ESD-TR-70-130

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DEPARTMENT OF DEFENSE

ELECTROMAGNETIC COMPATIBILITY ANALYSIS CENTER

INTERFERENCE PREDICTION GUIDELINES FOR VHF NON-TACTICAL FM COMMUNICATIONS

Prepared by G. Morgan of the IIT Research Institute

May 1970

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Technical Report

No. ESD-TR-70-130

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Published by
Electromagnetic Compatibility Analysis Center
North Severn
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FOREWORD

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This report was prepared as part of AF Project 649E under Contract F-19628-69-C-0073 by the staff of the IIT Research Institute at the Department of Defense Electromagnetic Compatibility Analysis Center.

To the extent possible, all abbreviations and symbols used in this report are taken from American Standard Y10.19 (1967) "Units Used in Electrical Science and Electrical Engineering" issued by the United States of America Standards Institute.

Users of this report are invited to submit comments which would be useful in revising or adding to this material to the Director, ECAC, North Severn, Annapolis, Maryland 21402, Attention ACX.

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ABSTRACT

This technical report presents guidelines which may be used for the prediction of interference effects between collocated VHF non-tactical FM equipments. Pertinent technical characteristics and interference susceptibility levels representative of this type of equipment are included.

The interference mechanisms discussed include cochannel and adjacent channel effects and non-linear interactions due to spurious receiver responses, and transmitter and receiver intermodulation interference. Sample problems are set forth and solved to illustrate the step by step procedure for prediction of each type of interference phenomenon considered, and the equipment modifications required to prevent degradation.

KEYWORDS

ANALYSIS
DEGRADATION
INTERFERENCE
VHF COMMUNICATIONS
TWO-WAY COMMUNICATIONS
NON-TACTICAL COMMUNICATIONS

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INTRODUCTION

A recently completed project at the Electromagnetic Compatibility Analysis Center (ECAC) required an investigation of the expected effects resulting from the addition of four new two-way VHF non-tactical communication terminals into a site containing 21 existing terminals. The total number of operating frequencies which needed to be considered in this cosite analysis was 27. Each of the terminals consisted of commercial VHF two-way FM base-station equipment such as that manufactured by Motorola, General Electric, Comco, and others.

In addition to the usual interference prediction type of output, a second requirement of the project was a set of technical guidelines which could be used by field-level personnel to determine the expected effects of any additional terminals of the same type which might be proposed for installation at the site in the future. Because of the similarities in the design and performance of this type of equipment, regardless of its commercial source, a set of generalized guidelines based on representative equipment characteristics was a feasible endeavor.

After completion of the project, it became apparent that such a set of guidelines could also be useful at ECAC. It was decided, therefore, to prepare a separate version of the guidelines and publish them in a technical report. Although the specific equipment characteristics contained herein are applicable only to the commercial type equipments used for FM non-tactical VHF voice communications, the methodology described is pertinent to any cosite analysis, regardless of the equipments employed at the site.

Accordingly, this technical report contains guidelines describing an approach to the prediction of cosite interference between VHF non-tactical equipments. The interference mechanisms discussed in this report include cochannel and adjacent channel interactions, and nonlinear effects due to spurious receiver responses and transmitter and receiver intermodulation. The presentation for each interference phenomenon contains a step-by-step method for predicting its occurrence, severity, and required corrective equipment modification. Each step-by-step method is followed by an example problem which illustrates the steps involved.

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SECTION 2

INTERFERENCE PREDICTION GUIDELINES

This section sets forth guidelines which may be used to determine whether proposed VHF installations will result in potentially degrading interference. It should be emphasized that these guidelines are applicable only to installations operating with commercial VHF two-way voice equipment, or the military equivalent. Virtually all non-tactical communications operations employ this class of equipment.

INTERFERENCE EXPRESSION

Potential interference will occur when the following equation is satisfied:

$$P_r - P_S = P_T - C_e - L_f - P_S \geqslant 0 \quad (2\text{-}1)$$

where

P_r = the undesired power delivered to the terminals of the desired receiver in dBm.

P_S = the susceptibility threshold of the receiver in dBm for the interference mechanism being considered.

P_T = the power of the undesired transmitter in dBm.

C_e = the effective coupling loss between the undesired transmitter and the desired receiver in dB.

L_f = the off-frequency rejection of any external RF devices, such as cavities, in dB.

The power of the undesired transmitter, P_T, is readily available. However, it is usually expressed in watts rather than decibels relative to 1 milliwatt. The conversion is done with equation 2-2:

$$P_{T(dBm)} = 10 \log P_{T(watts)} + 30 \quad (2\text{-}2)$$

EFFECTIVE COUPLING LOSS

The effective coupling loss in dB is obtained from equation 2-3:

$$C_e = -(G_{Te} + G_{Re}) + L_P + L_{ST} + L_{SR} \text{ dB} \qquad (2\text{-}3)$$

where

C_e = the effective coupling loss in dB.

G_{Te} = the antenna gain in dB, relative to an isotropic radiator, of the transmitting antenna in the direction of the receiving antenna.

G_{Re} = the antenna gain in dB, relative to an isotropic radiator, of the receiving antenna in the direction of the transmitting antenna.

L_P = propagation loss in dB between isotropic radiators.

L_{ST} = attenuation in dB due to the coupling devices and transmission lines associated with the transmitter.

L_{SR} = attenuation in dB associated with the coupling devices and transmission lines associated with the receiver.

Effective Antenna Gains

The antenna gains in the direction of maximum radiation are normally specified by the manufacturer. It should be noted, however, that the value specified is usually related to a half-wave dipole, rather than an isotropic radiator. The specified gain should therefore be increased by 2.2 dB to reflect the gain of the antenna relative to an isotrope. Thus:

$$G_{Ti}, G_{Ri} = (G_{Td}, G_{Rd}) + 2.2 \text{ dB}, \qquad (2\text{-}4)$$

where the subscripts i and d represent an isotrope and a half-wave dipole respectively.

The value obtained from equation 2-4 is not necessarily the value to be used in equation 2-3. It is merely the gain of the antenna relative to an isotrope in the direction of maximum radiation. The effective gain in some other direction is determined by the directional properties of the antenna under consideration. Since an isotropic radiator does not exist in the practical world, all antennas exhibit directional properties in either the horizontal plane or the vertical plane. Most of the base station antennas used for nontactical VHF communications are omnidirectional in the horizontal plane but are directional in the vertical plane. For example, consider Figure 2-1. This illustrates the relative vertical field strength pattern of a Communications Products Type 200-509 base station antenna. This antenna is omnidirectional in the horizontal plane and has a horizontal gain of 8 dB relative to an isotrope in the direction of the horizon. However, note that at an angle of 10 degrees above the horizon, the field intensity from this antenna is only 62 percent of that at the horizon. Then the effective gain at 10° is (8 dB − 20 log 1/0.62), which is equal to 4 dB.

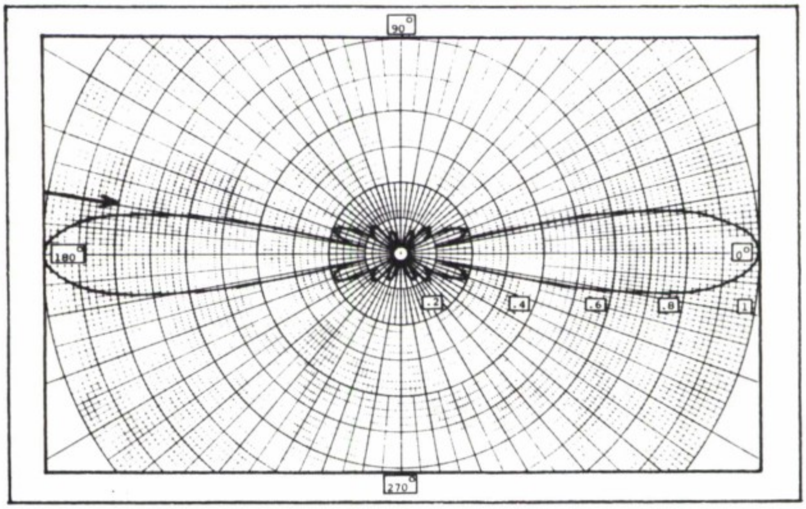


Figure 2-1. Vertical Field Strength Pattern of Communications Products Type 200-509 Antenna (Extracted from Reference 1)

The appropriate vertical angle to be used in determining the effective antenna gain is obtained from the geometry of the site and installations. For virtually all intrasite considerations:

$$\theta = \pm \text{ arc tan} \frac{h_1 - h_2}{d_H} \text{ degrees} \tag{2-5}$$

where

θ = the vertical angle in degrees between antenna 1 and antenna 2.

h_1 = the height of the center of antenna 1 in feet.

h_2 = the height of the center of antenna 2 in feet.

d_H = the horizontal distance between the supporting structures for antennas 1 and 2 in feet.

The directional radiation patterns for antennas used in this service are generally contained in the manufacturer's catalogs.

Propagation Loss

The propagation loss model used in expression 2-3 is the free-space loss equation:

$$L_P = 20 \log f_{MHz} + 20 \log d_{ft} - 38 \quad (2\text{-}6)$$

where

L_P = the propagation loss in dB between isotropic radiators.

f_{MHz} = the transmitted frequency in MHz.

d_{ft} = the distance between the respective antenna centers in feet.

Note that the distance specified in equation 2-6 is the slant distance between the antenna centers and not the horizontal distance between the supporting structures. If there is a significant vertical separation between the antennas, a slight error could result from the use of the horizontal distance above. When this is the case:

$$d_s = [d_H^2 + (h_1 - h_2)^2]^{1/2} \quad (2\text{-}7)$$

where

d_s = the slant distance in feet.

d_H = the horizontal distance between the supporting towers in feet.

h_1 = the height of the center of antenna 1 in feet.

h_2 = the height of the center of antenna 2 in feet.

