

EXCHANGE SPECIAL SERVICE TELEPHONE LINES

USE OF HYBRID TYPE REPEATERS

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1. GENERAL

1.01 As indicated in other sections of these practices the transmission design problems of exchange special service lines requiring voice repeaters can be solved in the majority of cases by the use of repeaters of the negative impedance type. The availability of the ET and EL arrangements of the E2 and E3 repeaters will still further reduce the necessary field of use of the more expensive types. There will, however, still be some cases where because of 4-wire operation, exceptionally high gains (10 db or more), or where existing repeaters are available, it is desired to utilize V-type repeaters or existing repeaters of older types.

1.02 This section discusses the use of these "V" repeaters or older similar types on exchange special service lines and some of the design factors applicable to exchange type facilities.

1.03 The detailed design of repeated special service lines requires consideration of repeater location and the choice of the associated line facilities so as to attain transmission objectives taking into consideration singing, echo, crosstalk, and overloading of the repeater.

1.04 In addition to the specific design problems for individual cases, the use of repeaters involves the general consideration that considerable economies can usually be realized by the concentration of repeaters of this type in a few central offices in order to obtain savings in equipment, engineering, installation, and maintenance expense, and yet be so located as to provide flexibility for use with the particular distribution of special service lines.

1.05 Many special service lines are of types which involve dc supervision, and 20-cycle or other signaling systems. Repeater arrangements must provide for these systems with adequate ranges for the equipment involved. Signaling equipment which effectively opens the line in some operating condition will tend to limit the gain obtainable if it is located within the portion of the line balanced by the repeater networks. In some cases the use of bypass arrangements which either disable the repeater or reduce the gain in the idle or pulsing condition have been used to advantage.

1.06 In the make-up of special service lines, either 2-wire or 4-wire repeaters may be used together with suitable signaling arrangements for repeating or bypassing dial pulse or supervision signals around the repeater. Because of its greater expense, particularly in line facilities, 4-wire operation is regarded as a desirable alternative only in cases where the desired net losses can not be obtained with 2-wire arrangements. This may be due to the impracticability of obtaining circuit layouts with good balances under 2-wire operation or because very low operating net losses, in some cases approximately zero db, are desired such as in the case of a PBX tie trunk intended for use in switched connections.

1.07 As installations of repeaters of these types in local central offices will usually be comparatively small, certain equipment refinements, such as jacks, usually applied to toll repeaters can be omitted. It is usually desirable that these small installations for special service lines be made as flexible as reasonably possible to permit of future rearrangements and to permit installation in a reasonably short interval. The choice of a particular arrangement should take into consideration the signaling requirements involved and the balance difficulties which will occur if equipment not simulated in the network is included in the line adjacent to the repeater. Except where repeaters installed for toll message trunks may be utilized, such simplified repeater assemblies will generally be the most economical arrangement for special service lines.

1.08 In specifying the gain of 2-wire V-type repeaters, the net gain requirements should of course be increased by the losses of

the two hybrid arrangements to obtain the amplifier gains.

## 2. BALANCE REQUIREMENTS

2.01 In the design of 2-wire lines the gain that may be obtained from repeaters is generally limited by the combination of intermediate and terminal return losses with the structural return loss referred to the repeater location. See Table A for terminal return loss values.

2.02 In order to provide satisfactory operation of repeaters in special service lines, it has been the experience that an overall singing margin of about 10 db around the repeater under the subscriber-to-subscriber talking condition is a workable design objective. In instances where tests are made of the various terminating and holding conditions, and the existing assignment of facilities appears reasonably permanent, it may be satisfactory to operate with lower singing margins. In any case, however, the margin should not be so low that the circuit is sufficiently unstable to produce noticeable distortion. The above practices will usually assure a sufficiently high active balance so that on switched connections to toll circuits the resulting service will be satisfactory from the singing and echo standpoints. In all cases it is desirable to check the line in all possible switching and holding conditions to avoid the possibility of singing.

