communications

DATAFILE BULLETIN

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DUPLEX OPERATION
(SAM 40-D)

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HOW TO USE

DUPLEX OPERATION CURVES

ABSTRACT

When a transmitter and a receiver operate simultaneously, close to each other, it is necessary to provide adequate attenuation between the output of the transmitter and the input of the receiver to maintain the intelligibility of desired signals. This Bulletin describes how duplex operation curves are prepared and how they can be used to calculate the amount of attenuation required between the transmitter and the receiver (using DATAFILE Form 10007-5). It also describes how to find the amount of antenna spacing and/or the type of filters required to obtain this attenuation.

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When a transmitter and a nearby receiver operate simultaneously, the signal from the transmitter may cause interference in the receiver --- especially if their operating frequencies are close together. That is, the intelligibility of desired signals (particularly weak signals) heard from the receiver may be reduced. There are three situations where this is likely to occur:

1. In duplex operation.

2. In radio repeater stations.

3. In simplex operation where radio users share an antenna site.

Duplex operation curves are valuable in predicting the amount of interference which will be encountered in these situations, and also in determining how this interference can be reduced to a level where desired messages can be heard.

INTERFERENCE IN DUPLEX SYSTEMS

In this discussion of duplex operation curves, the term "duplex" will be used simply to indicate that a transmitter and a nearby receiver are operating simultaneously -- even if they are not in the same radio system (as in situation number 3 above).

TYPES OF INTERFERENCE

Two types of interference are primarily responsible for the degradation in the quality of signals heard from the receiver in duplex operation. First, the portion of the transmitter noise spectrum which falls within the passband of the receiver increases the noise level, with respect to the desired signal. In other words, the signal-to-noise ratio is decreased. Second, RF voltages generated by the transmitter are rectified in the receiver, producing bias voltages that reduce the gain of the RF and IF stages and thereby reduce the sensitivity of the receiver. This is commonly called receiver desensitization. Transmitter noise and receiver desensitization are discussed in detail in DATAFILE Bulletin 10002-2, RF Interference in Two-Way FM Radio Systems.

The closer the frequencies of the transmitter and receiver are together, the more severe are the effects of both transmitter noise and receiver desensitization. With very little frequency separation, the effect of transmitter noise is predominant. At greater separations, the effect of receiver desensitization usually becomes greater.

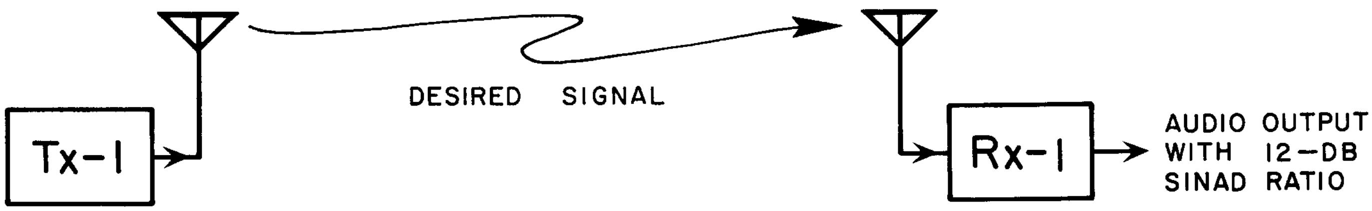

Figure 1 - Reception from a "Fringe" Area

MEASURING SYSTEM DEGRADATION

In order to engineer a new radio system, it is necessary to know the amount of degradation which will be produced in each receiver by near-by transmitters. Since receiver desensitization produces a loss in receiver sensitivity, this type of degradation is measured in terms of lost sensitivity. As previously mentioned, transmitter noise decreases the signal-to-noise ratio for desired signals. To the person listen-ing to the receiver, this has the same effect as reducing the receiver's sensitivity --- very weak signals are more difficult to understand, due to the increased amount of noise heard with the signal. Therefore, degradation caused by transmitter noise is also measured in terms of the effective loss in sensitivity.

So --- to measure transmitter noise and receiver desensitization, a practical, realistic method for measuring receiver sensitivity is re-quired. Since the most realistic measurement of FM or PM receiver sensitivity is the 12-db SINAD sensitivity* method (EIA Standard RS204, Section 3), measurement of degradation caused by duplex operation is also based on this method.

What does a SINAD ratio really tell about the audio output from a re-ceiver? It is a good indication of how easily the audio signal from the receiver can be understood. An audio signal with a high SINAD ratio can be easily understood because it is accompanied by only a small amount of noise and distortion in proportion to the signal. An increase in either the noise level or distortion decreases the SINAD ratio. A signal producing a very low SINAD ratio at the output of the receiver is very difficult or impossible to understand, because of the noise and distortion present.

Just how good or how poor is the quality of signals of various SINAD ratios? Suppose that transmitter Tx-1 in Figure 1 is in a fringe area and the weak signal from this transmitter, received by Rx-1, produces a 12-db SINAD ratio at the output of the receiver. The recovered audio would be just at the low edge of acceptability. No one would care to listen to it very long, because of the hissing and popping noise in the background. However, the message from Tx-1 would be understandable and would constitute a useable signal (through a few messages might have to be repeated). Since the signal which produces a 12-db SINAD ratio at the output of a receiver is considered the minimum useable signal, this signal level is used as the standard EIA measurement of receiver sensitivity.