The value of propagation loss obtained from equation 2-6 will be representative for intrasite considerations but is expected to be slightly conservative for intersite considerations. A chart showing the free-space propagation loss versus separation distance is shown in Figure 2-2 for an operating frequency of 150 MHz. The variation of the free-space loss over the entire nontactical VHF band from the value shown is approximately 1 dB.

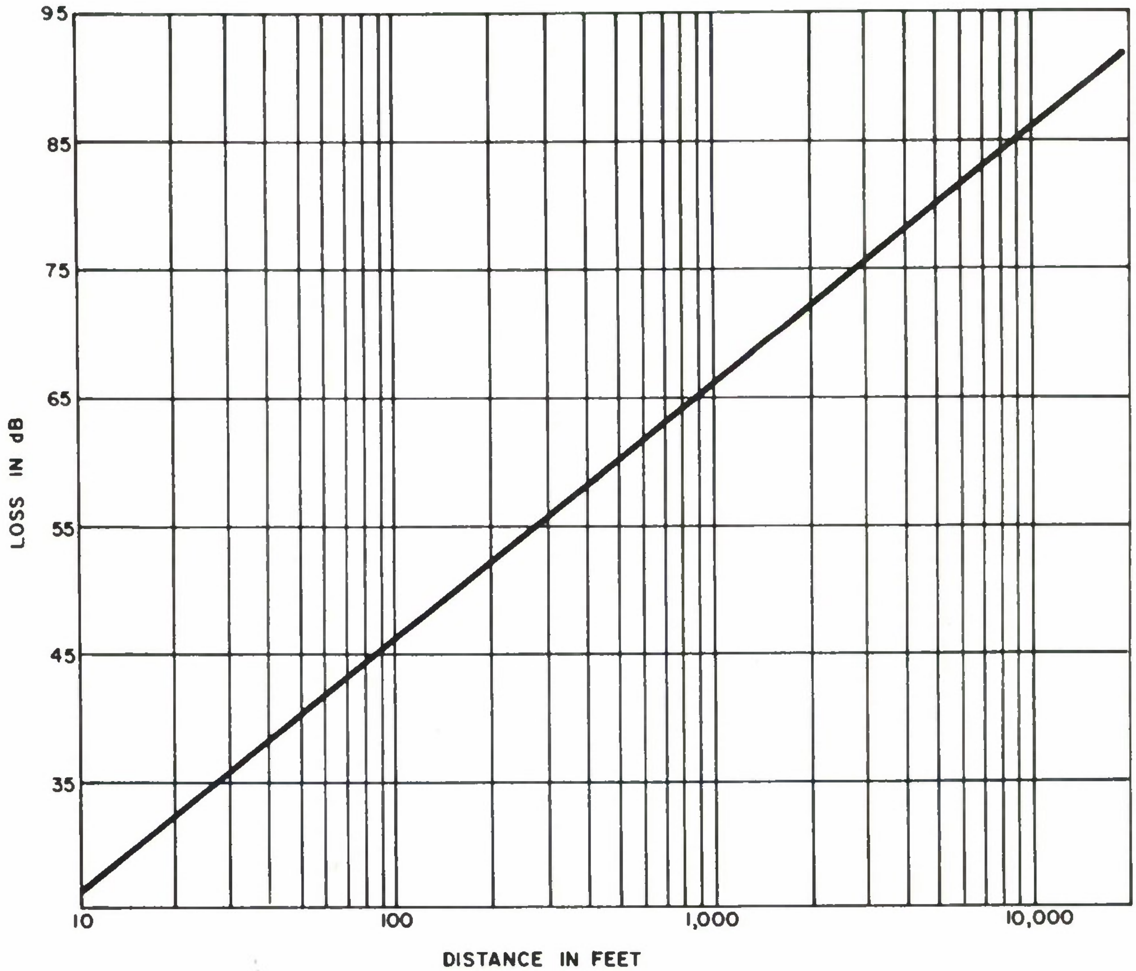


Figure 2-2. Free-Space Loss Versus Distance at 150 MHz

Transmission Line Losses

The additional coupling losses due to attenuation in the transmission lines associated with the transmitter or receiver can usually be obtained from data supplied by the manufacturer of the transmission lines. This information is usually stated as attenuation in dB per 100 feet in length. These losses are, however, generally quite minimal and can usually be ignored in the interest of conservatism.

Sample Calculation

The following problem will illustrate the procedure for determining effective coupling loss:

Determine the effective coupling loss between two Communications Products Type 200-509 antennas which are installed as shown in Figure 2-3.

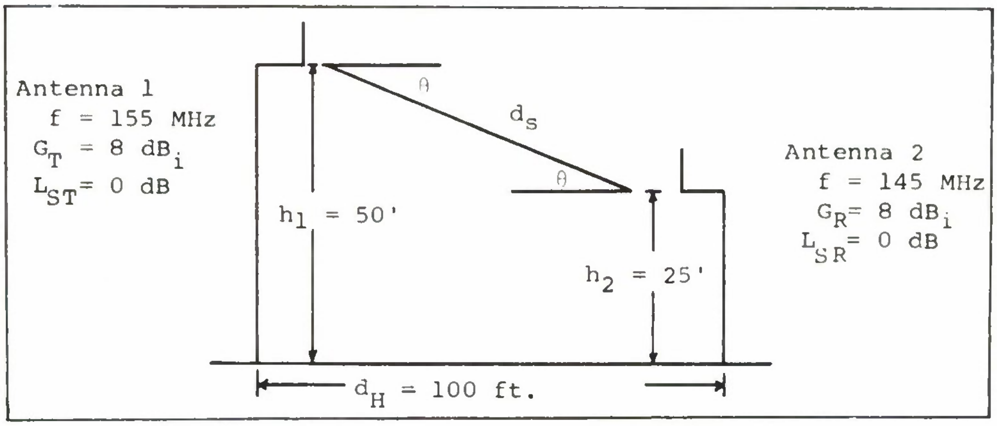


Figure 2-3. Sample Antenna Installation

Step 1. Determine the slant distance, d_s (equation 2-7).

$$d_s = [d_H^2 + (h_1 - h_2)^2]^{1/2} = [100^2 + 25^2]^{1/2} = 103'$$

Step 2. Determine L_P (Figure 2-2) for 103'.

$$L_P = 46 \text{ dB}$$

Step 3. Determine θ (equation 2-5).

$$\tan \theta = \frac{h_1 - h_2}{d_H} = \frac{25}{100} ; \theta = 14°$$

Step 4. Determine G_{Te} (Figure 2-1).

$$G_{Te} = 8 - 20 \log 1/0.2 = -6 \text{ dB}_i$$

Determine $G_{Re} = G_{Te} = -6 \text{ dB}_i$

Step 5. Determine C_e (equation 2-3).

$$C_e = -(G_{Te} + G_{Re}) + L_P + L_{ST} + L_{SR}$$

$$C_e = -(-6\ dB_i - 6\ dB_i) + 46\ dB + 0 + 0 = 58\ dB$$

Effective Coupling Matrix

A convenient method for presenting the effective coupling losses between a large number of antennas is to prepare a matrix containing the loss between each antenna at the site. A matrix of intrasite coupling losses has been prepared for a sample site and is presented in Figure 2-4.

ATTENUATION OF RF FILTERING DEVICES

Additional attenuation of undesired signals can be obtained through the use of frequency selective circuits between the transmitter or receiver and its associated antenna. Two types of devices are commercially available for this type of application: cavity resonators and crystal filters.

Cavity resonators can be used with either a transmitter or receiver to increase the RF selectivity of the terminal. Cavities are usually supplied with three sets of loops. They are identified as 0.5 dB, 1 dB, or 3 dB loops and the identifier refers to the amount of attenuation offered to the desired signal. A cavity which offers a higher attenuation to the desired signal will also offer greater rejection to off-frequency undesired signals. However, the higher desired signal attenuations also tend to reduce the effective range of the communications link. Because of this factor, it is sometimes more operationally desirable to obtain added selectivity by using multiple low-loss cavities rather than a single higher loss cavity.

Crystal filters can be used only with receivers because of a one watt input power limitation, but they have a higher rejection to closely spaced, undesired frequencies than do cavities. However, in an area containing many transmitters on closely adjacent frequencies, it would probably be necessary to use a cavity as well as a crystal filter to insure that the power rating of the crystal filter was not exceeded. In addition, a crystal filter can have as much as a 6 dB insertion loss, which is an undesirable feature.

Figure 2-5 illustrates the additional attenuation which can be realized from typical cavity and crystal filters. For multiple units, the loss values shown should be multiplied by the number of units.

