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OPERATIONAL EVALUATION OF A VOICE CONCENTRATOR OVER AUTOVON INT--ETC(U)
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DEFENSE COMMUNICATIONS ENGINEERING CENTER

TECHINICAL REPORT NO. 5-80

OPERATIONAL EVALUATION OF A VOICE CONCENTRATOR OVER AUTOVON INTERSWITCH TRUNKS

DECEMBER 1980

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

Results of test and evaluation of a commercial voice concentrator are reported. The device tested concentrated 17 voice channels into 9 AUTOVON interswitch trunks operating between Ft. Detrick, MD and Feldberg, Germany. Tests of voice channel parameters indicated acceptable performance provided by the voice concentration. Tests of data signals operated over this voice concentrator revealed problems when using VFCT's. Traffic data analysis showed minimal speech loss and blocking occurred during busy hours.

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OPERATIONAL EVALUATION OF A

VOICE CONCENTRATOR OVER AUTOVON

INTERSWITCH TRUNKS

DECEMBER 1980

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EXECUTIVE SUMMARY

This report describes results of test and evaluation of a commercial voice concentrator applied to AUTOVON interswitch trunks between Feldberg, Germany and Ft. Detrick, Maryland. By virtue of time assignment speech interpolation (TASI) techniques, the voice concentrator provided approximately a 2 to 1 compression of voice channels onto trunks, with a configuration of 17 channels onto 9 trunks selected for this AUTOVON application. Tests consisted of (1) voice channel characterization of the nine selected trunks, before and after cutover of the voice concentrator, (2) performance characterization of data signals operated through voice concentrator channels, (3) traffic data collection and analysis and (4) user subjective evaluation.

The test period extended from October 1979 to February 1980, at which time the voice concentrator installation was approved by DCA as a result of the findings presented herein. In summary, voice channel performance, established via quality control (QC) tests, indicated that all channels met performance standards specified by DCA for AUTOVON interswitch trunks. In comparing results before and after cutover of the voice concentrator, negligible degradation of voice channel performance was observed. Tests of VFCT's indicated that the voice concentrator in general failed to properly recognize these signals as data and preempted these connections after a short period. Various modems tested provided marginally acceptable performance, both before and after cutover of the voice concentrator. However, it should be pointed out that these particular AUTOVON trunks are not specified for data carrying capability, and that these data tests should be repeated over data grade trunks. Traffic data collection and analysis indicated that the 17 channels were heavily used as expected on those already saturated trunks. Percentages of speech loss and blocking, two potential problems with any TASI system, were quite low and judged to be acceptable. Finally, user subjective evaluations collected for over a thousand calls indicated user acceptance of the system.

Although approval is indicated for AUTOVON IST's, application of the voice concentrator to other DCS networks, such as AUTOSEVOCOM or AUTOVON access lines, will require additional testing. Additionally, certain tests originally scheduled for the Ft. Detrick - Feldberg installation could not be practically accomplished in an operational configuration. Hence, tests which involve voice concentrator performance as a function of certain transmission or equipment impairments will have to be done in a laboratory controlled environment.

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I. INTRODUCTION

DCA's interest in improving the grade of service on AUTOVON interswitch trunks has led to the installation, test and evaluation, and approval of the COM2 Voice Concentrator* for AUTOVON IST's operating between Ft. Detrick, MD and Feldberg, FRG. The COM2 Voice Concentrator utilizes time assignment speech interpolation (TASI) to concentrate up to (2n-1) voice circuits into n trunks, thus providing improved grade-of-service on existing trunks or allowing a reduction in existing number of trunks with attendant cost savings. Several voice grade interswitch trunks were selected from CONUS-Europe AUTOVON IST's as a means of alleviating already saturated communications facilities.

This technical report provides results, analyses, conclusions and recommendations derived from tests conducted on the COM2 system during the period October 1979 through February 1980. A COM2 configuration of 17 channels on 9 trunks was selected for test between Ft. Detrick and Feldberg. Additionally, a mix of media and transmission eqiupment was selected for routing of the nine trunks. The selection of heavily used AUTOVON trunks, a mix of media with different trunk routing, and a mix of FDM and PCM transmission equipment meant that the COM2 would be subjected to a stringent and perhaps worse case test environment.

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* The COM2 Voice Concentrator is manufactured by STC Communications Corporation, which is a subsidiary of Storage Technology Corporation and is located in Broomfield, Colorado. See Appendix A for a detailed description of the COM2 System.

II. BACKGROUND

1. TEST CONFIGURATION

The objective of this evaluation was to verify the application of the COM2 Voice Concentrator to AUTOVON Interswitch Trunks (IST's) within the Defense Communications System. Testing was accomplished on transoceanic IST's between CONUS (AT&T switch at Cedarbrook) and the Federal Republic of Germany (490L switch at Feldberg). The COM2 equipment was located at the East Coast Telecommunications Center, Ft. Detrick, MD., and at the Feldberg AUTOVON switch. Figure 1 indicates the COM2 operational configuration.

The COM2 configuration employed with this test provided compression of 17 channels into 9 trunks (called facilities within the COM2). Of the 17 channels, 9 tail circuits already existed between Ft. Detrick and the AUTOVON switch at Cedarbrook, leaving 8 additional tail circuits required which were leased from AT&T. At Feldberg eight additional channels were programmed into the 490L AUTOVON switch. Of the nine trunks, seven were routed through the Digital Communications Subsystem (DCSS) of the DSCS between Ft. Detrick and Landstuhl, Germany. From Landstuhl, these seven trunks were routed to the Feldberg switch via Donnensberg using analog (FDM/FM) line-of-sight (LOS) links. The remaining two trunks were routed through Frequency Division Multiplex (FDM) of the DSCS between CONUS and Croughton, England. From Croughton, these two trunks were extended to Feldberg via LOS links, although initially a combination of troposcatter and LOS links was used which proved unacceptable because of noise levels which exceeded DCA standards.

Interface of the COM2 at Ft. Detrick and Feldberg required signalling and level conversion as indicated in Figure 2. The access lines from Cedarbrook to Ft. Detrick were all 4-wire with SFC in-band signalling. Interface with the COM2 required conditioning (pads and amplifiers), SF to E&M signalling conversion and Pulse Link Repeaters (PLR) for conversion of E lead to M lead and vice versa. Conditioning provided level conversion from 0/0 (transmit/receive) dB levels (relative to Transmission Level Points) at Cedarbrook and Ft. Detrick to the +7/-16 dB COM2 levels. Normal COM2 signalling is done in-band and therefore is compatible with the FCC-98. However, in the bypass* mode of the COM2, E&M signalling is connected straight through the COM2 as shown by the dashed lines in Figure 2. Since this particular utilization of the FCC-98 required SF signalling, a SF/E&M converter was required to interface COM2 facilities, when in the bypass mode, with FCC-98 VF channels. At Feldberg, -2/-2 dB levels are used so that level conversion was required for interface with the COM2 +7/-16 dB levels. Also at Feldberg, SF/E&M signalling conversion was required to interface FCC-98 SF signalling with COM2 E&M signalling.

2. TEST PLAN AND PROCEDURES

Testing of the COM2 was conducted per the test plan developed by DCEC/DCA[1] specifically for the Ft. Detrick-Feldberg application. Tests described in this plan were separated into one of four categories, briefly described below.

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* See page A-3 for discussion of bypass mode in the COM2.

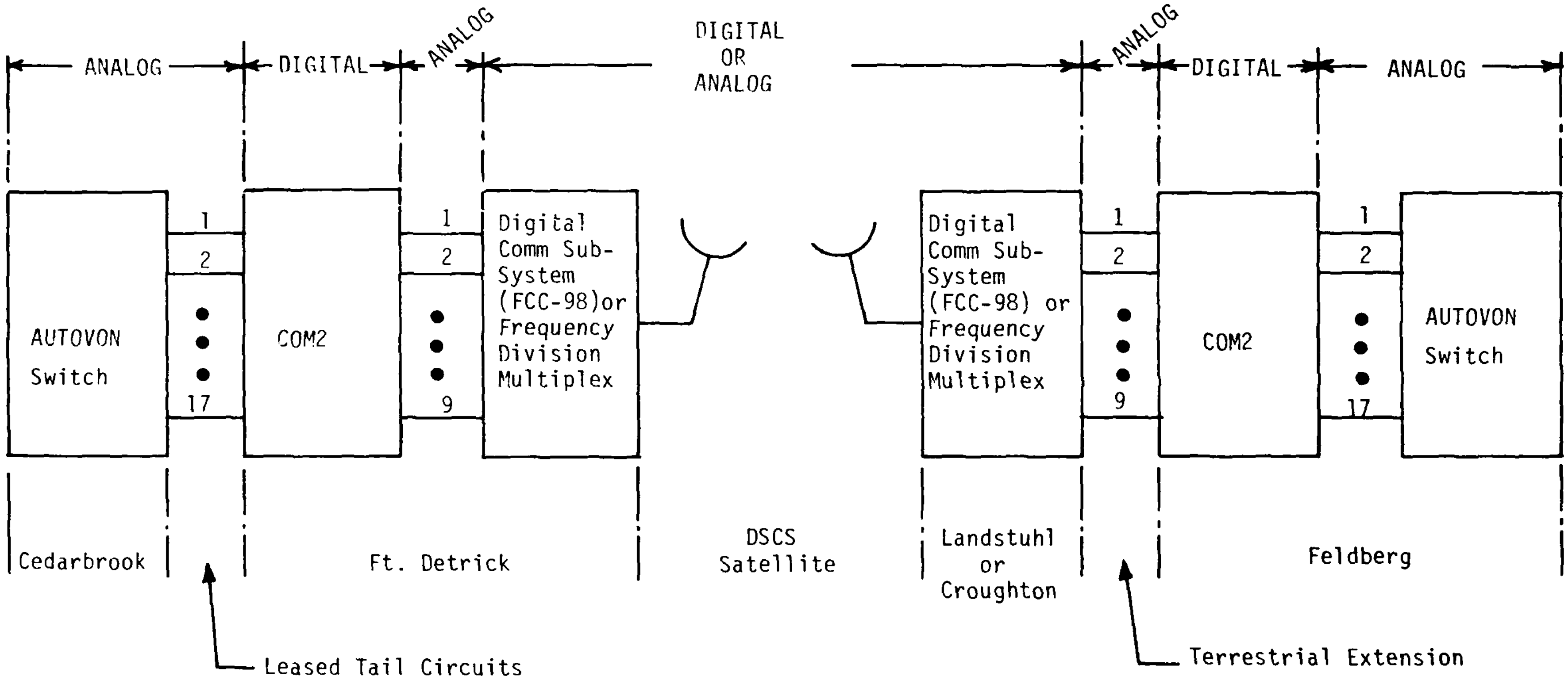
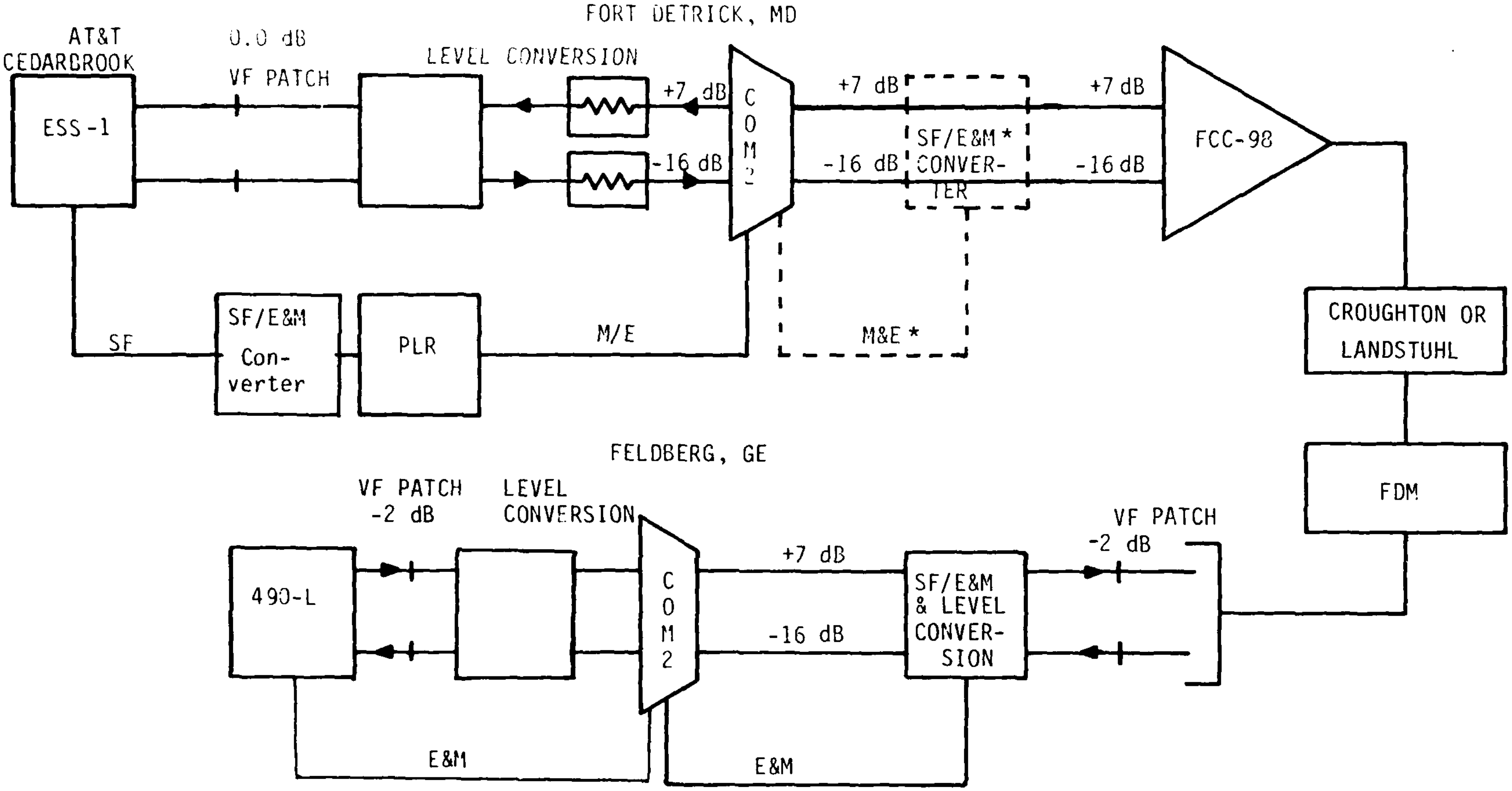


Figure 1. COM2 Operat'onal Configuration



FELDBERG - 2 dB
FT. DETRICK 0.0 dB
COM2 +7, -16 dB

* Used only for bypass mode of COM2

Figure 2. COM2 Level and Signalling Interfaces.

a. Baseline Performance Characteristics. These tests provided voice channel characterization using procedures prescribed in DCAC 310-70-1, Vol II, Supplement 1[3] and DCAC 310-70-57, Supplement 1[4]. Circuit parameters tested were to conform to V2 standards as stated in reference (2). This portion of the test plan was carried out at Ft. Detrick by looping test signals at Feldberg and recording data at Ft. Detrick.

b. Performance Characterization of Data Signals. Various modems and VFCT's were identified for testing in conjunction with the COM2. These tests were also conducted at Ft. Detrick by looping test signals at Feldberg and recording results at Ft. Detrick. Test parameters were bit error rate (BER) for modems, and telegraph distortion and BER for VFCT's.

c. Impaired Performance Characterization. In this category of testing, sources of impairment include (1) BER, (2) noise, (3) variation of input level, (4) multiple analog/digital/analog conversions, (5) multiple TASI operations and (6) loading of data signals. The individual effects on COM2 performance from each of these impairments was to be determined for both speech and data signals. Tests of source level sensitivity and effects of data signals loading were conducted readily at Ft. Detrick; however, the other impairment tests could not be accomplished in an operational configuration and will be conducted later as part of a laboratory controlled test.

d. Operational Tests. Once configured for normal operation, tests consisted of (1) subjective evaluation by voice users and (2) collection of traffic data. A special NYX area code was programmed at the Feldberg and Langerkopf AUTOVON switches to allow any user homed on either of those switches to force calls through the COM2. A subjective evaluation sheet was prepared and provided to AUTOVON users. Traffic data collection was accomplished via the Traffic Data Collection System (TDCS) at the AUTOVON switch in Feldberg and the management reporting system located within the COM2. A 300 baud ASCII printer was provided at both Ft. Detrick and Feldberg and interfaced with the COM2 management reporting system. Summary data for both ends was collected at Ft. Detrick every hour from the COM2 for the first three weeks of operation to allow detailed analysis of COM2 system usage and system outages. Thereafter, summary data was collected every 24 hours from the COM2 at Ft. Detrick. The TDCS test periods for COM2 were selected to coincide with regularly scheduled traffic data collection at Feldberg.

III. TEST RESULTS

Results of COM2 testing are presented in this section. These results are divided into four test areas: (1) voice channel characterizations, (2) data signal performance, (3) traffic data analysis and (4) user subjective evaluation. Conclusions derived from these results are deferred to the following section.

1. PERFORMANCE CHARACTERISTICS OF VOICE CHANNELS

a. General. The effect of COM2 on voice channel parameters was determined by means of two baseline tests. First, the nine interswitch trunks (ISTs) were tested for voice channel performances before cutover of the COM2. Secondly, the 17 channels were tested through the COM2. Tests consisted of a routine quality control (QC) test of those circuit parameters called out in DCAC 300-175-9[2]. A comparison of trunk vs. channel (thru COM2) performance then indicated the effect of COM2 on voice channel performance. The required level of performance was known to be V2[2], which pertains to interswitch voice grade circuits.

b. Interswitch Trunk Performance. Figure 3 shows the equipment configuration used for testing interswitch trunks. A Transmission Impairment Measuring Set (TIMS) was utilized at Ft. Detrick to accomplish both directions of testing. Results of testing the nine IST's (without the COM2) are shown in Tables I and II and in Figures 4 through 7. Tables I and II are results of testing on the following circuit parameters per reference (2):

(1) Idle channel noise
(2) Single tone interference
(3) Frequency translation
(4) Inpulse noise*
(5) Harmonic distortion
(6) Net loss variation
(7) Phase jitter*

Figures 4 and 5 show a summary of frequency response measurements taken at Ft. Detrick for transmit and receive directions, respectively. Figures 6 and 7 show a summary of envelope delay* measurements taken at Ft. Detrick for transmit and receive directions, respectively. For each of Figures 4 through 7, curves have been fitted to data taken over 300 to 3000 Hz for frequency response and 500 to 2800 Hz for envelope delay. These curves are shown on each figure, corresponding to the curve fit to minimum values, the maximum values, and the mean for the data points taken at each test frequency for each of nine trunks.

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* Not specified for V2 circuits but tested for comparison with other type circuit requirements.

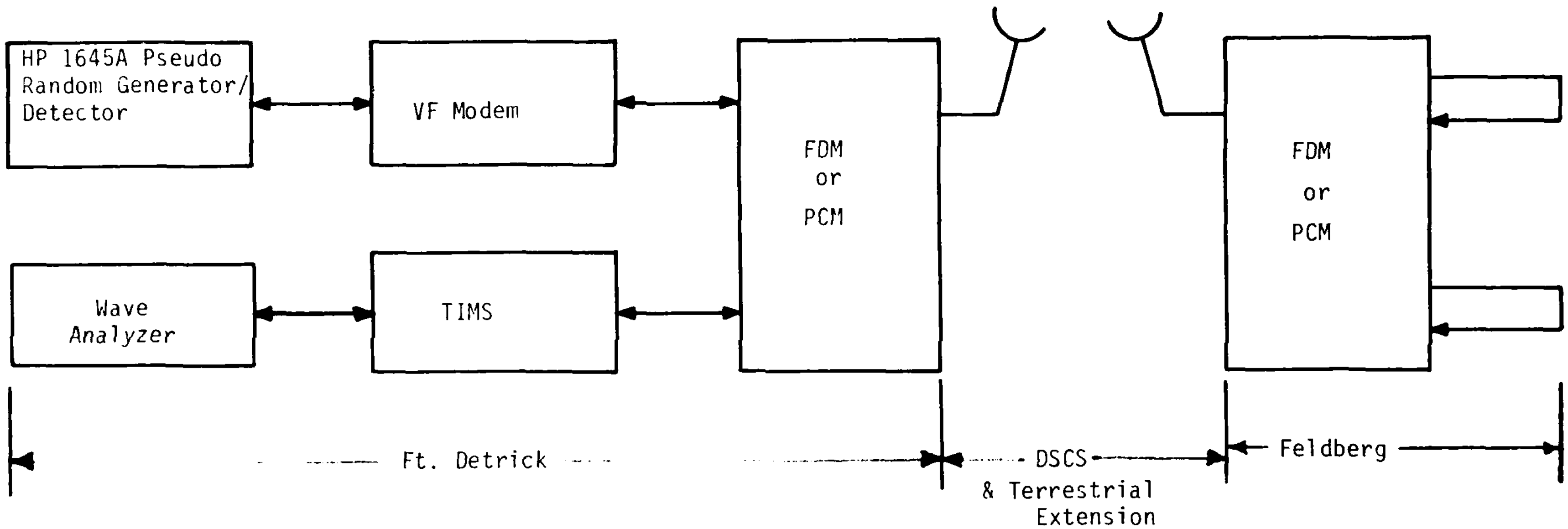


Figure 3. Baseline Performance of Interswitch Trunks.

