E7 REPEATER
APPLICATION TO MTWX CIRCUITS

CONTENTS PAGE

1. INTRODUCTION

1.01 This section discusses the factors involved in using E7 repeaters on MTWX circuits. It also presents information on the electrical characteristics and performance of E7 repeaters and E7-repeatered loops.

1.02 The E7 repeater is applicable only at the central-office end of a nonloaded cable pair. It cannot be used as an intermediate repeater in a nonloaded loop. This follows from the fact that the E7 converts the impedance of the loop, terminated at the station, to approximately that of 900 ohms in series with 2 μf, the desired value for all TWX loops. Any further nonloaded cable or excessive length of office wiring on the side opposite the station will alter this impedance to such an extent that transmission requirements are unattainable. This effect is covered in more detail in Part 2.

1.03 For the sake of simplicity and to keep costs reasonably low, the E7 repeater was designed to work with only 22-, 24-, and 26-gauge cable pairs and combinations of these gauges. It is not generally applicable to loops predominantly of coarser gauge, but trivial amounts of coarser gauge should not affect performance adversely. Where there is doubt about amounts of coarser gauge in the loop, early installation and tests must be made to find out whether requirements are met, before it is too late to change the layout.

1.04 As a result of the considerations mentioned in Par. 1.02 and 1.03, it may be found necessary to remove bridged taps, to load certain loops, or to use other facilities.

1.05 Where it is impracticable to make advance tests on doubtful layouts proposed for TWX use, artificial sections of cable can be helpful in making decisions. The artificial sections are laid out to simulate the proposed loop, as shown in the cable records, and tested just as the latter would be if it were available. This method naturally is conclusive only when the actual line facilities are as specified in the records. If artificial cables are used to simulate TWX loops for preliminary line-up of E7 repeaters, the repeater network settings so obtained must be considered as initial settings only. Optimizing of settings as described in Section 332-207-301 is still required since the records used to establish the artificial loop may not express the actual plant conditions. Also, the E7 repeater used on the actual loop will, in some cases, differ slightly from the one used in the preliminary line-up.

1.06 Three adjustments of the E7 repeater are made during installation.

(a) Transformer taps (two screws)

(b) Network capacitance (one or more screws)

(c) Network resistance (screwdriver-adjusted rheostat)

1.07 Only one of these adjustments, the transformer tap, can be determined before the E7 repeater is applied to a loop. The tap is primarily determined by the 900-ohm measured insertion loss (AML, actual measured loss) of the bare loop at 2300 cps, but also is in some cases dependent on the dc resistance of the loop. The other two adjustments are determined with the help of an auxiliary network adjusted to simu-

late the impedance of the terminated loop. This method is the only practicable one that has been found for the wide variety of loops encountered in the field. Tables are furnished in Section 332-207-301 giving the approximate settings of the E7 network capacitance and resistance.

1.08 Although, in a few cases, these network settings might meet minimum requirements, they must be optimized in order to meet the system objective for TWX. The requirements are shown in Table XII of Section 332-207-301. It should be borne in mind that the TWX system would not work if only minimum return loss and maximum insertion loss were attained for any considerable percentage of the repeatered loops. The line-up procedure has been devised to result in ranges of return losses and insertion losses that insure a workable system.

1.09 Two different line-up procedures are used for loops falling into two different ranges of insertion loss. The large majority of loops, those in the lower range of losses, are lined up by means of return-loss measurements and adjustments only. Other transmission measurements are not required. A small percentage of loops, those having the highest permissible losses, require insertion loss measurements in addition to the return loss measurements. In some of these cases, further adjustments of the E7 network are then required in order to meet both the return-loss and insertion-loss objectives. All measurements and adjustments are made at the central office. This technique requires the test gear listed in Section 332-207-301, E7 Repeater Line-Up.

1.10 After the repeater has been lined up in accordance with Section 332-207-301, the loop will be stable (will not sing) in service and when idle.

1.11 The E7 repeater will not work satisfactorily on a loop whose 900-ohm insertion loss at 2300 cps is less than 4 db or more than 17 db. Also, if one or more loading coils have been left on the loop by mistake, it will be impossible to line up the repeater properly, and loading coils on any of the bridged taps will prevent satisfactory line-up.

1.12 Since disablers are not used with E7 repeaters, it is best to locate the repeaters on shelves not equipped with disablers. If all available shelves are equipped with disablers, however, E7's may be installed on such shelves but the associated disablers should be modified in order to avoid signaling penalty. This penalty is imposed by the 120-ohm dc resistance of the disabler relay windings. The modification consists, in part, of shorting out these windings with temporary straps that can later be removed, if necessary. The other part of the modification requires a temporary strap across the relay contacts to feed power to the E7 continuously. This modification is described on the SD drawing.

1.13 The E7 is monitored by plugging in a high-impedance receiver at the front pin-jacks. These jacks are connected across a "dry" winding of the line transformer to keep direct current out of the receiver. Only the KS-14418 high-impedance receiver equipped with a 419A plug (same as for E6 repeater) should be used.

1.14 Testing of E7 repeaters is done in 51B test stands. Test jacks are optional in shop-wired repeater mounting bays, but are not used with E7 repeaters. Where test jacks have been installed, 1-type or 2-type signal plugs should be placed in the jacks to avoid inadvertent bypassing of the repeater.

2. APPLICATION PRINCIPLES

2.01 In general, the E7 repeater is used on nonloaded TWX or DATA-PHONE loops that would otherwise have too much loss to meet transmission requirements. There are limits, however, to the characteristics of loops that the E7 can bring within requirements, as follows:

(a) Loops must be 22-, 24-, or 26-gauge nonloaded pairs or a combination of these gauges.

(b) Loop resistance, excluding bridged taps, must not be more than 1200 ohms at 68° F.

(c) Loop length, excluding bridged taps, must not be more than 18 kilofeet.

(d) No bridged tap may exist within 600 feet of the central office.

(e) Total length of all bridged taps may not be more than 6 kilofeet.

(f) Where a dial long line circuit is located in the same central office as the E7 repeater, the loop resistance must be at least 500 ohms, part of which may be building-out resistance equally divided between the tip and ring sides of the pair.

2.02 The line-up procedure to be used for a given loop depends upon the 1000-cps insertion loss of the bare loop and upon the total length of bridged taps. Procedure No. 1 makes use of return-loss measurements and adjustments. Procedure No. 2 is more elaborate, making use of both insertion loss and return loss. Table I indicates the field of use of the two procedures. Procedure 1 does not include measurements of repeatered insertion losses, because the latter are closely predictable. If the procedure is followed correctly, both the 1-kc and the 2.3-kc insertion loss of the repeatered loop will be within ± 1 db of the nonrepeatered insertion loss at 1 kc.

TABLE I

FIELDS OF USE OF LINE-UP PROCEDURES 1 AND 2

TOTAL LENGTH OF BRIDGED TAPS	900-OHM INSERTION LOSS OF BARE LOOP INCLUDING BRIDGED TAPS	
	Line-Up 1	Line-Up 2
0–3000 ft.	1.5–5 db	5–7 db
3001–6000 ft.	1.9–7 db	7–8 db

2.03 The impedance of the loop as compared to the office impedance of 900 ohms in series with 2 μf is considerably improved by the E7 repeater at both 1000 and 2300 cps. In Procedure 2, the amount of improvement obtained depends, to a great extent, on the care with which the adjustments of the repeater network are made. As pointed out in the line-up procedure, trimming of the network from the initial settings should be done to obtain better than minimum results.