	N1	N2	N3	A1	A2	A4	A5	A6	AF-5-T	AF-5-R	AF-6-T	AF-6-R	AEC-1	AEC-2	AEC-3	AEC-4	AEC-5
NAVY 1 141.0 MHz	--	69	69	38	64	54	54	41	41	71	41	71	38	52	37	38	40
NAVY 2 138.6 MHz		--	0	58	66	59	58	46	57	71	57	71	38	53	37	39	40
NAVY 3 140.46 MHz			--	58	66	59	58	46	57	71	57	71	38	53	37	39	40
ARMY 1 139.035 MHz				--	62	37	37	40	56	78	56	78	29	50	30	32	34
ARMY 2 148.77 MHz					--	20	21	46	69	79	69	79	33	66	35	36	38
ARMY 4 143.98 MHz						--	7	26	41	59	41	59	28	61	32	33	32
ARMY 5 139.095 MHz							--	26	44	58	44	58	28	62	32	33	33
ARMY 6 149.595 MHz								--	32	36	32	36	28	63	40	37	29
AF-5-T 150.315 MHz									--	51	16	51	40	48	33	34	36
AF-5-R 163.5875 MHz										--	51	16	38	61	37	35	38
AF-6-T 148.485 MHz											--	51	40	48	33	34	36
AF-6-R 149.505 MHz												--	38	61	37	35	38
AEC-1 166.275 MHz													--	50	34	26	27
AEC-2 168.0 MHz														--	33	23	25
AEC-3 173.7125 MHz															--	16	26
AEC-4 170.75 MHz																--	23
AEC-5 163.075 MHz																	--

Figure 2-4. Representative VHF Intrasite Coupling Losses in dB

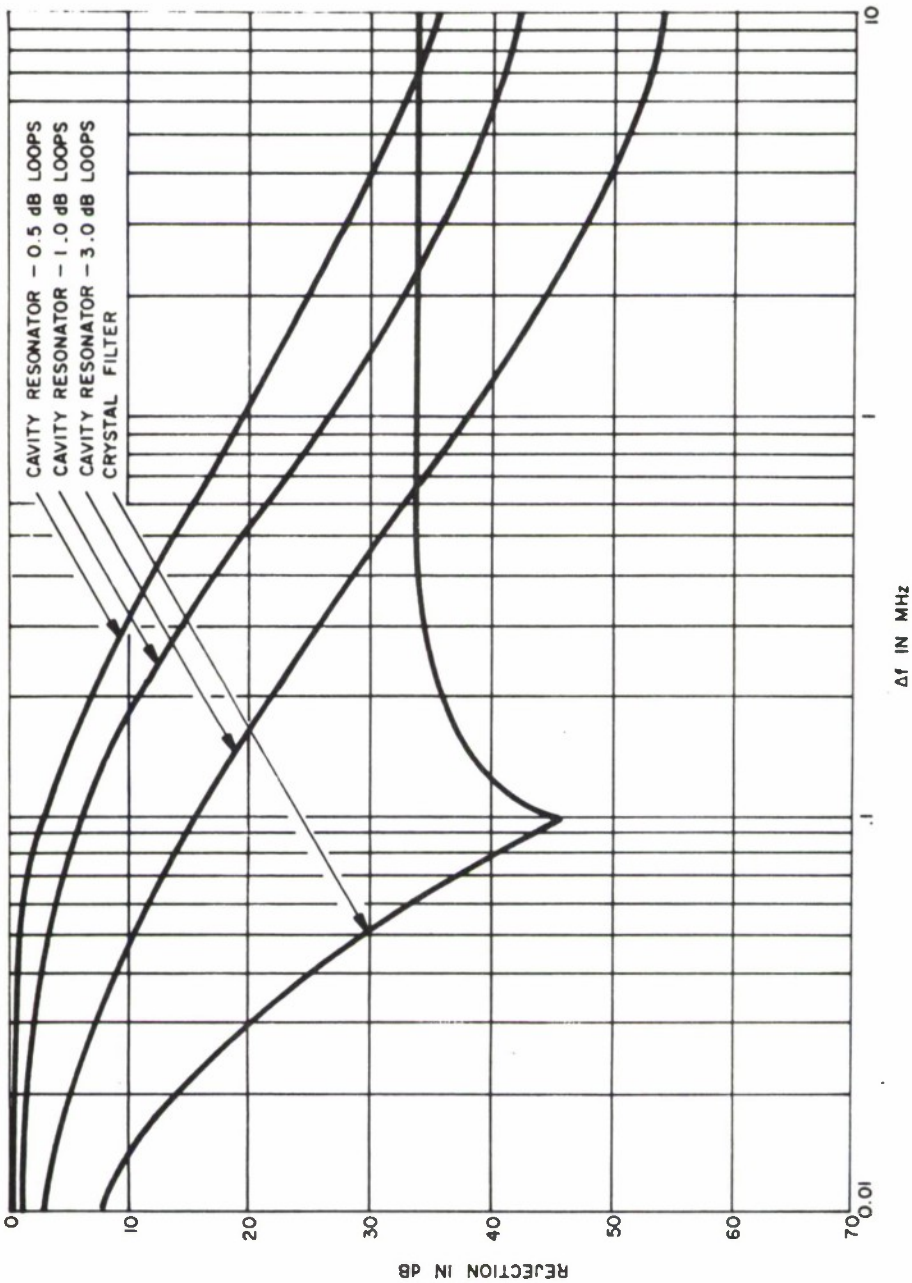


Figure 2-5. Selectivity Characteristics of RF Filtering Devices

VHF RECEIVER INTERFERENCE SUSCEPTIBILITY

In this section, the susceptibility of typical VHF nontactical FM voice receivers to different interference mechanisms is defined. The term interference, as used herein, refers to degrading interference as differentiated from nuisance interference.

Degrading interference to these receivers is considered to exist by the Electronic Industries Association (EIA) when the undesired signal reduces a desired 12 dB signal-plus-noise-plus-distortion to noise-plus-distortion (SINAD) ratio to 6 dB. This corresponds to an equivalent loss in the desired signal power of 3 dB.

The interference mechanisms treated are cochannel, adjacent channel, spurious receiver responses, transmitter intermodulation products and receiver intermodulation products.

COCHANNEL INTERFERENCE

As used in this report, cochannel interference is considered to occur as a result of emissions from an undesired transmitter which fall within the passband of a desired receiver when the effective coupling loss between the two equipments is not sufficient. These undesired emissions may consist of the normal modulation envelope, spurious emissions, or wideband transmitter noise, but do not include intermodulation products.

A typical example of the measured output spectrum of a VHF nontactical two-way FM transmitter is shown in Figure 2-6 (see Reference 2). The curve sloping in a downward direction from left to right represents the amplitude of the output spectrum relative to the level of the unmodulated RF carrier. The dashed line shows the additional attenuation realized when a 1 dB cavity is installed at the output of the transmitter.

The curve sloping upward from left to right shows the effective coupling loss required to prevent an undesired 60 watt transmitter from degrading the operation of a desired 0.5 microvolt receiver. In this instance, the dashed line shows the effect of adding the 1 dB cavity to the output of the transmitter. In other words, the required coupling loss curve is a frequency-dependent solution to equation 2-1 for cochannel interference. All that remains for the final solution is a determination of the frequency separation of the equipments involved. It should be noted, however, that if the undesired transmitter has an output power of 120 watts, an additional 3 dB of coupling loss would be required to preclude degradation.

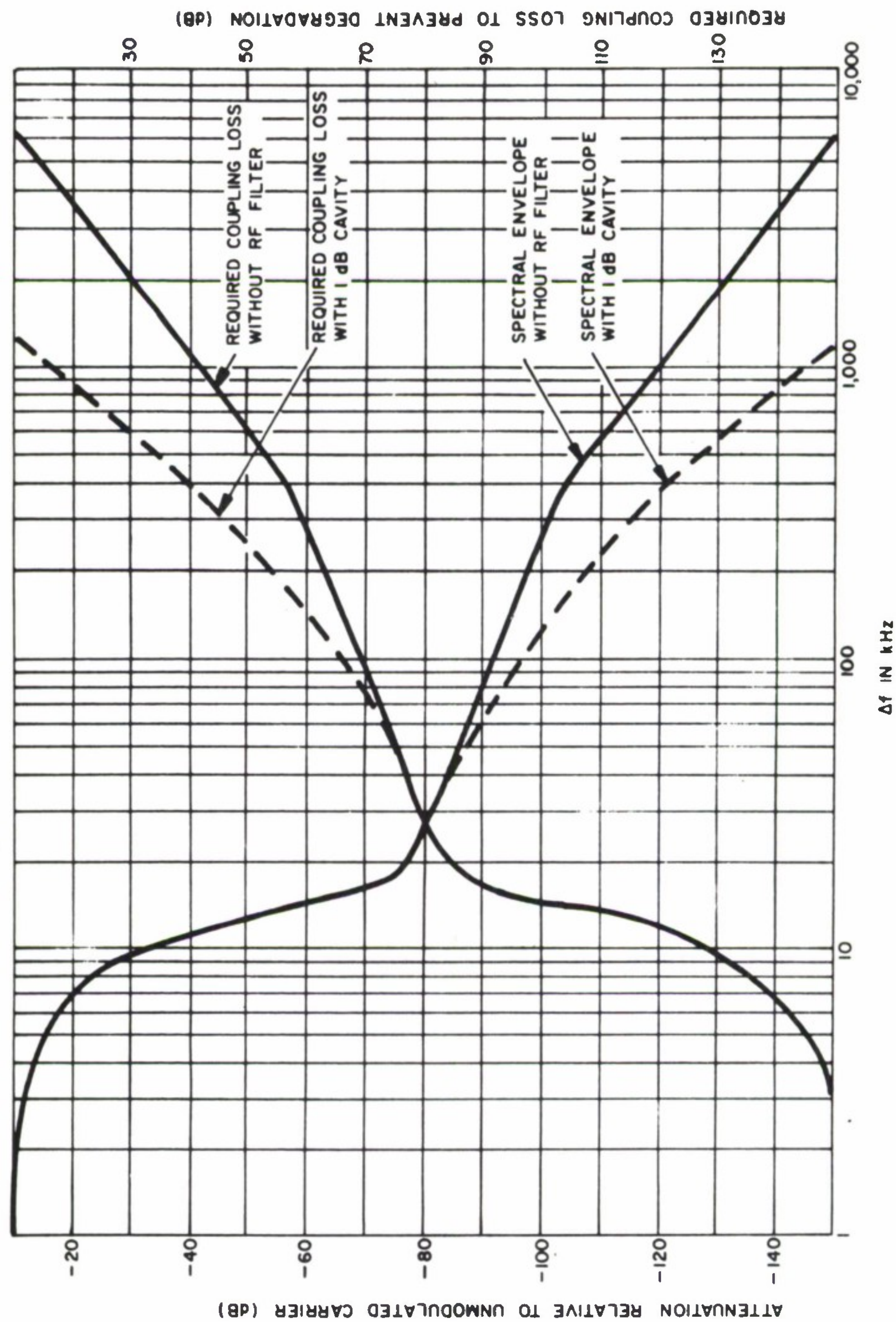


Figure 2-6. Measured Output Spectrum of VHF Nontactical FM Transmitter

Sample Calculation

The following problem will illustrate the use of Figure 2-6 for the prediction of cochannel interference

Determine whether a 60 watt transmitter operating on 139.095 MHz band will degrade a 0.5 microvolt receiver operating on 139.035 MHz due to cochannel interference. No external RF filtering is used on either equipment.

