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DUPLEX OPERATION CURVES FOR 25-54 MC PROGRESS LINE TRANSMITTERS AND RECEIVERS

The curves included in this Bulletin have been compiled from extensive laboratory tests and theoretical propagation data. Although an attempt has been made to make the curves self-explanatory, some explanation may be required for those who are unfamiliar with duplex operation of transmitters and receivers. The information supplied in these instructions should solve most problems that result from simultaneous transmission and reception of signals. In other cases, further investigation and consultation with Engineering will be necessary.

MEASUREMENT PROCEDURES

Measurement procedures used in the laboratory must be chosen to closely duplicate those conditions found in actual installations where receivers and transmitters are operated close together in frequency or physical spacing. The best basic method of measuring sensitivity is by the 12-db sinad* ratio method. A given amount of interference can then be measured by a 6-db reduction in the 12-db sinad ratio. A signal which will give a 12-db sinad ratio on tone modulation is equivalent to 100% readibility on voice modulation. A 6-db loss in a 12-db sinad ratio is equivalent to about a 3-db loss in the desired signal. This means that 100% readibility can be re-established by doubling the power of the desired signal. This loss in desired signal seems like a drastic loss in power, but is a necessary basis for making measurements because of the non-linear characteristics of the receiver at smaller values of the undesired signal. To illustrate this characteristic, the typical curves of Fig. 1 are drawn for various levels of undesired signal.

The shaded areas between the two curves in Fig. 1 shows the wide variation in results that may be obtained when less than a 3-db loss in the desired signal is realized, another good reason why it is necessary to establish some stable amount of loss in signal when making measurements. For losses in signal greater than 3 db, the receiver characteristic is approximately linear.

Since the loss in the desired signal normally results from two factors, transmitter noise and receiver desensitization, it is possible that both types of loss in signal occur at the same level. When this happens with both independently producing a 3-db loss in desired signal, the combined loss will be between 4 and 5 db.

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*Sinad is the ratio of signal + noise + distortion to noise + distortion.

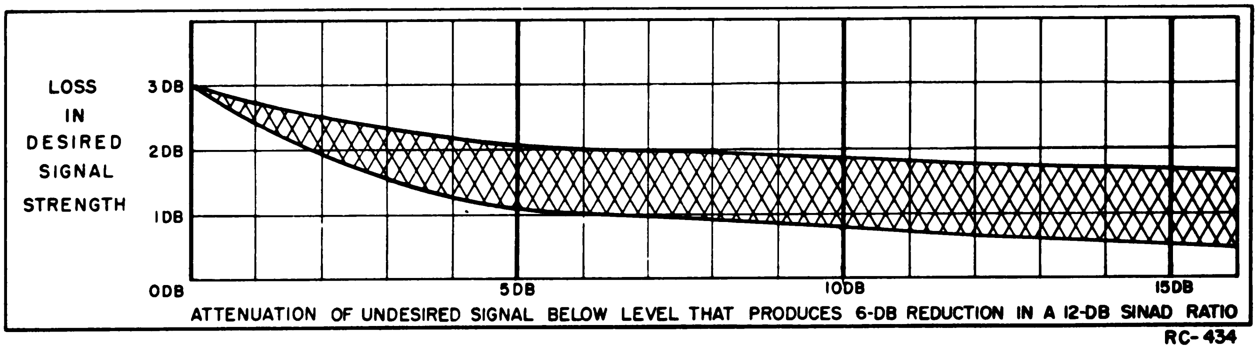


Fig. 1 - Variation in Loss of Desired Signal below 3 db

The same test procedure is used for measuring both desensitization and transmitter noise. For measuring desensitization, a filter is used to remove transmitter noise. The carrier of the transmitter is removed by a similar filter when measuring transmitter noise. In performing these tests, the setup shown in Fig. 2 and the procedure described below were used.

