

THROUGH AND TERMINAL BALANCE GENERAL ENGINEERING CONSIDERATIONS

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1. INTRODUCTION

1.01 The via net loss (VNL) design concept permits the assignment to a trunk of the lowest practical operating loss consistent with the length and type of trunk transmission facility. This section discusses the factors involved in determining the echo return loss (ERL) and singing return loss (SRL) balance requirements needed to permit VNL trunk design.

1.02 This section is reissued for the following reasons:

- (1) To update paragraph 2.06, through balance requirements, and paragraph 3.09, terminal balance requirements
- (2) To update Tables A and B

(3) To remove all references pertaining to singing point measurements.

Revision arrows are used to emphasize the more significant changes.

1.03 The VNL design concept for overall trunking connections in the Public Switched Network (PSN) is discussed in Section 853-100-101. Familiarity with the contents of that section is necessary for the understanding of this section.

1.04 The VNL design assumes that the lowest echo return losses in a connection are encountered at the class 5 (end) offices because of the generally poor impedance matching between the toll connecting trunks and the local loop plant. Any additional reflections will further degrade expected performance. Thus, it is necessary to constrain all intermediate reflections in PSN connections between class 5 offices to control talker echo and to prevent singing or near-singing conditions. (Control of talker echo is the basis of VNL design.) Since the same techniques are needed for controlling both phenomena, balance includes requirements for singing return loss as well as for echo return loss. The definitions of these terms follow.

ERL: The weighted average measurement of the return losses over the echo range (500 to 2500 Hz). The measurement corresponds to the results of subjective tests discussed in Section 853-100-101. The weighting, known as C-message weighting, corresponds to a transmitted signal having a spectrum like that of an average male talker and a receiver having the response of an average listener.

SRL: The average return loss (RL) in the singing bands (200 to 500 Hz and 2500 to 3200 Hz) that is measured with a return loss measuring set (RLMS). Two measurements are made: one of the 200- to 500-Hz band and one of the 2500- to 3200-Hz band. The lower number of the two

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measurements is taken as the SRL of the circuit. For description and operation of the KS-20501 RLMS, see Section 103-106-115.

2. THROUGH BALANCE

A. General

2.01 All intertoll trunk transmission facilities are designed on a 4-wire basis. This prevents intermediate echoes. However, many of the switching machines used for the interconnection of intertoll trunks (control switching points [CSPs] or class 3 and higher switching entities) are 2-wire and, therefore, require hybrids to effect the necessary 4-wire to 2-wire conversions. The regional centers (class 1), a majority of the sectional centers (class 2), and some of the larger primary centers (class 3) situated within the United States are equipped with 4-wire switching systems. The remainder of the CSPs employ 2-wire switching systems at the present time. When intertoll trunks are switched together by a 2-wire switching system, it is necessary that the switching impedances of all the trunks, as well as the impedances of all the possible paths through the switching machine, be very nearly the same. The overall procedure for effecting this impedance control at these 2-wire CSPs in order to prevent objectionable echo is called **through balancing** (formerly known as office or office cable balancing).

B. Through Balance Control

2.02 Figure 1 shows, schematically, the 4-wire to 2-wire to 4-wire conversion which takes place at a 2-wire CSP. For signals coming from facility A, there is no reflection if the impedance of network "NET. A" is equal to the sum of the impedance of the 2-wire path and the input impedance of facility B. Similarly, a signal arriving on facility B will have no echo degradation if the impedance of network "NET.

B" is equal to the sum of the impedance of the 2-wire path and the input impedance of facility A.

2.03 There are two procedures in use for controlling the impedances, one for electromechanical switches (crossbar, step-by-step, etc) and the other for Electronic Switching Systems (ESS). (Presently only No. 1/1A ESS is suitable for applications requiring through balance.) In both procedures, the networks (known as balancing networks) consist of two parts, a fixed part and a variable part. (See Fig. 2.) The fixed part ($600\Omega + 2.16 \mu\text{F}$ in step-by-step, No. 5 crossbar, and manual switchboards; $900\Omega + 2.16 \mu\text{F}$ in crossbar tandem and No. 1/1A ESS) mirrors the 2-wire input impedance to the facility and includes a 25-ohm allowance for the resistive component of the office wiring. The variable capacitive part of the networks is known as network buildout (NBO).

