

Engineering Standard

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Circuit Measuring Techniques

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Saudi Aramco DeskTop Standards

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1 Scope

This Saudi Aramco Engineering Standard recommends the test equipment to be used for measuring the performance of data communications channels and the operating performance of data communications equipment. Also incorporated are methods of making these measurements, leading to fault-finding techniques and recommended practices for the preventative maintenance of data communication channels.

This SAES will be a reference document for all persons involved in the provision and maintenance of data communications.

2 Conflicts and Deviations

Any deviations, providing less than the mandatory requirements of this standard require written waiver approval as per Saudi Aramco Engineering Procedure [SAEP-302](#).

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below, unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

[SAEP-302](#)

*Instructions for Obtaining a Waiver of a
Mandatory Saudi Aramco Engineering
Requirement*

3.2 Industry Codes and Standards

International Telecommunication Union-Telecommunication

Bell System Std C2

Conditioned Voiceband Circuit

4 General

4.1 Recognizing that the Saudi Aramco communications network is based upon North American equipment and standards and that many technicians are most familiar with such standards and the associated operating practices, the circuit test equipment and procedures have been specified in accordance with this.

4.2 Section 3 details the test equipment suggested for the Saudi Aramco data network.

- 4.3 Section 4 outlines the methods to be used for measuring voiceband and baseband circuits and the recommended approach for provision and fault-finding for such circuits.
- 4.4 Section 5 outlines the methods to be used for measuring operating performance and the recommended approach for performing bit error rate testing and protocol monitoring on point-to-point and multipoint circuits.
- 4.5 It is necessary to consult the handbook associated with each item of test equipment for a detailed explanation of each measurement or control setting.
- 4.6 Section 6 recommends procedures for preventative maintenance and general practices to enable efficient and reliable performance to be achieved.
- 4.7 Reference in this standard to any particular manufacturer by name, in connection with any product, is only intended for the purpose of description (i.e., type, specification and quality) of that product. Items actually purchased may be of any manufacture that meet the technical requirements for that product.

5 Test Equipment

- 5.1 The test equipment required for data communications is readily divided into two sections. The equipment associated with testing and commissioning the circuit which is of the analog transmission parameter-measuring type and that equipment which is used for objective measurement of circuit performance which is of the type that interfaces to a modem and simulates a data source and/or sink and monitors the conditions on the modem digital interface.

The suggested Bit Error Rate Tester and Protocol Monitoring Device are not currently available for evaluation within SAO, but from vendor specifications, they would appear to meet the requirement. It is desirable that some hands-on experience be gained before a firm recommendation is made.

- 5.2 The test equipment for circuits is detailed in paragraphs 5.3 and 5.4. The equipment for performance measurement is detailed in paragraphs 5.5 and 5.6.

5.3 Level Measuring Set

5.3.1 General Requirement

For field technicians, a means of measuring signal levels at user's locations is necessary both for commissioning testing and for fault localization.

The instrument should be small, rugged and portable. It shall be easy to use and have a minimal number of controls. It shall incorporate a dB

meter, a test oscillator and selection of terminating impedances (135, 600 and 900 ohms and a bridging position). As an option, noise and frequency measurement facilities may be incorporated.

5.3.2 Recommended Item

The recommended item is the Hewlett-Packard 3551 A. An alternative item is the Halcyon 701 A.

5.4 Transmission Impairment Measuring Set

5.4.1 General Requirement

In order to ensure that an FDM carrier channel meets the required standard for data transmission on commissioning of a circuit and to determine the cause of any subsequent failure to meet that standard, a comprehensive test set is required by microwave maintenance personnel and occasionally by specialist data technicians.

5.4.1.1 The instrument shall use the measurement techniques given in Bell System Technical Reference Pub. 41009: Transmission Parameters Affecting Voiceband Data Transmission-Measuring Techniques, May 1975.

5.4.1.2 The instrument should include with it a comprehensive operating manual explaining the control positions for each measurement.

5.4.1.3 This instrument is not a simple test set and training and practice will be required by staff who use it.

5.4.1.4 The following parameters shall be measured by the instrument:

Insertion Loss

Attenuation/Frequency Distortion

Idle noise (C-message and 3 KHz weighting)

Noise-with-Tone

Impulse noise

Phase and Gain Hits

Dropouts

Phase Jitter (20-300 Hz)

Envelope Delay Distortion

Non-Linear Distortion

Low Frequency Phase Jitter (4-20 Hz, i.e., Wobulation)
(Optional)

Noise-to-Ground (Optional)

Peak-to-Average Ratio (Optional)

5.4.1.5 The instrument shall have a comprehensive self-check capability.

5.4.1.6 The instrument shall have selection of terminating impedance (600 and 900 ohms and a bridging position).

5.4.2 Recommended Item

The recommended item is the Hewlett-Packard 4940 A with Option 002 giving Non Linear Distortion measurement. Other possible options including Non Linear distortion are 003 (incorporating P/AR) or 004 (incorporating P/AR and low frequency phase jitter). An alternative item is the Halcyon 520B2/500B. The Hekimian 3900 is not recommended for field staff due to a relatively complicated layout of controls. The Hekimian 3900 series is a very good family of testing equipment but it will require special training and is more complicated than either the Halcyon or H-P. It is ideally suited to a data test center but not for microwave technicians, many of whom cannot use the Halcyon 520B to a satisfactory degree.

5.5 Bit Error Rate Tester

5.5.1 General Requirement

In order to measure the performance of a data circuit between local and remote sites, a bit error rate tester is required by field data technicians and by staff at the computer center. The instrument shall fulfil the following requirements. It shall be able to:

- a) measure bit error rates, block error rates and the number of blocks received.
 - b) transmit block sizes of 32 bits through 10^6 bits.
 - c) transmit various bit patterns including 511 pseudo-random pattern at data rates from 300 bits/s to 19200 bits/s.
 - d) permit half and full duplex operation.
 - e) accept external clock signals.
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In addition the bit error rate tester shall be portable and rugged in construction.

5.5.2 Suggested Item

The suggested item is the General Data Communications BERT 901. An alternative is the Trend Data Test Set No. 1-8

The testers presently used in SAO are IDS 1310's and Racal-Milgo 350's. The 1310 suffers from an inability to simultaneously display bit and block errors and also, when a long error burst is received it tends to lose synchronisation and reset all counters. Not a good idea. The 350 is a basic bit error rate tester for a go/no-go test. Not suitable for anything other than bit error rate determination. The Sierra 1914B is not known but could be suitable if it conforms with the requirement stated.

5.6 Protocol Monitoring Device

5.6.1 General Requirement

A protocol monitoring device is required primarily at computer centres to check on the polling of multipoint circuits but also will be required occasionally in the field for isolating "special" faults. The instrument shall also be capable of interactive protocol testing.

The device shall display the data transmitted and the response (if any) received from the remote terminal.

A protocol monitoring device is not a simple instrument and some programs are required to be written in order to derive maximum benefit from the tester. It is further recommended that suitable technicians undergo a period of training or attend a course on the use of the tester, including coverage of the major protocols in use within Saudi Aramco - BISYNC (Binary Synchronous) and SDLC (Synchronous Data Link Control).

5.6.2 Suggested Item

The suggested item is the Halcyon 803A-02 together with the 8000-0004-40 giving additional non-volatile memory for Bit oriented protocols. Alternatives are the Tektronix 834 or Spectron 502B.

