TRANSMISSION TESTING CONSIDERATIONS
SWITCHED SPECIAL SERVICE CIRCUITS

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1. GENERAL

1.01 This section provides general information on transmission and signaling tests that are required during installation and maintenance of switched special services circuits. Switched special services circuits have access to the message telecommunication service (MTS) network.

1.02 When this section is reissued, the reason for reissue will be given in this paragraph.

1.03 The primary reasons for performing transmission and signaling tests are:

(a) to ensure that all the various elements making up a circuit are in proper alignment, and

(b) to verify that the circuits meet the transmission and operational requirements for which they were designed.

1.04 Circuits not meeting the requirements, after normal corrective action, should be investigated for wiring and installation errors, equipment troubles, etc. All tests ***must*** be made and all test requirements ***must*** be met before the circuits are placed in service.

1.05 ***Any circuit failing to meet its requirements should not be turned up for service.***

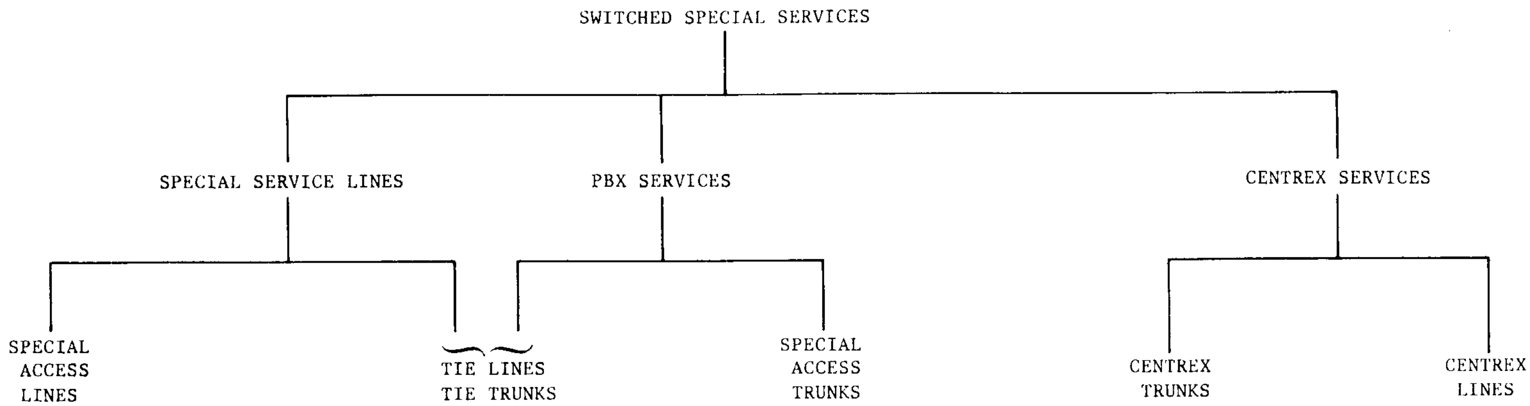
2. DESCRIPTION OF SWITCHED SPECIAL SERVICES

2.01 A brief description of many switched special service circuits is given in this part. See Fig. 1 for an organization of switched special services types.

A. Switched Special Services Lines

2.02 A ***foreign exchange line,*** common language designation (per Section 795-402-100) FX, provides a direct connection between a station at a customers premises and a remote central office (CO) other than the CO which normally would serve that customer location.

2.03 ***Wide area telecommunications service (WATS)*** permits a measured number of toll calls within selected wide geographical regions (bands) for a fixed monthly charge. WATS lines or trunks may provide incoming or outgoing service connecting a WATS customer with a CO equipped



SPECIAL ACCESS LINES	TIE LINES / TIE TRUNKS	SPECIAL ACCESS TRUNKS	CENTREX TRUNKS	CENTREX LINES
FOREIGN EXCHANGE LINE (FL)	INTERTANDEM (IT)	FOREIGN EXCHANGE (FT)	ATTENDANT (AD)	CENTREX CO (CL)
OUT WATS LINE (WO)	NONTANDEM (TL)	OUT WATS (WS)	AIOD (AI)	CENTREX CU (CX)
IN WATS LINE (WX)	TANDEM (TA)	IN WATS (WI)	DIRECT IN DIAL (DI)	CENTREX CU OFF PREMISES EXT (OC)
OFF PREMISES EXTENSION (OP/OS)	SATELLITE (SA)	PBX CO (TK)	DATA LINK (DK)	
SECRETARIAL LINE (SL)	CONCENTRATOR - IDENTIFIER LINE (CI)		DIRECT OUT DIAL (DO)	
ON PREMISES EXTENSION (PX)	CONCENTRATOR - IDENT SIG CKT (CP)		NONTANDEM - TIE TRUNK (TL)	
			ACD TRUNK (TR/TU)	

Fig. 1—Switched Special Services Types and Designations

to provide WATS. This WATS-equipped CO may be the office that would ordinarily serve that customer, or it may be a remote office.

2.04 An ***outgoing WATS line,*** designated WO, is used exclusively for outgoing bulk-rate calls from a customer station to a defined geographic area via the toll network.

2.05 An ***inward (incoming) WATS line,*** designated WX, is used exclusively for incoming calls from a defined geographic area to a customer station. If this service connects to an ACD at the customer location, it is considered for purposes of establishing transmission objectives to be an inward WATS ***trunk,*** designated WI.

2.06 An ***off-premises extension line,*** designated OP, connects an extension station to a main station line. The extension set is at a customer location which is remote from the main station location. The extension line may be bridged at the main station location, but more often the main station line and the extension line are bridged at the CO serving the main station.

2.07 ***Secretarial service line,*** designated SL, provides telephone answering service when a customer is not available to answer his calls. These SL lines, similar to off-premises extension lines, bridge the customer's line to the secretarial service location and usually terminate in a secretarial service switchboard or console.

B. PBX and CENTREX Services

2.08 A private branch exchange ***(PBX)*** is a manual or automatic telephone switching system located on a customers premises. It can interconnect PBX stations on the customers premises, connect these stations to the message network via PBX-CO, foreign exchange, long distance, or WATS trunks (all described in Part 2C), or connect these stations to other PBXs via tie trunks (described in Part 2D). A ***Centrex*** performs these same functions via switching equipment located on company owned or leased premises.

2.09 A tandem trunk network ***(TTN) Configuration*** is a switched customer network using tie trunks to interconnect PBXs or Centrexs in different locations; the component tie trunks in a tandem-tie trunk network (TTTN) have functions described in Part 2D. Figure 2 shows nontandem and tandem tie trunk networks.

2.10 A ***main PBX/Centrex*** is one which has a directory number and can connect PBX/Centrex stations to the message network for both incoming and outgoing calls. A main PBX/Centrex may have an associated satellite PBX/Centrex. A main PBX/Centrex homes on a tandem switch in an electronic tandem network (ETN) or TTTN configuration.