TABLE I. IST VOICE CHANNEL PARAMETER MEASUREMENTS

FOR FELDBERG TO FT. DETRICK

Trunk Number	Idle Channel Noise (dBrnCo)	Single Tone Interference (# Above ref Level)	Frequency Translation (Hz)	Impulse Noise (# Above ref Level detected in 5 minutes)	Harmonic Distortion (DBm0) 700 Hz	1400 Hz	2100 Hz	2800 Hz	Net Loss Variation (dB)	Peak to Peak Phase Jitter (degreess)	Remarks
0	22	0	1	0	-11	-50	-67	-75	0	4.2	
1	26	0	1	0	-10	-55	-54	-65	0	5	
2	23	0	1	0	-8	-50	-60	-60	1	4.6	
3	25		1	0	-11.4	-55	-70	-75	0	7	
4	23	0	1	0	-9	-64	-72	-75	.1	4.1	
5	25	0	1	0	-12.5	-50	-62	-65	-1	5.1	
6	22	0	.1	0	-11	-55	-65	-66	0	5	
7	44		0	0	-11	-65	-68	-70	0	6	#8 trunk initially out of spec. Transmission levels were adjusted and trunk retested.
8	48		1	0	-10	-55	-60	-65	1	6.1	

TABLE II. IST VOICE CHANNEL PARAMETER MEASUREMENTS

FOR FT. DETRICK TO FELDBERG

Trunk Number	Idle Channel Noise (dBrnCo)	Single Tone Interference (# Above ref Level)	Frequency Translation (Hz)	Impulse Noise (# Above ref Level detected in 5 minutes)	Harmonic Distortion (dBm0) 700 Hz	1400 Hz	2100 Hz	2800 Hz	Net Loss Variation (dB)	Peak to Peak Phase Jitter (degrees)
0	26	0	0	0	-10	-52	-68	-70	±.1	7
1	23	0	0	2	-11	-59	-59	-68	1	7
2	25	0	0	2	-10	-59	-63	-57	1	5
3	25		0	0	-7.5	-56	-59	-62	0	6
4	27	0	0	2	-10	-60	-61	-69	0	8
5	25	0	0	4	-11	-68	-68	-72	.2	10
6	29	0	0	0	-11	-62	-68	-70	.1	9
7	39		1	0	-10	-57	-58	-61	2	5
8	41		2	0	-9.5	-63	-60	-62	2	6

Figure 4. IST Frequency Response for Ft. Detrick to Feldberg.

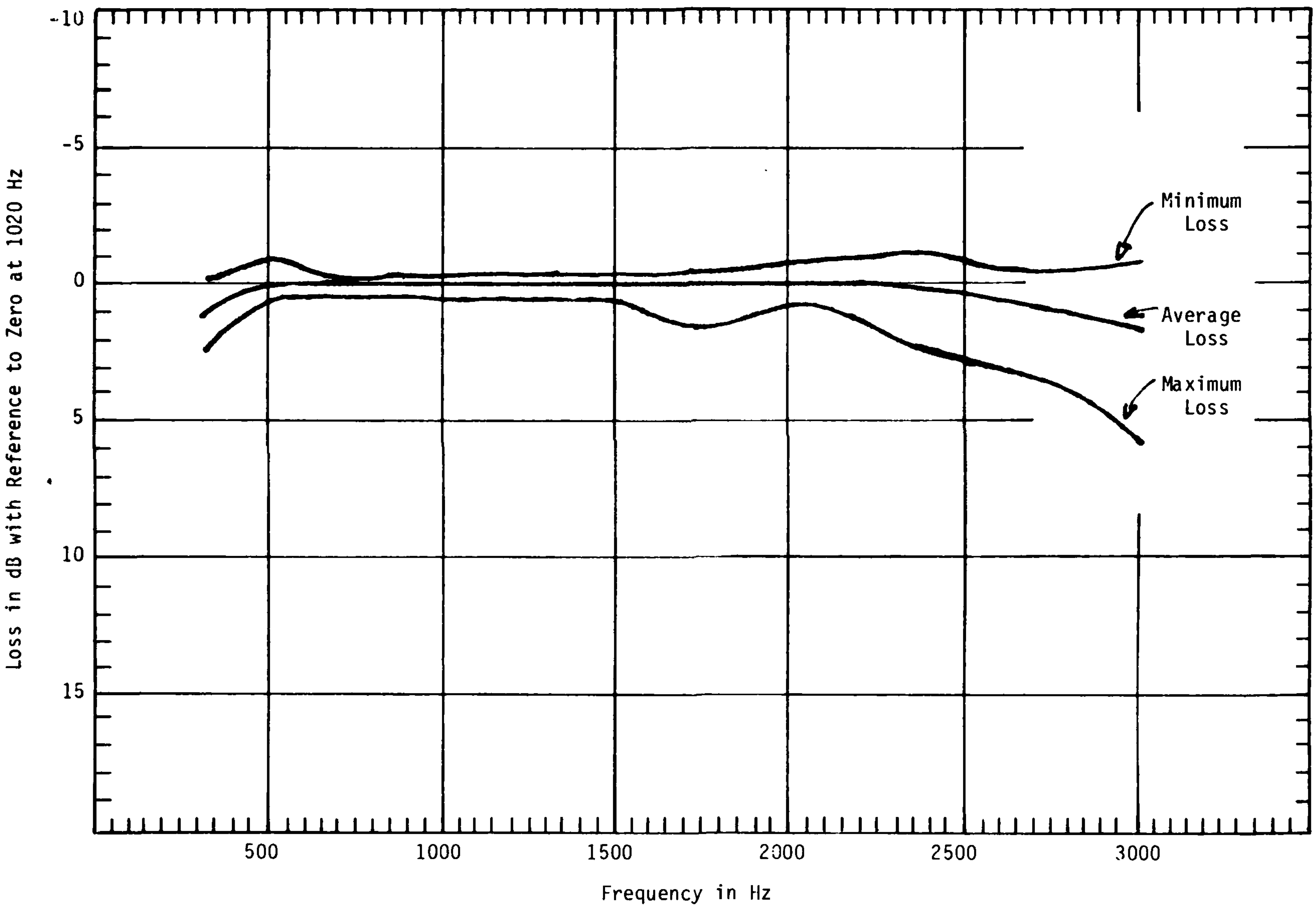


Figure 5. IST Frequency Response for Feldberg to Ft. Detrick.

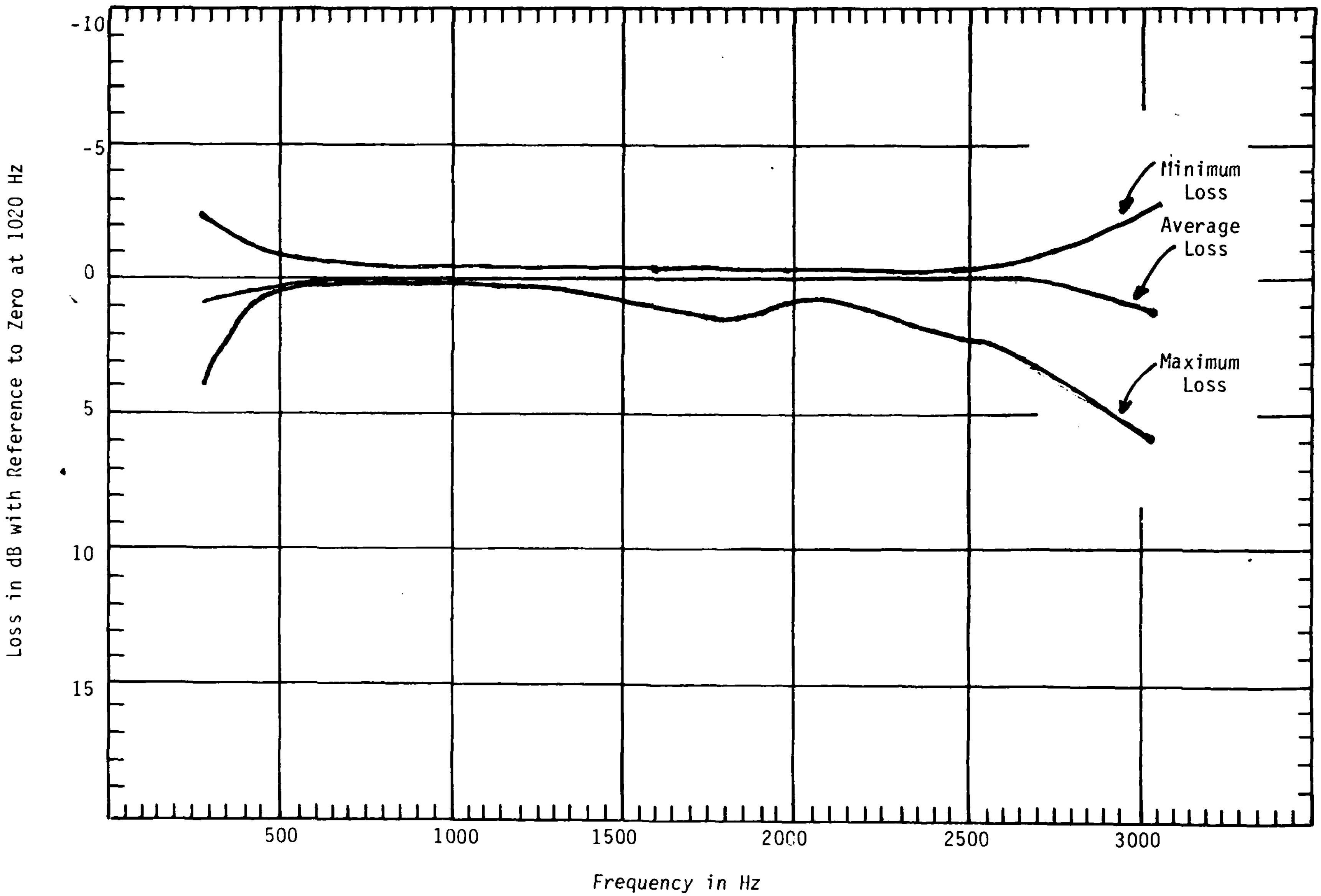


Figure 6. IST Envelope Delay for Ft. Detrick to Feldberg

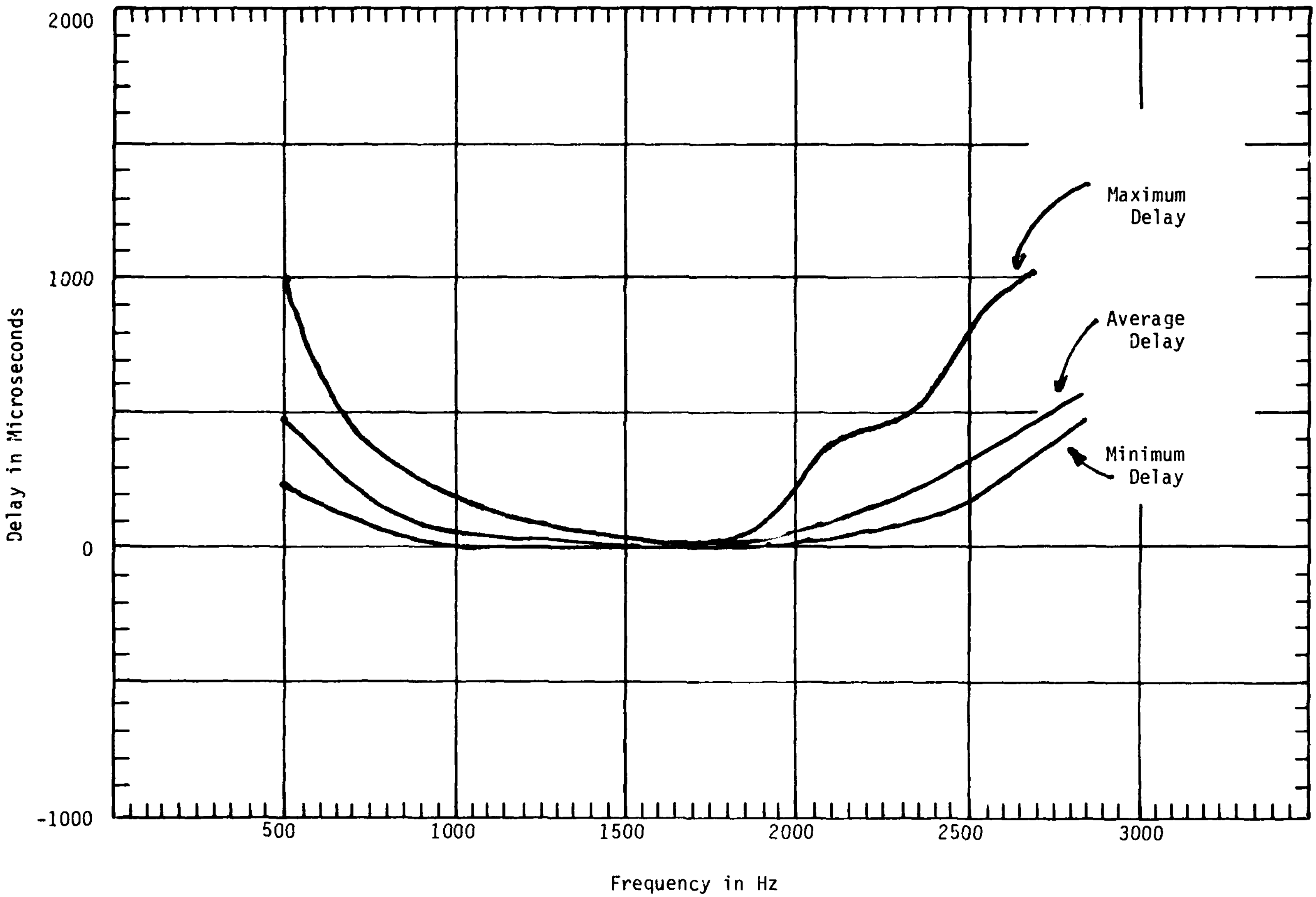
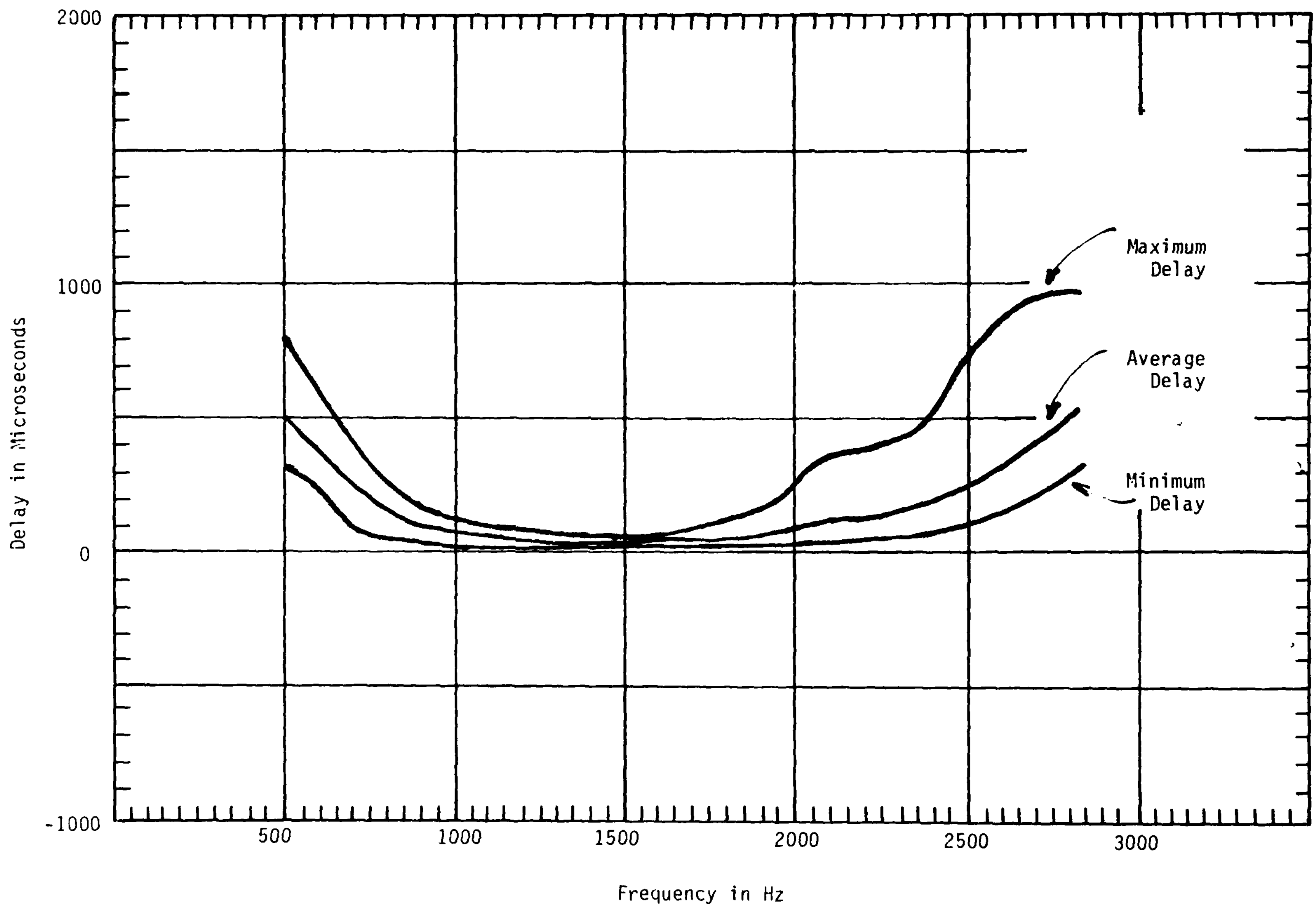


Figure 7. IST Envelope Delay for Feldberg to Ft. Detrick



A comparison of the test results on the nine ITS's with the V2 requirements of reference (2) indicate that all trunks met V2, although trunk #8 was initially out-of-spec and required transmission level adjustments and retest to achieve specification conditions. Other test results were:

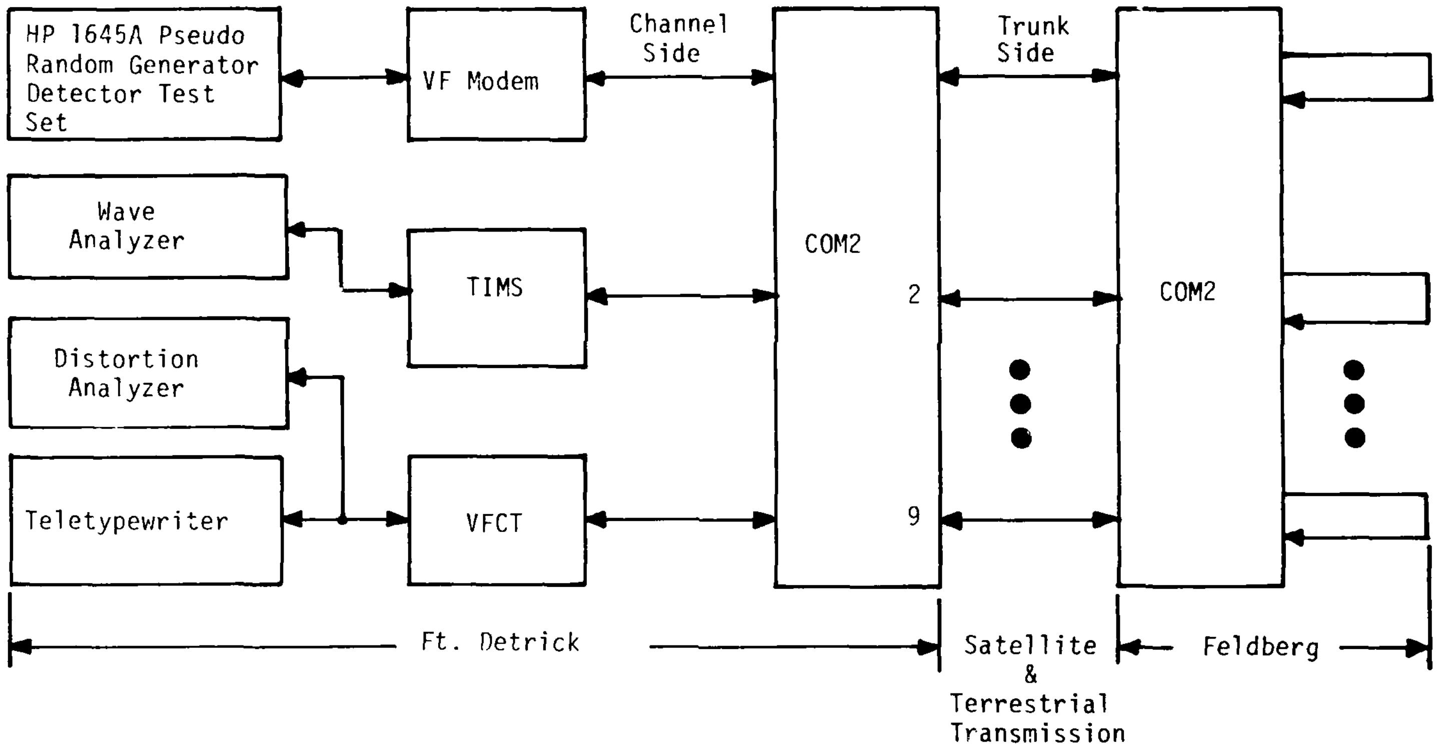
(1) Trunks 0 through 6 which were routed through the AN/FCC-98 PCM multiplex of the Digital Communications Subsystem (DCSS) had idle channel noise measurements in the range 22-29 dBrnCo. Trunks 7 and 8 were routed over conventional FDM satellite and terrestrial links and provided significantly worse idle channel noise, in the range 39 to 48 dBrnCo. Idle channel noise, specified in reference (2) as a function of circuit length, should be no greater than 47 dBrnCo for these circuits which are approximately 4000 miles long. Those trunks routed via analog transmission were therefore marginally acceptable.

