CHAPTER 8

# MINIMIZING SITE INTERFERENCE

This chapter provides information on preventing radio frequency (RF) interference at a communications site. The following topics are included:



This chapter describes the minimum filtering and techniques that should be applied at any fixed site to minimize interference. These techniques should be used by a site manager or carrier to define the minimum essential elements to achieve successful operation. Implementation of these requirements will help provide an environment for successful operation and future expansion.

The requirements defined in this chapter pertain to eliminating interference, and are separate from the RF Engineering design of the site.

## 8.1 INTERFERENCE PROTECTION RECOMMENDATIONS

Unlike mobile units that can be moved to an interference-free area, fixed sites must incorporate equipment and techniques to reduce the likelihood of interference. The ability to successfully receive the desired radio signal at the fixed receiver is dependent upon providing the best possible radio frequency environment at the site. To accomplish this, the level of undesirable energy occurring on the received frequency must be minimized. In most cases, minimizing the level of undesirable energy emitted by the local transmitters and filtering out undesirable signals coming into the receiver eliminates received interference in the receiver environment. Interference is more likely to be a problem at sites with multiple antennas. If these measures have been taken and the receiver is still picking up noise, then noise sources in the surrounding environment must be identified and eliminated.

A successful communication site should have standards that are applied to all users of the site and recommended to other communications sites in the general vicinity. Another site within a 400 m (1/4 mile) radius may interfere with your site or may receive interference from your site unless protective equipment and techniques are used.

The techniques described in this section have a history of successful implementation, and are not specific to any particular radio or filter vendor. The protective equipment to be used is available from numerous vendors that have met Motorola's criteria for product performance, reliability, and support. Contact the local Motorola Engineering team for additional details.

Transmitter noise, receiver desensitization and unwanted intermodulation caused by objects in the site environment are the most common causes of receiver interference. Other common interference terms are Co-Channel and Adjacent Channel interference. Some analysis of the existing or proposed frequencies at an antenna site can help in the site design process. Requirements for preventing problems in each of these areas are described below.

## 8.1.1 MINIMUM TRANSMITTER PROTECTION REQUIREMENTS

A properly designed site will incorporate several techniques to reduce the likelihood of the transmitters causing interference to a receiver signal. Each transmitter should have an isolator, low pass filter and bandpass cavity setup. The number of isolators and bandpass cavities needed for a transmitter to achieve proper filtering is dependent upon the transmitter equipment and frequencies at the communication site and other transmission sites in the local area. If additional help is needed to determine these requirements, contact the local Motorola Engineering team for additional support.

An isolator is used on a transmitter to reduce the amount of radio energy, which is coming back into the final amplifier stage from the antenna system. This action in turn reduces the undesirable signal levels of other radio signals coming back into the final amplifier stage and helps to prevent a mixing of two or more different frequencies within the non-linear device. The mixing process is called transmitter intermodulation and it can generate interfering frequencies for receivers. In some situations, the isolator can produce second harmonic spurious emissions, which are also harmful to receiver reception. To protect against this a low pass filter should used between isolator stage and the antenna system.

A bandpass cavity is a high Q resonant circuit, which is designed to pass a narrow band of frequencies with very little energy loss while attenuating all other non-resonant frequencies. Bandpass cavities should be installed between the transmitter and antenna system to reduce spurious signals and transmitter sideband noise that might otherwise be radiated from the transmitter and degrade the performance of nearby receivers. The use of a bandpass cavity will also reduce and minimize transmitter intermodulation since all off-frequency signals from other nearby transmitters will be attenuated as they pass through the cavity.

For successful operations and future expansion of the site, the following recommendations should be considered when installing transmitters within the following frequency bands. See Figure 8-1 for proper configuration of the recommended filtering devices.

