STANFORD RESEARCH INSTITUTE
Menlo Park, California 94025 · U.S.A.

Kahn

AD-A954 770

November 1974

SRI Packet Radio Temporary Note 4

PACKET RADIO LINK-RELATED MEASUREMENTS TEST PLAN

By: R. C. Kunzelman

Prepared for:

ADVANCED RESEARCH PROJECTS AGENCY
1400 WILSON BLVD.
ARLINGTON, VIRGINIA 22209

Attention: DR. R. KAHN

CONTRACT DAHC15-73-C-0187

SRI Project 2325

DTIC FILE COPY

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION IS UNLIMITED (A)

DTIC
ELECTE
JUN 17 1985
S D
G

85 06 13 013

CONTENTS

Accession For
NTIS GRA&I ☒
DTIC TAB ☐
Unannounced ☐
Justification

By
Distribution/
Availability Codes
Dist | Avail and/or Special
A/1

DTIC COPY INSPECTED 2

UNANNOUNCED

ILLUSTRATIONS

TABLES

I INTRODUCTION

The experiments outlined herein are part of an ongoing ARPA program to implement a first working model of an experimental, packet switched, distributed radio network. This plan describes the details of a link-related series of tests which ~~SRI plans to~~ conduct in the time frame of November 1974 through July 1975.

These link-related experiments constitute the second phase of an overall plan for measurement and testing of the experimental Packet Radio (PR) network. The four major phases of experimental activity which have been planned are as follows:

Phase 1 - Propagation and Noise Measurements at 430 MHz and 1370 MHz, using special test set. (Completed). Time frame was January 1974-June 1974.

Phase 2 - Link-Related Experiments in the 1710-1850 MHz band, using three experimental transceivers. (Described in this test plan). Time frame is November 1974-July 1975.

Phase 3 - Network-Related Experiments in the 1710-1850 MHz band, using nine experimental transceivers. Time frame is June 1975-on.

Phase 4 - User and Operational Experiments in the 1710-1850 MHz band, using approximately 25 experimental transceivers. Time frame has not yet been established.

II OBJECTIVES AND SCOPE

A. Objectives

The following objectives were established for the link-related experiments in the system design plan*:

"a. Identify difference between predicted and actual radio link performance in such areas as: bit error rate (BER), range contours, and transfer reliability.

b. Assess the performance of a community of terminals and repeaters sharing a common rf channel. Performance measures include: number of blocked packets, capture statistics, packet error rates, and interference profiles.

c. Assess the impact on performance of alternative design approaches for: channel access and management, power level control mechanisms, and routing techniques.

d. Determine the degradation in transfer performance caused by signals emanating from other rf systems in the same general area.

e. Identify specific rf systems that may be interfered with by the Packet Radio signals. Conduct cooperative experiments with the systems to identify interference relationships."

B. Scope

Within the above objectives, the scope of this phase of testing is fairly well-defined by the availability of certain hardware and software elements within the time frame of interest. Elements expected to be available include the following:

1. Three transceivers, including rf and microprocessors.

2. Transceiver-based software for test traffic generation, using

*R. E. Kahn, et al., "Experimental Packet Radio System Design Plan", 13 March 1974, pp. 2-5.

teletype* terminal only.

3. Two packet terminal simulators, interfaced to transceivers so that they can operate as a terminal, as a repeater, or as an artificial traffic source.

4. One instrumented mobile repeater, using van-mounted Interdata minicomputer system.

5. One simulated station, using SRI laboratory Interdata minicomputer system and 80-foot station tower.

C. Time Constraints

The scope of this phase is also limited by a number of time constraints. These include the following:

1. Three Collins transceivers--available in January 1975.

2. Two SRI packet terminal simulators--available March 1975.

3. Necessary hardware upgrades to mobile measurement system--available January 1975.

4. Packet transport protocols--available for installation in May 1975.†

5. Network protocols--available for installation in July 1975.†

---

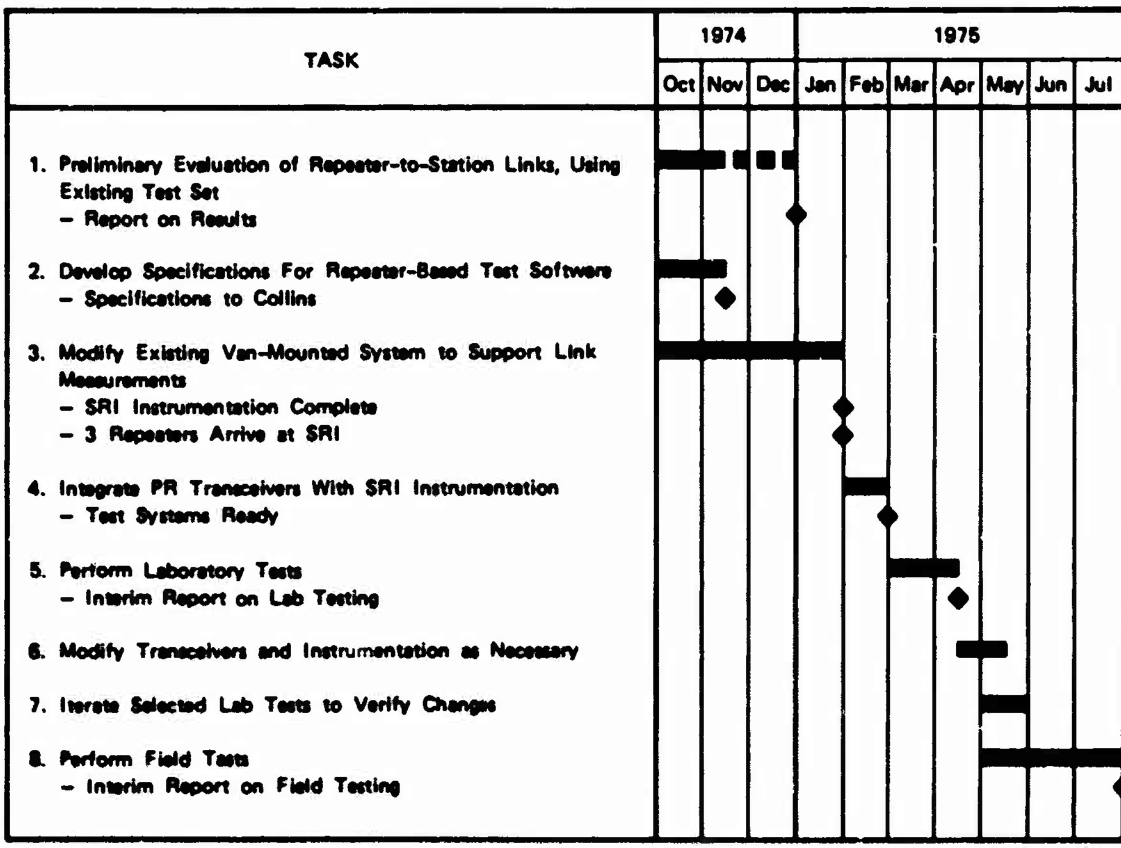
*ASR-33 teletype, or TI 733 ASR cassette terminal.

†SRI estimates only; dates for availability of coded and debugged protocols have not been firmly established at this time.

III TASKS, SCHEDULES, AND MILESTONES

Figure 1 lists the tasks which have been identified for the link-related measurements. Anticipated time schedules are shown, along with major milestones. These series of measurements are classed as: preliminary measurements (Task 1), lab testing (Tasks 2 through 7), and field testing (Task 8).

A detailed discussion of these tasks can be found in the remaining sections of this test plan.



SA-2325-38

FIGURE 1 SCHEDULE FOR LINK-RELATED PACKET RADIO MEASUREMENTS

IV PRELIMINARY EVALUATION OF REPEATER-TO-STATION LINKS

An 80-foot high antenna tower is currently being installed alongside building 308 at SRI, to be used for the experimental PR station. Since this tower did not exist during our earlier series of propagation and noise experiments, we do not actually know the characteristics of the radio paths between this tower and the several candidate repeater sites. (See Figure 2 for a map of locations for the PR test bed.)

A. Objectives

The 80-foot tower structure has already been erected and is available. We plan to immediately perform a preliminary evaluation of these repeater-to-station (R-S) links, using the existing van-mounted PREMS* system and test set at 1370 MHz to measure path losses and multipath propagation characteristics. Specific questions which we intend to answer in this series of tests include the following:

1. Are the candidate R sites favorably situated with respect to the S site?

2. Do actual path losses agree with the free-space model?

3. Is the time-spread of multipath propagation sufficiently short to support a 400 K bit per second data rate on the R-S links?

B. Frequency Band and Coexistence Consideration

Although the existing test set is very well-suited for making these path sounding measurements, we do face several limitations.

---

*PREMS is an acronym for Packet Radio Experimental Measurement System.

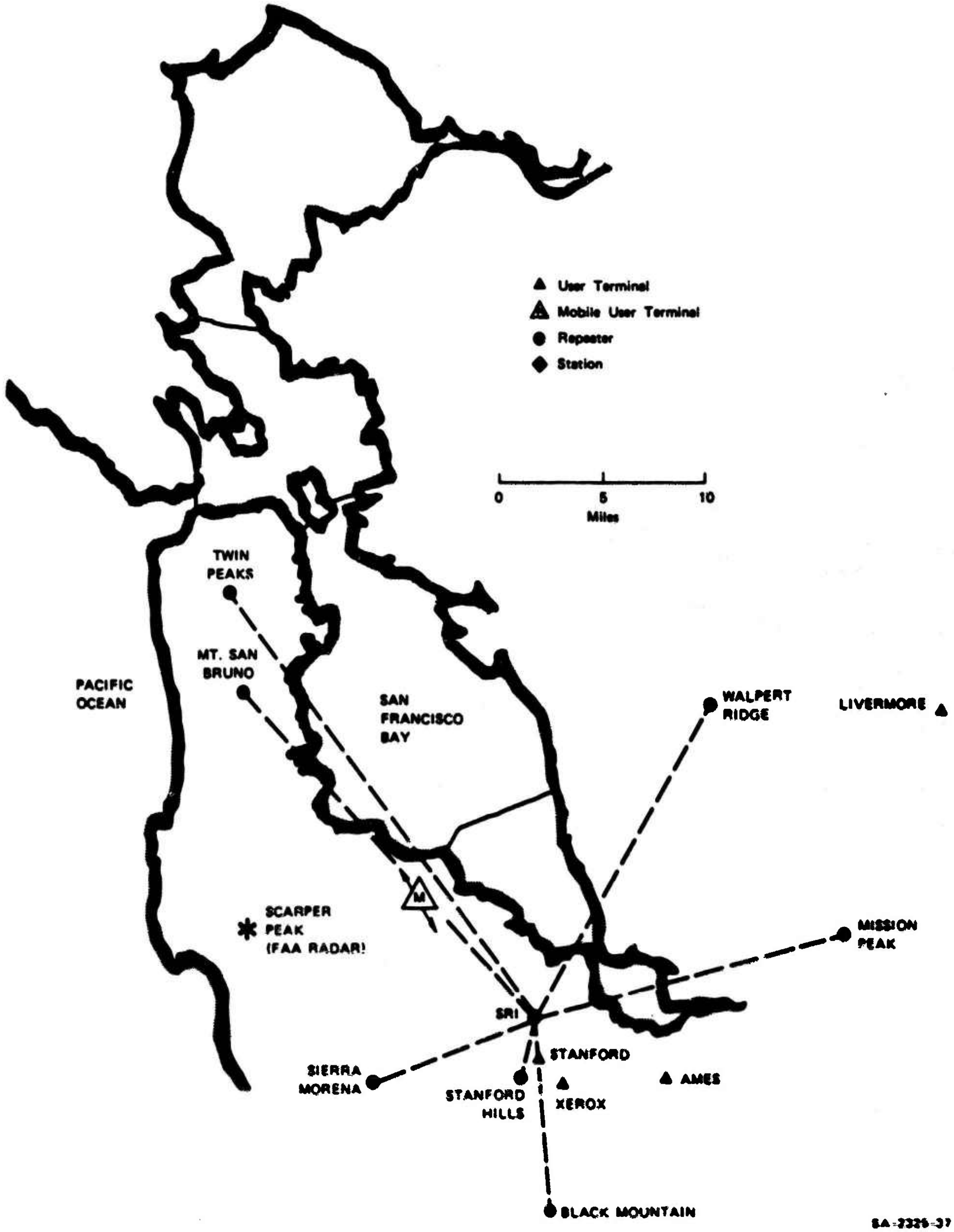


FIGURE 2 AN EXAMPLE OF REPEATER LOCATIONS FOR THE PACKET RADIO TEST BED

The first consideration is that the test set is fixed-tuned at 1370 MHz, but the experimental transceivers will operate in the 1710-1850 MHz band. This is approximately a 30 percent change in operating frequency. It is expected that the propagation and man-made noise characteristics will not change greatly over this range, and hence, our measurements at 1370 MHz should apply well at the higher frequencies.

On the other hand, any preliminary interference or coexistence investigations that we might undertake at this time would necessarily require other equipment which is capable of operating in the desired band--for example, we might use our Hewlett-Packard spectrum analyzer which covers up to 2 GHz.

Another important consideration for the planned testing is that we do indeed have a potential coexistence problem at 1370 MHz, with the FAA long range air route surveillance radar on Scarper Peak operating at approximately 1340 MHz. Our spread-spectrum signals can jam the radar unless suitable precautions are taken.

