Meridian 1

Electronic Switched Network

Transmission guidelines

Document Number: 309-3001-181
Document Release: Standard 4.00
Date: April 2000

Printed in Canada

Revision history

April 2000

Standard 4.00. This is a global document and is up-issued for X11 Release 25.0x.

December 1994

Standard 3.00. Reissued to include editorial changes and indexing.

December 1991

Standard 2.00. This document was reissued to include technical content updates.

August 1990

Standard 1.00. Reissued for compliance with Nortel Networks standard 164.0.

Contents

Introduction

The Electronic Switched Network (ESN) is a private communications network intended for use by large business customers with distributed operating locations.

This document describes the major transmission considerations that must be taken into account when planning an ESN network. The ESN transmission objective is to provide transmission quality comparable to public network calling. While this objective can easily be met for on-network calls, it is unreasonable to meet this objective for tandem combinations of public and private network trunks, because this produces a connection with inherently poorer performance. However, the sacrifice in performance should be small enough to be unnoticeable or at least tolerable. Noticeably poorer performance leads to an excessive number of calls placed by manually initiated bypass routing through the Direct Distance Dialing (DDD) network.

Transmission considerations

Echo

All voice connections between telephones require two directions of transmission for conversation to take place. When the signal transmitted in one direction is reflected over the other directional path, the caller hears the caller's own voice, with a slight delay.

Depending on the delay, the effect is perceived as sidetone, rain barrel effect, or echo. Two-wire facilities require care in matching impedances to prevent reflections. Four-wire facilities do not generate reflections. But they do not eliminate the reflection problem in built-up connections, because there are, in most cases, 2-wire connections to the telephones.

The objection to echo increases with the echo delay. The via net loss (VNL) plan provides an increasing loss depending on delay. However, the loss also reduces the received volume. Limits are placed on the amount of loss used to suppress echo. If these limits are exceeded, use echo suppressor devices instead.

Loss

The provision of good transmission requires the following compromises:

- sufficiently low (one-way) loss in each direction to provide satisfactorily high received volumes
- minimum contrast in received volumes on different calls
- sufficiently high round-trip losses to ensure adequate performance from the standpoint of suppressing talker echo, noise, and near-singing

The following loss plan has been developed for the Electronic Switched Network (ESN). The network is partitioned into node-to-node connections, node-to-main connections and main-to-satellite or tributary connections. The plan requires that

- node-to-node trunks have a maximum loss of 3.5 dB
- node-to-node tandem connections have a maximum loss of 4.1 dB
- node-to-main trunks have a maximum loss of 2.5 dB

You can meet these loss objectives by installing echo suppressors and reducing the loss to 0 dB on trunks when the objective loss is exceeded with VNL alone.

Tandem switching

Public network tandem switching

A public network tandem switch is usually collocated with the carrier facilities that serve the switch. You can make tandem connections between trunks terminating at this switch without significant degradation of transmission performance.

PBX network tandem switching

A PBX network tandem switch is usually located on customer premises, remote from the carrier facilities that serve the PBX switch. These carrier facilities are generally located at a telephone company (telco) switching center and connected to the PBX switch by local loop plant (cable). If the telco switching center does not have long-haul carrier facilities, short-haul carrier facilities are used to connect to another telco switching center that has these facilities. Thus, a tandem connection made at the PBX switch can introduce the distortion of two loop plant connections and two carrier facility connections, both avoided in the public network tandem connections.

Trunk routing rules

Trunk routing rules define the allowed connections between node, main, tributary, and satellite PBX switches. These routing rules are summarized in Table 1.

Table 1
Trunk routing rules

To: **From:**	**Node**	**Main**	**Tributary**	**Satellite**
Node	Yes (up to 4 links)	Yes (Note 4)	No (Note 3)	No (Note 3)
Main	Yes (one node only)	No (Note 1)	Yes (one main only)	Yes (one main only)
Tributary	No (Note 3)	Yes (one main only)	No (Note 2)	No (Note 2)
Satellite	No (Note 3)	Yes (one main only)	No (Note 2)	No (Note 2)

Note 1: Permitted for non-tandem trunks if the connected main PBX switches are part of a coordinated dialing plan. Also, routes of this type already in place when ESN is installed may be allowed to remain. However, these routes should be eliminated as part of network evolution to support the dialing plan.