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*SINAD ratio is defined as: $\frac{\text{signal} + \text{noise} + \text{distortion}}{\text{noise} + \text{distortion}}$

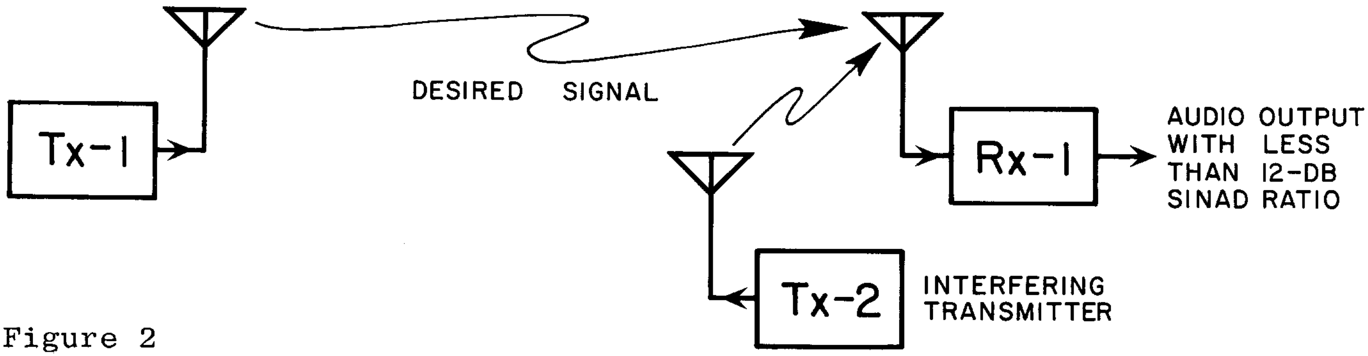


Figure 2

As the SINAD ratio increases from 12 db, the audio signal can be understood more easily. By the time a signal has improved to a 20-db SINAD ratio, the noise level has dropped to the point where it is still discernible, but not objectionable in most systems. All messages of this quality should be nearly 100% readable. Two-way radio FM receivers are usually capable of producing SINAD ratios of about 25 db, limited by noise and distortion in the test equipment and power supplies. High fidelity FM broadcast receivers should be capable of 30-db SINAD ratios.

If a transmitter on a nearby frequency were installed in the vicinity of the receiver in Figure 1, the sensitivity of the receiver would be degraded. Receiver desensitization and transmitter noise caused by Tx-2 (see Figure 2) could reduce the 12-db SINAD ratio at the receiver's output to a point where signals from Tx-1 would no longer be intelligible. If the SINAD ratio were degraded to 6-db, for instance, the signal would be unintelligible to most listeners.

Increasing the attenuation between Tx-2 and Rx-1 would improve the SINAD ratio at the output of the receiver. This can usually be accomplished by moving their antennas farther apart, or by using filters in their transmission lines. But --- it is important to realize that additional attenuation alone will <u>never</u> restore the signal from Tx-1 to its <u>original quality</u>. That would require an infinite amount of attenuation between Tx-2 and Rx-1, an impossibility. So --- the question is --- to what extent <u>can</u> the original quality of the signal be restored? Here, duplex operation curves are of great help.

HOW DUPLEX OPERATION CURVES ARE PREPARED

Figure 3 shows the results of three desensitization measurements --- either on the same receiver or on three different receivers of the same model. Notice that a <u>small</u> interfering signal may desensitize one receiver only slightly (Curve #1), while another receiver of the same model may be desensitized appreciably (Curve #3). Even the same receiver may show different amounts of desensitization when measured several times. To be of general value, a desensitization curve would have to accurately show the desensitization characteristics of all receivers for which it is published.

Note that the three curves in Figure 3 begin to coincide (overlap) as the desensitization becomes more and more severe. By the time the

SINAD ratio at the receivers output has been reduced to 6-db, the curves are almost identical. This is the reason why duplex operation curves published for G-E two-way radios show the desensitization characteristics of receivers for a 6-db reduction in a 12-db SINAD ratio. For smaller amounts of desensitization, a generalized curve could not be drawn. A 6-db reduction is the least degradation which is similar for receivers of the same model.

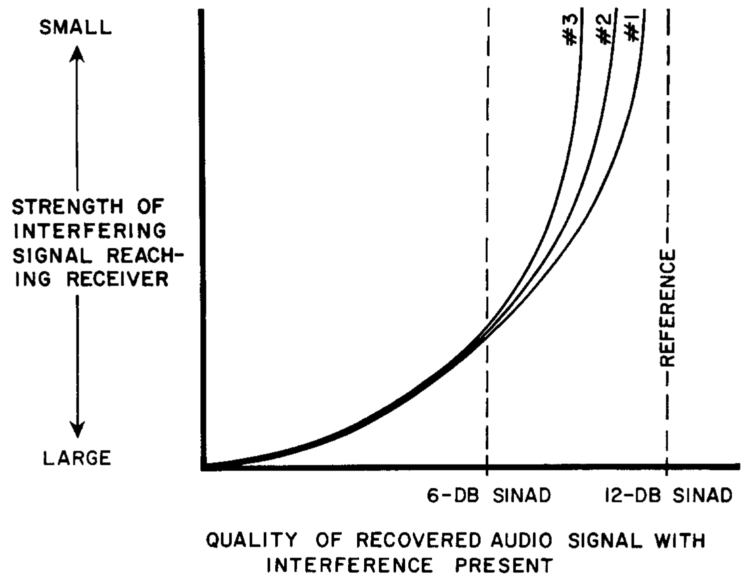


Fig. 3 - Typical Desensitization Curves (Reference: 12-db SINAD Ratio)

Receiver desensitization and transmitter noise measurements are made using the test setup shown in Figure 4. Following the standard EIA test procedure, the signal generator (modulated at two-thirds of rated deviation by a 1000-cps test tone) is adjusted to produce a 12-db SINAD ratio on the distortion analyzer. This signal represents a weak, desired signal. The transmitter, adjusted to the frequency of the interfering signal, is then turned on. For measuring receiver desensitization, the cavity resonator is tuned to the transmitter frequency. This prevents transmitter noise from reaching the receiver, so that the effects of receiver desensitization alone can be measured. The attenuator is now adjusted to give a 6-db reduction in the previously established 12-db SINAD ratio. Knowing the total attenuation between the transmitter and the receiver, the transmitter power output, and the sensitivity of the receiver, a curve showing the attenuation required between the transmitter and the receiver to prevent greater than 6-db reduction in a 12-db SINAD ratio can now be drawn.

