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AN/FPS-95 RESEARCH AND DEVELOPMENT PROGRAM (FINAL TECHNICAL REPORT, NAVAL RESEARCH LABORATORY, LONG-PATH ONE-WAY PROPAGATION EFFECTS) (U)

D. B. Trizna
Naval Research Laboratory
Washington, D. C. 20375

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JM Headrick
JAMES M. HEADRICK, Branch Head
Radar Techniques Branch
Radar Division, Naval Research Laboratory

Richard W. Coraine
RICHARD W. CORAINE, Lt Col, USAF
Chief, 441 A
Engineering Division

FOR THE COMMANDER

Donald W. Lambrecht
DONALD W. LAMBRECHT, Colonel, USAF
System Program Director

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Reciprocal tests were run between the U.K. and a station on Cyprus to measure (1) the dynamic range constraints imposed by a one-way ionospheric path between two points in over-the-horizon HF propagation, and (2) possible AN/FPS-95 antenna and/or ground screen noise sources in transmission or reception which are not excitable by line-of-sight measurements.

Results indicate that the ionosphere presents no source of noise as a transmission medium at low elevation angles (3° to 5° elevation),

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within the capabilities of the transmitting and receiving equipment used. The noise limitations measured in the AN/FPS-95 receive tests were -77 dB and -85 dB, mean noise levels in a two-Hertz bandwidth centered at 5 and 18 Hertz, respectively, from the spectrum peak. These levels are thought to be skirts of the transmitted spectrum, although line-of-sight monitoring by the test van could not conclusively verify this because of local aircraft contamination of signal. On the reciprocal path test, in which a receiver/processor test van measured the AN/FPS-95 transmission, the received signal was clean 80 to 83 dB from spectrum peak across 4 to 12 Hertz from the spectrum peak.

Data are presented which show the expected behavior of signal improvement as a function of integration time and A/C sample averaging, as if the observed noise were broadband and time stationary. Vibrational resonance effects in the antenna configuration are found to appear as discrete Doppler frequency peaks 65 to 70 dB down from the spectral peak.

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FINAL TECHNICAL REPORT ON THE AN/FPS-95 RESEARCH AND DEVELOPMENT PROGRAM

VOL. II, PART F. LONG-PATH ONE-WAY PROPAGATION EFFECTS (U)

A. INTRODUCTION (U)

(S) The operation of the AN/FPS-95 was debilitated by the existence of a spectrally-spread clutter-related noise, relatively flat, some 65 to 70 dB down from the spectrum peak. The phenomenon arose as a result of the high dynamic range operational requirements of the AN/FPS-95. The Design Verification System Tests were suspended in June of 1972 and a comprehensive set of hardware tests were begun by the on-site DVST team. These progressed through the hardware chain and culminated in some preliminary over-the-horizon propagation testing in November of 1972. A Scientific Advisory Committee was then convened to direct a set of tests much broader in scope than those conducted by the on-site team. This report is the result of one of those tests.

(S) The objective of the one-way path tests was to determine the effects of ionospheric propagation in degradation of the spectrum of a known clean transmitted signal. A secondary objective was to identify and isolate antenna contamination of the spectrum received OTH by each of the three antennas used in the test: that at the COBRA SHOE transmit site, the AN/FPS-95 antenna, and the Yagi test antenna.

(S) The test covered a six-day period March 6-11, data taken on each day but the 10th. The plan was to first transmit for a two-hour period from COBRA SHOE to the AN/FPS-95 in 14-minute periods, interspersed by a one-minute key break, with different receive configuration used for each period. Line-of-sight monitoring of the COBRA SHOE signal was attempted for the entire five test days, but was generally contaminated by local aircraft reflections. The following two-hour period was devoted to AN/FPS-95 transmission and reception at a Cyprus site with a gated receiver. Measurements were made of the received spectrum with the range gate placed upon the main pulse, and beyond to look for secondary delayed scatter paths via meteors and other D- and E-region irregularities. Prior to the six-day test period, validation of the receive module used at Cyprus was done at Orfordness, and line-of-sight measurements of the AN/FPS-95 signal were made from a point along the North Sea coast. Results of each of the measurements discussed above are described in detail.

B. LOCAL MEASUREMENTS OF AN/FPS-95 (U)

(S) The receiving-processing system used for the L.O.S. measurements of AN/FPS-95, and later L.O.S. monitoring of COBRA SHOE and OTH one-way reception of the AN/FPS-95, was provided by the MITRE Corporation. It is block diagrammed in Appendix 1, and described in some detail. The equipment is contained in a van, on top of which is mounted an adjustable vertical monopole antenna which was used in some of the measurements. The other antenna used was a rigid simple dipole, horizontally polarized, cut to 23.145 MHz. The receiver is gated to allow isolation in range of main pulse energy from energy returned delayed in time, for example from meteor or auroral

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activity, which could be expected to be considerably broadened in spectral width. Other features include an active bandpass filter to notch the carrier; a gating system, which takes a fraction of the carrier energy and reinserts it after processing at an offset frequency in the spectrum, so that a comparison of spectral skirts and peak level over the same period in time is available; a deltic analyzer, with 60-dB dynamic range, CRT display, and 2/T filter bandwidth; and an HP correlator with CRT display, for ensemble averaging of spectra obtained from the spectrum analyzer. Polaroid photographs of the correlator CRT was the means of data recording.

(S) The processing system was bench tested by P. Bentley of SRI at Orfordness. The receiver was shown to be clean to -85 dB when operated with a ten-second coherent integration time, with 0.2-Hz bandwidth. The entire configuration was then validated as a module, including the two test antennas described earlier, run in a cross-polarized configuration. Tests were also run between two identical horizontally polarized antennas transmitting a CW signal from a Fluke synthesizer into one antenna, propagating via free space with ground reflection to the second antenna, by double shielded coax into the receiving-processing van. The system was validated to -85 dB on one occasion, although -80 to -82 dB was generally typical. These tests were run at Orfordness prior to moving to a site up the coast for line-of-sight testing.

(S) The line-of-sight tests were conducted at a site located on Dunwich Heath, roughly 8 miles up the coast, at 10^{o} azimuth relative to Orfordness, the path to the site being actually overland. A single string of the AN/FPS-95 antenna was used, number 2, since Beam 1 centers at 23^{o} azimuth. Considering the 4-Hz to 20-Hz portion of the spectrum displayed on the spectrum analyzer CRT display, the AN/FPS-95 antenna was measured clean to the validation level of the van system at 23.145 MHz. Measurements were attempted at lower frequencies as well but lack of time and other validation difficulties precluded any definitive measurements. It is planned to conduct such tests in the future. Mention might be made here of the difficulty encountered when attempting to measure the vertically polarized signal transmitted with the horizontal dipole receive antenna. The signal loss due to the attempt to measure with a cross-polarized antenna was sufficient to allow local aircraft returns to contaminate the spectrum measurement. This was not a problem when the monopole atop the van was used. In conclusion, the AN/FPS-95 system appeared clean at 23 MHz to the limits of the receiving van, and the receiving van was shown to be workable at an isolated site under field conditions.

C. OTH AN/FPS-95 RECEPTION OF COBRA SHOE (U)

1. Receive Configuration (U)

(S) Data for the one-way OTH test was collected on five days. The 10:00 to 12:00Z period was devoted to reception of the COBRA SHOE signal at Orfordness; then 12:00 to 14:00, AN/FPS-95 transmitted to the van at Cyprus.

In the receive test, a different receive configuration was used for each fourteen-minute transmit period, and a data tape recorded. Although some deviation from the planned configurations occurred (e.g., use of the SRI Fax recorder and reception with full beams), the following antenna configurations were used, with antenna output fed into the sum receiver:

(a) Yagi
(b) String 16, Vertical Polarization
(c) Strings 16 and 17, Vertical Polarization
(d) Strings 16 and 17, Vertical Polarization, Transmit on 16
(e) Strings 16 and 17, Horizontal Polarization, Transmit on 16
(f) Strings 16 and 17, Horizontal Polarization
(g) String 16, Horizontal Polarization
(h) Yagi

For configurations (b) through (g), the signal from the Yagi was fed into the difference receiver. (In normal operation, when the system is run with 6 strings forming a full beam, the sum of outputs from the first three strings is subtracted from the sum of the last three strings for azimuthal monopulsing information, and the result fed into this difference receiver. A single product detector is available for the output of this receiver, so that only data unambiguous in Doppler to PRF/2 is available. The sum receiver on the other hand is fed the full sum of the six strings, with I and Q product detectors and data channels available.) This technique allowed simultaneous data taping of the outputs of the Yagi and system antenna, for comparison of fading structure, and for isolation of receive antenna spectral contamination from transmission. For cases (a) and (h), string 16V and 16H, respectively, were fed into the difference receiver.

(S) The elevation angle pattern of the three receive antennas are quite different, the main peak of the Yagi being at 6°, roughly the same as that of the system antenna used with vertical polarization, while the peak of a horizontally polarized string is at 14°. The system antenna has a single lobe in elevation in the forward direction in either polarization, while the Yagi has two additional lobes above the main one. Boresight for the Yagi was along the Great Circle path through Cyprus, at 114° azimuth, midway between strings 16 and 17.

2. Data Processing (U)

(S) The data were submitted to the SAC standard processing technique used with the other SAC tests: a 3.2-second integration time with 100-dB Taylor time weighting, total power measured in a ten-Hertz bandwidth centered upon the spectrum peak each integration period, and median noise measured in ten-Hertz bands centered -10, +10, and +20 Hertz from the spectrum peak. The dB average of these quantities are then taken for a full ten-minute tape.

(S) Additional processing was done for allowing a more qualitative examination of the spectra, e.g., for isolation of discrete spectrum contributions from vibrational resonances of the various transmit and receive antennas used, for examination of the spectral skirts for the different antenna configurations, etc. This required a longer integration time than the standard, and 25.6 seconds was chosen, with cosine-sixth time weighting. The 3.2-second processed data were reviewed in a Doppler-time format for identification of aircraft tracks which sometimes contaminated the spectra and were edited from the longer integration time data. Power-averaged signal-to-noise ratios were calculated for these edited spectra, using narrow bandwidths centered between obvious spectral contaminants. These bands were just two Hertz wide and were centered away from discrete Doppler contamination, at five and eighteen Hertz from the spectrum peak. The ionosphere imposed a Doppler shift upon the spectrum of roughly +2.1 Hz on April 11th, and -1.3 Hz on the rest of the days.

Some additional postprocessing was done of the type described above, using shorter integration times for identical time periods, to investigate the behavior of signal-to-noise with changes in integration time. Processing was also done in which the number of ADC samples used to form a range bin was varied as described in a paper on some earlier COBRA SHOE tests done on 14-16 November 197[illegible].([illegible]) All of these data are described in full in the following section.

3. Results (U)

(a) Receiver Chain/Processor Validation (U)

(S) The first set of results to be considered are the spectra using a 25.6-second integration time, processed with the Sigma V NRL processor. As part of a validation procedure, raw data test tapes were collected in which CW signals from two different models of synthesizers were input into the receiver front end. These data were processed with the same techniques used on the data which is to follow, and therefore present the sensitivity and dynamic range of the receive chain from the receiver front end to processing display routines.

(S) Figure 1 is a spectrum of an H.P. synthesizer signal. The integration time used is 25.6 seconds, $\cos^6$ time weighted, a 4096 point FFT at 160 PRF. Twenty integration periods were averaged for this spectrum. The peak signal occurs at +10 Hz, offset to show the DC offset and image. The image, due to random phase variation between the sum and quadrature channels, is at -10 Hz, 45 dB down from the main signal, 10 dB better than contract specification. The peak at 0 Hz is the DC offset in the A/C converter, which is not normally monitored because it is clutter filtered for on-line analysis by the RCA processor. The hum lines are 60 Hz on either side of the carrier, along with other harmonics, all greater than 90 dB down from the peak signal. Note that there are harmonics 70 Hz either side of the peak value at +80 and -60 Hz. These cannot be higher order harmonics of the 60-Hz lines since those will always lie at the odd ten-Hertz frequencies when folded. They are not processor induced as can be seen in

Figure 2, an identical spectrum analysis run on a John Fluke synthesizer, in which the 60-Hz lines are seen, along with higher harmonics, spaced by 20 Hz. The lines at 70 Hz about the peak are not seen in this spectrum. Note that the noise floor 80 Hz from the peak is more than 10 dB below that from the Hewlett-Packard. The spectrum of the Fluke is flatter over a wider portion of the spectrum as well.

(S) These results show that the receiver through processing chain is as clean as the synthesizers used, and that the largest contaminants, the synthesizer power line spurious signals, are of the order of 90 dB down from peak input signal. (The spur on the skirt of the Fluke Signal was due to the synthesizer, which was a spare test model not normally used in the system.) Note that the receiver front end was not connected to the antenna terminals, so that ambient noise experienced in normal operation is not displayed.

(b) Coherent Contamination by COBRA SHOE (U)

(S) Figure 3 is a typical spectrum ensemble average of the COBRA SHOE transmission. The receive frequency was offset +40 Hertz from that transmitted so that the peak of the spectrum lies at -40 Hertz. Fifteen consecutive spectra were ensemble averaged to form the spectrum shown. That is, the power of each effective filter output of the FFT is averaged over fifteen consecutive integration periods, and the dB value then calculated. Ensemble averaging of consecutive spectra should not improve the signal peak to mean noise level, but should cause a reduction in the variance of the noise about the mean. This in turn will allow an effective enhancement of weak coherent contributions to the spectrum, which are seen quite clearly in the plot.

(S) Consider first lines identified with the transmitter site. The power line spurious contaminants lie spread every multiple of fifty Hertz from the spectrum peak. Allowing for frequency aliasing, the first pair lie at +10 and +70 Hertz; the second pair at +60 and +20 Hertz; the third pair at -50 and -30 Hertz, etc. The net result is that these lines fall spaced every ten Hertz from the carrier. The pair closest to the peak is ±10 Hertz about it, these the ±150 Hertz lines. All of these lines appear circled in the figure. These apparently all originate at COBRA SHOE since they suffer the same few Hertz offset as the spectrum peak, due to ionospheric motions.

(S) Other spurious lines which were identified with the transmitter site lie at ±7 Hertz and ±14 Hertz about the spectrum peak, about 70 and 75 dB down, respectively, and are identified wind vibrations induced on the COBRA SHOE transmitting antennas. These varied in amplitude relative to the spectrum peak from one coherent integration period to the next, and relative to one another as well, including cases in which the ±7 Hertz peaks vary independently of one another. This is possibly due to phase modulation introduced by the relative motion of the transmit antenna elements relative to one another. Other lines were also present, which faded identically as the spectrum peak. These included a cluster of three lines beginning at 24.5 Hz either side of the peak, in a band roughly 3 Hz wide, beginning 65 dB down, and a second pair 48 Hz about the main peak, roughly 75 dB down. These were known to exist by the COBRA SHOE personnel and are identified as being due to transmitter blower motor lines. There was also a 22.5-Hz component which appeared on both the system and Yagi spectra generally 80 dB down or greater which was identified with COBRA SHOE.

(c) Coherent Contamination by AN/FPS-95 (U)

(S) Contamination by the local antennas did not provide much of a problem on receive mode and was difficult to identify for certain on the Yagi as well. If present it existed greater than 80 dB down on all the days of operation. An interesting feature appeared during one of the transmit periods on the clutter spectrum at ±22.5 Hz only 50 dB down from the peak of the clutter, and was obvious during the key break. As the COBRA SHOE came back up, such contamination did not appear upon it to the same level as on the clutter. This feature was discovered only toward the end of the analysis and has not been investigated thoroughly. It appears in Figure 4 as a broad series of lines about 5 Hz wide but is difficult to see during the transmit period. A cluster of about three lines exists at ±60 Hz about the clutter as well, about 55 dB down and must be transmitter associated. A search for this effect was not made for the period of transmission only, after 1200Z, to see if the effect required COBRA SHOE to be transmitting as well. Spectra are shown for each configuration for March 11, Julian day 70 in Figures 5 through 8, complementing Figure 3. Suffice it to say that spectral contamination by the receive antennas alone were generally never observed worse than 80 dB clean.

(d) SAC Test Standard Processing (U)

(S) The data were all submitted to the standard processing technique described earlier, in which median noise levels were compared with total power levels in a ten-Hertz band centered about the COBRA SHOE spectrum peak. The median noise was calculated in a band in order to eliminate large discrete Doppler contributions, such as CW users in the clutter experiments. However, the large number of coherent contaminants in the spectrum in evidence in the previous plots undoubtedly biased the noise statistics, particularly when considering the 9 dB broadening of these contaminants by the shorter 3.2-second integration time used. In addition the spectrum skirts found biased the noise levels as well. This was first noticed when the total power, ten-Hertz window was centered directly upon -40 Hz, not accounting for a 1.8-Hz offset in the spectrum due to the ionosphere. The noise in one ten-Hertz window was biased upward by an average of 3 dB due to this effective asymmetry in the spectrum. Thereafter, all of the data were first examined for the spectrum peak, and the windows adjusted accordingly. The results of this processing are listed in Table 1, where the data have been sorted according to receive configuration, and dB averages taken to produce a single set of values for each of the receive configurations.

(S) It was found that ionospheric conditions changed from one fifteen-minute period to the next such that apparent differences resulted between configurations, which were first thought to be due to receive antenna effects. Fortunately, these changes were not monotonic in time over the two-hour period. Had they been, they would have biased the data due to the fact that the data were always collected in the same order. Note that data collected with AN/FPS-95 transmitting while receiving were not processed with the standard method since the data were collected with a key break in the middle of the data tape.

(S) The data in the table show little asymmetry in the spectrum between the +10 and -10 Hz noise bands. The asymmetry which does appear does not show a preferable Doppler direction over all of the data, and are probably due to aircraft targets which did appear in the Doppler time displays generated. In the averages taken over all days operating for a given configuration, the greatest asymmetry observed is 1.4 dB for the case of Strings 16 and 17, horizontal polarization.

(S) There is an apparent difference in averages between the configurations in which the two adjacent strings, 16 and 17, are summed. A degradation in average of 4 dB is observed in going from a single string to two strings summed, vertical polarization, if one compares the total averages. However, the single string average is biased upward by a large value on days 67 and 68, when no data were collected on the paired strings. With these values omitted, the averages for the single string are 71.0 and 70.0, respectively. In the case of horizontal polarization, however, in comparing day by day there is an improvement of three to six dB on two of the days in summing the strings as one would expect. Because of the fading experienced, examples of which will be shown later, and the overall change in the ionosphere with time, the differences or lack of such are probably not significant. It would probably be necessary to compare the pairs simultaneously or against the Yagi on the difference channel. This was not done for the standard processing, but may be further considered in the future.

(S) One can conclude that the ionosphere does not impose any asymmetric shift of power within the spectrum on a large scale, and that there are no significant differences in signal-to-noise levels between the various receive antenna configurations. The level of signal to noise which is observed is of the same order of magnitude observed in CRN and may be due to the same agent. More will be said about this possibility in the final summary, after the Episkopi L.O.S. measurements of COBRA SHOE are discussed.

(e) Statistics on 25.6-Second I. T. Data (U)

(S) As discussed earlier, statistics similar to those in the previous section were calculated for the spectra which were used to produce the plots presented earlier. That is mean noise levels were calculated in 2-Hz bands set between the discrete spectrum contaminants seen in the data processed with 25.6 seconds integration time. These bands were set at +5 Hz and +18 Hz relative to the spectrum peaks to give some indication of the noise floor below the discrete peaks, which was probably heavily contaminated by the broadened discrete components in the earlier data review. Table 2 presents signal-to-noise ratios for each configuration for Julian day 70. Subtracting 9-dB gain for the 9-dB increase in integration time, one gets +68.0 and +76.4 dB signal-to-noise for the two windows defined, indicating roughly a 3-dB bias due to the broadened discrete components not fully discarded in the 3.2-second integration time processing. These numbers also reflect the frequency dependence of the noise floor observed earlier.

(f) Processing Parameter Variation (U)

(S) The Yagi antenna and a single string, vertical polarization, were compared processing a single data tape for each with a variation in two processing parameters: integration time and number of samples averaged to form a range bin. Both of these techniques were used in processing data taken in November on COBRA SHOE, in comparing the system antenna with a simple fan dipole.[1] The ADC sample averaging technique is used in the RCA processor to achieve effective receiver bandwidth narrowing if the dominant noise is white and time stationary. The receiver front end bandwidth is 5 kHz, matched to the 250-microsecond pulse, but much broader than necessary for the longer pulses available with the system, up to 3 milliseconds. The ADC rate of 4 kHz provides 24 samples between pulses at 160 PRF, and 96 samples between pulses at 40 PRF. To save radar computer memory, and to match to the longer pulses used at 40 PRF, four consecutive ADC samples are averaged before coherent processing so that the 96 samples are cut to 24 bins at 40 PRF. The rational behind the averaging is that any coherent pulse returns (or CW signals) sampled will add coherently, like the number of samples added, squared. If the noise is Gaussian and white, the noise samples from one ADC sample to the next in time will be statistically independent and will add incoherently, proportional to the number of samples added. The effective signal-to-noise gain per pulse is proportional to the number of samples so averaged before coherent processing. For processing CW signals this technique can be extended over as many samples available between pulses, 24 at 160 PRF, for a S/N gain of just over 13 dB. (Some loss would be encountered for the lack of phase adjustment in adding adjacent samples[1], but for our present purpose these can be neglected.)

(S) In the November test the gain of the simple dipole was sufficiently small so that the dominant noise was white and appeared very flat across the spectrum. An effective signal-to-noise improvement was achieved for this case, which lowered the noise in the spectrum and allowed the skirts on the spectrum peak to become more prominent. No improvement by sample averaging was seen on the system antenna, in which case the greater antenna gain caused the skirts on the COBRA SHOE spectrum to dominate the entire available Doppler spectrum.

(S) In the data presented here the Yagi and string 16V of the system were compared in the way described above. Since each had sufficient gain to show the skirts of the received spectrum, which again dominated the entire available Doppler spectrum, no more than a few tenths dB improvement in signal-to-noise was achieved by sample averaging. Both antennas were compared in this way for two different values of integration period covering identical total time periods. The results of this processing are shown in the first part of Table 3. The noise levels measured were in the two-Hertz band quoted earlier, at +5 and +18 Hertz relative to the system peak, and were averaged linear in power over the number of integration periods indicated. Virtually no improvement in signal-to-noise is obtained for data from either antenna, for either of the 25.6-second or 6.4-second integration period choices. One can conclude therefore that the noise measured in these bands is coherent, that is, either transmitted from COBRA SHOE itself, or imposed by forward scattering or scintillation effects in the propagation medium. The poorer signal-to-noise level observed on the Yagi in the band at 5 Hertz was later found to be apparently due to an aircraft which passed through the Doppler window slowly through the time period. This was ascertained from a Doppler time output run with a 3.2-second integration period. Note that the expected signal-to-noise improvement with increase in integration time is achieved in each case, roughly 6 dB.