2.04 Supervision, up to a maximum loop current of 150 milliamperes, and 20-cycle ringing are passed through the E7 repeater without the need for auxiliary bypass equipment.

2.05 For pulsing and supervision, the E7 repeater adds to the loop the resistance of its primary and secondary windings, as shown in Table II.

TABLE II

	TOTAL
Primary — 14 ohms	
Secondary, Taps 1-1	18 ohms / 32 ohms
" " 2-2	24 " / 38 "
" " 3-3	35 " / 49 "
" " 4-4	44 " / 58 "

2.06 For 20-cycle ringing, including frequencies between 16 and 22 cps, the basic ringing range is reduced by 200 ohms. The basic ringing range is proportional to the signaling voltage; for 84-volt ringing systems, it is about 3000 ohms. For ringing systems using frequencies below 16 cps or above 22 cps, tests must be made to determine suitability.

2.07 In standard cable plant installed during the past 40 years, cross-induction between TWX circuits, and between TWX and message circuits, should be so slight as to cause no interference. In plant that contains nonstaggered-twist cable or nonstandard cable, however, certain precautions should be taken in order to avoid possible interference. These precautions all apply to nonloaded cable; loaded nonstaggered-twist cable should never be assigned to TWX loops.

2.08 Tables III, IV and V show the suggested limits for the length of nonstaggered-twist (NST) cable to be used in three types of DATA-PHONE and TWX loops. Where the length of NST cable does not exceed the limit, no action is needed. Where it does exceed the limit, the following steps may be considered:

(1) Reroute the loop, avoiding NST cable.

(2) Replace enough NST cable to meet the limits.

TABLE III

DIAL TWX LOCAL LOOPS (NON-RX CIRCUITS)

NET LOOP LOSS* AT 2.3 KC (db)	TOTAL LOSS (db)	DESEN. PAD (db)	SPACE-HOLD CUTOFF (dbm)	DISTURBER F2 TRANSMIT (dbm)	MIN. COUPLING LOSS (db)	MAX. LENGTH NST ADJ. TO STATION INCLUDING BRIDGED TAPS
0–2		8	–50	–8	42	All
2.1–3		4	–54	–8	46	All
3.1–5		4	–54	–6	48	All
5.1–6		4	–54	–4	50	All
6.1–7		0	–58	–4	54	6000′ } See Note,
7.1–9		0	–58	–2	56	1500′ } Fig. 1
9.1–14		0	–58	0	58	500′ }

TABLE IV

METROPOLITAN AREA REMOTE EXCHANGE CIRCUITS WITHOUT DALC (ASSUMED INTEROFFICE FACILITY LOSS EQUALS 4 DB AT 2300 CPS)

0–1	4–5	4	–54	–6	48	All
1.1–2	5.1–6	4	–54	–4	50	All
2.1–3	6.1–7	0	–58	–4	54	6000′ } See Note,
3.1–5	7.1–9	0	–58	–2	56	1500′ } Fig. 1
5.1–10	9.1–14	0	–58	0	58	500′ }

TABLE V

INTERCITY RX CIRCUITS USING DALC (ASSUMED INTEROFFICE FACILITY LOSS EQUALS 3 DB AT 2300 CPS)

0–3	3–6	4	–54	–8	46	All
3.1–5	6.1–8	0	–58	–6	52	All
5.1–7	8.1–10	0	–58	–4	54	6000′ } See Note,
7.1–9	10.1–12	0	–58	–2	56	1500′ } Fig. 1
9.1–11	12.1–14	0	–58	0	58	500′ }

* Includes E7 Repeater, if one is used, but not office losses on office side of repeater.

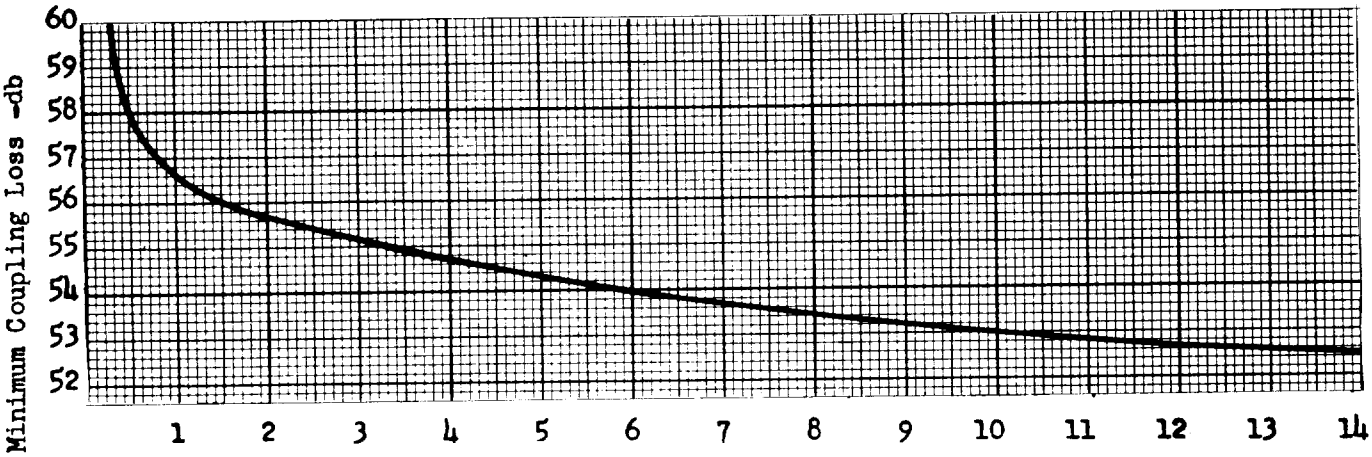


Fig. 1 – Length of NST Cable Adjacent to Station — Kilofeet

Note: If there is staggered-twist (ST) cable between the NST cable and the station, decrease the minimum coupling loss by twice the 2.3 kc loss in that ST cable, and enter Fig. 1 at the resultant coupling loss. The curve will indicate the permissible length of NST cable.

2.09 Table VI shows the minimum one-way loss of ST cable required adjacent to the station in order to permit the remainder of a long loop to be NST. It also shows the lengths of several types of nonloaded cable that approximate that loss at 2.3 kc.

TABLE VI

MIN. CPLG. LOSS REQUIRED AT STATION (db)	MIN. 1-WAY LOSS OF ST CABLE REQUIRED ADJ. TO STATION (db)	CORRESPONDING LENGTH OF NONLOADED CABLE (kft.) 19LC	19HC	22	24	26
54	1	3.3	3.0	2.0	1.5	1.25
56	2	6.7	6.0	4.0	3.0	2.50
58	3	10.0	9.0	6.0	4.5	3.75

2.10 The E7 repeater's ability to handle single-frequency power decreases as frequency increases. Its power-handling ability is least when the cable pair is connected to Tap 4 on the transformer. Table VII shows the input levels that may not be exceeded without likelihood of serious overloading when Tap 4 is used.