Note 2: Routes of this type already in place when ESN is installed may be allowed to remain. These routes should be eliminated as the network evolves.

Note 3: This route is permitted by upgrading the tributary or satellite switch to main switch capabilities.

Note 4: One-way routes from nodes to main PBX switches are not restricted.

Transmission planning

The planning of Electronic Switched Networks (ESNs) can be partitioned into four major tasks:

- assessing the current equipment to identify locations of nodes, and designating existing equipment to remain in place as main, satellite, and tributary PBX switches
- planning the tie trunk routes
- planning the network routing
- planning off-network call routing

Placement of nodes

The first decision is the choice of locations for node switches. The following transmission factors should be considered:

- The node should be located near a telco toll switching center to minimize the loop plant and short-haul facilities between the node and long-haul facilities.
- The node should be near the middle of its cluster of main PBX switches so that most main-to-node facilities fall in the short-haul category.
- If earth satellite facilities are used extensively, nodes should be located near the earth station facilities.

Once the nodes are designated, the remaining PBX switches are designated as main, satellite, or tributary switches. All switches that have direct trunk groups to a node are main PBX switches. Those switches that access a node via the main PBX are satellite or tributary switches, depending on whether or not they have incoming central office trunks (COTs).

Tie trunk routes

Each pair of nodes in the network represents a potential tie trunk route. Traffic considerations and tariffs determine how many routes are equipped and how many trunks are required for each route. In general, the objectives of lowest cost and best transmission both dictate that the number of tandem trunks required to establish any connection be kept to a minimum. Thus, direct trunk routes should be established wherever practical.

Direct trunk routes represent a radical departure from Tandem Tie Trunk Networks (TTTNs). For TTTNs, routing is usually organized into major trunk route highways with feeder routes. This structure is efficient when alternate routing is not permitted, as with TTTNs, but it is not efficient when alternate routing is supported, as with ESNs. Thus, converting a large TTTN to an ESN can have significant impact on permitted routing.

Network call routing

The direct and alternate routes used for routing calls must be planned so that transmission can be evaluated on each route and appropriate controls established on individual trunks to meet objectives. Table 2 gives the maximum number of node-to-node routes possible in networks of various sizes. The table establishes the upper limits on the number of routes to ensure that no potential route is overlooked.

Table 2
Route count table (maximum number of node-to-node routes)

Nodes	Direct routes	2 trunks in tandem	3 trunks in tandem	4 trunks in tandem
1	0	0	0	0
2	1	0	0	0
3	3	3	0	0
4	6	12	12	0
5	10	30	60	60
6	15	60	180	360
7	21	105	420	1260
8	28	168	840	3360
9	36	252	1512	7560
10	45	360	2520	15,120
11	55	495	3960	27,720
12	66	660	5940	47,520

Assumptions:

Each node has trunks to every other node.

All routes that do not include the same node more than once are valid. (In practice, the number of valid routes is considerably less, since many of the routes will not make sense in a real work environment.)

Transmission controls

Transmission controls are established first for each direct trunk route then for two-trunk tandem routes, then for three-trunk tandem routes, and so on. For each route, an echo suppressor (ES) control or via net loss (VNL) value is specified. (VNL applies to land circuits shorter than 1800 miles [2800 km]; longer land circuits and all satellite circuits require echo suppressor control.)

The required via net loss (VNL) value is determined from the round-trip delay, which depends primarily on the type of facility and distance. Table 3 gives approximate VNL values for varying distances (in airline miles), based on the type of facilities typically provided by a telco. The actual distance could be considerably greater, because the actual signal path is less direct. However, the value includes a margin to accommodate average deviation from direct routing.

Table 3
Loss table for land circuits

Distance in miles (km)	VNL (dB)
0–100 (0–160)	
100–400 (160–640)	1.0
400–700 (640–1120)	1.5
700–1000 (1120–1600)	2.0
1000–1300 (1600–2080)	2.5
1300–1600 (2080–2560)	3.0
1600–1800 (2560–2880)	3.5

Note: Land circuits longer than 1800 miles (2880 km) and all satellite circuits require echo suppressor control.

