NEGATIVE IMPEDANCE REPEATERS
RETURN LOSS COMPUTATIONS FOR THE STABILITY AND SINGING MARGIN DESIGN METHODS
EXCHANGE AREA FACILITIES

CONTENTS PAGE

1. GENERAL

1.01 This section outlines methods for estimating line section return losses and provides references to the data ordinarily needed in the application of negative impedance telephone repeaters in the exchange plant. The return losses discussed in this practice are developed from considerations of singing phenomena only, as limitations on repeater gain, and neither methods nor data are applicable to problems of echo design, which are treated separately in other sections of this series.

1.02 In the remainder of this section, the term "repeater" means one of the various types of negative impedance (E-type) telephone repeaters.

1.03 For the design of special service lines, the use of somewhat simplified calculation methods may be justified. For example, since existing trunk pairs will ordinarily be used, structural return losses based on typical load spacing may be used. On the other hand, in laying out new trunk plant, it will ordinarily be best in the long run to make sure that the proposed loading systems meet the design requirements of the comtemplated trunk groups. Observance of the load spacing standards discussed in Section AB22.125 will generally provide satisfactory structural return losses.

2. METHODS OF CIRCUIT DESIGN

2.01 Circuit design methods and checks for idle line stability based on avoiding singing are classified below under three different headings in Parts A, B, and C.

A. Stability Method

2.02 The stability design method is the simplest and safest basis for the design of repeatered circuits. It is based on the principle that a circuit must be designed so that singing will not occur in the ***idle condition*** even without idle line terminations or other stabilizing means. The resulting limitations on repeater gain provide a degree of stability in the ***talking condition*** which is usually more than sufficient under average conditions to prevent echo and near-singing effects. Line section return losses computed by methods described in this practice are used to determine maximum usable gains by methods described in the practice covering each type of repeater. In estimating the line section return losses, terminal return losses which are typical of an idle condition, without terminations, are used at the end of each line section furthest from the repeater, as discussed in Parts 3 and 4 of this section.

B. Singing Margin Method Based on Talking Condition Return Losses

2.03 The singing margin basis of circuit design is used for special service lines and other applications which require the highest gains obtainable with satisfactory freedom from hollowness and other near-singing effects. In this method of design, terminal return losses typical of those likely to be controlling in the talking condition are used at the end of each line section furthest from the repeater. This design approach usually requires that singing in the idle condition be avoided by the use of idle line terminations, by opening the circuit at a series repeater, or by other means. In the case of the series repeater, as a means for avoiding excessive gains, each line section return loss is combined with a return loss of 26 db on a current or in a phase basis. The results of these combinations are the return losses to be used in the margin formula to determine the repeater gain. A computed margin of at least 10.0 db is considered to be a reasonable minimum for the difference between (a) the sum of the two return loss values and (b) the 2-way gain of the repeater. A margin as large as 10 db is considered necessary to allow for expected differences between the computed and actual results and for variations from the assumed line conditions.

2.04 The design method described in 2.03 is intended for use only for the design of exchange area special service lines and similar applications. It is based largely on the assumption of fixed layouts and a limited range of terminal conditions.

C. Via Net Loss Method—Idle Line Terminations

2.05 The basic design of via net loss trunks is based primarily on echo considerations and hence does not fall within the scope of this section. To determine whether the design, once established, will require idle line terminations at ***only one*** or at ***both*** circuit terminals is a singing problem, and a procedure is covered in this section.

3. LINE SECTION CONSIDERATIONS

3.01 The first step in the usual repeater application is the selection of a facility layout and a location for each repeater. The sections dealing with the various types of repeaters give general rules for the selection of favorable layouts. At each repeater location there will be two line sections, one on either side, for which the line return losses must be estimated as a preliminary to determining the maximum usable gain of the repeater. For a line with a single intermediate repeater, each line section extends from the repeater location to the end of the circuit except when special considerations apply, as discussed in 4.03. For a terminal repeater one line section is of negligible length, hence its return loss is identical with the terminal return loss.

3.02 A special method is used to determine the maximum usable gain in the case where a nonloaded line section is associated with a series-type repeater if the other line section is loaded. In Section 852-305-102 a chart is provided whereby, for convenience, the effective facility loss of the nonloaded line section, rather than the return loss, determines the maximum usable gain.

3.03 When using the ***stability design method,*** if two or more repeaters are used in tandem, the line section on the side of any repeater which faces another repeater will be considered to terminate at a point located between the two repeaters in accordance with rules developed to simplify the overall design. These rules are discussed in Sections 852-305-101 and 852-305-102.

