

## BALANCE TESTING CONSIDERATIONS PBX 4-WIRE VIA NET LOSS TIE TRUNKS AND ACCESS LINES

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### 1. GENERAL

**1.01** This section describes the general considerations and test requirements for both through (office) and terminal balance tests to be made at 2-wire PBXs where via net loss (VNL) tie trunks equipped with switchable pads or equivalent (101 ESS) are terminated or interconnected with other tie trunks, central office trunks, or FX trunks. This section does not cover CENTREX-CO.

**1.02** This section is reissued to add information on balance measurement objectives for 600-ohm PBXs and the use of the KS-20501 return loss measuring set (RLMS). Since this reissue covers a general revision, arrows ordinarily used to indicate changes have been omitted.

**1.03** To meet present overall transmission objectives, intertandem tie trunks are designed to operate as close to 0-dB loss as possible. This loss is called "via net loss" (VNL), and is defined as the lowest loss at which a facility (cable, carrier system, etc) may be operated without objectionable impairment from echo, singing, noise, and crosstalk. This low loss operation requires *adequate balance* at all points where VNL tie trunks are connected together

or to other trunks or lines. Therefore, these balance tests are a necessary part of the lineup and acceptance tests for tie trunks operated at VNL. The determination of VNL loss values for the various types of facilities is covered in the appropriate design sections.

**1.04** A VNL tie trunk is a 4-wire tie trunk that is operated at its VNL design loss value when it is switched to other facilities and the terminating pad is switched out. A non-VNL tie trunk is any 2- or 4-wire tie trunk that is designed to operate at some loss other than VNL, ie, VNL + 2, VNL + 4, or a designated loss not based on VNL design concepts.

**1.05** Terminal balance objectives must be met at all PBXs and Switched Service Network (SSN) offices where VNL tie trunks are connected to non-VNL tie trunks. Through balance measurements must be made and objectives met at PBXs where VNL tie trunks are switched together.

**1.06** Test procedures, required equipment, and connection arrangements are covered in Section 311-350-500.

**1.07** Although the balance tests and objectives covered in this and in the test section are a requirement for specific tie trunks (1.01), the test procedures are applicable for checking the balance on any 4-wire circuit terminating in a 2-wire PBX.

**1.08** A discussion of balance theory is included to acquaint the tester with the basic principles of and the reasons for the tests covered. Although the test procedures are so presented that this basic knowledge is not essential, such knowledge will be beneficial to the tester in performing lineup and trouble location tests.

**1.09** Prior to making the balance tests prescribed in this and in the test section, the tie trunks must be operational and meet the circuit net loss

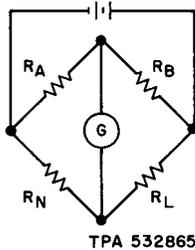
requirements specified in other sections. Switched pad operation shall have been verified by appropriate net loss measurements.

**1.10** Facilities should be checked for irregularities such as defective loading, incorrect impedance compensation, and repeater strapping, which may adversely affect terminal balance. Completion tests will generally reveal troubles that must be cleared before proceeding with balance tests.

**2. BALANCE THEORY**

**2.01** Because the voice path through most PBX switching machines is 2-wire, it is necessary to convert the voice paths of a 4-wire tie trunk to a 2-wire voice path at the PBX. A 4-wire terminating set (term. set) is used to accomplish this conversion. Most term. sets designed for voice facilities use hybrid transformers to accomplish the actual conversion between the 2- and 4-wire voice paths.

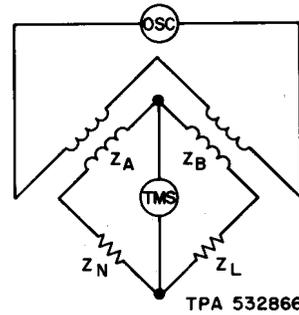
**2.02** The operation of the hybrid transformers used in a term. set can be explained by the wheatstone bridge concept as shown in Fig. 1. If  $R_A = R_B$  and  $R_L = R_N$ , then there is no difference of potential (voltage) across the galvanometer (G), and no current will flow through G. The bridge is balanced. If  $R_A = R_B$ , but  $R_L$  does not equal  $R_N$ , then an amount of current determined by the degree of unbalance (or mismatch) between  $R_L$  and  $R_N$  will flow through G.