Two-trunk tandem routes

Wherever two VNL trunks are in tandem, their VNL losses are summed. If the loss exceeds 4.1 dB, at least one of the trunks should be equipped with echo suppressors (ES) if the route is to be permitted. Normally, the higher loss trunk is selected for echo suppression; the minimization of the number of trunks that must be changed should also be considered. Thus, trunks that appear most frequently in high-loss connections should also be considered prime candidates. Table 4 summarizes this requirement.

Table 4
Transmission control requirements for two-trunk tandem connections

Trunk 1	Trunk 2	Requirement
ES	ES	No action
ES	VNL	No action
VNL	ES	No action
VNL	VNL	If total loss is less than 4.1 dB, no action; otherwise, change trunk 1 to ES or prohibit this connection.

Three-trunk tandem routes

For smaller networks, all three-trunk tandem routes should be sorted and tested for proper controls. For larger networks, the number of three-trunk tandem routes actually permitted is small in comparison to the number of possible routes. Therefore, the more efficient approach is to sort out the permitted routes and to consider only them.

For three-trunk tandem routes, echo suppressor combinations must be considered, as well as total loss. Whenever a VNL tie trunk is connected with echo suppressors between two trunks, the VNL tie trunk must be equipped with echo suppressors (ES) to make sure that intermediate echo suppressors are disabled.

Table 5 summarizes the transmission control requirements for three-trunk tandem connections.

Table 5
Transmission control requirements for three-trunk tandem connections

Trunk 1	Trunk 2	Trunk 3	Total loss if less than 4.1 dB	Total loss if greater than 4.1 dB
ES	ES	ES	No action required	No action required
VNL	ES	ES	No action required	No action required
ES	VNL	ES	Prohibit this connection (preferred) or change trunk 2 to ES	
ES	ES	VNL	No action required	No action required
VNL	ES	VNL	No action required	Change trunk 1 or 3 to ES or connection prohibited
ES	VNL	VNL	No action required	Trunk 2 must be ES or connection prohibited
VNL	VNL	ES	No action required	Trunk 2 must be ES or connection prohibited
VNL	VNL	VNL	No action required	One or more must be ES or connection prohibited

Note: When a trunk is changed to echo suppressor (ES) control, check all combinations in which it appears for routing violations.

Off-network call routing

The transmission properties of a call depend to a large extent on the type of facilities over which the call is transmitted (see Table 7). Because of these properties, certain destinations are disallowed for some types of off-network call routing. These are summarized in Table 6.

Table 6
Permitted off-network call routing

Route off-network call			Destinations permitted				
From	**By**	**By**	**Station**	**CO trunk**	**FEX trunk**	**WATS trunk**	**Other common carrier**
Node			Yes	Yes	Yes	Yes	Yes
Tie trunk	Node		Yes	Yes	Yes	Yes	Yes
Node	Main		Yes	Yes	No	No	No
Node	Main	Tributary or satellite	Yes	No	No	No	No
Main	Tributary or satellite		Yes	Yes	Yes	No	No

Note: Off-network calls to CO or FEX trunks are allowed only within local calling areas.

Network facilities

Private network facilities

You can order private network facilities from the local telephone company and other common carriers. Although you order facilities on a point-to-point basis, the telco must be informed of the overall planned network and generally assists in the design and selection of facilities. The following facilities can be ordered from the telephone company:

— 2-wire trunks

- TL 11M/E (E&M Type I signaling)
- TL 12M/E (E&M Type II signaling)

— 4-wire trunks

- TL 31M/E (Type I signaling)
- TL 32M/E (Type II signaling)

Conditioning is the tolerance on frequency response and delay distortion. Several degrees of conditioning beyond basic line quality are available, including: C1, C2, C3, C4, and D1. Generally, the basic line quality is adequate for voice applications. Conditioning is usually required for voiceband data applications.

