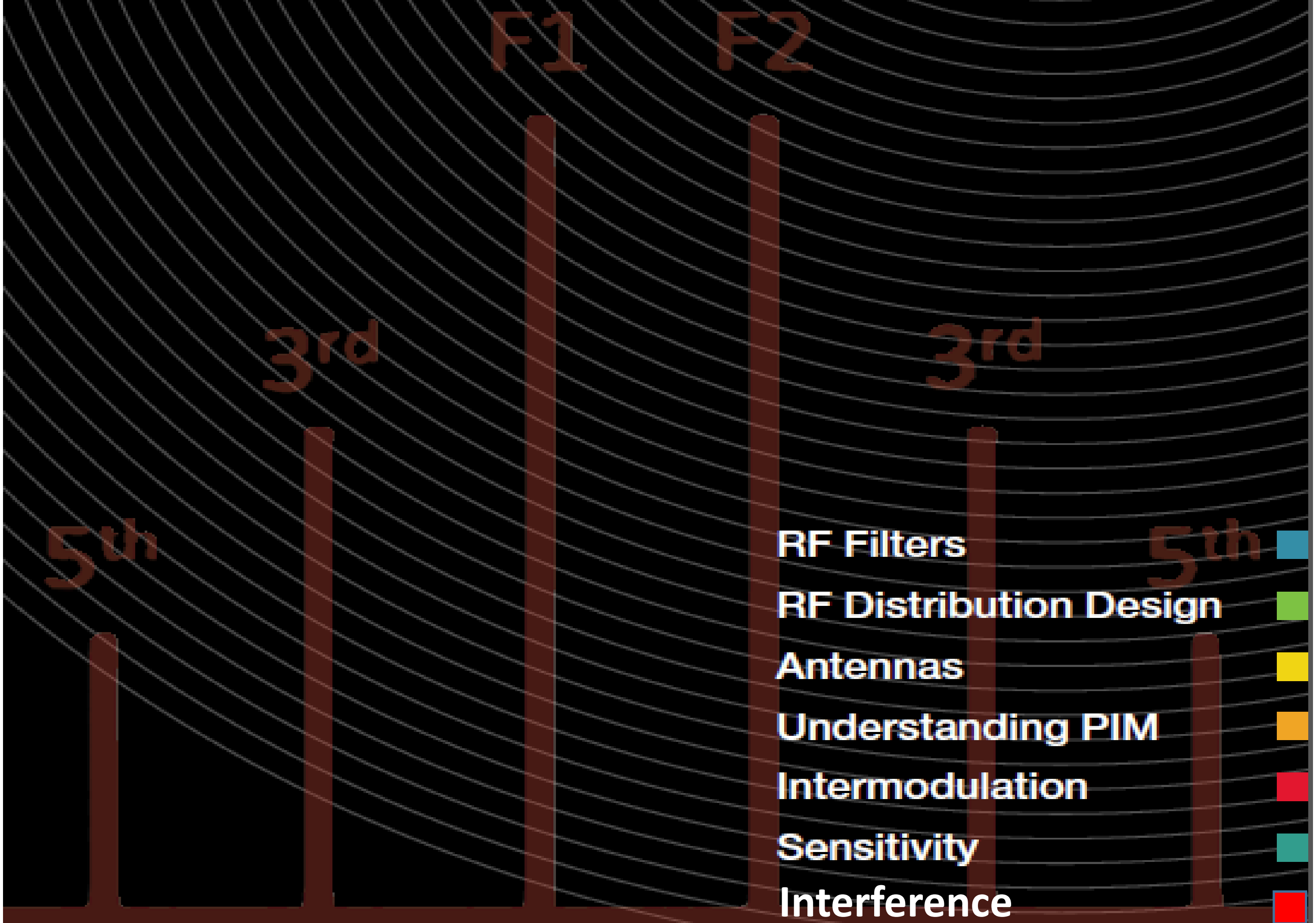
dbSpectra

TECHBOOK

Series

INTERFERENCE



- RF Filters
- RF Distribution Design
- Antennas
- Understanding PIM
- Intermodulation
- Sensitivity
- Interference