TABLE VII

FREQUENCY — cps	INPUT LEVEL — dbm
1000–1300	+8.0
2000–2300	+2.0
3000	−3.0

These input levels are not restrictive for TWX transmission, but impose restrictions on testing levels at frequencies above 2500 cps. At these levels, the compression (a decrease in gain as a result of high levels) is about 0.5 db.

3. DESIGN PROCEDURES

3.01 Sketch the proposed layout on the circuit layout card, showing all bridged taps.

3.02 Calculate the dc resistance of the loop from the repeater location to the customer's premises, using the appropriate unit resistance values from Table VIII.

TABLE VIII

OHMS PER KILOFOOT AT 68° F

19 ga.*	16.1
22 ga.	32.5
24 ga.	51.9
26 ga.	83.3
OFFICE CABLE	32.5

* Only trivial amounts may be used on repeatered loop.

3.03 When a Dial Long Line Circuit, SD-96234, is to be used on an E7-repeatered loop at the same point as the E7 repeater, it must be modified to improve return loss. The modification consists of substituting 120-type repeating coils for 94-type. In order to avoid signaling difficulties with 120-type coils, the loop resistance must be at least 500 ohms. If the cable pairs themselves have less than 500 ohms resistance, balanced building-out resistors should be placed in series with the tip and ring wires of the loop at Terminals 8 and 16 of the repeater socket. The tip and ring resistors should not differ by more than 3 ohms. Power ratings of 2 watts per resistor are recommended. Total resistance of cable conductors plus building-out resistors should lie between 500 and 600 ohms.

3.04 Observe the location of bridged taps. If bridged taps of total length greater than 100 feet exist within 600 feet of the central office, they must be reduced to a total of 100 feet or less before the E7 may be applied to the loop.

3.05 If the total length of all bridged taps is more than 6000 feet, enough bridged tap must be removed to bring the total under 6000 feet. For better results and for economy, give preference to removing the longer taps.

3.06 Calculate the 1000 and 2300 cps loss of the bare loop from the repeater shelf to the station, using the following information:

TABLE IX

ATTENUATION IN DB PER KILOFOOT (Nonloaded)

	1000 cps	2300 cps
19 CNB	.24	.35
22 CSA	.34	.51
24 DSM	.44	.66
26 BST	.54	.81
OFFICE CABLE	.40	.70

The bridged tap loss may be taken as 0.22 and 0.56 db per kilofoot for 1000 and 2300 cps, respectively, for all gauges. If the loss of the loop plus bridged taps at 2300 cps is less than 5 db, no repeater is required for TWX service. If the loss lies between 5 db and 14 db, an E7 repeater may be required. If the loss is greater than 14 db, the loop is not suitable for TWX service.

Example

3.07 Consider the following loop:

TABLE X

RESISTANCE

LOOP LENGTH IN KILOFEET		OHMS PER KILOFOOT	RESISTANCE — OHMS
.220	19 ga.	x 16.1 =	3.6
3.392	22 ga.	x 32.5 =	110.0
9.030	24 ga.	x 51.9 =	465.0
2.770	26 ga.	x 83.3 =	230.4
Total 15.412			Total 809.0
OFFICE CABLE .2 kft.	22 ga.	x 32.5 =	6.5
REPEATER RESISTANCE FOR TRANSFORMER TAP 3			49.0
		Total =	864.5

This total is less than the 1200 ohms permitted, and is therefore satisfactory.

TABLE XI

LOSS

LOOP LENGTH IN KILOFEET		ATTENUATION 1000 CPS db/kft	1000 CPS LOSS — db	2300 CPS db/kft	2300 CPS LOSS — db
.220	19 ga. x	.24 =	.05	x .35 =	.08
3.392	22 ga. x	.34 =	1.15	x .51 =	1.73
9.030	24 ga. x	.44 =	4.00	x .66 =	6.00
2.770	26 ga. x	.54 =	1.50	x .81 =	2.24
OFFICE CABLE .2 kft.	x	.4 =	.08	x .7 =	.14
BRIDGED TAP 6.47 kft.	x	.22 =	1.40	x .56 =	3.60
COMPUTED TOTAL (68° F)			8.18		13.79
CORRECTION			−1.00		− 1.00
* EXPECTED MEASURED LOSS (EML)			7.2 Approx.		12.8 Approx.
ACTUAL MEASURED LOSS (AML)			7.3		13.0

Since the bridged taps amount to more than 6000 feet, some must be removed before the E7 repeater is lined up.

* Since the "Computed Total" is in terms of attenuation, but the EML and AML are insertion losses, an average correction of −1 db is applied.

3.08 Because of possible discrepancies between records and actual plant, verification tests described in Section 332-207-301 are always made on the bare loop. It is required that the measured values be within ±1 db of the computed values.

3.09 Record the EML's at 1000 and 2300 cps and the total resistance on the circuit layout card to be furnished to the central office people who will place the loop in service.

4. PERFORMANCE

4.01 The performance of an E7 repeater varies with the loop layout. In general, the lower-loss circuits tend to give better insertion-loss and return-loss performance. Circuits near the limiting loss, hence requiring Tap 4 on the transformer, can often just be brought within the performance limits.

4.02 If the power supply to the repeater is interrupted, net-loss and return-loss performance are poorer than they would be without a repeater. A "dead" repeater inserts a loss ranging from 2 to 8 db, depending upon the transformer tap used.

4.03 Charts 1 to 8 show insertion losses and return losses, both with and without repeaters, for four different E7 repeatered loops. Charts 1 and 2 apply to the first loop, Charts 3 and 4 to the second, etc, the odd-numbered charts showing insertion loss and the even-numbered charts the return loss.