(S) The variation of signal-to-noise with integration time was investigated over yet a wider range of integration times, and one example of this is provided for string 16H. A single two-minute data period was processed at 3.2, 6.4, 12.8 and 25.6 second coherent integration times. The shortest integration time used was 3.2 seconds, commensurate with a filter width narrow enough to avoid contamination by the coherent spurs in a two-Hertz band. The largest integration times, 25.6 seconds, is the maximum available at 160 PRF, a 4096 point transform. The results are also shown in Table 3. The signal-to-noise improves as expected, even though fades of ten dB or more occur over a time scale 3.2 seconds or less. The smoothing of such fades by increased integration time can be seen in amplitude-time plots of Figures 9 through 11, for the same data in Table 3. The plot also shows the time behavior of the noise levels in the bands indicated in the legend. The total power was measured in the band -35 to -45 Hz in this case, the two filter bins set from -32 to -34 Hz, and -21 to -19 Hz, 5 and 18 Hz from the identified spectrum peak, respectively. The signal power mean and variance are calculated over this period, as well as the mean RMS noise levels and variances, as indicated. A signal to RMS noise level is then determined from these levels and also printed in the plot legend. It is seen that the variation in signal level is at least 3.2 seconds on some occasions, where maxima and minima occur in consecutive integration periods. The smoothing of these variations is observed as the integration period is increased, making evident the longer period polarization fades. (Note that the first time recorded is at the end of the first integration period, accounting for the slight differences in start times. This also has the effect of apparently shortening the total time length plotted relative to the previous plot.)

(S) The rapid variation observed on these data was not always present and is thought to be due to multimoding due to high angle rays, as these data were taken on horizontal polarization. Figure 12 shows data taken on the Yagi over a longer period of time, processed at 3.2 seconds integration period, showing the key break at the beginning of the data tape as well. The key break affects the variances and means calculated for the period which are not valid. The figure does illustrate the rise in noise level at the onset of the COBRA SHOE signal, and the relatively highly correlated behavior in time of the noise with the signal peak. From this observation one could again draw the conclusion that the noise is either transmitted on the COBRA SHOE spectrum or is imposed by scintillation effects in the ionosphere.

(g) Impulsive Bursts and Fading Variability (U)

(S) The data for Figure 12 show spikes in time in the noise which do not appear to have an associated spike in peak signal. Those occurring at the onset of the signal are just switching transients, but those occurring at 210 seconds into the data are not easily explainable. They appear to occur within the 3.2-second integration time, and may in fact be broad spectrum scatter from overdense meteor trails, receiver crow-barring, or simple bits dropped in the data tape. These are the types of glitches which required the data editing at 25.6-second integration times discussed earlier, though not quite as large. One burst is sufficiently broad to affect both windows in frequency which are now spaced a minimum of 75 Hz from one another, while the second burst affects just one of the windows, the one nearer to the signal peak. These data were collected using the Yagi antenna. A second, larger example of impulsive noise is seen in Figure 13, also on the Yagi, representing a rise of more than 60 dB, and extending over sufficient Doppler to enclose both Doppler bands, spaced 60 Hz apart, and lasting for two consecutive integration periods. There is a simultaneous slight drop in peak level of a few dB as well, indicating such large effects may be due to the transmitter site. Evidence that not all of the impulses are associated with the transmitter is shown in Figure 14, in which impulses as large as 12 dB can be seen during the key break. These data were collected on string 16H, and show a higher rate of pulse occurrence. Finally, consider Figure 15, the same type of display for .8 seconds I.T., on the H.P. synthesizer data presented earlier, as an ensemble-averaged spectrum. The two-minute section features two impulsive spikes ten to twelve dB above the noise floor, in the bandwidth closest to the spectrum peak, one lasting through two consecutive integration periods, or 1.6 seconds. There is virtually no observable variation in the peak of the spectrum at this time, and the variance of the peak is zero to within less than 0.01 dB. A similar plot for the Fluke spectrum shows no such impulse over a similar period. The lower, nearly equal, mean noise levels over the two-minute period reflect the flatter spectrum observed earlier (Fig. 16).

(S) The variances of the noise levels over this period are essentially the same as that of the H.P. window which had no impulsive behavior.

It is difficult to say whether the impulse originated in the synthesizer or receive chain. The fact that the larger one lasted more than .8 seconds indicates that the problem was not a dropped bit on the data tape. Perhaps an analysis of the distribution in time of such events might provide some insight into their origin. In conclusion, this selection of data plots shows that impulsive noise seen on the system can originate in hardware components comprising the radar receive-processing chain, probably exists in nature in broadband form as exemplified by the events seen during the key break, and probably also exists in transmitters in large amplitude events observed while COBRA SHOE transmitted. Such large impulses might be expected to occur on the AN/FPS-95 transmitters and be seen in clutter. This effect should be monitored if possible in future testing.

(S) The amplitude-time plots shown above also provide a variety of fading structure. The fades in Figures 13 and 14 are quite similar with polarization fade rates of the order of 8 seconds, and longer period fades of the order of 1 to 3 minutes, due probably to focusing by ionospheric structure variations at midpath. Figure 12 data, taken on Julian day 67, shows deeper polarization fades with about 15-second period polarization fades. Finally, consider the unusual fading structure observed on the full beam, 13V. These show the same rapid variation seen earlier on day 70 data and are identical to all data taken on the fan dipole in November. The Great Circle path to COBRA SHOE, at 114°, lies in the first null of beam 13, which points at 107°. The fan dipole variation was thought to be due to a multiplicity of paths available via reflections off the sea surface, since it was situated upon the sea wall. The same explanation might hold here, since weaker off-bearing paths would compete with the main path which is being received in the null. The signal level in this case was about 12 dB too weak to bring up the highly correlated noise to a point where it was obvious.

D. EPISKOPI MEASUREMENTS (U)

(S) The measurements made at Cyprus were made at Episkopi, atop a bluff 900 feet above the plain on which the Cyprus transmit site is situated, roughly 9 miles from this site, and within a few degrees along the Great Circle path to AN/FPS-95. The site was chosen because it lay just a few degrees off the Great Circle path to the AN/FPS-95 and almost at identical elevation angle for the expected OTH transmission path. The site was free of other HF antennas which might have noisily reflected the COBRA SHOE transmitted signal and been interpreted as a noisy transmission. It was considered important to avoid ground wave path transmission to the monitoring site also. Such vertically polarized signals, possibly generated by fixed rigid antenna masts, could appear extremely clean to a nearby monitor and yet contribute only slightly to an OTH transmission path. In this case a potentially noisy signal generated by the horizontally polarized antenna elements and transmitted via an ionospheric path would not be properly measured by a local monitor.

(S) The measuring apparatus used was a mobile van of equipment contracted from the MITRE Corporation and is described in some detail in an attachment by J. N. Schneider of RADC, who accompanied the team and participated in the tests. The purpose of the measurement was threefold: (a) to monitor the COBRA SHOE signal while it transmitted toward the U.K.; (b) to measure the OTH direct one-way spectrum from AN/FPS-95 in a pulsed mode, with their range gate placed in time upon the strongest return; and (c) to slide the range gate in time to search for delayed meteor-scattered energy.

1. COBRA SHOE Monitor (U)

(S) Some of the problems encountered are reviewed by Mr. Schneider in the attached Appendix 1. The primary problem was L.O.S. reflections of the AN/FPS-95 signal from local circling aircraft traffic at a nearby airport. The effect of this upon the measurement was to fill all Doppler bins in the deltic analyzer with energy returned from the accelerating aircraft making a measurement of the true noise floor impossible. This contamination existed for the first four days of the test, Tuesday through Friday. A final measurement was attempted on Sunday, March 11, and these results are listed in the accompanying report as labeled photographs for that date. The first to be considered, taken at 1015Z during a key break, shows the receiver noise floor with a calibration signal input at -102 dBm, attenuated by 10 dB. The second photograph, taken at 1020Z during COBRA SHOE transmission is the primary validation spectrum, showing 16 Hz of Doppler, approach folded upon recede. The edge of the clutter filter at the left is at 4 Hz and the peak at the right-hand side at 20 Hz, not accounting for a 1.5-Hz shift of the signal peak to separate the -54 dB calibration sidebands. The peak just to the left of the calibration pair is then identified as one of the 7-Hz wind vibration lies of COBRA SHOE. The other 7-Hz peak is shifted to the right (accounted for by the ambiguous folded spectrum) and should lie on the right shoulder of the right calibration peak. One of the 14-Hz wind vibration lines is identified as the second discrete peak to the right of the calibration pair; the second would be shifted further to the right. The first peak to the right of the calibration is apparently the 50-Hz power line of the measuring equipment folded into the middle of the spectrum, as the batteries used for power were not available the last day. The next two photographs show the COBRA SHOE 50-Hz line and the 24.5-Hz motor blower line. It was necessary to change PRF and offset in such a combination that the spectrum peak still falls in the clutter notch. This allowed these other features to be identified as they normally lie outside the 0-20 Hertz analyzer display band. This was requested of the crew after these features had been identified on AN/FPS-95 reception.

(S) A four-minute spectrum of AN/FPS-95 data is shown in Figure 17 and consecutive spectra within the same four minutes shown in Figure 18. The 10-Hz interference peak has been omitted. The 24.5 blower line, that which was found to fade identically with the spectrum peak, is found to lie essentially directly on the AN/FPS-95 measurement. The 7- and 14-Hz lines are present in about the same proportion, these being two pairs which faded all relative to one another. The 50-Hz line is down from the AN/FPS-95 measurement, as apparently are the higher harmonics which lay ±10 and ±20 Hz about the peak since these are not seen in the photograph.

(S) Although the continuous portion of the spectrum slopes in general agreement with the AN/FPS-95 measurement of the spectrum, it is difficult to say whether this is the same noise floor. The AN/FPS-95 spectrum used an integration time 2.56 longer than the analyzer (+4.1 dB), unfolded the spectrum unambiguously (+3 dB), but uses a wider 6-dB noise bandwidth for cosine-sixth time weighting than the analyzer's cosine squared (2.3/I.T. vs 1.5/I.T. : -1.85 dB; Ref 2). The total improvement over the analyzer should be just over 5 dB. The measured improvement however is 10 dB or more over most of the ensemble average as well as over individual spectra taken during the period. Because of all of the line structure on the COBRA SHOE signal within ±20 Hz, and because of the necessity of offsetting the signal a few Hertz to display the calibration, it is the author's opinion that the line-of-sight analyzer data are not showing the true noise floor of the transmitted signal, and that it would be able to do so only if the line structure transmitted were eliminated.

2. OTH Reception of the AN/FPS-95 (U)

(S) The reciprocal OTH test, in which the MITRE van measured the AN/FPS-95 signal, appeared to show no noise on the transmission to the limits of the equipment, -83 dB at 0.2-Hz resolution bandwidth, on occasions when there was sufficient signal strength to drive the receiver properly. Specific examples of best data of the set include a series of four taken on 8 March, from 1240 to 1300Z. The values range from 78 to 83 dB clean, with no apparent skirts seen on the AN/FPS-95 spectrum, as was observed on COBRA SHOE. Additional data were taken on this day as well with 0.02-Hz resolution, and AN/FPS-95 was measured clean and flat 80 to 85 dB in a two-Hertz display band from 4 to 6 Hz. This requires a 100-second integration time however during which fading certainly occurs, so that such a measurement may not be meaningful because of weak signal limitations.

(S) A search for meteor backscatter paths to the site were made by sliding the range gate behind the pulse up to 1.5 milliseconds, taking all antenna attenuation out of the system but no such scatter was seen. The crew was requested on the last day to remove the signal from the clutter notch to see if any weak broadened delayed scatter was present. The calibration photo taken at 1245Z on March 11, has the gate on the pulse, the signal attenuated 76 dB, producing the spectrum shown. The gate was slid 1.5 milliseconds ahead of the pulse and the attenuation removed for calibration and produced the next photo at 1250Z. The 10-dB signal seen was thought to be gate leakage, which might be expected with the system operating in the unorthodox mode. When the gate was slid after the pulse at 1.5 milliseconds with no attenuation to search for meteor scatter, the photo at 1255Z resulted. The spectrum is about 10 dB greater in amplitude and much broader than the calibration data, indicating the possibility of such scatter. The test crew however dismissed this hypothesis and felt that gate leakage again produced the effect.

(S) One can conclude from these measurements that the AN/FPS-95 signal on a one-way direct path to Cyprus at 23 MHz is clean and flat to at least 80 dB. There appears to be no meteor scatter on a one-way path, delayed at 1.5 milliseconds, of a level sufficient to produce CRN.

E. SUMMARY AND CONCLUSIONS (U)

(S) The data indicate that the received spectrum from COBRA SHOE has skirts that begin to broaden at about 70 dB from the peak. When processed with a 25.6-second, cosine-sixth time-weighted integration period, the noise measured on this skirt, in a two-Hertz bandwidth, has a mean value of -77 dB at 5 Hertz and -85 dB at 18 Hertz, both frequency and amplitude quoted relative to the spectrum peak. Line-of-sight measurements made simultaneously on COBRA SHOE verified spectral contamination from 50-Hz power lines and 7- and 14-Hz wind vibrations. The noise spectrum of COBRA SHOE as measured line-of-sight, on the day that local aircraft did not contaminate measurements, was about 6 dB higher than that measured OTH at the AN/FPS-95, all processing differences accounted for. It is felt by the author that the multiplicity of coherent spectrum contamination present on the COBRA SHOE spectrum prevented the true noise floor from being measured line-of-sight. Simultaneous measurements made at the same site by COBRA SHOE personnel using a processor with a one-Hertz bandwidth showed a spectrum shape similar to that measured OTH. However, the skirts of the filter may be producing the observed shape, also affected by the power line and wind vibration contamination. If one accepts spectrum broadening as transmitted skirts, then Cyprus-to-UK path measurements are probably not useful in attempting to determine propagation broadening from these data.

(S) There was no outstanding spectrum contamination due to either the system antenna or Yagi observed worse than 80 dB down from the spectrum peak. The spectrum skirts prevented identification of any such contamination below this value. Some contamination was observed in the clutter spectrum during C.S. transmission, however, and should be investigated in the future. Interesting noise impulses were observed under a series of conditions, which showed that these could exist in nature, in the receive-process chain, or in the transmitter.

(S) The UK-to-Cyprus path test produced results which showed no spectrum contamination 20 Hz either side of the spectrum greater than the level of validation of the receive and processing equipment, 80 to 83 dB. One can probably conclude from these measurements that the ionosphere does not provide contamination of a spectrum of a level seen in backscatter clutter data. Secondary meteor scatter was also looked for in the UK-to-Cyprus path test but was not observed in any of the measurement attempts.

(S) In conclusion the author would recommend that a line-of-sight measurement be made of the COBRA SHOE transmission, for processing elsewhere if necessary, to determine whether the skirts observed OTH are on the transmitted spectrum. Although these are not of a level to explain clutter-related noise, they may present the next level of limitation if they are ionospherically induced.

(S) TABLE 1

STANDARD PROCESSING - LISTING BY ANTENNA

	Julian Day	Total Power (-dBm)	Median Noise+	Median Noise-	SN+	SN-
Yagi	70	48.6	127.2	123.7	78.6	75.1
	70	45.0	118.1	115.3	73.1	71.3
	68	49.1	120.4	119.8	71.3	70.7
	67	54.5	124.8	125.1	70.3	70.6
	67	39.7	117.3	118.0	77.6	78.3
	66	50.5	118.8	119.4	68.3	68.9
	66	49.7	117.5	117.8	67.8	68.1
	65	45.1	118.6	119.5	73.5	74.4
	65	54.0	127.8	128.6	73.8	74.6
	70	45.1	119.3	116.4	74.2	71.3
		48.13	121.0	120.4	72.85	72.23
				σ =	3.37	3.00
16V	70	46.3	122.0	117.5	75.7	71.2
	68	45.1	112.6	123.9	77.5	78.8
	67	44.0	125.2	125.1	81.3	81.1
	66	48.2	117.3	117.3	69.0	69.1
	65	46.3	114.8	116.0	68.5	69.7
		45.98	120.38	119.96	74.10	73.98
				σ =	3.51	3.51
16H	70	53.0	125.2	122.2	72.2	69.2
	67	42.3	122.8	123.1	80.6	80.8
	66	60.3	130.8	131.6	70.5	71.3
	65	56.0	129.3	130.3	73.3	73.3
		52.9	127.03	126.80	74.13	73.90
				σ =	2.43	2.77
16 + 17V	70	57.7	130.8	126.6	73.1	68.1
	66	48.0	116.4	116.8	68.4	68.8
	65	49.9	121.4	122.0	71.5	72.1
		51.87	122.87	121.80	71.00	69.93
				σ	1.20	0.96
16 + 17H	70	62.4	139.8	135.2	77.4	72.8
	66	51.3	127.6	127.7	76.3	76.4
	65	58.5	131.5	132.0	73.0	73.5
		57.40	133.0	131.63	75.60	74.23
				σ =	1.02	0.85

(S) TABLE 2

25.6-SECOND INTEGRATION TIME STATISTICS FOR DAY 70

Antenna Receiving Configurations	S/N (+5 Hz)	S/N (+18 Hz)	
Yagi	72.9	86.9	
16 V	77.9	88.5	
16 V, 17 V	76.0	80.9	
16 V, 17 V while transmitting on 16	77.2	84.1	(on period only)
16 H, 17 H	75.8	84.1	
16 H, 17 H while transmitting on 16	80.1	90.0	(on period only)
16 H	77.5	85.0	
Yagi	77.6	84.2	
Yagi	78.0	84.8	
Average S/N	77.0	85.4	
σ	1.59	2.25	

(S)TABLE 3. VARIATION OF SIGNAL-TO-NOISE WITH INTEGRATION TIME

Table 3A

Antenna Configuration	Total Time (# of Integration Periods x Period of Integration)	RMS (5 Hz)	RMS (18 Hz)	Peak	S/N (5 Hz)	S/N (18 Hz)
Yagi	6 x 25.6	114.0	129.4	43.2	70.8	86.2
	24 x 6.4	107.7	125.8	42.9	64.8	82.9
16 V	6 x 25.6	113.5	124.8	34.0	79.4	90.7
	24 x 6.4	107.5	118.3	33.7	73.8	84.6

As above, but using 20 consecutive A-D samples averaged to form a Range Bin.

Antenna Configuration	Total Time	RMS (5 Hz)	RMS (18 Hz)	Peak	S/N (5 Hz)	S/N (18 Hz)
Yagi	6 x 25.6	114.5	130.0	43.9	70.7	86.1
	24 x 6.4	108.1	126.1	43.4	64.7	82.7
16 V	6 x 25.6	114.0	125.7	35.1	78.9	90.6
	24 x 6.4	107.9	118.8	34.2	73.9	84.6

RMS noise levels, peak signal, and signal-to-noise averages in a two-Herz band centered at +5 and +18 Hz from the spectrum peak. Values are time averages for similar time periods for two antennas. Comparison is made for FFT samples for a fixed range bin and a wide range bin consisting of a twenty ADC sample average.

Table 3B

Integration Time	RMS (5 Hz)	RMS (18 Hz)	Peak	S/N (5 Hz)	S/N (18 Hz)
25.6	120.2	128.2	45.0	75.3	83.0
12.8	117.2	127.3	43.6	73.6	83.8
6.4	114.5	123.7	43.3	71.1	80.4
3.2	110.9	118.4	43.6	67.3	74.8

RMS noise levels, peak signal, and signal-to-noise averages in a two-Herz band centered at +5 and +18 Hz from the spectrum peak. Values are time averages over a single 76.8-second period, using different integration periods.

All RMS and peak values are given in (-dBm).

REFERENCES

1. Trizna, D. B., Hudnall, J. M., "Ionospheric Propagation One-Way Path Tests," NRL Memorandum Report. In Press. (S)

2. Rafuse, R. P., "On the Shape of the Frequency-Domain Window for Cosine-Nth Time Weighting," Tech. Memo RATM-73-13, 9 Mar 73. (U)

LIST OF ILLUSTRATIONS

are identified as circled; COBRA SHOE antenna vibration lines are identified by arrows; COBRA SHOE cooler-blower motor lines are identified by B. These contaminants were observed on all receive antenna configurations of the AN/FPS-95, including the test Yagi, and are therefore identified as COBRA SHOE contaminants. Remaining spectral peaks are generally greater than 80 dB down and may be identified with the receive antenna. The skirts of the spectrum are thought to be transmitter-associated rather than ionospherically induced.

(U) Figure 6 - Two ten- spectra averages of COBRA SHOE transmission as received on AN/FPS-95 strings 16 plus 17 combined. The first spectrum contains a noisy contribution which has brought the noise floor up to -80 dB below spectrum peak. Its cause was not established.

(U) Figure 7 - As in Figure 6, but using horizontally polarized strings.

(U) Figure 8 - As in Figure 7, but using only a single string, number 16.

(U) Figure 9 - A time history of peak signal amplitude and RMS noise averages as measured on the string 16 + 17 combination. Noise averages were calculated for a series of Doppler bins for each integration period in a bandwidth chosen to lie between obvious contaminants of the COBRA SHOE spectrum. (These were two Hertz wide, centered at -33 Hz and -20 Hz, respectively.) Mean peak signal for the entire period was -43.6 dBm, with a 5.31 dB variance. Means calculated over the same time period, of the RMS noise values, are listed as TMNRMS, and variances for the period are TVAR. Signal peak to noise averages in these bandwidths are 67.3 and 74.8, respectively, over the same time period. Integration time used was 3.2 seconds. The high correlation between signal and noise through this period (indicated by the first number following the word, CORFNS) indicates that the measured noise was probably associated with the transmitted spectrum.

(U) Figure 10 - A time history for the same period as Figure 9, but for 6.4-second integration time. Note the increase in signal-to-noise ratios, S/RMS, and correlation functions.

(U) Figure 11 - A time history for the same period as Figure 9, but for 12.8-second integration time. Increase in signal-to-noise continues, whereas noise-signal peaks become less correlated.

(U) Figure 12 - A time history of peak signal and noise as measured on the Yagi test antenna, including a key break at the beginning (which invalidate averages and correlation functions). The figure features noise spikes in time associated with the turn-on transient, and some which appear later in time, of the order of 20 dB in amplitude. In one case the noise is observed of equal amplitude in both filter bands, and in the second case in only one. As these data were collected on the Yagi antenna the AN/FPS-95 ground screen could not be responsible for these particular effects in this case.

