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Managing the Coexistence of Multiple Wireless Systems

Many different wireless communications standards must often operate within the same frequency spectrum, requiring guidelines to allow them to work effectively with each other.

Coexistence refers to the functioning of different wireless devices and standards in the same frequency band. The various IEEE 802.11 wireless standards, for example, are packed into the 2.4-GHz unlicensed Industrial-Scientific-Medical (ISM) frequency band. IEEE 802.15.4 wireless sensor networks share the 2.4-GHz ISM unlicensed frequency band. Bluetooth is yet another wireless standard operating in that same frequency band.

While it be ideal to have different frequencies for each wireless standard, as with radio and television broadcast channels, frequency spectrum is limited. The growing number of wireless standards makes it difficult, if not impossible, to allocate separate frequency spectrum for each standard. In addition, new applications being added to the same crowded frequency spectrum, such as Internet-of-Things (IoT) wireless devices and machine-to-machine (M2M) devices in the 2.4-GHz ISM band, make the task of achieving wireless coexistence even more challenging.

Interference from intentional or unintentional electromagnetic (EM) radiators can disrupt the operation of wireless devices in the same or adjacent frequency bands. Interference can result in lost data, poor voice quality, and decreased operating range, depending upon the type of wireless device. Wireless devices may be designed for point-to-point communications; for access to a cellular base station; for communication to a satellite; or access to a network node, such as a wireless local area network (WLAN). Multiple devices must operate within the same or closely spaced frequencies without interfering with each other.

The ISM band is just one portion of the frequency spectrum in which spectrum sharing takes place. Coexistence issues can impact all different wireless applications in all market areas, including military, medical, and automotive applications, as well as in commercial electronics. Regulatory organizations such as the Federal Communications Commission in the United States are responsible for establishing acceptable transmitter standards for both licensed and unlicensed frequency spectrum. But when multiple wireless standards occupy the same portion of frequency spectrum, it is possible for one standard to comply with regulatory limits and still interfere with another wireless standard in that same frequency spectrum.

THE ROAD TO COEXISTENCE

Achieving coexistence among wireless standards starts with the design of the wireless protocol, such as the various IEEE standards for IEEE 802.11 WLANs, but then relies on modeling, design, and testing to ensure that a wireless product will operate as expected in the presence of existing wireless devices and networks. Device and circuit modeling can ensure proper electrical performance for a given set of circuit elements and parameters, but modeling for wireless coexistence is performed at a different level—more in terms of the operating environment.

Accurate models for wireless coexistence must anticipate the total number of radiators within a frequency band of interest and the waveform types for each. But they also must take into account the emissions that may occur as the result of second- and third-harmonic signals from lower-frequency sources that may fall within the band of interest, assuming they are at sufficient power levels to interfere with the subject of the modeling procedure.

Lessons learned from system-level modeling of a wireless operating environment can provide guidance on possible modifications for a prototype wireless product in preparation for achieving wireless coexistence. By modeling a device for electromagnetic compatibility (EMC), for example, the effects of both internal and external EM sources can be studied on the performance of the device.

A prototype wireless radio device may suffer excessive signal leakage from its local oscillator (LO), causing unintended EM emissions to reach the same device's antenna and resulting in self-interference with that device. Or instability in the LO may cause a shifting of that device's operating bandwidth, leaving it susceptible to interference from signals in adjacent frequency bands. Device and circuit modeling can help identify such problems at the device/circuit design stage, prior to modeling the device within the wireless operating environment for its capability to operate while surrounded by other EM sources.

Testing a prototype design for its own internal sources of radiated interference can be challenging, since even low-level leakage from a signal source such as an LO can couple to a nearby amplifier and result in EM energy that can be received by the device's own antenna. Isolating and measuring such internally generated interference requires eliminating the measurement of external sources of radiation, from outside emitters, and this can require the extreme of testing within an anechoic chamber.

Because of differences in transmission format among wireless standards (such as modulation), wireless coexistence especially in shared spectrum requires that a device with one transmission format not be affected by another device operating at the same frequency, but in a different transmission format. Test signals should be carefully chosen for wireless coexistence testing.

While a simple continuous-wave (CW) test signal can check the basic operation of a radio's performance, the device should be tested with waveforms representing both devices like it and other wireless devices with different transmission formats that are sharing the same spectrum. Resistance to these other waveforms sharing the same spectrum can reveal a great deal about the capabilities of a wireless design to operate effectively while surrounded by nearby EM emissions.

CREATING COEXISTENCE

Obviously, with the steady growth of wireless applications, and only limited frequency spectrum, wireless coexistence is an ongoing issue for radio designers in all application areas. In some operating environments, such as for medical electronic equipment in hospitals, failure to achieve wireless coexistence can be life-threatening. The frequencies and bandwidths may change, such as the millimeter-wave frequencies used for automotive radars and safety systems, but each part of the spectrum contains its own sets of interference issues and challenges for coexistence.

Circuit designers are increasingly aware of wireless coexistence as a design requirement, and such technologies as software-defined radios (SDRs) and cognitive radios provide the capabilities to dynamically change a radio's operating parameters in response to problems posed by interference in the operating environment.

As an example of a transceiver designed for coexistence, Mercury Systems (www.mrcy.com) recently introduced its Ensemble DCM-MU-4R2G-2T3G low-latency transceiver nominally for electronic-warfare (EW) applications. It can be applied as much for contested military signal environments as for congested commercial communications signal environments.

The Ensemble transceiver was designed according to OpenVPX high-speed interconnectivity standards for maintaining high performance in battlefield environments with potentially hostile signal threats, but it is also constructed according to the same requirements as shared spectrum within a congested signal environment. The transceiver is optimized for low probability of intercept (LPOI) RF signal detection in heavily contested and congested signal environments. It uses a multiple-channel, multiple-board configuration to instantly detect occupied (and available) bandwidth and respond by generating a timely response in terms of transmitting on available spectrum.

This transceiver follows a design trend established by SDRs, with heavy reliance on high-speed data converters for achieving flexible programmability in the realization of the radio transmit and receive functions. It incorporates four high-speed analog-to-digital converters (ADCs) sampling at 2 GSamples/s, with an option for two ADC channels operating at rates to 4 GSamples/s. On the transmit site, two low-latency digital-to-analog converters (DACs) operate at sampling rates to 3 GSamples/s to produce transmit waveforms types and frequencies as dictated by available spectrum.

To encourage SDR-based radio designs capable of dynamically achieving wireless coexistence even within a crowded portion of the spectrum, such as the 2.4-GHz band, manufacturers such as Pentek (www.pentek.com) and Texas Instruments (www.ti.com) offer free downloadable design handbooks and also designer's kits. These kits provide board-level SDRs with all components in place—including high-speed ADCs, DACs, and digital-signal-processing (DSP) integrated circuits (ICs)—for tuning and testing when developing a programmable radio design that can adapt to a changing EM environment, whether in the shopping mall or on the battlefield.