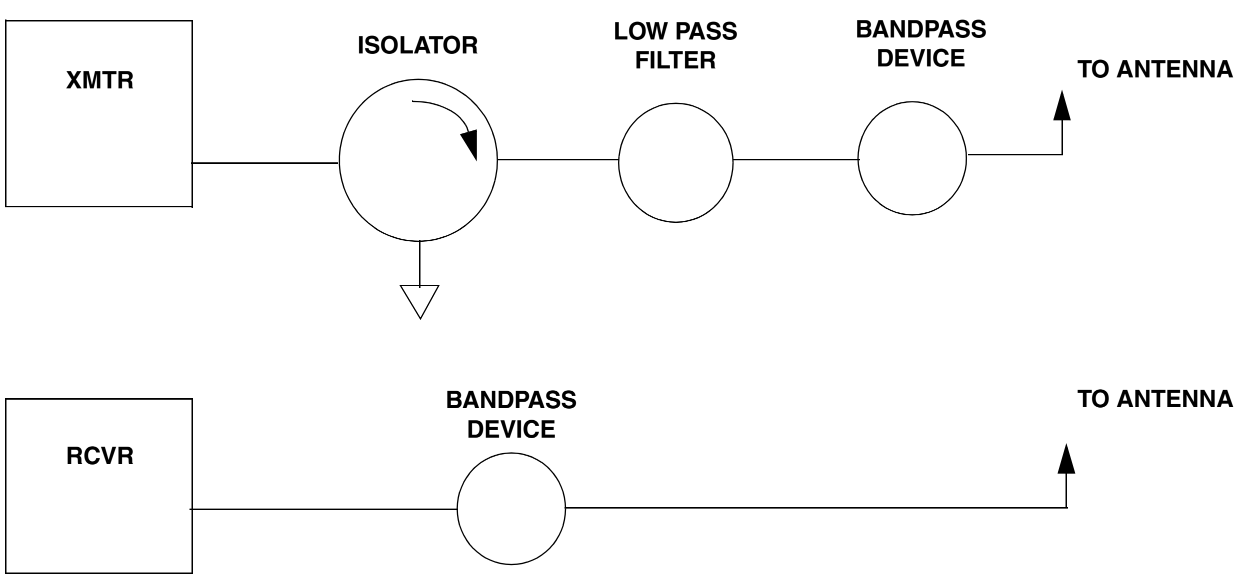


**FIGURE 8-1** CONFIGURATION OF FILTERING DEVICES

**25-54 MHz** - Transmitters in this range **shall** have an isolator with a minimum of 20dB reverse isolation followed by a low pass filter and a bandpass cavity setup, which provides a minimum of 20dB of attenuation at 1 MHz from the transmit frequency.

**66-88 MHz** - Transmitters in this range **shall** have an isolator with a minimum of 25dB reverse isolation followed by a low pass filter and bandpass cavity setup, which provides a minimum of 20dB of attenuation at 1 MHz from the transmit frequency.

**130-225 MHz** - Transmitters in this range **shall** have a set of isolators with a minimum of 50dB reverse isolation followed by a low pass filter and a bandpass cavity setup, which provides a minimum of 25dB of attenuation at 1 MHz from the transmit frequency.

**276-284 MHz** - Transmitters in this range **shall** have a set of isolators with a minimum of 50dB reverse isolation followed by a low pass filter and a bandpass cavity setup, which provides a minimum of 25dB of attenuation at 1 MHz from the transmit frequency.

**400-512 MHz** - Transmitters in this range **shall** have a set of isolators with a minimum of 50dB reverse isolation followed by a low pass filter and a bandpass cavity setup, which provides a minimum of 15dB of attenuation at 1 MHz from the transmit frequency.

**764-960 MHz** - Transmitters in this range **shall** have a set of isolators with a minimum of 50dB reverse isolation followed by a low pass filter and a bandpass cavity setup, which provides a minimum of 15dB of attenuation at 1 MHz from the transmit frequency.

### 8.1.2 MINIMUM RECEIVER PROTECTION REQUIREMENT

A properly designed fixed site will require that each receiver input be connected to a crystal filter, window filter and/or bandpass cavity to minimize or eliminate receiver desensitization. These devices will create a narrow band window to allow only the desired receive signal to enter the receiver. If the interference is very close in frequency to the receiver frequency, a dual or triple bandpass cavity setup or notch filter may be required. This is normally a less costly and more permanent option to moving the receiver antenna to an alternate location. If additional support is necessary contact the local Motorola Engineering team.

## 8.2 GENERAL SITE ENVIRONMENTAL REQUIREMENTS

A properly designed communication site uses the following preventive measures to minimize and eliminate locations where radio signals can mix and create intermodulation frequencies or broadband noise.

- Rust - All materials must be free of rust.
- Braided wire **shall not** be used because it can corrode and cause intermodulation signals.
- Rigid metal connections - Metal to metal connections must be rigid.
- All loose metal should be removed from the site.
- Fencing - Chain link type fence material should be vinyl clad.

- Dissimilar metals - Connection of dissimilar metals should only be made after reviewing section 4.5.2, “Galvanic Corrosion” on page 4-36. for each metal. The connections must be rigid and tight.
- Cable ties – Bare metallic cable ties **shall not** be used unless they are stainless steel.
- Power line insulators (glass type) – Cracked insulators are a very likely source of broadband noise. If broadband noise cannot be eliminated by implementing the above recommendations, contact the local utility company and ask them to perform a noise sweep of the general area.