**Fig. 1—Wheatstone Bridge**

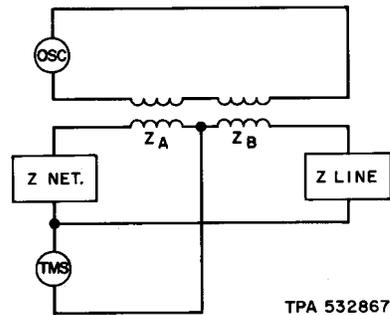
**2.03** In Fig. 2, alternating current equipment has been substituted for the direct current equipment of Fig. 1. The battery has been replaced by an oscillator (OSC), the galvanometer with a transmission measuring set (TMS), and the resistances (R) with impedances (Z). The power in this case

is transformer-coupled to the bridge. If  $Z_A = Z_B$  and  $Z_L = Z_N$ , no current will flow through the TMS. If  $Z_A = Z_B$ , but  $Z_L$  does not equal  $Z_N$ , an amount of current determined by the degree of unbalance (or mismatch) between  $Z_L$  and  $Z_N$  will flow through the TMS. The rest of the current divides between  $Z_L$  and  $Z_N$ , with the division also depending upon the degree of unbalance.



**Fig. 2—AC Bridge**

**2.04** Figure 3 is the same as Fig. 2, but redrawn in the hybrid form.  $Z_L$  and  $Z_N$  become the impedances of the 2-wire line and the network, respectively.



**Fig. 3—Hybrid Transformer**

**2.05** The principles discussed can be used to describe the operation of 4-wire term. sets. Figure 4 illustrates an arrangement consisting of a hybrid transformer and a balancing network to convert a 4-wire voice path to a 2-wire voice path.

**2.06** Power entering the hybrid coil over the receive leg divides between the 2-wire line facility and the balancing network. If the network

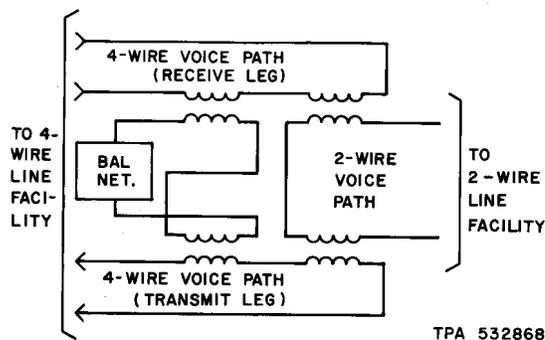


Fig. 4—4-Wire Terminating Set

and 2-wire line balance each other perfectly (their impedances are identical), the power divides equally between them and no power enters the transmit leg. If the network and the 2-wire line do not balance each other perfectly (their impedances are not identical), then an amount of power determined by the degree of unbalance (or mismatch) enters the transmit leg and is returned to the originating end. The purpose of balance tests is to adjust the network impedance, thus reducing the power returned to the originating end to a minimum.

**2.07** Power received into the hybrid from the 2-wire line divides (refer to Fig. 4). Half of it goes into the receive leg where it is dissipated in the output circuit of the amplifier. The other half goes into the transmit leg and is sent over the line facilities to the distant end.

**2.08** The impedance of both the 2-wire line and the network will vary with frequency. In the practical case, the network and the 2-wire line impedances are not identical. The degree of balance between the network and the 2-wire line will depend on the frequency of the applied signal and will change as the frequency is varied.

**2.09** Under certain conditions, the power reflected at a 4-wire term. set, due to impedance mismatch between the network and the 2-wire line, may cause transmission impairments. If sufficient power in the range of 500 to 2500 Hz is reflected, the talker may hear his own voice repeated to him to the extent that it will interfere with his ease of conversation. This effect is called "talker echo."

**2.10** Power reflected at a single frequency may result in the circuit going into sustained oscillations. This is known as "singing" and may occur at any frequency in the voiceband, but usually occurs in the 200- to 500-Hz or 2500- to 3200-Hz ranges.

**2.11** It should be noted that talker echo is dependent upon the degree of balance at the distant end of the connection and the round trip transmission time between the talker and the distant end. Singing depends upon the degree of balance at both ends of a circuit, the frequency response, and the phase relationship between the original and reflected power.

**2.12** To reduce the possibility of transmission impairments, networks are designed to match the impedance of 2-wire facilities over the voice frequency range to a degree sufficient to limit the reflected power to acceptable levels. The network is called a "balancing network," and the resultant degree of impedance match is called "balance."