A similar curve can be prepared for transmitter noise, with the cavity resonator tuned to the receiver frequency. The filter then prevents

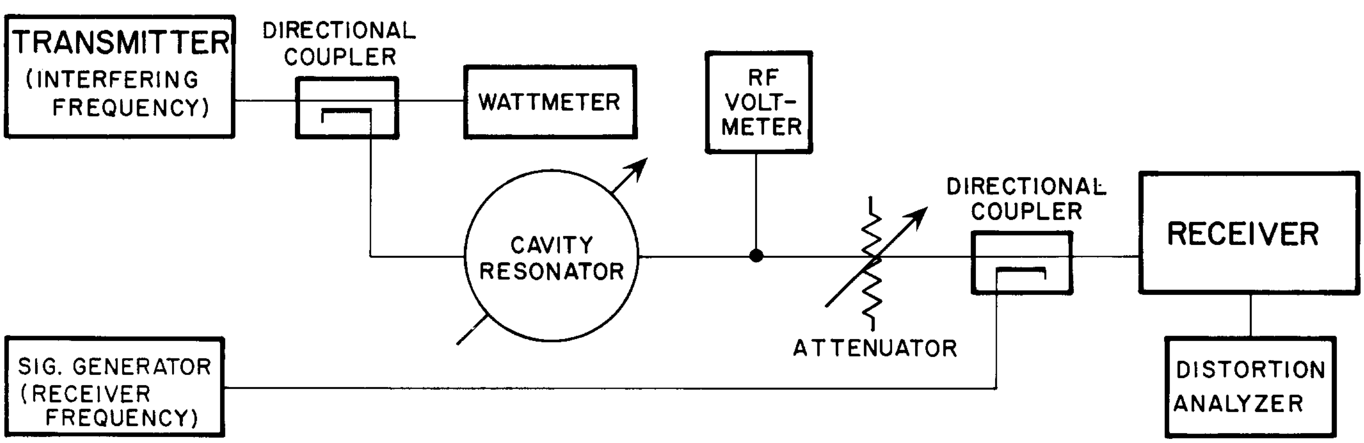


Figure 4 - Test Setup for Measuring Rcvr Desensitization & Xmtr Noise

receiver desensitization, so that the effects of transmitter noise alone can be measured.

The transmitter power output and the receiver SINAD sensitivity are normalized for both duplex operation curves. Scales are provided with the curves to make corrections for transmitters with slightly different power outputs and for receivers with different sensitivities

METHODS OF REDUCING LOSS IN DESIRED SIGNAL

Three methods are commonly used to obtain the isolation required between the transmitter and receiver to prevent excessive degradation of desired signals:

1. Using separate antennas for the transmitter and receiver and spacing the antennas the required amount vertically or horizontally.

2. Using a common antenna for the transmitter and receiver with cavity filters or duplexers in the transmitter output and the receiver input.

3. Using both antenna spacing and cavity filters.

For transmitters and receivers operating in the same cabinet, additional shielding may also be necessary to prevent RF coupling between the output stages of the transmitter and the input of the receiver. Figures 10 and 11 show the attenuation which can be obtained by spacing the antennas vertically or horizontally. The instructions for cavity filters and duplexers (multiple-cavity filters) include graphs showing the attenuation which these devices will provide.

DUPLEX OPERATION CALCULATIONS

DATAFILE Form 10007-5* (see Figure 9) is designed to simplify making duplex operation calculations from the duplex curves in your DATAFILE. On the following pages, the use of this form will be described, using an example to illustrate proper use of the curves. First, we will calculate the amount of attenuation required in the example. Then we will show how the problem could be solved by each of the three methods listed above.

THE EXAMPLE

A proposed mobile relay station, using MASTR Progress Line equipment, is to receive on 157.200 MC and transmit on 156.100 MC. The transmis-

*Available in limited quantities from General Electric Co., A & SP, Communication Products Dept., Mountain View Road, Lynchburg, Virginia.

sion lines each have a 1/2-db insertion loss. The transmitter power output is 32 watts and the effective receiver 12-db SINAD sensitivity when connected to the antenna (due to received noise) is 0.4 microvolt.

After finding the amount of attenuation required between the transmitter and the receiver, we will find (1) the amount of antenna spacing which would be required if this attenuation were obtained by spacing the antennas vertically, (2) what cavities would be required if a common antenna were used for the transmitter and the receiver, and (3) what cavities would be required if separate antennas were used, spaced 90 feet horizontally. We will assume that all antennas are half-wave dipoles (unity-gain antennas).

Pages 11 and 12 show Form 10007-5, filled in for our example. Since the station is to use high-band MASTR Progress Line equipment, the calculations will be based on the duplex operation curves found in Bulletin 10007-7.

Steps 1 and 2 on page 11 have been filled in with a description of the receiver and the interfering transmitter. The transmitter output power is measured at the transmitter. Receiver sensitivity should be measured at the site of the installation, as described below, so that the SINAD sensitivity will reflect the actual noise environment in which the receiver will be operating. Step 3 is the frequency separation between the transmitter and the receiver.

DETERMINING EFFECTIVE RECEIVER SENSITIVITY

The rated sensitivity of FM receivers can seldom be realized in actual installations, due to the noise received along with desired signals. Therefore, the sensitivity figure used in duplex calculations should reflect the actual noise environment in which the receiver will be operating.

The presence of noise can be recognized by an increase in 1st limiter voltage when the antenna is connected. Curves are available for some receivers, showing the signal strength required to produce a 12-db SINAD ratio in the presence of various noise levels, as indicated by first limiter voltage. Using these curves, the receiver's effective sensitivity can be measured at the actual site of the installation. If a calibrated signal generator, a distortion meter and a noise meter are available, a specific receiver can be calibrated and curves drawn for it.

