



Introduction to Radio Frequency Interference (RFI)

An Online Continuing Education Course for Engineers

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Introduction to Radio Frequency Interference (RFI)

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Introduction

In today's society, wireless networks exist to facilitate the flow of information, whether it is for a simple voice call, to send a message, or to watch a movie. With these networks, people have the capability of doing things that to previous generation seemed impossible. You are probably familiar with the most common form of wireless system today: the cellular phone or your home's Wi-Fi. But there are others not so famous, for example, microwave point-to-point backhaul, or emergency service radios (i.e. police radios).

These wireless networks, due to the nature of radio frequency propagation, are susceptible to interference; however, depending on the technology of the system, the performance could be partially protected by a handful of techniques, some of which include the use of licensed spectrum, polarization, filtering, physical spacing, etc.

Achieving an interference-free system can prove to be quite challenging depending on the location where the network is being deployed, the technology of choice, and existing RF environment (i.e. other systems). For example, if deploying in a rural area, it is possible to find available frequencies that are far away from other systems with the same frequency (i.e. co-channels); on the other hand, if a system were to be deployed in a densely populated area, the availability of frequencies can be non-existent or extremely costly, forcing the service provider to reconsider the approach, or use unlicensed spectrum.

Under these conditions, the designer will need to adapt to the environment in order to consider all the available techniques that will provide the least interference to its system, which will in turn maximize the system's performance. Note however, that over time, other service providers might come into the area, which will keep the RF environment very dynamic forcing designers to continuously monitor and evaluate their systems' performance.

What Is Radio Frequency Interference (RFI)?

Before we move into the various types of radio frequency interference (RFI), how it's calculated, and how it can be mitigated, let's first define what interference is. In simple terms, interference is the presence of an "unwanted" signal that affects a "wanted" signal.

For example, imagine two people having a conversation, let's call it Conversation A; in this example, the voices are the "wanted" signals. By themselves, the conversation will occur uneventful. Now, let's add two more people carrying a separate conversation some distance away, this will be Conversation B. As long as Conversation B is far away or their voices are soft enough, then Conversation A will not be affected by Conversation B.

But, what if Conversation B was only a few feet away from Conversation A, or if the people from Conversation B were talking loudly? In this case, Conversation B would become interference, or the "unwanted" signal, to Conversation A.

Translating the above example to the radio world, Conversation A can be thought of as the communication between two devices, for example a cell phone and a base station, or between two point-to-point microwave radios; where each voice represents a specific frequency. Keep in mind that modern cellphone communications are more complex since multiple users can co-exist on the same frequency, but for this example it will be assumed a single user is on the channel. The actual access technologies in cell phone communication are beyond the objective of this course. Ultimately, Radio Frequency Interference (RFI) is the interference experienced by a radio-based communication channel, also known as a wireless communication system.

Let's visualize the example above where we have Table 1 showing the relationship between Voice and Frequency, and Conversation and Communication Link (Comm Link). It is worth noting that this example is based on full-duplex communications, but the concept is also applicable to half-duplex, or simplex communications.

Table 1 - Example Correlation Between Voice and Frequency

Conversation A	Person 1 Speaks Voice 1 Person 1 Hears Voice 2	Transmitter 1 transmits Frequency 1 Receiver 1 receives Frequency 2	Comm Link 1
	Person 2 Speaks Voice 2 Person 2 Hears Voice 1	Transmitter 2 transmits Frequency 2 Receiver 2 receives Frequency 1	
Conversation B	Person 3 Speaks Voice 3 Person 3 Hears Voice 4	Transmitter 3 transmits Frequency 3 Receiver 3 receives Frequency 4	Comm Link 2
	Person 4 Speaks Voice 4 Person 4 Hears Voice 3	Transmitter 4 transmits Frequency 4 Receiver 4 receives Frequency 3	

Where Does RFI Come From?

Having understood what RFI is, it is important to understand where does it come from in order to develop an approach to mitigate it. If we look back at the example of the conversation in the previous section, we can find a few similarities between a conversation and a radio communications link. Interference can be externally generated, as in the case of the

appearance of Conversation B, or it can be self-generated, as in the case of echo where the other person receives the same message but with multiple arrival times, making the conversation hard to understand (for example, echo in a telephone conversation, or from reflections on a wall). The same can occur in the wireless world.