**2.13** Historically, PBXs were engineered assuming a nominal impedance of 900 ohms. Later, it was determined that a 500-type telephone set on a short loop presented an impedance closer to 600 ohms. Consequently, current standards provide for a nominal PBX impedance of 600 ohms. The impedance match obtained between a 600-ohm network and the PBX should provide higher return losses and thus improve echo performance. During the transition from 900- to 600-ohm PBX impedance, both types will be in service. It is important, therefore, that the impedance of the PBX be determined before any measurements or tests are made.

**2.14** The degree of balance is usually expressed in terms of return loss (in dB) at specified frequencies. Return loss can be most clearly defined by means of a specific example of measurement.

**2.15** If a short is placed across the 2-wire line at the hybrid coil and a known amount of power is sent into the receive leg, the reflected power can be measured at the transmit leg (refer to Fig. 4). For example, if a frequency of 1000 Hz at a power level of 0.0 dBm is sent into the receive leg and the power measured at the transmit leg is 7.5 dB, the total 1000-Hz loss from the receive leg input to the transmit leg output is 7.5 dB. This is the loss of the hybrid from the receive leg

to the transmit leg and is generally referred to as the trans-hybrid loss, with 0-dB return loss (total reflection of power) at the 2-wire terminals. The actual measured loss (AML) will depend on the type of hybrid and the loss of the receive and transmit pads (if any) in the measuring path.

**2.16** With the short removed, the 2-wire side of the hybrid connected to its 2-wire line facility, and the distant end terminated in the correct impedance, another measurement is taken with the same input power and frequency at the receive leg. The level of the power measured at the transmit leg will be lower than with the 2-wire leg shorted because the network and the 2-wire line facility with its terminating impedance will absorb most of the power sent in at the receive leg. For example, if the power measured at the transmit leg is now  $-26.5$  dBm, the loss from the receive leg to the transmit leg is 26.5 dB. Since the losses of the hybrid and pads (if any) are common to both tests, the 7.5-dB loss for the 0-dB return loss condition is subtracted from the 26.5 dB, leaving 19.0 dB. This 19.0 dB is the return loss and represents the degree of balance between the 2-wire line facility and the balancing network at the frequency of the applied power. Higher degrees of balance are indicated by larger values of return loss.

**2.17** *Echo return loss (ERL)* is a weighted average (on a power basis) of the return losses at all frequencies in the echo range (500 to 2500 Hz). This weighting is accomplished automatically by networks in the testing equipment.

**2.18** *Singing point (SP) or singing return loss (SRL)* is a measure of the nearness of a circuit to a singing (oscillating) condition. SP measures the gain needed to cause singing in the voiceband (200 to 3200 Hz). SRL is a return loss measurement in the 200- to 500-Hz and 2500- to 3200-Hz singing frequency bands. Measurements using either technique will verify that a circuit meets the SP/SRL requirement. Sufficient balance must be obtained to prevent the circuit from operating in a near-singing condition, which results in transmission impairment, readily recognized as a hollowness or "rain-barrel" effect caused by multiple echoes.

### 3. SWITCHING PADS

**3.01** When a 4-wire VNL tie trunk is switched to a station at a main or tandem PBX, 2-dB

switchable pads are required at the PBX to improve the balance of the wide range of station loop impedances against the network in 4-wire term. sets. The pads are included in the tie trunk circuits, such as SD-65718-01 and SD-66799-01, and are switched *out* on connections to other PBX tie trunks, except when the loss of the tie trunk facility is less than 2 dB or when its impedance cannot be corrected to meet terminal balance objectives. The pads should be switched *out* on connections to other special service circuits such as FX trunks, WATS trunks, and PBX central office trunks, provided that the facility loss is greater than 2 dB and the impedance of the special service circuits meets terminal balance objectives.

**3.02** At a manual switch (switchboard), the pad control relay is controlled by the PBX switchboard THRU jack associated with the tie trunk. At SXS PBXs, the pad relay is operated by a bent-out cam tooth associated with a normal post spring on the step switch. At a No. 5 crossbar CENTREX-CO, pad switching is controlled by the marker.

**3.03** In the 101 Electronic Switching System (ESS) PBX, an equivalent pad-switching function is done by switching *gain in* on through connections and *out* on terminating connections.

### 4. THROUGH BALANCE TESTS

**4.01** *Through balance tests are required at all PBXs where there are two or more groups of 4-wire VNL tie trunks that can be connected together.* A tie trunk group is defined as one or more tie trunks terminated at the same two PBXs. For example, in Fig. 5, if at PBX C there is a 4-wire VNL tie trunk group to PBX B and another group to PBX D, through balance tests will be required at PBX C.

