PROBLEMS INVOLVING INTERFERENCE

INTRODUCTION:

Study of the subject of interference becomes more vital as the two way spectrum space fills to the brim with users. Such interference is on the increase and a working knowledge of the various types is essential to every sales representative or serviceman to aid in combatting it.

Basically there are five types of interference which are likely to plague users of Land-Mobile equipment. Most interference will fall into one of these categories:

Type	Abbreviation
1. Spurious, Harmonics Images	SP
2. Intermodulation	IM
3. Noise	NS
4. Desensitization	DS
5. Skip	SK

DISCUSSION:

1. Spurious and Images result in a receiver in the presence of certain off frequency signals which bear particular relationships to the high and low IF frequencies. By a combination of correct IF frequencies and high front end selectivity these responses can be made negligible. In a receiver having broad front end selectivity the problem will be more severe. Harmonics, on the other hand, are generated in the interfering transmitter independent of the receiver.

2. Intermodulation is the result of two or more signals combining to produce a signal in the receiver which appears as an on-frequency signal except for modulation. In order for intermodulation to be present all the interfering signals must be on the air simultaneously. Intermodulation can best be minimized in a receiver by using cavities or a highly selective front end. But even the best available techniques fall short of perfection and intermodulation does occur. The intermodulation problem results primarily from the fact that most receivers have a very broad acceptance or pass band preceding the first grid and in addition, the relationship of grid voltage to plate current in the RF Amplifier is not linear. That is, the best of RF Amplifier tubes when operating as amplifiers are also detectors. This is especially true for relatively large grid voltages. The plate current characteristic of the RF amplifier tube, due to its curvature, is a fair harmonic generator, detector and mixer.

As a typical example of what happens in intermodulation suppose a station is at 150 mc and there are two other stations in the vicinity, one at 150.80 mc and another at 150.160 mc. The antenna picks up both signals and carries them to the first RF grid. Due to the RF Amplifiers harmonic generating and mixing characteristics (due to non-linearity) the 150.8 will double giving 300.16. This will mix with the 150.16 by subtraction giving 150, right on the acceptance band. If the front end were selective enough it could knock the amplitude of these signals down to where they were ineffective. Frequency spacings of 80 and 160 KC are not the only combinations giving trouble. 40 and 80 KC, 100 and 200 KC would also be combinations giving the same result. In general any two frequencies with spacings of $\triangle f$ ad $2\triangle f$ will combine to cause intermodulation.

Another combination of stations that would give trouble on frequency "f" would be:

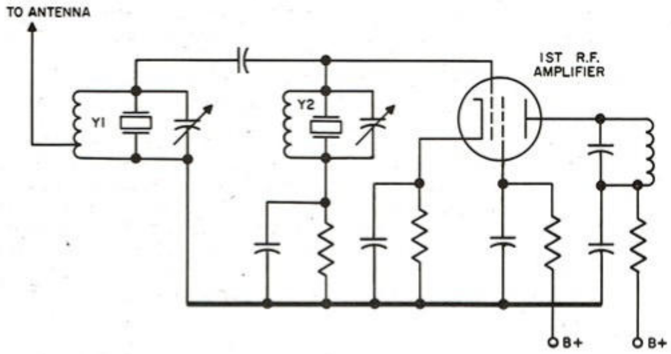
	Numerical Example	
$f_1 = f + m\triangle f$ (m is <u>any</u> whole number)	$f_1 = 152.27$	$\triangle f = .12$
$f_2 = f + n\triangle f$ (n is any whole number)	$f_2 = 152.51$	$m = 1$
$f_3 = f + (m + n)\triangle f$	$f_3 = 152.63$	$n = 3$
	$f = 152.15$	
$m \neq n$		

The action would be as follows, assuming all three signals hit the air simultaneously and appear on the RF amplifier grid: f_1 and f_2 would add giving $2_f + m\triangle f + n\triangle f$. F_3 would then subtract from this sum and give f, right on frequency.