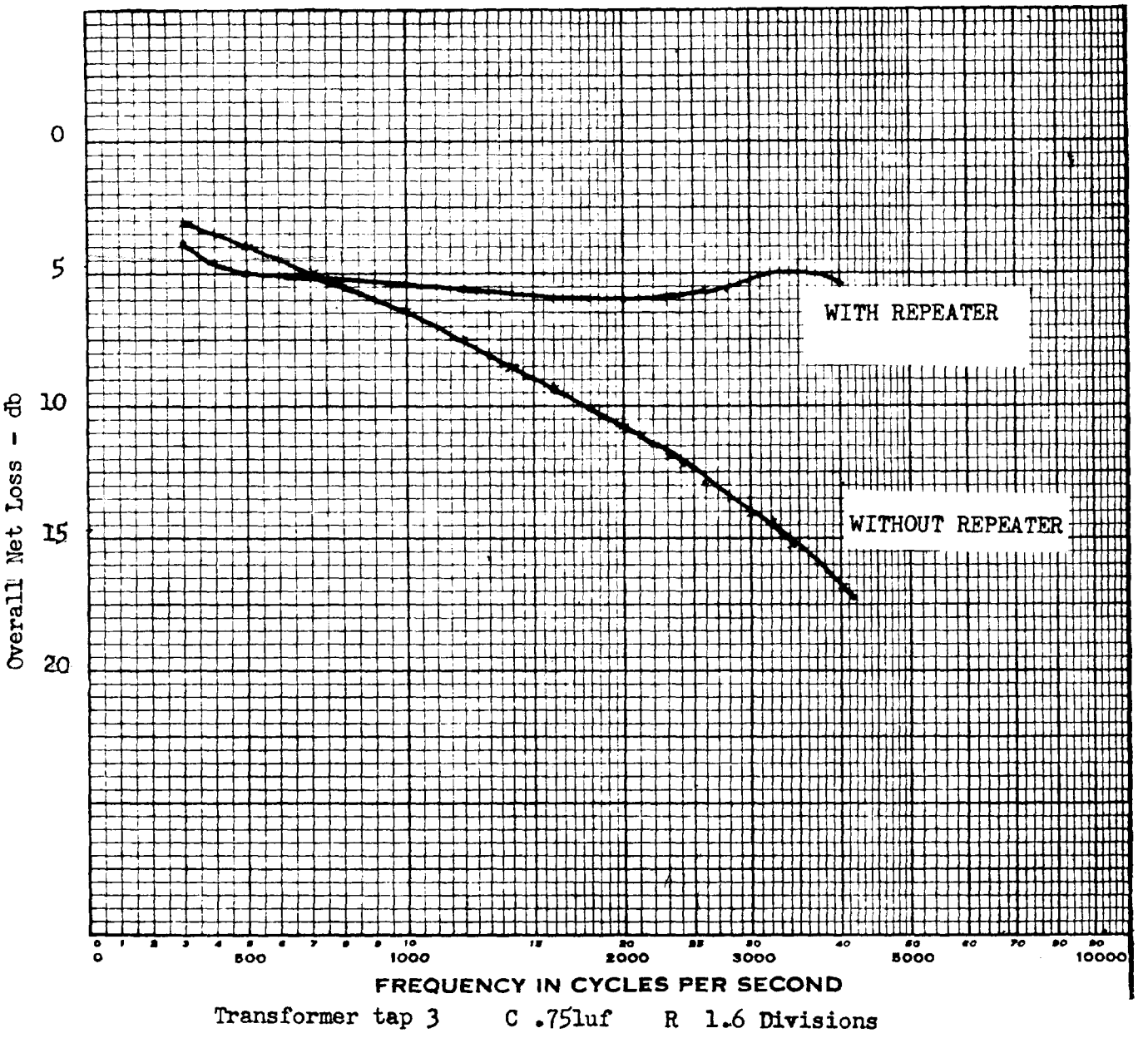
4.04 Chart 3 also illustrates the improvement obtained by reducing or removing bridged taps, while Chart 4 shows the ill effect of adding 500 feet of office wiring on the office side of the

E7 repeater, as well as the change produced by reducing bridged taps.

4.05 In Charts 5 and 6, note the increase in the insertion loss and the decrease in return loss when the power supply is disconnected.

4.06 Charts 7 and 8 show the performance of an E7 repeater on a mixed-gauge loop containing four bridged taps. The dashed lines represent the performance with a 5800-foot bridged tap completely removed.

4.07 Where loops were altered to illustrate certain effects, the repeaters were realigned for the second set of measurements. All alignments were made from the office side of the E7 repeater before any office cabling was connected; adjustment of the repeater cannot compensate for the effects of cabling on that side.



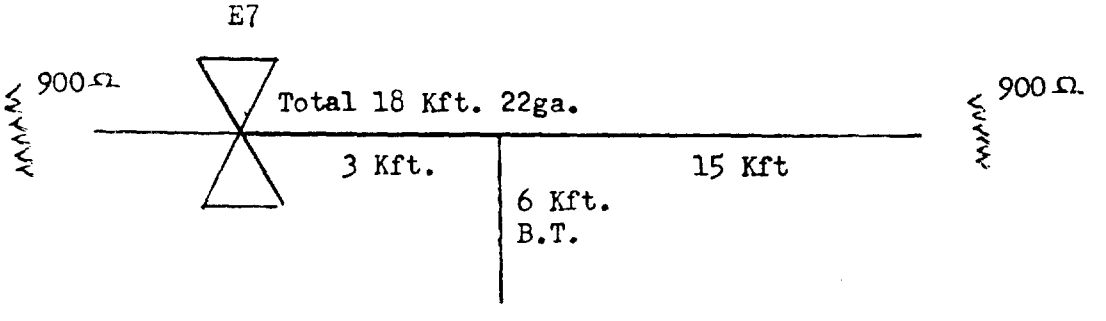


Chart 1 – Insertion Loss of E7 Repeatered Loop 22-Gauge Cable Pair With Bridged Tap

