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ATIS

Alliance for Telecommunications Industry Solutions

Problem Solvers to the Telecommunications Industry

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July 22, 1999

Anna Gomez, Chief
Network Services Division
Common Carrier Bureau
Federal Communications Commission
445 – 12th Street, S.W.
Floor Five
Washington, D.C. 20024

Received
JUL 23 1999
Common Carrier Bureau
Network Service Division
Office of the Chief

Re: April 6, 1999 Request of the Alliance For Telecommunications Industry Solutions, Inc. In Conjunction with CC Docket No. 98-163, In the Matter of 1998 Biennial Regulatory Review -- Modifications to Signal Power Limitations Contained in Part 68 of the Commission's Rules.

Dear Ms. Gomez:

Enclosed please find a report entitled "An Investigation of the Crosstalk Potential of Digital Modems Conforming to ITU-T Recommendation V.90" (the "V.90 Modem Report"). This report was prepared in response to your April 6, 1999 request that ATIS, in cooperation with the Telecommunications Industry Association ("TIA"), conduct appropriate testing prior to the Federal Communications Commission ("FCC" or "Commission") enactment of the proposed change from -12dBm to -6dBm to its signal power limits.

The testing was done consistent with the test plan specified in Committee T1 Technical Report No. 58 ("T1 TR 58") -- A Test Plan for Investigating the Crosstalk Potential of Digital Modems Conforming to ITU-T Recommendation V.90. The V.90 modem testing was conducted by Telcordia Technologies, Inc. as arranged by ATIS. A laboratory, equipment, and personnel were volunteered by ATIS and TIA member companies to conduct the month-long testing and data analysis. The V.90 Modem Report was reviewed by technical experts from TIA and ATIS-sponsored Committee T1, specifically Technical Subcommittee T1A1-- Performance and Signal Processing, the Technical Subcommittee which developed the plan used in the testing. Every effort was made to preserve the integrity of the data and ensure that the testing was done in conformance with the test plan.

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The V.90 Modem Report concludes that "no crosstalk in excess of the threshold of harm specified in T1 TR 58 was detected in either series of tests, nor was any degradation to the performance of other modems operating in the test binder group observed."

We believe this report is responsive to your request. Should you have any further questions or would find a more detailed discussion of this matter helpful, please contact me at (202) 434-8828, and I will arrange the opportunity. Thank you.

Sincerely,

Susan M. Miller
Vice President and
General Counsel

cc: Vincent Palladini, Common Carrier Bureau,
Network Services Division

Matthew Flanigan, TIA President

An Investigation of the Crosstalk Potential of Digital Modems Conforming to ITU-T Recommendation V.90

Prepared for the
Alliance for Telecommunications Industry
Solutions, Inc. (ATIS)

Alliance for Telecommunications
Industry Solutions

by

Telcordia Technologies, Inc.
Data Communications and Transport Integration

July 19, 1999

For ordering information, please contract: ATIS, Inc.
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This Report presents the results of the testing conducted in conformance with the ATIS-sponsored Committee T1's Technical Report 58, "A Test Plan for Investigating the Crosstalk Potential of Digital Modems Conforming to ITU-T Recommendation V.90." It was prepared at the request of the Federal Communications Commission's Network Services Division (Letter From Anna M. Gomez, Chief, Network Services Division to George L. Edwards, President, ATIS, dated April 16, 1999). Telcordia Technologies, Inc. performed the test. Technical experts from the Telecommunications Industry Association (TIA) reviewed the test report as did technical experts from Committee T1, sponsored by ATIS.

Notice of Disclaimer

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An Investigation of the Crosstalk Potential of Digital Modems Conforming to ITU-T Specification V.90

Executive Summary

This report provides the results of an investigation of the crosstalk potential of digital modems conforming to ITU-T Recommendation V.90 [1]. The investigation was conducted by Telcordia Technologies, Inc. pursuant to a contract between ATIS and Telcordia in accordance with the provisions of the Test Plan specified in T1 Technical Report No. 58 (T1 TR 58) [2] – A Test Plan for Investigating the Crosstalk Potential of Digital Modems Conforming to ITU-T recommendation V.90.

ITU-T Recommendation V.90 specifies a digital/analog modem pair for use between Internet service providers (ISP) and end-users. The maximum rates at which the modems operate are dependent upon several factors such as ISP-to-end-user channel architecture, power level of the encoded analog signal transmitted by the digital modem, and customer premises network wiring architecture. The power level of the signal transmitted by the digital modem (that used by the ISP) is of particular concern because, as the power level is increased, the potential for the modem to generate harmful interference in the subscriber loop section of the channel also increases.

Currently, Federal Communications Commission (FCC) Rules and Regulations - Part 68 [3] constrain the maximum power of the encoded analog signal to -12 dBm averaged over any 3-second time interval, thereby limiting the theoretical maximum downstream (from ISP to end-user) data rate to 53 kbps. To improve the theoretical maximum downstream data rate achievable by the modems (i.e., to 56 kbps), the FCC proposed, via a Notice of Proposed Rulemaking [4], relaxation of the signal power constraint to -6 dBm. In this FCC proceeding, the Alliance for Telecommunications Industry Solutions (ATIS), on behalf of Committee T1, responded that "Committee T1 suggests that empirical data be collected to confirm that no harmful interference is generated by equipment operating at the higher power level" and suggested the Test Plan [2] developed for that purpose by Committee T1's Working Group T1A1.7.

The test phase of the investigation was conducted during the period of June 1 - June 7, 1999 at Ameritech facilities in Hoffman Estates, Illinois using a 25-pair binder group in 12 kft of physical subscriber cable connected through a Lucent Technologies 5ESS® central office switch to an ITU-T Recommendation V.90 conformant Remote Access Server (RAS) manufactured by 3Com Corporation. Twenty-four 3Com V.90 U.S. Robotics® 56K client modems operated by 24 Pentium laptop computers served as clients for the investigation.

Tests were conducted first with the RAS transmit signal power at -12 dBm, the current FCC Part 68 constraint, followed by tests with RAS transmit signal power at -6 dBm.

No crosstalk in excess of the threshold of harm specified in T1 TR 58 was detected in either series of tests, nor was any degradation to the performance of other modems operating in the test binder group observed.