2.04 The procedure for electromechanical switches is as follows:

- (a) Make the capacitive part of the impedance of all 2-wire paths through the office equal. This is accomplished by bridging capacitance, called a drop build-out (DBO) capacitor, on the shorter paths to make them all capacitively equivalent to the longest path in the office plus a growth factor. The maximum allowed cross-office capacitance is set at $0.080 \mu\text{F}$ because of amplitude-distortion (frequency-response) considerations.
- (b) Set the NBO capacitance of all networks to be equal to that of the longest path through the office (plus a growth factor).
- (c) Control the maximum cross-office resistance to be less than 65 ohms in a 900-ohm switch and 45 ohms in a 600-ohm switch. This ensures that the impedance mismatch caused by variations of the resistive component from the 25-ohm allow-

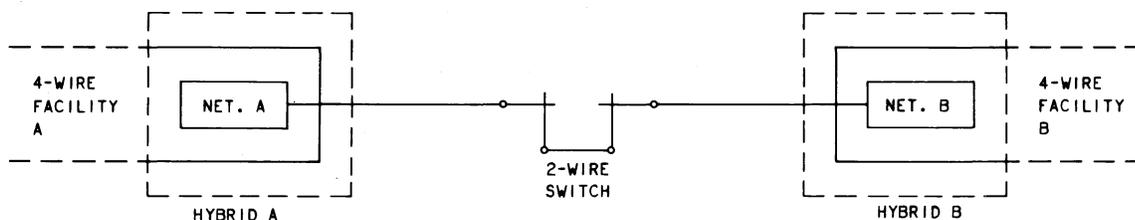


Fig. 1—Switching of 4-Wire Trunks at a 2-Wire CSP

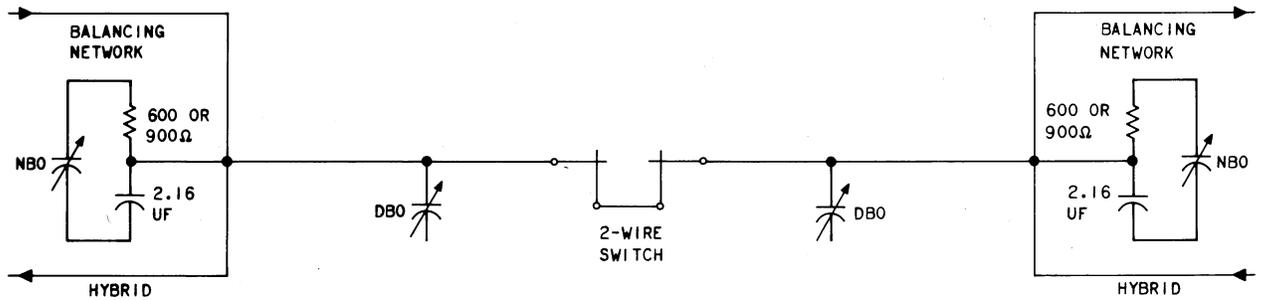


Fig. 2—Balancing Networks and Building-Out Capacitors

ance of the cross-office path will not cause echo greater than that allowed.

2.05 The procedure for electronic switches is as follows:

(a) Set the impedance (resistance and capacitance) of each network to be optimum for a nominal connection. This connection will consist of the 2-wire path between the hybrid and the center of the switch, plus some amount of cable from the center of the switch to the hybrid on the connected facility. This additional amount of cable has been chosen to be 400 feet to allow for a maximum amount of growth and still give satisfactory results on the shortest possible paths.