3.04 For the ***singing margin method*** or for ***checks of stability on via net loss trunks,*** the loss of the line between two repeaters should ordinarily be divided into two equal line sections. If a major irregularity exists in the line between repeaters, the maximum combined gain will generally result if the point of division between line sections is taken at the irregularity.

4. COMPONENTS OF LINE SECTION RETURN LOSS

4.01 Each line section return loss associated with a repeater is obtained by combining the effect of such of the following items, Parts A through F, as are applicable to the particular facility layout.

A. Terminal Return Loss

4.02 In Part 2 of this section the concept of terminal return losses based on either ***idle line*** or ***talking*** conditions was discussed as the distinguishing feature of the different design methods. The following discussion will be of value in applying the principles involved to specific cases.

4.03 ***Stability Design Method:*** In the stability design method the idle circuit condition is used as a design basis; 0 db, which is typical of an open or short, is used as the terminal return loss. The location of the remote end of each line section is selected as the nearest point at which an open or short circuit or the equivalent may occur, usually at the end of the circuit. A line section, however, should not extend beyond the location of equipment which effectively opens the line in the idle condition. This rule unnecessarily restricts the gain in the special case when the open is located immediately adjacent to a series-type repeater. In this case, because of the resulting line stability, the open may be disregarded or, as an alternative, the singing margin design method may be used. Similarly, if advantage is to be taken of the presence of idle line terminations, the singing margin design method should be used.

4.04 ***Singing Margin Method:*** The singing margin type of design is concerned primarily with the talking condition of the line for the various types of connections which may occur. A terminal return loss of 6.0 db is used as a typical controlling value for established connections. The 6.0-db terminal return loss may be considered to occur at:

(a) A PBX or central office switching point.

(b) A telephone instrument or a nonloaded loop terminated by a telephone instrument.

4.05 ***Via Net Loss Method:*** For some trunks, such as 2-wire links between two crossbar tandem offices or other 2-wire toll switching centers in the same metropolitan area, the facility layout and ET repeater gain requirements are based on via net loss (VNL) considerations. Idle line terminations may be needed at either one or at both ends of such links to prevent singing in the idle condition. In such cases line return losses may be computed by assuming a 9-db terminal return loss at a circuit terminal where an idle line termination is provided and 0 db where none is provided. Any combination of these terminal arrangements, based on the preceding assumptions, for which the "maximum usable gain" as discussed in Section 852-305-101 is as great as or greater than the gain proposed on the VNL basis will be considered satisfactory with respect to idle line stability. This procedure is illustrated by Example 7 in 6.07.

B. Structural Return Loss

4.06 A length of loaded facility has a structural return loss which results from the small irregularities distributed along the line. The structural return loss is treated as though it occurred at the end of the facility at, or nearest to, the repeater location. It summarizes the effect of random variations in (a) spacing between loading coils, (b) loading coil inductance, and (c) cable pair capacitance. Structural return losses for exchange-type loaded facilities are given in Section 304-403-100 for values of the reference deviation of a particular loading system. The reference deviation is obtained as described in Part 5A.

4.07 The structural return losses for loaded facilities given in Section 304-403-100 are based on infinite length lines. If the loss of a loaded facility is less than about 8 dB, the structural return loss as obtained from Section 304-403-100 may be increased by a correction obtained from Section 304-403-101. If a line section is made up of two or more lengths of loaded facilities of the same type which have appreciably different structural return losses, the following procedure may be applied. The structural return loss of each section as found in Section 304-403-100 is corrected for the finite loss of the particular facility length by the use of Section 304-403-101. The structural return losses for the remote lengths are then referred to the repeater location as described in Part 5B. The final values are combined on the power basis as described in Part 5C. In practice, it will be found that, in many cases, the structural return losses of circuits designed on the stability design basis have too small an effect on the maximum usable gain to justify the refinement just described. However, for cases involving the use of the higher gain steps and for the singing margin method, the more refined method may be very helpful.

4.08 ***Deviation Test Splicing:*** In some cases higher structural return losses may be required than are ordinarily obtained with loaded exchange-type facilities. Little improvement can be obtained by taking extreme measures to obtain exact load spacings because of the rather wide variations between the capacitances of individual cable pairs. A further degree of improvement with reasonably good load spacings may be obtained by ***deviation test splicing,*** which is described in some detail in Section 853-316-100. In nonquadded cable, the pairs between adjacent loading points are kept open at the coils and at a splice near the middle. By making tests with a capacitance bridge the pairs of each half-section are sorted into a number of groups, based on their measured capacitances. At the middle splice, pairs from high groups on one side are spliced to pairs from low groups on the other side and vice versa. This reduces the spread of the capacitances of the pairs in the loading section. The chart of Section 304-409-100 gives the improvements over the structural return losses of Section 304-403-100 which can be expected for B, D, H, or M load spacing by the application of deviation test splicing to a 50-pair group.

