

**TWX, WADS AND DATA-PHONE LOOPS  
 GENERAL TRANSMISSION DESIGN  
 CONSIDERATIONS**

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**1. INTRODUCTION**

1.01 Data-type Services, using tone signals in the voice frequency spectrum instead of DC-type telegraph signals, require an entirely different approach to the transmission design of their circuits. In addition the data-type signals employed in these services impose more stringent transmission requirements on facility considerations than those for regular voice operation.

1.02 TWX, WADS and DATA-PHONE are three distinct data services, which employ this type signal transmission. As such, the design engineering of their customer loops is common and for most part identical. For this reason the general transmission design considerations of customer loops for TWX, WADS and DATA-PHONE are covered in combination in the three sections, outlined below. For the purpose of this section, the term TWX refers to 3 row TWX only. 4 row TWX is considered in the WADS objectives.

SECTION	SUBJECT
AB22.077.1	General Transmission Design Considerations
AB22.077.2	Basic Characteristics and Line Treatment of Nonloaded and Loaded Facilities
AB22.077.3	Application of Prescription Design
While this series of sections discusses loop design primarily in terms of TWX, the information is directly applicable to WADS access lines and DATA-PHONE loops. Specific deviations or additional considerations for WADS and DATA-PHONE loop design are covered in the following sections:	
SECTION	SUBJECT
AB22.077.4	Additional Engineering Considerations for WADS
AB22.077.5	Additional Engineering Considerations for DATA-PHONE

2. GENERAL

2.01 Since TWX dial service uses the general Direct Distance Dialing (DDD) network, transmission loss variations will be encountered, depending upon the routing of the call from the originating office to the terminating office. In this connection, because the data subset lacks the high degree of tolerance and redundancy to transmission impairments that the talker and listener possess in voice communication, the loops must be designed to more rigid requirements than those for regular telephone service.

2.02 Operator assistance for TWX dial customers will be provided by the 6A Switchboard, which also serves WADS customers. The transmission aspects of the 6A Switchboard and its connecting trunks will be covered in other practices. However, it is worth noting here that there is no through switching at the 6A Switchboard as in regular switchboard type service. The data signal is completely regenerated by the cord circuit in the 6A Switchboard.

2.03 The local crossbar and step-by-step offices are the only types of offices presently suitable for use as TWX serving offices, for two

reasons. Firstly, the crossbar and step-by-step offices are the only offices currently equipped to provide automatic ticketing for TWX calls. Secondly, panel-type offices are inherently more noisy and should not be used. In this regard crossbar is preferred over step-by-step which also tends to have some adverse noise. Since there are TWX customers located in areas served by other types of offices, their loops must be extended via interoffice trunking facilities to a designated TWX serving office.

2.04 A customer's loop so extended, is termed a remote exchange (RX) loop. There are two conditions for RX loops. The first is where the customer originates and receives calls over the RX loop to his TWX serving central office. The second is where he originates calls over the RX loop to the serving central office, but receives calls from the local central office from which he receives regular telephone service. In this second case a Divided Access Line Circuit (DALC), which will be covered later, is required at the local (terminating) office. DALC arrangements will disappear as 4-row TWX is implemented. The two RX loop situations are illustrated in Fig. 1.

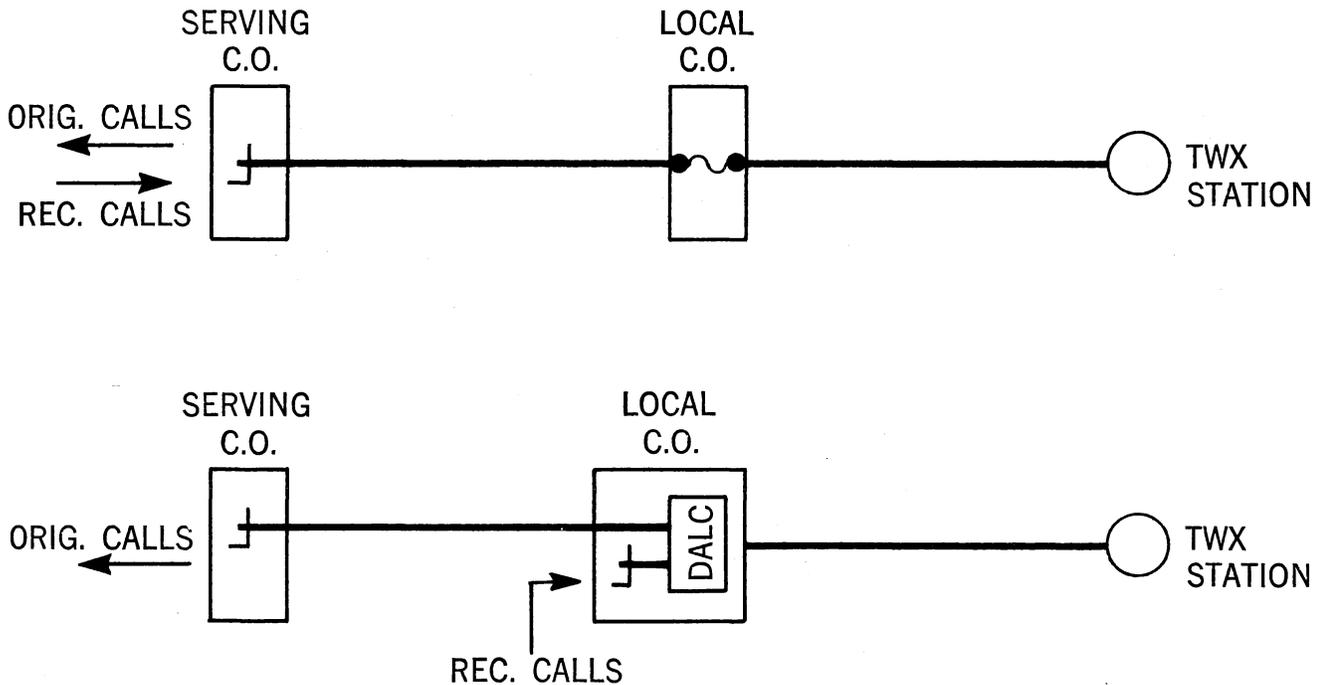


Fig. 1 - RX Type Loops — With and Without Divided Access Line Circuit

**2.05** Arrangements are provided for calling between TWX and WADS customers. In the case of TWX station calling a WADS station, the call will be routed part way via the DDD network and then over special "data only" trunks into the WADS network. In the call originated by a WADS station to a TWX station the call routes completely via the DDD network.

**2.06** DATA-PHONE services will use the regular DDD network the same as the TWX customer.

### 3. GENERAL TRANSMISSION ASPECTS OF THE TWX/WADS DATA SUBSET

**3.01** The data subset produces DC signals and provides the means of converting them to AC signals at frequencies in the voice-band, which can be transmitted over the message network. The subscriber set associated with the data subset contains an adjustable ringer, receive only handset and/or a speaker and a station dial. The TWX/WADS data subset can be associated with a 3-row, 60 word per minute (45 bits per second) machine or a 4-row, 100 word per minute (110 bits per second) machine. The same general loop transmission design considerations are applicable to both speeds.

**3.02** When a TWX data subset is called, it will receive a frequency, F1; and will transmit a frequency F2. The F1 frequency is 1170  $\pm$  100 cps. The F2 frequency is 2125  $\pm$  100 cps.

**3.03** The called TWX/WADS data subset upon receipt of a standard 20-cycle ringing signal goes off-hook, either automatically if it is an unattended station, or manually by an attendant throwing an answer key. After a short delay of about one-half second, the called station transmits a steady F2 mark signal (2225 cps) back to the calling station. Upon receipt of this F2 mark, the calling station transmits F1 mark (1270 cps). After the calling station has identified itself, it proceeds to send the data message by shifting from "mark" to "space" while it is always expecting F2 mark as an indication the called station is still on the line. When the call is completed, either station sends a space signal which is interpreted as an on-hook condition. A failure in the transmission facility will also cause the station to restore to an on-hook condition.