(b) Control the length variability so that the longest path from the center of the switch to a hybrid is less than about 800 feet. This ensures that the maximum mismatch (± 400 feet) will still allow return-loss requirements to be met. This is possible to do since all hybrids on intertoll trunks are part of the trunk circuits.

C. Through Balance Requirements

2.06 The present through balance requirements are presented in Table A. For initial installation of a circuit, no trunk below the maintenance limit (ML) (old median value) should be turned up for service without concurrence from the area transmission engineer. Bell System Practice (BSP) layers 660-47Y-100, -300, and -301 instruct the central office to notify their area transmission engineer for any initial balance tests with results less than the ML. The area transmission engineer may elect to change the ML value, not less than the immediate action (IA) limits (old minimum value) under constraint of Section 853-500-110 (see Maintenance Limits and Immediate Action Limits). The adjusted ML now becomes the new ML for purposes of further maintenance testing and should be posted in the trunk records by the responsible central office personnel. On subsequent testing, any trunk measuring below the IA limits must be removed from service and repaired immediately and brought up to the ML value or the adjusted ML value.

2.07 This discussion has concerned itself primarily with balancing the office paths through the

TABLE A

THROUGH BALANCE REQUIREMENTS

	MAINTENANCE LIMIT CIRCUIT ORDER REQUIREMENT (NOTE)	IMMEDIATE ACTION LIMIT
ERL	27 dB	21 dB
SRL	20 dB	14 dB

Note: See paragraph 2.06.

switches. There are other paths for assistance traffic through associated switchboards which also need to be taken into account in the through balance job. Techniques depend on types of equipment, office layout, etc, but the same broad principles apply as for the paths through the switches.

D. Analysis of Through Balance Performance

2.08 To evaluate the adequacy of through balance requirements, it is necessary to understand the effects of echo generated at 2-wire toll switching entities as referred to a class 5 office in a ♦PSN♦ connection. (See Fig. 3.)

2.09 For purposes of illustration, the echo effect has been referred to the class 5 office at the A end of the connection in the form of first talker echo. No attempt has been made to take into account round-trip delay times for the purpose of determining sidetone components as opposed to echo effects or for evaluating multiple echo effects. At the present time, little is known about the subjective effect of multiple echoes on the customer's grade-of-service. The relatively low trunking losses of trunks have been ignored in referring ERL values to the class 5 office. An estimate of the talker echo effect can, however, be obtained by a power loss summation of the ERLs in the connection.

2.10 The ERL distribution at the class 4 toll office at the B end of the connection is the summation of the following:

(a) The ERL distribution at the junction of the toll connecting trunk and the loop at the class 5 office at the B end of the connection (mean = 11 dB, sigma = 3 dB) referred to the class 4 toll office by adding twice the loss of the toll connecting trunk (approximately 6 dB). This approximates a distribution with a mean of 17 dB with a sigma of 3 dB.

(b) The structural ERL distribution of the 2-wire cable toll connecting trunk with impedance compensation meeting the requirements for terminal balance as discussed in Part 3 of this section (mean = 18 dB, sigma = 2.5 dB). The summation of this distribution and the distribution from (a) above (mean = 17 dB, sigma = 3 dB) approximates a distribution with a mean of 14 dB and a sigma of 2.3 dB.

2.11 The ERL distributions shown in Fig. 3 (mean = 27 dB, sigma = 3 dB) for the two class 3 of-

fices are based on the through balance requirements shown in Table A. The summation of these two distributions gives an ERL distribution with a mean of 25.4 dB and a sigma of 3 dB. (Assume inserted connection loss (ICL) equals 1.4 dB; therefore $27 \text{ dB} + (2 \times 1.4 \text{ dB}) \approx 30 \text{ dB}$. This 30 dB combined with other class 3 office ERL of 27 dB equates to 25.4 dB). The summation of this distribution, offset by $2 \times \text{ICL}$, combined with the ERL distribution at the class 4 toll office (mean = 14 dB, sigma = 2.3 dB) has no appreciable effect on the ERL distribution at the class 5 office at the A end of the connection.

