + \lambda_{12} M(2) + \lambda_{13} M(3) + \lambda_{14} M(4)$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

$$ZN = \lambda_N \frac{K}{10} \; KNZ \; M(2) + \lambda_{N3} M(3) + \lambda_{N4} M(4)$$

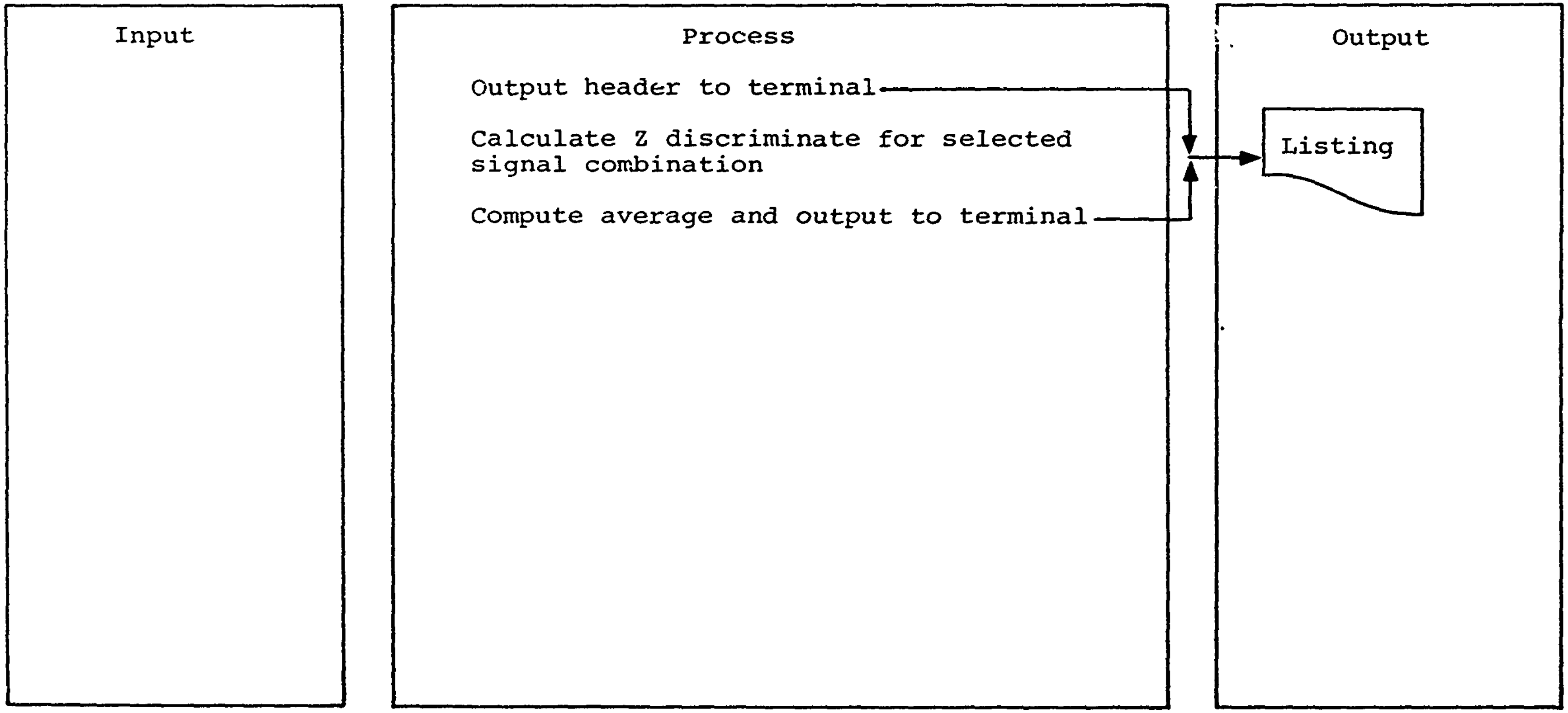
These Z values will be used in the discriminating process and are derived off line for the 28 combinations of the 8 signal types.

A-2.0-b PDL FOR SUBROUTINE ZFORM

```
OUTPUT HEADER TO TERMINAL

I = 1

DO UNTIL I = 2

   P = 1

   SUM = 0.0

   COMPUTER FIRST TWO TERMS OF THE Z DISCRIMINATE

      IF N = 4

         COMPUTE 3RD AND 4TH COMPONENT OF Z DISCRIMINATE

      ENDIF

   COMPUTE Z DISCRIMINATE SUMS

   OUTPUT SUMS TO TERMINAL

   P - P + 1

   COMPUTE AVERAGE Z DISCRIMINATE

   OUTPUT AVERAGE Z DISCRIMINATE TO TERMINAL

   ENDDO

   RETURN

   END
```

```
DO UNTIL I = 28

   Z VALUE = 0.0

   J = 1

   DO UNTIL J = 4

      COMPUTE Z VALUE AS FOLLOWS:  Z VALUE = LAMBDA (J,I)*IN(J)
      OUTPUT LAMBDA VALUE FOR Z PARTIAL SUM TO THE LISTING

   ENDDO

   PUT COMPUTED Z VALUE INTO ARRAY 'ZT'

   OUTPUT ARRAY ZT TO THE LISTING

ENDDO

I = 1

DO UNTIL I = 28

   MAKE EVERY 2ND ITEM OF A Z ITEM PAIR EQUAL TO THE COMPUTED Z

ENDDO

I = 1

DO UNTIL I = 56 STARTING AT 2 AND VARYING BY 2

   MAKE EVERY 1ST ITEM OF A 2 ITEM PAIR EQUAL TO THE COMPUTED Z

ENDDO

I = 1

DO UNTIL I = 56

   OUTPUT EACH ELEMENT OF ARRAY 'ZTI' TO THE TERMINAL

ENDDO

INPUT THE SELECTED Z LIST TO BE USED FOR COMPARISON

I = 1

DO UNTIL I = 56
```

A-2.0-b. HIPO for Subroutine Z Form



NOTES:

COMMON

A - Moments for two Races

S - Calculated S coefficients

NUM - Number of items per trial

AZ - Calculated Z discriminate

MEAN - calculated MEAN by row

N - Number of trials per race

AS - calculate 0 Values

H I P O N.O: A-2.0-c
TITLE: FORM Z DISCRIMINATES
(Z FORM)

SERVICES REQUIRED

1. Calculate the Z discriminate for each combination of signal types

A.1-1.0-b HIPO for Subroutine Signal

Input	Process	Output
K, M(2),M(3),M(4)	1. Input the K and 2nd through 4th moments	Array 'IN'
	2. Compute the Z values by taking a set of Lambda values for each of the 28 possible combinations of signal types	
	3. Output running Z sum	Listing
	4. Put Z values into array 'ZT'	
	5. Construct array 'ZTI' which is twice the size of array 'ZT' and contains two entries from each item in 'ZT'	Array 'ZTI'
	6. Output the 'ZTI' array to the terminal	
	7. Select which set of 2 values is to be used for the compression	
	8. Generate an absolute difference array 'ZTO' which is ABS (ZARRAY-ZTI)	Array 'ZTO'
	9. Determine the absolute minimum in the 'ZTD' array and construct a pointer to the item	XMIN, JPOINT

NOTES:

Array LAM contains the LAMBDA values obtained by comparing all possible combinations of the signal types

Array ZARRAY contains the Z values obtained by comparing all possible combinations of the signal types

H I P O N O: C-6.0-b

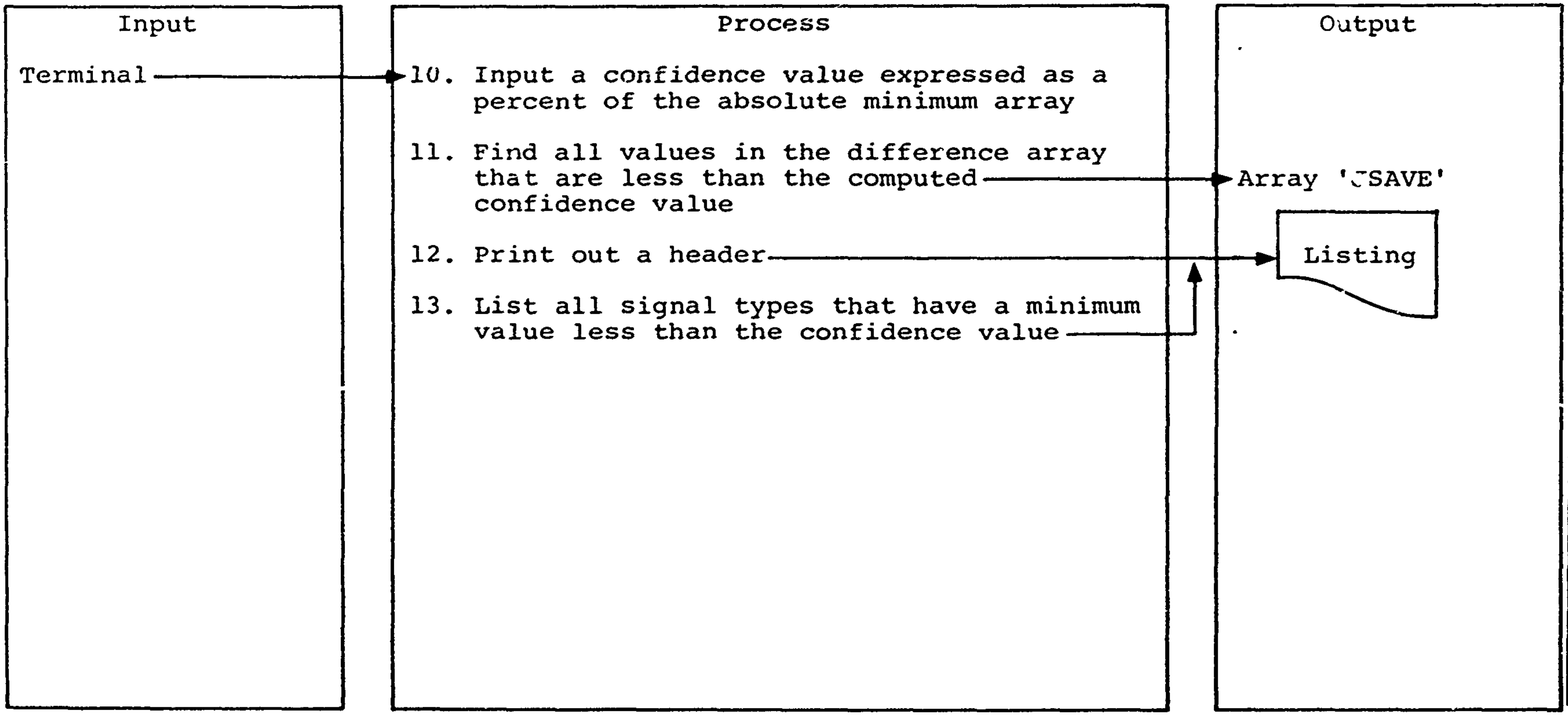
TITLE:

DISCRIMINATE SIGNAL TYPE

SERVICES REQUIRED:

1. Determine which of the B possible signal types most closely matches the unknown signal.

A.1-1.0-b HIPO for Subroutine SGHDD (continued)



NOTES:

H I P O N O: 0.0

TITLE:

DISCRIMINATE SIGNAL TYPE

SERVICES REQUIRED:

Determine which of the 8 possible signal type most clearly matches the unknown signal.

```
   GENERATE AN ABSOLUTE DIFFERENCE ARRAY WHICH IS THE DIFFERENCE

   OUTPUT THE DIFFERENCE ARRAY TO THE TERMINAL

ENDDO

SET XMIN EQUAL TO THE 1ST VALUE IN THE DIFFERENCE ARRAY

I = 1

DO UNTIL I = 56

   FIND THE MINIMUM VALUE IN THE DIFFERENCE ARRAY AND SET XMIN
   EQAUL TO IT

   FORM A POINTER TO THE MINIMUM VALUE

ENDDO

OUTPUT THE MINIMUM VALUE AND THE POINTER TO THE TERMINAL

REQUEST A CONFIDENCE VALUE

INPUT THE CONFIDENCE VALUE AS A PERCENTAGE

DETERMINE PCENT EQUAL TO A PERCENTAGE OF THE MINIMUM DIFFERENCE
PLUS THE MINIMUM DIFFERENCE.  (ESTABLISH A BANDPASS)

I = 1

DO UNTIL I = 56

   JSAVE(I) = 0

   FOR EACH VALUE IN THE DIFFERENCE ARRAY WHICH FALLS WITHIN THE
   BANDPASS ESTABLISHED BY THE CONFIDENCE VALUE, MAKE A
   CORRESPONDING ENTRY IN ARRAY JSAVE

ENDDO

PRINT THE HEADER

FOR EACH ENTRY IN ARRAY JSAVE, PRINT THE CORRESPONDING SIGNAL
TYPE

STOP

END
```

APPENDIX B

STRUCTURED PROGRAM DOCUMENTATION FOR THE SOLUTION BY THE COLLOCATION METHOD

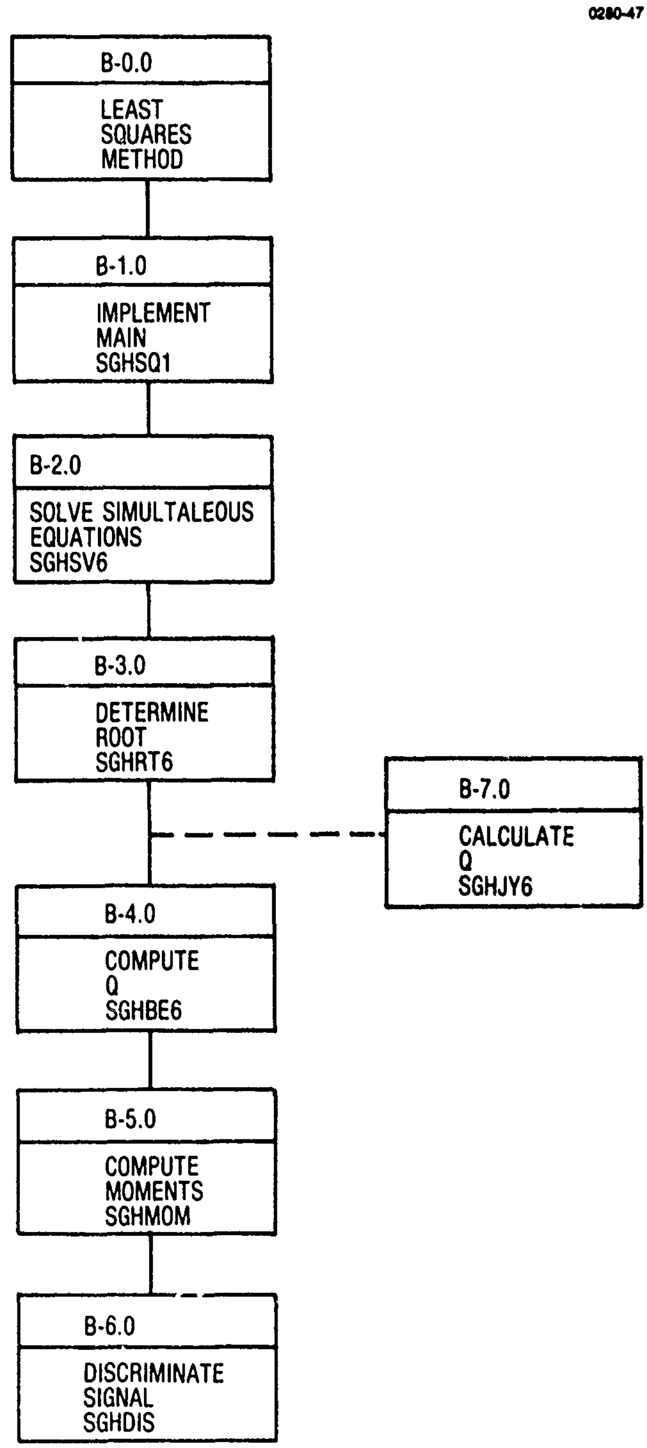


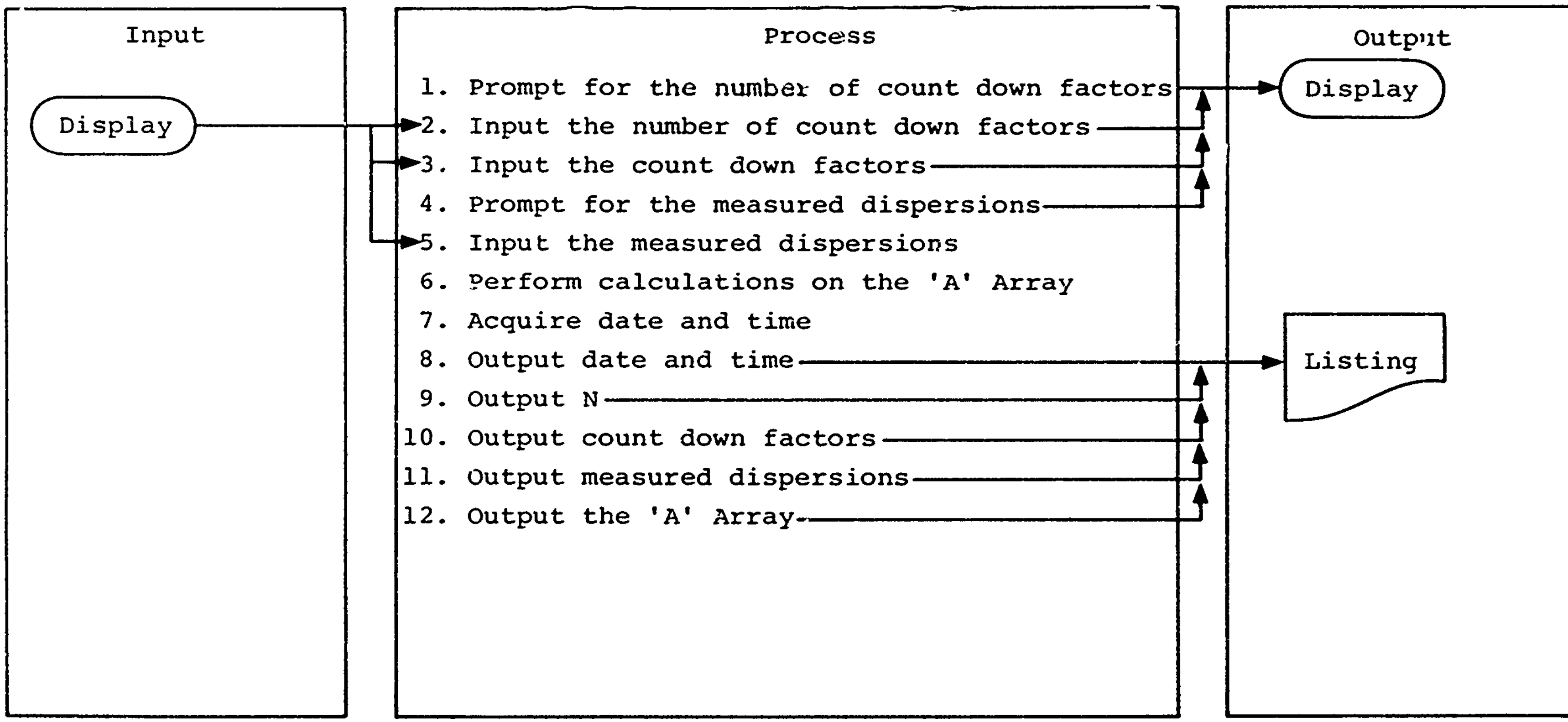
FIGURE B.1. HIERARCHY CHART FOR THE SOLUTION BY THE COLOCATION METHOD

```
THIS PROGRAM PERFORMS A CURVE FITTING PROCEFDURE
USING ACCUMULATED DISPERSION DATA AND UTILIZING
THE COLLOCATION METHOD. THE INPUT DATA REQUIRED
IS AS FOLLOWS :

   1. NUMBER OF COUNT DOWN FACTORS
   2. THE COUNT DOWN FACTORS
   3. THE MEASURED DISPERSIONS


THE OUTPUT CONSISTS OF DATA POINTS WHOSE PLOT REPRESENTS
THE COMPLEMENTRY DISTRIBUTION FUNCTION AGAINST A NORMALIZED
RANDOM VARIABLE WHOSE VARIANCE IS ONE.

THIS SUBROUTINE READS THE INPUT VALUES AND CONSTRUCTS AN ARRAY 'A'
COMPOSED OF THE COEFFICIENTS OF N EQUATIONS OF THE N TH ORDER.
IT IS THESE EQUATIONS WHICH ARE SOLVED FOR THE NORMALIZED
COMPLEMENTARY DISTRIBUTION BY SUBSEQUENT SUBROUTINES.


THE EQUATIONS ARE ARRIVED AT AS FOLLOWS :
THE PSEUDO ERROR RAT   [illegible]TION IS DEFINED AS
P=G(A*D)+G(D), WHERE P IS FOUR TIMES THE PSEUDO ERROR RATE , OR COUNT
DOWN FACTOR, AND A IS A KNOWN PARAMETER WHICH IS PROVIDE BY BEM
MEASUREMENTS FOR EACH SELECTED P.

USING THE APPROXIMATION
       G(Z)=.5+a*Z+b*Z**2+c*Z**3+d*Z**4 , FOR N=4 CASE,
IN THE PSEUDO ERROR RATE EQUATION GIVES THE FOLLOWING :

P-1=a(A*D)+b*(A*D)**2+c*(A*D)**3+d(A*D)**4


SINCE A =a/d, WHERE a=(MEASURED DISPERSION)/11.05, AND d=0.9,
THEN A =(MEASURED DISPERSION)/9.945.

DEFINING G=P-1, THE EQUATIONS EVALUATED AT 4 POINTS ARE
G1=a(A1*D)+b(A1*D)**2+c(A1*D)**3+d(A1*D)
 .
PLUS THREE OTHER SIMILAR EQUATIONS EVALUATED AT THE OTHER SELECTED
POINTS, A2,A3,A4 AND G2,G3,G4.

THEN LET THE NEW UNKNOWNS t,u,v,w BE INTRODUCED BY THE RELATIONS :
              aD=t
              bD**2=u
              cD**3=v
              dD**4=w
THEN SUBSTITUTION INTO THE G EQUATIONS GIVES
   G1=(A1+1)t+(A1**2+1)u+(A1**3+1)v+(A1**4+1)w
   G2=(A2+1)t+(A2**2+1)u+(A2**3+1)v+(A2**4+1)w
   G3=(A3+1)t+(A3**2+1)u+(A3**3+1)v+(A3**4+1)w
   G4=(A4+1)t+(A4**2+1)u+(A4**3+1)v+(A4**4+1)w
WHICH ARE FOUR LINEAR EQUATIONS FOR THE FOUR UNKNOWNS T,U,V,W
DETERMINED BY THE KNOWN VALUES G1,G2,G3,G4,A1,A2,A3,A4
```

B-0.0. LEAST SQUARES METHOD, ROUTINE SGHDF6

B-0.0-a. Program Description

B-0.0-b HIPO for Solution by the Collation Method



NOTES: SOLUTION BY COLLOCATION METHOD

H I P O NO. B-1.0-b

TITLE: MAIN PROGRAM FOR SGHDF6

Services Required:

1. Input parameters and data
2. Prepare matrix 'A' for the solve program

Input	Process	Output
	13. Call SGHSV6 to solve N simultaneous equations 14. Upon return, end	

NOTES:

B-1.0-c PDL for Program SGHDF6

```
ASK FOR THE NUMBER OF COUNT DOWN FACTORS

INPUT THE NUMBER (N)

I=1

DO UNIT I=N

   INPUT THE DESIRED COUNT DOWN FACTORS INTO ARRAY 'CDF'

   PERFORM A DOUBLE PRECISION FLOAT OF ARRAY 'CDF' INTO ARRAY
   'A' COLUMN N+1

ENDDO

I=1

DO UNTIL I=N

   DUPLICATE ARRAY 'A' INTO ARRAY 'F'

ENDDO

ASK FOR THE INPUT OF THE MEASURED DISPERSIONS

I=1

DO UNTIL I=N

   INPUT THE MEASURED DISPERSIONS INTO ARRAYS 'M' AND 'M'

ENDDO

DEVELOP ARRAY 'A' TO CONTAIN T E COEFFICIENTS OF THE G EQUATIONS

I=1

DO UNTIL I=N

   A (I,N+1) = 4.0/ACI,N+1) - 1.0

ENDDO

J=1
```

```
DO UNTIL J=N

   I=1

   DO UNTIL I=N

      CASE ENTRY (J)

         CASE 1

            M(I) = M(I)/9.945
            A(I,J) = M(I)+1.0

         CASE 2

            A(I,J) = M(I)**2+1.0

         CASE 3

            A(I,J) = M(I)** 3+1.0

         CASE 4

            A(I,J) = M(I)** 4+1.0

      ENDCASE

         IF N=4
            EXITDO

         ENDIF
         IF J=5
            A(I,J) = M(I)** 5+1.0

         ENDIF
         IF J = 6
            A(I,J) = M(I)** 6+1.0
         ENDIF

   ENDDO

ENDDO

ACQUIRE DATE AND TIME

WRITE DATE AND TIME ON LINE PRINTER

WRITE N ON THE LINE PRINTER

I=1
```

```
DO UNTIL I = N
   WRITE THE COUNT DOWN FACTORS ON THE LINE PRINTER
ENDDO
I=1
DO UNTIL I=N
   WRITE THE MEASURED DISPERSIONS ON THE LINE PRINTER
ENDDO
I=1
DO UNTIL I=N+1
   J=1
   DO UNTIL J=N
      WRITE THE "A' ARRAY ON THE LINE PRINTER
   ENDDO
ENDDO
CALL SGHSV6 TO SOLVE THE SIMULTANEOUS EQUATIONS ON RETURN, END
```

B-3.0 DETERMINE ROOT, SUBROUTINE SGHRT6

B-3.0.a Program Description

This program finds the root of a polonomial equation in two steps which are as follows:

1. Isolates the root by a stepwise search between two numbers, specified by the root inteval.

2. Improves the root to a pre-specified accuracy by a Newton iteration procedure.

The test value accuracy is specified by variable T1, and K is the distance on the Z nondimensional axis to where Q is reduced to 0.01.