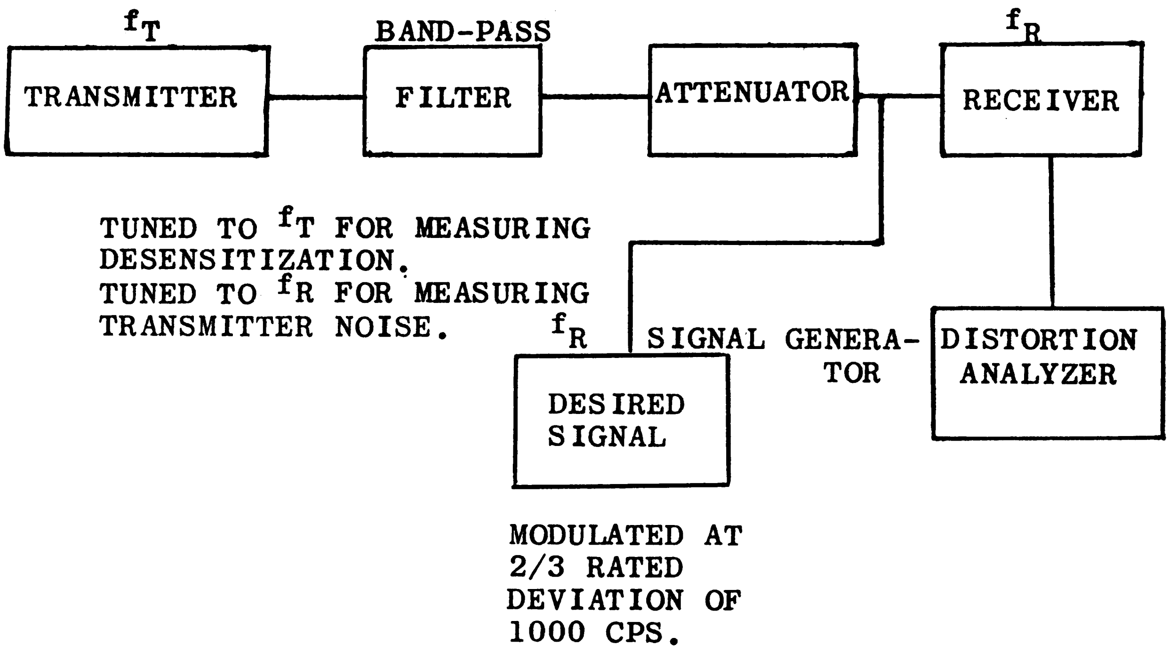


Fig. 2 - Test Setup for Measuring Desensitization & Transmitter Noise

1. With the undesired transmitter turned off, the signal generator is adjusted to f_R to give a 12-db sinad ratio on the distortion analyzer. This ratio is equivalent to measuring the RMS voltage of the audio output of the receiver and comparing it to the RMS voltage with the 1000-cps signal filtered out.

2. The transmitter is then adjusted to the frequency at which desensitization is to take place (f_T). The filter is also adjusted to f_T.

3. The attenuator on the undesired transmitter is now adjusted to give a 6-db reduction in the previously established 12-db sinad ratio.

4. To calculate the attenuation as given on the attached curves, the following equation was used:

$$D = 20 \log \frac{(A)\ (10^6)}{0.3} \qquad -20 \log \frac{(A)\ (10^6)}{B} + C$$

or

$$D = 20 \log \frac{B}{0.3} + C$$

in which

A = Output of the transmitter in volts,

B = Sensitivity of the receiver in microvolts,

C = Attenuation between transmitter and receiver, which includes insertion loss of filter and setting on attenuator in db, and

D = Attenuation required between the transmitter and receiver to prevent greater than 6-db reduction in a 12-db sinad ratio, as shown on the attached curves.

The first term, containing 0.3 microvolt, appears in the above equation because the curves are normalized for a 0.3-microvolt sensitivity receiver. The same procedure is used for measuring transmitter noise, except that the band-pass filter is tuned to f_R throughout the test. Since the squelch setting has an effect upon the desensitization, the curves were taken with the squelch disabled.

METHODS OF REDUCING LOSS IN DESIRED SIGNAL

Three basic methods are available for reducing loss in desired signal due to interference caused by desensitization or noise from a nearby transmitter:

1. Increase the attenuation between transmitters and receivers by using separate antennas, spaced the required amount vertically or horizontally.

2. Increase the selectivity of both transmitters and receivers by adding cavity filters. (Slot filters may also be used.)

3. Receiver desensitization may be reduced by using a crystal filter in the receiver's r-f circuit.* Only slight improvement in sensitivity can be expected, if the frequency separation is less than 200 kilocycles, because of transmitter noise.

EXPLANATION OF CURVES

The curves provided with this Bulletin may be considered as typical and only slight variations will be noted when the same models of equipment are operated under the same conditions. Under different conditions, consideration must be given to the type of operation employed. Figures A through F provide the following curves:

Fig. A - Duplex Operation Curves (25-40 Mc, Wide Band)
Fig. B - " " " (25-40 Mc, Narrow Band)
Fig. C - " " " (40-54 Mc, Wide Band)
Fig. D - " " " (40-54 Mc, Narrow Band)
Fig. E - Composite Curves (25-54 Mc)
Fig. F - Typical 1st Limiter Curves (25-54 Mc)

FIGURES A THROUGH D

Curves 1 and 2

Curves 1 and 2 give the attenuation required, due to transmitter noise, between Transmitter ET-23-A (60-watt), EF-2-A (250-watt) and respectively, and Receiver ER-24-A so as not to reduce the 12-db sinad ratio more than 6 db. When the transmitter power output is not adjusted to 60 watts, Curve 7 must be used to apply the proper power correction. The required ATTENUATION is found by reading the value from Curve 1 or 2 which corresponds to the FREQUENCY SEPARATION between the transmitter and the receiver.