(2) The phase jitter and impulse noise performance, unspecified for V2 circuits, met requirements specified for any other type circuit prescribed in Table 2 of reference (2).

(3) The envelope delay performance, also unspecified for V2 circuits, met the requirements of D2, as used for example on AUTODIN access lines for rates up to 1200 baud.

c. COM2 Voice Channel Performance. Figure 8 shows the equipment configuration utilized for tests of COM2 channels. The TIMS located at Ft. Detrick was used to collect data for both directions of transmission. Results of testing the 17 COM2 channels are shown in Tables III and IV and in Figures 9 through 12, reflecting measurement of appropriate circuit parameters as prescribed by reference (2).

Testing of voice channel parameters through the COM2 presented certain problems unique to a TASI system. Because the COM2 will TASI any non-continuous input signal and, more importantly, because the COM2 will drop test tones after a 7 to 14 minute period, a tone in the 2010-2240 Hz band was initially transmitted to simulate a modem call and cause the COM2 to allocate a facility (trunk) full period to that channel. Thereafter, so long as energy was present in that same channel, the selected facility remained dedicated and thus allowed voice channel testing for an indefinite period. This technique was used with each successive channel tested to ensure continuity during testing. Another unique feature of COM2 testing was that the matchup between channel and trunk was not unique and changed from test to test. Further, COM2 selection of a trunk is independent between transmit and receive directions, making it unlikely that the same trunk would be allocated for both transmit and receive directions of the channel under test. This made it difficult to directly compare channel performance with a given trunk, so that such a comparison was not attempted.



NOTE: All channels not under test remained available for normal traffic.

Figure 8. Baseline Performance of COM2

TABLE III. COM2 VOICE CHANNEL PARAMETER MEASUREMENTS:

FELDBERG TO FT. DETRICK

COM2 Channel Number	CCSD #	SNR (dB)	Single Tone Interference (# Above ref Level)	Frequency Translation (Hz)	Harmonic Distortion (DBmo)				Net Loss Variation (dB)	Peak to Peak Phase Jitter (Degrees)
					700 Hz	1400 Hz	2100 Hz	2800 Hz		
0	B192	18	0	1	-10	-56	-64	-67	± 1.0	7.2
1	B193	18	0	1	-10	-54	-64	-65	± 0.1	4
2	B194	18	0	± 1	-9	-50	-54	-65	± 0.1	5.8
3	B195	18	0	1	-6	-50	-65	-70	0	4.9
4	B244	18	0	1	-6	-52	-50	-60	± 0.1	4
5	B245	18	0	4	-10	-55	-63	-70	± 0.0[illegible]	4
6	B254	19	0	0	-10	-50	-65	-63	0	4
7	B544	19	0	0	-11	-43	-62	-65	1	7
8	B555	18	0	0	-15	-45	-60	-66	1	4.1
9	B011	18	0	0	-10	-43	-50	-65	0	4
10	B012	18	0	.1	-11	-45	-59	-62	.1	4
11	B013	19	0	0	-15	-47	-50	-60	0	4
12	B014	18	0	0	-11	-42	-50	-55	0	4
13	B015	18	0	0	-12	-43	-55	-60	0	8
14	B018	27	0	0	-11	-45	-59	-60	0	4
15	B022	18	0	0	-10	-43	-55	-58	0	4
16	B028	18	0	1	-11	-42	-60	-65	0	7

TABLE IV. COM2 VOICE CHANNEL PARAMETER MEASUREMENTS:

FT. DETRICK TO FELDBERG

COM2 Channel Number	CCSD #	Single Tone Interference (# Above ref Level)	Frequency Translation (Hz)	Harmonic Distortion (dBm0)				Net Loss Variation (dB)	Peak to Peak Phase Jitter (Degrees)
				700 Hz	1400 Hz	2100 Hz	2800 Hz		
0	B192	0	0	-10	-56	-66	-70	± 1.0	4
1	B193	0	1	-11	-53	-57	-59	± 0.1	5
2	B194	0	0	-10	-50	-58	-60	± 0.1	4
3	B195	0	0	-13	-55	-58	-60	0	4
4	B244	0	0	-10	-50	-60	-60	± 0.1	4
5	B245	0	1	-10	-50	-57	-58	± 0.1	4
6	B254	0	3	-10	-55	-59	-67	0	4
7	B544	0	1	-11	-52	-55	-63	1	4
8	B555	0	1	-13	-51	-57	-60	1	5
9	B011	0	1	-13	-52	-55	-60	1	4
10	B012	0	1	-11	-57	-59	-61	0	6
11	B013	0	1	-13	-56	-58	-59	0	5
12	B014	0	0	-9	-56	-53	-58	2	4
13	B015	0	0	-10	-50	-58	-60	1	5
14	B018	0	1	-10	-58	-56	-58	0	5
15	B022	0	0	-10	-48	-58	-58	1	4
16	B028	0	0	-9	-48	-52	-60	1	4

Tables III and IV are results of testing on the following circuit parameters:

(1) Signal-to-noise ratio
(2) Single tone interference
(3) Frequency translation
(4) Harmonic distortion
(5) Net loss variations
(6) Phase Jitter*

Measurements of idle channel noise and impulse noise were not taken since they are meaningless tests for the COM2. The absense of any transmitted energy, as prescribed in reference (2) for these two tests, will result in the momentary dropping of such a channel by the TASI circuitry until such time as the transmit channel again becomes active. During the period of transmit channel inactivity, the far-end receive channel will be quiet, that is, no background noise would exist since the "channel" has been disconnected from the trunk. The test used in place of idle channel and impulse noise was the signal-to-C-notched noise ratio, accomplished by measuring test tone plus noise levels and noise levels with tone notched out, and subtracting the two levels to arrive at SNR in dB.

Figure 9 and 10 show frequency response measurements taken at Ft. Detrick for transmit and receive directions, respectively. Figures 11 and 12 show envelope delay measurements taken at Ft. Detrick for transmit and receive directions, respectively. For each of Figures 9 through 12, curves have been fitted to data taken over the appropriate frequency range. Three curves are shown with each figure, corresponding to minimum values, maximum values, and mean values for data points taken at each test frequency for the 17 COM2 channels.

A comparison of the test results on the 17 COM2 channels with the V2 requirements of reference (2) indicates that all channels met V2. Other test results were:

(1) The phase jitter performance, unspecified for V2 circuits, met requirements specified for any other type circuit prescribed in Table 2, reference (2).

(2) The envelope delay performance, also unspecified for V2 circuits, met the requirements of D2, as used for example on AUTODIN access lines for rates up to 1200 baud.

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* Not specified for V2 circuits but tested for comparison with requirements of other type of circuits.

Figure 9. COM2 Frequency Response for Ft. Detrick to Feldberg

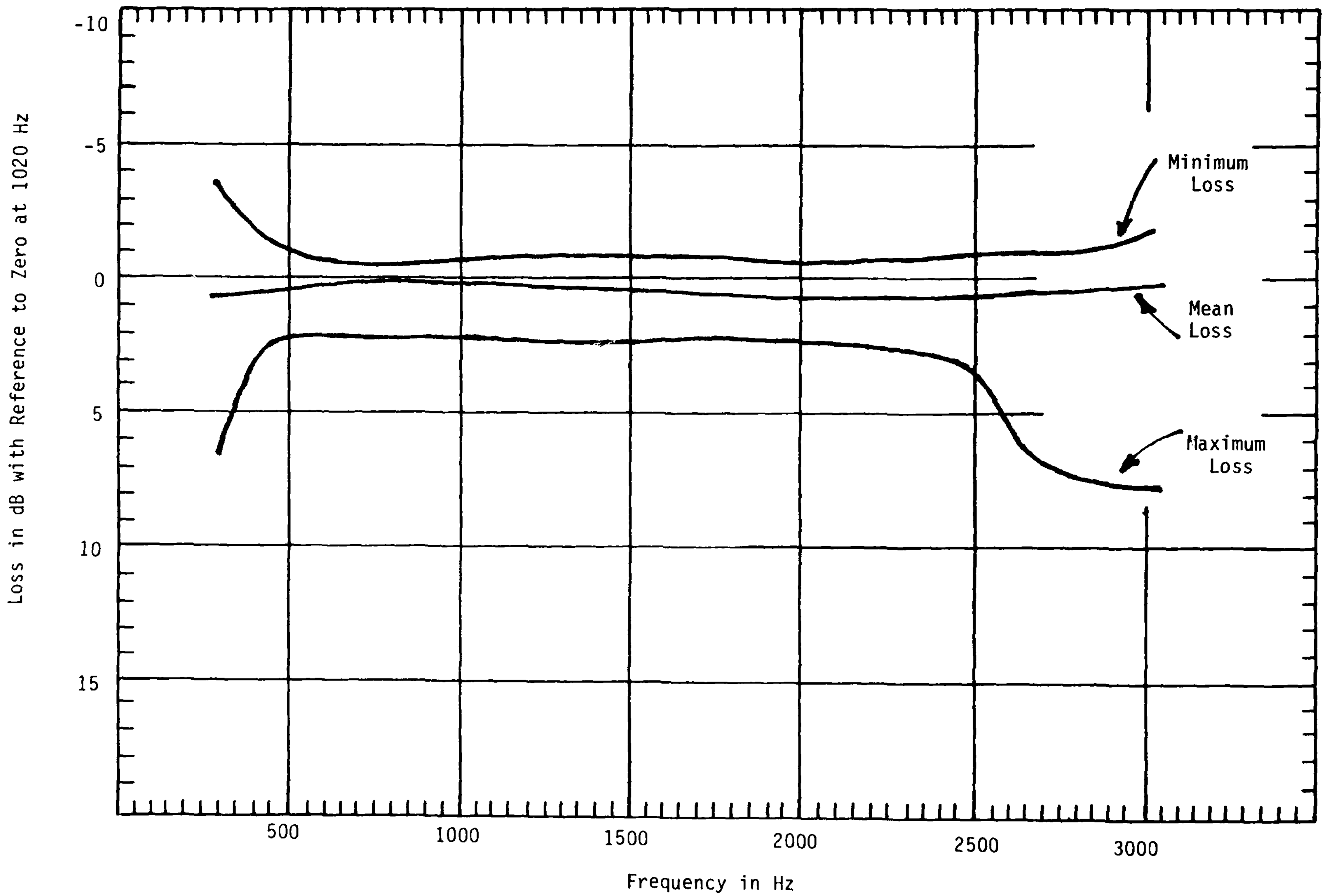


Figure 10. COM2 Frequency Response for Feldberg to Ft. Detrick

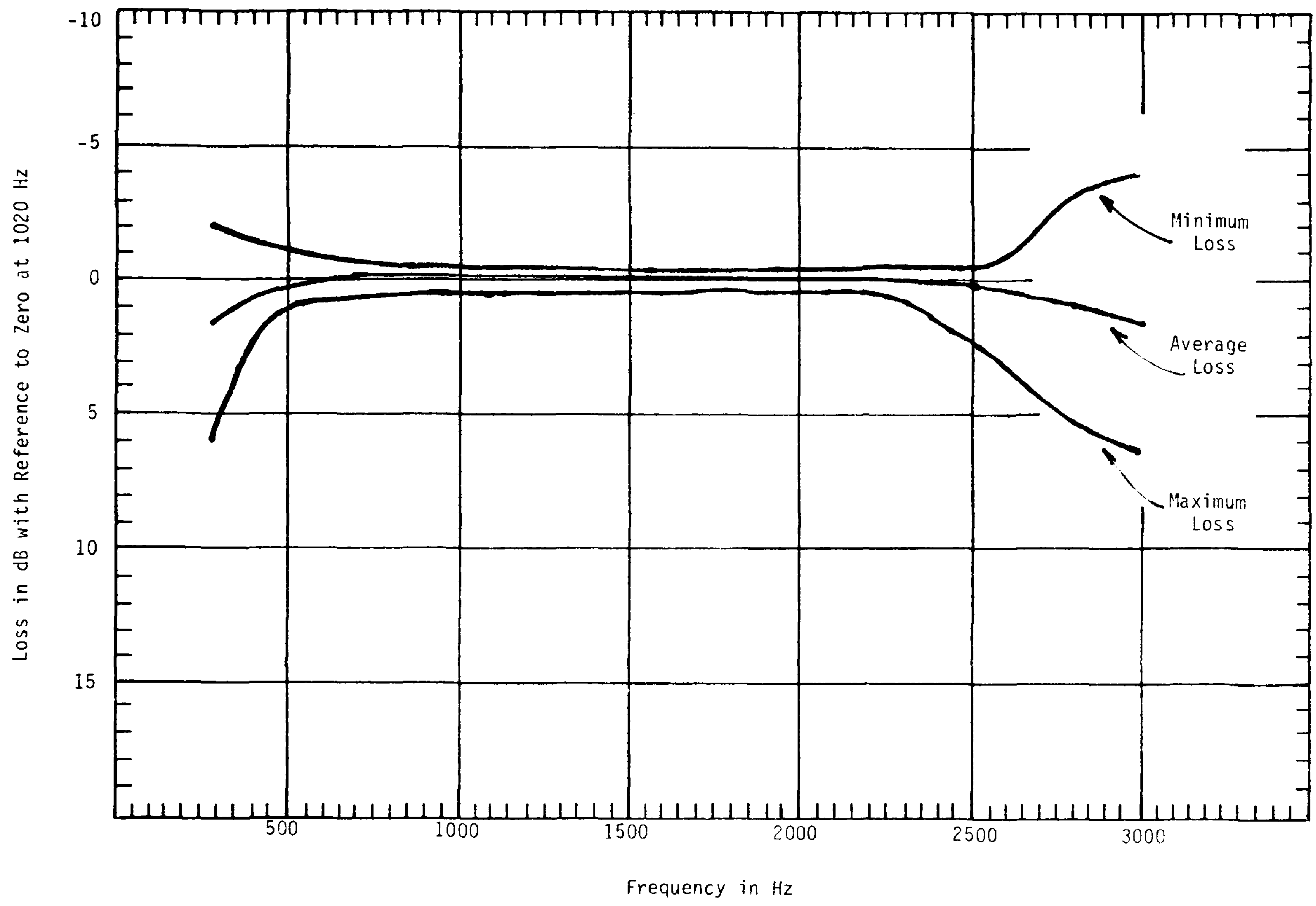


Figure 11. COM2 Envelope Delay for Ft. Detrick to Feldberg

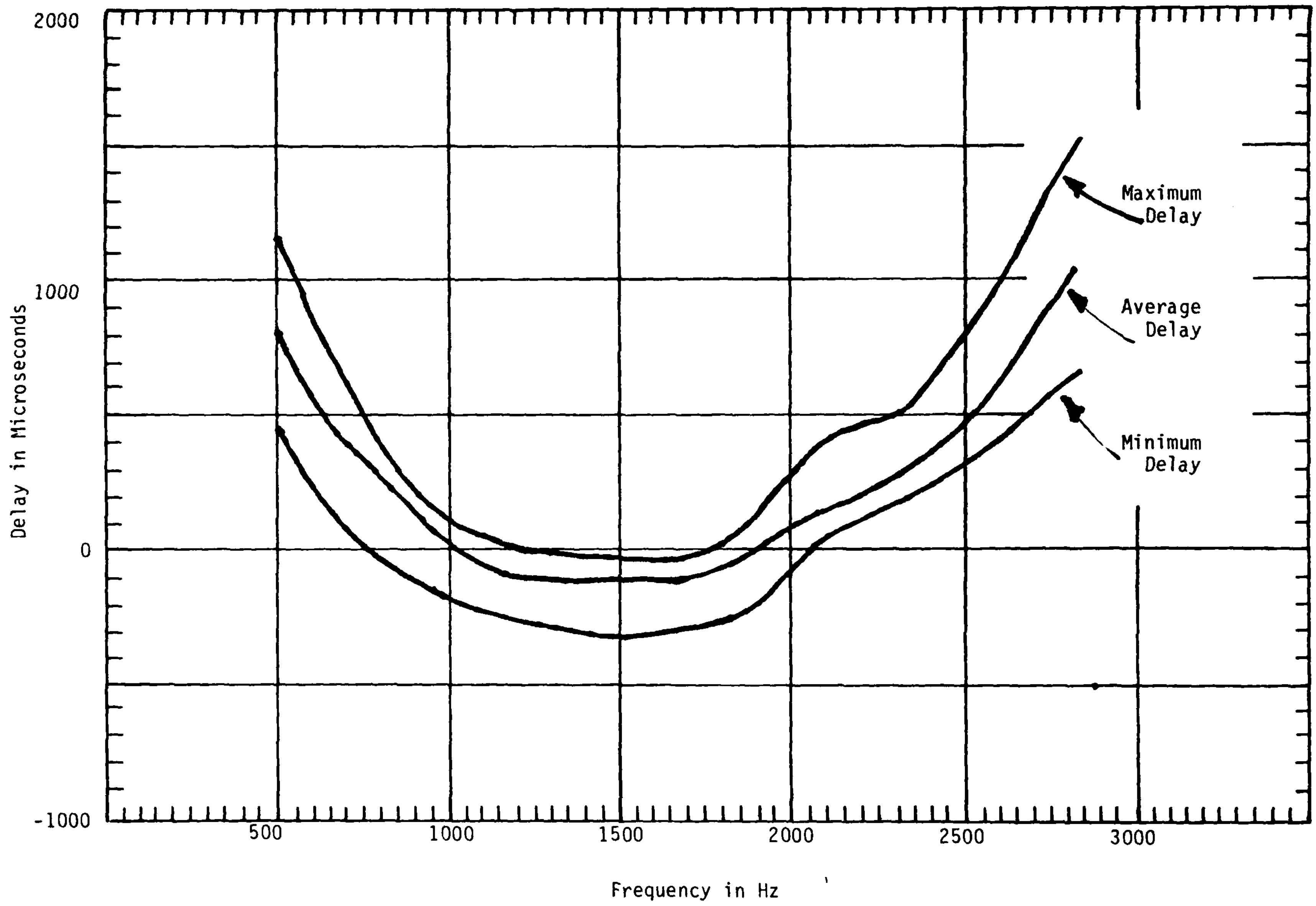
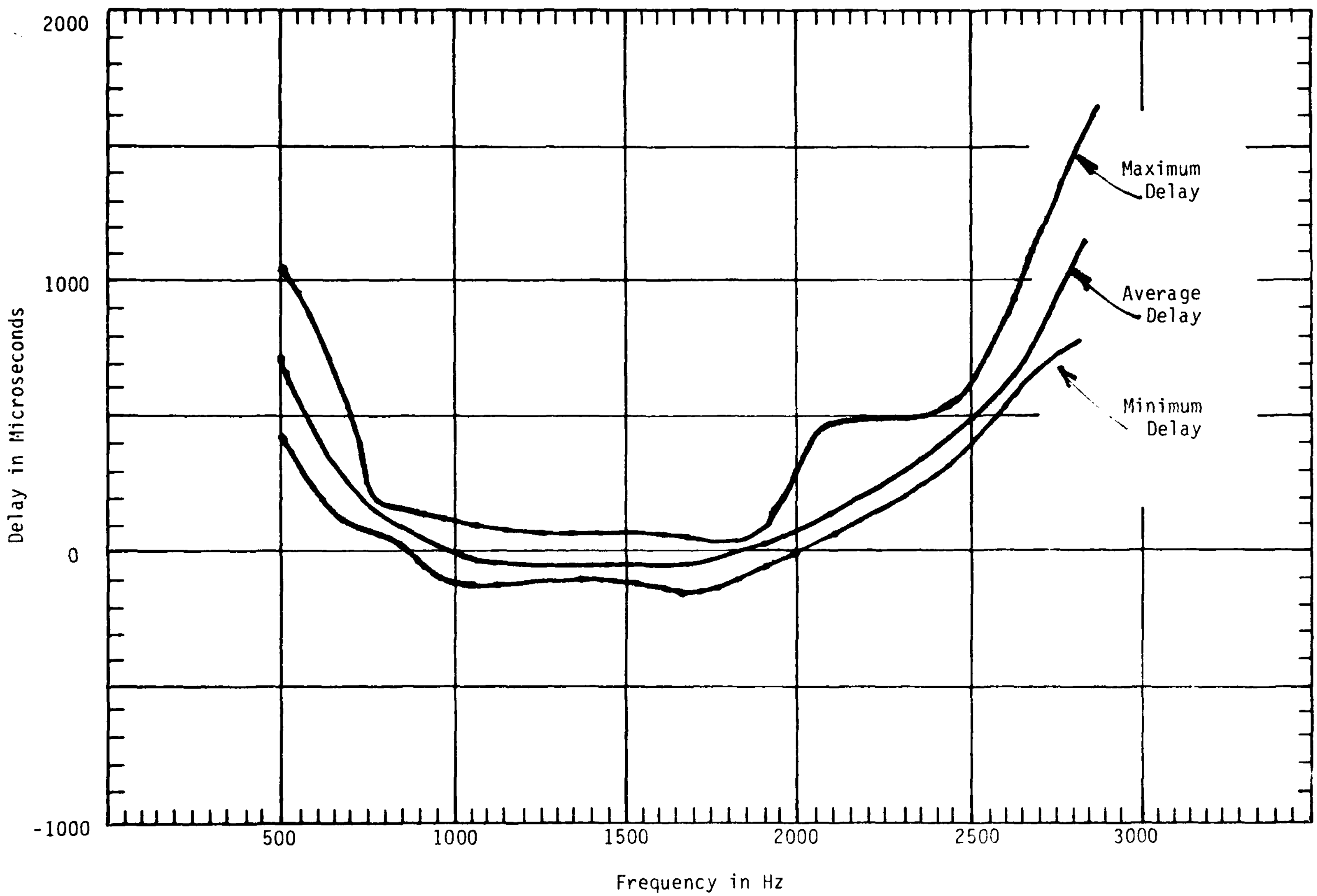