B-4.0 COMPUTE Q, SUBROUTINE SGHBE6

B-4.0-a Program Description

This program calculates values of the complimentary distribution function of a normalized random variable. The nondimensional random variable X is incremented by a step function from 0.0 to 0.5 by an increment of 0.01. The complimentary distribution function is printed out on the line printer for each value of X.

B-4.0-b HIPO for Subroutine SGHBE6

Input	Process	Output
	1. Write header for X and Q 2. Do until K = SO V = K/10 Call SGHVY6 to calculate Q Write value for X & Q ENDDO 3. Call SGHMON to calculate the moments	

NOTES:

H I P O NO. C-4.0-b

TITLE: COMPUTE Q

Services Required:

COMPUTE AND PRINTS A TABLE OF THE COMPLIMENTARY DISTRIBUTION AS A FUNCTION OF NORMALIZED RANDOM VARIABLE

B-4.0-c PDL for Subroutine SGHBE6

```
Write header on line printer

K=0

Do until K=SO

   V = K/10
   Call SGHVY6 to calculate Q

ENDDO

Call SGHMON to compute the moments
```

B-5.0 COMPUTE MOMENTS SUBROUTINE SGHMOM

B-5.0-a Program Description

THIS SUBROUTINE IS PART OF THE BEM DISPERSION ANALYSIS, USING THE LEAST SQUARES FIT METHOD. IT COMPUTES THE MOMENTS OF Q(Z), THE COMPLEMENTRY PROBABILITY DISTRIBUTION FUNCTION, AS A FUNCTION OF THE NORMALIZED DISPERSION VOLTAGE FOR BEM DATA.

THIS PROGRAM PERFORMS LINEAR AND NONLINEAR PATTERN RECOGNITION TECHNIQUES. IT HAS BEEN CONCLUDED THAT THE USE OF LINEAR DISCRIMINATES WOULD SUFFICE FOR SIGNAL IDENTIFICATION. THE DISCRIMINATE WHICH WAS SELECTED WAS THE MOMENTS OF THE Q(Z) CURVES.

THE MOMENTS ARE DEFINED AS:
M = THE INTEGRAL OF Z*Q(Z)dz EVELUATED FROM 0 TO INFINITY

M(K) = INTEGRAL OF ((Z-M)**K)*Q(Z)dz FOR K=1,2,3,.....
EVALUATED FROM 0 TO INFINITY.

WHERE K=1,2,3,.....

B-5.0-c HIPO for Subroutine SGHMOM

Input

Process

1. Compute a,b,c,d
2. Output a,b,c,d,k^2,k^3,k^4
3. Compute 1st moment
4. Print 1st moment
5. Compute 2nd moment
6. Print 2nd moment
7. Compute 3rd moment
8. Print 3rd moment
9. Print 3rd moment
10. Print 4th moment

Output

Listing

NOTES:

H I P O NO: C-5-0-c

TITLE: COMPUTE MOMENTS

Service Required:

COMPUTES $\overline{M}$, THE 2ND, 3RD, AND 4TH MOMENTS

B-6.0 DISCRIMINATE SIGNAL, SUBROUTINE SGHDIS

B-6.0-a Program Description

This program discriminates between an unknown signal and one of the eight signal types studied. This is done by determining a z value for the unknown signal by multiplying the computed K, M(2), M(3), and M(4) by each set of lambda values and determining the computation which most closely matches one of the eight known signal types studied. A confidence value is input to establish a band pass for comparison purposes. The value is expressed as a percentage. A 10 percent confidence would be input as 110.. The decimal point is required.

B-6.0-b HIPO for Subroutine SGHDIS

Input	Process	Output
K, M(2),M(3),M(4)	1. Input parameters	Array 'IN'
	2. Compute the Z values by taking a set of Lambda values for each of the 28 possible combinations of signal types	
	3. Output running Z sum	Listing
	4. Put Z values into array 'ZT'	
	5. Construct array 'ZTI' which is twice the size of array 'ZT' and contains two entries from each item in 'ZT'	Array 'ZTI'
	6. Output the 'ZTI' array to the terminal	Listing
Terminal	7. Select which set of Z values is to be used for the comparison	
	8. Generate an absolute difference array 'ZTO' which is ABS (ZARRAY-ZTI)	Array 'ZTO'
	9. Determine the absolute minimum in the 'ZTD' array & construct a pointer to the item.	XMIN, JPOINT

NOTES:

Array LAM contains the LAMBDA values obtained by comparing all possible combinations of the signal types

Array ZARRAY contains the Z values obtained by comparing all possible combinations of the signal types

H I P O NO: C-6.0-b

TITLE: DISCRIMINATE SIGNAL TYPE

Services Requied:

1. Determine which of t B possible signal types most closely matches the unknown signal.

B-6.0-b.1 HIPO for Subroutine SCHDIS (Continued)

Input	Process	Output
Terminal	10. Input a confidence value expressed by a percent of the absolute minimum array	
	11. Find all values in the difference array that are less than the computed confidence value	Array 'JSAVE'
	12. Print out a header	Listing
	13. List all signal types that have a minimum value less than the confidence value	

NOTES:

H I P O NO: B-6.0-b1

TITLE: DISCRIMINATE SIGNAL TYPE

Services Required:

Determine which of the 8 possible signal type most clearly matches the unknown signal

B-6.0-c PDL for Subroutine SGHDIS

```
I=1
DO UNTIL I=4
   INPUT VALUE INTO ARRAY 'IN
ENDDO
I=1
DO UNTIL I=28
   Z VALUE = 0.0
   J=1
   DO UNTIL J=4
      COMPUTE Z VALUE AS FOLLOWS:  Z VALUE - LAMBDA (J,I)*IN(J)
      OUTPUT LAMBDA VALUE AND PARTIAL SUM TO THE LISTING
   ENDDO
   PUT COMPUTER Z VALUE INTO ARRAY 'ZT'
   OUTPUT ARRAY ZT TO THE LISTING
ENDDO
I=1
DO UNTIL I=28
   MAKE EVERY 2ND ITEM OF A Z ITEM PAIR EQUAL TO THE COMPUTED Z
ENDDO
I=1
DO UNTIL I = 56 STARTING AT 2 ND VARYING BY 2
   MAKE EVERY 1ST ITEM OF A 2 ITEM PAIR EQUAL TO THE COMPUTED Z
ENDDO
I=1
```

```
DO UNTIL 1=56

   OUTPUT EACH ELEMENT OF ARRAY 'ZTI' TO THE TERMINAL

ENDDO

INPUT THE SELECTED Z LIST TO BE USED FOR COMPARISON

I=1

DO UNTIL I=36

   GENERATE A ABSOLUTE DIFFERENCE ARRAY WHICH IS THE DIFFERENCE
   OUTPUT THE DIFFERENCE ARRAY TO THE TERMINAL

ENDDO

SET XMIN EQUAL TO THE 1ST VALUE IN THE DIFFERENCE ARRAY

I=1

DO UNTIL I=56

   FIND THE MINIMUM VALUE IN THE DIFFERENCE ARRAY AND SET XMIN
   EQUAL TO IT

   FORM A POINTER TO THE MINIMUM VALUE.

ENDDO

OUTPUT THE MINIMUM VALUE AND THE POINTER TO THE TERMINAL

REQUEST A CONFIDENCE VALUE

INPUT THE CONFIDENCE VALUE AS A PERCENTAGE

DETERMINE PCENT EQUAL TO A PERCENTAGE OF THE MINIMUM DIFFERENCE
   PLUS THE MINIMUM DIFFERENCE (ESTABLISH A BANDPASS)

I=1

DO UNTIL I=56

   JSAVE(I)=0
   FOR EACH VALUE IN THE DIFFERENCE ARRAY WHICH FALLS WITH THE
      BANDPASS ESTABLISHED BY THE CONFIDENCE VALUE, MAKE A
      CORRESPONDING ENTRY IN ARRAY JSAVE
```

ENDDO

PRINT THE HEADER

FOR EACH - ENTRY IN ARRAY JSAVE, PRINT THE CORRESPONDING SIGNAL TYPE

STOP

END

B-7.0-b HIPO for Subroutine SGHUY6

Input	Process	Output

	1. Q = 0
	2. I = 1
	3. Do until I = N
	    Calculate a value of Q
	  ENDDO
	4. Q = Q+.5
	6. Return	

NOTES:

ALL INTRA-SUBROUTINE COMMUNICATION IS VIA COMMON

H I P P O NO. C-7.0-b

TITLE: CALCULATE Q

Services Requird:

Computes a numerical value of Q

B-7.0 CALCULATE Q, SUBROUTINE SGHVY6

B-7.0-a Program Description

This program computes a numerical value of Q

B-7.0-c PDL for Subroutine SGHVY6

```
Q=0.0

I=1

DO UNTIL I=N

   Q = Q+A(I,N+1)/D9**I*(V**I)

ENDDO

Q = 0.5 + 0

RETURN
```

APPENDIX C

STRUCTURED PROGRAM DOCUMENTATION FOR THE SOLUTION BY THE LEAST SQUARES METHOD

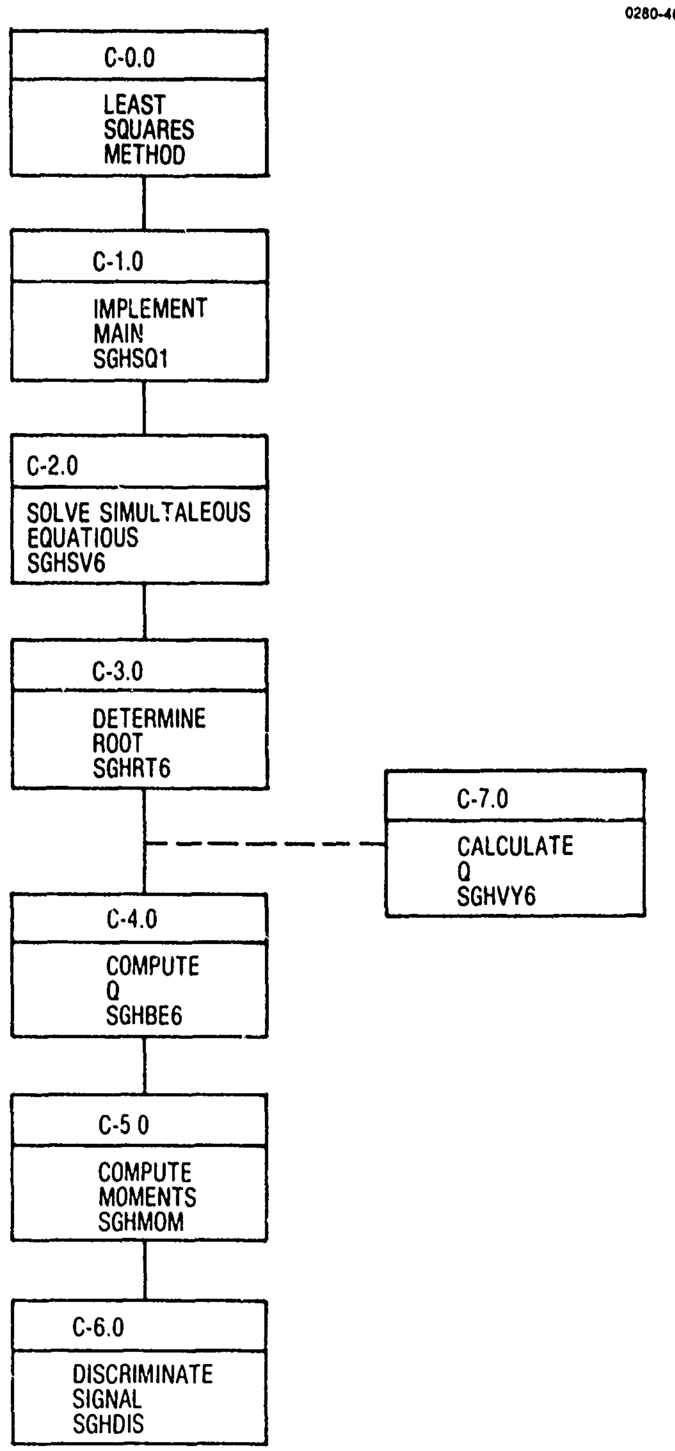


FIGURE C-1. HIERARCHY CHART FOR THE SOLUTION BY THE LEAST SQUARES METHOD

```
THIS PROGRAM PERFORMS A CURVE FITTING PROCEEDURE
USING ACCUMULATED DISPERSION DATA AND UTILIZING
THE LEAST SQUARES APPROXIMATION METHOD. THE INPUT DATA REQUIRED
IS AS FOLLOWS :


   1. NUMBER OF COUNT DOWN FACTORS
   2.THE ORDER OF THE EQUATION
   3. THE COUNT DOWN FACTORS
   4. THE MEASURED DISPERSIONS

THE OUTPUT CONSISTS OF DATA POINTS WHOSE PLOT REPRESENTS
THE COMPLEMENTRY DISTRIBUTION FUNCTION AGAINST A NORMALIZED
RANDOM VARIABLE WHOSE VARIANCE IS ONE.

THIS SUBROUTINE READS THE INPUT VALUES AND CONSTRUCTS AN ARRAY 'A'
COMPOSED OF THE COEFFICIENTS OF N EQUATIONS OF THE N TH ORDER.
IT IS THESE EQUATIONS WHICH ARE SOLVED FOR THE NORMALIZED
COMPLEMENTARY DISTRIBUTION BY SUBSEQUENT SUBROUTINES.



THE EQUATIONS ARE ARRIVED AT AS FOLLOWS :
THE PSEUDO ERROR RATE EQUATION IS DEFINED AS
P=Q(A*D)+Q(D), WHERE P IS FOUR TIMES THE PSEUDO ERROR RATE , OR COUNT
DOWN FACTOR, AND A IS A KNOWN PARAMETER WHICH IS PROVIDE BY BEM
MEASUREMENTS FOR EACH SELECTED P.

USING THE APPROXIMATION
       Q(Z)=.5+a*Z+b*Z**2+c*Z**3+d*Z**4 , FOR THE  N=4 CASE,
IN THE PSEUDO ERROR RATE EQUATION GIVES THE FOLLOWING :

P-1=a(A*D)+b*(A*D)**2+c*(A*D)**3+d*(A*D)**4


SINCE A =a/d, WHERE a=(MEASURED DISPERSION)/11.05, AND d=0.9,
THEN A =(MEASURED DISPERSION)/9.945.

DEFINING G=P-1, THE EQUATIONS EVALUATED AT 4 POINTS ARE
G1=a(A1*D)+b(A1*D)**2+c(A1*D)**3+d(A1*D)**4

PLUS THREE OTHER SIMILAR EQUATIONS EVALUATED AT THE OTHER SELECTED
POINTS, A2,A3,A4 AND G2,G3,G4.

THEN LET THE NEW UNKNOWNS t,u,v,w BE INTRODUCED BY THE RELATIONS :
            aD=t
            bD**2=u
            cD**3=v
            dD**4=w
THEN SUBSTITUTION INTO THE G EQUATIONS GIVES
   G1=(A1+1)t+(A1**2+1)u+(A1**3+1)v+(A1**4+1)w
   G2=(A2+1)t+(A2**2+1)u+(A2**3+1)v+(A2**4+1)w
   G3=(A3+1)t+(A3**2+1)u+(A3**3+1)v+(A3**4+1)w
   G4=(A4+1)t+(A4**2+1)u+(A4**3+1)v+(A4**4+1)w
WHICH ARE FOUR LINEAR EQUATIONS FOR THE FOUR UNKNOWNS t,u,v,w
DETERMINED BY THE KNOWN VALUES G1,G2,G3,G4,A1,A2,A3,A4
```

C-1.0 IMPLEMENT MAIN, PROGRAM SGHSQ1

C-1.0-a Program Description

C-1.0-b HIPO for the Solution by the Least Squares Method

Input	Process	Output
Display	1 Zero Arrays 'C', 'M',"g",'A','F','B', and 'T'	Arrays in Common
	2 Prompt for comment	Display
Display	3 Input comment line	
	4 Prompt for the number of count down factors (k) and the order of the equation (N)	
Display	5 Input K and N	Common
	6 Prompt for the count down down factors	
Display	7 Input the count down down factors	Common
	8 Prompt for the measured dispersions	
Display	9 Input the measured dispersions	Common
	10 Zero array 'A'	
	11 Build up array 'A' for the solve program which will solve the N simultaneous equations	

NOTES: SOLUTION BY LEAST SQUARES APPROXIMATION METHOD

H I P O NO: C-1.0b

TITLE: MAIN PROGRAM SGHSQ1

Services Required

1. Input Program Parameters
2. Input data
3. Prepare data matrix for the solve program

C-1.0-b (Continued)

Input

Process

12. Write the note
13. Get the time and date from the operating system
14. Write the time and date
15. Write N and K
16. Write the count down factors
17. Write the measured dispersions
18. Write matrix 'A'
19. Call SGHSV6 to solve the N simultaneous equations
20. Upon return, end

Output

Listing

NOTES:

H I P O NO: 0.0.1

TITLE: MAIN PROGRAM SGHSQ1

Services Required

1. Write parameters and data to the line printer
2. Call SGHSV6 to solve the N simultaneous equations

C-10-c PDL for Program SGHSQ1

```
I = 1
DO UNTIL I = 8
   ZERO ARRAY 'C'
ENDDO
I = 1
DO UNTIL I = 8
   ZERO ARRAY 'M'&'G'
ENDDO
I = 1
DO UNTIL I = 8
   ZERO ARRAY 'A','F','B','T'
ENDDO
ASK FOR COMMENT LINE
INPUT COMMENT LINE
ASK FOR K, THE NUMBER OF COUNT DOWN FACTORS
INPUT K
ASK FOR N, THE ORDER OF THE EQUATION
INPUT N
ASK FOR THE COLUMN OF COUNT DOWN FACTORS
I = 1
DO UNTIL I = K
   READ A COUNT DOWN FACTOR INTO ARRAY 'G'
   DUPLICATE ARRAY 'G' AS THE KTH+1 COLUMN OF ARRAY 'F'
   CHANGE EACH ELEMENT OF ARRAY 'G' TO BE 4/G-1
```

```
ENDDO
ASK FOR THE MEASURED DISPERSIONS
I = 1
DO UNTIL I = K
   INPUT A MEASURED DISPERSION INTO ARRAY 'D'
ENDDO
I = 1
DO UNTIL I = K
   MAKE ARRAY 'M' EQUAL TO ARRAY 'D'/9.945
ENDDO
I = 1
DO UNTIL I = N
   J = 1
   DO UNTIL J = N+1
      MAKE ELEMENT OF ARRAY 'A' = 0
   ENDDO
ENDDO
L0=1
DO UNTIL L0=N
   L1=1
   DO UNTIL L1=N
      I=1
      DO UNTIL I=K
         A(L1,L0)=A(L1/L0)+(M(I)**L0+1)+(M(I)**L1+1
      ENDDO
   ENDDO
```

```
ENDDO
L1=1
DO UNTIL L1=N
   I=1
   DO UNTIL I=K
      A(L1,N+1)=A(L1,N+1)+(G(I)*(M(I)**L1+1
   ENDDO
ENDDO
OUTPUT THE COMMENT LINE TO THE LINE PRINTER
GET THE TIME AND DATE FROM THE OPERATING SYSTEM
WRITE THE TIME AND DATE ON THE LINE PRINTER
WRITE N AND K ON THE LINE PRINTER
I=1
DO UNTIL I=K
   WRITE THE COUNT DOWN FACTORS ON THE LINE PRINTER
ENDDO
I=1
DO UNTIL I=K
   WRITE THE MEASURED DISPERSIONS ON THE LINE PRINTER
ENDDO
J=1
DO UNTIL J=N+1
   WRITE MATRIX 'A' BY COLUMNS
ENDDO
CALL SGHSV6 TO SOLVE THE SIMULTANEOUS EQUATIONS
END
```

C-3.0 DETERMINE ROOT, SUBROUTINE SGHRT6

C-3.0-a Program Description

This program finds the root of a polonominal equation in two steps which are as follows:

1. Isolates the root by a stepwise search between two numbers, specified by the root inteval.

2. Improves the root to a pre-specified accuracy by a Newton iteration procedure.

The test value accuracy is specified by variable T1, and K is the distance on the Z nondimensional axis to where Q is reduced to 0.01.