**3.04** The loop supervision, dial tone, etc, are provided on a TWX loop in the same manner as for a regular telephone customer's loop.

**3.05** Other pertinent transmission features of TWX data subset, which will be covered later in more detail, are:

(a) **OUTPUT POWER** — arrangements are provided in the data subset to transmit maximum F1 and F2 signal powers of 0 dbm.

(b) **OUTPUT PADS** — these are adjustable to control the F1 and F2 signal level inputs to the line facilities and the received levels at the serving central office.

(c) **HYBRID NETWORK** — one of two network strapping arrangements are used in order to obtain the best balance between the hybrid and line, which provides maximum trans-hybrid loss between the transmitting and receiving branches of the subset.

(d) **DESENSITIZING PADS** — these pads are controlled by strapping and are inserted in the receiving branch of the hybrid to reduce the received signal level.

**3.06** In the off-hook condition, the data subset provides the equivalent of a 900-ohm resistive termination for the loop. In the on-hook condition, there is the open circuit termination the same as that presented by a regular telephone set in the same condition. In some cases, idle circuit terminations may be required.

### 4. OVER-ALL TRANSMISSION LOSS OBJECTIVES

**4.01** Over-all TWX transmission design is based on a minimum received power of -50 dbm at 2300 cycles. The design objectives are expressed in terms of 2300 cycles (just above the F2 mark frequency). The 1000-cycle loss objectives (just below F1 space frequency) will usually be lower in accord with the normal slope differences between these two frequencies.

#### (A) Maximum Loop Facility Loss Requirements for Non-RX Loops

**4.02** The over-all 3 row TWX and WADS net loop loss requirements at 2300 cps for non-RX-type loops are given in Table I.

TABLE I

NON-RX LOOPS MAXIMUM  
(2300 cps net loss)

VNL Operation	
Nonloaded facilities	14 db
Loaded facilities	12 db
Non-VNL Operation	
Nonloaded facilities	10 db
Loaded facilities	8 db

**Note:** DATA-PHONE loop loss objectives are given in Sections AB22.077.5 and AB27.425.00.

These net loss values are from the data subset to the serving central office MDF including all line treatment items; i.e., 1613-A Inductors, 837-A Networks, E-7 and E-6 Repeaters. (These items are covered in Section AB22.077.2.) It is not intended that all loop losses should be designed to these values. These are limiting values not to be exceeded. It is expected that the prudent application of Section AB22.077.3 will result in a normal distribution of losses with an average of 7 or 8 db.

**4.03** The 2 db difference in the maximum allowable losses for loaded and nonloaded facilities stems from crosstalk limitations at the line input from the data subset. In compliance with crosstalk objectives, the maximum output level for a single frequency of 2300 cps into a nonloaded facility is 0 dbm. Due to the inherent higher characteristic impedance of loaded facilities which results in lower crosstalk coupling losses, the maximum output level into loaded facilities has to be reduced 2 db.

**4.04** The maximum 2300-cycle values given in Table I under "VNL operation" **are allowed only** if the following conditions are met:

- (a) Toll connecting trunks between the serving central office (Class 5) and higher ranking offices are designed and are meeting VNL + 2 db objectives.
- (b) These higher ranking offices, upon which the serving office homes, have been balanced.
- (c) The intertoll trunks between these ranking offices are operating at VNL.

With the subscriber plant in the serving central office meeting current subscriber loop design standards (through proper construction and correct operation), only a very few loops should exceed the stated 14 db maximum loss. These higher loss loops will generally be nonloaded in the order of 15 to 18 kilofeet in length and having the maximum allowable 6 kilofeet of bridged tap. By removing the bridged tap or by the use of E-7 Repeaters, these relatively few loops can be brought below the 14 db maximum. However, if a 15 to 18 kilofeet exceeds 14 db, it may very possibly exceed the 1200-ohm maximum loop resistance limit of the E-7 Repeater. When this occurs the loop will require full loading, instead of a repeater.

**4.05** Where toll connections are not completely up to VNL objectives as outlined in Par. 4.03, an additional 4 to 5 db loss is generally encountered. For this reason, the maximum 2300-cycle loop losses have been reduced by 4 db for loops not having the benefit of VNL operation. To meet these lower maximum loss values, E Repeaters will have to be provided as is covered in a later section. In some instances, it may be economical to install additional loading or remove bridged taps, in lieu of repeaters, to meet these lower limits.

#### (B) Maximum Loop Facility Losses for RX Loops

**4.06** The over-all net loop loss requirements as stated in Table I (Par. 4.02) are also applicable to **establishing loss objectives for** RX-type TWX loops. The classification of nonloaded and loaded facilities is applied to RX loops on the basis of the subscriber cable pair extending the loop from the end of the RX section to the TWX station. That is, if the extension is with a nonloaded pair, then the nonloaded objectives apply to the over-all loop, or accordingly, the loaded objectives, if a loaded pair is used. With the RX section generally operating at a 4 db 2300-cycle loss, the allowable loss allotted to the subscriber cable portion is reduced accordingly. This will in turn necessitate the use of more E-Repeaters in the subscriber cable portion of RX loops than will probably be needed in non-RX type loops. A more complete breakdown of the allocation of losses between sections of RX loops is given in connection with return loss objectives covered in Par. 5.

**4.07** The maximum 14 db loss must be reduced to 12 db where the RX section contains line concentrators in tandem with other facilities. This reduction is necessary to care for the increased distribution grade over that of a single link carrier RX section.

**(C) Distribution of Loop Losses**

**4.08** Although maximum loop loss values have been stated, it is important that there be a reasonable uniform distribution of loop facility losses. That is, in selecting loop facilities in a given route the best available facilities should be used, rather than intentionally picking higher loss facilities just because they are less than the allowable maximum values. Application of the "prescription design" to the 1960 thousand loop survey, serves to show the resultant distribution of loop facility losses. Fig. 2 shows the distributions on the basis of VNL operation for non-RX, metropolitan RX, and the combination of all 3 row TWX loops. The intercity RX curve was purposely deleted for clarity, since it closely followed the metropolitan RX loop results. The mean loss value for the different types of loops range from a little over 6 db to about 9 db with standard deviations of about 3 to 4 db.

**(D) Relationship of Loop Loss Objectives to Message Network**

**4.09** From various studies and surveys, it is expected that 99% of all connections will have 2300-cycle losses between serving offices of less than 28 db, where toll connections have not been brought up to VNL objectives at either end. Where VNL objectives have been met, this 2300-cycle loss for the serving office to serving office connection will be about 22 db.

**4.10** In addition to the TWX loop and message network losses, when accounting for the over-all station-to-station loss, an allowance of about 1 db must be taken at each serving office for equipment and wiring losses at 2300 cycles.

**4.11** The minimum signal level the TWX subset can satisfactorily receive is about -50 dbm. However, to provide some additional margin, against noise and crosstalk interference a minimum received level of -47 dbm should be used. Also, to prevent overloading of the various carrier and microwave systems operating in the message network, the 2300 cps and 1000 cps

tones must be adjusted at the TWX subset, by use of the output pads, so that the nominal power will be -10 dbm and -15 dbm, respectively, at the serving central office. (More details for these restrictions will be covered in Section AB22.077.3.)

**4.12** Of course where both ends are operating in accordance with VNL toll objectives, two limiting 14 db loops may be involved but the serving office to serving office loss over the message network for the 99% case is expected to be about 17 db. It is important again to re-emphasize the need for strict adherence to the TWX loop design objectives in order to insure satisfactory operation for 99% or more of the TWX calls with the variation in routings and losses that can be incurred via the message network.