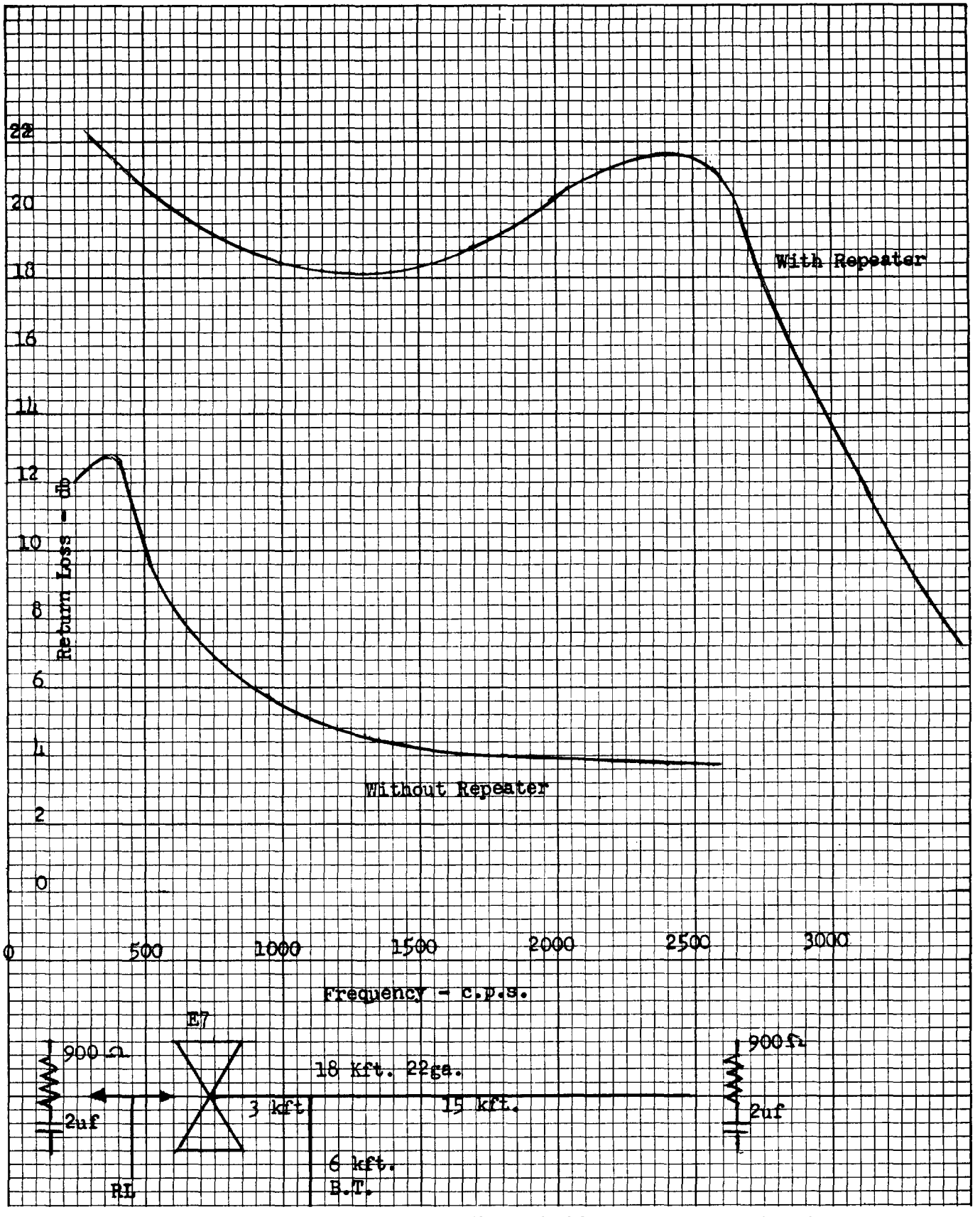
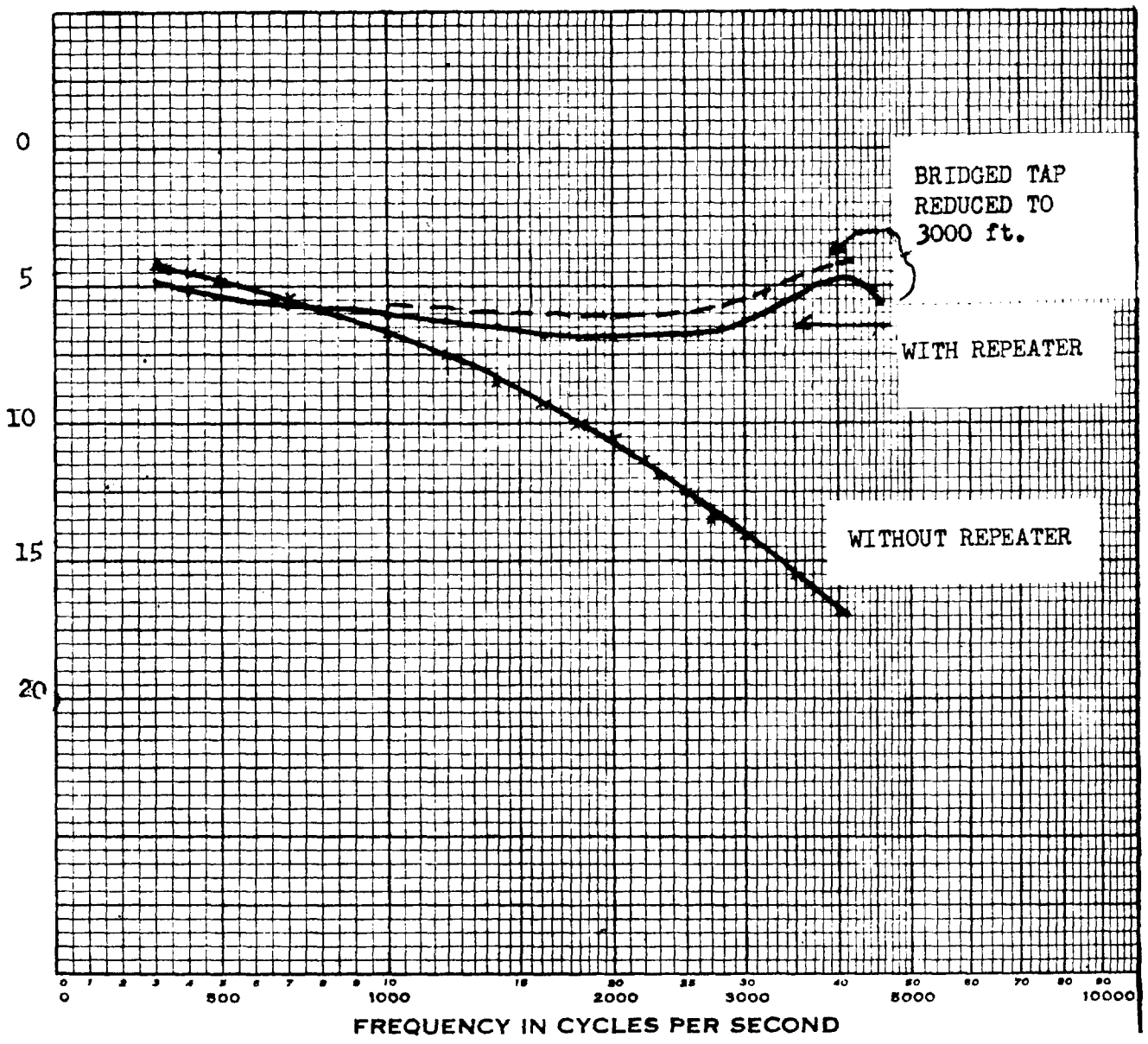


Chart 2 – Return Loss at Central Office End of Repeatered Loop With and Without E7 Repeater on 22 ga.



B.T.

6 kft	Transformer tap	3	C	.558 uf	R	1.8 Divisions
3 kft	Transformer tap	3	C	.456 uf	R	2.2 Divisions

E7

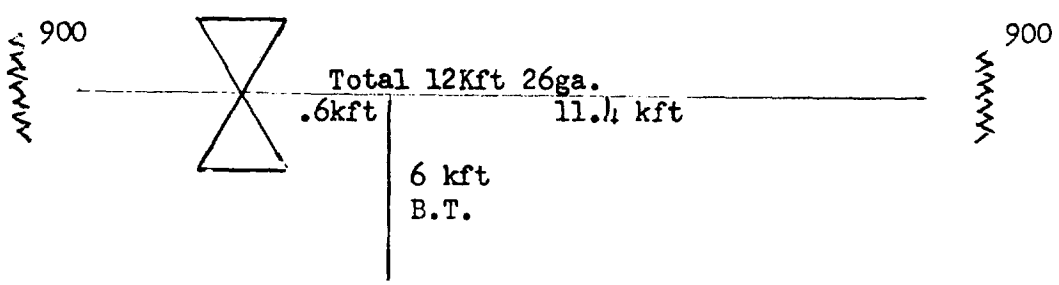


Chart 3 – *Transmission Performance of E7 Repeater on 24-Gauge Loop With Bridged Tap*

