

Transmission Measurements on Carrier Equipment

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1. Introduction

1.1 This section describes measurements pertaining to carrier multiplex equipment. The methods of measuring are subject to slight variations among equipment manufacturers. Documented here are brief, sometimes general, procedural guidelines for performing these tests. The details given should enable a technician (or similarly qualified test person) to perform these tests (with perhaps some referral to manufacturers' recommendations and specifications).

1.2 Standardization of telecommunications measurements is now in progress. Some of the measurements here have been addressed by various organizations and some guidelines have been set. However, it may be years before complete standards are issued. As these standards are adopted, test procedures should be modified to reflect the national standards.

1.3 The tests and measurements outlined here include many standard transmission tests. Not all of these tests need be performed at one time, and these tests are mainly for checking system performance during operation. These tests can be performed on carrier equipment in the laboratory and on operating systems (in the field). Of course, laboratory tests are more precise because of the controls applied. Field tests may require some data adjustment and experimentation to attain the desired level of precision.

1.4 Since modern telecommunications testing equipment is likely to be of high quality, no specifications or minimum required characteristics for test equipment are given.

1.5 This section comprises the following: a subsection on channel seizure and access and which tests they apply to (paragraph 2); a subsection on voice frequency (VF) tests that includes impedance tests (paragraphs 3 through 6), noise, distortion, and response tests (paragraphs 7 through 11), signaling tests; (paragraphs 12 and 13) and, a subsection on high frequency (HF) tests for analog and digital systems (paragraphs 14 through 16). Also included are brief comments on data systems and automatic test equipment (ATE).

1.6 When terms are defined, where possible, the 1984 edition of the IEEE Standard Dictionary of Electrical and Electronics Terms was used.

2. Channel Access and Seizure

2.1 Access

2.1.1 On most of the measurements where channel seizure is required, access is made at the two-wire drop. This disconnects the central office equipment. Test jacks are very often available for access.

2.1.2 If access is gained at the four-wire connections, some data (level) adjustment may be necessary. Details for these adjustments on specific measurements are given in the test descriptions (and may be provided by the carrier equipment manufacturer).

2.1.3 When an end is to be terminated rather than measured, use 900 ohms (or 600 ohms at a toll center) in series with 2 F, or other networks as required. Many instruments provide built-in termination networks. When using discrete components for the termination networks, resistors should be no greater than one (1) percent tolerance and capacitors no greater than five (5) percent tolerance.

2.2 Seizure

2.2.1 For most voice frequency measurements, the carrier channel must be seized at both ends to place it in a normal operating condition. The method of seizure will depend on the type of signaling used. (Signaling test sets usually provide for channel seizure.)

2.2.2 E & M signaling will usually be used at the toll center on toll connecting trunks. However, the toll connecting trunk may use loop dial signaling. Following is a description of channel seizure for systems using different types of signaling:

2.2.3 E & M - To seize a channel that uses E & M signaling, apply minus (-)48 volts d.c. (fused) to each terminal "M" lead.

2.2.4 Loop dial - When making measurements on carrier channels equipped with loop dial signaling (one-way), the method of seizure may vary among systems:

2.2.4.1 outgoing loop dial - On outgoing (originating) loop dial systems, the channel is seized by providing a d.c. path (using a holding coil) across the carrier two-wire drop. Most newer test instruments provide a voice frequency (VF) holding coil internally that can be switched in to provide a d.c. path to seize the channel. Make certain that the specified impedance (600 or 900 ohms) is used. When the outgoing loop dial end is to be terminated rather than measured place a high impedance holding coil (CO battery feed relay, for example) in parallel with the termination.

2.2.4.2 incoming loop dial - Follow the instructions of the carrier equipment manufacturer. One method used to seize incoming loop dial employs an external battery (of specified polarity and voltage) to simulate return supervision from the central office equipment.

2.2.5 Subscriber carrier - On the subscriber end, the holding coil provides a d.c. path to seize that end. Seizure is not required at the CO terminal end.

2.3 Measurements Requiring Seizure

1. VF insertion loss
2. echo return loss and singing return loss
3. VF longitudinal balance
4. DC loop current
5. channel noise
6. impulse noise
7. intrasystem crosstalk
8. VF level tracking
9. noise measurements concerning battery and power supplies

3. VF Insertion Loss

3.1 Insertion loss is the ratio of the power delivered to that part of the system following the transducer to the power delivered to that same part of the system after insertion of the transducer. In our case, the transducer is the carrier equipment and transmission line. Insertion loss is essentially a measure of the attenuation imposed on a signal by a carrier system. (On a transmission line, the insertion loss equals the attenuation if the impedances of the sending and receiving terminals are equal and also match the characteristic impedance of the transmission line connecting them. With carrier equipment at both ends (and perhaps along the line), insertion loss will not equal attenuation.) Since insertion loss is measured at various frequencies, it is often termed frequency response.

3.2 Measurement:

1. Access and seize the channel as in paragraph 2.
2. Set the transmission test set output for the carrier manufacturer's recommended test tone level (generally 0 dBm). If using a separate oscillator and voltmeter, calibrate the oscillator for the needed test tone level as in Figure 1. This calibration includes the loss of the VF repeating coils at the sending and receiving ends (approximately 0.5 dB per coil from 300 Hz up).

3. Connect the test set to the carrier drop at one terminal end as shown in Figure 3 making sure that the test set output impedance matches that of the drop. This will be the sending end. (If using an oscillator and VF coil, connect as in Figure 2.)

4. Also connect another transmission test set to the receiving (distant) end as shown in Figures 2 and 3. Again, be sure that the receiving test set (input) impedance matches the line impedance.

5. Record the sending and receiving levels. The insertion loss is the difference between these two levels.

Example 1. With the sending level set at 0 dBm, the test set is receiving -3.8 dBm. The difference of the two readings is, $0 - (-3.8) = 3.8$ dB. Thus, the insertion loss is 3.8 dB.

3.3 VF insertion loss measurements should be made at 1004 Hz and at various other frequencies throughout the voice range. If the carrier has Inband Signaling (i.e. 2600 Hz), the frequency response cannot be accurately determined without using special techniques. (On these systems, the use of single tones to make frequency response measurements will show a notch in the response around the signaling frequency. A voice signal activates a guard circuit that removes this notch -- a single tone will not. On such systems, insertion loss is generally a laboratory measurement.)

4. Echo Return Loss and Singing Return Loss

4.1 Return loss is a measure of impedance match. The difference (in dB) between the applied signal and the returned (or reflected) signal is the return loss. The higher the return loss, the better the impedance match. Echo return loss (ERL) is the composite return loss over the echo range (generally 500-2500 Hz; see Figure 4) when the two-wire voice frequency impedance of a carrier channel is compared to some standard impedance (such as 600 ohms in series with 2 F). A hybrid coil (see Figure 6B) is usually used to compare two impedances in determining the ERL.

4.2 Singing return loss (SRL) is the lowest value of return loss between some standard impedance and the input impedance of the two-wire voice drop of a carrier channel within a specified frequency range. Singing return loss is measured in two frequency bands--low and high (generally 250-500 Hz and 2500-3200 Hz; see Figure 4). Singing return loss is an actual measure of return loss, not to be confused with the singing of the channel being measured. Singing return loss has replaced singing point as the measurement technique to determine impedance (or return loss) at the voice frequency passband edges. Singing return loss (using noise) is easier to measure, and yields more repeatable results than singing point.

4.3 ERL and SRL measurements are made by transmitting bandlimited noise of known energy and measuring the energy reflected back to the transmitter (or receiver for a four-wire measurement).

4.4 Some manufacturers provide equipment specifically to measure ERL and SRL (Wiltron's TMS 9601 or Bowmar's 481). These instruments have built-in impedance matching networks and also include built-in hybrid and termination networks.

4.5 Echo return loss and singing return loss measurements are made from the toll center (Class 4 office) on toll connecting trunks terminating at the end office (Class 5). (This implies that the measurements would always be made at a 600 ohm office. However, where carrier equipment is used to make up only part of the toll connecting trunk, both ends of it may have 900 ohm terminals. So to ensure that carrier equipment in this application does not degrade the overall toll connecting trunk performance, ERL and SRL measurements are sometimes made on 900 ohm equipment.)

4.6 The following procedures outline the methods for measuring ERL and SRL of the carrier terminal only; it may be necessary to follow a similar procedure to include the central office equipment. Two methods for determining ERL are presented. The first ERL measurement procedure describes testing with a modern (Bowmar or Wiltron or equivalent) test set, the second uses a noise generator, noise measuring set, hybrid coil, and termination network; the SRL measurement procedure is described only for a modern test set.

4.7 ERL Measurement:

4.7.1 Modern Test Set Procedure

1. Access and seize the channel as in paragraph 2.
2. Terminate the distant end as in paragraph 2.
3. Connect the test set at the two-wire drop (using the correct impedance) as in Figure 5. For four-wire circuits, connect the four wires as directed by the manufacturer.
4. Set the measure control to return loss and the send control to ERL and read the display. This value is the ERL.

4.7.2 Noise generator and hybrid coil method

1. Preliminary Calibration: When making ERL measurements, the signal level at the carrier two-wire drop should be approximately equal to the manufacturer's recommended test tone level. The average coil hybrid exhibits about 7 dB loss from the oscillator terminals to the voltmeter terminals (See Figure 6A). Therefore, for zero dBm at the carrier terminals the noise generator should be set for approximately +4 dBm output (band-weighted according to carrier manufacturer's instructions). As shown in Figure 6A, this will be approximately +0.5 dBm at the line terminals of the hybrid. If using a noise measuring set with a built-in hybrid, adjust the noise generator accordingly for approximately zero dBm at the carrier terminals.

2. ERL Reference: In making ERL measurements, the first measurement is a reference. This takes into account the loss of the test hybrid. When making many ERL measurements, the reference is taken initially and may be checked from time to time. It is not necessary to take a reference for each ERL measurement.

3. Referring to Figure 7, record the reading from the noise measuring set (NMS) (600 ohm noise-metallic C-message weighted) with the hybrid line terminals open and again with the line terminals shorted. The average of the two readings is the reference.

4. Connect the test hybrid (or appropriate NMS) line terminals to the carrier two-wire terminals at the toll center (Figure 8).

5. Read and record the value shown on the NMS.

6. Subtract the reference (step 3) from this reading to get the ERL (in dB).

Example 1. Suppose the NMS reading in the above paragraph was 59 dBrnC. With a reference level of 87 dBrnC (from the reference measurement), $ERL = 87 - 59 = 28$ dB.

4.8 SRL Measurement:

1. Access and seize the channel as in paragraph 2.

2. Terminate the distant end as in paragraph 2.

3. Set the output level for SRL (low) and connect the line terminals to the measuring-input terminals on the test set.

4. Set the send control to SRL (low) and the measure (or receive) control to return loss.

5. Record the display value as SRL (low). (See Figure 4.)

6. Repeat the measurement with the SRL output on the opposite setting (SRL high).

5. VF Longitudinal Balance

5.1 Longitudinal balance is the ratio of the disturbing longitudinal voltage to the measured metallic voltage for the network under test. Longitudinal voltage is the voltage common to all conductors of a group (one-wire--usually measured to ground from tip or ring), and metallic voltage is the voltage across a metallic circuit (parallel--tip to ring). Longitudinal balance is the measurement of the ability of a circuit to reject common-mode signals.

5.2 Several test circuits and procedures have been developed by different segments of the telecommunications industry. Most of these refer to IEEE Standard 455-1976, which was developed for passive devices in the voice-

band. Some manufacturers offer longitudinal balance test sets specifically for this measurement. The method for measuring longitudinal balance will depend on the test set used. The procedure described below does not discuss calibration or specific details. This is covered by the test equipment manufacturer.

5.3 Measurement:

1. Access and seize the channel as in paragraph 2.
2. Calibrate the test set according to manufacturer's instructions.
3. Connect the equipment to the two-wire drop at the subscriber terminal according to the test equipment manufacturer's instructions. Also connect the longitudinal balance test set's companion termination unit to the distant (CO) end. See Figure 9.
4. Activate the test set and read and record the value of longitudinal balance. The test set (if made to IEEE Standard 455-1976) may be similar to Figure 10. Longitudinal balance = $10 \log (V_s/V_m)$.
5. Repeat the measurement at the CO terminal.

6. D.C. Loop Current

6.1 The DC loop current (at the voice drop) represents the current into the telephone loop. This measurement is usually made with various values of resistance representing the minimum to maximum range of resistance (outside plant and telephone set).

6.2 Measurement:

1. Access as shown in Figure 11 and seize the channel as in paragraph 2.
2. With the channel seized and the ammeter set up as shown in Figure 11, measure and record the DC current.
3. Repeat the measurement using different values of resistance and cover a range of values, including the maximum loop resistance specified by the carrier equipment manufacturer.