Curve 3

This curve gives the attenuation required between a 60-watt transmitter, assuming no transmitter noise interference, and an appropriate receiver which requires 0.3 uv to produce a 12-db sinad ratio, so as not to reduce the 12-db sinad more than 6 db. If the receiver is not operated at a 0.3-uv sensitivity, Curve 6 and Fig. F should be used to make the proper sensitivity corrections.

*See Radio Communication Service Bulletin VII-103 for installing crystal filter in receiver.

The proper correction must also be made, using Curve 7, if the transmitter power output is not 60 watts. The required ATTENUATION can be read from Curve 3 which corresponds to the FREQUENCY SEPARATION between the transmitter and the receiver. Interference caused by transmitter or receiver spurious radiation is not covered in these curves.

Some variation in the required attenuation may be experienced if the receiver is operated under conditions different from those used in making the measurements. This variation in results can be attributed mainly to the fact that, because the r-f transformer in the receiver is tuned to the desired signal, a large VSWR will result when undesired signals are introduced into the receiver. In most cases, the resulting VSWR will cause little variation from Curve 3.

Curves 4 and 5

Curves 4 and 5 can be used to find the attenuation between either vertically- or horizontally-spaced half-wave dipoles, when both are mounted for vertical polarization. The attenuation thus obtained is given at the receiver terminals when the receiver is assumed to have the same impedance as the antenna. As explained above for receiver desensitization, a slight variation in attenuation will be experienced as the length of transmission line between the antenna and the receiver is adjusted. This variation becomes less and less as the transmission line becomes longer. Curve 5 is based on free-space propagation, while Curve 4 is based on calculated data. The ATTENUATION in db corresponding to the ANTENNA SPACING in feet between centers of any two antennas may be determined from Curves 4 and 5.

Curve 6

This curve is included as an aid in calculating the correction in db that is required when the receiver is operated at various sensitivities. For example, a receiver located in an area having a high noise level might operate with a sensitivity of 0.6 microvolt. Curve 10 indicates that the correction for a sensitivity of 0.6 microvolt is -6 db. This means that 6 db can be subtracted from the required attenuation determined from Curves 1, 2 and 3. Fig. F gives the approximate operating sensitivity of receivers where random noise is being received.

Curve 7

Curve 7 is provided for making corrections for transmitter power outputs other than 60 watts. Since the attenuation curves are based on a 60-watt output, the correction is zero for that value of power.

Curves 8 and 9

Curves 8 and 9 give the attenuation required between the transmitter and the receiver to prevent greater than 12-db or 20-db reduction in desired signal performance, respectively. Both curves represent the combined effect of desensitization due to signal and transmitter noise. For most frequency separations, only one of the two effects will largely determine the desensitization. Both curves are normalized for a 60-watt transmitter and a 0.3-microvolt receiver. For different transmitter power outputs or receiver sensitivities, use the appropriate correction curves.

FIGURE E

Figure E is included for making rough calculations of antenna spacings and should not be followed when accurate figures are desired. The four curves were taken from an average of the values found on Figures A, B, C and D. Antenna spacings are shown for both 60-watt and 250-watt transmitters. In making the curves, transmission line loss was neglected and transmitter noise and desensitization curves were combined. The receiver sensitivity was assumed to be 0.3 microvolt.

FIGURE F

The four curves of Fig. F indicate the typical first limiter voltage reading which will be obtained with a given signal (Curves 1 and 3) or with random noise (Curves 2 and 4).

<u>Curves 1 and 3</u>

Curves 1 and 3 show typical 1st limiter voltage readings vs signal for wide-band and narrow-band receivers, respectively. Readings were taken with a VTVM connected to the 1st limiter jack on the receiver. This jack is shunted within the receiver by a nominal 18K-ohm resistor. When meters having an internal resistance of less than about 180K ohms are used, it will be necessary to apply a correction factor to the curves. For the standard 20,000 ohm-per-volt meter with a 3-volt range, the curve scale should be multiplied by 0.78 for correct readings.

It should be remembered that variations can be expected from receiver to receiver, due to variations in line voltage and variations in gain up to the 1st limiter grid. If more accurate data is required than is given by these typical curves, it will be necessary to calibrate a given receiver with a standard signal generator, maintaining a constant line voltage.

<u>Curves 2 and 4</u>

Curves 2 and 4 show typical 1st limiter voltage readings due to random noise vs the signal required to provide a 12-db sinad ratio for wide-band and narrow-band receivers, respectively. These curves are necessary to make the proper corrections for local noise conditions. A low-band receiver operating with a 3-db noise figure will provide a sensitivity of 0.16 microvolt on narrow band or 0.23 microvolt on wide band to produce a 12-db sinad ratio under standard test conditions. Such sensitivities can seldom, if ever, be realized when the receiver is connected to an antenna in an actual installation, due to noise being received or to the receiver's operating frequency. This noise condition can be recognized by an increase in 1st limiter voltage when the antenna is connected. Curves 2 and 4 can be used to determine the effective sensitivity of the receiver when the 1st limiter voltage rises due to random noise. (See examples listed below on use of Curves 2 and 4.)