2.03 In general, the repeater balance requirements are controlling factors in the selection of the associated line facilities and it is usually desirable to select a layout that, as far as practicable, consists of but one type of line facility on each side of the repeater and in which there are no substantial loading irregularities, particularly near the repeater. In some cases, line facilities with the higher transmission losses, such as a smoothly loaded 22H88 facility, may be preferable because they happen to provide better balances. It is, of course, generally impractical to avoid some of the large irregularities which result from such conditions as the termination of a loaded trunk in a subscriber loop or the switching of a special service line to trunks and loops of varied impedances. In some instances, however, it may be feasible to locate the repeater at such points of discontinuity in order to obtain satisfactory balances. For example, if in a foreign exchange line to an individual station the repeater can be placed at the junction between loaded trunk facilities and a nonloaded loop, singing points higher than at any other point in the circuit may frequently be obtained.

2.04 Because of the comparatively wide variation in the structural return losses of existing loaded facilities in the exchange plant, it would be preferable when designing such lines to obtain measured values of the singing points and possibly the impedances in each direction from the repeater for the condition with the complete circuit set up and the switched end or ends terminated in several conditions representative of those which may occur in operation. The impedance data are especially helpful in the selection of a balancing network if the measured singing points against the networks chosen for the tests are not as high as desired. In many cases, however, it may be impractical to measure singing points or impedances of the existing facilities and it will be necessary, therefore, to compute the singing points on a theoretical basis, assuming representative return loss values. Where such computations indicate adequate balances, it appears that satisfactory operation of the repeated circuit may be expected.

2.05 For balancing the line, a precision type network, a compromise network, or a duplicate line facility may be used. Precision type networks of the 115-type are available for the common types of exchange facilities and will provide a very high degree of balance where the line facilities are relatively long and smoothly loaded.

2.06 An adjustable network, the 115D, is also available for balancing a section of non-loaded cable. This is a 4-terminal network and more than one may be connected where required and may be terminated by either a resistance for compromise balance or by a dummy station network such as the 115BL. In some cases, where the maximum balance condition is not required, the use of a simple compromise network termination may be satisfactory.

2.07 Where a repeater is located at a terminal of a special service line at which the line may be switched to subscribers' loops or trunks, it will generally be desirable to make use of the usual compromise network of a 600-ohm resistance in series with a 2 MF condenser.

2.08 In some cases, because of an irregularity, short length or method of termination, it may not be possible to obtain sufficient balance by use of the standard precision or compromise networks. In these cases it may be necessary to make up by line measurements a network using variable resistors and capacitors, adjusting these by trial on the specific line to obtain the maximum balance.

2.09 When short electrical lengths, irregular loading spacing, impedance irregularities at junctions of loaded and nonloaded cable, or other causes make it impractical to obtain reasonable balances with networks a solution may frequently be found by the use of balancing pairs. The cost of the second local pair required will in many cases be considerably less than the cost of other remedial measures.

2.10 The use of a duplicate line for balancing, when properly terminated, affords a high degree of balance. The balancing line need not of course be a duplicate of the talking circuit in that direction for the entire distance but might be terminated at some intermediate point in a precision or compromise network which sufficiently matches the impedance of the remainder of the circuit to give a satisfactory balance. Should it be desirable to extend the balancing line to a point at which the special service line may be switched to trunks and loops, the balancing line could be terminated in a compromise network of 600-ohm resistance and a 2 MF condenser. Similarly, in some cases where a balancing line is extended to a terminal at which the talking pair may be switched to PBX extensions, the balancing line might be built out to the average length of extension and terminated in a subset network. Should the special service line not be switched at the terminal in question but be wired to a particular station, the balancing line might be correspondingly designed and terminated in a subset network.

2.11 The use of balancing pairs is not necessarily limited to the cases where loops are composed of loaded and nonloaded facilities. In general, when the working pair and the balancing pair are exact duplicates the effect of the unbalance between pairs on the over-all singing point will be negligible and the singing point to be expected will be that of the remote network and the portion of the circuit it balances plus twice the attenuation of that portion of the line simulated by the balancing pair.

### 3. LEVEL REQUIREMENTS

3.01 The maximum and minimum levels at which repeaters may be operated on special service lines are limited by crosstalk, circuit noise, and the possible undistorted output volume of the repeater. Ordinarily, noise will not be an important factor in the consideration of possible layouts as the other limitations will usually control objectionable amplification of the circuit noise.

