AIR SERVICES
TELECOMMUNICATIONS AND
ELECTRONICS BRANCH

CANADA

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DEPARTMENT OF TRANSPORT
OTTAWA

VHF FREQUENCY SELECTION

BY

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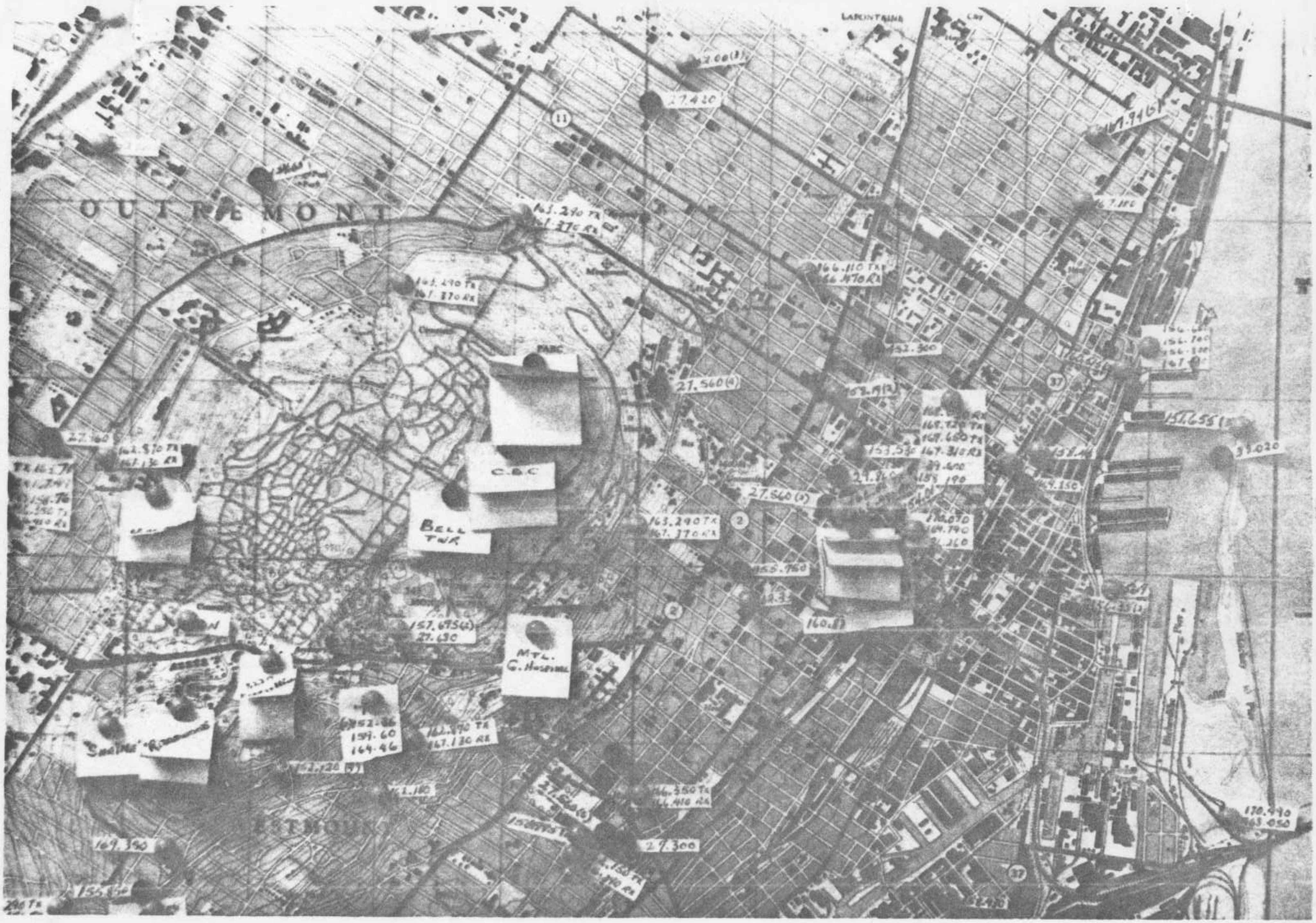
RADIO REGULATIONS DIVISION

NOVEMBER 1966



Wall Map of Montreal

VHF FREQUENCY SELECTION PROCEDURE

A systematic method of making frequency selections in the 150 MC/s band, with special attention given to assessing and avoiding Intermodulation Interference.

This procedure is in 4 parts: -

PART I

Typical Documentation, a listing of the forms and administration procedures to be used.

PART II

Technical Procedure, a method of setting up the general problem, with the various technical steps to perform.

PART III

Interference Assessment, an elaboration of one of the steps in Part II, mainly mathematical, giving in detail the methods of estimating and overcoming interference.

PART IV

Making the frequency selection, using the results of Part III and other information.

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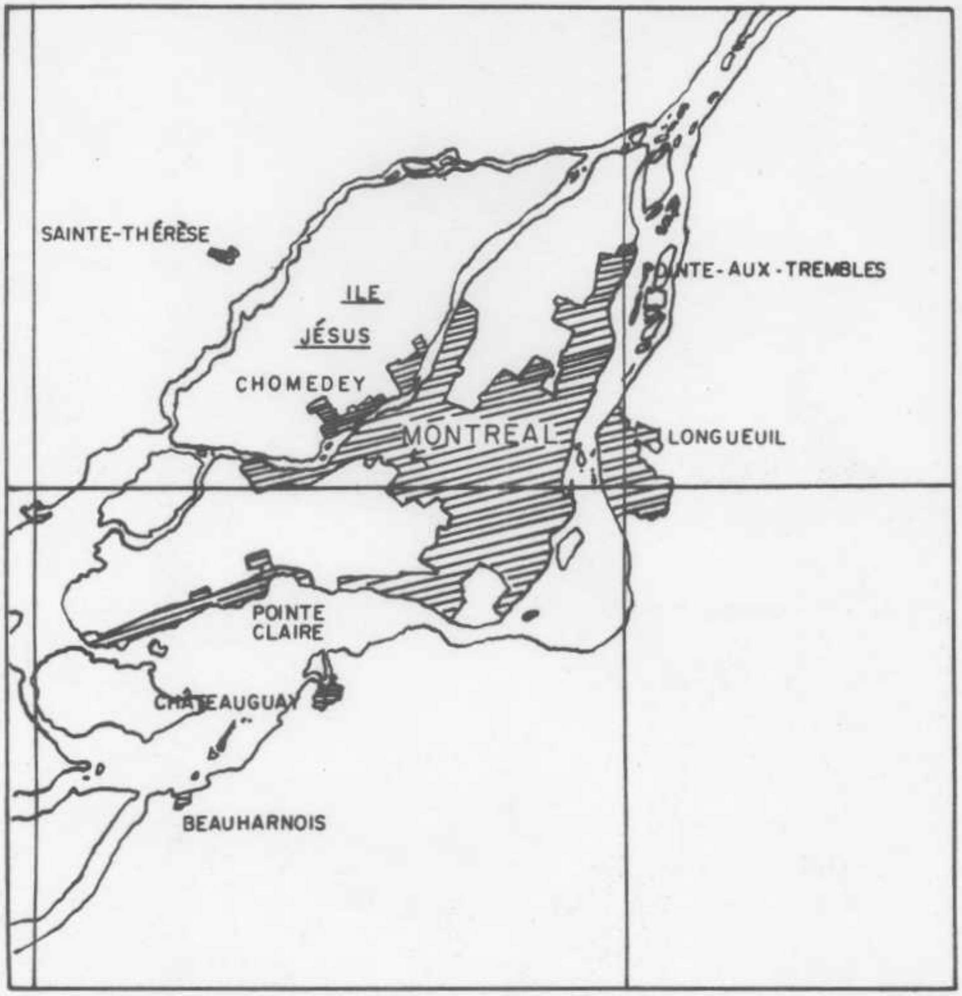
MAIN FREQUENCY CONGESTED AREAS SHOWN ON WALL MAPS

MONTREAL



PART I

DOCUMENTS

This section provides a listing of the forms and documents which give the information necessary in the task of selecting a frequency.