6 Measurement of Circuits

6.1 Test Level Points

A Test Level Point (TLP) is a reference level which is numerically equal to the level at that point of a standard 1 milliwatt test tone (0 dBm) applied at a point of zero relative level in the circuit. In the data circuits detailed in this standard, the zero relative level point is the transmit output of the modem and the TLP levels elsewhere in the circuit signify the levels which will be measured at those points when a 0 dBm test tone is applied to the circuit from the point where the modem transmit is applied i.e the user's location. In data circuits, all measurements are made at data level, which is 13 dB below TLP, i.e., -13 dBmO. In the circuits detailed in SAES-T-556, a point-to-point circuit is designed to have a nominal loss of 0dB end-to-end. Therefore, at the modem the transmit level is -13 dBm (which, since this is 0 TLP may also be written -13 dBmO). At the MOD IN jack of a 4-wire carrier system it will also be -13 dBmO but this is by convention a -16 TLP so the level measured will be -29 dBm. At the DEMOD OUT jack (a +7 TLP) the measured level will be -6 dBm (i.e., -13 dBmO) and at the far end modem receive (0 TLP) the measured level should be -13 dBm. An overall tolerance of ± 2 dB is permitted on the measured values. Multipoint circuits will be similar except that the overall loss between the installation modem and any remote spur is designed to be 3 dB to compensate for branching points.

6.2 Measurements Using a Level Measuring Set (LMS)

6.2.1 The LMS shall be adjusted to the correct line termination for the circuit to be tested. A fourwire presented voiceband circuit requires a 600 ohm termination, a two wire voiceband circuit (e.g., a dial-up line) requires a 900 ohm termination. A four-wire baseband circuit requires a 135 or 140 ohm termination. Measurements may also be made with the instrument in the bridged position provided that the line is suitably terminated, e.g., by a modem.

6.2.2 When a test tone is applied to the circuit, it shall be at the data level, -13 dBmO.

6.2.3 Receive Level Measurement

This test is to ensure that signals from a distant modem are being received at the correct level. The receive terminals of the instrument shall be connected to the receive pair and the incoming level measured.

In order to verify that a modem is producing the correct output, the modem shall be disconnected from the line and the modem transmit terminals connected to the LMS receive terminals. The modem output level will be read with the LMS set for providing a terminal measurement.

6.2.4 Insertion Loss Measurement

This test is to determine the loss of a circuit at 1004 Hz (voiceband circuit) or 10 KHz (baseband circuits). A LMS is required at each end of the circuit or section under test. Each instrument shall be connected to line in the four-wire mode (for two wire voiceband circuits one instrument shall transmit and the other receive), the appropriate frequency (1004 Hz or 10 KHz) selected and transmitted at data level and the insertion loss in each direction measured (one direction only for two-wire circuits), and compared with the calculated value on the circuit design.

6.2.5 Frequency Response Measurement

This test is to determine the Attenuation Distortion of a voiceband circuit. A LMS is required at each end of the circuit or section under test. Tones of various frequencies (see 4.3.5) are to be sent in each direction, at data level and the resultant levels measured. Subtracting the value obtained at 1004 Hz (Insertion Loss) from each reading gives the Attenuation Distortion.

6.2.6 Noise Measurement

For idle noise measurement on voiceband circuits, only one LMS is required but the distant end of the circuit or section is to have a "quiet" (i.e., passive) termination. Message Circuit Noise and C-Message Weighting shall be selected and the resultant noise reading in dBnc noted. For C-notched noise (noise with tone), two LMS are required. One instrument shall be set to Hold Tone (i.e., transmitting a tone to the circuit) and the other instrument to With Tone and C-message weighting. The display gives the noise in dBnc.

Idle noise measurement on baseband circuits is performed in the same manner excepting that 3 KHz Flat Weighting shall be used instead of C-Message Noise-with-Tone measurement is not required for this type of circuit.

6.3 Measurements Using a Transmission Impairment Measuring Set (TIMS)

- 6.3.1 The TIMS shall be adjusted to the correct line termination for the voiceband circuit to be tested. A four-wire circuit requiring a 600 ohm termination and a two-wire circuit, 900 ohms. Measurements may also be made in the bridged position provided that the line is suitably terminated, e.g., by a modem.
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6.3.2 When a test tone is applied to the circuit, it shall be at the data level, -13 dBmO.

6.3.3 It is anticipated that a TIMS will usually be used to confirm that a particular four-wire channel on a microwave system is capable of meeting the specification laid down for the particular type of data circuit. Therefore most of the measurements will be made from microwave station to microwave station, prior to the connection of the local ends (see 4.4), requiring the same type of TIMS at each end of the circuit or section.

6.3.4 Insertion Loss and Frequency Shift Measurement

This measurement may be made simultaneously for both directions of transmission. The TIMS at each end shall be set to Level Measurement or Amplitude Response and a stable 1004 Hz tone sent in each direction, at data level. The channel gains and attenuators shall then be adjusted as necessary to ensure the correct level of signal at each point and at the receiving ends, providing that the loss of the local ends has been accurately determined. If this has not yet been done, the attenuators may require further adjustment when an end-to-end (i.e., user's location to user's location) loss measurement is made.

If fitted to the TIMS, a 60 Hz filter shall now be switched in on each TIMS. If the received level changes by more than 0.2 dBm, this filter shall remain switched in for all subsequent tests.

Close observation of the received frequency display and comparison with that transmitted (stability ± 0.5 Hz) will give a measure of the frequency shift produced by the system. Careful adjustment of the oscillator tuning controls of the TIMS may be required to obtain a stable frequency reading.

When the insertion loss and frequency shift have been determined, the Level Zero button (if fitted) shall be depressed or the input attenuator thumb wheels adjusted in order to provide a zero receive reference at 1004 Hz in preparation for attenuation/frequency distortion measurements.

6.3.5 Attenuation/Frequency Distortion Measurement

This measurement shall be made separately for each direction of transmission. Once the zero reference has been obtained at each station at 1004 Hz it should not be changed. One station shall proceed to tune the oscillator of the TIMS to the frequencies given below, using either

manual tuning or stepping controls. The other station shall observe the level variation (+ or -) from the zero reference, at each frequency and note the reading. The frequencies to be used are:

304 Hz	1404 Hz	2604 Hz
504 Hz	1604 Hz	2704 Hz
604 Hz	1804 Hz	2804 Hz
804 Hz	2004 Hz	3004 Hz
1004 Hz	2204 Hz	
1204 Hz	2504 Hz	

The procedure shall be repeated for the other direction of transmission.

6.3.6 Idle Noise and Single Frequency Interference Measurement

This measurement may be made simultaneously for both directions of transmission. The TIMS at each end shall be set to Message Circuit Noise or Noise and, if necessary, quiet termination for the transmit side. The displays shall be monitoring the receive level and C-Message Weighting selected. The C-Message Noise level may then be read directly in dBrc.

If the Line Monitor volume control is turned to a comfortable listening level, a test for any predominant tone on the circuit may be made. If any tone is heard, a frequency selective voltmeter, spectrum analyzer, or oscilloscope or equivalent equipment shall be connected to determine the frequency, level and thence origin of the tone.