C-4.0 COMPUTE Q, SUBROUTINE SGHBE6

C-4.0-a Program Description

This program calculates values of the complimentary distribution function as a function of a normalized random variable. The nondimensional random variable X is incremented by a step function from 0.0 to 0.5 by an increment of 0.01. The complimentary distribution function is printed out on the line printer for each value of X.

C-4.0-b HIPO for Subroutine SGMBE6

Input	Process	Output
	1. Write header for X and Q → LISTING 2. Do until K = SO V = K/10 Call SGHVY6 to calculate Q Write value for X & Q ENDDO 3. Call SGHMON to calculate the moments	LISTING

NOTES:

Services Required

H I P O NO: C-4.0-6

Title: COMPUTE Q

COMPUTE AND PRINTS A TABLE OF THE COMPLIMENTARY DISTRIBUTION AS A FUNCTION OF NORMALIZED RANDOM VARIABLE

C-4.0-c PDL for Subroutine SGHBE6

```
WRITE HEADER ON LINE PRINTER
K=0
DO UNTIL K=30
   V=K/10
   CALL SGHVY6 TO CALCULATE Q
ENDDO
CALL SGHMON TO COMPUTE THE MOMENTS
```

C-5.0 COMPUTE MOMENTS, SUBROUTINE SGHMOM

C-5.0-a Program Description

THIS SUBROUTINE IS PART OF THE BEM DISPERSION ANALYSIS, USING THE LEAST SQUARES FIT METHOD. IT COMPUTES THE MOMENTS OF Q(Z), THE COMPLEMENTRY PROBABILITY DISTRIBUTION FUNCTION, AS A FUNCTION OF THE NORMALIZED DISPERSION VOLTAGE FOR BEM DATA.

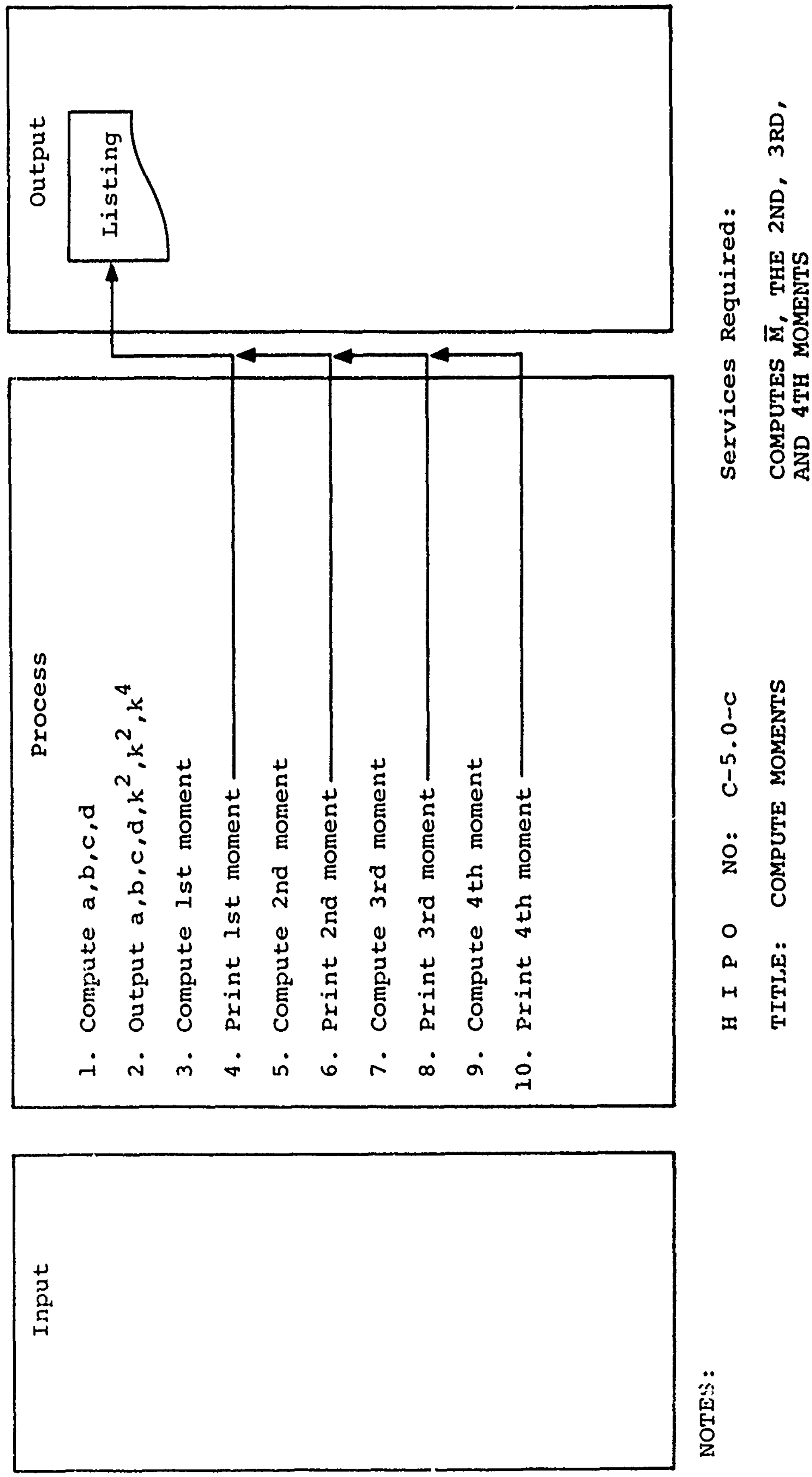
THIS PROGRAM PERFORMS LINEAR AND NONLINEAR PATTERN RECOGNITION TECHNIQUES. IT HAS BEEN CONCLUDED THAT THE USE OF LINEAR DISCRIMINATES WOULD SUFFICE FOR SIGNAL IDENTIFICATION. THE DISCRIMINATE WHICH WAS SELECTED WAS THE MOMENTS OF THE Q(Z) CURVES.

THE MOMENTS ARE DEFINED AS:
M = THE INTEGRAL OF Z*Q(Z)oz ELEVLUATED FROM 0 TO INFINITY

M(R) = INTEGRAL OF ((Z-M)**K)*Q(Z)oz FOR K=1,2,3,.....
EVALUATED FROM 0 TO INFINITY.

WHERE K=1,2,3,.....

C-5.0-c HIPO for Subroutine SGHMOM



C-6.0 DESCRIMINATE SIGNAL, SUBROUTINE SGHDIS

C-6.0-a Program Description

This program discriminates between an unknown signal and one of the eight signal types studied. This is done by determining a Z value for the unknown signal by multiplying the computed K, M(2), M(3), and M(4) by each set of lambda values and determining the computation which most closely matches one of the eight known signal types studied. A confidence value is input to establish a band pass for comparison purposes. The value is expressed as a percentage. A 10 percent confidence would be input as 110.. The decimal point is required.

C-6.0-b HIPO for Subrotine SGHDIS

Input	Process	Output
K, M(2),M(3),M(4)		Array 'IN'
	2. Compute the Z values by taking a set of Lambda values for each of the 28 possible combinations of signal types	
	3. Output running Z sum	Listing
	4. Put Z values into array 'ZT'	
	5. Construct array 'ZTI' which is twice the size of array 'ZT' and contains two entries from each item in 'ZT'	Array 'ZTI'
	6. Output the 'ZTI' array to the terminal	Listing
Terminal	7. Select which set of Z values is to be used for the comparison	
	8. Generate an absolute difference array 'ZTO' which is ABS (ZARRAY-ZTI)	Array 'ZTO'
	9. Determine the absolute minimum in the 'ZTD' array and construct a pointer to the item	XMIN, JPOINT

NOTES:

Array LAM contains the LAMBDA values obtained by comparing all possible combinations of the signal types

Array ZARRAY contains the Z values obtained by comparing all possible combinations of the signal types

H I P O NO: C-6.0-b

TITLE: DISCRIMINATE SIGNAL TYPE

Services Required:

1. Determine which of t B possible signal types most closely matches the unknown signal.

C-6.0-b (Continued)

Input	Process	Output
Terminal →	10. Input a confidence value expressed as a percent of the absolute minimum array	
	11. Find all values in the difference array that are less than the computed confidence value →	Array 'JSAVE'
	12. Print out a header →	Listing
	13. List all signal types that have a minimum value less than the confidence value	

NOTES:

H I P O NO: 0.0

TITLE: DISCRIMINATE SIGNAL TYPE

Services Required:

Determine which of the 8 possible signal type most clearly matches the unknown signal

<u>C-6.0-c PDL for Subroutine SGHDIS</u>

```
I=1

DO UNTIL I=4

   INPUT VALUE INTO ARRAY 'IN

ENDDO

I=1

DO UNTIL I=28

   Z VALUE = 0.0
   J=1
   DO UNTIL J=4

      COMPUTE Z VALUE AS FOLLOWS:  Z VALUE = LAMBDA(J,I)*IN(J)

      OUTPUT LAMBDA VALUE AND Z PARTIAL SUM TO THE LISTING

   ENDDO

   PUT COMPUTED Z VALUE INTO ARRAY 'ZT'

   OUTPUT ARRAY ZT TO THE LISTING

ENDDO

I=1

DO UNTIL I=28

   MAKE EVERY 2ND ITEM OF A Z ITEM PAIR EQUAL TO THE COMPUTED Z

ENDDO

I=1

DO UNTIL I=56 STARTING AT 2 AND VARYING BY 2

   MAKE EVERY 1ST ITEM OF A 2 ITEM PAIR EQUAL TO THE COMPUTED Z

ENDDO

I=1

DO UNTIL I=56

   OUTPUT EACH ELEMENT OF ARRAY 'ZTI' TO THE TERMINAL
```

```
ENDDO

INPUT THE SELECTED Z LIST TO BE USED FOR COMPARISON

I=1

DO UNTIL I=36

   GENERATE AN ABSOLUTE DIFFERENCE ARRAY WHICH IS THE DIFFERENCE
   OUTPUT THE DIFFERENCE ARRAY TO THE TERMINAL

ENDDO

SET XMIN EQUAL TO THE 1ST VALUE IN THE DIFFERENCE ARRAY

I=1

DO UNTIL I=56

   FIND THE MINIMUM VALUE IN THE DIFFERENCE ARRAY AND SET XMIN
   EQUAL TO IT

   FORM A POINTER TO THE MINIMUM VALUE

ENDDO

OUTPUT THE MINIMUM VALUE AND THE POINTER TO THE TERMINAL

REQUEST A CONFIDENCE VALUE

INPUT THE CONFIDENCE VALUE AS A PERCENTAGE

DETERMINE PCENT EQUAL TO A PERCENTAGE OF THE MINIMUM DIFFERENCE
   PLUS THE MINIMUM DIFFERENCE. (ESTABLISH A BANDPASS)

I=1

DO UNTIL I=56

   JSAVE(I)=0

   FOR EACH VALUE IN THE DIFFERENCE ARRAY WHICH FALLS WITHIN THE
      BANDPASS ESTABLISHED BY THE CONFIDENCE VALUE, MAKE A
      CORRESPONDING ENTRY IN ARRAY JSAVE

ENDDO

PRINT THE HEADER

FOR EACH ENTRY IN ARRAY JSAVE, PRINT THE CORRESPONDING SIGNAL
TYPE
STOP
END
```

C-7.0 CALCULATE Ç, SUBROUTINE SGHVY6

C-7.0-a Program Description

This program computes a numerical value of Ç

C-70-b HIPO for Subroutine SGHVY6

Input	Process	Output

	1. Q = 0
	2. I = 1
	3. Do until I = N
	      Calculate a value of Q
	   ENDDO
	4. Q = Q+.5
	6. Return	

NOTES:

ALL INTRA-SUBROUTINE COMMUNICATION IS VIA COMMON

H I P O NO.: C-7.0-b

TITLE: CALCULATE Q

Services Required:

Computes a numerical value of Q

C-7.0-c PDL for Subroutine SGHVY6

```
Q=0.0

I=1

DO UNTIL I=N

   Q=Q+A(I,N+1)/D9**I*(V**I)

ENDDO

Q=0.5+Q

RETURN
```

APPPENDIX D

DETAILED PROGRAM LISTINGS

```
      PROGRAM SGHSW1
C-----------------------------------------------------------
C
C
C  THIS PROGRAM PERFORMS A CURVE FITTING PROCEEDURE
C  USING ACCUMULATED DISPERSION DATA AND UTILIZING
C  THE LEAST SQUARES APPROXIMATION METHOD. THE INPUT DATA REQUIRED
C  IS AS FOLLOWS :
C
C
C     1. NUMBER OF COUNT DOWN FACTORS
C     2.THE ORDER OF THE EQUATION
C     3. THE COUNT DOWN FACTORS
C     4. THE MEASURED DISPERSIONS
C
C  THE OUTPUT CONSISTS OF DATA POINTS WHOSE PLOT REPRESENTS
C  THE COMPLEMENTRY DISTRIBUTION FUNCTION AGAINST A NORMALIZED
C  RANDOM VARIABLE WHOSE VARIANCE IS ONE.
C
C  THIS SUBROUTINE READS THE INPUT VALUES AND CONSTRUCTS AN ARRAY 'A'
C  COMPOSED OF THE COEFFICIENTS OF N EQUATIONS OF THE N TH ORDER.
C  IT IS THESE EQUATIONS WHICH ARE SOLVED FOR THE NORMALIZED
C  COMPLEMENTARY DISTRIBUTION BY SUBSEQUENT SUBROUTINES.
C
C
C
C  THE EQUATIONS ARE ARRIVED AT AS FOLLOWS :
C  THE PSEUDO ERROR RATE EQUATION IS DEFINED AS
C  P=G(A*D)+G(D), WHERE P IS FOUR TIMES THE PSEUDO ERROR RATE , OR COUNT
C  DOWN FACTOR, AND A IS A KNOWN PARAMETER WHICH IS PROVIDE BY BEM
C  MEASUREMENTS FOR EACH SELECTED P.
C
C  USING THE APPROXIMATION
C             G(Z)=.5+a*Z+b*Z**2+c*Z**3+d*Z**4 , FOR THE  N=4 CASE,
C  IN THE PSEUDO ERROR RATE EQUATION GIVES THE FOLLOWING :
C
C  P-1=a(A*D)+b*(A*D)**2+c*(A*D)**3+d*(A*D)**4
C
C
C  SINCE A =a/d, WHERE a=(MEASURED DISPERSION)/11.05, AND d=0.9,
C  THEN A =(MEASURED DISPERSION)/9.945.
C
C  DEFINING G=P-1, THE EQUATIONS EVALUATED AT 4 POINTS ARE
C  G1=a(A1*D)+b(A1*D)**2+c(A1*D)**3+d(A1*D)**4
C
C  PLUS THREE OTHER SIMILAR EQUATIONS EVALUATED AT THE OTHER SELECTED
C  POINTS, A2,A3,A4 AND G2,G3,G4.
C
C  THEN LET THE NEW UNKNOWNS t,u,v,w BE INTRODUCED BY THE RELATIONS :
C                aD=t
C                bD**2=u
C                cD**3=v
C                dD**4=w
C  THEN SUBSTITUTION INTO THE G EQUATIONS GIVES
C     G1=(A1+1)t+(A1**2+1)u+(A1**3+1)v+(A1**4+1)w
C     G2=(A2+1)t+(A2**2+1)u+(A2**3+1)v+(A2**4+1)w
```

```
C      G3=(A3+1)t+(A3**2+1)u+(A3**3+1)v+(A3**4+1)w
C      G4=(A4+1)t+(A4**2+1)u+(A4**3+1)v+(A4**4+1)w
C  WHICH ARE FOUR LINEAR EQUATIONS FOR THE FOUR UNKNOWNS t,u,v,w
C  DETERMINED BY THE KNOWN VALUES G1,G2,G3,G4,A1,A2,A3,A4
C
C
C-----------------------------------------------------------
C
C  COMMON VARIABLES
C
      COMMON N,C(8),A(8,8),F(8,8),M(8),B(8,8),T(8,8),Q,D9,V,DD,K9,RIN(4)
C
C  DECLARATIONS
C
      DOUBLE PRECISION G,M,A,F,D,B,T,Q,D9,V,DD,K9
      DIMENSION ARRAY1(3),ARRAY2(3),G(8),D(8)
      INTEGER ARRAY1,ARRAY2,C
      CHARACTER* 80 ANOTE
C
C      ZERO ARRAYS
C
      I=1
C     DO UNTIL (I.GT.8)
         GO TO 9001
 9002    CONTINUE
       IF(I.GT.8)GOTO 9003
 9001    CONTINUE
         C(I)=0
         I=I+1
           GO TO 9002
C     ENDDO
 9003      CONTINUE
      I=1
C     DO UNTIL (I.GT.8)
         GO TO 9004
 9005    CONTINUE
       IF(I.GT.8)GOTO 9006
 9004    CONTINUE
         M(I)=0.0D0
         G(I)=0.0D0
         I=I+1
           GO TO 9005
C     ENDDO
 9006      CONTINUE
      I=1
C     DO UNTIL (I.GT.8)
         GO TO 9007
 9008    CONTINUE
       IF(I.GT.8)GOTO 9009
 9007    CONTINUE
         J=1
C        DO UNTIL (J.GT.8)
            GO TO 9010
 9011       CONTINUE
          IF(J.GT.8)GOTO 9012
 9010       CONTINUE
```

```
              A(J,I)=0.0D0
              F(J,I)=0.0D0
              B(J,I)=0.0D0
              T(J,I)=0.0D0
              J =J+1
             GO TO 9011
C          ENDDO
 9012        CONTINUE
           I=I+1
             GO TO 9008
C        ENDDO
 9009        CONTINUE
C
C  PROMPT FOR COMMENT.
C
C
        WRITE (7,200)
C  ASK FOR COMMENT
C
        READ (7,500) ANOTE
C
C  ASK FOR K, THE NUMBER OF COUNT DOWN FACTCRS.
C
        WRITE (7,1000)
C
C  INPUT K, THE NUMBER OF COUNT DOWN FACTORS.
C
        READ (7,1010) K
C
C  ASK FOR N, THE ORDER OF THE EQUATION
C
        WRITE (7,1020)
C
C  INPUT  N, THE ORDER OF THE EQUATION
C
        READ (7,1030) N
C
C  ASK FOR COLUMN OF COUNT DOWN FACTORS.
C
        WRITE (7,1040)
C
C  INPUT COLUMN OF COUNT DOWN FACTORS.
C
        I=1
C       DO UNTIL (I.GT.K)
           GO TO 9013
 9014      CONTINUE
         IF(I.GT.K)GOTO 9015
 9013      CONTINUE
           READ (7,1050) G(I)
           F(I,K+1)=G(I)
C
C
C
           G(I)=4.0D0/G(I)-1.0D0
           I=I+1
```

```
            GO TO 9014
C       ENDDO
 9015       CONTINUE
C
C  ASK FOR MEASURED DISPERSIONS.
C
        WRITE (7,1060)
C
C  INPUT THE MEASURED DISPERSIONS.
C
        I=1
C       DO UNTIL (I.GT.K)
          GO TO 9016
 9017     CONTINUE
         IF(I.GT.K)GOTO 9018
 9016     CONTINUE
          READ (7,1070) D(I)
          I=I+1
            GO TO 9017
C       ENDDO
 9018       CONTINUE
C
C
C
        I=1
C       DO UNTIL (I.GT.K)
          GO TO 9019
 9020     CONTINUE
         IF(I.GT.K)GOTO 9021
 9019     CONTINUE
          M(I)=D(I)/9.945D0
          I=I+1
            GO TO 9020
C       ENDDO
 9021       CONTINUE
C
C  ZERO OUT ARRAY A
C
        I=1
C       DO UNTIL (I.GT.N)
          GO TO 9022
 9023     CONTINUE
         IF(I.GT.N)GOTO 9024
 9022     CONTINUE
          J=1
C         DO UNTIL (J.GT.N+1)
            GO TO 9025
 9026       CONTINUE
           IF(J.GT.N+1)GOTO 9027
 9025       CONTINUE
            A(I,J)=0.0D0
            J=J+1
          GO TO 9026
C         ENDDO
 9027       CONTINUE
          I=I+1
```

```
              GO TO 9023
C      ENDDO
 9024         CONTINUE
C
C
C
        L0=1
C          DO UNTIL(L0.GT.N)
           GO TO 9028
 9029      CONTINUE
         IF(L0.GT.N)GOTO 9030
 9028      CONTINUE
              L1=1
C             DO UNTIL (L1.GT.N)
              GO TO 9031
 9032         CONTINUE
            IF(L1.GT.N)GOTO 9033
 9031         CONTINUE
                 I=1
C                DO UNTIL (I.GT.K)
                 GO TO 9034
 9035          . CONTINUE
               IF(I.GT.K)GOTO 9036
 9034            CONTINUE
                    A(L1,L0)=A(L1,L0)+(M(I)**L0+1.0D0)*(M(I)**L1+1.0D0)
                    I=I+1
             GO TO 9035
C                ENDDO
 9036        CONTINUE
                 L1=L1+1
             GO TO 9032
C             ENDDO
 9033        CONTINUE
           L0=L0+1
             GO TO 9029
C       ENDDO
 9030        CONTINUE
C
C
C
        L1=1
C       DO UNTIL (L1.GT.N)
           GO TO 9037
 9038      CONTINUE
         IF(L1.GT.N)GOTO 9039
 9037      CONTINUE
           I=1
C          DO UNTIL (I.GT.K)
              GO TO 9040
 9041         CONTINUE
            IF(I.GT.K)GOTO 9042
 9040         CONTINUE
              A(L1,M+1)=A(L1,M+1)+(G(I)*(M(I)**L1+1.0D0))
              I=I+1
             GO TO 9041
C          ENDDO
```

```
 9042        CONTINUE
           L1=L1+1
             GO TO 9036
C       ENDDO
 9034        CONTINUE
C
C  WRITE THE NOTE.
C
        WRITE (9,550) ANOTE
C
C  GET THE TIME AND DATE.
C
        CALL TIME (ARRAY1)
        CALL DATE (ARRAY2)
C
C  WRITE THE TIME AND DATE.
C
        WRITE (9,1080) ARRAY2(2),ARRAY2(3),ARRAY2(1),ARRAY1
C
C  WRITE N AND K
C
        WRITE (9,1090) K,N
C
C  WRITE THE COUNT DOWN FACTORS
C
        WRITE (9,1095)
        I=1
C       DO UNTIL (I.GT.K)
           GO TO 9043
 9044      CONTINUE
          IF(I.GT.K)GOTO 9045
 9043      CONTINUE
           WRITE (9,2000) F(I,K+1)
           I=I+1
             GO TO 9044
C       ENDDO
 9045        CONTINUE
C
C  WRITE THE MEASURED DISPERSIONS.
C
        I=1
C       DO UNTIL (I.GT.K)
           GO TO 9046
 9047      CONTINUE
          IF(I.GT.K)GOTO 9048
 9046      CONTINUE
           WRITE (9,2010) U(I)
           I=I+1
             GO TO 9047
C       ENDDO
 9048        CONTINUE
C
C  OUTPUT MATRIX 'A'.
C
        WRITE (9,2015)
        J=1
```

```
C       DO UNTIL (J.GT.N+1)
           GO TO 9049
  9050     CONTINUE
          IF(J.GT.N+1)GOTO 9051
  9049     CONTINUE
           I=1
C          DO UNTIL (I.GT.N)
              GO TO 9052
  9053        CONTINUE
            IF(I.GT.N)GOTO 9054
  9052        CONTINUE
              WRITE (9,2020) A(I,J),I,J
              I=I+1
             GO TO 9053
C          ENDDO
  9054       CONTINUE
            WRITE (9,2030)
            J=J+1
             GO TO 9050
C       ENDDO
  9051       CONTINUE
        CALL SGHSV6
200     FORMAT (1H1,'ENTER DESCRIPTION')
500     FORMAT (A80)
550     FORMAT (1H1,A80,///)
1000    FORMAT (1H ,'INPUT K = NUMBER OF COUNT DOWN FACTORS.')
1010    FORMAT (I1)
1020    FORMAT (1H ,'INPUT N = ORDER OF EQUATION.')
1030    FORMAT (I1)
1040    FORMAT (1H ,'INPUT COLUMN OF COUNT DOWN FACTORS.')
1050    FORMAT (F4.0)
1060    FORMAT (1H ;'INPUT COLUMN OF MEASURED DISPERSIONS.')
1070    FORMAT (F5.3)
1080    FORMAT (1H ,'THE DATE IS ',I2,':',I2,':',I4,4X,I2,':',I2,':',I2,9X
     &      ,'LEAST SQUARES APPROXIMATION METHOD.')
1090    FORMAT (1H ,'THE NUMBER OF COUNT DOWN FACTORS ARE = ',I1,
     &      /,1H ,'THE ORDER OF THE EQUATION IS = ',I1)
1095    FORMAT (1H ,'COUNT DOWN FACTORS ARE = ')
2000    FORMAT (1H ,27X,8(5X,D10.4))
2010    FORMAT (1H ,'MEASURED DISPERSIONS ARE :  ',8(4X,D10.4))
2015    FORMAT (1H ,///,'OUTPUT A(I,J) BY COLUMNS AND I,J.')
2020    FORMAT (1H  E16.8,6X,I1,6X,I1)
2030    FORMAT (1H
        END
   0  DIAGNOSTICS SGHSQ1
```

