BELL SYSTEM PRACTICES
Transmission Engineering and Data
Exchange Area Transmission Practices

SECTION AB22.150.4
Issue 1, January, 1955
AT&TCo Standard

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 esti-
mating line section return losses and
provides references to the data ordinarily needed
in the application of negative impedance tele-
phone repeaters in the exchange plant. The
return losses discussed in this practice are
developed from considerations of singing phe-
nomena only, as limitations on repeater gain,
and neither methods or 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 calcula-
tion 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 re-
quirements of the contemplated trunk groups.
Observance of the load spacing standards dis-
cussed in Section AB22.125 will generally pro-
vide 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 dif-
ferent headings (A), (B), and (C).

(A) Stability Method

2.02 The stability design method is the sim-
plest and safest basis for the design of
repeatered circuits. It is based on the prin-
ciple 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 (1) the sum of the two return loss values and (2) 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 Paragraph 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 Paragraph 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 AB22.151.1 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 over-all design. These rules are discussed in Sections AB22.151.1 and AB22.151.3.

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 (A) to (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 were discussed
as distinguishing features of the different de-
sign 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 and 0 db, which is
typical of an open or short, is used as the
terminal return loss. The location of the re-
mote 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, how-
ever, 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 se-
ries 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 mar-
        gin 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 con-
nections. The 6.0 db terminal return loss may
be considered to occur at:

    (1) A PBX or central office switching point.

    (2) 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 fa-
cility 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 termi-
nal where an idle line termination is provided
and 0 db where none is provided. Any combina-
tion of these terminal arrangements, based on

the preceding assumptions, for which the "maximum
usable gain," as discussed in Section AB22.151.3,
is as great as or greater than the gain pro-
posed on the VNL basis will be considered sat-
isfactory with respect to idle line stability.
This procedure is illustrated by Example 7,
Paragraph 6.07.

(B) Structural Return Loss

4.06   A length of loaded facility has a struc-
        tural 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 (1) spacing
between loading coils, (2) loading coil in-
ductance and (3) cable pair capacitance. Struc-
tural return losses for exchange-type loaded
facilities are given in Section AB42.050.01 for
values of the reference deviation of a partic-
ular loading system. The reference deviation
is obtained as described in Part 5(A).

4.07   The structural return losses for loaded
        facilities given in Section AB42.050.01
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 AB42.050.01 may be increased by a cor-
rection obtained from Section AB42.050.02. 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 AB42.050.01 is corrected for the fi-
nite loss of the particular facility length by
the use of Section AB42.050.02. The structural
return losses for the remote lengths are then
referred to the repeater location as described
in Part 5(B). The final values are combined on
the power basis as described in Part 5(C). In
practice it will be found that in many cases
the structural return losses of circuits de-
signed 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 AB23.191. 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 AB42.050.10 gives the improvements over the structural return losses of Section AB42.050.01 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 AB42 Series. Specifically, it is proper to treat a load section as an irregularity if its per cent 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 AB42.050.03. The irregularity return losses in Section AB42.050.03 are based on the per cent 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 5(B).

(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 AB42.050.04 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 AB42.050.04 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 per cent 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 AB42.050.04 and spotted on the 100 per cent 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 per cent "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 per cent junction section between H88 and B88 high capacitance facilities which have a "normal" junction section return loss from the table of Section AB42.050.04 of 15.7 db. The 15.7 db value falls just below the contour which crosses the 100 per cent line of the chart of Section AB42.050.04 at 16.0 db. By following along just under this contour to the 50 per cent 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 per cent junction section is then 8.2 db.

4.13 Junction return losses between loaded and nonloaded facilities are given in Section AB42.050.05.

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 AB42.050.11. 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 AB42.050.06 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 AB42.050.06. The procedure is illustrated by Example 6, Paragraph 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 5(B).

(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 (1) about 15.0 db for the higher inductance exchange coils such as the 94E and 120 types or (2) 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 5(B).

4.18 The irregularity return losses for intermediate equipment described in Paragraph 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 AB22.152.1.

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 AB22.277 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 AB22.151.1 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 Paragraph 2.03.

5. OPERATIONS REQUIRED TO COMPUTE LINE SECTION RETURN LOSSES

(A) Determining the Reference Deviation of a Loading System

5.01 In Section AB42.050.01, which covers structural return losses for exchange type loaded facilities, the column headings are for reference deviations ranging from 1 to 15 per cent. The process by which the reference deviation of a particular loading system is obtained is discussed in Paragraph 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:

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

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

The two types of deviation (1) and (2) are used to read the reference deviation value from the chart of Section AB42.050.09. The average deviation is used in (2) 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 Paragraph 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 AB42.050.09)

120/6000 = 0.02 = 2%
(2% on horizontal scale of AB42.090.09)
Reference Deviation from AB42.050.09 = 3.5%

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

5.03 In the above example, a deviation from standard spacing of three times the reference deviation is about 630'. Since the largest actual deviation from 6000' is 290' 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 Paragraph 5.06.