Table 7
Private network facility requirements

From	To	Facility required	SL-1 cards
Node	Node	TL 31M/E interface (4-wire E&M Type 1)	QPC237
Node	Main	TL 31M/E interface (4-wire E&M Type 1)	QPC237 QPC71
Main	Satellite	TL 11M/E or TL 12M/E (2-wire E&M Type 1)	QPC71

When ordering telco facilities, you must provide the FCC registration number. Different interfaces must be ordered for non-registered equipment. It is acceptable to have registered and non-registered equipment attached to the same facility, as well as to have a tie trunk between telco and customer-provided PBX equipment. Facilities ordered from a telco are furnished with VNL loss (0 dB loss if echo suppression is provided). When customer-owned facilities are used, it is the customer's responsibility to insert the VNL loss into the facility.

Public network facilities

Public network facilities must be ordered from the telephone company. A summary of these facilities is given in Table 8. The facilities must be identified as connecting to customer-provided equipment, and the FCC registration number provided. The facilities ordered can include:

— PBX central office trunks

— PBX foreign exchange trunks to specific foreign exchanges

— PBX inward WATS trunks

— PBX outward WATS trunks

— off-premise stations

In addition, you may order direct trunks to SPRINT and other common carrier systems from these service suppliers. These services provide indirect access to the public network.

Table 8
Public network facility requirements

Service required	Facility required
Local calling area	PBX/CO trunk
Calling area local to a distant exchange	PBX/FEX trunk
Wide calling area within the same state	Intrastate WATS outgoing PBX trunk
Calling area, all bordering states	Interstate WATS outgoing PBX trunk, band 1
Calling area within USA, Canada, bordering states, and beyond	Interstate WATS outgoing PBX trunk, band 2 and higher
Calling to major cities in United States	Non-Bell services such as Sprint or MCI

Transmission performance

Voice quality performance

The quality of voice connections made over tandem trunks is a function of the composite characteristics of the trunks. Each trunk added to the connection degrades the overall transmission performance. Thus, some limits must be placed on the number of trunks permitted in tandem, as well as on which trunks may be connected.

To maintain adequate voice quality while keeping the routing restrictions from becoming unduly complex, ESN is partitioned into two basic connection categories, each with its own set of requirements. The connection categories are as follows:

— node-to-node

— node-to-main, satellite, or tributary

Node-to-node connections

The restrictions on node-to-node connections are the following:

— No trunk has a loss exceeding 3.5 dB.

— No combination of trunks used for a valid connection have a loss exceeding 4.1 dB.

— Split echo suppressors are provided at each end of each trunk equipped with echo suppressors. Each echo suppressor is enabled or disabled by the switch at its end.

— Tandem connections of echo suppressor-controlled trunks are permitted, provided the intermediate echo suppressors are disabled. The switch disables the echo suppressors it controls when a direct connection is made between two echo suppressor-controlled trunks, thus meeting this requirement. Routes with one (or more) intermediate non-echo-suppressor-controlled trunks between echo suppressor-controlled trunks are not allowed because the intermediate echo suppressor is not disabled.

— Generally, no more than three tie trunks should be connected in tandem. A limit of four is imposed between echo suppressor-controlled trunks. Software is arranged to disable echo suppressors when it tandems a call from an echo suppressor-controlled trunk to another such trunk. It does not disable echo suppressors on other connections.

Node-to-main, satellite, or tributary connections

Restrictions on these tie trunks follow.

— The node-to-main trunk is normally a land circuit not exceeding 250 miles (400 km). If this is not the case, the main PBX is treated as a node for transmission planning. The transmission planning of the node-to-main tie trunk is considered part of node-to-mode transmission planning.

— The node-to-main tie trunk, if less than 250 miles, must have a loss not exceeding 2.5 dB.

— Main-to-satellite and main-to-tributary trunks must have a loss not exceeding 2 dB.

Note: In some cases, the telco may be able to provide only non-VNL trunks, which have a loss exceeding these objectives. If the loss is significantly higher than VNL, the switchable pad must be in the "pad-out" mode for connection to these trunks.

To minimize toll charges, ESN can route calls over private network facilities to public network trunks. The public network has a designed loss that does not take into account the added loss of extending the call over private network facilities.