PROGRAM COMPILED WITH FOLLOWING COMMAND LINE PARAMETERS:
SGHSQ1
-COUT >SPD>LPT00

```
      SUBROUTINE SGMSVN
C-----------------------------------------------------------------
C
C  PROGRAM DESCRIPTION
C
C     THIS SUBROUTINE SOLVES THE N EQUATIONS IN N UNKNOWNS
C     WHICH IS REPRESENTED BY THE 'A' ARRAY.  THE METHOD
C     USED IS THE GAUSS-JORDAN ELIMINATION.
C
C     GIVEN A SYSTEM OF N LINEAR EQUATIONS IN N UNKNOWNS,
C     OF THE FORM :
C
C         A(1,1)X(1)+A(1,2)X(2)+.....+A(1,N)X(N) = C(1)
C         A(2,1)X(1)+A(2,2)X(2)+.....+A(2,N)X(N) = C(2)
C         .........................................
C         A(N,1)X(1)+A(N,2)X(2)+.....+A(N,N)X(N) = C(N)
C
C
C
C    DEVIDE THE 1ST EQUATION BY A(1,1). THEN SUBTRACT
C    A(2,1) TIMES THIS FIRST RESULT FROM THE 2ND EQUATION,
C    A(3,1) TIMES THE INITIAL RESULT FROM THE THIRD, ETC. ,
C    UNTIL WE HAVE N-1 EQUATIONS IN THE N-1 VARIABLES X(2),
C    X(3),.....,X(N). USING THESE N-1 EQUATIONS, ELIMINATE
C    X(2) IN THE SAME WAY, LEAVING N-2 EQUATIONS IN X(3),
C    X(4),.....,X(N). REPEATING THIS PROCESS A TOTAL OF N-1
C    TIMES, WE FINALLY COME DOWN TO ONE EQUATION IN THE
C    VARIABLE X(N). THE RESULTANT SYSTEM OF EQUATIONS IS
C    OF THE FORM :
C
C    X(1)+A'(1,2)X(2)+A'(1,3)X(3)+.....+A'(1,N)X(N)     = C'(1)
C                X(2)+A'(2,3)X(3)+.....+A'(2,N)X(N)     = C'(2)
C                .........................................
C                               X(N-1)+A'(N-1,N)X(N)  = C'(N-1)
C                                              X(N)  = C'(N)
C
C    USE THE LAST EQUATION TO ELIMINATE X(N) IN THE TOP
C    N-1 EQUATIONS AND THEN USE X(N-1) IN THE NEXT TO LAST
C    EQUATION TO ELIMAINATE ALL THE X(N-1)'S, ECT. , WE WILL
C    COME TO A DIAGONAL SYSTEM OF EQUATIONS WITH THE
C    SOLUTION EXPLICITLY GIVEN.
C
C    A RENUMBERING OF EQUATIONS WILL BE NECESSARY IF, AT ANY
C    STAGE, THE COEFFICIENT OF X(K) IN THE K'TH EQUATION
C    IS ZERO.
C
C
C---------------------------------------------------------------------
C
C  COMMON VARIABLES
C
      COMMON N,C(8),A(8,8),F(8,8),M(8),B(8,8),T(8,8),Q,D9,V,DD,K9,RIN(4)
C
C  DECLARATIONS
C
      DOUBLE PRECISION A,F,M,D,B,T,S7,Q,D9,V
      INTEGER C
C
C
```

```
C
C
C  COPY ARRAY 'A' INTO ARRAY 'B'.
C  THE ARRAY 'A' CONTAINS THE COEFFICIENTS OF THE SIMULTANEOUS
C  EQUATIONS TO BE SOLVED.  ARRAY 'B' IS TO BE USED FOR MANIPULATION
C  BY THE GAUSS-JORDAN METHOD.  THIS TECHNIQUE REDUCES THE SQUARE
C  COEFFICIENT MATRIX
C  TO A DIAGONAL FROM WHICH THE SOLUTIONS ARE GIVEN BY THE ELEMENTS
C  OF THE RIGHT HAND SIDE.
C
      J=1
      DO UNTIL (J.GT.N+1)
         I=1
         DO UNTIL (I.GT.N)
            B(I,J)=A(I,J)
            I=I+1
         ENDDO
         J=J+1
      ENDDO
C
C  SOLVE THE N SIMULTANEOUS C EQUATIONS.
C
C  THESE WILL BE SOLVED BY SELECTING PIVITS FOR PERFORMING THE
C  GAUSS REDUCTION AND CHECKS TO SEE IF POTENTIAL PIVIT IS ZERO.
C  IF IT IS, THE ROWS ARE INTERCHANGED SUCH THAT THE PIVIT IS
C  NON-ZERO.
      K=1
      DO UNTIL (K.GT.N)
         IF (A(K,K).EQ.0)
            L=1
            DO WHILE (A(K+L,K).EQ.0)
               IF (K+L.EQ.N)
                  EXITDO
               ELSE
                  L=L+1
               ENDIF
            ENDDO
            J1=1
            DO UNTIL (J1.GT.N+1)
               T(K,J1)=A(K,J1)
               A(K,J1)=A(K+L,J1)
               A(K+L,J1)=T(K,J1)
               J1=J1+1
            ENDDO
         ENDIF
         B(K,K)=A(K,K)
C
C  DIVIDE THE COEFFICIENTS OF THE EQUATIONS BY THE
C  (K,K)TH COEFFICIENT SO THAT THE (K,K)TH COEFFICIENT IS 1.
C
         J=K
         DO UNTIL (J.GT.N+1)
            A(K,J)=A(K,J)/B(K,K)
            J=J+1
         ENDDO
C
C
C
         I=K
         DO UNTIL (I.GT.N)
            B(I+1,K)=A(I+1,K)
            J=K
            DO UNTIL (J.GT.N+1)
               A(I+1,J)=-B(I+1,K)*A(K,J)+A(I+1,J)
               J=J+1
            ENDDO
```

```
            J=J+1
         ENDDO
         K=K+1
      ENDDO
C
C
C
      K=1
      DO UNTIL (K.GT.N-1)
         I=1
         DO UNTIL (I.GT.N)
            B(I,K+1)=A(I,K+1)
            J=K
            DO UNTIL (J.GT.N)
               A(I,J+1)=-B(I,K+1)*A(K+1,J+1)+A(I,J+1)
               J=J+1
            ENDDO
            I=I+1
         ENDDO
         K=K+1
      ENDDO
C
C
C  THE FOLLOWING SEQUENCE USES THE GAUSS-JORDAN PROCEEDURE TO
C  MODIFY THE ARRAY,RIGHT HAND SIDE.
C
      S7=0.0D0
      I=1
      DO UNTIL (I.GT.N)
         S7=S7+A(I,N+1)
         WRITE (9,1000) A(I,N+1),I
         I=I+1
      ENDDO
C
C
C  THE FOLLOWING SEQUENCE OF OPERATIONS CHECKS FOR CONSISTANCY
C  OF THE SOLUTION.
C
      C=0
      I=1
      DO UNTIL (I.GT.N)
         J=1
         DO UNTIL (J.GT.N)
            IF (A(I,J).NE.0)
               C=C+1
            ENDIF
            J=J+1
         ENDDO
         I=I+1
      ENDDO
C
C
C  IF C IS NOT EQUAL TO N, THERE DOESN'T EXIST A CONSISTANT SOLUTION.
C
      WRITE (9,1020) C(1),N
C
C
C
      IF (C.NE.N)
         WRITE (9,1050)
      ELSE
         C=C
      ENDIF
      CALL SUMMTO
      RETURN
```

```
C
C  FORMAT STATEMENTS
C
1000   FORMAT (1H ,D10.1I,I4)
1020   FORMAT (1H0,'C= ',I1,5X,'N=  ',I1)
1030   FORMAT (1H ,'NO SOLUTION')
       END
```

--------- END-OF-THIS-ROUTINE ----------

THERE WERE NO ERRORS IN THE ABOVE ROUTINE DETECTED BY PRE4TY

PRE4TY REV 15   AVIONICS/ST PETE TEST SOFTWARE

```
C-----------------------------------------------------------
C
C   THIS PROGRAM FINDS THE ROOTS OF A POLONOMIAL EQUATION WHOSE
C   DEGREE MAY BE SELECTED TWO AND EIGHT. IT WAS SO LIMINTEN
C   BECAUSE EIGHT COUNT DOWN FACTORS WERE TAKEN IN THE EXPERIMENTIAL
C   DATA. THE PROGRAM IS EASY TO MODIFY TO A HIGHER NUMBER OF COUNT
C   DOWN FACTORS IF DESIRED. THE PROGRAM SOLVES FOR THE REAL ROOTS OF THE
C   EQUATION. THE TECHNIQUE OF SOLUTION IS DEVIDED INTO TWO PARTS. THE FIRST
C   PART IS A SEARCHING ROUTINE WHICH EVALUATES THE POLONOMIAL AND IDENTIFIES
C   THE INTERVAL IN WHICH THE POLONOMIAL VALUE CHANGES SIZE. THIS INSURES
C   THAT THERE IS AT LEAST ONE ROOT IN THAT INTERVAL.  THE SEARCH INTERVAL
C   IS SELECTED SUFFICIENCLY SMALL SO THAT ONLY ONE ROOT IS FOUND IN THE
C   INTERVAL. HAVING FOUND THE INTERVAL WHICH CONTAINS A ROOT, THE EXACT
C   VALUE OF A ROOT TO WITHIN A SPECIFIED ACCURACY IS THEN FOUND BY A
C   NEWTON ITERATIVE ROUTINE.  THE ITERATION IS BASED ON THE CRITERIAL
C   THAT SUCCESSIVE VALUES OF THE ITERATION HAVE AN ABSOLUTE DIFFERENCE
C   OF LESS THAN THETEST VALUE.
C
C
C-----------------------------------------------------------
      SUBROUTINE SGHRT6
      COMMON N,C(8),A(8,8),F(8,8),M(8),B(8,8),T(8,8),Q,D9,V,DD,K9,RIN(4)
C
C   DECLARATIONS
C
      DOUBLE PRECISION A,F,M,K9,T1,DD,L0,H,A0,A1,A2,A3,A4,A5,A6,A7,A8
      DOUBLE PRECISION S,X,G,X1,N9,B,G1,S9,K9,D9,T,Q,V,L,D
      INTEGER C,FLAG,FLAG1
C
C   SET TEST T1, DEGREE, LAST SEARCH, FIRST SEARCH, AND STEP.
C
C   THESE INPUTS DESCRIBE THE TEST VALUE USED TO TERMINATE THE ITERATION,
C   THE DEGREE OF THE EQUATION, THE LAST VALUE WHICH TERMINATES THE SEARCHING
C   PART OF THE PROGRAM, THE FIRST SEARCH VALUE, AND THE STEP SIZE OF THE
C   SEARCHING INTERVAL.
      T1=.0001D0
      D=4.0D0
      L=2.0D0
      L0=0.0D0
      H=.1D0
C
C
C   A0 AND A1 THROUGH A8 ARE THE COEFFICIENTS OF THE POLONOMIAL.  THE
C   FOLLOWING SEQUENCE OF OPERATIONS COMPUTES THE COEFFICIENTS OF THE
C   POLONOMIAL EQUATION. COEFFICIENTS FOR DEGREES NOT BEING USED ARE
C   SET TO ZERO.
C
      A0=.5D0
      A1=A(1,N+1)
      A2=A(2,N+1)
      A3=A(3,N+1)
      A4=A(4,N+1)
      A5=A(5,N+1)
      A6=A(6,N+1)
      A7=A(7,N+1)
      A8=A(8,N+1)
C
C   PRINT A0 THROUGH A8
C
```

```
      WRITE (9,1000) A0
      WRITE (9,1010) A1,A2,A3,A4
      WRITE (9,1015) A5,A6,A7,A8
C
C
C  THE FOLLOWING SEQUENCE OF OPERATIONS FORM A SEARCH TO ISOLATE A ROOT.
C
      S=A0
      X=L0-H
      FLAG=1
      FLAG1=0
      DO UNTIL (FLAG.NE.1)
         DO UNTIL (G*S.LE.0.0D0)
            IF (FLAG1.EQ.1)
               S=G
            ENDIF
            FLAG1=1
            X=X+H
            IF (X.GT.L)
               FLAG=0
               RETURN
            ENDIF
            G=A0+A1*X+A2*X**2+A3*X**3+A4*X**4
            G=G+A5*X**5+A6*X**6+A7*X**7+A8*X**8
         ENDDO
         X1=X
C  THE FOLLOWING OUTPUT IDENTIFIES THE INTERVAL AT WHICH THE SEARCH HAS
C  INDICATED THAT THE ROOT IS CONTAINED.
         WRITE (9,1020) X-H,X
C  THE FOLLOWING SEQUENCE OF OPERATIONS FORM A NEWTON ITERATIVE ROUTINE
C  TO IMPROVE THE VALUE OF THE ROOT SUCH THAT THE ERROR IN THE ROOT
C  IS LESS THAN THE TEST VALUE (TEST T1).
         N9=0
         S=G
         DO UNTIL (DABS(B-X1).LT.T1)
            B=X1
            G=A0+A1*X1+A2*X1**2+A3*X1**3+A4*X1**4
            G=G+A5*X1**5+A6*X1**6+A7*X1**7+A8*X1**8
            G1=A1+2.0D0*A2*X1+3.0D0*A3*X1**2+4.0D0*A4*X1**3
            G1=G1+5.0D0*A5*X1**4+6.0D0*A6*X1**5
            G1=G1+7.0D0*A7*X1**6+8.0D0*A8*X1**7
            X1=X1-G/G1
            N9=N9+1
         ENDDO
C  THE FOLLOWING PRINTS THE VALUE OF THE ROOT, THE SPECIFIED ACCURACY
C  WHEREIN THE ROOT, AND FOR REFERENCE, THE TEST VALUE IS
C  AGAIN PRINTED OUT. ALSO FOR REFERENCE, THE VALUE OF THE POLONOMIAL
C  CALLED 'G' IS PRINTED OUT AS A CHECK ON THE VALUE OF THE ROOT. THE
C  VALUE OF 'G' NEAR ZERO INDICATING THE ROOT.
         WRITE (9,1030)
         WRITE (9,1040) X1,T1
         WRITE (9,1050) G
         S9=.5D0/2.D0+A1/3.D0*X1+A2/4.D0*X1**2
         S9=S9+A3/5.D0*X1**3+A4/6.D0*X1**4
         S9=S9+A5/7.D0*X1**5+A6/8.D0*X1**6
         K9=.25D0/S9
         K9=DSQRT(K9)
         WRITE (9,1060)
         D=K9/X1
C  THE FOLLOWING PRINT STATEMENT, FOR REFERENCE, REPEATES THE VALUE OF THE
C  ROOT AND PRINTS OUT AN INTERMIDIATELY VALUE 'D', WHICH  THE VALUE
C  K IS COMPUTED ACCORDING TO THE EQUATIONS WHICH INDICATE THE VALUE OF
C  THE NON-DIMENSIONAL RANDOM VARIABLE WHERE THE COMPLIMENTARY DISTRIBUTION
C  FUNCTION HAS BEEN REDUCED TO LESS THAN .1 OF A PERCENT.  THIS K VALUE
C  IS LATER USED AS ONE OF THE DISCRIMINATES FOR IDENTIFYING AN UNKNOWN
C  STUFEL TYPE.
```

```
          WRITE (6,1070) X1,KY/X1,KY
          RIN(1)=K9/10.0
          DO=...
          DY=DO
          KK=K9
          CALL SGHPE6
       ENDDO
       RETURN
 1000  FORMAT (1H ,'OUTPUT A0 AND THEN A1 THROUGH A8 IN TWO ROWS',D18.11)
 1010  FORMAT (1H ,4D18.11)
 1015  FORMAT (1H ,4D18.11)
 1020  FORMAT (1H ,'ROOT INTERVAL IS ',2D18.11)
 1030  FORMAT (1H ,'        ROOT            T1')
 1040  FORMAT (1H ,D18.11,5X,D18.11)
 1050  FORMAT (1H ,'G =  ',D18.11)
 1060  FORMAT (1H ,'   ROUT           D              K')
 1070  FORMAT (1H ,3D18.11)
       END
```

---------- END-OF-THIS-ROUTINE ----------

THERE WERE NO ERRORS IN THE ABOVE ROUTINE DETECTED BY PREATY

PREATY REV 15   AVIONICS/ST PETE TEST SOFTWARE

```
      SUBROUTINE SGHBE6
C-----------------------------------------------------------
C
C  THE FOLLOWING PROGRAM PRINTS OUT THE VALUE OF THE COMPLIMENTARY
C  DISTRIBUTION FUNCTION Q AS A FUNCTION OF THE NON-DIMENSIONAL
C  RANDOM VARABLE X.
C
C
C
C-----------------------------------------------------------
      COMMON N,C(8),A(8,8),F(8,8),M(8),B(8,8),T(8,8),Q,D9,V,D,K9,RIN(4)
C
C  DECLARATIONS
C
      DOUBLE PRECISION V,Q,A,D9,F,M,B,T,D,K9
      INTEGER C
      WRITE (9,1000)
      K=0
      DO UNTIL (K.GT.50)
         V=DFLOAT (K)/10.0D0
         CALL SGHVV6
         WRITE (9,1010) V,Q
         K=K+1
      ENDDO
C
C     OUTPUT THE MOMENTS.
C
      CALL SGHMOM
      RETURN
 1000 FORMAT (1H ,'            X                    Q')
 1010 FORMAT (1H ,2(D18.11))
      END
```

---------- END-OF-THIS-ROUTINE ----------

THERE WERE NO ERRORS IN THE ABOVE ROUTINE DETECTED BY PREATY

PREATY REV 15   AVIONICS/ST PETE TEST SOFTWARE

```
      SUBROUTINE SGHVY6
C-----------------------------------------------------------
C
C
C  IN  HIS SUBROUTINE A NUMERICAL VALUE OF Q IS COMPUTED
C  FO  A RETURN TO THE CALLING PROGRAM
C
C
C
C-----------------------------------------------------------
      COMMON N,C(8),A(8,8),F(8,8),M(8),B(8,8),T(8,8),Q,D9,V,D,K9,RIN(4)
C
C  DE  ARATIONS
C
      DOUBLE PRECISION Q,A,D9,V,F,M,B,T,D,K9
      INTEGER C
      Q=0.0D0
      I=1
      DO UNTIL (I.GT.N)
         Q=Q+A(I,N+1)/D9**I*(V**I)
         I=I+1
      ENDDO
      Q=.5D0*Q
      RETURN
      END
```