**4.13** In connection with providing TWX dial operation over the message network there are some other pertinent factors that must be considered:

**ECHO SUPPRESSORS** — Certain intertoll trunks, because of their length, are equipped with 1A echo suppressors. Basically the echo suppressor permits only one direction of transmission at a time. For TWX dial operation simultaneous transmission of data signals in both directions over a four-wire circuit is required. To do this, all 1A echo suppressors in the intertoll network have been equipped with a tone disabler circuit.

**2000-CYCLE SF Signaling Units** — These signaling units cannot be used on any trunks that will carry data signals at frequencies near 2000 cps. In TWX operation, the F2 space signal of 2025 cps would actuate the 2000-cycle SF unit causing it to disconnect and thereby result in a circuit cutoff. Other data sets can also cause similar difficulties. With the ever increasing growth of data type transmission the elimination of all 2000-cycle SF signaling units has become mandatory.

**Heavily Loaded Facilities in The Message Network** — Such facilities as H174 loading on high capacity cable (nominal 0.083 mf per mile) have considerable loss differences between 1000 cps and 2300 cps, due to approaching cutoff. Alternate facilities should

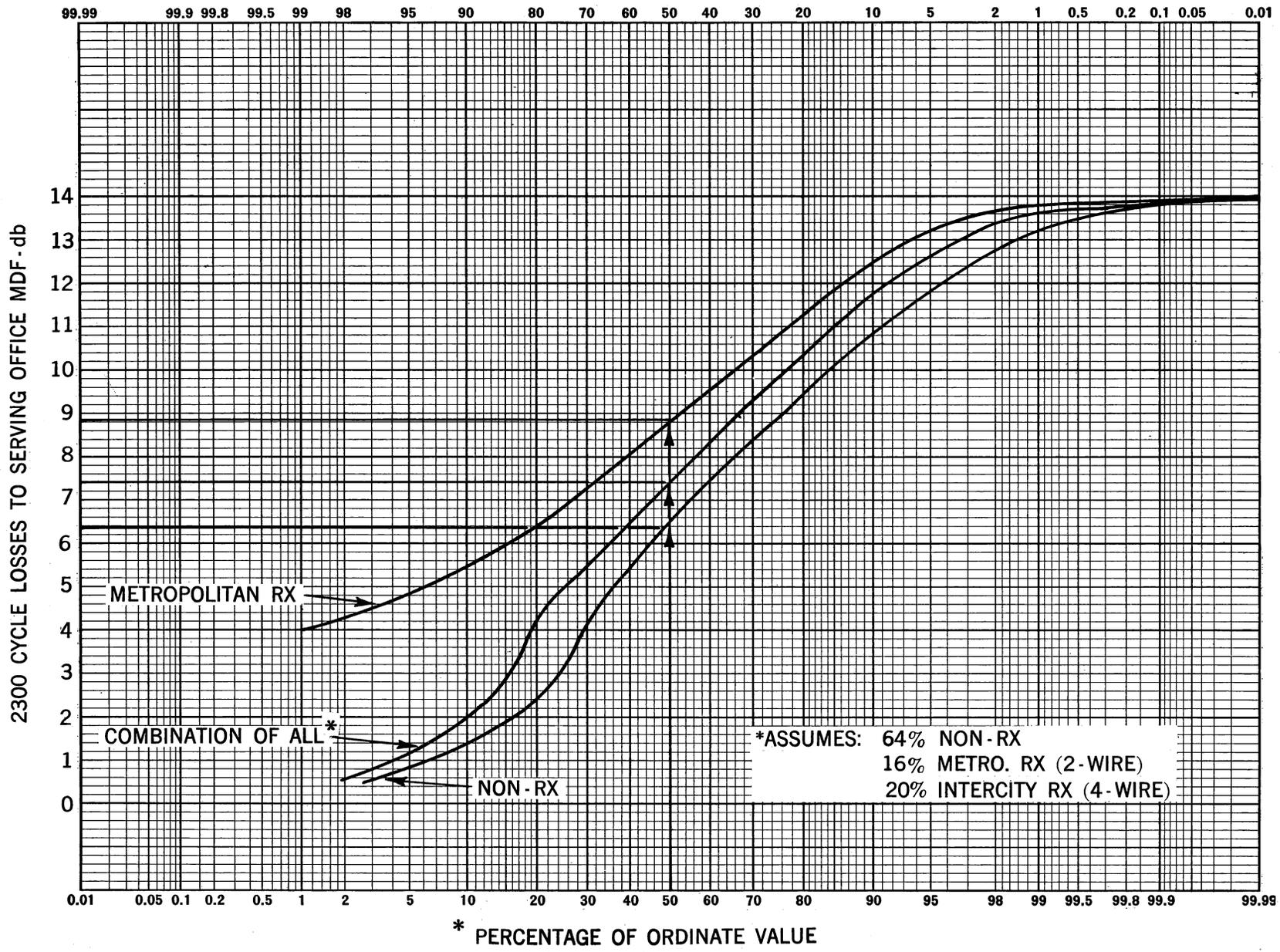


Fig. 2 – Bell System Estimated Distribution of 2300-Cycle Losses for TWX Loops Served from VNL Offices

be used wherever possible. However, if these must be used for direct interoffice trunks that will carry TWX calls, the length of such facilities should not exceed 10 miles. This heavy loading on low capacity cable can be tolerated in lengths up to about 100 miles. Nevertheless, it will be necessary to remove any 128B filters that were originally required to suppress "chirps" on long built-up connections, involving H174 and H172 loaded trunks. A 128C filter should be substituted, but this may necessitate some reduction in repeater gains in order to meet singing point requirements at or near the cutoff frequency. If these heavy loaded toll facilities are used, it is assumed they will only be used in direct trunk groups involving one intertoll link. They cannot be used in TWX calls involving more than one intertoll trunk. For DATA-PHONE service heavily loaded facilities add large amounts of envelope delay distortion, and therefore, cannot be tolerated.

**Frequency Stability of Carrier Systems —**

Frequency drift in carrier systems used in the message network is a potential source of error in Data-Type calls. In order to hold the average bias distortion for 3-Row TWX calls to 7% or less, it is necessary to maintain all message network carrier systems within  $\pm 10$  cycles. With 4-Row TWX, WADS, and DATA-PHONE operation the carrier frequency shift must be held to within  $\pm 5$  cycles.

**Noise Requirements —** The noise requirements for loops are covered under noise objectives of this section.

**(E) Circuit Net Loss Variation in TWX Loop Designs**

**4.14** It is known that circuits containing gain devices will tend to deviate from their initial aligned losses. The circuit transmission loss variations used in establishing TWX loop objectives are:

- (a) A nongain facility section will vary with a standard deviation (sigma or  $\sigma$ ) of 0.5% of its loss. That is, if the 2300-cycle loss of 6000 feet of 26-gauge nonloaded cable is 4.9 db, then for 99% of the time or the 2.33 sigma ( $\sigma$ ) case, the loss will be within 2.33 x (0.5% of 4.9 db) or  $\pm 0.3$  db of the 4.9 db value.

(b) For E-type repeatered sections a standard deviation of 1 db is used. This sigma ( $\sigma$ ) applies to the *net* transmission, i.e., the facility loss less the repeater gain.

(c) For carrier and 4-wire voice repeatered sections, a standard deviation of 1.4 db is used. Thus in this case the 99% or 2.33 sigma point can be  $\pm 3.3$  db from the initial lineup value. These circuit loss variations not only have an effect on minimum received levels but are tremendously important in return loss considerations which are covered later in this section.

**(F) Data Signal Level Objectives at TWX Serving Central Office**

**4.15** The TWX and WADS data subset output level is adjustable as follows:

F2 (2025-2225 cps) from 0 to -8 dbm

F1 (1070-1270 cps) from 0 to -14 dbm

Using these pads the output level from subsets on *non-RX and RX loops without a DALC* should be adjusted to deliver at the serving office switch the following levels:

F2 -10 dbm  $\pm 1$  db.

