Carrier over Interference…

What is it and why does it matter?

By: Tom Duckworth

The use of the unlicensed bands has become a very popular way to provide access to the Internet (Wi-Fi, WISPs) and to realize an inexpensive and rapidly deployable wireless LAN. In addition, new technologies promise to provide access to even more customers (Wi-MAX, Mesh). However, this ever-increasing deployment of unlicensed radio links brings with it a serious problem: potential interference from other sources.

Today, many unlicensed wireless bands are so crowded that availability issues and interference are the norm. This problem will only get worse over time as more people make use of these bands. Wireless systems currently being deployed are known by many names and encompass many flavors: Wi-Fi, WLAN, Wi-MAX, Bluetooth, and so forth. All have one thing in common: their transmission path is free-space—the definition of wireless.

Though there are many possible measurements of transmission path quality through free-space, the most relevant and revealing is the relationship between the transmitting radio's "carrier" channel power and the "interference" power (normalized to the carrier bandwidth), both measured at the receive end. This carrier-to-interference (C/I) measurement tells whether the intended radio signal has sufficient power to overcome delayed reflected signals (Fresnel fading) and interference present from other sources, in order to operate as expected. Doing on-site carrier and interference measurements and analysis can be the only realistic and reliable way to identify and resolve interference for the unlicensed operator.

C/I. Every communications receiver has a minimum Carrier-to-Interference ratio (C/I) that must be maintained in order to deliver its promised speed, bit-rate accuracy, availability, and to recover 100% of the information from a desired signal. This minimum ratio is defined on the radio manufacturer's data sheet for each model and modulation scheme employed, and is referred to as the C/I requirement—sometimes called the fade margin—and is expressed in dB. If this minimum ratio of signal to interference is not met, communications will be disrupted and the system may become unusable. The specific receiver C/I margin depends on the usable dynamic range of the receiver's front-end, the type of demodulator, the modulation schemes used, and the error correction being employed by the radio manufacturer.

Carrier. In a digital wireless system, radios use a band of frequencies for transmission of the coherent (intelligent) signal. This band may be referred to as the radio's "carrier," "carrier pass-band," carrier bandwidth," "modulation bandwidth," "emission bandwidth," or "channel". Whatever the name, it describes a contiguous group of frequencies used to transmit coherent data to the receiver. From the receiver's perspective, what matters is how much total energy from the intended transmitter is present within the transmitter's bandwidth, relative to the amount of total energy present from other sources (interference, fading, and noise) occupying the same transmitter bandwidth.

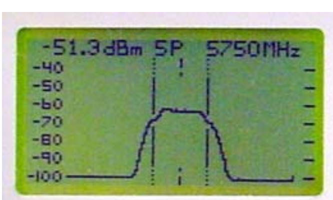
Interference. Radio communications can experience several different types of interference. They range from static thermal noise to inter-modulation noise caused by the blending of two or more signals. Static thermal noise can be addressed through proper system design, which ensures that adequate fade margin is built into the system. Inter-modulation noise, on the other hand, is the classic form of interference that, sooner or later, confounds most unlicensed systems. The conditions that create interference are unique to each individual case. There is no standard level of interference nor is there a single formula that can be used to compute it. What constitutes interference in one system may be totally invisible or inconsequential in another. To understand interference within its unique environment, we need to define it in terms of its amplitude relationship to the amplitude of the desired or carrier signal within the receiver's modulation bandwidth.

Pendulum Instruments, Inc. (incorporating XL Microwave)
5811 Racine Street
Oakland, CA 94609-1519 USA
Phone: 510-428-9488
Fax: 510-428-9469
e-mail: sales@pendulum-instruments.com
Internet: www.pendulum-instruments.com

It should be noted that, although often used interchangeably, signal-to-noise (S/N) and carrier-over-interference (C/I) are not the same thing. Signal-to-noise refers to the difference between the received signal level (RSL) and the thermal noise floor of the receiver. Noise is random in nature (Gaussian) and does not contain intelligence. On the other hand, because of its frequency relationship and coherent characteristics, an interfering signal is capable of causing destructive results, even at levels below the thermal noise threshold of a receiver. Whenever the receiver's demodulator acquires and locks on to a signal within its tracking bandwidth, an interfering signal within all or part of the receiver's bandwidth—which would normally be hidden in the noise—becomes a factor. When the difference in magnitude between the two coherent signals becomes small enough, the resulting inter-symbol interference confuses the demodulator, rendering it unable to track the desired signal. If this condition is short and sporadic the receiver will usually ask the transmitter to re-transmit, causing an overall slow-down in data throughput. But, if the condition is more serious, the receiver will come unlocked and the link will go down altogether.