The measurement of noise levels is full of pitfalls. For example, the noise level may change over a period of time --- an hour, a day or a month. If measurements are taken with a mobile unit at the proposed site, the noise level picked up by the station antenna system finally erected is likely to be much greater, since an elevated antenna "sees" a much larger area and the noise generated within that area. If the noise level is checked using a mobile unit, a large area around the proposed site must be explored in order to locate potential sources of noise, such as leaky power line insulators and transformers.

TABLE I - TYPICAL NOISE LEVELS AT BASE STATION RECEIVERS

Frequency	Typical Noise Levels
50 MC	2.0 microvolts
80 MC	1.0 microvolt
160 MC	0.5 microvolt
450 MC	0.1 microvolt

The safest and surest method for determining noise level is to make measurements over a period of several days --- using the type of station antenna, the frequency and the antenna height contemplated for the final installation. For rough duplex operation calculations, use the typical noise levels in Table I as the effective receiver sensitivity --- unless the rated 12-db SINAD sensitivity of the receiver is higher than the noise level. The actual receiver sensitivity should then be used.

DETERMINING THE REQUIRED AMOUNT OF ATTENUATION

Step 4 in our example can be quickly determined from Duplex Operation Curves 1 and 2 in Bulletin 10007-7, using the frequency separation of 1.1 MC (found in step 3). Since the curves have been drawn for an 80-watt transmitter and a receiver with 0.5-microvolt sensitivity, steps 5 and 6 must be used. The correction factors were determined from scales 3 and 4 on the duplex operation curves. If separate antennas are used for the transmitter and the receiver, the sum of the two transmission line losses should be entered in both columns of step 7. In our example, both lines have an insertion loss of 1/2 db. Therefore, the sum of 1 db has been entered in both columns.

In radio systems where maximum intelligibility and talk-back range are needed, it is desirable to exceed the amount of attenuation indicated in the duplex operation curves. The amount of additional attenuation desired is disucssed in the following section and should be entered in both columns of step 8.

By adding the two columns (step 9), we find that we need 43.5 db of attenuation between the transmitter output and the receiver input to prevent excessive degradation of desired signals by receiver desensitization and 52.5 db to prevent degradation by transmitter noise.

CALCULATING DEGRADATIONS LESS THAN 6-DB

A 6-db degradation in a 12-db SINAD ratio is used in making measurements for duplex operation curves because it is the smallest loss for which receiver desensitization characteristics are approximately linear. Such a loss is comparable to a 3-db loss in the power of the desired signal and would drastically degrade reception from fringe areas. (It would be similar to cutting the transmitter's power in half, for instance, or receiving only half as much power at the

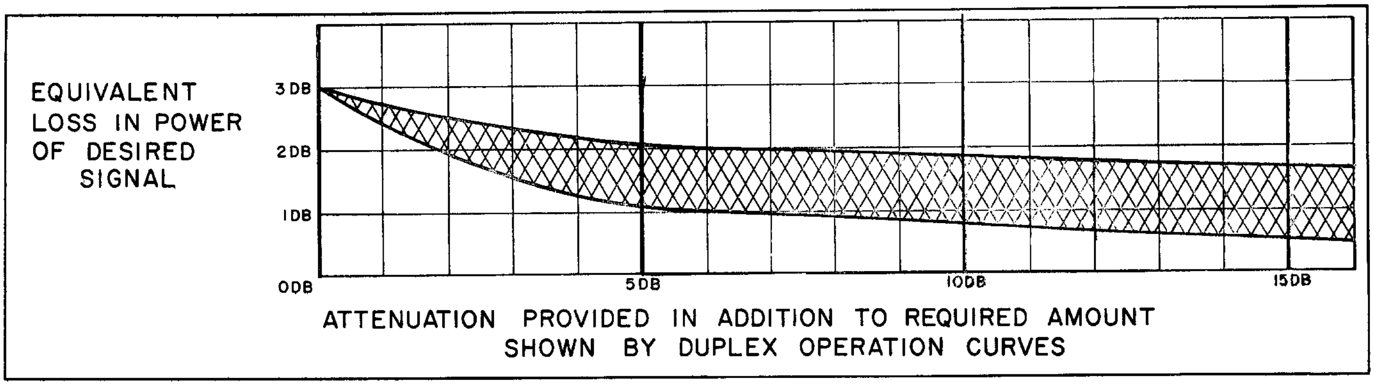


Figure 5 - Additional Attenuation Required for Less than a 6-db Reduction in a 12-db SINAD Ratio

receiver's input). The power of the desired signal would have to be doubled to restore the original 12-db SINAD ratio (with the interference present).

If the total attenuation between the receiver and the interfering transmitter is equal to the attenuation which duplex operation curves show is required to prevent more than a 6-db degradation, the equivalent loss in the power of a desired signal will be 3 db. This point is shown at the left end of the curves in Figure 5. The curves show the equivalent loss of power in duplex systems having more than the amount of attenuation which duplex curves show is required. For less than a 6-db degradation, not all receivers will be desensitized the same amount and will therefore require different amounts of attenuation for the same effective sensitivity. Even the same receiver will be desensitized different amounts at different times. The shaded area between the two curves indicates the variation which can be expected, due to variations between receivers, variations in the type of noise, frequency spacing, etc. Notice that for an equivalent loss in desired signal of only 2 db, some systems will require as little as 2 db additional attenuation, while others will require as much as 6 or 7 db. For an equivalent loss of only 1 db, some systems may require only 6 db of additional attenuation; others may require an extremely large amount --- too much to be practical.