What is dbSpectra TECHBOOK series

To ensure a high-quality RF distribution system there are subjects that must be understood. dbSpectra "**TECHBOOK**" series provide simple discussions of important topics and show ways to ensure the highest quality is designed into the delivered system. Understanding these topics and working with our professional RF system engineers, will allow the design requirements to be met in the first design. Each booklet will discuss topics in as low a technical manner as possible. The **TECHBOOK** series is the first step in understanding complex and complicated RF Topics. Detailed training is available from dbSpectra that will provide more in-depth discussions and understanding. Contact dbSpectra for more information and to schedule training.

dbTECHBook editors:

- Bryan Corley
- Jim Bankston
- Graham Jones
- Mike Lee

dbSpectra
1590 E Hwy 121 Business
Bldg A Suite 100
Lewisville TX 75056
Phone: 469-322-0080
Website: www.dbSpectra.com

Introduction

Designing an RF Distribution system to provide the best performance possible is only the first step in delivering coverage. Coverage is dependent on how well the RF Distribution system operates when connected to an antenna. The filters and amplifiers included in the design establish the capability of the system. This is similar to the design of a race car. Every effort of the design is focused on making it go as fast as possible. The actual delivered speed of the car is determined by the condition of the race track. An RF design is similar because the system may be capable of very low sensitivity but due to external influences such as noise, internal interference and external interference the delivered sensitivity may be significantly degraded. This booklet will discuss what can degrade delivered sensitivity and thus delivered coverage. Some components of interference may be resolvable, but a considerable number are not. We will discuss techniques to identify and possibly resolve interface.

What is Interference

Interference is a speed bump to performance. The hardware may be designed for high performance operation but in the presence of interference the interference limits the delivered operation. Many times in this paper there will be references to delivered coverage, delivered sensitivity, and delivered performance. These references identify operation as seen by the subscriber in a fully functional system. There are several terms that must be understood to fully understand interference:

Noise Limited design – RF distribution systems have limitations set by the amplifiers, filters, and attached receivers. These limitations are part of the design and establish the best performance possible. A noise limited system delivers the best sensitivity possible and assumes no external influence of interference. This is normally the goal for any design. Noise limited systems are evaluated without the antenna connected and a 50 Ohm load attached in place of the antenna. The system is then evaluated with the antenna connected. The relationship between these two tests determine the degradation to operation from external interference. Understanding this relationship is very important because it identifies Internal vs. External interference.

Many sources influence a noise limited system, and some can be minimized:

- **Thermal Noise** – Thermal noise is noise generated by electrical components such as amplifiers. This noise is injected by the component and sets the limitation of the design. In Physics the noise generated is reference as noise figure (NF). Design engineers work to minimize the noise figure of the design which improves the delivered sensitivity.
- **Insertion loss** – Insertion loss between the receive antenna and the first active stage will directly reduce sensitivity one for one. Every dB of insertion loss will reduce the delivered sensitivity by the same amount. Cable, connector, surge protectors, filters, and splitters are the main contributors for insertion loss. Every effort should be made to minimize the losses in front of the first amplifier.
- **Amplifier Gain** – Amplifiers are used to reduce the system sensitivity by reducing the noise figure of the

system. While all electrical devices inject some noise, the amplifiers used in the RF receive path are designed for very low noise and are thus called **Low Noise Amplifiers (LNA)**. *Figure 1* shows how an amplifier is used to increase the input signal. The relationship between the signal and the noise floor is called Signal to Noise (S/N) ratio. When the signal is amplified the S/N is maintained because the signal and noise are both amplified equally by the gain of the amplifier. There will be a small amount of electrical noise added to the output signal, but this is normally very small (< 1 dB). The noise figure of the first stage in a system primarily establishes the overall system noise figure.