2.11 A ***satellite PBX/Centrex*** is characterized by having no attendant at the satellite location for an incoming call to the local directory number from the message network. All incoming calls are routed to or from the main PBX/Centrex over satellite tie trunks. This definition places no restrictions on the handling of outgoing calls from the satellite PBX/Centrex. A satellite PBX/Centrex may have one-way outgoing trunks to the CO, in addition to outgoing service on its tie trunks to the main PBX/Centrex. Satellite switches can also have direct-in-dial trunks. A satellite PBX/Centrex is usually unattended and usually located in the same exchange area as its main PBX/Centrex. A satellite PBX/Centrex usually homes on a main PBX/Centrex in an ETN or TTTN configuration. However, a satellite PBX/Centrex can also home on a tandem switch.

2.12 A ***tandem PBX/Centrex*** is one which is used as an intermediate switching point in a TTTN configuration in addition to the usual PBX/Centrex functions.

C. PBX/Centrex Trunks and Lines

2.13 ***PBX-central office (PBX-CO) trunks,*** designated TK, connect the PBX to the CO which normally serves the PBX location. These trunks appear as station lines (loop-start or ground-start) at the CO equipment.

2.14 ***Foreign exchange trunks,*** designated FT, are similar to PBX-CO trunks except that they terminate in a remote CO rather than the one which normally serves the PBX/Centrex location.

2.15 ***Long distance trunks,*** designated LT, provide a direct connection from a PBX at a customer's location to a toll switchboard. An LT trunk performs a function analogous to a toll

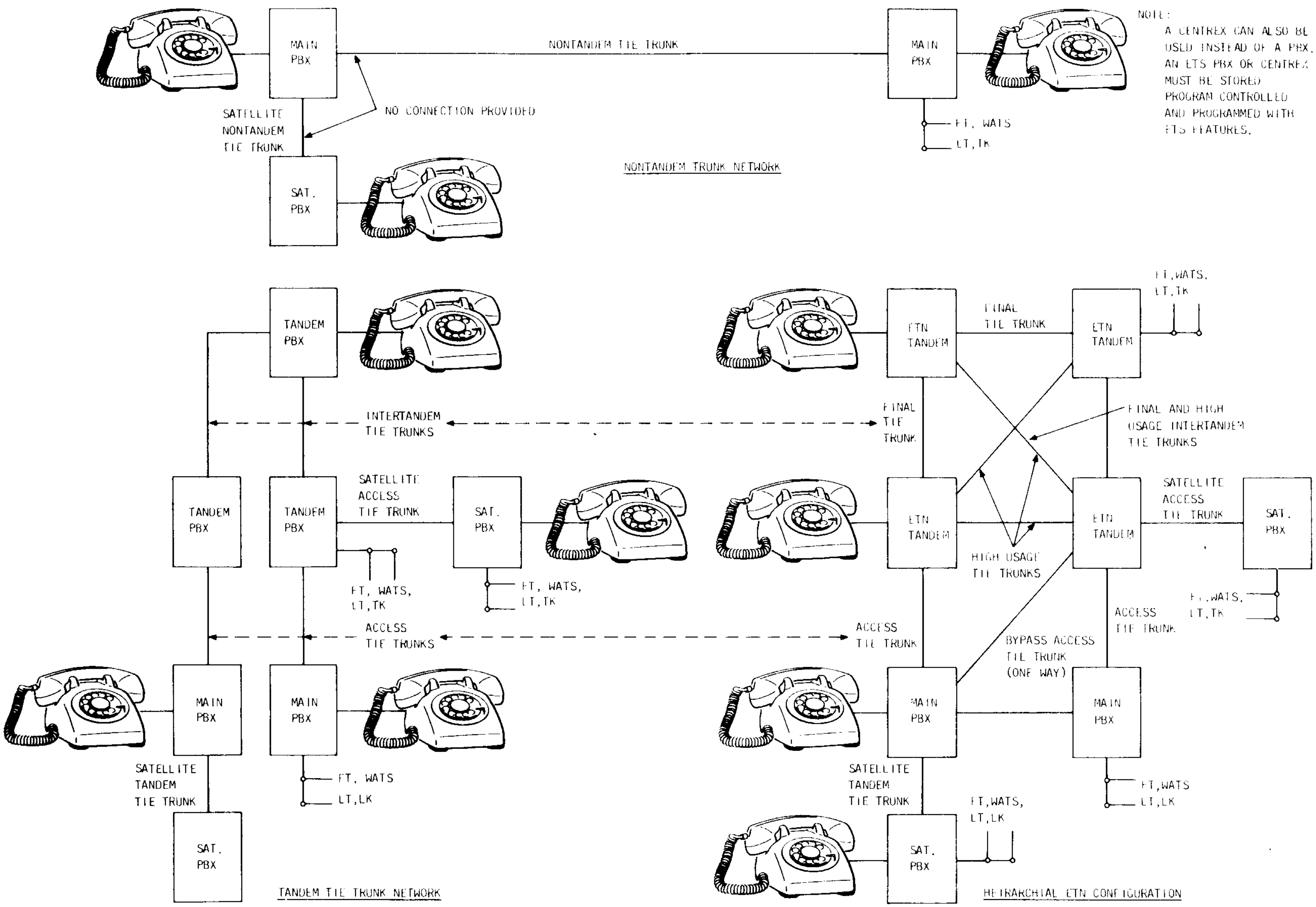


Fig. 2—Example of PBX Tie Trunk Networks

connecting trunk in the message network. There are two subclassifications of these trunks:

> ***Long-Distance Trunks*** connect hotel-motel switching machines to a local or remote 3CL toll switchboard for operator assistance in completing "Long Distance" calls and handling billing functions.
>
> ***Special Access Trunks (SATs)*** connect hotel-motel switching machines to a local or remote class 5 CO with common-control features for number identification into a TSPS, to allow the customer's station to "direct-dial" all calls into the MTS Network.

2.16 ***WATS trunks*** are similar to WATS lines except that they connect a PBX/Centrex to a WATS-equipped CO. Incoming WATS trunks are designated WI, and outgoing WATS trunks are designated WS.

2.17 ***Direct Indialing (DID) trunks,*** designated DI, use direct inward dial trunk circuits at dial PBXs to provide for the connection of an incoming call from the MTS directly to the desired station without the assistance of an attendant.

2.18 ***PBX on-premises station lines,*** designated PX, connect stations on the PBX premises to the PBX. The station lines can be switched by the PBX to other station lines, tie trunks, or to universal service message network access trunks. ***Centrex station lines,*** designated CL, connect stations on the customer premises to the Centrex where they can be switched in a similar manner as PBX lines.

2.19 ***PBX off-premises station lines,*** designated OS, provide the same services as on-premise station lines except that the station equipment is located off the PBX premises to which it is connected. ***Centrex off-premises station lines,*** designated CL serve customer station equipment located away from the local serving area of the Centrex.

