RADIO ENGINEERING
MICROWAVE RADIO
INTERFERENCE
GENERAL

1. GENERAL

1.01 When engineering microwave radio systems for the transmission of television programs or other purposes it is important to consider the possibilities of interference between a proposed installation and existing systems in order that frequencies may be chosen or other measures taken if necessary to avoid interference. This section outlines certain basic assumptions and a method of computation for use in studies of this nature.

1.02 In applying this material it should be realized that where tests of the interference to be expected can be made conveniently, these will provide a better basis for procedure than computations, since the latter at present are necessarily based on somewhat limited data.

1.03 In addition to considering interference between different systems, the methods discussed herein may be employed in multi-section systems to determine whether overreach from a transmitter may cause interference with a receiver in a later link operating at the same frequency. In this connection the methods of this section ordinarily will yield a conservative answer, since they assume that the receiver is not below the horizon from the transmitter. At times, however, atmospheric conditions have been such as to cause microwaves to travel around the curve of the earth to considerable distances, and a conservative viewpoint, therefore, appears desirable.

2. BASIC ASSUMPTIONS

2.01 This section assumes that the microwave systems in question will use highly directive antennas having the characteristics either of the shielded lens type (such as is employed in the New York-Boston radio relay system) or the parabolic reflecting type (57-inch dish) ordinarily employed with the TE system. The gain of the former is approximately 37 db and of the latter 31 db with respect to a half wave dipole. Therefore, the difference in antenna gains between the two types covered in this section is 6 db.

Note: Where Western Union systems are involved, it is assumed that they have the same directional characteristics as the 57-inch dish, and that they employ horizontal polarization. Their gain with respect to a half wave dipole, however, should be assumed to be 28 db.

2.02 If there are known to be substantial differences in transmitter output, these should be taken into account. In this connection the power output of TDX transmitters may be considered to be about +27 dbm, while TE transmitters produce from +23 dbm at 3890 mc up to +26 dbm at 4170 mc.

Note: Western Union transmitters may be assumed to produce about +20 dbm output power.

2.03 Free space transmission is assumed to apply, i.e., the received power varies inversely as the square of the distance from the transmitter (except for fading effects which are treated as discussed in the next paragraph).

2.04 Allowance must be made for differences in fading which may occur on the interfering and desired transmission paths simultaneously. The following allowances for this factor may be assumed:

(a) If the interfering and desired signals traverse entirely different paths (except as noted in "c" and "d" below).	30 db
(b) If both signals traverse nearly but not identically the same path, so that it may be assumed that fading would take place similarly on both paths.	20 db
(c) If the interfering path is short (under about ten miles) so that fading will be confined principally to the desired path.	20 db
(d) If the desired path is short (under about ten miles).	10 db
(e) If the interfering and desired paths are identical, as when the desired and the disturbing transmitting antennas are on the same rooftop. (This does not apply if they are on the same building but at substantially different levels, such as two or three floors apart.)	0 db

Note: Interpolation between the above fading allowances is permissible, keeping in mind, however, that the entire computation method is intended to provide a guide rather than to produce accurate results.

2.05 The minimum value of signal to interference ratio (S/I) which can be tolerated during fades is assumed to be 50 db.

2.06 A factor required in some cases in determining interference is the amount of frequency tolerance or drift which may be experienced in the transmitters. Assumptions for use in this connection tentatively are as follows:

(a) Transmitters in TDX systems	± 2 mc
(b) Transmitters in TE systems indoors, attended	± 2 mc
(c) Transmitters in TE systems other than (b)	± 5 mc
(d) Transmitters in Western Union systems	± 0.5 mc

3. COMPUTATION OF INTERFERENCE

3.01 In order to determine the interference likely to result between two microwave radio systems, it is necessary to know:

(1) The angle at the disturbing transmitter between the direction in which its antenna is aimed (center of the beam) and the direction of the disturbed receiver.

(2) The angle at the disturbed receiver between the direction in which its antenna is aimed (center of its beam) and the direction of the interfering transmitter.

(3) The distance from the desired transmitter to the receiver.

(4) The distance from the disturbing transmitter to the receiver.

(5) The relative antenna polarization.

3.02 The angles and distances in Items 1 to 4 above may be scaled from topographical or other suitable maps or may be computed trigonometrically by methods such as are used in surveying or navigation.

