Rural Electrification Administration
Telephone Engineering and Construction Manual

Section 462
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R1 AND R2 TRANSPOSITION SYSTEMS

1. GENERAL

1.01 This section is intended to provide REA borrowers, consulting engineers, and other interested parties with technical information for use in the design and construction of REA-financed systems. It discusses in particular the R1 and R2 transposition systems and supersedes present REA-TE & CM-661 in its entirety. Section 661 is to be removed from the files and destroyed.

1.02 The R1 system is normally used where average span lengths are 300 feet or over and the R2 where under 300 feet, except for windy or salt spray areas as discussed below.

2. FEATURES COMMON TO THE R1 AND R2 SYSTEMS

2.01 Both these systems have been found to be effective in control of voice frequency crosstalk and metallic noise induction. Although it is anticipated that open wire leads will seldom carry more than ten circuits, these transposition systems are applicable up to twenty circuits and the drawings attached hereto are made up accordingly.

2.02 A circuit on brackets or two-pin crossarm should be transposed as pairs 3-4, 5-6 or 7-8 depending on the pin position which the circuit will occupy if crossarms are subsequently placed on the line.

2.03 Circuits on a six pin crossarm should be handled as 3-4, 5-6, and 7-8.

2.04 Any circuit can be bridged or terminated at any point on the line without regard to neutral points.

an average pole spacing not greater than 370 ft. To get the top frequency for other pole spacings, multiply 220 kc by 370/L where L is the average pole spacing. For example, if L is 400 feet the top frequency is 220 kc X $\frac{370}{400}$ or about 200 kc.

2.03 The successful application of carrier systems to various R1 transposed pairs not only depends upon the crosstalk losses between pairs, but also, upon the co-channel crosstalk advantages of the carrier equipment used. This advantage is obtained from a device known as a compandor or is inherent by using certain angular modulation techniques. Measured crosstalk advantages among types of systems are:

Type of System	Approximate Crosstalk Advantage
± 3 kc Angular Modulated Carrier, FM	6-8 db
± 5 kc " " "	18 db
Compandored Carrier	22 db

2.031 For non-compandored AM or for narrow-swing 3 KC FM carrier the minimum crosstalk loss between pairs should be at least 50 db.

2.032 For compandored AM or for wide-swing 5 KC FM carrier, the minimum crosstalk loss should be at least 35 db.

2.04 Considering crosstalk losses, it is readily seen from Table I that if more than one carrier system is to be transmitted over the R1 the low crosstalk losses above 150 kc establish a limitation on the frequency range of the second system.

2.05 As can be seen from Table I, pair combinations are available for non-compandored or narrow-swing FM carrier with 50 db crosstalk losses up to 100 kc. This then means that a second non-compandored carrier system or narrow-swing FM on the R1 is limited to 100 kc. It is further evident that a third carrier system with frequencies up to 50 kc is possible with the R1.

2.06 For compandored or wide-swing FM carrier with a 35 db far end crosstalk limit, various pairs are available for various carrier systems.

2.07 It must be remembered that the crosstalk losses given in Table I are equal level far end crosstalk losses. Any difference in levels among carrier systems will decrease the crosstalk figure by the amount of the level differences. Many complaints of carrier crosstalk are the result of lack of level coordination.

TE & CM Section 901, "Fundamentals of Carrier Telephone" Paragraph 15 and TE & CM Section 463, REA-1 Transposition System contain more information on the importance of level coordination.

2.08 Near end crosstalk losses are not given since they are not normally controlling in carrier applications. In a properly assigned carrier layout, all identical channels transmit and receive in the same direction. TE & CM Section 463 discusses Frequency Coordination which reduces the effect of near end crosstalk losses.

2.09 Other factors affecting crosstalk in using the data herein:

2.091 If the deviation in span lengths exceed the sum of $U^2 = 9L$, the crosstalk losses would be decreased. TE & CM Section 463 explains the concept of deviation measure for span lengths.

2.092 If the average pole spacing is shorter than 370 ft. the crosstalk losses would be improved and frequency headings on Table I can be multiplied by the ratio of 370 ft. to the average shorter span and the crosstalk losses thus increased. Conversely, if the pole spacing is greater than 370 the frequency heading of Table I can be multiplied by the ratio of 370 ft. to the average longer span and the crosstalk losses decreased.

2.093 If the length of the line is much greater than 11 miles, the length of the line measured, the crosstalk losses should be reduced by $10 \log_{10} \frac{L}{11}$ where L is the length of the line in miles. For example, if L is 22 miles the crosstalk losses should be reduced by 3 db.

$$10 \log_{10} \frac{22}{11} = 3 \text{ db}$$

2.10 Data involving the pole pairs is not included since carrier should not be transmitted on this pair. The data herein applies only to the top crossarm of a pole line.