Since omni-to-omni testing will be highly desirable in order to simulate the planned mode of PR broadcasting, we will investigate the feasibility of using an omni transmitting antenna on the SRI tower. This test will be carefully coordinated with FAA personnel at the Scarper Peak radar site.

C. Tasks

The following tasks are planned for this preliminary evaluation:

(1) Preparatory Tasks

(a) Bring ARPA Interdata-70 computer system back up and perform maintenance as required.

(b) Install full PREMS system in SRI van and check out all hardware and software elements.

(c) Install test set 1370 MHz transmitter in lab, connect to tower antenna systems, and check out coexistence with FAA radar.

(2) Experimental Tasks

(a) Develop experiment plan details.

(b) Acquire data and prepare off-line plots of multipath.

(c) Analyze results and write interim report (possibly as a Packet Radio Temporary Note).

D. Time Constraint

The SRI bread truck van will be available for these tests from now through approximately November 15 only, and therefore the data acquisition must be completed by then. (Another SRI project will need the van at that time, for one to two months, to perform a series of wet-weather power line noise tests.)

V MEASUREMENT APPROACH

Our planned method of approach for accomplishing the link-related measurements is presented in this section. Subsection A discusses the quantities to be measured, and subsection B outlines the instrumentation and processing which are planned to carry out the indicated measurements and tests.

A. Quantities to be Measured

Six distinct areas of testing and measurement are planned:

(1) Error rate measurements

(2) Coding experiments

(3) Coexistence measurements

(4) Access mode experiments

(5) Range and path loss experiments

(6) Moving terminal experiments.

These areas will be addressed with a mix of both laboratory and field testing, in a time-phased series of activities, the timing of which will depend partly on the availability of certain key hardware and software support elements.

1. Error Rate Measurements

A variety of error rate measurements will be made, first in the laboratory under controlled conditions, and then in the field under actual operating conditions in the test bed.

Specific parameters to be measured will include:

(a) Bit error rate (BER)

(b) Packet error rates--actual and detected

(c) Checksum error rates

(d) Preamble error rates

(e) Skew--percentage of ones versus zeros in error.

Bit error rates will be measured in the Interdata minicomputer, by comparing each received packet on a bit-by-bit basis with a local copy of what it should have been. Histograms of the number of errors occurring in each bit position will be available in graphic form, in order to explore the presence of any systematic error mechanisms.

Statistics will be gathered on the number of bit errors in a packet and burst lengths. These are described in more detail in the next section on coding experiments.

Packet error rates will be measured in two ways. First, the data portion (header plus text) will be checked for error using the method described above for bit errors. This will determine the "actual" packet error rate for data. Second, the hardware checksum status from the transceiver will be used to establish the "detected" packet error rate.

Also, the received checksum words will be compared with what should have been received, in order to establish the checksum error rate.

Preamble error rates will be measured by sending a predetermined number of packets (say 100,000 packets) and counting the number of packets actually received. All losses will be attributed to failure of the receiver end of preamble detection function (EOP). The 16-bit sequence number in the test packet header* will identify which packets were lost, and will maintain synchronism of the coded text. By using the sequence number, we will be able to look for periodicities (if any) in loss of sync.

Skew is defined as the percentage of ones versus zeros in error. It will be measured by maintaining a tally each time a 1 is received as a 0, and also maintaining another tally each time a 0 is received as a 1. It is expected that this parameter will be useful to Collins† for

---

* See Figure 10 for a description of the proposed packet format for link testing.

† Collins Radio Group, Rockwell International Corp., Richardson, Texas

evaluating detector threshold settings, bit sync timing, and other hardware-related functions where biases might be creeping in.

a. BER Measurement Resolution

The resolution required for the planned bit error rate measurements will vary over a wide range, depending on the purpose of the particular tests. As Appendix B shows, the confidence criteria for bit error measurements depend directly on the number of observed errors and not simply on the number of samples taken. Thus, our measurement approach will be to continue to take data until a required number of errors have been observed. (For example, take data until at least ten errors are observed.)

At the low end of the scale, it can be shown that a given rf link will be satisfactory for use in the PR network as long as the BER is on the order of 10^{-5}. A measurement involving approximately 10^{6} (one million) bits will probably provide satisfactory resolution for this purpose.

On the other extreme, for determining equipment capabilities under controlled conditions, the BER is expected to be at least 10^{-7} to 10^{-8} or better. A measurement involving the order of 10^{8} to 10^{9} (one trillion) bits, or more, will probably be needed to establish the upper limits of equipment capability.

b. Text Throughput Rates and Times

Overhead bits in the packet format will reduce the text throughput rate to a value that is always less than the link bit rate of 100 K (or 400 K) bits per second. This overhead can have significant impact on the time required for BER testing, depending on the packet length under test.

In order to illustrate the relationship between packet length and throughput, let us assume the following test parameters:

- 112 overhead bits--48 preamble, 32 header, and 32 checksum.

- A fixed interpacket delay of 100 μsec. This is equivalent to 10 (40) additional bits of overhead per packet at a bit rate of 100 K (400 K) bits per second.

Figure 3 illustrates the throughput rates versus packet length for these assumptions.

The time required for one run of BER testing may thus be inferred as follows, assuming a 100 K bit rate:

Text Length	Simulated Use	TP*	Time Required for Test at 100 K Bit/Sec: 10^6 bits	10^7 bits	10^8 bits	10^9 bits
1 byte	Character Mode	6%	2.9 min	29 min	4.8 hr	48 hr
10 byte	Conversational	40%	25 sec	4.2 min	42 min	7 hr
80 byte	Card Image	84%	12 sec	2 min	20 min	3.3 hr
252 byte	Block Mode	94%	11 sec	1.8 min	18 min	3 hr

*TP = Throughput, in percent of link bit rate.

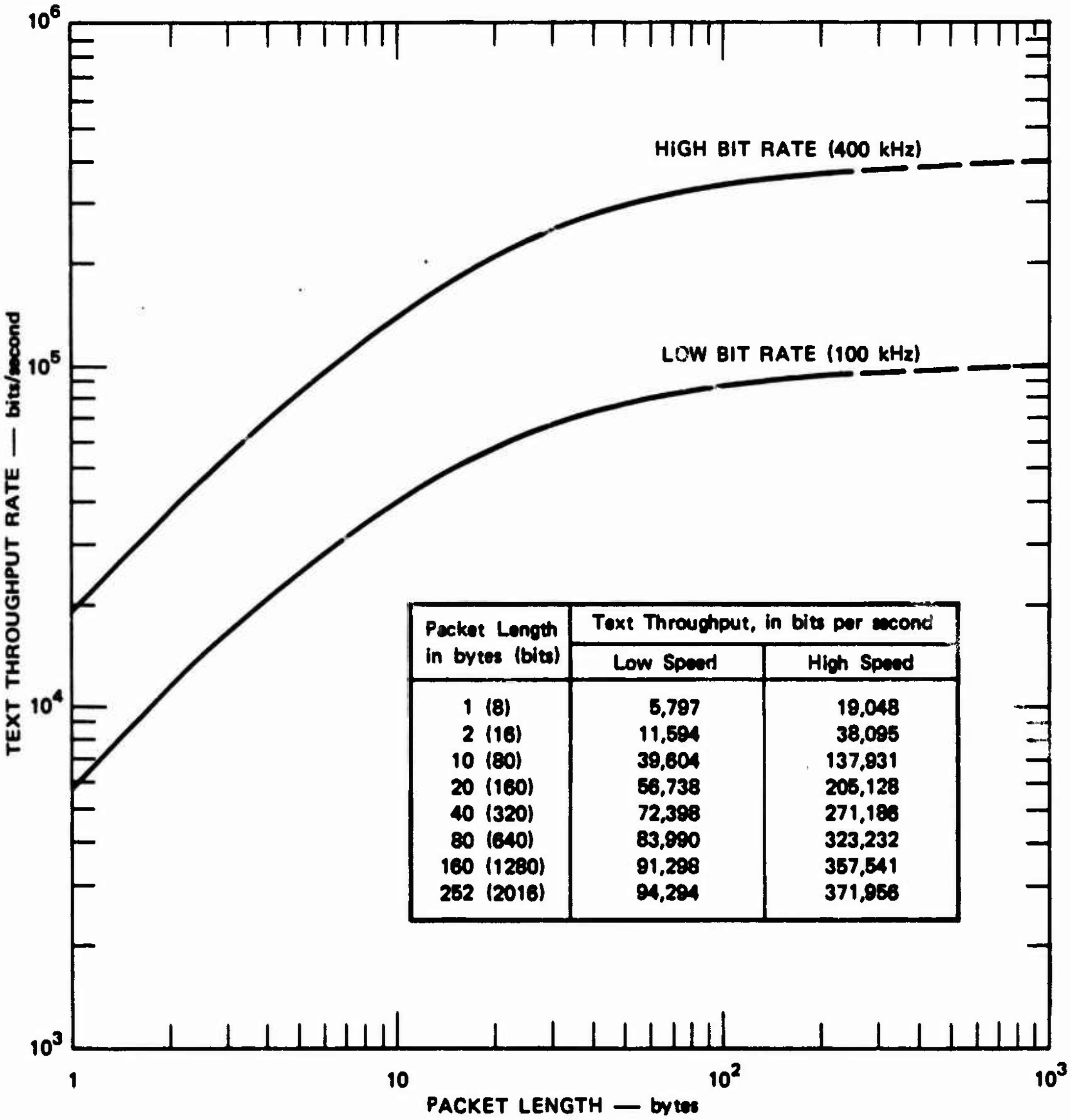
The above times will be reduced by approximately a factor of four, for tests using the higher 400 K bit rate.

It is clear from the foregoing that we have experiment design tradeoffs among BER resolution, packet lengths, and testing time. Practical limitations on the time (and cost) required to run the tests will probably control our final choices of testing schedules. For example, it takes 48 hours to transmit 10^9 bits of text in character mode. Even if we ran tests continuously (24 hours a day, 7 days a week), we could make only 15 BER measurements per month this way.

Detailed test sequences and schedules will be developed as we go along, keeping the above tradeoffs in mind.

2. Coding Experiments

Experiments on both error-detecting coding and error-correcting coding will be made during this phase of link testing. Details of the planned tests are described below.



Packet Length in bytes (bits)	Text Throughput, in bits per second	
	Low Speed	High Speed
1 (8)	5,797	19,048
2 (16)	11,594	38,095
10 (80)	39,604	137,931
20 (160)	56,738	205,128
40 (320)	72,398	271,186
80 (640)	83,990	323,232
160 (1280)	91,298	357,541
252 (2016)	94,294	371,956

FIGURE 3 TEXT THROUGHPUT RATES FOR LINK B.E.R. TESTING, VERSUS PACKET LENGTH

Assumes 112 bits of overhead, plus 100 μsec interpacket delay.

The first three transceivers from Collins will have a 32-bit checksum coder/decoder implemented in hardware. We will evaluate its performance in two ways. First, we will measure the undetected packet error rate, in order to assess the overall utility of the technique. This can easily be done by correlating the output of the hardware detector with an actual software checksum on each packet in the minicomputer, as was discussed previously in the section on BER testing. Second, we will measure the checksum error rate (i.e., false alarm rate) in order to show the impact on throughput reduction.

If any alternative scheme becomes implemented in hardware during this phase (such as a 16-bit checksum in lieu of the 32-bit code), we would measure its performance in the same ways.

Error-correcting codes offer a potential for enhanced performance of the packet radio network, because of possible errors from impulse noise, and the desire to coexist with other users. Accordingly, we will collect statistics relevant to their use.

We plan to measure the distribution of the number of errors in a packet--i.e., the number of packets having zero errors, the number of packets having one error, two errors, three errors, and so on up to (say) the number of packets having 12 errors. These data will greatly assist in the design and selection of appropriate error-correcting codes for implementation in later phases of the packet radio program.

It is appropriate to mention in this regard that the 32 bits currently dedicated to header plus text checksum are probably sufficient to accommodate a useful error-correcting code, in the future.

We also are planning to measure burst length statistics; i.e., the number of occurrences in a packet of two consecutive bit errors, three consecutive bit errors, four consecutive bit errors, and so on up to (say) 12 consecutive bit errors. This information will be output in the form of a burst error histogram. We do expect that collection of this statistic will be relatively time-consuming and may significantly slow down BER testing; hence, its use will be optional.

3. Coexistence Measurements

A major goal of the packet-radio program is to develop a network that will coexist with other users of the radio spectrum. To explore this issue and to demonstrate that a given design can indeed coexist, it will be necessary (but not sufficient) to determine the extent of disruption caused by other users. It will be possible to use the mobile test facility to find other users by spectrum monitoring and to measure the effects of these users by logging error rates. These "targets of opportunity" will be supplemented by our own transmitters, to simulate user environments as needed to explore the issues involved.

The other half of the coexistence coin consists of interference by the packet-radio network <u>to</u> other users. Some interference tests have been made using the existing test set and two operational radars. These tests will be repeated, and similar tests with other types of equipment will be undertaken. These tests will be performed, where possible, on targets of opportunity; however, in many cases it will be necessary to employ users simulated by sensitive receivers, or to take the packet-radio repeater to a location where users exist within the same operating frequency band.

We plan to run a number of simulated tests of interference in the laboratory, to determine the degree to which various forms of competing signals can be tolerated. Specific modulation types to be used for these laboratory simulations will include:

- Narrowband (CW) interference
- Pulse interference
- Broadband interference.

These tests will be made over a wide range of signal to interference (S/I) ratios.