Method of Computation

3.03 Computation of signal to interference ratio (S/I) may be made conveniently on **a form similar to the one employed in the examples shown in the back of this section.**

3.04 Space is provided at the top of the form for designating the sending and receiving terminals of the radio television circuit in question, for noting the frequency being considered, and for designating the affected receiver, and the transmitter of which the interfering effects are being studied.

3.05 The center portion of the form provides space for a sketch of the geographical layout, showing the distances and angles called for in Paragraph 3.01, Items 1 to 4.

3.06 The bottom portion of the form may be used as follows:

(1) Disturbing transmitter antenna discrimination. Apply the angle called for in Paragraph 3.01, Item 1 to the directional pattern in Fig. 1 for the type of antenna used at the disturbing transmitter. Read from the curve the disturbing transmitter antenna discrimination in db and note this on the form as a favorable factor.

(2) Receiving antenna discrimination. Apply the angle of Paragraph 3.01, Item 2 to the curve in Fig. 1 corresponding to the type of antenna used at the receiver, and note the receiving antenna discrimination on the form as a favorable factor.

(3) Difference in transmission paths. From the distances of Paragraph 3.01, Items 3 and 4 determine the db difference in path loss from the desired and disturbing transmitters to the receiver. This is equal to $20 \log \frac{\text{longer path length}}{\text{shorter path length}}$. Note this (the nearest whole number of db) as favorable or unfavorable, according to whether the disturbing or the desired path is the longer.

(4) Lens vs. dish antenna gain. If the desired and disturbing antennas are of different types, note the difference in gain as 6 db favorable if the desired transmitter has a lens type antenna, and unfavorable if the lens type is associated with the disturbing transmitter.

(5) Difference in transmitter power output. Note any significant difference in output power of the desired and disturbing transmitters as favorable or unfavorable depending on which transmitter has the higher output.

(6) Fading allowance. Note as unfavorable the appropriate fading allowance as discussed in Paragraph 2.04.

(7) Effect of building shielding (if any). If a substantial portion of a building is between the disturbing transmitter and the receiver, a favorable allowance may be

made for this factor. The amount of shielding actually realized will vary with circumstances and is not accurately predictable. However, a 25 db favorable allowance probably would be reasonable in a case such as where the transmitting antenna is on the roof of a building and the receiving antenna is two or three floors lower, on the side of the building. Care should of course be taken that there are no building walls or other surfaces so located as to reflect the signals from the transmitter into the receiving antenna.

(8) Polarization allowance. Unless a polarization difference will exist for reasons other than the case under consideration, this item should be omitted in the first determination of signal to interference ratio. When it is to be considered, however, the improvement to be expected from opposite polarization of desired and disturbing signals varies with the angle of arrival of the interfering transmission at the receiving antenna. For computing purposes a favorable allowance of 20 db may be assumed for polarization, with the exception that the polarization allowance plus the receiving antenna discrimination (Item 8 plus Item 2 of this paragraph) should not total more than 50 db for a dish or 60 db for a lens type antenna.

(9) Insertion of attenuation in transmitter feed. In some cases the radio link of which the disturbing transmitter is a part may be sufficiently short that a reduced power output is permissible, thereby reducing the interfering effect on other circuits. In such a case, the appropriate allowance should be noted under Item 9 on the form as a favorable factor. If loss is to be inserted in the transmitter feed of the desired transmitter in the case under study, the factor would of course be unfavorable instead.

3.07 The favorable and unfavorable factors noted as above should be totaled, and the difference will be the net signal to interference ratio. As mentioned in Paragraph 2.05, if this is 50 db or more, interference would not be expected and the disturbing and disturbed circuits may be operated at the same frequency. Example 1 illustrates the computation of a case of this kind.

3.08 If the net S/I is less than 50 db, and conditions permit opposite polarization to be used, the improvement to be obtained thereby should be determined as in Item 8 of Paragraph 3.06 and the S/I again computed. Examples 2 and 3 involve the use of polarization.

3.09 The possibility of adding attenuation in the antenna feed of the disturbing transmitter (Paragraph 3.06, Item 9) should be considered.