5ESS is a registered trademark of Lucent Technologies, Inc.

U.S. Robotics is a registered trademark of 3Com Corporation

1 Introduction

In September 1998, ITU-T Recommendation V.90 [1], specifying a digital/analog modem pair for use between Internet service providers (ISP) and end-users was approved. This modem pair has the theoretical capability to transmit data at a maximum rate of 56 kbit/s in the downstream direction (from ISP to end-user) and at a maximum rate of 33.6 kbit/s in the upstream direction. The maximum rates at which the modems operate are dependent upon several factors such as ISP-to-end-user channel architecture, power level of the encoded analog signal transmitted by the digital modem, and customer premises network wiring architecture.

The power level of the signal transmitted by the digital modem (that used by the ISP) is of particular concern because, as the power level is increased, the potential for the modem to generate harmful interference in the subscriber loop section of the channel also increases. Currently, FCC Rules and Regulations - Part 68 [3], limit the maximum power of the encoded analog signal to -12 dBm, but the FCC, is considering a relaxation of the constraint (i.e., raising the maximum level to -6 dBm.), to permit higher data rates, thereby improving service to end-users. Such a change will permit an increase in the maximum possible downstream data rate, but the effect of such a change on the potential for generation of harmful interference in the form of crosstalk in the subscriber loop is unknown.

When the FCC proposed relaxation of the signal power constraint via a Notice of Proposed Rulemaking in CC Docket 98-163 [4], ATIS, on behalf of Committee T1, responded that "Committee T1 suggests that empirical data be collected to confirm that no harmful interference is generated by equipment operating at the higher power level." Working Group T1A1.7 of ANSI accredited Committee T1 - Telecommunications has developed a test plan to investigate the crosstalk generation potential of the digital modem conforming to ITU-T Recommendation V.90. This test plan is published as T1 Technical Report (TR) 58 [2]. ATIS suggested that the Committee T1 test plan be used.

This report was prepared at the request of the FCC's Network Services Division. Specifically, the FCC agreed that testing would be beneficial before the FCC enacted the proposed change to its power signal limits and directed that the testing be done cooperatively with the Telecommunications Industry Association ("TIA"). ATIS engaged Telcordia Technologies to conduct this test and technical experts from TIA reviewed the test report as did technical experts from Committee T1.

2 Scope of Testing[1]

The scope of the testing described in this report is limited to:

1. determining the level of crosstalk generated by 24 modem pairs that conform to ITU-T Recommendation V.90 operating over 24 subscriber loop pairs in a single binder group detected on the remaining subscriber loop in the same binder group over which the modem transmissions are carried; and

[1] The scope of testing focused on the investigation of potential voiceband crosstalk that could degrade voice services and that could affect the speed of transmission of similar modems operating over adjacent cable pairs. No attempt was made to quantify effects on other voiceband services (e.g., facsimile) or services operating at frequencies above the voiceband.

2. investigating the mutual effect on the modem throughput by other like modem traffic in the same cable binder group.

3 Report Organization

This report has been organized to follow the sequence in CommitteeT1 TR-58.

- Specifications from the TR are stated.
- Actions taken during the testing phase are described. Any deviation from the specified procedures is explicitly noted with rationale where appropriate, and results of the test actions are enumerated.
- A section with conclusions summarizes findings supported by the results of the testing.

References are listed in the final section.

4 Test Arrangement

The test phase of the investigation was conducted during the period of June 1 - June 7, 1999 at Ameritech facilities in Hoffman Estates, Illinois using a contiguous 25-pair binder group in 12 kft of in-ground physical subscriber cable connected through a Lucent Technologies 5ESS central office switch to an ITU-T Recommendation V.90 conformant Remote Access Server (RAS) manufactured by 3Com Corporation. Twenty-four 3Com V.90 U.S. Robotics 56K client modems operated by 24 Pentium laptop computers served as clients for the investigation. The test arrangement mirrored the intra-office architecture shown in Figure 1 of T1 TR 58. Figure 1 of this report provides a detailed diagram of the test arrangement.

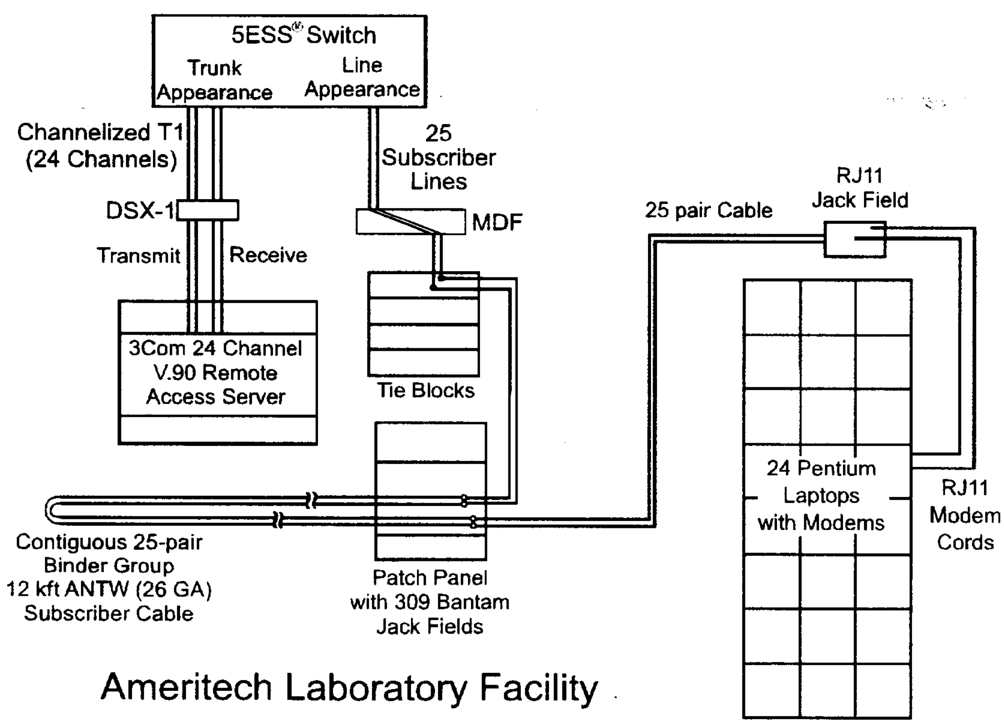

Figure 1 Test Arrangement

4.1 Test Cable Details

Test Plan Specification

T1 TR-58 specifies that subscriber "loops for the test should be between 10 and 12 kft. Approximately 3 kft of the test cable should be paper-insulated cable with the remainder being plastic-insulated cable."