7. Channel Noise

7.1 Channel noise is a measure of the noise on a channel when the channel is connected but no conversation is taking place. This is also referred to as message circuit noise or circuit noise. The measurement indicates the quality of the circuit by measuring the ambient noise of the electronic circuitry plus the coupling from other voice and carrier frequency paths.

7.2 Access to the carrier channel, seizure of the channel (because of signaling), and proper adjustment of the recorded data are items that require close attention. The noise measuring set (NMS) (often combined with other measuring instruments in a common test set) should have a C-message filter.

7.3 Access:

7.3.1 At the measuring end, the carrier channel may be accessed at either the carrier two-wire drop or the carrier demodulator (see Figure 12). With proper adjustment of the data (because of level differences), measurements should yield the same results at both points. Access to the four-wire connections is not always available in some carrier systems. It is usually easiest to access the two-wire connections. At the distant end, the channel should be accessed at the two-wire drop and terminated (as in paragraph 2). Make sure that the central office equipment is disconnected at both ends. Seize the channel as in paragraph 2. Omit the 2 F capacitor and resistor and use a holding coil (that does not exceed the stated maximum loop resistance) if the outgoing loop dial end is to be terminated rather than measured.

7.4 Measurement:

1. If the NMS has a calibration adjustment, calibrate as indicated.
2. Set the NMS for 900 ohms (or 600 ohms at toll center or if measured at carrier demodulator), noise-balanced (metallic), C-message weighted.
3. Measure the channel noise on each channel as shown in Figure 12 and record the data in dBrnC.

7.5 Data Adjustment:

The data recorded in the previous paragraph (although valid) has little significance until properly adjusted. Requirements for noise on a carrier channel are specified with reference to the sending end or zero transmission level point (0 TLP). The noise is specified in terms of dBrnC 0, with the 0 being referred to the sending end or 0 TLP. If the channel is aligned for X dB net loss, and the noise is read at the two wire drop, X dB must be added to the reading obtained in the previous paragraph to get dBrnC 0. However, if the noise were read at the carrier demodulator (Figure 12), this is likely to be Y dB higher (+Y point) than the sending end (the demodulator output level is usually approximately 7 dBm). In this case, Y dB must be subtracted from the dBrnC reading to get dBrnC 0. Four-wire connections are often not accessible in digital systems. If not, the dB loss for which the channel is aligned is the only adjustment needed. See the manufacturer's specifications for the dB adjustment factor to be used if the four-wire connection is available and is accessed.

Example 1. The noise measured (as above) at the two-wire drop terminals of a carrier channel is 18 dBrnC. The circuit is aligned for 3 dB loss from drop to drop. The noise is thus, $18 + 3 = 21$ dBrnC 0.

Example 2. The same channel as in Example 1 was measured at the carrier demodulator and a reading of 28 dBrnC was obtained. According to the manufacturer, this point is 7 dB higher than the sending end so the resultant noise is $28 - 7 = 21$ dBrnC 0. This is identical to the adjusted noise of Example 1.

8. Impulse Noise

8.1 Impulse noise is characterized by transient disturbances (impulses) separated in time by quiescent intervals. In digital systems transmitting voice or data, these measurements can be very important if large amplitude, short duration pulses are present. Impulse noise measurements are different from channel noise measurements in that the instrument used for measuring is a counter--it counts the number of transient high-amplitude pulses exceeding a specified reference value (or values).

8.2 Access:

8.2.1 At the measuring end, the carrier channel may be accessed at either the carrier two-wire drop or the carrier demodulator (Figure 13). With proper adjustment of the impulse noise counter (because of differences in levels), measurements should yield the same results at both points. Many digital PCM carrier systems do not make available access to their four-wire connections so it is usually easiest to access the two-wire drop.

8.2.2 At the distant end, the channel should be accessed at the two-wire drop and terminated (as in paragraph 2). Make sure that the central office is disconnected at both ends. Seize the channel as in paragraph 2. (Omit the 2 F capacitor and resistor and substitute a holding coil if the outgoing loop dial end is to be terminated rather than measured.)

8.2.3 On many facilities, impulse noise measurements must be made with a holding tone on. This tone is nominally 1 kHz (usually 1004 Hz) and is applied at the two-wire drop of the sending, or distant end. When using a holding tone, an impulse noise counter with a notch filter (at the nominal 1 kHz) must be used. See the carrier equipment manufacturer's instructions to determine whether or not a holding tone is needed, and the level of this tone.

8.3 Measurement:

8.3.1 Unlike channel noise measurements where the data is adjusted after the measurements are taken, the impulse noise counter must be adjusted to the zero transmission level point (0 TLP) before measuring. If the impulse noise is measured at the two-wire drop, the reference level dials should be reduced by the amount of the circuit net loss (drop to drop) at 1700 Hz. The 1700 Hz loss may be denoted by the average loss between 1000 and 2300 Hz. If the impulse noise is measured at the demodulator of the analog carrier channel, set the reference dials 7 dB higher than the impulse noise requirements (assuming the demodulator level is 7 dB higher than the sending-end level). If accessing the receive terminals of the four-wire connection in a digital PCM channel bank, refer to the manufacturer's specifications for the set output level. This level will determine where to set the reference level dials.

8.3.2 The noise is measured in terms of X counts in Y minutes above Z reference level (at 0 TLP). One of the most common objectives is for toll connecting trunks. One objective is no more than 15 counts above Z in 15 minutes during the busy hour. Make sure to know the requirement for the facility under test.

8.3.4 Most counters have 3 or 4 registers in them. These can be set at the objective and also at several dB above and below the objective to determine a range of the impulse amplitudes.

8.3.5 To measure impulse noise, proceed as follows:

1. Connect the line terminals of the counter to the carrier two-wire drop (or demodulator or four-wire receive terminals in a digital system).

2. If on a system where a holding tone is necessary, connect an oscillator (set at 1004 Hz) to the two-wire drop of the distant end and set the level according to the carrier equipment manufacturer's instructions.

3. Select the weighting (usually C-message). Switch in the notch filter if using a holding tone.

4. Select reference levels.

5. Select the counting time.

6. Set the counters to zero. See Figure 13.

7. After waiting the required time, record the readings.

Example 1. A compandored trunk is aligned for 3.0 dB net loss at 1004 Hz (and is also approximately 3.0 dB at 1700 and 2300 Hz) and is being checked to see if it meets impulse noise objectives. Our objective is no more than 15 counts in 15 minutes during the busy hour above 44 dBrnC 0 (for example), C-message weighted. This would make the reference level $44 - 3$ (net loss) = 41 dB. The main reference level is set for 30 dBrnC and incremental levels A, B, and C are set for 5, 11, and 17 respectively. This checks the impulses 6 dB above (C=47) and below (A=35) the requirement, as well as the requirement itself (B = 41 dBrnC). The filter is set for C-message weighting, time for 15 minutes and last, the counters (displays) are set to zero. After 15 minutes, A=140, B=30, and C=17. This means that there were B = 30 counts that exceeded the 44 dBrnC 0 level objective. This circuit will not meet the specified impulse noise objectives.

9. Intrasystem Crosstalk

9.1 Crosstalk is undesired energy appearing in one signal path as a result of coupling from other signal paths. Crosstalk is expressed in dB. To be completely accurate, the terms crosstalk coupling and crosstalk loss should be used instead of only crosstalk. Crosstalk coupling is the dB difference between the disturbed circuit level and the disturbing circuit level (originating or intended signal). This should be small (large magnitude negative value). Crosstalk loss is just the opposite--the difference in dB between the disturbing circuit level and the disturbed circuit level. This is desired to be large. The circuits referred to will likely be different paths on carrier equipment. Crosstalk loss is equal in magnitude to crosstalk coupling but opposite in sign. Crosstalk loss is more often used since this reduces the use of negative signs. Henceforth in this section, the term crosstalk will be used to mean crosstalk loss.

9.2 The terms intrasystem crosstalk and intersystem crosstalk are often discussed in telecommunications testing. Since intersystem crosstalk usually concerns crosstalk between cables (outside plant), only intrasystem crosstalk is addressed here. Intrasystem crosstalk is a function of equipment design, but also takes into account the noise coupled from various paths in the system.

Example 1. Looking at Figure 14, the noise generator output level is set at 0 dBm. The near-end NMS measures -72 dBm and the far-end NMS measures -80 dBm. If the insertion loss (IL) is known, just subtract this from the transmitted level to get the far-end reference level. If the insertion loss isn't known, it must be measured (see paragraph 3). Say IL = 3 dB. Then far-end and near-end crosstalk loss are determined as follows:

$$\begin{aligned}\text{far-end crosstalk loss} &= \text{far-end reference level} - \text{far-end NMS reading} \\ &= -3 \text{ dB} (= \text{transmitted} - \text{IL}) - (-80 \text{ dBm}) \\ &= \underline{77 \text{ dB}}\end{aligned}$$

$$\begin{aligned}\text{near-end crosstalk loss} &= \text{transmitted level} - \text{near-end NMS reading} \\ &= 0 \text{ dBm} - (-72 \text{ dBm}) \\ &= \underline{72 \text{ dB}}\end{aligned}$$

9.3 Access:

9.3.1 It is advantageous to have a noise generator and a noise measuring set at both the CO terminal and subscriber terminal. Access and seize the channel as in paragraph 2.

9.4 Crosstalk Loss Measurement:

1. Referring to Figure 14, connect the noise generator and noise measuring sets as indicated. (There is no need to disturb the other channels that are in service.)
2. With the noise generator output level set at 0 dBm and the NMS's set for C-message weighting (and their hold coils switched in), record the crosstalk loss values from the NMS's.
3. Repeat the measurements with the noise generator at the subscriber end.
4. Repeat the measurements for all channels and then connect the noise generator to another channel to allow it to act as the new disturbing circuit.

10. VF Level Tracking

10.1 When measuring VF level tracking, it is necessary to measure in both directions--CO to subscriber and subscriber to CO. The VF level tracking error determines the compandor's compression and expansion tracking match over the speech range. A compandor with a significant tracking error will introduce distortion. This measurement also may be used to check any nonlinearity in the voice frequency levels.

10.2 Measurement:

1. Access and seize the channel as in paragraph 2.

2. With the channel seized as in Figure 2, a reference measurement must be taken if the circuit net loss is as yet unknown. If it is known from installation data or a previous measurement (such as in paragraph 3 "Voice Frequency Insertion Loss"), this reference may not be taken but should be verified if possible.

The reference is determined by sending 0 dBm (or the level specified by the carrier equipment manufacturer) and recording the received level. Send at 1004 Hz. This level is taken to be the circuit net loss. This loss is due to the carrier equipment exclusive of the compandor since the compandor does no compressing or expanding of a 0 dBm level signal (or the specified level).

3. For all succeeding level data points, reduce the reference level dial by the net loss amount. If the exact amount is not available on the level meter dial, use the closest value and adjust calculations accordingly (see example following).

4. After the circuit net loss is calculated, lower the input level in steps of a few dB at a time and record the received levels. The VF level tracking error is the difference between the sent level, and the received level adjusted by the net loss.

Example 1. On a particular analog carrier system, it is known (or measured) that the trunk is aligned for a 3 dB net loss. On the test set used, levels can only be adjusted in steps of 5 dB, so the receiver reference dial is left at 0 dB. As one data point, the level transmitted is -2 dBm and the level received is -5.4 dBm. First adjust the received level, $-5.4 \text{ dBm} + 3 \text{ dB (net loss)} = -2.4 \text{ dBm}$. Next, calculate the VF level tracking error. (VF level tracking error = VFLTE)

VFLTE = adjusted received level - transmitted level
 = $-2.4 \text{ dBm} - (-2 \text{ dBm})$
 = -0.4 dB

11. Noise Measurements Concerning Battery and Power Supplies

11.1 These measurements reflect the amount of noise coupled from the battery and power supply systems to the carrier system. Many devices are connected to a power board, which is connected to the CO battery. (The battery acts as a large filter capacitor.) One of these measurements determines noise at the connection point (power board). This noise is generated by various devices in the CO, and is transmitted through a common power lead. The other measurement determines channel noise introduced into the carrier system by these various devices. The measurements described are just guidelines; it will probably be necessary to adapt the set-ups to the particular powering system under test.

11.2 Connection Point Noise

11.2.1 This test simply measures the noise at the power board. Some experimentation with resistor values and connections may be needed to determine the best configuration of equipment.

11.2.1 Measurement:

1. With all channels idle, connect the noise measuring set as in Figure 15. Set it for C-message weighting.
2. Measure and record the noise values (in dBrnC) from the noise measuring set.
3. Repeat this measurement with channels in operation, going off-hook, dialing, and ringing. Also repeat the measurement using a 3 kHz flat weighting.

