E1 TELEPHONE REPEATER

GENERAL FEATURES AND ENGINEERING CONSIDERATIONS

CONTENTS PAGE

1. GENERAL

1.01 This section summarizes the general transmission and equipment features of the E1 telephone repeater. It also outlines the general considerations relating to the engineering, installation and operation of these repeaters.

1.02 The purpose of this section is to provide engineering personnel, otherwise unfamiliar with the E1 repeater, with a brief picture of its characteristics and the more general considerations affecting its use. This section is not to be used for detailed engineering, since separate sections in their appropriate functional series are available covering the detailed description, engineering practices and maintenance requirements.

1.03 The E1 repeater is different in operating principle and design from the 22 and V-type repeaters, and is proposed primarily for use on exchange area trunks and special service lines.

1.04 Generally these repeaters will be installed in local central office buildings, unassociated with toll, and will be under the service care of the local maintenance personnel. In view of this, a large amount of information on the repeaters will be available to both engineering and local plant personnel by means of dual numbered sections in the AB and A Series.

2. TRANSMISSION FEATURES

(A) General

2.01 The E1 repeater employs an entirely different type of circuit from the 22 or V-type telephone repeaters generally used and can be considered from the transmission standpoint as a negative series impedance inserted in the line. Its gain is a function of the sum of the impedances of the two lines looking away from the repeater and the negative impedance introduced by the repeater. The magnitude of the negative impedance is controlled by a variable network furnished as a part of the repeater and which is adjusted locally to provide the desired gain. Because of its nature the repeater cannot be adjusted for unequal gains in the two directions of transmission. The theory of the negative impedance repeater will be covered in a section of Practices in the AB93 Series.

2.02 The maximum practical gain of the E1 repeater under the most favorable conditions will be about 10 db, and its output capacity is approximately +10 vu.

2.03 The term "gain" as used with E1 repeaters does not imply a value determined at 1000 cycles, and adjustable by means of a potentiometer, as is the case with the 22 or V-type repeaters. With E1 repeaters the gain introduced into the working line is determined as an average value from an insertion gain-frequency characteristic measured with the lines connected and a particular strapping of the gain adjusting network. A significant change in this gain can be obtained only with a different strapping of the network. A given gain-frequency characteristic may be reshaped at the lower or upper frequencies by only a minor adjustment of the network units without significantly changing the average value of the gain.

2.04 The E1 repeater may be used at either an intermediate or terminal location on a circuit. It should not be located at or too near a toll office or tandem office at which intertoll trunks are terminated due to the low return loss resulting from the negative impedance introduced by the repeater.

2.05 The repeater will maintain gain stability with d-c loop currents of up to 100 milliamperes. Also its gain will remain substantially unchanged for plate battery voltage drops of about 20% from nominal.

(B) Nominal Gains

2.06 The gain obtainable with the E1 repeater will depend on the return losses on each side, and their variations between working and idle circuit conditions. As a rough guide, it appears feasible for regularly loaded circuits having return losses usually found in exchange plant, to reduce the circuit loss to about one-half of the non-repeatered value.

2.07 The repeater may be located at either an intermediate point or the terminal of a circuit. Maximum gains up to 8 (or 10 db in favorable cases) may be realized where the repeater is located at or near the loss center of the circuit. On a loaded line where the loss is less than 7 db more, satisfactory gain characteristics can usually be obtained by placing the repeater at one end. The maximum gain obtainable for a terminal repeater is 4 db.

2.08 On non-loaded circuits somewhat better performance with the repeater will be obtained than on loaded circuits. For example, a 10 db non-loaded circuit may be reduced to 3 or 4 db by the use of an intermediate repeater. The gain limitation of 4 db for a terminal repeater also applies on a non-loaded circuit.

2.09 On non-loaded cable circuits the network of the E1 repeater can be adjusted to provide greater gains at the higher speech frequencies than at the lower, thus providing a measure of attenuation equalization. The extent of equalization which may be realized varies inversely with the length of the non-loaded facility and the nominal amount of gain required.