If a radio system requires maximum intelligibility and talk-back range, the amount of attenuation indicated by the duplex operation curves should be exceeded. For an effective loss in the power of desired signals of only 2 db, add 4 to 6 db of attenuation in both columns of step 8; for an equivalent loss of approximately 1 db, add from 6 to 12 db of attenuation. Two factors will determine the amount of attenuation added:

1. The cost of additional cavities and antenna separation to provide the extra db's.

2. The importance of maximum talk-back range in the system.

The extra attenuation added in step 8 is intended to improve reception of marginal signals (signals producing SINAD ratios of approximately 12 db). In radio systems where received signals are always strong, no additional attenuation may be needed.

METHODS OF OBTAINING REQUIRED AMOUNT OF ATTENUATION

We will now show how to obtain the required attenuation (step 9) by each of the three methods previously mentioned.

Method 1: Obtaining Attenuation by Antenna Spacing Alone

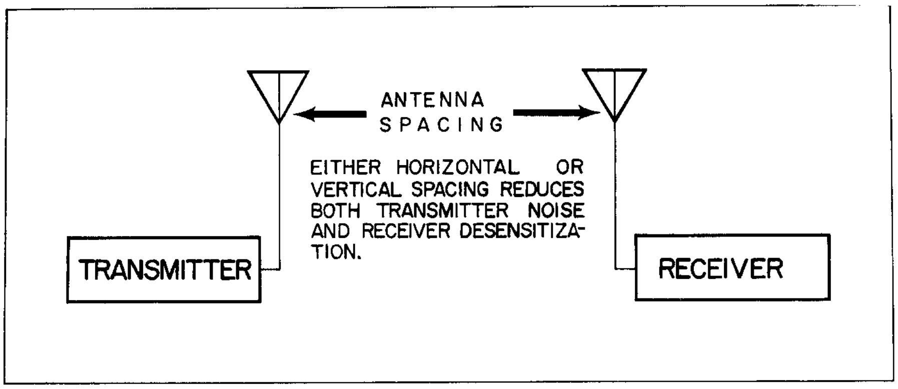


Fig. 6 - Isolation Obtained by Antenna Spacing

The attenuation obtained by increasing the spacing between the transmitting antenna and the receiving antenna will be almost identical at either 156.100 MC or 157.200 MC. That is, the attenuation at the receiver frequency will be about the same as the attenuation at the transmitter frequency. In our example, more attenuation is required to reduce transmitter noise than to reduce receiver desensitization. Therefore, if we have enough attenuation for transmitter noise, there will be more than enough attenuation for receiver desensitization. The required 52.5 db can be obtained with 25 feet of vertical spacing (from Figure 10).

The antenna-spacing attenuation curves (Figures 10 and 11) are based on the use of half-wave dipole (unity-gain) antennas. For vertically spaced gain antennas, Figure 10 will give acceptable results if the spacing is measured between the antenna centers and if one antenna is mounted directly above the other with no horizontal offset. No correction is required for the antenna gains.

Figure 11 will give acceptable results for gain antennas at horizontal spacings in excess of 50 feet if the indicated isolation is decreased by the sum of the antenna gains. For horizontal spacing of gain antennas by less than 50 feet, each individual installation should be measured or the antenna manufacturer should be contacted for specific data.

Method 2: Obtaining Attenuation by Cavity Filters or Duplexers

It is sometimes desirable to use a common antenna for the transmitter and the receiver. To do this, cavity filters or duplexers (multiple-cavity filters) must be used to obtain isolation between the units (Figure 7). The transmitter output cavity (tuned to the transmitter frequency) reduces only transmitter noise, and the receiver input cavity (tuned to the receiver frequency) reduces only receiver desensitization. More than one cavity may be required in each leg of the transmission line to obtain adequate attenuation. Remember that it is usually better to use two or more cavities with low-loss loops than to use a single cavity with high-loss loops, because greater interference attenuation can be obtained for the same loss of desired signal.

Using Method 2, we do not have the loss of the transmission lines to contribute attenuation between the transmitter and the receiver. Therefore, step 7 would be left blank and the totals in step 9 would be 44.5 db and 53.5 db, 1 db higher than for Method 1. These values are entered in step 13.

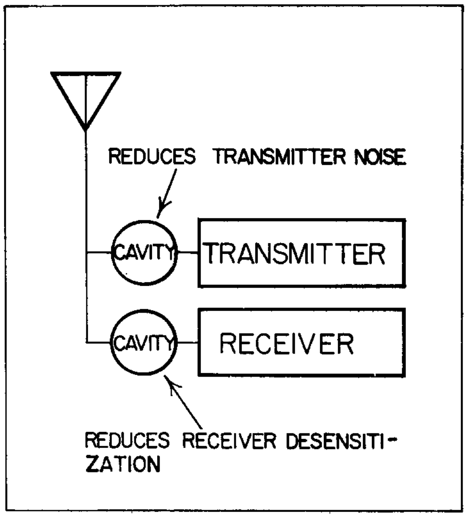


Figure 7 - Isolation Obtained by Cavities

Attenuation curves for 148-174 MC Cavity Filter KY-5-A are included in DATAFILE Bulletin 10007-7. In our example, two of these cavities (one with 1/2-db loops and one with 1-db loops) in the receiver input will provide sufficient attenuation (47.5 db) to prevent excessive receiver desensitization. Two transmitter output cavities with 1-db loops will provide sufficient attenuation (55 db) to prevent excessive transmitter noise. The extra attenuation will contribute to improved intelligibility and talk-back range.

Method 3: Obtaining Attenuation by Both Antenna Spacing & Cavities

It may not always be feasible to obtain all of the necessary attenuation by antenna spacing. Cavity filters will then prove useful. (See Figure 8). As in Method 2, the transmitter output cavity (tuned to the transmitter frequency) reduces only transmitter noise, and the receiver input cavity (tuned to the receiver frequency) reduces only receiver desensitization. More than one cavity may be required in each transmission line to obtain adequate attenuation. Remember that it is usually better to use two or more cavities with low-loss loops than to use a single cavity with high-loss loops, because greater interference attenuation can be obtained for the same loss of desired signal.