**4.02** Through balance tests consist of network building-out capacitor (NBOC) adjustment tests, ERL tests, and SP tests. The purpose of the NBOC adjustment tests is to select a value of capacitance, to be included in the 4-wire term. set networks, that will balance the capacitance of the PBX switching equipment and wiring that is involved in connections through the PBX. Since there are numerous paths through the PBX for the various connections, an optimum value of capacitance is selected that will provide adequate balance for any connection. The ERL and SP tests are used

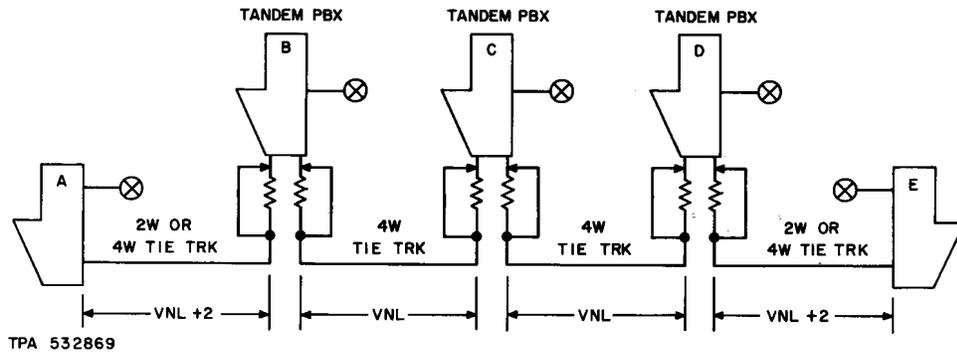


Fig. 5—PBX Tandem Arrangement

to determine whether objectives are met or whether corrective measures are required to meet the objectives.

**4.03** From the transmission standpoint, the most critical balance requirements at PBXs are those for through or intertandem PBX tie trunk connections. Under this condition, the tie trunks are switched at VNL and interconnected by either the PBX switchboard or switching machine. The required balance is achieved by modifying the basic 4-wire term. set compromise network impedance by adding shunt capacitance in the NBOC. This adjustment of the compromise network impedance should closely approximate the impedance of the 2-wire side of the connected 4-wire term. set, as modified by the shunt capacitance of the intervening PBX cabling and equipment at all frequencies in the critical range.

**4.04** The optimum NBOC capacitance value is determined by making return loss measurements with broadband noise on representative connection paths through the switching equipment and switchboard. Figure 6 illustrates the equipment arrangements used for these tests.

**4.05** More accurate measurements are obtained by using the SRL/HI (setting of the RLMS) rather than a low frequency. The various equipment components have less effect on capacitance values, and the shunt cable capacitance is more easily measured.

**4.06** The NBOC tests are made by using a test hybrid (if available) with associated 2-wire equipment and wiring to the switching machine and switchboard. In the absence of a test hybrid,

one of the 4-wire term. sets associated with a working circuit that can be taken out of service may be used for the tests.\* A representative sample of the 4-wire tie trunks terminated at the PBX is tested by connecting each trunk with the 4-wire legs terminated through the PBX switching machine or switchboard to the test tie trunk. As a general rule, where the total number of 4-wire VNL tie trunks is five or less, all trunks are included in the NBOC test. When there are more than five, the following numbers are recommended for the tests:

TOTAL NUMBER OF 4-WIRE TIE LINES	NUMBER TO BE TESTED
6 to 10	5
11 to 15	6
16 to 25	7
26 to 50	8
over 50	18%

**\*Important: Two trunks or lines are involved in each balance test;** therefore, the length of wiring and the trunk equipment used with a test hybrid must be the same as the average of the 2-wire sides of all the 4-wire trunks at the PBX. If working or spare equipment is used, the tests should not all be made with the same circuit. This would tend to bias the test results unless the test circuit is truly representative of the average circuit wiring and equipment. The selection of tie trunks for the tests should be divided as evenly as possible