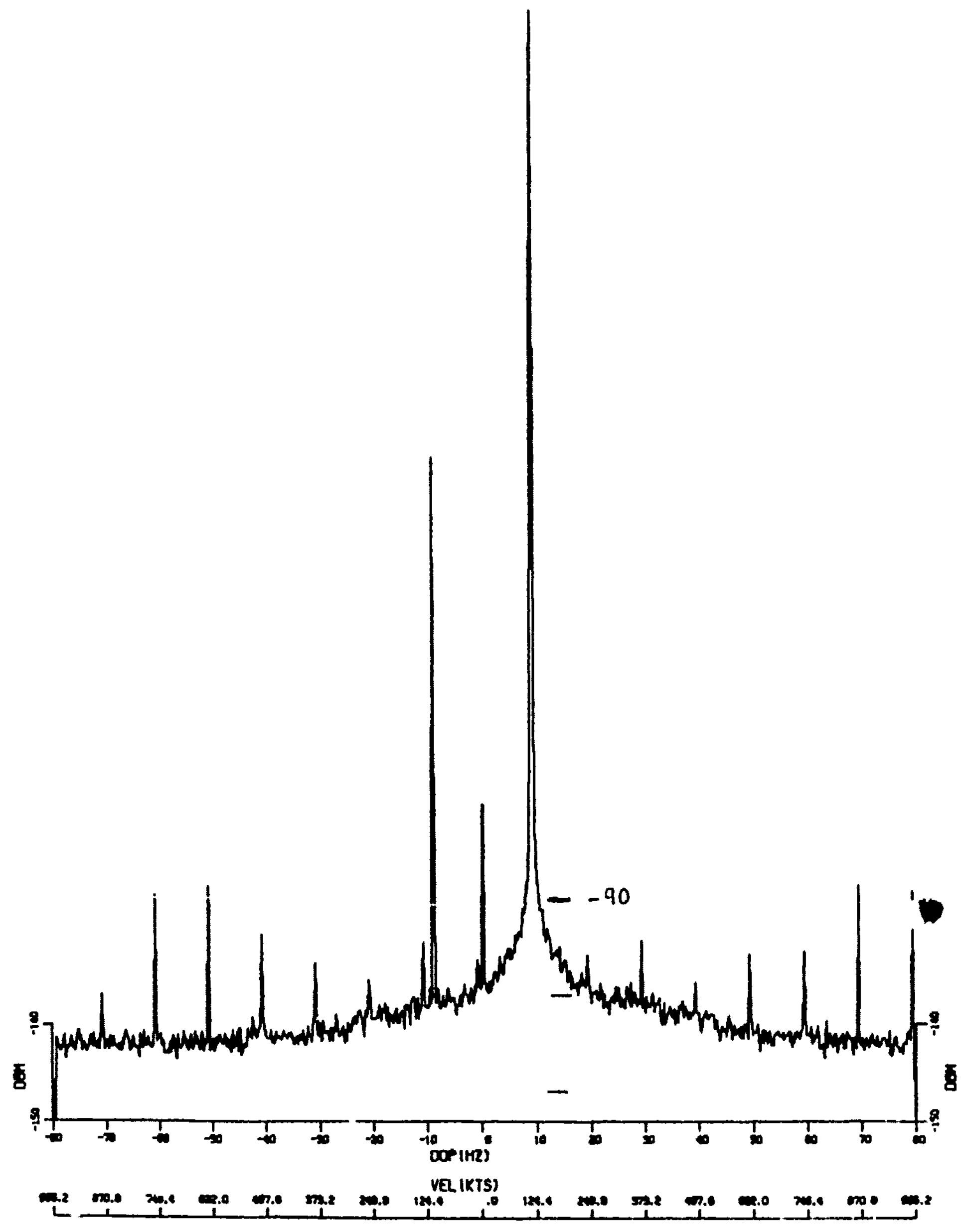
(U) Figure 13 - A time history for the COBRA SHOE signal as measured on the test Yagi. Featured here is a noise peak extending over two 3.2-second integration periods, roughly 50 dB above normal levels. This is probably associated with the COBRA SHOE transmitter, and similar noise effects might be expected for the AN/FPS-95 transmitter. As the transmitter is not monitored for such causes, effects on the noise problem cannot be ascertained in general.

(U) Figure 14 - A time history of noise and peak COBRA SHOE signal as measured by string 16 of the AN/FPS-95 antenna. Featured are transient spikes and more prevalent noise spikes during the transmit period. However noise spikes of the order of 12 dB also appear prior to the onset of the signal and may arise in nature, for example due to spherics.

(U) Figures 15 and 16 - Time histories for the synthesizer signals, HP and Fluke respectively. Featured are the lack of correlation of noise with signal, the occurrence of a pair of noise spikes greater than 12 dB (source unknown), and the flatter noise floor measured on the Fluke (as evidenced by more nearly equal signal-to-noise averages in the two bands measured).

(U) Figure 17 - A pair of averaged spectra of the COBRA SHOE signal, consisting of ten coherent spectra each. Points have been abstracted from the MITRE van line-of-sight measurements of COBRA SHOE for the same time, on March 11, 1973 (Julian day 70), photograph #2 of the March 11 data in the Appendix. Detailed comparison of the two is found in the text.

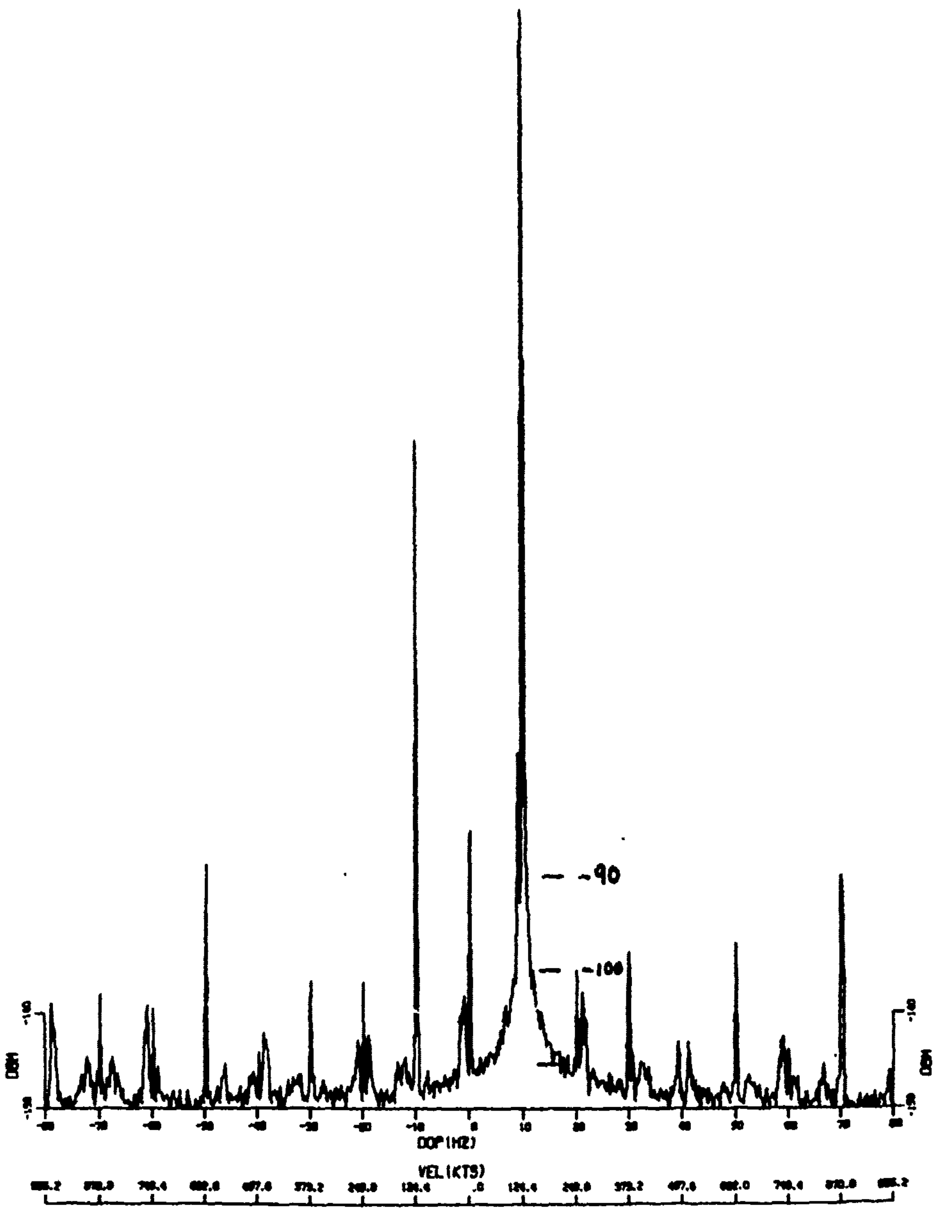
(U) Figure 18 - Consecutive spectra used to create the average of Figure 17, again with the line-of-sight measurements for the same total period superimposed.



B 3,+20

BM PRF I-T OVLAP THRESPL TRUNC START FREQ DAY
13 160. 25.6 1.0 -150. 200.0 21, 5, 5 23500000 11
5 DATA PT PER 1 PLOT PT

(U) Fig. 1 - Average Spectrum of Hewlett-Packard Synthesizer Signal into AN/FPS-95 Receiver at 23.5 MHz +10 Hz

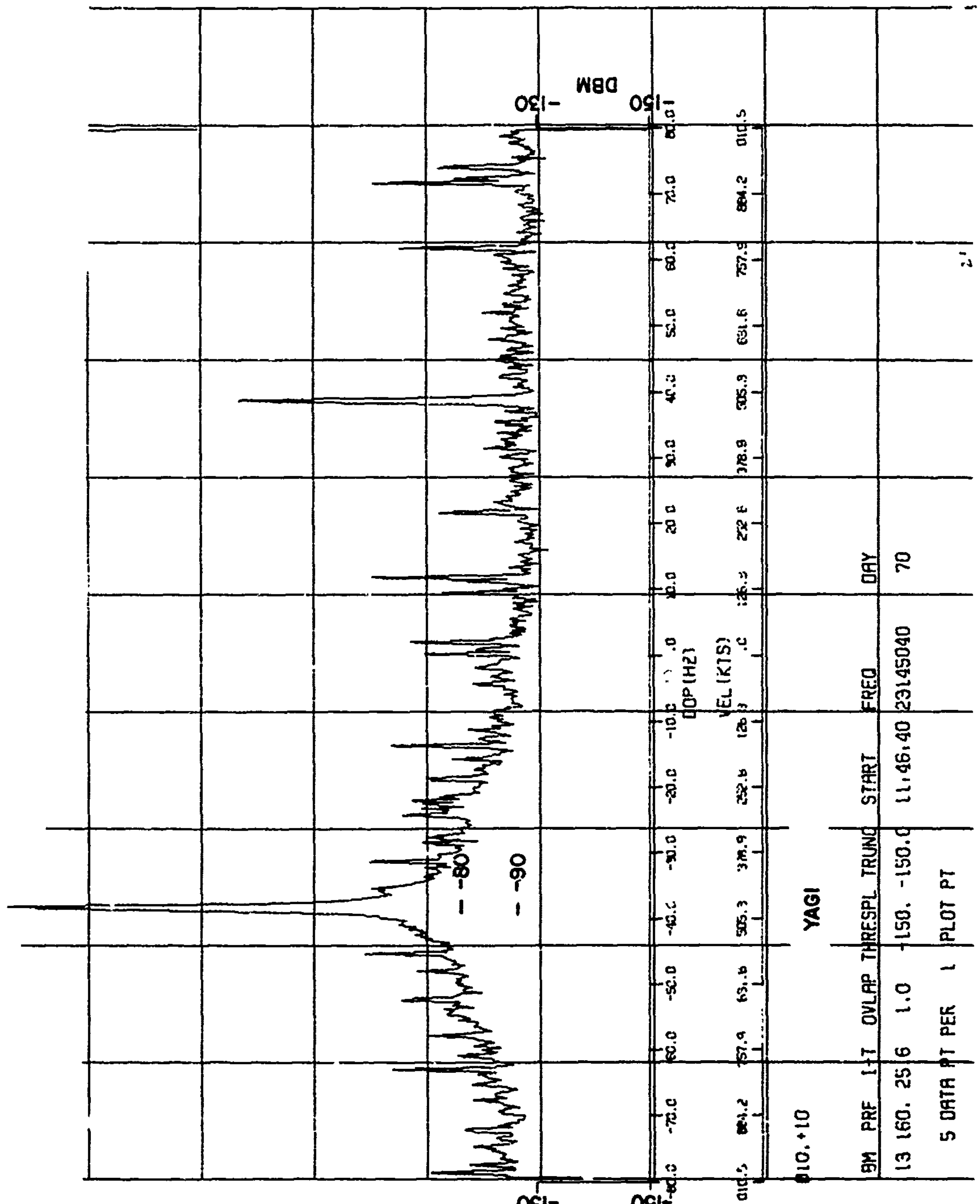


B 3,+20

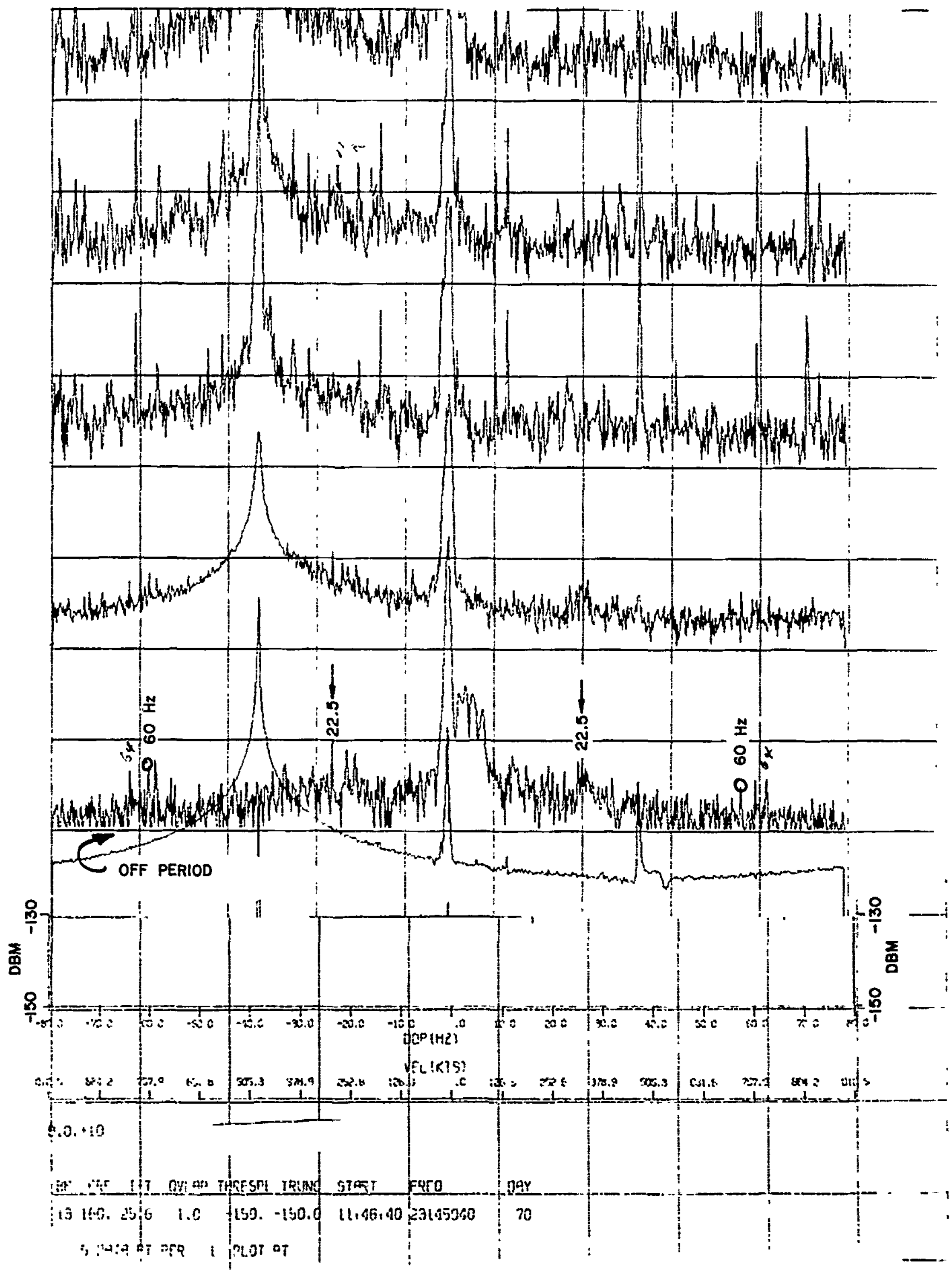
BM	PRF	I-T	OVLAP	THRESPL	TRUNC	START	FREQ	DAY
13	160.	25.6	1.0	-150.	200.0	20:48:24	23500000	11

5 DATA PT PER 1 PLOT PT

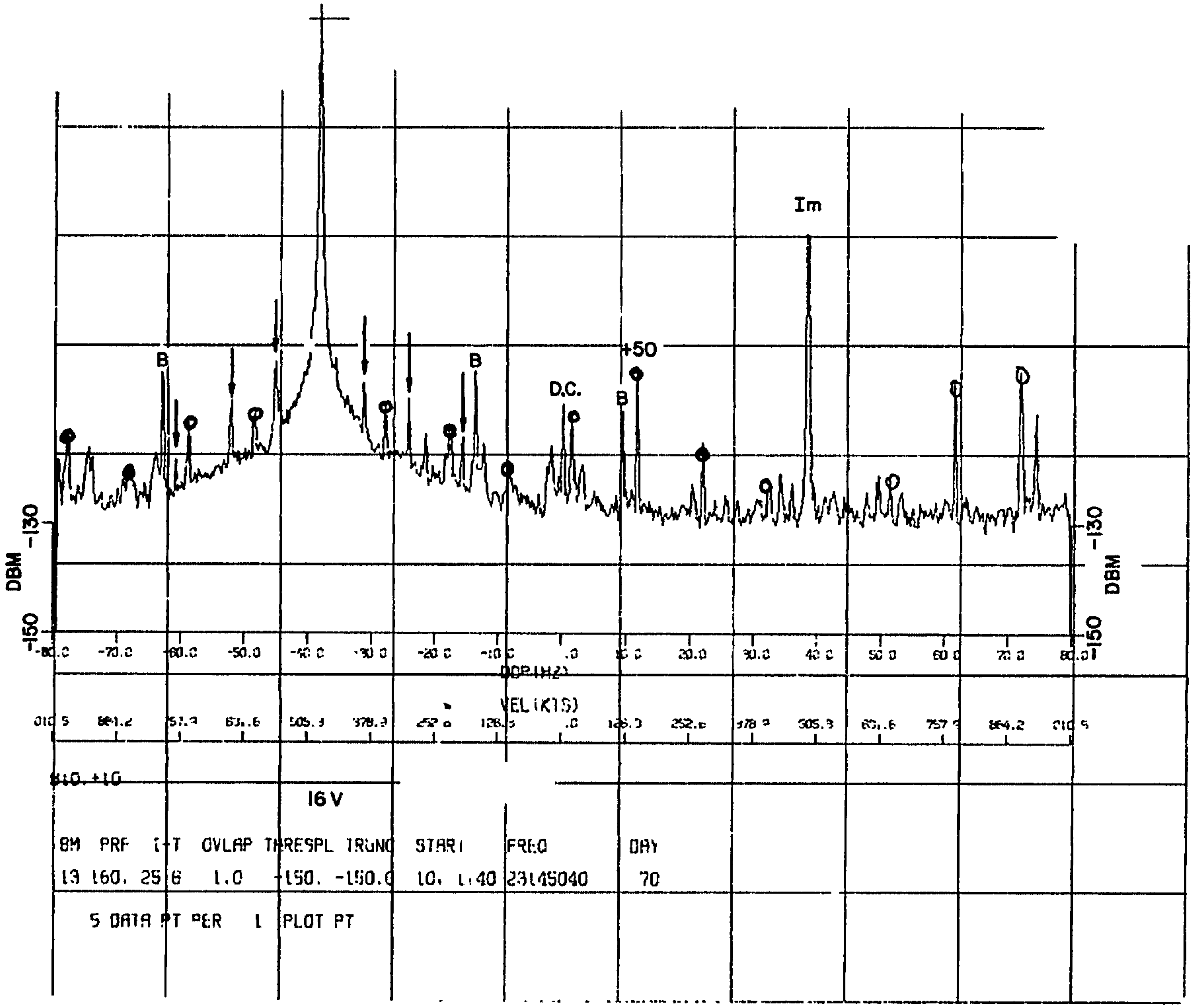
(U) Fig. 2 - Average Spectrum of Fluke Synthesizer into AN/FPS-95 Receiver at 23.5 MHz +10 Hz



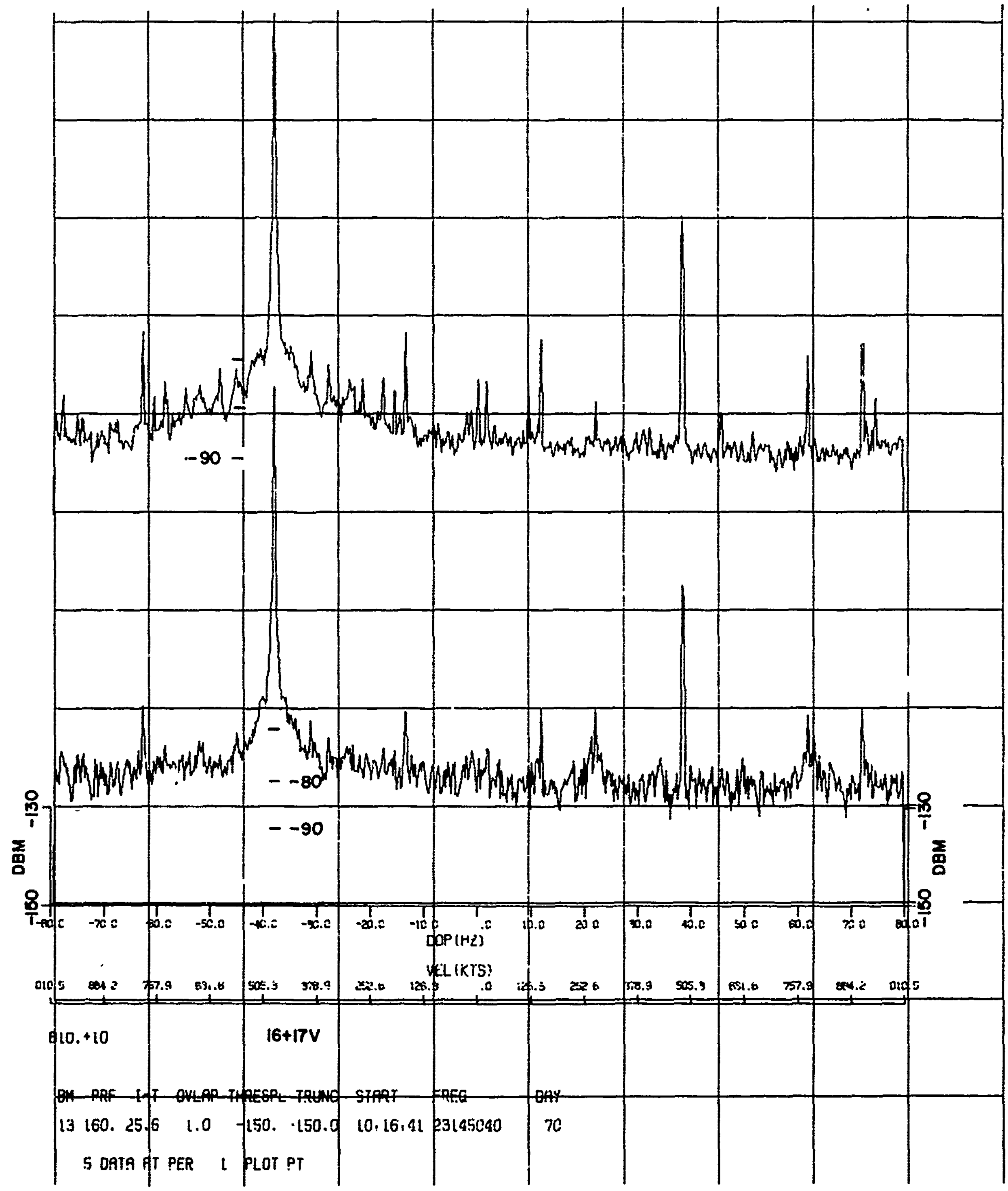
(U) Fig. 3 - Average Spectrum of COBRA SHOE Signal when received by test Yagi Antenna and processed by AN/FPS-95 Receiver