4.09 For nonloaded facilities the structural return losses are so high that they may be ignored.

C. Return Loss Due to Load Spacing Irregularity

4.10 Load spacings which are longer or shorter than those typical of the remainder of a loading system are likely to occur, for example, when loaded facilities are cross-connected at intermediate offices. Such irregularities may be treated as specific irregularities. To do this requires determining the percentage deviation from average spacing of each irregular load spacing. For layouts which include lengths of both high and low capacitance pairs, the spacings should be figured on a capacitance basis, rather than on actual sheath lengths. Pair capacitances per unit length may be found in the appropriate sections of the 304 Division. Specifically, it is proper to treat a load section as an irregularity if its percent deviation from the nominal standard spacing for the system is greater than about three times the reference deviation of the system remaining if the irregular spacing is removed from the reference deviation calculation. Deviations of this magnitude can usually be identified by inspection to avoid making repeated calculations of the reference deviation. Return losses for loading irregularities are given in Section 304-412-100. The irregularity return losses in Section 304-412-100 are based on the percent deviation of the irregular spacing from the average spacing for the balance of the loading system. For practical purposes the irregularity may be assumed to be at the middle of the irregular section. Each irregularity return loss should be referred to the repeater location as described in Part 5B.

D. Junction Return Loss

4.11 In some cases line sections will necessarily be made up of more than one type of facility. At a junction between two unlike facilities, a junction return loss occurs because of the discontinuity in line impedance. The ***junction section*** between the two loaded facilities is described as being "normal" if the total capacitance between the two adjoining coils is equal to the sum of the half-section capacitances for the two systems, based on the system average values in each case. The table of Section 304-408-100 gives junction return losses for ***normal junction sections*** between various types of loaded exchange facilities.

4.12 If a junction section is longer or shorter than "normal," the junction return loss tends to become lower, at least for part of the frequency band. The chart of Section 304-408-100 has been developed to provide an approximate solution for this effect. In order to read this chart, the total junction section capacitance is expressed as a percent of the "normal" junction capacitance and considered as a junction section "length." A ***"normal" junction section*** return loss for the joined types of facilities is obtained from the table of Section 304-408-100 and spotted on the ***100 percent*** vertical line of the chart. From this point the contours drawn on the chart are used as a guide to locate a point above the actual percent "length" of the junction section. The junction section return loss is then read by referring this point to the vertical scale. For example, consider a 50 percent junction section between H88 and B88 high capacitance facilities which have a "normal" junction section return loss from the table of Section 304-408-100 of 15.7 db. The 15.7-db value falls just below the contour which crosses the ***100 percent*** line of the chart of Section 304-408-100 at 16.0 db. By following along just under this contour to the ***50 percent*** line, find a point which in this case is located at about 8.2 db on the vertical scale. The junction return loss for the 50 percent junction section is then 8.2 db.

4.13 Junction return losses between loaded and nonloaded facilities are given in Section 304-408-101.

4.14 If a nonloaded line section is made up of mixed gauges, an impedance irregularity occurs at each change of gauge. From a return loss viewpoint, this effect may be of some importance when a section of cable near the repeater differs in gauge from the predominating or typical gauge on which the repeater network design is based. This situation may be recognized by considering the solid gauge lines shown on the chart of Section 304-164-100. From the length and resistance of the nonloaded line section, locate a point on the chart and select the nearest solid gauge line based on the vertical spacing. If the section of cable nearest the repeater differs in gauge from the typical gauge so determined, a junction return loss from Section 304-408-102 should be considered to occur at the repeater end of this section. If the 1000-cycle loss of this section is less than 4.0 db, the junction return loss may be increased by a correction also given in Section 304-408-102. The procedure is illustrated by Example 6 in 6.06. In order to avoid undue complexity, this type of junction return loss may be disregarded for lengths of the adjacent gauge which do not exceed the values given in the following table:

Typical Gauge	Gauge Adjacent to Repeater 26	24	22	19
26	-	640'	390'	300'
24	490'	-	770'	430'
22	240'	620'	-	770'
19	130'	240'	530'	-

4.15 Junction return losses other than those which occur at the repeater should be referred to the repeater location as described in Part 5B.

E. Intermediate Equipment Return Loss

4.16 The presence of intermediate equipment which includes repeating coils or bridged retard coils may be a significant factor in the design of a repeatered line. The maximum effect on line return losses tends to be in the lower frequency range. At the higher frequencies, the effects will be small except for the possible case of an inequality ratio repeating coil. The following rules which are a compromise between the high- and low-frequency effects should provide a satisfactory design basis without necessitating return loss computations at two frequencies.