ESN, like any other private network, provides lower quality connections than a call routed directly to the public network. The amount of degradation must be kept small enough that the connection is acceptable to most users. This loss is restricted as follows:

— Off-network long-distance connections are to be established only from trunks terminating on nodes. The private network loss added to the public network loss is limited to the following:

  - 4.1 dB for calls originating at node stations
  - 6.6 dB for calls originating at main stations

— Off-network local connections can terminate at nodes and main PBXs. For nodes, the loss is the same as above. For mains, the loss is limited to the following:

  - 6.6 dB for calls originating at node stations
  - 9.1 dB for calls originating at main stations

Voiceband data performance

Voiceband data modems are used to transmit data between private network switches. General guidelines on the expected performance of various modem types for different ESN connections are provided in Table 9 and Table 10.

These guidelines are based on documented transmission performance of Bell System private lines and actual measurement of the Meridian 1 and several metropolitan area private lines. The expected performance is stated in statistical terms only to reflect the wide performance range of actual circuits.

The probability of success in completing a data call is based on an overall average of all Bell System private lines. A particular line or group of lines may be better or worse than the average. The expected performance stated here should be used only as a general indication.

Tables 9 and 10 specify the expected performance for ESN connections with one, two, and three trunks in tandem. The percentage of successful calls is given for a given modem bit-rate. Table 9 applies to modems with automatic adaptive equalizers; no significant improvement is expected with C2 or C1 conditioned lines compared with basic-quality private lines. Using D1 conditioned lines (guaranteed lower noise) can improve performance as shown in Table 9. For modems without automatic (fixed) equalizers, significant improvement over basic line performance can result from using C1 or C2 conditioning, as shown in Table 10.

Table 9
Performance of modems with automatic adaptive equalizers

Modem bit rate (probability of success)		
Number of trunks connected in tandem	**Basic C1, C2 conditioning**	**D1 conditioning (4-wire facility)**
1	2400 b/s (80%)	4800 b/s (<80%)
2	2400 b/s (50%)	4800 b/s (50%)
3	Not recommended	2400 b/s (50%)

Table 10
Performance of modems with fixed equalizers

	Modem bit rate (probability of success)		
Number of trunks connected in tandem	**Basic conditioning**	**C2 conditioning**	**C3 conditioning**
1	2400 b/s (75%)	2400 b/s (80%)	2400 b/s (90%)
2	2400 b/s (50%)	2400 b/s (60%)	2400 b/s (75%)
3	Not recommended	2400 b/s (50%)	2400 b/s (50%)

Maintaining transmission performance

Maintaining high transmission performance in private networks requires constant vigilance on the part of the network administrators. Experience with the Northern Telecom network demonstrates that transmission performance degrades over time. The degradation can be traced to inadequate maintenance of the facility by the supplier and administrative changes by the supplier in the assignment of equipment to provide tie trunk service.

Installation

After a tie trunk facility is installed, the installer runs a transmission test to verify that the facility meets tariffed requirements. Only after the performance has been verified is the facility ready to be turned up for service.

Scheduled maintenance

Scheduled maintenance should be performed at regular intervals whether or not trunk faults are known to exist. Testing should be carried out once a week until it is determined that less frequent testing is adequate.

Corrective maintenance

Follow-up to trouble reports generated by users or software diagnostics identifies various trunk problems in need of correction.

Transmission testing of tie trunks

ESN switches are capable of accessing a quiet termination or a 1020 Hz test tone at a remote ESN switch. These capabilities permit the testing of tie trunk transmission performance.

Testing loss

The following test is performed at each end of each tie trunk so that both directions of transmission are checked:

1 From the maintenance terminal, load the trunk test program and access the remote test tone for the trunk to be tested.

2 Connect a transmission level meter to the “facility in” access jacks of the trunk under test. Measure the level of the 1020 Hz test tone. The permitted level requirements, based on a switched-in pad mode at the far-end switch, are given in Table 11.

Table 11
Transmission level requirements

Trunk design loss (dB)	Minimum (dBm)	Maximum (dBm)
0	–17.5	–11.5
0.5	–18	–12
1.0	–18.5	–12.5
1.0	–19	–13
2.0	–19.5	–13.5
2.5	–20	–14
3.0	–20.5	–14.5
3.5	–21	–15

If the requirements in Table 11 are not met, you must isolate the fault to the trunk facility or equipment. The following test aids in this isolation. Perform the test at each end of the facility.