4. Access-Mode Experiments

Network throughput and delay depend on many variables. An important factor in both performance measurements is the access mode used by terminals and repeaters. Analyses of throughput and delay have modeled the users as an infinite population of Poisson sources and have ignored the effects of noise and of acknowledgement packets. Simulations have used finite populations, but other aspects of the simulations have necessarily been idealistic. Network experiments will ultimately be made to validate the network models, simulations, and designs; but it is also necessary to perform link measurements by using a single repeater and many terminals, to validate some aspects of the access-mode models.

Several experiments are possible if the equipment is properly designed. For example, models suggest that the carrier sense mode is more efficient than the ALOHA mode, so long as terminals can hear each other, but that as soon as terminals are "hidden" from each other, performance degrades. A field demonstration and measurement of this effect can readily be made if the equipment has both a carrier sense and an ALOHA mode.

A packet transport protocol (ACK protocol) will be necessary to support these access-mode experiments. Our test planning and scheduling indicate that protocols for both random-access and carrier-sense access modes need to be available for installation in the test bed no later than May 1975.

5. <u>Range and Path Loss Experiments</u>

In order to satisfy the objective of evaluating radio range contours, we plan to measure the signal level received by the instrumented repeater during all field tests for bit error rate. Received signal power versus range will be compared with appropriate models (free space and Okumura), and differences will be identified and analyzed.

6. <u>Moving-Terminal Experiments</u>

In order to identify the degree of degradation caused by terminal motion, error rates will be measured for both moving and fixed terminals.

The approach we plan to follow here is to mount a terminal in a vehicle (SRI pickup truck or utility van) and transmit test packets from this terminal. Test transmissions will be made on selected courses, both with the vehicle moving (15 to 25 mph) and with the vehicle parked. Error rates will be measured at the instrumented repeater. Based on our earlier propagation measurements, considerable degradation is expected with a moving terminal. The results of these experiments are expected to contribute to future design efforts, in the area of diversity reception and combining, to accommodate moving terminals.

7. Received Signal Level

Signal power is one of the most basic determinants of bit error rate. Accordingly, we plan to monitor the signal level for each received packet, and then to calculate the mean value and standard deviation for each data run.

Since the PR transceivers will have automatic gain control (AGC), we must monitor the analog AGC control voltages in order to determine received signal level. In fact, there are two AGC loops in tandem, and hence, we must monitor them both. There is a "non-coherent" AGC in the receiver front end, and there is a "coherent" AGC in each SAWD detector channel. Collins will be providing a connector that will bring these (and a number of other signals) to the outside world. SRI will develop an analog instrumentation interface to monitor the relevant signals.

We plan to use two existing 8-bit A/D converters in the PREMS instrumentation system for this purpose. These A/D channels formerly were used to measure the "I" and "Q" Doppler signals from the test set. These channels will be nicely suited to the task, with the addition of suitable input amplifiers and lowpass filters. The end of preamble (EOP) signal from the Collins receiver will be used to initiate a new A/D measurement of AGC voltages for each packet.

An accurate calibration of the relationship between the AGC voltages and received signal level will be needed. A compatible spread-spectrum signal will be needed for this purpose, since we are especially interested in bit error rates near threshold--where a CW calibration signal would not have the needed processing gain in the "coherent" AGC for the SAWD detector circuitry.

These considerations mean that we will need to use one of the three PR transceivers as the calibrator for the instrumented repeater, since they are the only existing source of compatible spread-spectrum signals. Until we have determined the time-stability of these AGC calibrations, we plan to re-calibrate at least once per day.

Preliminary estimates have been made by Collins of the bit error rate versus received signal level, assuming a noise figure of 8 dB and an ideal DCMSK demodulator. These calculations show the following theoretical required signal levels for a bit error rate of 10^{-5}:

Theoretical Bit Error Rate	Noise Figure	Required Signal Level 100 K b/s	Required Signal Level 400 K b/s
10^{-5}	8 dB	-105.7 dBm	-99.3 dBm

The above values will serve as a reference against which measured lab and field performance characteristics can be compared.

8. Multipath Measurements

We plan to measure the multipath propagation on each rf link, using techniques essentially the same as we used during our recent series of propagation and noise experiments. The main differences will be that the new packet radio transceivers will be the source of signals, rather than the Collins test set receiver formerly used, and all the processing will be done on-line in the van minicomputer.

Specific multipath parameters to be measured will include time spread (second central moment) and maximum width. These parameters were formerly computed off line on the SRI laboratory Interdata, using data tapes from the van system. The programmed upgrades to the van system will permit us to move these calculations on line now.

Also, plots of the multipath propagation waveforms will be available in the van after each run, using the Tektronix 4010 display and 4610 hard copy unit. These plots can be either of individual shots, or of averaged data from a number of shots, or both, at the operator's choice.

Raw input signals containing the multipath information will come from the detectors in the repeater. The $\Sigma + \Delta$ port shows both ones and zeros; we may also monitor the Σ port, which indicates ones only, or the Δ port, which indicates zeros only. As these signals from the Collins transceiver are of high impedance (1 K ohms), we will use active FET probes such as the Tektronix P6201 or Hewlett-Packard 1120A to monitor these signals and feed them to the Biomation 8100 transient recorder. The 8100 provides probe power.

9. Noise Measurements

We are still evaluating alternatives for ways to measure impulse noise. The preferred approach would be to measure input noise simultaneously with the reception of each packet. Then, we could correlate observed errors with measured noise, on a packet by packet basis. This could perhaps even be carried to its logical conclusion by measuring the noise for each bit period, and correlating errors on a bit by bit basis.

The existing test set and the existing PREMS noise counting hardware are not ideally suited for these noise measurements. The test set is not compatible with either the new DCMSK modulation or with the new 1710-1850 MHz frequency band. Thus, the test set would have utility only for out-of-band noise measurements.

We are currently considering the possibility of modifying the existing threshold detectors and counting circuitry to work with the new repeaters. We are also considering use of the Biomation model 8100 transient recorder to capture impulse noise data.

10. Experiment Parameters to be Controlled and Monitored

In order to conduct all these link experiments in the lab and in the field, a rather large number of parameters need to be controlled and monitored. The approach we intend to follow is to conduct a series of experimental "runs"; the total number of runs needed is expected to be on the order of several hundred.

The output from each run will consist of the measured error statistics and measured propagation parameters, along with considerable information and data describing the pertinent test parameters. We intend to record all this on a disc file in the minicomputer, for later evaluation and analysis. Hard copy graphics and printouts will also be available at the end of each run. The categories of parameters for link testing are as follows:

(a) Measured error statistics
(b) Measured propagation parameters
(c) Link parameters
(d) Transmission parameters
(e) Noise parameters
(f) Interference parameters
(g) Date, time, and comments.

Table 1 illustrates in more detail the specific parameters for these categories.

B. Instrumentation and Processing

Subsection A above has outlined the quantities to be measured and the methods that we plan to use in making these measurements. In this section, we will now present the instrumentation configurations needed to support these measurements and discuss the software approaches that we plan to take.

1. Experimental Configurations

Figure 4 below shows the family of equipment configurations that we intend to employ for laboratory and field testing. A total of

Table 1

PARAMETERS FOR LINK TESTING

A. MEASURED ERROR STATISTICS

1. Bit error rate
2. Packet error rate, detected
3. Packet error rate, actual
4. Checksum error rate
5. Preamble error rate
6. Skew
7. Bit errors per packet histogram
8. Bit error location histogram (graphical plot only)
9. Burst length histogram

B. MEASURED PROPAGATION PARAMETERS

1. Received signal level--mean and standard deviation
2. Multipath--time spread, and maximum width
3. Multipath plot (graphical plot only)

C. LINK PARAMETERS

1. Path length
2. Terrain type (coded)
3. Transmitter: location, ident, ERP, antenna gain, and height
4. Receiver: location, ident, noise figure, antenna gain, and height
5. Input attenuator setting
6. Speed--moving terminals only

D. TRANSMISSION PARAMETERS

1. Frequency
2. Power control
3. Bit rate
4. Packet length
5. Code type (ones, zeros, alternating ones and zeros, PRBS)
6. Total number of packets or bits in test run
7. Time delay (duty cycle)
8. Type of ACK protocol used
9. Type of error detecting coding used

E. NOISE

F. INTERFERENCE

1. Present or absent
2. Type--CW, pulse, broadband
3. S/I ratio

G. DATE, TIME, COMMENTS, AND RUN NUMBER

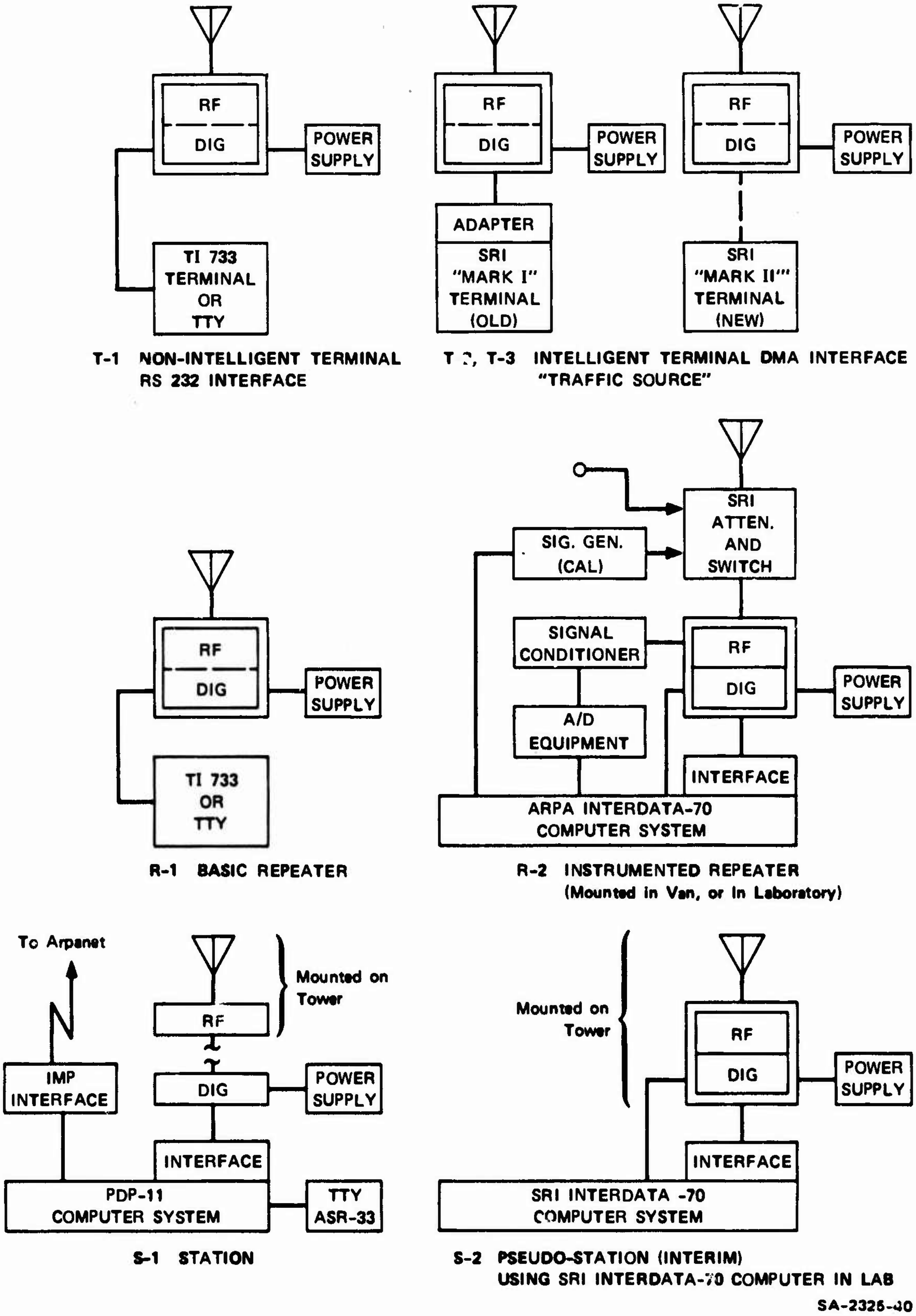


FIGURE 4 PACKET RADIO—EQUIPMENT CONFIGURATIONS FOR EXPERIMENTAL USE

seven distinct configurations are shown, including three types of terminals, two types of repeaters, and two station types. It is apparent that there will be considerable shared use of the first three transceivers, to support these various arrangements.

2. Mobile Instrumented Repeater (MIR) Layouts

The way we plan to undertake the required measurements is to modify the existing van-mounted measurement system as necessary to provide a mobile instrumented repeater facility. The equipment is capable of being readily removed and switched between the van and the laboratory, in order to perform both lab and field testing with the same setups and the same equipment.

Figure 5 shows a preliminary rack layout of the MIR equipment, and Figure 6 provides a plan view of this arrangement. There will be 3½ racks of equipment needed. Cabinets #1 and #2 are the original set, and cabinets #3 (RF) and #4 (test equipment) will be installed on the right side of the van as shown.

Details on functional aspects and equipment configurations will be presented in the next few subsections.

3. RF Test Setups

Figure 7 shows the planned RF test setups for the mobile instrumented repeater.

Collins transceiver #1 is connected to the mobile instrumentation system. It will receive all test packets and pass them on to the mini-computer via the DMA channel. Several internal signals in this radio (AGC, detected video, etc.) will be monitored by the instrumentation system, and Collins has provided a 36-pin connector on all transceivers that will supply the needed signals.