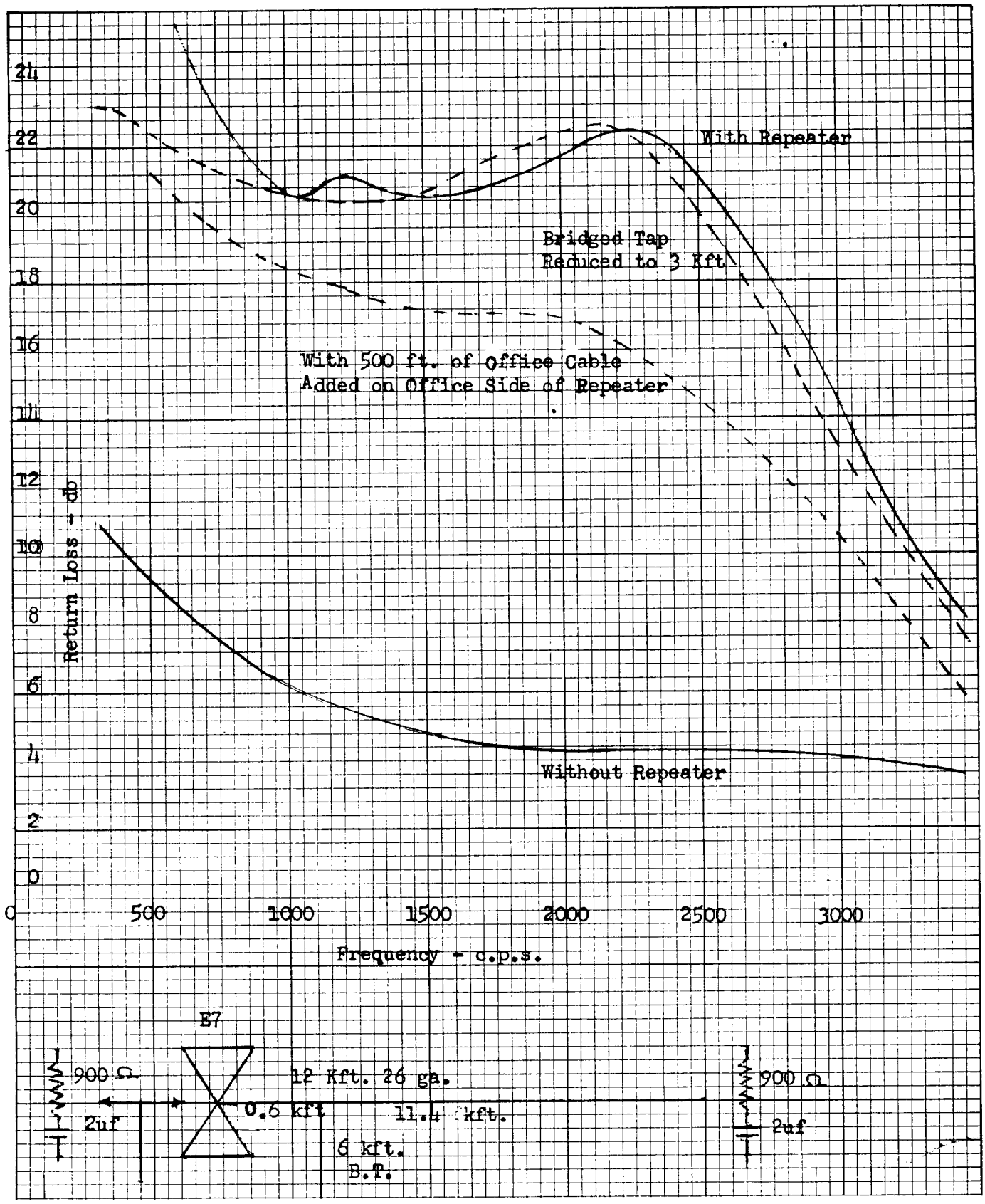
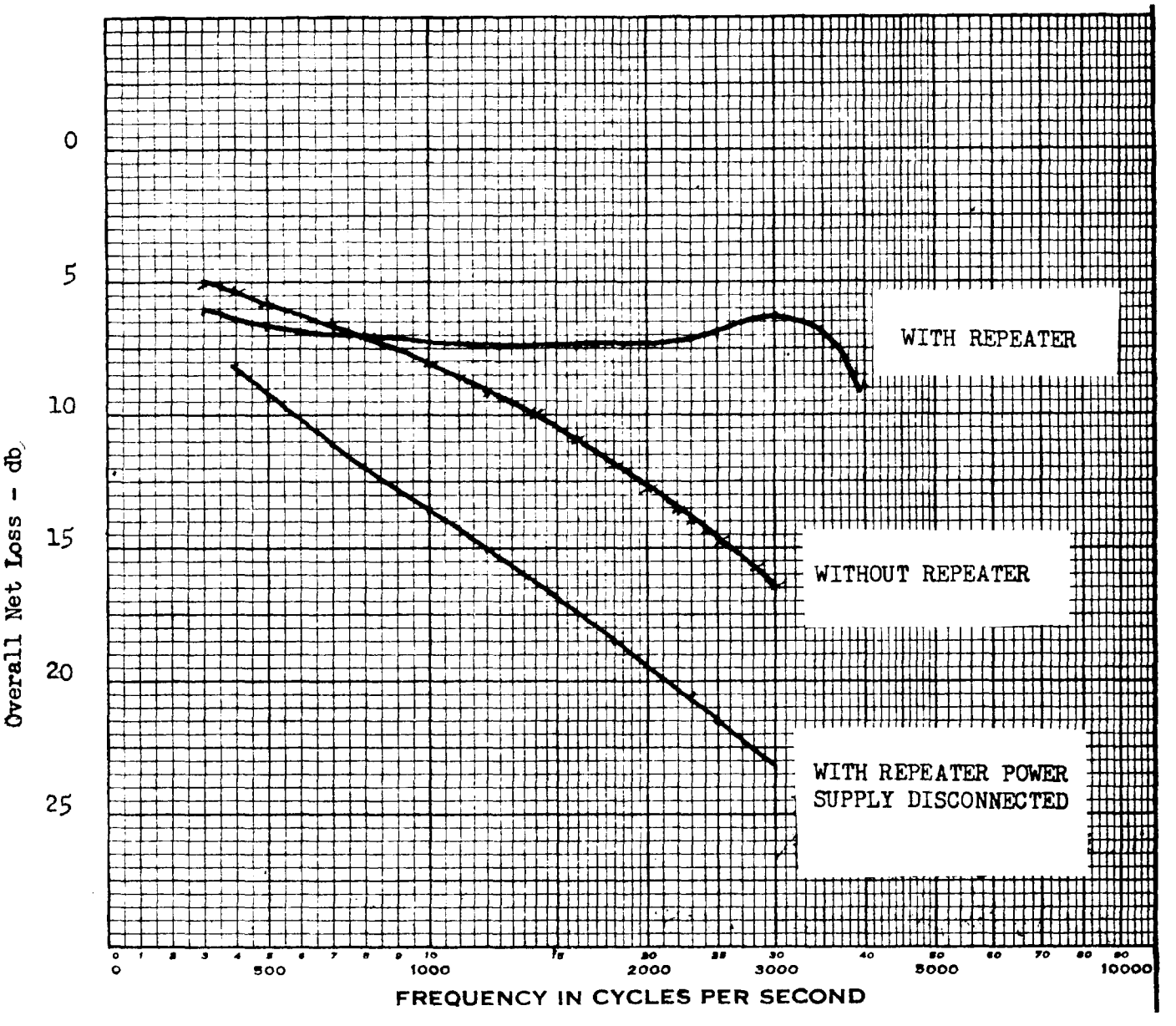


Chart 4 – Return Loss at Central Office End of Repeatered Loop With and Without E7 Repeater on 26 ga.