These are the documents which will be used or referred to by someone making such a frequency selection.

(1) Domestic Frequency Assignment Listings -

This is the list of all frequencies assigned for non-military use. It provides information on what frequencies are used in what locations and by whom.

(2) Policy Manual (PM-1) - Radio Licensing -

This gives the Department's policy on the subject of Radio Licensing, and states what portions of the spectrum are allocated to what usage.

(3) Individual Frequency Assignment Sheets -

These are sheets which will have to be made up by the Regional Offices to carry detailed information on all assignments in the local area. (Form A).

(4) Wall Maps - Main Frequency Congested Area -

This is a special tool, also to be prepared by the Regional Office, used to provide an instant visual presentation of all established and proposed fixed stations located within the area of concern.

It has been found convenient to use National Topographic System Maps, mounted on tentest or other convenient material. Each assignment is shown on the map by a pinned marker, showing the operating frequency(ies) by positive integer(s). A decode book provides the necessary particulars of the systems involved as per attached sample sheet. (Form A).

These maps facilitate the measurement of distances between co-channel and adjacent channel stations and by enabling one to have a quick picture, greatly lessen the risk of gross mistakes in frequency selection.

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(5) Particulars of Special Installations

There is an increasing trend towards large rooftop antenna farm systems, where as many as ten different transmitters may be operating out of a collection of antennas. Such farms will present special problems and it is best to keep separate records of installation details such as is shown in Form B, Form C.

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FORM "A"

(a) FREQUENCY: 162.510 Mc/s

(b) PREFERRED SERVICE

(c) LAND TRANSPORTATION (TAXI)

(e) Location	(f) Station C/S	(g) Licensee	(h) Service	(i) Emission	(j) No. Mobiles	(k) File
St. Laurent	XND 58	Leo McMahon	Taxi	20F3	7	6208-420
Hull	XNA 228	Emile Lalonde	Taxi		1	6208-711
Buckingham	XNA 376	Osias Lepine	Taxi	40F3	1	6208-5358
Montreal North	XNA 385	Yvon Garceau	Taxi	20F3	2	6208-8165
Shawinigan	XNW 99	Bruno Goulet	Taxi	40F3	3	6208-693
Duvernay	XNH 79	Gaston Bastien	Taxi	20F3	1	6208-8618
Rivière du Loup	XNA 343	Oscar Pelletier	Taxi	40F3	4	6208-676
Roxboro	XNA 387	Paul L. Poce	Taxi	20F3	2	6208-9335
Ancienne Lorette	XNW 52	Joseph Blondeau	Taxi	40F3	1	6208-606
Mistassini	XNA 252	Roland Asselin	Taxi	20F3	1	6208-9531
Valleyfield	XNA 281	Paul Grenier	Taxi	40F3	4	6208-599
Drummondville	XND 79	Alphonse Blanchette	Taxi	20F3	4	6208-10011
St. Louis Courville	XNC 76	Roger Duchesneau	Taxi	40F3	4	6208-579

(d) CODE: QB

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PLACE VILLE-MARIE------------------- -------PENTHOUSE ROOF PLAN

ANT. TYPE- SINCLAIR 210-A2 GAIN 5·5 DB

CABLE TYPE- RG. 17-300' LOSS-3DB

CAVITY SINCLAIR C-257 2·2 DB LOOP LOSS AT 1 MC. 115 DB

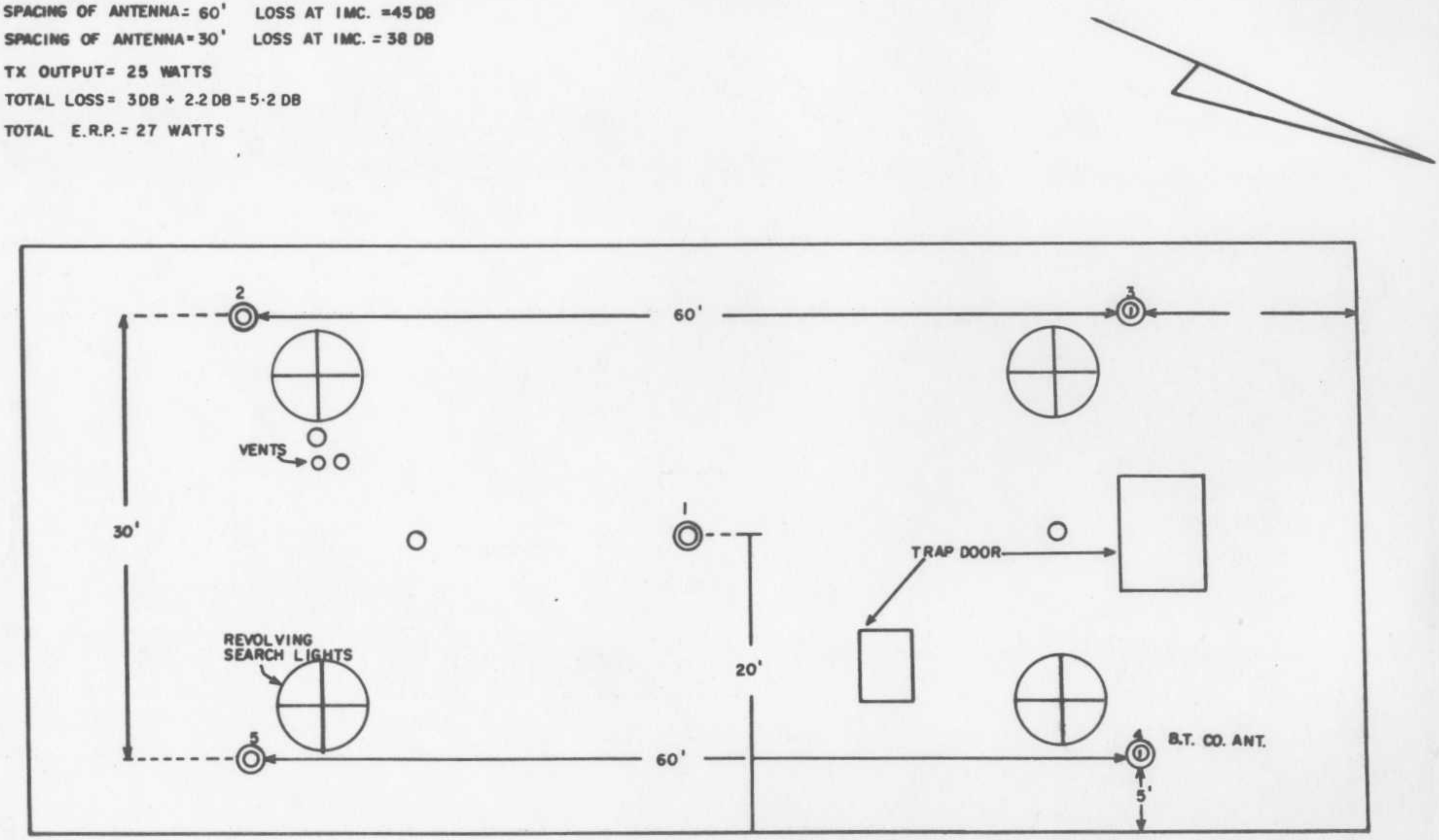
SPACING OF ANTENNA= 60' LOSS AT 1MC. =45 DB