1 From the maintenance terminal, load the trunk test program and access the local test tone.

2 Connect a transmission level meter to the “equipment” out jack of the suspect trunk. The level requirements are

- for QPC71 circuit packs: –15 dBm minimum, –13 dBm maximum
- for QPC237 circuit packs: –15.5 dBm minimum, –13.5 dBm maximum

If the second requirement is not met at either or both facility ends, perform corrective maintenance and repeat the test. If the requirement is met at both facility ends, the facility supplier should perform corrective maintenance.

Testing noise

The following test is to be performed at each end of each tie trunk so that both directions of transmission are checked.

1 From the maintenance terminal, load the trunk test program and access the remote quiet termination for the trunk to be tested.

2 Connect a noise meter to the “facility in” access jacks of the trunk under test. The noise requirements are given in Table 12.

Table 12
Transmission noise requirements

Distance in miles (km)	Maintenance (dBrnC)	Immediate action (dBrnC)
0–15 (0–24)	28	36
16–50 (26–80)	28	36
51–100 (82–160)	29	36
101–200 (162–320)	31	36
201–400 (322–640)	33	40
401–1000 (642–1600)	35	40
1001–1500 (1602–2400)	36	40
1501–2500 (2402–4000)	39	44
2501–4000 (4002–6400)	41	46

Note: Trunks with a noise measurement in the maintenance range may be left in service. Trunks with a noise measurement in the immediate action range should be immediately removed from service. In either case, initiate maintenance action promptly.

If the requirements in Table 12 are not met, you must isolate the fault to the trunk facility or equipment. The following test will accomplish this isolation. Perform the test at each end of the facility.

1 From the maintenance terminal, load the trunk test program and access the local quiet termination.

2 Connect a noise meter to the “facility out” jack of the suspect trunk. The requirement is that the noise not exceed 23 dBrnC.

If the requirement is not met at either or both facility ends, perform corrective maintenance on the appropriate Meridian 1 and repeat the test. If the requirement is met at both facility ends, the facility supplier should perform corrective maintenance.

Transmission considerations for remote network access

One application of private networks is to reduce toll charges on public network to public network calls. The user in the public network makes a local or toll-free (INWATS) call to one of the private network switches, then calls to an off-network destination via either Direct Inward System Access (DISA) or attendant assistance.

Gain

The public network transmission plan does not support tandems of two or more connections. Such tandems inherently occur when using the private network to make a public network to public network call. The loss can be partially offset by gain.

Public network to public network calling via the private network has relatively small usage and savings, so it does not justify a change to the private network transmission plan. Instead, gain is applied on the access trunks, which are used exclusively for incoming calls. The gain is applied independently of the connection established through the private network. Thus, the amount of gain provided is a compromise that optimizes grade of service on the more important connections but possibly degrades service on some others.

Gain devices

The gain required is bidirectional between 2-wire interfaces and is provided by devices called repeaters. There are two types of suitable bidirectional gain devices: fixed and switched gain. Fixed-gain devices are extremely sensitive to impedance mismatches at the 2-wire interfaces. Such mismatches can cause oscillation. Switched-gain overcomes the oscillation problem, but introduces speech impairments due to the switching action.

Fixed gain

You can implement bidirectional fixed gain by adding either an amplifier on a 2-wire path or two unidirectional amplifiers in a 4-wire arrangement, interfacing the 2-wire path through hybrids. Both schemes are sensitive to the impedances at the 2-wire interfaces. Adjustable matching networks are required to allow the device to interface a variety of facilities.

The more gain required, the closer you must match the impedances to the interfaces to prevent oscillation or poor transmission associated with near oscillation. The impedance at the interfaces is partly determined by the impedances of facilities switched into a connection. Ultimately, those impedances limit the practical gain.

Voice-switched gain

The voice-switched gain amplifier avoids stability problems by applying gain dynamically. Only one direction of transmission can have gain at a time. A loss equal to the gain is provided in the opposite transmission direction.

Gain is applied by monitoring for speech and applying gain in the talker-to-listener direction when speech is detected. In the idle mode, a small loss is inserted in both directions. Compensation for impedances is required for the direction sensing circuitry to function properly. Table 13 compares fixed gain and voice-switched gain.