D. Tie Trunks

2.20 A tie trunk is used to interconnect two PBXs or Centrexes.

2.21 A ***satellite tie trunk,*** designated SA, connects a satellite PBX/Centrex to its main PBX/Centrex, or to a tandem PBX/Centrex if in an ETN or TTTN configuration. It is usually characterized by being dial repeating for incoming calls to the satellite PBX/Centrex and either ring-down or dial repeating for outgoing calls to the main (or tandem) PBX/Centrex. If the PBX/Centrex, on which the satellite PBX/Centrex homes, is part of a tie trunk network connecting it to other PBXs or Centrexes, the satellite tie trunk functions as a nontandem, tandem, access, or bypass tie trunk and must meet the objectives corresponding to that function. ***Satellite tandem tie trunks,*** designated SA, are used to connect satellite to main PBXs/Centrexes which are connected into a customers tie trunk network (not SSN). ***Satellite access tie trunks*** (for both ETN and TTTN), or satellite bypass access tie trunks (for ETN), designated SA, connect a satellite PBX/Centrex to a homed or distant tandem switch, respectively.

2.22 A ***nontandem tie trunk,*** designated TL, connects two PBXs/Centrexes and is primarily intended to connect station lines at both ends. A nontandem tie trunk may also be connected to a PBX-CO, foreign exchange, or WATS trunk. Simultaneous connections to these trunks at both ends of ***any*** tie trunk are contrary to intended use and cannot be expected to provide good transmission. ***A tie trunk which may be connected to other tie trunks at either or both of its ends must be considered a tandem, access, bypass access, or intertandem tie trunk.***

2.23 In an ETN or TTTN configuration, the tie trunk between the main PBX/Centrex and tandem switch is called an ***access or bypass access tie trunk,*** both designated TA. The distinction between an access tie trunk and a bypass access tie trunk is shown in Figure 2. An access tie trunk interconnects a tandem switch with a homing main PBX/Centrex. A bypass access (or simply bypass) tie trunk is a (one way) circuit, in an ETN configuration only, connecting a tandem switch to a distant main PBX/Centrex not homed on that tandem.

2.24 In larger tie trunk networks, some tandem tie trunks may be connected to other tie trunks at both ends simultaneously. Tie trunks which may be connected in this manner are referred to as ***intertandem tie trunks,*** designated IT. When electronic tandem switch (ETS) is used to provide a hierarchical ETN configuration with alternate routing flexibility, there may be both HIGH USAGE and FINAL intertandem tie trunks in the same manner as intertoll trunks in the message network (see Figure 2). All intertandem tie trunks have the same transmission considerations, however.

E. Commercial ACD Service, ACD Trunks

2.25 An ACD is a switching machine that apportions incoming calls equitably and in order of their arrival to attendants. ACDs may be located either at the customer premises or on telephone company premises (for example, a No. 1 ESS equipped with ACD features).

2.26 ***ACD-CO trunks,*** designated TR, connect the ACD to the CO which normally serves the ACD location.

2.27 ***ACD foreign exchange trunks,*** designated FT, are similar to ACD-CO trunks except that they terminate in a remote rather than a local CO. These trunks use short-haul objectives and design considerations and are limited to mileage lengths less than 1000 miles.

2.28 ***ACD incoming WATS trunks,*** designated WI, connect an ACD to a WATS-equipped CO. (The WATS equipped office is often a class 4 or higher toll office, but may be a class 5 office). These trunks are used exclusively for incoming toll calls routed over the toll MTS network.

2.29 ***ACD overflow trunks,*** designated TR, are one-way trunks that connect two ACDs, one of which has the capability of routing calls to the other when traffic exceeds its capacity. Another form of such trunks is the ACD transfer trunk used for load balancing between collocated ACDs.

3. INSTALLATION AND REPAIR SERVICES

3.01 The installation and repair (I&R) services role in providing a special service circuit is two-fold. First, the circuit must be installed per the engineering instructions (with the prescription settings), and then it must be aligned to meet the design requirements. If the actual performance deviates from the expected performance too much, the installation forces must know the expected performance of each portion of the circuit in order to sectionalize the trouble. The second major job of the I&R services is maintenance. This includes both routine maintenance and repair or trouble clearing. Repair requires a knowledge of the performance circuit elements to enable a tester to sectionalize the problem and effect repair in the quickest fashion.

3.02 The principles given in this part are based on the following concepts:

(a) To provide good volume, the circuits are designed at the lowest loss which noise objectives, other design parameters, and economic considerations will permit.

(b) To ensure echo protection on long-haul circuits and built-up connections, the minimum losses are based on via net loss (VNL) design.

(c) To ensure minimum contrast in transmission performance between calls of similar functional natures but different connection configurations, loss objectives are established to be consistent with other circuits with similar functions.

These factors must receive careful consideration in the ***design, lineup,*** and ***maintenance*** of all circuits which can be involved in switched connections. The cumulative effect of relatively small errors in the ***design, lineup*** and ***maintenance*** of individual circuits can result in frequent trouble incidences in overall switched connections.

Plant Control Office

3.03 The plant control office (PCO) has responsibility for installation and maintenance of switched special services circuits.

3.04 The PCO, as operations control for these circuits, is responsible for service order control, preservice testing, equipment turn up/turn down, sectionalizing, repair tracking, routine testing and trouble analysis. As appropriate, the PCO will maintain all routine and trouble records for circuits.

Serving Test Center

3.05 A serving test center (STC) is the designated office responsible for the quality of service for an interexchange special service customer at a specified location. It has circuit responsibility for the portion of the circuit from the distributing frame at the STC to and including the customer station equipment. The responsibility includes circuit order work, transmission requirements, and service performance. The STC coordinates circuit activities with the PCO.

Special Service Center

3.06 The special service center (SSC) is the operations center that centralizes administrative control and some installation and maintenance operations associated with exchange and toll special services. The SSC is customer service oriented and has overall responsibility for all activities associated with the installation and maintenance of special services within a geographical area. Depending on the amount of special services work activity in the given geographical area, the SSC will administer installation and maintenance craft through direct dispatch or referral. The directed dispatch of installation and repair (I&R) forces under the SSC normally occurs in metropolitan areas. The referral is to a Repair Service Bureau for station work at the customer's premises. The SSC will refer central office work to the switching control center.

3.07 An SSC is a test center with operations control responsibilities for the installation and maintenance of remote testable (eg, SARTS testable) special services circuits in a geographical area. The SSC is most effective in an environment of one-person remote testing. The SSC is to be provided with trained personnel and adequate test equipment to test, control installation, and maintain the circuits assigned to it.