SPACING OF ANTENNA=30' LOSS AT 1MC. = 38 DB

TX OUTPUT= 25 WATTS

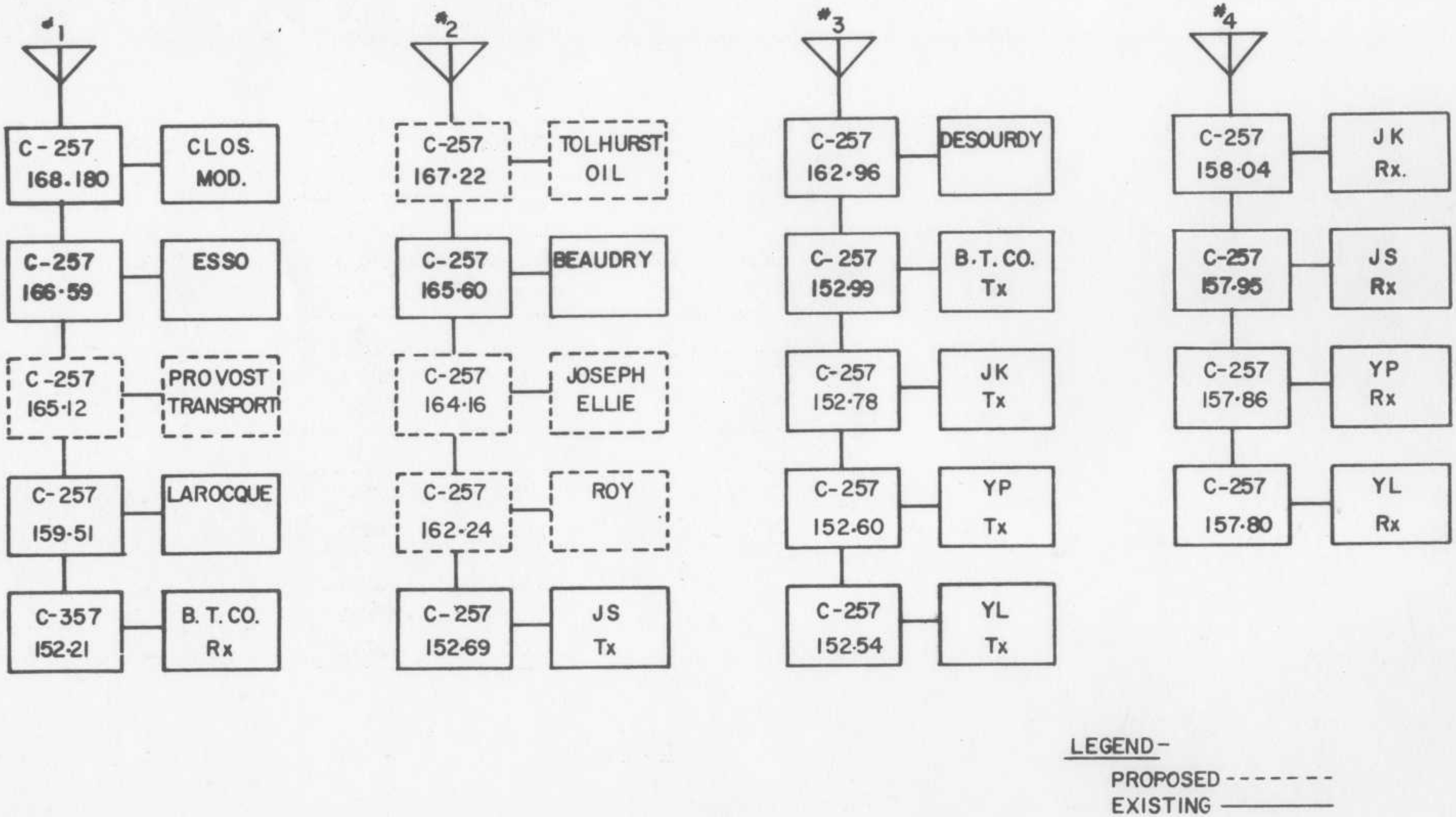
TOTAL LOSS= 3DB + 2.2 DB = 5·2 DB

TOTAL E.R.P. = 27 WATTS



FORM B

PLACE VILLE-MARIE ------------ MULTICOUPLER DESIGN



FORM C

PART II

Frequency Selection Procedure.

The typical situation that presents itself is that someone requests that he be granted a channel, in the 150-174 Mc/s band. The Regional office has to select from the channels available one which could be assigned to this person.

This problem may be broken down into the following steps:

(1) Find a frequency of the group from which an assignment may be made to this particular person, based on the service to which the channel will be put.

(2) Determine whether the use of this channel at the proposed location is likely to cause interference to any other user.

(3) Determine whether this channel at the proposed location is likely to suffer interference from any established station.

Category of Service, Loading

With regard to step (1) above,

a) Establish the category of service to be performed by the proposed system, e.g., Maritime Mobile Service, Safety Category of Service, Preferred Category of Services, Non-preferred Category of Service.

b) Having established this the next step would be to review the individual Frequency Assignment sheets, covering the frequencies specifically sub-allocated to the category of service, and consider the following points:

(I) Current Loading on each of the channels.

(II) Bandwidth of the existing stations and the proposed station.

On the basis of these considerations make a preliminary selection of the most suitable frequency.

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Interference Consideration

With regard to steps (2), (3) above,

a) The first step at this point is to plot the location of the proposed frequency on the wall map.

b) Note all stations within three miles radius which are operating on frequencies within 1.5 Mc/s of the proposed frequency.

c) Note all stations, regardless of frequency which operate on the same site, or within a radius of 200 feet.

d) Check whether any of the channels within 0.5 Mc/s are used within a distance of 1 mile of the antenna. Within this area, receivers may be de-sensitized or be subject to transmitter noise. Appendix D gives a relationship between the separation in frequency and the amount of protection needed. Adjacent channels should not be used within 1 mile, without special precautions.

e) Check whether the proposed frequency, designated fc, and any of the frequencies determined in (b), (c) above, satisfy any of the relationships:

I) $fc = 2fb - fa$

II) $fc = fb + fa - fd$

Where fb, fa, fd are contained in (b), (c)

These are the conditions for 3rd order intermodulation. We shall neglect higher orders.

In the event that these relationships are satisfied, then use the methods described in the following section to estimate the interference.