3. Conclusions from Data

3.01 The R1 is good for one system of carrier up to 220 kc from an absorption loss standpoint.

3.02 More systems may be added on other pair combinations as permitted by the crosstalk losses of Table I. It is significant to note that within the limit of 35 db for compandored carrier that the R1 is good on two-pair combinations up to 156 kc. This would allow two systems of AM single sideband compandored carrier which provides up to 16 channels per system.

4. Recommendations

4.01 On new plant to be constructed where carrier is to be used or could be used at a later date, the preferable transposition system is the REA-1 as presented in TE & CM-463. Table II clearly demonstrates the crosstalk advantage of the REA-1 over the R1. Also Curve I clearly shows the absence of absorption losses with the REA-1 up to frequencies of 350 kc and shows how much better the REA-1 is over the R1.

4.02 Where the R1 is existing on a pole line to which carrier is to be added, the limitations set forth herein may be used.

4.03 Where the existing line under consideration deviates very far from the line on which this data was derived, measurements at carrier frequencies are required. If only one carrier system is to be applied, the measurements may be limited to insertion loss measurements as described in TE & CM-407. If more than one carrier system is to be applied crosstalk measurements should be made. Usually both measurements are made on an existing line and the carrier capabilities of the line are thereafter known.

TABLE I

Minimum Equal Level Far End Crosstalk Losses in DB. Line Length 10.9 Miles, R1 Transposed, 370 Ft. Spans, .080-30 Copper-Covered Steel.

Pair Combi-nations	0-50 KC Far End	50-100 KC Far End	100-150 KC Far End	150-200 KC Far End	200-250 KC Far End	250-300 KC Far End	300-350 KC Far End
1-2 to 3-4	56	45	41	36	28	16	6
1-2 to 7-8	62	52	44	36	27	9	10
1-2 to 9-10	43	36	32	27	21	11	16
3-4 to 7-8	52	42	30	32	21	6	1
3-4 to 9-10	68	56	43	39	30	18	15
7-8 to 9-10	68	51	43	35	29	8	4

Notes:

1. If a line is appreciably greater than 11 miles the crosstalk loss should be reduced by $10 \log_{10} \frac{L}{11}$ where L is the length of the line in miles. For example, if L is 22 miles the crosstalk loss should be reduced by 3 db.

$$10 \log \frac{22}{11} = 3 \text{ db}$$

2. For span lengths shorter than 370 ft. the frequency heading is multiplied by the ratio of 370 ft./average shorter span and the crosstalk losses thus increased.

   For span lengths greater than 370 ft., the frequency heading is multiplied by the ratio of 370 ft./average shorter span and the crosstalk losses thus decreased.

TABLE II

Comparison of Far End Crosstalk Losses Between the R1 and REA-1 Systems.