3.08 SARTS 1A is an operation support system for remotely accessing and testing special service circuits. This system has centralized test locations and remotely located testing capabilities that permit a testperson to access and test circuits between or from either of two Switched Maintenance Access System (SMAS) access points without assistance. The SARTS 1A can be operated on a stand-alone basis using access information obtained from nonmechanized circuit layout records (CLRs), or can be functionally interfaced with a Circuit Maintenance System 3A (CMS 3A), to provide the required basic systems for an SSC, or an STC when implementing the Special Service Installation and Maintenance System (SSIMS) Program. Figure 3 illustrates the elements of SARTS.

Repair Service Bureau

3.09 A Repair Service Bureau (RSB) is responsible for the maintenance of customer premise equipment (PBXs, station equipment, Customer Administration Center System (CACS) and station loops (including outside plant equipment) within its geographic area. The RSB administers repair forces within its service scope for maintenance activities and works with the appropriate PCO to initiate the activity required to maintain the customer service.

Plant Service Center

3.10 The Plant Service Center (PSC) is responsible for the installation of customer premise equipment (PBXs, station equipment, CACS) and station loops (including outside plant equipment) within a geographic area. The PSC administers installation forces within its service scope for installation activities, and works with the appropriate SSC to initiate the CO activity required to install customer service.

4. TEST CONSIDERATIONS

A. General

4.01 This part reviews the current transmission loss philosophy for the design and ***maintenance*** of special services circuits. Three loss terms used for design, installation and maintenance purposes are defined as follows:

(a) ***Inserted Connection Loss (ICL):*** The 1004-Hz transducer loss between the originating and terminating outgoing switch appearances for a trunk and between the line-side switch appearance and the customer station for a line. All trunk inserted connection losses are specified with the proper terminating impedances for each end of the facility (600- or 900-ohms), depending on the nominal impedance of the CO, PBX, or ACD to which the trunk connects. Lines should be considered as terminated at the CO or PBX/ACD with the proper corresponding nominal impedance and with 600 ohms at the customer station end.

(b) ***Expected Measured Loss (EML):*** A calculated loss quantity which specifies the end-to-end 1004-Hz transducer loss that one would expect to measure on a terminated test connection between two readily accessible manual or remote

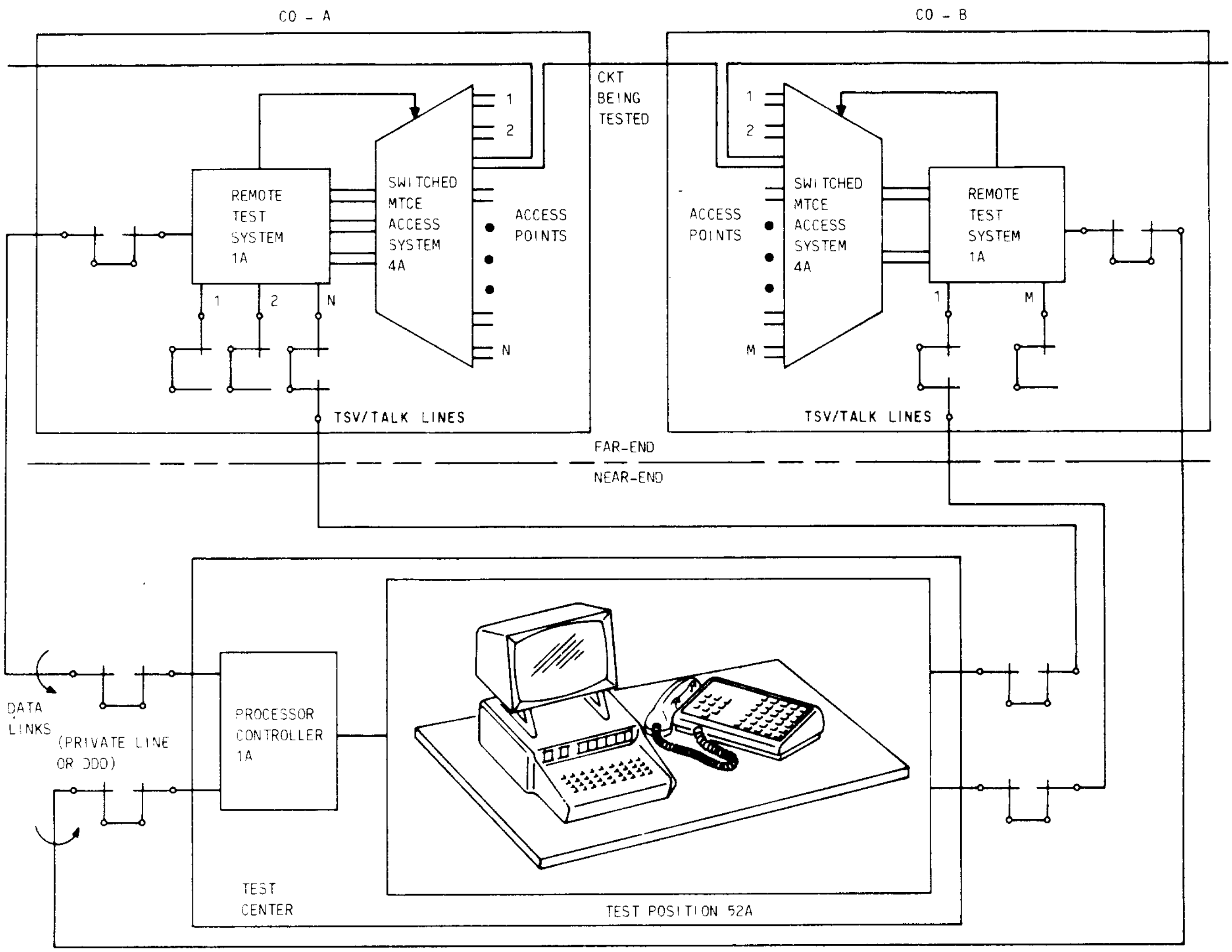


Fig. 3—Elements of SARTS

test points, such as switched access associated with the Switched Access Remote Test System (SARTS) for remote, centralized testing from a Special Service Center (SSC). The EMLs are always calculated with the proper terminating impedance (600- or 900-ohms) at each end of the circuit as with ICL.

(c) ***Actual Measured Loss (AML):*** The actual measured 1004-Hz transducer loss between the same two access points for which the EML is computed. The AML is recorded at the time of measurement and later compared to the EML for the measured circuit. The loss measurement connection, including test pads in the milliwatt supply (or equivalent) and transmission measuring set (TMS) access arrangements, is often referred to as the AML connection.

4.02 ***Circuit transmission loss objectives are specified in terms of ICL because this eliminates terminating connection losses peculiar to a specific circuit loss measurement.*** The ICLs of individual circuits can be summed directly to obtain the overall loss objective for a connection composed of several circuits in tandem.

4.03 ***Installation and maintenance loss objectives and requirements are specified in terms of EML and AML because these are defined as a terminated***

test connection between specified test access points.

4.04 In the definitions given above, ICL is used to design circuits. EML and AML are used for installation and maintenance testing.