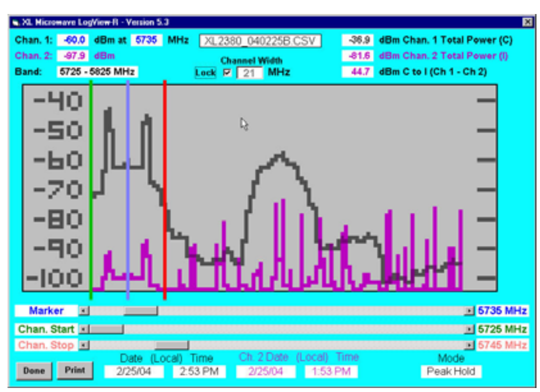
Site Analysis. With C/I performance information from the radio manufacturer's data sheet and use of a spectrum analyzer, one can measure and locate any interfering signal at the input to the victim receiver. One could also measure the far-end radio's carrier power at the victim receiver and compute the difference between the two measurements. One would then use the comparison between the published C/I requirement and the measured C/I at the site to verify a properly operating link and/or to quantify the severity of any interference problem.

Spectrum Analyzer. A spectrum analyzer is the appropriate tool to use to view the carrier and interference signals because it is the only way of *seeing* signals across a spectrum of frequencies. When used with an antenna, a spectrum analyzer becomes a tunable receiver with the ability to identify associated frequency/power points across a defined span or bandwidth. Given the proper application of their measurement functions, some spectrum analyzers can derive real-world C/I measurements on-site. What is required is that the analyzer has adequate dynamic measurement range, a low noise floor, sufficient sensitivity (better than the radio's threshold) across the entire modulation bandwidth, and an ability to measure and store both the carrier and interference sweeps in order to compute the real-world C/I. In addition, the analyzer must also be able to compute the sum of all powers (total channel power) across the carrier bandwidth and capture energy over time (using a peak hold function)—as the total channel power of all interfering sources may take 10 minutes or more to reveal themselves (e.g.: hopping radios). All these requirements are necessary to insure that *you see* what the radio receiver's front-end must deal with order to capture, lock on to, and demodulate the transmitted signal.



The figure at left shows a 100 MHz span covering 5.700–5.800 GHz. The RF signal is a typical unlicensed radio carrier with a 20 MHz-wide carrier bandwidth (shown between markers). The radio's carrier bandwidth is centered at 5.750 GHz and the total-channel-power between markers is -51.3 dBm. This RF signal would be considered an ideal carrier signal shape, for it is free of multipath (no tear-out of the signal), and free of interference (a symmetrical trace indicating no adjacent channel or hopping interference). The RF signal shown was captured with a Pendulum Instruments / XL Microwave model 2261A analyzer, capable meeting the above mentioned criteria, defining the modulation bandwidth measurement, and computing the total-channel-power of this RF signal.

Another example at right shows both the carrier and the interference traces superimposed on the same screen. The channel markers have been set to the radio's modulation bandwidth (20 MHz) and the auto calculation of the C/I figure is shown in the upper right of the display screen. This example was done with the model 2261 analyzer and software from the same manufacturer.



Examination of the C/I measurement can reveal not only the carrier received signal level, but the presence of signal distortion due to multi-path reflection or equipment problems. Notches or ripples in the carrier RF signature are generally an indication of multi-path reflection or a high antenna system VSWR as is shown in the left-hand section of the upper trace. An asymmetrical RF signature is usually an indication of interference or antenna/equipment issues.

Armed with an appropriate spectrum analyzer capable of seeing total-channel-power across a carrier bandwidth, an installer can directly view the RF signal at the transmitter's output jack (through an appropriate attenuator) for proper operation. This test can also be done with an omni antenna near the output of the transmitting antenna, to observe the carrier bandwidth through the connecting cables/waveguides to verify expected normal operation. This same approach can be done at the victim receiver site to verify system performance at the far end of the link. This will identify any problems that may be occurring and exactly where and what those problems are.

Conclusion. As you can see, the information gained from a thorough site analysis with an appropriate spectrum analyzer capable of determining C/I and total-channel-power is invaluable. The results of this analysis can be used to determine optimum site locations; equipment required; carrier frequency; antenna type; antenna height, and polarization; need for diversity antennas; and the like. The time invested in this analysis will greatly improve ones chances of having a predictable and reliable link on the initial installation. With already installed systems, a site analysis will help determine the best way to mitigate interference problems and insure that the system provides reliable service.

Pendulum Instruments, Inc. (incorporating XL Microwave)
5811 Racine Street
Oakland, CA 94609-1519 USA
Phone: 510-428-9488
Fax: 510-428-9469
e-mail: sales@pendulum-instruments.com
Internet: www.pendulum-instruments.com