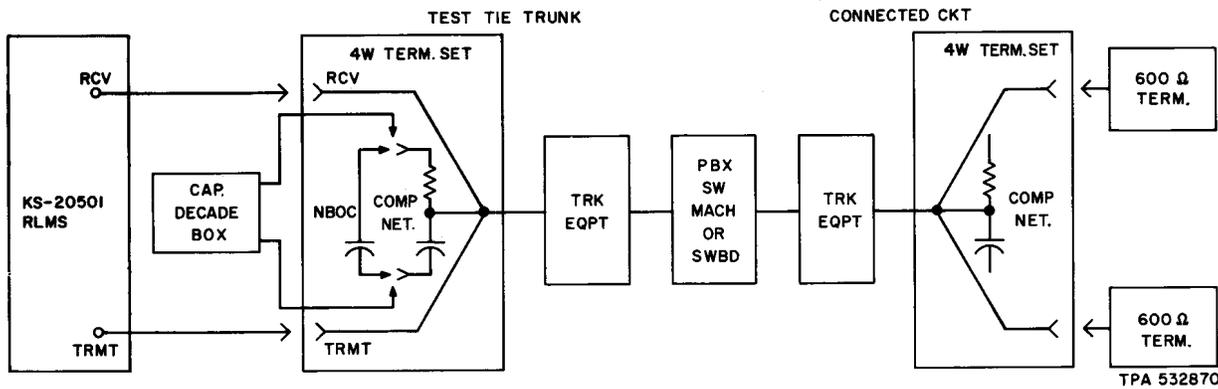


Fig. 6—Network Building-Out Capacitor Test

among all groups, with at least one trunk from each group. It is important that the longest paths (highest capacitance) and the shortest paths (lowest capacitance) be represented in the sample.

**4.07** The test hybrid is connected via a dialed connection and a switchboard connection to each trunk to be tested. The capacitor decade box is substituted for the NBOC in the test tie trunk, as shown in Fig. 6. The 4-wire legs of the connected circuit are terminated in 600 ohms (the adjustment of the network in the terminating circuit has negligible effect on this test). The variable capacitor is adjusted to obtain the highest return loss, and this capacitance value is recorded for each connection. After all trunk connections in the sample have been tested, the arithmetic average of the variable capacitor values is obtained. The average and individual capacitance values should be referred, in accordance with the local instructions, to the appropriate transmission or circuit design groups for approval. When approved, the NBOCs of all 4-wire term. sets are adjusted to the approved value. Where there are 4-wire non-VNL facilities terminated at the PBX, their NBOCs are also adjusted to the average capacitance.

**4.08** PBXs are usually compact and should not have large differences of capacitance between the longest and shortest connection paths. Hence, the compromise value of NBOC will closely approximate the value of the capacitance of the equipment and wiring involved in connections through the PBX. The through balance objective can be met if the longest or shortest connection path capacitance does not deviate more than about  $\pm 0.008 \mu\text{F}$  from the average path. This is equivalent to approximately

300 feet of office cabling, or a total spread of 600 feet between the shortest and longest paths. It is apparent that judicious locations of equipment and cable runs will have considerable effect on balance.

**4.09** If, at a particular PBX, most of the VNL connections that require through balance are handled on a dial basis with only a small percentage through the switchboard, it is desirable to base the NBOC values on dialed connections only. This is especially true if the capacitance of the switchboard path varies appreciably from that of the dialed path.

**4.10** If, in some large and complex systems, the use of a compromise value of NBOC is not adequate to meet through balance objectives, it may be necessary to employ the precise methods that require drop building-out capacitors (DBOCs), as specified for toll offices. The present PBX tie trunk equipment does not provide DBOC options; hence, if drop building-out is required, it will be necessary to cross-connect external capacitors to the appropriate 2-wire equipment.

**4.11** When the NBOCs of all 4-wire term. sets have been adjusted, the ERL and SP portions of the through balance tests can be made. While the ERL and SP tests can be made on the same sampling basis as outlined in 4.06, it is highly desirable to test as many of the connections as possible to reveal trouble conditions. The objectives for through balance given in Tables A and B should be met. Equipment arrangements for ERL and SP tests are illustrated in Fig. 7. Detailed procedures are outlined in Section 311-350-500.