Test Action

The subscriber loop cable used for the test was 12 kft of ANTW type cable (hereinafter "ANTW"). ANTW is 26-gauge, water resistant, polyethylene insulated cable (PIC), with 80° C petroleum jelly filling compound, and a water-resistant sheath. The 12 kft of cable used for this test was all direct-buried cable with minimum above-ground appearances. The full 12-kft length consisted of sections of 100-pair, 50-pair, and 25-pair ANTW cables. Between the cable protector frame and the main distribution frame (MDF) was approximately a 100-ft run of 25-pair, 26 gauge, unshielded, fire-resistant inside plenum cable. This plenum cable has approximately the same cable constants as the ANTW cable. For this test, a suitable field cable plant containing a section of paper-insulated cable was not available. After thorough discussion and coordination with representatives of several local exchange companies to attempt to find such cable, and with ATIS, the decision was made to proceed with the test using the available plastic insulated cable.

Table 1 provides a comparison of the electrical characteristic requirements of PIC and Pulp cable taken from Telcordia TR-NWT-000421 [5]. The similarity of the characteristics for the two cable types support the Telcordia conclusion that, if the subscriber cable has no physical leakage fault (i.e., is not wet) the results of the test would be the same whether or not a 3-kft section of paper-wrapped cable is included in the test cable.

Table 1 26-Gauge PIC and Pulp (Paper) Cable Characteristics

Parameter	PIC	Pulp
Resistance per Sheath Mile	232.0 Ω/mile max	232.0 Ω/mile max
DC Resistance Unbalance (pair conductor-to-conductor)	5% max	6% max
Mutual Capacitance (pair conductor-to-conductor)	92 nF/mile max	87 nF/mile max
1 kHz Capacitance Unbalance (pair-to-pair)	80 pF/kft max	143 pF/kft
Attenuation @ 772 kHz	6.4 dB/kft max	8.1 dB/kft
Crosstalk @ 150 kHz Equal Level FEXT Power Sum NEXT Power Sum	 57 dB/kft (worst pair) 53 dB/kft (worst pair)	 51 dB/kft (worst pair) 52 dB/kft (worst pair)

4.2 Pair Selection

Test Plan Specification

For the disturbed pair, select the pair that exhibits the worst-case crosstalk effect (i.e., the least coupling loss).

Test Action

Pairs 1 through 24 in the test binder group were selected for the client loops and the disturbed pair was pair 25. Actual measurements were not conducted on the test cable due to time contraints.

Telcordia personnel who have been involved in spectrum management work and the development of requirements for telecommunication cables, indicate that the average crosstalk powersums for pairs in a PIC binder group are at or below the noise threshold of -90 dBm in the voiceband region. In addition, since different sized cables were used in the makeup of the 12 kft test cable, there are random variations from cable-to-cable and pair-to-pair as a result of manufacturing processes. Consequently, we concluded that selection of "worst-pair" was not a significant factor in the results.

4.3 Quiescent Subscriber Loop Loss, Echo Return Loss, Metallic Noise, and Spectral Observations

Test Plan Specification

Measure the echo return loss of each connected pair.

Test Action

With no modems connected to the test pairs and the cable disconnected from the switch, the loss, and 3-kHz Flat metallic noise for each pair in the test binder group were measured using a SAGE 930A Communications Test Set at the subscriber end and a Hewlett Packard 4935A Transmission Impairment Measuring Set at the central office (CO) end. The cable was then connected to the switch and the echo return loss (2-wire return loss) was measured. The Sage 930A was used to dial the silent termination in the switch and the return loss measurement was made. The results are given in Table 2. While the test plan specifies measurement of echo return loss only, a more complete baseline picture is presented with the additional measurements.

Table 2 Cable Transmission Impairments with No Modems Operating

Cable Pair	1 kHz Loss (dB) (See Note)	3 kHz Flat Noise (dBrn) (See Note)	2-wire Return Loss (dB)		Spectrum Observations 10 Hz to 5100 Hz (Maximum Level Observed)
			Unterminated	Terminated	
1	6.2	0	7.5	10.5	-63 dBm @ 185 Hz
2	6.1	0	7.5	10.5	-64 dBm @ 185 Hz
3	6.1	0	7.5	10.5	-63 dBm @ 185 Hz
4	6.1	0	7.5	10.5	-63 dBm @ 185 Hz
5	6.1	0	7.5	10.5	-63 dBm @ 185 Hz
6	6.3	0	7.5	10.5	-63 dBm @ 185 Hz
7	6.1	0	7.5	10.5	-63 dBm @ 185 Hz
8	6.1	0	7.5	10.5	-63 dBm @ 185 Hz
9	6.2	0	7.5	10.5	-63 dBm @ 185 Hz
10	6.1	0	7.5	10.5	-63 dBm @ 185 Hz
11	6.1	0	7.5	10.5	-63 dBm @ 185 Hz
12	6.2	0	7.5	10.5	-63 dBm @ 185 Hz
13	6.2	0	7.5	10.5	-63 dBm @ 185 Hz
14	6.1	0	7.5	10.5	-63 dBm @ 185 Hz
15	6.1	0	7.5	10.5	-63 dBm @ 185 Hz
16	6.2	0	7.5	10.5	-63 dBm @ 185 Hz
17	6.2	0	7.5	10.5	-63 dBm @ 185 Hz
18	6.1	0	7.5	10.5	-63 dBm @ 185 Hz
19	6.1	0	7.5	10.5	-63 dBm @ 185 Hz
20	6.1	0	7.5	10.5	-63 dBm @ 185 Hz
21	6.2	0	7.5	10.5	-63 dBm @ 185 Hz
22	6.2	0	7.5	10.5	-63 dBm @ 185 Hz
23	6.2	0	7.5	10.5	-63 dBm @ 185 Hz
24	6.2	0	7.5	10.5	-63 dBm @ 185 Hz
25	6.1	0	7.5	10.5	-63 dBm @ 185 Hz

Note: 1 kHz Loss and 3-kHz flat noise were measured with the HP-4935A with the cable disconnected from the switch and no modems at the subscriber end.