Lineup and Maintenance

4.05 The lower loss design objectives and the use of VNL design require good lineup and maintenance procedures. Stable circuit operation cannot be achieved and maintained unless procedures at least as good as those used for the message network are developed and implemented. A lineup procedure including circuit layout information is necessary to ensure accurate lineup and maintenance.

4.06 Switched special service circuits should be measured under the same condition for which the EML was computed. The EML and other transmission objectives as calculated and placed on CLRs or work order and details (WORD) documents assume that the measurements are made from specific points in a circuit.

4.07 The specific points from where these measurements are made are called access points. These access points are jacks, Switch Maintenance Access System (SMAS) connector or "shoes" that give a test desk access to metallic facilities at the main distributing frame.

4.08 Test access for transmission tests can also be found at amplifiers, equalizers, 4-wire term set inputs and outputs, carrier terminals, and test board locations. At these access locations, impedance matching of the test equipment is often not required since the nominal input impedance of the test equipment is normally 600 ohms. Impedance matching is usually required when testing at the following circuit access locations: cable pair appearances, station sets, telephone sets, key telephone set (KTS) terminals, demarcation strips or terminals, and at most distributing frame appearances.

4.09 Transmission objectives or TLPs given on CLRs assume that the measurements are made from specific points in a circuit. The test equipment used to make the measurements is also assumed to have a specific impedance. For example, in the calculations of EML the test set impedance is assumed to be 600 ohms; and the terminating impedance of the circuit is usually assumed to be 600 or 900 ohms. In a few instances the circuit impedance may be assumed as 1200 ohms; for example, when measuring at the AMPL IN or AMPL OUT jacks of a V4 Repeater on the 359A or 359D equalizer side of the repeater. The impedance on the 4-wire side of Metallic Facility Terminal (MFT) repeaters may also be 1200 ohms. When the impedance of the test equipment and/or the circuit impedance differs from 600 ohms, correction factors should be applied to take into account reflection losses.

Transmission Level Point (TLP)

4.10 When testing a circuit, it is sometimes necessary to describe the power present at a particular point in the circuit and to compare this power to the power present at other points in the circuit. The power present at a particular point in a circuit is dependent upon the power at the source, and the loss or gain between the source and that point. Since this information is not always available, it is convenient to describe the power present in the circuit by comparing it to some standard reference point.

4.11 The reference point for measuring power in the Bell System is called the zero transmission level point or 0 TLP. This reference point makes it possible to compare the signal power at two points in a circuit even though the points are many miles apart.

4.12 With the establishing of the 0 TLP concept, the power present in a circuit is described by stating what this power would be if it were measured at the 0 TLP. The standard notation used to describe the power in this case is dBm0. For example, the term "-5 dBm0"; ie, if a -5 dBm signal were measured at the 0 TLP the meter would indicate -5 dBm.

4.13 After the power at the 0 TLP is described, the power at any point of the circuit can be determined. For example, if the signal power is -5 dBm when measured at the 0 TLP, it will be 5 dB below the value of any TLP on the circuit when measured at that TLP. If the signal power is -5 dBm at the 0 TLP, then the power at the -3 TLP would be -8 dBm [-3 + (-5) = -8]. Similarly, if a -5 dBm0 signal were measured at the -16 TLP, the meter would indicate -21 dBm [-16 + (-5) = -21].

Note: To know the power expected at any given TLP, it is necessary to know the power at another TLP on the circuit. For example, if a -10 dBm signal is applied to a circuit at the -7 TLP, the signal is -3 dBm at the 0 TLP [-10 - (-7) = -3]. The power at the -7 TLP is 7 dB lower than the power at the 0 TLP.

B. Common Tests

4.15 Certain tests are required in installation and maintenance. The following tests are typical for special service circuits. The tests are divided into groups according to transmission and signaling applicability.

Transmission Tests:

(1) 1004-Hz Loss Test

(2) Frequency Response Test

(3) Message Circuit Noise Test

(4) Balance Tests (Echo and Singing Return Loss)

(5) Singing Point Test

(6) Voltmeter Tests.

Signaling Tests:

(1) Listening or Operational Tests

(2) Pulsing Tests

(3) E & M Lead Signaling Tests

(4) Voltmeter Tests.

4.16 The individual ***transmission*** tests for special service circuits are described in the following paragraphs.

1004-Hz Loss Test

4.17 The 1004-Hz loss test determines that the circuit will provide the correct talking volume. The other frequencies in the voice band are "set" according to the level established for the 1004-Hz frequency. In other words the 1004-Hz point in the voice band of frequencies is selected as the reference point for the circuit. The transmission level of the entire circuit is referenced to the 1004-Hz level. All the TLPs of the circuit are measured at the 1004-Hz frequency. Since the 1004-Hz loss test establishes the AML of the circuit, no other tests should be performed until the 1004-Hz loss test has been performed. All other tests are ***level sensitive.***

4.18 Two functions of the 1004-Hz loss test are: (1) continuity check of the circuit (losing the 1004-Hz signal constitutes a loss of continuity, when it occurs in the transmission facility), and (2) deviations from the EML or TLP given on the CLR must be within prescribed limits, depending on the circuit type. Excessive deviations probably indicate that a problem exists in the gain- or loss-producing elements of the circuit.

Frequency Response Test

4.19 (Other names for frequency response are attenuation distortion, frequency attenuation, and slope.) Frequency response tests are made for at least two frequencies other than 1004-Hz. The lower test frequency (LTF) is 404 Hz and the upper test frequency (UTF) is 2804 Hz. Ideally, the frequency response test will cover all the frequencies from 404 to 2804 Hz at 200-Hz intervals. Frequency response requirements determine how much deviation from the measured 1004-Hz loss level is allowed for the whole voice frequency spectrum. The measured levels for each of the test frequencies are said to deviate from the measured 1004-Hz level by having more or less loss in dB. Normally, in designing the circuit, consideration is given to the fact that higher frequencies suffer greater loss in cable pairs than do the lower frequencies; thus lower frequencies often have less loss in the circuit than does the 1004-Hz frequency used as the reference point. Equalization networks usually compensate the frequency response of the circuit by adding sufficient loss to the lower frequencies, bringing their levels into the required limits. In order that the volume level of the circuit remains high enough when this loss is added, the original circuit design increases the gain proportionately.

4.20 Poor frequency response degrades the voice frequency transmission. If the deviations from the 1004-Hz level are great enough at the other frequencies in the voice band, then the volume levels can become too high, too low, or nonexistant.