TABLE A  
900-OHM PBX — BALANCE OBJECTIVES

THROUGH BALANCE MEASUREMENT OBJECTIVES						
TYPE OF CONNECTION		CONNECTED CIRCUIT TERMINATION	2-dB SWITCH PAD	TYPE TEST *	AVERAGE OF ALL CIRCUIT MEASUREMENTS	NO CIRCUIT MEASUREMENT LESS THAN
FROM (TEST CIRCUIT)	TO (CONNECTED CKT TERM.)					
4-Wire VNL Tie Trunk	4-Wire VNL Tie Trunk	4-Wire Legs Terminated In 600 Ohms	OUT (Pad Out of Both Tie Trunks)	ERL	27 dB	23 dB
				SP	20 dB	16 dB
TERMINAL BALANCE MEASUREMENT OBJECTIVES						
4-Wire VNL Tie Trunk at the PBX	4-Wire Non-VNL Tie Trunk	900 Ohms + 2.16 $\mu$ F at the Distant PBX	OUT	ERL	22 dB	16 dB
				SP	15 dB	11 dB
	2-Wire Short-Haul Tie Trunk	900 Ohms + 2.16 $\mu$ F at the Distant PBX	OUT†	ERL	18 dB	13 dB
				SP	10 dB	6 dB
	CO Trunk, FX Trunk, or WATS Trunk	900 Ohms + 2.16 $\mu$ F at CO	OUT†	ERL	18 dB	13 dB
				SP	10 dB	6 dB
	On-Premises or Off-Premises PBX Station Lines	Station Off-Hook	IN	ERL	12 dB	9 dB
				SP	8 dB	6 dB
PBX Test Balance Termination	900 Ohms + 2.16 $\mu$ F at the PBX	IN	ERL	24 dB	20 dB	
			SP	18 dB	14 dB	

\* ERL — Echo Return Loss      SP — Singing Point

† The 2-dB pad should not be switched out where the loss of the connected facility is less than 2 dB or where these balance objectives are not met.

**TABLE B**  
**600-OHM PBX — BALANCE OBJECTIVES**

THROUGH BALANCE MEASUREMENT OBJECTIVES						
TYPE OF CONNECTION		CONNECTED CIRCUIT TERMINATION	2-dB SWITCH PAD	TYPE TEST *	AVERAGE OF ALL CIRCUIT MEASUREMENTS	NO CIRCUIT MEASUREMENT LESS THAN
FROM (TEST CIRCUIT)	TO (CONNECTED CKT TERM.)					
4-Wire VNL Tie Trunk	4-Wire VNL Tie Trunk	4-Wire Legs Terminated In 600 Ohms	OUT (Pad Out of Both Tie Trunks)	ERL	27 dB	23 dB
				SP	20 dB	16 dB
TERMINAL BALANCE MEASUREMENT OBJECTIVES						
4-Wire VNL Tie Trunk at the PBX	4-Wire Non-VNL Tie Trunk	600 Ohms + 2.16 $\mu$ F at the Distant PBX	OUT	ERL	22 dB	16 dB
				SP	15 dB	11 dB
	2-Wire Short- Haul Tie Trunk	600 Ohms + 2.16 $\mu$ F at the Distant PBX	OUT†	ERL	18 dB	13 dB
				SP	10 dB	6 dB
	CO Trunk, FX Trunk, or WATS Trunk	900 Ohms + 2.16 $\mu$ F at CO	OUT†	ERL	18 dB	13 dB
				SP	10 dB	6 dB
	On-Premises PBX Station Lines	Station Off-Hook	IN	ERL	16 dB	10 dB
				SP	8 dB	6 dB
	Off-Premises PBX Station Lines	Station Off-Hook	IN	ERL	12 dB	9 dB
				SP	8 dB	6 dB
	PBX Test Balance Termination	600 Ohms + 2.16 $\mu$ F at the PBX	IN	ERL	24 dB	20 dB
				SP	18 dB	14 dB

\* ERL — Echo Return Loss      SP — Singing Point

† The 2-dB pad should not be switched out where the loss of the connected facility is less than 2 dB or where these balance objectives are not met.