This section will describe the most common forms of RFI that will have a negative impact on a communication link. These are:

- Co-Channel Interference (See Figure 1) - refers to the signal from another source with the same frequency, which due to unaccounted conditions (i.e. atmospheric conditions, or insufficient planning), the unwanted signal is received by a designated receiver.
- Intermodulation (Intermod or IM) Interference (See Figure 2) - refers to the mixing of frequencies at various points in a communication path, generating a totally new frequency that impacts the receiver of interest. This phenomenon can occur either at the transmitter, at the receiver, or metallic junctions (i.e. nearby rust, passive components such as loose connectors, damaged coaxial lines, etc.). Figure 3 represents how the mixing of F1 and F2 generate F3 which matches another frequency F3 of interest.
- Transmitter Noise Interference (See Figure 3) - refers to emissions from a transmitter outside of the operating frequency that are received within the passband (window of operation) of a receiver. Because this is energy that is radiated by the transmitter, it can fall within the operating frequency of a receiver, which in turn affects the receiver's ability to detect incoming signals.
- Receiver Desensitization (Desense) Interference (See Figure 4) - refers to the reception of sideband noise, unwanted co-channels or intermodulation signals that pass through the filters of a receiver. The net effect is a reduction of sensitivity, or the ability to "hear" weaker signals, since the desired signal now has to compete with undesired signals.
- Electrical Disturbances - refers to unintended emissions caused by intentional, or non-intentional events. For example, lightning can affect wireless communications during fractions of a second during the lightning strike; rotating motors, engines or transformers can also generate electromagnetic waves that can disrupt communications, particularly at lower frequencies.
- Environmental - refers to the effects of the environment on the behavior of the frequencies of interest. "Solar Radiation", "Skipping" and "Ducting" are examples of this type of interference.