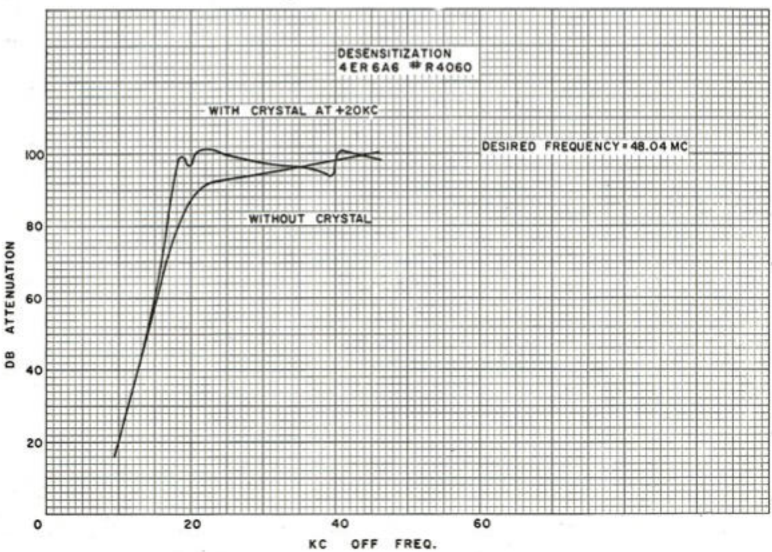
In the numerical example $f_1 = 152.15 + .12$ and $f_2 = 152.15 + .36$. These add giving $2\ (152.15) + .48$. Note that f_3 is $152.15 + .48$. It is easily seen how this will subtract from the previous sum giving 152.15. This is an actual case history incidentally.

A third type of intermodulation would involve AM broadcast stations. Assume a station at f another at f + 1 MC and a broadcast station at 1 MC. The subtraction will give f, right on frequency.

The third type of intermodulation is best alleviated by bypassing the broadcast signal out of the antenna circuit by filtering with a trap. Situations of the first two types have till now been almost impossible to combat. The answer has been found in the use of standard piezoelectric quartz crystals when properly applied to the circuit or circuits preceding the first grid. The crystals cause a negligible loss in the input circuit on the desired frequency.



LO-BAND ANTENNA CIRCUIT FIG. 1



TYPICAL DESENSITIZATION CURVE FIG. 2

The circuit in Figure 1 shows how the crystals are applied. An inspection of the circuit shows that for series resonance of the crystal each coil of the antenna transformer will be loaded with the equivalent resistance of the crystal (approximately 30 ohms for undesired frequencies) which is, of course, a very effective short across each winding of the antenna transformer at the undesired carrier frequency. The impedance, of the coils in the antenna transformer, is in the order of 100,000 ohms within its band pass. Within a 20 KC channel the crystals will also pass through their parallel resonances which will occur at a slightly higher frequency than that of the series resonance point. At parallel resonance, the crystals have an absorption effect which broadens the effective frequency spectrum over which the crystals disable the antenna transformer. The total effect is sharp enough so that the crystals may be used as protection against adjacent 20 KC channels in the 25-50 MC band, with a negligible loss to the desired signal.

In case of severe desensitization, either adjacent channel or for any frequency within the pass band of the antenna transformer, the low resistance of the crystal at series resonance can be used very effectively to improve the desensitization characteristic of the receiver up to the point where transmitter noise is the limiting condition. The crystal is applied to the secondary winding of the antenna transformer as shown in the circuit of Figure 1 (Y_2). Where a single crystal is used the improvement obtained in desensitization for an adjacent 20 KC channel is 10 to 15 db. Should a further improvement in desensitization be desired, another 10 db can be obtained by placing a series resonant crystal across the resonant circuit associated with the antenna (Y_1). A typical desensitization curve is shown in Fig. 2. In this case, only crystal Y_2 was used.

The following information should be considered before ordering the crystal or crystals:

(1) Order crystal on the frequency you want to suppress. Use the same drawing number as used for the first oscillator of this receiver. The interfering signal must be on the same frequency as the frequency of the crystal to be ordered. If the interfering signal is not on the correct frequency, then the use of the crystal and antenna transformer as a rejection filter will not be successful, as the crystal is a very sharp device. When ordering state that the crystal is to be used for intermodulation suppression.

(2) If one of the signals causing intermodulation is much stronger than the other, then it is usually only necessary to utilize a single crystal. When only one crystal is used, it should be placed across the secondary of the antenna transformer.

In this case it is not necessary to remove the antenna transformer as one side of the crystal can be soldered directly to the grid of the first RF amplifier, and the other side of the crystal will connect to ground at the socket. Use short leads and solder them directly to the crystal pins. When soldering leads to the crystal do so at the end of the pins so as not to damage the crystal.