Step 1. Determine the frequency separation.

Transmitter frequency: 139.095 MHz
Receiver frequency: 139.035 MHz
Frequency separation: 0.06 MHz = 60 kHz

Step 2. Determine the required coupling loss.

Since there is no cavity on the 60-watt transmitter, the required loss is obtained from the solid line in Figure 2-6.

Required loss = 74 dB

Step 3. Determine the actual coupling loss.

From Figure 2-4: Army 1 to Army 5, Loss = 37 dB

Step 4. Determine additional loss required.

Additional required loss = 74 − 37 = 37 dB

Step 5. Determine required transmitter filtering to preclude degradation.

From Figure 2-5: 37 dB = 3 (3 dB cavity) + 1 (1 dB cavity)
= 3 (11 dB) + 1 (4 dB) = 37 dB

Thus, four cavities would have to be added to the circuit 5 transmitter to preclude excessive degradation: three 3 dB cavities and one 1 dB cavity. However, the overall insertion loss to the transmitted signal would be 10 dB, which is equivalent to a reduction in the output power of the transmitter from 60 watts to 6 watts.

ADJACENT CHANNEL INTERFERENCE

Adjacent channel interference occurs when a strong undesired signal is incident on a receiver at a frequency which is near to the desired frequency but not within the receiver passband and the frequency rejection characteristics of the receiver are inadequate to preclude degradation.

A typical example of the measured selectivity curve of a VHF two-way FM receiver is shown in Figure 2-7 (see Reference 3). The curves sloping downward from left to right indicate the rejection offered to off-frequency signals relative to the desired signal. The broken curves illustrate the improvement in the selectivity characteristic obtained with a 1 dB cavity and a crystal filter. The curves sloping in an upward direction from left to right indicate the effective coupling loss required to prevent degradation from a 60-watt transmitter to a 0.5 microvolt receiver, and the reduction in required loss if a cavity or crystal filter is added to the receiver. Again, if the undesired transmitter has a power of 120 watts, the required loss must be increased by 3 dB.

Sample Calculation

The following problem will illustrate the use of Figure 2-7 for the prediction of adjacent channel interference:

Determine whether the transmitter described in the preceding example will degrade the described receiver due to adjacent channel interference.

Step 1. Determine the frequency separation.

Transmitter frequency: 139.095 MHz
Receiver frequency: 139.035 MHz
Frequency separation: 0.06 MHz = 60 kHz

Step 2. Determine the required coupling loss.

Since there is no RF filter on the receiver, the required loss is obtained from the solid line in Figure 2-7.

Required loss = 64 dB

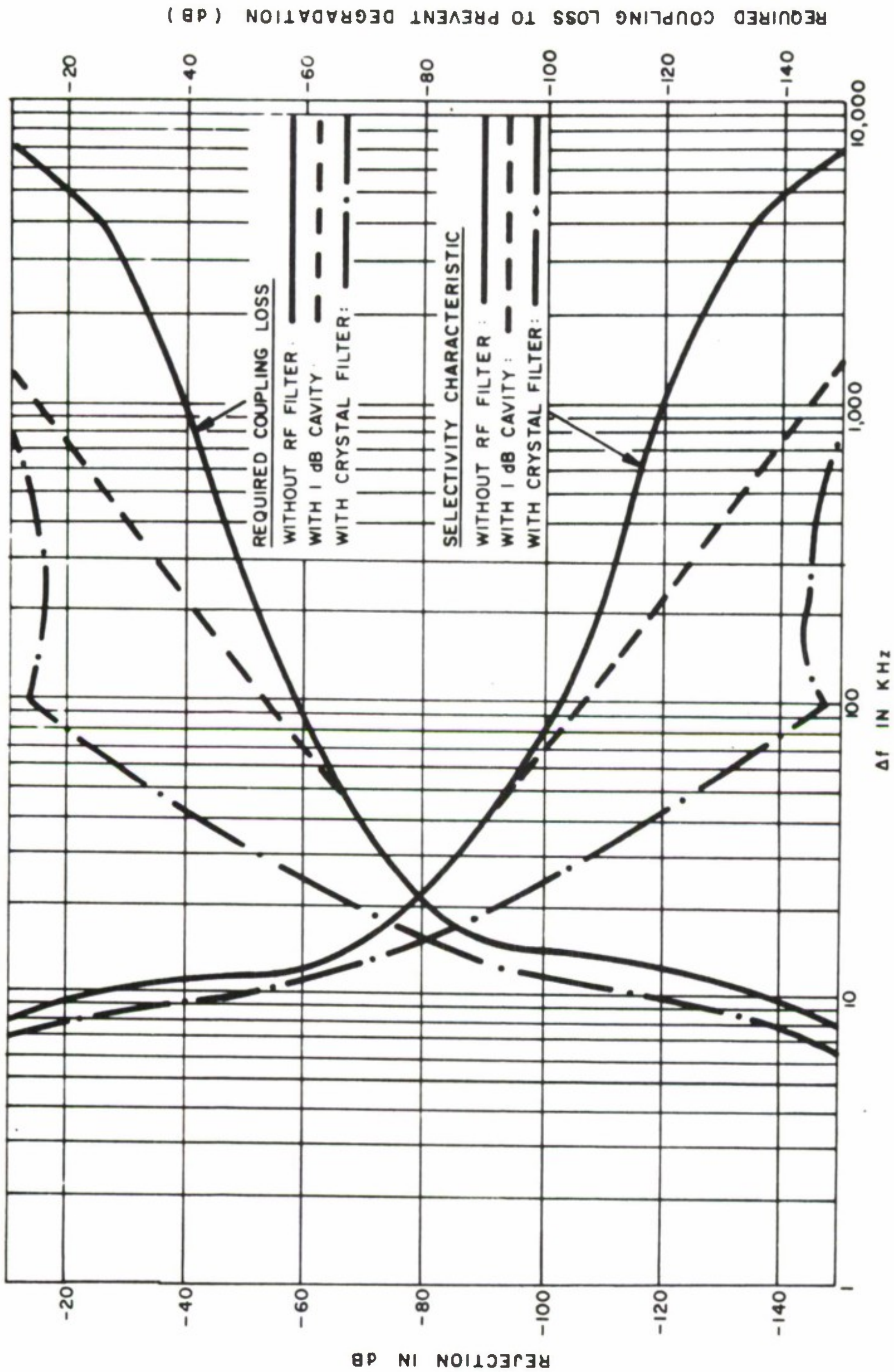


Figure 2-7. Two-Signal Selectivity Characteristics of VHF Nontactical FM Receiver

Step 3. Determine the actual coupling loss.

From Figure 2-4, Army 1 to Army 5 = 37 dB

Step 4. Determine additional loss required.

Additional required loss = 64 dB − 37 dB = 27 dB

Step 5. Determine required receiver filtering to preclude degradation.

From Figure 2-5, 27 dB < 1 crystal filter = 33 dB.

From Figure 2-7, required loss with a crystal filter is 30 dB, which is less than actual 37 dB.

Step 6. Determine if crystal filter can be used.

Rated power on crystal filter is 1 watt = 30 dBm (from equation 2-2).
Transmitter power = 60 watts = 48 dBm.
Actual coupling loss = 37 dBm.
Input power to receiver = 11 dBm < 30 dBm.
A crystal filter can be used.

In this instance also, the performance of the receiver would be seriously degraded by the operation of the transmitter. The corrective hardware modification, however, must be made to the receiver to preclude degradation due to adjacent channel interference. This modification will impair the effectiveness of the desired communication link, since the 6 dB insertion loss associated with the crystal filter is equivalent to reducing the power of the mobile transmitter originating the desired message by a factor of 4.

It is significant to note that the same undesired transmitter has been shown to be a source of degrading interference due to cochannel and adjacent channel effects. Such a phenomenon can always be expected when operations on closely adjacent frequencies are attempted. The actual cause of observed interference under these conditions is difficult to determine since both effects can occur simultaneously.

In the example chosen, the cochannel effects would mask the adjacent channel effects until corrective action was taken at the transmitter. However, such actions would not remove all of the interference until the receiver also was modified.

RECEIVER SPURIOUS RESPONSES

Spurious responses occur in a receiver when an undesired interfering signal combines in the receiver mixer with the local oscillator signal and a signal within the receiver intermediate frequency passband is produced. All of the commercially available VHF nontactical FM receivers are double conversion superheterodyne receivers. For such a receiver, virtually all of the detectable spurious responses that occur can be calculated from equation 2-8:

$$f_{sp} = \frac{p_1 f_{lo_1}}{q_1} \pm \frac{p_2 f_{lo_2} \pm f_{IF_2}}{q_1\ q_2} \pm \Delta f_{bw} \qquad (2\text{-}8)$$

where

f_{sp} = the frequency of the undesired signal which causes the response.