4.4 Test Equipment

Test Plan Specification

Record the Identification and limit specifications for all test measuring equipment to demonstrate that no measured signals are masked by test equipment limitations.

Test Action

Sage 930A Communications Test Set

3-kHz Flat Noise:	Range: 10 dBrn to 100 dBrn (Balanced) Resolution: 1.0 dB Accuracy: 0.5 dB
Receiver:	Level Range: -50 dBm to +12 dBm Frequency Range: 20 Hz to 5 kHz Resolution: 0.1 dB Accuracy: ±0.1 dB @ 1004 Hz ±0.2 dB @ 200 Hz to 5 kHz
2-Wire Return Loss:	Transmitter Level: -10 dBm0 Receiver Range: 0 dB to 40 dB Resolution: 1.0 dB Accuracy: 0.5 dB Hybrid: 600 Ω (1%) with 2.16 μF (1%)

Hewlett Packard 4935A Transmission Impairment Measuring Set

3-kHz Flat Noise:	Range: 0 dBrn to 100 dBrn (Balanced) Resolution: 1.0 dB Accuracy: ±1.0 dB @ 10 to 100 dBrn ±2 dBrn @ 0 to 10 dBrn
Receiver:	Level Range: -60 dBm to +13 dBm Frequency Range: 20 Hz to 110 kHz Resolution: 0.1 dB Accuracy: ±0.1 dB @ 1004 Hz ±1.0 dB @ 20 Hz to 50 Hz ±0.5 dB @ 50 Hz to 200 Hz ±0.2 dB @ 200 Hz to 15 kHz

Hewlett Packard 3561A Dynamic Signal Analyzer

Frequency:	Range: 0 to 100 kHz (selectable) Resolution: Span/400 Accuracy: ±0.003% of reading
Amplitude:	Input Range: 27 dBV (+22.4 V) to -51 dBV (3.0 mV) Distortion: ≥80 dB below input range Resolution: 0.01 dB Accuracy: ±0.15 dB ±0.015% of input range @ +27 dBV to -40 dBV ±0.25 dB ±0.025% of input range @ -41 dBV to -51 dBV

4.5 Connection

Test Plan Specification

Verify switch translations to ensure no network loss pads are inserted in the connections between the RAS and the client modems.

Test Action

Translations revealed that no network loss pads were inserted, but it was determined that the "P-OFF Loss" option was in effect. P-OFF Loss inserts 2 dB loss in both transmit and receive direction at the line card and is used during cutover of a new switch to prevent potential singing on short loops. Action was taken to disable the P-OFF Loss feature.

In addition, the 5ESS switch, the T1 system, and the RAS used in the test arrangement were optioned for binary 8-zero substitution (B8ZS). Signaling format was not clear-channel and robbed-bit signaling was used. The signal format was not specified in the test plan.

4.6 Test Steps

Step 1.A - Test Plan Specification

On the disturbed pair, dial the milliwatt supply in the serving switch; measure and record power at the analog modem test site to determine loop loss and to verify that no network loss pads have been inserted.

Step 1.B - Test Action

See results in Section 4.3. Loss on the order of 6 dB is consistent with the expected loss of a 12 kft, 26 GA loop.

Step 2.A - Test Plan Specification

On a disturbing pair, establish modem communications with the RAS operating at the FCC power constraint of -12 dBm. Measure and record the 3 kHz Flat power on the downstream side of the 4-wire channel between the RAS and the switch, observe the communication, and record the spectrum of the modem signal.

Step 2.B - Test Action

Measurements[2] were made with the Sage 930A at the monitor jacks on the rear of the RAS and spectrum observations were made with the HP 3561A at the central office end of the subscriber loop. Results are given in Table 3 and spectrum observations are shown in Figure 2. In Table 3, it is noted that the measured average power was -10.5 dBm when -12 dBm was expected. This is not considered significant to the conclusions in this report, since observed crosstalk levels were below the threshold of harm even at the higher transmit power level observed in subsequent test steps.

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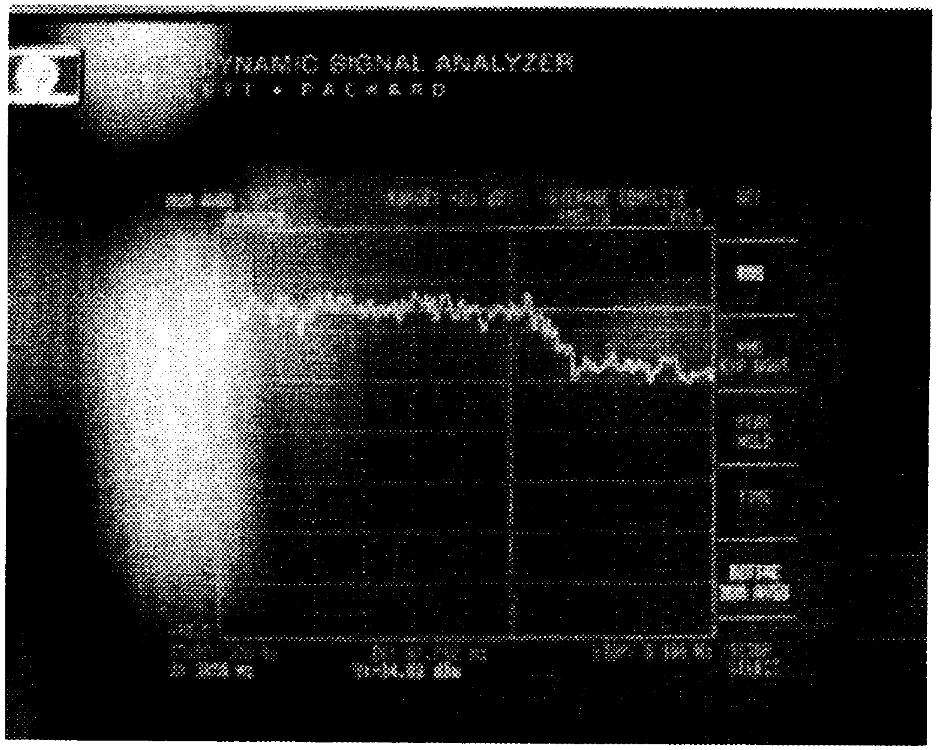
[2] While RMS and average power measurements are clearly defined for pure sine waves, the measurements shown in Tables 3 and 4 are those of a complex analog signal obtained by extracting and decoding a single channel from the DS1 RAS signal. The Sage 930A detector transfer function that would apply to this signal is not known and the values reported in the tables should be viewed as relative.