Should it be necessary to trap both interfering signals then the second crystal should go directly across the primary of the antenna transformer. The antenna transformer need not be removed. Unsolder the grid lead and the cover can be removed from the transformer and the crystal soldered directly across the upper trimmer.

The capacity of a crystal is usually 6 or 7 uuf, consequently the trimmers must be reset after the crystals are attached. Should the operating frequency be very near the high end of the band it will be necessary to remove the fixed ceramic condenser across the trimmer.

After installation of the crystal or crystals the receiver should be checked for sensitivity. If the sensitivity is not normal, after retuning the antenna transformer, then check to see if the trimmers are at a minimum capacity. Should proper retuning of the antenna transformer fails to restore normal sensitivity then the crystal used to suppress an undesired carrier has a spurious which falls on the desired carrier. All crystals do have spurious responses and they are higher in frequency than the mode frequency the crystal is calibrated for. Should it occur then it would be necessary to obtain another crystal and this condition noted on the returned crystal.

(3) Noise is on frequency interference generated external to the receiver. Noise may be either man made or atmospheric. Both sources produce either impulse or random NS. The principal effect of noise is to make the receiver less sensitive. In that capacity it contributes to desensitization.

(4) Desensitization is the term generally given to loss in receiver sensitivity due to the presence of a strong signal of a nearby frequency. It appears as an off channel effect.

(5) Skip is on frequency interference caused by atmospheric conditions. Skip can also cause intermodulation under proper conditions.

ANALYSIS

Before interference can be reduced or eliminated, it is necessary to determine the cause of the interference and to analyze the various possibilities of solution. To do the job systematically and efficiently, it is necessary to obtain pertinent information on all electronic equipment in the vicinity of the subject interference which may radiate signals strong enough to cause interference.

The following hints will help to identify the kind of interference, and taken with other pertinent information, should pinpoint the source.

It is important to observe certain indications in the receiver when determining the type and cause of interference. The observation should include:

1. Action of First and Second Limiter with and without interference.

2. Action of Discriminator meter during and after interference.

3. Audio output due to interference if such exists.

4. Action of Squelch during and after interference.

To assist in identifying various types of interference, the following rules may be followed:

1. The first test to try in locating any interference is to determine whether the interference enters through the antenna input or through some other door. This is done by removing the antenna input and making all the observations listed above.

2. Spurious, Harmonics and Images (SP): In general, it is very difficult to distinguish between these three types of interference. To determine whether the fault lies in the transmitting source, or in the receiver, it is usually necessary to test with an RF filter preceding the antenna input to the receiver. This filter can be a trap or a 1/4-wavelength shorted stub tuned to the receiver frequency. If the interference remains unchanged or drops a few db due to insertion loss of the filter, then the offender is a transmitter on spurious harmonic. If, however, the interference is reduced more than the filter insertion loss, it is an indication that an off channel signal is causing a spurious to be generated in the receiver, which is the fault of the receiver.

This same filter technique can be used in the cases of intermodulation and desensitization, but care must be taken that the filter provides at least 3 db attenuation at the adjacent channels.

Other important observations regarding spurious, image, and harmonics are:

A. These three types of interference will always make the limiter currents increase when the interference is on.

B. If the interference is from FM Signals of the same deviation, the audio may be intelligible in the case of images and some types of spurious if the discriminator indicates a signal close to the center frequency.

C. If the audio is unintelligible and the limiter current and/or discriminator currents fluctuate during modulation, the interference may be a result of harmonics of a transmitter. Spurious or IM of the transmitter or receiver can also give this same type of indication.

D. CW Signals causing interference may come on without producing audio in the receiver. The discriminator reading should always be observed to determine the stability and apparent frequency of such signals.

AM signals cause very low level audio with probable increase in limiter current during modulation.

E. These three types of interference differ from intermodulation in that a single interfering transmitter can produce them.

3. Intermodulation (IM) is the result of two or more interfering transmitters on the air together. Important observations regarding intermodulation are:

A. Limiter currents rise during interference.

B. Audio may or may not be intelligible depending on whether harmonics are involved in the mixing action in the receiver head end. The swing varies directly with the harmonic and may exceed receiver bandpass.

C. Since IM is caused by two or more signals, the interference may start and finish in the middle of transmissions of the interfering signals. This is not the case when one of the interfering signals remain on for long periods of time such as broadcast stations.