4.17 A repeating coil may be treated as causing an irregularity return loss of either (a) about 15.0 db for the higher inductance exchange coils, such as the 94E and 120 types, or (b) about 10.0 db for the lower inductance coils used in dial pulse repeating circuits, such as the 94N or the older 101A types. In general, bridged retard coil type circuits have shunt inductances of at least 0.5 henry. Such coils may be treated as causing irregularity return losses of about 15.0 db at a similar location. Irregularity return losses caused by equipment are referred to the repeater location as described in Part 5B.

4.18 The irregularity return losses for intermediate equipment described in 4.17 also apply in the case of a location adjacent to a repeater if the line section is loaded. This rule holds also for nonloaded line sections except when two such sections are associated with a series-type repeater. In the latter case, an available inductor in the repeater network may be used to compensate for the adverse effect of the equipment located between the repeater and a nonloaded line section. As a result the return loss effect of the coil can be disregarded in estimating the line return loss. Further details are covered in Section 852-305-103.

4.19 For use in making return loss calculations the following transmission losses for intermediate equipment are suggested:

Type of Equipment	Loss
Repeating coil with permalloy core such as 120C	0.3 db
Repeating coil with silicon steel core such as 120CS	0.6 "
Repeating coil of the older general purpose type such as 94E	0.6 "
Repeating coil used in dial pulse circuit 101A, 94N	0.3 "
Bridged retard coil (0.5 henry or higher)	0.0 "

Note: Additional information on repeating coils will be found in Sections 852-108-103 and AB47.006. Information on currently manufactured equipment may be obtained from the Western Electric Co. card catalog.

4.20 Margin is provided in the ***stability design*** method to take care of the effect of equipment at the remote end of a line section. For this reason the presence of such equipment can ordinarily be disregarded in computing the line return loss. In applying the ***singing margin*** method to special service lines the 6.0-db terminal return loss at a nonloaded loop is considered to include the effect of a battery supply coil. As a result the effect of a coil associated with a loop does not appear directly in the return loss calculation.

F. Bridged Taps on Nonloaded Facilities

4.21 In applying the ***singing margin*** method to nonloaded line sections, the effect of bridged taps may be disregarded in making the return loss calculations. The presence of such taps may, however, require network adjustments based on tests at the time of installation. If such tests are made, the permissible gain determined by the computed return losses may be increased by an amount sufficient to overcome the bridged tap loss. This credit is somewhat higher than that given in Section 852-305-102 for use with the ***stability design*** method. The more liberal treatment is permitted because, when the singing margin method is used, the line by itself does not necessarily need to meet the requirements for idle line stability as discussed in 2.03.

5. OPERATIONS REQUIRED TO COMPUTE LINE SECTION RETURN LOSSES

A. Determining the Reference Deviation of a Loading System

5.01 In Section 304-403-100, which covers structural return losses for exchange-type loaded facilities, the column headings are for reference deviations ranging from 1 to 15 percent. The process by which the reference deviation of a particular loading system is obtained is discussed in 5.02.

5.02 The reference deviation of a loading system is a measure of the combined effect of two types of spacing deviation which are:

(a) ***The departure of the average spacing of the system from the nominal standard spacing for the type of system.***

(b) ***The average of the differences, with signs disregarded, between the individual spacings and the system average spacing.***

The two types of deviation (a) and (b) are used to read the reference deviation value from the chart of Section 304-409-100. The average deviation is used in (b) to avoid the more difficult calculation required to obtain the root mean square deviation. The chart is constructed in such a way that with a normal distribution of spacing deviations the reference deviation is correctly obtained by this simplified procedure. The elimination of large deviations which are not within the probable spread of a normal distribution was discussed in 4.10. The separate treatment of such irregularities as individual spacing irregularities has the advantage of taking into account the actual location of the irregularities in the line. As an example of the procedure, consider the following loading system:

	Spacings between Coils	Sign of Dev.	Deviation from Avg. Spacing
	5990'	-	130'
	6290'	+	170'
	5910'	-	210'
	6270'	+	150'
	6220'	+	100'
	6040'	-	80'
Sum	36,720'		840'
Avg. (6)	6120'		140'
Std.	6000'		140/6120 = 0.023 = 2.3%
Dev.	120'		(2.3% on vertical scale of the chart of Section 304-409-100)

120/6000 = 0.02 = 2%
(2% on horizontal scale of AB42.090.09)
Reference Deviation from Section 304-409-100 = 3.5%

Three times Reference Deviation (4.10)
3 x 0.035 x 6000' = 630'

5.03 In the previous example, a deviation from standard spacing of three times the reference deviation is about 630 feet. Since the largest actual deviation from 6000 feet is 290 feet, there is no reason to consider any of the spacings as individual load spacing irregularities.