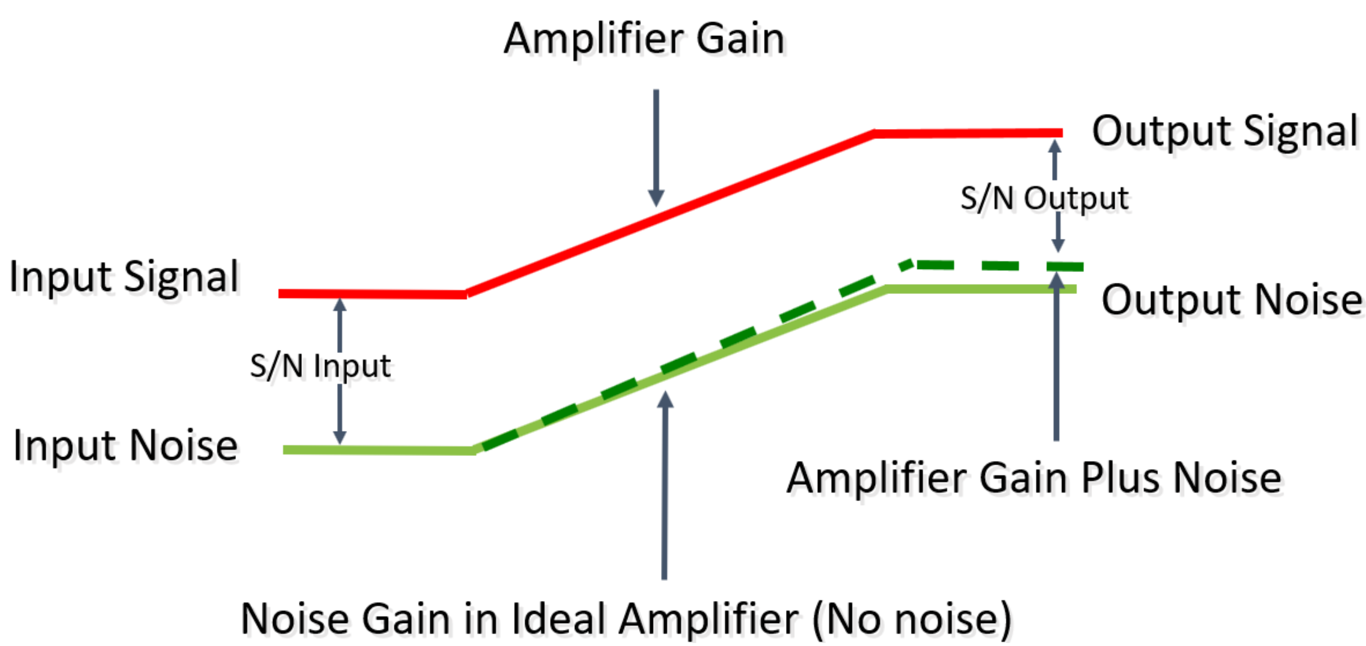


Figure 1: Effects of Amplifier Gain

- **External Noise** – External noise can be derived from many sources such as environmental noise, cosmic noise, and external interference. External noise is induced into the RF distribution system when the antenna is connected. As the name implies the effects seen by a system is external to the receiver and can only be eliminated by identifying and eliminating at the source. One major source of interference at the lower frequencies is power line noise generated from faulty transformers or connections. ***Figure 2*** shows a typical power line transformer that could cause interference. While all power line transformers will not cause interference the effects on subscribers that move around the coverage area may vary and create coverage holes that may be difficult to identify and resolve. External noise is more evident at lower frequencies (150 MHz) than higher frequencies (800 MHz).

***Figure 2:** External noise vs. Frequency*

- **Degradation** – Sensitivity is established within the RF distribution system but can be degraded when influenced by externally injected noise and interference. The external noise or interference is added to the noise within the receive system and can only deteriorate the overall sensitivity. **Figure 4** shows the effects of external noise on the delivered sensitivity. When the external noise is combined with the internal noise the new composite noise floor now determines the delivered sensitivity. The difference between the deteriorated sensitivity and the static internal sensitivity is called degradation.