11.3 Channel Noise from CO Noise

11.3.1 This measurement depends greatly on the physical configuration of the battery, leads, and power supply, so again, experimentation with the test set-up (noise source, impedance of power leads) may be needed.

11.4 Measurement:

1. Access and seize the channel as in paragraph 2.
2. Connect the noise measuring sets and noise generator as in Figure 16. Set the impedances of the noise measuring sets to match the line impedances and the noise generator to its low impedance setting.
3. Adjust the noise generator output so that at point A in Figure 16 the noise is approximately 60 dBrnC.
4. Measure and record the channel noise read from the noise measuring sets. For reference, a measurement taken without the noise generator may be useful.

12. Pulse Signaling

12.1 Pulse signaling measurements are made to determine the accuracy of the equipment under test when dialing is done. Trunk carrier terminals are equipped with either E&M or loop dial signaling. Following are some notes on these configurations.

12.1.1 E&M: Carrier terminals employing E&M signaling at both ends are generally two-way trunks and usually must be checked in both directions.

12.1.2 Loop dial: If both carrier terminals have loop dial signaling, one end is outgoing loop dial (sending end) and the other is incoming loop dial (receiving end) for signaling in one direction only. Two-way loop dial signaling is not used on carrier trunks.

12.1.3 E&M and Loop dial: This combination consists of outgoing or incoming loop dial signaling at one end and E&M signaling at the receive end. This restricts signaling to one direction only.

12.1.4 Subscriber Carrier: Subscriber carrier can only be dialed in one way--from the subscriber terminal to the CO terminal. In checking pulsing, it is the same as one-way loop dial signaling on trunks.

12.2 Access:

12.2.1 E&M: At the sending end, access the carrier "M" lead; at the receiving end, access the carrier "E" lead. These points must be disconnected from the COE.

12.2.2 Loop dial and Subscriber Carrier: Access the two-wire drop for both sending and receiving pulses.

12.3 Measurement:

12.3.1 The pulsing test set must be capable of generating at least 12 pulses per second (pps) and receiving pulses over a range of 7.5 to 12 pps. The test set should measure pulse ratios in the range of 30 to 70 percent break (% BRK) and generate pulse ratios at 60% BRK. If the carrier equipment manufacturer requires the equipment to send and receive at other pulse ratios, the pulsing test set should accommodate them. The test set should be equipped to measure both E&M and loop dial signaling. The received pulses must be read across "dry" contacts (contacts that do not make or break current). With "wet" contacts, a slave relay (or meter relay, or A-relay) must be used. The test set must employ a low impedance receiver containing the equivalent of an A-relay or slave relay for loop dial pulsing tests. High impedance receivers in some older test equipment may cause erroneous readings unless they are modified to include an A-relay or slave relay.

12.3.2 E&M:

1. Adjust the test sets at each end for E&M signaling.
2. With an off-hook at the distant (sending) end, calibrate the receiving test set (Figure 17).
3. Connect the sending test set and send 10 pps at 60% BRK on the "M" lead as shown in Figure 18. Read and record the received percent break.
4. Send at other speeds and percent break as required by the carrier equipment specification. Where inband signaling is used, special attention should be given to the pulsing limits of the signaling units under test.

12.3.3 Loop Dial and Subscriber Carrier:

1. Adjust the test sets at each end for loop signaling. A low impedance receiver must be used for loop dial and subscriber carrier pulsing tests.
2. With an off-hook at the distant (sending) end, calibrate the receiving test set.
3. Connect the sending test set and send 10 pps at 60% BRK. Apply the pulses under the following three conditions: 1) direct from the pulser (Figure 19); 2) through loop (Figure 20); and 3) through "A" leak (Figure 21). These conditions can usually be switched in on modern pulsing test sets. (Loop and "A" leak are described below.)
4. Read and record the received percent break from the receiving test set.

12.4 Loop and "A" leak tests as applied to loop dial signaling: The loop network represents the longest loop resistance that the carrier signaling is likely to encounter. For loop dial signaling, this is 1900 ohms; for subscriber carrier, it is the manufacturer's specified loop resistance limit. The "A" leak network represents 5 ringers bridged across the loop with high leakage (15,000 ohms on the line and drop wire). An "A" leak network is shown in Figure 22.

12.4.1 Loop and "A" leak tests are used to test the carrier signaling under limiting conditions. Pulses sent at 60% BRK at 10 pps through loop and across the "A" leak network must be received within the range of 50 to 70 percent break.

13. Ringling Voltage

13.1 This measurement is made to determine if a system is providing the proper voltage to power a telephone ringer. There are single frequency (usually 20 Hz) straight line ringers usually used for single party service and frequency selective ringers usually used for multiparty service (16-66 Hz). The particular voltage needed may vary between ringers.

13.2 Measurement:

Regardless of the type of ringling, it must be known where the ringling voltage is applied (tip-to-ring bridged, usually).

1. Access these leads.
2. Connect the voltmeter (or test set).
3. Apply the necessary ringling signal to the central office terminal channel voice drop. For in-service equipment, the subscriber's number may be dialed to initiate ringling.
4. Measure the voltage applied to the ringer.

13.3 An "A" leak network was formerly used to simulate 5 ringers bridged across the loop with high leakage. A more representative load for 5 bridged straight line ringers would be 1600 ohms coupled with a 50 F nonpolarized capacitor. Connect this load to the ringing leads and then measure the ringing voltage.

14. Carrier Frequency Levels

14.1 This measurement is simply the determination of levels at various carrier frequencies. It may indicate the presence of an existing or potential problem in a system's carrier frequency operation. In fact, with the reliability and accuracy of present-day carrier equipment, carrier frequency levels are usually only measured when a problem is suspected. This is a test for analog carrier systems.

14.2 Since this is a carrier frequency measurement, access must be made to the carrier frequency terminals of the CO. If on a repeatered system, levels can also be measured at the inputs and outputs of repeaters to help ascertain their performance. This measurement can be made on in-service equipment and can also be made at the central office terminal using an artificial line and termination unit.

14.3 Measurement:

14.3.1 Levels can be measured with a frequency selective voltmeter (FSVM), transmission test set, or similar carrier test set. The equipment must operate in a bridging mode (have high (about 5000 ohms) input impedance) so as not to alter the line impedance.

14.3.2 The measurement procedures for the two methods (on in-service equipment and using an artificial line at the CO) are identical except that the artificial line measurements are made at the CO only.

1. For both methods, seize the channel as in paragraph 2. Refer to the appropriate figures for each method (Figure 23 for the artificial line method and Figure 24 for the in-service equipment method).

2. With the channel seized, activate and position the level meter at the point closest to the CO terminal. Also set the meter to the correct frequency, as indicated by the carrier equipment manufacturer.

3. Read and record the level indicated on the meter when transmitting from CO to subscriber, and then from subscriber to CO. Make sure to reconnect the meter to the corresponding pair transmitting in the reverse direction. Also be sure to be on the correct frequency.

4. Repeat the level measurements for all channels and then measure at a different distance, placing the meter at increasing distances from the CO terminal.

14.3.3 On a longer system where repeaters are used (see Figure 24) these level measurements can supplement conventional repeater tests.

15. Digital High Frequency Measurements

15.1 With the proliferation of digital transmission techniques in telecommunications, many varied measurements for testing digital system quality have been proposed. Along with some standard measurements, done as on analog systems, there have been some measurements unique to certain manufacturers (Sierra's crosstalk margin and S/N margin for example). Most of these measurements are similar and most give an indication of a system's S/N ratio or noise immunity. Some may be for cable spans and equipment. Each manufacturer should give an explanation of the special measurements, and many will give tables or graphs for conversion of their special value to a standard transmission test term.

16. Error Detection Measurements

16.1 As previously mentioned, there are a number of measurements used to check errors on digital systems. Since these are usually variations of the types of test equipment themselves and not external configuration differences, the set-up procedures and actual testing procedures are nearly identical.

16.2 Two of the most common error detection tests are bipolar violations count and bit error rate (BER). Bipolar violations are errors in the alternate mark inversion T1 coding scheme. These occur when two (or more) pulses of like polarity are not separated by a pulse of opposite polarity (on the T1 line).

16.3 Bit error rate is a measure of system performance that denotes the ratio of the number of characters of a message incorrectly received to the number of characters of the message received. It is usually expressed as 10 to the X power, X being a negative number. The larger the magnitude of the negative exponent X , the better the performance. For example, 10^{-6} , one error in one million bits, is better than 10^{-3} , one error in one thousand bits. The actual number of errors is of course not always 1 in 10^X but is usually rounded off (by the test equipment) to the nearest power of ten. For small BER's (10^{-5} and below), the BER is approximately equal to the number of bipolar violations.

16.4 Other fairly common tests of digital system quality are error-seconds and error-free seconds. Error seconds is simply a measure of the number of seconds out of the total test time in which errors (one or more) were detected. Error-free seconds is just the opposite -- the number of seconds out of the total in which there were no (zero) errors.

16.5 Measurement:

1. Connect the PCM error counter (or Error Performance Analyzer) to the four-wire drop as in Figure 25. If measuring bipolar violations, error-seconds, or error-free seconds, only one test counter is used and it can be bridged at the receive pair of the four-wire terminals. If the BER is being measured, a signal generator is needed at the transmit end of the pair and a test counter at the receive end of the same pair. Usually a quasi-random

signal source (QRSS) is used to transmit the bit stream and a companion receiver compares the received signal to the known (quasi-random) signal, thus determining the BER. BER is mainly a facility measurement but can be applied to the terminal equipment if appropriate sources and receivers are available.

2. With the equipment connected as in Figure 25, set the dials to count the appropriate type of errors (or measure the appropriate quantity).

3. Set the timer for a specified time period or continuous setting (refer to test equipment manufacturer's recommendations).

4. After the prescribed time has passed, read and record the display value.

17. Data Systems

17.1 With the trend in communications toward digital transmission, much interest has been focused on data systems. In the telephone system, data is transmitted at various speeds (bit rates) using various types of modulation, requiring various forms of line treatment (equalization).

17.2 On the present-day telephone system bit rates of up to 2.4 kbit/s are possible on untreated facilities. With some minor gain and delay equalization at the terminals (modems), bit rates of 4.8 kbit/s and even 9.6 kbit/s (on dedicated facilities) are possible.

17.3 Some low speed data systems are currently in use. These include Telex, telegraph, telephotograph, and some facsimile. These systems usually transmit at no more than a few thousand bits per second.

17.4 The (former) Bell System's Digital Data System provides users with data capabilities over analog circuits greater than that permitted over the standard voice-band lines. This requires a greater frequency band utilization--6, 12, or 60 voice-band telephone channels are the current standards.

17.5 The modulation (or coding) schemes used are similar to some of the techniques used in digital radio. These include AM, VSB, QAM, FSK, and PSK. The application of these techniques is identical to that of digital radio.

17.6 Since data requirements are more stringent than voice transmission requirements, the equalization procedures taken are more critical. Data systems also may have a much lower tolerance for impulse noise than voice communication systems. Data systems suffer many of the same impairments as analog systems, but offer some advantages (compatibility with modern switching systems and devices, easier implementation of signaling).

17.7 Although some data systems may have special requirements and features, many such systems can still be tested using the methods employed in testing PCM voice systems. Bit-error rate can be measured to determine system performance. If long distances are covered by the data system, bipolar violations and signal-to-noise margin may also be valid measurements.

18. Automatic Test Equipment

18.1 Automatic and semi-automatic test equipment for telecommunications systems are finding wider use as their costs come down and capabilities increase. Just as the boundary between computers and communications is becoming less clear, so is the boundary between automatic and semi-automatic telecommunications test equipment. Manual equipment has capabilities that were termed semi-automatic a few years ago. Semi-automatic test equipment sometimes seems automatic. And automatic test equipment (ATE) and test systems have capabilities that surpass all previous generations of test equipment. The trend is toward greater sophistication and user-friendliness at all levels of testing.

18.2 This subsection gives a brief list of some of the functions available on some present ATE. It also mentions some of the applications for various types of ATE.

18.3 ATE can be classified in a number of ways: full time or part time, subscriber loop checking, trunk testing, and CO testing. Many of these categories overlap.

18.4 The tests that automatic systems provide include most or all of the basic transmission tests: transmission level; return loss; C-message noise; propagation delay; ac and dc voltages, resistance and capacitance between all combinations of tip, ring, and ground; dial pulsing and DTMF; dial tone; bipolar violations; all 1's condition on T1 systems; longitudinal balance; and pay station testing. Not every system will perform all these tests.

18.5 Some forms of ATE are designed specifically for certain applications such as E&M, FX, and CO switches. Some also have provisions for predicting trouble in advance, record administration, and statistical analysis of calls and faults.