On the basis of these extra considerations, confirm or reject the preliminary selection.

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Method of Assessing Interference Potential Using Tx and Rx Susceptibility Charts

(A) Transmitter Susceptibility - Third Order Intermodulation

When one transmitter signal on frequency A enters another transmitter on frequency B, and reciprocally, third order intermodulation products are generated in the output tank circuits at frequencies 2A-B and 2B-A.

Third order intermodulation interference can be estimated and attenuated to an acceptable level by proceeding as follows:

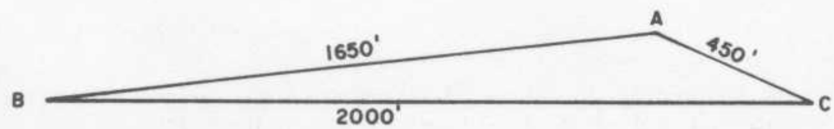
1) Determine the system characteristics. e.g. ERP, Net antenna gain, locations. Of the transmitters determined under Interference Considerations (b), (d) of Part II, consider only those that lie within 1/2 mile of each other.

2) Assess the level of intermodultion products.

3) Calculate the decoupling required between Transmitters A and B.

Example

Assume 2 transmitters A and B and a receiver C at certain fixed locations in a typical urban area. Assume no RF filters are used with any of the equipment.



Problem

Will there be any interference to Receiver C due to intermodulation in transmittar B?

The steps to be followed for this problem are illustrated graphically in Figure 1, and the solution is given on the following pages.

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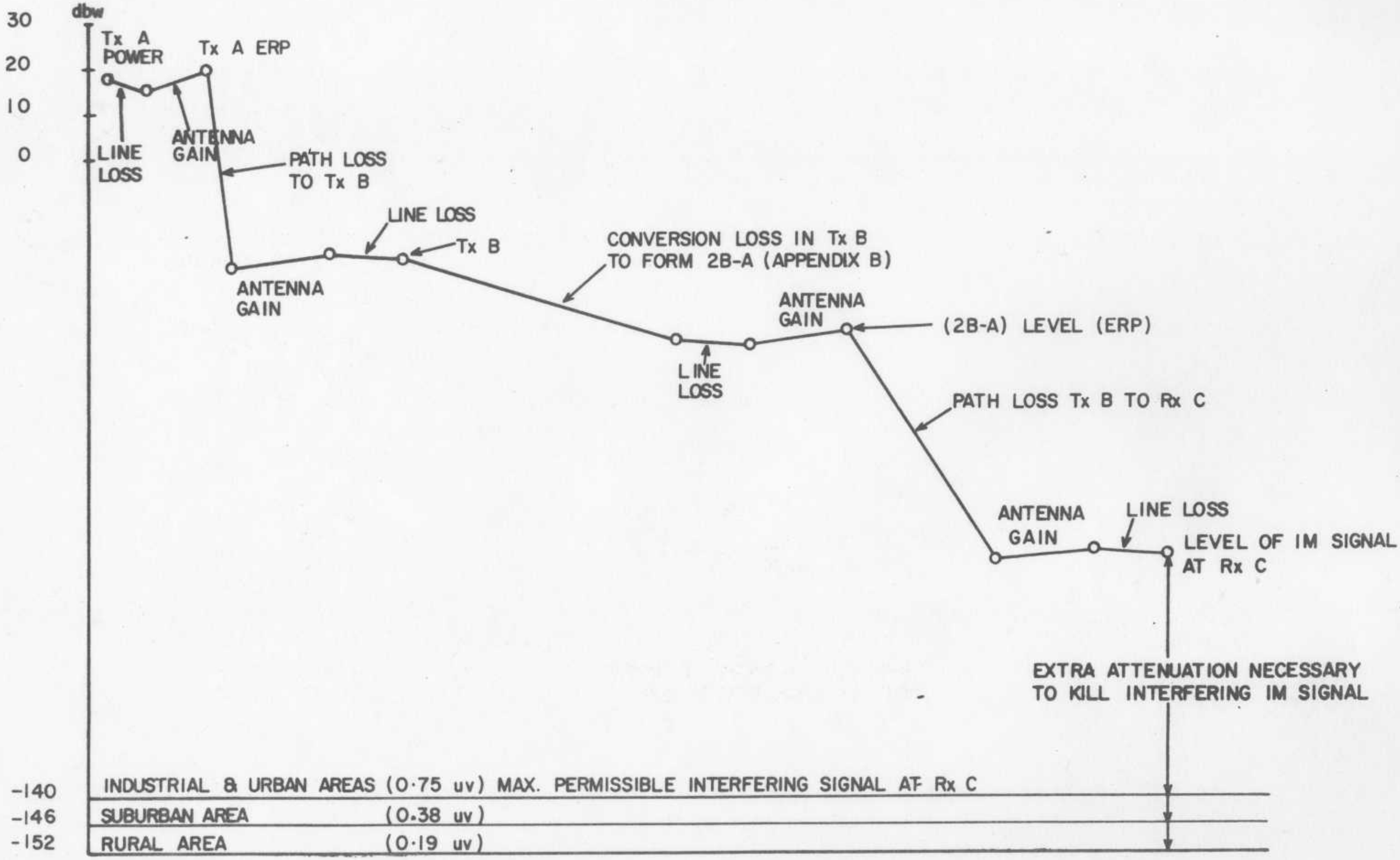
FIG. 1

TRANSMITTER INTERMODULATION CHART



TRANSMITTER INTERMODULATION PERFORMANCE CALCULATIONS

Associated With Figure I

Step

(1)	TxA: Fa = 160.00 Kc/s,	This is the Tx supplying external Mixing Signal. (see Rx)	
(2)	TxB: Fb = 160.500 Kc/s,	IM signal is generated in this Tx which operates on frequency midway between Fa, Fc.	
(3)	RxC: Fc = 161.00 Kc/s,	Rx interfered with.	
(4)	ΔF: = 500 Kc/s,	Frequency Separation (2) - (1).	

	DESCRIPTION	CALCULATION	REFERENCE
(5)	Tx A Power, dbw	17.8 dbw	DOT Rating
(6)	Tx A Antenna gain	4.5 db	Over dipole
(7)	Tx B Antenna gain X 2	6. db	Gain in + Gain out
(8)	Total Gain	28.3 db	(5) + (6) + (7)
(9)	Tx A to Tx B Path Loss	66 db	Appendix A
(10)	Tx A Line Loss	1 db	
(11)	Tx A Filter(s) Insertion Loss	0 db	
(12)	Tx B Line Loss X 2	2.6 db	Loss in + Loss out
(13)	Tx B IM Conversion Loss	14 db	Appendix B
(14)	Total Loss	83.6 db	(9)+(10)+(11)+(12)+(13)
(15)	IM Signal, ERP, dbw	-55.3 dbw	(8) - (14)
(16)	Maximum permissible interfering Signal at Rx	-140. dbw	Figure I
(17)	Necessary attenuation for Interference free situation	84.7 db	(15) - (16)
(18)	Tx B to Rx C Path Loss	68 db	Appendix A
(19)	Rx C Antenna gain	6 db	

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(20)	Rx C Line Loss	1 db	
(21)	Rx C Filter Insertion Loss	0 db	
(22)	Total Attenuation Tx B to Rx C	63 db	18 - 19 + 20 + 21
(23)	Extra attenuation necessary to kill interfering IM signal	27.1 db	(17) - (22)

NOTE: Fc = 2 Fb - Fa can also be generated in the output tank circuit of Tx A. To calculate interference potential of Tx A at Rx C, follow a procedure identical to the above, except that in step (13) increase the number found in Appendix B by 20 db. This is an empirical number found to be approximately correct when IM is generated in the Tx which is 2ΔF removed from Rx C. Remember that ΔF is always the frequency difference between the middle and the end frequency of the 3 frequencies involved.