3.02 In order to prevent overloading of the repeater, the level at the output of the repeater should preferably be no more than 6 db outside of the hybrid on 2-wire operation or 10 db for 4-wire operation above the level at the subscriber terminal or at the switching point as indicated in the level diagram Fig. 1a.

3.03 If the level of a special service line is permitted to fall too low at a repeater input, unfavorable crosstalk conditions may result. If the majority of other pairs in the cable unit or color group are repeatered, the crosstalk conditions are affected also by the output levels at which the repeaters are operated. Crosstalk performance is considered good in staggered twist cable (see Fig. 1b) if the sum of the gains in both directions exceeds twice the loss to either circuit terminal by no more than 8 db for H88 loaded facilities, 18 db for nonloaded facilities or 2 db for B135 loaded facilities. Values for other weights of loading may be obtained by interpolation. Where a repeater is located at a central office switching point a 4.0 db loss should be assumed beyond the terminal for crosstalk purposes.

3.04 If the repeatered special service lines are on about 10% or less of the pairs in the unit or color group, the sum of the gains in both of the directions may exceed twice the loss to either circuit terminal by 16 db, 36 db and 4 db for H88, NL, and B135 facilities, respectively, mentioned in Paragraph 3.03, and still produce good crosstalk conditions.

3.05 The above values assume that the special service lines as well as other facilities in the same cable are connected to FLA-HAL subscriber sets. Where 500-type sets are involved, the values in Paragraph 3.03 should be decreased by the increased efficiency  $((T+R)/2)$  of the 500 set over the FLA-HAL set on the loop involved. This, of course, also applies to other station equipment with higher efficiency than the FLA-HAL set.

3.06 Since the coupling in nonstaggered twist cable is of a magnitude which results in poor crosstalk conditions, even with very small repeater gains, the use of repeaters on cable facilities which have large amounts of nonstaggered twist cable should be avoided.

### 4. 4-WIRE OPERATION

4.01 Where it is desirable to obtain net losses substantially better than can be secured with a 2-wire repeater, it may be desirable to make use of a 4-wire repeater and operate the line or a portion of the line on

a 4-wire basis. By locating the hybrid sets at offices where the major irregularities occur or so that they will be included in the 4-wire portion of the circuit, it is usually possible to obtain sufficiently high return losses at the 4-wire terminals to operate the circuit at a very low equivalent. In determining the minimum operating net loss of the 4-wire section, these cases can be treated in the same manner as for a 2-wire repeater, but using the return losses of the 2-wire portions of the line referred to the hybrid set locations. Network selection considerations are similar to those for 2-wire repeaters.

4.02 With the 4-wire arrangement, the maximum output level into the line without overloading is increased by the difference between the hybrid coil loss and that of an output coil. This usually amounts to about 4 db.

4.03 However, within the 4-wire section it may be possible to locate the repeater at one of several offices which may permit different gains from a crosstalk or overloading standpoint. Four-wire repeater arrangements for special service lines can, of course, utilize existing 44-type toll repeaters but more economical arrangements can be obtained in new installations by 4-wire arrangements of repeaters of the V types.

4.04 When the special service line is associated with but one station at a terminal, it may be desirable to provide 4-wire substitution equipment. With this plan, the acoustic coupling between the transmitter and receiver at the 4-wire subset would be low so that the return loss as viewed from the distant hybrid coil would be high and the gain would usually be controlled by crosstalk and overloading restrictions. With this arrangement, therefore, it should be possible in many instances to obtain lower net losses than with 2-wire sets.