(See Sensitivity TECHBOOK for more information)

External noise is different for each frequency band. ***Figure 3*** shows the amount of degradation from external noise as related to frequency. As the frequency increases the effects of external noise is less and in most cases not a risk above 700 MHz. While the effects of external noise vary between environments such as dense business and industrial areas and rural areas, the overall risk can be predicted.

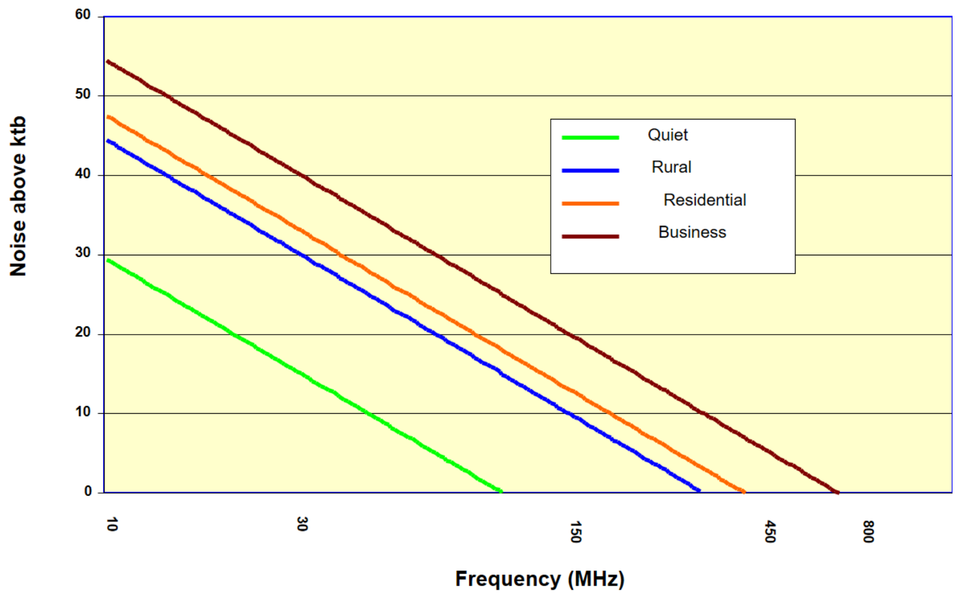


***Figure 3:** External noise vs. Frequency*

Delivered Sensitivity – Delivered sensitivity relates to the sensitivity as seen by the companion receiver. For an infrastructure receiver, the delivered sensitivity is focused on the sensitivity the subscriber will see. ***Figure 4*** shows the components of delivered sensitivity.