2.12 In the initial balancing process, no trunks with ERLs lower than the specified ML in Table A should be turned up for service unless approved by the area transmission engineer (paragraph 2.06). However, even with this echo control measure, the above analysis of the echo effect at the class 5 office indicates that the present through balance requirement ♦(maintenance limit = 27 dB, immediate action limit = 21 dB)♦ is satisfactory if only one such office exists on each end of that portion of a connection involving class 1, 2, or 3 offices. This is generally true today since all class 1 and most class 2 offices are 4-wire. However, if in the future a larger 2-wire office is developed which could be generally applicable to any class of office, the requirement may have to be made more stringent.

3. TERMINAL BALANCE

A. General

3.01 Via net loss operation of trunks is based on having sufficiently low echo powers generated between class 5 offices on all ♦PSN♦ connections. This requires having adequate balance at all points where trunks are connected (switched) together plus controlling echoes on toll connecting trunks with 2-wire facilities. As explained in Part 2, when two intertoll trunks are switched together, the resultant balance is called through balance. When an intertoll trunk is connected to a toll connecting trunk, the resultant balance is called terminal balance. Terminal balance testing is required in each toll switching office (class 4 and higher, both 2-wire and 4-wire) having trunks to or from a class 5 office. ♦Four-wire toll offices with 4-wire toll connecting trunks terminating in digital class 5 offices need not make terminal balance tests. There are no hybrid arrangements on a toll connecting trunk with a 4-wire switch, 4-wire facility, and 4-wire switch arrangement. The digital class 5 office is