---------- END-OF-THIS-ROUTINE ----------

THERE WE NO ERRORS IN THE ABOVE ROUTINE DETECTED BY PRE4TY

PRE4TY R V 15   AVIONICS/ST PETE TEST SOFTWARE

```
C-----------------------------------------------------------------
C
C  THIS SUBROUTINE IS PART OF THE BEM DISPERSION ANALYSIS,
C  USING THE LEAST SQUARES FIT METHOD.  IT COMPUTES THE MOMENTS
C  OF Q(Z), THE COMPLEMENTRY PROBABILITY DISTRIBUTION
C  FUNCTION, AS A FUNCTION OF THE NORMALIZED DISPERSION
C  VOLTAGE FOR BEM DATA.
C
C
C  THIS PROGRAM PERFORMS LINEAR AND NONLINEAR PATTERN
C  RECOGNITION TECHNIQUES.  IT HAS BEEN CONCLUDED THAT THE
C  USE OF LINEAR DISCRIMINATES WOULD SUFFICE FOR SIGNAL
C  IDENTIFICATION.  THE DISCRIMINATE WHICH WAS SELECTED
C  WAS THE MOMENTS OF THE Q(Z) CURVES.
C
C  THE MOMENTS ARE DEFINED AS:
C  M = THE INTEGRAL OF Z*Q(Z)dZ EVELUATED FROM 0 TO INFINITY
C
C  M(K) = INTEGRAL OF ((Z-M)**K)*Q(Z)dZ FOR K=1,2,3,.....
C  EVALUATED FROM 0 TO INFINITY.
C
C  WHERE K=1,2,3,.....
C
C---------------------------------------------------------
C
C  COMMON VARIABLES
C
      SUBROUTINE SGHMOM
      COMMON N,CC(8),AA(8,8),F(8,8),M(8),BB(8,8),"(8,8),Q,D9,VV,DD,K
      COMMON RIN(4)
C
C  DECLARATIONS
C
      DOUBLE PRECISION t,u,v,w,AA,F,M,BB,T,Q,D9,VV,DD
      DOUBLE PRECISION a,b,c,d,MO,MO2,MO3,MO4,K
      INTEGER CC
C
C  COMPUTE a,b,c,d.
C
      a=AA(1,N+1)/DD
      b=AA(2,N+1)/DD**2
      c=AA(3,N+1)/DD**3
      d=AA(4,N+1)/DD**4
      WRITE (9,500) a,b,c,d,DD,K
      WRITE (9,500) K**2,K**3,K**4
500   FORMAT (1H ,6D18.11)
C
C  COMPUTE FIRST MOMENT
C
      MO=(.25D0+(a/3.D0)*K+(b/4.D0)*K**2+(c/5.D0)*K**3+
     &    (d/6.D0)*K**4)*(K**2)
C
C     PRINT FIRST MOMENT
C
      WRITE (9,1000) MO
1000  FORMAT (1H ,'MOMENT =  ',D18.11)
```

```
      C
      C     COMPUTE 2ND MOMENT
      C
            M02=((.5D0/3.D0)*K**3+(a/4.D0)*K**4+(b/5.D0)*K**5+
           &     (c/6.D0)*K**6+(d/7.D0)*K**7)-(2*M0)*(.25D0*
           &     K**2+(a/3.D0)*K**3+(b/4.D0)*K**4+(c/5.D0 *K**5+
           &     (d/6.D0)*K**6)+(M0**2)*(.5D0*K+(a/2.D0)*K**2+
           &     (b/3.D0)*K**3+(c/4.D0)*K**4+(d/5.D0)*K**5)
            RIN(2)=M02
      C
      C  PRINT 2ND MOMENT
      C
            WRITE (9,1010) M02
       1010 FORMAT (1H ,'M(2) =  ',D18.11)
      C
      C  COMPUTE 3RD MOMENT
      C
            M03=(.125D0*K**4+(a/5.D0)*K**5+(b/6.D0)*K**6+
           &     (c/7.D0)*K**7+(d/8.D0)*K**8)-(3.D0*M0)*((.5D0/
           &     3.D0)*K**3+(a/4.D0)*K**4+(b/5.D0)*K**5+(c/6.D0)*
           &     K**6+(d/7.D0)*K**7)-(M0**3)*(.5D0*K+(a/2.D0)*K**2+
           &     (b/3.D0)*K**3+(c/4.D0)*K**4+(d/5.D0)*K**5)+
           &     (3.D0*M0**2)*(.25D0*K**2+(a/3.D0)*K**3+(b/4.D0)*K**4+
           &     (c/5.D0)*K**5+(d/6.D0)*K**6)
            RIN(3)=M03
      C
      C     PRINT THIRD MOMENT.
      C
            WRITE (9,1020) M03
       1020 FORMAT (1H ,'M(3) =  ',D18.11)
      C
      C     COMPUTE 4TH MOMENT.
      C
            M04=(.1D0*K**5+(a/6.D0)*K**6+(b/7.D0)*K**7+
           &     (c/8.D0)*K**8+(d/9.D0)*K**9)-(4.D0*M0)*(.125D0*
           &     K**4+(a/5.D0)*K**5+(b/6.D0)*K**6+(c/7.D0)*K**7+
           &     (d/8.D0)*K**8)+(6.D0*M0**2)*((.5D0/3.D0)*K**3+
           &     (a/4.D0)*K**4+(b/5.D0)*K**5+(c/6.D0)*K**6+(d/7.D0)*
           &     K**7)-(4.D0*M0**3)*(.25D0*K**2+(a/3.D0)*K**3+
           &     (b/4.D0)*K**4+(c/5.D0)*K**5+(d/6.D0)*K**6)+(M0**4)*
           &     (.5D0*K+(a/2.D0)*K**2+(b/3.D0)*K**3+(c/4.D0)*K**4+
           &     (d/5.D0)*K**5)
            RIN(4)=M04
      C
      C     PRINT 4TH MOMENT.
      C
            WRITE (9,1030) M04
       1030 FORMAT (1H ,'M(4) =  ',D18.11)
            CALL SGHOIS
            RETURN
            END
   0  DIAGNOSTICS SGHMOM
```

PROGRAM COMPILED WITH FOLLOWING COMMAND LINE PARAMETERS:
SGHMOM

```
SGHMUM      GCUS6 M00400-L120-11/08/1426  FORTRAN/200 10/06 0702  1901/01/01 0752:59.3 LAF  PAGE 003

                        -COUT      >SPD>LPT00
```

```
C-----------------------------------------------------------------
C   THIS PROGRAM DISCRIMINATES BETWEEN AN UNKNOWN SIGNAL AND ONE
C   OF THE EIGHT SIGNAL TYPES STUDIED.  THIS IS DETERMINING A SET OF
C   Z VALUE FOR THE UNKNOWN SIGNAL BY MULTIPLYING THE COMPUTED K, M(2),
C   M(3), AND M(4) BY EACH SET OF LAMBDA VALUES AND DETERMINING THE
C   COMPUTATION WHICH MOST CLOSELY MATCHES ONE OF THOSE OF THE EIGHT
C   KNOWN SIGNAL TYPES.  A CONFIDENCE VALUE IS INPUT TO ESTABLISH A
C   BANDPASS FOR COMPARISON PURPOSES.  THE VALUE IS EXPRESSED AS A
C   PERCENT.  A 10% CONFIDENCE WOULD BE INPUT AS 110. .  THE DECIMAL
C   POINT IS REQUIRED.  ANY SIGNAL WHICH FALLS WITHIN THE BANDPASS
C   IS CONSIDERED TO BE A POSSIBILITY FOR A SIGNAL MATCH, AND THE
C   SIGNAL TYPE IS LISTED ON THE TERMINAL.  IN ADDITION, ONE OF THE 5
C   Z VALUES COMPUTED FOR EACH KNOWN SIGNAL MAY BE USED AS THE REFERENCE.
C   THE PROGRAM OUTPUTS A STATEMENT AS FOLLOWS:  "SELECT COLUMN FOR
C   SPECIFIC Z".  TO THIS A NUMERAL OF 1 TO 5 MAY BE ENTERED.
C-----------------------------------------------------------------
      SUBROUTINE SGHDIS
C
C   COMMON VARIABLES
C
      COMMON N,CC(8),AA(8,8)   3,8),M(8),BB(6,8),T(8,8),Q,D9,VV,DD,KK
      COMMON RIN(4)
C
C   DECLARATIONS
C
      DOUBLE PRECISION AA,F,M BB,T,Q,D9,VV,DD,KK,RIN
      INTEGER CC
      DIMENSION LAM(4,28),ZARRAY(56,5),ZT(28)
      DIMENSION DIFF(1),IN(4),ZTI(56),ZTO(56),JSAVE(56)
      REAL LAM,IN
      DIMENSION Z1(56,1),Z2(56,1),Z3(56,1),Z4(56,1),Z5(56,1)
      EQUIVALENCE (ZARRAY(1,2),Z2(1,1))
      EQUIVALENCE (ZARRAY(1,3),Z3(1,1))
      EQUIVALENCE (ZARRAY(1,4),Z4(1,1))
      EQUIVALENCE (ZARRAY(1,5),Z5(1,1))
      EQUIVALENCE (RIN,IN)
C
C   LAMBDA VALUES.
C
      DATA LAM/660.531,-12146.5,9427.67,-2013.94,
     &   635.325,-12145.6,9335.31,-1980.56,
     &   644.46,-12401.,9518.9,-2017.5,
     &   66.177,197.00,62.612,-44.199,
     &   -1.9534,-273.08,161.59,-27.165,
     &   645.93,-12437.,9544.9,-2022.9,
     &   -10.233,276.02,-190.30,37.825,
     &   -6029.4,-24669.,35255.,-10449.,
     &   -34520.,-52604.,103125.,-28577.,
     &   463.46,397.25,565.48,-810.65,
     &   -43.775,-533.71,223.74,-21.650,
     &   -18037.,-157910.,195411.,-50576.,
     &   -2041.3,16437.,-7560.0,-76.942,
     &   -5921.8,-16662.,27074.,-7637.1,
     &   497.80,491.58,618.59,-836.49,
     &   -41.528,123.20,-215.06,62.608,
     &   -2728.6,-22125.,27335.,-8081.5,
     &   -1950.6,15002.,-6411.2,-248.91,
     &   465.74,464.06,606.03,-824.39,
     &   -41.913,-416.76,150.81,-8.5482,
     &   3727.0,-8335.4,2989.6,-943.13,
     &   -1867.4,14921.,-6444.9,-230.20,
     &   -11.331,-32.387,-9.4493,6.4765,
```

```
     &    -487.32,-467.56,-607.68,825.94,
     &    -114.94,-412.85,-68.243,21.260,
     &    41.945,436.31,-164.03,11.087,
     &    -5.1395,364.29,-244.42,47.948,
     &    -1898.8,15009.,-6505.9,-223.75/
C
C  Z VALUES.
C
      DATA Z1    /-466.83,-560.67,-463.84,-571.38,
     &    -496.72,-585.46,54.591,53.539,
     &    -20.686,-21.065,-496.39,-587.35,
     &    14.832,14.678,-1413.9,-1413.9,
     &    -4537.8,-4538.9,101.44,-13.305,
     &    -54.206,-65.854,-7751.2,-7752.5,
     &    801.10,164.61,-1172.2,-1173.1,
     &    120.23,11.442,-11.160,-20.177,
     &    -1112.9,-1113.0,760.76,185.78,
     &    114.31,4.9970,-46.398,-56.699,
     &    -132.67,-133.05,747.52,169.84,
     &    -9.0116,-9.6905,-5.8967,-115.06,
     &    -127.71,-135.41,56.071,47.745,
     &    23.155,23.217,750.05,168.42/
      DATA Z2/ -453.77,-563.60,-471.21,-574.31,
     &    -483.91,-588.17,56.320,53.021,
     &    -20.968,-21.355,-485.56,-589.50,
     &    14.613,14.509,-1413.9,-1413.7,
     &    -4538.0,-4539.1,104.42,-5.7037,
     &    -51.667,- 3.236,-7752.4,-7752.6,
     &    811.41,139.62,-1172.8,-1172.9,
     &    122.85,18.894,-9.7336,-17.591,
     &    -1112.9,-1113.2,769.81,161.36,
     &    112.11,12.436,-44.343,-54.160,
     &    -132.82,-132.74,757.22,145.57,
     &    -8.8658,-8.8826,-13.339,-117.25,
     &    -125.00,-136.22,55.530,46.391,
     &    23.783,23.209,757.49,144.07/
      DATA Z3/ -463.85,-563.55,-480.88,-574.48,
     &    -493.75,-588.16,56.250,53.855,
     &    -21.074,-20.940,-495.43,-590.13,
     &    14.777,13.888,-1413.8,-1413.6,
     &    -4537.6,-4538.8,104.58,-20.501,
     &    -51.252,-64.807,-7751.7,-7752.0,
     &    811.68,140.45,-1172.4,-1172.9,
     &    123.09,4.3890,-9.0810,-19.154,
     &    -1112.9,-1113.1,770.79,162.75,
     &    117.00,-2.0495,-44.494,-55.713,
     &    -132.92,-132.91,756.95,147.05,
     &    -9.0188,-9.5110,1.1472,-117.91,
     &    -128.46,-134.84,57.083,45.624,
     &    23.734,22.501,760.06,145.54/
      DATA Z4/-459.93,-563.32,-477.14,-573.46,
     &    -489.94,-588.11,55.853,53.141,
     &    -20.955,-21.574,-491.60,-590.02,
     &    15.062,13.979,-1413.8,-1413.8,
     &    -4537.9,-4538.4,104.73,-13.508,
     &    -50.687,-66.415,-7751.4,-7751.5,
     &    811.62,163.32,-1172.4,-1172.7,
     &    122.79,11.237,-8.4156,-20.725,
     &    -1112.6,-1112.9,769.01,184.29,
     &    117.50,4.7900,-42.980,-57.235,
     &    -132.73,-132.81,758.50,168.32,
     &    -8.6297,-9.7631,-5.6914,-118.26,
     &    -126.73,-136.72,58.605,44.429,
     &    23.958,22.844,761.35,166.89/
      DATA Z5/ -461.098,-562.769,-478.275,-573.410,
     &    -491.08,-587.48,55.754,53.389,
```

```
     &    -20.971,-21.234,-492.75,-589.25,
     &    14.92,14.263,-1413.9,-1413.8,
     &    -597.9,-598.9,103.7,-13.255,
     &    -31.443,-65.078,-7751.7,-7752.2,
     &    804.44,152.06,-1172.5,-1172.9,
     &    122.24,11.49,-9.5976,-19.412,
     &    -1112.8,-1113.1,707.59,173.54,
     &    116.42,5.0435,-49.554,-55.952,
     &    -132.79,-132.87,755.04,157.09,
     &    -8.0615,-9.06185,-5.9449,-117.12,
     &    -120.98,-135.80,57.323,46.047,
     &    25.058,22.943,757.24,150.23/
      DO 40 I=1,28,1
      ZTS=0.0
      DO 50 J=1,4,1
      ZTS=ZTS+LAM(J,I)*IN(J)
C
C  OUTPUT RUNNING SUM FOR Z VALUE FOR UNKNOWN SIGNAL.
C
      WRITE(9,25) LAM(J,I),ZTS,I,J
025   FORMAT(1H ,E15.6,4X,E15.6,4X,I2,4X,I2)
050   CONTINUE
C
C  PUT Z VALUES FOR THE UNKNOWN SIGNAL IN ARRAY 'ZT'.
C
      ZT(I)=ZTS
      WRITE(9,90) I,ZT(I)
040   CONTINUE
C
C  MAKE ARRAY 'ZT' TWICE ITS SIZE IN ARRAY 'ZTI'.
C
      DO 60 I=1,28,1
      I2=2*I
      ZTI(I2)=ZT(I)
060   CONTINUE
      DO 70 I=2,56,2
      IM1=I-1
      ZTI(IM1)=ZTI(I)
070   CONTINUE
      DO 80 I=1,56,1
C
C  OUTPUT THE 'ZTI' ARRAY TO THE TERMINAL.
C
      WRITE(9,90) I,ZTI(I)
090   FORMAT(1H ,I2,4X,E15.6)
080   CONTINUE
C
C  SELECT WHICH Z IS TO BE USED FOR COMPARISON.
C
      WRITE(7,82)
082   FORMAT(1H ,'SELECT COLUMN FOR SPECIFIC Z')
      READ (7,87) LZJ
087   FORMAT(I1)
C
C  GENERATE AN ABSOLUTE DIFFERENCE.
C
      DO 100 I=1,56,1
      ZTD(I)=ABS(ZARRAY(I,LZJ)-ZTI(I))
      WRITE(9,95) I,ZTD(I),ZARRAY(I,LZJ)
095   FORMAT(1H ,I3,4X,E15.6,4X,E15.6)
100   CONTINUE
C
C  DETERMINE THE ABSOLUTE SMALLEST MINIMAL VALUE.
C
      XMIN=ZTD(1)
      DO 110 I=1,56,1
```

```
      XMINI=XMIN
      IF(ZTD(I).LT.XMIN) XMIN=ZTD(I)
C
C  CONSTRUCT A POINTER AT THE MINIMUM.
C
      IF(ZTD(I).LT.XMINI) JPOINT =I
110   CONTINUE
      WRITE(9,120) JPOINT,XMIN
120   FORMAT(1H ,'JPOINT =  ',I4,4X,'  XMIN =  ',E15.6)
C
C  INPUT THE CONFIDENCE VALUE AS A PERCENTAGE.
C
      WRITE(7,122)
122   FORMAT(1H ,'INPUT CONFIDENCE  VALUE')
      READ(7,125)PCENT
      TEST=PCENT/100.*XMIN
125   FORMAT(E15.6)
C
C  FIND THE VALUES IN THE DIFFERENCE ARRAY THAT ARE
C  LESS THAN THE CONFIDENCE VALUE.
C
      DO 130 I=1,56,1
      JSAVE(I)=0
      IF(ABS(ZTD(I)).LE.TEST)JSAVE(I)=I
130   CONTINUE
C
C  PRINT OUT THE SIGNAL TYPES THAT ARE LESS THAN
C  THE CONFIDENCE.
C
      WRITE(9,135)
135   FORMAT(1H ,//,1H ,'THE FOLLOWING COMBINATION OF SIGNALS GIVE EQUAL
     &   CONFIDENCE VALUE',/)
      DO 140 I=1,56,1
      IF(JSAVE(I).NE.0) WRITE (9,150) I
150   FORMAT(1H ,'JSAVE = ',I2)
140   CONTINUE
      DO 400 I=1,56,1
      IF(JSAVE(I).EQ.0) GO TO 400
      JJ=JSAVE(I)
      GO TO(201,202,201,203,201,204,201,205,201,206,
     &   201,207,201,208,202,203,202,204,202,205,202,206,
     &   202,207,202,208,203,204,203,205,203,206,
     &   203,207,203,208,204,205,204,206,204,207,
     &   204,208,205,206,205,207,205,208,206,
     &   207,206,208,207,208),JJ
201   WRITE(9,301)
      GO TO 400
202   WRITE(9,302)
      GO TO 400
203   WRITE(9,303)
      GO TO 400
204   WRITE(9,304)
      GO TO 400
205   WRITE(9,305)
      GO TO 400
206   WRITE(9,306)
      GO TO 400
207   WRITE(9,307)
      GO TO 400
208   WRITE(9,308)
      GO TO 400
400   CONTINUE
301   FORMAT(1H ,'GAUSSIAN NOSIE')
302   FORMAT(1H ,'SINE WAVE')
303   FORMAT(1H ,'FM MOD 100HZ TONE')
304   FORMAT(1H ,'FM MOD 5KHZ TONE')
```

```
305     FORMAT(1H ,'AM MOD 50% 1 KHZ TONE')
306     FORMAT(1H ,'AM MOD 100% 100 HZ TONE')
307     FORMAT(1H ,'FM MOD 1KHZ TONE')
308     FORMAT(1H ,'AM MOD 100% 1KHZ TONE')
        END
```