Figure 12. COM2 Envelope Delay for Feldberg to Ft. Detrick



A comparison of IST vs COM2 channel performance indicates that all circuit parameters' performance were essentially the same except for frequency response and envelope delay. The COM2 channel frequency response maximum and minimum curves showed 1 to 2 dB of degradation at the end points, around 300 to 500 Hz and 2800 to 3000 Hz, but no noticable degradation for mid-band frequencies, as compared to the same curves for IST's. The mean value curves for frequency response were essentially identical (within 1 dB across the measured band) for IST's and COM2 channels. Envelope delay maximum, minimum and mean curves for COM2 channels showed 200-500 microseconds increase at the end point, around 500 Hz and 2800 Hz. For mid-band frequencies, between 1000 and 2500 Hz, the maximum, minimum and mean envelope delay curves for COM2 channels showed from 0 to 200 microseconds increase.

Crosstalk measurements were also made on the 17 COM2 channels, per the test procedures of DCAC 310-70-57, Supplement 1[4]. Near-end crosstalk (NEXT) was measured first since NEXT is a more significant source of degradation than far-end crosstalk (FEXT). These tests were conducted by inserting a 1004 Hz, -10 dBm0 tone into channel 0 which acted as the disturbing channel. Crosstalk into near-end (at Ft. Detrick) channels was measured and recorded as shown in Table V. Since these measurements necessitated the seizing of normally operational COM2 channels, and because of the time required to measure crosstalk in the very large number of possible combinations of disturbing and disturbed channels, only one combination of disturbing and disturbed channels was measured. Because the resulting NEXT data fell well within DCA standards[2], and for reasons cited earlier, no further testing of crosstalk was done.

2. PERFORMANCE CHARACTERISTICS OF DATA SIGNALS

a. General. The COM2 provides detection of data calls in two different ways. First, COM2 detects data by sensing energy in the frequency range of 2010-2240 Hz above a threshold of -30 dBm0. To accomplish this energy detection the COM2 uses a bandpass filter with a center frequency of 2125 Hz and rolloff to 10 dB attenuation at 2010 and 2240 Hz. With this form of data detection, the echo suppressors are simultaneously removed in both the transmit and return directions. This connection remains dedicated to the facility selected as long as there is constant energy above threshold in either direction of transmission.

The second data detection scheme looks for energy above and below 1100 Hz. If the total energy above 1100 is greater then the energy below 1100 Hz by at least 10 dB, the COM2 recognizes the call as being data. The tuned circuit used here has a high end cutoff at about 2800 Hz. Unlike the first data detection criterion, the echo suppressors are not disabled. However, the selected facility remains dedicated as long as constant energy is detected.

In either data detection mode, the COM2 immediately seizes a facility and removes the fixed and variable delay used for TASI operation*, since such delays are unacceptable for data transmission. The connection is maintained for 7 seconds; this assures that the system can accommodate very short

* See page A-1 for discussion of processing delay in the COM2.

TABLE V. COM2 NEAR-END CROSS TALK

Channel	Crosstalk
1.	47 DMBO
2.	42
3.	47
4.	45
5.	46
6.	46
7.	46
8.	46
9.	47
10.	47
11.	47
12.	48
13.	48
14.	47
15.	47
16.	47

Note: A -10 dBm0, 1004 Hz test tone was placed on channel 0 and crosstalk measured on the remaining channels.

bursts of set-up tone occurring immediately after a call is established. If no energy is detected by the end of 7 seconds, the facility is released from its dedicated status. Otherwise, the connection remains dedicated so long as constant energy is detected.

For a modem, VFCT or test tone signal which does not meet either COM2 criteria for a data call, the COM2 will initially connect the signal to a facility and then hold that signal for a period of 7 to 14 minutes, after which time the signal will be dropped and that channel freed to accept another call. The drop criteria is satisfied if the signal has frequency less than 1000 Hz and energy greater than approximately -23 dBmo. The reason for terminating such a connection is to minimize the time in which an inadvertent test tone signal would occupy a facility and reduce the number of facilities available for TASI.

Figure 8 shows the test configuration utilized for both modem and VFCT testing. Testing was accomplished by transmitting a test signal into the modem (or VFCT), through the channel of the COM2, and over satellite and terrestrial links to Feldberg. At the far end COM2, the quasi-analog signal was looped on the channel side of the COM2 and transmitted back over the satellite and terrestrial links to the near-end site, Ft. Detrick. This double COM2, double satellite hop test configuration was necessitated by two factors: (1) matching modems and test sets were not available at Feldberg, so that all testing was originated and terminated at Ft. Detrick; and (2) the COM2 requires a companion COM2 in order to function in a normal TASI mode, i.e., the COM2 cannot perform TASI when looped on itself.

b. VFCT Test Results. Testing consisted of operating 16 channel VFCT's through the COM2 and measuring error rate, distortion and holding times. Error rate was measured by repeatedly transmitting a teletype test code and noting errors in the received code. Distortion was measured by a wave form distortion analyzer. Holding times were measured as the time the teletype test signal was held by the COM2. Tables VI and VII display test results for the FCC-19 and FCC-31, respectively, the two VFCT's selected for testing. Individual test runs consisted of selected number, location, and transmit power level of active VFCT channels operating through the COM2. A list of the mark and space frequencies for each of the 16 channels is shown in Table VIII.

Referring to Table VI, the first three tests consisted of transmitting the test code through channels 1, 8, and 16, respectively, with all other channels in a mark hold condition. As indicated for each three tests, the test signal was dropped by the COM2 after an approximate 8 minute holding time. The reason for this action is that significant energy lies below 1100 Hz and insufficient energy lies in the 2010-2240 Hz frequency band, so that neither data call criterion is satisfied; the COM2 then dropped the signal after a 7-14 minute timeout since the VFCT signal had frequency less than 1000 Hz and energy greater than -23 dBmo. The remaining five tests of Table VI were also of channel 1, 8, 16, but with all other channels quiet. As expected, channel 1 was dropped within the 7-14 minute window, while channels 8 and 16 were held beyond the 14 minute timeout. This result was due to the respective frequencies used with the three channels tested and the COM2 data call recognition criteria. The only exception to the expected result was with

TABLE VI. FCC-19 VFCT TEST RESULTS

Test #	Channel Tested	Channel Level	Other Channels	Composite Level	Distortion	Error Rate	Length of Test
1	1		MARK HOLD	-13 dBm 600 ohms	16%	Error Free	Dropped at 8 min
2	8		MARK HOLD	-13 dBm 600 ohms	12%	Error Free	Dropped at 8 min
3	16		MARK HOLD	-13 dBm 600 ohms	24%	Error Free	Dropped at 8 min
4	1	-15 dBm	ABSENT		5%	Error Free	Dropped at 14 min
5	16	-15 dBm	ABSENT		10%	1 line in error	Held for 25 min. No drop.
6	1	-23 dBm	ABSENT		20%	1 Line in error	Dropped at 14 min
7	8	-23 dBm	ABSENT		12%	Error Free	Held for 25 min. No drop.
8	16	-23 dBm	ABSENT			Error Free	Dropped at 7 min.

TABLE VII. FCC-31 VFCT TEST RESULTS

Test #	Channel Tested	Channel Level	Other Channels	Composite Level	Distortion	Error Rate	Length of Test
1	2		MARK HOLD	-13 dBm	14%	0	Dropped at 7 min.
2	11		MARK HOLD	-13 dBm	15%	2 lines in error	Dropped at 8 min.
3	16		MARK HOLD	-13 dBm	13%	0	Dropped at 7 min.
4	2	Nominal (-13 dBm)	ABSENT		14%	0	Dropped at 7min.
5	7	Nominal (-13 dBm)	ABSENT		19%	0	Held for 28 min. No drop.
6	11	Nominal (-13 dBm)	ABSENT			0	Held for 20 min. No drop.
7	16	Nominal (-13 dBm)	ABSENT		13%	0	Dropped at 8 min
8	2	-23 dBm	ABSENT		35%	2 lines in error	Dropped at 7 min.
9	7	-23 dBm	ABSENT		17%	0	Held for 20 min. No drop.
10	11	-23 dBm	ABSENT			0	Held for 20 min. No drop.
11	16	-23 dBm	ABSENT		15%	0	Dropped at 7 min.

TABLE VIII. VFCT MARK AND SPACE FREQUENCIES

Channel	Frequency (Hz)	
	Mark	Space
1	382.5	467.5
2	552.5	637.5
3	722.5	807.5
4	892.5	977.5
5	1062.5	1147.5
6	1232.5	1317.5
7	1402.5	1487.5
8	1572.5	1657.5
9	1742.5	1827.5
10	1912.5	1997.5
11	2082.5	2167.5
12	2252.5	2337.5
13	2422.5	2507.5
14	2592.5	2677.5
15	2762.5	2847.5
16	2932.5	3017.5

the last entry of Table VI where channel 16 was tested at a transmit power level of -23 dBm with all other channels quiet. Here the test was dropped at 7 minutes apparently because of insufficient energy (-23 dBm) at channel 16 frequencies to meet the COM2 data call criteria. Finally, note that distortion levels are generally within teletype tolerances (typically 10-15%), although it is noted that the distortion level and error rate both increased for lower transmit levels (e.g., -23 dBm).

Referring to Table VII, results similar to those of Table VI are observed. Note that for tests 6 and 11, where channel 16 was tested with all other channels quiet, the holding time was 8 minutes indicating that insufficient energy was present to meet the COM2 data call criteria.

As a final test, an oscillator was used to input a frequency varying signal to determine at what frequencies the COM2 would recognize a data call. The COM2 front panel display was monitored while sweeping through a 1-3 KHz frequency range. Starting at a test tone of 1 KHz at -16 dBm, the frequency was slowly increased and the following was noted:

(1) At 1060 Hz, data call criterion #2 (energy above "1100" Hz) was recognized.

(2) At 1930 Hz, data call criterion #1 (energy in 2010-2240 Hz range) was recognized.

Then, starting at a test tone of 3 KHz at -16 dBm, the frequency was slowly decreased and the following was noted:

(3) At 3000 Hz, criterion #2 was recognized.

(4) At 2300 Hz, criterion #1 was recognized.

The above data indicate the upper and lower frequencies at which the COM2 data call criteria is satisfied.

c. Modem Test Results. Testing consisted of operating voice channel modems through the COM2 and measuring bit error rates. Modems tested were the Codex LSI 9600, Paradyne LSI 9600, Lenkurt MD 701 and Stelma MD 674. As shown in Figure 8, bit error rates were measured by using the HP 1645A test set which provides generation and detection of a selectable length, pseudo random bit pattern. Error rates were averaged over 10-15 minute measuring periods. Performance of each modem was characterized for several transmission conditions, as described below.

(1) Bit Error Rate Performance With and Without COM2.

Table IX indicates results of BER testing of each modem, at the bit rate specified, for two test configurations: (1) with the modem operating through a COM2 derived facility as shown in Figure 8, and (2) with the COM2 removed from the test configuration and the modem operating directly into a PCM derived trunk, as shown in Figure 3. For the former test, COM2 facilities selected for modem testing were those operating into the PCM voice channels

TABLE IX. MODEM BER PERFORMANCE

WITH AND WITHOUT COM2

Modem	Bit Rate	Bit Error Rate With COM2	Bit Error Rate Without COM2
MD-674	300 bps	8.3×10^{-4}	2.7×10^{-5}
MD-701	1200 bps	4.0×10^{-5}	3.4×10^{-6}
Paradyne	7200 bps	2.8×10^{-5}	1.3×10^{-5}
	9600 bps	3.8×10^{-5}	1.8×10^{-5}

NOTE: Nominal -13 dBm Transmit Level used for all tests.

(7 of 9 facilities operated through a PCM channel bank). In this way, background noise was nearly the same for all channels, allowing a fairer comparison of modem performance with and without the COM2. The difference in BER performance with and without the COM2 is noted to be relatively small for each modem, although a slight degradation in BER was observed for modems operating through the COM2. This degradation is perhaps explained by the slight increase in envelope delay distortion of the COM2 derived channel compared to a PCM derived channel. However, even with the test conditions described above, slight variations in channel background noise may have been the major contributor to bit errors.

(2) Sensitivity to Transmit Level.

In this test BER performance of each modem operating over COM2 was measured as a function of modem transmit level. As shown in Figure 13, the transmit levels were varied from a nominal -13 dBm to 10 dB below nominal. Resulting BER's indicated a slight degradation in BER for 2 to 6 dB reduction in transmit level and more significant degradation (approaching one order of magnitude) for 8 to 10 dB of reduced level. This same test conducted without the COM2 resulted in the same relative degradation in BER with reduced transmit levels, but with a shift in BER as predicted by Table IX.

(3) Sensitivity to Noise.

To determine modem sensitivity to noise, BER measurements were made as a function of idle channel noise (ICN). This was accomplished by use of the COM2 Management Reporting System, which provides a report entitled Private Line Status that gives recent idle channel noise for both transmit and receive directions of each facility. The ICN measurement range is 26 to 56 dBrnc0, where facilities with ICN's greater than 56 dBrnc0 can not be used for COM2 trunking. Since the modem tests involved two paths and hence two separate facilities of the COM2's, it was necessary to note which facilities were used for the transmit and receive modem signals. The ICN's for both directions of transmission were noted along with the BER of the modem under test. The results are given in Figure 14 where it should be noted that (1) the ICN for each data point was taken as the worse of the transmit and receive facility ICN's and (2) a straight line approximation has been drawn between the data points for each modem. As expected, results show degradation of modem performance with increasing idle channel noise.

3. TRAFFIC DATA ANALYSIS

a. General. This section describes results of statistical analysis applied to COM2 traffic data collected during the period 29 Sep 1979 to 18 Oct 1979 inclusive. Traffic data was collected via the COM2 management reporting system, which was connected to a terminal for direct printout and key-in capability. Several reports are available from the COM2 which provide traffic data on a periodic basis or per terminal input keyed request (see Appendix A). The reports used for the analysis presented herein were the Automatic Hourly Dump (see Appendix B) and the Traffic By Hour, All channels. The statistical analysis which follows has been divided into four areas;

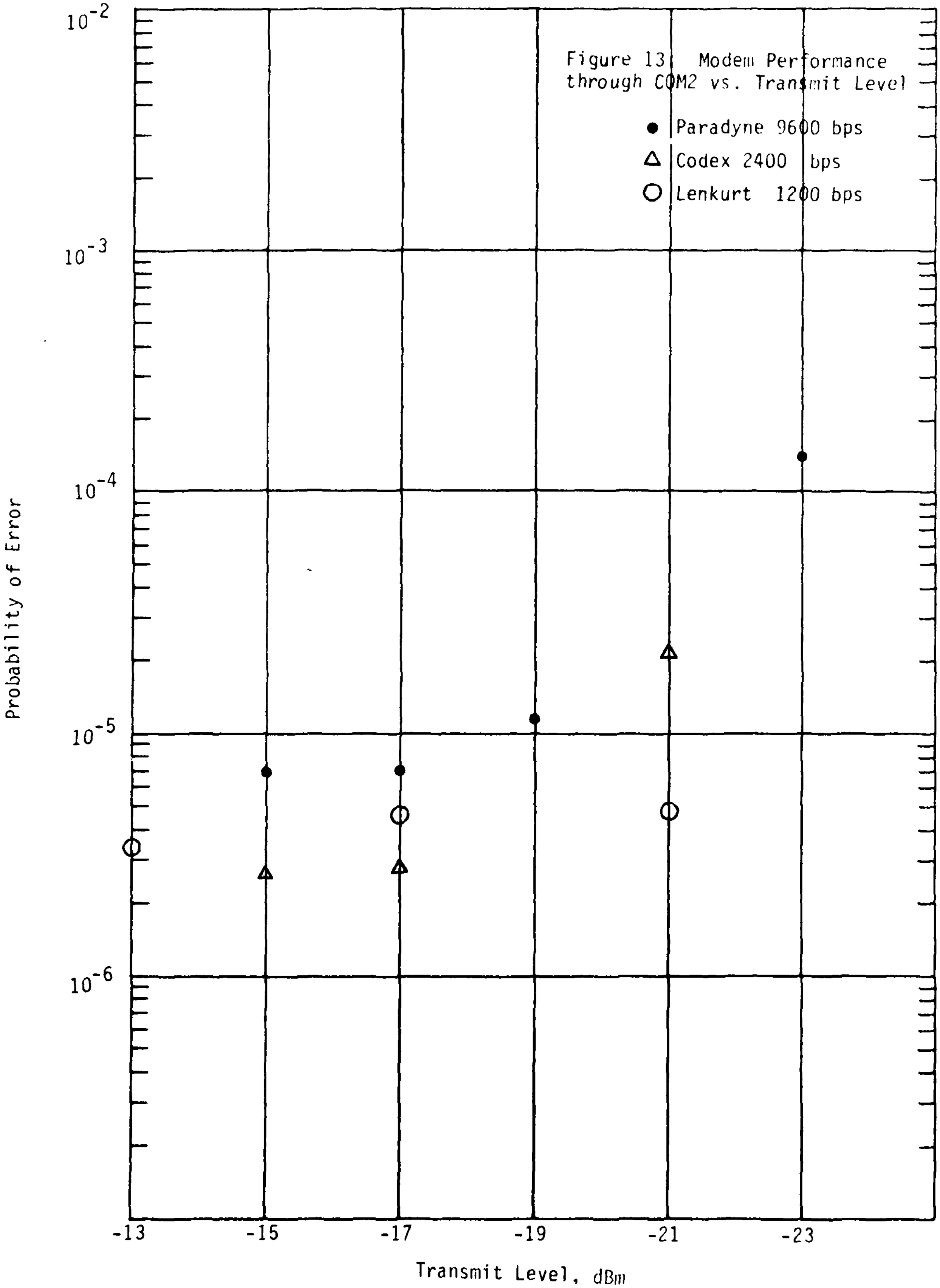


Figure 13 Modem Performance through COM2 vs. Transmit Level
Paradyne 9600 bps
Codex 2400 bps
Lenkurt 1200 bps
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
Probability of Error
-13
-15
-17
-19
-21
-23
Transmit Level, dBm