Switch #1 selects input signals either from the roof-mounted antenna or from test signals generated in the van.

The internally generated signals either can be spread-spectrum,

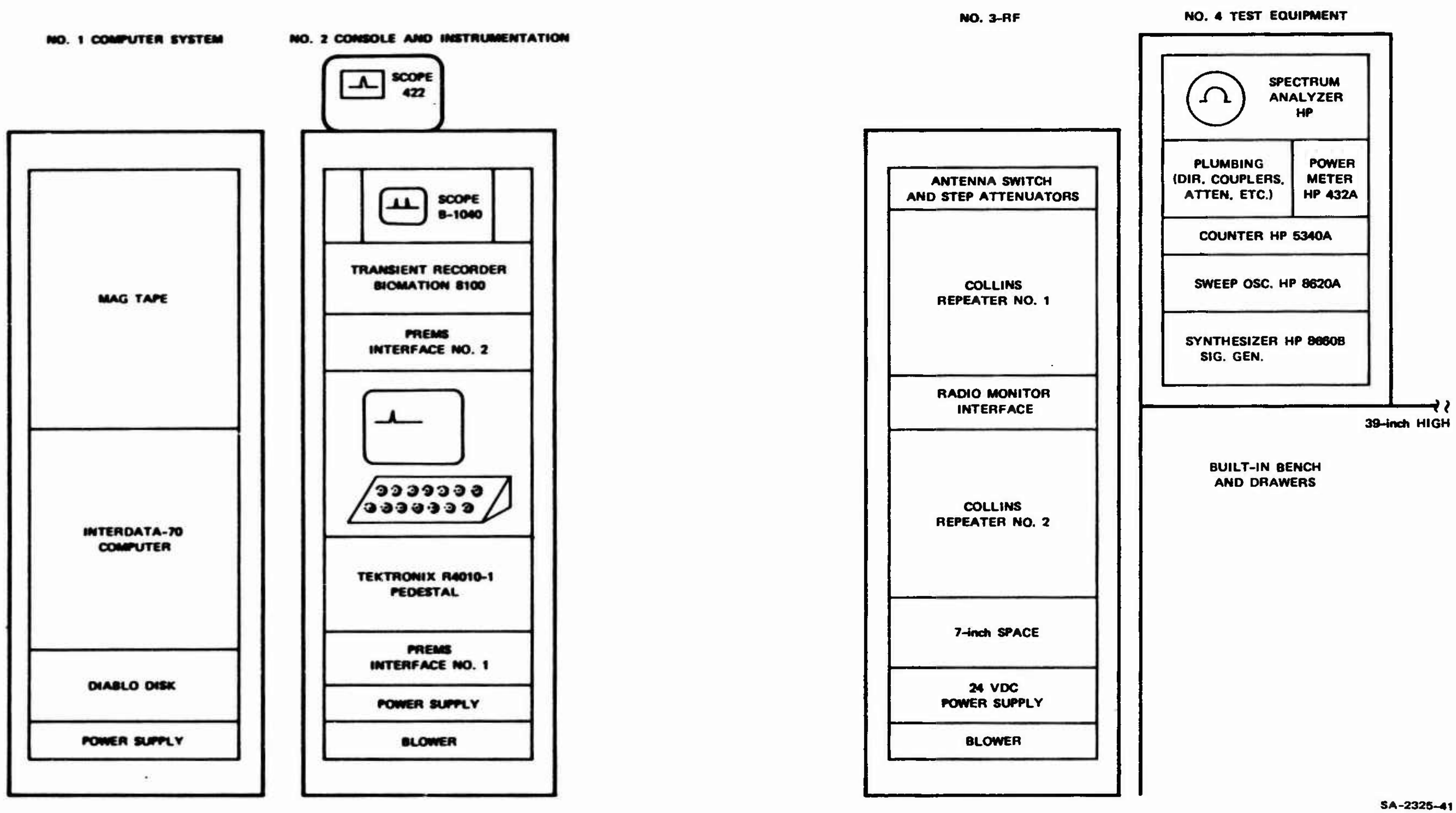


FIGURE 5 MOBILE INSTRUMENTED REPEATER (MIR) PRELIMINARY RACK LAYOUT

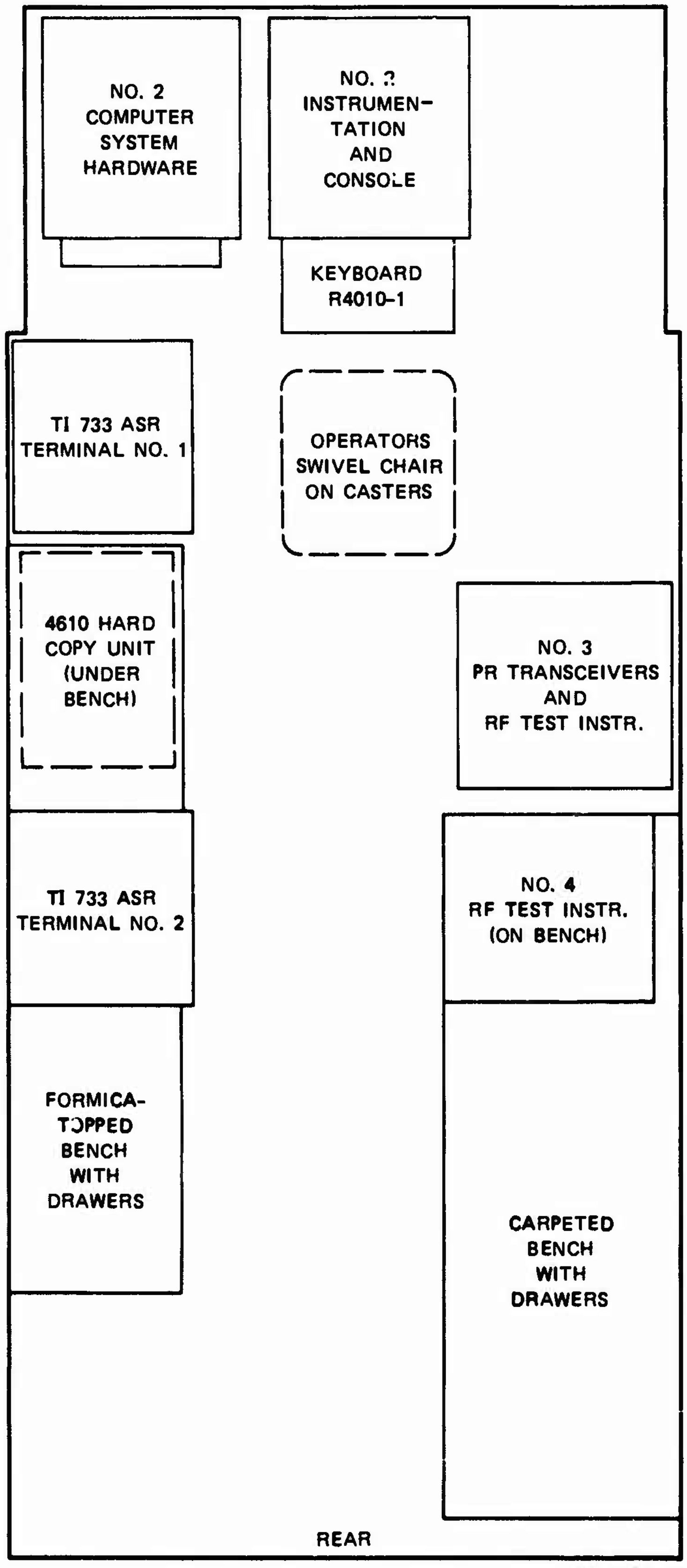
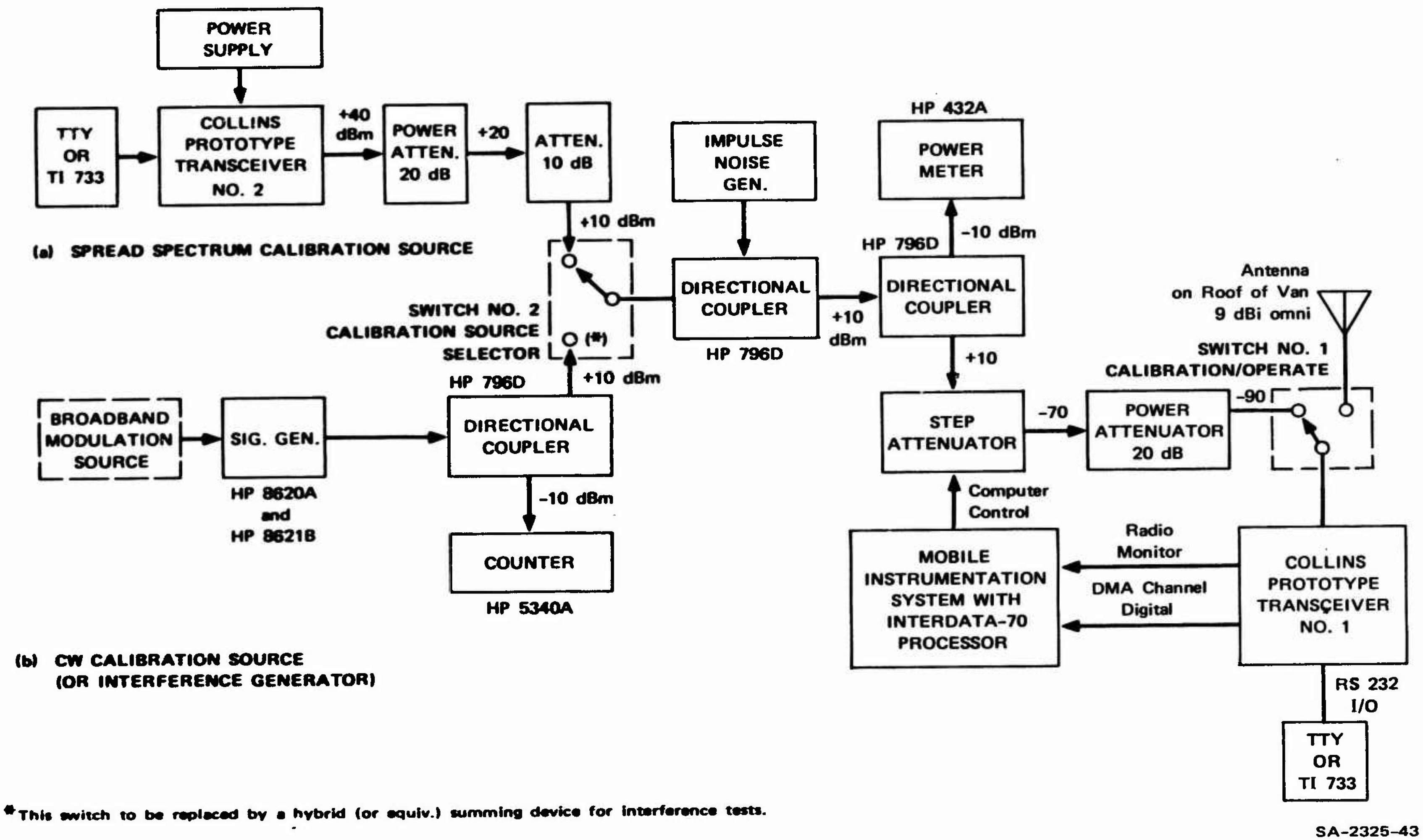


FIGURE 6 MOBILE INSTRUMENTED REPEATER (MIR) PLAN VIEW LAYOUT



*This switch to be replaced by a hybrid (or equiv.) summing device for interference tests.

FIGURE 7 RF TEST SETUP FOR INSTRUMENTED REPEATER generated by Collins tranceiver #2, or can be CW calibration signals. Switch #2 is used to select which source is to be used, as can be seen in the figure.

Whenever S/I interference tests are run, switch #2 will be replaced by a hybrid summing device. Transceiver #2 will provide the signal (S), and the signal generator will supply interference (I). CW interference can be generated directly as shown. Broadband interference will be simulated by connecting a suitable signal source such as a noise generator to the modulation input. A mixer and pulse generator (not shown in Figure 7) will be inserted in the signal generator output to provide pulsed RF interference, simulating radars and other pulsed systems.

An impulse noise generator is shown connected up, using a directional coupler, to permit tests of susceptibility to man-made noise.

A power meter will also be interconnected into the test setup, using another directional coupler, in order to accurately measure the calibration inputs and S/I values.

4. Instrumentation Setups

Figure 8 shows a block diagram of the planned setup for the mobile instrumented repeater (details on the RF portion of this setup were discussed above, and were shown in Figure 7).

The Collins packet radio repeater will be connected to the Interdata-70 minicomputer by a digital DMA interface. A terminal device will also be connected to the repeater's RS-232 I/O port, in order to load software and control repeater operation. A TI 733 ASR terminal is shown in Figure 8; alternatives we are considering include the use of an ASR-33 Teletype, or possibly a direct connection to the mini via a PASLA (programmable asynchronous line adapter).