$f_{lo_{1,2}}$ = the frequency of the first or second local oscillator.

f_{IF_2} = the second intermediate frequency of the receiver.

Δf_{bw} = a difference frequency equal to one-half of the receiver passband, i.e. a maximum of 10 kHz for this receiver.

$p_{1,2}$ = an integer used to denote the harmonic of the first or second local oscillator which contributes to the mix.

$q_{1,2}$ = an integer denoting the harmonic of the undesired signal which contributes to the mix in the first or second mixer.

Although many potential responses can be calculated using equation 2-8, the receiver design and transmitter output powers in this service are such that four spurious responses are significant under actual operating conditions. These four responses can be set forth in four equations:

$$f_{sp} = f_r \pm 2f_{IF_1} \pm \Delta f_{bw} \quad (p_1 = q_1 = p_2 = q_2 = 1) \qquad (2\text{-}8a)$$

$$f_{sp} = f_r \pm 1/2 f_{IF1} \pm \Delta f_{bw} \quad (p_1 = q_1 = 2;\ p_2 = q_2 = 1) \qquad (2\text{-}8b)$$

$$f_{sp} = f_r \pm 2f_{IF2} \pm \Delta f_{bw} \quad (p_1 = q_1 = p_2 = q_2 = 1) \qquad (2\text{-}8c)$$

$$f_{sp} = f_r \pm 1/2 f_{IF2} \pm \Delta f_{bw} \quad (p_1 = q_1 = 1;\ p_2 = q_2 = 2) \qquad (2\text{-}8d)$$

where in each equation f_r represents the tuned frequency of the receiver.

In equations 2-8a through 2-8d, the first sign is positive if the first local oscillator operates above the tuned frequency and is negative if the first local oscillator operates below the tuned frequency. The reason for this is that the second local oscillator always operates below the first intermediate frequency in this type of receiver. Since Δf_{bw} represents one-half of the receiver passband, the second sign must always be considered with both senses.

Susceptibility Level

The commercially available VHF receivers have a minimum spurious response rejection of 100 dB. Accordingly, the threshold sensitivity for this phenomenon is −13 dBm. If the interfering transmitter has a power output of 60 watts, the required coupling loss to preclude this type of interference is 61 dB. A 120-watt transmitter would require 64 dB coupling loss.

Interference Analysis

The following procedure can be used to evaluate potential interference due to spurious receiver responses:

Step 1. From the manufacturer's instruction manual for the victim receiver, determine the intermediate frequencies used and whether the first local oscillator operates above or below the receiver tuned frequency.

Step 2. Solve equations 2-8a through 2-8d to determine the transmitter frequencies capable of producing each response.

Step 3. Check the potentially interfering frequencies against the proposed transmitter frequencies. (Remember the 20 kHz range due to Δf_{bw}.)

Step 4. For each transmitter with a frequency that falls within the interfering range, determine the effective coupling loss to the receiver.

Step 5. If the loss is less than 61–64 dB, set Δf_{bw} to zero and resolve 2-8a through 2-8d to determine the frequency difference between the transmitter frequency and the exact solution to the equations with Δf_{bw} equal to zero.

Step 6. Using Figure 2-7, determine if any additional rejection occurs as a result of this frequency difference and add it to the coupling loss determined in Step 4.

Step 7. If the result of Step 6 is less than 61–64 dB, determine the frequency separation between the transmitter and receiver tuned frequency.

Step 8. At the frequency separation found in Step 7, use Figure 2-5 to determine the receiver RF filtering required to provide rejection equal to the difference between the result of Step 6 and 61–64 dB.

Sample Calculation

The following problem will demonstrate the procedure for the prediction of receiver spurious responses:

Receiver A operates at 160.0 MHz. The first IF is at 10.0 MHz, the first local oscillator operates at 150.0 MHz, and the second IF is at 0.5 MHz. Transmitter B operates at 159.741 MHz with a power of 60 watts. The effective coupling loss from transmitter B to receiver A is 40 dB. Determine whether transmitter B will cause a spurious response in receiver A.

Step 1. The first local oscillator operates below the tuned frequency, f_{IF_1} = 10.0 MHz, f_{IF_2} = 0.5 MHz.

Step 2. $f_{sp} = (160.0 - 20 \pm .01)$ MHz = 139.99 – 140.01 MHz (2-8a)

$f_{sp} = (160 - 5 \pm .01)$ MHz = 154.99 – 155.01 MHz (2-8b)

$f_{sp} = (160 - 1 \pm .01)$ MHz = 158.99 – 159.01 MHz (2-8c)

$f_{sp} = (160 - 0.25 \pm .01)$ MHz = 159.74 – 159.76 MHz (2-8d)

Step 3. Transmitter B frequency satisfies 2-8d.

Step 4. Effective coupling loss = 40 dB given.

Step 5. 160 – 0.25 = 159.75 MHz

159.75 – 159.741 = 0.009 MHz = 9 kHz

Step 6. From Figure 2-7, at 9 kHz, rejection = 18 dB,

40 dB + 18 dB = 58 dB, which is less than 61 dB.

Step 7. 160.0 – 159.741 = 0.259 MHz

Step 8. From Figure 2-5, at 0.259 MHz, rejection = 8 dB for a 0.5 dB cavity. Total loss = 58 + 8 = 66 dB. In this case, the addition of a 0.5 dB cavity to Receiver A will preclude spurious response interference from Transmitter B.

INTERMODULATION INTERFERENCE

Interference due to intermodulation products results when two or more signals combine in a nonlinear device and produce an undesired signal on or near the tuned frequency of the victim receiver. The combining process can occur in the final stage of a transmitter or in the RF or first mixer circuitry of a receiver.

The frequency of an intermodulation product can be calculated from the following equation:

$$f_r \pm \Delta f_{bw} = mf_1 \pm nf_2 \pm kf_3 \pm \ldots \qquad (2\text{-}9)$$

where

f_r = the tuned frequency of the victim receiver.

Δf_{bw} = a difference frequency equal to a maximum of one-half of the passband of the receiver.

$f_{1,2,3}$ = the frequencies contributing to the mix which results in the product.

m, n, k = integers used to denote the harmonics of the contributing frequencies.

m+n+k = the order of the intermodulation product.

Because of the design of the commercially available equipments used for nontactical two-way FM communications, only a few of the many products which can be calculated from equation 2-9 have any significance under actual operating conditions. These products are summarized in TABLE 2-1.

TABLE 2-1
IMPORTANT INTERMODULATION PRODUCTS

Equation	Description of Mix	
$f_r = 2f_1 - f_2$	two-signal, third-order	(2-9a)
$f_r = f_1 + f_2 - f_3$	three-signal, third-order	(2-9b)
$f_r = 3f_1 - 2f_2$	two-signal, fifth-order	(2-9c)
$f_r = f_1 + 2f_2 - 2f_3$	three-signal, fifth-order	(2-9d)

It should be evident from equations 2-9a through 2-9d that when the total number of possible contributing frequencies is large, the computation of all of the resulting intermodulation products is an extremely tedious effort. However, a tool does exist which greatly simplifies the computation time and the subsequent prediction process. This tool is known as a difference matrix.

Concept of the Difference Matrix

The concept of the difference matrix, and its application in the prediction of intermodulation products, is easy to understand if the form of equations 2-9a through 2-9d is slightly modified. Consider the following:

$$f_r = 2f_1 - f_2 = f_1 + f_1 - f_2; \text{ thus } f_r - f_1 = f_1 - f_2 \qquad (2\text{-}9a)$$

$$f_r = f_1 + f_2 - f_3; \text{ thus } f_r - f_1 = f_2 - f_3 \qquad (2\text{-}9b)$$

$$f_r = 3f_1 - 2f_2 = f_1 + 2f_1 - 2f_2; \text{ thus } f_r - f_1 = 2(f_1 - f_2) \qquad (2\text{-}9c)$$

$$f_r = f_1 + 2f_2 - 2f_3; \text{ thus } f_r - f_1 = 2(f_2 - f_3) \qquad (2\text{-}9d)$$

Note that each expression now equates distinct pairs of frequency differences. Hence, if a matrix is constructed which illustrates the differences between each individual frequency involved, then potential third-order intermodulation problems can be identified by inspection by merely noting when any difference frequency is duplicated. If potential fifth-order problems are being considered, it is necessary to prepare a second matrix in which all of the frequency differences from the third-order matrix are exactly doubled. The doubled frequency differences are then compared against the frequency differences in the third-order matrix; if a match occurs, a potential fifth-order intermodulation product is identified. It must be remembered that each "match" has a possible spread of ± 10 kHz because of the receiver passband.

Sample Calculation

The following problem will demonstrate the procedure for the prediction of intermodulation products:

Given the operating frequencies listed below, construct the necessary difference matrices and identify the potential intermodulation products.

f_1 = 138.6 MHz

f_2 = 141.0 MHz

f_3 = 143.4 MHz (receiving only)

f_4 = 143.98 MHz

f_5 = 148.79 MHz

Step 1. Prepare the matrices by listing the frequencies in a row and a column and then inserting the frequency difference for third-order, and twice the difference for fifth-order, at the intersection point of the row and column.

	$138.6 = f_1$	$141.0 = f_2$	$143.4 = f_3$	$143.98 = f_4$	$148.79 = f_5$
$f_1 = 138.6$	--	2.4	4.8	5.38	10.19
$f_2 = 141.0$		--	2.4	2.98	7.79
$f_3 = 143.4$			--	0.58	5.39
$f_4 = 143.98$				--	4.81
$f_5 = 148.79$					--

THIRD-ORDER MATRIX

$148.79 = f_5$	$143.98 = f_4$	$143.4 = f_3$	$141.0 = f_2$	$138.6 = f_1$	
20.38	10.78	9.6	4.8	--	$138.6 = f_1$
15.58	5.98	4.8	--		$141.0 = f_2$
10.78	1.16	--			$143.4 = f_3$
9.82	--				$143.98 = f_4$
--					$148.79 = f_5$

FIFTH-ORDER MATRIX

Step 2. Identify the potential third-order intermodulation products by examining for difference matches (± 10 kHz) within the third-order matrix.