3.10 If the S/I ratio determined as above is still less than 50 db, operation of the proposed system at the same frequency as existing ones probably would be unsatisfactory, at least at times, and additional consideration of the situation is required.

3.11 The simplest measure ordinarily will be choice of a different frequency of operation. The nominal spacing between adjacent channels for which TE system filters have been designed is 40 mc, and this is sufficient to permit two systems to operate over the same path without interference. In some cases, however, it may be desired to consider channels less than 40 mc apart, and for such cases the discrimination afforded by differences between the disturbing and disturbed circuit frequencies may be evaluated as outlined below.

3.12 Assume the band of frequencies radiated by a TDX or TE system to be 10 mc wide, with the energy anywhere in the band equal to that of the carrier. (For a Western Union system, assume the band to be only 6 mc wide.) Select the appropriate allowances for transmitter frequency tolerance (maximum drift or deviation from assigned frequency as tabulated in Paragraph 2.06) for the disturbing and desired transmitters. Calling these deviations d_1 and d_2 respectively, if the assigned frequencies differ by X mc, then the actual separation between the centers of the disturbing and desired frequency bands under most unfavorable conditions (i.e., both frequencies drifted a maximum amount toward each other) would become $X - d_1 - d_2$. Furthermore, under the assumption that power in the transmitter output is distributed uniformly throughout its frequency band, it is the distance from the edge of the disturbing band of frequencies to the center of the disturbed receiver pass band which must be considered, and hence another 5 mc (3 mc if the disturbing system is Western Union) must be subtracted to determine the effective separation. The discrimination against interference may now be obtained from Fig. 2 by reading the loss in the appropriate receiver IF band pass characteristic at a frequency $X - d_1 - d_2 - 5$ mc from its center. (This will be $X - d_1 - d_2 - 3$ mc for a Western Union disturbing transmitter.) This method of considering the transmitted energy as uniformly distributed over the band, and of assuming extreme frequency shifts of the transmitters toward each other, is obviously a very conservative one, and in practice the interference would be almost certain to be less than estimated on this basis. Example 4 shows the computation for a case where frequency discrimination is required.

3.13 One other factor which must be taken into account is the matter of image frequencies. These depend of course on the intermediate frequency of the receiver under consideration. At image frequencies the radio frequency suppression in the TDX or TE systems may be taken as 16 db. The Western Union advise that the image suppression in their system is at least 20 db. Image frequencies of the various systems under discussion are listed below.

3.14 If an S/I ratio of 50 db is computed to be unobtainable in a proposed layout at frequencies at which available microwave equipment can be operated, after taking into account all the possible factors for improvement discussed in this section, tests in some cases may show that the actual interference will be sufficiently less than indicated by the conservative methods of computation outlined herein that a satisfactory installation may be undertaken. If, however, computations and tests both indicate that satisfactory results cannot be obtained, it will of course be necessary to select other locations for the proposed radio installation.

TDX System		TE System		Western Union	
Channel Frequency	Image Frequency	Channel Frequency	Image Frequency	Channel Frequency	Image Frequency
3930 mc	3800 mc	3890 mc	4020 mc	4035 mc	4100 mc
3970	3840	3930	4060	4045	4110
4130	4260	3970	4100	4055	4120
4170	4300	4090	4220	4065	4130
		4130	4260	4165	4230
		4170	4300	4175	4240
				4185	4250
				4195	4260

EXAMPLE 1

FREQUENCY & INTERFERENCE DETERMINATION

Page____

Radio Television Circuit - From Yankee Stadium

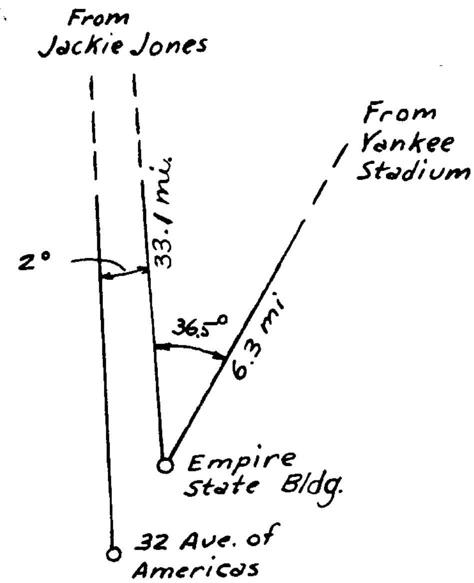
To Empire State Bldg.