For those loops having a 2300-cycle loss from 10 to 14 db (as covered in Par. 4.02) F2 can drop in level to a minimum of -15 dbm for a limiting circuit at a "VNL" office.

F1 -15 dbm  $\pm 1$  db.

**Note:** For TWX purposes the serving office switch is defined as the line link frame in a serving crossbar office or the connector points in a serving step-by-step office. From the maximum loss values given in Par. 4.02, which are to the MDF, there is an allowance for about 1 db for the 2300-cycle loss from the MDF to the serving office switch.

**4.16** For *RX loops with a DALC* the F1 output level is adjusted, as covered in Par. 4.15, but the F2 output level from the subset is adjusted to -10 dbm  $\pm 1$  at the serving office switch in the terminating office where the DALC is located. The additional allowance up to -15 dbm for the F2 output level in VNL offices also applies in this situation.

4.17 With regard to overloading the -10 dbm level for F2 is well within the capability of short-haul carrier systems, which are normally used for toll connecting trunks. For toll connecting trunks using A-type channel banks the -10 dbm level is about 1 db over the suggested level of -11 dbm, if *all* channels of the system are carrying TWX traffic simultaneously (100% loading of the system). It has been assumed that such loading would seldom ever occur. However, if it is otherwise expected that 100% system loading will occur in any specific case, the maximum F2 level must be dropped to -11 dbm at the serving office switch for the particular serving office.

4.18 This maximum acceptable over-all station-to-station 2300-cycle loss is limited predominantly by the subsets minimum sensitivity. Lower received signal levels would tend to approach normal noise levels and, consequently cause errors. Noise requirements are covered in a later part of this section.

## 5. OVER-ALL RETURN LOSS OBJECTIVES

5.01 At the serving central office, all TWX loops must meet certain prescribed minimum return losses over the F1 and F2 frequency bands (1000 to 1350 cps and 1950 to 2300 cps). In using these single frequency signals the return loss requirements become more stringent, since the return losses may add on an inphase or current basis and not on a random basis as is normal in voice transmission. Furthermore, listener echo is the controlling factor in data transmission, and not talker echo as in voice transmission. The return loss objectives to be stated herein apply to both transmission loss designs of "VNL" and "non-VNL" toll operation.

### (A) Return Loss Characteristics of TWX Data Subset

5.02 The TWX data subset was designed to provide at least 15 db return loss against a 900-ohm termination over the band 1000 to 2300 cps. The hybrid card in the subset provides a 900-ohm termination to the loop in the off-hook condition; on-hook the loop is unterminated the same as any regular telephone customer's

loop. The hybrid performs the normal functions of connecting 4-wire and 2-wire facilities. In the originating call the subset transmits F1 and receives F2; the second harmonic of F1, or 2 F1, being just about the same frequency as F2. In order to insure sufficient transhybrid loss the network of the hybrid has a strap arrangement to provide one of two values, depending on the type of loop connected. The selection of the network value will be covered in Section AB22.077.3.

### (B) Minimum Return Loss at Serving Central Office

5.03 The maximum "listener" echo level must be at least 12 db below the primary signal level in the limiting connection for 3 row TWX, and 18 db for 4 row TWX and WADS. The "listener" echo occurs when part of the signal coming toward a station is reflected back toward the sending station by some impedance mismatch junction in the connection. This reflected signal is again partially reflected at some other mismatch point so that a portion is redirected toward the receiving station. This second reflection or "listener" echo signal, if too high a level, can be another source of error. In order to achieve the 12 db signal-to-listener echo, the minimum return loss of TWX loops against 900 ohms + 2 mf at the serving office becomes critical.

5.04 The signal-to-listener echo principle, using the serving office as a mismatch junction, can be seen from Fig. 3. With a standard -10 dbm signal level transmitted into Loop B the "listener" echo at the same point must be 12 db less; or, the sum of  $RL_b$  and  $RL_a$  must be at least 12 db. Therefore, for a three sigma deviation from the 10.5 db return loss objective for 2-wire metropolitan RX loops, or a three sigma deviation from the 12 db return loss objective for 4-wire intercity loops, the resulting loop return loss at the serving office will still meet a minimum of 6 db. This 6 db return loss, as will be discussed later, is a minimum requirement for all loops terminating at the serving office, and is required in connection with maintaining the minimum 12 db signal-to-listener echo.

5.05 The minimum return loss requirements at the serving office, which are applicable to both "VNL" and "non-VNL" operation, are summarized by type of loop in Table II.

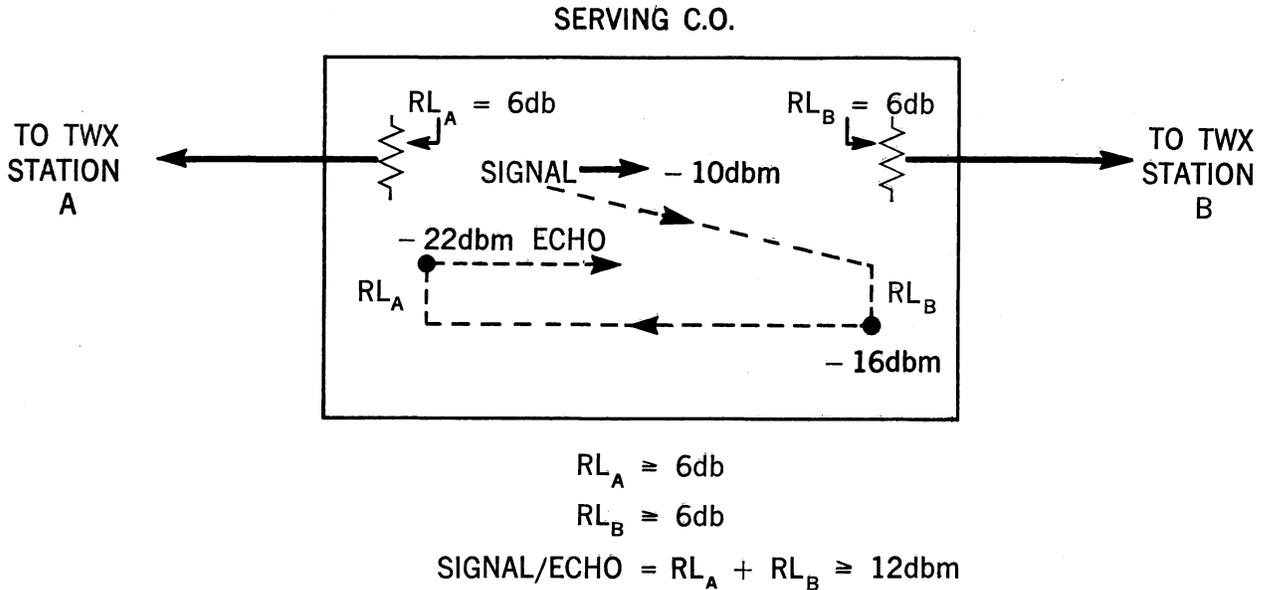


Fig. 3 – Signal-to-Listener Echo Effect at Serving C.O.