5.05 In using the stability design method for certain cases, as noted in Paragraph 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 make-up. 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 Paragraph 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 AB42.050.11.

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 per cent. 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 per cent 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 per cent for areas where 0° F temperatures may be expected. Some variation of the per cent 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 AB42.050.07 for underground and Section AB42.050.08 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 AB47.872 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 AB47.872. 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 "
    18.6 "
    13.4 "

(a) 18.6 - 17.4 = 1.2 db Difference
    Comb. term = 2.5 db (Section AB47.872)
17.4 - 2.5 = 14.9 db

(b) 14.9 - 13.4 = 1.5 db Difference
    Comb. term = 2.3 db (Section AB47.872)
13.4 - 2.3 = 11.1 db

(c) 12.8 - 11.1 = 1.7 db Difference
    Comb. term = 2.2 db (Section AB47.872)
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 AB47.872 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 (Paragraph 2.03):

    26.0 - 14.6 = 11.4 db Difference
    Comb. term = 2.1 db (Section AB47.872)
    14.6 - 2.1 = 12.5 db (Current Combination)

Junction Return Loss at ET Repeaters

5.13 In Section AB22.151.3 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 AB47.872.
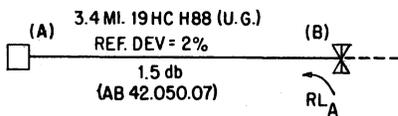
5.14 Suppose that a line return loss of 13.9 db is to be combined with a junction return loss of 15.7 db at an ET repeater.

$$15.7 - 13.9 = 1.8 \text{ db Difference}$$
Comb. term = 5.2 db (Section AB47.872)
$$13.9 - 5.2 = 8.7 \text{ db (Combined Value)}$$

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% Reference Deviation) (Section AB42.050.01)
Add correction for 1.5 db
$23.4 + 2.8 = 26.2$ db (AB42.050.02)
Power Combination of RL's at (B) (5.08)
$26.2 - 3.0 = 23.2$ db Difference (5.09)
$3.0 - 0.0 = 3.0$ db (Section AB47.872)
$RL_A = 3.0$ db

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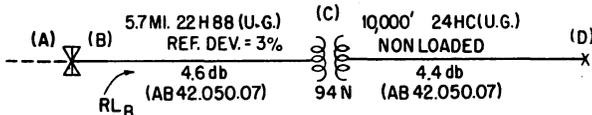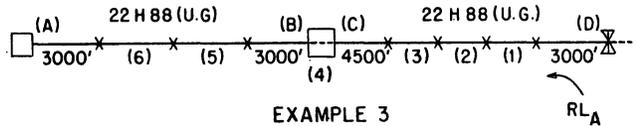

EXAMPLE 2

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 (AB42.050.05, 4.19, 5.04)
Structural RL = 23.7 db (3% Reference Deviation) (Section AB42.050.01)

Add correction for 4.6 db
$23.7 + 0.5 = 24.2$ db (Section AB42.050.02)
Power combination of RL's at (B) (5.08)
$24.2 - 19.2 = 5.0$ db Difference (5.09)
$19.2 - 1.2 = 18.0$ db (Section AB47.872)
$18.6 - 18.0 = 0.6$ db Difference (5.09)
$18.0 - 2.7 = 15.3$ db (Section AB47.872)
$15.3 - 14.2 = 1.1$ db Difference (5.09)
$14.2 - 2.5 = 11.7$ db (Section AB47.872)
$RL_B = 11.7$ 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 AB42.050.09.

$$30/6000 = 0.005 = 0.5\%$$

(Locate 0.5% on horizontal scale of Section AB42.050.09)
Reference Deviation from Section AB42.050.09 = 2.0% Approx.
Structural Return Loss = 25.6 db (Section AB42.050.01)
Three times Reference Deviation (4.10)

$$3.0 \times 0.02 \times 6000' = 360'$$

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

Loading Irregularity at (4)
7500 - 6030 = 1470'
1470/6030 = 24.4% (4.10)
Irregularity Return Loss = 12.6 db (Section AB42.050.03)
Facility Loss (A)-(D) (43,650' = 8.3 miles) = 6.6 db (Section AB42.050.07)
Facility Loss (C)-(D) (24,950' = 4.7 miles) = 3.8 db (Section AB42.050.07)

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 AB42.050.02)
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 AB47.872)
19.1 - 13.2 = 5.9 db (5.09)
13.2 - 1.0 = 12.2 db (Section AB47.872)
RL_A = 12.2 db

6.04 Example 4: Find the Line Section Return Loss $\overline{RL_B}$ for the layout shown in Example 4.
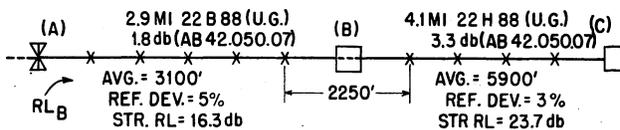
EXAMPLE 4

Junction Return Loss at (B)