Table 3 RAS Signal at -12 dBm Transmit

RMS Power (dBm)	Avg. Power (dBm)	Connect Rate (bits/s)	Spectrum Observations
-9.3	-10.5	49,333	See Figure 2

-18.8 dBm →

-98.8 dBm →



↑ 100 Hz

↑ 5100 Hz

Figure 2 Composite Upstream/Downstream Signal at -12 dBm RAS Transmit

Step 3.A - Test Plan Specification

On a disturbing pair, establish an analog modem to server communication channel with one modem to a V.90 server that exceeds the FCC power constraint. The modem (digital modem associated with V.90 server) output level setting used for this test should be recorded for reference and repeatability purposes. Measure and record the 3 kHz Flat power on the downstream side of the 4-wire channel between the RAS and the switch, observe the communication, and record the spectrum of the modem signal.

Step 3.B - Test Action

For this test, the FAS was set to transmit at -6 dBm. Measurements[2] were made with the Sage 930A at the monitor jacks on the rear of the RAS and spectrum observations were made with the HF' 3561A at the central office end of the subscriber loop. Results are given in Table 4 and spectrum observations are shown in Figure 3. It should be noted that spectrum observations in Figure 3 show very little difference from those in Figure 2. The HP

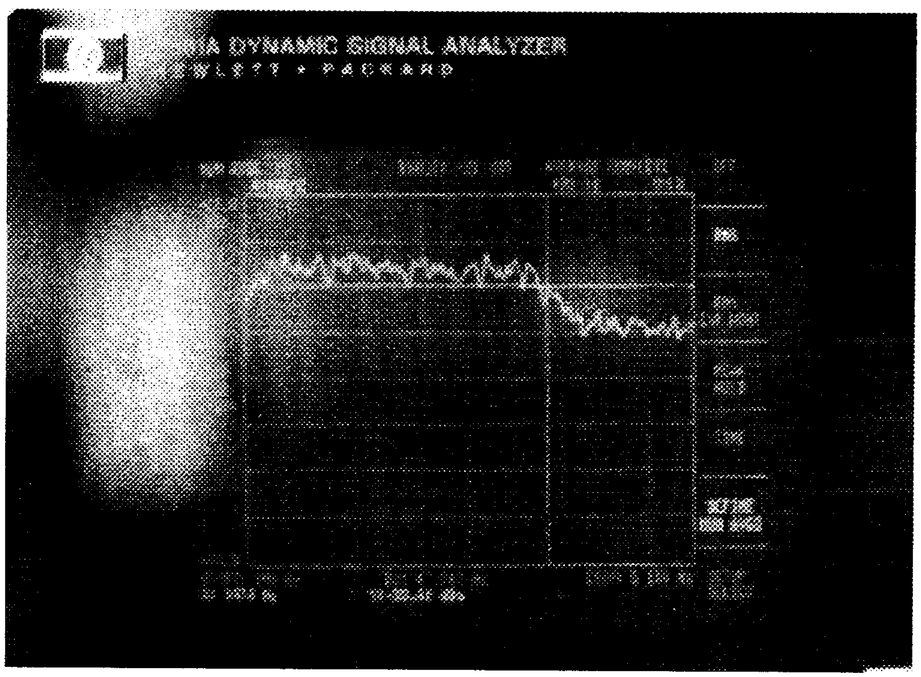
3561A is a 2-wire analog instrument with no capability to "break-out" one channel of a digital signal. Consequently the observed spectrum in Figures 2 and 3 is a composite of the upstream and downstream signals. This apparently affected the samples displayed by the analyzer.

Table 4 RAS Signal at -6 dBm Transmit

RMS Power (dBm)	Avg. Power (dBm)	Connect Rate (bits/s)	Spectrum Observations
-5.0	-6.0	49,333	See Figure 3

-18.8 dBm →

-98.8 dBm →



↑ 100 Hz

↑ 5100 Hz

Figure 3 Composite Upstream/Downstream Signal at -6 dBm RAS Transmit

Step 4.A - Test Plan Specification

Connect the disturbed pair to a directory number on the central office switch. At the subscriber end of the pair, measure and record the C-message and 3-kHz flat noise, and observe the spectrum with no disturbers (baseline measurement).

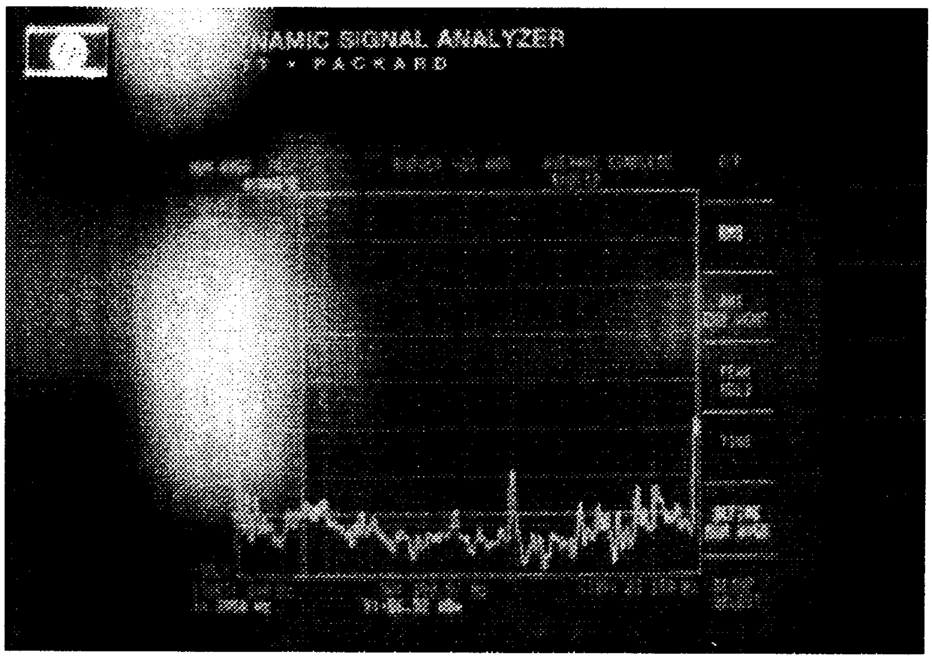
Step 4.B - Test Action

Results are provided in Table 5 and spectral observations are shown in Figure 4.