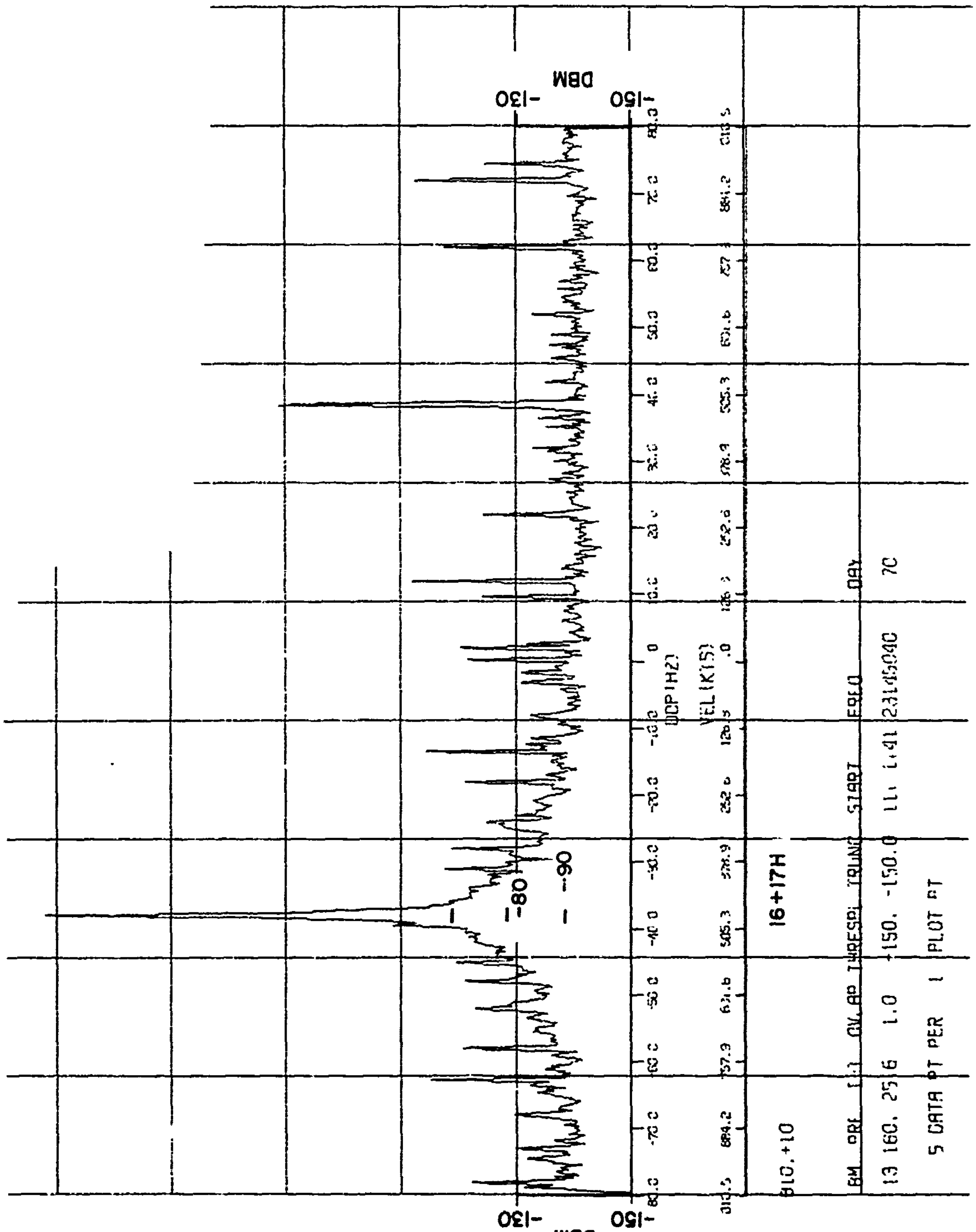
(U) Fig. 4 - Consecutive Spectra of AN/FPS-95 Transmitted Signal in Presence of Received COBRA SHOE Signal



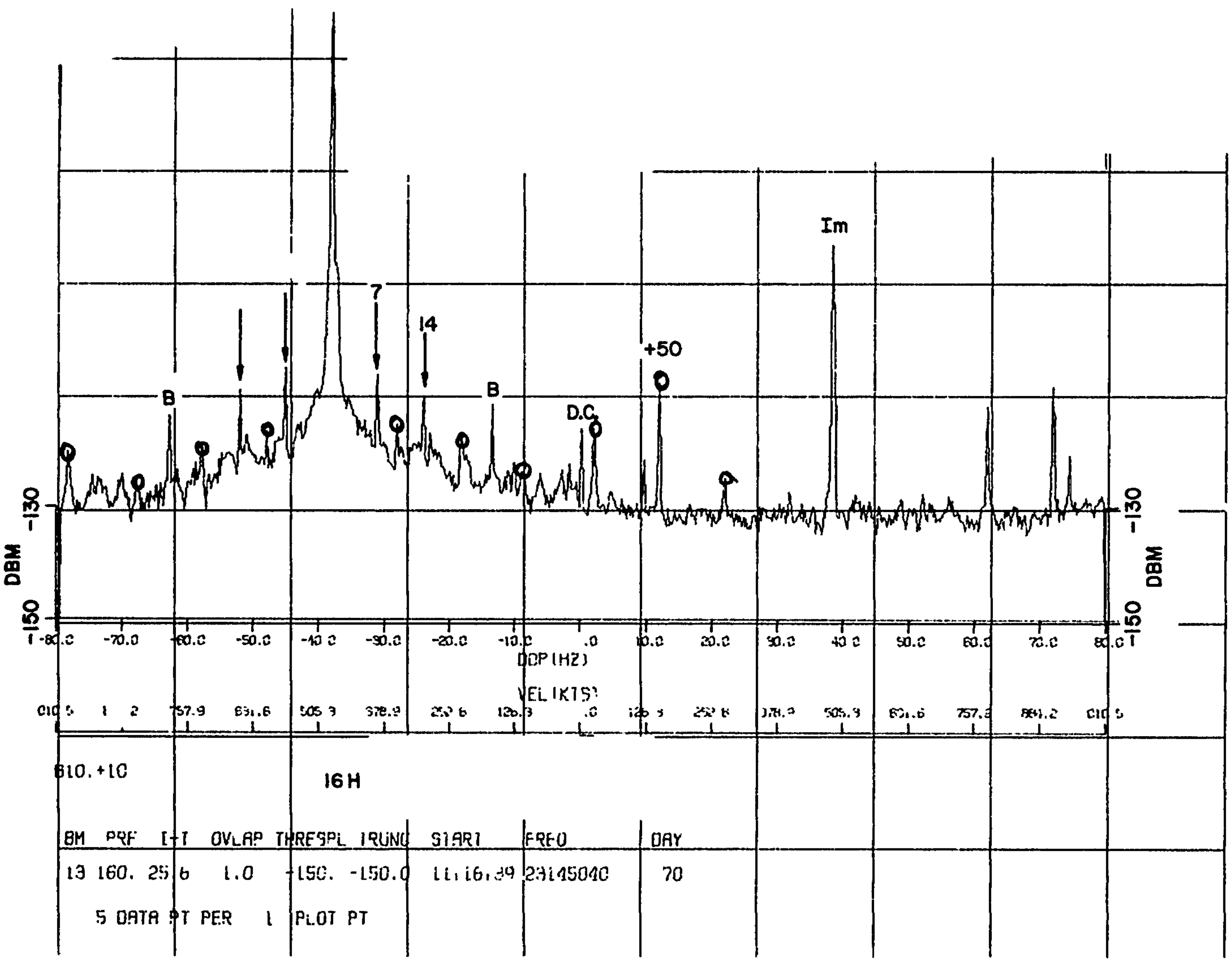
(U) Fig. 5 - Average Spectrum of COBRA SHOE Signal when received on String 16 of AN/FPS-95 System Antenna (Vertical Polarization)



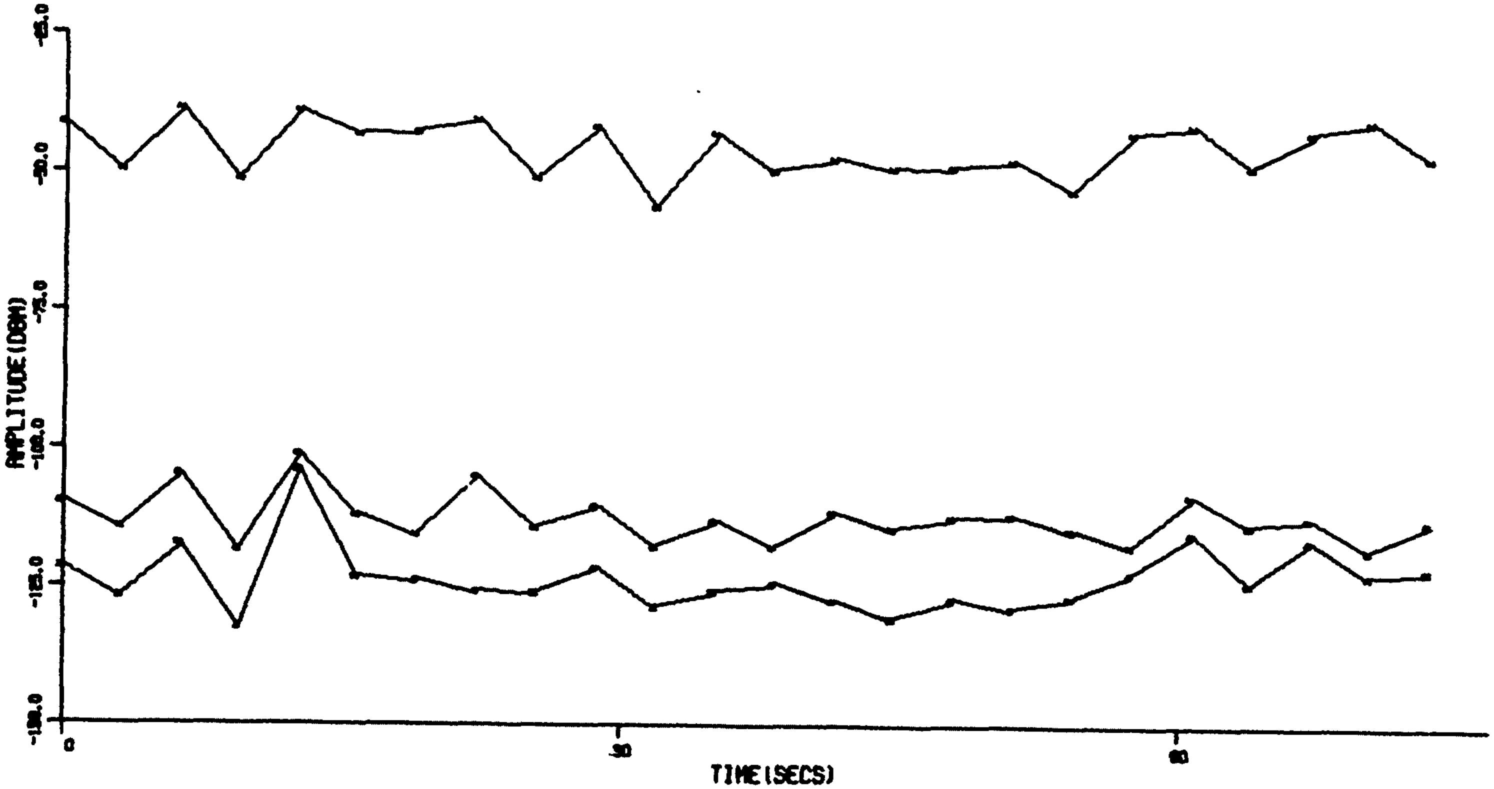
(U) Fig. 6 - Average Spectrum of COBRA SHOE Signal when received on Strings 16 and 17 (combined) of AN/FPS-95 System Antenna (Vertical Polarization)



(U) Fig. 7 - Average Spectrum of COBRA SHOE Signal when received on Strings 16 and 17 (combined) of AN/FPS-95 System Antenna (Horizontal Polarization)

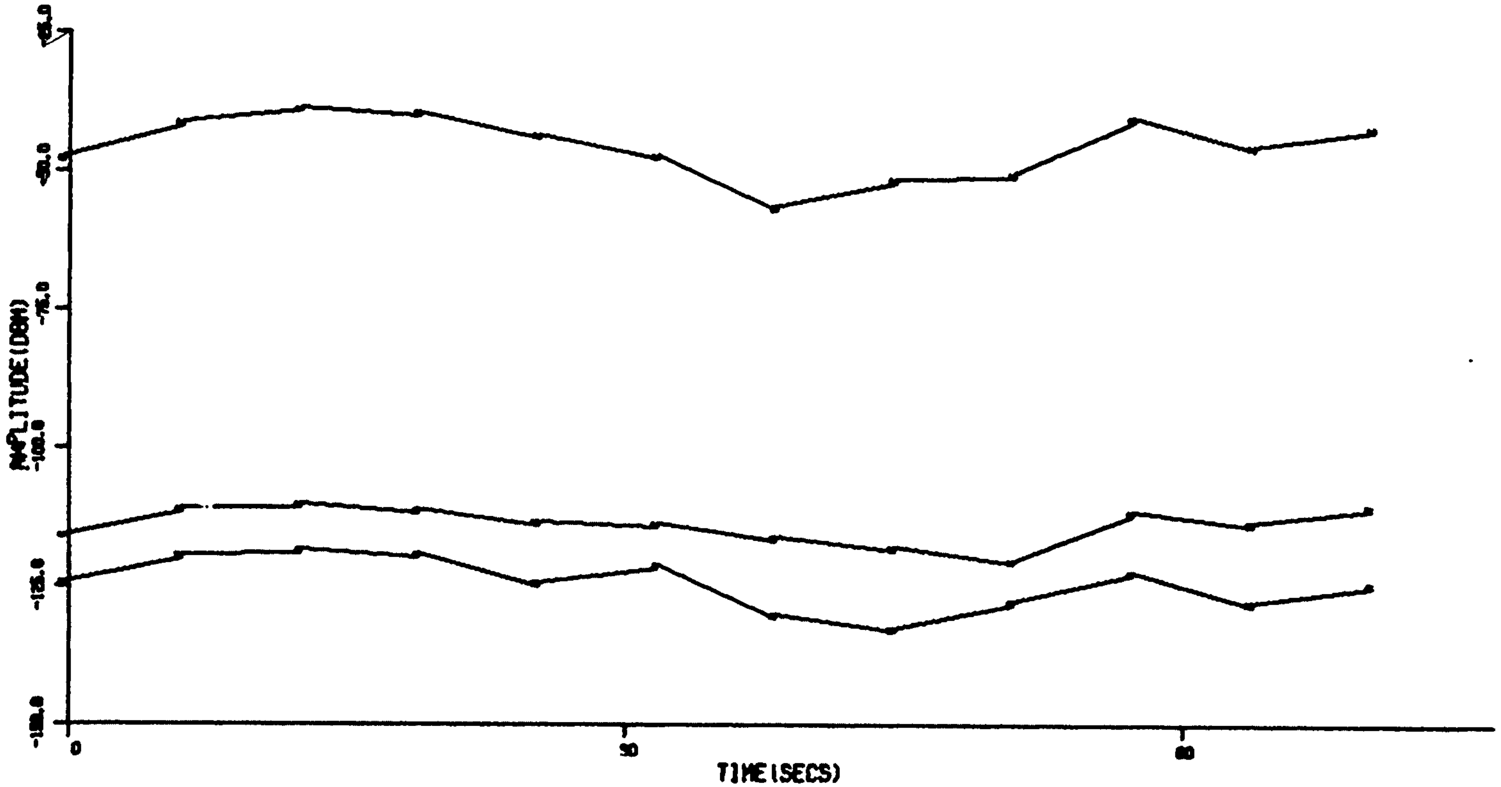


(U) Fig. 8 - Average Spectrum of COBRA SHOE Signal when received on String 16 of AN/FPS-95 System Antenna (Horizontal Polarization)



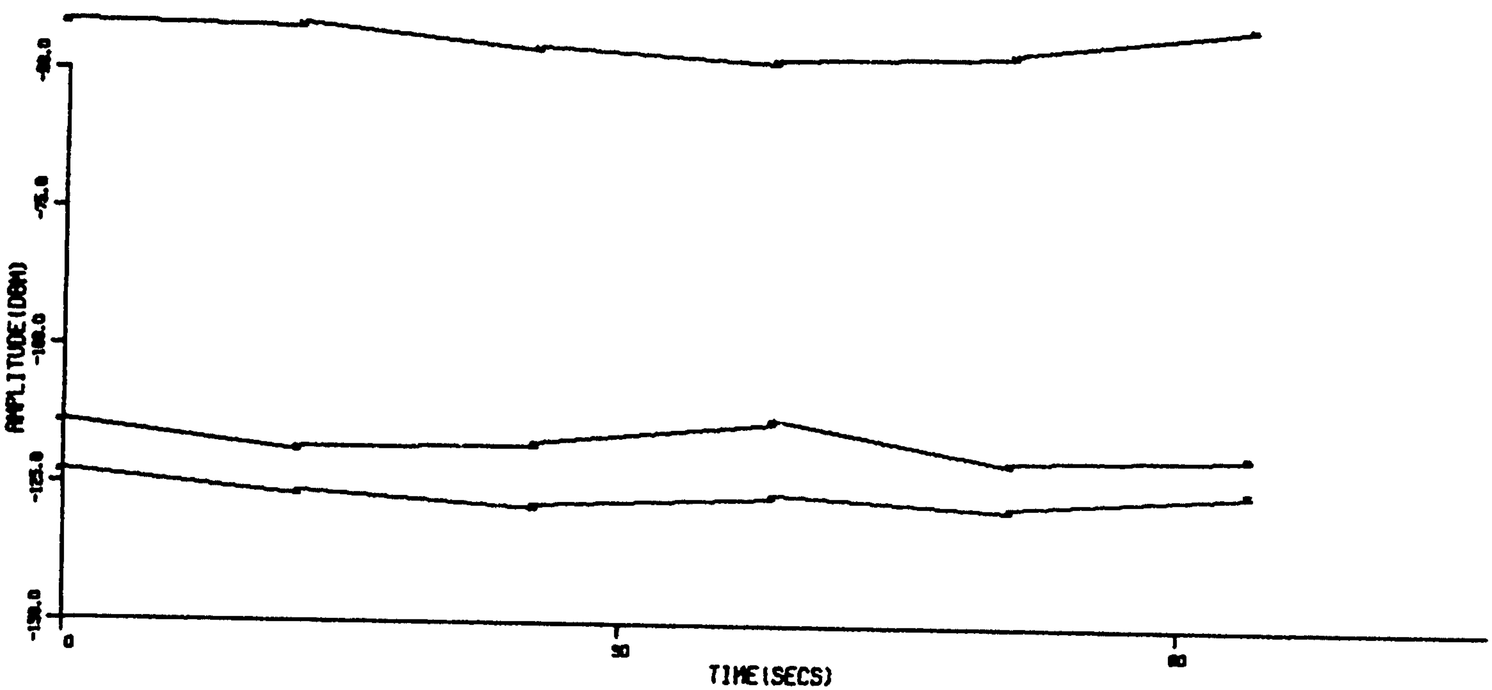
HZ1,2	BM,DAY	BIN	FULLWIDTHS	I.T.	FREQUENCY	TIME	S MEAN	VAR
-35.0,-45.0	13 70	10	0 70 75 80	3.2	23145040	10:16:18	-43.6	5.31
-34.0,-32.0	CORFNS= .70-.59-.46 .83			TMNRMS=-110.9		TVAR= 5.1	S/RMS=	67.3
-21.0,-19.0	CORFNS= .74-.76-.63 .88			TMNRMS=-118.4		TVAR= 8.6	S/RMS=	74.8

(U) Fig. 9 - Time History of Peak Signal Amplitude of COBRA SHOE Signal when received on Strings 16 and 17 (combined) of AN/FPS-95 System Antenna (Integration Time = 3.2 sec.)



HZ1,2	BM,DAY	BIN	FULLWIDTHS	I.T.	FREQUENCY	TIME	S MEAN	VAR
-35.0,-45.0	13 70	10	0 70 75 80	6.4	23145040	10:16:21	-43.3	5.81
-34.0,-32.0	CORFNS= .84-.61-.61 .84			TMNRMS=-114.5		TVAR= 3.0	S/RMS=	71.2
-21.0,-19.0	CORFNS= .87-.66-.67 .91			TMNRMS=-123.7		TVAR= 4.7	S/RMS=	80.4

(U) Fig. 10 - Time History of Peak Signal Amplitude of COBRA SHOE Signal when received on Strings 16 and 17 (combined) of AN/FPS-95 System Antenna (Integration Time = 6.4 sec.)