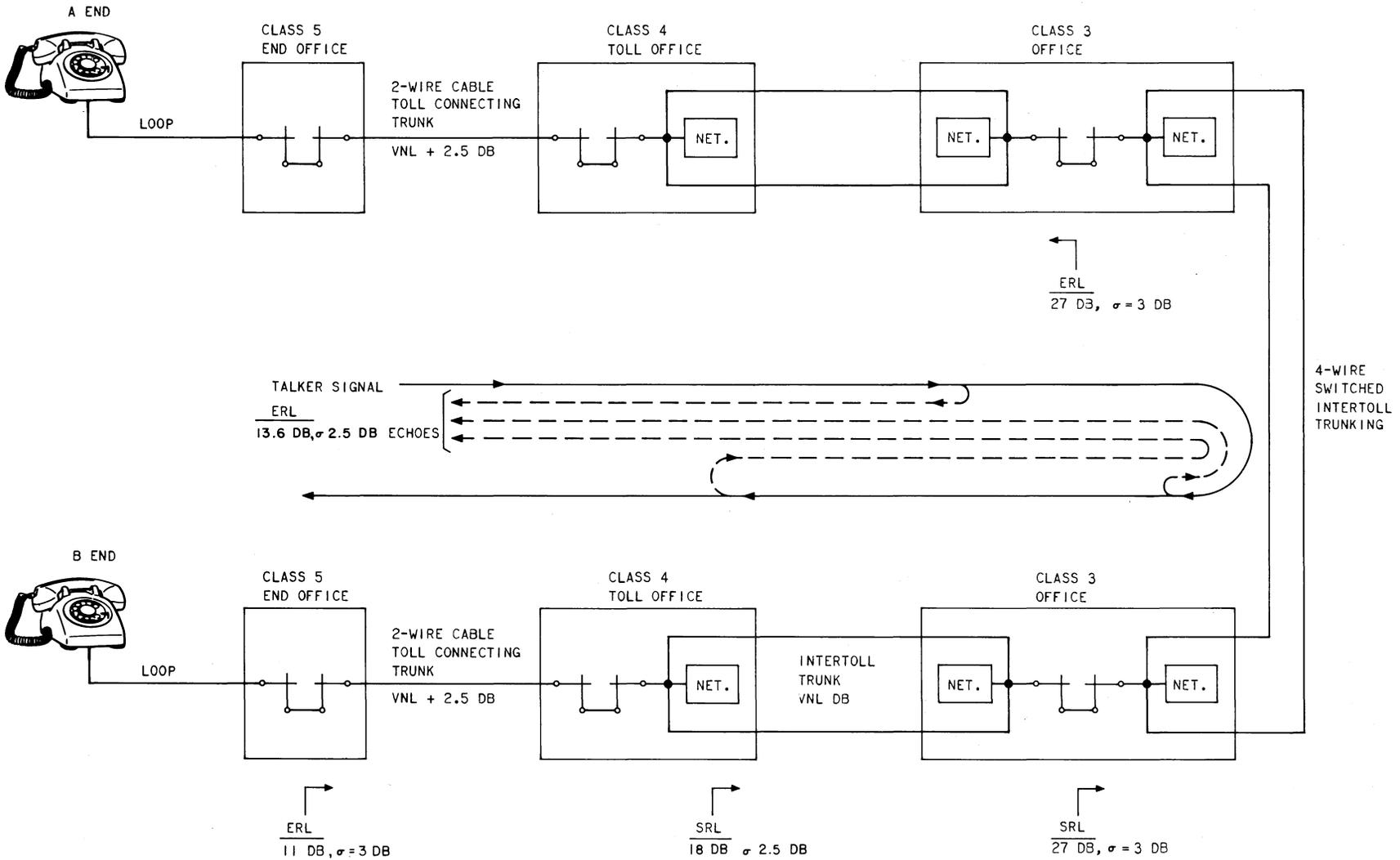


Fig. 3—Echo Return Losses in a DDD Network Connection

now responsible for hybrid balance testing on the *subscriber line* side of its switch.♦

B. Terminal Balance Control

3.02 Figure 4 shows the typical connections for terminal balance. Unlike through balance, which involves a cross-office connection only, terminal balance includes the toll connecting trunk facility as well. Terminal balance tests are made from an intertoll trunk or equivalent test circuit, through the switch to a toll connecting trunk, through the distant class 5 office to a balance termination (900Ω + 2.16 μF).

3.03 Thus, there are three factors which may affect terminal balance: impedance matching in the toll office, irregularities in the toll connecting facility, and impedance matching at the class 5 office balance termination.

3.04 In 2-wire toll offices, the interface between the switch and the toll connecting facility is nominally at a fixed impedance point (600Ω or 900Ω + 2.16 μF). This is generally either at a cable facility impedance compensator or a hybrid in a carrier system channel bank or signaling unit. Echo control at this point requires controlling the impedance between the intertoll hybrid and the fixed impedance point. This is accomplished by controlling the length variability of the 2-wire path between these two points. In electromechanical switching machines, drop buildout (that is, bridged capacitors) is sometimes used on the shorter paths to control the variability. In No. 1/1A ESS offices, there is no provision for drop buildout, and thus cabling limits must be adhered to.

3.05 In the case of a 4-wire switch, if the toll connecting facility is also 4-wire, the only possible source of echo is the 4-wire to 2-wire hybrid conver-