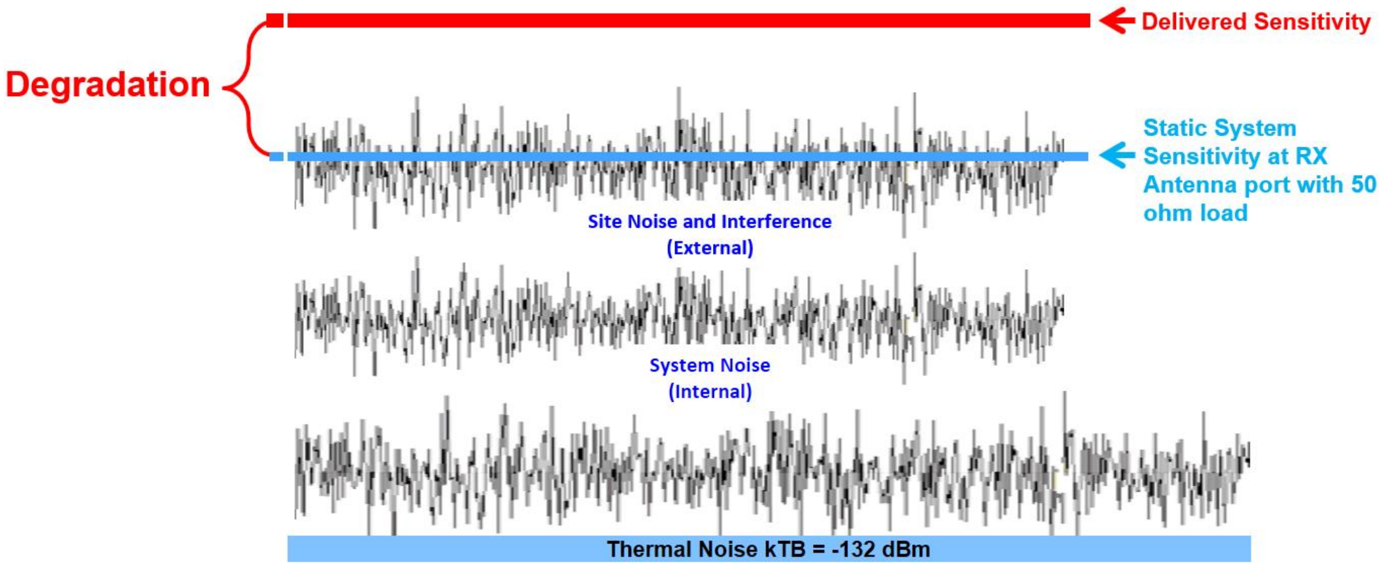


Figure 4: ***Degradation caused by External noise and Interference***

Delivered sensitivity is composed of many components: RF Distribution design, cable loss, external noise, external interference, effects of external RF carriers from other transmitters, and other forms of interference as seen by the infrastructure receiver. While delivered sensitivity cannot be calculated it can be estimated. A rule of thumb allows 10 dB of degradation for VHF, 6 dB of degradation for UHF, less than 1 dB of degradation for 700/800 MHz and 10 dB of degradation possible for 900 MHz (due to nearby cellular transmit frequencies). These estimates are derived from hundreds and thousands of tests performed on sites and compared with expectations. Considering the varying degree of RF site density that may exist, use of these predictions allows engineers to consider degradation in the pre-design stage before construction. To validate the delivered sensitivity of a receiver the effective receiver sensitivity (ERS) must be measured with a test port installed in the receive distribution system.

(See Sensitivity TECHBOOK for more information)

Sources of External Noise and Interference

While externally generated noise and interference have the same results of degrading delivered sensitivity, the source of each of these is completely different. Large congested sites can have a significant influence on the delivered sensitivity and should be evaluated and considered. ***Figure 5*** shows pictures of a congested site that may offer undesirable influence on delivered sensitivity.

Figure 5: ***Very congested site example***

Some sources of externally generated noise and interference on congested sites are:

Transmitter sideband noise – Transmitters not only generate a carrier frequency but also sideband noise on both sides of the carrier that can extend many MHz. This energy should be considered as co-channel RF since it will fall on any nearby receive frequency. Transmitter sideband noise is greatly reduced with filtering (as provided by combiners or transmit filters) between the transmitter and antenna. If this filtering is not included in the design the sideband noise will be radiated.

Figure 6 shows how transmitter sideband noise can fall on the receive frequency and cause interference.

(See RF Filter TECHBOOK for more information)