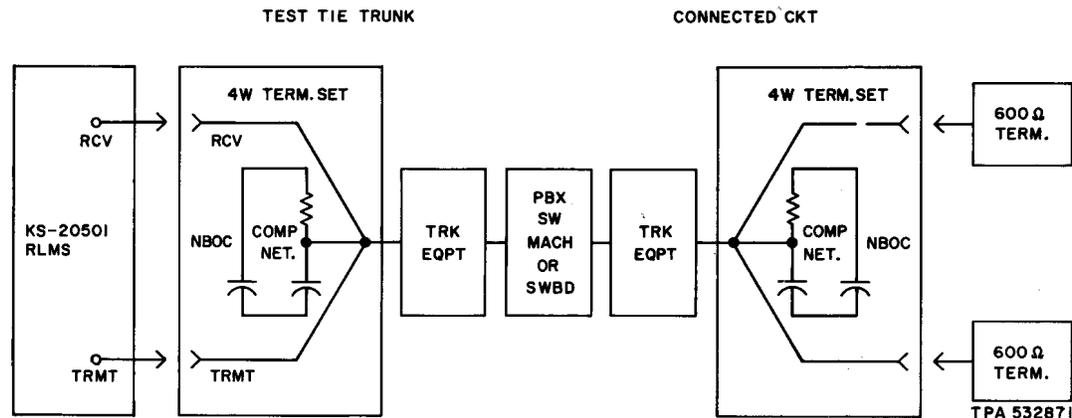


Fig. 7—Through Balance Echo Return Loss and Singing Point Tests

## 5. TERMINAL BALANCE TESTS

5.01 Terminal balance tests are required under any of the following conditions:

- (a) At PBXs where VNL tie trunks or access lines are switched (with 2-dB pad *out*) to tie trunks or other facilities operating at VNL + 2 dB or higher loss
- (b) At PBXs where VNL tie trunks or access lines are switched (with 2-dB pad *in*) to PBX station lines or other facilities
- (c) At SSN switching offices on those access lines that are operated at VNL + 2 dB with no switchable pad at the distant end.

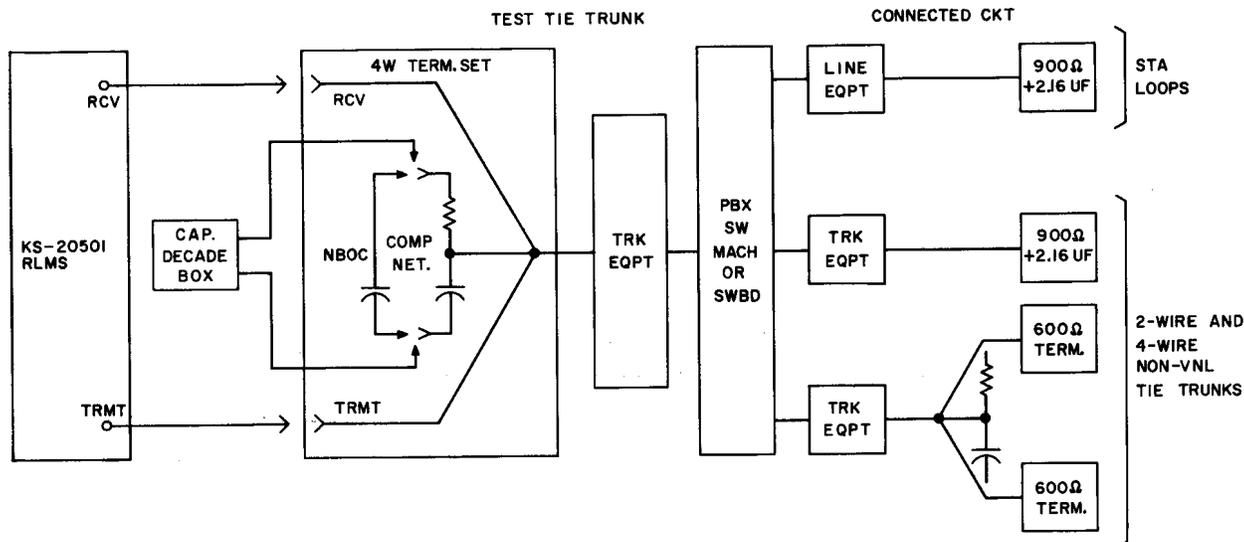
Terminal balance tests are not required at PBXs at which only VNL + 2 dB or higher loss facilities are terminated.

5.02 Terminal balance tests are designed to check the degree of balance between the compromise network in the 4-wire term. set of the VNL tie trunk and the 2-wire impedance of the connected circuit. The tests are made with a termination at the distant end of the connected facility. Hence, the test is also a check of all components of the connected circuit such as office cabling, trunk equipment, and line facilities; it will detect any significant irregularities that affect the 2-wire impedance.

5.03 Terminal balance tests may be made to a representative sample of on-premises PBX stations covering the range of loop lengths. However, all other connections, such as non-VNL tie trunks, central office trunks, FX trunks, or off-premises stations, and especially those that are able to switch the 2-dB pad out of the tie trunk, should be tested individually. This will assure that irregularities that will result in inadequate balance and inferior transmission on built-up connections will be detected.