SRI will develop an Analog Instrumentation Interface (AII) in order to monitor several radio parameters. (See Appendix A for a

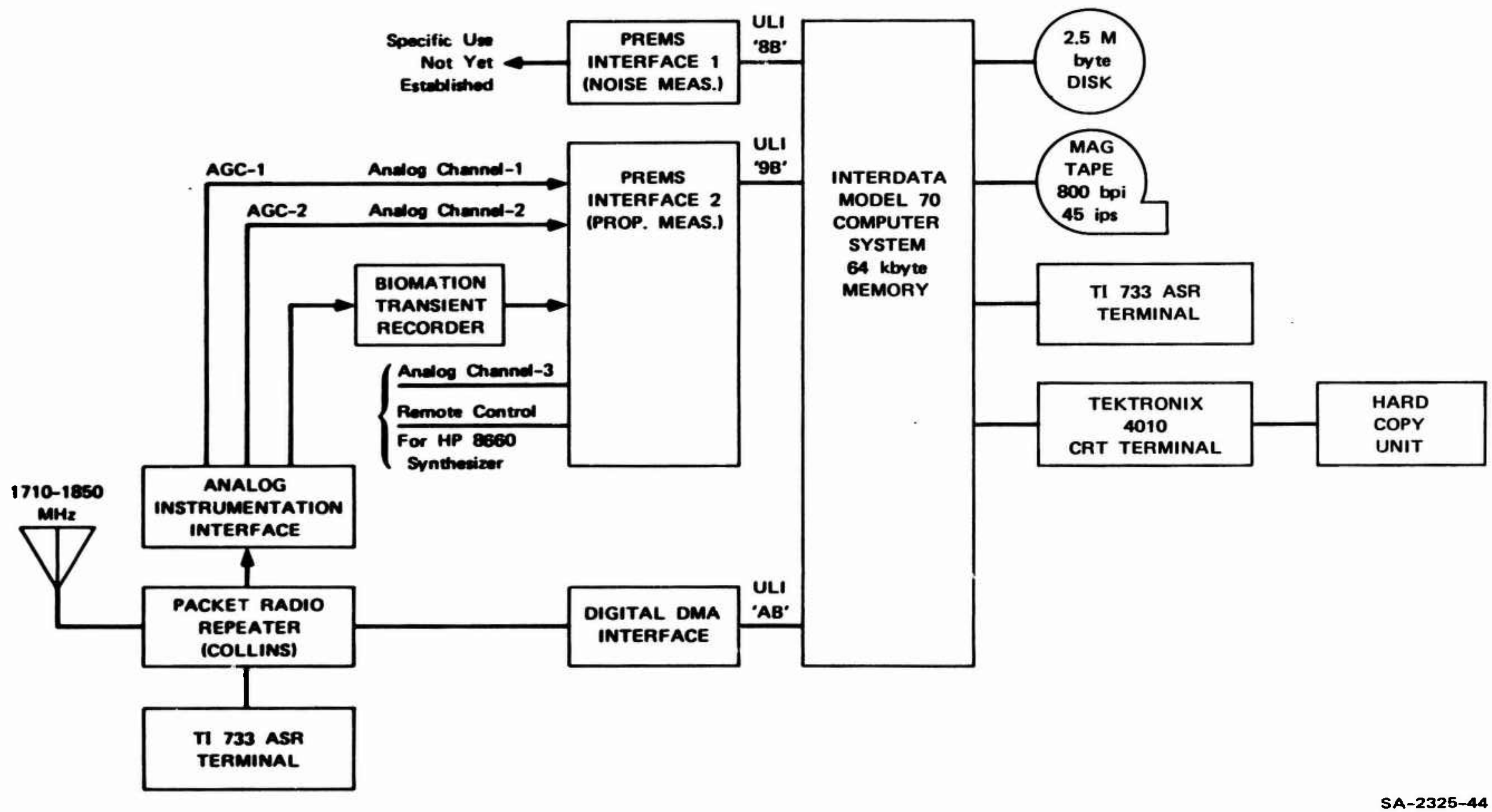


FIGURE 8 INSTRUMENTATION BLOCK DIAGRAM, FOR MOBILE INSTRUMENTED REPEATER

description of the signals available on the radio monitor connector.) This interface will provide, at a minimum, four analog channels as follows:

(1) Non-coherent AGC
(2) Coherent AGC
(3) Detected Video
(4) 300 MHz receiver IF.

The AGC channels will be fed to two existing 8-bit A/D converters in PREMS Interface #2; suitable amplification and filtering will be installed in the AII for this purpose. The AII will also contain one or two active FET probes to match the 50-ohm input impedance of the Biomation transient recorder to the 1K-ohm source impedance of the radio's detector outputs. The 300 MHz receiver IF signal will be routed directly to a Hewlett-Packard spectrum analyzer (not shown in Figure 8) for a panoramic display of the received signal environment. This IF signal will be at a high level (-15 dBm, AGC'd) and therefore, no amplification will be required.

PREMS Interface #1 is shown in Figure 8 for completeness, although specific interconnections have not yet been defined. This unit currently contains noise-measuring hardware, consisting of six threshold detectors (140 MHz input) and a variety of counters and timers.

The remainder of Figure 8 shows the Interdata-70 minicomputer system and its peripheral equipment, connected to the other instrumentation. The next subsection will describe the computer configuration.

5. Computer System Configuration

Figure 9 illustrates the bussing and I/O structures of the ARPA Interdata-70 minicomputer, as it will be when the upgrades are installed. The system configuration will include the following items:

(1) Interdata model 70 processor
(2) 64 K bytes core memory

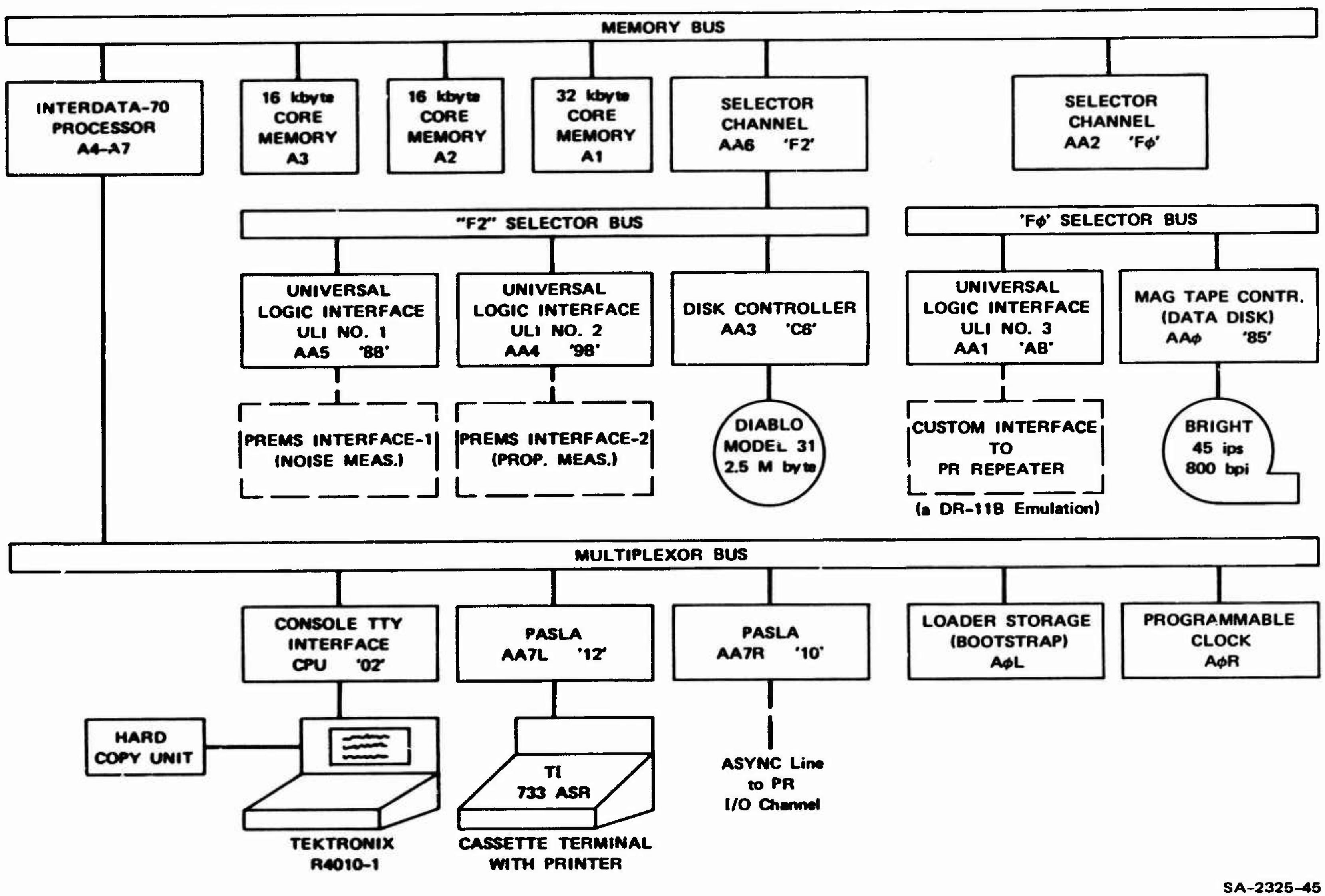


FIGURE 9 INTERDATA-70 COMPUTER SYSTEM BUSSING AND I/O

(3) Loader storage unit (bootstrap)

(4) Real time clock

(5) 2.5 M byte cartridge disk

(6) 45 ips 9-track magnetic tape

(7) Two selector channels

(8) Three universal logic interfaces

(9) Two asynchronous channels - RS 232

(10) TI 733 ASR terminal

(11) Tektronix R4010-1 graphics terminal with 4610 hard copy unit.

6. <u>DOS Operating System</u>

We are planning to install the Interdata DOS disk operating system in the ARPA van-mounted minicomputer, in order to reduce the time and costs associated with the development and maintenance of software for the experimental instrumentation system.* The necessary hardware upgrades are on order†, with delivery expected in January. Meanwhile, we are using the SRI-owned system for software development and checkout. The two hardware configurations are compatible for this purpose.

We have SYSGENNED their current release (DOS R03), with the addition of a software clock to provide the time of day. The necessary modifications to support the clock were supplied to us by Interdata, and we currently have this new system up and running on the SRI machine. It appears to be working satisfactorily, based on the few preliminary tests that have already been run.

---

*We previously used the PBOSS basic operating system without a disk, and software development time and costs were observed to be a problem. Incorporation of frequently needed changes were very slow, because of lack of on-line storage of the source code and the required language processors.

†Subject to ARPA approval and government inventory search.

7. On-Line Application Software

The approach we are using for application software is to code as much as possible in a high level language, namely FORTRAN. We will write optimized assembly language routines only for the time-critical functions, which in this case mean the bit-error checking algorithms. The executive and all of the on-line file-transfer and maintenance will be at the FORTRAN level.

Existing FORTRAN-coded routines for calibration and extraction of multipath parameters will be moved on line.

The time-flow we expect to support will be as follows:

(1) Initialization--parameter selection, file positioning, choices and options selected.

(2) Calibration.

(3) Propagation measurements.

(4) Error-rate measurements (hopefully, with simultaneous noise measurements).

8. Off-Line Data Reduction

The output from the on-line instrumentation system will be a file (disk or tape*) containing all the measured and recorded parameters for all the experimental runs.

The primary "off-line" functions expected (using this file as input) will be as follows:

(1) Merge (i.e., aggregate, or average) data from several runs or sets of runs.

(2) Perform error-rate calculations on these aggregate data sets.

(3) Provide plots for selected data sets, such as:

- BER versus range
- BER versus multipath time-spread
- Path loss versus range.

---

*These off-line functions could be performed on either the ARPA or the SRI Interdata-70, with the cartridge disks. Tapes would be needed to communicate with other computers for off-line reductions.

VI SPECIFICATIONS FOR TRANSCEIVER-BASED TEST SOFTWARE

A number of IMP-16 microprocessor programs will be needed for the first three Collins transceivers, in order to support our link-related measurements. Several functions will be needed, as outlined below.

The suggested approach for implementing these programs is for SRI to write a set of specifications, and then for Collins to develop and check out the required software. Recognizing that the time required to develop this software may be pacing in the overall experimental schedule, we are expediting these specifications as much as possible. We plan to deliver a draft of these specifications to Collins by November 15 for their review and comment.

Fortunately, the test software needed in January is rather simple and is probably very similar to that which Collins will need anyway as part of a maintenance and diagnostic package.

If it turns out that the total development of this software at Collins would significantly delay the test series, then SRI could contribute to the effort in order to reduce the time factor. Our programmers who developed the SRI portable terminal IMP-16 microprocessor software could be made available for this purpose.

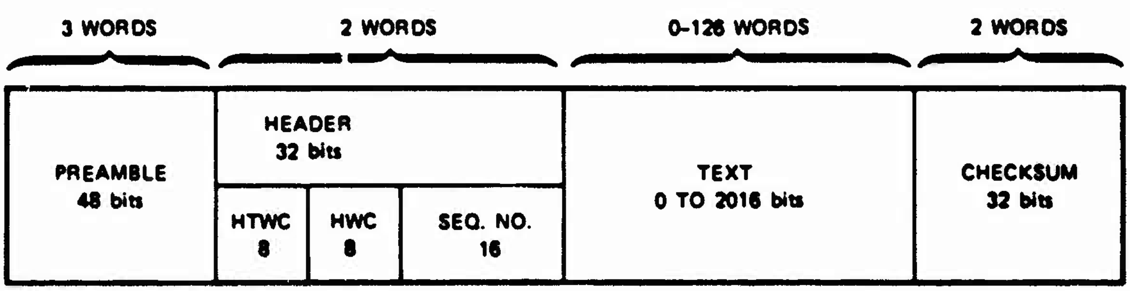
The transceiver-based test software that we currently envision as being needed is described below.