# 8.3 OTHER BAND ARCHITECTURE—OVERVIEW

Some additional RF site design techniques are required to mitigate radio frequency interference for sites utilizing frequencies below 700 MHz. This is typically referred to as Other Band Architecture (OBA) and may include trunking, conventional, data, and paging systems.

With the limited number of frequencies available in the 800 MHz and 900 MHz bands, expansion into other bands is occurring. The 450 MHz and 150 MHz bands are being utilized for trunking. This utilization of older bands has introduced multi-carrier operation in bands that were originally used primarily for single carrier or limited multi-carrier. Understanding the interference obstacles within these bands requires different solutions than those used at 700 MHz and above.

## 8.3.1 SPECTRUM USAGE HISTORY

The 700 MHz, 800 MHz and 900 MHz frequency spectrum was coordinated to facilitate combining and trunking system design. These frequency band plans facilitate the use of multiple transmitters connected to a single antenna, as well as receivers connected to a single receive antenna. This allows for the use of standard combining and multicoupling schemes. These bands are divided by a defined spacing between the transmit and receive channel pairs. (45 MHz for 800 MHz, 39 MHz for 900 MHz and 30 MHz for 700 MHz). This spacing helps isolate the intermodulation interference that occurs when two or more frequencies mix in non-linear devices, producing carriers on the existing receiver frequencies.

The VHF and UHF bands were not organized with the same standards as the 700 MHz, 800 MHz and 900 MHz bands. Therefore standard combining and multicoupling schemes cannot be utilized and extensive frequency planning must occur within the system design. These items alone can add significant design time and cost to a project. The UHF and VHF frequency bands have far less immunity to interference because the spacing between transmit and receive channels is not a defined constant. The result can be catastrophic interference if systems are not properly designed. Thus interference will have an effect on sites with OBA systems if not properly addressed.

## 8.3.2 FORMS OF INTERFERENCE

Interference can have many sources. All forms of interference must be monitored regularly for reliable communication. Interference is normally classified as internal or external. Internal interference is generated within the components of the system. External interference is generated externally and radiated into the affected system. External interference can be prevented with good radio system design practices. All external interference must be eliminated at the source.

Examples of interference include internal and external intermodulation (IM), transmitter sideband noise (TN), receiver desensitization (RD), Co-channel interference and passive intermodulation (PIM). These are briefly described below.

- **IM:** normally caused locally within the system or on site. This form of interference is caused by the mixing of multiple transmitters producing an on frequency carrier.
    - Internal IM is generated within system components. This can occur within the transmitter power amplifier, within the transmitter combining isolator and within the receiver, when strong off-frequency signals are allowed to enter the front end of the receiver and mix.
    - External IM is generated external to the transmitter or receiver system components. This interference can be produced in non-linear components on the site. Rusty tower joints, rusty fences, guy wires, corroded connectors, and inadequate grounding can also be sources of intermodulation. In all cases the only solution for external intermodulation is to find the source and eliminate it.
- **Transmitter Sideband Noise:** All transmitters emit some noise. Transmitters should have bandpass filtering added to reduce this noise and protect collocated receivers.
- **Receiver Desensitization:** - A receiver's ability to process weaker signals is reduced by the influence of a strong signal occurring on a closely spaced channel. Unlike the other types of interference, there are no audible indications of interference; There is only a reduction in receiver sensitivity.
- **Co-channel:** Multiple transmitters within the same coverage area assigned the same frequency.
- **Adjacent Channel:** Interference from users on a frequency assignment next to the operating frequency is adjacent channel interference.
- **PIM:** Another type of intermodulation, evident in non-active (thus passive) system components. Common mixing points are connectors, cables, surge protectors, combiners and antennas. Use of high quality (PIM rated) components can mitigate these issues.

## 8.3.3 OBA INTERFERENCE MITIGATION

When designing a new system utilizing OBA frequencies the following items should be considered and practiced:

- Frequency Layout
- Create Band Plan (Specific Tx/Rx Pairs)
- Perform Intermodulation Analysis
- Perform TN / RD Analysis
- Antenna Network Components PIM analysis and PIM sourcing
- Optimization / Testing
- RF Maintenance

Each of these items is discussed in more detail below.

### 8.3.3.1 DOCUMENT FREQUENCY LAYOUT

All available frequencies that may be used, as well as those already in use, should be defined and documented. Therefore a through "frequency inventory" should be performed consisting of the following activities:

- Collect/search for available frequencies.
- Conduct site audits of existing frequencies used on site.
- Document existing user antenna locations as an aid in the antenna/combining design.