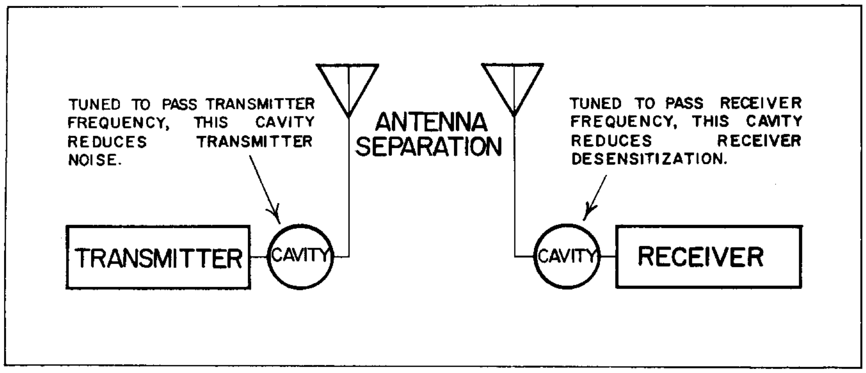


Figure 8 - Isolation Obtained by Antenna Spacing and Cavity Filters

In our example, we have 90 feet of horizontal spacing available. Figure 11 indicates that this will provide 41 db of attenuation, if we use half-wave dipole antennas. This means that we will need 2.5 db more attenuation to reduce receiver desensitization and 11.5 db more to reduce transmitter noise. A single receiver input cavity (Type KY-5-A) with 1/2-db loops and a single transmitter output cavity (Type KY-5-A) with 1/2-db loops will provide more than sufficient attenuation (20 db) in both cases. The margin of attenuation will provide a significant improvement in intelligibility and talk-back range.

DATAFILE

DUPLEX OPERATION CALCULATION FORM 10007-5

Use DATAFILE Bul. 10007-4 as a guide when making duplex operation calculations.

DESCRIPTION OF TRANSMITTER AND RECEIVER

1. Transmitter ...	Output Power 32 watts	Operating Frequency 156.1	MC
2. Receiver	Effective 12-db SINAD sensitivity 0.4 µv	Operating Frequency 157.2	MC
3. Subtract to find separation between transmitter and receiver frequencies		1.1	MC

DETERMINING THE REQUIRED AMOUNT OF ATTENUATION

For the frequency separation found in step 3, use the appropriate duplex operation curves to find the amount of attenuation required to prevent excessive degradation of desired signals by ....

	RECEIVER DESENSITIZATION	TRANSMITTER NOISE
4. Attenuation required for frequency separation found in step 3	42.5 db	51.5 db
5. Correction for receiver sensitivity (±)	+ 2 db	+ 2 db
6. Correction for transmitter power output (±)	− 4 db	− 4 db
7. Sum of transmission line losses (if separate antennas are used)	− 1 db	− 1 db
8. For 2-db effective power loss add 4—6 db; for approx 1-db loss add 6—12 db..	+ 4 db	+ 4 db
9. Total attenuation required	43.5 db	52.5 db

This is the amount of attenuation which must be obtained between the transmitter output and the receiver input (by one of the 3 following methods) to prevent excessive degradation of desired signals.

METHOD 1: OBTAINING ATTENUATION BY ANTENNA SPACING ALONE

10. Type of antenna spacing to be used ..... Vertical ☑ ..... Horizontal ☐

11. Maximum attenuation required to prevent excessive degradation of desired signals (from step 9) .... 52.5 db

12. Refer to the appropriate antenna-spacing attenuation curve (Figure 10 or 11 in Bulletin 10007-4) and determine how many feet of antenna spacing will be needed to obtain the required amount of attenuation in step 11* .... 25 feet

METHOD 2: OBTAINING ATTENUATION BY CAVITY FILTERS (COMMON ANTENNA)

	TO PREVENT EXCESSIVE RCVR DESENSITIZATION	TO PREVENT EXCESSIVE TRANSMITTER NOISE
13. Total attenuation required (from step 9). Do not use step 7 (transmission line losses) with Method 2.	At least 44.5 db in the rcvr input	At least 53.5 db in the xmtr output

- OVER -

14. Refer to the cavity attenuation curves and select receiver input and transmitter output cavities which will provide the attenuation found in step 13. Use the frequency separation found in step 3.

Remember that 3-db loops produce a 50% power loss, 1-db loops produce a 22% loss, and 1/2-db loops produce an 11% loss.

RCVR INPUT CAVITIES		XMTR OUTPUT CAVITIES	
Cavity with 1/2-db loops	20 db	Cavity with 1-db loops	27.5 db
Cavity with 1-db loops	27.5 db	Cavity with 1-db loops	27.5 db
Cavity with -db loops	— db	Cavity with -db loops	— db

15. Add to find the total attenuation in each column ....

Total cavity attenuation	47.5 db	Total cavity attenuation	55 db

The total attenuation of the receiver input cavities selected must equal or exceed the total attenuation required to prevent receiver desensitization (step 13). The total attenuation of the transmitter output cavities must equal or exceed the attenuation required to prevent transmitter noise (step 13).

METHOD 3: OBTAINING ATTENUATION BY BOTH ANTENNA SPACING & CAVITY FILTERS

16. Available antenna spacing: 90 feet of vertical spacing ..... [ ] horizontal spacing ... [✓]

	TO PREVENT EXCESSIVE RCVR DESENSITIZATION	TO PREVENT EXCESSIVE TRANSMITTER NOISE
17. Total attenuation required (from step 9)	At least 43.5 db in the rcvr input	At least 52.5 db in the xmtr output
18. Attenuation provided by available antenna spacing (step 16)* ...	41 db	same value → 41 db
19. Subtract step 18 from step 17	Additional atten req'd 2.5 db	Additional atten req'd 11.5 db

20. Refer to the cavity attenuation curves and select receiver input and transmitter output cavities which will provide the additional attenuation found in step 19. Use the frequency separation found in step 3.