---------- END-OF-THIS-ROUTINE ----------

THERE WERE NO ERRORS IN THE ABOVE ROUTINE DETECTED BY PREATY

THERE WERE 18 LABEL NUMBERS (EXCLUDING FORMATS) IN THE ABOVE ROUTINE

PREATY REV 15 AVIONICS/ST PETE TEST SOFTWARE
ROY:

```
C
C------------------------------------------------------------
C
C  THIS PROGRAM PERFORMS A CURVE FITTING PROCEEDURE
C  USING ACCUMULATED DISPERSION DATA AND UTILIZING
C  THE COLLOCATION METHOD. THE INPUT DATA REQUIRED
C  IS AS FOLLOWS :
C
C
C     1. NUMBER OF COUNT DOWN FACTORS
C     2. THE COUNT DOWN FACTORS
C     3. THE MEASURED DISPERSIONS
C
C
C  THE OUTPUT CONSISTS OF DATA POINTS WHOSE PLOT REPRESENTS
C  THE COMPLEMENTRY DISTRIBUTION FUNCTION AGAINST A NORMALIZED
C  RANDOM VARIABLE WHOSE VARIANCE IS ONE.
C
C  THIS SUBROUTINE READS THE INPUT VALUES AND CONSTRUCTS AN ARRAY 'A'
C  COMPOSED OF THE COEFFICIENTS OF N EQUATIONS OF THE N TH ORDER.
C  IT IS THESE EQUATIONS WHICH ARE SOLVED FOR THE NORMALIZED
C  COMPLEMENTARY DISTRIBUTION BY SUBSEQUENT SUBROUTINES.
C
C
C
C  THE EQUATIONS ARE ARRIVED AT AS FOLLOWS :
C  THE PSEUDO ERROR RATE EQUATION IS DEFINED AS
C  P=Q(A*D)+Q(D), WHERE P IS FOUR TIMES THE PSEUDO ERROR RATE , OR COUNT
C  DOWN FACTOR, AND A IS A KNOWN PARAMETER WHICH IS PROVIDE BY BEN
C  MEASUREMENTS FOR EACH SELECTED P.
C
C  USING THE APPROXIMATION
C          Q(Z)=.5+a*Z+b*Z**2+c*Z**3+d*Z**4 , FOR N=4 CASE,
C  IN THE PSEUDO ERROR RATE EQUATION GIVES THE FOLLOWING :
C
C  P-1=a(A*D)+b*(A*D)**2+c*(A*D)**3+d*(A*D)**4
C
C
C  SINCE A =e/d, WHERE e=(MEASURED DISPERSION)/11.05, AND d=0.9,
C  THEN A =(MEASURED DISPERSION)/9.945.
C
C  DEFINING G=P-1, THE EQUATIONS EVALUATED AT 4 POINTS ARE
C  G1=a(A1*d)+b(A1*D)**2+c(A1*D)**3+d(A1*D)
C
C  PLUS THREE OTHER SIMILAR EQUATIONS EVALUATED AT THE OTHER SELECTED
C  POINTS, A2,A3,A4 AND G2,G3,G4.
C
C  THEN LET THE NEW UNKNOWNS t,u,v,w BE INTRODUCED BY THE RELATIONS :
C                aD=t
C                bD**2=u
C                cD**3=v
C                dD**4=w
C  THEN SUBSTITUTION INTO THE G EQUATIONS GIVES
C     G1=(A1+1)t+(A1**2+1)u+(A1**3+1)v+(A1**4+1)w
C     G2=(A2+1)t+(A2**2+1)u+(A2**3+1)v+(A2**4+1)w
C     G3=(A3+1)t+(A3**2+1)u+(A3**3+1)v+(A3**4+1)w
C     G4=(A4+1)t+(A4**2+1)u+(A4**3+1)v+(A4**4+1)w
C  WHICH ARE FOUR LINEAR EQUATIONS FOR THE FOUR UNKNOWNS T,U,V,W
C  DETERMINED BY THE KNOWN VALUES G1,G2,G3,G4,A1,A2,A3,A4
C
C
```

```
C
C----------------------------------------------------------
      PROGRAM SGHDFS
C
C  COMMON VARIABLES
C
      COMMON ?,C(8),A(8,8),F(8,8),W(8),B(8,8),I(8,8),Q,Q9,V
C
C  DECLARATIONS
C
      DOUBLE PRECISION A,F,W,B,T,U,Q9,V,E
      DIMENSION ARRAY1(3),ARRAY2(3),CDF(8),MD(8)
      INTEGER ARRAY1,ARRAY2,CDF,C
      REAL MD
C
C  ASK FOR THE NUMBER OF COUNT DOWN FACTORS.
C
      WRITE (7,1000)
C
C  INPUT THE NUMBER (N).
C
      READ (7,1010) N
      WRITE (7,1020)
C
C  INPUT THE DESIRED COUNT DOWN FACTORS INTO
C  ARRAY 'CDF'. PERFORM A DOUBLE PRECISION FLOAT OF ARRAY 'CDF'
C  INTO ARRAY 'A', COLUMN N+1.
C
      I = 1
      DO UNTIL (I .GT. N)
         READ (7,1030) CDF(I)
         A(I,N+1) = DFLOAT(CDF(I))
         I = I+1
      ENDDO
C
C  DUPLICATE ARRAY 'A' IN ARRAY 'F'.
C
      I = 1
      DO UNTIL (I .GT. N)
         F(I,N+1) = A(I,N+1)
         I = I+1
      ENDDO
C
C  REQUEST THE INPUT OF THE MEASURED DISPRESIONS.
C
      WRITE (7,1040)
C
C  INPUT THE DISPERSIONS INTO ARRAYS 'MD' AND 'W'
C
      I = 1
      DO UNTIL (I .GT. N)
         READ (7,1050) MD(I)
         W(I) = MD(I)
         I = I+1
      ENDDO
C
C
C  DEVELOP ARRAY 'A' TO CONTAIN THE COEFFICIENTS OF THE G EQUATIONS.
C  WHICH ARE ARRIVED AT AS FOLLOWS :
C  THE COEFFICIENTS OF THESE EQUATIONS ARE ARRANGED IN THIS ORDER
C  IN THE ARRAY 'A'.
C
C     (A1+1)t+(A1**2+1)u+(A1**3+1)v+(A1**4+1)w=G1
C     (A2+1)t+(A2**2+1)u+(A2**3+1)v+(A2**4+1)w=G2
C     (A3+1)t+(A3**2+1)u+(A3**3+1)v+(A3**4+1)w=G3
C     (A4+1)t+(A4**2+1)u+(A4**3+1)v+(A4**4+1)w=G4
```

```
C
C-----------------------------------------------------------
      PROGRAM SGHDFN
C
C  COMMON VARIABLES
C
      COMMON N,C(8),A(8,8),F(8,8),W(8),H(8,8),I(8,8),Q,Q9,W
C
C  DECLARATIONS
C
      DOUBLE PRECISION A,F,W,B,I,Q,Q9,V,E
      DIMENSION ARRAY1(3),ARRAY2(3),CDF(8),MD(8)
      INTEGER ARRAY1,ARRAY2,CDF,C
      REAL MD
C
C  ASK FOR THE NUMBER OF COUNT DOWN FACTORS.
C
      WRITE (7,1000)
C
C  INPUT THE NUMBER (N).
C
      READ (7,1010) N
      WRITE (7,1020)
C
C  INPUT THE DESIRED COUNT DOWN FACTORS INTO
C  ARRAY 'CDF'. PERFORM A DOUBLE PRECISION FLOAT OF ARRAY 'CDF'
C  INTO ARRAY 'A', COLUMN N+1.
C
      I = 1
      DO UNTIL (I .GT. N)
         READ (7,1030) CDF(I)
         A(I,N+1) = DFLOAT(CDF(I))
         I = I+1
      ENDDO
C
C  DUPLICATE ARRAY 'A' IN ARRAY 'F'.
C
      I = 1
      DO UNTIL (I .GT. N)
         F(I,N+1) = A(I,N+1)
         I = I+1
      ENDDO
C
C  REQUEST THE INPUT OF THE MEASURED DISPRESIONS.
C
      WRITE (7,1040)
C
C  INPUT THE DISPERSIONS INTO ARRAYS 'MD' AND 'W'
C
      I = 1
      DO UNTIL (I .GT. N)
         READ (7,1050) MD(I)
         W(I) = MD(I)
         I = I+1
      ENDDO
C
C
C  DEVELOP ARRAY 'A' TO CONTAIN THE COEFFICIENTS OF THE G EQUATIONS.
C  WHICH ARE ARRIVED AT AS FOLLOWS :
C  THE COEFFICIENTS OF THESE EQUATIONS ARE ARRANGED IN THIS ORDER
C  IN THE ARRAY 'A'.
C
C     (A1+1)t+(A1**2+1)u+(A1**3+1)v+(A1**4+1)w=G1
C     (A2+1)t+(A2**2+1)u+(A2**3+1)v+(A2**4+1)w=G2
C     (A3+1)t+(A3**2+1)u+(A3**3+1)v+(A3**4+1)w=G3
C     (A4+1)t+(A4**2+1)u+(A4**3+1)v+(A4**4+1)w=G4
```

```
      I = 1
      DO UNTIL (I .GT. N)
         A(I,N+1) = 4.0D0 / A(I,N+1) - 1.0D0
         I = I+1
      ENDDO
      J = 1
      DO UNTIL (J .GT. N)
         I = 1
         DO UNTIL (I .GT. N)
            CASEENTRY (J)
               CASE 1
                  M(I)=M(I)/9.945D0
                  A(I,J)=M(I)+1.0D0
               CASE 2
                  A(I,J)=M(I)**2+1.0D0
               CASE 3
                  A(I,J)=M(I)**3+1.0D0
               CASE 4
                  A(I,J)=M(I)**4+1.0D0
            ENDCASE
            IF (N.EQ.4)
               EXITDO
            ENDIF
            IF (J.EQ.5)
               A(I,J)=M(I)**5+1.0D0
            ENDIF
            IF (J.EQ.6)
               A(I,J)=M(I)**6+1.0D0
            ENDIF
            I = I+1
         ENDDO
         J = J+1
      ENDDO
C
C  ACQUIRE DATE AND TIME.
C
      CALL DATE(ARRAY1)
      CALL TIME(ARRAY2)
C
C  WRITE DATE AND TIME ON LINE PRINTER.
C
      WRITE (9,1060) ARRAY1,ARRAY2
C
C  WRITE THE NUMBER OF COUNT DOWN FACTORS ON THE LINE PRINTER.
C
      WRITE (9,1070) N
C
C  WRITE THE COUNT DOWN FACTORS ON THE LINE PRINTER.
C
      I = 1
      DO UNTIL (I .GT. N)
         WRITE (9,1080) CDF(I)
         I = I+1
      ENDDO
      WRITE (9,1090)
C
C  WRITE THE MEASURED DISPERSIONS ON THE LINE PRINTER.
C
      I = 1
      DO UNTIL (I .GT. N)
         WRITE (9,2000) MD(I)
         I = I+1
      ENDDO
C
C  WRITE THE 'A' ARRAY ON THE LINE PRINTER.
C
```

```
         WRITE (9,2010)
         I = 1
         DO UNTIL (I .GT. N+1)
            WRITE (9,2020)
            J = 1
            DO UNTIL (J .GT. .)
               WRITE (9,2030) A(I,J),I,J
               J = J+1
            ENDDO
            I = I+1
         ENDDO
C
C  CALL NEXT SUBROUTINE
C
1000   FORMAT (1H ,'INPUT N= NUMBER OF COUNT DOWN FACTORS')
1010   FORMAT (I1)
1020   FORMAT (1H ,'INPUT COLUMN OF COUNT DOWN FACTORS')
1030   FORMAT (I4)
1040   FORMAT (1H ,'INPUT COLUMN OF MEASURED DISPERSIONS')
1050   FORMAT (F5.3)
1060   FORMAT (1H1,'THE DATE IS ',I2,':', I2,':',I4,4X,I2,':',I2,':',I2,9X
     &    'COLLOCATION ANALYSIS TECHNIQUE')
1070   FORMAT (1H ,'N= NO. OF COUNT DOWN FACTORS IS  ',I1,///,'THE COUNT
     &    DOWN FACTORS ARE    ')
1080   FORMAT (1H+,I4,3X)
1090   FORMAT (1H ,/,'THE MEASURED DISPERSIONS ARE ')
2000   FORMAT (1H ,F5.3)
2010   FORMAT (1H ,'OUTPUT A(I,J) BY COLUMNS AND I,J')
2020   FORMAT (1H )
2030   FORMAT (1H ,E18.10,5X,I1,5X,I1)
       END
```

---------- END-OF-THIS-ROUTINE ----------

THERE WERE NO ERRORS IN THE ABOVE ROUTINE DETECTED BY PRE4TY

PRE4TY REV 15   AVIONICS/ST PETE   TEST SOFTWARE

```
      SUBROUTINE SGHSV6
C-----------------------------------------------------------------
C
C  PROGRAM DESCRIPTION
C
C     THIS SUBROUTINE SOLVES THE N EQUATIONS IN N UNKNOWNS
C     WHICH IS REPRESENTED BY THE 'A' ARRAY.  THE METHOD
C     USED IS THE GAUSS-JORDAN ELIMINATION.
C
C     GIVEN A SYSTEM OF N LINEAR EQUATIONS IN N UNKNOWNS,
C     OF THE FORM :
C
C         A(1,1)X(1)+A(1,2)X(2)+....+A(1,N)X(N) = C(1)
C         A(2,1)X(1)+A(2,2)X(2)+....+A(2,N)X(N) = C(2)
C         ..........................................
C         A(N,1)X(1)+A(N,2)X(2)+....+A(N,N)X(N) = C(N)
C
C
C
C    DEVIDE THE 1ST EQUATION BY A(1,1). THEN SUBTRACT
C    A(2,1) TIMES THIS FIRST RESULT FROM THE 2ND EQUATION,
C    A(3,1) TIMES THE INITIAL RESULT FROM THE THIRD, ETC. ,
C    UNTIL WE HAVE N-1 EQUATIONS IN THE N-1 VARIABLES X(2),
C    X(3),....,X(N). USING THESE N-1 EQUATIONS, ELIMINATE
C    X(2) IN THE SAME WAY, LEAVING N-2 EQUATIONS IN X(3),
C    X(4),....,X(N). REPEATING THIS PROCESS A TOTAL OF N-1
C    TIMES, WE FINALLY COME DOWN TO ONE EQUATION IN THE
C    VARIABLE X(N). THE RESULTANT SYSTEM OF EQUATIONS IS
C    OF THE FORM :
C
C    X(1)+A'(1,2)X(2)+A'(1,3)X(3)+....+A'(1,N)X(N)    = C'(1)
C                X(2)+A'(2,3)X(3)+....+A'(2,N)X(N)    = C'(2)
C                .........................................
C                               X(N-1)+A'(N-1,N)X(N)  = C'(N-1)
C                                               X(N)  = C'(N)
C
C    USE THE LAST EQUATION TO ELIMINATE X(N) IN THE TOP
C    N-1 EQUATIONS AND THEN USE X(N-1) IN THE NEXT TO LAST
C    EQUATION TO ELIMAINATE ALL THE X(N-1)'S, ECT. , WE WILL
C    COME TO A DIAGONAL SYSTEM OF EQUATIONS WITH THE
C    SOLUTION EXPLICITLY GIVEN.
C
C    A RENUMBERING OF EQUATIONS WILL BE NECESSARY IF, AT ANY
C    STAGE, THE COEFFICIENT OF X(K) IN THE K'TH EQUATION
C    IS ZERO.
C
C
C-----------------------------------------------------------------------------
C
C  COMMON VARIABLES
C
      COMMON N,C(8),A(8,8),F(8,8),M(8),P(8,8),T(8,8),Q,D9,L,DD,K9,RIN(4)
C
C  DECLARATIONS
C
      DOUBLE PRECISION A,F,W,D,R,T,S7,Q,C9,V
```

```
      INTEGER C
C
C
C
C
C     COPY ARRAY 'A' INTO ARRAY 'B'.
C     THE ARRAY 'A' CONTAINS THE COEFFICIENTS OF THE SIMULTANEOUS
C     EQUATIONS TO BE SOLVED.  ARRAY 'B' IS TO BE USED FOR MANIPULATION
C     BY THE GAUSS-JORDAN METHOD.  THIS TECHNIQUE REDUCES THE SQUARE
C     COEFFICIENT MATRIX
C     TO A DIAGONAL FROM WHICH THE SOLUTIONS ARE GIVEN BY THE ELEMENTS
C     OF THE RIGHT HAND SIDE.
C
      J=1
C     DO UNTIL (J.GT.N+1)
          GO TO 9001
 9002     CONTINUE
       IF(J.GT.N+1)GOTO 9003
 9001     CONTINUE
          I=1
C         DO UNTIL (I.GT.N)
              GO TO 9004
 9005         CONTINUE
           IF(I.GT.N)GOTO 9006
 9004         CONTINUE
              B(I,J)=A(I,J)
              I=I+1
            GO TO 9005
C         ENDDO
 9006       CONTINUE
          J=J+1
            GO TO 9002
C     ENDDO
 9003       CONTINUE
C
C     SOLVE THE N SIMULTANEOUS G EQUATIONS.
C
C     THESE WILL BE SOLVED BY SELECTING PIVITS FOR PERFORMING THE
C     GAUSS REDUCTION AND CHECKS TO SEE IF POTENTIAL PIVIT IS ZERO.
C     IF IT IS, THE ROWS ARE INTERCHANGED SUCH THAT THE PIVIT IS
C     NON-ZERO.
      K=1
C     DO UNTIL (K.GT.N)
          GO TO 9007
 9008     CONTINUE
       IF(K.GT.N)GOTO 9009
 9007     CONTINUE
*         IF (A(K,K).EQ.0)
           IF(A(K,K).EQ.0)GOTO 9011
             GO TO 9010
 9011        CONTINUE
             L=1
C            DO WHILE (A(K+L,K).EQ.0)
 9012           CONTINUE
              IF(A(K+L,K).EQ.0)GOTO 9013
                GO TO 9014
```

```
9013          CONTINUE
*             IF (K+L.EQ.N)
               IF(K+L.EQ.N)GOTO 9016
                 GO TO 9015
9016             CONTINUE
*                EXITDO
                     GO TO 9014
                 GO TO 9017
C             ELSE
9015             CONTINUE
                 L=L+1
9017             CONTINUE
C             ENDIF
          GO TO 9012
C          ENDDO
9014      CONTINUE
           J1=1
C          DO UNTIL (J1.GT.N+1)
              GO TO 9018
9019          CONTINUE
            IF(J1.GT.N+1)GOTO 9020
9018          CONTINUE
              T(K,J1)=A(K,J1)
              A(K,J1)=A(K+L,J1)
              A(K+L,J1)=T(K,J1)
              J1=J1+1
          GO TO 9019
C          ENDDO
9020      CONTINUE
9010       CONTINUE
C       ENDIF
        B(K,K)=A(K,K)
C
C  DIVIDE THE COEFFICIENTS OF THE EQUATIONS BY THE
C  (K,K)TH COEFFICIENT SO THAT THE (K,K)TH COEFFICIENT IS 1.
C
        J=K
C       DO UNTIL (J.GT.N+1)
           GO TO 9021
9022       CONTINUE
         IF(J.GT.N+1)GOTO 9023
9021       CONTINUE
           A(K,J)=A(K,J)/B(K,K)
           J=J+1
          GO TO 9022
C       ENDDO
9023      CONTINUE
C
C
C
        I=K
C       DO UNTIL (I.GT.N)
           GO TO 9024
9025       CONTINUE
         IF(I.GT.N)GOTO 9026
9024       CONTINUE
```

```
              B(I+1,K)=A(I+1,K)
              J=K
C             DO UNTIL (J.GT.N+1)
                 GO TO 9027
      9028       CONTINUE
               IF(J.GT.N+1)GOTO 9029
      9027       CONTINUE
                 A(I+1,J)=-B(I+1,K)*A(K,J)+A(I+1,J)
                 J=J+1
             GO TO 9028
C             ENDDO
      9029     CONTINUE
              I=I+1
             GO TO 9025
C           ENDDO
      9026     CONTINUE
           K=K+1
             GO TO 9008
C       ENDDO
      9009     CONTINUE
C
C
C
        K=1
C       DO UNTIL (K.GT.N-1)
           GO TO 9030
      9031 CONTINUE
         IF(K.GT.N-1)GOTO 9032
      9030 CONTINUE
           I=1
C          DO UNTIL (I.GT.K)
              GO TO 9033
      9034    CONTINUE
            IF(I.GT.K)GOTO 9035
      9033    CONTINUE
              B(I,K+1)=A(I,K+1)
              J=K
C             DO UNTIL (J.GT.N)
                 GO TO 9036
      9037     . CONTINUE
               IF(J.GT.N)GOTO 9038
      9036       CONTINUE
                 A(I,J+1)=-B(I,K+1)*A(K+1,J+1)+A(I,J+1)
                 J=J+1
             GO TO 9037
C             ENDDO
      9038     CONTINUE
              I=I+1
             GO TO 9034
C           ENDDO
      9035     CONTINUE
           K=K+1
             GO TO 9031
C       ENDDO
      9032     CONTINUE
C
```

```
C
C  THE FOLLOWING SEQUENCE USES THE GAUSS-JORDAN PROCEEDURE TO
C  MODIFY THE ARRAY,RIGHT HAND SIDE.
C
         S7=0.0D0
         I=1
C        DO UNTIL (I.GT.N)
            GO TO 9039
 9040       CONTINUE
          IF(I.GT.N)GOTO 9041
 9039       CONTINUE
            S7=S7+A(I,N+1)
            WRITE (9,1000) A(I,N+1),I
            I=I+1
              GO TO 9040
C        ENDDO
 9041         CONTINUE
C
C
C  THE FOLLOWING SEQUENCE OF OPERATIONS CHECKS FOR CONSISTANCY
C  OF THE SOLUTION.
C
         C=0
         I=1
C        DO UNTIL (I.GT.N)
            GO TO 9042
 9043       CONTINUE
          IF(I.GT.N)GOTO 9044
 9042       CONTINUE
            J=1
C           DO UNTIL (J.GT.N)
               GO TO 9045
 9046          CONTINUE
             IF(J.GT.N)GOTO 9047
 9045          CONTINUE
*              IF (A(I,J).NE.0)
                IF(A(I,J).NE.0)GOTO 9049
                  GO TO 9048
 9049             CONTINUE
                  C=C+1
 9048             CONTINUE
C              ENDIF
               J=J+1
              GO TO 9046
C           ENDDO
 9047         CONTINUE
            I=I+1
              GO TO 9043
C        ENDDO
 9044         CONTINUE
C
C
C  IF C IS NOT EQUAL TO N, THERE DOESN'T EXIST A CONSISTANT SOLUTION.
C
         WRITE (9,1020) C(1),N
C
```

```
C
C
*       IF (C.NE.N)
         IF(C.NE.N)GOTO 9051
           GO TO 9050
  9051     CONTINUE
           WRITE (9,1030)
           GO TO 9052
C       ELSE
  9050     CONTINUE
           C=C
  9052     CONTINUE
C       ENDIF
            CALL SGHRT6
        RETURN
C
C  FORMAT STATEMENTS
C
1000    FORMAT (1H ,D18.11,I4)
1020    FORMAT (1H0,'C=  ',I1,5X,'N=  ',I1)
1030    FORMAT (1H ,'NO SOLUTION')
        END
   0  DIAGNOSTICS SGHSV6
```

