Interference Classifications and Measurement

Using N934xC/B Handheld Spectrum Analyzers

Agilent Technologies

Introduction

Interference to radio signals can come from a number of sources including one's own radio system, other radio systems, or unintentional radiators such as nearby electrical equipment and mechanical machinery. Identifying the type of interference can be useful in correcting the issue.

This paper defines the various types of interference and explains how the use of a handheld spectrum analyzer (HSA), such as Agilent Technologies N934xC family of HSAs and the N9340B HSA, are used to quickly identify the type of interference so that it can be expediently resolved.

In-Band Interference

In-band interference is an undesired transmission from a different communication system or unintentional radiator that falls inside the operating bandwidth of the desired system. This type of interference will pass through the receiver's channel filter and if the interference amplitude is large relative to the desired signal, the desired signal will be corrupted.

Figures 1 and 2 show a few examples of in-band interference. In Figure 1, a different radio system is transmitting directly in the operating channel of the desired system. This figure shows a potential interference located at a center frequency slightly higher than the desired. In Figure 2 another form of in-band interference is created from an unintentional radiator, in this case, the desired RF signal is being modulated by fluorescent lighting. In the cases when the interferer is intentionally attempting to disrupt communications, this in-band interferer would be considered a radio "jammer".
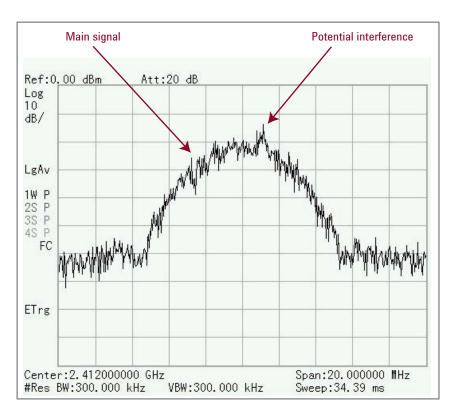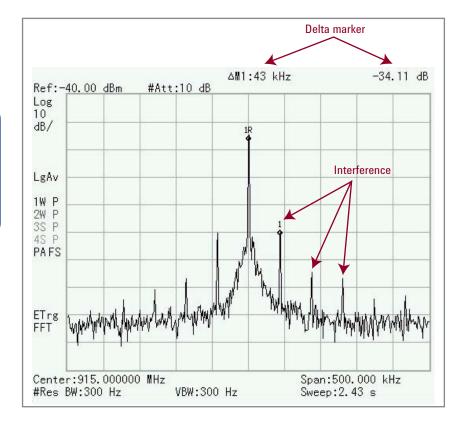
Figure 1. Measured spectrum of a wireless communications signal with a lower than expected performance and potential in-band interference

Figure 2. Measured spectrum of a CW carrier showing modulation sidebands creating by fluorescent lighting

The easiest way to observe in-band radio interference is to turn off the transmitter of the desired radio and use the spectrum analyzer tuned to the channel frequency to look for other signals operating in the channel of interest (Figure 1). For unintentional radiators potentially modulating the desired signal, turn off the offending radiator, such as the lighting in Figure 2.

Co-Channel Interference

Co-channel interference is one of the most common types of radio interference as system designers attempt to support a large number of wireless users within a small number of available frequency channels. This type of interference creates similar conditions as in-band interference except that co-channel interference comes from another radio operating in the same wireless system. In this case, two or more signals are competing for the same frequency spectrum.

For example, cellular base stations will re-use the same frequency channel when the base stations are physically located far apart, but occasionally the energy from one base station will reach a neighboring cell area and potentially disrupt communications. Wireless LAN networks also experience co-channel interference, as the WLAN radios listen for an open channel before transmitting and the potential exists that two radios would transmit simultaneously and collide in the same frequency channel.