Table 5 Disturbed Pair Baseline with No Disturbers

C-Message Noise (dBrnC0)	3-kHz Flat Noise (dBrn)	Spectrum Observations
-13	57	See Figure 4

-18.8 dBm →



-98.8 dBm →

↑ 100 Hz ↑ 20,100 Hz

Figure 4 Disturbed Pair Baseline with No Disturbers

Step 5.A - Test Plan Specification

Connect the noise-measuring test equipment to the subscriber end of the disturbed pair and a standard 900 Ω resistive termination to the central office end of the disturbed pair. Measure and record the flat noise to at least 4 kHz, and observe the spectrum between 100 Hz and 20 kHz with no disturbers (baseline measurement). If necessary, attempt to minimize baseline noise by improving balance, changing grounding, or eliminating external sources of interference.

Step 5.B - Test Action

Results are provided in Table 2 and spectral observations are shown in Figure 4. For the noise observation shown in Table 2, the central office end of the disturbed pair was terminated by the HP 4935A which contains a standard termination. For the ERL measurements shown in Table 2 and the spectral observations shown in Figure 4, the silent termination in the central office switch provided a standard termination.

Step 6.A - Test Plan Specification

On the disturbing pairs, establish modem communications between all 24 modems and the server with the server transmitting at -12 dBm. Monitor the communications on each established connection as each subsequent modem connection is established and record any variation in throughput. Measure and record flat noise to at least 4 kHz, and observe the spectrum at the subscriber and central office ends of the disturbed pair as each modem connection is established. Record any pertinent spectrum data observed on the disturbed pair between 100 Hz and 20 kHz.

Step 6.B - Test Action

Spectral observations are shown in Figure 5 and results are provided in Table 6. In Table 6, it is noted that the upstream connect rate for modem 7 is one step lower than that for all other client modems. This modem was configured with an earlier firmware version than the other clients and appeared to operate at hotter levels than the others. Consequently the modem slowed the connect rate to accommodate the hotter levels. The results in Table 6 (except for 3-kHz Flat noise and spectrum observations) were obtained from monitoring registers in the client modems.

It should be noted that for these tests, connect rate rather than throughput is reported. Because there was no Internet access or computer server access by the RAS, there was no source of data to use for throughput measurements. Consequently, other than short login strings as each client was connected, there was only carrier and handshaking occurring between the clients and the RAS. To determine if there was any effect on the average power level of the encoded analog signal by the lack of live data streams, an additional test was conducted in the Telcordia laboratory on June 24, 1999. For this test, communication between a single V.90 client and a single V.90 server modem was established. Using the same spectrum analyzer as was used during the tests on June 7, 1999, RMS power with 200 samples over the 0 to 4000 Hz band was observed both without live data transmission and with data at a rate of 5000 characters per second (cps) downstream.

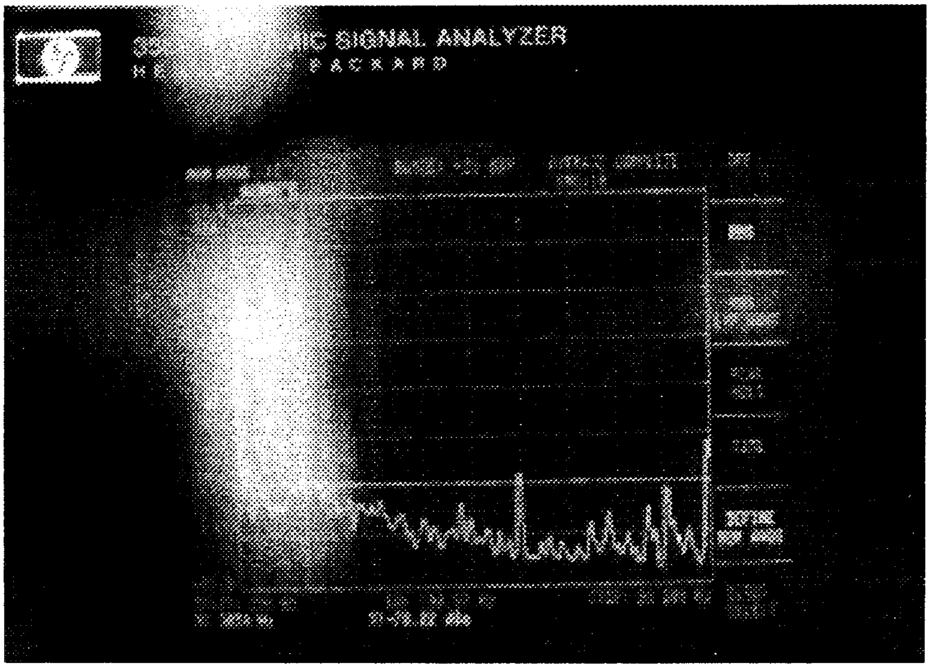
The following observations were made:

- Maximum RMS power with no data transfer: -25.22 dBm @ 710 Hz.
- Maximum RMS power with 5000-cps transfer: -25.45 dBm @ 620 Hz.
- The spectrum observation revealed most of the energy with and without live data transfer occurred in the 300 - 1500 Hz and 2600 - 3500 Hz bands.

For this test, the server modem was transmitting at -12 dBm. While the equipment used for the tests on June 24, 1999 did not have the capability to increase transmit power level, we believe that similar results would be observed with a server transmitting at a power level other than -12 dBm.