**TABLE II**  
**MINIMUM RETURN LOSS OBJECTIVES AT SERVING OFFICE**  
**(1000 and 2300 cps)**

	F1	F2
<b>(a) Non-RX Loops</b>		
Nongain .....	8	6 db
With an E-7 (or E-6) .....	10	8 db
<b>(b) Metropolitan RX Loops (2-Wire)</b>		
Nongain .....	10.5	10.5 db
With E-6 in RX Section .....		10.5 db
<b>(c) Intercity RX Loops (4-Wire)</b>		
Single carrier or voice		
Repeaterd RX Section .....	12	12 db
RX Section Consists of 4-Wire Facility Extended with 2-wire or Line Concentrator in Tandem with Another Facility .....	14	14 db

**(C) Minimum Return Loss Objectives at Local Office of RX Loops**

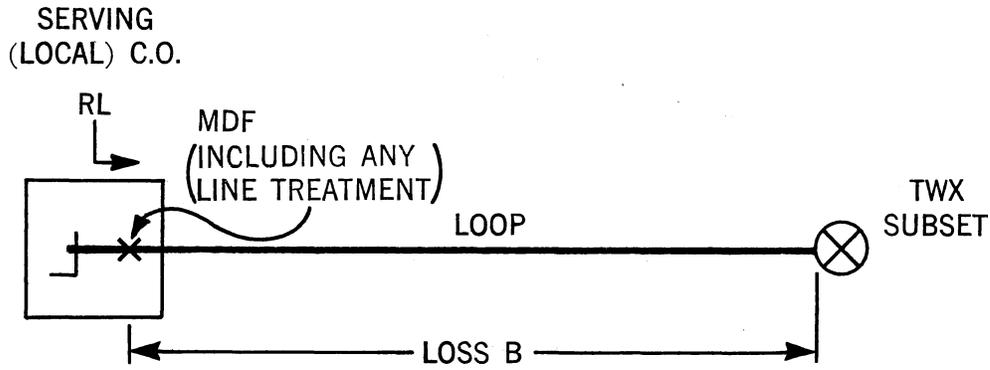
**5.06** Besides the serving office being a critical return loss point, the point of interconnection at the local wire center office (between

the end of the RX section and its extension via the local subscriber cable to the TWX station) is also important. The minimum return loss requirements at the local office for RX type loops without a DALC is dependent upon the transmission loss and type of facility used in the RX section. The local office return loss objectives are specified in following Pars. 5.09 and 5.12 covering the return loss objectives for RX-type loops.

**(D) Return Loss for Non-RX Loops**

**5.07** For these loops the 1000 and 2300 cps return loss objectives at the serving (local) office have been arbitrarily set at 8 and 6 db or higher respectively for nongain loops. The table given in Fig. 4 summarizes the return loss objectives along with the transmission losses for non-RX type loops.

When a E-6 or E-7 Repeater is used, a 2 db increase in minimum return loss is required to care for possible variations in the cable characteristic impedance with changes in temperature. This effect is amplified by the repeater, such that the image impedance of the total loop (loop facility plus repeater) is changed. Also, the related loop loss objectives are given for non-loaded and loaded loops under "VNL" and "non-VNL" conditions.



TYPE OF LOOP	MINIMUM 1000 AND 2300 CPS RET. LOSS	LOSS B 2300 CPS			
		VNL		NON-VNL	
		NL	LD	NL	LD
Nonloaded or Loaded without E-Reptr	6 db	14 db	12 db	10 db	8 db
Nonloaded with E7 Reptr or Loaded with E6 Reptr	8 db				

Fig. 4 – Return Losses Versus Transmission Losses for Non-RX Loops

**(E) Return Loss at DALC Office of RX Loops**

5.08 The same return loss objectives as stated in Par. 5.07 are applicable at the Terminating Office for RX loops having a Divided Access Line Circuit (DALC). As far as a terminating call is concerned, the loop from the DALC to the TWX station must normally meet the same design criteria as for Non-RX loops, shown in Fig. 4, or for RX loops shown in Figs. 5 and 7.

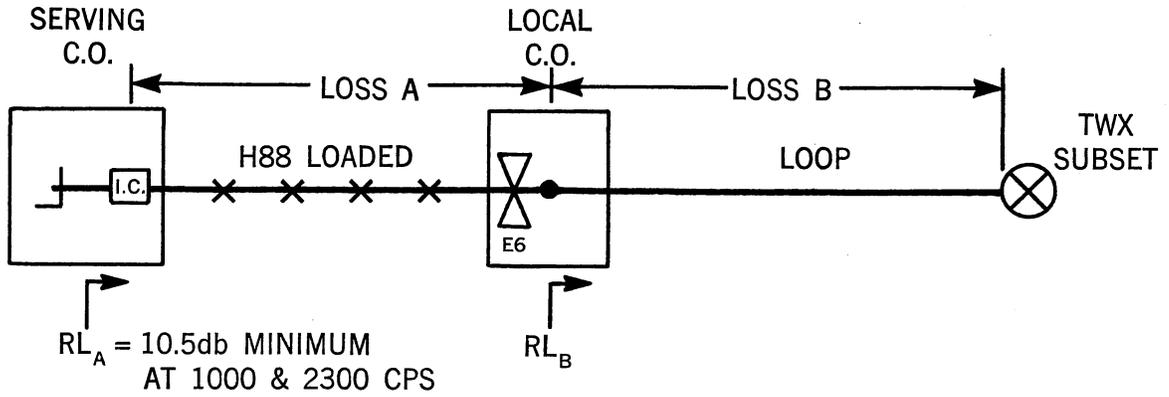
**(F) Return Loss Objectives for Metropolitan (two-wire) RX Loops**

5.09 In metropolitan RX loops, the RX section should normally be worked at a transmission loss of 4 db, which in many cases will require the use of an E-6 Repeater. For such repeatered loops, as it will be observed from the derivation in Par. 5.11, a minimum return loss of 10.5 db is required at the serving office. Fig. 5 summarizes the return loss objectives at the local office, relative to loop treatment and the transmission loss of the two-wire RX section.

5.10 The two-wire loaded interoffice facility used must have a 4% reference deviation or better. It is, therefore, suggested that the best facilities available be used. If any serious errors exist in load coil spacings, they must be cor-

rected prior to using the facilities for TWX RX services. The total RX section facility (cable plus repeaters, impedance compensators, signaling circuits, etc.), when terminated in 900 ohms plus 2 mf in place of the loop extension, must have a "structural" return loss of 20 db or more at any single frequency in the bands of 1000 to 1350 cps and 1950 to 2300 cps, and across the entire data band for DATA-PHONE services. The return loss at the serving office is measured against 900 ohms plus 2 mf. This procedure provides a measure of how well the image impedance of the facility at the TWX frequencies has been transformed to 900 ohms plus 2 mf. If there are irregularities in the "structure" of the facility, the image impedance varies and hence the "transformed" impedance fails to match the desired compromise value.

5.11 The increase to 10.5 db return loss objective at the serving office for metropolitan RX loops, over the 6 db value for non-RX loops, is necessary to insure sufficient margins in connection with loss variations of circuits containing gain devices. As mentioned in Par. 4.15, a sigma of 1 db is applied to E-repeatered facilities. The development of the 10.5 db return loss objective for metropolitan RX loops is discussed in connection with Fig. 6.



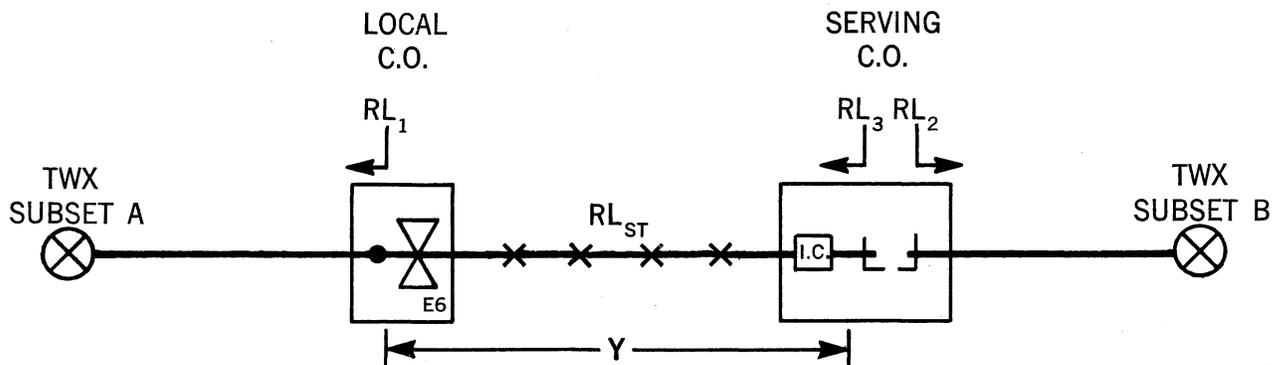
2300 CPS LOSS A	MAXIMUM PERMISSIBLE DESIGN LOSS B-2300 CPS				MINIMUM RL <sub>b</sub> *			
	NONLOADED		LOADED		WITHOUT E-7		WITH E-7	
	VNL	NON-VNL	VNL	NON-VNL	1000 CPS	2300 CPS	1000 CPS	2300 CPS
3 db	11 db	7 db	9 db	5 db	10 db	8 db	12 db	10 db
4 db	10 db	6 db	8 db	4 db	8 db	6 db	10 db	8 db
5 db	9 db	5 db	7 db	3 db	6 db	4 db	8 db	6 db

\* If a DALC is provided at the Local C.O. and it is necessary to use an E-6 Repeater on the loop section to meet requirements for Loss B in Table, use the same RL<sub>b</sub> requirements as given under E/W E-7.