PROGRAM COMPILED WITH FOLLOWING COMMAND LINE PARAMETERS:

```
                                SGHSV6
                                -COUT     >SPD>LPT00
```

```
C------------------------------------------------------------
C
C  THIS PROGRAM FINDS THE ROOTS OF A POLONOMIAL EQUATION WHOSE
C  DEGREE MAY BE SELECTED TWO AND EIGHT. IT WAS SO LIMINTEN
C  BECAUSE EIGHT COUNT DOWN FACTORS WERE TAKEN IN THE EXPERIMENTIAL
C  DATA. THE PROGRAM IS EASY TO MODIFIY TO A HIGHER NUMBER OF COUNT
C  DOWN FACTORS IF DESIRED. THE PROGRAM SOLVES FOR THE REAL ROOTS OF THE
C  EQUATION. THE TECHNIQUE OF SOLUTION IS DEVIDED INTO TWO PARTS. THE FIRST
C  PART IS A SEARCHING ROUTINE WHICH EVALUATES THE POLONOMIAL AND IDENTIFIES
C  THE INTERVAL IN WHICH THE POLONOMIAL VALUE CHANGES SIZE. THIS INSURES
C  THAT THERE IS AT LEAST ONE ROOT IN THAT INTERVAL.  THE SEARCH INTERVAL
C  IS SELECTED SUFFICIENCLY SMALL SO THAT ONLY ONE ROOT IS FOUND IN THE
C  INTERVAL. HAVING FOUND THE INTERVAL WHICH CONTAINS A ROOT, THE EXACT
C  VALUE OF A ROOT TO WITHIN A SPECIFIED ACCURACY IS THEN FOUND BY A
C  NEWTON ITERATIVE ROUTINE.  THE ITERATION IS BASED ON THE CRITERIAL
C  THAT SUCCESSIVE VALUES OF THE ITERATION HAVE AN ABSOLUTE DIFFERENCE
C  OF LESS THAN THETEST VALUE.
C
C
C------------------------------------------------------------
      SUBROUTINE SGHR16
      COMMON N,C(8),A(8,8),F(8,8),M(8),B(8,8),T(8,8),Q,D9,V,DD,K9,RIN(4)
C
C  DECLARATIONS
C
      DOUBLE PRECISION A,F,M,K9,T1,DD,L0,H,A0,A1,A2,A3,A4,A5,A6,A7,A8
      DOUBLE PRECISION S,X,G,X1,N9,B,G1,S9,K9,D9,T,Q,V,L,D
      INTEGER C,FLAG,FLAG1
C
C  SET TEST T1, DEGREE, LAST SEARCH, FIRST SEARCH, AND STEP.
C
C  THESE INPUTS DESCRIBE THE TEST VALUE USED TO TERMINATE THE ITERATION,
C  THE DEGREE OF THE EQUATION, THE LAST VALUE WHICH TERMINATES THE SEARCHING
C  PART OF THE PROGRAM, THE FIRST SEARCH VALUE, AND THE STEP SIZE OF THE
C  SEARCHING INTERVAL.
      T1=.000100
      D=4.000
      L=2.000
      L0=0.000
      H=.100
C
C
C  A0 AND A1 THROUGH A8 ARE THE COEFFICIENTS OF THE POLONOMIAL.  THE
C  FOLLOWING SEQUENCE OF OPERATIONS COMPUTES THE COEFFICIERTS OF THE
C  POLONOMIAL EQUATION. COEFFICIENTS FOR DEGREES NOT BEING USED ARE
C  SET TO ZERO.
C
      A0=.500
      A1=A(1,N+1)
      A2=A(2,N+1)
      A3=A(3,N+1)
      A4=A(4,N+1)
      A5=A(5,N+1)
      A6=A(6,N+1)
      A7=A(7,N+1)
      A8=A(8,N+1)
```

```
C
C   PRINT A0 THROUGH A8
C
        WRITE (9,1000) A0
        WRITE (9,1010) A1,A2,A3,A4
        WRITE (9,1015) A5,A6,A7,A8
C
C
C   THE FOLLOWING SEQUENCE OF OPERATIONS FORM A SEARCH TO ISOLATE A ROOT.
C
        S=A0
        X=LO-H
        FLAG=1
        FLAG1=0
C       DO UNTIL (FLAG.NE.1)
          GO TO 9001
  9002    CONTINUE
        IF(FLAG.NE.1)GOTO 9003
  9001    CONTINUE
C         DO UNTIL (G*S.LE.0.0D0)
            GO TO 9004
  9005      CONTINUE
          IF(G*S.LE.0.0D0)GOTO 9006
  9004      CONTINUE
*           IF (FLAG1.EQ.1)
             IF(FLAG1.EQ.1)GOTO 9008
              GO TO 9007
  9008        CONTINUE
              S=G
  9007        CONTINUE
C           ENDIF
            FLAG1=1
            X=X+H
*           IF (X.GT.L)
             IF(X.GT.L)GOTO 9010
              GO TO 9009
  9010        CONTINUE
              FLAG=0
              RETURN
  9009      . CONTINUE
C           ENDIF
            G=A0+A1*X+A2*X**2+A3*X**3+A4*X**4
            G=G+A5*X**5+A6*X**6+A7*X**7+A8*X**8
          GO TO 9005
C         ENDDO
  9006    CONTINUE
          X1=X
C   THE FOLLOWING OUTPUT IDENTIFIES THE INTERVAL AT WHICH THE SEARCH HAS
C   INDICATED THAT THE ROOT IS CONTAINED.
          WRITE (9,1020) X-H,X
C   THE FOLLOWING SEQUENCE OF OPERATIONS FORM A NEWTON ITERATIVE ROUTINE
C   TO IMPROVE THE VALUE OF THE ROOT SUCH THAT THE ERROR IN THE ROOT
C   IS LESS THAN THE TEST VALUE (TEST T1).
          N9=0
          S=G
C         DO UNTIL (DABS(G-X1).LT.T1)
```

```
SGHRI6      GCUSo 400400-L126-11/08/1426  FORTRAN/200 10/06/0702  1901/01/01 0756:50.9 LAF  PAGE 003

                GO TO 9011
      9012      CONTINUE
               IF(DABS(B-X1).LT.T1)GOTO 9013
      9011      CONTINUE
              B=X1
                G=A0+A1*X1+A2*X1**2+A3*X1**3+A4*X1**4
                G=G+A5*X1**5+A6*X1**6+A7*X1**7+A8*X1**8
                G1=A1+2.0D0*A2*X1+3.0D0*A3*X1**2+4.0D0*A4*X1**3
                G1=G1+5.0D0*A5*X1**4+6.0D0*A6*X1**5
                G1=G1+7.0D0*A7*X1**6+8.0D0*A8*X1**7
                X1=X1-G/G1
                N9=N9+1
               GO TO 9012
C             ENDDO
      9013       CONTINUE
C  THE FOLLOWING PRINTS THE VALUE OF THE ROOT, THE SPECIFIED ACCURACY
C  WHEREIN THE ROOT, AND FOR REFERENCE, THE TEST VALUE IS
C  AGAIN PRINTED OUT. ALSO FOR REFERENCE, THE VALUE OF THE POLONOMIAL
C  CALLED 'G' IS PRINTED OUT AS A CHECK ON THE VALUE OF THE ROOT. THE
C  VALUE OF 'G' NEAR ZERO INDICATING THE ROOT.
              WRITE (9,1030)
              WRITE (9,1040) X1,T1
              WRITE (9,1050) G
              S9=.5D0/2.D0+A1/3.D0*X1+A2/4.D0*X1**2
              S9=S9+A3/5.D0*X1**3+A4/6.D0*X1**4
              S9=S9+A5/7.D0*X1**5+A6/8.D0*X1**6
              K9=.25D0/S9
              K9=DSQRT(K9)
              WRITE (9,1060)
              D=K9/X1
C  THE FOLLOWING PRINT STATEMENT, FOR REFERENCE, REPEATES THE VALUE OF THE
C  ROOT AND PRINTS OUT AN INTERMIDIATELY VALUE 'D', WHICH  THE VALUE
C  K IS COMPUTED ACCORDING TO THE EQUATIONS WHICH INDICATE THE VALUE OF
C  THE NON-DIMENSIONAL RANDOM VARIABLE WHERE THE COMPLIMENTARY DISTRIBUTION
C  FUNCTION HAS BEEN REDUCED TO LESS THAN .1 OF A PERCENT.  THIS K VALUE
C  IS LATER USED AS ONE OF THE DISCRIMINATES FOR IDENTIFYING AN UNKNOWD
C  SIGNAL TYPE.
              WRITE (9,1070) X1,K9/X1,K9
            RIN(I)=K9/10.0
              DD=K9/X1
              D9=DD
              KK=K9
             CALL SGHBE6
                GO TO 9002
C          ENDDO
      9003        CONTINUE
           RETURN
      1000 FORMAT (1H ,'OUTPUT A0 AND THEN A1 THROUGH A8 IN TWO ROWS',D18.11)
      1010 FORMAT (1H ,4D18.11)
      1015 FORMAT (1H ,4D18.11)
      1020 FORMAT (1H ,'ROOT INTERVAL IS ',2D18.11)
      1030 FORMAT (1H ,'        ROOT               T1')
      1040 FORMAT (1H ,D18.11,5X,D18.11)
      1050 FORMAT (1H ,'G =  ',D18.11)
      1060 FORMAT (1H ,'    ROOT            D              K')
      1070 FORMAT (1H ,3D18.11)
```

```
SGHRT6      SC S- 03400-L120-11/06/1426  FORTRAN/200 10/05/0702  1901/01/01 0756:50.9 LAF  PAGE 004

  169          END
     0  DIAG OSTICS SGHRT6

  PROGRAM COMPILED WITH FOLLOWING COMMAND LINE PARAMETERS:
                                  SGFRT6
                                  -COUT      >SPD>LPT00
```

```
      SUBROUTINE SGHBE6
C-------------------------------------------------------
C
C  THE FOLLOWING PROGRAM PRINTS OUT THE VALUE OF THE COMPLIMENTARY
C  DISTRIBUTION FUNCTION Q AS A FUNCTION OF THE NON-DIMENSIONAL
C  RANDOM VARABLE X.
C
C
C
C-------------------------------------------------------
      COMMON N,C(8),A(8,8),F(8,8),M(8),B(8,8),T(8,8),Q,D9,V,D,K9,RIN(4)
C
C  DECLARATIONS
C
      DOUBLE PRECISION V,Q,A,D9,F,M,B,T,D,K9
      INTEGER C
      WRITE (9,1000)
      K=0
C     DO UNTIL (K.GT.50)
         GO TO 9001
 9002    CONTINUE
       IF(K.GT.50)GOTO 9003
 9001    CONTINUE
         V=DFLOAT (K)/10.0D0
         CALL SGHVY6
         WRITE (9,1010) V,Q
         K=K+1
           GO TO 9002
C     ENDDO
 9003      CONTINUE
C
C     OUTPUT THE MOMENTS.
C
      CALL SGHMOM
      RETURN
1000  FORMAT (1H ,'        X                    Q')
1010  FORMAT (1H ,2(F18.11))
      END
  0  DIAGNOSTICS SGHBE6

PROGRAM COMPILED WITH FOLLOWING COMMAND LINE PARAMETERS:
                                SGHBE6
                                -CONT      >SPD>LPT00
```

```
      SUBROUTINE SGHVY6
C-----------------------------------------------------------
C
C
C  IN THIS SUBROUTINE A NUMERICAL VALUE OF Q IS COMPUTED
C  FOR A RETURN TO THE CALLING PROGRAM
C
C
C
C-----------------------------------------------------------
      COMMON N,C(8),A(8,8),F(8,9),M(8),B(8,8),T(8,8),Q,D9,V,O,K9,RIN(4)
C
C  DECLARATIONS
C
      DOUBLE PRECISION Q,A,D9,V,F,M,B,T,D,K9
      INTEGER C
      Q=0.0D0
      I=1
C     DO UNTIL (I.GT.N)
        GO TO 9001
 9002   CONTINUE
       IF(I.GT.N)GOTO 9003
 9001   CONTINUE
        Q=Q+A(I,N+1)/D9**I*(V**I)
        I=I+1
          GO TO 9002
C     ENDDO
 9003     CONTINUE
      Q=.5D0*Q
      RETURN
      END
  0  DIAGNOSTICS SGHVY6

PROGRAM COMPILED WITH FOLLOWING COMMAND LINE PARAMETERS:
                                  SGHVY6
                                  -COUT     >SPD>LPT00
```

```
C-----------------------------------------------------------------
C
C  THIS SUBROUTINE IS PART OF THE BEM DISPERSION ANALYSIS,
C  USING THE LEAST SQUARES FIT METHOD.  IT COMPUTES THE MOMENTS
C  OF Q(Z), THE COMPLEMENTARY PROBABILITY DISTRIBUTION
C  FUNCTION, AS A FUNCTION OF THE NORMALIZED DISPERSION
C  VOLTAGE FOR BEM DATA.
C
C
C  THIS PROGRAM PERFORMS LINEAR AND NONLINEAR PATTERN
C  RECOGNITION TECHNIQUES.  IT HAS BEEN CONCLUDED THAT THE
C  USE OF LINEAR DISCRIMINATES WOULD SUFFICE FOR SIGNAL
C  IDENTIFICATION.  THE DISCRIMINATE WHICH WAS SELECTED
C  WAS THE MOMENTS OF THE Q(Z) CURVES.'
C
C  THE MOMENTS ARE DEFINED AS:
C  M = THE INTEGRAL OF Z*Q(Z)dz EVELUATED FROM 0 TO INFINITY
C
C  M(K) = INTEGRAL OF ((Z-M)**K)*Q(Z)dz FOR K=1,2,3,.....
C  EVALUATED FROM 0 TO INFINITY.
C
C  WHERE K=1,2,3,.....
C
C-------------------------------------------------------
C
C  COMMON VARIABLES
C
      SUBROUTINE SGHMOM
      COMMON N,CC(8),AA(8,8),F(8,8),M(8),BB(8,8),T(8,8),Q,D9,VV,DD,K
      COMMON RIN(4)
C
C  DECLARATIONS
C
      DOUBLE PRECISION t,u,v,w,AA,F,M,BB,T,Q,D9,VV,DD
      DOUBLE PRECISION a,b,c,d,MO,MO2,MO3,MO4,K
      INTEGER CC
C
C  COMPUTE a,b,c,d.
C
      a=AA(1,N+1)/DD
      b=AA(2,N+1)/DD**2
      c=AA(3,N+1)/DD**3
      d=AA(4,N+1)/DD**4
      WRITE (9,500) a,b,c,d,DD,K
      WRITE (9,500) K**2,K**3,K**4
500   FORMAT (1H ,6D18.11)
C
C  COMPUTE FIRST MOMENT
C
      MO=(.25D0+(a/3.D0)*K+(b/4.D0)*K**2+(c/5.D0)*K**3+
     &    (d/6.D0)*K**4)*(K**2)
C
C     PRINT FIRST MOMENT
C
      WRITE (9,1000) MO
1000  FORMAT (1H ,'MOMENT =  ',D18.11)
C
C     COMPUTE 2ND MOMENT
C
```

```
      =((.5D0/3.D0)*K**3+(a/4.D0)*K**4+(b/5.D0)*K**5+
     &  (c/6.D0)*K**6+(d/7.D0)*K**7)-(2*MC)*(.25D0*
     &  [illegible]
     &  (c/6.D0)*K**6)+(MO**2)*(.5D0*K+(a/2.D0)*K**2+
     &  (b/3.D0)*K**3+(c/4.D0)*K**4+(d/5.D0)*K**5)
      RT (2)=MO2
C
C  PRINT 2ND MOMENT
C
      WRITE (9,1010) MO2
 1010 FORMAT (1H ,'M(2) =  ',D18.11)
C
C  COMPUTE 3RD MOMENT
C
      MO3=(.125D0*K**4+(a/5.D0)*K**5+(b/6.D0)*K**6+
     &  (c/7.D0)*K**7+(d/8.D0)*K**8)-(3.D0*MO)*((.5D0/
     &  3.D0)*K**3+(a/4.D0)*K**4+(b/5.D0)*K**5+(c/6.D0)*
     &  K**6+(d/7.D0)*K**7)-(MO**3)*(.5D0*K+(a/2.D0)*K**2+
     &  (b/3.D0)*K**3+(c/4.D0)*K**4+(d/5.D0)*K**5)+
     &  (3.D0*MO**2)*(.25D0*K**2+(a/3.D0)*K**3+(b/4.D0)*K**4+
     &  (c/5.D0)*K**5+(d/6.D0)*K**6)
      RIN(3)=MO3
C
C     PRINT THIRD MOMENT.
C
      WRITE (9,1020) MO3
 1020 FORMAT (1H ,'M(3) = ',D18.11)
C
C     COMPUTE 4TH MOMENT.
C
      MO4=(.1D0*K**5+(a/6.[illegible])*K**6+(b/7.[illegible])*K**7+
     &  (c/8.D0)*K**8+(d/[illegible]D0)*K**9)-[illegible]D0*MO[illegible].125D0*
     &  K**4+(a/5.D0)[illegible](b/6.D0)*K**6+[illegible]/7.[illegible])*K**7
     &  (d/8.D0)[illegible](6.D0*MO**2)*((.5D0/3[illegible])*K**3+
     &  (a/4.D0)*K[illegible](b/5.D0)*K**5[illegible](c/6.D0)[illegible]
     &  K**2)-[illegible]D0*MO**3)*(.25D0*[illegible]2+(a[illegible]D0)*K**3+
     &  (b/4.D0)*K**4[illegible]/5.D0)*K**5[illegible]/6.[illegible])*K**6[illegible](MO**4)*
     &  (.5D0*K[illegible](a/2.[illegible])*K**2+(b/3.D0)*K**3[illegible]D0)*K**4+
     &  (d/5.D0)*K**5)
      RIN(4)=MO4
C
C     PRINT 4TH MOMENT.
C
      WRITE (9,1030) MO4
 1030 FORMAT (1H ,'M(4) =  ',D18.11)
      CALL SGNDTS
      RETURN
      END
---------- END-OF-THIS-ROUTINE -----------
```

THERE WERE NO ERRORS IN THE ABOVE ROUTINE DETECTED BY PREATY

PREATY [illegible] 15   AVIS ICS/SI PEIE   TEST SOFTWARE

```
C-----------------------------------------------------------------
C  THIS PROGRAM DISCRIMINATES BETWEEN AN UNKNOWN SIGNAL AND ONE
C  OF THE EIGHT SIGNAL TYPES STUDIED.  THIS IS DETERMINING A SET OF
C  Z VALUE FOR THE UNKNOWN SIGNAL BY MULTIPLYING THE COMPUTED K, M(2),
C  M(3), AND M(4) BY EACH SET OF LAMBDA VALUES AND DETERMINING THE
C  COMPUTATION WHICH MOST CLOSELY MATCHES ONE OF THOSE OF THE EIGHT
C  KNOWN SIGNAL TYPES.  A CONFIDENCE VALUE IS INPUT TO ESTABLISH A
C  BANDPASS FOR COMPARISON PURPOSES.  THE VALUE IS EXPRESSED AS A
C  PERCENT.  A 10% COFIDENCE WOULD BE INPUT AS 110. .  THE DECIMAL
C  POINT IS REQUIRED.  ANY SIGNAL WHICH FALLS WITHIN THE BANDPASS
C  IS CONSIDERED TO BE A POSSIBILITY FOR A SIGNAL MATCH, AND THE
C  SIGNAL TYPE IS LISTED ON THE TERMINAL.  IN ADDITION, ONE OF THE 5
C  Z VALUES COMPUTED FOR EACH KNOWN SIGNAL MAY BE USED AS THE REFERENCE.
C  THE PROGRAM OUTPUTS A STATEMENT AS FOLLOWS:  "SELECT COLUMN FOR
C  SPECIFIC Z".  TO THIS A NUMERAL OF 1 TO 5 MAY BE ENTERED.
C-----------------------------------------------------------------
      SUBROUTINE SGHDIS
C
C  COMMON VARIABLES
C
      COMMON N,CC(8),AA(8,8),F(8,8),M(8),BB(8,8),T(8,8),Q,D9,VV,DD,KK
      COMMON RIN(4)
C
C  DECLARATIONS
C
      DOUBLE PRECISION AA,F,M,BB,T,Q,D9,VV,DD,KK,RIN
      INTEGER CC
      DIMENSION LAM(4,28),ZARRAY(56,5),ZT(28)
      DIMENSION DIFF(1),IN(4),ZTI(56),ZTD(56),JSAVE(56)
      REAL LAM,IN
      DIMENSION Z1(56,1),Z2(56,1),Z3(56,1),Z4(56,1),Z5(56,1)
      EQUIVALENCE (ZARRAY(1,2),Z2(1,1))
      EQUIVALENCE (ZARRAY(1,3),Z3(1,1))
      EQUIVALENCE (ZARRAY(1,4),Z4(1,1))
      EQUIVALENCE (ZARRAY(1,5),Z5(1,1))
      EQUIVALENCE (RIN,IN)
C
C  LAMBDA VALUES.
C
      DATA LAM/660.531,-12146.5,9427.67,-2013.94,
     &    635.325,-12145.6,9335.31,-1980.56,
     &    644.46,-12401.,9518.9,-2017.5,
     &    68.177,197.00,62.612,-44.199,
     &    -1.9534,-273.08,161.59,-27.165,
     &    645.93,-12437.,9544.9,-2022.9,
     &    -10.233,276.02,-190.30,37.825,
     &    -6029.4,-24669.,35255.,-10449.,
     &    -34570.,-52604.,103125.,-28577.,
     &    463.46,397.25,585.48,-810.65,
     &    -43.775,-533.71,223.74,-21.650,
     &    -18037.,-157910.,195411.,-58576.,
     &    -2041.3,16437.,-7560.0,-76.942,
     &    -6921.8,-16662.,27074.,-7637.1,
     &    497.80,491.58,618.59,-836.49,
     &    -41.528,123.20,-215.08,62.608,
     &    -2728.6,-22125.,27335.,-8081.5,
     &    -1884.6,15002.,-6411.2,-248.91,
     &    485.74,464.06,606.03,-824.39,
     &    -41.913,-416.76,150.81,-8.5482,
     &    3727.0,-8335.4,2989.6,-943.13,
     &    -1887.4,14921.,-6444.9,-230.20,
     &    -11.331,-32.387,-9.4493,6.4765,
```

```
     &    -487.32,-467.86,-607.08,825.94,
     &    -116.94,-412.85,-68.243,21.266,
     &    41.085,436.51,-164.03,11.047,
     &    -5.1395,364.29,-244.42,47.998,
     &    -1898.8,15019.,-6505.9,-223.75/
C
C   Z VALUES.
C
      DATA Z1    /-466.83,-560.67,-483.84,-571.38,
     &    -496.72,-585.46,54.591,53.539,
     &    -20.886,-21.065,-498.59,-587.35,
     &    14.832,14.676,-1413.9,-1413.9,
     &    -4537.8,-4536.9,101.44,-13.305,
     &    -54.206,-65.854,-7751.2,-7752.5,
     &    801.10,164.61,-1172.2,-1173.1,
     &    120.23,11.442,-11.160,-20.177,
     &    -1112.9,-1113.0,760.76,185.78,
     &    114.31,4.9970,-46.398,-56.699,
     &    -132.67,-133.05,747.52,169.89,
     &    -9.0116,-9.6905,-5.8967,-115.06,
     &    -127.71,-135.41,58.071,47.745,
     &    23.155,23.217,750.05,168.42/
      DATA Z2/ -453.77,-563.60,-471.21,-574.31,
     &    -483.91,-588.17,56.320,53.021,
     &    -20.968,-21.355,-485.56,-589.50,
     &    14.613,14.509,-1413.9,-1413.7,
     &    -4538.0,-4539.1,104.42,-5.7037,
     &    -51.627,-63.236,-7752.4,-7752.6,
     &    811.41,139.62,-1172.8,-1172.9,
     &    122.85,18.894,-9.7336,-17.591,
     &    -1112.9,-1113.2,769.81,161.36,
     &    117.11,12.436,-44.343,-54.160,
     &    -132.82,-132.74,757.22,145.57,
     &    -8.8658,-8.8826,-13.339,-117.25,
     &    -125.00,-136.22,55.530,46.391,
     &    23.783,23.209,757.49,144.07/
      DATA Z3/ -463.85,-563.55,-480.88,-574.48,
     &    -493.75,-588.16,56.250,53.855,
     &    -21.074,-20.940,-495.43,-590.13,
     &    14.777,13.888,-1413.8,-1413.6,
     &    -4537.6,-4538.8,104.58,-20.501,
     &    -51.252,-64.807,-7751.7,-7752.0,
     &    811.66,140.45,-1172.4,-1172.9,
     &    123.09,4.3890,-9.0810,-19.154,
     &    -1112.9,-1113.1,770.79,162.75,
     &    117.00,-2.0495,-44.494,-55.713,
     &    -132.92,-132.91,756.95,147.05,
     &    -9.0188,-9.5110,1.1472,-117.91,
     &    -128.46,-134.84,57.083,45.624,
     &    23.734,22.501,760.06,145.54/
      DATA Z4/-459.93,-563.32,-477.14,-573.46,
     &    -489.94,-588.11,55.853,53.141,
     &    -20.955,-21.574,-491.60,-590.02,
     &    15.062,13.979,-1413.8,-1413.8,
     &    -4537.9,-4538.4,104.75,-13.508,
     &    -50.667,-66.415,-7751.4,-7751.5,
     &    911.62,163.32,-1172.4,-1172.7,
     &    122.74,11.237,-8.4156,-20.725,
     &    -1112.6,-1112.9,769.01,184.29,
     &    117.50,4.7900,-42.980,-57.235,
     &    -132.73,-132.81,758.50,166.32,
     &    -8.6247,-9.7631,-5.6914,-118.26,
     &    -126.73,-136.72,58.605,44.429,
     &    23.958,22.844,761.35,156.89/
      DATA Z5/ -461.098,-562.789,-478.275,-573.010,
     &    -491.08,-587.48,55.754,53.389,
```

```
     &     -20.971,-21.234,-492.75,-549.25,
     &     14.821,14.263,-1413.9,-1413.8,
     &     -4537.8,-4536.8,103.79,-13.255,
     &     -51.943,-65.078,-7751.7,-7752.2,
     &     808.94,152.00,-1172.5,-1172.9,
     &     122.24,11.49,-9.5976,-19.412,
     &     -1112.8,-1113.1,767.59,173.54,
     &     116.48,5.0435,-44.554,-55.952,
     &     -132.79,-132.67,755.04,157.69,
     &     -8.8815,-9.46185,-5.9449,-117.12,
     &     -126.98,-135.80,57.323,46.047,
     &     23.658,22.943,757.24,156.23/
      DO 40 I=1,28,1
      ZTS=0.0
      DO 50 J=1,4,1
      ZTS=ZTS+LAM(J,I)*IN(J)
C
C  OUTPUT RUNNING SUM FOR Z VALUE FOR UNKNOWN SIGNAL.
C
      WRITE(9,25) LAM(J,I),ZTS,I,J
025   FORMAT(1H ,E15.6,4X,E15.6,4X,I2,4X,I2)
050   CONTINUE
C
C  PUT Z VALUES FOR THE UNKNOWN SIGNAL IN ARRAY 'ZT'.
C
      ZT(I)=ZTS
      WRITE(9,90) I,ZT(I)
040   CONTINUE
C
C  MAKE ARRAY 'ZT' TWICE ITS SIZE IN ARRAY 'ZTI'.
C
      DO 60 I=1,28,1
      I2=2*I
      ZTI(I2)=ZT(I)
060   CONTINUE
      DO 70 I=2,56,2
      IM1=I-1
      ZTI(IM1)=ZTI(I)
070   CONTINUE
      DO 80 I=1,56,1
C
C  OUTPUT THE 'ZTI' ARRAY TO THE TERMINAL.
C
      WRITE(9,90) I,ZTI(I)
090   FORMAT(1H ,I2,4X,E15.6)
080   CONTINUE
C
C  SELECT WHICH Z IS TO BE USED FOR COMPARISON.
C
      WRITE(7,82)
082   FORMAT(1H ,'SELECT COLUMN FOR SPECIFIC Z')
      READ (7,87) LZJ
087   FORMAT(I1)
C
C  GENERATE AN ABSOLUTE DIFFERENCE.
C
      DO 100 I=1,56,1
      ZTD(I)=ABS(ZARRAY(I,LZJ)-ZTI(I))
      WRITE(9,95) I,ZTD(I),ZARRAY(I,LZJ)
095   FORMAT(1H ,I3,4X,E15.6,4X,E15.6)
100   CONTINUE
C
C  DETERMINE THE ABSOLUTE SMALLEST MINIMAL VALUE.
C
```

```
      XMIN=ZTD(1)
      DO 110 I=1,56,1
      XMIN1=XMIN
      IF(ZTD(I).LT.XMIN) XMIN=ZTD(I)
C
C  CONSTRUCT A POINTER AT THE MINIMUM.
C
      IF(ZTD(I).LT.XMIN1) JPOINT =I
110   CONTINUE
      WRITE(9,120) JPOINT,XMIN
120   FORMAT(1H ,'JPOINT =  ',I4,4X,'  XMIN =  ',E15.6)
C
C  INPUT THE CONFIDENCE VALUE AS A PERCENTAGE.
C
      WRITE(7,122)
122   FORMAT(1H ,'INPUT CONFIDENCE VALUE')
      READ(7,125)PCENT
      TEST=PCENT/100.*XMIN
125   FORMAT(E15.6)
C
C  FIND THE VALUES IN THE DIFFERENCE ARRAY THAT ARE
C  LESS THAN THE CONFIDENCE VALUE.
C
      DO 130 I=1,56,1
      JSAVE(I)=0
      IF(ABS(ZTD(I)).LE.TEST)JSAVE(I)=I
130   CONTINUE
C
C  PRINT OUT THE SIGNAL TYPES THAT ARE LESS THAN
C  THE CONFIDENCE.
C
      WRITE(9,135)
135   FORMAT(1H ,//,1H ,'THE FOLLOWING COMBINATION OF SIGNALS GIVE EQUAL
     &    CONFIDENCE VALUE'./)
      DO 140 I=1,56,1
      IF(JSAVE(I).NE.0) WRITE (9,150) I
150   FORMAT(1H ,'JSAVE =  ',I2)
140   CONTINUE
      DO 400 I=1,56,1
      IF(JSAVE(I).EQ.0) GO TO 400
      JJ=JSAVE(I)
      IF (JJ.GT.50) GO TO 500
      IF (JJ.GT.40) GO TO 510
      IF (JJ.GT.30) GO TO 520
      IF (JJ.GT.20) GO TO 530
      IF (JJ.GT.10) GO TO 540
      GO TO (201,202,201,203,201,204,201,205,201,206),JJ
500   JJ=JJ-50
      GO TO (206,207,206,208,207,208),JJ
510   JJ=JJ-40
      GO TO (204,207,204,208,205,206,205,207,205,208),JJ
520   JJ=JJ-30
      GO TO (203,206,203,207,203,208,204,205,204,206),JJ
530   JJ=JJ-20
      GO TO (202,206,202,207,202,208,203,204,203,205),JJ
540   JJ=JJ-10
      GO TO (201,207,201,208,202,203,202,204,202,205),JJ
201   WRITE(9,301)
      GO TO 400
202   WRITE(9,302)
      GO TO 400
203   WRITE(9,303)
      GO TO 400
204   WRITE(9,304)
      GO TO 400
205   WRITE(9,305)
      GO TO 400
```

```
206    WRITE(9,306)
       GO TO 400
207    WRITE(9,307)
       GO TO 400
208    WRITE(9,308)
       GO TO 400
400    CONTINUE
301    FORMAT(1H ,'GAUSSIAN NOSIE')
302    FORMAT(1H ,'SINE WAVE')
303    FORMAT(1H ,'FM MOD 100HZ TONE')
304    FORMAT(1H ,'FM MOD 5KHZ TONE')
305    FORMAT(1H ,'AM MOD 50% 1 KHZ TONE')
306    FORMAT(1H ,'AM MOD 100% 100 HZ TONE')
307    FORMAT(1H ,'FM MOD 1KHZ TONE')
308    FORMAT(1H ,'AM MOD 100% 1KHZ TONE')
       RETURN
       END
```