ILLUSTRATIVE EXAMPLE

The following example is provided to illustrate the use of the Duplex Operation Curves.

EXAMPLE

Find the parameters required for duplex operation of the following transmitter and receiver:

Transmitter Frequency	48.2 Mc
Power Output	200 watts (power to antenna)
Receiver Frequency	47.8 Mc
1st Limiter Voltage Reading with Antenna Connected	0.25 volt (read on standard 3-volt meter)
Loss in Desired Signal	To be less than 4 db

SOLUTION

This problem can be solved by using the following steps. Other installations for duplex operation may be worked out in a similar manner.

1. Assuming a wide-band system, the receiver's effective sensitivity may be found by referring to Curve 2 of Fig. F. The 0.25-volt 1st limiter voltage (measured on a 3-volt meter) is equivalent to a 0.32-volt reading (0.25 ÷ 0.78 = 0.32) on a VTVM. The sensitivity (read from Curve 2) is about 0.65 microvolt.

2. The attenuation required to prevent a greater than 3-db loss of the desired signal due to transmitter noise is found as follows:

Transmitter Frequency	48.2 Mc
Receiver Frequency	-47.8 Mc
Frequency Separation	0.4 Mc

Attenuation Required for Transmitter Noise (Fig. C, Curve 2)	45.0 db
Correction for Receiver Sensitivity (Fig. C, Curve 6)	- 6.5 db
Correction for Transmitter Power (Fig. C, Curve 7)	5.0 db
Assumed Receiver Transmission Line Loss	- 1.0 db
Total Required Attenuation at 47.8 Mc	42.5 db

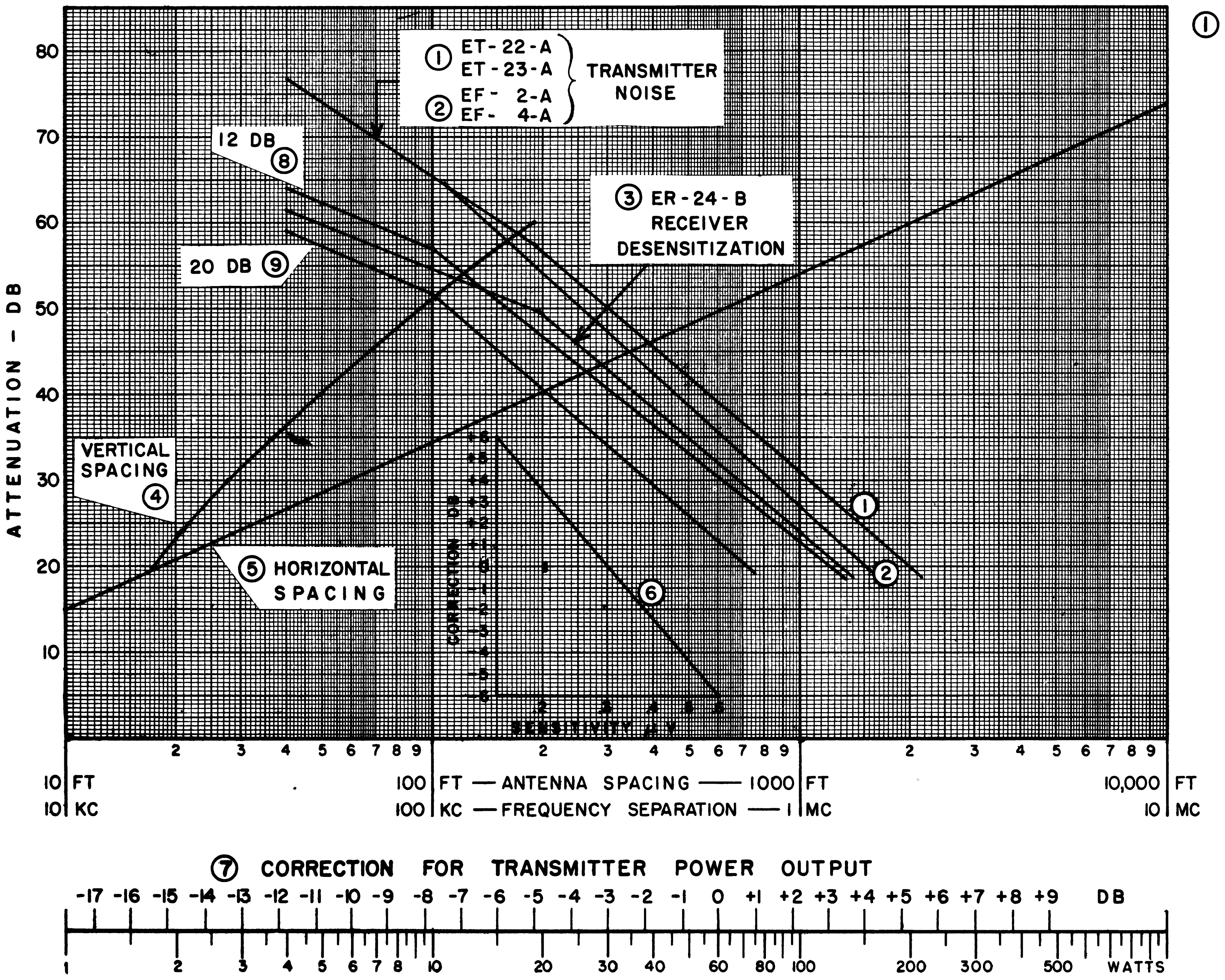
3. The attenuation required to prevent a greater than 3-db loss of desired signal due to carrier desensitization of the receiver is found as follows:

Attenuation Required for Receiver (Fig. C, Curve 3)	41.0 db
Correction for Receiver Sensitivity (Fig. C, Curve 6)	- 6.5 db
Correction for Transmitter Power (Fig. C, Curve 7)	5.0 db
Assumed Receiver Transmission Line Loss	- 1.0 db
Total Required Attenuation at 48.2 Mc	38.5 db

4. Since 4.0 db more attenuation is required to prevent desensitization due to transmitter noise (42.5 db) than to prevent desensitization due to carrier desensitization of the receiver (38.5 db), the antenna spacing must be based on noise desensitization. Loss of desired signal due to signal desensitization will be slight and the combined loss will be less than 4 db. The required antenna spacing is found as follows:

For vertical antenna spacing (Fig. C, Curve 4)	50 feet
For horizontal antenna spacing (Fig. C, Curve 5)	200 feet

FIG. A — DUPLEX OPERATION (25-40 MC WIDE BAND)



① ② ③ REQUIRED ATTENUATION TO PREVENT GREATER THAN 6-DB REDUCTION IN A 12-DB SINAD RATIO (EQUIVALENT TO 3-DB LOSS OF DESIRED SIGNAL)

④ ⑤ ANTENNA ATTENUATION

⑥ CORRECTION FOR RECEIVER SENSITIVITY OF 12 DB SINAD RATIO.

⑦ CORRECTION FOR TRANSMITTER POWER OUTPUT.

⑧ ⑨ REQUIRED ATTENUATION TO PREVENT GREATER THAN INDICATED LOSS OF SIGNAL.

FIG. B - DUPLEX OPERATION (25-40 MC NARROW BAND)