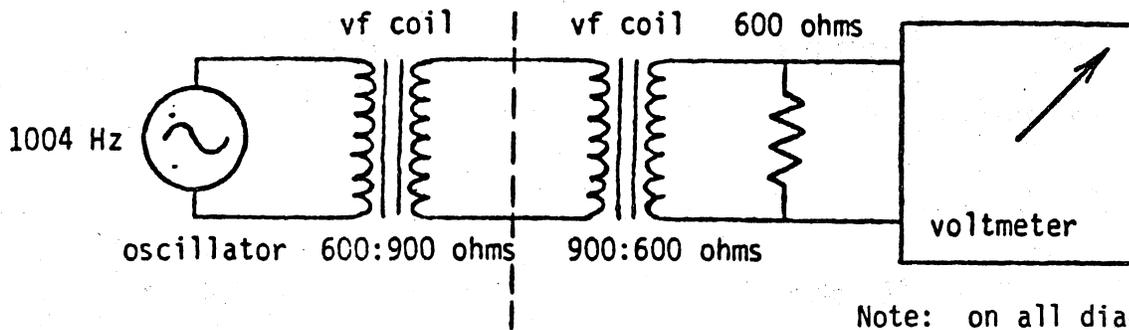
18.6 The monitoring and maintenance ATE systems do exactly what their names imply--monitor and maintain. These systems are usually full time. They provide fault reporting and often advance notice of possible problems. Alarm reporting is included in many cases. The conditions that trigger alarms are sometimes adjustable. Advanced maintenance systems notify maintenance personnel for dispatching. This dispatching can usually be done quite accurately--to within 100 feet of a line fault.

18.7 As research and development progress, more efficient ATE and systems will be produced. The already high reliability may be increased and as competition and mass production are induced, costs should come down. Although ATE and systems may be considered luxury items today, much greater use of them can be expected in the future.

19. References

19.1 Following is a list of reference materials consulted in preparing this section of the TE&CM.

1. IEEE, "IEEE Standard Dictionary of Electrical and Electronics Terms," ANSI/IEEE Std 100-1984.
2. Bell Laboratories, "Transmission Systems for Communications," Fifth Ed., 1982
3. "Glossary of Telecommunication Terms," Federal Standard-1037, 1980
4. "Transmission Parameters Affecting Voiceband Data Transmission Measuring Techniques," Bell System Technical Reference, PUB 41009, May 1975
5. Rural Electrification Administration, Telephone Engineering and Construction Manual, Section 925, "Transmission Measurements Involving Carrier Multiplex Equipment," November 1966
6. IEEE, "IEEE Standard for Measuring Longitudinal Balance of Telephone Equipment Operating in the Voice Band," IEEE Std 455-1976
7. NTCA, "NTCA Plant Testing Seminar," November 1976
Test Equipment Bulletins and Catalogs
8. Northeast Electronics, "Telecommunications Test Equipment," August 1983
9. Northern Telecom Inc., "Test Equipment for the Digital World," 1984
10. Wiltron Test Equipment Bulletins, September 1983
11. Sierra Test Equipment Bulletins, 1976-1978
12. Bowmar Test Equipment Bulletins, 1978-1979
13. Hekimian Laboratories Test Equipment Bulletin, 1983