**Note 1:** "VNL" and "non-VNL" refers to classification of serving central office.

**Note 2:** If the 2-wire RX section is operating on a nonrepeated basis, the transmission and return loss objectives given for non-RX loops are applicable.

**Fig. 5 – Transmission Losses Versus Return Losses for Metropolitan (2-wire) RX Loops**



**Fig. 6 – Return Loss Diagram for Metropolitan (2-wire) RX Loops**

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At the switches, the basic requirement for signal-to-listener echo is 12 db; or, the sum of the return losses  $RL_2$  and  $RL_3$  must be at least 12 db. From Non-RX loop designs  $RL_2$  must have a minimum of 6 db (Par. 5.07). Also,  $RL_1$  should be 6 db or more (Par. 5.06). It would appear, at first, that  $RL_3$  has to be 6 db, which would be the

case if the station A loop did not contain a gain device. However, in order to insure a minimum of 6 db when the RX section becomes shorter (less than 4 db) for the three sigma deviation, the average  $RL_3$  must be higher than 6 db. From Fig. 6, the following equations can be used to verify the 10.5 db value for  $RL_3$ .

(a) Signal/Echo =  $RL_2 + RL_3$  (Requirement: Minimum 12 db)

Since:  $RL_3 = \left[ RL_1 + 2(Y \pm 3\sigma) \right] \frac{x}{c} RL_{st}$

Where:  $RL_1$  = Return Loss of Non-RX loop at local C.O. = 6 db (Par. 5.06)

$Y$  = Design Loss of 2-wire RX section at 2300 cps

$\sigma$  = One-way standard deviation of 2-wire repeatered trunk at 2300 cps = 1 db (Typical)

$RL_{st}$  = Structural Return Loss = 20 db (Par. 5.10)

$\frac{x}{c}$  — Denotes combining return loss on an inphase or current basis.

$RL_2$  = Return Loss of Non-RX loop at serving office = 6 db (Par. 5.07)

And If: Nominal value of  $Y = 4$  db (Par. 5.09) is used and circuit loss variation is neglected, or  $\sigma = 0$ , then:

$$RL_3 = \left[ 6 + 2(4) \right] \frac{x}{c} 20 = \underline{10.5 \text{ db}}$$

Then: For the most limiting condition; deviation =  $-3\sigma$ :

$$RL_3 = \left[ 6 + 2(4-3) \right] \frac{x}{c} 20 = 6.1 \text{ db or } \underline{6 \text{ db}}$$

Sub. In (a): Signal/Echo =  $RL_2 + RL_3 = 6 + 6 = \underline{12 \text{ db}}$  (Check)

In this derivation the three sigma deviation is used to insure that echo is sufficiently reduced to a tolerable level. This is due to the fact that listener echo is more difficult to detect and may be more destructive than an equal amount of background noise. It can be seen, that by increasing the value of  $Y$  to 5 db, the 2300 cps  $RL_1$  can be decreased to 4 db. Conversely, if  $Y$  is decreased to 3 db,  $RL_1$  must be increased to, at least, 8 db. This shows the relationship between  $RL_1$  and the loss of the RX section ( $Y$ ).

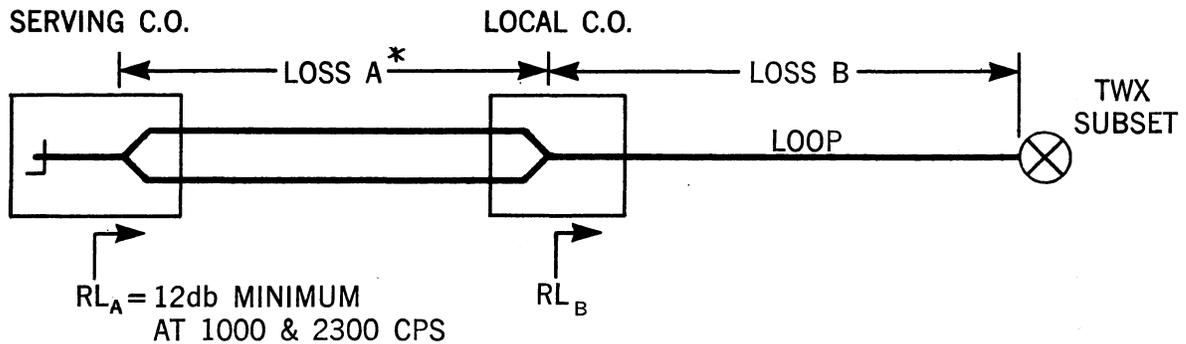
**(G) Return Loss Objectives for Intercity (4-wire) RX Loops**

**5.12** Loss variations in the trunks of intercity RX loops, involving 4-wire RX sections of carrier and/or voice repeatered facilities, are

typically greater than 2-wire trunks using gain devices. It is expected, therefore, that a return loss objective for intercity RX loops will be higher. For such loops, as it will be observed from the derivation in Par. 5.13, a minimum return loss of 12 db is required at the serving office. Based on this 12 db requirement, Fig. 7 summarizes the return loss objectives of the Non-RX local loop at the local office with respect to the transmission loss of the 4-wire RX section.

**5.13** The increase to a 12 db minimum return loss objective at the serving office for intercity RX loops, compared to the 6 db value for non-RX loops, is necessary to provide sufficient margin against loss variations in these gain device equipped circuits. As covered in Par. 4.14, a

INTERCITY (4-WIRE) RX LOOPS



\*If more than one carrier in A increase A by 1 db and decrease A + B by 2 db.

2300 CPS LOSS A	LOSS B — 2300 CPS				MINIMUM RL <sub>B</sub>			
	NONLOADED		LOADED		WITHOUT E REPTR		WITH E REPTR	
	VNL	NON-VNL	VNL	NON-VNL	1000 CPS	2300 CPS	1000 CPS	2300 CPS
2 db	12 db	8 db	10 db	6 db	12 db	8 db	14 db	10 db
3 db	11 db	7 db	9 db	5 db	10 db	6 db	12 db	8 db
4 db	10 db	6 db	8 db	4 db	8 db	4 db	10 db	6 db

*Note:* "VNL" and "non-VNL" refers to classification of serving central office.