B. Referring Return Losses to a Repeater Location

5.04 In order to refer each of the intermediate and terminal irregularity return losses to the repeater location, it is necessary to add to each twice the loss between the irregularity and the repeater. For ***loaded*** exchange grade facilities of the types currently in use, the effective facility losses are suitable for use in referring return losses, except that for ***aerial*** cable the losses are adjusted as discussed in 5.06.

5.05 In using the stability design method for certain cases, as noted in 3.02, the effective facility loss of a nonloaded line section associated with a series repeater is used directly in reading a chart to determine the maximum usable gain. In using the singing margin design method, ***nonloaded loops,*** whether adjacent to the repeater or at a remote location, are treated as causing a 6.0-db return loss without detailed calculations based on the actual makeup. In other cases the return loss of a nonloaded line section should be computed for use in the design procedure. In referring return losses to the repeater location, twice the 1000-cycle loss of nonloaded facilities should be used rather than twice the effective loss. For nonloaded circuits, when the effective facility loss is known, the 1000-cycle loss can be found with sufficient accuracy by dividing the effective facility loss by 1.2. Adjustments of aerial cable losses for temperature variation effects are discussed in 5.06. For convenience the approximate 1000-cycle loss of a nonloaded underground loop, for which the length and resistance are known, can be read from the chart of Section 304-164-100.

5.06 The transmission losses of facilities vary with the temperature of the conductors and, when telephone repeaters are used, singing will be most likely to occur when the cable temperature is lowest. In the case of ***underground cable,*** winter conditions with minimum outdoor temperatures of about 0°F may result in cable temperatures which lower the transmission losses below the 68°F values by about 7 percent. The design and installation procedures, however, include some margin which, in general, will be adequate to prevent winter singing for layouts in underground cable. Particular care should be used, of course, to obtain an adequate margin against singing when circuits are installed during warm weather. For ***aerial cable*** the temperature of the conductors follows more closely the daily outdoor temperatures, and under similar weather conditions the losses may reach values about 15 percent below the 68°F values. The greater range of variation should be taken into account in referring return losses to the repeater location. In order to provide additional margin, not needed for underground cable, the facility losses for aerial cable, should be reduced below the 68° F values by about 8 percent for areas where 0° F temperatures may be expected. Some variation of the percent adjustment may be desirable to suit local conditions in areas with unusually large or small temperature changes.

5.07 In order to consolidate the information needed for computing line return losses, Section 304-408-103 for underground and Section 304-408-104 for aerial cable have been prepared to include facility losses for exchange-type facilities.

C. Combining Return Losses

Power Basis of Combination

5.08 The various referred return losses and the structural return loss applicable to a line section are combined on the power or energy summation basis. Section 304-007-100 includes data in the upper table to aid in this process.

5.09 In combining a number of return loss values, they are selected by pairs usually, as a matter of convenience, starting with the two highest values. From the difference between the two values of the pair, a combining term is found in Section 304-007-100. The combining term is then subtracted from the lower of the two return loss values of the pair. The result is then treated as a return loss value in continuing the process. The result for the last remaining pair is the line return loss.

5.10 As an example, consider the following group of four return losses all being values referred to the repeater location:

12.8 db

17.4 db

18.6 db

13.4 db

(a) 18.6 − 17.4 = 1.2 db Difference
Comb. term. = 2.5 db (Section 304-007-100)
17.4 − 2.5 = 14.9 db

(b) 14.9 − 13.4 = 1.5 db Difference
Comb. term. = 2.3 db (Section 304-007-100)
13.4 − 2.3 = 11.1 db

(c) 12.8 − 11.1 = 1.7 db Difference
Comb. term. = 2.2 db (Section 304-007-100)
11.1 − 2.2 = 8.9 db (Power Combination for the Group)

Line Return Loss = 8.9 db

Current Basis of Combination

5.11 Although the current or in-phase basis of combination is not normally used in obtaining the line return loss, it is used in some associated processes. The lower table of Section 304-007-100 provides data for making this type of combination.

5.12 Suppose, for example, that a line return loss of 14.6 db is to be combined on a current basis with 26.0 db (2.03):

26.0 − 14.6 = 11.4 db Difference
Comb. term = 2.1 db (Section 304-007-100)
14.6 − 2.1 = 12.5 db (Current Combination)

Junction Return Loss at ET Repeaters

5.13 In Section 852-305-101 the current basis is recommended for combining junction return losses at ET repeaters with line return losses. This method of computation provides an approximation of the minimum values of the combined return loss when the repeater impedance is not matched to that of the line. The necessary data may be obtained from Section 304-007-100.