5.04 If required, through balance tests are to be completed before any terminal balance tests are attempted. The NBOC values determined from the through balance tests are to be used in the networks of all 4-wire term. sets. At locations where through balance tests are not required (no VNL tie trunks switched together with pads out) and most of the connections under normal operating conditions are made to short PBX station loops, the best terminal balance will be obtained with the NBOC disconnected. Therefore, if the terminal balance objective for connections to tie trunks, central office trunks, and off-premises stations can be met, no NBOC should be used. If NBOCs are required to meet terminal balance objectives on connections to tie trunks, FX trunks, etc, the methods outlined for through balance NBOC tests (4.04 through 4.10) may be used, except that connections should also be made to representative 2-wire trunk and line circuits, as shown in Fig. 8.

5.05 After the NBOCs have been determined and strapped into all networks of the 4-wire



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Fig. 8—Terminal Balance NBOC Tests

term. sets, the ERL and SP tests are made to determine whether the objectives given in Tables A and B are met. Equipment arrangements for these tests are illustrated in Fig. 9. Detailed procedures for terminal balance tests are given in Section 311-350-500.

## 6. BALANCE TEST MEASUREMENT OBJECTIVES

**6.01** ERL and SP objectives for both through and terminal balance tests on 4-wire VNL tie trunks are given in Tables A and B.

**6.02** Circuit designs should be such that these objectives can be met. If the tests indicate that the objectives are not met and thorough investigation fails to reveal trouble conditions, the case should be referred to the department designated by local instructions to review the circuit design. Give the complete details of the balance test results and trouble investigation procedures.

## 7. TROUBLE INVESTIGATION HINTS

**7.01** Many transmission irregularities can result in failure to meet balance objectives. The more obvious cases of potential trouble should be found and corrected during the course of a thorough net loss frequency lineup of the circuits involved in the balance testing. Such tests should be completed prior to attempting the balance tests.

**7.02** The following general hints may aid in locating potential trouble sources:

### SWITCHED PAD

Not operating, component or wiring error.

### PBX OR TRUNK EQUIPMENT

Incorrect ratio repeating coil, repeating coil wired in reverse, foreign capacitance or inductance across voice path, or voice path to ground. Wiring error in voice path circuitry.

### 4-WIRE TERM. SET

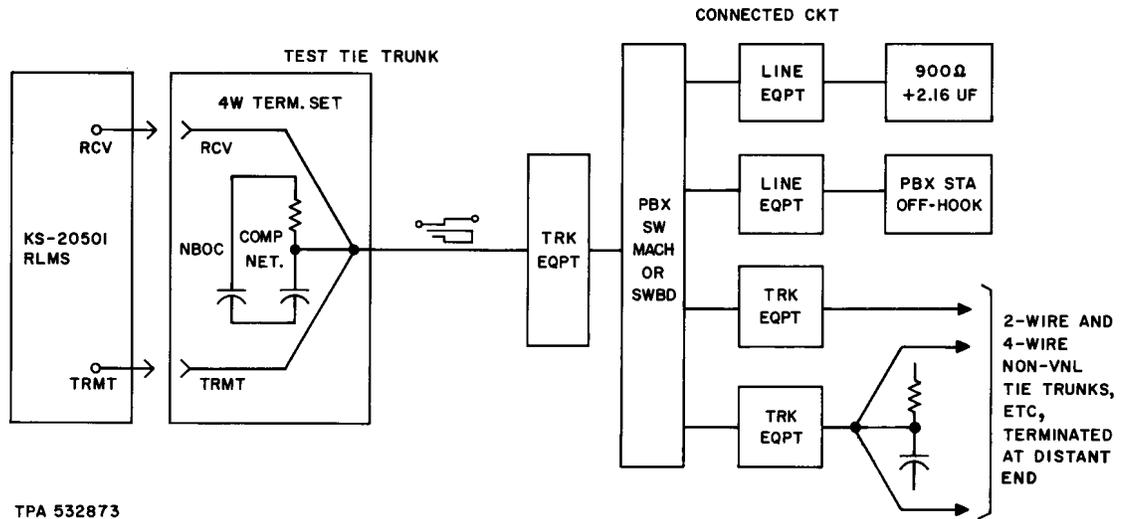
Defective hybrid, incorrect impedance value, incorrect type or value of balancing network.

### NONLOADED CABLE

Excess bridge tap. Cable may require impedance compensator or loading.

### LOADED CABLE

Loading irregularities, bridge tap, improper end section. Impedance compensator omitted, improperly wired, strapping error. Wrong type.



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Fig. 9—Terminal Balance Echo Return Loss and Singing Point Tests