The matches are circled in the matrix.

Step 3. List the potential products in equation form.

From the matrix:

141.0 – 138.6 = 143.4 – 141.0, thus 2(141.0) – 138.6 = 143.4, or 2(141.0) – 143.4 = 138.6

143.4 – 138.6 = 148.79 – 143.98. This equation can be written in the form of 2-9b in four different ways. Note that Δf = 10 kHz.

143.98 – 138.6 = 148.79 – 143.4. This is the equation previously found but restated differently.

Step 4. Eliminate the products which are not possible because they call for a receiver frequency to contribute to the mix or call for interference to a transmitter frequency:

Since 143.4 MHz is a frequency for receiving only, it cannot contribute to an intermodulation product. Thus:

2(141.0) – 143.4 = 138.6 is not possible.

Three of the four ways to state the second equation are not possible because of the receive-only frequency.

Hence, the remaining potential third-order intermodulation products are:

2(141.0) – 138.6 = 143.4

138.6 + 148.79 – 143.98 = 143.4

Step 5. Identify the potential fifth-order intermodulation products by examining for difference matches (± 10 kHz) between the two matrices, and list the potential products in equation form.

2(141.0 – 138.6) = 143.4 – 138.6, thus 2(141.0) – 138.6 = 143.4

2(143.4 – 141.0) = 143.4 – 138.6, thus 2(141.0) – 138.6 = 143.4

2(141.0 – 138.6) = 148.79 – 143.98, (this can be stated 2 ways)

2(143.4 – 141.0) = 148.79 – 143.98, (this can be stated 2 ways)

Step 6. Eliminate the impossible products, just identified.

Note that the first two equations are repetitions of the third-order product and can be ignored.

The third identification can be stated two ways, both of which are possible products:

148.78 = 143.98 + 2(141.0) – 2(138.6)

143.99 = 148.79 + 2(138.6) – 2(141.0)

The fourth identification is impossible since it calls for the receive-only frequency to contribute to the mix, no matter which of the two ways it is stated.

Step 7. Summarize and describe the remaining potential intermodulation products.

143.4 = 2(141.0) – 138.6, two-signal, third-order.

143.41 = 138.6 + 148.79 – 143.98, three-signal, third-order

148.78 = 143.98 + 2(141.0) – 2(138.6), three-signal, fifth-order

143.99 = 148.79 + 2(138.6) – 2(141.0), three-signal, fifth-order.

This example illustrates how a difference matrix can be used to predict the occurrence of intermodulation products which are potential interference sources. However, there are restrictions on the interfering power levels which must be considered before the potential interference cases are identified as "expected" interference cases.

TRANSMITTER INTERMODULATION PRODUCTS

The output power level of transmitter intermodulation products must be determined by measurements. When the power level of the undesired product has been determined, it is then treated in the same manner as any other emission. The susceptibility of a receiver to a transmitter intermodulation product is defined by the two-signal selectivity curve (see Figure 2-7) when the reference level is −113 dBm. However, the required effective coupling loss must be reduced by an amount equal to the difference, in dB, between the fundamental output power of the transmitter and the output level of the intermodulation product.

Typical measured levels of transmitter intermodulation products relative to the level of the incoming contributing undesired signal are shown in Figure 2-8 as a function of the frequency separation between the contributing signals (see Reference 4). The following steps should be used to evaluate the effects of transmitter intermodulation products:

Step 1. Identify the transmitters which contribute to the intermodulation products (use equations 2-9a and 2-9d). Remember that the product can be generated from any of the contributing transmitters.

Step 2. Select one of the contributing transmitters for examination.

Step 3. Determine the frequency differences between the contributing transmitters.

For a two-signal mix, this difference can be obtained from the third-order difference matrix:

$$f_d = f_1 - f_2$$

For a three-signal mix, the value used is the average frequency difference between the contributors.

$$f_d = f_1 - \frac{f_2 + f_3}{2}$$

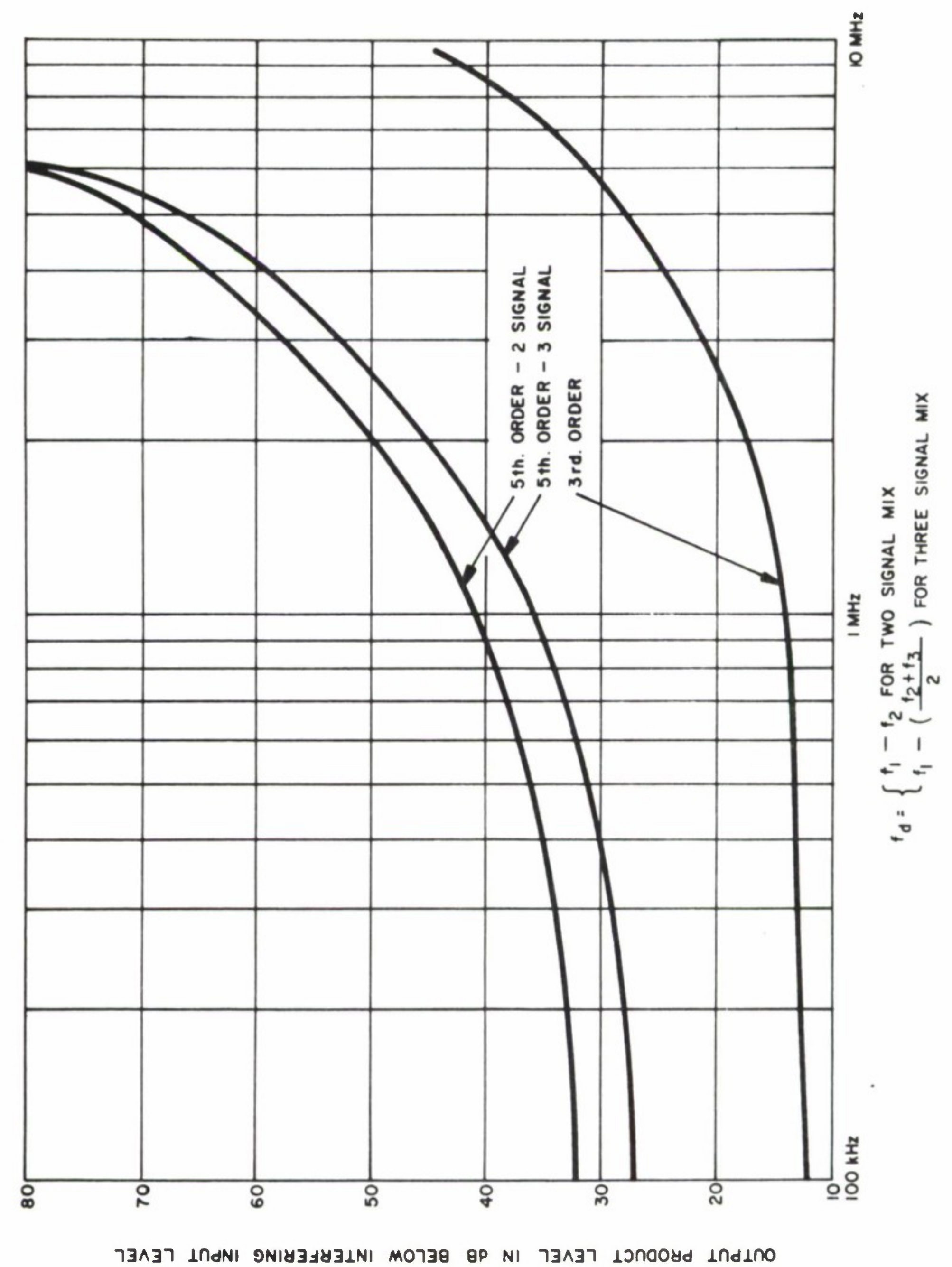


Figure 2-8. Conversion Loss of VHF Nontactical FM Transmitter Intermodulation Products

Step 4. Determine the input level of the signals from the remaining transmitters at the transmitter under consideration.

For a two-signal mix (equations 2-9a and 2-9c), the input level of transmitter 2 (f_2) at transmitter 1 (f_1) is obtained by subtracting the $T_2 - T_1$ coupling loss from the power of T_2. If T_1 has a cavity, any rejection offered to f_2 is also subtracted from the T_2 power.

For a three-signal mix (equations 2-9b and 2-9d), the input level used is the average input level of the two undesired contributors. Under these conditions:

$$P_{iu} = [(P_2 - C_{2_1} - L_{f_{2_1}}) + (P_3 - C_{3_1} - L_{f_{3_1}})]/2$$

where

P_{iu} = the effective input undesired power in dBm.

$P_{2,3}$ = the power of transmitter 2 or 3 in dBm.

C_{2_1} C_{3_1} = the effective coupling loss from transmitter 2 to transmitter 1 or transmitter 3 to transmitter 1 (from Figure 2-4).

$L_{f_{2_1}}, L_{f_{3_1}}$ = the rejection of the cavity on transmitter 1 to f_2 or f_3, respectively (Figure 2-5).

Step 5. Using Figure 2-8, determine the conversion loss in dB associated with the intermodulation product.

Step 6. Determine the output level in dBm of the intermodulation product.

$P_{IM} = P_{iu}$ – Conversion loss in Figure 2-8.