Fig. 7 — Transmission Losses Versus Return Losses for Intercity (4-wire) RX Loops

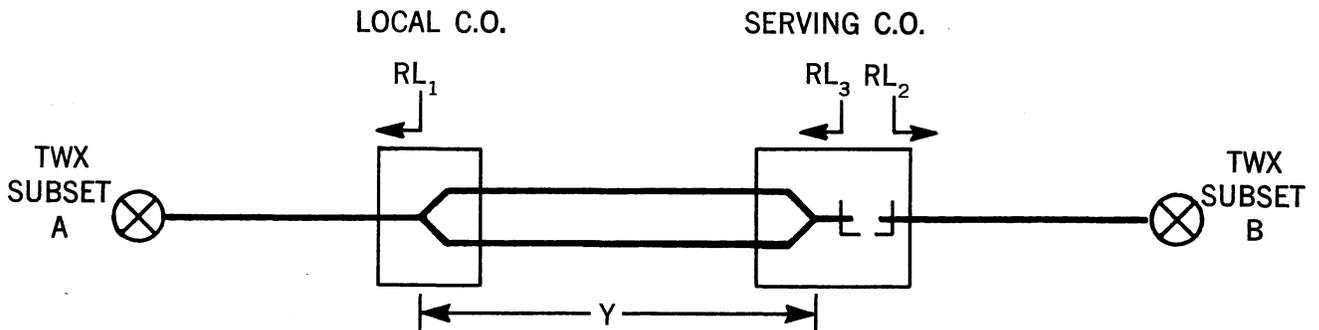


Fig. 8 — Return Loss Diagram for Metropolitan (4-wire) RX Loops

standard deviation of 1.4 db or a 99% sigma of 2.33 is applied to these RX sections. By referring to Fig. 8 it may be seen how the 12 db return loss objective for intercity RX loops was derived. However, this derivation employs the 3 sigma deviation instead of the assigned 2.33 sigma deviation, normally used in other calculations.

At the switches the signal-to-listener echo of

12 db is a basic requirement; or the sum of the return losses  $RL_2$  and  $RL_3$  must be 12 db or higher. Also, from non-RX loop designs each of the return losses  $RL_1$  and  $RL_2$  should be at least 6 db (Par. 5.05 and 5.06, or as indicated in Fig. 7). Using Fig. 8 and the 12 db signal-to-listener echo requisite, the 12 db value for  $RL_3$  can be supported by the following expressions:

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(a) Signal/Echo =  $RL_2 + RL_3$  (Requirement: Minimum 12 db)

Since:  $RL_3 = 2Y \pm 3\sqrt{2}\sigma + RL_1$

Sub. In (a): Signal/Echo =  $RL_2 + (2Y \pm 3\sqrt{2}\sigma + RL_1)$

Where:  $RL_2$  = Return Loss of Non-RX loop at serving office =  
6 db (Minimum) (Par. 5.17)

$Y$  = Design Loss of 4-Wire RX section at 2300 cps

$\sigma$  = One-way standard deviation of 2300 cps RX  
trunk loss from design value = 1.4 db (Typical).

Note — In both directions of 4-wire section:

$$\sigma_{\text{round trip}} = \sqrt{\sigma^2 + \sigma^2} = \sqrt{2\sigma^2} = \sqrt{2}\sigma$$

For the three sigma case in both directions:  $3\sqrt{2}\sigma$

$RL_1$  = Return Loss of Non-RX loop at local C.O. = 6 db (Par. 5.06)

Then: For most limiting condition; deviation =  $-3\sqrt{2}\sigma$ :

$$RL_1 = 12 - 2Y$$

When:  $Y = 3$  db

$$RL_3 = RL_1 + 2Y = (12 - 2Y) + 2Y = \underline{12 \text{ db}}$$

It can be seen that by decreasing the value of  $Y$  to 2 db the minimum 2300 cps value of  $RL_1$  must be increased to 8 db. Conversely, if  $Y$  is increased to 4 db,  $RL_1$  can be decreased to 4 db. This shows the relationship between  $RL_1$  and the loss of the RX section  $Y$ .

### (H) Singing Return Loss

**5.14** In general, loop return loss is specified at the serving central office, but in cases of RX lines utilizing gain, it also becomes necessary to examine requirements at the junction between the active interoffice facilities and the 2-wire loop.

The return loss for RX lines with 2-wire or 4-wire repeatered interoffice facilities should meet a 6 db minimum at the serving office. For such a circuit to be stable its total singing path loss, for any given frequency within the band, may not be less than zero. These requirements

apply to frequencies in the band 300-3300 cps and refer to 900 ohms and 2 mf terminations.

**5.15** In meeting the listener-echo return loss objectives of the preceding paragraphs, the singing return loss requirements in the data frequency range (1000-2300 cps) and higher voice-band frequencies, will have been satisfied. However, due to the slope of some facilities, the low frequency singing path loss is less than that at higher frequencies. This may cause appreciable reduction in return loss at low frequencies.

Also, return losses at all of the discernible frequencies may be seriously degraded during periods of dialing, ringing, idle-line and on-hook conditions, which correspond to open circuit.

**5.16** With reference to Fig. 9 and 10 the following examples have been developed which may be used to illustrate the singing return loss principle.

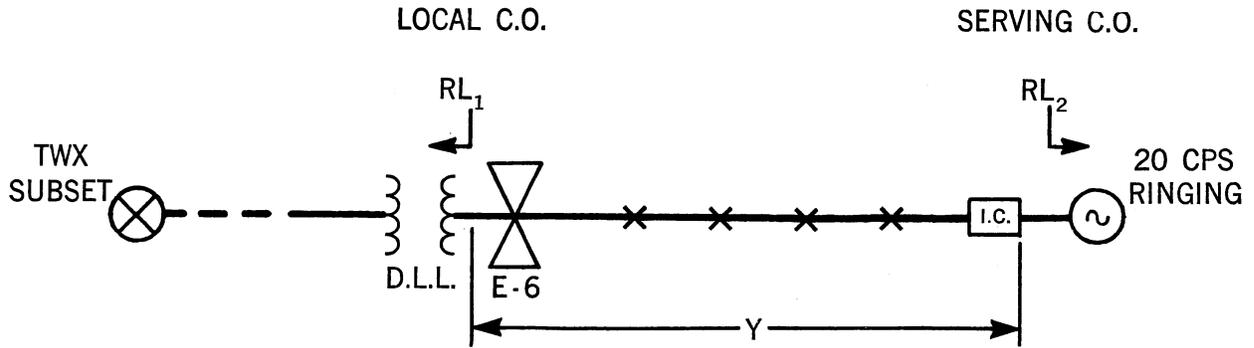


Fig. 9 - Singing Return Loss Diagram for Metropolitan (2-wire) RX Loops

For Low Singing Frequency (300 cps) :

**Requirement:** Total Singing Path Loss  $\leq 0$  db

- (a) Total Singing Path Loss<sub>2300</sub> =  $RL_1 + RL_2 + 2Y - 3 \times 2 \sigma$
- (b) Total Singing Path Loss<sub>300</sub> =  $RL_1 + RL_2 + 2(Y - 1) - 3 \times 2 \sigma$

Where:  $RL_1$  = Return Loss of loop at junction of repeater trunk = 0 db (during ringing).

$RL_2$  = Return Loss at C.O. = 0 db (open).

$\sigma$  = One-way standard deviation of 2-wire repeater trunk = 1 db. Note — In each direction of gain section:

$$\sigma_{\text{round trip}} = 2\sigma$$

For a 3 sigma, or 99% plus, condition:  $3 \times 2 \sigma$

$Y$  = Trunk loss at 2300 cps

$Y-1$  = Trunk loss at 300 cps (assumes a 1 db slope between singing frequency and 2300 cps).

$$\text{Sub. In (b): } 0 \text{ (Min)} = 0 + 0 + 2Y - 2 - 6$$

$$2Y = 8$$

$$Y = 4 \text{ db}$$

Trunk Loss  $Y$  at 2300 cps should be at least 4 db to meet the 300 cps singing frequency singing return loss requirement, or  $Y$  should vary according to Fig. 5 as  $RL_1$  varies.