Message Circuit Noise Test

4.21 Message circuit noise disturbs the normal operation of the circuit. The primary types and causes of message circuit noise are listed as follows:

- Normal facility background noise or "white" noise (partly produced as thermal noise from environmental causes and from heated components)
- "Frying", "crackle" produced by wet cable
- Crosstalk (produced by excessive carrier or repeater gain or by misalignment of carrier facility—usually intelligible)
- Cross modulation (produced by carrier misalignment or malfunction—distorted voice)
- Power hum (induced due to proximity with AC power lines—60 Hz or odd harmonic—180 Hz, 300 Hz, 420 Hz)
- Telegraph VF carrier (produces a whine in adjacent voice channels due to cross modulation)
- Working data (produced by various data sets, the sound varying according to the type and bit rate)
- Data polling (morse code sounds, in bursts)
- Microphonics (caused by contacts reproducing vibrations).

4.22 The end objective of the message circuit noise tests is to remove, or to reduce to acceptable levels, the noise components degrading the voice frequency transmission. The tests accomplish this by first verifying that the noise exists and is above acceptable levels; and, secondly, the tests can sectionalize the circuit by isolating the noise to a particular section of the circuit. Sectionalization is accomplished by repeating the noise tests, if necessary, at different test access points for the same circuit.

Balance Tests (Echo and Singing Return Loss)

4.23 Balance procedure is the combination of adjustment, measurement and evaluation process employed to control the amount of impedance mismatch. This is a fundamental means of controlling echo and singing at a hybrid junction needed to provide the necessary conversion between 2-wire and 4-wire facilities. The 4-wire terminating set (4WTS), or hybrid, permits transfer of voice frequencies from the 4-wire facility receive path into the 2-wire facility and from the 2-wire facility into the 4-wire facility transmit path. Because of the transformer type hybrid in the 4WTS, and the fact that power reflections will occur whenever impedance irregularities exist at interconnections of 2-wire circuits with 4-wire circuits, control of impedance at the interconnection point is necessary.

4.24 A portion of the power that is reflected within the 4WTS is returned to the transmit path of the 4-wire facility. This power is then amplified and returned to the distant end. If this returned power is received at the distant end with sufficient magnitude, impairments to transmission will occur.

4.25 When return losses are small and power is returned in the frequency band between 500 to 2500 Hz, the transmission impairment known as echo return loss (ERL) occurs. When return losses are small and power is returned at a single frequency with sufficient magnitude to start self-sustained oscillations, the RL impairment known as singing or near-singing, occurs. A singing condition often occurs when the gains exceed the losses in a circuit from termination to termination.

4.26 Although singing can occur at any frequency in the voice band, it generally occurs in the frequency ranges from 200 to 500 Hz and 2500 to 3200 Hz.

4.27 Since the same techniques are used for controlling the two phenomena, that is, balancing the impedance mismatch at various circuit junctions, current balance objectives include requirements for ERL and singing return loss (SRL).

4.28 Since some confusion may exist concerning definitions of RL, the following definitions are given:

Return Loss—The RL is the measure of an impedance match between circuits at the point of their interconnection. If, ***at a given frequency,*** the impedances exactly match one another, the RL is infinite. Stated another way, no transmitted energy is reflected, or returned, as echo or singing. Of course, the path followed by this reflected energy is typically from the 4-wire receive side of the facility through the term set and back through the transmit side of the 4-wire facility (arriving finally at the originating telephone set). A complete mismatch or imbalance will cause the RL to be zero (for example, if one impedance is zero due to a short circuit).

Echo Return Loss—The ERL is a weighted average of the RLs for all the frequencies in the echo range (500 to 2500 Hz). This measurement is made at the 4-wire side of the 4WTS where the 4-wire and 2-wire portions of a circuit interconnect. This measurement does not necessarily indicate the RL at an individual frequency. However, if ERL is maximized by adjusting the network building-out capacitance (NBOC), or a precision balancing network in the 4WTS, the average impedance of the 4WTS over the echo range will more closely approach the average impedance of the 2-wire circuit over the echo range. The ERL is measured with a KS-20501 return loss measuring set (RLMS), or equivalent.

Singing Point (SP)—The SP is a measure of the RL for a single frequency in the entire voice band (200 to 3200 Hz). This single frequency is often called the critical frequency. When singing or near-singing conditions exist, it may occur at any frequency in the voice band; however, since impedances are better controlled in the 500- to 2500-Hz band, the critical frequency usually occurs in the upper and/or lower ends of the voice band. The SP is measured with a 2D or 2E Singing Point Test Set, or equivalent.

Singing Return Loss (SRL)—The SRL is the weighted average of the RL in the singing bands (200 to 500 Hz and 2500 to 3200 Hz) and is measured with a KS-20501 RLMS, or equivalent. Switch settings on the KS-20501 RLMS determine the frequency band in which SRL is measured. The SRL switch position measures singing in the low portion of the band (200 to 500 Hz) and the SRL-HI switch position measures singing in the upper portion of the band (2500 to 3200 Hz). The SRL readings correspond closely with SP measurements and, for a given circuit, may be considered equivalent.

Singing Point Test

4.29 The primary difference between the SRL test and the singing point (SP) test is in the way the singing point is detected. The SRL test is described above. The SP test does not use an oscillator to introduce voice frequency energy into the circuit. This test, using the 2D or 2E Singing Point Test Set, adds gain to the circuit until the circuit sings at some frequency. The test set is placed in the circuit and functions as an amplifier increasing the gain sufficiently to cause singing at the critical frequency of the circuit being tested.

4.30 The relationship between the singing point and the gain of the circuit should be apparent from this procedure. The gain introduced during singing point testing may create high levels in the circuit, which, when transmitted into a carrier system, may disable the carrier. An excessively high level in a circuit can cause crosstalk in adjacent channels.

4.31 Certain categories of special service circuits have return loss objectives which must be achieved. These categories are lines or trunks which connect directly between a subscriber location and a toll switching machine or a toll switchboard multiple. Examples of these circuits are LD trunks, WATS lines (IN or OUT) and WATS trunks (IN or OUT). Another category of circuits which have return loss objectives are PBX services, such as PBX-CO trunks, PBX-FX trunks, PBX-WATS trunks and/or PBX station lines which connect to 4-wire PBX tie trunks.

4.32 Even though return loss objectives may not be specified for other types of special access circuits, there are many instances where return loss measurements should be made to ensure circuit stability. In those cases where circuits are unstable and no return loss objectives are given, the NBOC and/or precision balancing network, if provided, should be adjusted for maximum echo and singing return loss.

4.33 The individual ***signaling*** tests for special service circuits are described in the following paragraphs.

Listening and Operational Tests

4.34 When signaling failure is due to marginal condition or mutilation of signaling pulses, the human ear may not be able to determine at which point the distortion of signals occurs. In these cases signaling test equipment must be used. But if the signaling problem is something like loss of ringing or dial tone, then listening tests at different points in the circuit constitute the simplest method of sectionalizing the trouble. "Operational tests" attempt to reproduce the circumstances of the original signaling failure by dialing the same number from the test board position, or by connecting the headset to the tip and ring of the station set having difficulty and having the distant end attempt to dial; connected to the station set it is a simple matter to try to receive dial tone, for example.