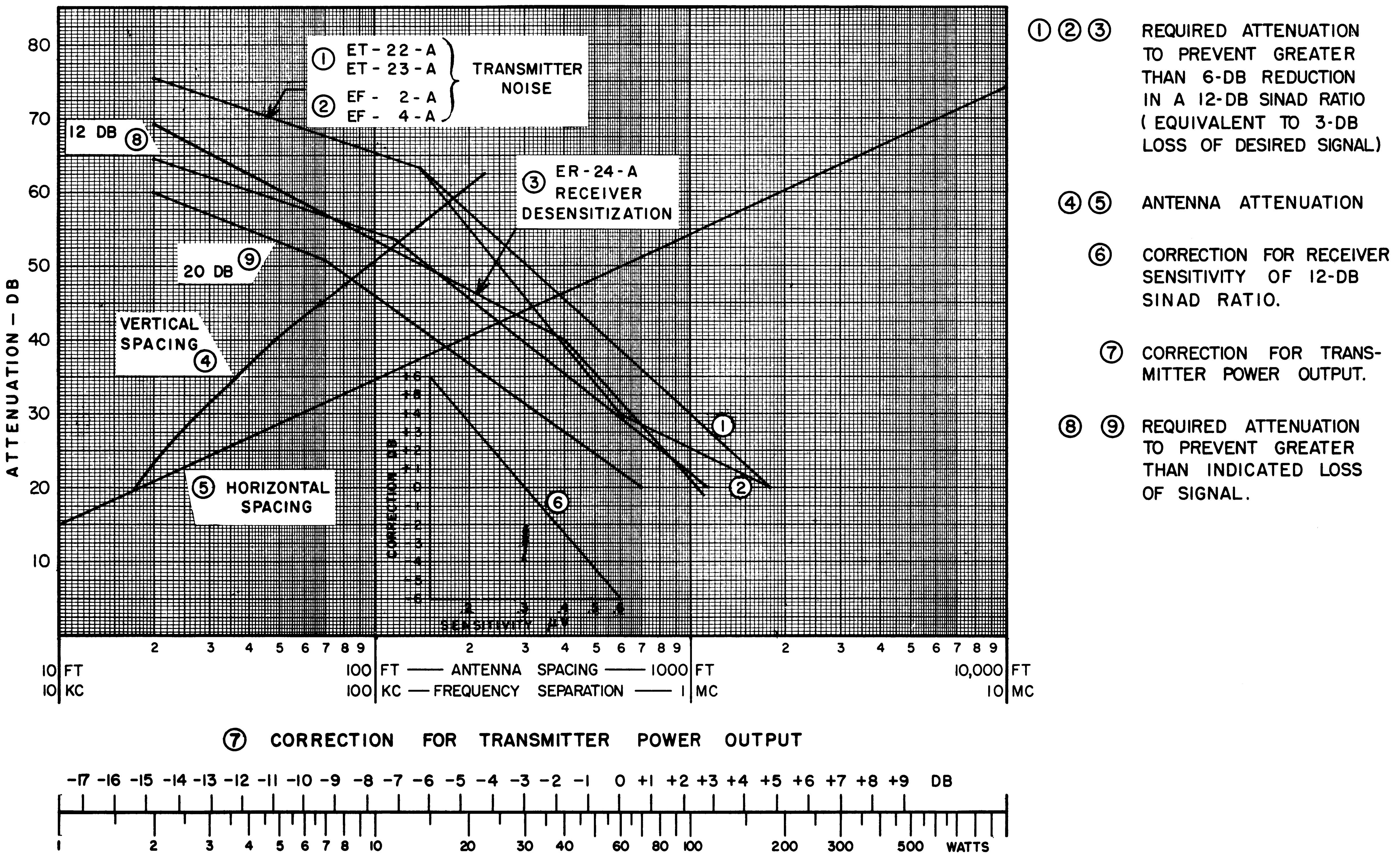
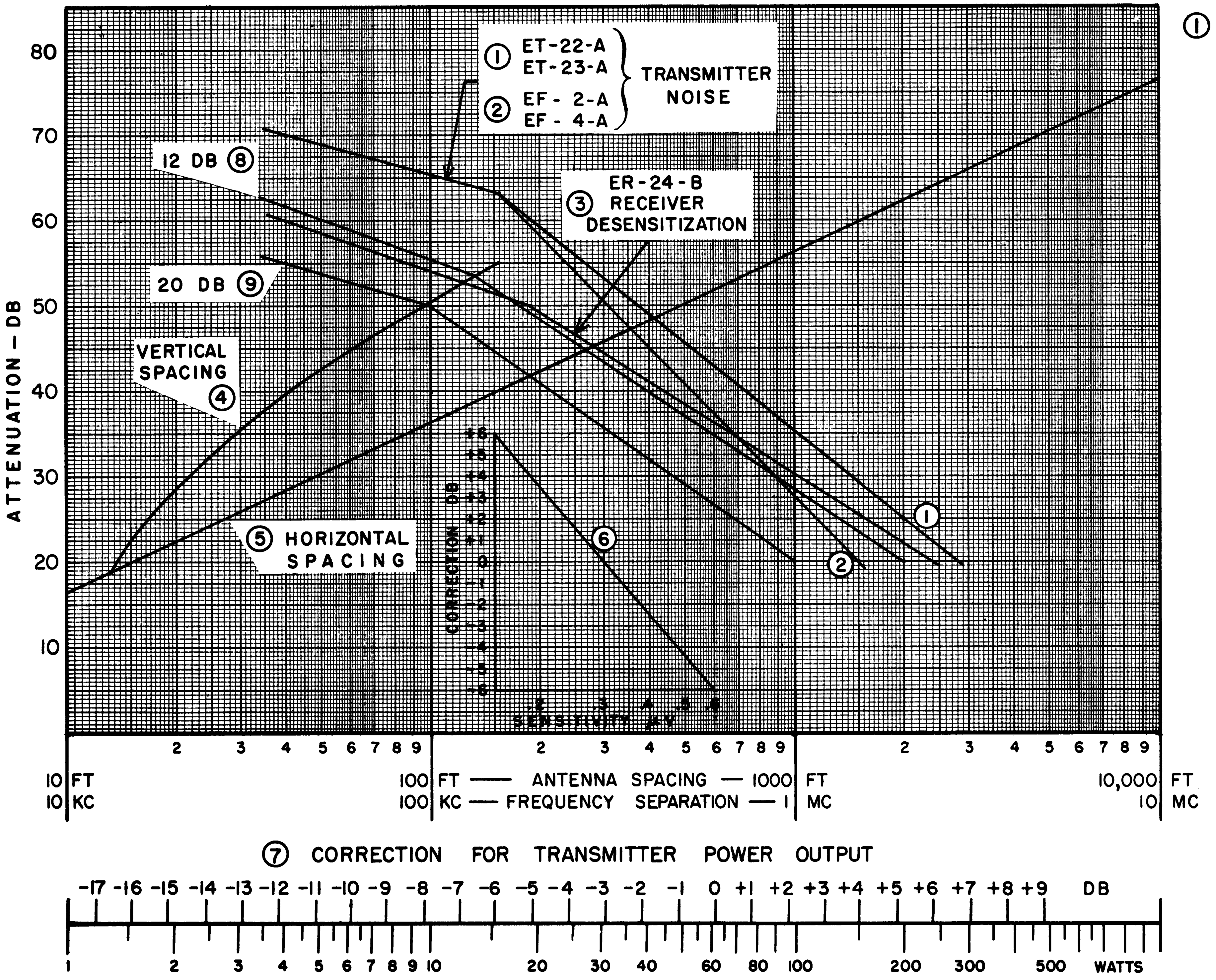


FIG. C — DUPLEX OPERATION (40-54 MC WIDE BAND)



① ② ③ REQUIRED ATTENUATION TO PREVENT GREATER THAN 6-DB REDUCTION IN A 12-DB SINAD RATIO (EQUIVALENT TO 3-DB LOSS OF DESIRED SIGNAL).