Transformer tap 4 C 1.04 uf R 2.0 Divisions

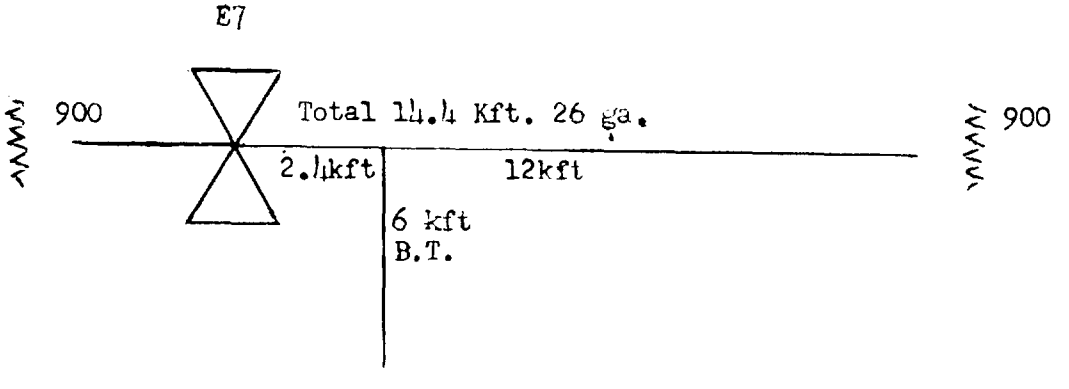


Chart 5 – Transmission Performance of E7 Repeater on 26-Gauge Loop With Bridged Tap

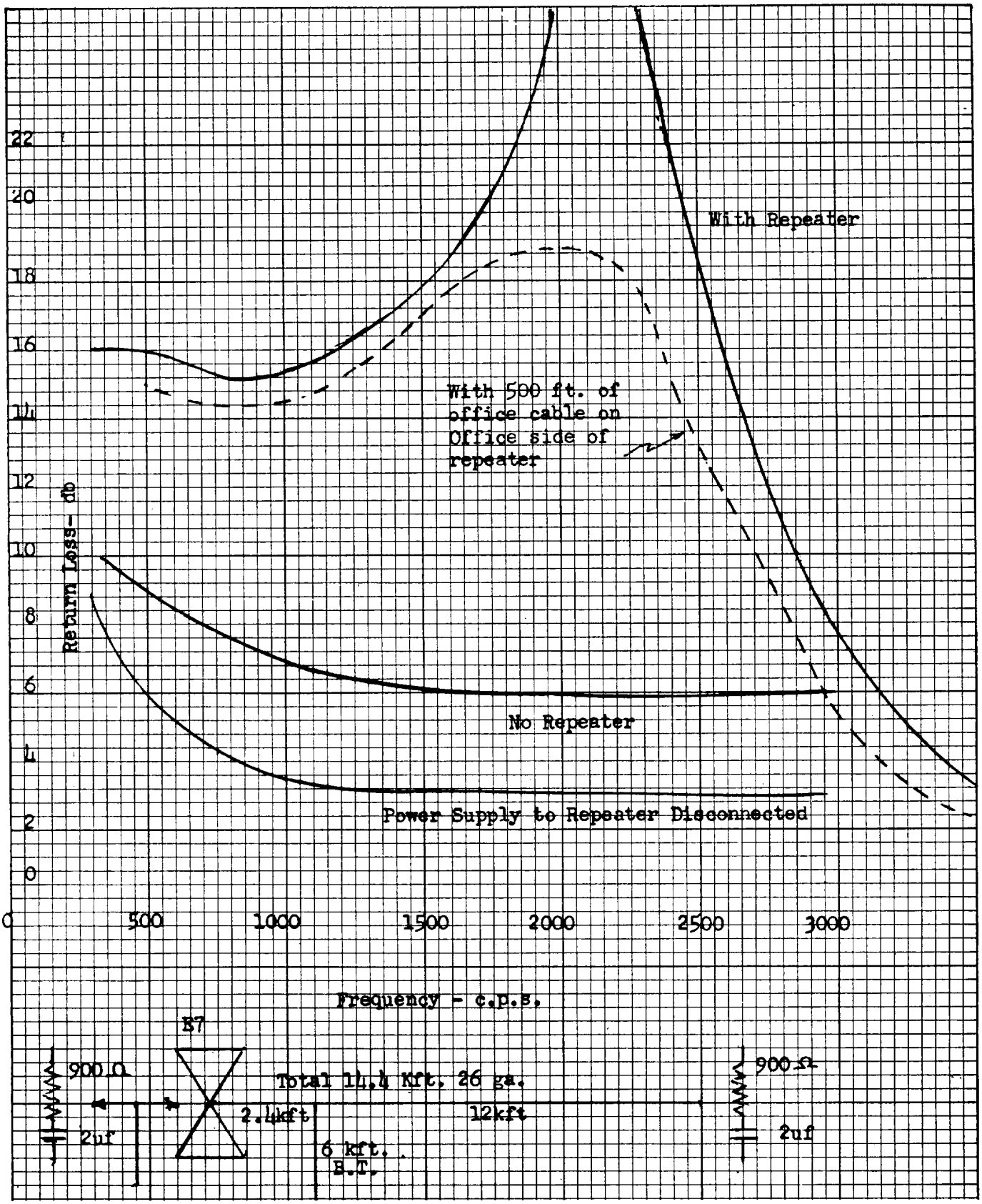
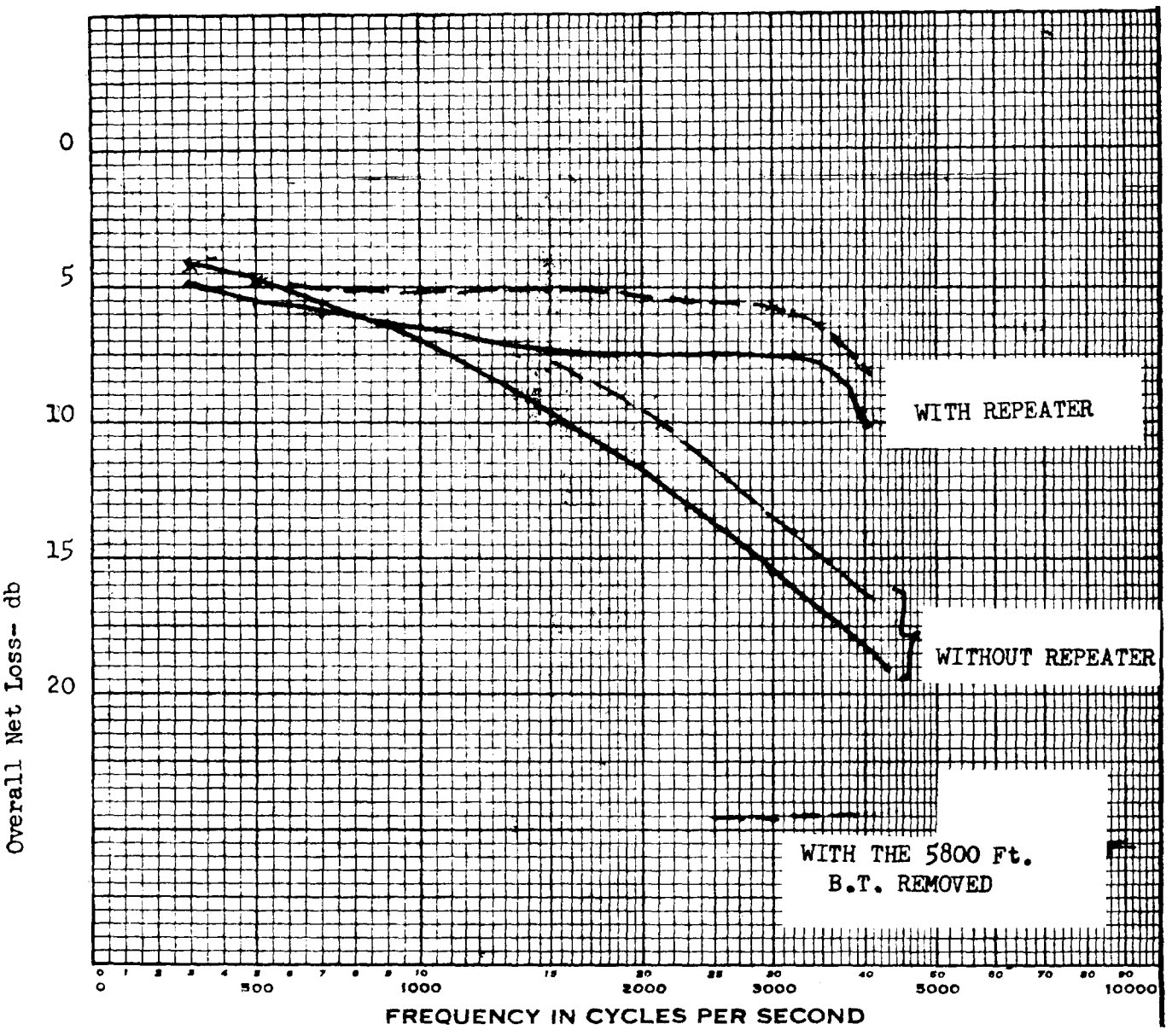