2.10 It will be practicable to operate E1 repeaters in tandem on the same circuit provided the repeaters are separated by sufficient line loss. Generally, however, the maximum total gain from all the repeaters in tandem will not exceed one-half the non-repeatered loss of a loaded line. Somewhat better results are obtainable from tandem repeaters on a non-loaded facility.

2.11 In some cases two circuits with terminal repeaters in the same office may be switched together. In such cases the total gain will be greater than the sum of the gains for which the repeaters are individually adjusted, and care is required in the individual gain assignments to insure a stable condition when interconnected.

2.12 Section AB22.151 presents in detail the considerations involved and the data for determining the permissible gain of E1 repeaters for any specific application to message circuits or special service lines.

2.13 Section AB22.152 gives a table of standard strappings for the gain adjusting network for a range of gains for various types of facilities associated with the repeater.

(C) Trouble Conditions

2.14 Loss of power, a burnt out tube, or an open in the repeater circuit connecting the secondary of the input transformer to the tubes will result in the repeater introducing a loss up to 15 db in the circuit, due to the insertion loss of the windings of its input coil which are in series with the line and have an inductance of about 1.35 henry.

2.15 An open in the network circuit, with the repeater otherwise operating will usually result in a singing condition. A short-circuited network will introduce about a 1 db loss in the line.

3. EQUIPMENT FEATURES

(A) General

3.01 Two complete repeaters are mounted on a standard 1-3/4" x 19" mounting plate.

3.02 Each repeater employs a single 407A vacuum tube which is a twin triode of the nine-pin miniature type. The two heaters of this tube may be arranged either in parallel or in series, for use with 24 or 48-volt central office battery. The heater drain will be 100 milliamperes at 20 volts, or 50 milliamperes at 40 volts.

3.03 The plates require a battery supply of 130 $\pm$5 volts. The plate drain will be 11.2 milliamperes per repeater.

3.04 No signaling by-pass arrangements are required, since a d-c and low frequency signaling path is maintained through the repeater. The d-c resistance of the loop path is 40 ohms, and that of the simplex path is 10 ohms.

3.05 The loss to the ringing, dialing and pulsing ranges will vary with the length and type of circuit and the gain of the repeater. Generally this loss is expected to be in the order of 50 to 100 ohms, but might under adverse combinations of the above increase up to about 300 ohms. Specific limitations where available are covered in AB22.151.

3.06 The circuit of the El repeater is given on Drawing SD-95465 and the equipment arrangement is covered on ED-92200. The circuit and equipment features are described in AB22.153.

(B) Engineering and Installation

3.07 The El repeater has been designed to provide a unit of moderate gain at low cost with respect to the conventional 22 or V-type repeaters. In its design, emphasis has been placed on simplifying the transmission and equipment engineering and minimizing the amount of installation work involved in order to achieve the low cost objective, and unless advantage is taken of these features the economies anticipated for these repeaters will not be realized.

3.08 Practically all applications to the message plant and a large number of applications on special service lines will involve only nominal gains. Under such conditions transmission engineering will be reduced to a minimum and will consist chiefly of a check of the structural layout of the routes involved to determine that no major irregularities exist in the plant layout. Where the highest possible gains are desired, such as in certain cases of special service line layout, the amount of transmission engineering involved with the El repeater, and on-the-job testing to secure maximum gain, will correspond to that at present expended in connection with the circuit design involving a 22 or V-type repeater on similar facilities.

3.09 The "package" nature of the unit simplifies the equipment engineering aspects. There are no external jacks, coils or network equipment associated with the repeater. With the exception of the occasional use of building-out condensers for the loading end sections, the battery supply constitutes the only associated external apparatus and the only external connections made to the repeater are those of the battery supply and the two line circuits between which the repeater is connected.

3.10 Since El repeater installations usually will be at other than toll offices it is expected that a 130-volt power plant also will be required. Generally in such cases the minimum operating costs will be achieved from the use of one of the various small 130-volt power plants, such as the 403A, B or C or 405A type which range in capacity from 100 to 1500 milliamperes. Except for installations of less than nine repeaters, the costs of these auxiliary power plants expressed in terms of annual charge per repeater served will range from about $10 to $2 for the small to large installations respectively.