Remember that 3-db loops produce a 50% power loss, 1-db loops produce a 22% loss, and 1/2-db loops produce an 11% loss.

RCVR INPUT CAVITIES		XMTR OUTPUT CAVITIES	
Cavity with 1/2-db loops	20 db	Cavity with 1/2-db loops	20 db
Cavity with -db loops	— db	Cavity with -db loops	— db
Cavity with -db loops	— db	Cavity with -db loops	— db

21. Add to find the total attenuation in each column ....

Total cavity attenuation	20 db	Total cavity attenuation	20 db

Both of these totals must equal or exceed the "Additional atten req'd" figures in the same columns above (step 19).

* The antenna-spacing attenuation curves provided in Bulletin 10007-4 are based on the use of unity-gain antennas or vertically-spaced gain antennas. For gain antennas spaced horizontally over 50 feet, add both antenna gains to the attenuation required in step 11 (Method 1), or subtract both gains from the attenuation provided by antenna spacing in step 18 (Method 3). For horizontal spacing of gain antennas less than 50 feet, each installation should be measured or the antenna manufacturer contacted for specific data.

TABLE II - CALCULATIONS INVOLVING TWO PRODUCT LINES

To find attenuation required for	Use duplex operation curve for
transmitter noise	the transmitter model
receiver desensitization	the receiver model

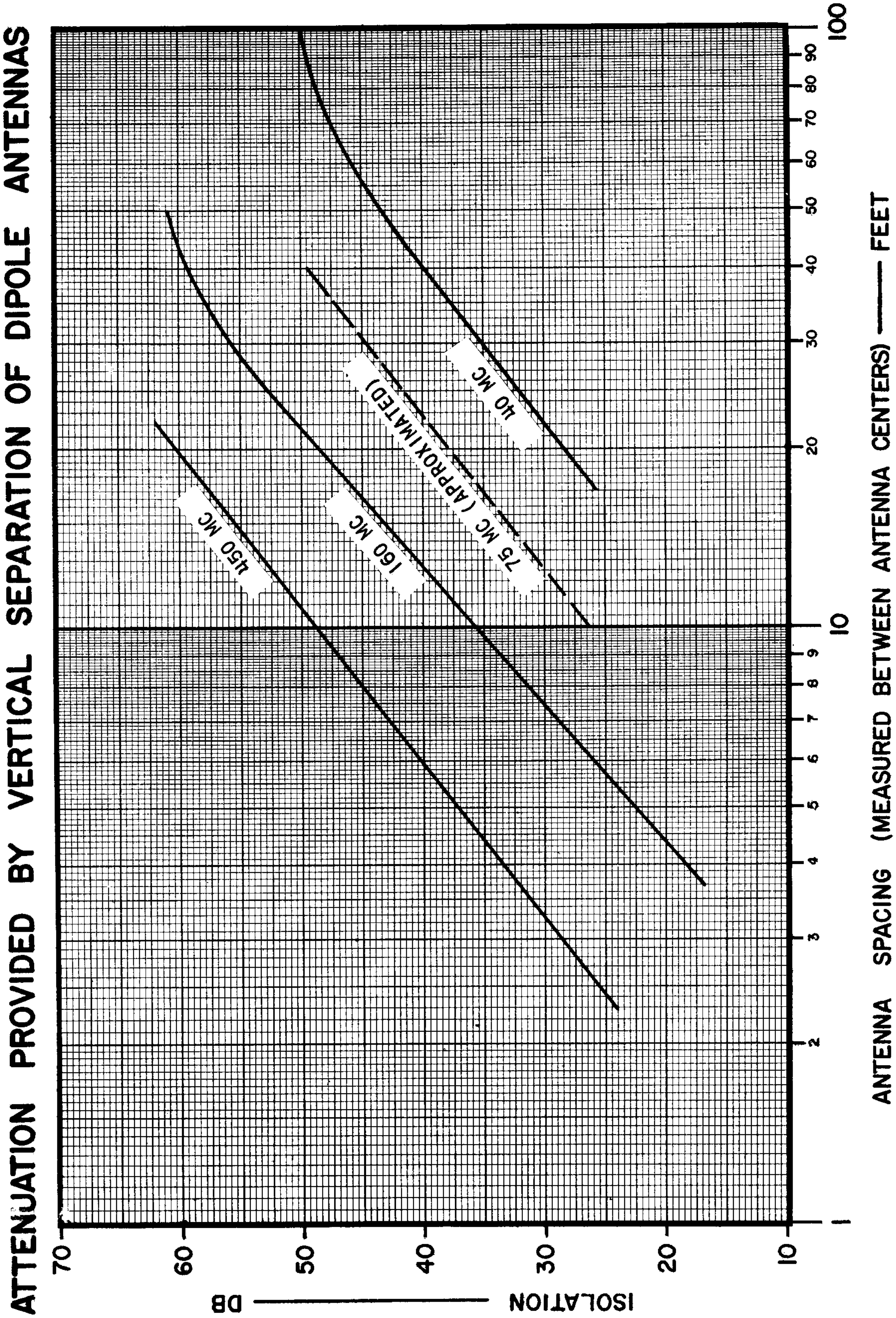
CALCULATIONS INVOLVING TWO PRODUCT LINES

Duplex operation curves are prepared for specific transmitters and receivers and should not be applied to other similar transmitters, power amplifiers or receivers --- even if a correction factor is used. Occasionally, the calculations may involve a transmitter and a receiver from different product lines --- a Progress Line transmitter and a MASTR receiver, for instance. In this case, use the transmitter noise curve for the transmitter model and the receiver desensitization curve for the receiver model.

