Technical White Paper
Microwave Fundamentals Series
Interference Mitigation in License-exempt Bands

Abstract

This technical paper describes in detail the techniques used to eliminate or minimize the potentially harmful effects of interference on microwave radio systems operating in license-exempt bands. Radio operators, engineers and installation professionals can use this document as a reference for effective license-exempt radio system deployment.

Introduction

Many organizations have realized the benefits of creating high throughput connections between locations using radio systems that operate in license-exempt spectrum. Rapid return on investment and quick deployment are just two of the many reasons these organizations turn to license-exempt radio technologies for wide area network (WAN) connectivity.

The growing popularity of these radio systems has placed greater demand on vendors and integrators to design and implement approaches that enable carrier-class performance in all types of environments, including those in which interference is present.

All license-exempt radio systems operating in the 2.4 GHz and 5 GHz bands in the United States are governed under the FCC's Part 15 rules. There are two requirements levied upon wireless systems operating in these bands:

1. Each Part 15 device may not cause harmful interference;
2. Each Part 15 device must accept any interference received, including interference that may cause undesirable operation.

With these two requirements in mind, this paper will outline the many techniques radio manufacturers, RF engineers and installation professionals use to avoid service-affecting interference in point-to-point microwave radio system deployments.

Installation Guidelines

Sound deployment practices greatly reduce or eliminate the potential for interference. These practices include but are not limited to:

- Antenna selection
- Antenna location
- Polarization selection
- Transmission line selection.
- Radio location

Antenna Selection

Perhaps the single most important component of a license-exempt radio system responsible for rejecting same and adjacent channel interference is the antenna. In point-to-point radio systems, highly directional antennas with narrow beamwidth and high forward gain are desirable. Larger antennas generally outperform smaller antennas. Antenna gain is directly related to the size of the antenna's reflector. A 1-foot diameter antenna operating at 5.8 GHz provides approximately 23 dBi of gain while a 2-foot diameter antenna offers approximately 29 dBi of gain. Choosing 2-foot antennas in favor of 1-foot antennas at each end of a radio system will increase the overall system gain by approximately 12 dB. Maximizing system gain is an effective countermeasure to potentially harmful interference.

Table 1. Typical Antenna Gain (dBi)					
Frequency	1-foot	2-foot	3-foot	4-foot	6-foot
2.450 GHz	14	21	24	27	30
5.300 GHz	22	28	31	34	37
5.800 GHz	23	29	32	35	38

Narrow antenna beamwidth is also an effective tool when designing a radio system to reject potential or existing sources of interference. Antenna beamwidth, like antenna gain, is directly related to antenna size. The larger the antenna reflector, the narrower the beamwidth.

Table 2. Typical 3 dB Antenna Beamwidth (degrees)					
Frequency	1-foot	2-foot	3-foot	4-foot	6-foot
2.450 GHz	28	14	9	7	5
5.300 GHz	12	6	4	3	2
5.800 GHz	12	6	4	3	2

Narrow beamwidth antennas have better off-azimuth rejection characteristics than wide beamwidth antennas. This means that potentially harmful signals coming from other locations will be rejected because the narrow beamwidth antenna does not “see” the harmful signal as well as a wide beamwidth antenna “sees” them. Choosing the narrowest beamwidth antenna possible for each location will provide the most isolation from neighboring radio systems operating on or near the chosen frequency of operation.

Antenna Location

When designing a radio system to avoid interference, antenna placement can be critical. Common sense may dictate that higher is better. In fact, higher antenna placement can be harmful to a radio system as the high location will likely expose the radio system to more potential interferers (as well as potential multi-path outages). When choosing a height for the antenna, placing it at an elevation just high enough to provide radio line-of-sight with proper path clearance to the far end is good practice.

When choosing a location on a rooftop, use man-made and natural obstructions to shield your antenna from as many directions as possible other than the intended direction. Rooftop mechanical rooms, parapet walls, HVAC equipment, nearby taller buildings and nearby trees can all serve as “shields” or “blinders” to off-azimuth, unwanted signals. Installing an antenna as far as possible from other rooftop or tower mounted antennas is also good practice. In many cases, installing the antenna away from the edge of a rooftop will shield the antenna from interference and reflective sources near the ground.

Polarization Selection

Polarization describes the orientation of the electric field of the transmitted wave. Point-to-point radio systems require that both ends of the link have their antennas operating on the same polarization. The most common type of polarization found in license-exempt radio systems is linear polarization. The polarization is dictated by the orientation of the antenna’s feedhorn or grid assembly. Most license-exempt radio systems operate on one of two dominant linear polarizations, vertical or horizontal.

The ability to choose and change polarization in license-exempt radio systems is an effective countermeasure to interference. Most quality antenna systems will reject opposite polarization signals by 20 to 30 dB. In fact, in many cases, two identical radio systems operating on the same frequency between the same locations can co-exist if they are operating on opposite polarizations. In many cases, when system performance degrades due to interference, simply changing the polarization of the antennas (at both ends of the link) rejects the offending signal sufficiently for error-free operation.