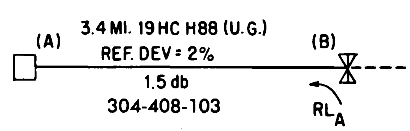
5.14 Suppose that a line return loss of 13.9 db is to be combined with a junction return loss of 15.7 db at an ET repeater.

15.7 − 13.9 = 1.8 db Difference
Comb. term. = 5.2 db (Section 304-007-100)
13.9 − 5.2 = 8.7 db (Combined Value)

6. EXAMPLES

A. Stability Design Method

6.01 ***Example 1:*** Find the Line Section Return Loss RL_A for the layout shown in Example 1.



EXAMPLE 1

Term RL at (A)

0 + 2(1.5) = 3.0 db (4.03, 5.04)

Structural RL = 23.4 db (2 percent Reference Deviation) (Section 304-403-100)

Add correction for 1.5 db

23.4 + 2.8 = 26.2 db (Section 304-403-101)

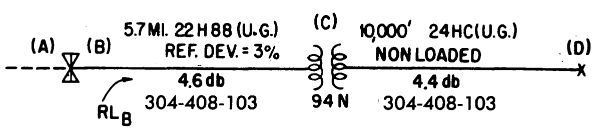
Power Combination of RLs at (B) (5.08)

26.2 − 3.0 = 23.2 db Difference (5.09)

3.0 − 0.0 = 3.0 db (Section 304-007-100)

RL_A = 3.0 db

6.02 ***Example 2:*** Find the Line Section Return Loss RL_B for the layout shown in Example 2.



EXAMPLE 2

Term RL at (D)

0 + 2(4.6 + 0.3 + 4.4) = 18.6 dB (4.03, 4.19, 5.04)

Repeating Coil (94N)

10.0 + 2(4.6) = 19.2 db (4.17, 5.04)

Junction RL at (C)

4.4 + 2 (4.6 + 0.3) = 14.2 dB (Section 304-408-101, 4.19, 5.04)

Structural RL = 23.7 db (3 percent Reference Deviation) (Section 304-403-100)

Add correction for 4.6 db

23.7 + 0.5 = 24.2 db (Section 304-403-101)

Power combination or RLs at (B) (5.08)

24.2 − 19.2 = 5.0 db Difference (5.09)

19.2 − 1.2 = 18.0 db (Section 304-007-100)

18.6 − 18.0 = 0.6 db Difference (5.09)

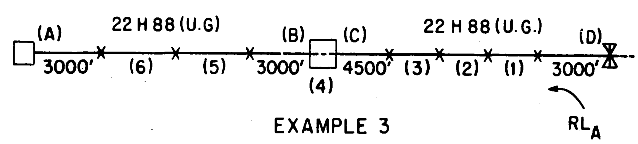
18.0 − 2.7 = 15.3 dB (Section 304-007-100)

15.3 − 14.2 = 1.1 db Difference (5.09)

14.2 − 2.5 = 11.7 db (Section 304-007-100)

RL_B 11.7 db

6.03 ***Example 3:*** Find the Line Section Return Loss RL_A for the layout shown in Example 3.



EXAMPLE 3

Loading System Deviations and Irregularities (5.02)

	Load Spacings	Deviation from Avg.
(1)	6200'	170'
(2)	5900'	130'
(3)	6100'	70'
(4)	7500' (Omit)	
(5)	6050'	20'
(6)	5900'	130'
Sum	30,150'	520'

Omitting (4) by inspection

Avg. (5)	6030'	104'
Std.	6000'	104/6030 = 0.0174 = 1.7% Approx.
Dev.	30'	Locate 1.7% on vertical scale of Section 304-409-100.

30/6000 = 0.005 = 0.5%

(Locate 0.5% on horizontal scale of Section 304-409-100.)
Reference Deviation from Section 304-409-100 = 2.0% Approx.
Structural Return Loss = 25.6 db (Section 304-403-100
Three times Reference Deviation (4.10)

3.0 x 0.02 x 6000' = 360'

7500 - 6000 = 1500' (greater than 360')

Loading Irregularity at (4)
7500 - 6030 = 1470'
1470/6030 = 24.4% (4.10)
Irregularity Return Loss = 12.6 db (Section 304-412-100)
Facility Loss (A)-(D) (43,650' = 8.3 miles) = 6.6 db (Section 304-408-103)
Facility Loss (C)-(D) (24,950' = 4.7 miles) = 3.8 db (Section 304-408-103)