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RECEIVER SUSCEPTIBILITY

(B) THIRD ORDER INTERMODULATION

Third order intermodulation interference occurs in receivers when foreign signals at frequencies A and B combine in the receiver front end to produce two new signals at frequencies 2A-B and 2B-A, one of which coincide with the frequency C of the desired signal.

Third order intermodulation interference can be estimated and attenuated to an acceptable level by proceeding as follows:

1) Determine the system characteristics.

2) Assess the level of intermodulation products.

3) Calculate the decoupling required between the transmitters (A and B) and the receiver (C).

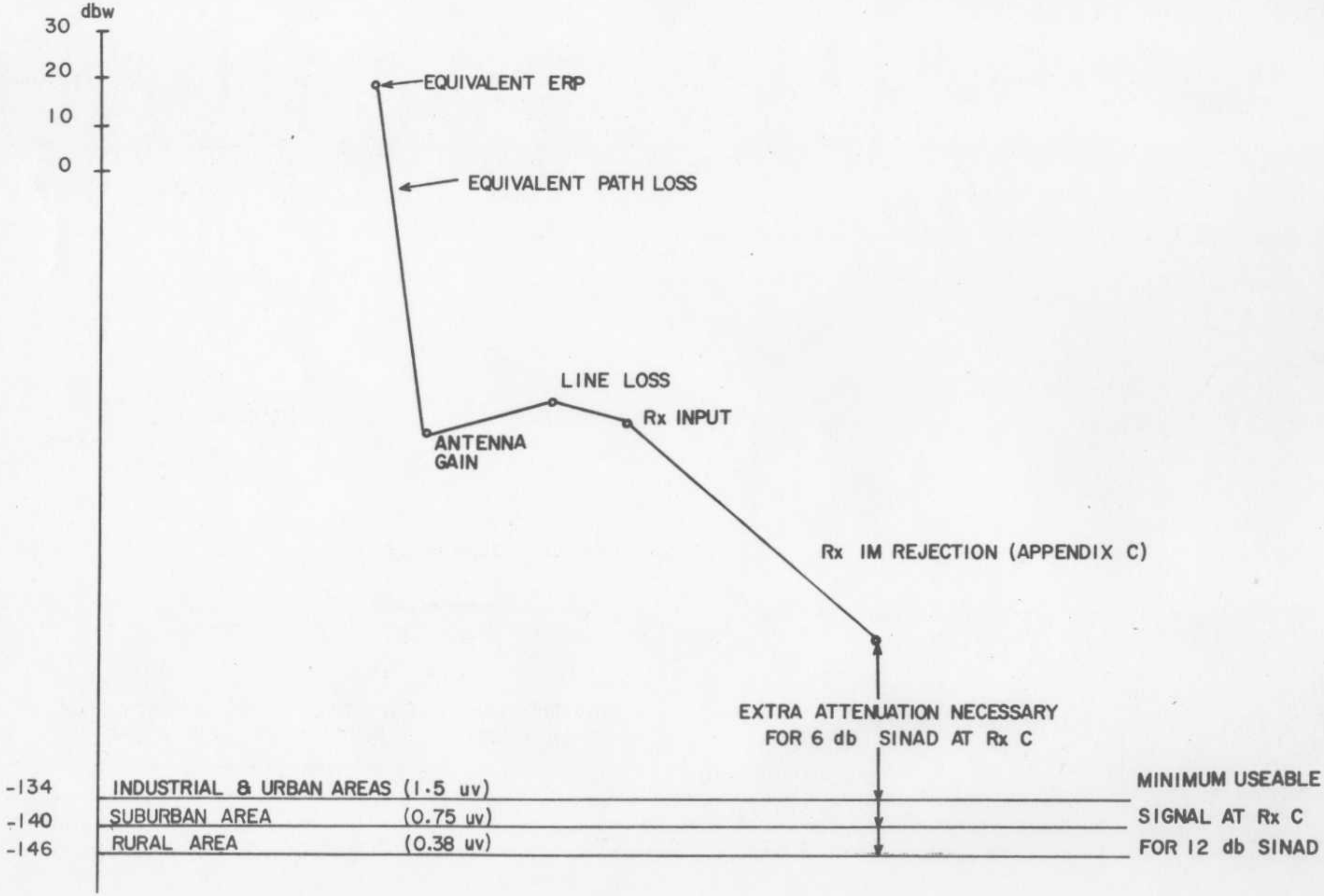
The method used to calculate the interference level and the required decoupling is as in the following example:

EXAMPLE

Assume the 2 transmitters A and B, and the receiver C are at the same locations as in the example for transmitter susceptibility. Will Receiver C generate harmful IM interference within itself? If so, how much attenuation is required to remove it? Steps to be followed are illustrated graphically in Figure 2, and the solution is given on the following pages.

FIG. - 2

RECEIVER INTERMODULATION CHART



RECEIVER INTERMODULATION PERFORMANCE CALCULATIONS

ASSOCIATED WITH FIGURE 2

Step

(1)	TxA:Fa	=	160.00 Mc/s,	Interfering Tx
(2)	TxB:Fb	=	160.500 Mc/s,	Interfering Tx nearest in frequency to Rx C
(3)	RxC:Fr	=	161.00 Mc/s,	Rx interfered with
(4)	ΔF:	=	0.500 Mc/s,	Frequency separation (3) - (2)

	DESCRIPTION	CALCULATION	REFERENCE
(5)	Tx A ERP (dbw)	21 dbw	Over dipole
(6)	Tx B ERP (dbw)	16.7 dbw	Over dipole
(7)	Equivalent interfering ERP	18 dbw	$\left\{\frac{(2 \times (6))+(5)}{3}\right\}$
(8)	Path Loss Tx A to Rx C	55 db	Appendix A
(9)	Path Loss Tx B to Rx C	68 db	Appendix A
(10)	Equivalent path loss	64 db	$\left\{\frac{(2 \times (9))+(8)}{3}\right\}$
(11)	Antenna gain Rx C	6 db	
(12)	Line Loss Rx C	1 db	
(13)	Duplexer Loss Rx C	0 db	
(14)	Net system gain	5 db	(11)-(12)-(13)
(15)	Equivalent interfering signals level at Rx input	-41 dbw	(7) -(10)+(14)
(16)	Minimun useable signal at Rx for 12 db SINAD	-134 dbw	Figure 2
(17)	Necessary attenuation for interference free situation	93 db	(15) - (16)
(18)	Rx IM Rejection	46 db	Appendix C
(19)	Extra attenuation on IM signal necessary for 6 db SINAD at Rx	47 db	(17) - (18)

This is a severe case of interference.