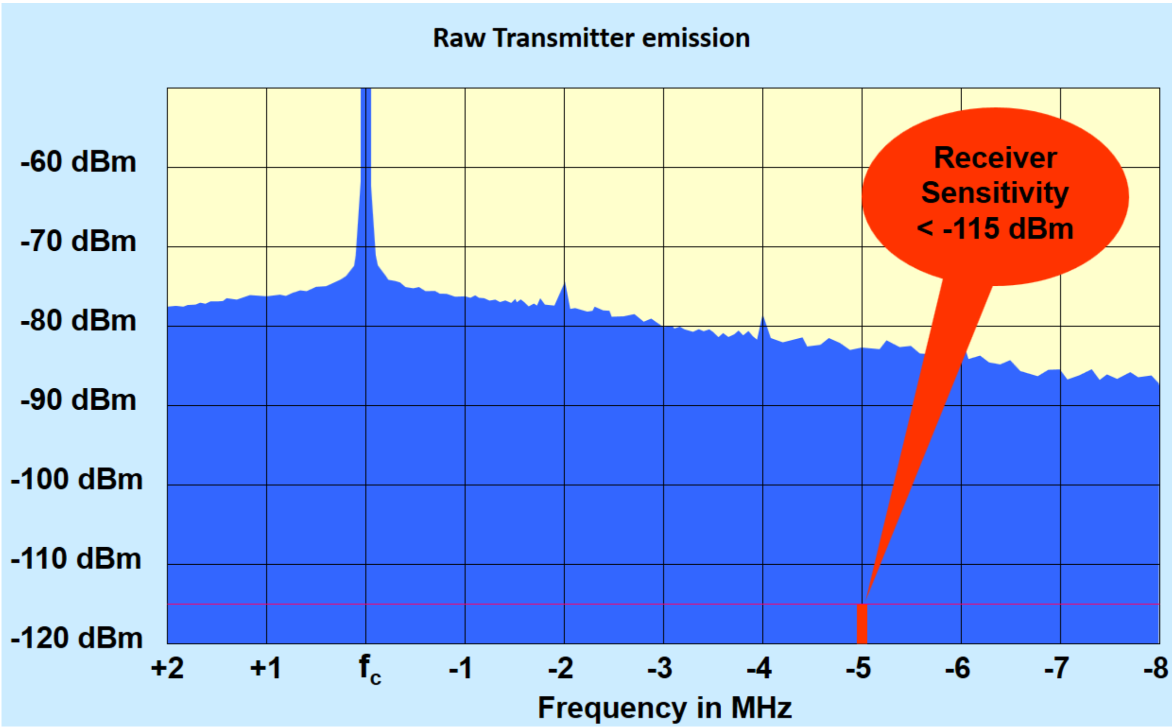


Figure 6: *Transmitter Sideband noise interference*

Intermodulation (Intermod or IM) – Intermodulation, or commonly called Intermod or IM, is created when two or more RF carriers are applied to a non-linear component or mixing point. These multiple carriers mixed together in the mixing point and produce other carriers. When intermodulation products fall on the receive frequency they are no different than other transmitters and will raise the noise floor and cause degradation. ***Figure 7*** shows the relationship between the fundamental carriers and the Intermod products mixing in a non-linear component.

(See Intermodulation TECHBOOK for more information)