Return Loss RL_A at (D) Example 3

Term RL at (A)
0 + 2(6.6) = 13.2 db
Irregularity RL at (C)
12.6 + 2(3.8) = 20.2 db
Structural RL 25.6 db
Add correction for 6.6 db
25.6 + 0.2 = 25.8 db (Section 304-403-101)
Power Combination at RL's at (D) (5.08)
25.8 - 20.2 = 5.6 db (5.09)
20.2 - 1.1 = 19.1 db (Section 304-007-100)
19.1 - 13.2 = 5.9 db (5.09)
13.2 - 1.0 = 12.2 db (Section 304-007-100)
RL_A = 12.2 db

Loading Irregularity at (4)

7500 − 6030 = 1470 ft

1470/6030 = 24.4% (4.10)

Irregularity Return Loss = 12.6 db (Section 304-412-100)

Facility Loss (A)−(D) (43,650 ft = 8.3 miles) = 6.6 db (Section 304-408-103)

Facility Loss (C)−(D) (24,950 ft = 4.7 miles) = 3.8 db (Section 304-408-103)

Return Loss RL_A at (D) Example 3

Term RL at (A)

0 + 2(6.6) = 13.2 dB

Irregularity RL at (C)

12.6 + 2(3.8) = 20.2 db

Structural RL 25.6 db

Add correction for 6.6 db

25.6 + 0.2 = 25.8 db (Section 304-403-101)

Power Combination at RLs at (D) (5.08)

25.8 − 20.2 = 5.6 db (5.09)

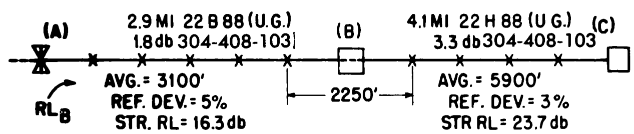
20.2 − 1.1 = 19.1 db (Section 304-007-100)

19.1 − 13.2 = 5.9 db (5.09)

13.2 − 1.0 = 12.2 db (Section 304-007-100)

RL_A = 12.2 db

6.04 ***Example 4:*** Find the Line Section Return Loss RL_B for the layout shown in Example 4.



EXAMPLE 4

Junction Return Loss at (B)

Normal Junction Section

0.5 (3100 + 5900) = 4500 ft

2250/4500 = 0.5 (50%)

Normal Junction Return Loss (HC H88 vs HC B88) = 15.7 dB (Section 304-408-100)

50% Junction Section RL = 8.2 db (Section 304-408-100)

Structural Return Loss

22B88 16.3 + 2.5 = 18.8 db (Section 304-403-101)

22H88 23.7 + 1.1 = 24.8 db (Section 304-403-101)

24.8 + (2 x 1.8) = 28.4 db

Combination at (A)

28.4 – 18.8 = 9.6 db

18.8 – 0.5 = 18.3 db (Section 304-007-100)

Line Section Return Loss

Term RL

0 + 2(1.8 + 3.3) = 10.2 db

Junction RL

8.2 ; 2(1.8) = 11.8 db

Structural RL = 18.3 db

Power Combination of RLs at (A)

18.3 – 11.8 = 6.5 db

11.8 – 0.9 = 10.9 db (Section 304-007-100)

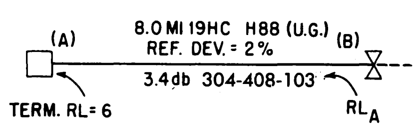
10.9 – 10.2 = 0.7 db

10.2 – 2.7 = 7.5 db (Section 304-007-100)

RL_B = 7.5 db

B. Singing Margin Method Based on Talking Condition Return Losses

6.05 ***Example 5:*** Find the Line Section Return Loss RL_A for the layout shown in Example 5 for use in the Singing Margin Method.



EXAMPLE 5

Term RL at (A)

6.0 + 2(3.4) = 12.8 db (2.03, 4.04)

Structural RL 23.4 (Section 304-403-100)

Add correction for 3.4 db

24.4 – 12.8 = 11.6 db

12.8 – 0.3 = 12.5 db (Section 304-007-100)

RL_A = 12.5 db

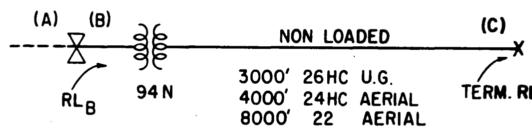
Current Combination of RL_A with 26.0 db (2.03)

26.0 – 12.5 = 13.5 db

12.5 – 1.7 = 10.8 db (Section 304-007-100)

RL_A term for margin formula = 10.8 db

6.06 ***Example 6:*** Find the Line Section Return Loss RL_B for the layout shown in Example 6 for use in the Singing Margin Method.