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In the case of interference of the type Fc = Fa + Fb - Fd, the method is identical to that just described for Fc = 2Fa - fd, except in: (1) calculation of Δ F, (2) calculation of Equivalent ERP, (3) calculation of Equivalent Path Loss. Illustrated below is an example, for which we will assume a third transmitter Tx D, situated on the same site as Tx A, provides the third signal.

Step

(1)	First write, Fc = Fa + Fb - Fd,		the order in which the frequencies appear is as follow.
(2)	Tx A: Fa	160.00 Mc/s	Interfering Tx
(3)	Tx B: Fb	160.50 Mc/s	Interfering Tx
(4)	Tx D: Fd	159.50 Mc/s	Interfering Tx
(5)	Rx C: Fc	161.00 Mc/s	Rx Interfered with.
(5)	ΔF :	0.75 Mc/s	1/2 (Fa + Fb) - Fd. It is essential that the equation in (1) be written as shown.

	DESCRIPTION	CALCULATION	REFERENCE
(6)	Tx A ERP (dbw)	21 dbw	Over dipole
(7)	Tx B ERP (dbw)	16.7 dbw	Over dipole
(8)	Tx D ERP (dbw)	15.0 dbw	Over dipole
(9)	Equivalent ERP (dbw)	18 dbw	$\frac{(6) + (7) + (8)}{3}$
(10)	Path Loss TxA to Rx C	55 db	Appendix A
(11)	Path Loss Tx B to Rx C	68 db	Appendix A
(12)	Path Loss Tx D to Rx C	55 db	Appendix A
(13)	Equivalent Path Loss	59 db	$\frac{(10) + (11) + (12)}{3}$
(14)	Antenna Gain Rx C	6 db	
(15)	Line Loss at Rx C	1 db	
(16)	Duplexer Loss Rx C	0 db	
(17)	Net system Gain	5 db	(14) - (15) -(16)

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(18)	Equivalent interference signal level at Rx input	-36 dbw	(9) - (13) + (17)
(19)	Minimum Usable signal at Rx for 12 db SINAD	-134 dbw	Figure 2
(20)	Necessary Attenuation for interference free situation	98 db	(18) - (19)
(21)	Rx IM Rejection	49 db	Appendix C
(22)	Extra Attenuation Necessary	49 db	(20) - (21)

External, or Hardware Intermodulation

This is the case where towers, rooftops, guy wires are the source of the intermod signal, as different from the transmitters or receivers themselves. Frequency separation affords little protection. Distance separation affords major protection. Therefore all frequencies within 300 feet should be checked and potentially harmful combinations avoided on the same site.

PART 4

Making the Frequency Selection

With the methods of estimation given in Part III it is possible to arrive at an answer to the original question.

In part II a preliminary selection based on loading was made and this was checked out from interference considerations. If interference did not present a problem then the original choice could be used. If Interference did present a problem then we could either,

(a) Repeat the entire process with a second frequency,
(b) Attempt to deal with the interference by use of filter, or change of location.

If IM is developing in the receiver, then either a cavity or crystal filter may solve the problem. A study of the characteristics of various filters will determine their suitability to provide the required attenuation.

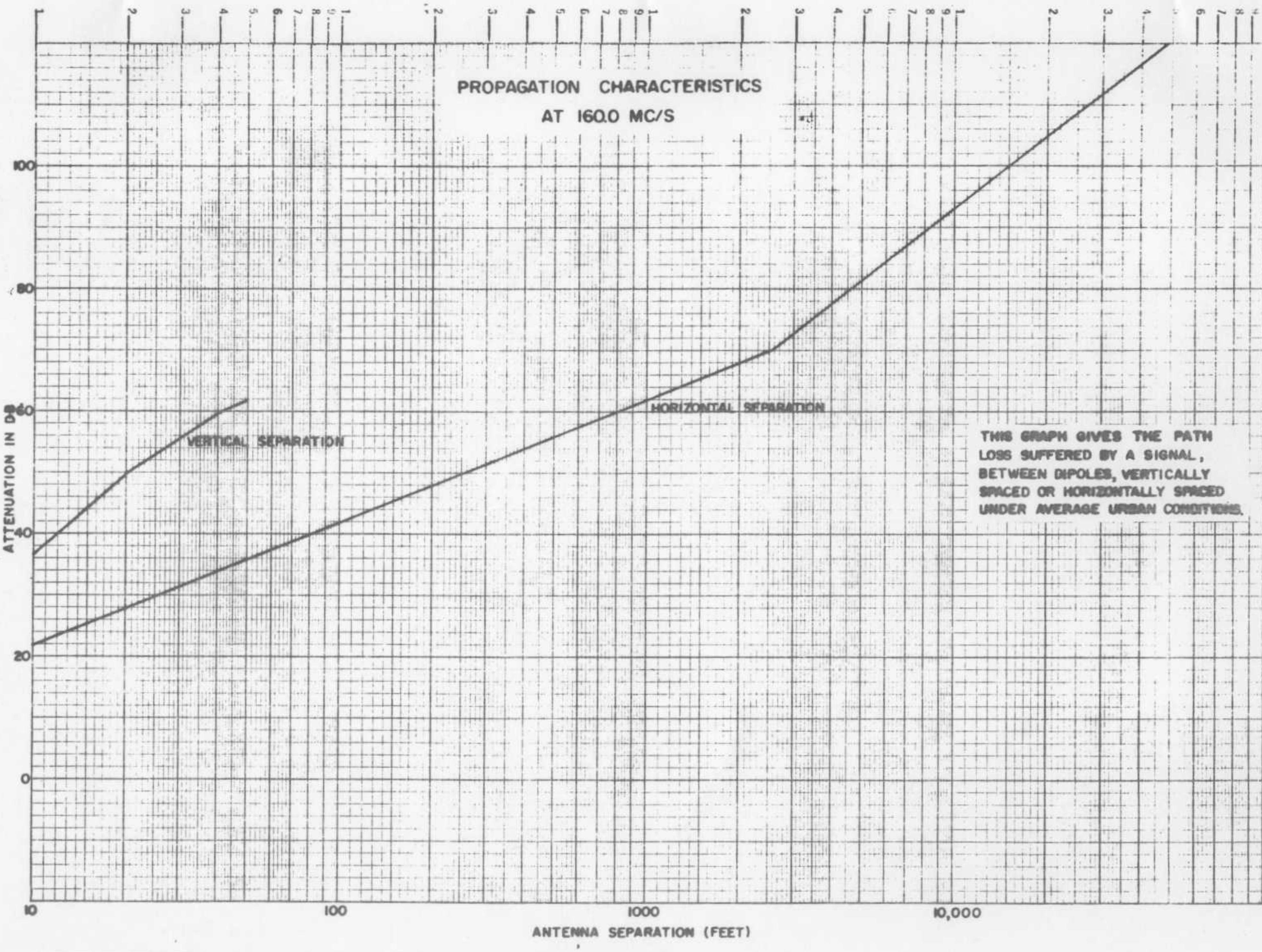
If intermodulation is developing in the transmitter then a cavity filter, or in extreme cases a ferrite circulator may be used. The circulator has the advantage that it is a one-way device and is effective no matter how close in frequency the second interfering transmitter may be.

If either of these efforts is satisfactory then a change of frequency or a change of location, may be necessary.