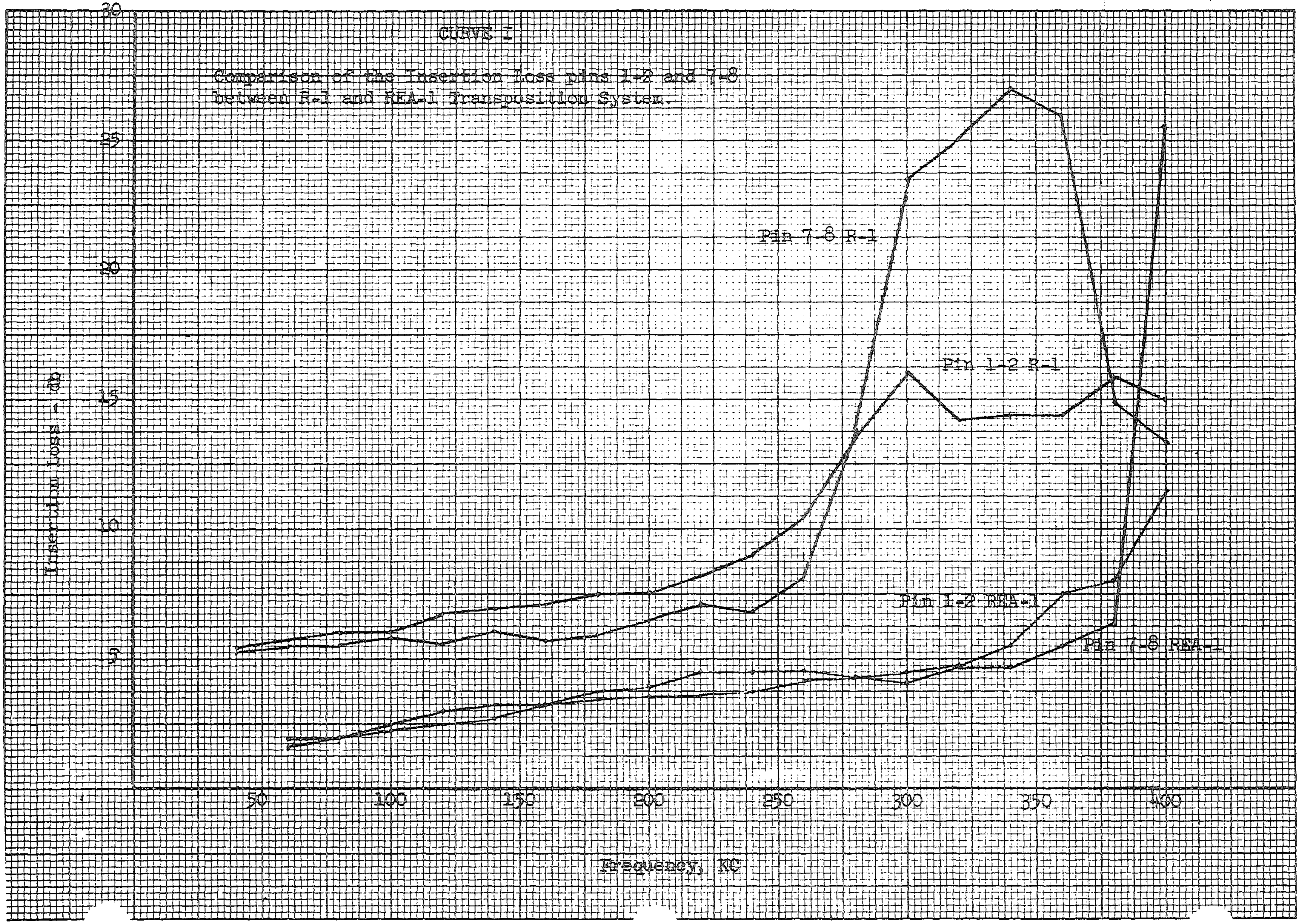
Transposition System	Pair Combination	0 KC to 50 KC	50 KC to 100 KC	100 KC to 150 KC	150 KC to 200 KC	200 KC to 250 KC	250 KC to 300 KC	300 KC to 350 KC
REA-1	1-2 to 3-4	75	68	57	52	52	34	30
R-1		56	45	41	36	28	16	6
Advantage		19	23	16	16	24	18	24
REA-1	1-2 to 7-8	71	70	65	58	58	50	41
R-1		62	52	44	36	27	9	10
Advantage		9	18	21	22	31	41	31
REA-1	1-2 to 9-10	80	67	60	53	51	43	37
R-1		43	36	32	27	21	10	3
Advantage		37	31	28	26	30	33	34
REA-1	3-4 to 7-8	63	56	52	46	46	45	39
R-1		52	42	30	32	21	6	1
Advantage		11	14	22	14	25	39	38
REA-1	3-4 to 9-10	71	70	58	54	52	45	38
R-1		68	56	43	39	30	18	15
Advantage		3	14	15	15	22	27	23
REA-1	7-8 to 9-10	73	58	52	53	53	41	37
R-1		68	51	43	35	29	8	4
Advantage		5	7	9	18	24	33	33

Transposition System	Length Miles	Transposition Interval	Sum U^2
REA-1	9.2	306 ft.	5.72
R-1	10.9	370 ft.	9.02

TABLE III

MEASURED INSERTION LOSS IN DB BETWEEN 600 RESISTORS,
DRY WEATHER, R-1 TRANSPOSITION SYSTEM.
10.9 Miles .080-30 Copper Covered Steel, 75°F.

Frequency KC	1-2	3-4	7-8	9-10	Calculated Attenuation Loss
40	5.4	5.1	5.2	5.3	4.9
60	5.7	5.7	5.4	5.3	5.0
80	6.0	5.8	5.5	5.8	5.1
100	6.1	5.3	5.8	5.8	5.2
120	6.8	5.7	5.6	5.7	5.3
140	6.9	6.1	6.1	6.2	5.4
160	7.1	5.8	5.7	5.7	5.5
180	7.5	5.8	5.9	6.0	5.6
200	7.6	6.8	6.5	6.2	5.7
220	8.2	6.4	7.2	6.1	5.9
240	9.0	6.6	6.8	6.3	5.9
260	10.4	8.0	8.2	6.8	6.0
280	13.5	9.3	13.8	8.7	6.1
300	16.1	10.1	23.5	8.5	6.1
320	14.2	13.0	25.0	11.2	6.2
340	14.4	31.8	27.0	9.0	6.5
360	14.4	10.9	26.0	9.4	6.6
380	15.9	16.5	14.9	8.1	6.7
400	15.0	11.2	13.3	8.0	7.0



CURVE I
Comparison of the Insertion Loss pins 1-2 and 7-8
between R-1 and REA-1 Transposition System.
Insertion Loss - db
30
25
20
15
10
5
Pin 7-8 R-1
Pin 1-2 R-1
Pin 1-2 REA-1
Pin 7-8 REA-1
50
100
150
200
250
300
350
400
Frequency, KC