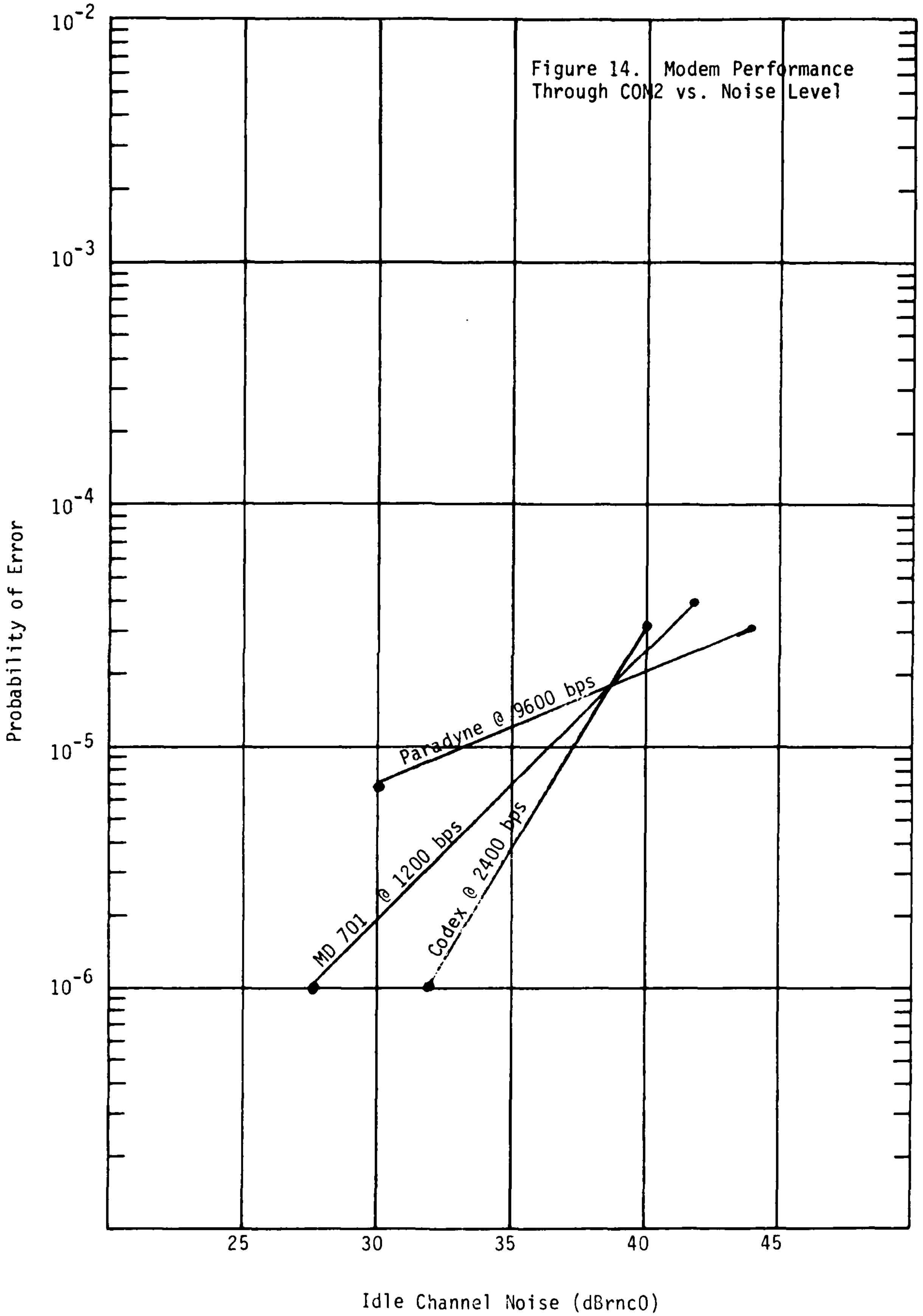


Figure 14. Modem Performance Through CON2 vs. Noise Level
Probability of Error
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
Paradyne @ 9600 bps
MD 701 @ 1200 bps
Codex @ 2400 bps
25
30
35
40
45
Idle Channel Noise (dBrnc0)

(1) CCS (Hundred Call Seconds) for both voice and data, (2) speech loss statistics, (3) blocking statistics and (4) effect of lost facilities on speech loss and blocking statistics.

b. CCS Statistics. Total call CCS statistics were collected from the Automatic Hourly Dump report, which reports total call CCS every hour on the hour. Figure 15 is a histogram of total CCS for all 17 COM2 channels averaged on a per hour basis for the 20 day test period. The busy hours were as expected, between 1200 and 1700 Zulu, where office hours overlapped between CONUS and Europe. With a maximum CCS perhour of (17 channels) x (36 CCS/channel) = 612 CCS, it is readily apparent that these 17 channels were heavily used, especially during busy hours. For the 13 working days of the 20 day test, the busiest hour was 1500-1600 Zulu with an average CCS of 553.

Total data call CCS statistics were collected from the Traffic By Hour, All Channels report, which provides total data call CCS for each hour. Figure 16 is a histogram of total data call CCS for all 17 COM2 channels averaged on a per hour basis for the 20 day test period. The busy hours ranged between 1200 and 2100 Zulu. As indicated, data call activity through these 17 channels was quite small, even though for part of that 20 day period modem tests were being conducted through the COM2 and hence were included in these statistics. The bimodal shape of this distribution was due to (1) normal data call activity during the busy hours of approximately 1200 to 1600 Zulu and (2) modem and VFCT testing conducted at Ft. Detrick between 1700 and 2100 Zulu.

c. Speech Loss Statistics. Speech loss will occur in the COM2 (or in any TASI device) when speech activity per channel becomes excessively high and when the number of channels simultaneously having this high speech activity becomes excessive. When this condition arises in the COM2, speech loss can occur due to the dropping of speech samples or the lack of buffer space for storage of speech samples. Speech loss statistics in the COM2 were collected from the Automatic Hourly Dump, which provides two entries for speech loss information each entry independent of the other:

(1) BUFF LOSS: indicates total speech in seconds that is lost for all channels due to no buffer being available when requested by a channel;

(2) SEG LOSS: indicates total speech in seconds for all channels that is lost due to (a) overload causing speech samples to be dropped, and (b) buffer already assigned to a given channel being full when accessed by that channel.

Analysis of this speech loss information first required the summing of BUFF LOSS and SEG LOSS times in seconds to arrive at the total speech loss for all 17 channels for each hour of the 20 day test period. The total speech loss per hour was then divided by total speech seconds for that hour to arrive at a fraction (to be expressed in percentage) of total speech lost (see Glossary for definition of terms). The first presentation of this data is the histogram of Figure 17, which shows the total speech loss per hour averaged over the 20 day period. Note that as expected the maximum speech loss occurred during the busy hours 1200 to 1700 Zulu.

Figure 15. Histogram of Average CCS Per Hour for Period 29 September - 18 October 1979

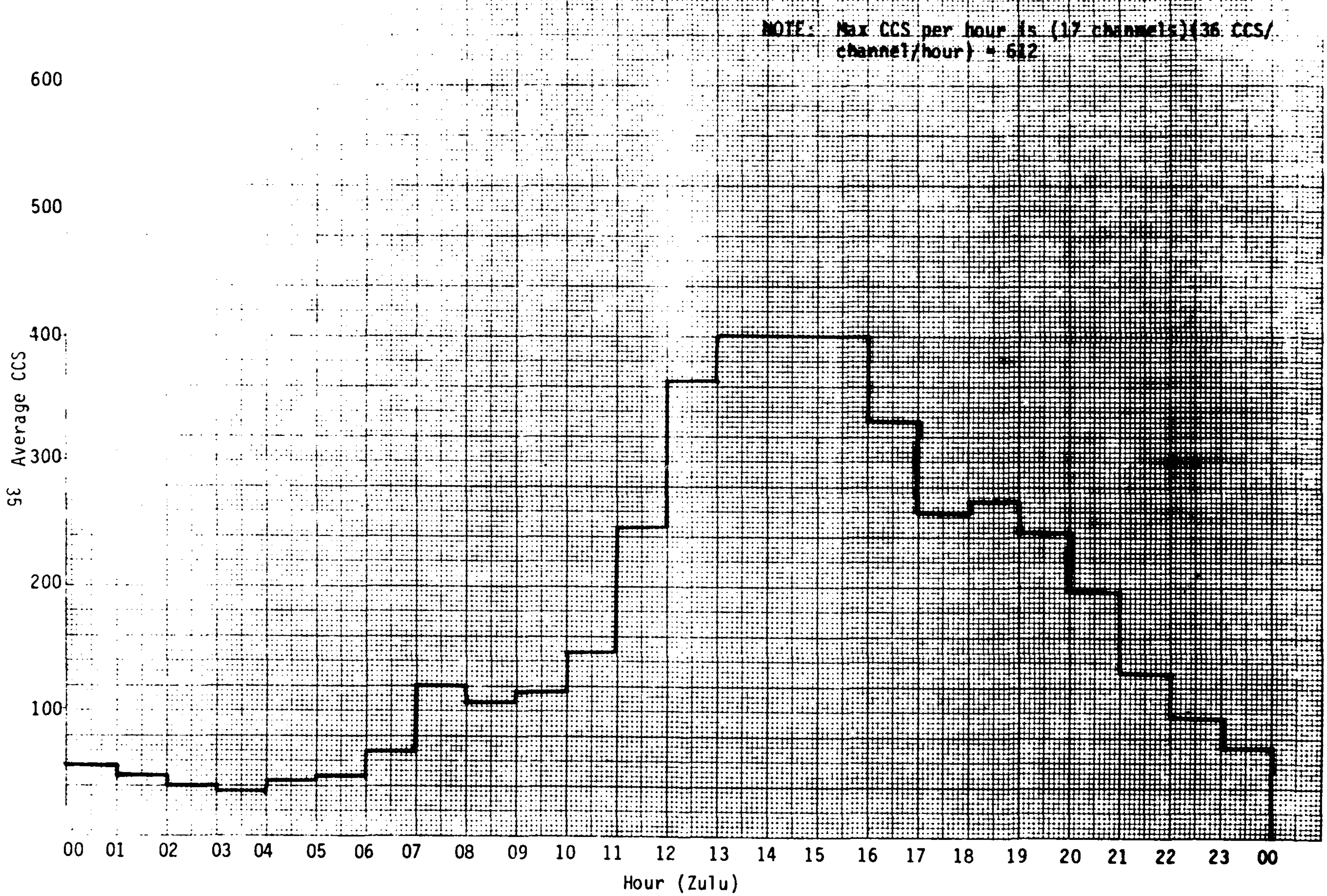
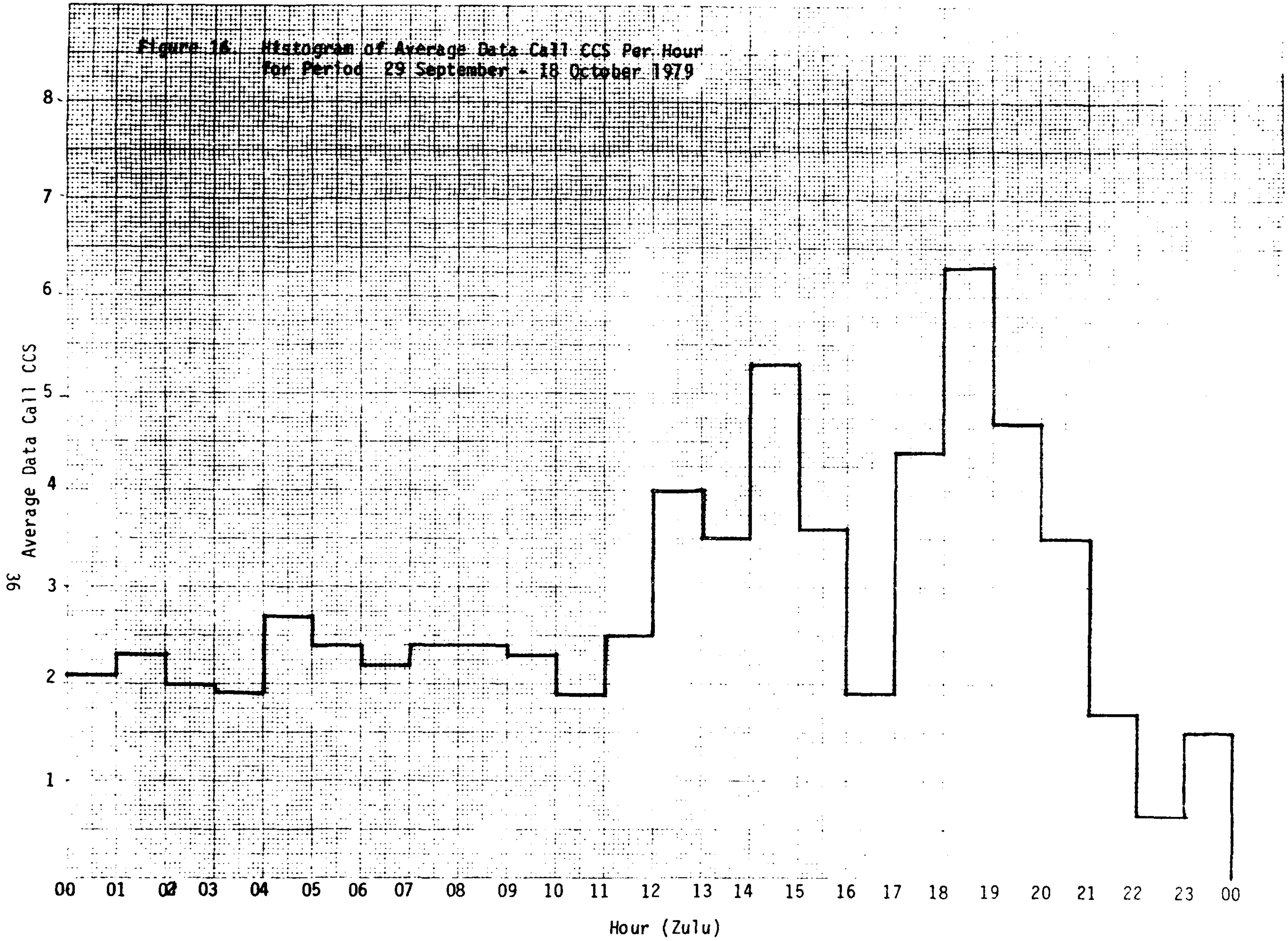


Figure 16. Histogram of Average Data Call CCS Per Hour For Period 29 September - 18 October 1979



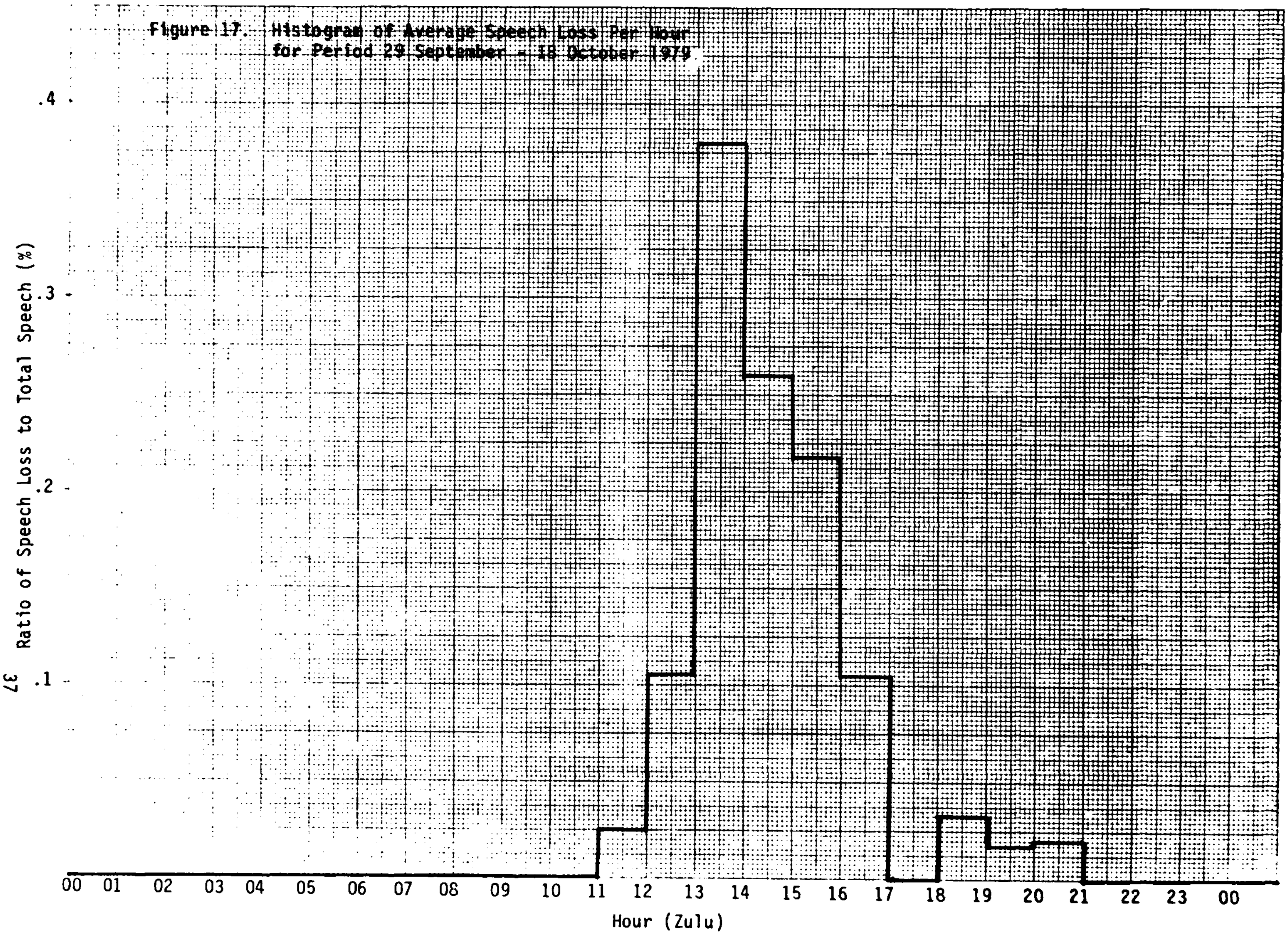


Figure 17. Histogram of Average Speech Loss Per Hour for Period 29 September - 18 October 1979

The second presentation of this data is given in Figure 18 which gives the distribution of speech loss percentage, again for all hours of the 20 day test period. For a choice of x% speech loss, the distribution shown is the probability (or % of all hours) that the speech loss was less than or equal to x%. For example, 99.2% of all hours had a speech loss percentage of less than 1.0%, and 74% of all hours had no speech loss.

Figure 19 shows the distribution of speech loss for the busiest hour of each day for the 20 day test period. Here note that the maximum speech loss observed was 1.3% (for only one hour), and that 30% of the busiest hours had no speech loss. Here busiest hour was defined to be that hour of each day that had the maximum speech loss percentage.

d. Blocking Statistics. Blocking of incoming channels occurs in the COM2 when existing loading indicates that additional channels, if accepted, would experience speech loss greater than the COM2 specification. Calls are prevented from accessing the COM2 by indicating a busy tone on the channel(s) to be blocked. The actual speech activity, number of data calls, and number of facilities out of service, are all used by the COM2 in an algorithm to determine when blocking (overload) conditions exist. The activation of blocking in no way effects existing calls but rather acts to maintain voice quality on existing connections.

COM2 overload events are reported via the Automatic Hourly Dump. The OVD SECS indicates the total time in seconds for all channels that an overload condition existed during the hour reported. Using these blocking times from the OVD SECS entry, a blocking percentage was arrived at by dividing the total blocking time in seconds by the total system usage in seconds for each hour (see Glossary for definition of terms).