---------- END-OF-THIS-ROUTINE ----------

THERE WERE NO ERRORS IN THE ABOVE ROUTINE DETECTED BY PREATY

THERE WERE 23 LABEL NUMBERS (EXCLUDING FORMATS) IN THE ABOVE ROUTINE

PREATY REV 15 AVIONICS/ST PETE TEST SOFTWARE

```
PLINKER=011 0=05/02/1213                    CC.So MC 040=1120=11/06/142
\cn
BUE SGHSV1          L1 RF  O  1901/01/01 1020:44.5  =LAF

 SGHSW1  01010100
   FORTRAN/200 10/05/0702  1901/01/01 0726:55.6 LAF  PAG

 SGHSV6  01010100
   FORTRAN/200 10/06/0702  1901/01/01 0726:00.5 LAF  PAG

 SGHRT6  01010100
   FORTRAN/200 10/06/0702  1901/01/01 0756:50.9 LAF  PAG

 SGHBL6  01010100
   FORTRAN/200 10/06/0702  1901/01/01 0729:30.1 LAF  PAG

 SGHVY6  01010100
   FORTRAN/200 10/06/0702  1901/01/01 0739:34.5 LAF  PAG

 SGHMOM  01010100
   FORTRAN/200 10/06/0702  1901/01/01 0752:59.3 LAF  PAG

 SGHDIS  01010100
   FORTRAN/200 10/05/0702  1901/01/01 0019:53.6 LAF  PAG

 TIME     78062800
 HRS ASSEMBLER 5.05  09/14/78  0813.8 edt Thu

 DATE     78062800
 HRS ASSEMBLER 5.05  09/14/78  0813.2 edt Thu

 ZFTFIO  78091300
 HRS ASSEMBLER 5.05  09/13/78  2046.3 edt Wed
 (C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC

 ZFSFIO  78062700
 HRS ASSEMBLER 5.05  09/14/78  0751.2 edt Thu
 (C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC

 ZFGFIO  78080900
 HRS ASSEMBLER 5.05  09/16/78  0638.5 edt Mon
 (C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC
 ZFGN00

 ZFPFIO  78081000
 HRS ASSEMBLER 5.05  09/14/78  0752.5 edt Thu
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 ZFEFIO  78062700
 HRS ASSEMBLER 5.05  09/14/78  0755.3 edt Thu
 (C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC

 ZFLACS  78091300
 HRS ASSEMBLER 5.05  09/13/78  2033.5 edt Wed
 (C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC

 ZFCSGR  78091300
 HRS ASSEMBLER 5.05  09/13/78  2042.6 edt Wed
 (C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC

 ZFDFLO  78091300
 HRS ASSEMBLER 5.05  09/13/78  2034.1 edt Wed
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```

```
ZFASM   78091300
HRS ASSEMBLER 5.05  09/13/78  1859.6 edt Wed
(C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC

ZFGFIO  78091300
HRS ASSEMBLER 5.05  09/13/78  1915.7 edt Wed
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ZFTIME  78091300
HRS ASSEMBLER 5.05  09/13/78  2046.7 edt Wed
(C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC

ZFDATE  78091300
HRS ASSEMBLER 5.05  09/13/78  2035.9 edt Wed
(C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC

Z1SFIO  78090700
HRS ASSEMBLER 5.05  09/14/78  0757.8 edt Thu
(C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC

Z1IOTE  78110100
HRS ASSEMBLER 5.05  11/01/78  1444.6 est Wed
(C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC
ZFIN00
Z1IN01
ZF2M02

Z1PFIO  78082100
HRS ASSEMBLER 5.05  09/14/78  0758.6 edt Thu
(C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC

Z1EFIO  78102700
HRS ASSEMBLER 5.05  10/27/78  1529.7 edt Fri
(C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC
ZF2B36
ZF2M01
ZF2M03

ZFDSTO  78091300
HRS ASSEMBLER 5.05  09/13/78  2043.2 edt Wed
(C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC
ZFDS00

ZFIOTE  78062700
HRS ASSEMBLER 5.05  09/14/78  0754.4 edt Thu
(C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC

Z1UFIO  78110100
HRS ASSEMBLER 5.05  11/01/78  1501.8 est Wed
(C) COPYRIGHT 1977 BY HONEYWELL INFORMATION SYSTEMS INC
ZFUN00
ZFUN01
Z1UN02
**********
ROOT  SGMSG1
**********
HIGHEST OVLY    /NUM OF SYMS    0
**********
 LAF
**********
ROOT  SGMSG1            BASE 0000  0000 SI 0000  0571 -...I HIGH=000
\C0  36C3
**********
*SIZE OF ROOT AND STATIC OVLYS= 0000  36C3 HI REL RCU= 119
**********
LINK DONE
**********
```

```
MAIN

* THIS SERIES OF PROGRAMS IS USED TO DISCRIMINATE BETWEEN TWO
* SIGNALS ON THE BASIS OF SEVERAL PROPERTIES OF THOSE SIGNALS.
* THE PROPERTIES CHOSEN ARE K/10.THE 2ND, 3RD, AND 4TH MOMENTS.
* IT IS USED TO GENERATE DATA FOR THE MAXIMUM OF 28 COMBINATIONS
* OF 8 POSSIBLE SIGNAL TYPES STUDIED.  THIS DATA IS THEN INSERTED
* INTO THE LEVEL 4 SUBROUTINE SGHDIS AS AN ARRAY WHICH DESCRIBES
* THE MEASUREMENTS OF THE 8 KNOWN SIGNAL TYPES STUDIED.  THIS
* FIRST ROUTINE GENERATES THE COEFFICIENTS OF A SET OF SIMULTANEOUS
* EQUATIONS WHICH ARE SOLVED IN THE NEXT SUBROUTINE.
      COMMON A(4,2,12),MEAN(4,4),S(4,4),N,NUM,AS(8,8),AZ(4)
      INTEGER Q,P
      REAL MEAN
      N=4
      NUM=4
* FILL ARRAY A WITH THE MOMENTS FOR THE TWO CASES TO BE EXAMINED.
      CALL FILLA
* CALCULATE THE MEANS BY ROW.
      DO 210 L=1,2,1
      DO 200 M1=1,N,1
      X=0.0
      DO 190 N3=1,NUM,1
      X=X+A(M1,L,N3)
  14 FORMAT(1H ,F9.4)
 190 CONTINUE
      MEAN(M1,L)=X
      MEAN(M1,L)=(MEAN(M1,L))/NUM
 200 CONTINUE
 210 CONTINUE
*  OUTPUT THE MEANS TO THE TERMINAL.
      WRITE (9,400)
 400 FORMAT (1H1)
      WRITE(9,500)
      DO 220 J=1,2,1
      DO 230 I=1,N,1
 500 FORMAT(1H ,20X,'MEAN(I,J)')
      WRITE (9,240) I,J,MEAN(I,J)
 240 FORMAT(1H ,'I =  ',I1,'   J =  ',I1,'  MEAN = ',E15.6)
 230 CONTINUE
 220 CONTINUE
*  CALCULATE THE S COEFFICIENTS.
      DO 245 P=1,N,1
      DO 250 Q=1,N,1
      X=0.0
      DO 260 I=1,2,1
      DO 270 J=1,NUM,1
      X=X+(A(P,I,J)-MEAN(P,I))*(A(Q,I,J)-MEAN(Q,I))
 270 CONTINUE
 260 CONTINUE
      S(P,Q)=X
 250 CONTINUE
 245 CONTINUE
*  OUTPUT THE S COEFFICIENTS TO THE TERMINAL.
      WRITE(9,510)
      DO 280 P=1,N,1
      DO 290 Q=1,N,1
 510 FORMAT(1H ,20X,'S(P,Q)')
      WRITE(9,300) P,Q,S(P,Q)
*  FILL THE 'AS' ARRAY WITH THE S COEFFICIENTS.
      AS(P,Q)=S(P,Q)
 300 FORMAT (1H ,'P =  ',I1,'   Q =  ',I1,5X,E15.6)
 290 CONTINUE
 280 CONTINUE
```

```
*  CALCULATE D1 THROUGH D4, WHICH ARE THE RIGHT HAND SIDE OF THE
*  EQUATIONS.
      D1=MEAN(1,1)-MEAN(1,2)
      D2=MEAN(2,1)-MEAN(2,2)
      IF(N.EQ.2) GO TO 305
      D3=MEAN(3,1)-MEAN(3,2)
      D4=MEAN(4,1)-MEAN(4,2)
*  OUTPUT D1 THROUGH D4 TO THE TERMINAL
  305 WRITE (9,310)
      I=N+1
      AS(1,I)=D1
      AS(2,I)=D2
      AS(3,I)=D3
      AS(4,I)=D4
  310 FORMAT(1H )
      WRITE(9,320) D1,D2
      IF(N.EQ.2) GO TO 325
  320 FORMAT(1H ,'D1 =  ',E15.6,'  D2 =  ',E15.6)
      WRITE (9,330) D3,D4
  325 N1 =N1
  330 FORMAT(1H ,'  D3 =  ',E15.6,'  D4 =  ',E15.6)
*  SOLVE THE N SIMULTANEOUS EQUATIONS.
      CALL SOLVE
      STOP
      END
```

! ¢T FLI

```
*  THIS SUBROUTINE FILLS ARRAY 'A  WITH K/10, THE 2ND,3RD, AND
*  4TH MOMENTS FOR THE TWO KNOWN SIGNALS WHICH ARE TO BE
*COMPARED.  THESE VALUES HAVE BEEN OBTAINED BY ANALYSIS OF THE
*  KNOWN SIGNAL TYPES.
      SUBROUTINE FILLA
      COMMON A(4,2,12),MEAN(4,4),S(4,4),N,NUM,AS(8,8),AZ(4)
      REAL MEAN
      INTEGER PP
      DIMENSION DAT1(4,4,8)
*  K/10,2ND, 3RD, AND 4TH MOMENTSOF THE KNOWN SIGNALS.
      DATA DAT1/.32145,.36409,.39281,.33506,
     +          .18688,.18896,.19659,.24211,
     +          .27064,.28319,.31734,.44545,
     +          .47704,.53074,.65901,.96329,
     +          .19739,.18168,.17955,.17642,
     +          .13471,.12435,.12292,.12079,
     +          .13212,.11279,.11026,.10654,
     +          .14915,.11745,.11351,.1078,
     +          .20225,.1878,.18117,.17446,
     +          .13793,.12839,.12401,.11944,
     +          .13844,.12015,.11219,.10422,
     +          .16006,.1292,.1165,.10429,
     +          .20194,.18768,.18867,.17883,
     +          .13767,.128301,.12897,.12243,
     +          .13793,.11999,.12122,.10939,
     +          .15921,.12895,.13095,.11217,
     +          .34674,.24943,.25541,.14590,
     +          .17880,.19496,.20032,.11324,
     +          .26183,.27518,.28965,.90459,
     +          .49137,.44392,.47867,.80889,
     +          .39049,.27254,.34665,.29250,
     +          .18384,.18478,.22861,.23400,
     +          .26884,.24954,.40836,.39060,
     +          .49852,.39343,.87698,.74435,
     +          .20208,.19275,.18760,.17994,
     +          .13783,.13163,.12826,.12318,
     +          .13823,.12621,.11990,.11072,
     +          .15970,.13919,.12880,.11422,
     +          .35553,.38500,.40000,.42744,
     +          .19175,.18663,.18000,.17742,
     +          .29343,.27802,.26000,.24446,
     +          .56132,.52464,.47000,.42048/
      WRITE(9,10)
*  ASK FOR FIRST SIGNAL TYPE.
   10 FORMAT(1H ,'INPUT FIRST CARD NUMBER ',/
      READ(9,20) K
   20 FORMAT(I1)
*  TRANSFER SIGNAL TYPE MOMENTS TO THE 'A' ARRAY WITH I =1.
      DO 30 J=1,4,1
      DO 40 I=1,4,1
      II=1
      A(J,II,I)=DAT1(I,J,K)
      WRITE(9,25) J,II,I,A(J,II,I)
  025 FORMAT (1H ,I2,2X,I2,2X,I2,2X,E15.6)
  040 CONTINUE
  030 CONTINUE
*  ASK FOR THE SECOND SIGNAL TYPE.
      WRITE(9,70)
  070 FORMAT(1H ,'INPUT SECOND CARD NUMBER ',/
      READ (9,20) K
*  TRANSFER SIGNAL TYPE MOMENTS TO THE 'A' ARRAY WITH I=2.
```

```
      DO 80 JJJ=1,4,1
      DO 90 III=1,4,1
      II=2
      A(JJJ,II,III)=DAT1(III,JJJ,K)
      WRITE(9,25) JJJ,II,III,A(JJJ,II,III)
   90 CONTINUE
   80 CONTINUE
      RETURN
      END
```

```
THIS SUBROUTINE SOLVES THE N SIMULTANEOUS EQUATIONS IN N UNKNOWNS
TO GIVE THE LAMBDA VALUE WHICH ARE USED TO CALCULATE THE LINEAR
DISCRIMINATE FUNCTIONS.  ARRAY A CONTAIN THE COEFFICIENTS
OF THE SIMULTANEOUS EQUATIONS TO BE SOLVED.
      SUBROUTINE SOLVE
      COMMON AM(4,2,12),MEAN(4,4),S(4,4),NNU,NUM,A(8,8),A2(4)
      DIMENSION B(8,8),T(8,8)
      INTEGER C
      REAL MEAN
      N=NNU
      NNN=N+1
 THE SOLUTION WILL BE BY THE GAUSS-JORDAN METHOD.  THE GAUSS
JORDAN TECHNIQUE REDUCES THE SQUARE COEFFICIENT MATRIX TO DIAGIALNJONAL
FROM WHICH THE SOLUTIONS ARE GIVEN BY THE ELEMENTS OF THE GIGHT
 HAND SIDE.  THE FOLLOWING SEQUENCE SELECTS PIVITS FOR PERFORMING
 THE GAUSS REDUCTION AND CHECKS TO SEE IF THE POTENTIAL VIVIT
 IS ZERO.  IF IOT IS ZERO THE ROWS ARE INTERCHANGED SUCH THAT
THE PIVIT IS NON-ZERO.
      DO 80 K=1,N,1
      AA=A(K,K)
      IF(AA.NE.0) GO TO 135
      L=1
  120 KPL=K+L
      IF(A(KPL,K).NE.0) GO TO 100
      IF((KPL).EQ.N) GO TO 100
      L=L+1
      GO TO 120
  100 DO 130 J1=1,NNN,1
      T(K,J1)=A(K,J1)
      KPL=K+L
      A(K,J1)=A(KPL,J1)
      A(KPL,J1)=T(K,J1)
  130 CONTINUE
  135 B(K,K)=A(K,K)
      DO 90 J=K,NNN,1
      A(K,J)=A(K,J)/B(K,K)
  090 CONTINUE
      DO 110 I=K,N,1
      III=I+1
      B(III,K)=A(III,K)
      DO 140 J=K,NNN,1
      A(III,J)=-B(III,K)*A(K,J)+A(III,J)
  140 CONTINUE
  110 CONTINUE
  080 CONTINUE
      NM1=N-1
      DO 150 K=1,NM1,1
      DO 160 I=1,K,1
      KKK=K+1
      B(I,KKK)=A(I,KKK)
      DO 170 J=K,N,1
      JP1=J+1
      A(I,JP1)=-B(I,KKK)*A(KKK,JP1)+A(I,JP1)
  170 CONTINUE
  160 CONTINUE
  150 CONTINUE
      WRITE (9,180)
  180 FORMAT (1H ,/)
 THE FOLLOWING SEQUENCE OF OPERATIONS USES THE GAUSS JORDAN
 PROCEEDURE TO MODIFY THE ARRAY'S RIGHT HAND SIDE.
      S7=0.0
```

```
      WRITE(9,500)
      DO 190 I=1,N,1
      S7=S7+A(I,NNN)
  500 FORMAT(1H1,20X,'LAMBDA VALUES')
      WRITE (9,200) A(I,NNN),I
  200 FORMAT (1H ,E18.11,5X,I4)
      AZ(I)=A(I,NNN)
  190 CONTINUE
      WRITE (9,180)
*  THE FOLLOWING SEQUENCE OF OPERATIONS CHECKS FOR CON-
*SISTANCY OF A SOLUTION.
      C=0
      DO 210 I=1,N,1
      DO 220 J=1,N,1
      AIJ=A(I,J)
      IF (AIJ.NE.0) GO TO 230
      GO TO 220
  230 C=C+1
  220 CONTINUE
  210 CONTINUE
      WRITE (9,240) C,N
  240 FORMAT (1H ,/,1H ,'C =  ',I1,'  N =  ',I1)
      CALL ZFORM
      RETURN
      END
```

LIST Z

```
*  THIS SUBROUTINE CALCULATES THE LINEAR DISCRIMINATE FUNCTIONS
*  FOR THE TWO KNOWN SIGNALS SELECTED.  THESE DISCRIMINATES WILL
*  BE USED BY THE ON LINE PROGRAM AS A COMPARISON BASE WITH WHICH
*TO COMPARE AN UNKNOWN SIGNAL.
        SUBROUTINE ZFORM
        COMMON AM(4,2,12),MEAN(4,4),S(4,4),N,NUM,A(8,8),AZ(4)
        DIMENSION ZF(4,2,12)
        REAL MEAN
        INTEGER P
        WRITE(9,50)
*  OUTPUT HEADER TO TERMINAL.
    050 FORMAT(1H ,///,1H ,20X,'LINEAR DISCRIMINATE FUNCTIONS')
        WRITE(9,55)
    055 FORMAT(1H ,//,1H ,'RACE A')
        DO 10 I=1,2,1
        P=1
        SUM=0.0
        DO 20 J=1,NUM,1
        Z=AZ(1)*AM(1,I,J)+AZ(2)*AM(2,I,J)
        IF(N.EQ.2) GO TO 30
        Z=Z+AZ(3)*AM(3,I,J)+AZ(4)*AM(4,I,J)
    030 SUM=SUM+Z
*   OUTPUT PARTIAL SUN TO TERMINAL.
        WRITE(9,40) Z
    040 FORMAT(1H ,E15.6)
        ZF(P,I,J)=Z
        P=P+1
    020 CONTINUE
*   COMPUTE AVERAGE AND OUTPUT TO TERMINAL.
        AVE=SUM/NUM
        WRITE(9,100) AVE
    100 FORMAT(1H ,'AVERAGE ='E15.6)
        WRITE(9,60)
    060 FORMAT(1H ,///,1H ,'RACE B')
    010 CONTINUE
        RETURN
        END
```

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