### 8.3.3.2 CREATE A BAND PLAN

After all frequencies have been identified, create a band plan for specific transmit/receive pairs. The following tasks should be performed:

- Arrange frequencies in contiguous transmit and receive blocks to create guard bands.
- Create the band plan (specific transmit/receive pairs).
- Minimize implicit band plan elements used for system expansion (maximum of 16 elements).
- Maximize guard bands between transmit frequency blocks and receive frequency blocks.
- Maximize transmit/receive frequency separation for each channel to help control combining size and cost.
- Assign channel pairs to sites.
- Avoid narrow separations from existing frequencies on site whenever possible. This helps keep combining size/cost down.

### 8.3.3.3 PERFORM INTERMODULATION ANALYSIS

Intermodulation (IM) products are generated whenever two or more frequencies mix together at a radio site. Under the worst adverse conditions, the reception of the desired on-channel frequency can be suppressed by the FM capture effect of stronger undesired IM products. If the intensity of the IM product is lower than that of the desired signal it can still cause audible interference during periods in which the affected channel is not in use.

An IM study can help detect interference products and the root frequencies that can mix to cause interference. Motorola Engineering can perform the intermodulation analysis. The following guidelines apply when working with the IM analysis results:

- Run third, fifth, and seventh order IM.
- Determine PIM risk and design.
- Avoid third-order IM within a single combiner.
- Avoid third-order IM on site or tower if possible.
- Avoid fifth- or seventh-order IM within combiner.

#### 8.3.3.4 PERFORM TRANSMITTER NOISE / RECEIVER DESENSE ANALYSIS

Systems affected by Transmitter Noise/Receiver Desense (TN/RD) conditions will show signs of reduced radio coverage. A TN/RD analysis can provide the information needed to determine what two-way radio systems, whether existing or planned, have the potential to cause interference. This knowledge will help systems engineers select equipment needed to correct or prevent interference.

Motorola Engineering can perform the TN/RD analysis. The following guidelines apply when working with the
TN/RD analysis results:

- Design for all frequencies on site, not just customer frequencies.
- Transmitter Combiner Network:
  - 45 dB minimum selectivity at each Guard Band plus 45 dB minimum transmit-to-receive antenna isolation (90 dB total)
  - Insertion loss balanced within 4.5 dB across ports
  - 6 channel ports or fewer on each combiner
  - 90-100 kHz minimum Tx-to-Tx frequency separation
  - Install second Tx antenna to mitigate third-order IM
  - Use greater vertical separation between transmit and receive antennas to mitigate fifth- and seventh-order IM risk. 6 vertical metres (20 vertical feet) provides 55 dB isolation.
- Receiver Multicoupler Network:
  - 65 dB minimum selectivity at each Guard Band plus 45 dB minimum transmit-to-receive antenna isolation (110 dB total)
  - 15 dB reserve gain available
  - 45 dB third-order Intercept Point in Amplifier
  - < 2 dB noise figure in Amplifier
  - Use greater vertical separation between transmit and receive antennas to mitigate fifth- and seventh-order IM risk. 6 vertical metres (20 vertical feet) provides 55 dB isolation.

### 8.3.4 ANTENNA NETWORK COMPONENTS

Follow these Best Practices during design when selecting antenna network components:

- Always use PIM rated components, including antennas and combiners with PIM specifications.
- Use 7/16 inch DIN connectors on all transmit network components.
- Superflex cable from combiner output to transmit antennas **shall not** be used.
- Follow mounting recommendations:
  - Try to mount transmit antennas on top of tower.
  - Mount transmit antennas as far apart as possible.
  - Mount transmit antennas on different mounting structures.
  - Mount antennas as far from tower as possible.
  - Mount the receive antenna as far from the transmit antenna as possible.

- Use proper torque on all connectors.
- Cables should be continuous with as few connections, jumpers, and adapters as possible.
- Clean all connections before assembly/re-assembly.

### 8.3.5 OPTIMIZATION AND TESTING

When installing a new system, the following should be performed and documented:

- Measure Effective Receiver Sensitivity (ERS) on the receivers.
- Measure TN / RD degradation from **all** transmitters on site.
- Perform Frequency Domain Reflectometer (FDR) testing on antenna systems, verifying all installed components meet the manufacturer's specifications.

### 8.3.6 MAINTENANCE

Throughout the life of a system, the following should be considered for system maintenance:

- Frequency changes should be considered a redesign.
- Frequency additions to site must be monitored.
- Interference degradation must be monitored with periodic effective receiver sensitivity (ERS) tests.
- Perform periodic Frequency Domain Reflectometer (FDR) testing on antenna systems, verifying the antenna system has not degraded from original installation testing (commissioning).