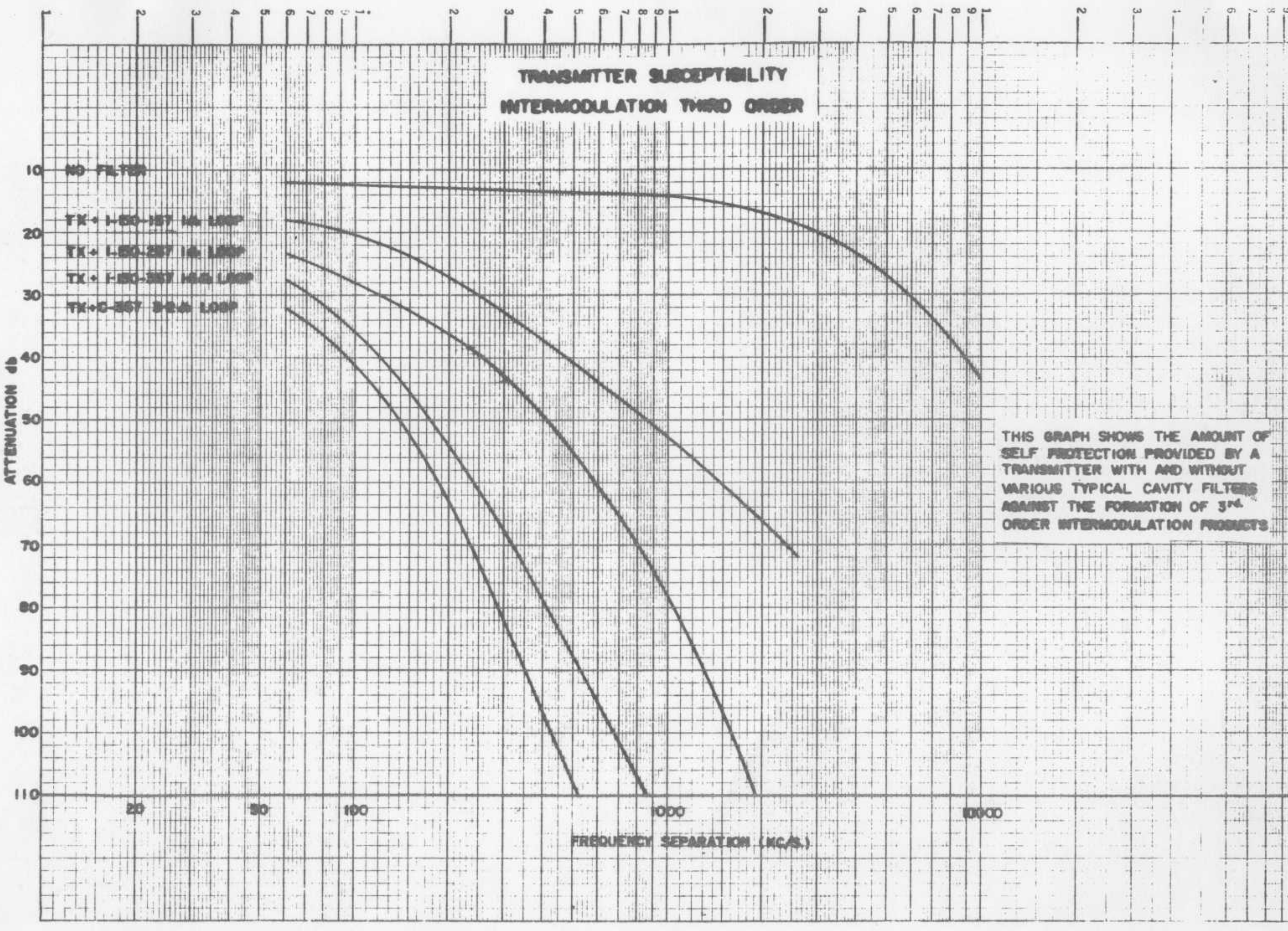
It is to be stressed that elaborate methods such as these are only necessary in areas of congestion. In most parts of the country congestion is not the case and only simple choices based on loading will suffice.

Finally, proposed assignments are recorded in a stenographer's notebook in the order that they are processed pending favourable frequency co-ordination. The following are the particulars that should be recorded:

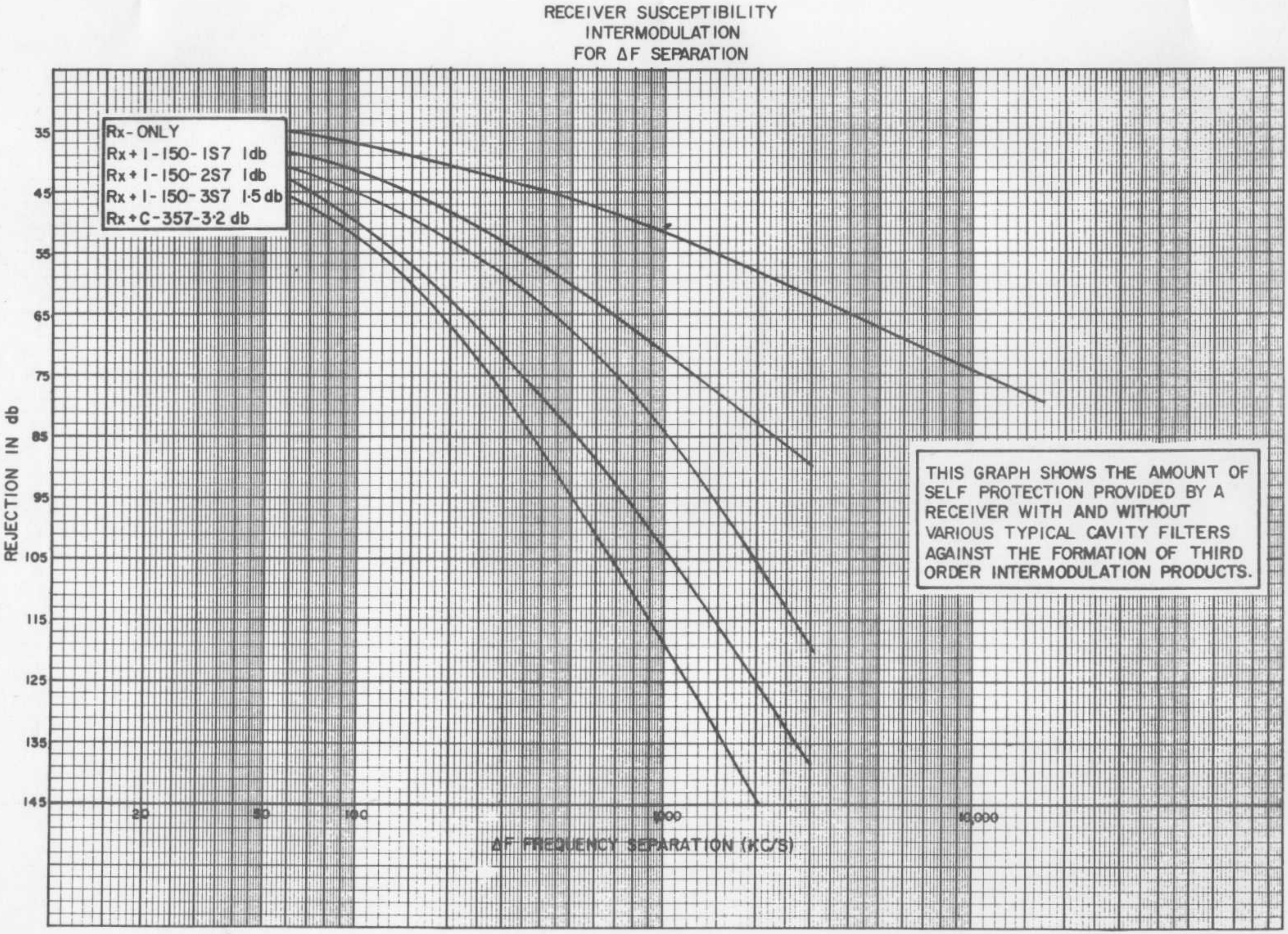
1) Selected frequency.
2) Location of proposed base or fixed station.
3) Effective Radiated Power.
4) Name of applicant.
5) Regional office file number.
6) Date application forwarded to Headquarters.
7) Frequency Code Identifier.