D. It is not necessary that all the interfering signals enter the receiver by the same means. In the case of Low Frequency Broadcast Stations, one signal might enter the receiver through the cabinet wiring while the VHF signal could enter through the antenna.

E. Transmitters operated close to each other can produce an intermodulation product which will cause the receiver to produce a spurious.

4. Desensitization (DS) is normally caused by one signal of close physical and frequency proximity. The desensitizing signal develops a voltage on the RF amp grid causing the tube to conduct more heavily decreasing its gain. Characteristics of DS are:

A. Decrease in limiter current.

B. Decrease in sensitivity.

C. Discriminator unstable and having larger fluctuations in the presence of modulation or interfering signal closer than 60 KC off center frequency.

5. Noise: The presence of NS at the receiver is evidenced by a decrease in the sensitivity and an increase in the limiter currents. NS may sometimes affect the desired squelch setting while the limiter current continues to seek some stable reading.

Interference Check List and Station Locations

This instruction has been prepared to assist in locating and reducing interference which, from all indications, is on the increase. Any comments or suggestions will help Field Engineering improve the usefulness of this instruction in the future. If interference is encountered and assistance is desired to anaylze and give aid in its reduction, it is suggested that the attached sheets be filled out and sent to the Communication Engineer who has charge of the district. Be as complete as possible. The more information that can be included on a given interference problem, the greater the chances of locating the source and suggesting ways of reduction. A separate sheet should be filled out for each case of interference. If more sheets are required, they can be obtained by requesting EBI 41002 from the G.E. in the district.

METHODS OF INTERMODULATION MEASUREMENT:

As mentioned above there are basically two methods of measuring intermodulation spurious response of a receiver.

Two Signal Generator Method

Two unmodulated signal generators (for example Measurements Corp. Model "80") shall be connected by means of suitable connectors and identical cables to the common RF antenna input circuit of the receiver under test. The receiver voice coil terminals shall be terminated with a standard load and an output meter connected across it.

With both generators connected to the receiver under test, measure and note the on-channel (desired signal frequency) signal level required from each individual generator to produce 20 db quieting.

Generator #1 is set to the alternate channel above (or below) the on channel frequency with a high RF output (5,000 to 10,000 uV). Generator #2 with an equal RF output is tuned to the adjacent channel above (or below) the on channel frequency. This will give an on-frequency spurious response. Generator #2 should be adjusted in frequency slightly to zero the discriminator. Maintaining equal signal ratios of actual power output level to "on-channel" 20 db quieting level as determined by above effective sensitivity measurements (this means that the absolute outputs may be different), the RF power outputs of the two generators are reduced simultaneously to that level which results in a 20 db quieting interference signal.

For higher level interference the Signal Generator levels are adjusted for a interference signal that produces the same limiter grid current as the desired level of on-frequency signal.

The AAR specification for nuisance interference requires that the two equal ratios of not less than 64 db above the "on-channel" effective

20 db quieting signal level, impressed simultaneously across the receiver terminals at frequencies displaced plus 60 kc and plus 120 kc from the desired frequency shall produce a nuisance interference signal which quiets the receiver not more than 20 db.

This is the intermodulation specification that is usually met in the field. By this method our high band equipment normally measures 68 db or better.

The AAR specification for reception interference requires that two equal signal ratios of not less than 80 db above the "on-channel" effective 20 db quieting signal level, impressed simultaneously across the receiver antenna terminals at frequencies displaced plus 60 kc and plus 120 kc from the desired frequency shall produce a reception interference signal equivalent to a 10 microvolt on-channel signal.

This reception interference specification has given very little additional information on the performance of the receiver, as 10 microvolts level is not high enough to result in appreciable difference in performance.

Lately there has been increasing interest in high level intermodulation interference with interference signals equivalent to 100 or 1000 microvolts. For high level measurements the two generator method is not satisfactory as desensitization may cause faulty measurements when IF grid current is used as a criterion of level.

For these measurements the three signal generator method should be used.