EXAMPLE 6

Facility Losses for Line Loss Corrections

26HC 3.000 x 0.542 = 1.63 = 1.6 db (Section 304-408-103)

24HC 4.000 x 0.403 = 1.61 = 1.6 db (Section 304-408-104)

22 8.000 x 0.312 = 2.50 = 2.5 db (Section 304-408-104)

Total 5.74 = 5.7 db

Typical Gauge

Total Loop Length = 15,000 ft

Total Loop Length = 717 ohms (AB43.521)

Typical gauge = 24HC (Section 304-164-100)

Junction Return Losses

26HC vs 24HC

17.5 db (Section 304-408-102)

Correction for 1.6 db is 4.5 db (Section 304-408-102)

17.5 + 4.5 = 22.0 db (4.14)

22.0 + 2(0.3) = 22.6 db (4.19)

Terminal Return Loss

Term. RL at (C)

6.0 + 2(5.7 + 0.3) = 18.0 db (4.19)

Equipment Return Loss

94N Repeating Coil at (B)

10.0 db (4.17)

Power Combination of RLs at (B)

22.6 − 18.0 = 4.6 db

18.0 − 1.3 = 16.7 db (Section 304-007-100)

16.7 − 10.0 = 6.7 db

10.0 − 0.8 = 9.2 db (Section 304-007-100)

RL_B = 9.2 db

Current Combination of RL_B with 26.0 db (2.03)

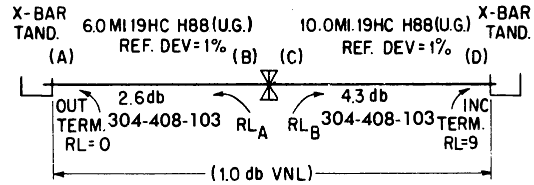
26.0 − 9.2 = 16.8 db

9.2 − 1.2 = 8.0 db (Section 304-007-100)

RL_B term for margin formula = 8.0 db

C. Check of Need for Idle Line Terminations on a Via Net Loss 2-Wire Trunk

6.07 ***Example 7:*** Check the adequacy of an idle line termination at the incoming end only of the trunk covered in Example 7.



EXAMPLE 7

Term. RL at (A)

0 + 2(2.6) = 5.2 db (4.05)

Structural RL

25.0 + 1.5 = 26.5 db (Sections 304-403-100 and 304-403-101)

Power Combinations of RLs at (B)

26.5 − 5.2 = 21.3

5.2 − 0.0 = 5.2 db (Section 304-007-100)

RL_A = 5.2 db

Term. RL at (D)

9.0 + 2(4.3) = 17.6 db (4.05)

Structural RL

25.0 + 0.6 = 25.6 db (Sections 304-403-100 and 304-403-101)

Power Combination of RLs at (C)

25.6 − 17.6 = 8.0

17.6 − 0.6 = 17.0 (Section 304-007-100)

RL_B = 17.0 db

Maximum Usable Gain with ET Repeater from Section 852-305-101, Fig. 1, (RL_A = 5.2, RL_B = 17.0) is 8.3 db.

Assigned gain (2.6 + 4.3) − 1.0 = 5.9 db

Since the assigned gain is lower than the computed idle line stable gain, the use of an idle line terminating circuit at (D) only will be sufficient to prevent singing in the idle condition.

7. REFERENCES

SECTION	TITLE
304-403-100	Structural Return Losses for Stability and Singing Margin Design Purposes—Exchange Area Facilities
304-403-101	Structural Return Loss Adjustments for Short Lengths of Loaded Facility
304-412-100	Loading Irregularity Return Losses
304-408-100	Junction Return Losses—Between Loaded Facilities
304-408-101	Junction Return Losses Between Loaded and Nonloaded Facilities
304-408-102	Junction Return Losses and Loss Corrections—Mixed Gauge Nonloaded Facilities
304-408-103	Facility Losses at 68°F for Referring Return Losses in Computing Line Section Return Losses—Loaded and Nonloaded Exchange-Type Underground Cable
304-408-104	Facility Losses Adjusted to Allow for Temperature Variations of Aerial Cable for Referring Return Losses in Computing Line Section Return Losses—Loaded and Nonloaded Exchange-Type Aerial Cable
304-409-100	Chart for Obtaining Reference Deviation of a Loading System
304-409-101	Typical Improvement in Structural Return Loss Obtainable with Deviation Test Splicing on Exchange Area Facilities
304-164-100	1000-Cycle Loss of Nonloaded Facilities from Length and Resistance
304-007-100	Combination of Return Losses on Power (Quadrature) Basis
304-007-100	Combination of Return Losses on Current (In-Phase) Basis