PROPAGATION CHARACTERISTICS
AT 160.0 MC/S
VERTICAL SEPARATION
HORIZONTAL SEPARATION
THIS GRAPH GIVES THE PATH LOSS SUFFERED BY A SIGNAL, BETWEEN DIPOLES, VERTICALLY SPACED OR HORIZONTALLY SPACED UNDER AVERAGE URBAN CONDITIONS.
ATTENUATION IN DB
ANTENNA SEPARATION (FEET)
10
100
1000
10,000
0
20
40
60
80
100

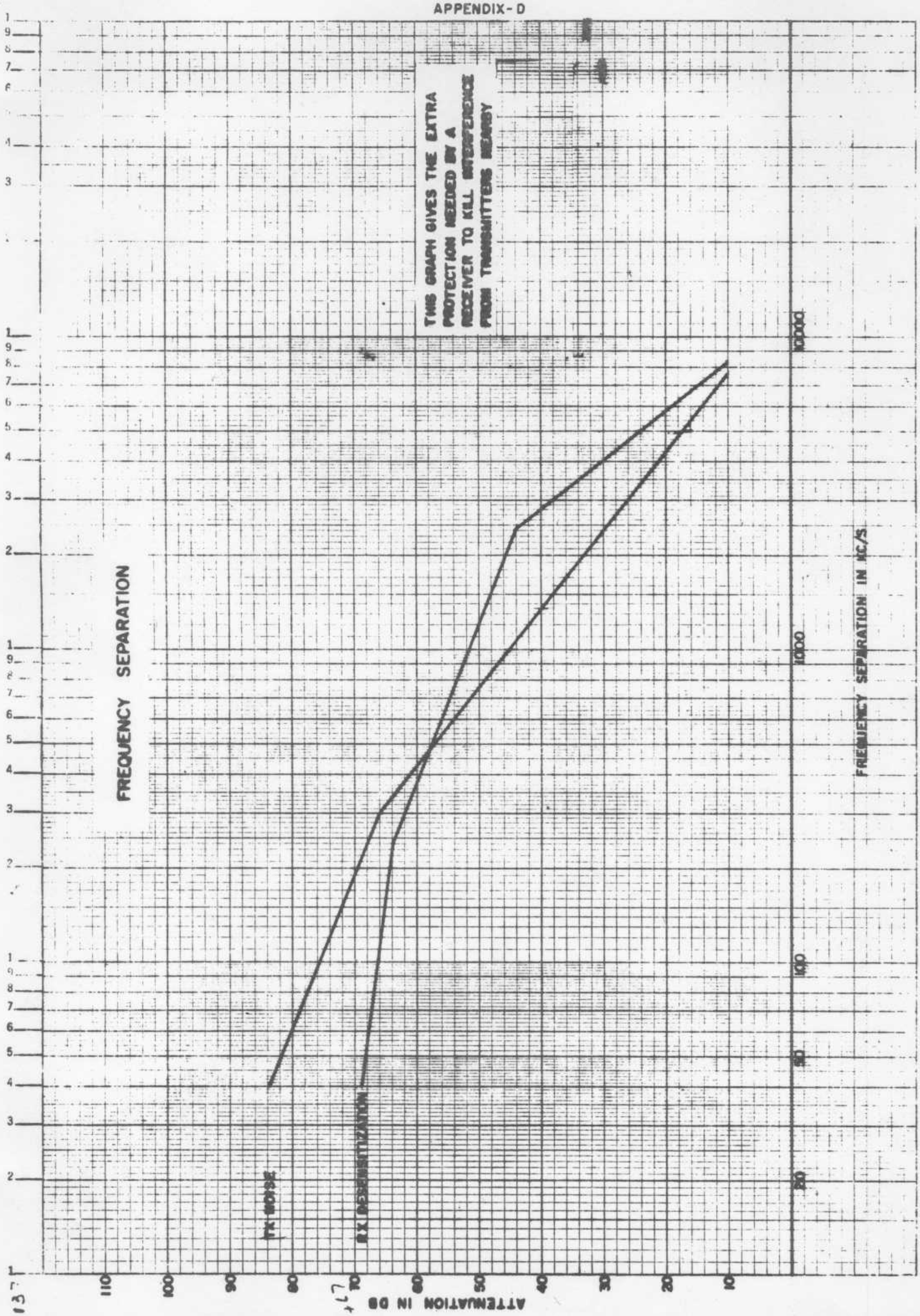
APPENDIX-A


TRANSMITTER SUSCEPTIBILITY
INTERMODULATION THIRD ORDER
NO FILTER
ATTENUATION db
10
20
30
40
50
60
70
80
90
100
110
20
50
100
1000
10000
FREQUENCY SEPARATION (MC/S.)
THIS GRAPH SHOWS THE AMOUNT OF SELF PROTECTION PROVIDED BY A TRANSMITTER WITH AND WITHOUT VARIOUS TYPICAL CAVITY FILTERS AGAINST THE FORMATION OF 3rd ORDER INTERMODULATION PRODUCTS

APPENDIX - B


RECEIVER SUSCEPTIBILITY
INTERMODULATION
FOR ΔF SEPARATION
Rx- ONLY
Rx + 1-150-1S7 1db
Rx + 1-150-2S7 1db
Rx + 1-150-3S7 1.5 db
Rx + C-357-3.2 db
THIS GRAPH SHOWS THE AMOUNT OF SELF PROTECTION PROVIDED BY A RECEIVER WITH AND WITHOUT VARIOUS TYPICAL CAVITY FILTERS AGAINST THE FORMATION OF THIRD ORDER INTERMODULATION PRODUCTS.
REJECTION IN db
35
45
55
65
75
85
95
105
115
125
135
145
20
50
100
1000
10,000
ΔF FREQUENCY SEPARATION (KC/S)

APPENDIX-D


THIS GRAPH GIVES THE EXTRA PROTECTION NEEDED BY A RECEIVER TO KILL INTERFERENCE FROM TRANSMITTERS NEARBY
FREQUENCY SEPARATION
FREQUENCY SEPARATION IN KC/S
10000
1000
100
50
20
TX NOISE
RX DESENSITIZATION
ATTENUATION IN DB
110
100
90
80
70
60
50
40
30
20
10