PLANNING DUPLEX SYSTEMS

When planning a new two-way radio system, any duplex operation problems should be considered. If signal strength calculations or radio coverage calculations are based on an effective 12-db SINAD receiver sensitivity, include a 3-db power loss if only the attenuation indicated by the duplex operation curves can be obtained. Reduce this loss to 2-db if additional attenuation of 4 to 6 db (beyond that indicated by the curves) can be obtained between the receiver and the interfering transmitter. This 4 to 6 db is included in step 8 on the Duplex Operation Calculation Form (Figure 9). For an attenuation of 6 to 12 db, use a power loss of 1 db. Be sure to include the insertion losses of any necessary filters when calculating signal strengths or coverage.

It is important to remember that duplex operation curves are made at a SINAD ratio which can be accurately measured. They are not intended to represent criteria for satisfactory intelligibility. If the signal strength of some desired signals is very weak, extra attenuation should be added in step 8 of Figure 9. If the attenuation obtained by antenna spacing already exceeds the minimum required by the amount indicated in step 8, then additional attenuation will be less effective and, in many cases, unnecessary. If only a 6-db SINAD ratio desired signal can be obtained, it is wise to consider increasing the desired signal strength as well as increasing the attenuation of interfering sources. On the other hand, if desired signals are strong, the attenuation calculated from the curves is often adequate.



THESE CURVES ARE BASED UPON THE USE OF HALF-WAVE DIPOLE ANTENNAS. THEY WILL ALSO GIVE ACCEPTABLE RESULTS FOR GAIN ANTENNAS IF THE SPACING IS MEASURED BETWEEN THE PHYSICAL CENTERS OF THE ANTENNAS AND IF ONE ANTENNA IS MOUNTED DIRECTLY ABOVE THE OTHER, WITH NO HORIZONTAL OFFSET. NO CORRECTION FACTOR IS REQUIRED FOR THE ANTENNA GAINS.

CAUTION

INCREASING THE ANTENNA SPACING BEYOND THAT SHOWN BY THESE CURVES MAY NOT ALWAYS PROVIDE ADDITIONAL ISOLATION, BECAUSE OF TOWER AND TRANSMISSION LINE COUPLINGS WHICH MAY EXIST.

Figure 10

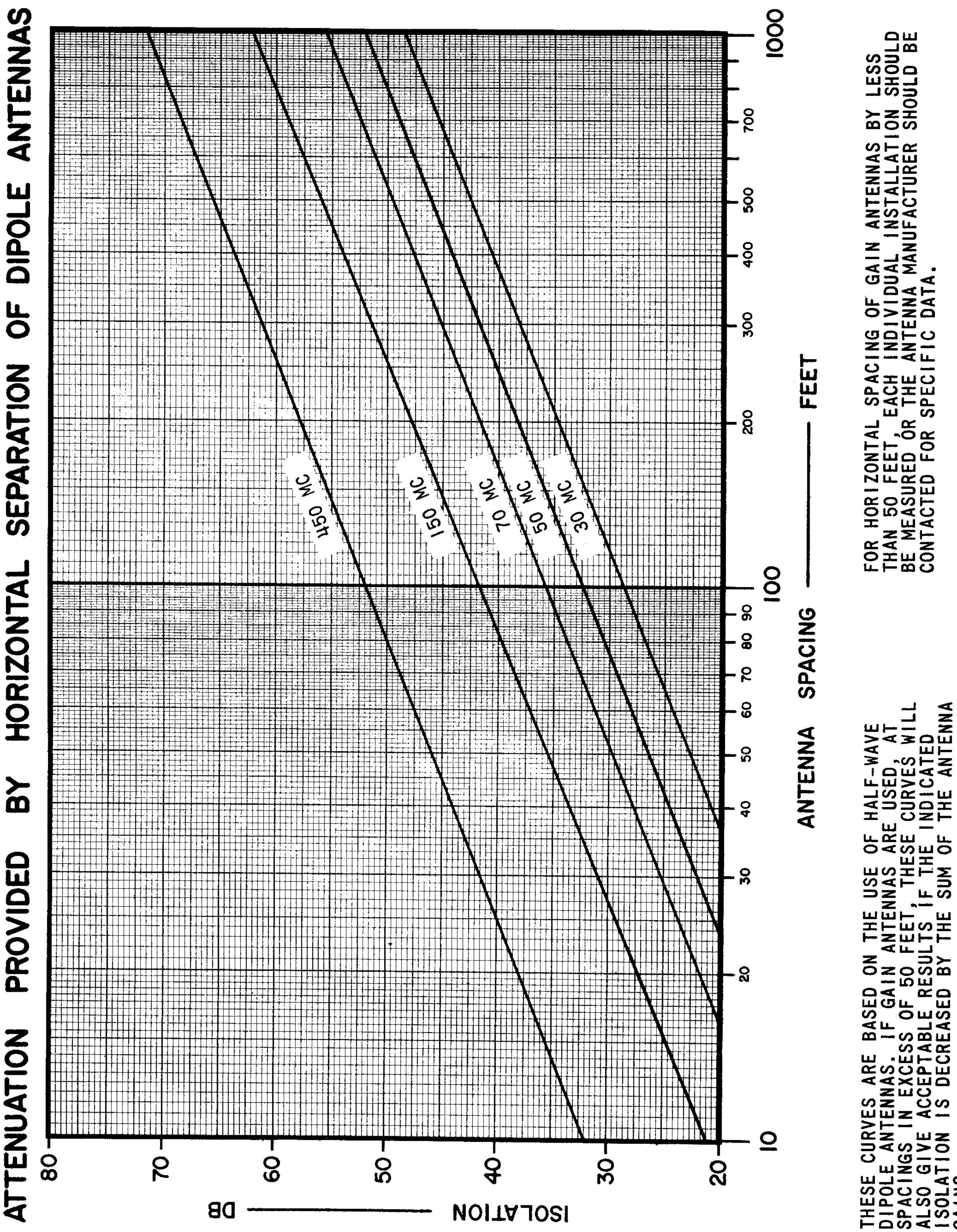


Figure 11

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