6.3.7 Noise-with-Tone and Signal-to Noise Ratio Measurement

This measurement may be made simultaneously for both directions of transmission. The TIMS at each end shall be set to Noise-with-Tone or Noise but with normal transmit termination. Each station shall verify that a 1004 Hz tone is being received and that C-Message Weighting is selected. The C-Notched Noise level may then be read directly in dBrc.

The tone level shall then be measured by either one end at a time selecting Message Circuit Noise and reading the tone level incoming to that end (Hewlett-Packard) or by one end at a time depressing the S/N button and the distant end reading the incoming tone level (Halcyon).

Tone Level-C-Notched Noise Level = S/N Ratio in dB.

6.3.8 Phase Jitter Measurement

This measurement may be made simultaneously for both directions of transmission. The TIMS at each end shall be set to Phase Jitter and each station shall verify that the 1004 Hz tone is being received. Phase Jitter in degrees may then be read directly.

6.3.9 Measurement of Impulse Noise, Hits and Dropouts

This measurement may be made simultaneously for both directions of transmission. The TIMS at each end shall be set to Hit Measurements or Impulse, Hits and Dropouts. Both ends shall verify that a 1004 Hz tone is being received, select C-Message Weighting and adjust the threshold settings for the transients to the appropriate values. A 15 minute timing period shall be used (Bell Standard Count Time on Hewlett-Packard) and the start button depressed.

The readings shall be noted at the end of the timing period.

6.3.10 Non-Linear Distortion Measurement

This measurement shall be made separately for each direction of transmission. Both ends of the circuit shall select Non-Linear Distortion (for Halcyon tester, the receive station shall select Noise and adjust Level In thumbwheels for a display of +90 dBm, prior to selecting Non-Linear). After a 30 second stabilization period, Hewlett-Packard sets require the Level Zero button to be depressed momentarily.

The second order products, relative to the signal level may be measured by selection via the appropriate switch. The transmit station is then to send Check Signal (for Halcyon tester this requires the S/N button to be depressed) and a further reading taken. The difference between these two readings shall then be used to derive from the correction table for the instrument, the factor to be added to the first reading to give the true figure for second order products. This procedure is then to be repeated to determine third order products.

The whole procedure shall then be repeated for the other direction of transmission.

6.3.11 Envelope Delay Distortion Measurement

The technique for this measurement uses the return direction of transmission as a reference, while measuring the delay of the forward direction. For this reason, the measurement in each direction must be made independently.

One end of the circuit is designated as the Normal Station and the other as the Repeat. The Normal Station selects Envelope Delay or Delay and the Repeat Station selects Repeat mode and tunes to 1800 Hz transmit frequency at data level. There is a considerable difference between the control positions for the Hewlett-Packard and Halcyon TIMS and the instruction manuals shall be consulted for precise detail on how to do the test. It should be noted that this important test is not easy to perform and requires careful adjustment. The frequencies at which the test shall be made are given in 4.3.5.

Exception:

304 Hz and 3004 Hz are not required.

6.3.12 Miscellaneous Measurements

Measurement of Peak-to-Average Ratio, and Low Frequency Phase Jitter are not specified in the Circuit Standard (SAES-T-556) as for the circuits considered they are not necessary for efficient turn-up of channels. If desired, the relevant manual shall be consulted. Measurement of crosstalk is covered in 4.5.10.

6.3.13 Impulse Noise Measurement for Baseband Circuits

This test requires the use of two TIMS, located at the ends of the circuit (user's locations). Since baseband circuits are short distance, local cable only circuits, it will only be necessary to conduct such a measurement in exceptional cases (i.e., if users complain of poor throughput due to errors). If required, the test shall be made with each TIMS in the bridged position and each line terminated with a 140 ohm resistor or similar value.

6.4 Procedure for Circuit Provision

6.4.1 This section describes the recommended procedure to be followed when providing a new circuit, rearranging a circuit or connecting a new spur to a multipoint circuit.

6.4.2 Local Ends

In addition to normal checks performed on telephone circuit local ends, such as DC resistance, a check of the insertion loss should be made for both voiceband (at 1004 Hz) and baseband circuits (at 10 KHz). It should be appreciated that for circuits containing a microwave routed section each local end will require separate testing, but for voiceband circuits passing only over local cable and baseband circuits, insertion

loss measurement should be made from user's location to user's location with MDF jumpers in position. Circuits containing a microwave section should have local end insertion loss measured between user's locations and microwave multiplex patching facility, thus incorporating tie cable pairs.

In all cases, the measured loss should be compared with the designed loss stated on the circuit provision order and any significant deviation (i.e., greater than 2 dB) reported as faulty and a new cable pair requested from the Assignment Center.

Once this test has been completed, the necessary attenuation may be calculated and provided at the multiplexers or branching facility.

6.4.3 Microwave Sections

This applies to the sections of point-to-point circuits routed over microwave facilities and the main or intermediate sections of multipoint circuits. See figure 1.

The basic requirement is a complete parameter scan using a TIMS, between the microwave facilities, incorporating the multiplexers. The tests required are given in Table 1 and a suitable proforma for use with the tests, in Table 2.

6.4.4 Multipoint Circuits

For initial provision of a completely new circuit, the procedures in 6.4.2 and 6.4.3 may be followed. However, this is not often the case with multipoint circuits as often a new spur is required to be connected to an existing circuit. If the spur is a local end, section 6.4.2 only needs to be followed. If a microwave section is involved, a parameter scan of that new section is required. It must also be remembered that the values assigned to circuit parameters in SAES-T-556 and on the proforma refer to maximum permitted values between user's locations. Circuit re-arrangements and provision of new spur will not usually permit end-to-end scans, but from remote site to the nearest hubbing or branching point only. See Figure 1. This means that the permitted values will need to be apportioned or that the measured values on the new section will require to be compared with those on the record card for the existing main or intermediate sections in order to determine if the permitted maxima will be exceeded. In a worst case condition, it may be assumed that values for the various sections in isolation will add in modulus fashion when the end-to-end circuit is being considered. For example, a multipoint main section with a peak-to-peak phase jitter of 7 degrees when tandem

connected to a series of spurs each of which has less than 3 degrees of phase jitter gives a circuit which is within limits. A new spur with a phase jitter of 5 degrees will produce an end-to-end figure outside the limit and re-engineering or re-design is required.

6.5 Procedure for Fault Finding on Circuits

6.5.1 This section gives guidance on the approach to locate the source of trouble in a circuit. An exhaustive description of procedure is not given as this will be dependent upon the geographic area and the existence or otherwise of a centralized data circuit test center.

6.5.2 It is assumed that a loop-back test or end-to-end test (see Section 5) has caused a circuit or line to be suspected as faulty.

6.5.3 Faults will usually fall into the following categories:

- a) Open circuit in one or both directions.
- b) Excessive attenuation in one or both directions.
- c) Short circuit or short to ground
- d) Excessive noise
- e) Conditioning problems

6.5.4 Many faults in circuits occur in the local cable. This should always be suspected first, but the fault report or other circumstances may indicate that other tests should be performed first. For example, a test tone check on a microwave channel proving correct may confirm a local cable problem in a "no signal"-type fault.