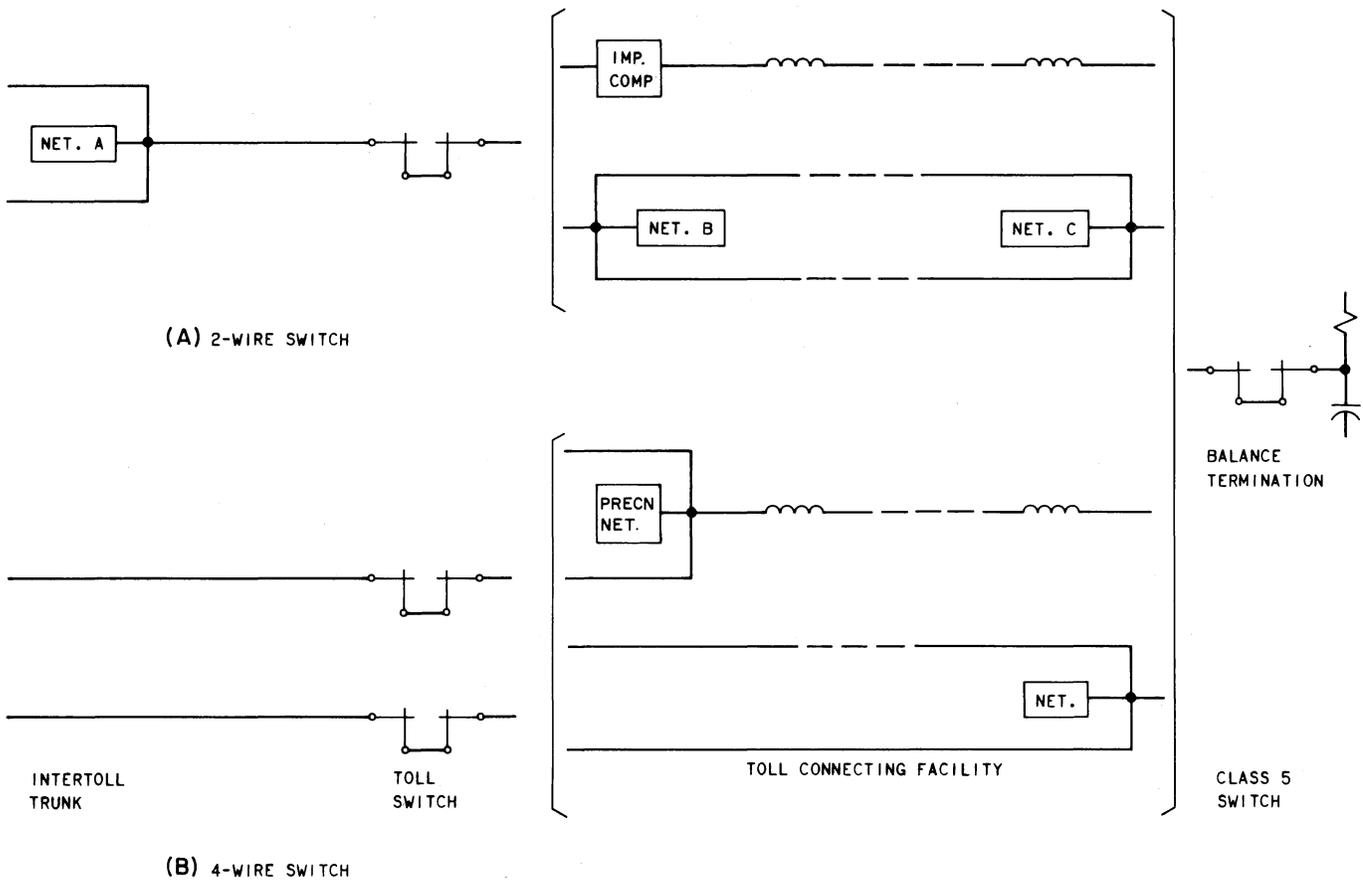


Fig. 4—Terminal Balance Arrangements

sion at the class 5 office. If, however, the toll connecting trunk uses a 2-wire cable facility, there is a source of echo at the hybrid used to interface the trunk and the 4-wire switching machine. This echo is controlled by the use of a precision network that will match the impedance of the 2-wire cable facility as closely as possible (Fig. 5). It should be noted that the precision network can be made to provide this impedance match only over the nominal voiceband. There is a possibility that rather poor mismatches will exist between the precision network and the 2-wire cable facility at frequencies above the nominal voiceband. To eliminate the possibility of singing at some critical frequency above the voiceband, a low-pass filter should be used whenever it is possible that there may exist a path with net gain and an insufficient low-pass filtering characteristic between the 2-wire sides of the two hybrids in the overall connection. In the case illustrated in Fig. 5, it is assumed that the 4-wire facilities do not have a cutoff frequency characteristic which is lower than the critical frequency of the 2-wire cable facility and the addition of the low-pass filter is required.