Pulsing Tests

4.35 Pulsing tests in effect simulate dialing, in either direction on a circuit. The signaling test equipment measures the circuit's response to these pulses. By transmitting idealized dial pulses at an appropriate rate, the condition of the pulses can be measured after traveling through the circuit. If the timing of the pulses or the percent break is not acceptable, then the pulsing tests can be repeated at enough locations (including different test board locations) to sectionalize the difficulty. For example, the pulse timing is often affected by the pulse repeating relays in the signaling path. On the other hand, cable pair capacitance is typically a cause of percent break deviations. Percent break, which in the simplest sense has to do with the rounding off of the signaling pulses, is easily affected by excessive cable capacitance which tends to delay, widen, and generally distort signaling pulses. The effect of this signaling malfunction is usually wrong numbers or the complete failure to get the call to go through.

E & M Signaling Tests

4.36 These tests analyze signaling systems which use E & M lead signaling. By monitoring the conditions, electrically speaking, of the E & M leads which tie two or more signaling systems together, the presence or absence of proper signals can be determined. The line and drop lamp indications are given for typical modes of operation, such as idle, busy, ringing, dialing, incoming calls, and outgoing ring. With these indications the circuit operation in any of these modes can be tested.

Voltmeter Tests (Transmission or Signaling)

4.37 The voltmeter at the test board enables the test board operator to observe the electrical status of the tip and ring at the station end of the loop. Voltmeter tests yield the following information concerning the loop or local channel (experienced test board operators might add other uses for the voltmeter to this fundamental list).

(1) Voltage on tip or ring (battery condition)

(2) Ground on tip or ring

(3) Open between tip and ring

(4) Short between tip and ring

(5) Tip and ring shorted to ground

(6) High and low resistance ground on tip or ring (tested by shunt key operation)

(7) Open in tip side of loop

(8) Open in ring side of loop

(9) False short—estimation of distance from CA (tested by shunt key operation)

(10) Loop capacitance as an indication of loop length

(11) Reversal (turnover) of tip and ring, T1 & R1, and A & B leads (Example: B-lead reflecting A-lead status due to improper wiring)

(12) Simplex continuity check.

5. MEASUREMENT CONSIDERATIONS

5.01 For initial lineup, the circuits should be lined up section by section, ie, from PBX to repeater or carrier, from carrier to carrier, etc. It is especially important to lineup the metallic loop from the PBX through the carrier channel unit, signaling unit, or first repeater as one section. This is because the cable makeup may not be known exactly when the circuit is designed and the loop loss shown on the circuit card may not be correct. If the loop and the carrier channel unit are lined up together, any minor errors in loop loss are compensated for.

5.02 The circuit may consist of more than one transmission facility. Each segment should be aligned separately to meet its own requirements. When an overall measurement indicates the need for corrective action, the segments should be checked individually and corrected. After changing any facility segment, overall measurements and operational tests ***must*** be made on each circuit to ensure proper alignment of the circuit.

5.03 Prior to making measurements on a special services circuit a number of preliminary steps must be taken to ensure that an orderly procedure is followed and the circuit is turned up for service and is working as designed on the due date. To aid in this, a transmission test check sheet is provided in Section 311-100-102. A check sheet similar to this should be completed as necessary for each circuit and kept with the CLR for the circuit for future reference in the event of trouble occurring on the circuit.

5.04 The CLR or WORD should be studied carefully and the types of facilities and equipment requested at each CO location and at the customer location noted. The tests listed in Section 311-100-102 or test detail page of WORD should then be performed on each circuit. The type of information and the amount of detail contained on CLRs is not the same throughout the Bell System. Therefore, an attempt to discuss certain items should be provided in order to perform transmission measurements properly.

Preservice Testing

5.05 When the CLR along with its assignment information is received, the subscriber cable pairs involved should be tested for opens, short circuits, crosses, leakages, and grounds. These tests should be made from the CO to the subscriber location. Measurements of dc loop resistance should also be made and compared with the value given on the CLR. Preservice testing of cable facilities prior to installation and alignment of equipment can significantly reduce plant installation time in the event of cable pair trouble.

Carrier Facilities

5.06 Any of the carrier systems that are used for the message network may also be used for most special access circuits. In general, the same considerations regarding assignment of channels, use of compandors, etc, will apply. In many cases, carrier systems will require terminal equipment different from that used for the message network.

5.07 Since very few carrier system terminals are installed on customer premises, a metallic 4-wire or 2-wire facility will be extended from the carrier terminal in a CO to the customer location. In fact, many circuits will be made up of a carrier section in the center with metallic facilities at both ends. The transmission objectives covered in Section 311-100-102 apply to the entire circuit including the carrier channel, the metallic end links, the terminals, and any intermediate equipment.

5.08 For description and alignment of carrier facilities making up any portion of a special access circuit, the appropriate BSP should be consulted. For reference purposes, the section division numbers are tabulated below:

DIVISION	SUBJECT
356	K and L Multiplex Terminals
358	L1 Carrier
359	L3, L4, and L5 Carrier
362	N, O, and ON Carrier
365	T Carrier

2-Wire Circuits

5.09 Two-wire circuits, or circuits which are combination 2-wire and 4-wire, may require gain in order to meet transmission objectives. The Metallic Facility Terminal (MFT) is an arrangement whereby transmission units may be used to apply gain on a 2-wire circuit. The MFT has a family of 2-wire repeaters for use on either loaded or nonloaded cable. These units are coded J99343PA through J99343PE. Line building-out, equalization, and impedance compensation are built into each 2-wire repeater. Description, installation, and prescription setting information will be contained in Sections 332-912-ZZZ. The transmission units are aligned and tested using the J99343TB test extender. The description and operation of the MFT test extender is contained in Section 332-910-102.

5.10 The E6 repeater and its associated 830- and 837-type networks are also currently used items of equipment. Descriptive and alignment information for any E-type repeater is contained in the 332-20Y-ZZZ series of BSPs. This series of sections also contains description, installation, and prescription setting information for the 830- and 837-type networks. Additional information on 837-type networks, also referred to as impedance compensators, is contained in Sections 332-205-100 and -500. Overall lineup of special access circuits with E6 repeaters will be found in other sections in this division (311) of BSPs.

4-Wire Circuits

5.11 Four-wire metallic circuits which require gain will usually have repeaters assigned. The V4 repeater and its associated 359-type equalizers, 227-type amplifiers, 849-type networks and/or 1-type terminating sets is most commonly used. The 332-1YY-ZZZ series of BSPs contain description, installation, and prescription setting information for the V4 family of equipment. Information on 1-type terminating sets and 4066-type balancing networks is contained in the 332-8YY-ZZZ series of BSPs.