6.5.5 Point-to-Point Circuits

6.5.5.1 These are the easiest to troubleshoot as the constant carrier mode of transmission means that a line signal is always present, in both directions. An audio check in each direction at microwave patching facilities will confirm the presence of modem carrier at those points and a level check with an LMS will confirm excessive attenuation or not. If carrier is not detected at a test point, a local end problem is usually indicated and fault location by use of LMS tones from microwave multiplex to user's location should prove conclusive. A technician will be required at the user's degrees location for this test.

- 6.5.5.2 If carrier levels are correct between each end of the circuit and the respective multiplex locations an idle noise check between these points with an LMS (i.e., excluding the microwave section) will confirm that local cable crosstalk, etc., is not causing noise or transient problems. The fault can then be assumed to lie with the microwave section. The tests indicated in the second column of Table 1 may then be performed using a TIMS at each end of the section. If the levels were correct throughout in 6.5.5.1, the problem will usually be noise or transients, necessitating reengineering or replacement of faulty channel cards. Intermediate stations may contribute the trouble and the circuit may need to be tested section by section when the parameter value measured in the test sequence exceeds that permitted.
- 6.5.5.3 The test sequence will also determine by attenuation / frequency and envelope delay/frequency scans, if there are any conditioning problems
- 6.5.5.4 If no fault is found after tests in 6.5.5.1 through 6.5.5.3, it may be assumed that no fault exists, on the first report. If subsequent reports are received, indicating the same trouble the problem is likely to be intermittent and exhaustive testing for a period will probably be required.

Assuming that the circuit is physically checked (modem connections, jumpers etc.) a TIMS at each end (at the multiplex facility or, exceptionally user's degrees premises) set to measure idle noise, hits and impulse noise) and regular readings taken, may determine the trouble.

6.5.6 Multipoint circuits

- 6.5.6.1 The tests performed on multipoint circuits are similar to those in 6.5.5 but it must be remembered that not only is switched carrier operation used (carrier always present in only one direction of transmission) but that end-to-end tests may not always be possible due to other remote sites on the circuit working normally. There is also the added complication of the hubbing or branching equipment contributing a fault.
- 6.5.6.2 Guidance may be obtained from the fault report in that if only one remote site reports a fault, the problem is likely to lie with that spur. If all stations report a fault the problem is likely to be in the main or intermediate sections.
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- 6.5.6.3 If the spur is suspected, the tests in 6.5.5.2 through 6.5.5.4 may be undertaken, remembering that modem tone will not necessarily be heard on the remote site transmit leg unless a loop is applied at that modem (modem transmit is under the control of the terminal device) and that care should be exercised when testing a spur which is part of a working circuit, due to the possible causing of interference to the other sites. The spur shall be isolated by use of disconnect plugs.
- 6.5.6.4 If the main section or intermediate sections are suspected, all associated spurs can be regarded as out-of-service and testing proceeded with on that basis.
- 6.5.6.5 Branching equipment is best checked by substitution with known working equipment and tones applied to the suspect one to confirm and isolate the fault. These equipments are generally reliable and other circuit faults are more common.

6.5.7 Local Cable Circuits

Voiceband, baseband and supervisory circuits provided totally on local cable pairs can generally be tested by the techniques of DC resistance and tone level measurement.

6.5.8 Co-axial Cable Circuits

Circuits provided totally on coaxial cable and usually having both ends of the circuit within the same building may be tested between the flexibility points provided on the route.

6.5.9 Tolerance

When measurements are made on a circuit which has been reported as faulty, the values obtained for the parameters measured shall be compared with those originally made on commissioning and entered on the circuit record. Significant deviation from the original values, even though the new values are still within limits, may indicate the source of the trouble.

6.5.10 Crosstalk and Return Loss

The measurements will normally only be required if the other tests have failed to isolate the trouble or indicate that the problem lies in echo or crosstalk.

6.5.10.1 Return Loss measurements will only be required on 2-wire circuits and alignment of 4-wire/2-wire terminating units shall follow the standard telephony practice.

6.5.10.2 Crosstalk may occur in the local cable or in the multiplexing facility. It can be of two types. The first type, Near End Crosstalk (or NEXT) is where the transmit side of a circuit interferes with the receive side of the same circuit at the one location. To measure this the distant station shall provide a Quiet termination to both transmit and receive. A test tone at data level shall be transmitted on the transmit pair and the level of signal induced by NEXT in the receive pair measured.

The second type, Far End Crosstalk (or FEXT) is where transmissions on other (usually adjacent) channels or pairs interfere with the wanted signal on a channel. To measure this, a quiet termination is required on both legs of the distant end of the channel to be tested. Either a test tone at data level may be applied to the transmit of the distant end of an adjacent channel and the received level due to FEXT measured, or the FEXT level produced by normal traffic on adjacent channels measured. In either case the near end transmit of the channel under test shall be Quiet (i.e., no possibility of NEXT).

Crosstalk is usually controlled by correct multiplex alignment, correct selection of pairs and control of levels on all circuits.

7 Measurement of Circuit Performance

This section gives guidance on modem and Circuit performance testing using a Bit Error Rate Tester (BERT) and a Protocol Monitoring Device (PMD). It also describes the circuit configurations, their characteristics insofar as they affect testing procedures and the circumstances under which various tests should be carried out. The tests described are for use with fault finding but a bit error rate test should be performed on commissioning to confirm the performance of the circuit.

7.1 Modems and Networks

7.1.1 The two major network configurations in use by Saudi Aramco are 4-wire point-to-point and 4-wire multipoint private circuits, as shown in Figure 2 (a) and (b). The modems operate in either a switched carrier or constant carrier mode as shown in the figure.

7.1.2 On point-to-point circuits, the modems operate in a constant carrier mode, that is the line signal is transmitted continuously, irrespective of

the condition on the RS 232/V24 interface circuit "Request to Send".

- 7.1.3 On multipoint circuits, the line signal is continuous from the central site (computer center) modem; the signal is received by all remote site modems. However, each remote site modem transmits in a switched carrier mode, that is the line signal is only transmitted under control of the associated terminal device which applies an ON condition to the "Request to Send" circuit when a message is to be transmitted. Such a transmission follows reception of a poll from the CPU via the central site modem. The poll incorporates a unique address only recognized by one terminal on the circuit, to ensure that only one remote site modem transmits a signal in a given time frame.
- 7.1.4 The message from each multipoint remote site modem is preceded by a synchronising/training pattern required by the central site modem to recover carrier, timing and for training equalizers, depending upon the modem type. The central site received line signal is discontinuous and therefore the signal detector switches on and off (as can be observed on the signal detector indicator). With reference to Figure (b), the periods of no transmission between blocks A, B, C and D is dependant upon the sensitivity of the central site modem signal detector and ideally should be as short as possible to maximize data throughput. Typical response times are 3-10 milliseconds. The synchronizing / training period should be as short as possible also, for the same reason and typical training times are 8-50 milliseconds.

7.2 Testing

When testing modems on point-to-point or multipoint circuits it is important to simulate the transmission modes as described. The data communication channel including the modems will be controlled by modem test keys, BERTs or PMDs, or a combination of these.

- 7.2.1 Modem test keys can be used to establish analog and digital loops as shown in Figure 3. On some types of modem a test pattern may be originated and transmitted via these loops. If this facility is not built in, an external BERT shall be used. When the facility is built in, error checking is also done by the modem, otherwise analysis is performed by the BERT. The loops required for the various tests, as indicated in Figure 3 are:

- a) No loops: end-to-end test using modem test keys or BERTs. Valid for point-to-point or specific remote site modem to central site modem.