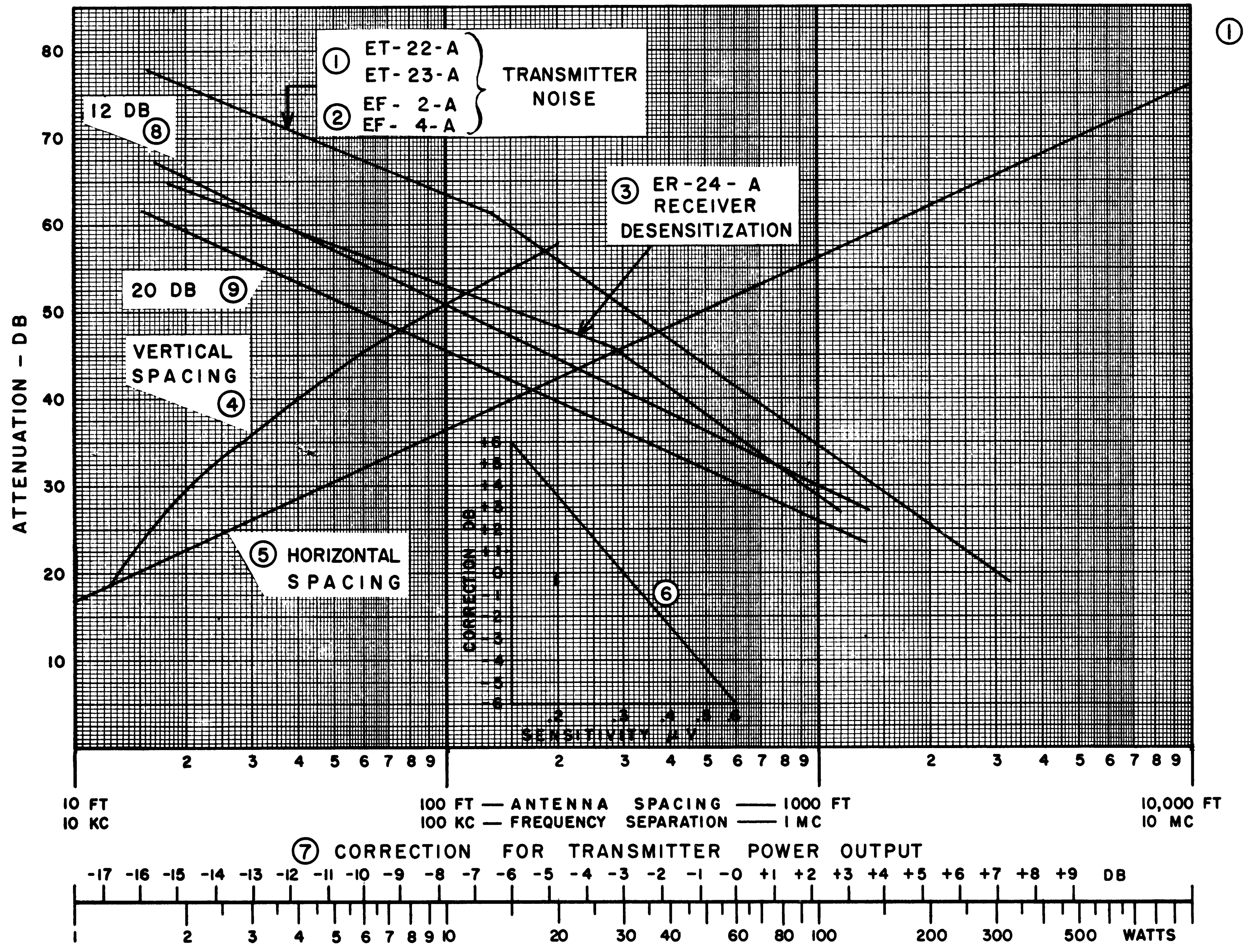
④ ⑤ ANTENNA ATTENUATION.

⑥ CORRECTION FOR RECEIVER SENSITIVITY OF 12-DB SINAD RATIO.

⑦ CORRECTION FOR TRANSMITTER POWER OUTPUT.

⑧ ⑨ REQUIRED ATTENUATION TO PREVENT GREATER THAN INDICATED LOSS OF SIGNAL.