Step 7. Determine the output level in dB of the intermodulation product relative to the nominal output power of transmitter 1.

$$P_{REL} = P_1 - P_{IM} + L_{f_{IM,1}}$$

where $L_{f_{IM,1}}$ = the rejection to the intermodulation product frequency offered by the cavity on transmitter 1.

Step 8. Determine the required coupling loss for this product to preclude interference to the receiver in question.

From the two-signal selectivity curve (Figure 2-7), this is the required loss shown minus P_{REL}. The frequency separation to be used in connection with Figure 2-7 is the difference between the intermodulation product frequency and the receiver tuned frequency. If this frequency separation is so small (less than 8 kHz) that the required coupling loss is not shown, then the required loss for the product is 160 − P_{REL}. The frequency difference between the intermodulation product and the receiver tuned frequency is noted as $\Delta f_{IM,r}$.

Step 9. Determine the actual coupling loss between transmitter 1 and the receiver (Figure 2-4).

Step 10. If the actual coupling loss is less than the required coupling loss obtained in Step 8, determine the cavity requirements for transmitter 1 which will preclude degradation to the receiver.

Remember that any cavity added to transmitter 1 will offer rejection to the other contributing frequencies to reduce P_{IM} (step 3) and to the intermodulation product frequency (step 7).

Step 11. Repeat Steps 1 through 10 using each of the other contributing transmitters as the intermodulation product emitter.

Sample Calculation

The following problem will demonstrate the procedure for predicting transmitter intermodulation interference:

Given the following equipment and frequency parameters listed below, determine whether interference will result to the receiver due to transmitter intermodulation. Transmitter 1 has a 1 dB cavity, and no other cavities are used.

f_r = 143.40 MHz

f_1 = 138.6 MHz, P_1 = 50 watts = 47 dBm.

f_2 = 148.79 MHz, P_2 = 47 dBm.

f_3 = 143.98 MHz, P_3 = 47 dBm.

Coupling losses are:

$C_{er,1}$ = 50 dB	$C_{e1,2}$ = 56 dB
$C_{er,2}$ = 48 dB	$C_{e1,3}$ = 50 dB
$C_{er,3}$ = 52 dB	$C_{e2,3}$ = 58 dB

Step 1. 143.41 = 138.6 (f_1) + 148.79 (f_2) – 143.98 (f_3)

$\Delta f_{IM,r}$ = 10 kHz (save for Step 8).

Step 2. Let T_1 be the generating transmitter.

Step 3. Determine $f_{d_{il}}$.

$f_{d_{12}}$ = 138.6 – 148.79 = 10.19 MHz

$f_{d_{13}}$ = 138.6 – 143.98 = 5.38 MHz

$$f_{d_{il}} = \frac{10.19 + 5.38}{2} = \frac{15.57}{2} \simeq 7.78 \text{ MHz}$$

Step 4. Determine the undesired input power to T_1.

$P_{i2} = P_2 - C_{e2,1} - L_{f2,1}$ = 47 – 56 – 42 = –51 dBm

$P_{i3} = P_3 - C_{e3,1} - L_{13,1}$ = 47 – 50 – 40 = –43 dBm

$$P_{iu} = \frac{(-51) + (-43)}{2} = \frac{-94}{2} = -47 \text{ dBm}$$

Step 5. Determine conversion loss.

From Figure 2-8 , at $f_{d_{il}}$ = 7.78 MHz,

Conversion loss = 38 dB

Step 6. Determine P_{IM},

$P_{IM} = P_{iu}$ – conversion loss = –47 – 38 = –85 dBm.

Step 7. Determine P_{rel}:

$Lf_{IM,1}$ = 39 dB at $\Delta f_{IM,1}$ = 4.81 MHz (Figure 2-5).

$P_{rel} = P_1 - P_{IM} + Lf_{IM,1} = 47 - (-85) + 39 = 171$ dB.

Step 8. Determine the required coupling loss.

From Figure 2-7, at Δf = 10 kHz, required loss = 136 dB.

Then C_{eIM} = 136 – 171 = –35 dB.

Note that the minus sign indicates that no coupling is required, but that a margin of 35 dB exists in this case.

Step 9. Determine $C_{er,1}$.

$C_{er,1}$ = 50 dB (Figure 2-4).

Step 10. The actual loss is 85 dB greater than the required loss, thus the product from Transmitter 1 will not degrade the receiver.

Step 11. Repeat above using the other transmitters. The reader can finish this example. The results indicate that the product from T_2 is 5 dB lower than the degrading level and the product from T_3 is 1 dB higher than the degrading level. A 0.5 dB cavity on transmitter 3 would preclude degradation but, in this case, such a cavity is not worth the improvement, since a 1 dB level of degradation is usually not detectable.

RECEIVER INTERMODULATION

As stated previously, intermodulation interference can result from a product generated in a transmitter or in a receiver. Accordingly, each time a potential interference situation exists, it must be evaluated as two distinct phenomena. The previous section of this report demonstrated how to evaluate interference caused by a transmitter intermodulation product and how to modify the appropriate transmitters to preclude this interference effect. It must be emphasized, however, that such a transmitter modification will not preclude receiver intermodulation interference.

The susceptibility of typical VHF nontactical FM receivers to this phenomenon has been measured and is shown in Figure 2-9 (see References 3 and 5) as a function of the frequency separation between the interfering signals which contribute to the product. It should be noted that the susceptibility levels shown in Figure 2-9 were derived empirically and are based on the assumption that the input interfering signals contributing to the product are of equal powers. Under these conditions, the average power is equal to the level of each interfering signal and the curves may be used directly.

If the incoming signal levels are not equal, then the effective average interfering level must be determined in order to use the curves. The procedure for determining the effective average interfering power is explained below (see Reference 5). The following steps are used to evaluate the effects of receiver intermodulation interference:

Step 1. Identify the transmitters which contribute to the intermodulation product (use equations 2-9a through 2-9d).

Step 2. Determine the frequency separation to be used with Figure 2-9.

For two-signal mixes: $f_d = |f_1 - f_2|$ from equations 2-9a and 2-9c.

For three-signal mixes: $f_d = |f_1 - \frac{f_2 + f_3}{2}|$ from equations 2-9b and 2-9d.

Step 3. Determine the effective average input power for the mix involved.

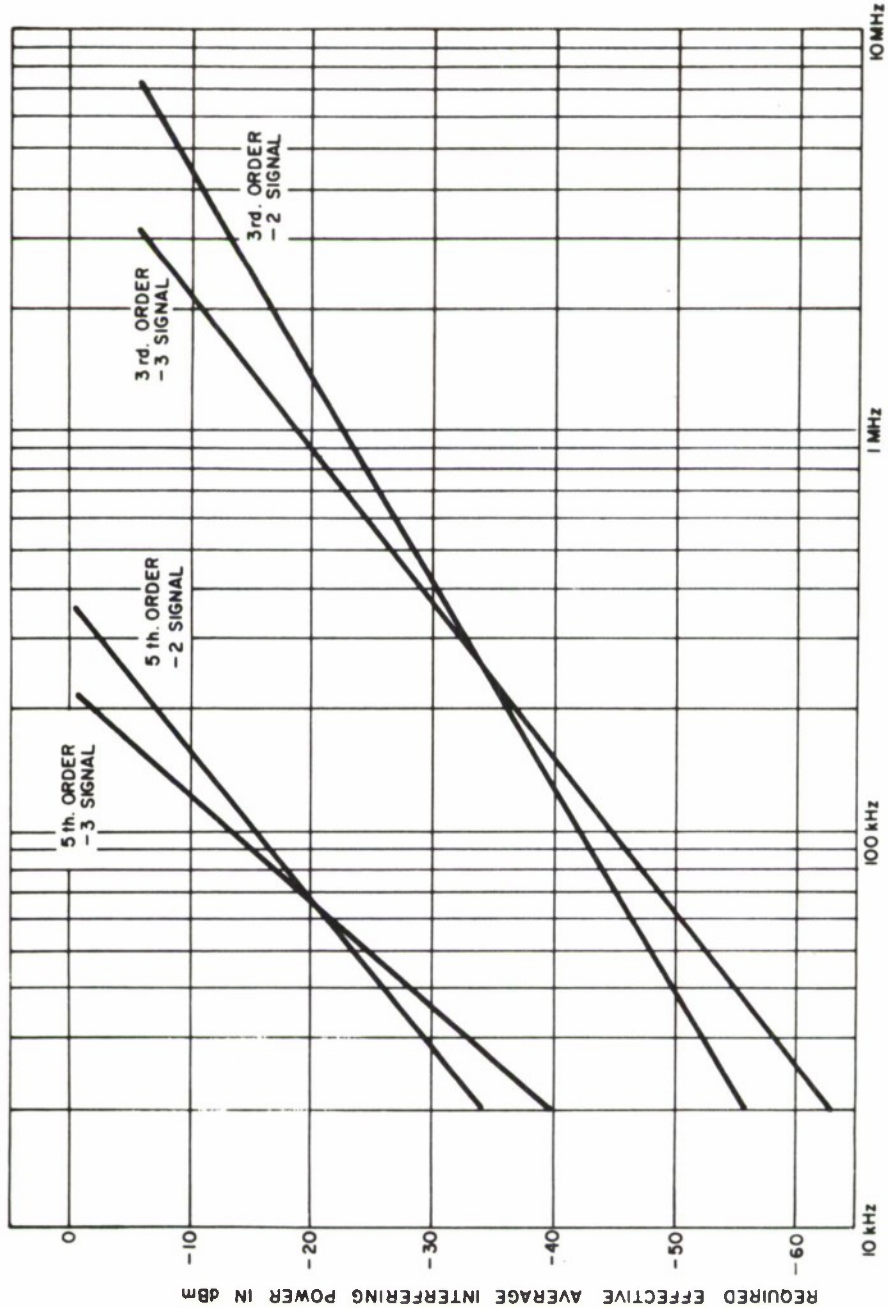
P_{il} = the input power from transmitter 1

$$= P_1 - C_{er,1} - L_{fr,1} \text{ dBm}$$

where

P_1 = output power of transmitter 1 in dBm

$C_{er,1}$ = effective coupling loss from transmitter 1 to the receiver (from Figure 2-4)



$$f_d = \begin{cases} f_1 - f_2 & \text{FOR TWO SIGNAL MIX} \\ f_1 - \left(\frac{f_2 + f_3}{2}\right) & \text{FOR TWO SIGNAL MIX} \end{cases}$$

Figure 2-9. Receiver Intermodulation Susceptibility for VHF Nontactical FM Receivers

$L_{fr,1}$ = the rejection of a cavity or filter associated with the receiver to f_1 (from Figure 2-5)

$P_{i,2}$ = $P_2 - C_{er,2} - L_{fr,2}$ dBm

$P_{i,3}$ = $P_3 - C_{er,3} - L_{fr,3}$ dBm

If $P_{il} = P_{i2} = P_{i3}$, the effective average intermodulation input power $\overline{P}_i = P_{il} = P_{i2} = P_{i3}$.