Figure 20 is a histogram of percentage of blocking time per hour averaged over the 20 day test period. The only significant blocking is indicated over the three hour period 1200 to 1500 Zulu, which coincides with the busy hours on these CONUS-Europe trunks. Figure 21 provides the distribution of blocking percentages for all hours of the 20 day test period, plotted on probability paper. This curve indicates that the blocking percentage is less than 10% for 90% of all hours tested, and that no blocking occurred for 75% of all hours. Because of three hours which showed excessive blocking (greater than 50%), the curve shows a steep slope beyond the 99% point. Finally, Figure 22 shows the distribution of blocking percentage for the busiest hour of each day for the 20 days. Note that 90% of the busiest hours had less than 12% blocking, and 35% had less than 1% blocking. Again, because of the three hours with excessive blocking, the curve has a steep slope beyond the .90 probability point. The busiest hour here was defined as that hour of each day which had the maximum percentage of blocking time.

e. Effect of Lost Facilities on Blocking and Speech Loss. Another means of characterizing blocking and speech loss performance is as a function of the number of total facilities available for processing calls. Data calls and out-of-service facilities will reduce the number of facilities available

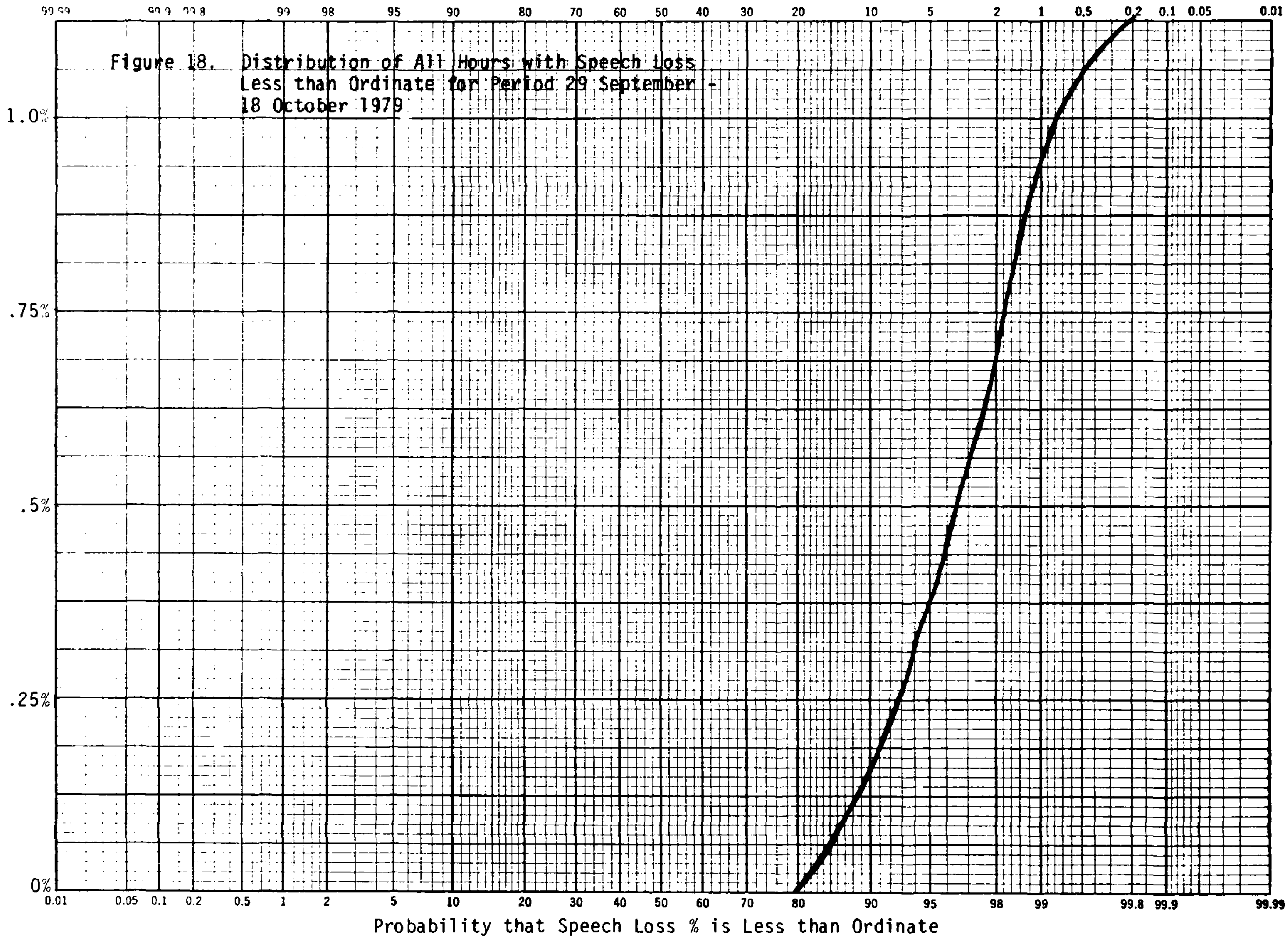


Figure 18. Distribution of All Hours with Speech Loss Less than Ordinate for Period 29 September - 18 October 1979

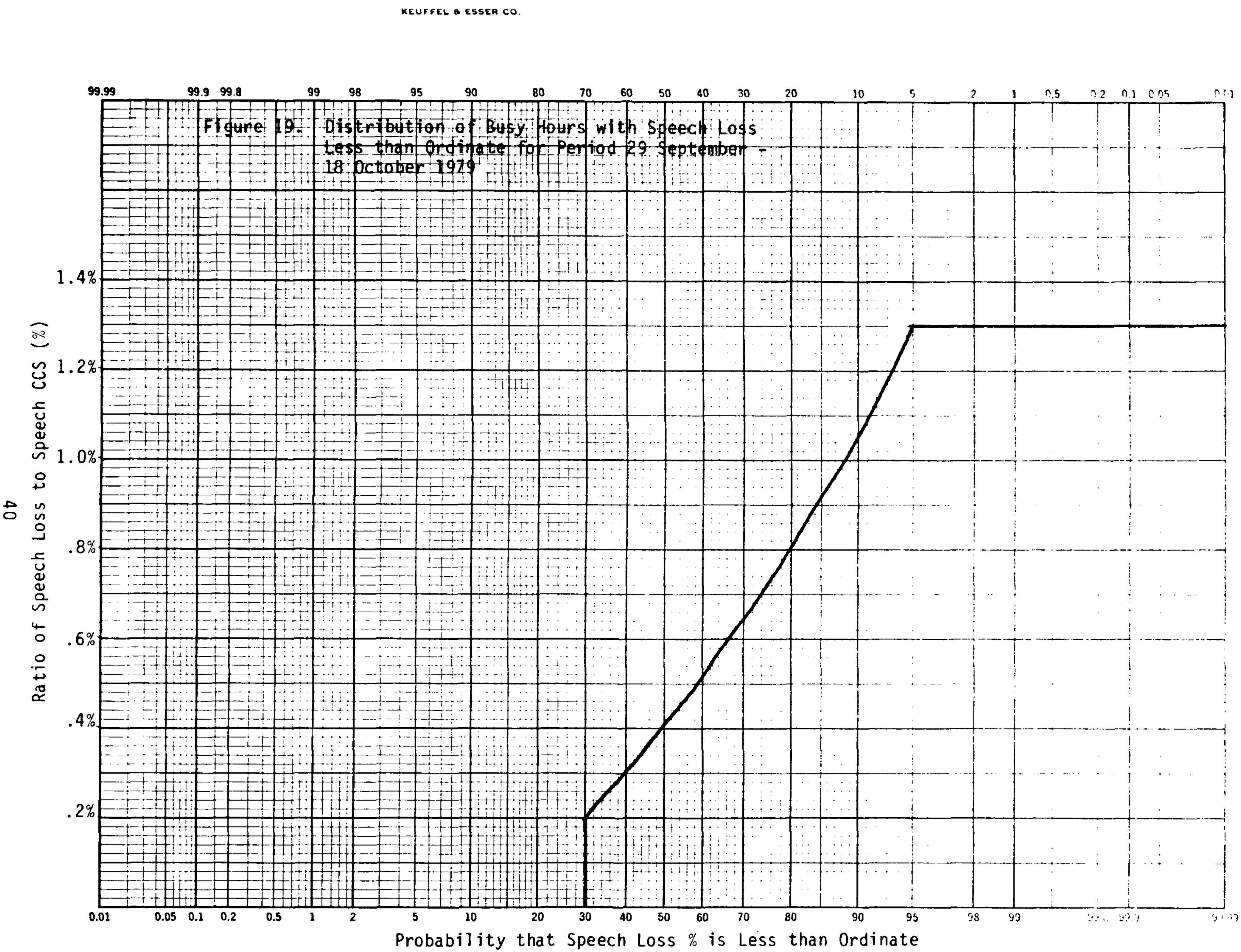


Figure 19. Distribution of Busy Hours with Speech Loss Less than Ordinate for Period 29 September - 18 October 1979

Figure 20. Histogram of Average Blocking Per Hour for Period 29 September - 18 October 1979

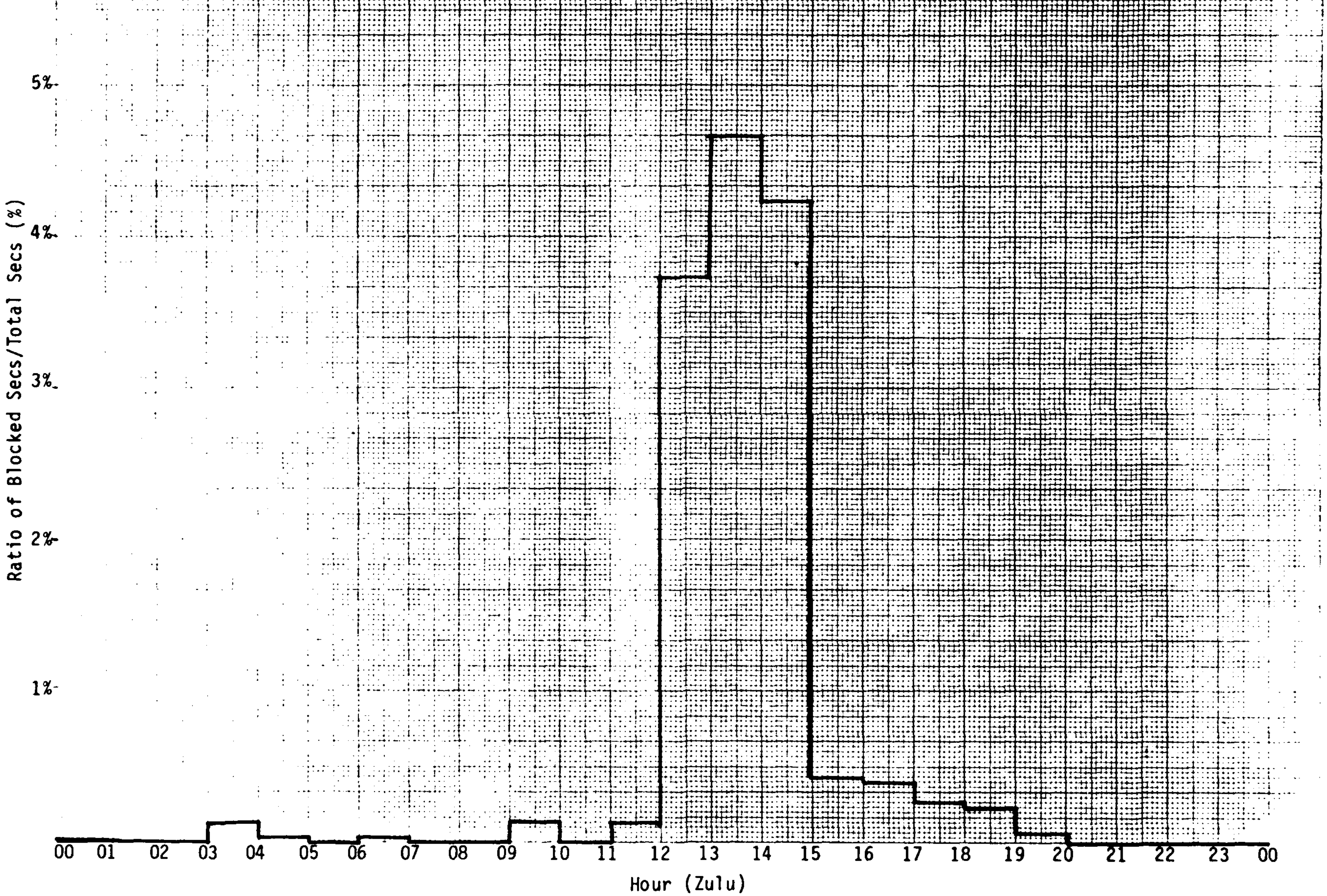
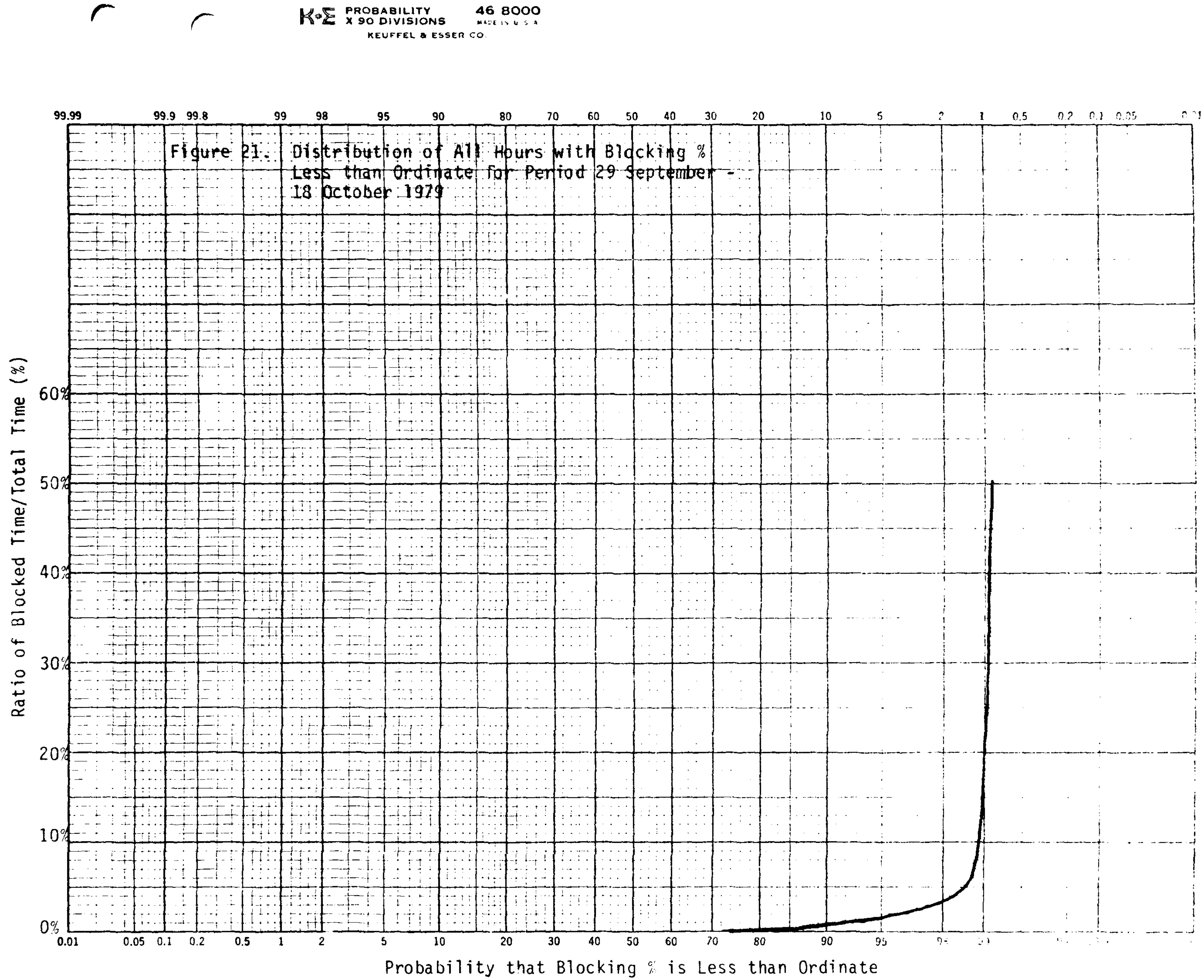


Figure 21. Distribution of All Hours with Blocking % Less than Ordinate for Period 29 September - 18 October 1979



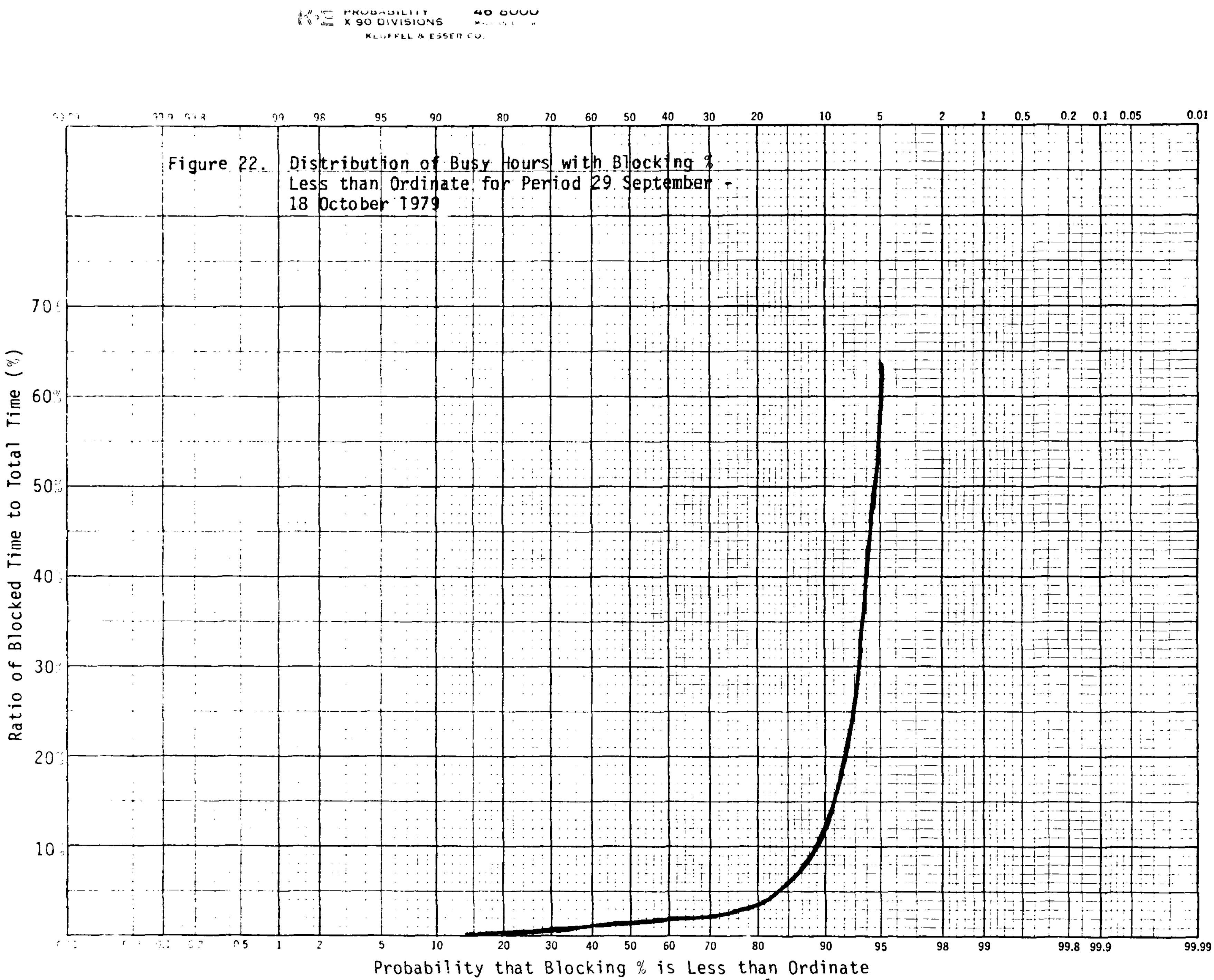


Figure 22. Distribution of Busy Hours with Blocking % Less than Ordinate for Period 29 September - 18 October 1979

for TASI operation. As the number of facilities is reduced, an increase in blocking can be expected, and an increase in speech loss is also suspected. The overall algorithm used to drop speech and block channels is complex and depends on more than just the number of available facilities. However, knowing that a direct dependence exists between speech loss/blocking and facilities availability, the test data was analyzed to quantify this relationship for the 20-day test period.

For each hour of the test period, the number of facilities available for normal TASI operation was determined by using the COM2 management reporting system to record (1) data calls and (2) out-of-service facilities. Data calls were reported by the Traffic by Hour, All Channels report. Because the COM2 dedicates a facility full period for each data call, the number of facilities lost due to data calls was immediately known. It should be noted that both routine, operational data calls and modem testing conducted under this test program reduced the number of available facilities and were listed within this COM2 management report. Out-of-service facilities were recorded by the Alarm report, which provides a printout of various alarm conditions including failed facilities. Out-of-service conditions occurred due to both equiment failure (COM2 or other transmission equipment) and high noise on a particular facility.