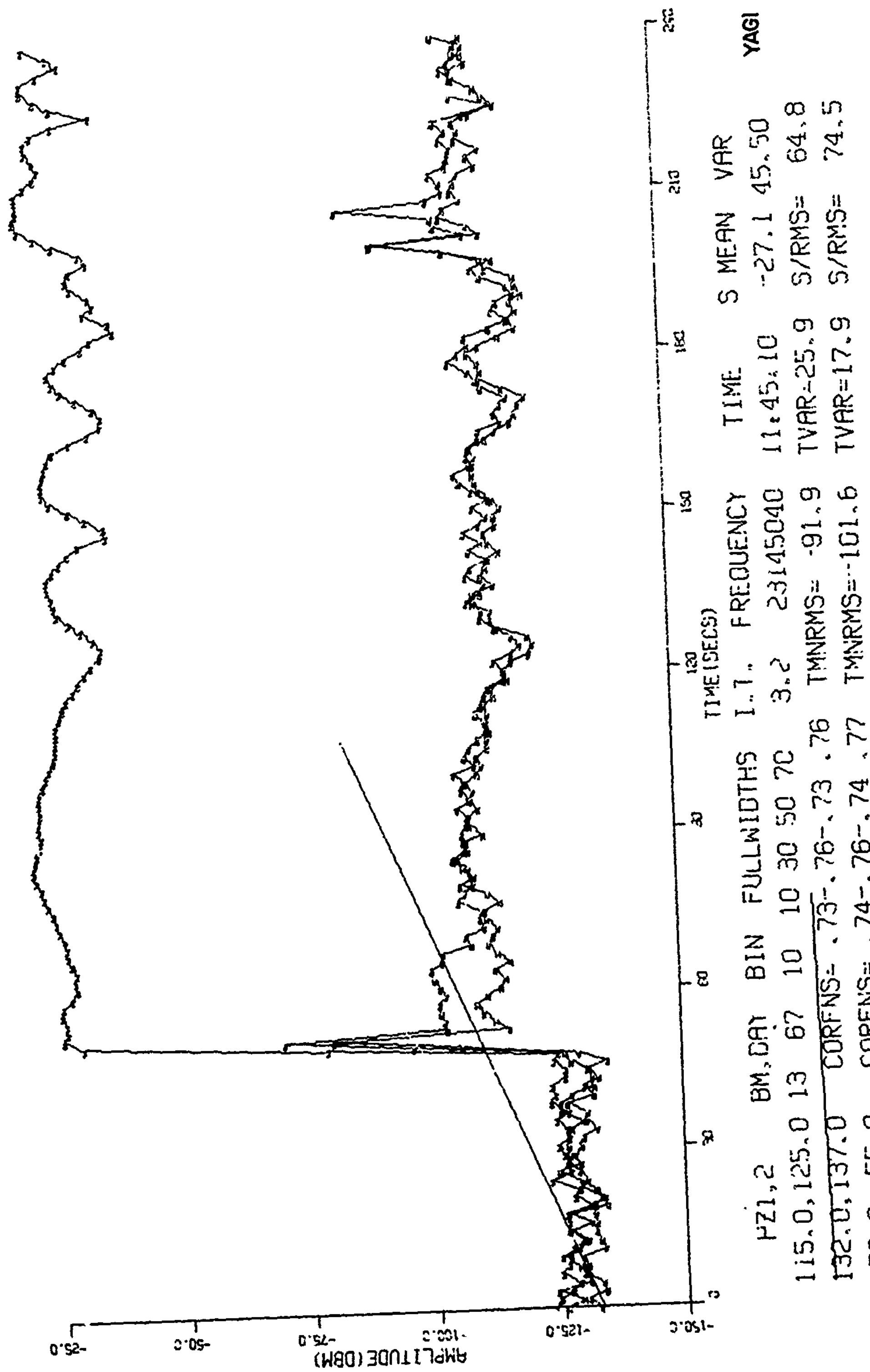
HZ1.2 BM.DAY BIN FULLWIDTHS I.T. FREQUENCY TIME S MEAN VAR

-35.0,-45.0 13 70 10 0 70 75 80 12.8 23145040 10:16:28 -43.6 2.74

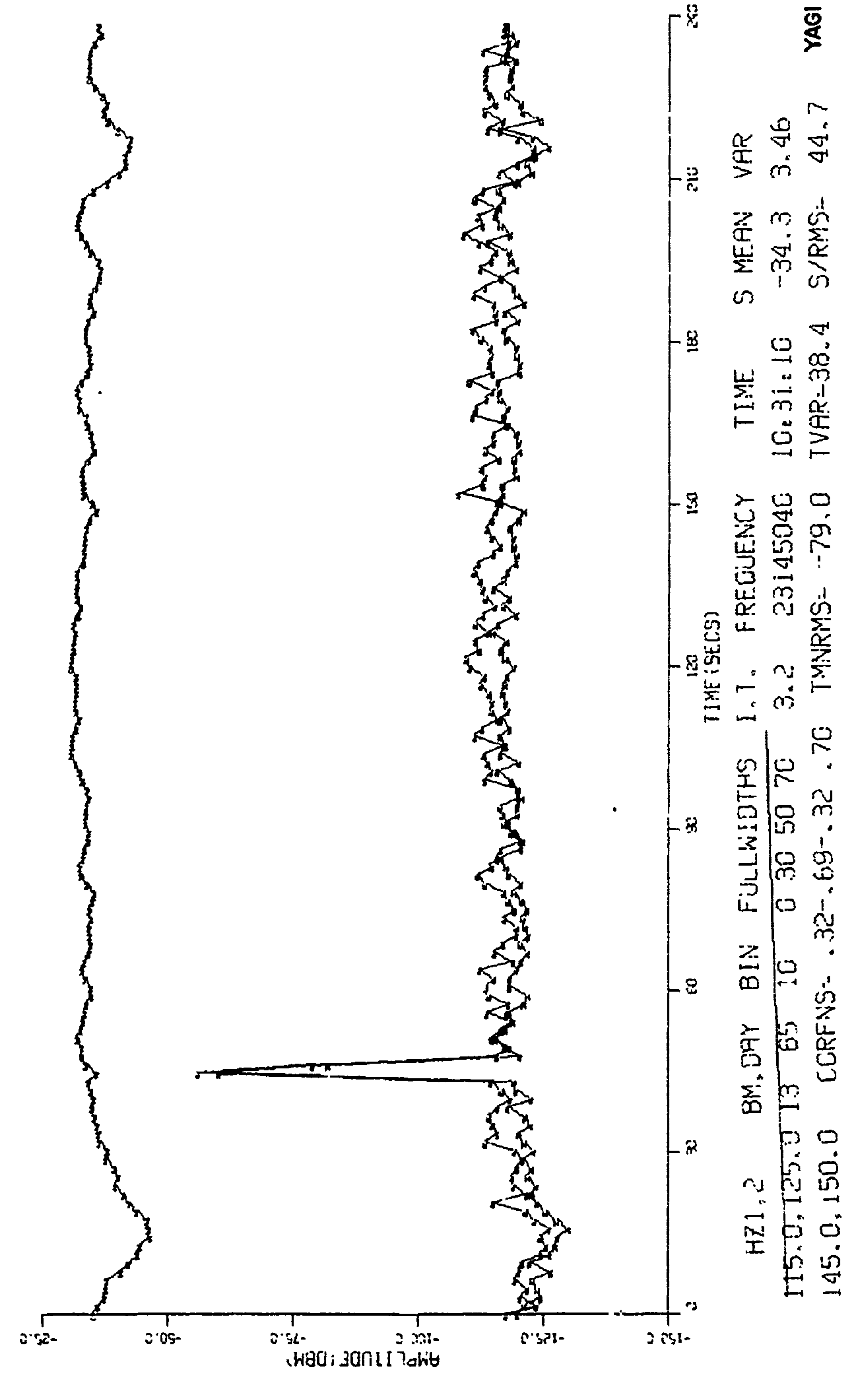
-34.0,-32.0 CORFNS=-.08-.17-.37 .91 TMNRMS=-117.2 TVAR= 2.9 S/RMS= 73.6

-21.0,-19.0 CORFNS= .69-.33-.25 .77 TMNRMS=-127.3 TVAR= 1.8 S/RMS= 83.8

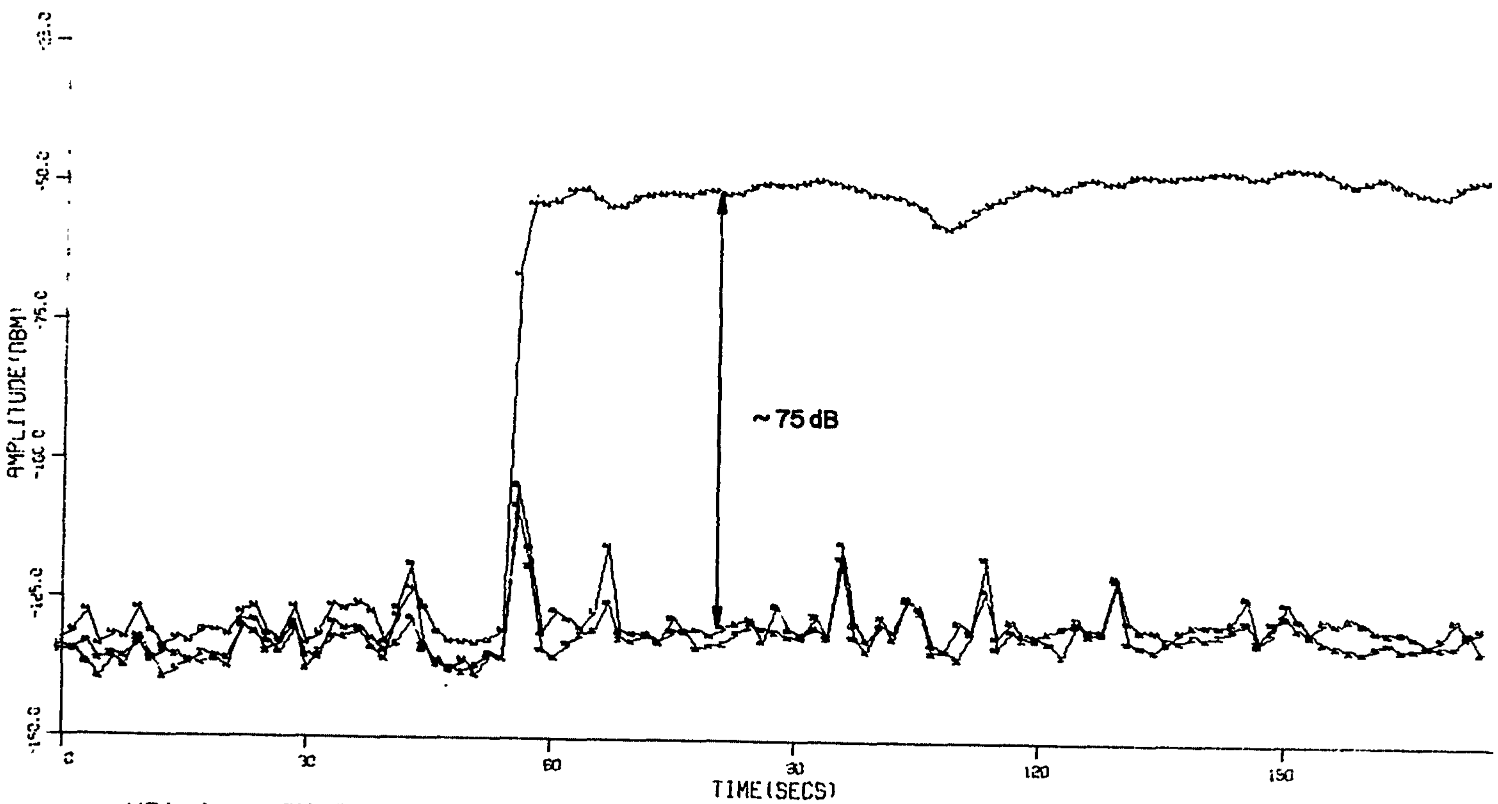
(U) Fig. 11 - Time History of Peak Signal Amplitude of COBRA SHOE Signal when received on Strings 16 and 17 (combined) of AN/FPS-95 System Antenna (Integration Time = 12.8 sec.)



(U) Fig. 12 - Time History of Peak Signal and Noise as Measured on Yagi Test Antenna with Key Break at Start



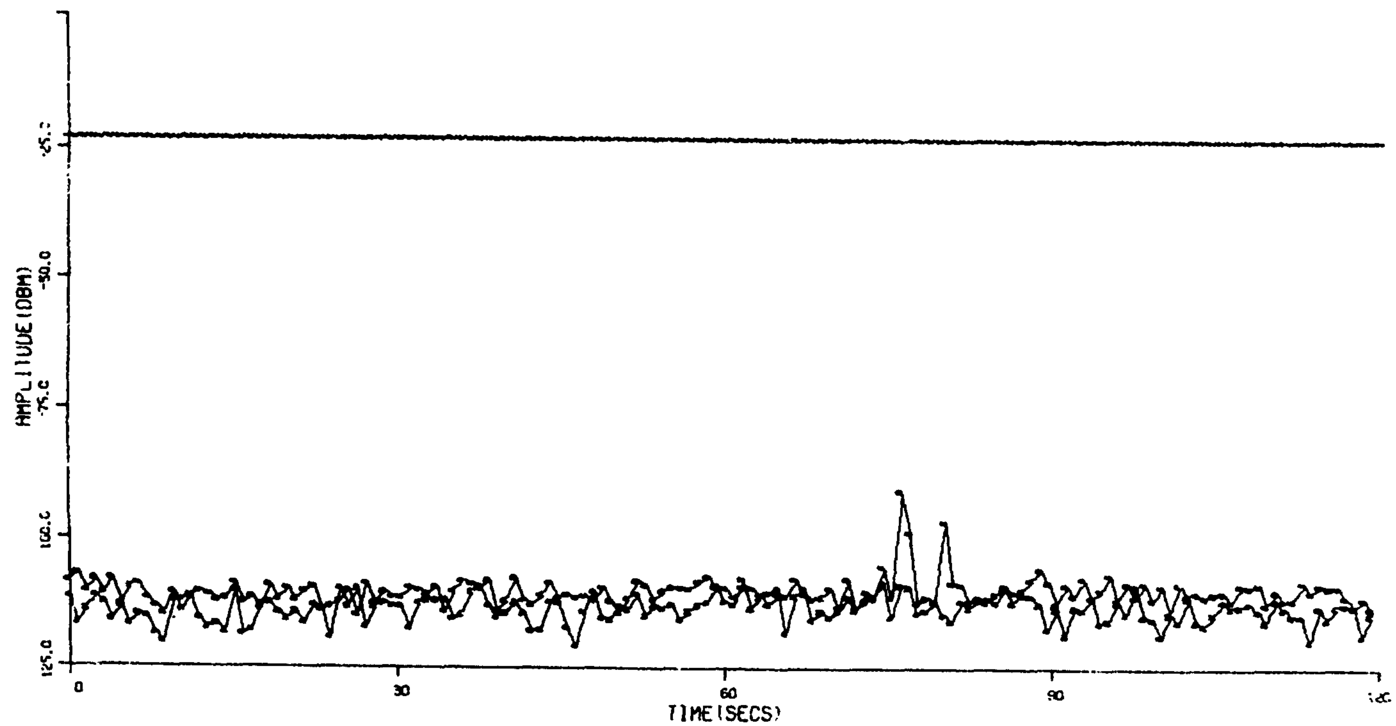
(U) Fig. 13 - Time History of COBRA SHOE Signal as Measured on Yagi Test Antenna



HZ1,2	BM,DAY	BIN	FULLWIDTHS	I.T.	FREQUENCY	TIME	S MEAN	VAR
115.0,125.0	13 65	10	0 30 50 70	3.2	23145040	11,45, 3	-51.5	44.58
145.0,150.0	CORFNS=		.71-.74-.72 .75	TMNRMS=-123.2		TVAR=10.0	S/RMS=	71.6
45.0, 55.0	CORFNS=		.63-.66-.67 .70	TMNRMS=-126.1		TVAR= 8.3	S/RMS=	74.6

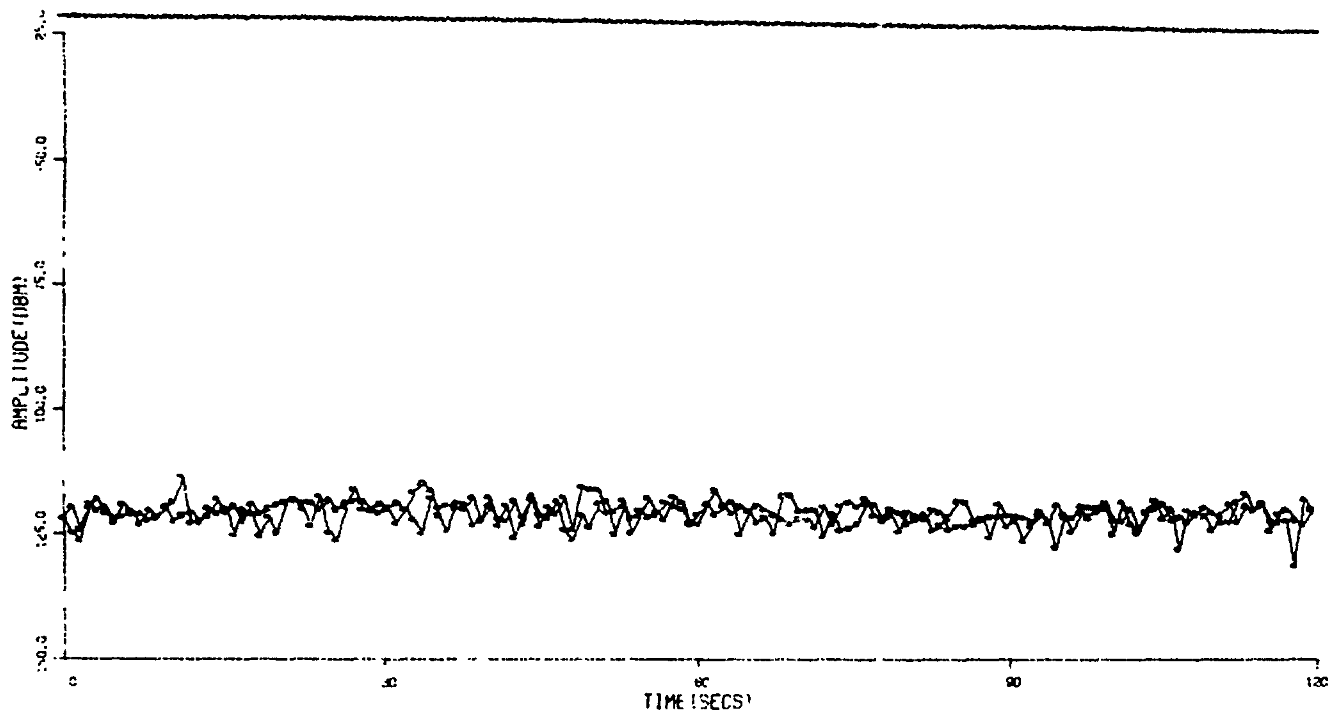
16H

(U) Fig. 14 - Time History of Noise and Peak COBRA SHOE Signal as Measured by String 16 of AN/FPS-95 Antenna



HZ1,2	BM,DAY	BIN	FULLWIDTHS	I.T.	FREQUENCY	TIMF	S MEAN	VAR
5.0, 15.0	13	11	3 10 30 50 70	.8	23500000	21: 6:30	-23.2	.00
-14.0, -19.0	CORFNS=-.06-.54 .01 .60			TMNRMS=-108.2		TVAR= 4.3	S/RMS=	84.9
-66.0, -61.0	CORFNS=-.12-.36 .06 .61			TMNRMS=-114.2		TVAR= 2.7	S/RMS=	91.0