If $P_{il} \neq P_{i2} \neq P_{i3}$, then the equation for effective average intermodulation power is obtained from the following:

$2f_1 - f_2$	$\overline{P}_i = (2P_{il} + P_{i2})/3$
$f_1 + f_2 - f_3$	$\overline{P}_i = (P_{il} + P_{i2} + P_{i3})/3$
$3f_1 - 2f_2$	$\overline{P}_i = (3P_{il} + 2P_{i2})/5$
$f_1 + 2f_2 - 2f_3$	$\overline{P}_i = (P_{il} + 2P_{i2} + 2P_{i3})/5$

Step 4. Determine the frequency separation between the intermodulation product and the receiver tuned frequency.

$$\Delta f = f_{IM} - f_r$$

Step 5. Determine the additional rejection to f_{IM} from the two-signal selectivity curve (Figure 2-7). Reduce the $\overline{P}_i$ by this rejection factor.

$$P_{IM} = \overline{P}_i - \text{(rejection in Figure 2-7)}$$

Step 6. If P_{IM} is greater than the level shown in Figure 2-9 , determine the filter requirements on the receiver to preclude degradation (Figure 2-5).

Sample Calculations

The following problems will demonstrate the procedure for predicting receiver intermodulation:

Given the equipment and frequency parameters listed below, determine whether the performance of the receiver will be degraded due to receiver intermodulation interference. The receiver has no external filter.

f_r = 143.40 MHz

f_1 = 138.6 MHz, P_1 = 50 watts = 47 dBm.

f_2 = 148.79 MHz, P_2 = 47 dBm

f_3 = 143.98 MHz, P_3 = 47 dBm

$C_{er,1}$ = 50 dB; $C_{er,2}$ = 48 dB; $C_{er,3}$ = 52 dB

Step 1. Identify the transmitters.

$$143.41 = 138.6\,(f_1) + 148.79\,(f_2) - 143.98\,(f_3)$$

Step 2. Determine f_d.

$$f_d = 138.6 - \frac{148.79 + 143.98}{2} = 138.6 - \frac{292.77}{2}$$

$$f_d = |138.6 - 146.38| = 7.78 \text{ MHz.}$$

Step 3. Determine P_{IM}.

$$P_{il} = P_1 - C_{er,1} = 47 - 50 = -3 \text{ dBm}$$

$$P_{i2} = P_2 - C_{er,2} = 47 - 48 = -1 \text{ dBm}$$

$$P_{i3} = P_3 - C_{er,3} = 47 - 52 = -5 \text{ dBm}$$

$$P_i = (P_1 + P_2 + P_3)/3 = -9/3 = -3 \text{ dBm}$$

Step 4. Determine $\Delta f_{IM,r}$

$$\Delta f_{IM,r} = |f_{IM} - f_r| = 143.41 - 143.40 = .01 \text{ MHz} = 10 \text{ kHz}$$

Step 5. Determine P_{IM}.

$$P_{IM} = \bar{P}_i - \text{(Figure 2-7 at 10 kHz)}$$

$$= -3 \text{ dBm} - 27 = -30 \text{ dBm}.$$

Step 6. Determine whether interference exists:

From Figure 2-9, for f_d = 7.8 MHz interference threshold level $\simeq$ +5 dBm.

P_{IM} = −30 dBm, which is 35 dB below the threshold level.

Determine the expected level of receiver interference and what filter is required to prevent its occurrence, given the same equipment and frequency parameters as in the preceding problem, except that:

$C_{er,1}$ = 9 dB; $C_{er,2}$ = 8 dB; $C_{er,3}$ = 7 dB

Step 1. As before

$$143.41 = 138.6\ (f_1) + 148.79\ (f_2) - 143.98\ (f_3)$$

Step 2. As before

$$f_d = 7.78 \text{ MHz}$$

Step 3. Determine $\bar{P}_i$.

$$P_{i1} = 47 - 9 = 38 \text{ dBm}$$

$$P_{i2} = 47 - 8 = 39 \text{ dBm}$$

$$P_{i3} = 47 - 7 = 40 \text{ dBm}$$

$$\bar{P}_i = (38 + 39 + 40)/3 = 39 \text{ dBm}$$

Step 4. Determine $\Delta f_{IM,r}$

As before $\Delta f_{IM,r}$ = 10 kHz

Step 5. Determine P_{IM},

$$P_{IM} = \overline{P}_i - 27\text{ dB} = 39\text{ dBm} - 27\text{ dB} = 12\text{ dBm}$$

Step 6. Determine interference level and filter requirements.

From Figure 2-9, for f_d = 7.8 MHz, interference threshold level $\simeq$ +5 dBm.

P_{IM} = +12 dBm, which is 7 dB above threshold.

For filter requirements, note that because of the averaging process, the total rejection must equal 7 dB times the order of the product.

From Figure 2-5 for a 0.5 dB cavity:

$$L_{fr,1} = 31.5\text{ dB at } f_r - f_1 = 4.8\text{ MHz}$$

$$L_{fr,2} = 32.5\text{ dB at } f_r - f_2 = 5.4\text{ MHz.}$$

$$L_{fr,3} = 14\text{ dB at } f_r - f_3 = 0.5\text{ MHz.}$$

$$L_f\text{ Total} = L_{fr,1} + L_{fr,2} + L_{fr,3} = 78\text{ dB.}$$

$$\text{Effective } L_f = 78/3 \simeq 26\text{ dB}$$

Alternatively, with a 0.5 dB cavity:

$$P_{i1} = P_1 - C_{er,1} - L_{fr,1} = 47 - 9 - 31.5 = 6.5\text{ dBm}$$

$$P_{i2} = 47 - 8 - 32.5 = 6.5\text{ dBm}$$

$$P_{i3} = 47 - 7 - 14 = 26\text{ dBm}$$

$$\overline{P}_i = \frac{(6.5 + 6.5 + 26)}{3} = \frac{39}{3} = 13\text{ dBm (Step 3)}$$

$$P_{IM} = 13 - 27\text{ dB} = -14\text{ dBm}$$ (Step 5), which is less than +5 dBm.

FINAL COMMENTS

In the different subsections of this technical report, the approach to interference prediction for VHF nontactical FM communications has been outlined and sample problems for each mechanism have been given. It is significant to note that one of the most difficult and time-consuming areas of interference prediction, namely intermodulation, has been greatly simplified through the use of a frequency separation matrix.

It is pertinent to point out that the frequency difference matrix can be applied to considerations of each interference mechanism discussed.

Note that the third-order frequency difference matrix yields the following required parameters by inspection:

1. The Δf needed for use with Figure 2-6 (cochannel interference).
2. The Δf needed for use with Figure 2-7 (adjacent channel interference).
3. A Δf that can be used to predict spurious responses if it is remembered that:

$$f_r \pm 2f_{IF'} = f_r \pm \Delta f_a$$

$$f_r \pm \tfrac{1}{2}f_{If'} = f_r \pm \Delta f_b$$

$$f_r \pm 2f_{If2} = f_r \pm \Delta f_c$$

$$f_r \pm \tfrac{1}{2}f_{If2} = f_r \pm \Delta f_d$$

It may be seen that the frequency difference matrix is a very useful tool for predictions of interference using manual techniques.

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DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Electromagnetic Compatibility Analysis Center	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	2b. GROUP
3. REPORT TITLE INTERFERENCE PREDICTION GUIDELINES FOR VHF NON-TACTICAL FM COMMUNICATIONS		
4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)* Technical Report		
5. AUTHOR(S) *(Last name, first name, initial)* Morgan, G.		
6. REPORT DATE May 1970	7a. TOTAL NO. OF PAGES 47	7b. NO. OF REFS 5
8a. CONTRACT OR GRANT NO. F-19628-69-C-0073 b. PROJECT NO. 649E c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) ESD-TR-70-130 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*	
10. AVAILABILITY/LIMITATION NOTICES Distribution of this document is unlimited.		
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Department of Defense	

13. ABSTRACT

ABSTRACT

This technical report presents guidelines which may be used for the prediction of interference effects between collocated VHF non-tactical FM equipments. Pertinent technical characteristics and interference susceptibility levels representative of this type of equipment are included.

The interference mechanisms discussed include cochannel and adjacent channel effects and non-linear interactions due to spurious receiver responses, and transmitter and receiver intermodulation interference. Sample problems are set forth and solved to illustrate the step by step procedure for prediction of each type of interference phenomenon considered, and the equipment modifications required to prevent degradation.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
ANALYSIS						
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