Note: on all diagrams,
----- (dashed line)
indicates an equipment
interface

Figure 1 IL Oscillator Calibration

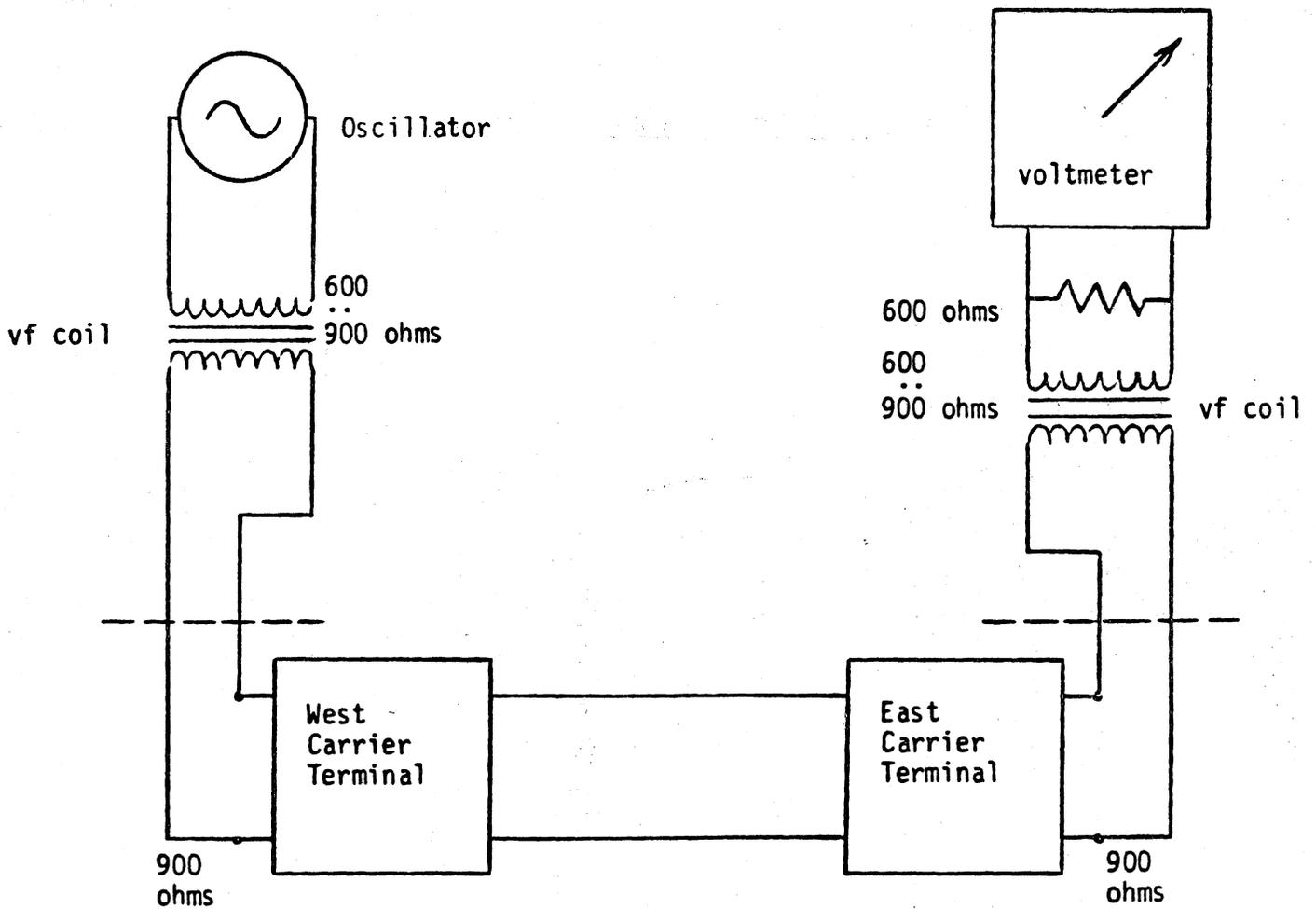


Figure 2 Insertion Loss Measurement

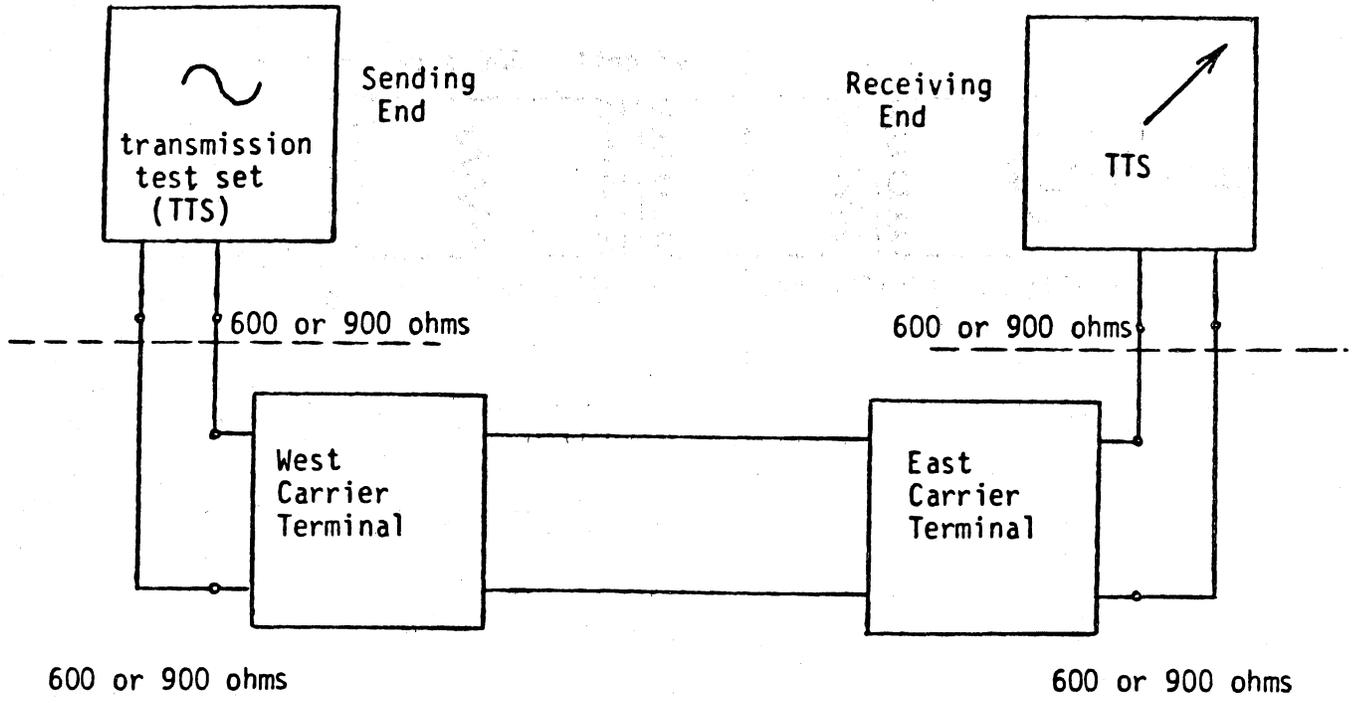


Figure 3 Insertion Loss Measurement

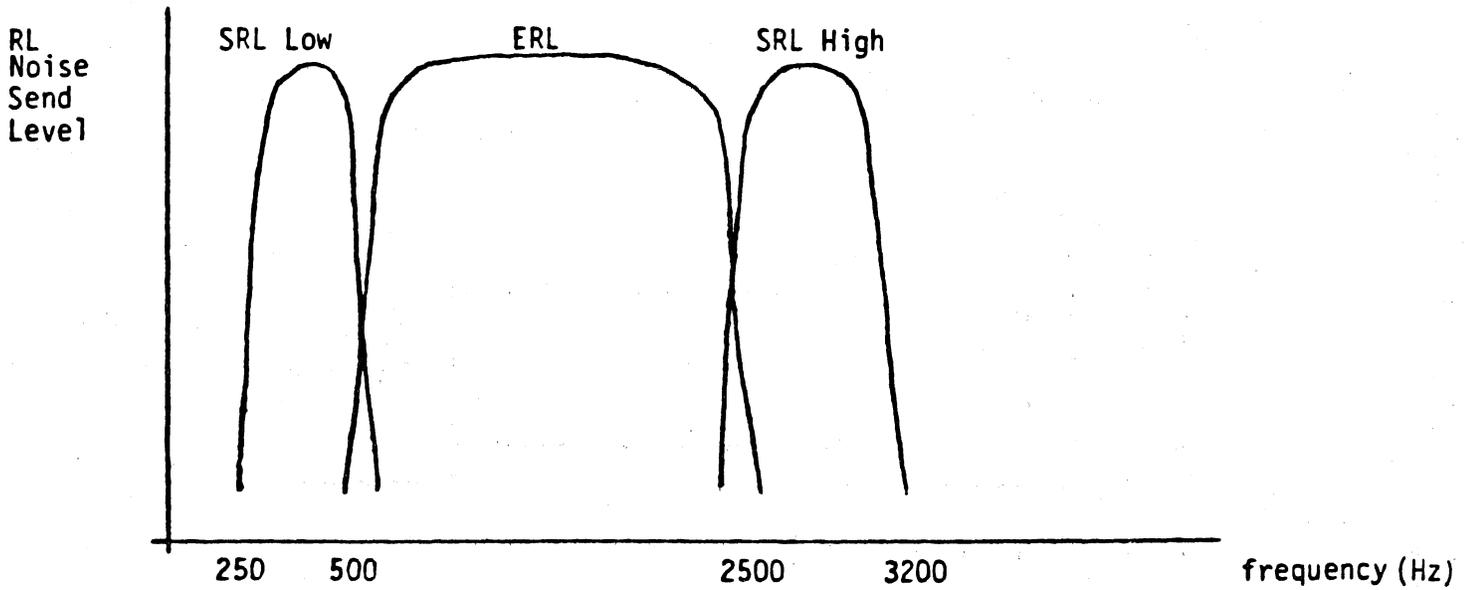
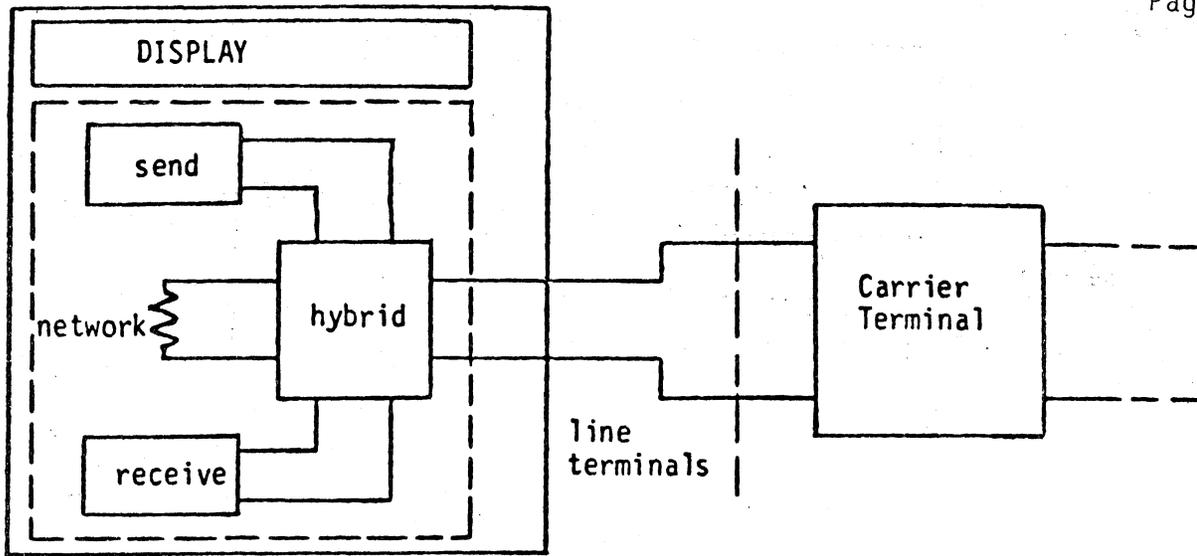
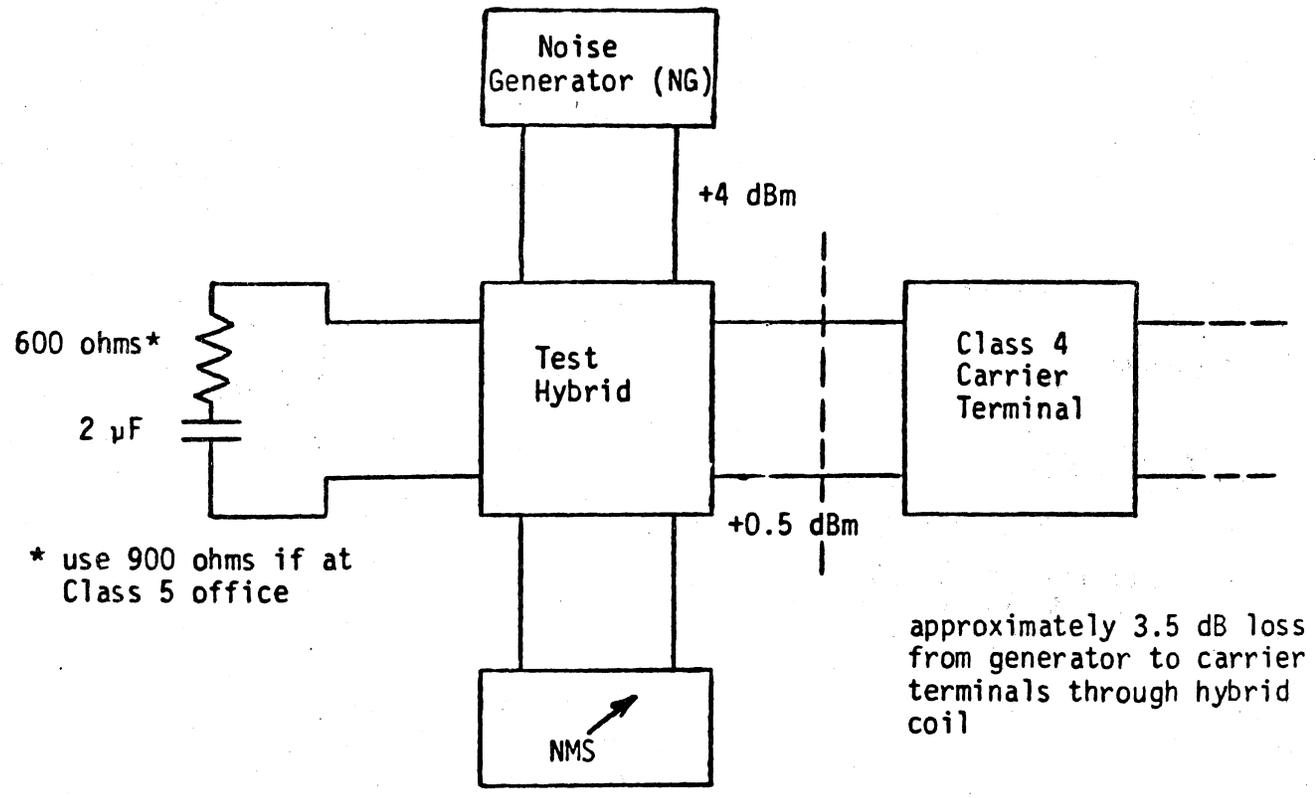


Figure 4 RL Send Levels



Wiltron, Bowmar, or equivalent
Return Loss Test Set

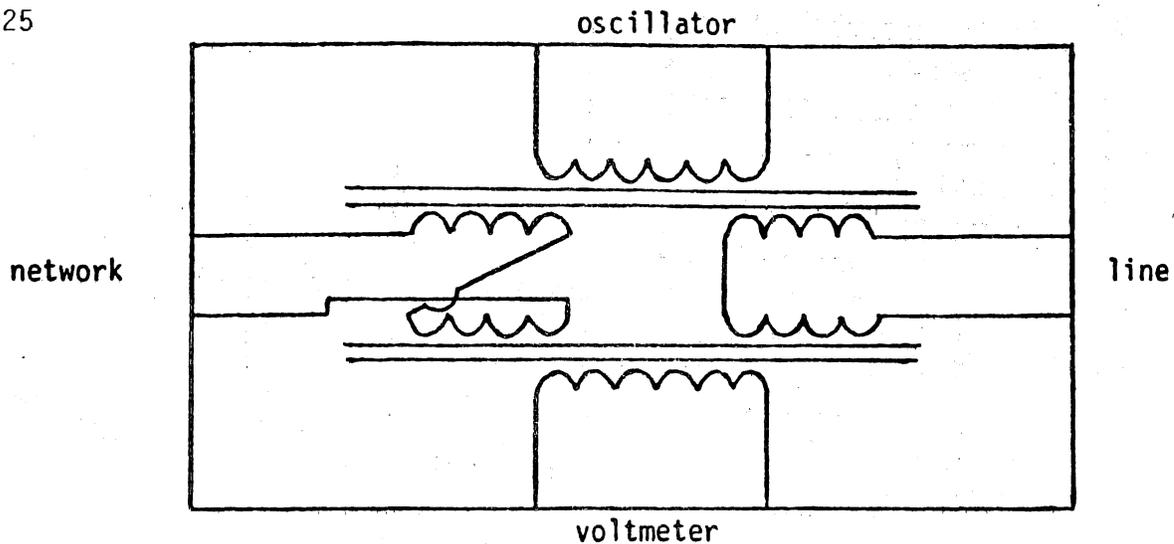
Figure 5 ERL and SRL Measurement



* use 900 ohms if at
Class 5 office

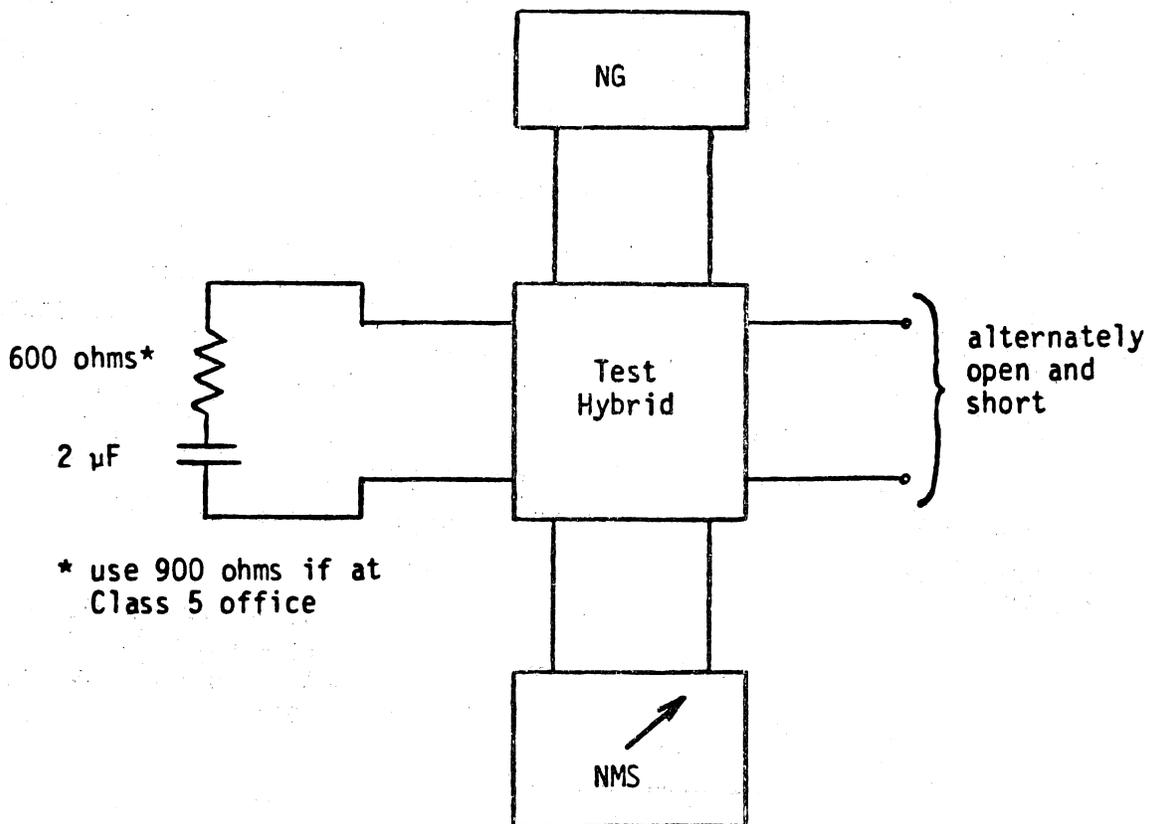
approximately 3.5 dB loss
from generator to carrier
terminals through hybrid
coil