- b) Analog loops: testing of individual modems with test keys or BERTs.
- c) Digital loop: testing of point-to-point modems and lines using a BERT.
- d) Digital loop: as for (c) but using modem test keys.
- e) Digital loop: testing of central site modem, remote site modem and line.
- f) Analog loop: testing of remote site modem.
- g) Analog loop: testing of central site modem.

7.2.2 Switched carrier operation should be simulated in association with loops (e) and (g), i.e., when a test involves measuring the performance of an central site modem receiver. An end-to-end test on a multipoint circuit should also be performed in switched carrier mode. However, since the central site modem transmits constant carrier signals which will be returned via the remote loop, switched carrier simulation will not be possible via loop (e). A local test at the central site modem via loop (g) may or may not operate in switched carrier mode. Check with modem manufacturers' information. If this test is possible a single BERT shall be used for transmission and reception of data.

7.2.3 Switched carrier simulation for an end-to-end test may be achieved by operating two BERTs in a half-duplex mode and measuring block error rates. Tester A shall put "Request to Send" ON, send a block of data and then put "Request to Send" OFF. Tester B, on receipt of this block, shall check for errors Put "Request to Send" ON and send a block of data back to Tester A, and so on. Due to the delay between received blocks, the central site modem received line signal detector will turn off and the modem receiver is conditioned to expect resynchronization/training before the next block. The modem is therefore tested in a realistic manner. Unfortunately, a further complication exists if the test is to be continuous end-to-end transmission because normally the received line signal detector remains high at the remote site modem.

Testers would normally await this control signal to turn off before transmitting a block of data. The problem can only be solved by having special test equipment (a simple modification to a BERT with half-duplex facility) or by temporarily arranging for simulated switched carrier operation (if the facility is available with the modems under test).

7.2.4 Bit error rate tests are sufficient for other test modes.

7.2.5 Test procedures are given in flowchart form in Figure 4. Explanation for point-to-point and multipoint tests are given in 5.3 and 5.4 respectively.

7.3 Multipoint Circuit Testing

7.3.1 Case 1 : No Polling on Multipoint Circuit

If no polling is observed within, say 5 minutes, then further testing is required. Polling may be observed by the illumination of the indicators on the modem or use of PMD in a monitor mode. Since no polling is taking place, the circuit may be interrupted and the following tests carried out.

7.3.1.1 Local test of the central site modem

Using the central site modem test keys an analog loop shall be established and a local pattern generated, received and analyzed by the modem. If the modem does not have this facility, an external BERT shall be substituted. A BERT is advisable in the former case also since the actual error rate is not normally displayed by the modem, only a general performance indication, i.e., flashing indicator when an error occurs.

When using test keys and the modem pattern generator, the test shall be repeated several times in order to establish that the modem synchronizes and/or trains adequately every time. If errors occur on some tests but not others the modem may be faulty, it is then necessary to use the BERT. The BERT shall be switched to have a delay between blocks transmitted (i.e., turn circuit 105 OFF) during which time the receiver signal detector will turn off, as per paragraph 5.2.3. The tester will display the number of blocks received, the number of block errors and the number of bit errors. At least 1000 blocks shall be transmitted using a block size of 32 or 64 bits. The block length is not critical and will depend on the BERT in use. For example, with the Trend 1-8 tester the block length for a half-duplex test is fixed at approximately 511 bits. The significant indication is the block errors which shall not exceed 1 in a 1000. If this figure is exceeded, the modem shall be replaced and sent for further testing and/or realignment.

7.3.1.2 Self-check of every remote modem on the circuit

The self check may be carried out with the use of a network

management system (e.g., Racal Milgo System 2000) from a central site or will require user-assistance at each remote site to operate modem test keys. An analog loop shall be established and a test pattern initiated with associated error check. This may only be done with modems so equipped. The test will determine if the remote modems are functional. It should be noted that this test may be achieved without interrupting the circuit.

7.3.1.3 Remote test of remote site modem

This shall be carried out by establishing a digital loop at the distant modem under test. A test pattern shall then be transmitted via the central site modem using the central site modem test keys or an external BERT.

It must be noted that since the central site modem is transmitting constant carrier signals, applying the digital loop will cause a constant carrier signal to be returned to the central site receiver. It must therefore be ensured that no other modem on the multipoint is transmitting signals, otherwise interference will occur.

If a BERT is used for this test a block size of 10^6 shall be used and the significant indication is bit errors since effectively only one block of data will be transmitted. Assuming the tests in 5.3.1.1 and 5.3.1.2 indicated no fault, this test will give an indication of line quality.

If an excessive number of bit errors are recorded (greater than 10 in 10^6 bits) then the line must be suspected. It remains to be determined which section of the multipoint is unacceptable. Depending upon the circuit configuration, it may be possible to isolate the fault to the spur. This may be achieved by a further similar test for each remote site modem, removing the previous digital loop in each case beforehand.

7.3.2 Case 2 : No Polling/Response to/from Terminal

In this case, polling of the other remote site terminals is occurring but polling of the terminal in question is not, or that terminal is not responding correctly. The fault is therefore at that remote terminal, its associated modem or that particular multipoint spur. The tests described in 5.3.1.1 and 5.3.1.3 shall be made. If no fault is detected then the terminal must be suspected.

A terminal fault may be confirmed by using the PMD in an interactive mode. The PMD shall be programmed to poll the particular terminal repetitively, to count the number of polls and the number of correct responses. The programme will depend on the protocol in use.

7.3.3 Case 3 : Fault not Found

If the fault is not found by use of the PMD as in 7.3.2, it may be assumed on the first report that no problem exists. If further complaints are received and no problem is apparent on monitoring the line, then additional testing will be necessary.

7.3.3.1 End-to-End bit/block error rate testing

This testing requires a technician at the remote site. The terminal and the CPU shall be disconnected at each end and replaced by BERTs. A bit error rate test shall be performed simultaneously in each direction, at least 3 times, using 10^6 bits for each test. No more than 1 bit per test should be received in error, on average, in either direction.

An end-to-end block error rate test shall also be made in a half duplex mode as per paragraph 7.2.3. A block length of 32 or 64 bits (as in paragraph 7.3.1.1, block length is not critical) shall be used and at least 1000 blocks sent. The block error rate shall not exceed 1 in a 1000.

7.3.3.2 Interactive protocol testing

The end-to-end bit/block error rate tests should prove beyond doubt whether the data communication channel, including modems, is acceptable.

If further complaints are received a PMD shall be used at the central site to simulate the host computer. The display shall be monitored to compare the exact data transmitted and the response (if any) received from the remote site. The data transfer can be continuous and the number of responses and average response times may be determined and various error checks made.

7.4 Point-to-Point Circuit Testing

7.4.1 Case 4 : No Received Signal

Saudi Aramco point-to-point data circuits are usually 4-wire, operating

in a constant carrier mode i.e., a line signal is present in each direction irrespective of user data being transmitted. If the received signal falls below a certain threshold level (typically -31 dBm) or completely disappears, then the modem signal detector lamp will not be illuminated. The most probable causes are that either the modem is disconnected from line or the circuit is broken. Other causes could be excessive line attenuation or a modem failure (transmitter or receiver). If the modem is connected to line (line relay operated) at the central site, the received signal level shall be measured and the procedures in 4.5 followed.