Gain with compression

On some connections, signal levels may already be high, and gain may increase the levels above FCC specified limits. Some manufacturers provide compression options to guard against exceeding FCC limits. Speech compression ensures that signal levels will not exceed a specified maximum, generally –9 dBm. When speech levels amplified without compression exceed that level, the gain is dynamically reduced so the output level does not exceed –9 dBm. The –9 dBm limit is specified in FCC requirements.

Gain with compression is possible on both fixed gain and voice-switched gain repeaters and does not change the adjustment procedure.

Table 13
Comparison of fixed gain and voice-switched gain

Fixed gain	Voice-switched gain
Does not degrade speech by gain switching action.	May degrade speed.
Must be permanently attached to a trunk and be adjusted for its impedance.	May be switched into connections as required, but is affected somewhat by facility impedance.
Is not sensitive to voice levels.	May require voice activation adjustment to provide required sensitivity.
May oscillate under certain circumstances.	Is “unconditionally” stable.
Is “transparent” to voiceband data and DTMF signaling.	Must be switched out for voice-band data and may impair DTMF signaling.

Recommendation

When the required test equipment is available and the type of facility provided by the telco is known, use fixed gain units because of their superior performance. Use switched gain units where transmission performance is not so critical or the more complex alignment procedure for fixed gain units cannot be performed.

Adjustment

The gain should be set initially to 6 dB in each transmission direction. This value of gain is a compromise between optimized grade of service and practical considerations of avoiding oscillation and other transmission impairments. Based on experience, you may then adjust the gain to greater or less than 6 dB.

Application to trunks

To minimize the effect on the overall transmission plan, install the gain units only on trunks used to access the network primarily for calling via tie trunk facilities or to off-network destinations. Calls originated on-network are to be blocked from accessing these trunks.

Arrange one-way incoming Direct Inward System Access (DISA) central office trunk (COT) groups, using ground start trunks. The trunks are used for calling over tie trunks and off-network. Calls terminating on the same PBX should be placed by the attendant or direct inward dial (DID) trunks, if provided.

When DISA is equipped on DID trunks, do not provide gain units. DID trunks carry traffic both to telephones and DISA, and gain is not desirable for the traffic to telephones. Instead, add a new ground-start CO trunk group and move DISA to that group. Gain units can then be provided on that group.

Glossary

Following are definitions of the terms used in this publication.

Public network facilities

PBX central office trunk

PBX central office (CO) trunks connect the PBX switch to the central office serving the PBX location. The trunks appear as station lines at the central office equipment.

Foreign Exchange Trunk

A Foreign Exchange (FEX) trunk provides a direct connection between a PBX switch and a remote central office other than the central office that serves the location of the PBX.

Wide area transmission service

Wide area transmission service (WATS) provides a bulk-rate service for incoming or outgoing toll calls within selected geographical regions (bands). A WATS trunk must terminate on a central office equipped to provide WATS, which may be the office that would normally serve that customer or may be a remote central office.

— Outgoing WATS

An outgoing WATS (OUTWATS) trunk is used exclusively for outgoing bulk-rate calls from a customer's PBX to a defined geographical area via the toll network.

— Incoming WATS

An incoming WATS (INWATS) trunk is used exclusively for incoming calls from a defined geographical area to a customer's PBX.

2-wire facility

A 2-wire facility is characterized by supporting transmission in two directions simultaneously, where the only method of separating the two signals is by the propagation directions. Impedance mismatches cause signal energy passing in each direction to mix with the signal passing in the opposite direction.

4-wire facility

A 4-wire facility supports transmission in two directions, but isolates the signals by frequency division, time division, space division, or other techniques that enable reflections to occur without causing the signals to mix together. A facility is also called 4-wire if its interfaces to other equipment meet this 4-wire criteria (even if 2-wire facilities are used internally), as long as crosstalk between the two transmission directions, as measured at the interface, is negligible.

PBX types

Main PBX

A main PBX is one which has a Directory Number (DN) and can connect PBX stations to the public network for both incoming and outgoing calls. A main PBX can have an associated satellite PBX, and can be part of a tandem tie trunk network (TTTN). If the main PBX provides tandem switching for tie trunks, it is called a tandem PBX. In the context of ESN, a main PBX has tie trunks to only one node.