FIG. D — DUPLEX OPERATION (40-54 MC NARROW BAND)



(1) (2) (3) REQUIRED ATTENUATION TO PREVENT GREATER THAN 6-DB REDUCTION IN A 12-DB SINAD RATIO (EQUIVALENT TO 3-DB LOSS OF DESIRED SIGNAL).

(4) (5) ANTENNA ATTENUATION.

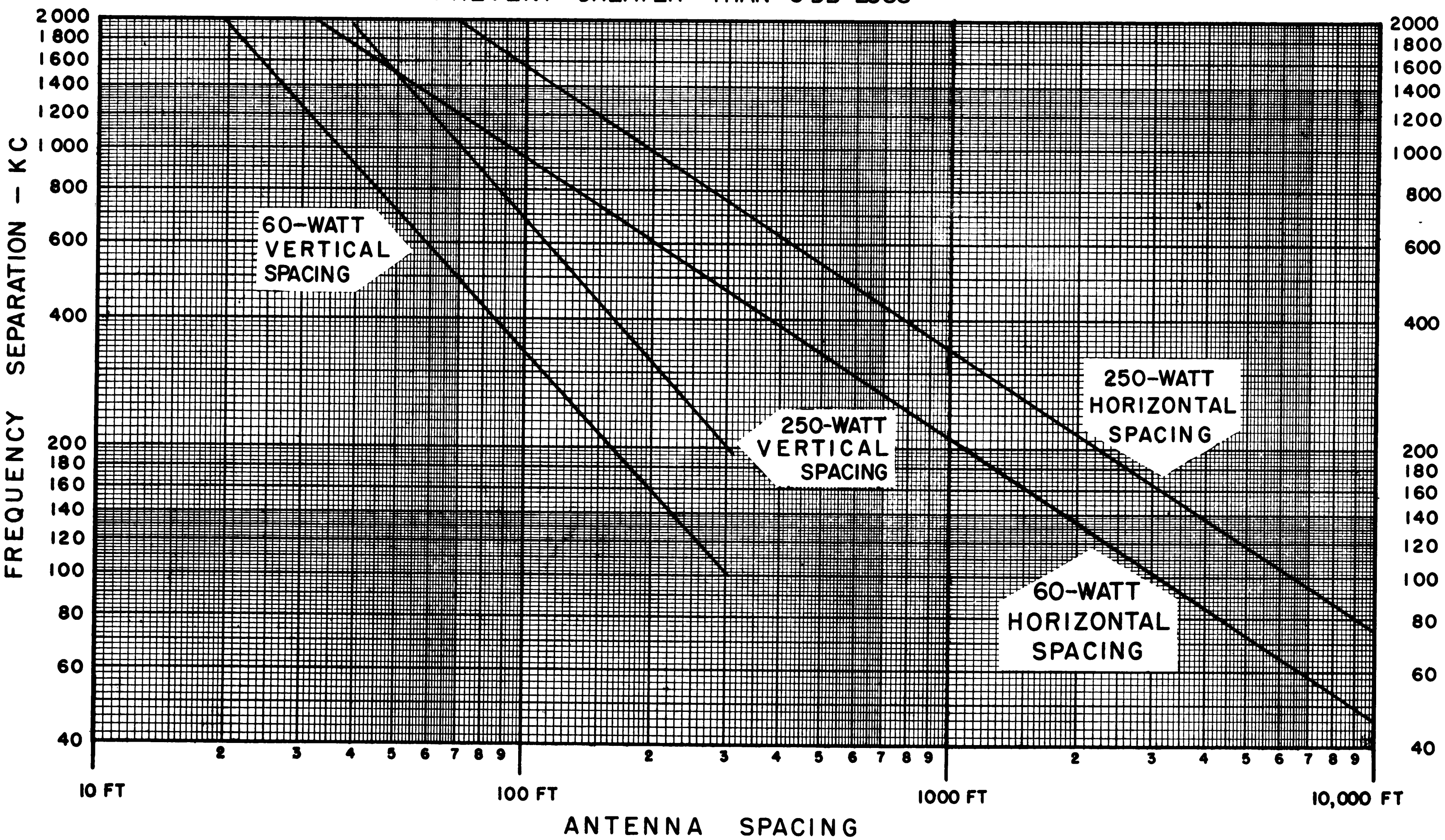
(6) CORRECTION FOR RECEIVER SENSITIVITY OF 12-DB SINAD RATIO.

(7) CORRECTION FOR TRANSMITTER POWER OUTPUT.

(8) (9) REQUIRED ATTENUATION TO PREVENT GREATER THAN INDICATED LOSS OF SIGNAL.

FIG. E – COMPOSITE DUPLEX OPERATION CURVE (25-54 MC)*

ANTENNA SPACING REQUIRED TO PREVENT GREATER THAN 3 DB LOSS



* THESE CURVES ARE AVERAGE AND SHOULD NOT BE USED WHEN ACCURACY IS DESIRED.