Frequencies 4170 mc

Receiver Affected Empire State receiver from Yankee Stadium

Interfering Transmitter Jackie Jones TDX transmitter to New York.

The angles and distances required for the computation are as shown in the following sketch:



	Favorable	Unfavorable
1. Disturbing transmitter antenna discrimination From Fig. 1, Lens antenna 2° off beam	18 db	xxx db
2. Receiving antenna discrimination From Fig. 1, Dish antenna 36.5° off beam	35	xxx
3. Difference in transmission paths. 33.1 mile vs. 6.3 mile path (20 log (path ratio))	14	
4. Lens vs. Dish Antenna Gain		6
5. Difference in Transmitter Power Output		1
6. Fading allowance. (Desired path short)	xxx	10
7. Effect of Building Shielding (if any)		
8. Polarization allowance.		xxx
9. Insertion of attenuation in transmitter Feed.		
Total	67 db	17 db
Net Signal to Interference ratio (S/I).	50 db	

EXAMPLE 2

FREQUENCY & INTERFERENCE DETERMINATION

Page ____

Radio Television Circuit - From 32 Ave. of Americas, New York (TE)

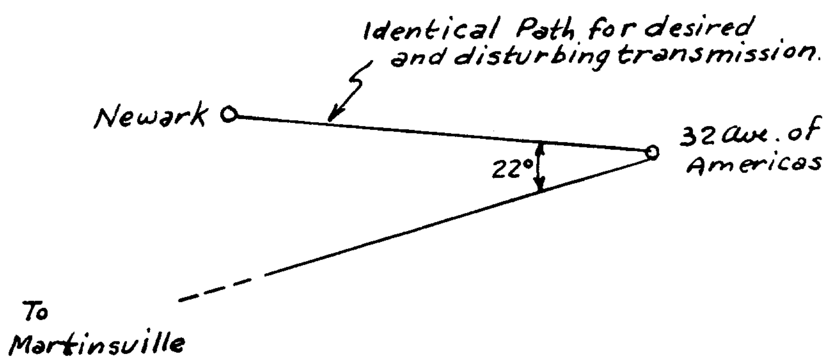
To 540 Washington St., Newark, N.J.

Frequencies 4130MC

Receiver Affected Newark

Interfering Transmitter 32 Ave. of Americas TE transmitter to Martinsville, N.J.

The angles and distances required for the computation are as shown in the following sketch:



	Favorable	Unfavorable
1. Disturbing transmitter antenna discrimination From Fig. 1, Lens antenna 22 ° off beam	38 db	xxx db
2. Receiving antenna discrimination From Fig. 1, Dish antenna 0 ° off beam	0	xxx
3. Difference in transmission paths. ____ mile vs. ____ mile path (20 log (path ratio)). . . . . . (Same path) . . .	0	0
4. Lens vs. Dish Antenna Gain		6
5. Difference in Transmitter Power Output (Both TE systems)	0	0
6. Fading allowance. . . . . (Identical Paths).	xxx	0
7. Effect of Building Shielding (if any)		
8. Polarization allowance.	20 ~~0~~	xxx
9. Insertion of attenuation in transmitter Feed.		
Total	58 ~~38~~ db	6 db
Net Signal to Interference ratio (S/I).	52 ~~32~~ db	