Figure 6A Preliminary Calibration of NG



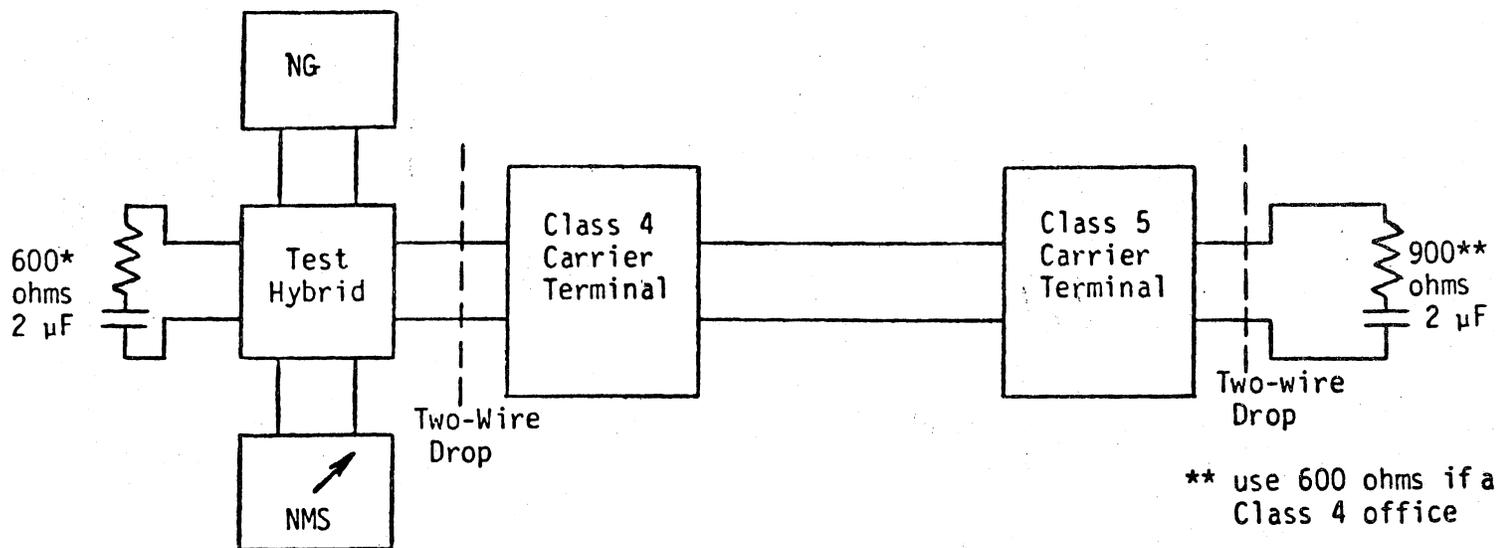
Test Hybrid Terminals

Figure 6B



* use 900 ohms if at
Class 5 office

Figure 7 ERL Reference



* use 900 ohms if at Class 5 office

Figure 8 ERL Measurement

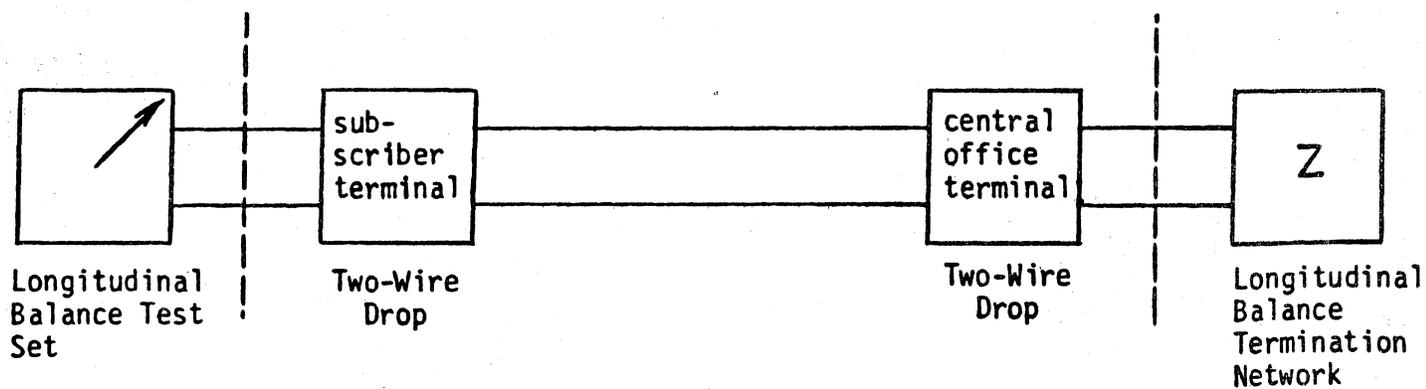


Figure 9 VF Longitudinal Balance

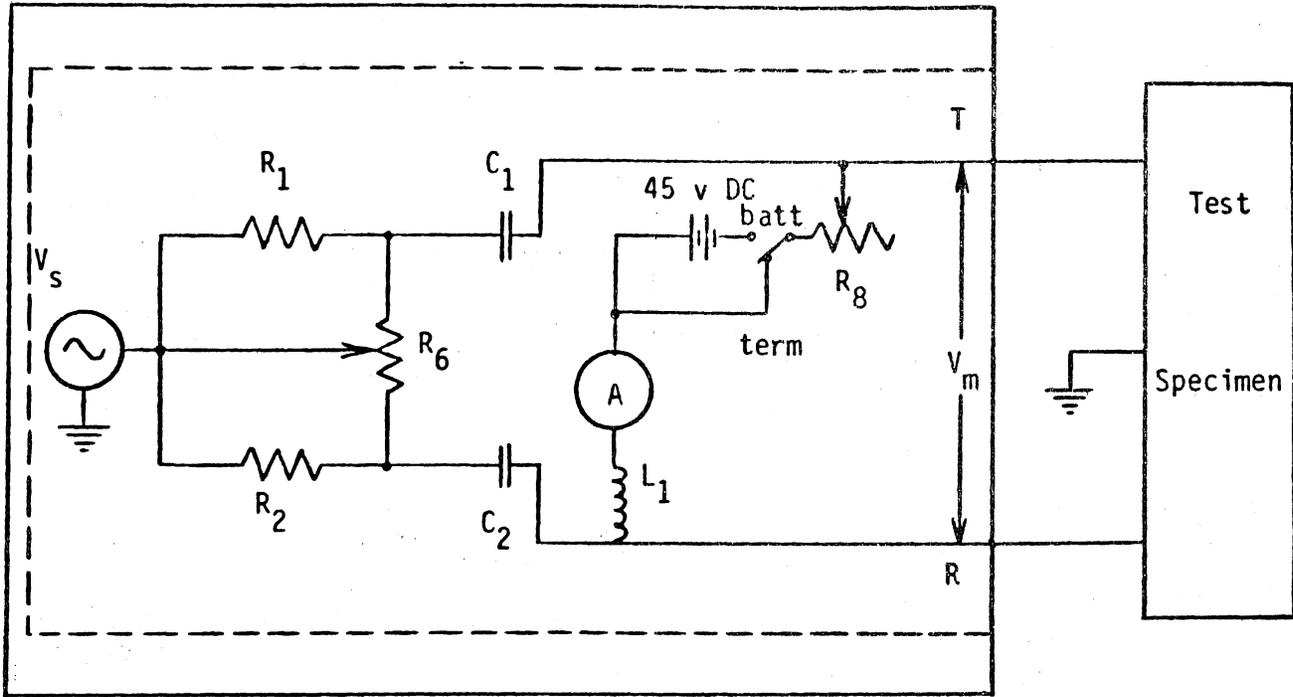


Figure 10 Longitudinal Balance Test Set

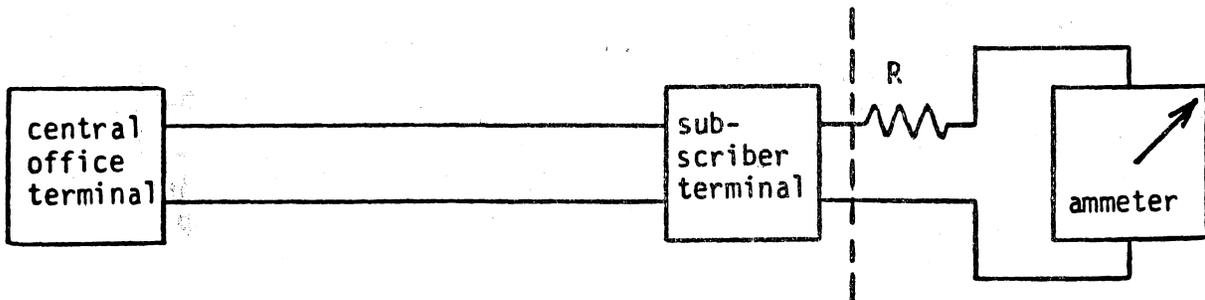
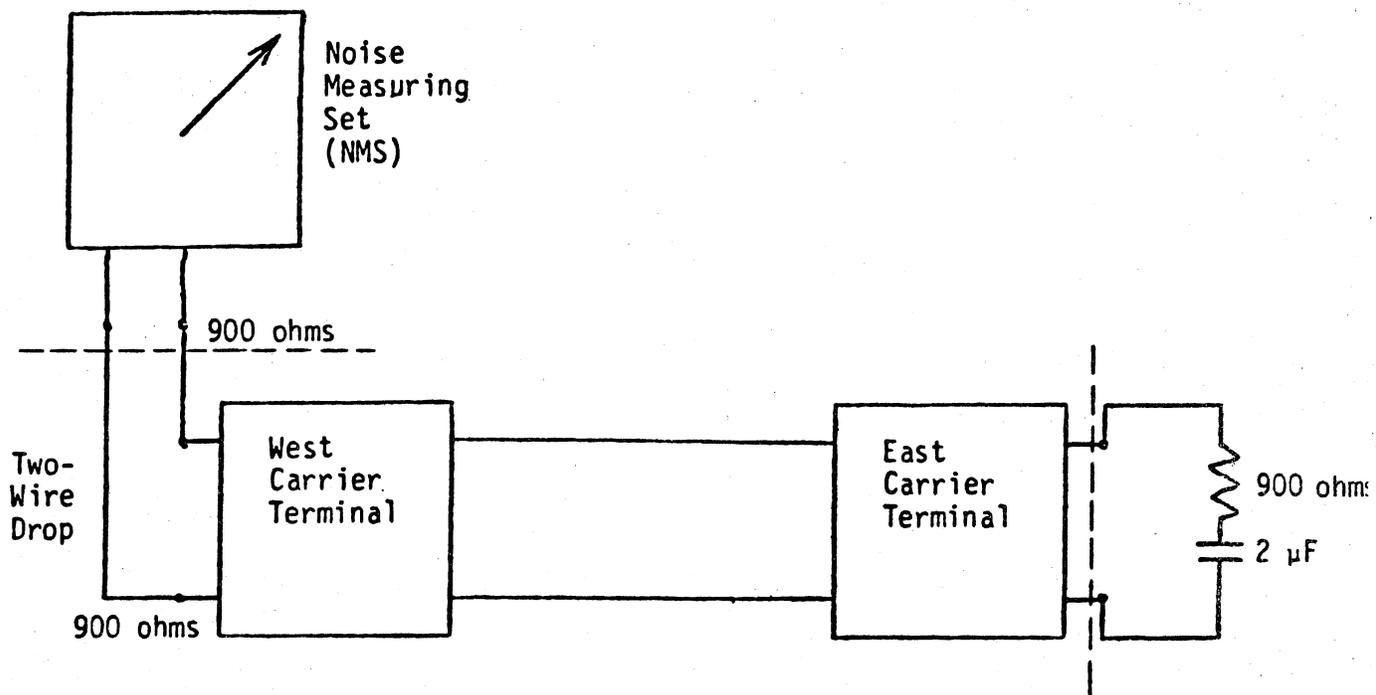
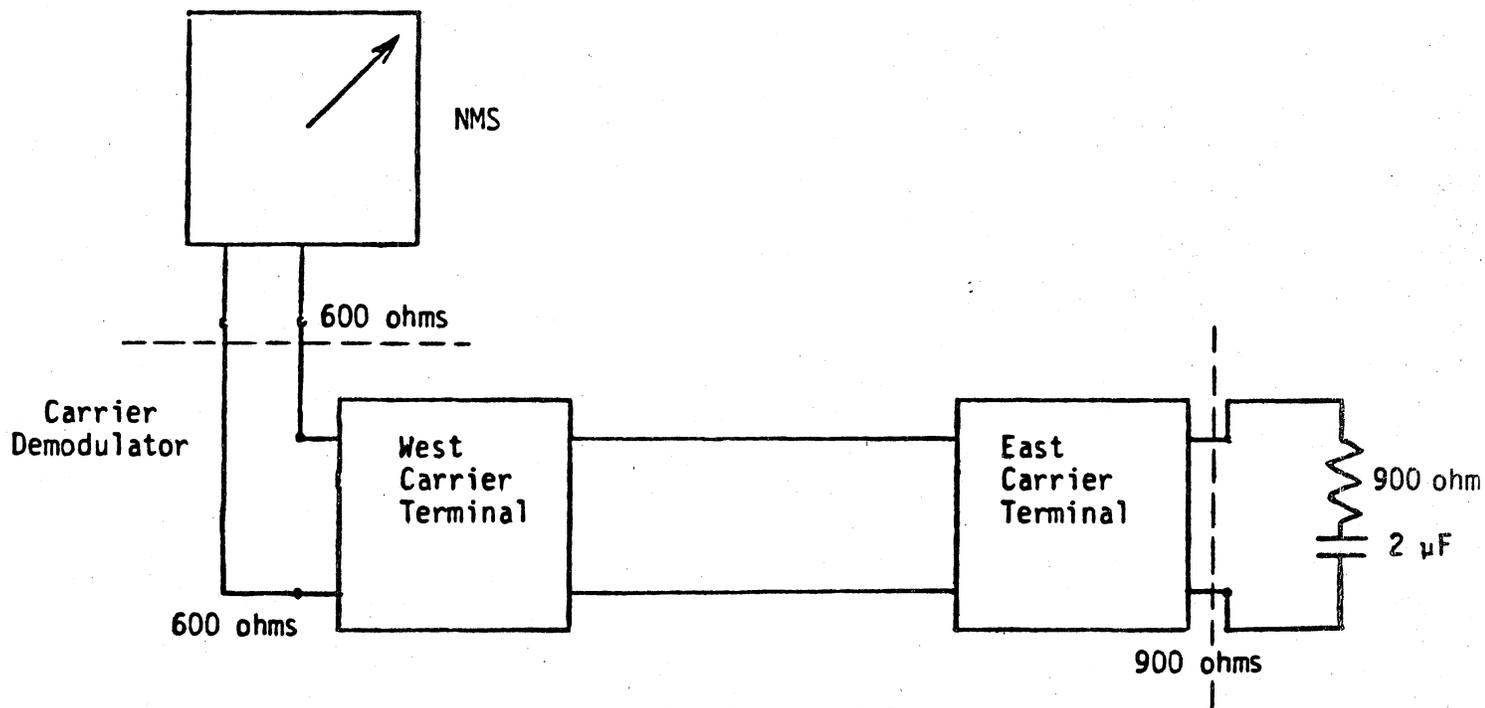