Figures 23 and 24 indicate the effect of the number of facilities lost on blocking and speech loss, respectively. As indicated on each figure, there were four different data points observed during the test period, corresponding to:

Data Point	# Facilities Lost	# Hours Observed
1	1	27
2	2	9
3	3	3
4	7	3

For each data point, the mean was calculated as shown on the appropriate figure. A straight line approximation has been drawn between the third and fourth data points. As expected, there existed a direct relationship between blocking and the number of lost facilities. With seven facilities lost, there existed only two facilities available for TASI and the mean blocking percentage exceeded 50%. With two facilities lost (seven facilities available), the mean blocking percentage was less than 2%. As shown in Figure 24, the relationship between speech loss and number of lost facilities was not as direct. This may be explained by the fact that this data does not take into account the number of active channels or the speech activity factor during periods of lost facilities, leading one to conclude that speech loss is more dependent on channel activity than on the number of available facilities.

Figure 23. Effect of # Facilities Lost (Out of 9) on Blocking Probabilities

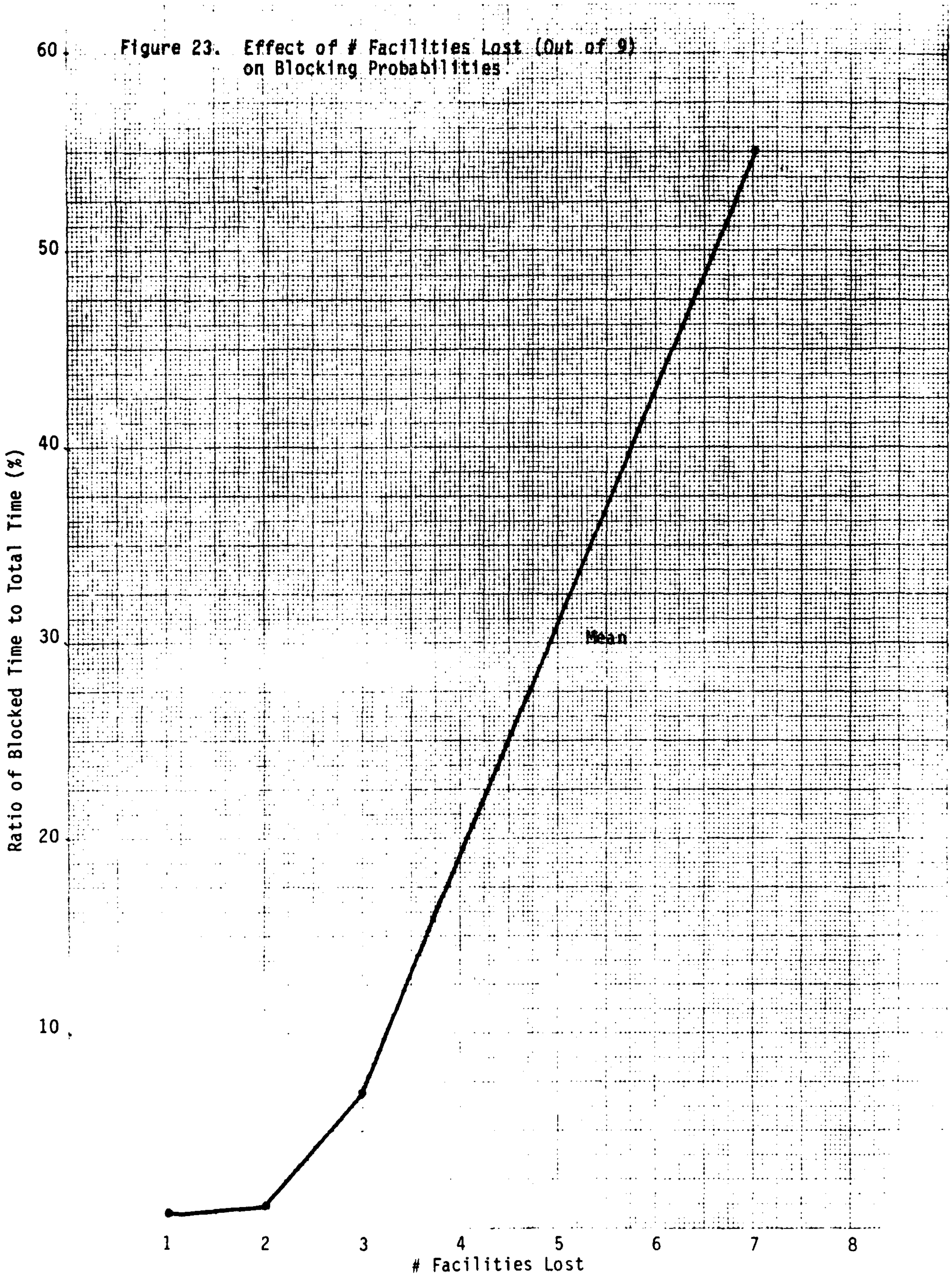
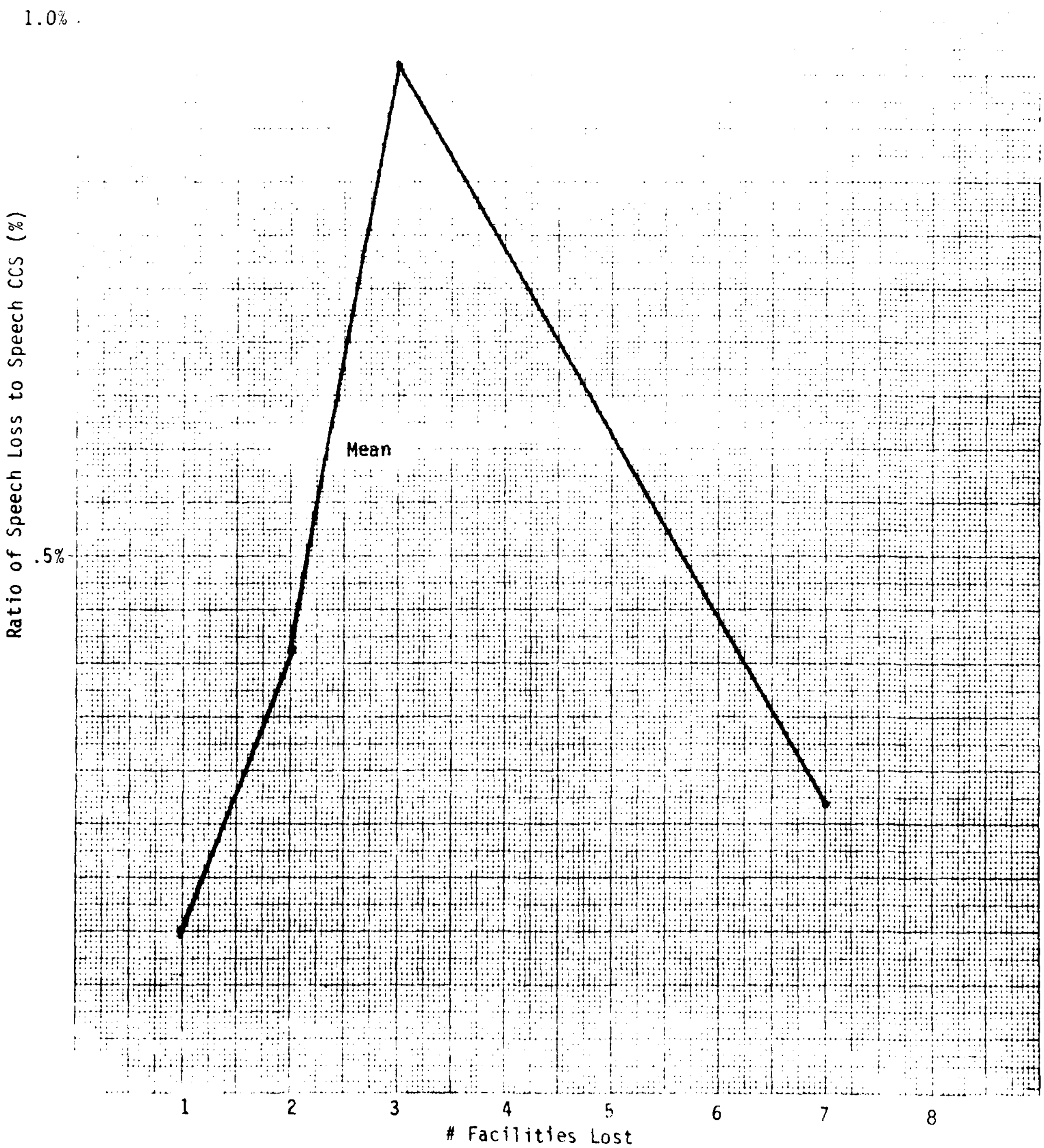


Figure 24. Effect of # Facilities Lost (Out of 9) On Speech Loss



4. USER SUBJECTIVE EVALUATION

a. Purpose. The purpose of this test was to evaluate the COM2 from the user's point-of-view. The acceptability of any new voice communications system cannot be determined from evaluation of just technical parameters. This test provided both the necessary subjective evaluation and a means of familarizing users with a new system.

b. Approach. The evaluation was designed to measure the extent that users liked or disliked the quality of calls made over the COM2 equipment. The COM2 equipment was configured for normal operation, as shown in Figure 1. A special NYX code of 319 was programmed at the Feldberg and Langerkopf AUTOVON switches that permitted callers to select transoceanic circuits using COM2 equipment. Selected AUTOVON subscribers in Europe were given the special NYX code of 319 and were asked to evaluate the performance of the COM2 voice channels. Voice users were provided an AUTOVON User Report Sheet (See Figure 25) to evaluate the quality of their calls. The AUTOVON User Report Sheet was specially designed to determine the following:

a. Intelligibility.
b. Quality (compared to normal AUTOVON service).
c. Effect of blocking and clipping.
d. Effect of fixed and variable processing delay.

c. Results. The AUTOVON User Report Sheets were collected and forwarded to Hq DCA/Code 520, Washington, DC. An analysis was made of over a thousand report sheets. The results indicate the subscribers involved in the evaluation used the COM2 with regularity. They reported the quality to be as good as, if not better, than the normal IST circuits. Based on a 100 point scale of overall acceptability, the subscriber on the average rated the COM2 as 95.

Operational Test

AUTOVON USER REPORT SHEET

Using Area Code 319 will trunk your CONUS AUTOVON calls over a special trunk group designed to improve AUTOVON service. This special trunk group is under evaluation. Please list and evaluate each 319 call.

	Date:			Time:		
Loud Intense	( )	( )	( )	( )	( )	Soft Mild
Continuous Sustained	( )	( )	( )	( )	( )	Intermittent Clipped
Natural Familiar	( )	( )	( )	( )	( )	Unnatural Foreign
Pleasant Pleasing	( )	( )	( )	( )	( )	Annoying Irritating
Intelligible Clear	( )	( )	( )	( )	( )	Unintelligible Hazy
Steady Stable	( )	( )	( )	( )	( )	Fluttering Unstable
No Interference	( )	( )	( )	( )	( )	Interference Crosstalk
No Echo Instantaneous	( )	( )	( )	( )	( )	Echo
Active Brisk	( )	( )	( )	( )	( )	Passive Dragging

How would you rate this system on a 100 point scale of overall acceptability? .... ________

Figure 25. User Subjective Evaluation Form

IV. CONCLUSIONS

1. VOICE CHANNEL CHARACTERIZATION

COM2 derived voice channels provided performance equivalent to or better than V2 as required for AUTOVON interswitch voice grade trunks[2]. Of those channel parameters tested, the only significant degradation introduced by COM2 was in envelope delay which may result in a limit on performance of certain high speed (9600 bps) modems operating through the COM2.

2. DATA CHANNEL CHARACTERIZATION

Testing of VFCT's indicated that the COM2 generally failed to recognize fully loaded VFCT's as a data call and dropped these connections within the 7-14 minute period allocated for inadvertent test signals. VFCT's do not meet COM2 criteria for data call recognition because (1) significant energy lies below 1100 Hz and (2) energy in the frequency band 2010-2240 Hz is insufficient. During the 7-14 minute holding time, however, bit error rate and distortion performance were found acceptable for the two VFCT's tested. It should be noted that the COM2 handled VFCT's exactly as expected because of the failure of VFCT's to satisfy COM2 data recognition criteria. Hence, VFCT's must be accommodated by non-COM2 trunks.

Tests of modems indicated marginally acceptable bit error rate performance* both with and without the COM2 for rates up to 9.6 kb/s. The slight degradation of BER when operating over the COM2 was probably within the test measurement error which occurred because of varying channel noise levels and limited statistical confidence in short term BER measurements. The COM2 degradation of envelope delay as described above may have also contributed to modem performance degradation. However, it should be pointed out that voice channels tested, both with and without the COM2, are not specified for modem operation and in fact failed to meet frequency response and envelope delay requirements as prescribed, for example, on AUTOVON access lines and trunks at rates of 7200 and 9600 bps[2]. Other modem testing of sensitivity to transmit power level and channel noise indicated that COM2 provided no additional degradation to performance.

3. TRAFFIC DATA ANALYSIS

Statistical analysis of COM2 traffic data indicated heavy usage of these AUTOVON IST's, particularly during busy hours. As expected, only a small percentage of usage was for data calls, as these circuits are specified for voice only. In view of the heavy loading of the COM2, the resultant speech loss and blocking statistics should indicate a worse case condition for

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* Reference (2) states that the average BER should be equal to or better than 1×10^{-5} over any 10^{6} bit interval 99 percent of the time for rates of 50 through 9600 bps.

AUTOVON IST's. Speech loss statistics indicated that more than 99% of all hours had less than 1% speech loss. This loss of speech takes the form of clipping, i.e., the loss of initial part of speech bursts which proved tolerable and in fact was unnoticed by users who completed the subjective evaluation form. Blocking statistics indicated that blocking percentage was less than 10% for 90% of all hours tested. The blocking of incoming channels in no way affects existing calls so that the net result is that the full 2:1 compression is not realized for all hours, but for a high percentage of all hours. Significant blocking (approximately 50%) occurred during a three hour period in which seven trunks were reported out, leaving only two trunks available for 17 incoming channels.

4. DIAGNOSTIC REPORTING

During the course of COM2 testing, occasional transmission equipment failures and link fading resulted in COM2 diagnostic action. Failed trunks were first eliminated from the TASI pool and then reported as an alarm condition via the terminal. Subsequent testing of the failed trunk, done automatically by the COM2, resulted in restoration upon removal of the failure. During periods of satellite or line-of-sight link fading the COM2 kept existing calls connected, as expected. The bypass mode, which normally is enabled only for a power failure or "sanity" failure of the COM2 processor, was intentionally enabled to evaluate its performance. Two minor problems were observed upon return to normal operation: (1) the timer of the management reporting system is reset after bypass and (2) all keyed-in requests for reports are disabled and must be reset after bypass.

V. RECOMMENDATIONS

1. FUTURE APPLICATIONS

Test results provided in this report apply to other AUTOVON interswitch trunks with certain qualifications pointed out here. Implementation of COM2 with other types of DCS circuits, such as AUTOVON access lines, AUTODIN and AUTOSEVOCOM, may require additional analysis or testing which should be determined on a case by case basis.

This test configuration provided for the application of COM2 to a combination of analog and digital transmission links, since part of the COM2 derived trunks were routed through analog equipment and the remainder through digital equipment. Satisfactory performance was observed, although it should be noted that out-of-spec circuits may be rejected by the COM2 as was found with the two trunks initially routed by troposcatter links from Croughton to Feldberg. Also, since all trunks were routed via satellite for the transoceanic portion, no problem with differential delay was observed among the nine trunks. Because of the shared nature of each trunk for TASI operation, there exists a 40 msec limit on differential delay allowed among COM2 trunks. Hence, use of a satellite link for some trunks and terrestrial links for other trunks is precluded for COM2 application.

Voice channel performance equivalent to V2 has been demonstrated and can be expected for other COM2 applications where V2 is already being met. VFCT's operating through the COM2 will not be held for longer than 14 minutes and therefore are not permitted for COM2 usage. Modem tests reported here indicate acceptable performance through the COM2, but additional tests and additional modems, as described below, must be evaluated before a definitive recommendation can be given. For the 17 on 9 system evaluated, acceptable speech loss and blocking percentages were observed. Since larger COM2 configurations will experience even smaller percentages of speech loss and blocking, configurations ranging from 17 on 9 to 31 on 16 are recommended. Smaller configurations would require additional analysis or test.

Experience with the COM2 management reporting system proved its usefulness for both traffic data analysis and fault diagnosis. Having a terminal collocated with the COM2 facilitated input/output and is recommended for all future COM2 applications for at least one end of the system. The ability to troubleshoot not only the COM2 but the entire circuit, from COM2 channel to COM2 channel, will eventually prove to be of great service to technical controllers. To completely remove the COM2 for troubleshooting purposes, channel testing should be done between the COM2 channel and the switch, and trunk testing done between trunk sides of the COM2. Testing of channels through the COM2 requires special procedures in order to continuously hold a given channel. Before initiating any 1004 Hz test tone which is to exceed a few seconds, a tone in the 2010-2240 frequency band should be transmitted which will cause the COM2 to disable the echo suppressor and provide a dedicated trunk for that channel under test. Thereafter, so long as constant energy is present, continuous testing without interruption can be acccomplished with a 1004 Hz tone.

C. FUTURE TESTING

Certain tests applicable to voice concentrators can not be conducted in this operational configuration because of the variability of transmission link performance. Test of COM2 performance as a function of various sources of impairment require a laboratory controlled environment and two COM2's operating in a looped configuration. (Note that a single COM2 cannot be looped on itself and still operate in a TASI mode.) A list of tests yet to be conducted but required to prove out COM2 for other applications is given in the following.

a. Bit Error Rate Sensitivity. For applications of the COM2 operating in conjunction with a PCM multiplexer (e.g., AN/FCC-98), this test will determine the effect of bit errors on COM2 performance. To accomplish this, the PCM multiplexer will have errors inserted in its composite bit stream (at 1.544 mbps) to simulate the effects of a transmission channel error rate. The PCM multiplexer transmit bit stream, after error insertion, will be looped back to the receive side of the multiplexer as shown in Figure 2 of reference (1). Performance of voice and data signals will be characterized for error rates of 10^{-3}, 10^{-5}, and 10^{-7}.

b. Noise Sensitivity. For applications of the COM2 operating with FDM equipment, this test will determine the effect of noise on COM2 performance. To accomplish this, the FDM equipment will have noise added to its composite spectrum (e.g., at 60-108 KHz for a FDM group) to simulate the effects of additive channel noise, as shown in Figure 5 of reference (1). Variation of the noise level will allow control of the signal-to-noise ratio. Both voice and data signals will be characterized as a function of S/N.

c. Multiple TASI. This test will determine the effect of multiple TASI operations on voice and data signal performnce. The test configuration requires successively looping through the channel side of the COM2 to increase the number of TASI operations and analog-to-digital conversions on a given input signal and measuring performance parameters appropriate for the signal under test, as shown in Figure 1 of reference (1).

d. Speech Recognition Sensitivity. This test will determine the ability of COM2 to recognize speech as a function of input level and duration of speech burst. Various types of background noise will be input to COM2 channels to determine the COM2's ability to distinguish speech from noise sources.

e. Speech Loss and Blocking. This test will determine the amounts of speech loss and blocking in the COM2 as a function of number of busy channels, speech activity factor per channel and number of available facilities.

f. Transmission Control. This test will determine the degree to which transmission levels and bandwidth are controlled by COM2 on its facility outputs. Longitudinal balance and impedance versus frequency and presence of transients will also be part of this test.

g. Signalling Characterization. The COM2 is designed to provide transparency to in-band signalling such as DTMF or MF. This test will verify COM2 interface with DCS versions of in-band signalling, with emphasis on the effect of delays introduced by COM2.

h. Alternate Voice/Data Circuits. This test will determine COM2 ability to recognize and maintain a data call when an alternate voice/data circuit is switched from the voice mode to the data mode.

REFERENCES

1. COM2 Voice Concentrator Test Plan, DCA/DCEC, 19 Sep 1979.

2. DCA Circular 300-175-9, DCS Operating-Maintenance Electrical Performance Standards, December 1977.

3. DCA Circular 310-70-1, Supplement 1, DCS Technical Control, Vol II, Procedures and Test Descriptions, November 1972.

4. DCA Circular 310-70-57, Supplement 1.

5. J. M. Fraser, D. B. Bullock, and N. G. Long, "Overall Characteristics of a TASI System," BSTJ, July 1962, pp. 1439-1454.