EXAMPLE 3

FREQUENCY & INTERFERENCE DETERMINATION

Page ______

Radio Television Circuit - From ______ B ______

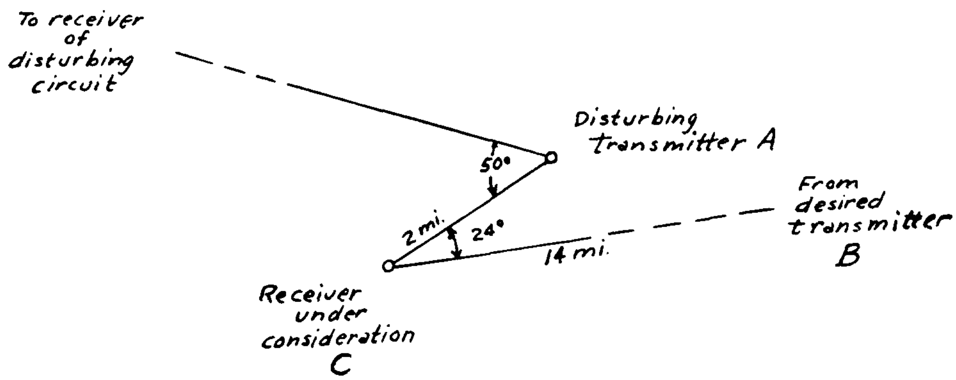
To ______ C ______

Frequencies ______ 3970 ______

Receiver Affected ______ C ______

Interfering Transmitter ______ A ______

The angles and distances required for the computation are as shown in the following sketch:



	Favorable	Unfavorable
1. Disturbing transmitter antenna discrimination From Fig. 1, Dish antenna 50° off beam	35 db	xxx db
2. Receiving antenna discrimination From Fig. 1, Dish antenna 24° off beam	34	xxx
3. Difference in transmission paths. 2 mile vs. 14 mile path (20 log (path ratio))		17
4. Lens vs. Dish Antenna Gain		
5. Difference in Transmitter Power Output		
6. Fading allowance. . . . . . (Interfering Path short) . .	xxx	20
7. Effect of Building Shielding (if any)		
8. Polarization allowance.	16 ~~0~~	xxx
9. Insertion of attenuation in transmitter Feed	2 ~~0~~	
Total	87 ~~69~~ db	37 db
Net Signal to Interference ratio (S/I).	50 ~~32~~ db	

An alternative solution might be to locate the receiving antenna at C on an offset on the side of the building away from A, if this could be so done as to obstruct effectively the path from A while still preserving an optical path from the desired transmitter at B. This would probably yield 25 db favorable allowance for building shielding, which would avoid the necessity for polarization or for insertion of attenuation in the disturbing transmitter output.

EXAMPLE 4

FREQUENCY & INTERFERENCE DETERMINATION Page ______

Radio Television Circuit - From: *Stadium A (TE - Indoors attended)*

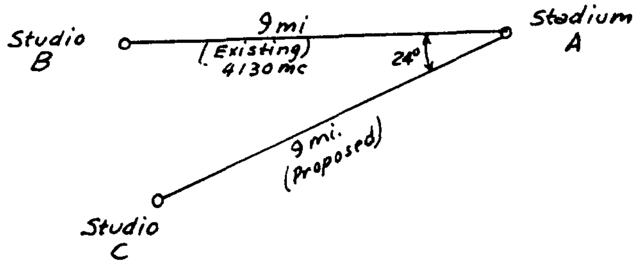
To: *Studio C*

Frequencies: *As close to 4130 mc as possible*

Receiver Affected: *C*

Interfering Transmitter: *Stadium A transmitter to Studio B (TE - Indoors - Attended)*

The angles and distances required for the computation are as shown in the following sketch:



	Favorable	Unfavorable
1. Disturbing transmitter antenna discrimination From Fig. 1, *Dish* antenna *24*° off beam	*34* db	xxx db
2. Receiving antenna discrimination From Fig. 1, *Dish* antenna *0*° off beam	*0*	xxx
3. Difference in transmission paths. ______ mile vs. ______ mile path (20 log (path ratio)) . . . . . *(Same length)*	*0*	*0*
4. Lens vs. Dish Antenna Gain		
5. Difference in Transmitter Power Output		
6. Fading allowance. . . . *(Short Desired Path)*	xxx	*10*
7. Effect of Building Shielding (if any)		
8. Polarization allowance.	*20* ~~*0*~~	xxx
9. Insertion of attenuation in transmitter Feed.		
Total	*54* ~~*34*~~ db	*10* db
Net Signal to Interference ratio (S/I).	*44* db	

Referring to the Form for Example 4, the layout is such that 6 db of frequency discrimination is required to be sure of avoiding interference from (and to) the existing service. Other circuits in existence or proposed make it desirable to use a frequency as close to 4130 as possible.

From Fig. 2, 6 db frequency discrimination due to the IF band-pass characteristic of TE systems would be realized at 11 mc from the center of the band.