Co-Channel Interference

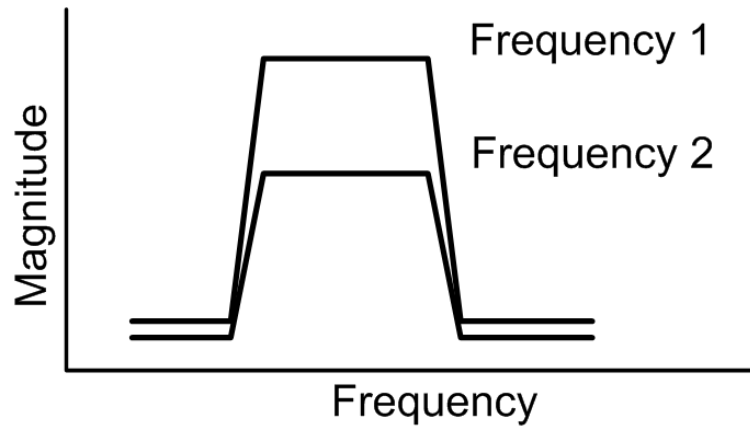


Figure 1 - Graphical Representation of Co-Channel Interference

Intermodulation Interference

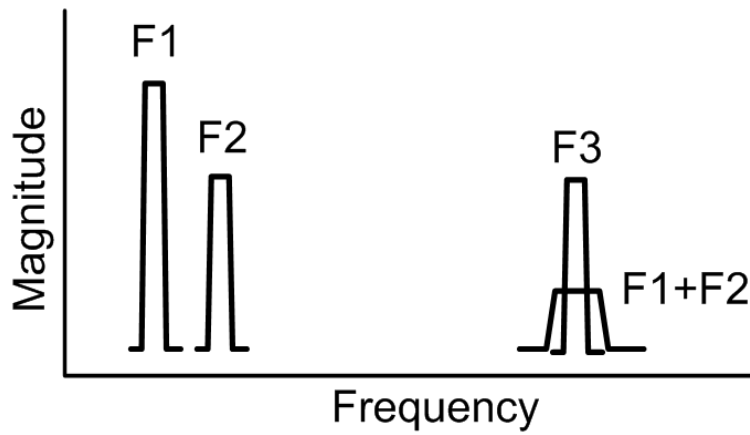


Figure 2 - Graphical Representation of Intermodulation Interference

Transmitter Noise

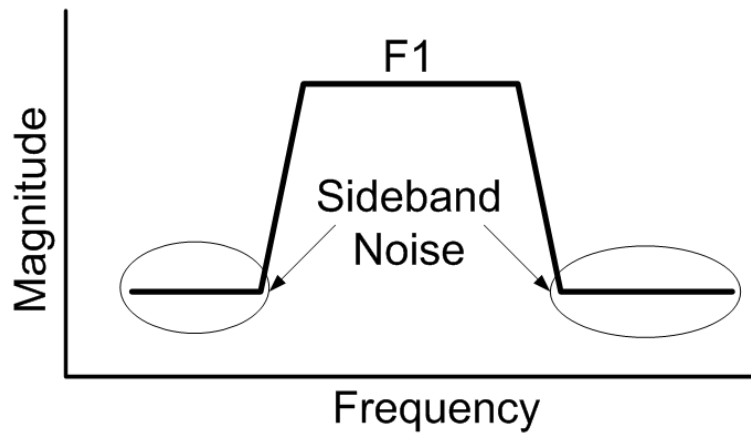


Figure 3 - Graphical Representation of Transmitter Noise Interference

Receiver Desensitization

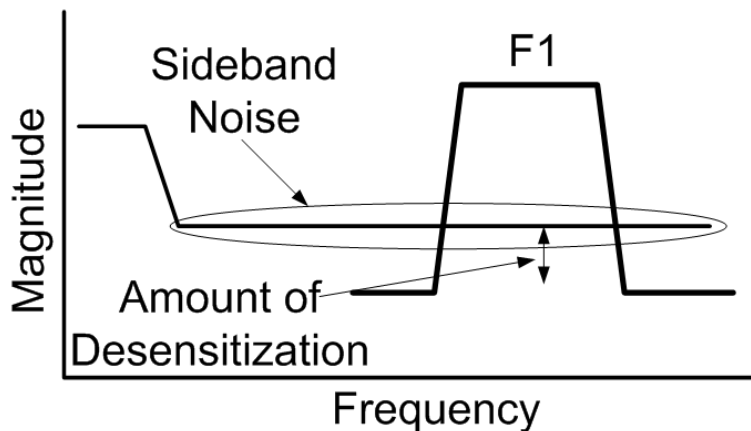


Figure 4 - Graphical Representation of Receiver Desensitization Interference

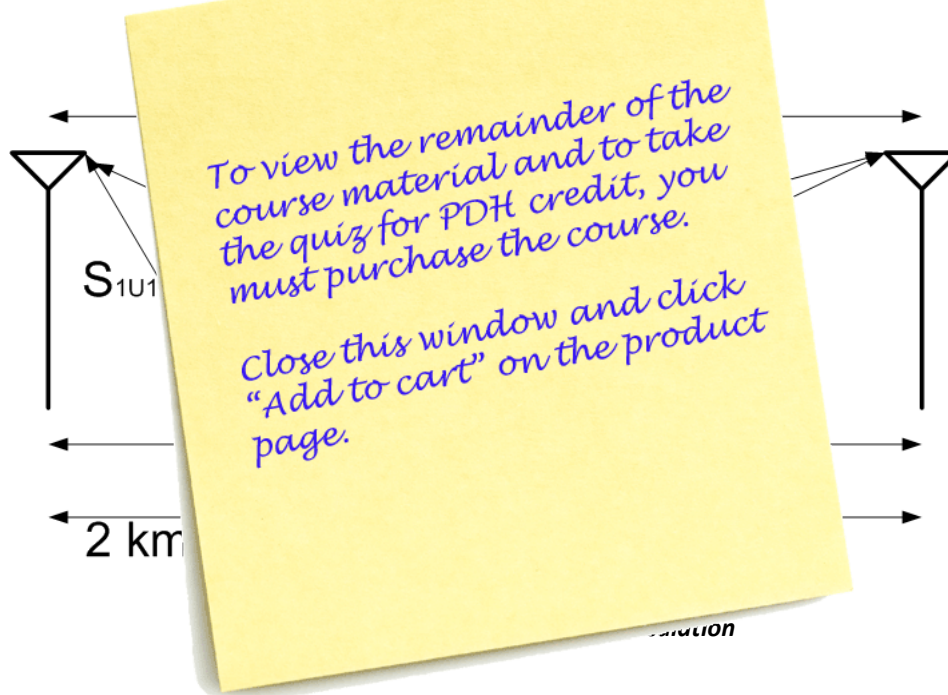
Since Electrical Disturbances and Environmental are for the most part, unpredictable, we'll focus on the others types. Since it would be too involved to go through all possible scenarios that cause receiver desense, it will be limited to its relationship with Transmitter Noise in this course.

Interference Generation Examples

This section will take a closer look at how Co-Channel Interference, Intermodulation Interference, and Transmitter Noise and Receiver Desense (TxNRxD) are calculated.

Co-Channel Interference

Co-Channel Interference is the reception of a non-desired signal operating on the same frequency as the desired signal. To illustrate this example, consider two sites, 10 kilometers apart, both radiating 50 dBm ERP (for simplicity, the link budget calculations and the antenna pattern will be ignored) with two users, one operating 2 miles from one site and correspondingly 8 miles from the other site (User 1), and another operating between the two sites (User 2). The operating frequency is 150 MHz. Illustration.



The first step in calculating co-channel interference is the calculation of pathloss. For this example, we'll use the Free Space Loss (FSL) for the 3 distances mentioned above. The Free Space Loss formula is as follows:

$$FSL = 32.44 + 20 \log_{10} d + 20 \log_{10} f$$

where:

FSL is in decibels (dB)

d is in kilometers (km)

f is in megahertz (MHz)