4. TESTING FEATURES

(A) Gain Measurements

4.01 Since the impedances of the two connected lines are factors in setting the gain of an El repeater, the true insertion gain can be determined only when measured with the actual lines connected and terminated, or between impedances closely simulating these lines. The usual gain measuring technique for 22-type repeaters, i.e., between 600-ohm transmission measuring sets is not applicable, since it is not practical to build up the sending and receiving impedances of these instruments to match the wide ranges of impedance conditions which will be encountered at various El applications.

4.02 With the usual 600-ohm transmission testing equipment, therefore, it would be necessary to measure on the over-all circuit with the repeater "in" and "out" to obtain its insertion gain, and would require testing personnel with suitable intercommunicating facilities at three locations. In order to avoid such a costly test method, the J94002G repeater test set has been made available for use with these repeaters. This set permits the use of standard transmission measuring apparatus at the repeater, and eliminates the need for personnel at the ends of the circuit. Also it permits testing without removing the repeater from the line. This test set applies the sending and receiving units to the two sides of the repeater, each across two 1-ohm resistors in series with the line on each side of the repeater. The test set is also arranged to short-circuit the repeater for the "out" condition. The 1-ohm test resistances are included in the repeater circuit, which is arranged to facilitate connection to the test set by means of a test plug mounted on the repeater panel.

(B) Test Equipment

4.03 The principal items of test equipment and their basic functions are:

(a) J94002G Repeater Test Set - used primarily as a coupler for gain measurements. It also provides a duplicate of the gain adjusting network in which the terminals of the component electrical units appear on pin jacks, so that a specified network strapping may be set up for gain check before it is permanently wired on the individual repeater network. This test set is described in Section AB22.154.

(b) A combination of a multi-frequency oscillator and a detector (or measuring) unit capable of an over-all gain of about 90 db is required for repeater gain measurements. The following combinations of equipment probably will be the most commonly available of those suitable for these tests:

Oscillator	Detector
19C, or 200B (Hewlett-Packard), or Spec. 9019*(Hewlett-Packard)	2-Type Noise Measuring Set, or equivalent
200B (Hewlett-Packard), or Spec. 9019*(Hewlett-Packard)	400C Vac. Tube Vm (Hewlett-Packard)

*(Now coded 200H in Hewlett-Packard Catalogue.)

Due to its low output level the 19C is the least desirable of the above oscillators.

The 19C oscillator and the 2-type noise measuring set are commonly available in the plant. The Hewlett-Packard 200B and earlier Spec. 9019 oscillators and the 400C vacuum tube voltmeter have found use in the plant in M1 carrier and radio applications.

Where new equipment of this type is to be procured for exclusive use in lining up E1 repeaters, the least expensive combination should be considered.

(c) A high resistance (20,000 ohm/volt), or vacuum tube voltmeter for measuring activity of the repeater tube.

(d) A high impedance monitoring head set.

(e) Miscellaneous items such as cords and plug for voltmeter, tube puller, pin straightener, etc.

4.04 It is expected that for large installations it will be desirable to provide a set of test equipment per installation. For smaller installations it appears that such equipment provided on the District or Division level and available on a portable basis would be adequate.

(C) Installation Tests

4.05 Sections in the A304. Series cover the procedures for putting a repeater into service, either with or without tests for gain adjustments.

4.06 Where the standard gain strapping tables are used for setting the gain, the repeater may be cut into service with only a check of the tube operation, and monitoring for stability. This will usually be the case where a 2G repeater test set and transmission measuring equipment are not available. However, where such equipment is available it will be desirable to check the gain of a repeater for each similar group of strappings after the first network has been strapped.

4.07 Where the gain of the repeater is to be determined locally, or a variation of a standard strapping is desired, gain measurements are required to determine the wanted performance.

(D) Service Tests

4.08 Routine tests on the repeater generally will involve only periodic checks of tube operation. Detailed procedures for this are covered in a section in the A204. Series.

4.09 Procedures for investigating trouble may require removing the repeater from service, and in some instances a gain check, before it is restored to service. A section in the A304. Series covers the trouble analysis and method of taking the equipment out of service.