Referring to the formula of Paragraph 3.12 and to Paragraph 2.06, $x - d_1 - d_2 - 5$ mc = 11 mc. $d_1 = 2$ mc, $d_2 = 2$ mc.

Therefore $x = 11 + 2 + 2 + 5 = 20$ mc = the nominal separation required.

A channel at 4110 mc would, therefore, be satisfactory, provided it would not cause interference at the image frequency of some other system, such as a 3970 mc TE system (image = 4100 mc) or a Western Union system operating at 4045 mc (image = 4110 mc).

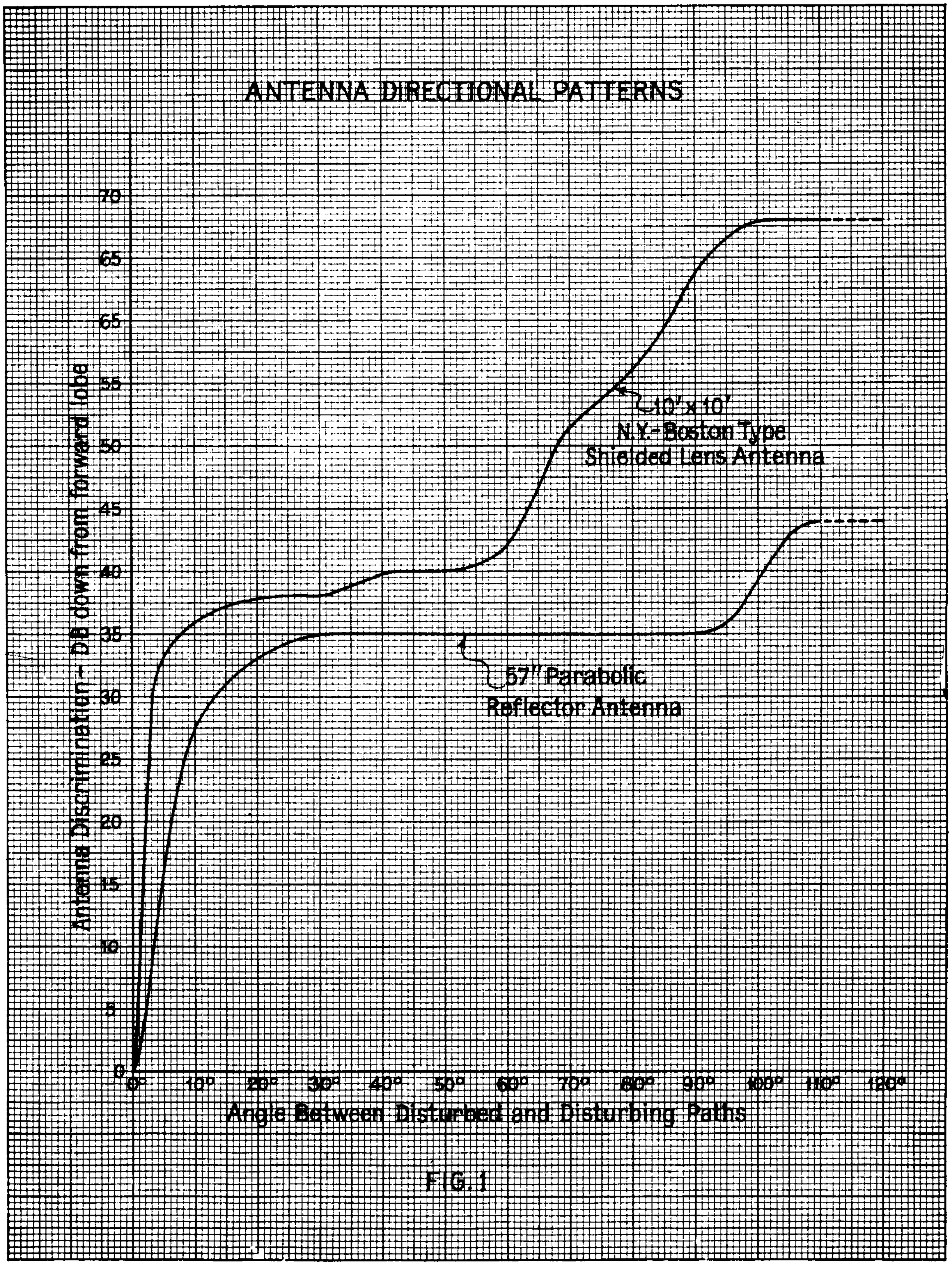


Fig. 1 – Antenna Directional Patterns

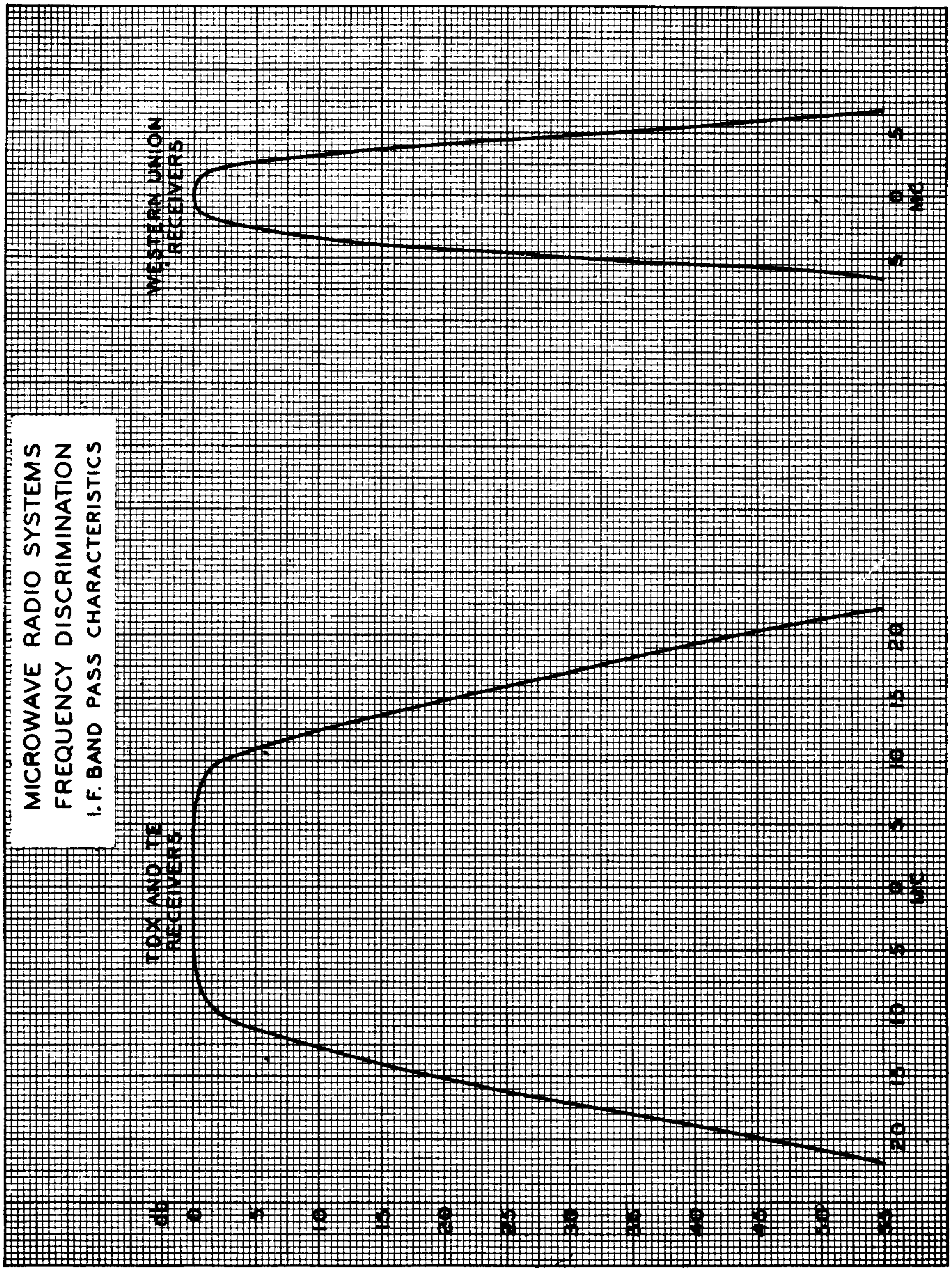


Fig. 2 – IF Band Pass Characteristics