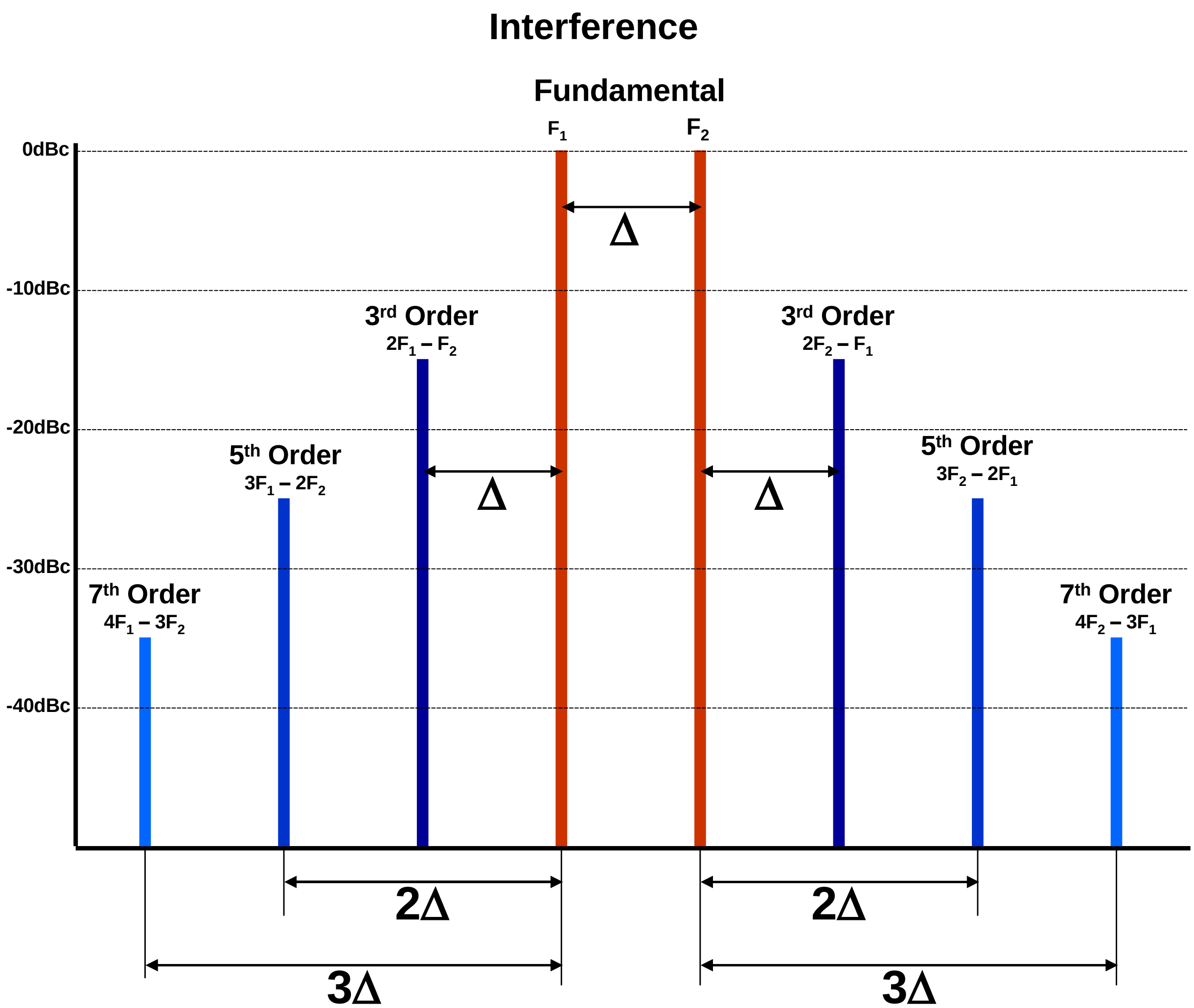


***Figure 7:* Intermodulation relationship to fundamental carriers**

Passive Intermodulation (PIM) - A very specific form of Intermodulation that can and will cause interference is PIM. PIM is the results of using low quality components in the transmit network of an RF distribution design. PIM can be reduced with good design practices and components. PIM is a significant risk at VHF and UHF.

(See Understanding PIM TECHBOOK for more information)

Interference Risk vs. Frequency (Frequency band overview)

The likelihood and risk of interference is different between frequency bands. Each band has their own special risk of degradation. Before interference can be evaluated the band of interest must be identified and the interference risk understood.

VHF Spectrum (138 MHz – 174 MHz) – Long ago, the FCC designed the VHF band for single carrier simplex operation (receive and transmit on the same frequency). Today, users are combining multiple frequencies to create multicarrier systems and trying to operate without interference. This is difficult because even if the customer's frequency plan is created that provides the protection to operate multicarrier, other frequencies on site must also be considered. Understanding the frequencies on site is not a luxury, but a necessity. Not only should the frequencies be understood at the time of installation but, regularly verified if continued reliable communication is desired. Interference can change at VHF as more users are added and other sites are created.

The environmental noise risk at VHF is the highest of any regularly used Land Mobile Radio (LMR) frequency band. VHF is susceptible to power line interference, industrial noise from large motors and generators. The nominal degradation for VHF may be as high as 10 dB in metropolitan environments. In less populated areas the degradation can be expected to be much less. It is a good recommendation to plan for the 10 dB of degradation during coverage design. Less degradation will only improve the coverage and provide better delivered communication.

UHF Spectrum **(380 MHz – 512 MHz)** – The UHF band was designed for duplex (transmit and receive on different frequencies). This frequency plan definition allows for inherent transmit and receive frequency separation. While this separation works for single radio duplex operation it creates issues for multi-carrier operation where the transmit band and receive band are contiguous (adjacent with no guardband) for the 450 MHz – 512 MHz segments. To create a multi-carrier frequency plan the useable frequencies must be reduced to create an artificial frequency plan. ***Figure 8*** shows a 4/1 MHz band plan (4 MHz bandwidth vs. 1 MHz guardband. This plan reduces the usable frequency plan by 1 MHz. The ability to use a 4/1 MHz band plan is rare due to filter restraints. Normal band plans will be 3.5/1.5 MHz or even 3/2 MHz.