(U) Fig. 15 - Time History of Hewlett Packard Synthesizer Signal

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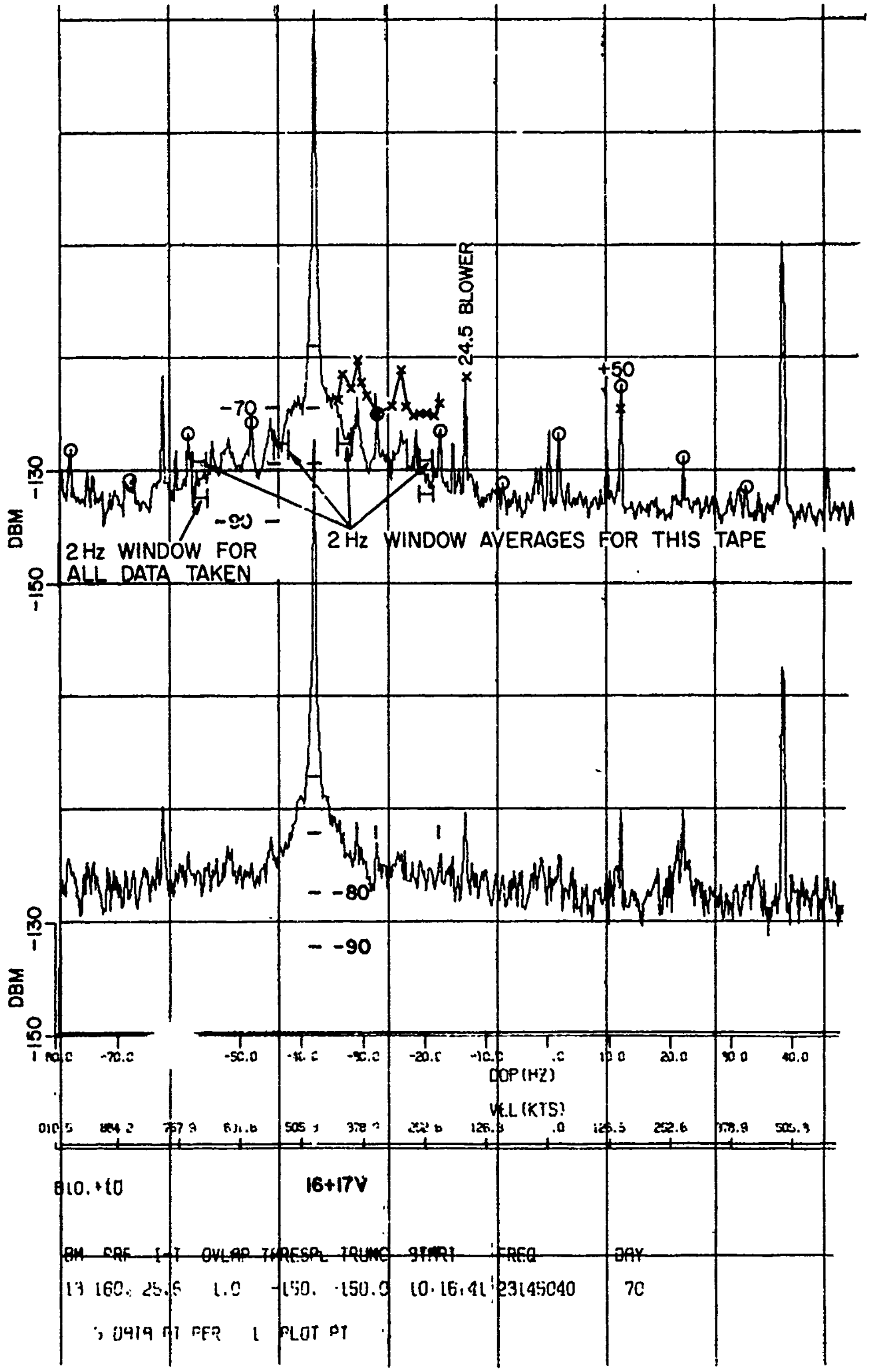
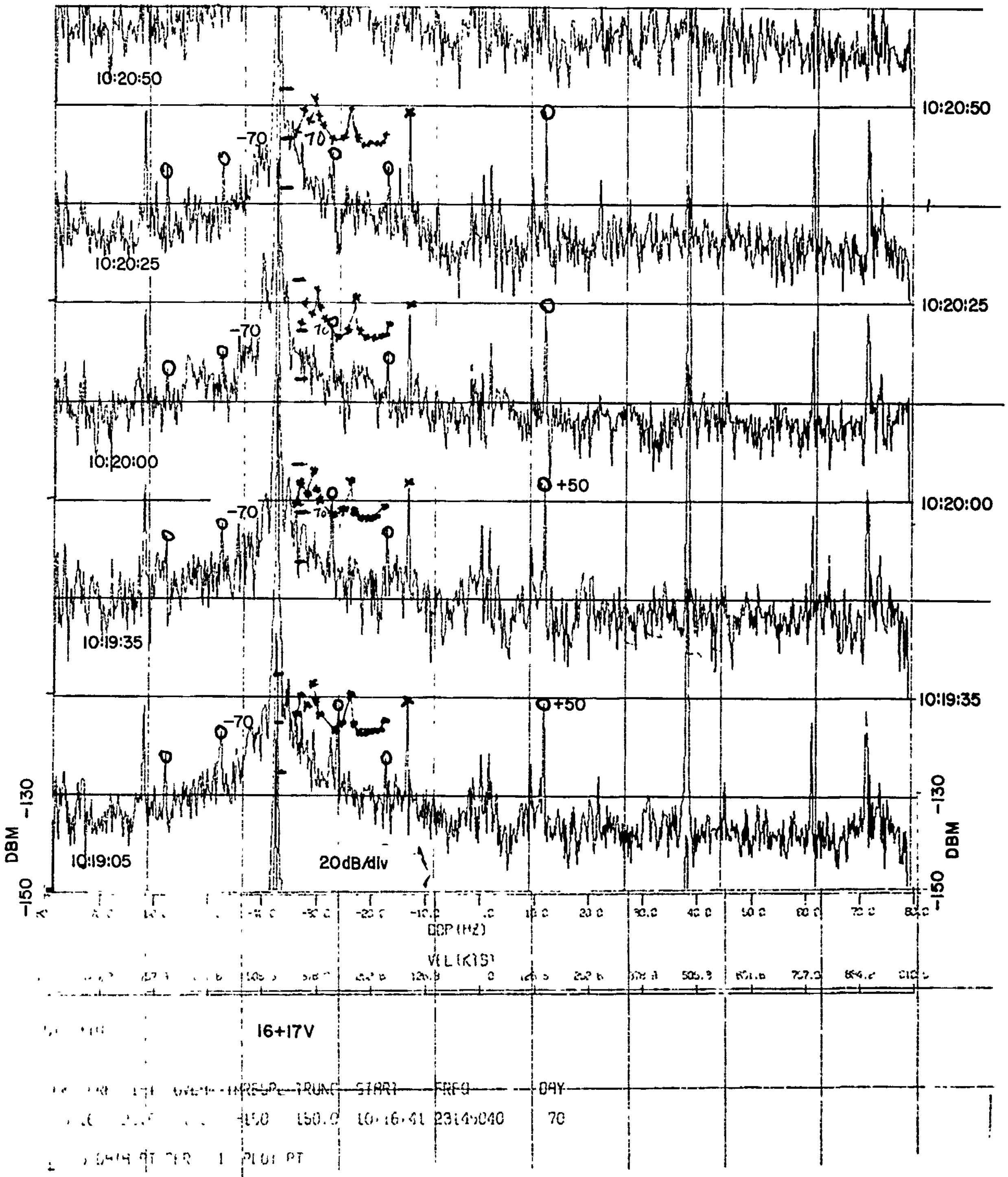
HZ1,2     BM,DAY  BIN  FULLWIDTHS  I.T.  FREQUENCY    TIME      S MEAN  VAR
5.0, 15.0 13  11    3  10 30 50 70    .8  23500000  20:50: 0    -21.7   .00
-14.0, 13.0   CORFNS=-.15-.26 .07 .67  TMNRMS=-121.0  TVAR= 2.6  S/RMS=  99.3
-66.0, -61.0  CORFNS=-.01-.12 .04 .62  TMNRMS=-121.1  TVAR= 2.3  S/RMS=  99.4
```

(U) Fig. 16 - Time History of Fluke Synthesizer Signal



(U) Fig. 17 - Average Spectra of COBRA SHOE Signal



(U) Fig. 18 - Time Consecutive Spectra of COBRA SHOE Signal

APPENDIX 1
FIELD MEASUREMENTS OF LINE-OF-SIGHT AND IONOSPHERIC HF TRANSMISSIONS

SUMMARY

(S) The S/N ratios of the AN/FPS-95 (COBRA MIST or CM) OTH and COBRA SHOE (CS) LOS signals were measured using the MITRE van equipment, with the CM signal being found to be clean down to the measurement equipment capabilities for all of the CM antennas. The CS signal was found to be less clean with the hum and blower lines present. The measurement data is questionable due to certain effects such as test antenna noise due to wind modulation not being seen during high wind conditions at the test site. Also, the noise of the CM and CS signals was not observed to decrease away from the carrier as one would expect. The test equipment requires validation in parallel with the CM receiver (same antenna) to provide credibility to the Cyprus measurements. Any future measurements should include a full dynamic range data recording capability. Also the equipment employed for future testing should be upgraded whether it is an improved version of the existing equipment or a new configuration.

INTRODUCTION (U)

(S) 1. This report is written to provide an input from the RADC representative present on the Cyprus measurements team. The tests were conducted during the period of 6 to 11 March 1973 with the following personnel participating:

Mr. William Talley	MITRE
Mr. Robert Wall	MITRE
Mr. Richard Coyle	MITRE
Mr. James Runkle	MITRE
Mr. Douglas Lee	SRI
Mr. John Schneider	RADC

The MITRE personnel conducted the measurement program using the MITRE equipment located within the van. Additional measurements were made using other equipment obtained in Cyprus.

PURPOSE (U)

(S) 2. The Cyprus experiment was initiated and conducted to measure signal-to-noise characteristics of the one-hop COBRA MIST (CM) signal in the pulse mode and of the line-of-sight COBRA SHOE (CS) CW signal. Secondary information such as signal strengths, fading characteristics, and Faraday rotation phenomena were to be observed. The third objective was to operate a delay line repeater on the CM signal so that the returns could be observed with the CM equipment.

BACKGROUND (U)

(U) 3. The CM system has demonstrated a detection capability significantly below expectations during a majority of the time. These expectations are based primarily upon the system design and to a lesser extent on the performance of existing comparable systems. The reduced capability has been traced to the clutter-related noise being higher than anticipated. The CM equipment within the building has been tested numerous times and shown to exhibit qualities which should provide consistent superior detection capability to that observed. This suggests that there are problems in the antenna system (including RF hardware) and/or some unknown or unobserved phenomena occurring in the signal propagation path including the reflection and scattering characteristics. The system capability at different times might be degraded by different and/or unrelated problems or phenomena which make individual isolation difficult due to each being an intermittent condition.

(U) 4. A number of theories have been advanced during the past year concerning the origin of the clutter-related noise. Two high level committees were established to study the situation and make recommendations. Several noted individuals and teams have been employed as consultants to aid in isolating the cause or causes of the problem.

(S) 5. The Cyprus tests were designed first to provide a measure of the signal-to-noise characteristics of the one-hop signals radiated by the CM vertically and horizontally polarized log periodic and horizontally polarized Yagi antennas to determine if there are any differences and/or any degradation due to the path. Secondly, the tests were to measure the signal-to-noise (S/N) characteristics of the line-of-sight CS CW carrier in the direction of propagation to the CM site. 23.145 MHz was chosen as the test frequency in order to have a reliable one-hop path during the daytime hours between England and Cyprus.

(S) 6. The receiving and measurement equipment (the van) used in the Cyprus experiment was first brought to the CM site and its operation verified by validation against certain signals of known characteristics. The van equipment was demonstrated to be capable of measuring S/N ratios of greater than 80 dB with the 0.02-Hz resolution and greater than 70 dB with 0.2-Hz resolution. Calm wind conditions were required to achieve these levels, as there was a significant contribution to the noise from antenna vibration and movement.

(U) 7. As part of the equipment validation, the van was taken about 8 miles north of the CM site to the Dunwich Heath area. Here the CM signal was received and S/N measurements made. Wind conditions prevented achieving acceptable S/N levels, presumably due to antenna vibrations. It is not known whether the noise was introduced primarily by the CM antenna or the van antenna. Retesting on a relatively calm day did show the CM signal to be noise free down to the measurement capability of the van equipment.

(S) 8. The van equipment was not compared with the CM system receiver due to a lack of time before the equipment had to be shipped to Cyprus. This comparison was considered essential by RADC before the equipment could be considered fully validated, and a recommendation to this effect was made to the ESD SPO and the CM Mission Director.

MEASUREMENT SITE (U)

(S) 9. The van location was specifically selected to be LOS with the CS site at Akrotiri and on approximately the same azimuth and elevation bearing as signals propagating to the CM site. The van was positioned at the Earth Station, a satellite terminal, on the Episkopi Souvereign Base about 8 miles distant from the CM site and with an elevation of about 900 feet above the CS site. The van was located directly between two large, closely spaced radomes, each with a metallic framework and housing a C-band microwave satellite antenna. A half-wave horizontal dipole antenna tuned to the test frequency was mounted about 20 feet above the ground on a wooden pole located approximately midway between the radomes on a line tangent to the radome edges. The Beverage antenna was installed beside one of the radomes, oriented toward the CM site. Some of the Lorch receiver measurements were made using an aluminum scaffold approximately 20 feet in height, located within one of the radomes, as an antenna. This antenna was employed on very windy occasions and when the horizontal dipole was not available due to being in use with the van.

TESTING (U)

(U) 10. The following CM schedule was established prior to beginning the tests so that the measurements could be accomplished with a minimum of communication between the CM and test sites:

0830 - 0930Z	Repeater with CM 23.145 MHz
0930 - 1000Z	CS set up on 23.145 MHz
1000 - 1200Z	CS transmit CW 23.145 MHz - 1 min off, 14 min on and repeat
1200 - 1400Z	CM operate on 23.145 MHz, 160 PRF

The CM system operated with only one HPA operating into a single antenna string with about 18 dB gain and a horizontally polarized Yagi with approximately 22 dBi gain. The CM radiated signal for these tests was 10 to 15 dB below that typically used when employing all 6 HPA's and 6 antenna strings. The following CM antennas were employed in the order shown:

Tue - Fri	Sun
1200 - 1230Z Vert LPA	1200 - 1300Z Yagi
1230 - 1300Z Yagi	1300 - 1330Z Vert LPA
1300 - 1330Z Hor LPA	1330 - 1400Z Hor LPA
1330 - 1400Z Yagi	

(U) 11. The repeater was operated using one of the 1-MHz RF bandpass filters located within the van to limit the operational bandwidth. The HF RF environment at the test site was found to contain numerous strong signals. The filters did aid in reducing the unwanted signals, but there were always unwanted strong signals still passing through into the repeater.

(U) 12. The CM signal received at the test site was typically found to begin after the 0830Z schedule time. Also the effectiveness of the repeater as viewed at the test site appeared small due to other large signals consuming the repeater power. The repeater signal was detected by the CM system on one occasion. The repeater signal appeared to be very dirty, as would be expected due to the modulation products being generated within the repeater by other strong HF signals.

CYPRUS TEST RESULTS (S)

(S) 13. Attachment 1 contains the data obtained during the week of testing in Cyprus and is separated into two sections, the first being that related to CM and the second to CS. The photographs were all taken of the HP correlator at the completion of the integration period. The graticule markings were inserted by the camera and were not part of the display tube which allows some graticule variations between pictures. The numbers on the immediate left of the photographs refer to representative peak signal levels at the van receiver antenna terminals. Unrecorded amounts of gain were employed ahead of these terminals for the Beverage antenna. The numbers on the right of the photographs are measurement levels below that of the peak signal which was being attenuated in the notch. The 0.2-Hz resolution photographs display a frequency range of approximately 4 to 20 Hz in the raised portion of the curve. The frequency extent is much less in the .02-Hz resolution pictures, and the range was not recorded, and it has not been determined to date. It is thought by Mr. Wall that about 5 Hz are displayed.*