Transmission Line Selection

When the chosen radio architecture or installation location requires that transmission line be installed between the radio transceiver and the antenna, selecting a high quality, low loss cable will benefit the overall system gain and ability to overcome unwanted interference. In general, it is good practice to use the largest diameter cable specified for the operating frequency of the radio system. For example, 5/8-inch diameter cable is the largest diameter, lowest loss coaxial cable that can be used on a radio system operating at 5.8 GHz. Insertion loss through 5/8-inch cable at 5.8 GHz is approximately is 5 dB per 100 feet. If a radio system required 100 feet of coaxial cable at each end of the link, total insertion loss through the cable would be approximately 10 dB. If a smaller diameter cable were chosen such as 3/8-inch cable, with an approximate insertion loss of 11 dB per 100 feet, that same link would have a total of 22 dB of cable loss.

Table 3. Coax Cable Signal Loss in dB per 100 feet

Frequency	3/8-inch	1/2-inch	5/8-inch	7/8-inch
2.450 GHz	6.7	4.4	3.0	2.2
5.300 GHz	10.3	6.9	4.6	N/A
5.550 GHz	10.6	7.1	4.7	N/A
5.800 GHz	10.8	7.3	4.9	N/A

Choosing the smaller diameter cable reduces the overall system gain by 12 dB in our example. Achieving the highest system gain possible will help prevent outages from unwanted interference, and thus, the lowest loss, highest diameter cable is always recommended.

Radio Location

Radio location is often determined by the maintenance philosophy of the service organization or end-user charged with maintaining the radio link. If all of the radio electronics are installed indoors for ease of access, transmission line must be used to connect the radio to the outdoor mounted antenna. If the chosen radio architecture allows for outdoor mounting or cabinet mounting near the antenna, the length of transmission line to the antenna, and thus the associated losses, can be greatly reduced or eliminated, resulting in higher system gain and greater immunity to harmful interference.

Radio System Features

In addition to sound installation practices, radio vendors are implementing features and functionality that better deal with the hostile RF environments where their systems are deployed. Some of these features are designed to optimize performance and are automatically controlled by the radio while others are set by the administrator and are manually controlled. Some of the more advanced and effective features are:

- Software controlled frequency agility
- Center frequency tuning resolution
- Variable occupied channel bandwidths
- Adaptive modulation
- Software controlled polarization switching
- Integral spectrum analyzer

Frequency Agility

The ability to change frequencies in the field is essential when it is determined that interference is affecting the performance of a radio link. Executing this change through the radio’s network management interface allows the administrator to steer around interference from a remote location. This feature can eliminate the need to dispatch the service technician to the radio location, saving both time and money for the end-user and service organization.

Center Frequency Tuning Resolution

While the ability to change frequencies through the management interface is an important countermeasure to interference, this feature is further enhanced by allowing fine, granular control of the operating center frequency. Radios offering small step tuning resolution, such as 1 MHz, allow the radio operator to precisely choose the frequency of operation and are not confined to a limited number of pre-defined channels. This fine tuning control greatly increases the ability to find and operate in a “clean” channel.

Variable Frequency Tuning Resolution

Some microwave radios systems on the market today offer an advanced feature allowing the radio operator to select the occupied channel bandwidth. This is a very important feature to consider in hostile RF environments. Being able to choose a very narrow channel reduces the likelihood of encountering interference and conserves valuable spectrum. If needed, wider channels can be selected that offer higher throughput performance.

Software Controlled Polarization Switching

Earlier in this paper, polarization was discussed as a countermeasure to interference. Remember, high quality antennas will provide 20 to 30 dB of rejection to the opposite polarization. If interference is encountered, a potential remedy is to rotate the antenna or antenna feed assembly by 90 degrees. This is not always an easy task as the antenna may be in a difficult to access location. Some vendors are offering radio systems with integral antennas that allow the polarization to be changed from the network management interface. This means a radio operator or administrator can change the radio system's antenna polarization from a remote location, eliminating the need to climb a tower or access a difficult antenna location. This feature can reduce outage time and eliminate the need for skilled labor to access the antenna location.

Integral Spectrum Analyzer

Understanding the current RF environment is necessary to determine how to best configure the radio system operating parameters for maximum performance. A spectrum analyzer is an essential tool for determining the impact neighboring radio systems will have on a new radio system. However, many end-users and systems integrators may not have a spectrum analyzer available to them.

The most advanced radio systems offered today are equipped with integral spectrum analyzers. An integral spectrum analyzer allows the systems integrator or radio operator to visually determine what, if any, signals are present at the RF input to the receiver. After analyzing this data, an installer can make an informed decisions about the appropriate frequency of operation, channel bandwidth and polarization settings for the radio system being installed. The integral spectrum analyzer is also a valuable tool during the operational lifespan of the radio system as it can be used to troubleshoot system outages caused by interference, radio hardware failures, transmission line problems and antenna issues without the associated cost, scheduling, or configuration of external test equipment.

Conclusion

In many areas, frequency congestion in the 2.4 GHz and 5 GHz license-exempt bands has become a concern to current and potential end-users as well as the professional services organizations that implement these systems. Signal crowding concerns can be overcome by choosing the latest generation radio technology that implements features and functionality that specifically address operation in the presence of interfering signals. Additionally, hiring a highly skilled professional services organization trained to install the chosen radio system will ensure that all measures are taken to provide the long-term reliability and availability of the radio system.