7.4.2 Case 5 : Local Test Failure

A local test failure at the central site indicates a modem fault and the modem shall be replaced.

The local test, in this case, shall be the transmission, reception and error checking of a test pattern either generated by the modem (indication of errors by modem indicator) or by use of an analog loop and transmission/reception of repeated 511 bit pseudo random pattern using an external BERT. No errors should occur.

7.4.3 Case 6 : Distant Modem Self-Check Failure

A failure of the self-check test proves that the distant modem is faulty. The test is, operationally, identical to 5.4.2 except that it is carried out on the distant modem. The test may be performed using a network management system (e.g., Racal Milgo System 2000) from a central location, by requesting a user to operate modem test keys at his location, or by a maintenance technician (this is not recommended as a procedure since the test may not be necessary and would therefore waste valuable technician time).

7.4.4 Case 7 : Remote Test Failure

The remote test checks the entire link from RS 232/V 24 interface to RS 232/V 24 interface. A test pattern (either modem or BERT generated) is transmitted from the local modem via a digital loop at the distant modem, back to the local modem again. Errors will be indicated by modem or BERT.

The digital loop may be applied by network management system, user assistance or by a maintenance technician as a last resort. With the latest modems conforming to ITU-T V54 it is also possible to set up a digital loop at the remote modem by applying an ON condition on interface

circuit 140 at the local modem. A block length of 10^6 shall be used if an external BERT is connected.

If errors occur, but tests 7.4.2 and 7.4.3 proved satisfactory then the line should be suspected. Since in a remote test mode, there are effectively 2 transmission links in tandem the permitted error rate is 2 in 10^6 bits. If an occasional error is observed on the modem "error" indicator when using the modem internal pattern generator/analyzer, then it may be necessary to use an external BERT to determine the exact error rate.

7.4.5 Case 8 : Fault not Found

The tests in 5.4.1 through 5.4.4 should prove whether the transmission medium, including modems, is acceptable.

Use of a PMD in an interactive mode will check a terminal, this being the only other potential problem area. A program to poll the device and check responses is required. If no fault is found on tests 7.4.1 through 7.4.4, then on the first report it may be assumed that no problem exists. If subsequent related faults are reported it may be necessary to undertake more sophisticated protocol testing as outlined in 7.3.3.2.

Revision Summary

12 October 2005

Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with editorial changes.

Table 1 – Required Transmission Tests

Test	On Commissioning A Circuit	On Fault Finding A Circuit
INSERTION LOSS	YES (Test also made on local ends using LMS)	YES (Test first made of modem carrier level on local ends using LMS)
FREQUENCY SHIFT	YES Microwave routed circuits only	YES Microwave routed circuits only
ATTENUATION/FREQ.	YES	YES
IDLE NOISE	YES	YES
SINGLE TONE	YES	NO (NOTE 2)
NOISE WITH TONE	YES	YES
S/N RATIO	YES	YES
PHASE JITTER	YES	YES
IMPULSE NOISE	YES	YES
HITS & DROPOUTS	YES	YES
NON LINEAR DISTORTION	YES	YES
ENVELOPE DELAY	YES	YES
CROSSTALK	NO (NOTE 1)	NO (NOTE 2)
RETURN LOSS	NO (NOTE 1)	NO (NOTE 2)
LOOP RESISTANCE	YES (NOTE 3)	NOTE 4

Notes:

1. Normally considered in planning.
2. Only tested if other tests do not indicate fault. Return Loss only significant for 2-wire circuits.
3. Normally measured by local line installation personnel.
4. Only measured for voiceband circuits if levels and loss are out of limits. An essential test for baseband or supervisory circuits.

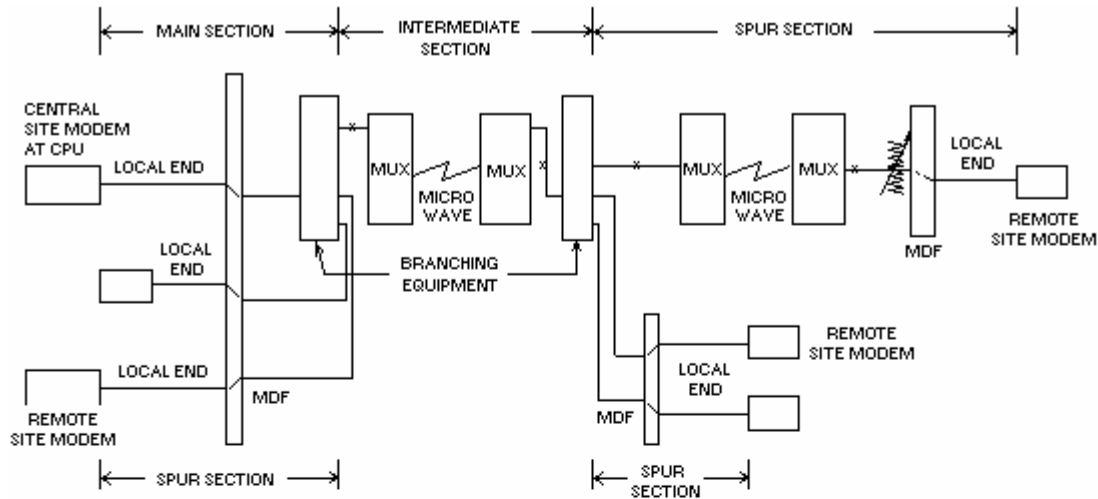
Table 2 – Data Parameter Test Sheet (C2 Conditioned Circuit)

Note: When testing at "MOD IN" and "DEMOD OUT" TEST JACKS, the correct data levels will be -29 dBm and -6 dBm respectively, i.e., the TLPs are -16 and +7 respectively.

Test	Voiceband Circuit Limits	Comments
a) CIRCUIT LOSS	0 dB ± 2 dB	3 dB ± 2dB for multipoint circuits end-to-end
b) FREQ. SHIFT	< 5 Hz	
c) IDLE NOISE	< 50 dBrcO	C-Message Filter
d) IDLE NOISE	< 56 dBrcO	3 kHz Filter
e) SINGLE TONE	CHANNEL SHOULD NOT HAVE A TONE PRESENT	Listen to monitor speaker
f) NOISE W/TONE	< 53 dBrcO	No greater than 24 dB below signal power
g) SIGN.-TO-NOISE	> 24 dB	Will usually be much better than limit
h) PHASE JITTER	< 10 degrees	Limit for end-to-end
i) IMPULSE NOISE	< 15 IN 15 MIN	68 dBrcO THRESHOLD
j) GAIN HITS	< 15 IN 15 MIN	± 2 dB THRESHOLD
k) PHASE HITS	< 15 IN 15 MIN	10 degree THRESHOLD
l) DROPOUTS	< 50 IN 24 HRS	OBSERVE FOR MORE THAN 2 ROPOUTS IN 15 MINS
m) NONLINEAR DIST 2ND ORDER 3RD ORDER	< -25 dB below < -30 dB below	With respect to fundamental (Use Corrosion Chart) With respect to fundamental (Use Corrosion Chart)
n) ATTENUATION AND ENVELOPE DELAY/FREQUENCY DISTORTION		