(U) 14. The CM measurements generally were power limited during 6 and 7 March which prevented observations below a S/N ratio of 70 dB, except in a few instances. Power limited means that there was insufficient gain in the van equipment as configured to bring the signal up to the maximum usable level. Measurements on 8, 9 and 11 March using the Beverage antenna consistently exhibited S/N ratios in the vicinity of 80 dB for all antennas employed for the CM transmissions. Amplification was added between the Beverage antenna and the van receiver antenna terminals due to the smaller signals received on the Beverage antenna and to overcome the power limit. Some measurements were made with the sampling gate set before and after the arrival of the main pulse to determine if related noise was varying with the time of arrival. This was intended to separate the effects of meteors, etc. It was found that the gate had insufficient isolation to block the main pulse signal, and the results are therefore of less value than if the gate had sufficient isolation.

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*It has been ascertained that 2 Hz were displayed. (DBT)

(U) 15. The early CS noise measurements (6 March) were limited by varying doppler sidebands generated by the many aircraft operating in the vicinity of the CS site. The testing was discontinued during the day and resumed during the evening of 7 March when the aircraft activity was decreased but still present. The evening measurement had minimum aircraft disturbance but was not during the portion of the day when propagation was possible to the CM site in the test frequency range. The remaining CS measurements were made on Sunday, 11 March, when the aircraft activity was low and propagation present to the CM site.

(U) 16. Some additional measurements were made of the CM and CS signals using a Lorch receiver (belonging to the CS site) having about 90-dB dynamic range in conjunction with a General Radio audio spectrum analyzer with a 1-Hz bandwidth. This equipment measures the average power passing through the 1-Hz filter as it scans through the frequencies of the PRF lines and the areas between. The sensitivity is reduced when analyzing pulse signals because of the power spreading among the numerous PRF lines. Also, the 1-Hz resolution bandwidth leaves something to be desired due to the excess width.

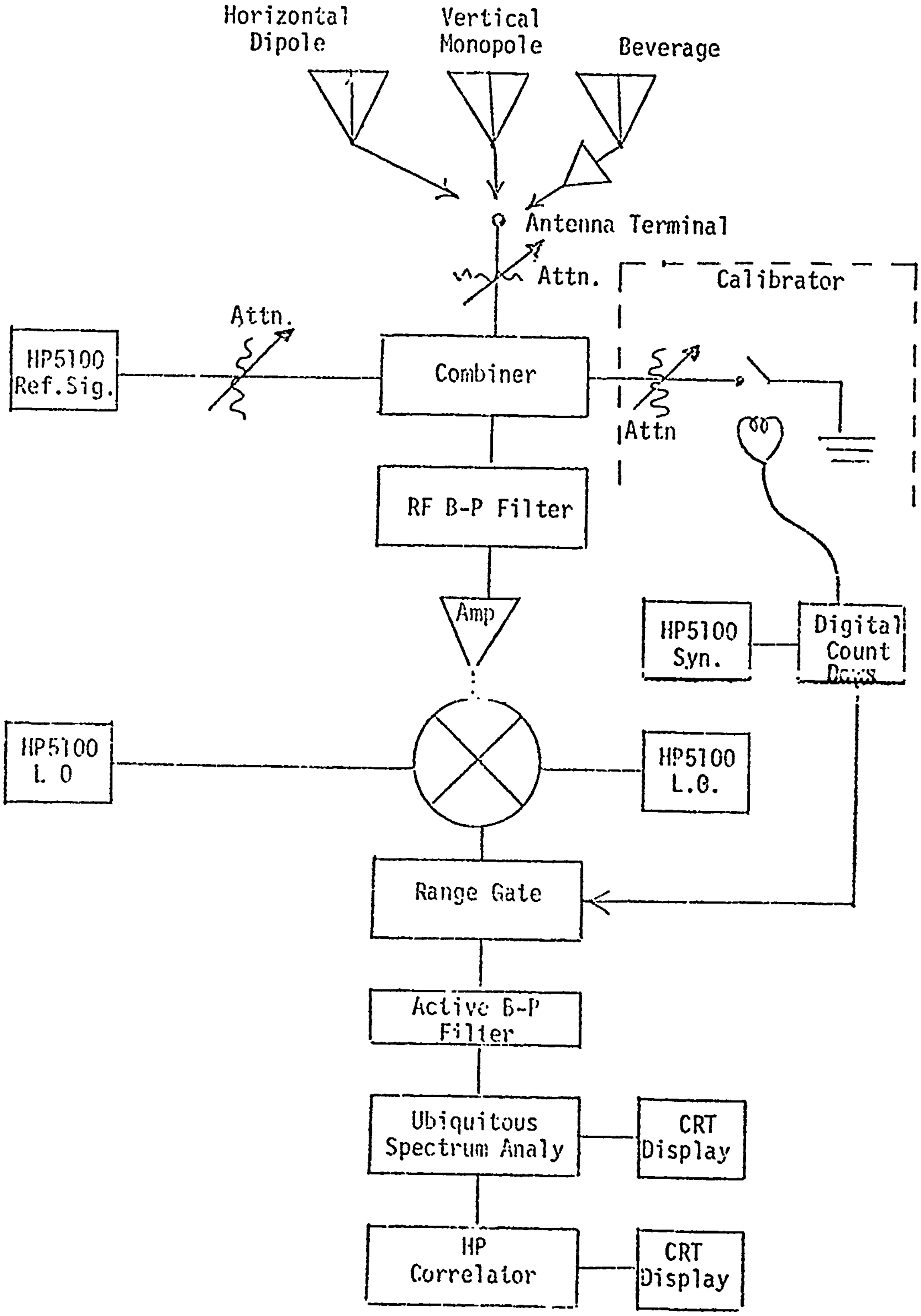
EQUIPMENT DESCRIPTION (U)

(U) 17. The van equipment consists of a vertical monopole antenna located on top of the van which can be tuned to the operating frequency by adjusting the length of the element, a combiner which combines the signal from the antenna with a reference signal and a calibrator signal, amplification, a local oscillator which mixes with the signal in the mixer, a gate which samples the signal during or between pulses, an active bandpass filter to notch out the carrier, a spectrum analyzer with display, and a correlator with display.

(U) 18. The combiner is employed to combine the attenuated input signal, the attenuated reference signal, and the calibration signal. The calibration signal is generated by coherently modulating the input signal by switching a small attenuation in and out. This creates coherent sidebands of known levels which can be positioned outside of the filter notch to give reference points. This provides a system calibration which is an absolute necessity when measuring S/N characteristics of fading signals located in the notch. The fading signal level within the notch could not be accurately determined without the calibration.

(U) 19. The RF bandpass filter actually consists of a number of filters in a bank, each with a passband of approximately 1 MHz. The desired filter in the range of 6 to 30 MHz is selected by connecting coaxial cables to its input and output terminals.

(U) 20. The range gate is provided to sample incoming signals during or between the pulses. The gate is accurately controlled by counting down



VAN EQUIPMENT BLOCK DIAGRAM

from the synthesizer reference frequency and can be set to PRF's which are binary multiples of 10 Hz. The gate width and delay can be set in increments of 50 μsec. The measurement system PRF is locked to the PRF of the pulse signal being received by adjusting the synthesizer to the frequency where the PRF's are equal. The delay is then adjusted to the correct amount and the measurements taken.

(U) 21. The active bandpass filter provides the capability to notch out the carrier and/or PRF lines of the signal being measured to prevent overloading of the spectrum analyzer. The frequency response of this filter is within 3 dB between 4 and 20 Hz. At least 80 dB attenuation is provided to frequencies below 2 Hz.

(U) 22. The Ubiquitous spectrum analyzer has only about a 50-dB dynamic range which is the reason that the notch filter is required. The analyzer provides 0.2-Hz and 0.02-Hz resolution with integration times of 10 and 100 seconds respectively. A logarithmic amplitude versus frequency CRT display is provided of the analyzer output on an oscilloscope.

(S) 23. An HP Correlator provides noncoherent integration to the spectrum analyzer output and displays it logarithmically on a storage CRT. All of the spectrum photographs taken during the measurement program in Cyprus were of the correlator display.

(U) 24. In addition to the van equipment, there were two auxiliary antennas employed during the testing. A half-wavelength horizontal dipole was mounted on a wooden pole approximately 20 feet above the ground. A four-element Beverage antenna was installed with the peak beam orientation toward the CM site. Additional gain was inserted between the Beverage antenna and the equipment antenna terminal to bring the signal level up sufficiently.

(U) 25. The van equipment was constructed during a short time period and did not have incorporated into it features to simplify operation. The actual measurements were very time-consuming and required a large amount of setup and adjustment time.

DISCUSSION OF RESULTS (U)

(U) 26. The CM measurements, when not power limited, exhibited S/N ratios approximating 80 dB for all CM antennas including the Yagi. The data were not extensive enough to assure that the CM is consistently clean, as it was taken in such a manner to accent larger S/N ratios. Lower S/N readings were considered to be a result of poor measurements and were disregarded to a large extent. There did not seem to be any correlation between wind conditions at the van measurement site and S/N ratios observed. Peak pulse signal levels were observed to be as high as +10 dBm on both the horizontal and vertical antennas. However, the CM signal was generally found to be in the -30 dBm range. Beverage antenna output signal levels were not recorded, because an unknown amount of amplification was inserted between the Beverage element combiner and the measurement equipment antenna terminals. It is known that the CM signal from the larger aperture Beverage was considerably below that of the horizontal dipole or the vertical monopole antennas.

(U) 27. Measurements made using the Lorch receiver on 6 March showed very large signal variations (as high as 30 dB) apparently due to Faraday rotation with a period of a few seconds. Fading was averaging about 5 dB with a period of slightly under 1 minute. The rotation variations were observed to be much less on the succeeding two days, 7-8 March.

(U) 28. The CM signal analyzed on the Lorch-GR equipment illustrated a power spectrum which tapered downward from the PRF lines. There were high level spikes which did not appear to repeat which could possibly be attributed to noise bursts or to aircraft activity. The noise typically dropped to a level of about 60 to 70 dB below the PRF line peaks. This level compares to 70 to 80 dB for 0.1-Hz resolution if the noise is considered to be relatively wide band. It is interesting to note that these measurements showed noise decreasing away from the PRF lines while the van equipment did not.

(U) 29. The same signal characteristic with noise level decreasing as the frequency departs from the carrier was noted with the CS signal. There were several repeatable spikes which are known to be hum and blower lines. Also, the large amount of aircraft activity resulted in many spikes which were not repeatable. The CS noise appeared to decrease to about 80 dB below the carrier as the distance from the carrier was increased. The hum and blower lines appeared to be about 60 dB below the carrier.

(U) 30. Gate leakage was found to be a problem when attempting to measure noise preceding or following the main pulse signal. The insufficient gate isolation masked any meaningful meteor data in this mode of operation.

CONCLUSIONS (U)

(S) 31. The CM signal, when measured by the van equipment, did not appear to have any noise down to the measurement capability of the equipment. This leads one to be suspect of the test equipment, including the antennas, because the measurements were made during windy conditions in Cyprus. Still, equipment validations were conducted under similar wind conditions between the horizontal and vertical test antennas without the addition of any apparent noise. This is contrary to the findings when validating the van equipment at the CM site prior to departing to Cyprus.

(U) 32. Both the CM and CS associated noise generally appeared to be flat across the measurement bandwidth. One would expect to observe a decreasing noise level as the frequency away from the signal increases. However, measurement limitations and folding could make the noise level appear more constant.

(U) 33. A close comparison between the CM logs and CM-received signal data (both CM and CS transmitted) with the Cyprus data is required to derive more meaning from the results.

(U) 34. The van equipment has not been validated in conjunction with the CM receiver by operating both on the same input signal and observing any differences in the noise data.

RECOMMENDATIONS (U)

(U) a. The van equipment should be validated in parallel with the CM system receiver using actual off-the-air signals. Simulated signals should be used in conjunction with those off the air to aid in making exact comparisons. Deliberate noisy signals could be employed to observe the comparison. This should be done whether or not the MITRE equipment is used further.

(U) b. The frequency coverage of the 0.02-Hz resolution photographs must be determined. It is feared that the small spectrum width makes the data of rather limited value because the full extent of interest was not measured and recorded.

(U) c. The influence of the nearby metallic radomes to the test antennas on the measurements made in Cyprus should be ascertained.

(U) d. A study should be initiated to determine if the 80-dB S/N measurement capability is sufficient to isolate one-way propagation abnormalities. The 80 dB consumed the complete dynamic range of the van equipment and greatly limited the measurement capability in fading conditions which always exist in OTH signals.