Figure 11 DC Current at Voice Drop

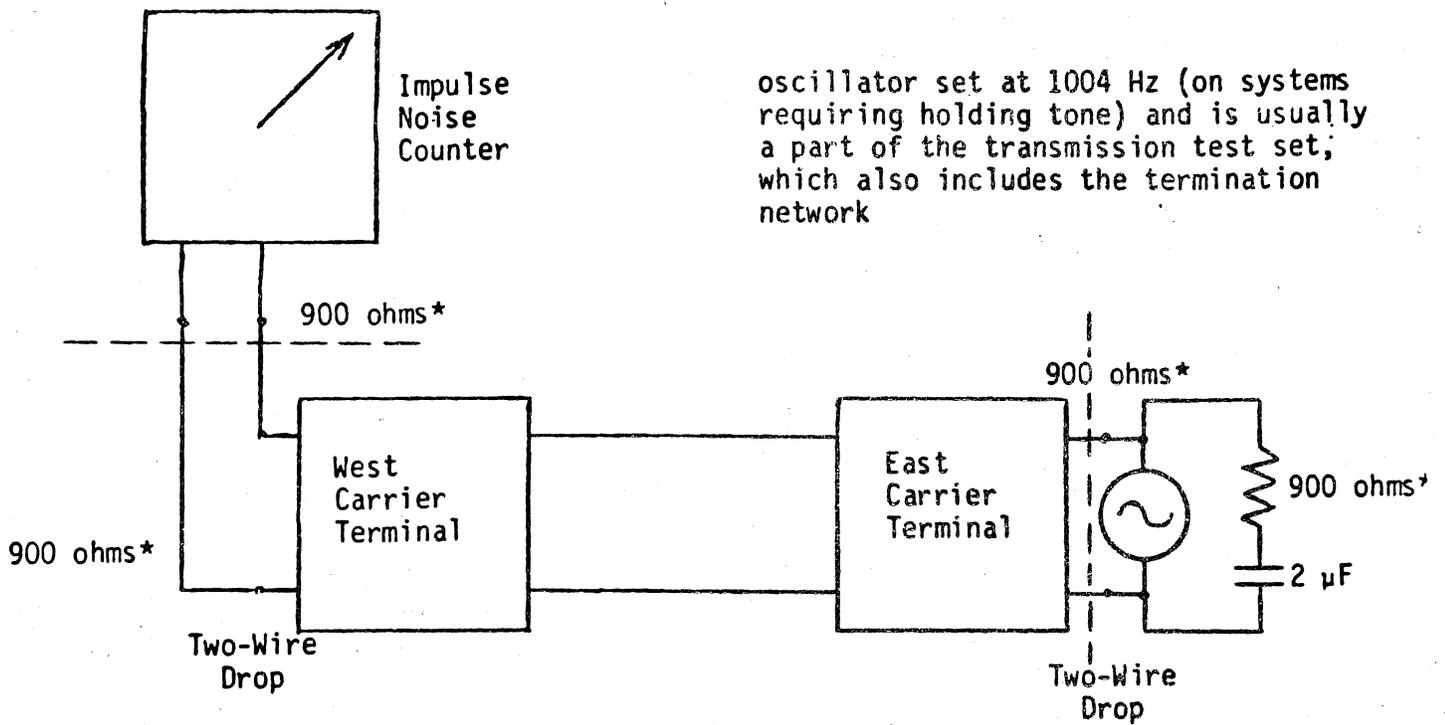


Measured at Two-Wire Drop



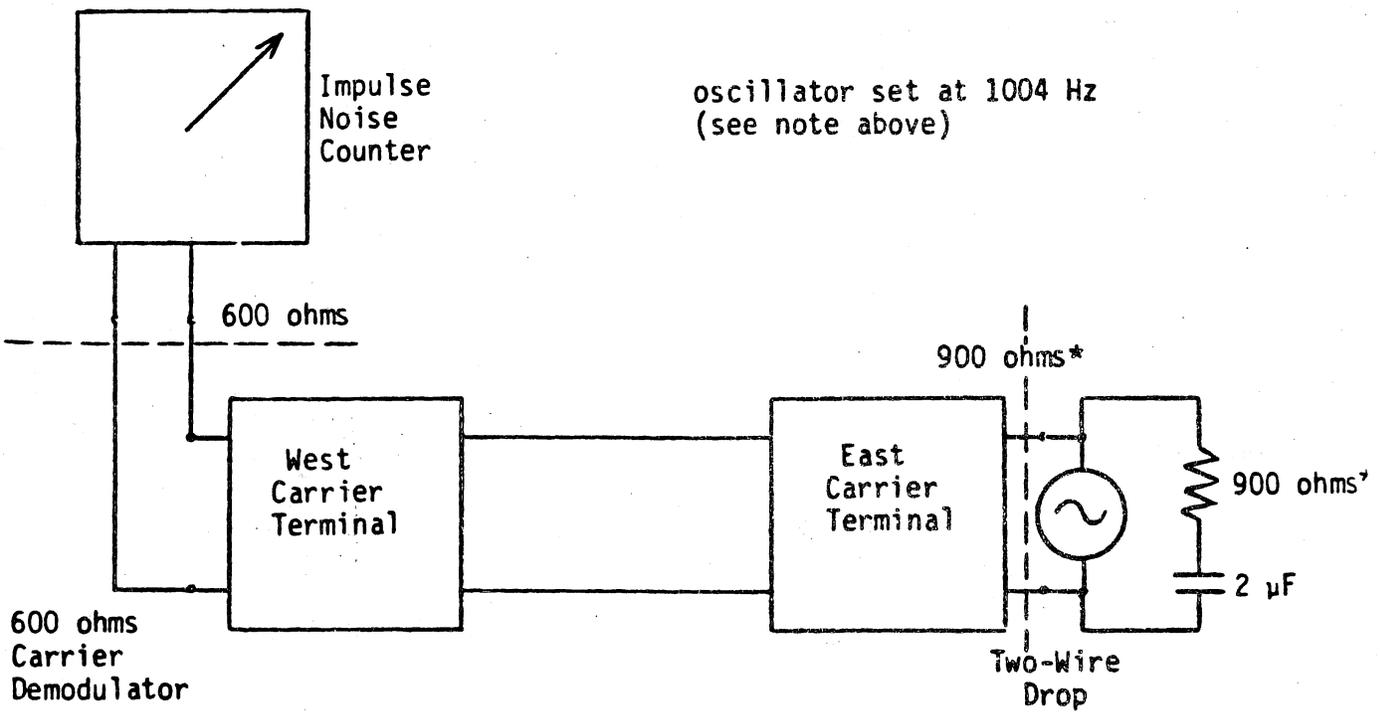
Measured at Carrier Demodulator

Figure 12 Channel Noise Measurements



Impulse Noise at Two-Wire Drop

* use 600 ohms if at toll center



Impulse Noise at Carrier Demodulator

* use 600 ohms if at toll center

Figure 13

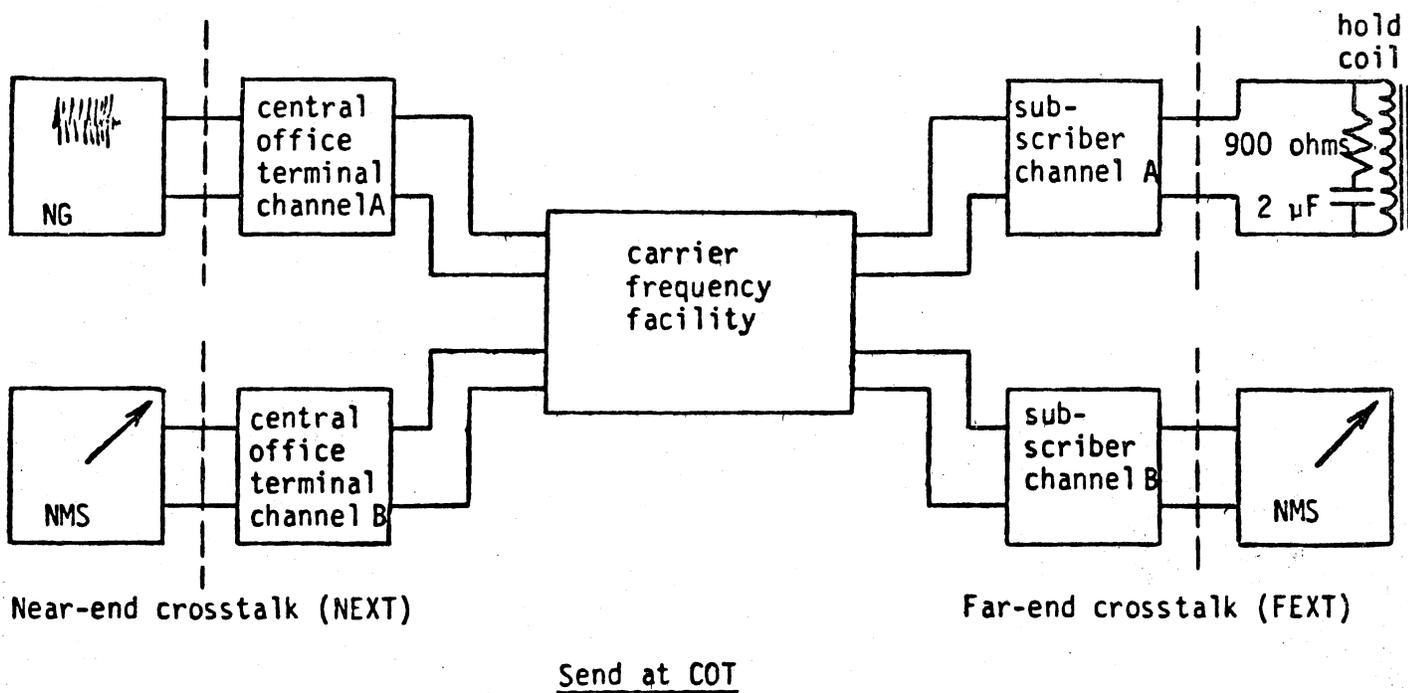


Figure 14 Intrasystem Crosstalk Measurement

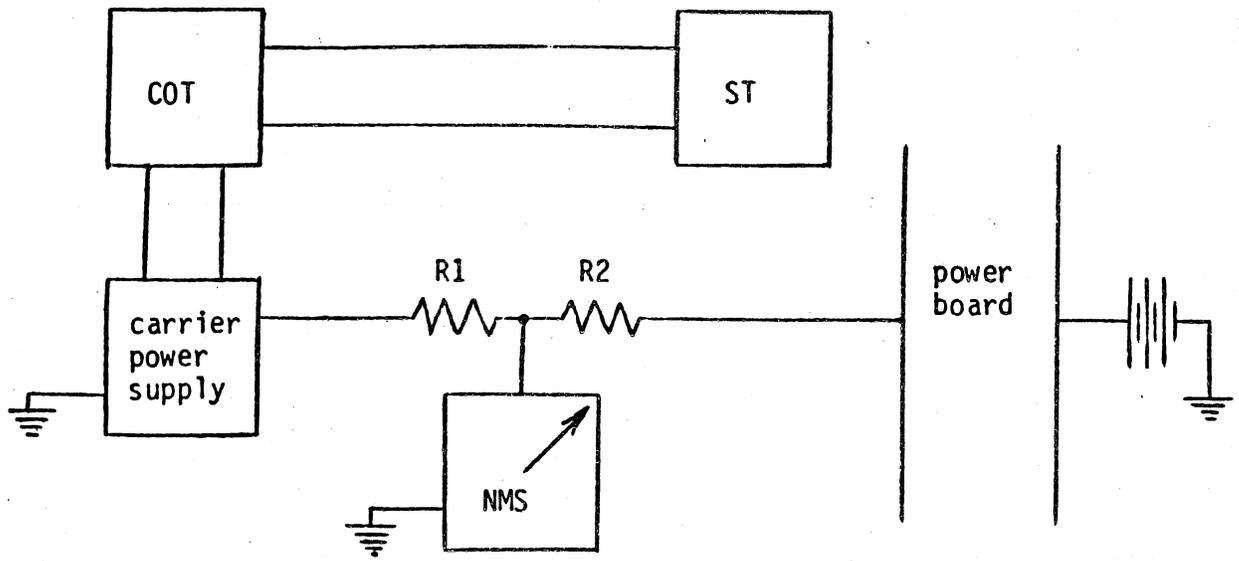


Figure 15 Connection Point Noise

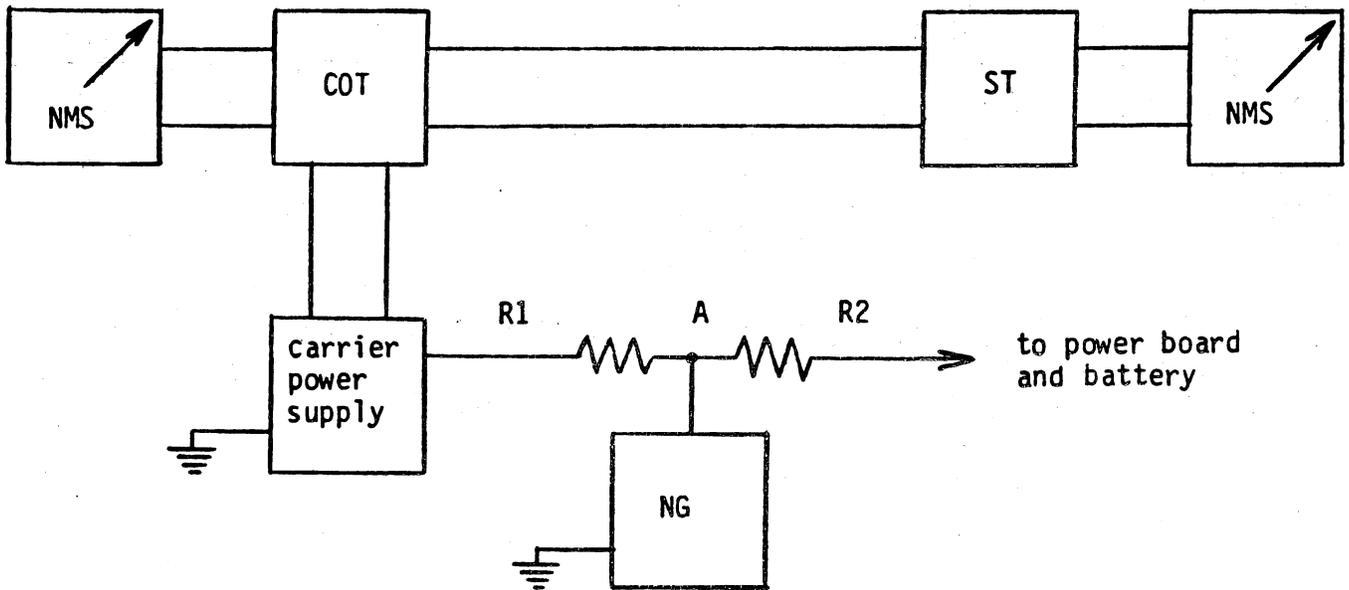


Figure 16 Channel Noise from CO Noise