## 8.4 MITIGATING EXTERNAL INTERMODULATION AND TRANSMITTER NOISE / RECEIVER DESENSE INTERFERENCE

Motorola is providing general guidelines to mitigate the effects of interference caused by intermodulation and Transmitter Noise / Receiver Desense (TN/RD) from the existing user community. Some general guidelines are provided below for each type of external interference. Motorola Engineering can assist in mitigation of external IM and TN / RD interference problems.

In most cases, minimizing the level of undesirable energy emitted by the local transmitters and filtering out undesirable signals coming into the receiver eliminates received interference in the receiver environment. Interference is more likely to be a problem at sites with multiple antennas.

## 8.4.1 INTERMODULATION

Every transmitter on site **shall** be equipped with a dual-stage isolator with second harmonic filter or bandpass cavity on the isolator output. Strong IM can be generated from the transmitter power amplifier (PA). The dual-stage isolator greatly reduces the amount of external frequency energy entering a transmitter PA and consequently, the level of IM generated. The radio site must be clear of any dissimilar metal connections, rusty metallic areas, rusty fence building and tower bolts, loose guy wires, etc. Much of the R56 site improvements are helpful to reduce or eliminate these sources where multiple frequencies mix to produce intermodulation products. Jacketed heliax transmission lines and type N connectors **shall** be used instead of RG-8 cable and UHF connectors. Where two or more transmit frequencies are combined to one antenna, connectors **shall** be 7/16 inch DIN connectors. Type N connectors have been found to be a mixing point source of IM products.

Every receiver should have a band pass cavity to prevent strong transmitter signals from swamping the receiver, then mixing to form IM products that are generated from a base station's receiver. Transmit antenna and receive antenna isolation is helpful to prevent harmful interference from IM products. A good rule of thumb is to have a transmit to receive antenna isolation of at least 45 dB. This is achieved by mounting the tip of the lower antenna 3 m (10 ft.) vertically below the base of the upper antenna. The idea is to reduce the level of IM reaching any given receiver. Because tower space is limited, the best way to achieve this for all users on site is to develop a master combining system where the receive antenna(s) occupy a defined receive-only zone on the tower, while transmit antenna(s) occupy a defined transmit-only zone. The receive and transmit antennas are separated by at least 3 vertical metres (10 vertical feet) to provide 45 dB of isolation. The more vertical separation between transmit and receive antenna, the better the isolation obtained. For example, 6 m (20 ft.) of vertical separation provides 55 dB of antenna isolation.

## 8.4.2 TRANSMITTER NOISE/RECEIVER DESENSE

All transmitters onsite should have sufficient transmitter noise filtering to reduce harmful on-channel noise to all receivers on site. This is best achieved through a bandpass cavity(s) that reduces the on-channel transmitter noise below the interference level. Transmitter noise problems are on-channel to a receiver frequency, therefore, transmitter noise problems must be addressed at the source. A good rule of thumb is for each transmitter to reduce its sideband noise by approximately 90 dB. This number varies depending on the particular base station model and make. If transmit antennas are spaced at least 3 vertical metres (10 vertical feet) from receive antennas, this means only 45 dB of transmit noise bandpass cavity suppression is needed, as the antenna separation achieves 45 dB isolation.

All receivers should have bandpass cavities to prevent receivers from being desensitized by nearby strong transmit frequency carriers. A good rule of thumb is to provide sufficient filtering to the 110 dB level. This number will vary depending on the model and make of the base station. Receive antenna to transmit antenna isolation of at least 45 db, achieved by 3 m (10 ft.) of vertical separation, is recommended. This reduces the amount of receiver band pass cavity filtering required by 65 dB. Because tower space is limited, the best way to achieve this for all users on site is to develop a master combining system where the receive antenna(s) occupy a defined receive-only zone on the tower, while transmit antenna(s) occupy a defined transmit-only zone. The receive and transmit antennas are separated by at least 3 vertical metres (10 vertical feet) to provide 45 dB of isolation. For example, 6 m (20 ft.) of vertical separation provides 55 dB of antenna isolation.

### 8.4.3 SIMPLEX MULTI-FREQUENCY STATIONS

Simplex multi-frequency stations cannot be combined or even have cavities installed on them. Because cavity filters are tuned to operate at one frequency, they cannot be used on multi-frequency stations. These types of stations must be evaluated carefully on a case by case basis because there is little that can be done to mitigate any interference involving them.