5.12 The MFT also has transmission units which may be used when gain required on a 4-wire circuit. These units are available in 2-wire to 4-wire (24), 4-wire to 2-wire (42) and 4-wire (44) configurations. These MFT transmission units are coded J99343RA through J99343RE for 24 and 42 repeaters and J99343SA and J99343SB for 44 repeaters. Equalization and impedance compensation is built into each MFT 4-wire repeater. Description, installation, and prescription setting information is contained in the 332-912-ZZZ series of BSPs. The transmission units are aligned and tested using the J99343TB test extender.

Prescription Settings and Touch-up Adjustments

5.13 The CLR should contain "prescription design" information for the equipment assigned for use on a special access circuit. Prescription design is the preselection of plug-in units, the screw-switch settings for each unit, and the gain or loss required for each amplifier or network selected. Prescription design is determined by the circuit layout forces based on their knowledge of the facilities assigned to a circuit. For some types of equipment, the prescription settings are final if the cable facilities are accurately known, but the prescription settings must be "touched-up" during alignment if the facilities are not accurately known.

5.14 Certain items of equipment may always require a touch-up adjustment. For example, the 830C network, which is used with the E6 repeater on nonloaded cable, will always require touch-up adjustments in order to meet E6 repeater return loss requirements. The 830E network also used with the E6 repeater on nonloaded cable may require touch-up. Prescription setting adjustments for the 830E network are available in Section 332-206-225. These prescription settings are usually adequate where the amount of bridged tap is small and when facility make-up is accurately known. Whenever terminal balance requirements are specified and 837-type networks are assigned, these networks must also be touched up to maximize return loss.

5.15 Procedures for optimizing the 830- and 837-type networks are found in the 311-240-50Z series of BSPs. Additional information about 837-type networks is contained in Section 332-205-100 and -500.

5.16 Where precision balancing networks of the 4066-type or older 115-type are used to balance 2-wire lines, touch-up adjustments of the associated building-out capacitors (BOCs) are required in order to achieve the required return losses and singing margin on the overall circuit. When the precision balancing networks are used with 1-type terminating sets, the BOCs in the terminating set should be used rather than those in the 115-type network, for example. The BOCs in the MFT repeaters will also require touch-up adjustments when return losses are specified.

5.17 Prescription settings for 359-type equalizers and the active equalizers in the MFT repeaters may also need touch-up if:

(a) the facilities are of mixed gauges

(b) loading sections are outside the length ranges for which settings are tabulated

(c) the facilities are not accurately described by the plant records.

Prescription setting information for 359-type equalizers can be found in the 332-116-ZZZ series of BSPs. Prescription setting information for MFT repeaters can be found in the 332-912-ZZZ series of BSPs.

5.18 After all prescription adjustments of LBO networks, impedance compensators, and equalizers have been made and touch-up adjustments completed, the overall loss, adjusted for temperature as described in Part 3D, should be measured. When the AML is not within ±0.5 dB of the EML after touch-up adjustments have been made, the individual link should be measured. Any link whose AML is not within the specified range of EML is investigated further to find the discrepancy. This investigation usually includes a measurement of the bare facility loss. If each link is within the requirements and the overall measurement is still not quite within range, minor adjustments can be made in the 4-wire link in order to meet objectives.

Temperature Effects

5.19 Temperature variations in cables cause corresponding variation to net loss and dc resistance. Net loss variations are not only undesirable in themselves, but may also cause hollowness and singing. Voice frequency links are generally not equipped to compensate automatically for net loss variations in cable pairs, thus the EML may have to be adjusted somewhat to provide this necessary compensation. (Similarly, temperature effects on resistance must be considered since variations in loop resistance can affect signaling range).

5.20 The circuit designer performs a number of calculations to take into account possible variations in temperature. These calculations consider, among other things, the gauge of cable, the length of cable, the percent of cable that is aerial vs underground or buried, as well as possible temperature extremes that may occur through the year.

5.21 If the cable temperature could be predicted or was known at circuit lineup time, the EML objective including temperature effects could be stated as a single figure on the CLR. Since this is not practicable, another means of stating the EML must be found. This is accomplished in the following manner. The circuit designer, after performing the computations mentioned above, determines a reference temperature for the cable facilities assigned to this circuit. Once the reference temperature is determined, a table is constructed, similar to that shown below, giving the actual temperature range and the required adjustment to the EML to prevent hollowness or singing. The table shown below is an example only. The actual adjustments to EML and the temperature ranges shown will vary depending on cable makeup and expected temperature extremes.

Example:

Assume that the following table was depicted on the CLR:

ACTUAL TEMPERATURE (°F)	ADJUSTMENT (dB)
-15° to -1°	-1.0
0° to +29°	-0.5
+30° to +60°	0.0
+61° to +90°	+0.5
+91° to +121°	+1.0

Actual cable temperature at lineup time must now be approximated. This is preferably done by reading the outdoor temperature in the shade. For layouts with aerial cable, it is best to line up when the sun has not warmed the cable much above air temperature. Assume, for this example, that the approximate temperature was 75° Fahrenheit. The EML given on the CLR must then be adjusted by +0.5 dB. That is, if the EML is stated as 3.5 dB, the circuit should actually be lined up to, and the AML should read, 4.0 dB. Note that since the cable temperature can only be approximated, adjustments to EML are given in 0.5 dB steps.

Signaling

5.22 There are two broad areas of signaling, customer line signaling and interoffice trunk signaling. Customer line signaling is the communication between the customers telephone set and the switching system serving the customer. An explanation of customer line signaling is covered in Section 975-110-100. Interoffice trunk signaling is concerned with the communication of call handling information between switching systems within the MTS network. An explanation of interoffice signaling is covered in Section 975-120-100. Emphasis will be on customer line signaling for switched special service circuits.

5.23 Signaling as discussed in detail in Section 311-100-101, is the communication between the subscriber and the telephone equipment. In ordinary telephone service the customer notifies the equipment that service is desired by removing the handset from the cradle or switch-hook. This action is called going "off-hook." The equipment at the CO tells the customer that it is ready to receive further information to process the call by giving the customer dial tone. Upon receipt of the dial tone signal the customer sends dial pulses or touch tone signals to the CO equipment to identify the telephone number being called. The CO equipment responds by causing the distant or called telephone to ring (providing the called telephone is not already "off-hook"). The equipment also sends back to the caller a tone called "audible ring" to indicate the called party's equipment (telephone set) is being signaled. The equipment is capable of sending a variety of signals to the calling station — busy, all trunks busy, camp on, and others. When the called party goes "off hook" or answers the call, the CO equipment recognizes the off hook, stops the ring signal to the called party, and connects through the talk path.

5.24 Switched special service circuits perform the same basic functions as message telephone service, but they may provide any one or more of the following features:

(a) Additional signaling stage (ie ground start)

(b) Function over greater distances from the serving central office (CO) (ie foreign exchange line)

(c) Special rate treatment (ie Wide Area Telecommunication Services)

(d) Remote and/or alternate answer of an incoming call to a main telephone (ie, off-premise extension)

(e) Special call handling (ie, hotel-motel LD lines).