Satellite PBX

A satellite PBX has no direct incoming connection from the public network. All incoming calls are routed from an associated main PBX over tie trunks. This definition places no restrictions on the handling of outgoing calls from the satellite PBX. A satellite PBX can have one-way outgoing trunks to the central office, in addition to outgoing service on trunks to the main PBX. In the context of ESN, a satellite PBX has no direct trunks to a node; however, calls to the node can be made through the main PBX.

Tributary PBX

The only difference between a satellite and a tributary PBX is that the tributary PBX has a direct incoming connection from the public network.

Tandem PBX

In addition to its usual PBX functions a tandem PBX is used as an intermediate switching point in a tandem tie trunk network (TTTN) to connect tie trunks together.

ESN node PBX

An ESN node PBX is a Meridian 1 system equipped with the node software package of ESN. It performs tandem switching with software-controlled alternate route selection to bypass busy trunk groups.

ESN main PBX

An ESN main PBX is a Meridian 1 switch with the ESN main software package. It performs tandem switching between a node and the main's satellite and tributary switches. An ESN main PBX has outgoing tie trunks to only one node.

PBX networks

Tandem tie trunk network

A tandem tie trunk network (TTTN) is a switched customer network that uses tie trunks to interconnect PBX switches in different locations. Calls are routed between the switches by progressive dialing of access codes.

Common Control Switching Arrangement

A Common Control Switching Arrangement (CCSA) is a Bell system offering that divides equipment between PBX switches and tandem switches. The tandem switches are located on telco premises and perform only a tandem switching function. A user makes network calls at a PBX switch by dialing an access code (typically the digit *8*), which connects the user to the telco tandem switch. The user then dials a seven digit number to reach the desired telephone at another connected switch. Routing between tandem switches is performed under common control.

Electronic Switched Network

An Electronic Switched Network (ESN) is a Northern Telecom private network offering with a dialing plan similar to that used in a CCSA. However, tandem switching functions are performed by PBX switches located on the customer's premises. Fewer restrictions on tie trunk routes are required by ESN than by the CCSA. CCSA requires that at least two tie trunks be connected in tandem to route a call between a pair of PBX switches. ESN uses one tie trunk to perform the same routing wherever there is sufficient traffic to justify the route.

Transmission level point

As an analog signal passes over a transmission facility, it encounters gains and losses that are part of the facility design and net out to zero. For example, a facility that uses a cable may have loss in the cable and may compensate for this loss by gain in one or more amplifiers. On the other hand, some losses are introduced to improve grade of service and are not recovered. The term *transmission level point* (TLP) is used to discriminate a gain or loss that is recovered from one that is not.

TLP requires the definition of a point in a transmission system as a reference level. Once this point is defined, the reference levels at other points can be derived. For example, the input to a transmission system might be defined as a –2 TLP. Assume that the signal passes through a 10 dB amplifier that compensates for loss elsewhere. The output of the amplifier is at a +8 TLP([–2] + [+10]). A –10 dBm signal at the input will be 0 dBm at the output. The same signal is –8 dBm0 (8 dB below the reference level) at the system input. It is also –8 dBm0 at the amplifier output. The signal has the same level, referenced by the TLP, because the gain in this case is offset by loss elsewhere and does not show up as gain or loss at the signal destination.

A second example is a transmission system with a 2 dB deliberate loss. The input and output TLPs are –2. A signal in at –10 dBM is –8 dBm0. The signal leaves the system with a level of –12 dBm, or –10 dBm0. The difference in level, even though the TLP is the same, is the loss introduced deliberately in the facility.

Two-wire and four-wire trunks in PBX networks are usually –2 TLP. However, some 4-wire trunks have a –16 TLP at the facility input and a +7 TLP at the facility output. If the trunk has a 0 dB loss, an input signal of –26 dBm (–10 dBm0) is received at a level of –3 dBm (23 dB gain), which is also –10 dBm0. Thus, loss elsewhere in the connection cancels out the 23 dB in the facility.

Index

Meridian 1

Electronic Switched Network

Transmission guidelines

Publication number: 309-3001-181
Document release: Standard 4.00
Date: April 2000
Printed in Canada

NORTEL NETWORKS

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