6. J. M. Elder and J. F. O'Neill, "A Speech Interpolation System for Private Networks," NTC 78, pp. 14.6.1-14.6.5.

GLOSSARY

Blocking	During overload of a voice concentrator, unseized channels will be blocked from being seized. Blocking prevents active channels from being further degraded during overload conditions.
Blocking Percentage	Percent blockage due to overload. $$\%\ \text{blocking} = \frac{\text{total seconds of system blocking}}{\text{total system CCS} \times 100} \times 100$$
CCS	Hundred call seconds. The unit of CCS indicates the length of time a connection existed on a particular channel per unit of time. There are a maximum of 36 CCS in one hour per channel. This unit of traffic data is often used in statistical analysis of data.
Overload	Overload can result from high speech activity on a relatively large number of input channels. Generally, an algorithm is used to sense overload conditions and initiate blocking.
Speech Activity	Period of time that speaker is active. Because of gaps, pauses, and listening times, typical speech activity factors are 30-40%, here $$\%\ \text{speech activity} = \frac{\text{speech CCS}}{\text{total CCS}} \times 100$$
Speech Loss	During periods of excessive speech activity or when buffer space becomes unavailable, a voice concentrator will be forced to drop speech segments. Such loss of speech is interpreted by the listener as a clip of the beginning, middle or end of a speech burst.
Speech Loss Percentage	$$\text{Percent speech loss} = \frac{\text{speech loss in seconds}}{(\text{speech CCS} \times 100)} \times 100$$
Time Assignment Speech Interpolation	TASI is a voice concentrator technique which uses gaps and pauses in the speech of one channel to transmit speech bursts from other channels. Concentrations of up to 2 = 1 have been commonly utilized within commercial telephone networks.

APPENDIX A.

COM2 DETAILED DESCRIPTION

1. INTRODUCTION

The COM2 is a voice concentrator that uses microprocessor and digital processing technology to statistically multiplex voice conversations onto private lines in an approximate two-to-one ratio. Each COM2 allows a maximum of 31 voice circuits to be concentrated onto 16 private lines, and a minimum configuration of 9 on 5. Within these limits the system is designed to multiplex 2N-1 incoming channels to N outgoing channels.

The COM2 combines Time Assignment Speech Interpolation (TASI) principles with the use of buffers to allow efficient multiplexing of even small trunk group sizes. TASI consists of filling in the silent gaps and pauses occurring in one voice channel with speech from another channel. This technique has previously found application with submarine cable and satellite for relatively large trunk groups[5].

2. SPEECH PROCESSING

The COM2 transmits and receives voice in an analog mode. Internally, it processes the voice signal in digital format by utilizing standard 64 kbps PCM with (255) law companding. Figure A-1 is a simplified block diagram of the COM2. Incoming speech on the channel side is detected by speech detectors and simultaneously is stored in a buffer assigned to that channel. If a trunk is available, a control symbol is first transmitted to direct the far-end to place the speech burst on the correct channel. The delayed speech burst follows the symbol on the same trunk. The fixed buffer delay serves the purpose of allowing time for speech detection and transmission of the symbol without clipping the leading portion of the speech burst. Should an idle trunk not be available, buffers with variable length are used to store speech until a trunk becomes available. At this point, following the transmission of the symbol, speech is transmitted from the buffer continuously until termination of the speech burst. Hence the buffer introduces a fixed plus variable delay equal to the time required to detect the initial part of the burst and to locate an available trunk for transmission. When the speech burst terminates, the buffer releases the memory it has acquired until the buffer contents are depleted, at which time the buffer is returned to the pool. The design and performance of these buffers is considered in greater detail in reference (6).

Loss of speech segments may result from initial delay while waiting to acquire a buffer and from buffer overflow when all buffer segments are in use. Once a buffer request is made, failure to provide a buffer because all are in use leads to loss of initial speech, called clipping. Once a buffer is assigned to a channel, speech will be stored in 32 msec segments with a total of 96 segments available. If the buffers begin to saturate, a speed-up release of segments is started. This is done to release segments faster for new incoming speech.

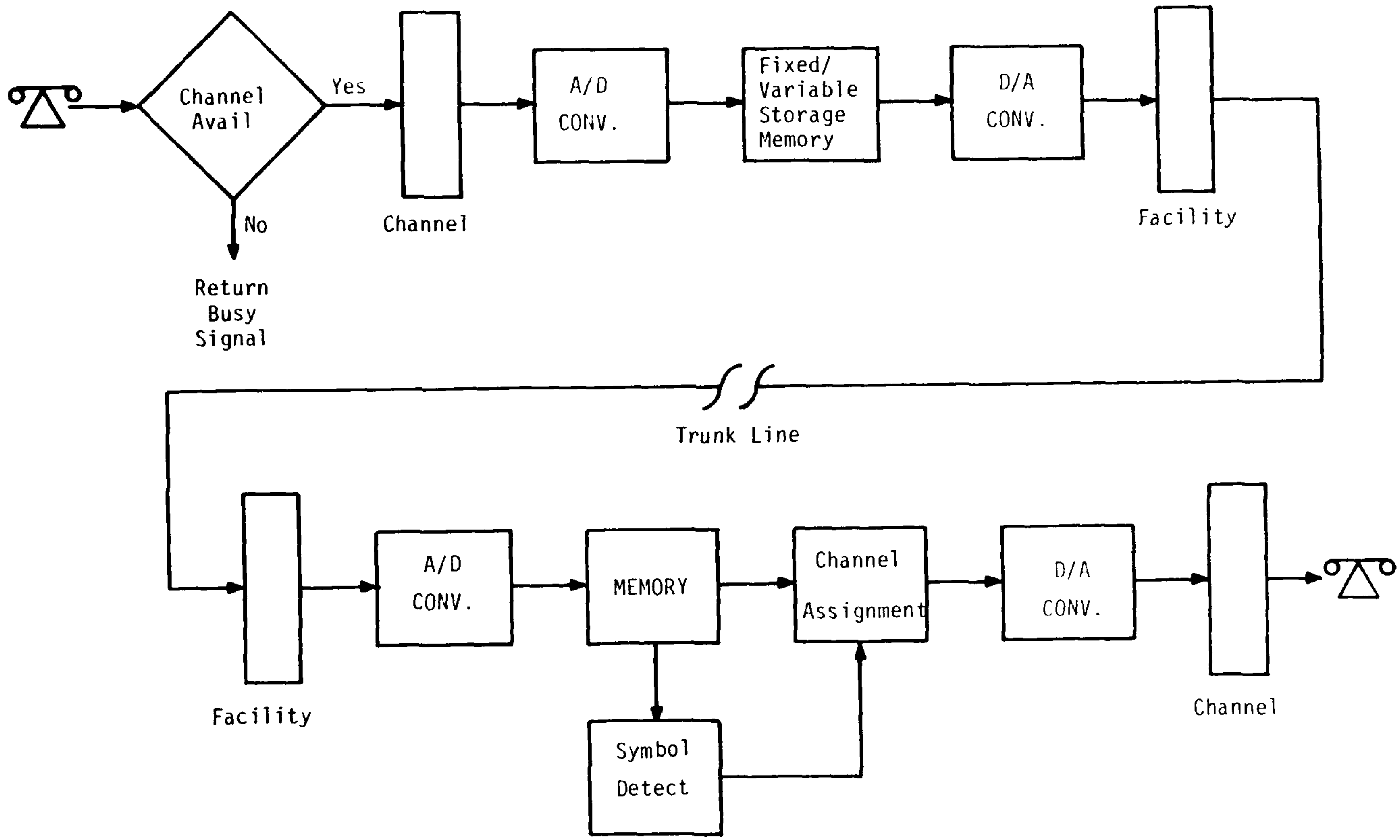

Figure A-1. COM2 Simplified Block Diagram

Under certain conditions of heavy traffic volume, overload of the COM2 may occur which will result in blocking any unseized channels from being seized. The COM2 monitors speech activity and compares it to a predetermined threshold for overload. This threshold is determined by the total number of speech-available facilities (total number of facilities minus total number of data calls currently active). To come out of overload, the COM2 continues to compare average speech activity against a threshold.

3. INTERFACES

COM2 channels and facilities are both designed for 4-wire operation plus E&M signalling, as shown in Figure A-2. The T, R and T1, R1 leads form voice transmission pairs and operate with 600 ohm impedances. The M lead on the COM2 channel side detects an incoming call. Local switching equipment applies a ground to the M lead for the idle state and -48 volt DC for the active state. The M lead on the COM2 facility side transmits a signal to the trunk lines; ground for idle, -48 volts DC for the active state. The E lead on the COM2 channel side provides a ground for the active state and an open circuit for the idle state to the switching equipment. On the facility side of COM2 the E lead detects ground as an active state and an open circuit as the idle state.

When the system automatically by-passes itself because of failure (system or power), the COM2 connects facility leads directly to corresponding channel leads via internal relays. The T,R leads on each side connect to the T1, R1 leads on the opposite side to preserve compatibility of direction and level. However, in by-pass operation channel 0 and facility 0 remain terminated in the COM2 rather than becoming connected to one another via relays. This permits COM2 to communicate end-to-end via this facility and allows re-initiation of the system. Channels 1 though n are available for call processing during by-pass, being connected through the relays to facilities 1 through n. Channels n+1 through 2n-1 have no corresponding facilities for connection; these channels (also channel 0) are accommodated by placing a ground on the E lead of the channel interface so the channel appears seized.

During overload, calls are prevented from accessing the COM2 by indicating a busy tone on the channel(s) to be blocked. Two options are provided for interface with the switch:

(a) E-lead idle and busy tone.
(b) E-lead active and busy tone.

Echo suppressors are contained within the channel interface circuitry. Hence, those normally provided with private lines (trunks) are not required and should be removed when the COM2 is on line.

The COM2 is transparent to all types of supervision and signalling. All such incoming signals at each end are recreated at the other end without attempting to recognize the protocol. E&M leads provided by the COM2 allow supervision but in-band supervision is also possible. Likewise, address signalling may appear on the E&M leads (dial pulse) or may be accommodated in-band (DTMF or MF).

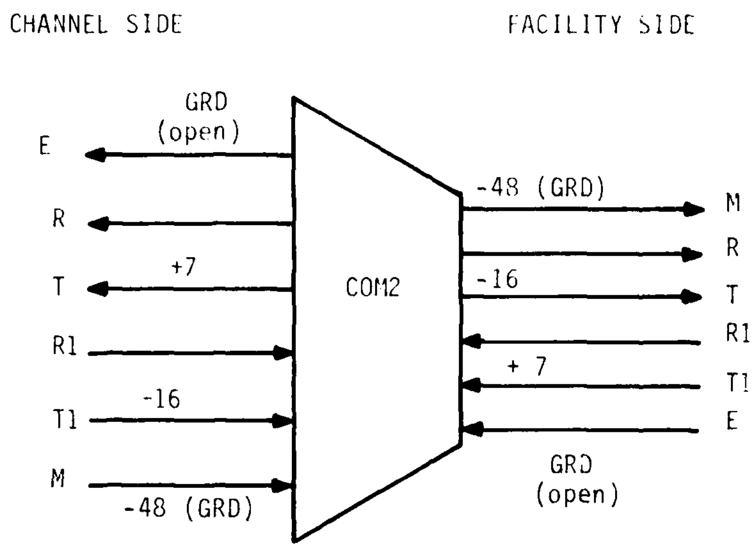

Figure A-2. COM2 Interfaces

In-band supervision and signalling is treated as speech by the COM2, although no variable delays are involved since supervision/signalling has highest priority for trunk usage. Signalling appearing as E&M is converted to in-band for transmission and is reconstituted as E&M at the distant end.

No variable delays are involved in supervisory signalling since it has highest priority for trunk usage. For E&M signalling, a fixed delay of 188 msec is introduced. For dial pulse signalling, a 220 msec fixed delay is involved with transmission of each dialed digit. For in-band (DTMF or MF) address signalling, COM2 introduces a fixed delay of 60 msec and a variable delay from zero to several hundred milliseconds, depending on the load at that instant.

A performance specification for COM2 interface is provided in Appendix B.

4. DATA HANDLING

The COM2 has been designed to accommodate data or facsimile by detecting such signals and providing a dedicated connection. When a trunk becomes dedicated to a data call, it's removed from the pool of facilities available for TASI operation. COM2's traffic management algorithm notes this removal and may reduce incoming channels by busying-out the necessary number to assure against voice overload. The exact number busied-out at any instant depends on the amount of other traffic present.

Full duplex data is recognized by sensing energy in the range 2010-2240 Hz above a threshold of -30 dBm0 and the absense of energy outside this band. (Note: Full duplex modems utilize tones in the 2010-2240 Hz range as protocols for initial call set-up.) For half-duplex operation, when no 2010-2240 Hz tone is necessarily generated, the COM2 compares energy above and below 1100 Hz. If energy above is sufficiently high and energy below sufficiently low, the system labels the call data. The resulting dedicated connection remains as long as there is constant energy in either direction of transmission. The system controller checks each data channel every seven seconds to determine if the data call is still in progress. When on two consecutive samples it finds no data present, it releases the facility to the voice pool and restores the variable delay capability.

5. DIAGNOSTIC AND MANAGEMENT REPORTING

The COM2 provides diagnostics which not only monitor system performance but line (trunk) performance as well. Line condition is routinely monitored, and lines found to have excessive noise levels (greater than 53 dBrn at OTPL) or loss are automatically removed from service with no interruption of ongoing calls. The controller periodically checks faulty trunk lines that have been removed from service and automatically restores them to full service when the source of the fault has been removed. The controller also runs diagnostic checks on COM2 circuits, removing those found faulty and restoring those from which the faults have been removed.

An EIA RS-232C 300 Baud terminal interface is provided for customer-owned hook-up to allow diagnostic reports to be displayed on a terminal. A field-engineering (FE) panel is also provided within the COM2 for in-depth trouble-shooting by the FE.

The management reporting system provides user with detailed information, in log form, on system usage including trunk utilization and call characteristics. The RS-232C terminal interface provided by COM2 allows these reports to be displayed on a terminal. Reports are available automatically on a periodic basis, or per terminal-input keyed request. A list of available reports with a summary description is given below:

1. Traffic By Hour, All Channels.

    The data in this report sums and averages traffic over all channels, combined for both directions, and is provided automatically every 24 hours. Data is updated each hour, and is stored for the most recent 24-hour period. Average CCS and data call statistics are provided.

2. Traffic By Channels.

    The data in this report is summed, averaged and reported automatically every 24-hour period. For each channel, near-end and far-end originations and average holding times are given.

3. Private Line Status.

    This report gives the most recent AGC and noise data for each private line, separated for each direction of transmission. Data is provided automatically every 24 hours.

4. Busy Hour Analysis.

    This automatic report shows traffic volume during the busiest hour of the last 24 hours. Data in the form of CCS is given for total channels and also for individual channels. Near-end and far-end originations and blocking percentage are also given.

5. Request System Status.

    Upon keyed request, this report provides system status including alarm indications (if any), current configurations, and identification of failed channels or facilities, indication of overload condition, and amount of data calls on the COM2.

6. Alarms.

    Within one minute of the occurrence of a panel alarm, this report indicates type of failure and identifies the failed channel or facility.

7. Automatic Hourly Dump.

    Once enabled by terminal input, this report provides basic traffic data and system performance which can be used to evaluate system performance. (Table A-I provides a detailed description of this report).

TABLE A-I. AUTOMATIC HOURLY DUMP REPORT

OVD CHAN - Overload Channels

Total number of channels that were blocked for all overload events.

OVD SECS - Overload Seconds

Total time in channels seconds, that channels were blocked in all overload events. (Channel seconds = seconds in overload x number of channels in overload.)

OVD EVNT - Overload Events

Total number of times overload conditions occurred.

TOT CCS - Total Hundred Call Seconds

Total time of seizures for all channels (in hundreds of seconds).

SPCH CCS - Speech Hundred Call Seconds

Total time of actual speech processed by all channels (in hundreds of seconds).

BUFF CCS - Buffer Hundred Call Seconds

Total time of buffer usage by all channels (in hundreds of seconds).

BUFF FAIL - Buffer Request Failures

Total number of times a channel, with speech, could not acquire a buffer because of facilities were currently active and all eight (8) buffers were already in use.

BUFF LOSS - Buffer Loss

The total amount of speech lost, in seconds, that all channels had, while waiting to acquire a buffer after incurring a buffer request failure.

SEG LOSS - Segment Loss

Total amount of speech lost, in seconds, that all channels, after acquiring a buffer, (1) had while waiting to obtain 32 msec segments, because all segments were in use and (2) had as a result of segment loss due to COM2 speed-up algorithm.

NEA ORIG - Near End Originations

Total number of near end originiations.

FAR ORIG - Far End Originations

Total number of far end originations.

APPENDIX B. COM2 INTERFACE SPECIFICATION

General

Minimum size system:	(9) channels on (5) facilities
Maximum size system:	(31) channels on (16) facilities
Private line compatibility:	Four-wire private line, Bell series 2000, 3000, or equivalent
Data handling:	Detects data and gives it a dedicated facility

Transmission Characteristics

Impedances:	Inputs: 600 ohms nominal, balanced to ground Outputs: 600 ohms nominal, balanced to ground
Levels:	All inputs and outputs: Selectable OTLP, -16TLP or 7 TLP
Envelope delay distortion:	Less than 200 usec from 500 Hz to 2500 Hz
Non-linear distortion:	45 dB below nominal signal
Noise: C-Msg:	Less than 29 dBrnCO
Frequency characteristics:	$\pm$1.5 dB from 300 Hz to 3000 Hz relative to 1004 Hz
Reduction in out-of-band hum and low frequency noise:	10 dB average
AGC action:	Will correct for +4 to -8 dB long-term variation in telco facilities relative to 1004 Hz
Tone used for circuit system testing:	1032 Hz: 500 Hz and 2437 Hz used for installation alignment (generated by COM2)
Tones used for control and maintenance functions:	3 tones selected from twelve in the frequency range 700-2400 Hz

Signaling Characteristics

E & M Signaling Tolerances Allowable (battery and ground):

Source voltage:	-48 V ± 10%
Source resistance:	Up to 100 ohms
Maximum signal cable resistance:	200 ohms
Maximum ground potential difference:	2V
Dial pulse percentage make-break required for detection:	58-62% break, 8-11 pps
Dial pulse rate upon regeneration:	10 ± 0.01 pps
Dial pulse percentage make-break upon regeneration:	59 to 62% break
Ringer equivalence number (FFC):	0.4B

COM2 Will Tolerate The Following Impairments:

Weighted noise on private line before removal from service:	53 dBrn at OTLP; 3 kHz flat
Equal-level cross talk:	60 dB (Customer acceptance criterion; not COM2 limit)
Telco carrier frequency drift:	± 5 Hz
Attenuation distortion:	+4 dB to -8 dB in the band 500-2437 Hz referenced to 1004 Hz
Long term gain variation:	+4 dB to -8 dB

Connectors

Telco interface:	50 pin ribbon jack, Amphenol 57 series or USOC RJ23X terminating on Type 66 punchdown blocks, or USOC RJ21X

Test Jacks (channel and facility boards):	Bridging test points T, R, T1, R1
	Will accept Standard Telco-type 310 jacks or standard 3 lead phone jacks on each channel and facility card (break Xmsn ckt. for COM2 isolation)
	1 Outward voice transmit pair 2 Outward signalling transmit pair 3 Inward signaling receive pair 4 Inward voice receiver pair
Data terminal connector:	Standard 25-pin RS 232C (300 BPS ASYN ASCII)
AC power:	Standard 115 VAC ground plug (400 watts max) 115 VAC convenience outlet for FE on lower front panel

Environmental

COM2 will tolerate:

Temperature:	32 degrees F. to 104 degrees F. ambient (65^{o} - 75^{o} recommended)
Relative humidty:	10-90% non-condensing
Vibration:	5 Hz - 26 Hz, 1 mm peak-to-peak 27 Hz - 30 Hz, 1 g
Shock:	5 g 15 msec $\pm$1
Heat dissipation:	1365 Btu/hour
Cooling:	Convection - no moving parts
Size:	28.3" W x 22.5" D x 74" H (72 cm W x 57.2 cm D x 188 cm H)
Weight:	Under 375 pounds (168 kg)
Service clearance front and rear:	Width of machine, 3 feet in depth

Reliability

Alarm conditions:

Major - Common control circuitry failure or a multiple failure of a channel, facility or private line.

Minor - Single channel, facility or private line failure

Near-end or far-end - Location of hardware failure

Interface - Indicates private line removed from service for degradation or PBX channel removed from service after detection of PBX trouble tone

Traffic - Indicates that system capacity has been reached and any new callers will receive busy tone. This indicator is not an alarm as such and can be expected to activate during normal operation with the fluctuating traffic load.

Loop around tests:	Channel - Tests channel board circuitry
	Facility - Tests facility board circuitry
	Private line - Tests private line integrity

Power Supply

AC input:	117.6 VAC, +10%-15% 60 Hz $\pm$ 3 Hz, 4 amps (up to 14 amps momentarily upon power up)
Memory supply bus:	Stays in regulation 250 msec after AC power interruption

DISTRIBUTION LIST

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