A. Packet Test Generator (Timed Version; No ACK)

Typical hardware configuration will include one Collins transceiver and one TI 733 ASR terminal having the 1200 baud binary cassette options.

The function is to generate and control the transmission of test packets. (See Figure 10 for a specification of the test packet format.) No ACK (acknowledgement) protocol is required; packets are repetitively transmitted on a timed basis using a software timer in the IMP-16. The total number of packets and interpacket delay is to be operator specifiable and variable. Operator control of the following transmitter parameters is required: frequency, power, and bit rate. The header will contain only packet length and sequence number. Text coding is to be any of the following, selectable by the operator: all ones; all zeros; alternating ones and zeros; or PRBS (pseudo-random binary sequence) with an operator-specifiable code length and initial value. Preloaded packet buffers are to be used and re-used in circular fashion. Packet length and number of buffers are to be operator selectable. See Table 2 for a summary of these parameters.

This packet test generator software will be needed immediately when the transceivers are delivered to SRI.



NOTE: HTWC = Header plus text word count—8 bits
HWC = Header word count—8 bits (a fixed value of 2 in this case)
SEQ. NO. = Packet sequence number—16 bits (modulo 65 K).

SA-2325-46

FIGURE 10 PACKET FORMAT FOR LINK TESTING

Table 2

CONTROL PARAMETERS FOR TRANSCEIVER-BASED TEST GENERATOR

Item	Parameter	Range	Comments
	TRANSMITTER CONTROL		
1.	Frequency	(1-20)	Twenty rf channels in set
2.	Power control	(0, 5, 10, 15, 20)	20 dB control in four steps
3.	Bit rate	(100, 400)	100 or 400 K bits/second
	PACKET BUFFER STRUCTURE		
4.	Packet length	(1-128)	Length of header plus text
5.	No. of buffers	(4-10)	Depends on available space
	TEXT CODING		
6.	Code type	(0, 1, ALT, PRBS)	0 = all zeros 1 = all ones ALT = alternating 1's and 0's PRBS = pseudo-random binary sequence
7.	PRBS code length	(n = 6, 9, 11, 20)	Code length = 2^n-1
8.	PRBS first word	(0001-FFFF)	
	DUTY CYCLE		
9.	Total number of packets	($1 - 10^6$)	One million upper limit
10.	Time delay	(1 - 1000)	Unit is 100 μsec. 1 = 100 μsec, 1000 = 100 msec.

B. Packet Test Receiver (NOACK Version, for Instrumented Repeater)

The hardware configuration includes one Collins transceiver, which is connected to the ARPA Interdata minicomputer system through a DMA channel, and one terminal device on the transceiver I/O port.

The function is to receive test packets which were generated by (A) above, and pass them on to the minicomputer system via the DMA channel. All packets received will be transferred to the mini, regardless of header or checksum condition. Regardless of actual received packet length, a fixed block length transfer to the mini is recommended. This block, consisting of the entire allocated packet buffer, will contain approximately 135 words: status words (5), header plus text (128), and checksum (2). The repeater should be capable of queuing several received packets, in order to maximize the throughput of experimental data for error-rate testing. A suitable warning flag will be raised if the queue overflows.

This receiving software will be needed immediately when the transceivers are delivered to SRI.

C. Packet Traffic Generator (ACK Version)

The hardware configuration for this version will include one Collins transceiver, which is connected to an SRI intelligent terminal through a DMA channel, and (optionally) one TTY-like terminal device on the transceiver I/O port.

Considering the heavy loading that the packet transport protocols are expected to place on the transceiver's microprocessor, it probably will be appropriate to move the test-packet-generating function out to a traffic-generating terminal.

Thus the function of the software in the transceiver will be to transmit test packets which are generated by the SRI terminal.

The transceiver should be capable of operating in either of two modes: ACK mode, using a packet transport protocol; or NOACK mode, which simply transmits each packet as it is presented.

It probably will be desirable to be able to remotely load and control this version of transceiver software, by means of radio packets. These program and control packets might originate at one of three locations: the instrumented repeater; the simulated station; or (ultimately) the PDP 11/40 station.

D. Packet Test Receiver (ACK Version, for Instrumented Repeater)

This is an expanded version of (B) above. The hardware configuration is the same, but the software functions are expanded.

The required functions will include the following:

(1) Receive test packets of either the NOACK or ACK type, and pass them on to the minicomputer for processing.

(2) Transmit program and control packets from the mini to other transceivers in the test bed.

This receiver will be a companion to the ACK-version traffic generator described in (C) above, and will be needed at the same time that (C) becomes available, in order to permit tests and measurements that depend on packet transport protocols.

It is hoped that software items (C) and (D) can be available by May 1975, although no dates have been firmly established at this time.

Appendix A

RADIO/DIGITAL INTERFACE
AND RADIO MONITOR INTERFACE

M E M O R A N D U M

Collins Radio Group

24 October 1974

To: Distribution

From: R. K. Marston

Subject: Radio/Digital Interface and Radio Monitor Interface

Radio/Digital Interface

The RF radio section and digital microprocessor interface functions is defined in Table I. The arrows denote direction of signal flow; i.e., arrow to the left is a signal from digital section to the radio section, arrow to the right vice-versa. The software functions are self-explanatory. The digital and radio drive capability and load parameters are listed for each interface function.

For long wire interfaces (up to 1000 feet), a special interface card is used at each end. The interface is then balanced twisted pair line with TTL type levels. Actual devices used are National DM8830/8820 (equivalent to T.I. SN75183/182) line drivers/line receivers. The RF interface card can be configured to do both ends of the interface. The card is configured as follows:

- -001 RF head interfacing, only radio/digital interfacing is patched (wired through) with no line drivers/receivers
- -002 RF head interfacing with line drivers/line receivers (10 drivers, 16 receivers)
- -003 Patched wiring only for interfacing digital section
- -004 Line drivers/receivers for digital section use (16 drivers, 10 receivers)

The connector chosen for interface connectors is the D series Amphenol rack and paired connectors with pin contacts. (Figure D1, Insert No. 50). Sheets B-129 through B-135 of Collins Component Standards Manual are enclosed, and parts chosen are labeled thereon.

The radio/digital interface connect together in some appropriate place in the repeater chassis. Remoting the digital card section merely requires a cable between interface connectors and installing the appropriate interface cards.

Radio Monitor Interface

The connector chosen is pin connector (Fig. D2, Insert no. 36W4) as indicated on pages B-120 through B-134 of the enclosed component standards manual.

Table II shows the functions brought out to the radio maintenance monitor connector, and a brief ~~conn~~ect on controls and/or signal levels on each function.

In the present repeater, both interface connectors and the maintenance monitor connector will physically be interior to the repeater shell, because these are not weather proof connectors. Thus, external cables must be carried thru the repeater shell to the appropriate connector.

After review by everyone concerned, this repeater installation information, along with physical installation characteristics, will be communicated to Stanford Research Institute.

R. K. Marston

RKM:cal

TABLE I: [illegible]io/Digital Interface

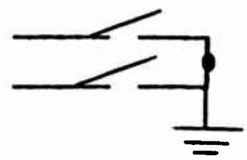
Conn-Pin	Function		Software Functions	Digital Source/Sink Drive	Radio Source/Sink Drive
P1-	Tx Enable	→	DTXI Tx Enable	±3.5ma	1 LSTTL load
	Hi/Lo Data Rate	←	DMA (TX) CTRL 3	±1.75ma	1 LSTTL load
	Tx Clock	→	DTXI BIT CLK	CMOS load	1 LSTTL drive
	Tx Timing	←	DTXI TX CLK	+0.35ma/-2.1ma	3 LSTTL load
	Tx Data	←	DTXI TX DATA	±1.75ma	2 LSTTL load
	Power Control a	←	DMA (TX) CTRL 4		2 LSTTL load
	b	←	CTRL 5		3 LSTTL load
	c	←	CTRL 6		2 LSTTL load
	Freq Control 1 NOT	←	CTRL 7		1 LSTTL load
	2 NOT	←	CTRL 8		1 LSTTL load
	4 NOT	←	CTRL 9		1 LSTTL load
	8 NOT	←	CTRL 10		1 LSTTL load
	10 NOT	←	CTRL 11		1 LSTTL load
	20 NOT	←	CTRL 12		1 LSTTL load
	Rcv Enab @ 100 KBPS	←	DRXI (100 KBS)	+.175/-.3ma	1 LSTTL load
	Rcv EOP @ 100 KBPS	→		CMOS load	1 LSTTL drive
	Rcv DATA @ 100 KBPS	→		CMOS load	1 LSTTL drive
	Rcv Timing @ 100 KBPS	→		CMOS	1 LSTTL drive
	Rcv Enab @ 400 KBPS	←	DRXI (400 KBS)	+.175/load .3ma	1 LSTTL load
	Rcv EOP @ 400 KBPS	→	DRXI (400 KBPS)	CMOS load	1 LSTTL drive
	Rcv DATA @ 400 KBPS	→	DRXI (400 KBS)	CMOS load	1 LSTTL drive
	Rcv Timing @ 400 KBPS	→	DRXI (400 KBS)	CMOS load	1 LSTTL drive
	Carrier Non-Sense	→	DMA 100 KBS & DMA 400 KBS	CMOS load	1 LSTTL drive
	Spare	←	-	-	
	Spare	→	-	-	
	Spare	→	-	-	

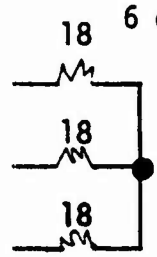
NOTE: 1 LSTTL load = -.36/.02ma
1 LSTTL drive = +.4ma/-3.6ma

TABLE II: Radio Maintenance Monitor Interface

Function		Comments
Self Test A	←	
Self Test B	←	
Self Test C	←	
Non-COH AGC Volt	→	R_s = 1000 , $0^{\underline{V}}$ (min) linear to $+5^{\underline{V}}$ (max)
COH AGC Volt (100 KBPS)	→	R_s = 1000 , $-1.5^{\underline{V}}$ (min) linear to $0^{\underline{V}}$ (max)
COH AGC Volt (400 KBPS)	→	R_s = 1000 , $-1.5^{\underline{V}}$ (min) linear to $0^{\underline{V}}$ (max)
Σ Detected @ 100 KBPS	→	$1^{\underline{V}}$ peak behind 1000 ohms
Δ Detected @ 100 KBPS	→	$1^{\underline{V}}$ peak behind 1000 ohms
Σ+Δ Detected @ 100 KBPS	→	$1^{\underline{V}}$ peak behind 1000 ohms
Σ Detected @ 400 KBPS	→	$1^{\underline{V}}$ peak behind 1000 ohms
Δ Detected @ 400 KBPS	→	$1^{\underline{V}}$ peak behind 1000 ohms
Σ+Δ Detected @ 400 KBPS	→	$1^{\underline{V}}$ peak behind 1000 ohms
100 KBPS Bit Sync In-Lock	→	Bridge across LSTTL (use CMOS)
400 KBPS Bit Sync In-Lock	→	Bridge across LSTTL (use CMOS)
100 KBPS $\overline{\text{EOP}}$ Detection	→	Bridge across LSTTL (use CMOS)
400 KBPS $\overline{\text{EOP}}$ Detection	→	Bridge across LSTTL (use CMOS)
Synth In-Lock	→	Bridge across LSTTL (use CMOS)
Synth Error Voltage	→	R_s = 10K
Bit Sync 100 KBPS Error Voltage	→	R_s = 1000
Bit Sync 400 KBPS Error Voltage	→	R_s = 1000
Forward Power	→	0 to +10 Vdc
Reflected Power	→	0 to +10 Vdc
Tx ENAB-Delayed	→	Bridge across LSTTL (use CMOS)
Tx Local Clock	→	Bridge across CMOS
Tx DATA	→	Bridge across CMOS
$\overline{\text{Rcv ENAB}}$ - Non-COH AGC	→	Bridge across LSTTL (use CMOS)
Rcv ENAB - COH AGC 100 KBPS	→	Bridge across LSTTL (use CMOS)
$\overline{\text{Rcv ENAB}}$ - COH AGC 400 KBPS	→	Bridge across LSTTL (use CMOS)
Rcv DATA - 100 KBPS	→	Bridge across LSTTL (use CMOS)
Rcv DATA - 400 KBPS	→	Bridge across LSTTL (use CMOS)

Table II continued

Function	Comments
Rcv GATED Clock - 100 KBPS	Bridge across LSTTL (use CMOS)
Rcv GATED Clock - 400 KBPS	Bridge across LSTTL (use CMOS)
Blanking - 100 KBPS	Bridge across LSTTL (use CMOS)
Blanking - 400 KBPS	Bridge across LSTTL (use CMOS)
Σ F Encoder	
Δ F Encoder	

COAX		
	6 dB combiner	
Tx 67 MHz Monitor		-20 dB (nominally -30 dBm)
Tx 300 MHz Monitor		-20 dB (nominally -20 dBm)
Rcv Monitor Return		
Rcv IF Output		-15 dBm AGC'd