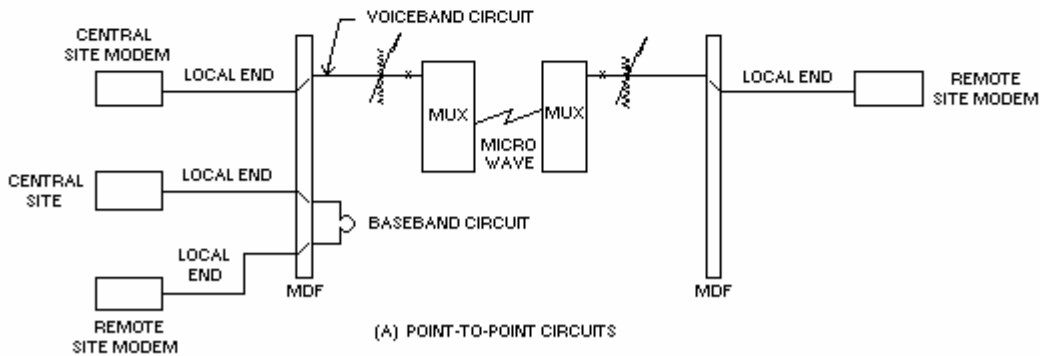
Frequency (Hz)	Attenuation Limit (dB)	Measured Attenuation (dB)	Delay Limit (Milliseconds)	Measured Relay (Milliseconds)
304	+ 2 to -6		-	
504	+ 1 to -3		3.0	
604	+ 1 to -3		1.5	
804	+ 1 to -3		1.5	
1004	+ 1 to -3		0.5	
1204	+ 1 to -3		0.5	
1404	+ 1 to -3		0.5	
1604	+ 1 to -3		0.5	
1804	+ 1 to -3		0.5	
2004	+ 1 to -3		0.5	
2204	+ 1 to -3		0.5	
2504	+ 1 to -3		0.5	
2604	+ 1 to -3		3.0	
2704	+ 1 to -3		3.0	
2804	+ 2 to -6		3.0	
3004	+ 2 to -6		-	

Note: Limits refer to attenuation, i.e., negative sign denotes loss.



(B) MULTIPPOINT CIRCUIT (VOICEBAND)

- NOTE:
1. IF THERE IS ONLY ONE BRANCHING EQUIPMENT IN THE CIRCUIT, THERE WILL BE NO INTERMEDIATE SECTION.
 2. SOME MULTIPPOINTS MAY NOT INVOLVE MICROWAVE FACILITIES.
 3. ONLY ONE DIRECTION OF TRANSMISSION SHOWN.
 4. 'X' DENOTES "MOD IN" AND "DEMOM OUT" TEST JACKS.



(A) POINT-TO-POINT CIRCUITS

- NOTE:
1. 'X' DENOTES "MOD IN" AND "DEMOM OUT" TEST JACKS.
 2. DENOTES TEST ACCESS POINT.
 3. ONLY ONE DIRECTION OF TRANSMISSION SHOWN.