3.06 The second source of echo in a 2-wire facility is impedance irregularities in the loaded cable pair. To control this source of echo, it is necessary to limit variations in load spacing and to eliminate gauge changes. A structural return-loss measurement is made as part of acceptance testing for the installation of loaded cable to determine whether adequate echo control has been accomplished. It should be noted that coarse-gauge cable is capable of performing somewhat better than fine-gauge cable with existing networks.

3.07 The final source of echo is at the class 5 office end. For 4-wire facilities, the balancing net-

work at the class 5 end must match $900\Omega + 2.16 \mu\text{F}$ (the impedance of the balance termination) combined with the cabling through the switch between the hybrid and termination. In some cases, the hybrid built into a signaling unit or channel bank may not have adjustments flexible enough to meet requirements.

3.08 For a 2-wire facility, the electrical length of the end section must be adjusted to match as closely as possible the impedance of the balance termination.

C. Terminal Balance Requirements

3.09 The present terminal balance requirements have been generalized and are presented in Table B. For initial installation of circuits, no trunk below the ML should be turned up for service without concurrence from the area transmission engineer. The BSP layers 660-47Y-100, -300, and -301 instruct the responsible central office personnel to notify their area transmission engineer for any initial test results less than the ML. The area transmission engineer may elect to change the ML value, not equal to or less than the IA value under the constraints of Section 853-500-110 (see Maintenance Limits and Immediate Action Limits).

D. Analysis of Performance

3.10 As with through balance, the important consideration is the effect that this amount of echo has on the echo generated at the class 5 office. The net reflection measured by terminal balance is one component in the total amount of energy reflected to the customer. Another significant compo-

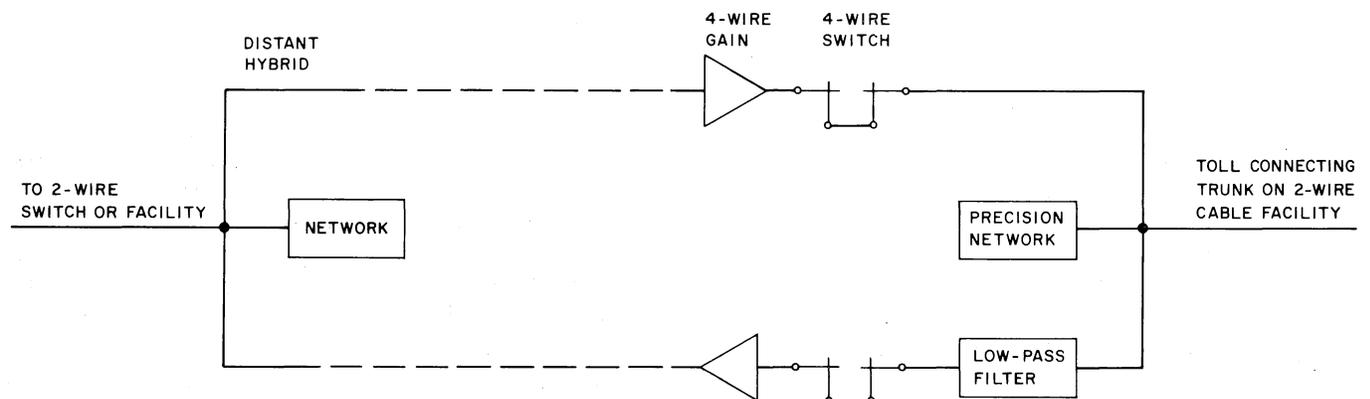


Fig. 5—Application of Precision Network and Low-Pass Filter

◆ TABLE B ◆

TERMINAL BALANCE REQUIREMENTS
(NOTES 1, 2, AND 3)