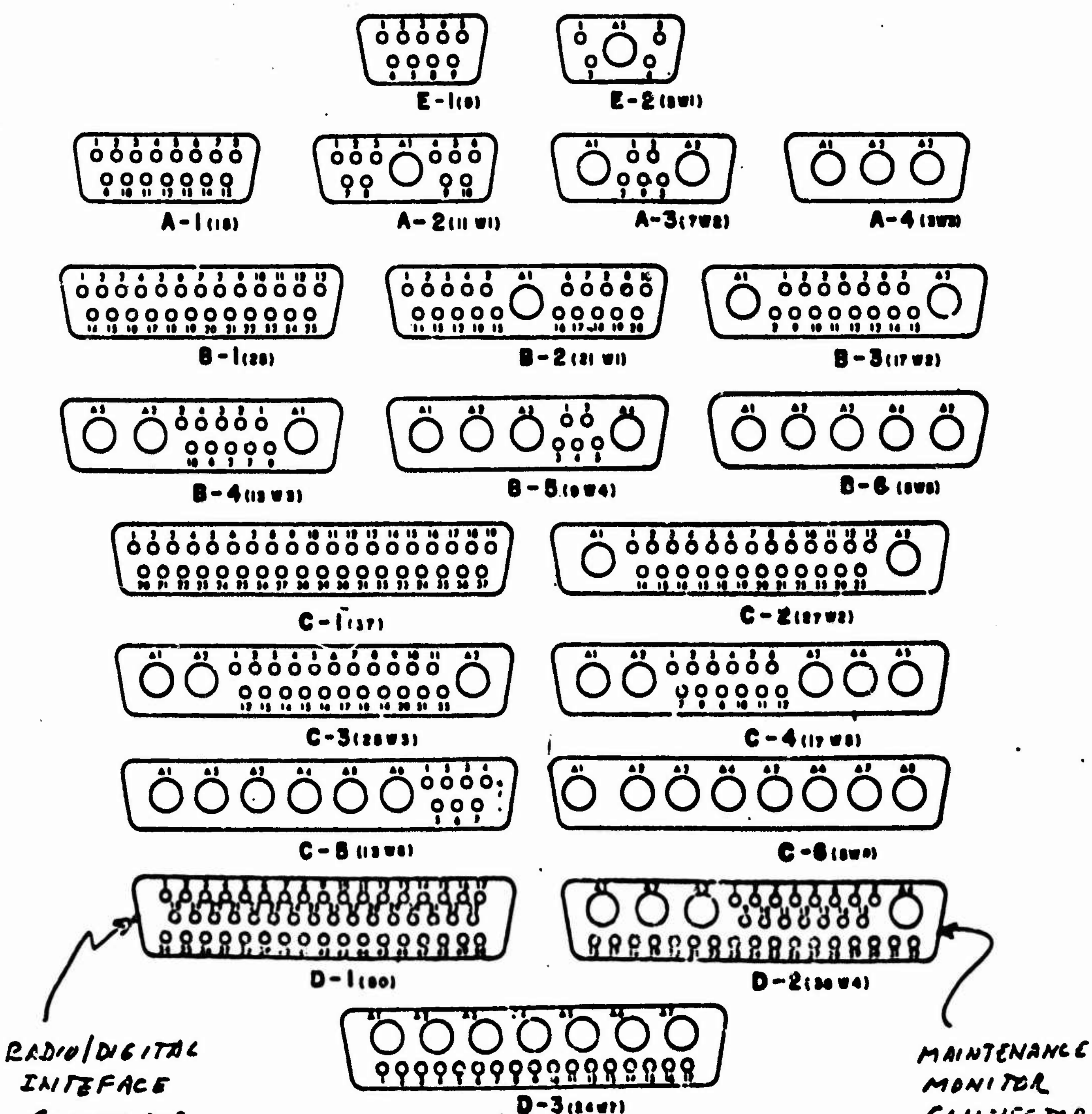
RKM:10/24/74

RACK AND PANEL

Miniature

DESCRIPTION: Available insert layouts of the miniature, rack and panel connectors as viewed from the engaging side of the connector with pin contacts.

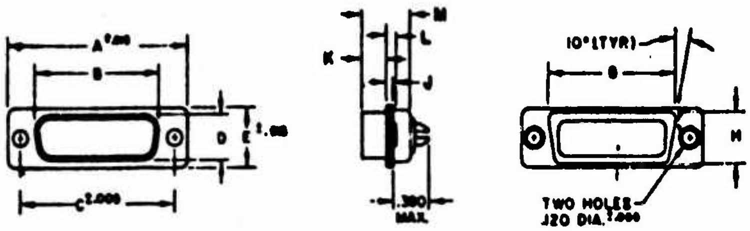
Note: Connectors with integral combinations of power and either coaxial or high voltage contacts are supplied without these snap-in contacts. The latter contacts are purchased separately and inserted into the basic block during assembly. This facilitates stocking and reduces the overall cost of the connector by taking advantage of the larger quantity prices.

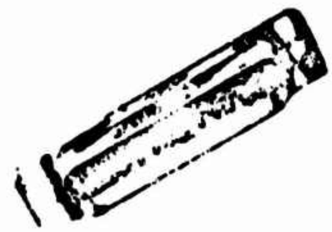


RACK AND PANEL

Miniature

Miniature, rack and panel connectors with pin contacts. Coaxial and/or high voltage contacts must be ordered separately.





*NOTES: Maximum solder pot extension: .078 inch.
Maximum straight coaxial or high voltage contact extension: .656 inch.
Maximum Right Angle coaxial or high voltage contact extension: .347 inch.
Tolerances are ±.010 unless otherwise noted.

SHELL SIZE	DIMENSIONS										
	A	B*	C	D*	E	G*	H*	J	K	L	M
E	1.213	.697	.984	.360	.494	.759	.422	.030	.236	.045	.422
A	1.541	1.025	1.312	.360	.494	1.083	.422	.030	.236	.045	.422
B	2.088	1.583	1.852	.378	.494	1.625	.422	.039	.231	.060	.426
C	2.729	2.231	2.500	.378	.494	2.272	.422	.039	.231	.060	.426
D	2.635	2.127	2.406	.484	.605	2.178	.534	.039	.231	.060	.426

*DIMENSIONS ARE OUTSIDE DIMENSIONS MEASURED AT BOTTOM OF DRAW.

FIG NO.	INSERT NO	#20 CONT.	COAX/HV CONT.	SHELL SIZE	MILITARY APPLICATION		COMMERCIAL
					COLLINS PN	MILITARY PN	COLLINS PN
E1	9	9	-	E	371-1284-200	M24308/3-1	371-0168-00D
E2	5W1	4:	1	E	371-1284-280	-	371-0906-00
A1	15	15	-	A	371-1284-210	M24308/3-2	371-0169-00D
A2	11W1	10	1	A	371-1284-260	-	371-0909-00
A3	7W2	-5	2	A	371-1284-250	-	371-0908-00
A4	3W3	--	3	A	371-1284-270	-	371-0907-00
B1	25	25	-	B	371-1284-220	M24308/3-3	371-0170-00D
B2	21W1	20	1	B	371-1284-330	-	371-0915-00
B3	17W2	15	2	B	371-1284-320	-	371-0914-00
B4	13W3	10	3	B	371-1284-310	-	371-0913-00
B5	9W4	5	4	B	371-1284-300	-	371-0245-00
B6	5W5	--	5	B	371-1284-290	-	
C1	37	37	-	C	371-1284-230	M24308/3-4	371-0171-00
C2	27W2	25	2	C	371-1284-380	-	371-0923-00
C3	25W3	22	3	C	371-1284-370	-	371-0924-00
C4	17W5	12	5	C	371-1284-360	-	-
C5	13W6	7	6	C	371-1284-350	-	-
C6	8W8	--	8	C	371-1284-340	-	-
D1	50	50	-	D	371-1284-240	M24308/3-5	371-0118-00
D2	36W4	32	4	D	371-1284-400	-	-
D3	24W7	17	7	D	371-1284-390	-	-

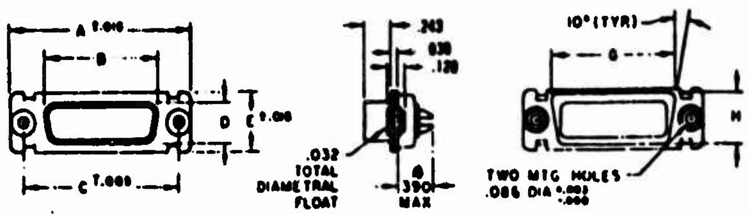
RADIO INTERFACE CONN.

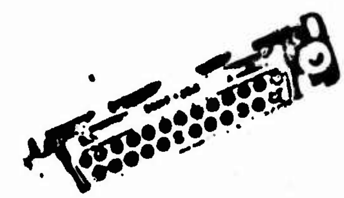
MAINT MONITOR "MATING" CONN.

RACK AND PANEL

Miniature

Miniature, rack and panel connectors with socket contacts and "Float" bushings. Coaxial and/or high voltage contacts must be ordered separately.





* NOTES: Maximum solder pot extension: .078 inch.
Maximum straight coaxial or high voltage contact extension: .656 inch.
Maximum Right Angle coaxial or high voltage contact extension: .547 inch.
Tolerances are ±.010 unless otherwise noted.

SHELL SIZE	DIMENSIONS						
	A	B*	C	D*	E	G*	H*
E	1.213	.640	.984	.308	.494	.759	.422
A	1.541	.968	1.312	.308	.494	1.083	.422
B	2.088	1.503	1.852	.308	.494	1.625	.422
C	2.729	2.156	2.500	.308	.494	2.272	.422
D	2.635	2.062	2.406	.420	.605	2.178	.534

*Dimensions are outside dimensions measured at bottom of draw.

FIG NO.	INSERT NO	#20 CONT	COAX/HV CONT	SHELL SIZE	MILITARY PREFERRED PN	COMMERCIAL COLLINS PN
E1	9	9	-	E	371-1285 210	371-0164-00D
E2	5W1	4	1	E	371-1285 290	371-0905-00
A1	15	15	-	A	371-1285 220	371-0165-00D
A2	11W1	10	1	A	371-1285 270	371-0912-00
A3	7W2	5	2	A	371-1285 260	371-0911-00
A4	3W3	--	3	A	371-1285 280	371-0910-00
B1	25	25	-	B	371-1285 230	371-0166-00D
B2	21W1	20	1	B	371-1285 340	371-0920-00
B3	17W2	15	2	B	371-1285 330	371-0919-00
B4	13W3	10	3	B	371-1285 320	371-0918-00
B5	9W4	5	4	B	371-1285 310	371-0281-00
B6	5W5	--	5	B	371-1285 300	371-0330-00
C1	37	37	-	C	371-1285 240	371-0167-00
C2	27W2	25	2	C	371-1285 390	371-0931-00
C3	25W3	22	3	C	371-1285 380	371-0932-00
C4	17W5	12	5	C	371-1285 370	-
C5	13W6	7	6	C	371-1285 360	-
C6	8W8	--	8	C	371-1285 350	-
D1	50	50	-	D	371-1285 250	371-0182-00
D2	36W4	32	4	D	371-1285 410	-
D3	24W7	17	7	D	371-1285 400	-

DIGITAL RADIO/DIG INTERFACE CONN.

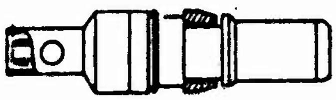
MAINTENANCE

RACK AND PANEL

Miniature

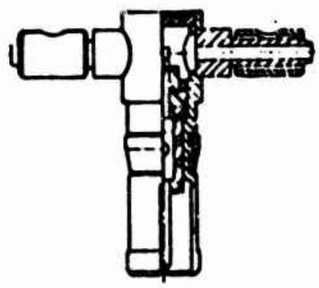
Coaxial contacts below snap-in the large holes in the connectors in this section.

Working Voltage: 300
Test Voltage: 1000
Current Rating: Determined by cable current rating.
Shell and Contact Material: Copper alloy, silver plated and gold flashed.
Insulation Material: Teflon.
Cable Assembly Instructions (CAI): 580-9084-00 line 1 for straight contact, line 6 for angle contact.

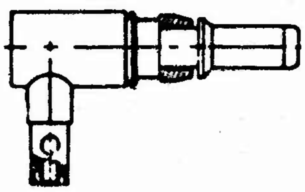


SOCKET FIGURE 1

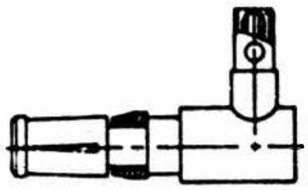
PIN FIGURE 3



PIN FIGURE 5



SOCKET FIGURE 2

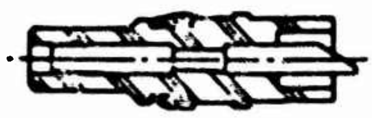


PIN FIGURE 4

FIG NO	TYPE	CABLE ACCOMMODATION	MILITARY COLLINS PN	COMMERCIAL COLLINS PN
1	Plug	RG-196/U	371-1283-120	371-0183-00
2	Plug, Angle	RG-196/U	371-1283-100	371-2471-00
3	Receptacle	RG-196/U	371-1283-110	371-2472-00
4	Receptacle, Angle	RG-196/U	371-1283-090	371-2470-00
5	Receptacle, Tee	RG-196/U	-	371-0230-00
1	Plug	RG-174, 188/U	371-1283-040	371-2493-00
2	Plug, Angle	RG-174, 188/U	371-1283-020	371-2491-00
3	Receptacle	RG-174, 188/U	371-1283-030	371-2492-00
4	Receptacle, Angle	RG-174, 188/U	371-1283-010	371-2490-00
4	Receptacle, Angle	RG-58/U	371-1283-130	371-2546-00

High voltage contacts snap-in large holes in the connectors in this section.
Working Voltage: 1000
Test Voltage: 3000
Current Rating: 3 amperes.
Contact Material. Copper alloy, silver plated and gold flashed.
Insulation Material: Nylon.