-18.8 dBm →

-98.8 dBm →



↑ 100 Hz

↑ 20,100 Hz

Figure 5 Disturbed Pair with 24 V.90 Disturbers - RAS Transmit -12 dBm

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Table 6 Data Collection with 24 V.90 Modems Operating and RAS Transmit at -12 dBm

Client Modem	Downstream Connect Rate (bps)			Rate Shifts	Up-stream Rate (bps)	3 kHz Flat Noise Disturbed Pair (dBrn)		SNR (dB)	Client Levels (dBm)		Spectrum Observations
	Initial	Final	Peak	Up/Down		CO End	Client End		Receive	Transmit	
1	49,333	49,333	49,333	0/0	28,800	54	57	50.2	-26	-13	None
2	49,333	50,666	52,000	1/1	28,800	54	57	50.6	-26	-13	None
3	49,333	50,666	52,000	1/1	28,800	54	57	50.4	-25	-13	None
4	49,333	52,000	52,000	1/0	28,800	54	57	51.9	-25	-13	None
5	52,000	50,666	52,000	1/3	28,800	54	57	51.8	-22	-13	None
6	49,333	50,666	52,000	1/1	28,800	54	57	51.3	-27	-13	None
7	49,333	49,333	49,333	0/0	26,400	54	57	51.9	-18	-10	None
8	49,333	52,000	52,000	1/0	28,800	54	57	52.1	-26	-13	None
9	49,333	50,666	52,000	1/1	28,800	54	57	51.0	-25	-13	None
10	49,333	48,000	49,333	1/2	28,800	54	57	49.7	-23	-13	None
11	49,333	52,000	52,000	2/1	28,800	54	57	51.7	-25	-13	None
12	49,333	49,333	49,333	0/0	28,800	54	57	49.4	-25	-13	Jump during training
13	49,333	52,000	52,000	2/1	28,800	54	57	52.1	-24	-13	None
14	49,333	50,666	52,000	1/1	28,800	54	57	51.5	-23	-13	None
15	52,000	50,666	52,000	0/1	28,800	54	57	51.2	-27	-13	None
16	49,333	52,000	52,000	1/0	28,800	54	57	51.9	-23	-13	None
17	49,333	50,666	52,000	1/1	28,800	54	57	51.1	-22	-13	None
18	49,333	49,333	52,000	1/2	28,800	54	57	50.8	-26	-13	Jump low end

Client Modem	Downstream Connect Rate (bps)			Rate Shifts	Up-stream Rate (bps)	3 kHz Flat Noise Disturbed Pair (dBrn)		SNR (dB)	Client Levels (dBm)		Spectrum Observations
	Initial	Final	Peak	Up/Down		CO End	Client End		Receive	Transmit	
19	49,333	52,000	52,000	1/0	28,800	54	57	51.9	-26	-13	None
20	49,333	50,666	52,000	1/1	28,800	54	57	51.1	-24	-13	None
21	49,333	49,333	52,000	1/2	28,800	54	57	52.6	-22	-13	None
22	49,333	52,000	52,000	1/0	28,800	54	57	52.4	-25	-13	None
23	49,333	50,666	52,000	1/1	28,800	54	57	51.8	-23	-13	None
24	49,333	50,666	52,000	1/1	28,800	54	57	50.7	-25	-13	None

Note: All modems had firmware version of 5.0.0 except for modem 7 which had version 4.9.1 and modem 8 which had version 4.9.4.

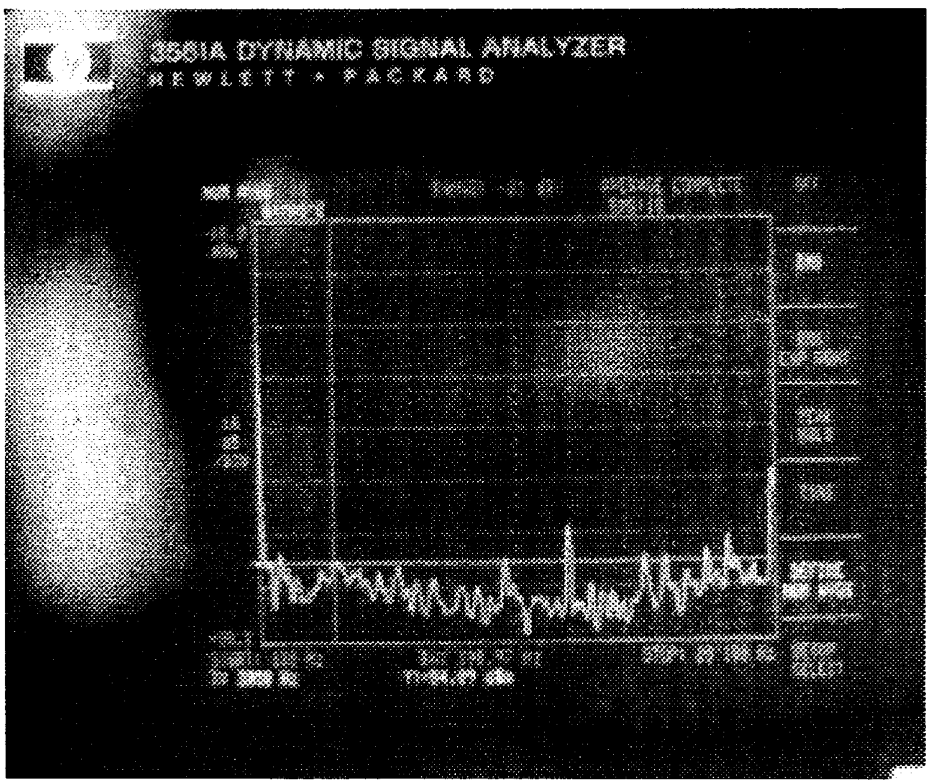
Step 7.A - Test Plan Specification

On the disturbing pairs, establish modem communications between all 24 modems and the server with the server transmitting at -6 dBm. Monitor the communications on each established connection as each subsequent modem connection is established and record any variation in throughput. Measure and record flat noise to at least 4 kHz, and observe the spectrum at the subscriber and central office ends of the disturbed pair as each modem connection is established. Record any pertinent spectrum data observed on the disturbed pair between 100 Hz and 20 kHz.

Step 7.B - Test Action

Spectral observations are shown in Figure 6 and results are provided in Table 7. As discussed in Step 6B, connect rate as opposed to trhoughput was observed. For modem 7, the same phenomenon as discussed in Step 6.B occurred in this test. That is, the upstream connect rate for modem 7 is one step lower than that for all other client modems. This modem was configured with an earlier firmware version than all other clients and appeared to operate at hotter levels than the others. Consequently, it slowed the connect rate to accommodate the hotter levels. The results in Table 7 (except for 3-kHz Flat noise and spectrum observations) were obtained from monitoring registers in the client modems.