TYPE OF SWITCH	TYPE OF FACILITIES	ERL (DB)		SRL (DB)	
		ML/COR (NOTE 4)	IA	ML/COR (NOTE 4)	IA
Analog	Interbuilding 2 wire	18	13	10	6
	4 wire with 2-wire extensions	18	13	10	6
	Intrabuilding 2 wire	22	16	14	10
	All 4 wire	22	16	15	11
Digital	Interbuilding 2 wire	18	16	13	11
	4 wire with 2-wire extensions	18	16	13	11
	Intrabuilding 2 wire	22	16	15	11
	All 4 wire	22	16	15	11

Note 1: ML = Maintenance Limit
COR = Circuit Order Requirement
IA = Immediate Action Limit

Note 2: The requirements given above are general requirements. Specific requirements for different types of trunks at various locations may be found in Bell System Practice layers 660-47Y-300 and -301.

Note 3: For 4-wire facilities equipped with E-Type signaling units which have built-in 4-wire terminating sets with *fixed* NBOC, the interbuilding 2-wire requirements may be used (eg, SD-98086-01 [E1C and E2C] and SD-98087-01 [E1D, E2D, and E3D]).

Note 4: The ML/COR values may be modified by the area transmission engineer per paragraph 3.09.

ment is the reflection at the interface with the loop. The toll connecting trunk is short enough that time delay is not important and both parts should be considered as one unit in calculating the total reflected energy. At the present time, there is insufficient information to characterize the office equipment in this manner. However, if the toll connecting trunk impedance at the class 5 office is $900\Omega + 2.16 \mu\text{F}$ and if the phase relation between the trunk and loop reflections are neglected, the return loss of the loop cal-

culated against $900\Omega + 2.16 \mu\text{F}$ plus twice the loss of the trunk can be power-added to the terminal balance return loss to obtain the effective return loss at the class 4 office (Fig. 3). The output impedance of a toll connecting trunk is close to this value for short nonloaded facilities, carrier facilities, and cable facilities with negative-impedance repeaters. These types constitute about 70 percent of all toll connecting trunks. Since such a large percentage of trunks meets this assumption, the power-addition model is used.

3.11 The 4-wire facility \blacklozenge ML value \blacklozenge of 22 dB appears to cause an almost negligible amount of degradation. Although some increase in the \blacklozenge IA value \blacklozenge might be desirable if lower-loss design is implemented, the \blacklozenge ML value \blacklozenge appears to be quite satisfactory. Indeed, the high proportion of 2-wire toll connecting trunks in today's plant will delay any move toward a lower-loss plan.

3.12 Loss in the intertoll trunks is not a desirable long-term solution. With the 18-dB terminal balance \blacklozenge ML \blacklozenge for 2-wire toll connecting trunks, the echo contributions from the class 5 office and the toll office are about equal. However, the major source of echo should be allocated to the loop plant, which is much more difficult to control than toll connecting trunks. The major reason for the existing 2-wire \blacklozenge ML \blacklozenge is economics: it is difficult, but not impossible, to meet the higher \blacklozenge ML \blacklozenge with present 2-wire trunk designs and higher-cost 4-wire facilities would be needed in many cases. In addition, some 4-wire toll connecting arrangements which utilize hybrids built into a channel unit or signaling unit at the class 5 office have difficulty meeting the 4-wire \blacklozenge ML \blacklozenge because

some of these hybrids do not permit adjustment of NBO capacitors. However, with the advent of more economical carrier-provided 4-wire channels, the higher value on a distributional basis should be more easily met. Thus, the long-term terminal balance objective for *all* toll connecting trunks is \blacklozenge ML = 22 dB, IA = 16 dB. \blacklozenge

3.13 If these objectives are to be met for a trunk, individual pieces of equipment in the trunk must meet considerably higher values. Even though it is contemplated that, at the present time, equipment will be used with existing 2-wire facilities, the equipment should be chosen to meet the higher values so that when the facilities are upgraded the terminal balance objectives will be met.

3.14 The exclusive use of the above 4-wire objective is the long-term goal. The interbuilding 2-wire objective will not be changed at this time for existing facilities. The desired improvement should occur as more equipment such as short-haul T-type digital transmission systems are introduced into the plant.