The easiest way to observe co-channel interference is to turn off the transmitter of the desired radio and use the spectrum analyzer tuned to the channel frequency to look for other signals from the desired system. It may be necessary to set the spectrum analyzer to HiSensitivity mode and use the Max Hold display or a spectrogram to record any intermittent signals.

Out-of-Band Interference

This form of interference originates from a wireless system designed to transmit in a different frequency band but unfortunately energy is also produced in the frequency band of the desired system.

Such is the case when a poorly designed or malfunctioning transmitter creates harmonics that fall into a higher frequency band. Harmonics are multiples (2x, 3x, 4x, etc) of the fundamental carrier transmission. For example, Figure 3 shows the spectrum of a transmitter designed to operate at 500 MHz. This measurement, taken from the Agilent HSA, shows the fundamental component at 500 MHz and a second harmonic transmitting at 1,000 MHz. This second harmonic signal could potentially interfere with other wireless systems operating near 1,000 MHz.
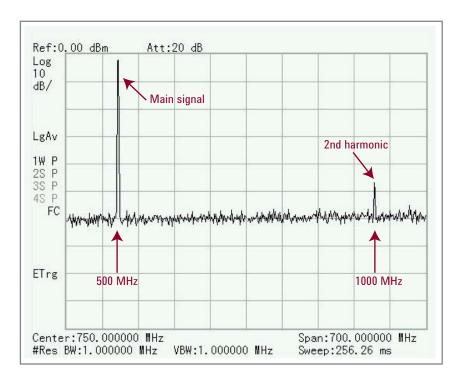

Figure 3. Measurement of 500 MHz unfiltered transmitter showing second harmonic generated at the output

Out-of-Band Interference (continued)

It is important, and often a regulatory requirement, to properly filter out the harmonics of a transmitter so that one wireless system does not affect another system operating in a higher frequency band.

When examining harmonics of a wireless transmitter, it is necessary to use a spectrum analyzer with a frequency range of at least three times the fundamental operating frequency of the system. For example, when verifying the performance of a transmitter operating at 6 GHz, it may be necessary to measure second and third harmonics at 12 and 18 GHz respectively. For this purpose, the Agilent N934xC HSAs include the 7-GHz N9342C, 13.6-GHz N9343C, and the 20-GHz N9344C.

Not all out-of-band interference is harmonically related to the fundamental carrier; spurious signals fall into this category. Spurious signals are typically generated in a transmitter resulting from improper shielding of the switching power supplies and clocking signals or from poorly designed frequency oscillators. Spurious signal interference that fall into the passband of the desired system may have an undesired effect on system performance.

Out of band interference may also occur when two or more wireless services operate in the same geographic area and experience a phenomenon called "near-far". A common form of this interference occurs in a cellular environment when a mobile radio is far from the desired base station (BTS) but very near to a BTS of a competing service provider. Even though both systems operate in different frequency bands, the mobile receives an energy level from the near BTS that is much higher than the desired BTS station. The front-end bandpass filter in the mobile will reject most of the energy from the near BTS energy but some energy will leak through the filter and into the pre-amp/down-converter and potentially corrupt the desired signal due to nonlinearities in the receiver's electronics.

The easiest way to observe out-of-band interference is to turn off the transmitter of the desired radio and first verify the amplitude levels of any signals across a wide frequency range. If all the signals are low relative to the desired signal then tune the spectrum analyzer to the channel frequency and look for other signals within the channel. It may be necessary to set the spectrum analyzer to HiSensitivity mode and use the Max Hold display or a spectrogram to record any intermittent signals.

Hint:

If interfering signals are low, it may be necessary to use HiSensitity mode and Max Hold to display, or use a spectrogram to record intermittent signals.

Adjacent Channel Interference

Adjacent channel interference is the result of a transmission at the desired frequency channel producing unwanted energy in other channels. This type of interference is common and primarily created by energy splatter out of the assigned frequency channel and into the surrounding upper and lower channels. This energy splatter, often referred to as intermodulation distortion or spectral re-growth, is created in the high-power amplifiers of the radio transmitter due to nonlinear effects in the power electronics.