Normal Junction Section
0.5 (3100 + 5900) = 4500'
2250/4500 = 0.5 (50%)
Normal Junction Return Loss (HC H88 vs HC B88) = 15.7 db (Section AB42.050.04)
50% Junction Section RL = 8.2 db (Section AB42.050.04)

Structural Return Loss

22B88 16.3 + 2.5 = 18.8 db (Section AB42.050.02)
22H88 23.7 + 1.1 = 24.8 db (Section AB42.050.02)
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 AB47.872)

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 RL's at (A)
18.3 - 11.8 = 6.5 db
11.8 - 0.9 = 10.9 db (Section AB47.872)
10.9 - 10.2 = 0.7 db
10.2 - 2.7 = 7.5 db (Section AB47.872)
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.
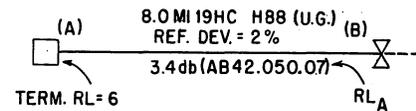
EXAMPLE 5

Term RL at (A)
6.0 + 2(3.4) = 12.8 db (2.03, 4.04)
Structural RL 23.4 (Section AB42.050.01)
Add correction for 3.4 db
23.4 + 1.0 = 24.4 db (Section AB42.050.02)
Power Combination of RL's at (B)
24.4 - 12.8 = 11.6 db
12.8 - 0.3 = 12.5 db (Section AB47.872)
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 AB47.872)
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.
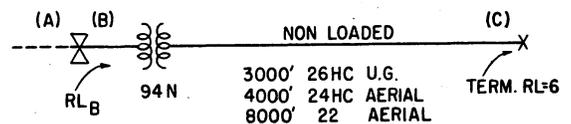
EXAMPLE 6

Facility Losses for Line Loss Corrections

 26HC 3.000 x 0.542 = 1.63 = 1.6 db
 (AB42.050.07)
 24HC 4.000 x 0.403 = 1.61 = 1.6 db
 (AB42.050.08)
 22 8.000 x 0.312 = 2.50 = 2.5 db
 (AB42.050.08)   ——
   Total   5.74 = 5.7 db

Typical Gauge

 Total Loop Length = 15,000'
  " " " = 717 ohms (AB43.521)
 Typical gauge = 24HC (Section AB42.050.11)

Junction Return Losses

 26HC vs 24HC
 17.5 db (Section AB42.050.06)
 Correction for 1.6 db is 4.5 db (Section
 AB42.050.06)
 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 RL's at (B)

 22.6 - 18.0 = 4.6 db
 18.0 - 1.3 = 16.7 db (Section AB47.872)
 16.7 - 10.0 = 6.7 db
 10.0 - 0.8 = 9.2 db (Section AB47.872)
 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 AB47.872)
 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.
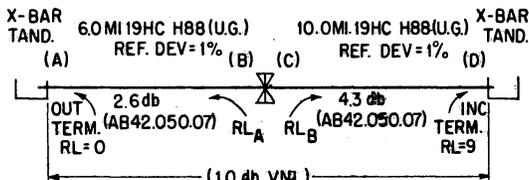
EXAMPLE 7

Term RL at (A)
0 + 2(2.6) = 5.2 db (4.05)
Structural RL
25.0 + 1.5 = 26.5 db (Sections AB42.050.01 and AB42.050.02)

Power Combination of RL's at (B)
26.5 - 5.2 = 21.3
5.2 - 0.0 = 5.2 db (Section AB47.872)
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 AB42.050.01 and AB42.050.02)

Power Combination of RL's at (C)
25.6 - 17.6 = 8.0
17.6 - 0.6 = 17.0 (Section AB47.872)
RL_B = 17.0 db

Maximum Usable Gain with ET Repeater from AB22.151.3, 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. LIST OF REFERENCES TO SOURCES OF DATA

Section AB42.050.01 - Structural Return Losses for Stability and Singing Margin Design Purposes - Exchange Area Facilities

Section AB42.050.02 - Structural Return Loss Adjustments for Short Lengths of Loaded Facility

Section AB42.050.03 - Loading Irregularity Return Losses

Section AB42.050.04 - Junction Return Losses - Between Loaded Facilities

Section AB42.050.05 - Junction Return Losses Between Loaded and Non-loaded Facilities

Section AB42.050.06 - Junction Return Losses and Loss Corrections - Mixed Gauge Nonloaded Facilities

Section AB42.050.07 - Facility Losses at 68° F for Referring Return Losses In Computing Line Section Return Losses - Loaded and Nonloaded Exchange Type Underground Cable

Section AB42.050.08 - 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

Section AB42.050.09 - Chart for Obtaining Reference Deviation of a Loading System

Section AB42.050.10 - Typical Improvement in Structural Return Loss Obtainable with Deviation Test Splicing on Exchange Area Facilities

Section AB42.050.11 - 1000-Cycle Loss of Nonloaded Facilities from Length and Resistance

Section AB47.872 - Combination of Return Losses on Power (Quadrature) Basis

Section AB47.872 - Combination of Return Losses on Current (in Phase) Basis