Chart 6 – Return Loss at Central Office End of Repeatered Loop With and Without E7 Repeater on 26 ga. With 6 kft. Bridged Tap



Transformer tap 3 C .62 uf R 3.2 Divisions

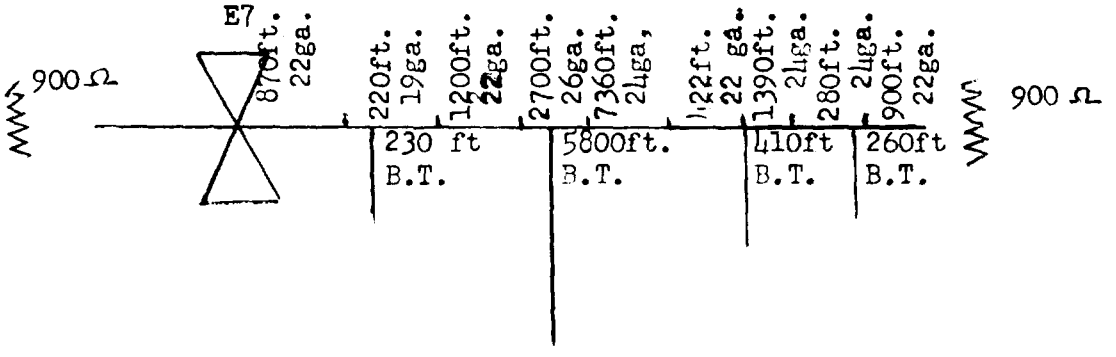


Chart 7 – Transmission Performance of E7 Repeater on Loop Made up of Mixed Gauges

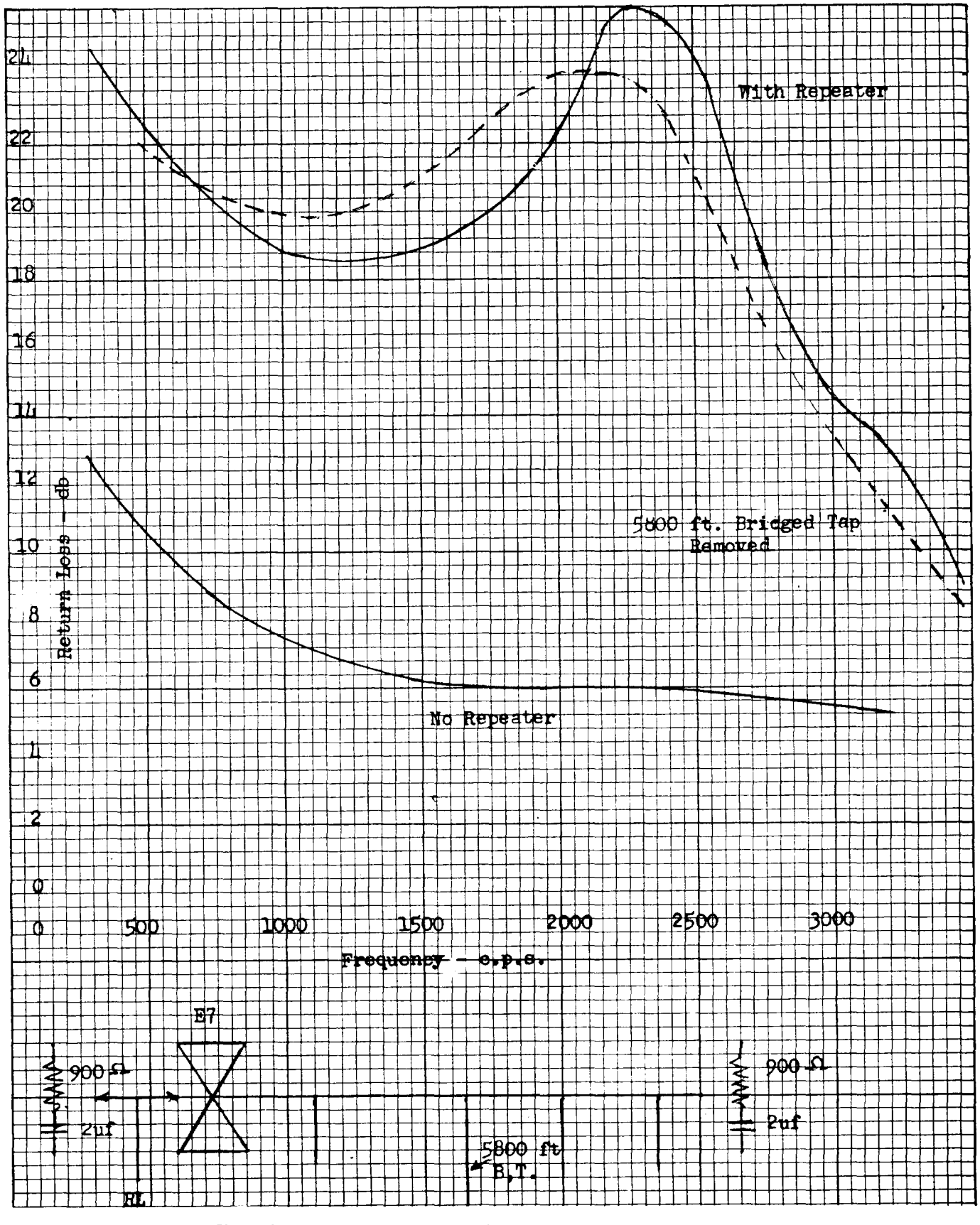


Chart 8 – Return Loss at Central Office End of Repeatered Loop