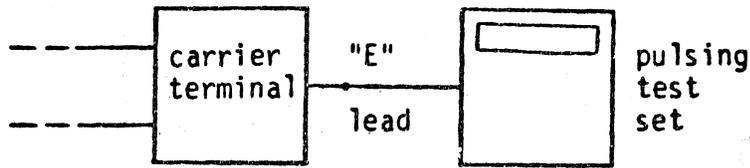


Figure 17: E&M Receive

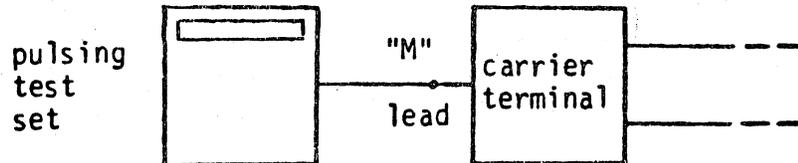


Figure 18: E&M Send

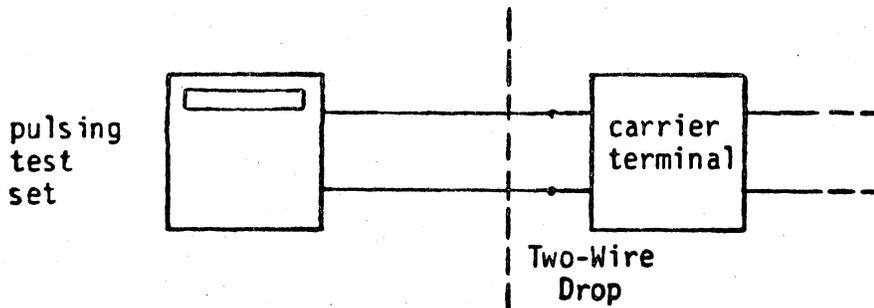


Figure 19: Loop Send: Direct

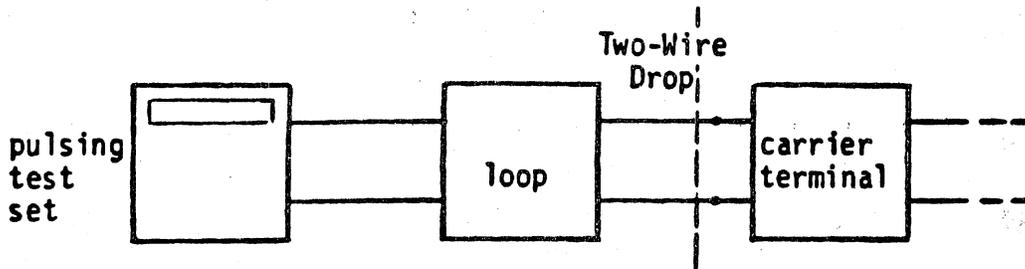


Figure 20: Loop Send: Through Loop

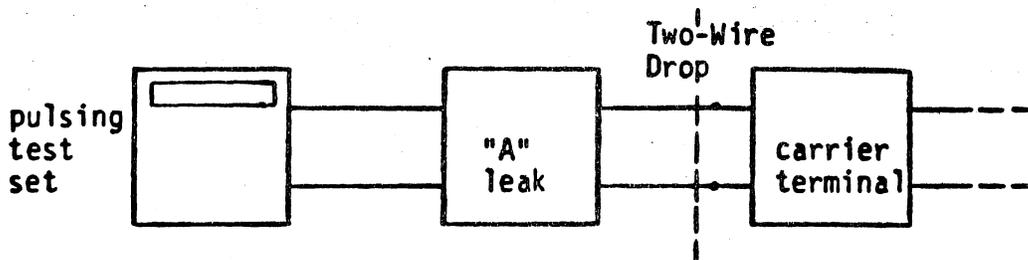


Figure 21: Loop Send: Through "A" Leak

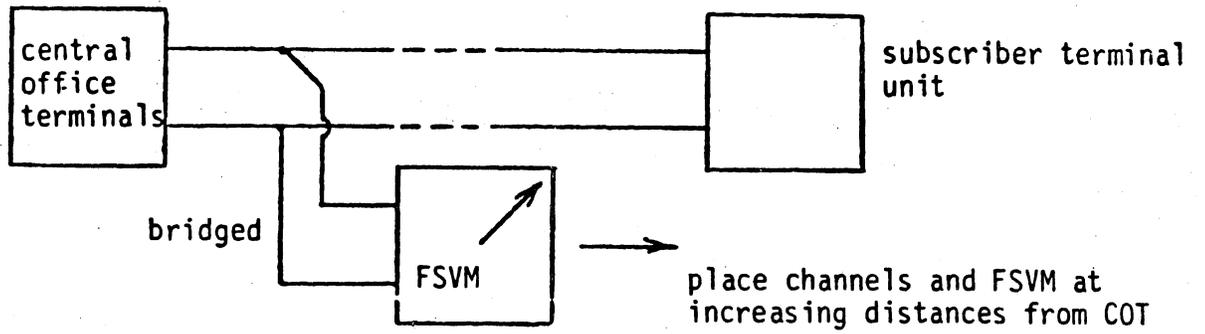
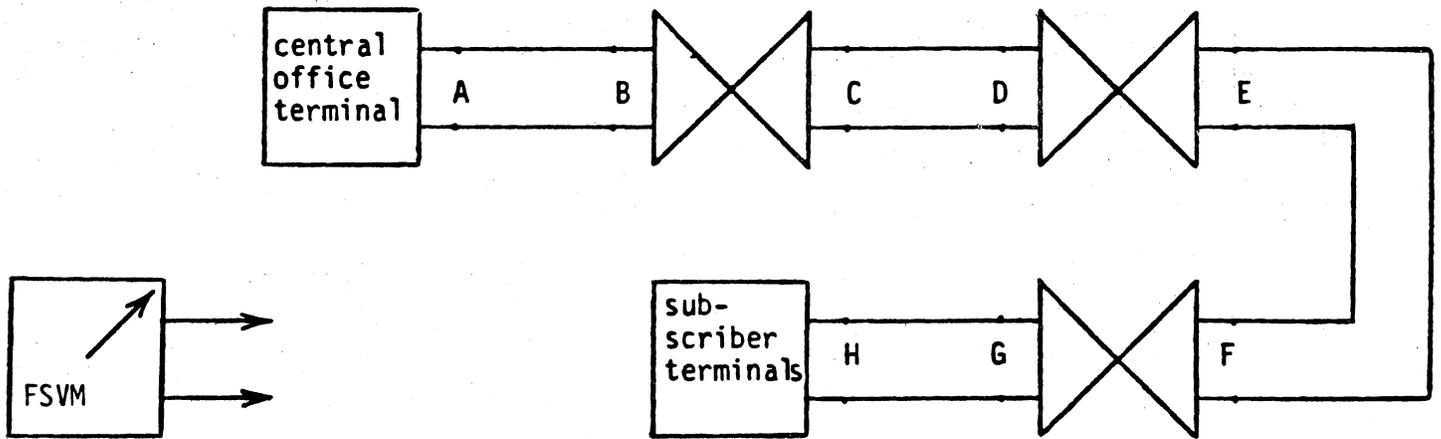


Figure 22 Artificial Line Method



measure levels at terminals A through H

Figure 23 CF Levels on In-Service Equipment

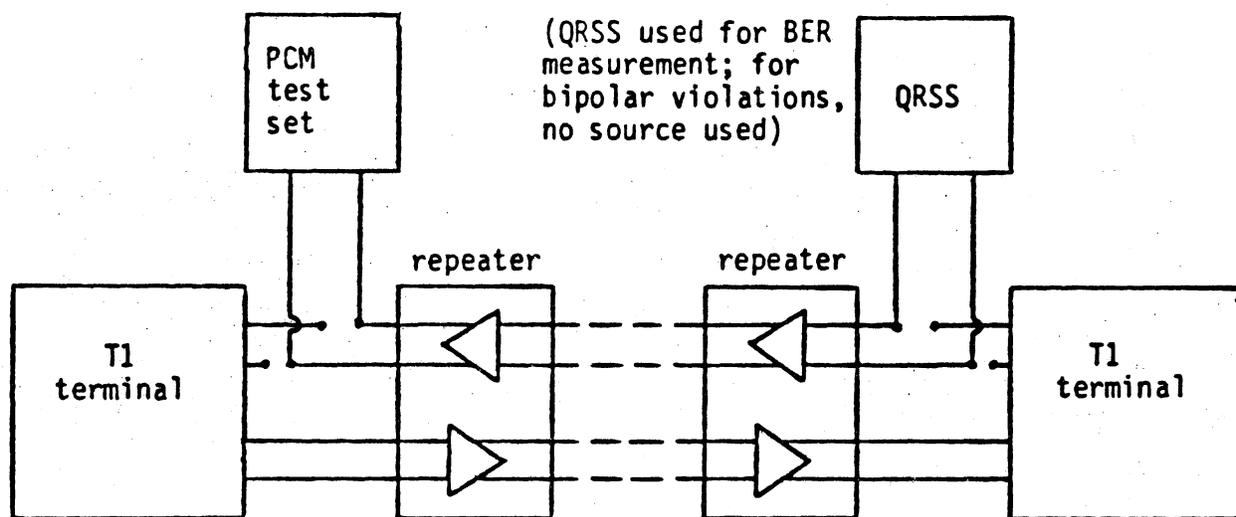


Figure 24 Error Detection Measurements