Three Signal Generator Method

The output of the radio receiver shall be terminated in a standard output load. Three similar signal generators shall be equally coupled to the receiver antenna input terminals. Signal generator #1 shall be modulated with 1000 cps and 70 percent rated system deviation. Signal generator #2 shall be unmodulated. Signal generator #3 shall be modulated 70 percent of rated system deviation with 400 cps. With signal generators #2 and #3 turned off, the frequency of signal generator #1 shall be adjusted to the resonant frequency of the receiver, and the output adjusted for equivalent desired reference level (i.e., input will be adjusted to compensate for effect of three generators being coupled in parallel). Generator #2 shall now be adjusted to the adjacent channel above (or below) the signal frequency, and Generator #3 shall be adjusted to the alternate channel above (or below) the signal frequency. The equivalent outputs of generators #2 and #3 shall be maintained at equal level and this level shall be increased until the signal-plus-noise-plus-distortion to noise-plus-distortion ratio is reduced to 6 db. The frequency of generator #3 shall be adjusted slightly to produce the maximum interfering signal before the final measurement is made. The ratio of the equivalent outputs of generators #2 and #3 to the equivalent output of generator #1 expressed in db is the measure of intermodulation spurious response.

By this method of measurement our high band equipment measures as follows for a typical receiver.

Reference Level Desired Signal	Ratio Interfering Signal Level to Reference Level Signal
	71 db
Signal to give 12 db. S+N+D/N+D (very closely the same as 20 db quieting level)	
10 uV	56 db
100 uV	47 db

The best signal generator to use for generator #3 is a Boonton 202C for the 152-174 mc band. For the 25-50 mc band it would be a Marconi FM-AM Signal Generator Type TF913/1.

INTERFERENCE CHECK LIST

Receiver Frequency_______________ Model_____________________

Type Antenna ____________________ Antenna Height______________

1. Is interference present when antenna is removed?____________

Meter Readings:	With Antenna Removed	Normal	During Interference	
			With Modulation	Without
2. Low IF Current				
3. 1st Lim.Current				
4. 2nd Lim.Current				
5. Discriminator				

6. Modulation on interfering signals is intelligible _____% Time; unintelligible________% Time; No modulation__________% Time;

7. Does interference seem to start or end in the middle of a transmission of the interfering station?_________________

8. Does the interference occur at regular intervals____________; hours________________; completely random________________?

9. If the interference is noise, give such information as: Man made, Atmospheric, temperature, humidity, duration, build up time, decay time, impulse, random:

____

____

____

____

10. Comments:___________________________________

____

____

____

11. Conclusions and Methods of reduction:__________________

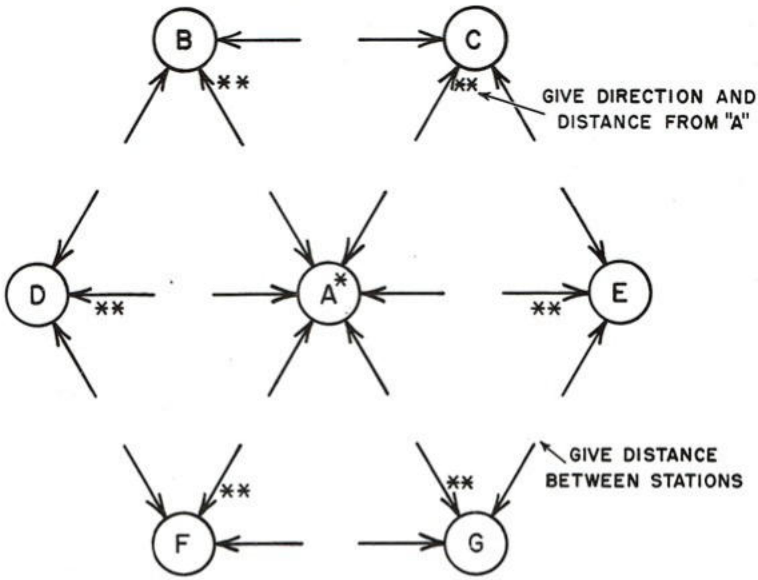
____

____

____

Name________________Date__________

LOCATION OF INTERFERING STATIONS



DISCRIPTION OF INTERFERING SIGNALS

LOCATION (CITY)	LOCATION (LETTER)	FREQUENCY (OUTPUT)	FREQUENCY (CRYSTAL)	POWER OUTPUT	TYPE MODULATION	TYPE ANTENNA	ELEVATION	ANTENNA HEIGHT	REMARKS
	*								

* A SHOULD BE USED AS THE LOCATION OF THE RECEIVER BEING INTERFERED WITH.

** GIVE TRUE AZIMUTH DIRECTION FROM "A"