The details of intermodulation distortion will not be included in this application note and additional information can be found in the Agilent application note *Optimizing Dynamic Range for Distortion Measurements*, literature number 5980-3079EN.

As an example of intermodulation distortion, Figure 4 shows a measurement of a digitally modulated signal transmitting on Channel 2. In the figure, Channels 1 (lower) and 3 (upper) represent the adjacent channels relative to this main transmission. The Agilent HSA was configured to automatically measure the power in the main channel and adjacent channels using the adjacent channel power ratio {ACPR} measurement found under the [MEAS] menu.
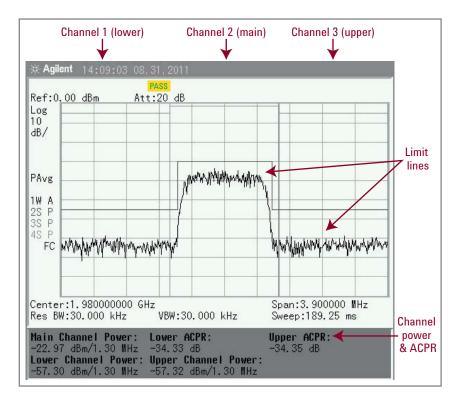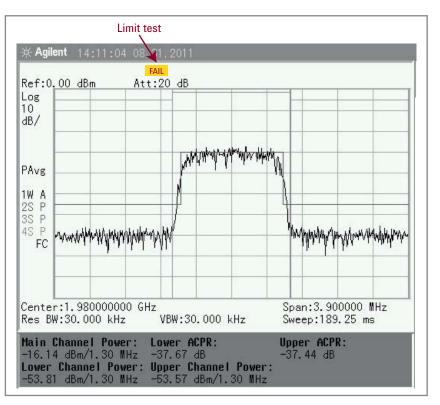

Figure 4. Measurement of adjacent channel power and limit testing

Adjacent Channel Interference (continued)

The table under the spectrum display lists the total power, in dBm, for the main channel and the adjacent upper and lower channels. The {ACPR} measurement also reports the power ratio, in dB, between the main channel and each of the two adjacent channels.

Limit lines can be placed on the display of the Agilent HSA as a quick check of compliance to the radio specifications. Limit lines are defined under the [LIMIT] menu. Figure 4 shows that the measured spectrum for this transmitter has "passed" the power and frequency requirements across the three channels.

Figure 5 shows a similar measurement but this transmitter has an increase in the adjacent channel power and exceeded the limit line specifications resulting in the "fail" notation to be displayed on the instrument screen.

Figure 5. Measurement of adjacent channel power and limit testing showing a out of limit condition

Downlink Interference

This is an interference that corrupts the downlink or forward link communications typically between a BTS and a mobile device. Because of the relatively widely-spaced distribution of mobile devices, downlink interference only impacts a minority of mobile users and has a minimal impact on the communication quality of the system as a whole.

Uplink Interference

Uplink interference, also called reverse link interference, affects the BTS's receiver and the associated communications from the mobiles to the BTS. Once the BTS is compromised, the cell site's entire service area may experience degraded performance.

Conclusion

The classifications for different types of interference including in-band, co-channel, out-of-band, and adjacent channel interference were discussed. The Agilent N9344C, N9343C, N9342C, and N9340B HSAs are valuable tools for measuring interference. With simple to use features, such as ACPR and limit testing. They provide valuable feedback when troubleshooting wireless components and systems. In addition, the wide frequency range of the HSAs, with models operating to 20 GHz, allows measurements of interference in all classifications.

For More Information

Visit any of the following handheld spectrum analyzer product pages and click on the "Document Library" tab to access additional application notes:

- www.agilent.com/find/n9344c

- www.agilent.com/find/n9343c

- www.agilent.com/find/n9342c

- www.agilent.com/find/n9340b

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