PLUGS WITH SOCKET CONTACT



STRAIGHT 371-0246-00

ANGLE 371-0248-00

RECEPTACLES WITH PIN CONTACT

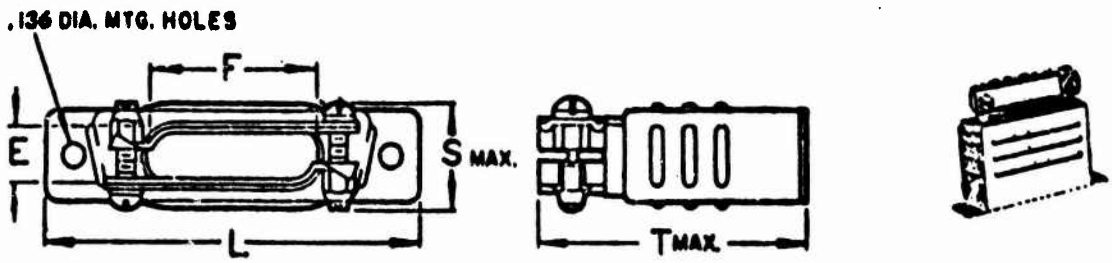
STRAIGHT 371-0247-00

ANGLE 371-0249-00

RACK AND PANEL

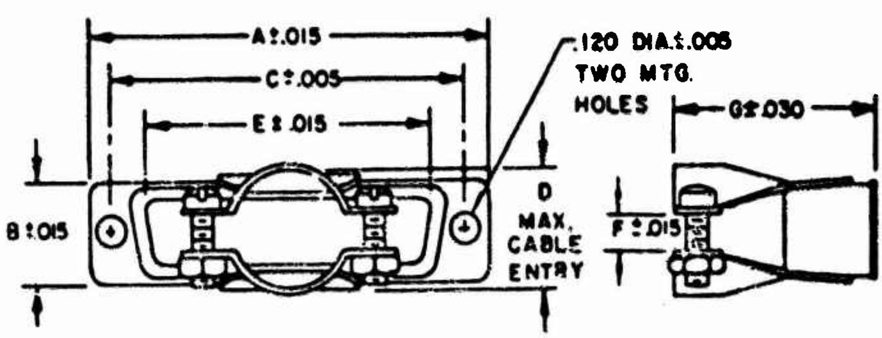
Miniature

Straight Hood



Shell Size	E	F	S	T	L	Collins Part Number
E	.375	.375	.578	1.219	1.203	371-0144-00
A	.312	.718	.578	1.250	1.531	371-0145-00
B	.312	1.000	.578	1.531	2.078	371-0146-00
C	.312	1.375	.578	1.531	2.718	371-0147-00
D	.406	1.406	.687	.656	2.625	371-0148-00

Hood, Top Opening

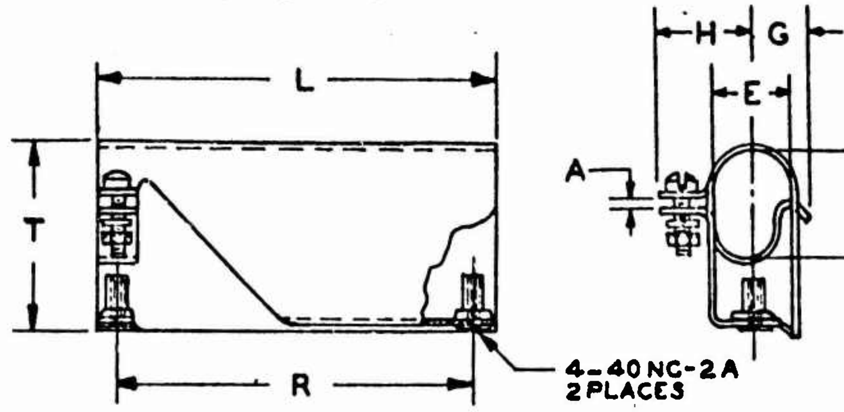


Shell Size	A	B	C	D	E	F	G	Collins Part Number
A	1.531	.500	1.312	.406	.984	.125	1.031	371-0184-00
B	2.078	.500	1.852	.593	1.515	.187	1.062	371-0185-00
C	2.718	.500	2.500	.718	2.171	.250	1.062	371-0186-00
D	2.625	.609	2.406	.812	2.093	.312	1.062	371-0187-00

RACK AND PANEL

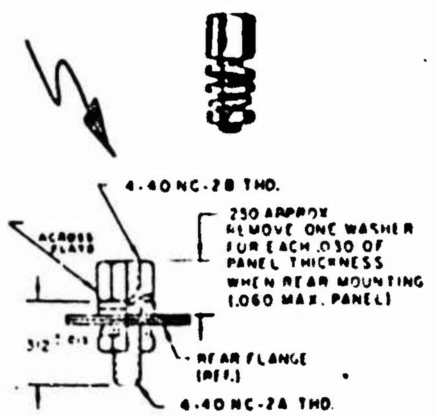
Miniature

Hood, Right Angle



Shell Size	A	E	F	G	H	L	R	T	Collins Part Number
E	.109	.437	.437	.281	.468	1.203	.984	.718	371-0241-00
A	.109	.437	.437	.281	.468	1.531	1.312	.718	371-0071-00
B	.109	.437	.625	.281	.468	2.078	1.852	.968	371-0072-00
C	.109	.437	.812	.281	.468	2.718	2.500	1.187	371-0073-00
D	.109	.562	.906	.343	.531	2.625	2.406	1.250	371-0074-00

Cable to chassis lock assembly: The receptacle assembly mounts with the panel mounted connector. The stud assembly slips over the cable connector and straight hood (if hood is used). By screwing the stud assembly into the receptacle assembly, the cable connector is locked to the chassis connector.



RECEPTACLE ASSEMBLY
371-0062-00

STUD ASSEMBLY

CONNECTOR SHELL SIZE	CONNECTORS HAVING PIN CONTACTS	
	WITHOUT JUNCTION SHELLS	WITH JUNCTION SHELLS
E	371-0040-00	371-0040-010
A		
B	371-0040-020	371-0040-030
C		
D	371-0040-050	371-0040-060
	CONNECTORS HAVING SOCKET CONTACTS	
	WITHOUT JUNCTION SHELLS	WITH JUNCTION SHELLS
E		
A	371-0040-00	371-0040-010
B		
C		
D		
D	371-0180-00	371-0040-040

Appendix B

CONFIDENCE LIMITS IN THE MEASUREMENT OF LOW ERROR PROBABILITIES

CONFIDENCE LIMITS IN THE MEASUREMENT OF LOW ERROR PROBABILITIES

1. INTRODUCTION

The experimental validation of an error-rate model for a communications system requires an estimate of the true binary error rate from a finite set of measurements. Two questions then arise: How much confidence can be placed in error-rate estimates made with limited measured data? How much measuring must be done to obtain a given degree of confidence in an estimate?

The general technique for measuring the binary error rate of a communications system is to transmit a known binary sequence over the channel, compare the receiver's decision with a local reference, and compute the ratio of the number of errors to the number of transmitted bits for some interval. The receiver decides, only through its normal detection scheme, which binary signal was transmitted. After some measuring interval, we are asked to give an estimate of the true binary error rate for the system from this data. Because our estimate must be based on a finite number of samples of a random phenomenon, it will be subject to some error. If we can describe this error in terms of a probability law, we can better assess the accuracy of our answer. When the true error rate is small, we may obtain a very few errors in our sample. We then have the classical problem of estimating the rate of occurrence of rare events from a small sample.

2. ERROR-RATE PROBABILITY LAW

A binary communications system transmits one of two possible signals (mark or space), and the receiver must decide at the end of each signaling element time which signal was transmitted. These receiver decisions can be described by Bernoulli trials where the results are traditionally termed success or failure. In this Appendix, the occurrence of an error will be designated by success and the absence of an error by failure. This definition is consistent with statistical conventions.

For a symmetrical binary channel, we define p as the probability of a detected error, where a detected error is defined as a mark received when a space was transmitted or a space received when a mark was transmitted. We desire to estimate the parameter p from our measurements.

3. LOW-ERROR CONFIDENCE INTERVALS

From a Bernoulli probability distribution, if we take n independent samples where the probability of error (or success) is p, the probability of obtaining x errors will follow a binomial distribution. (The case when the samples are not independent is discussed later.) If we know *a priori* that the probability of error is low (*i.e.* $p < 0.1$), we can approximate this adequately by a Poisson distribution.

We then find confidence intervals for this distribution by determining probabilities that k_1 or less errors occur and k_2 or more errors occur, given that the true error rate is p:

$$P[x \le k_1] = \sum_{x=0}^{k_1} \frac{e^{-np}(np)^x}{x!}$$

$$P[x \ge k_2] = \sum_{x=k_2}^{\infty} \frac{e^{-np}(np)^x}{x!} ,$$

where n ia the number of samples taken.

Note that the product, np, is also the expected number of errors we would observe with thia error rate and number of samples. The expected number of errors (or auccesaes) is more conventionally defined as the parameter of the Poisson distribution.

If we have observed a particular number of errors in an experiment but do not know the value of the parameter, we can reverse the procedure and determine rangea of parametera that could still give the obaerved value within a given probability.

From cumulative Poisson distribution tables we determine the following:

(1) The smallest integer value of the parameter, np_1, such that with k observed errors

$$\sum_{x=0}^{k} \frac{e^{-np_1}(np_1)^x}{x!} \le C$$

(2) The largest integer value of the parameter, np_2, such that with k observed errors

$$\sum_{x=k}^{\infty} \frac{e^{-np_2}(np_2)^x}{x!} \le C$$

where C is some confidence level (*e.g.*, 0.05).

If we observe k errors in a sample of n, the best estimator, $\hat{p}$, of the true binary error rate is simply the ratio k/n. The upper and lower confidence limits at some confidence level, C, are p_1 and p_2. Values of np_1 and np_2 for a confidence level of 5 percent are shown in Table B-I.

4. CONFIDENCE CRITERIA

It is convenient at this stage to seek a single-valued confidence parameter. For example, we could define a ratio, A, in terms of the upper and lower confidence estimates as

$$A = \frac{p_1}{p_2} \quad .$$

Or we could define a percentage error, P, between the confidence estimates and the estimate itself as follows:

$$P = \frac{p_1 - p_2}{\hat{p}} \times 100 \quad .$$

Table B-1.

UPPER AND LOWER 90-PERCENT CONFIDENCE ESTIMATES
OF POISSON PARAMETER WITH k OBSERVED SUCCESSES

k	UPPER CONFIDENCE LEVEL* (np_1)	LOWER CONFIDENCE LEVEL* (np_2)	RATIO (A)	PERCENTAGE ERROR (P)
0	3.0	--	--	--
1	4.75	0.052	91.3	470
2	6.3	0.36	17.5	297
3	7.76	0.82	9.46	231
4	9.15	1.38	6.63	194
5	10.5	1.97	5.33	171
6	11.85	2.61	4.54	154
7	13.15	3.29	4.0	141
8	14.43	3.98	3.62	131
9	15.8	4.7	3.36	123
10	17.	5.44	3.12	116
11	18.2	6.18	2.94	109
12	19.5	6.94	2.81	105
13	20.8	7.7	2.7	101
14	21.9	8.46	2.59	96
15	23.1	9.25	2.50	92
17	25.8	10.85	2.38	88
20	29.2	13.27	2.20	80
25	34.9	17.3	2.02	70
30	40.6	22.4	1.81	61
50	64.	39.9	1.60	48
70	86.5	58.1	1.49	41
100	118.8	85.6	1.39	33
200	228.	182.	1.25	23
300	335.	279.	1.20	19
500	543.	467.	1.16	15
1000	1063.	961.	1.11	10

* Confidence level = 0.05.

Both of these parameters are also tabulated in Table B-I. Notice that these confidence criteria depend directly on the number of *errors observed* and not on the number of samples taken.

We are now in a position to determine the amount of sampling we must do to obtain a given degree of confidence in our parameter estimate. If we use one of the above confidence definitions, our rule is to continue to sample until the observed errors are greater than a required number. Note that as the sample size is always increased until the number of observed errors exceeds a constant, then the number of samples required will be roughly inversely proportional to the error-rate estimate. This is intuitively satisfying in that more samples are required for lower error-rate estimates.

5. EXAMPLE

Assume we desire to state with 90-percent confidence that the difference between the upper and lower confidence levels is always less than the estimate itself. From Table B-I we see that this would require a minimum of 14 observed errors in our sample. If the number of observed errors in a string of 1000 transmitted bits were 6, we would defer making an error probability estimate until we observed, say, an additional 1000 bits. If the next 1000 bits contained 8 errors we would estimate the error probability as 14/2000 or 7×10^{-3}. And we could say with 90-percent confidence that the true error probability lies within 4.2×10^{-3} and 1.1×10^{-2}.

6. CORRECTIONS FOR NONINDEPENDENT ERRORS

It has been observed that errors do not occur independently. However, without a detailed knowledge of the exact statistics of the error distributions, we assume that the errors occur in average bursts of length, L, and that the *bursts* of errors are independent. To obtain confidence limits we consider that an "error" is in reality a burst of L errors so that the minimum number of actual errors required for a given confidence is L times the previously defined errors.

In the previous example, assume that the average burst is 7 errors in length. To observe 14 independent bursts of errors, we would need to accumulate slightly over 100 errors before obtaining the degree of confidence desired.