-18.8 dBm →



-98.8 dBm →

↑ 100 Hz

↑ 20,100 Hz

Figure 6 Disturbed Pair with 24 V.90 Disturbers - RAS Transmit -6 dBm

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Table 7 Data Collection with 24 V.90 Modems Operating and RAS Transmit at -6 dBm

Client Modem	Downstream Connect Rate (bps)			Rate Shifts	Up-stream Rate (bps)	3 kHz Flat Noise Disturbed Pair (dBrn)		SNR (dB)	Client Levels (dBm)		Spectrum Observations
	Initial	Final	Peak	Up/Down		CO End	Client End		Receive	Transmit	
1	50,666	52,000	52,000	1/0	28.800	54	57	52.9	-18	-13	None
2	49,333	52,000	52,000	2/0	28.800	54	57	52.2	-20	-13	None
3	50,666	52,000	52,000	3/0	28.800	54	57	52.8	-23	-13	None
4	50,666	52,000	52,000	1/0	28.800	54	57	52.3	-22	-13	None
5	50,666	52,000	52,000	2/0	28.800	54	57	51.5	-21	-13	None
6	50,666	52,000	52,000	1/0	28.800	54	57	52.7	-21	-13	None
7	50,666	50,666	50,666	0/0	26,400	54	57	54.3	-14	-10	None
8	50,666	49,333	52,000	2/2	28.800	54	57	47.8	-20	-13	None
9	50,666	52,000	52,000	2/0	28.800	54	57	52.3	-18	-13	None
10	49,333	49,333	49,333	1/1	28.800	54	57	51.6	-19	-13	None
11	50,666	52,000	52,000	1/0	28.800	54	57	53.3	-21	-13	None
12	49,333	50,666	50,666	1/0	28.800	54	57	49.6	-19	-13	None
13	50,666	52,000	52,000	1/0	28.800	54	57	53.2	-19	-13	None
14	50,666	52,000	52,000	1/0	28.800	54	57	52.2	-20	-13	None
15	50,666	52,000	52,000	1/0	28.800	54	57	52.0	-18	-13	None
16	50,666	52,000	52,000	1/0	28.800	54	57	53.6	-20	-13	None
17	50,666	52,000	52,000	1/0	28.800	54	57	52.8	-20	-13	None
18	50,666	52,000	52,000	1/0	28.800	54	57	52.5	-22	-13	None

Client Modem	Downstream Connect Rate (bps)			Rate Shifts	Up-stream Rate (bps)	3 kHz Flat Noise Disturbed Pair (dBrn)		SNR (dB)	Client Levels (dBm)		Spectrum Observations
	Initial	Final	Peak	Up/Down		CO End	Client End		Receive	Transmit	
19	50,666	52,000	52,000	1/0	28.800	54	57	53.6	-23	-13	None
20	50,666	52,000	52,000	2/0	28.800	54	57	52.8	-22	-13	None
21	50,666	52,000	52,000	1/0	28.800	54	57	53.1	-22	-13	None
22	50,666	52,000	52,000	1/0	28.800	54	57	53.0	-24	-13	None
23	50,666	52,000	52,000	1/0	28.800	54	57	53.7	-22	-13	None
24	50,666	52,000	52,000	1/0	28.800	54	57	52.6	-19	-13	None

Note: All modems had firmware version 5.0.0 except for modem 7 which had version 4.9.1 and modem 8 which had version 4.9.4.

5 Evaluation of Test Results

Steps 8.A and 8.B in this section are related to Test Step 8 in T1 TR 58.

Step 8.A - Test Plan Specification

Compare test results with the thresholds of harm below:

- **Service Threshold:** The threshold of harm for 24 V.90 disturbers into a disturbed pair, within the same binder group, is defined as +15 dBrn in the 0 to 4000 Hz frequency band. This power measurement shall be performed at the CO end of the facility.
- **Voiceband Data Rate Interference Threshold:** The threshold of harm for a V.90 disturber is said to have been exceeded when a V.90 modem operating at a power level in excess of that permitted by FCC Part 68 causes a reduction in the upstream or downstream data rates of a similar modem pair operating in the same cable binder group or in the upstream data rate of its own connection.

Step 8.B - Comparison of Results to Specified Thresholds of Harm

- **Service Threshold:** Comparing the results in Tables 6 and 7 and the spectrum observations shown in Figures 5 and 6, it can be seen that there was no detectable crosstalk in excess of the threshold of harm specified in T1 TR 58 generated in the disturbed pair when 24 V.90 modem pairs are operating in the same 25-pair binder group as the disturbed pair. Figure 6 shows that all energy in the 0 - 4000 Hz band is below -83 dBm. A power level of -83 dBm corresponds to +7 dBrn, a margin of 8 dBrn compared to the threshold of harm.
- **Voiceband Data Rate Interference Threshold:** Comparing the upstream and downstream connect rates in Table 6 and 7 it can be seen that there was no detectable degradation to either the upstream or downstream connect rates as successive modem connections were established in the binder group.

6 References

1. ITU-T Recommendation V.90, *A digital modem and analogue modem pair for use on the public telephone network (PSTN) at data signalling rates of up to 56,000 bit/s downstream and up to 33,600 bit/s upstream.*
2. T1 Technical Report No. 58, *A Test Plan for Investigation the Crosstalk Potential of Digital Modems Conforming to ITU-T Recommendation V.90*, Alliance for Telecommunications Industry Solutions, January 1999.
3. Code of Federal Regulations (CFR) Title 47, Part 68-308, *Connection of Terminal Equipment to the Telephone Network*, National Archives and Records Administration, October 1, 1997 [68.308(h)(1)(iv) and 69.308(h)(2)(v)].
4. Notice Of Proposed Rulemaking, 1998 Biennial Regulatory Review - Modifications to Signal Power Limitations Contained in Part 68 of the Commission's Rules, CC Docket No. 98-163, Federal Communications Commission, September 8, 1998.
5. TR-NWT-000421, *Generic Requirements for Metallic Telecommunication Cables*, Issue 3, Telcordia Technologies, Inc., September 1991.