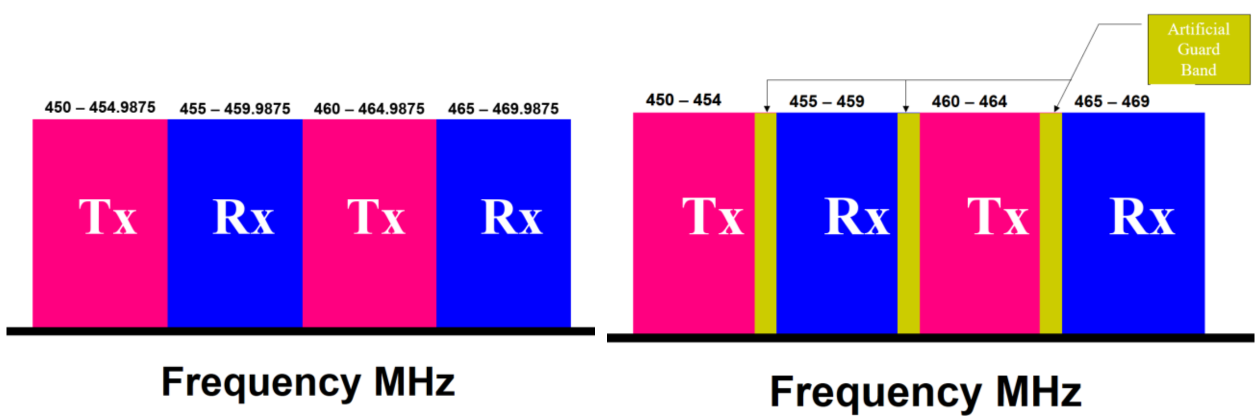


Figure 8: UHF frequency planning model

700/800 MHz spectrum – The 800 MHz spectrum was the first band released by the FCC for true multi-carrier operation. The guardband between transmit and receive is wider than the bandwidth which eliminates 3rd order IM risk. The 700 MHz band was released for public safety to complement the existing 800 MHz band. The interference risk for the 700/800 MHz band is also very low. There is an insignificant risk from environmental noise and the delivered sensitivity equals the static or reference sensitivity in most cases. It is common to have -124 dBm to -126 dBm delivered sensitivity that is constant and reliable.

Interference

The highest risk of interference for the 700/800 MHz spectrum is Distributed Antenna Systems (DAS). There are many new installations of DAS because of regulatory requirements dictating that all new buildings and construction must implement DAS systems to ensure internal building coverage for public safety, first responders. While this seems a logical requirement to ensure public safety communication inside buildings, it can be detrimental. These new DAS systems are being implemented with little or no control. In some cases, the installation of the systems is being done by unqualified shops that mistune the systems and cause interference to the public safety systems they are trying to complement. The DAS system can increase the noise radiated into a public safety system and cause degradation to the system. Additionally, when the gain of the DAS system is adjusted to high the DAS may oscillate causing interference.

Interference Mitigation

Reducing interference can be a difficult process. Before the interference can be reduced and if possible, eliminated, it first must be properly characterized. Characterization requires considerable experience as few situations of interference are common. Interference mitigation is like a detective working to find clues to an investigation. An interference mitigator also must look for clues to the source of the interference before it can be understood. Understanding and characterizing interference requires individuals with the skills and experience to perform tests to identify interference. There is never a script that can be followed. dbSpectra can provide the assistance required to understand interference in a short time frame. It is not unusual to find technicians working for weeks or months without success and experienced interference mitigators from dbSpectra identifying the interference and a resolution plan in days. Contacting dbSpectra services early results in savings not only in money but also in time.

Release History

Release 1.0 – September, 2019

Notes