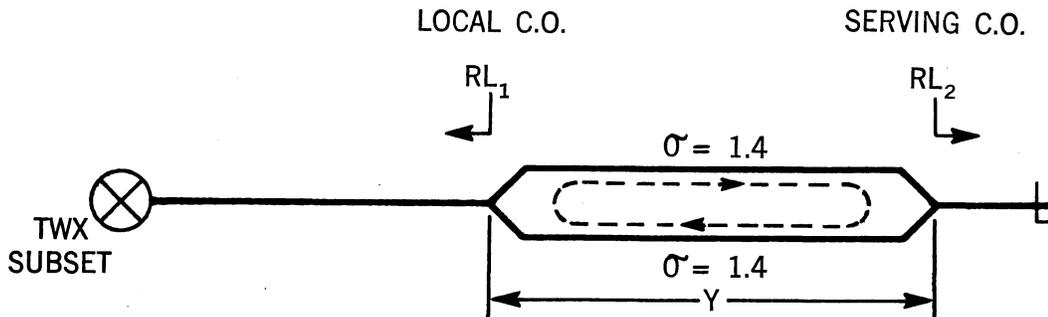


Fig. 10 - Singing Return Loss Diagram for Metropolitan (4-wire) RX Loops

For Low Singing Frequency (300 cps):

**Requirement:** Total Singing Path Loss  $\leq 0$  db

$$(a) \text{ Total Singing Path Loss}_{2300} = RL_1 + RL_2 + 2Y - 3\sqrt{2} \sigma$$

$$(b) \text{ Total Singing Path Loss}_{300} = RL_1 + RL_2 + 2(Y - 3) - 3\sqrt{2} \sigma$$

Where:  $RL_1$  = Return Loss of 2-wire extension at junction of  
4-wire trunk = 6 db (Minimum Design Requirement)

$RL_2$  = Return Loss at C.O. = 0 db (Assumes connection to  
unterminated register, before register is seized).

$\sigma$  = One-way standard deviation of 4-wire RX trunk =  
1.4 db. Note — In both directions of 4-wire section:

$$\begin{aligned} \sigma_{\text{round trip}} &= \sqrt{\sigma^2 + \sigma^2} = \sqrt{2\sigma^2} \\ &= \sqrt{2} \sigma \end{aligned}$$

For a 3 sigma, or 99% plus, condition:  $3\sqrt{2} \sigma$

$Y$  = RX trunk loss at 2300 cps

$Y-3$  = RX trunk loss at 300 cps (assumes a 3 db slope  
between singing frequency and 2300 cps).

$$\text{Sub. In (b): } 0 \text{ (Min.)} = 6 + 0 + 2Y - 6 - 6$$

$$2Y = 6$$

$$Y = 3 \text{ db}$$

Trunk Loss  $Y$  at 2300 cps should be at least 3 db to meet the 300 cps singing frequency singing return loss requirement, or  $Y$  should vary according to Fig. 7 as  $RL_1$  varies.

## 6. NOISE OBJECTIVES

**6.01** TWX, like any other DATA SYSTEM, will not provide good service if the received noise levels are too high. While *Steady Noise* or *Impulse Noise* may either individually or in combination affect data adversely, the impulse type noise is usually more restrictive. In order to prevent excessive copy error the noise levels are specified on the basis that sufficient signal-to-noise margins be provided at the data subset with respect to a limiting received signal of -47 dbm (Par. 4.11).

### (A) Steady Background Noise

**6.02** Steady background noise, including white noise and cross-induction, will not in itself pose serious problems in data transmission, if

*normal voice objectives are met.* This is so, because those objectives provide an adequate signal-to-noise ratio.

The voice objective is given in Section AB63.375. When this requirement is converted into terms of the 3A NMS with C message weighting, it equates to 26 dbrn at the station.

Steady noise objectives for TWX, which also apply to WADS and DATA-PHONE, were developed by referring the voice objective to the serving office switch. This permits the objectives to be applied conveniently to measurements made at any point in the loop when corrected for the serving office switch.

When a compandored carrier facility is used in a section of any loop, the compandored section should be measured separately at the data receiving end and corrected to the serving office switch for comparison with the objectives. (See Par. 6.06.) These compandored objectives include the effect of data signal levels, described in Section AB27.350.

The TWX, WADS and DATA-PHONE steady noise objectives for noncompandored loops and compandored sections of loops are given in Table III.

**TABLE III**  
**TWX, WADS AND DATA-PHONE STEADY (WHITE)**  
**NOISE OBJECTIVES**  
**(REFERRED TO SERVING OFFICE SWITCH)**  
**3A NMS (C Message) Noise Levels**

	Noncompandored Facilities and Over-all Loop	Compandored* Facility Sections
	DBRN	DBRN
Station or RX Loop	36	26

\* With Expander in the "Full Loss" Condition.

**Note:** Noise should always be measured at the subset end of the loop where the incoming data signal will be at its lower level, and then referred to the serving office switch for comparison with the objectives.

**(B) Impulse Noise**

**6.03** Impulse noise "Hits" of such short duration as a millisecond or less are the primary source of error in many data systems. These impulse noise spikes are of little importance in voice transmission since the ear is relatively insensitive to noise peaks of this short duration. In data transmission, however, they will seriously degrade the error rate, if the magnitude and frequency of occurrence is great enough. Also, peak portions of steady background noise in combination with single frequency interference may create impulse error in the data system.

**6.04** Since *Magnitude* and *Rate Of Occurrence* of instantaneous noise voltages are the major factors affecting error performance, it is only natural that these terms be used to specify the impulse noise objective. The objective is expressed as the noise peak level (referred to serving office switch), which will be reached or exceeded a given number of times during a specified period on a long-term average basis.

**6.05** Impulse noise should be measured with the 6A Impulse Noise Counter (Section E40.467). Such noise measurements should always be made at the end of the loop where an incoming data signal will be at its lower level,

and then referred to the serving office switch for comparison with the objectives. Because impulse noise is randomly distributed in frequency and its measurements are frequency sensitive, narrow-band data systems, such as TWX and WADS, are normally measured in a narrow-band (300-cycle bandwidth). For the majority of DATA-PHONE data sets, which operate at higher speed bit rates over a bandwidth approaching that of voice, the impulse noise is measured on a data-weighting basis, which is similar to C message weighting.

**6.06** Steady noise and impulse noise in compandored sections of a loop should be measured separately from the noncompandored sections, in addition to measurements on over-all loop. In making compandored circuit measurements it is necessary to have the expander in the "Full Loss" condition to obtain accurate noise level readings (Section AB27.350). Such readings may be compared directly with the objectives, which are based on this condition.

Compandored objectives assume the expander is in the "Full Loss" condition. This can be assured by disabling the expander. However, noise measurements may be made without disabling the expander, providing the noise objectives are not exceeded. If the objectives are exceeded with the expander active (normal condition), it will be necessary to disable the expander and repeat the noise measurement.

The TWX and WADS impulse noise objectives for noncompandored loops, and for compandored sections of loops, are given in Table IV.

**TABLE IV**  
**TWX AND WADS IMPULSE NOISE OBJECTIVES**  
**(REFERRED TO SERVING OFFICE SWITCH)**  
**6A Impulse Counter Noise Levels in Narrow-Band**  
**(300-Cycle Bandwidth)**

	Noncompandored Facilities and Over-all Loop		Compandored* Facility Sections	
	Counts Per. 30 Min.	DBRN	Counts Per. 30 Min.	DBRN
Station or RX Loop	20	53	20	45

\* With Expander in the "Full Loss" Condition.

**Note:** Noise should always be measured at the subset end of the loop where the incom-

## **SECTION AB22.077.1**

ing data signal will be at its lower level, and then referred to the serving office switch for comparison with the objectives.

DATA-PHONE impulse noise objectives are covered in Sections AB27.425.00 and AB22.0777.5.

## **7. OTHER CONSIDERATIONS**

**7.01** For TWX loops and WADS access lines, attenuation frequency distortion and envelope delay distortion are not critical, therefore, no objectives have been specified for these items. For DATA-PHONE service, objectives are specified in Sections AB27.425.00 and AB22.077.5.