(U) e. The van equipment could be upgraded in a relatively short time by the addition of a lower noise figure RF amplifier, a cleaner local oscillator, and a better mixer. Still, other limitations than those already observed might arise which could limit the amount of improvement. Equipment improvement should only be initiated if it is desirable to conduct additional measurements.

(U) f. It may be advantageous to construct a completely new higher dynamic range measurement capability to conduct future measurements if they are deemed necessary.

(U) g. Any future measurements should incorporate a full dynamic range recording capability to save the data for off-line analyzing at the CM site to provide a more accurate comparison with site data.

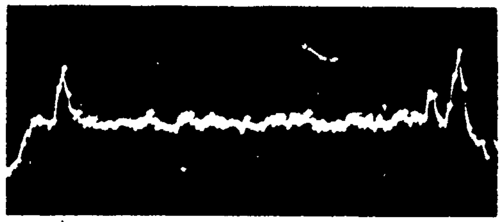
ATTACHMENT 1 - Section 1

COBRA MIST DATA

SECRET

6 March 1973
23.145 MHz
Monopole antenna
0.2 Hz resolution

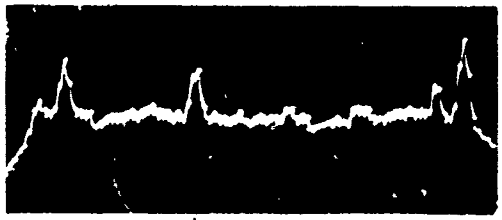
1. 1230Z
CM off



-92 dBm ref @ 5 Hz spurs

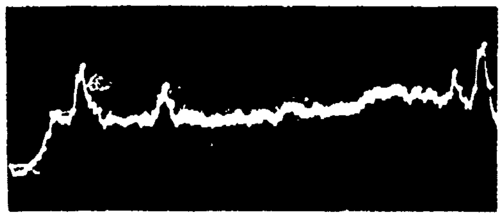
2. 1240Z
CM out of notch
CM xmit on yagi
CM signal -46 dBm

-40 dBm
-50 dBm
-60 dBm



CM atten 48 dB spurs
-92 dBm ref @ 5 Hz

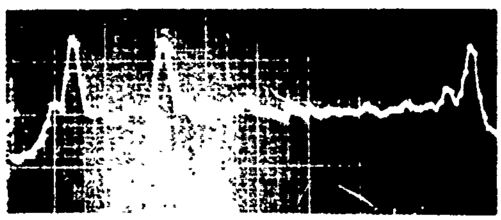
3. 1242Z
CM in notch
CM xmit on yagi
S/N 76 dB



-70 dB
-80 dB

-70 dB cal @ 8 Hz spurs
-92 dBm ref @ 5 hz

4. 1315Z
CM in notch
CM xmit on horiz LPA
S/N 64 dB



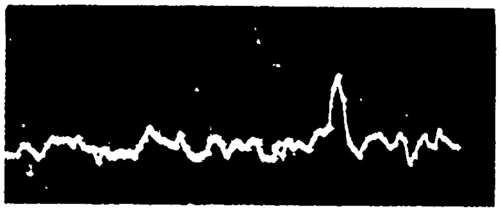
- 50 dB
- 60 dB
-70 dB

-50 dB cal @ 8 Hz spurs
-91 dBm ref @ 5 Hz

SECRET

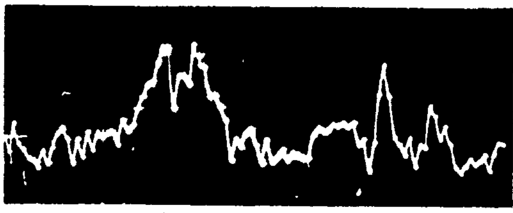
6 March 1973
23.145 MHz
Monopole antenna
0.02 Hz resolution

5. 1330Z
CM off



ref -112 dBm

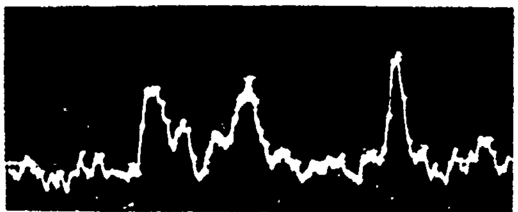
6. 1335Z
CM in notch
CM xmit on yagi
S/N 70-76 dB



-50 dB
-60 dB
-70 dB
-80 dB

54 dB cal
spur
ref -112 dBm

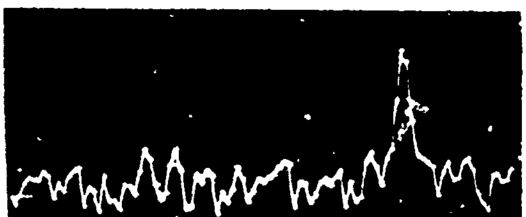
7. 1350Z
CM in notch
CM xmit on yagi
S/N 80 dB



-60 dB
-70 dB
-80 dB

64 dB cal
ref -112 dBm

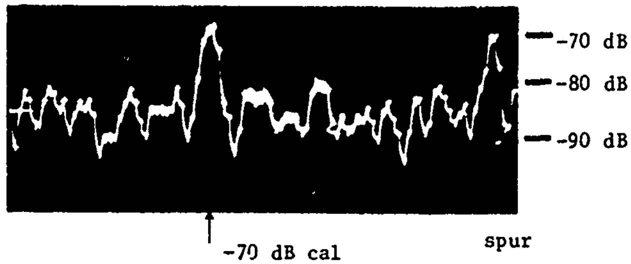
8. 1400Z
CM off



ref -112 dBm

6 March 1973
23.045 MHz
Monopole/dipole antennas
0.02 Hz resolution

9. 1420Z
Equipment validation
S/N 80-90 dB

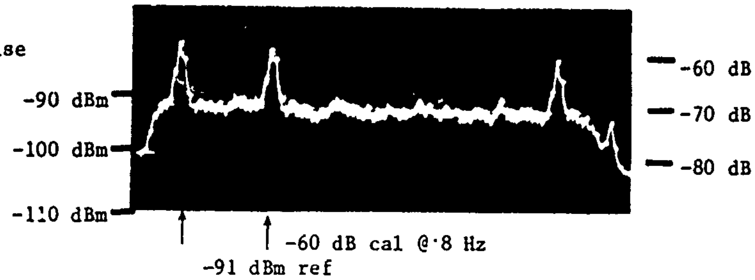


SECRET

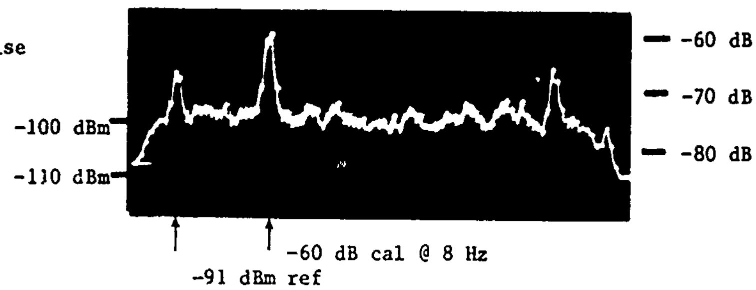
7 March 1973
23.145 MHz
Monopole antenna
0.2 Hz resolution

Antenna atten = 0 dB
CM in notch
CM xmit on yagi

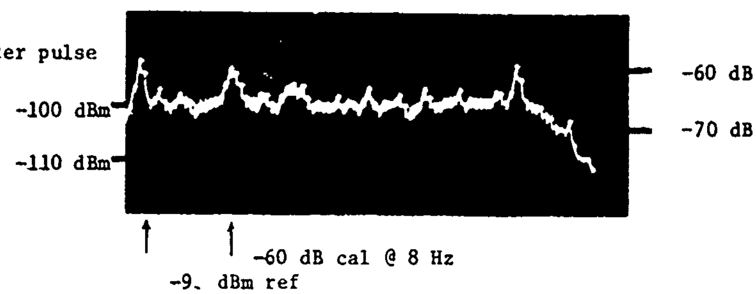
1. 1240Z
measure during pulse
S/N 70 dB



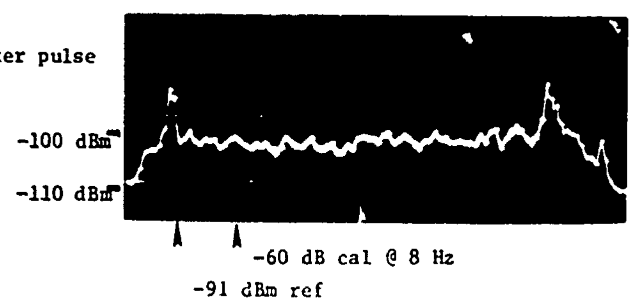
2. 1245Z
measure during pulse
S/N 75 dB



3. 1250Z
measure 150 ms after pulse
S/N 65 dB



4. 1252Z
measure 400 ms after pulse
S/N 60 dB



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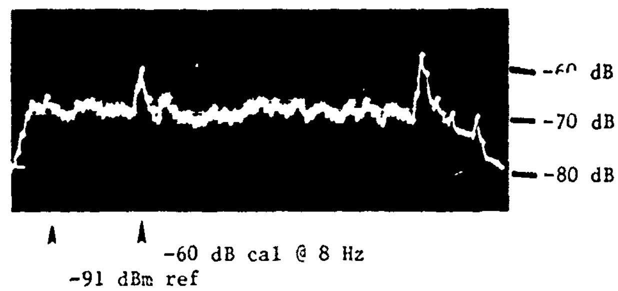
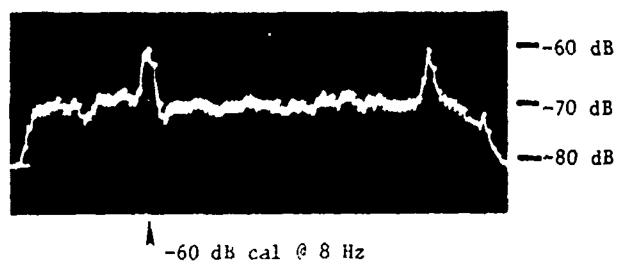
7 March 1973
23.145 MHz
Monopole antenna
0.2 Hz resolution

Antenna atten = 0 dB
CM in notch
CM xmit on yagi

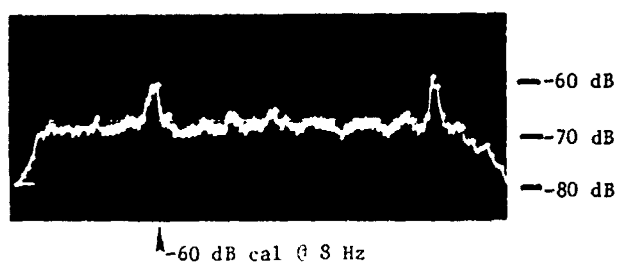
5. 1255Z
measure 150 ms before pulse



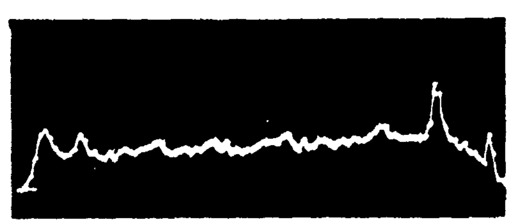
6. 1258 Z
measure during pulse



7. 1259Z
measure 150 ms after pulse



8. 1300Z
CM off



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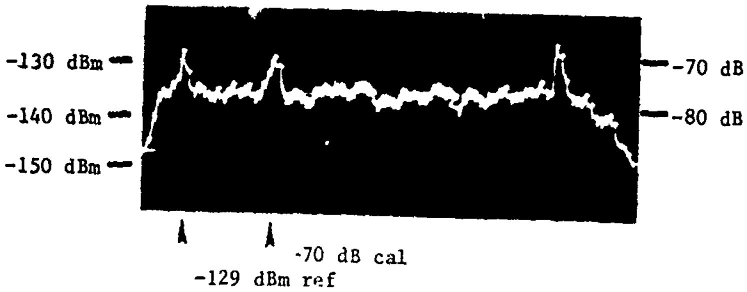
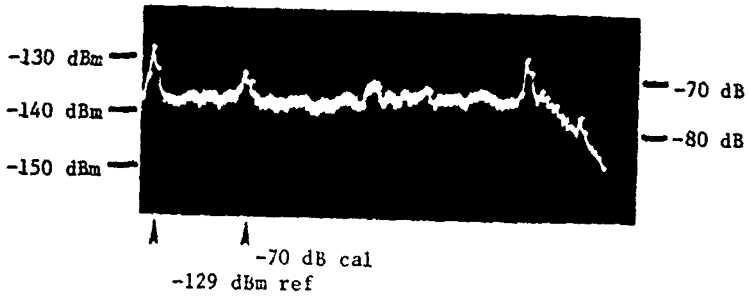
7 March 1973
23.145 MHz
Monopole antenna

CM in notch
CM xmit horiz LPA

9. 1310Z
0.2 Hz resolution
Ant att = 0 dB
S/N 76 dB

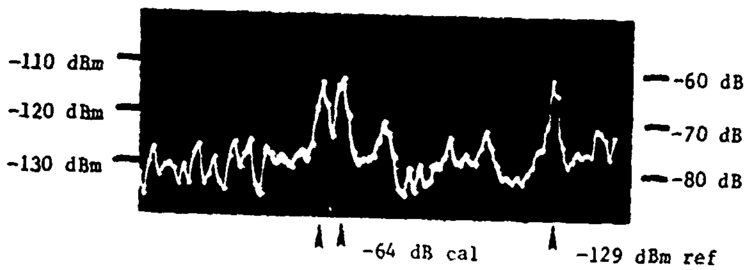


10. 1314Z
0.2 Hz resolution
Ant att = 0 dB
S/N 76 dB



11. 1330Z
0.02 Hz resolution
Ant att = 0 dB
CM off

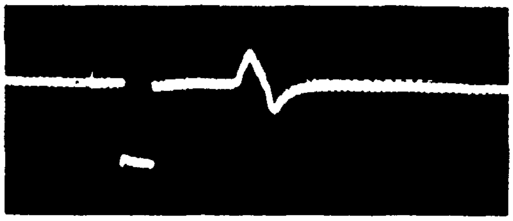
12. 1340Z
0.02 Hz resolution
Ant att = 15 dB
S/N 72-82 dB



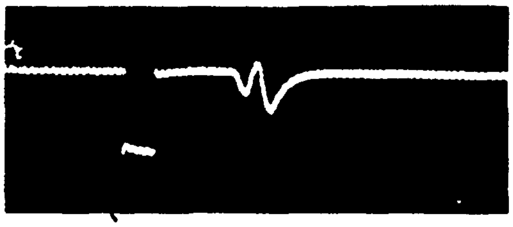
SECRET

7 March 1973
23.145 MHz
Monopole antenna

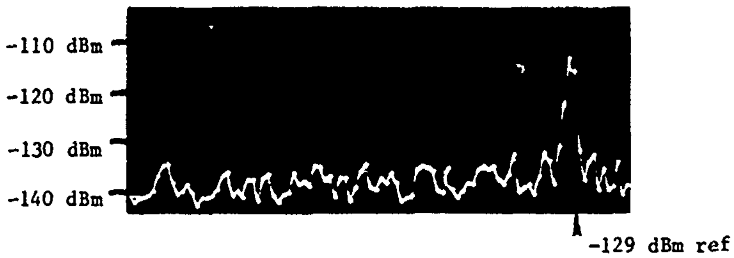
13. 1350Z
A-scope



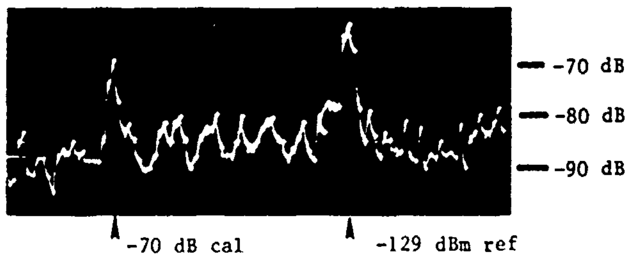
14. 1350Z
A-scope



15. 1400Z
Ant att = 15 dB
CM off



16. 1415Z
Equipment validation
S/N 80 dB

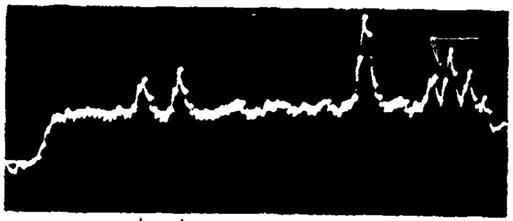


SECRET

8 March 1973
23,145 MHz
Beverage antenna
0.2 Hz resolution

CM in notch
CM xmit on yagi

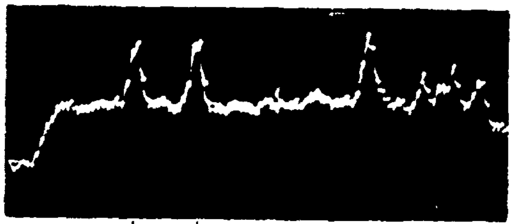
1. 1240Z
S/N 78 dB



-70 dB
-80 dB
-90 dB

-74 dB cal   -73 dBm ref

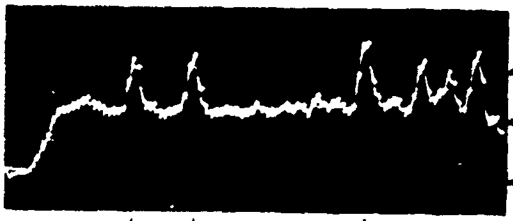
2. 1248Z
S/N 83 dB



-70 dB
-80 dB
-90 dB

-74 dB cal   -73 dBm ref

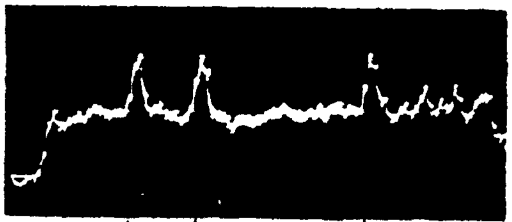
3. 1253Z
S/N 80 dB



-70 dB
-80 dB
-90 dB

-70 dB cal   -73 dBm ref

4. 1300Z
S/N 80 dB



-70 dB
-80 dB
-90 dB

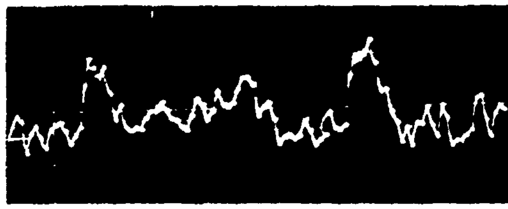
-70 dB cal   -73 dBm ref

SECRET

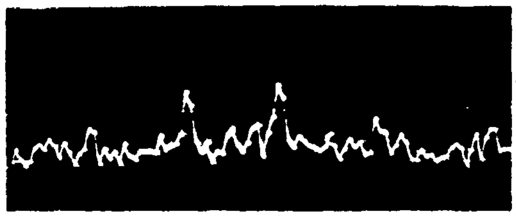
8 March 1973
23.145 MHz
Beverage antenna
0.02 Hz resolution

CM in notch
CM xmit horiz LPA

5. 1305Z
S/N 75-85 dB

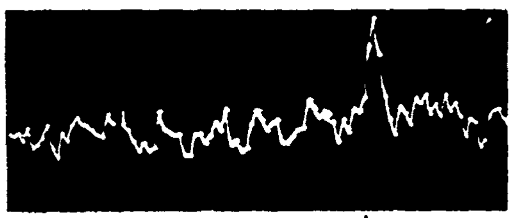


6. 1315Z
S/N 80-85 dB



7. 1325Z
S/N 65-70 dB
(Power limited)

8. 1330Z
CM off

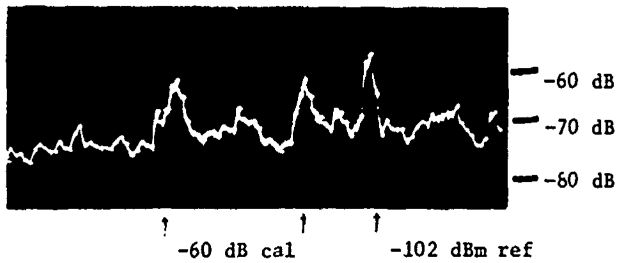


SECRET

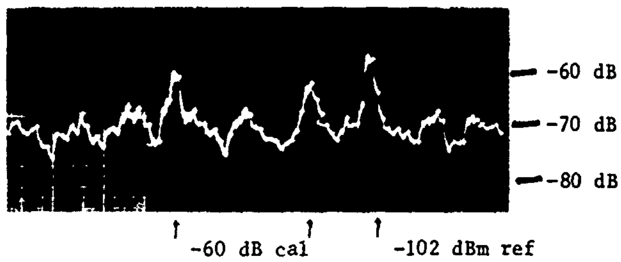
8 March 1973
23.145 MHz
Beverage antenna
0.02 Hz resolution

CM in notch
CM xmit on yagi

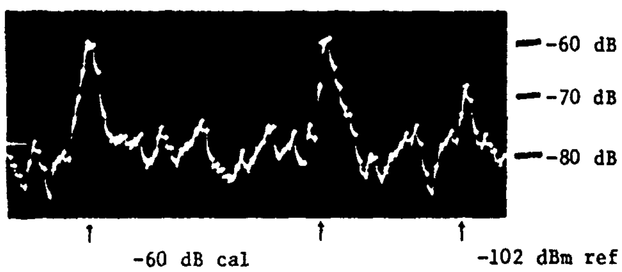
9. 1345Z
S/N 66-76 dB
(Power limited)



10. 1350Z
S/N 67-75 dB
(Power limited)



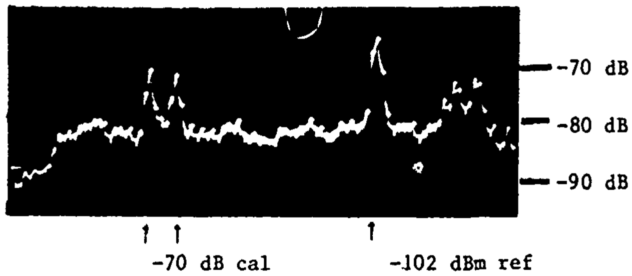
11. 1355Z
S/N 75-85 dB



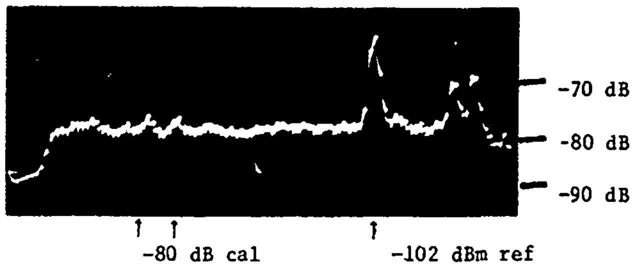
8 March 1973
23.145 MHz
Beverage antenna
0.2 Hz resolution

CM in notch
CM xmit vert LPA
Ant att 25 dB w/extra amp.

12. 1220Z
S/N 80 dB



13. 1225Z
S/N 80 dB

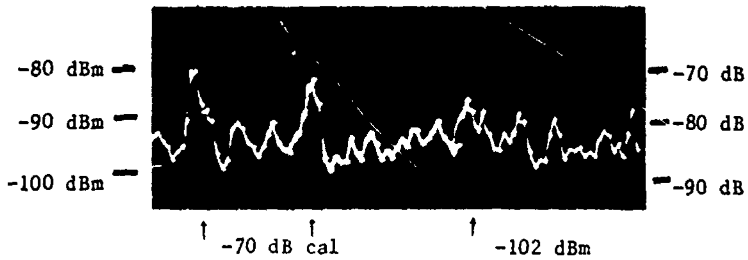


SECRET

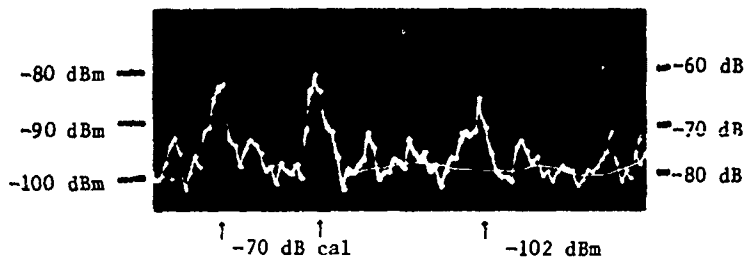
11 March 1973
23.145 MHz
Beverage antenna
0.02 Hz resolution

CM xmit on yagi

1. 1229Z
CM in notch
Ant att = 15 dB
S/N 75-86 dB

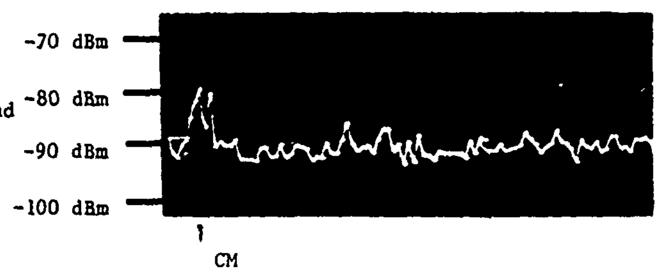


2. 1235Z
CM in notch
Ant att = 15 dB
S/N 73-83 dB



3. 1245Z
CM out of notch
Ant att = 76 dB

4. 1250Z
CM out of notch
Ant att = 16 dB
gate 1.5 ms ahead
(gate leakage?)

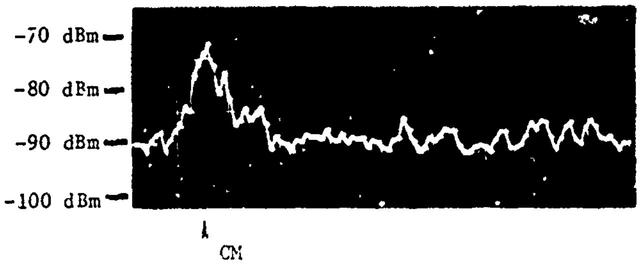


SECRET

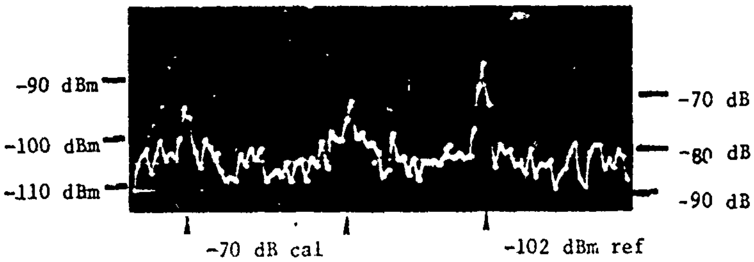
SECRET

11 March 1973
23.145 MHz
Beverage antenna
0.02 Hz resolution

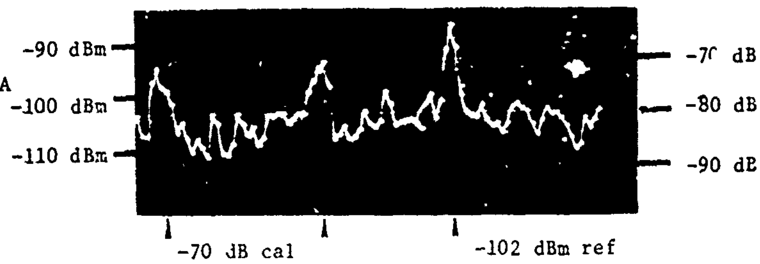
5. 1255Z
CM out of notch
CM xmit on yagi
Ant att = 16 dB
Gate 1.5 ms behind



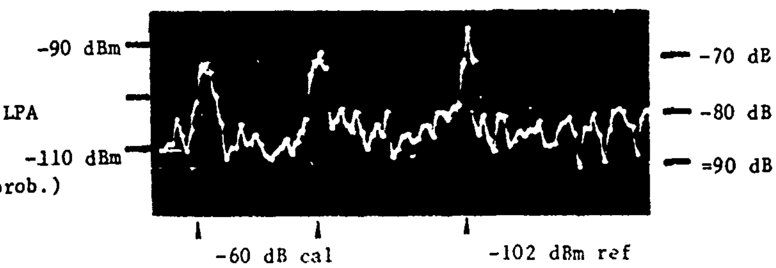
6. 1305Z
CM in notch
CM xmit vert LPA
Ant att 15 dB
S/N 75-85 dB



7. 1310Z
CM in notch
CM xmit on vert LPA
Ant att = 75 dB
S/N 76-86 dB



8. 1345Z
CM in notch
CM xmit on horiz LPA
Ant att 15 dB
S/N 70-80 dB
(Po-sible equip prob.)



SECRET

ATTACHMENT 1 - Section 2

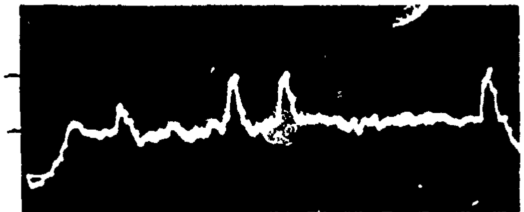
COBRA SHOE DATA

6 March 1973
23.145 MHz
Monopole antenna
0.2 Hz resolution

SECRET

1. CS out of notch
Ant att = 40 dB
CS signal = -31 dBm

-30 dBm
-40 dBm

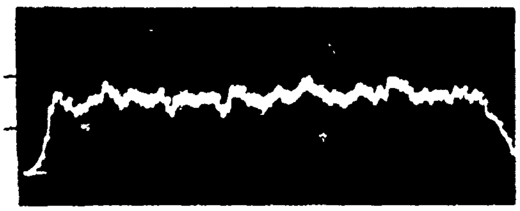


-70 dB
-80 dB

CS   -71 dBm ref

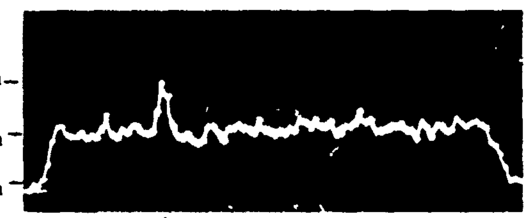
2. CS in notch
Ant att = 0 dB
S/N 45 dB
(Power limited)

-70 dBm
-80 dBm



3. CS in notch
Ant att = 0 dB
S/N 50 dB
(Power limited)

-70 dBm
-80 dBm
-90 dBm

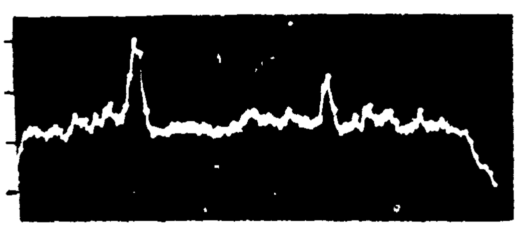


-40 dB
-50 dB

-40 dB cal @ 8 Hz

4. CS in notch
Ant att 10 dB
S/N 58 dB
(A/C limited)

-70 dBm
-80 dBm
-90 dBm
-100 dBm



-40 dB
-50 dB
-60 dB

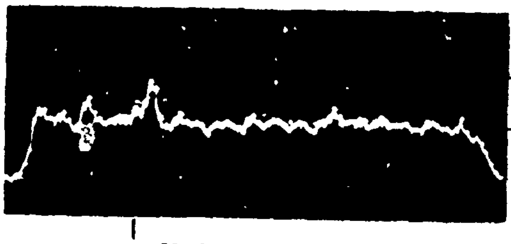
-40 dB cal @ 8 Hz

SECRET

6 March 1973
23.145 MHz
Horizontal dipole antenna
0.2 Hz resolution

5. CS in notch
Ant att = 10 dB
S/N 60 dB

-80 dBm
-90 dBm
-100 dBm

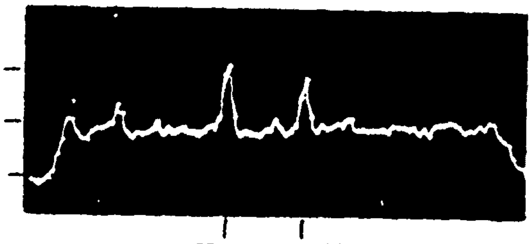


-50 dB
-60 dB

-50 dB cal @ 8 Hz

6. CS out of notch
Ant att = 60 dB
CS signal -30 dBm

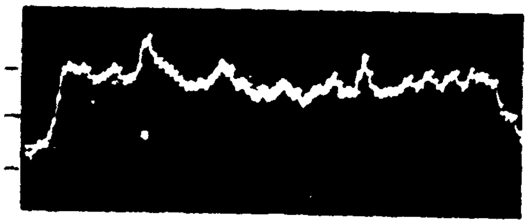
-30 dBm
-40 dBm
-50 dBm



CS
-91 dBm ref

7. CS in notch
Ant att 0 dB
(15 dB increase in S/N
due to A/C.)

-90 dBm
-100 dBm



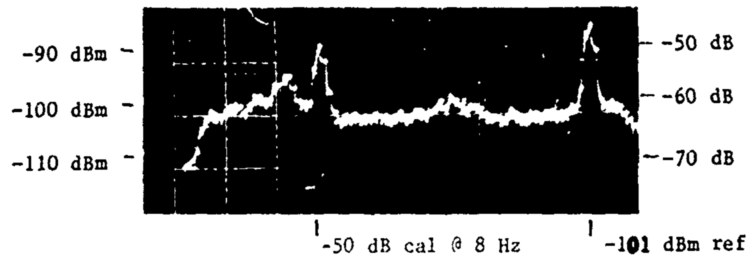
8. Equipment validation
Ant att = 0 dB
23.045 synth signal
S/N 78 dB

-70 dB
-80 dB

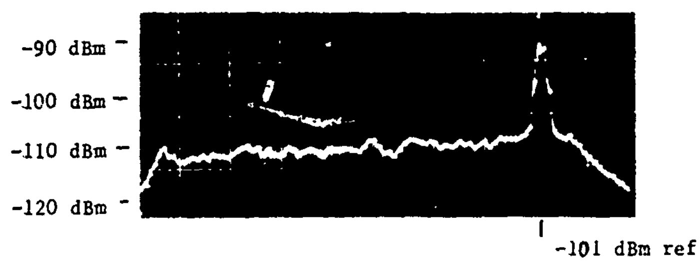
-70 dB cal @ 8 Hz

7 March 1973
23.145 Mhz
0.2 Hz resolution

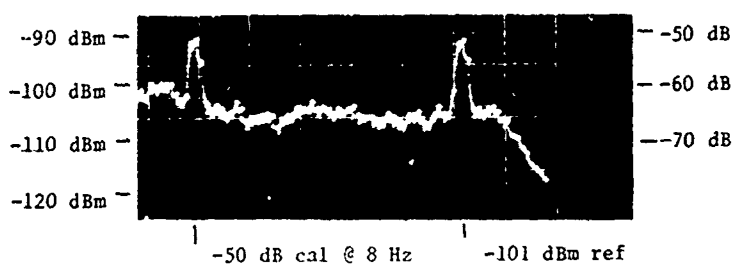
1. 1710Z
Monopole ant
Ant att 15 dB
CS signal -40 dBm
S/N 64 dB



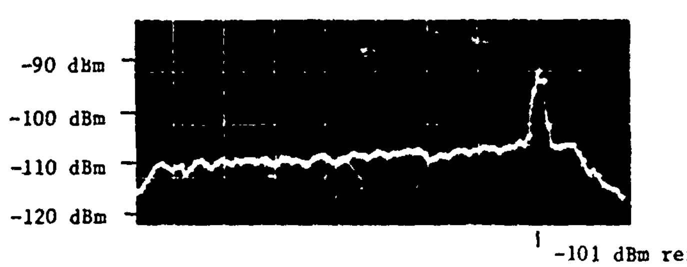
2. 1715Z
Monopole ant
Ant att 10 dB
CS off



3. 1720Z
Horiz dipole
Ant att 10 dB
CS signal -40 dBm
S/N 64 dB



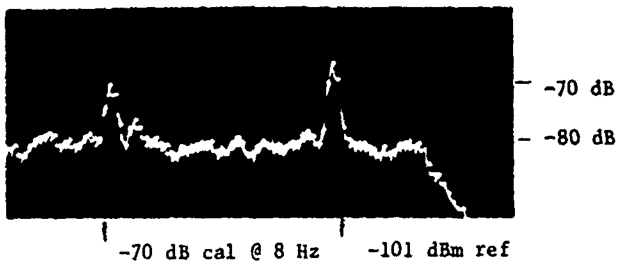
4. 1730Z
Horiz dipole
Ant att 10 dB
CS off



7 March 1973
23.145 MHz
0.2 Hz resolution

5. 1738Z
Horiz dipole
Ant att = 65 dB

6. 1740Z
Equipment validation
S/N 80 dB

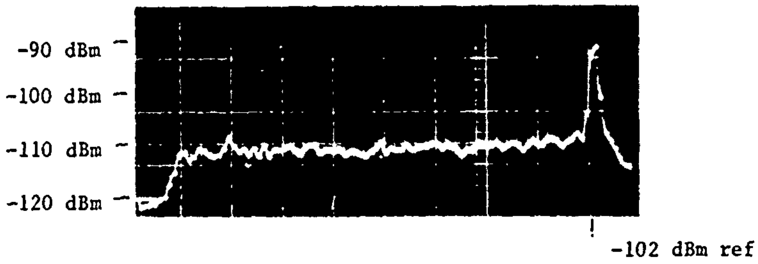


SECRET

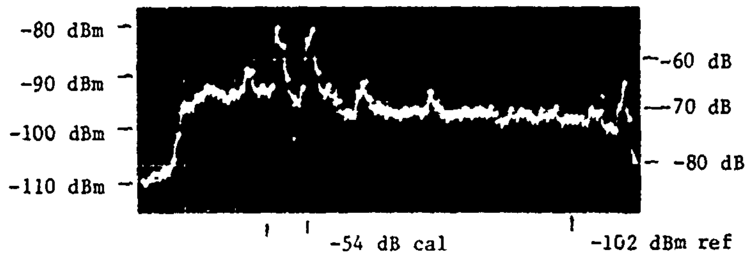
11 March 1973
23.145 MHz
Horizontal dipole antenna
0.2 Hz resolution

Ant atten = 10 dB

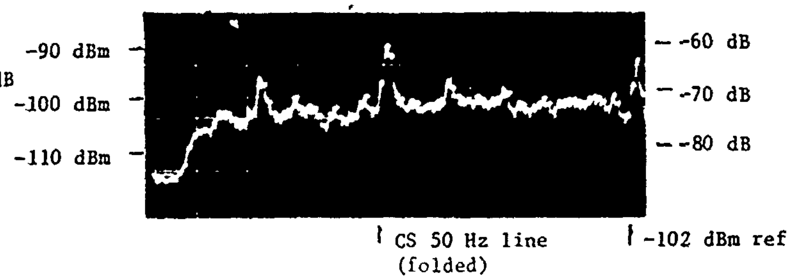
1. 1015Z
CS off



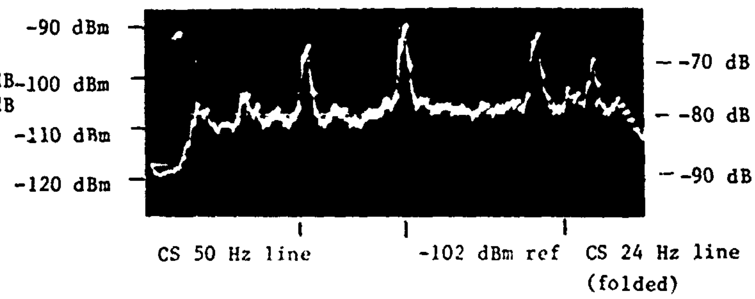
2. 1020Z
CS in notch
S/N 70 dB



3. 1025Z
CS offset 60 Hz
50 Hz/carrier 62 dB



4. 1035Z
CS offset 40 Hz
24 Hz/carrier 66 dB
50 Hz/carrier 68 dB

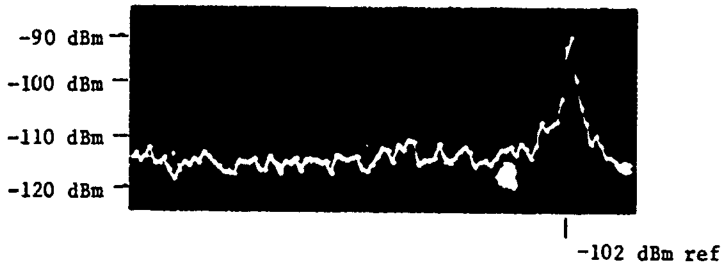


SECRET

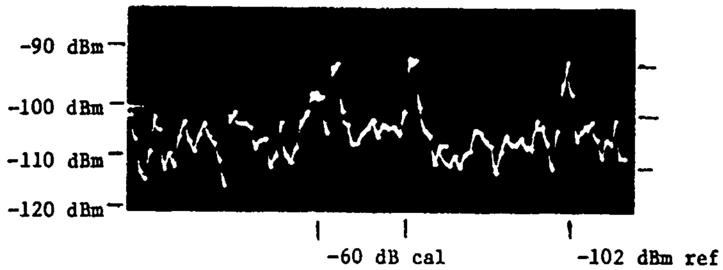
11 March 1973
23.145 MHz
Horizontal dipole antenna
0.02 Hz resolution

Antenna atten = 10 dB

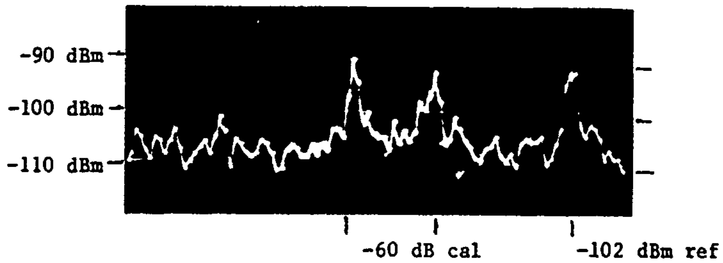
5. 1045Z
CS off



6. 1050Z
CS in notch
S/N 70-80 dB



7. 1105Z
CS in notch
S/N 70-80 dB

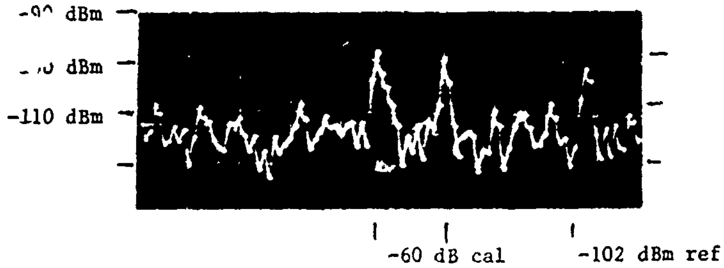


8. 1115Z
CS off

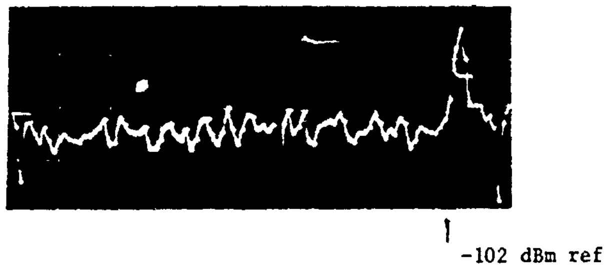
11 March 1973
Horizontal dipole antenna
0.02 Hz resolution

Antenna atten = 10 dB

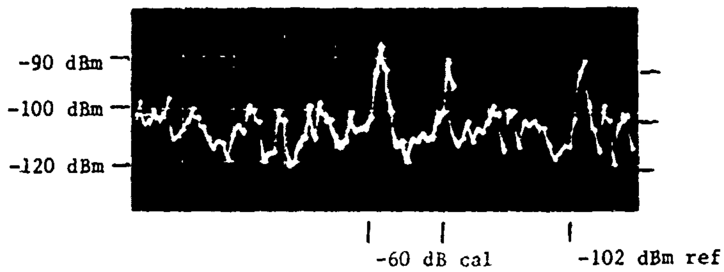
9. 1120Z
CS in notch
S/N 70-80 dB



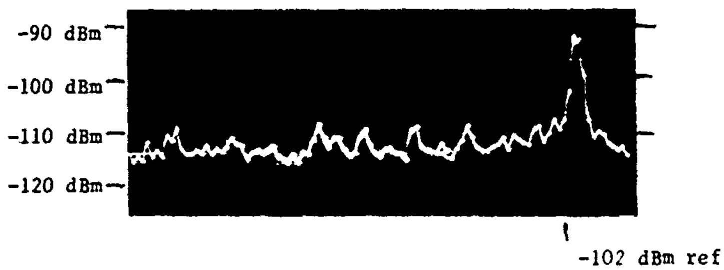
10. 1130Z
CS off



11. 1135Z
CS in not[illegible]
S/N 70-8[illegible]



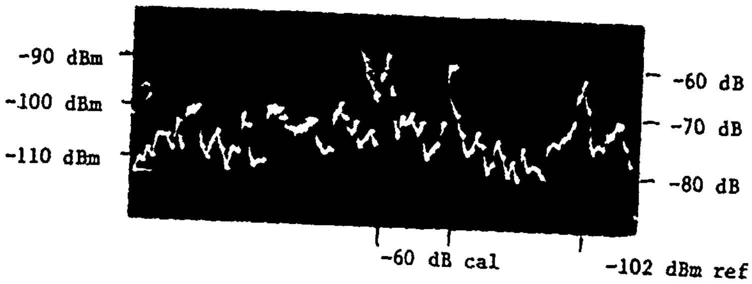
12. 1145Z
CS off



11 March 1973
Horizontal dipole antenna
0.02 Hz resolution

Antenna att = 10 dB

13. 1150Z
CS in notch



MEMORANDUM

20 February 1997

Subj: Document Declassification

Ref: (1) Code 5309 Memorandum of 29 Jan. 1997
(2) Distribution Statements for Technical Publications NRL/PU/5230-95-293

Encl: (a) Code 5309 Memorandum of 29 Jan. 1997
(b) List of old Code 5320 Reports
(c) List of old Code 5320 Memorandum Reports

1. In Enclosure (a) it was recommended that the following reports be declassified, four reports have been added to the original list:

Formal: 5589, 5811, 5824, 5825, 5849, 5862, 5875, 5881, 5903, 5962, 6015, 6079, 6148, 6198, 6272, 6371, 6476, 6479, 6485, 6507, 6508, 6568, 6590, 6611, 6731, 6866, 7044, 7051, 7059, 7350, 7428, 7500, 7638, 7655. Add 7684, 7692.

Memo: 1251, 1287, 1316, 1422, [redacted], 1500, 1527, 1537, 1540, 1567, 1637, 1647, 1727, 1758, 1787, 1789, 1790, 1811, 1817, 1823, 1885, 1939, 1981, 2135, 2624, 2701, 2645, 2721, 2722, 2723, 2766. Add 2265, 2715.

The recommended distribution statement for the these reports is: **Approved for public release; distribution is unlimited.**

2. The above reports are included in the listings of enclosures (b) and (c) and were selected because of familiarity with the contents. The rest of these documents very likely should receive the same treatment.

J. M. Headrick
J. M. Headrick
Code 5309

Copy:
Code 1221 — CR OK 7/2/97
Code 5300
Code 5320
Code 5324