Figure 1 – Typical Circuit Arrangements

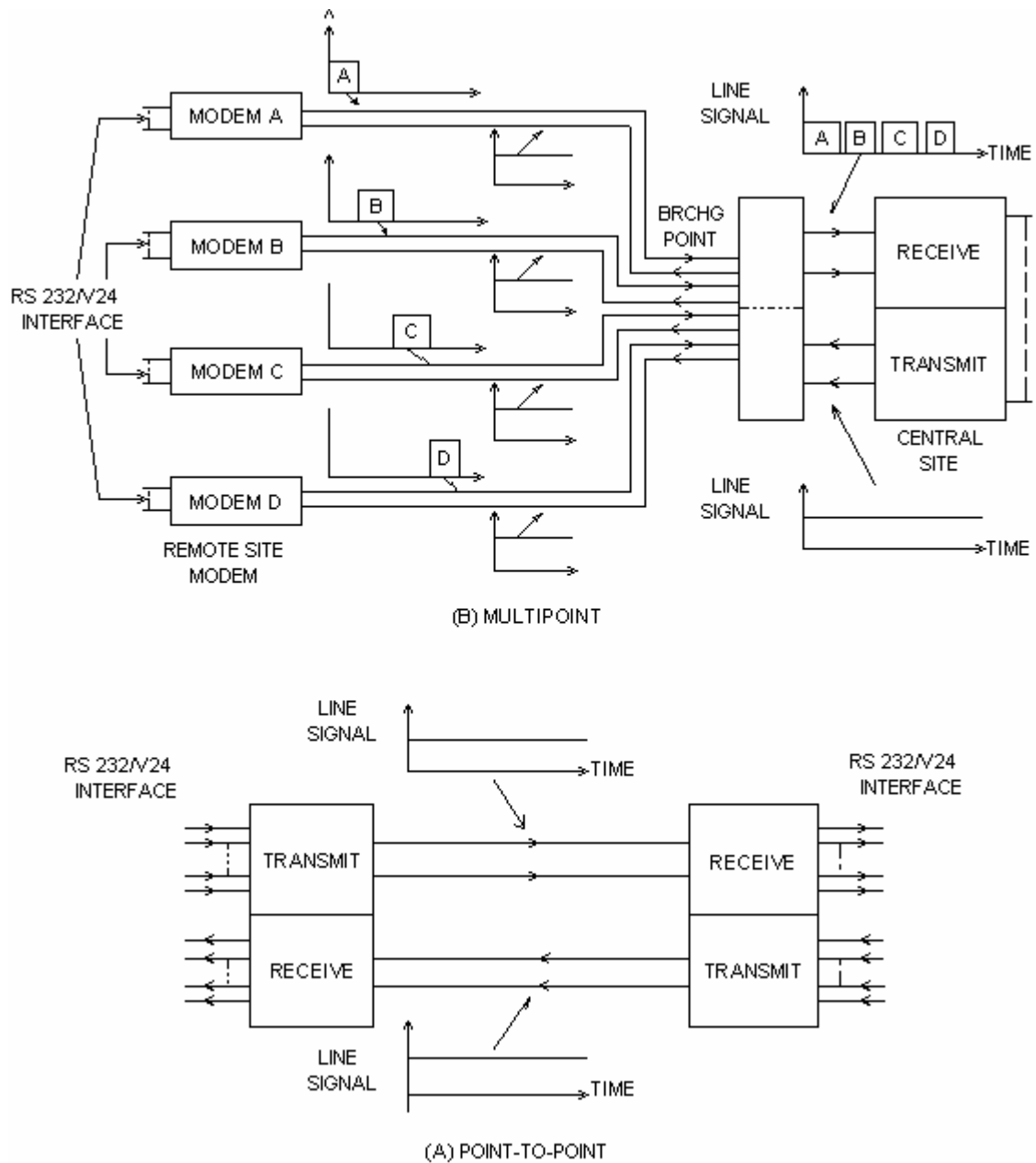


Figure 2 – Type of Circuit

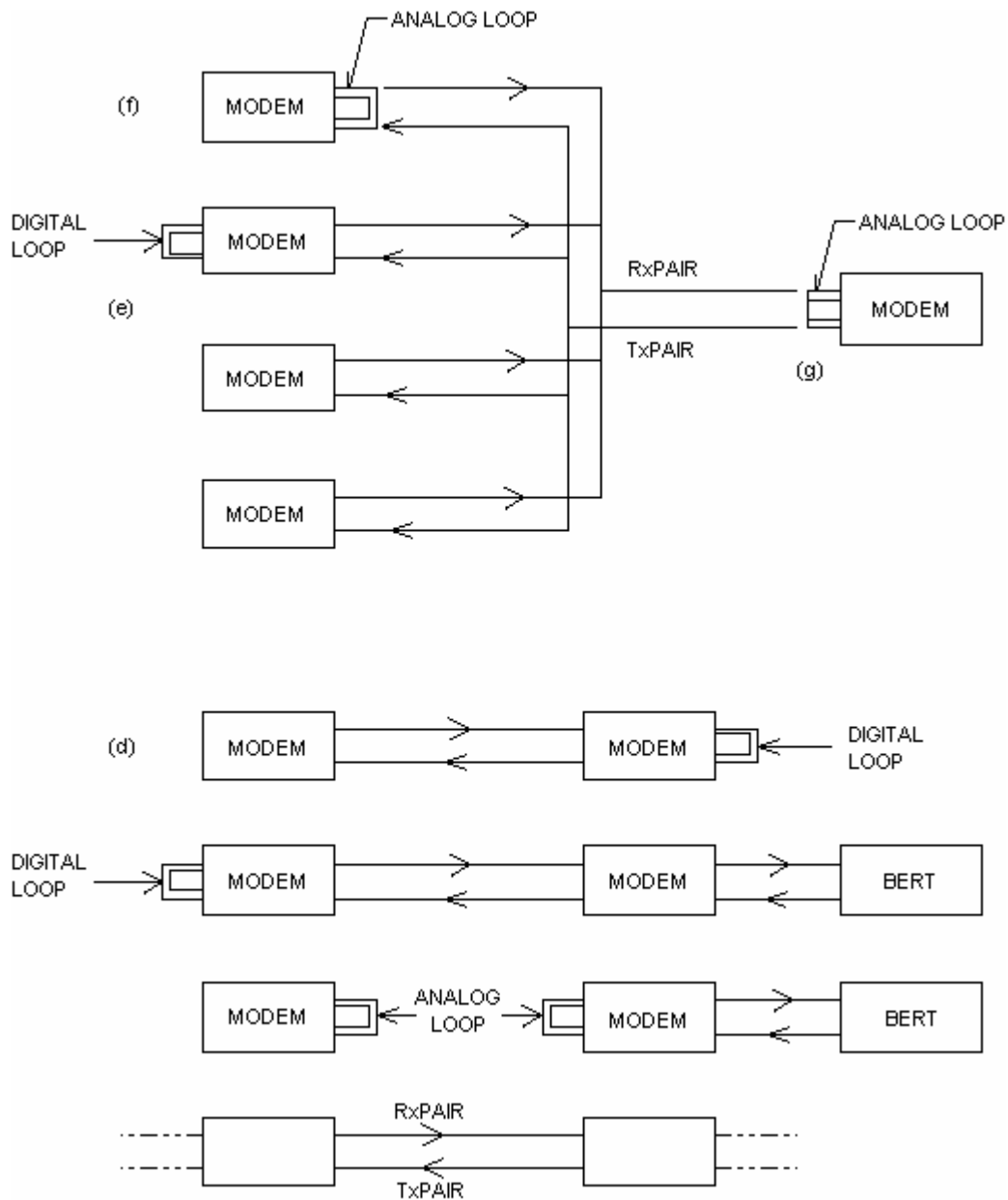


Figure 3 – Test Loops

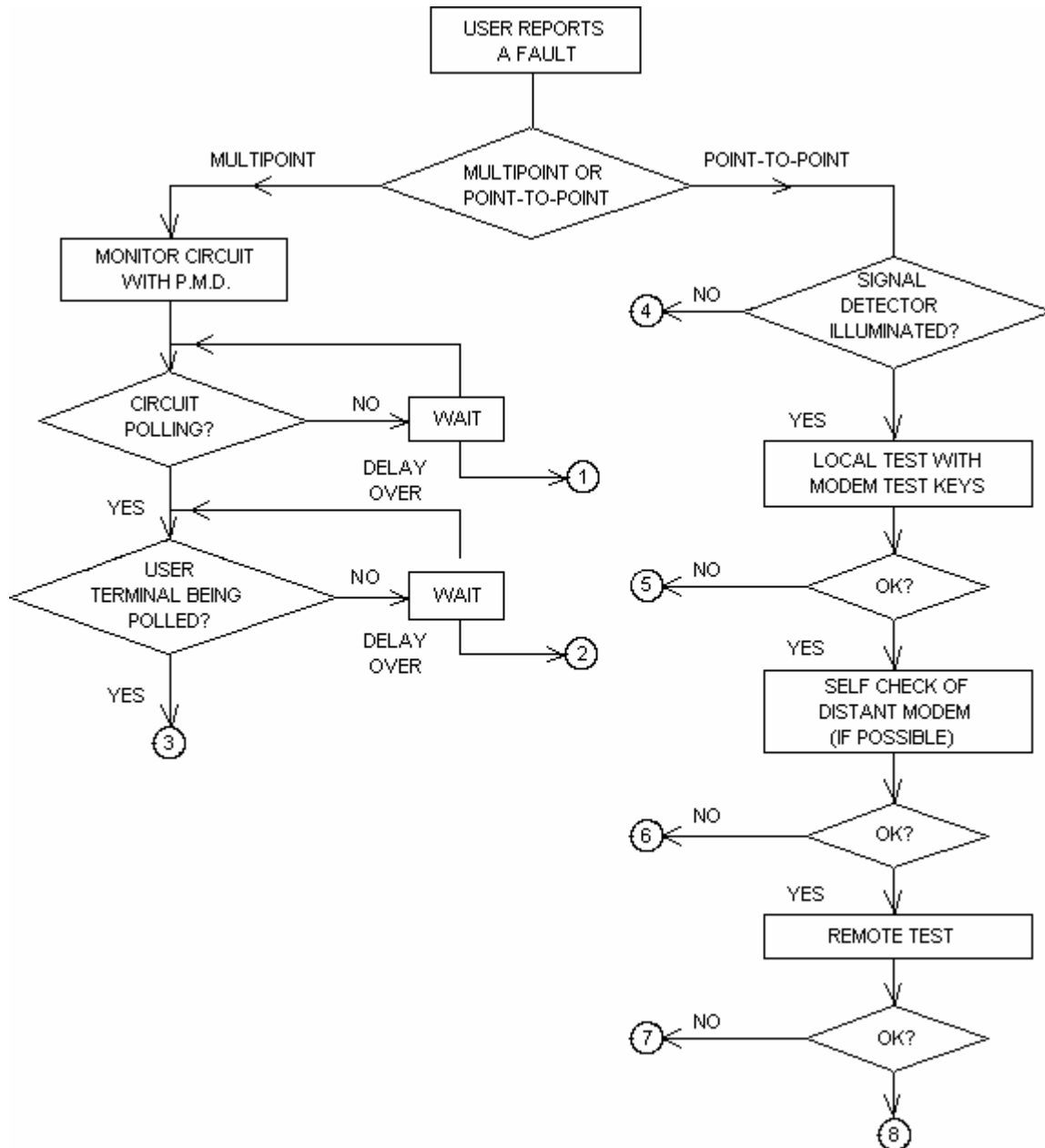


Figure 4 – Test Procedure Flowchart