5. FIELD OF APPLICATION

5.01 The E1 repeater, because of its relatively low cost and minimized reaction on dialing and supervision ranges as compared with the 22 or V-type repeaters, is expected to have a wide field of application on the following circuits:

(1) Exchange special services, including foreign exchange lines, off-premises P.B.X. extensions and P.B.X. tie trunks, particularly in connection with changes in design to conform with the F1A-AST exchange standards and to provide extended scope service where this is authorized.

(2) On longer tandem trunks, as a means of reducing over-all tandem standards or as a means of reducing existing tandem completing loss to a value suitable for toll completion via the tandem system where this method of operation is contemplated.

(3) On the longer toll connecting trunks to facilitate the transmission design.

(4) On tributary trunks, including two-way operator office trunks, where difficulty is encountered in meeting the design requirements due to the extensive use of cable in both the trunk and local office loop plant.

(5) On trunks to centralized intercept and information desks, particularly on the former where circumstances do not justify the use of the operator's telephone circuit with voice-controlled gain.

5.02 The El repeater may in special cases find application on interlocal trunks or on subscriber loops but these are not expected in any important quantity.

6. EFFECT ON TRANSMISSION DESIGN OF LOCAL PLANT

6.01 The El repeater becomes an important economical tool in future transmission design studies involving tandem and toll terminal losses.

6.02 In outlying offices and remote tributaries (including CDO's), where the loss in the toll connecting trunks is substantial, it has been necessary in the past to design the local office loops to large negative values in order to meet the toll terminal losses, since the use of 22-type repeaters to reduce these trunk losses generally has not been economically attractive.

6.03 Accelerated growth in the outlying and rural communities has multiplied the cable requirements by increases in both number and length of lines and the conversion of existing open wire loops to cable. With large negative loop losses, new construction will involve an unduly large investment per loop due to the use of coarse gauges to meet the design objective. This cost can be substantially reduced by the use of a more liberal loop loss, which can be obtained to the extent of 2 to 4 db by the use of El repeaters on the trunks. The economies of such a design can be determined from a comparison between the cost of the repeaters required and the differential copper savings in the loop plant. Assuming a differential copper annual cost of $2.75 per pair mile and a repeater annual cost of $40, a reduction in gauge, from 19 to 22, of only 15 pair miles in the loop plant will offset the cost of one El repeater in the trunk plant. An additional factor in such comparisons is that the installation of repeaters can be coordinated with requirements as they develop whereas cables are usually engineered for longer periods.

6.04 Another economic reaction resulting from liberalizing the loop design objective by using El repeaters on the trunks is a reduction in the number of local battery talking sets required. In offices with large negative loop design values this factor may be substantial, amounting to a saving of $3 to $5 a year per station from which the local battery set may be removed. Generally this reaction may be of secondary importance in view of the expected general replacement of these sets with the 500-type common battery set. However, situations may be encountered where because of existing plant conditions, the increased efficiency obtainable from the 500-type set is less than the transmission gain of the local battery set.

6.05 Future transmission studies at tributary offices should tend to larger loop losses not only because of availability of the El repeater but also in anticipation of the Nl carrier systems which may be applied as low loss trunks, and the 500-type set which produces its full efficiency only on the longer and higher resistance loops.

6.06 Where some of the traffic of an outlying office or a tributary is handled via a metropolitan tandem system, the loop loss cannot be extended without also considering this effect on the tandem terminal loss. Since generally transmission via tandem systems has negligible trunk margins, it will be necessary to effect an improvement in the tandem trunks equal to the amount by which it appears practical to extend the loop loss. If improvements in tandem standards are foreseen it will be important to consider the layout requirements necessary to obtain a total gain from the El repeater covering both the loop extension and the improvement in over-all tandem design. In many cases this total gain will exceed the maximum gain obtainable with a terminal repeater and consideration should be given to the selection of an intermediate location at which the desired ultimate gain may be obtained.

6.07 In special service line studies, account should, of course, be taken of the availability of the El repeater, and 500-type set, as well as the variable network set of the latter type, to be made available for special service lines. Both in such studies and in current engineering, consideration should be given to the V-type repeaters, as they will still have a field of use on these lines.