TABLE A

TERMINAL RETURN LOSSES

Loaded facilities against non-loaded loops, telephone instruments, or PEX terminations.	6.0 db
Loaded facilities against central office switching points.	4.0 db

Nonloaded facilities, not balanced by nonloaded repeater network, against telephone instruments, PBX terminations or central office switching points. 0.0 db

Compromise network against telephone instruments, PBX terminations or central office switching points. 6.0 db

Telephone instruments against correct type precision networks. 10.0 db

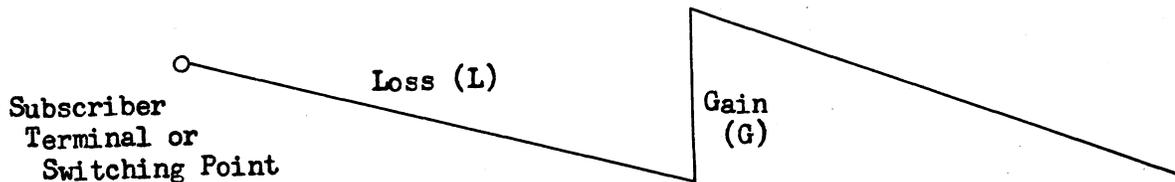
Nonloaded facilities balanced against one or more nonloaded cable 4-terminal networks terminated with -

(a) Compromise Network 6.0 db plus twice the 1000-cycle loss of the section of cable balanced by the 4-terminal network.

(b) Subset Network 10.0 db plus twice the 1000-cycle loss of the section of cable balanced by the 4-terminal network. This arrangement is useful only if the cable is fully simulated and if the line is terminated in a single instrument.

Combine the result in (a) or (b) with 20 db on a power summation basis to take into account the degree of precision with which the 4-terminal network can be designed to simulate the non-loaded cable.

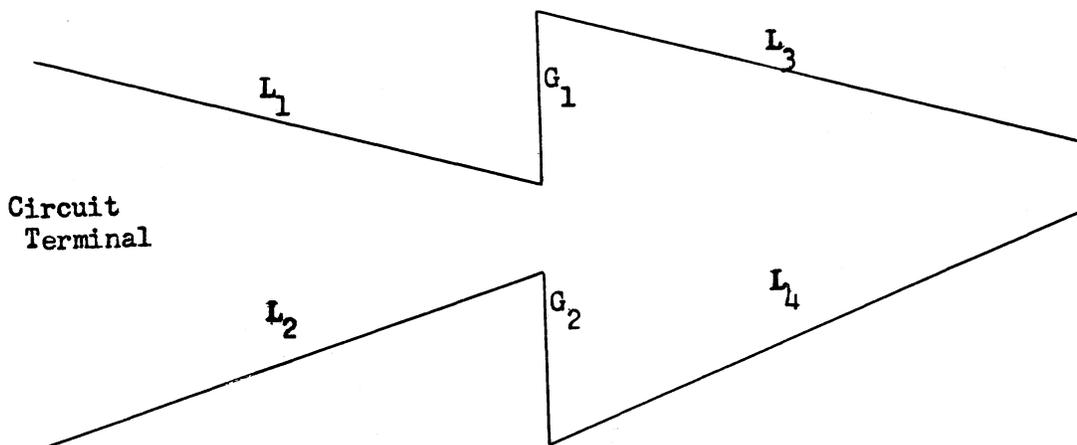
4.05 For structural return losses and junction return losses of exchange facilities refer to Section AB22.151. Due to the narrow transmission frequency band used with repeaters including filters, the structural return losses for B88 loaded facilities may be increased by 2 db for high capacitance cable facilities and by 3 db for low capacitance facilities.



Two-Wire Operation  $G-L=6.0$  db.

Four-Wire Operation  $G-L= 10.0$  db.

a. Overloading Limitations



b. Crosstalk Limitations

$$\begin{array}{l}
 G_1 + G_2 - (L_1 + L_2) \\
 \text{or} \\
 G_1 + G_2 - (L_3 + L_4)
 \end{array}
 \begin{array}{l}
 \text{equal or} \\
 \text{less than}
 \end{array}
 \left\{ \begin{array}{l}
 *8\text{db for H88 facilities} \\
 2 \text{ db for B135 facilities} \\
 18 \text{ db for N.L. facilities}
 \end{array} \right.$$

\* For other facilities, interpolate in accordance with facility impedance. Where less than about 10% of the facility color group is repeatered see Paragraph 3.04.

Fig. 1 Overloading and Crosstalk Limitations