Wireless Design for Regulatory Compliance

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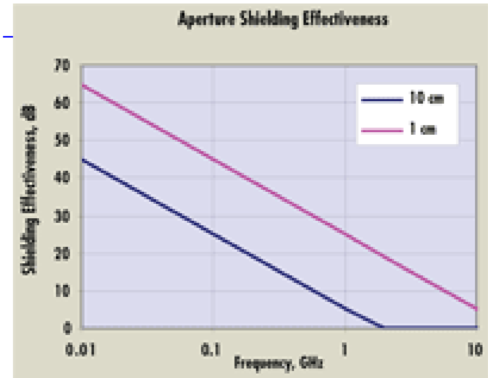
Roland Gubisch and Nicholas Abbondante, Intertek

Radio transmitters are being designed into more and more diverse commercial and consumer applications. Beyond toys, remote household controls, RFID and Bluetooth-enabled mobile phone headsets, radio technology is enabling many new emerging business applications.



[1]

However, pitfalls exist for engineers who are designing transmitters into their products. If they lack expertise in the radio technologies or if they are not familiar with regulatory constraints, their companies can easily run afoul of the law &#151 or at least face big delays in launching new products.

Based on our experiences with a wide variety of equipment suppliers, we can summarize the leading observed causes of initial failure as:

&#149Lack of knowledge of design principles &#149Failure to apply design principles &#149Application of incorrect regulations &#149Unpredicted interactions among circuit elements &#149Incorporation of non-compliant modules or subassemblies into the final product.

Meeting Regulations
The successful development of a radio transmitter, receiver or transceiver can depend directly on what is legal in the target market. Requirements from different administrations can conflict with each other. A radio designed to operate in one country may be illegal in another. The selection of the best frequency of operation or the highest output power &#151 or method of measuring power &#151 may depend on knowing these regulations.

In some cases the radio may be subject to electromagnetic immunity testing, as for military/aerospace applications and European Union requirements. In such cases, the RF disturbances caused by the radio may be greatly outweighed by external effects, and the designer has to know the issues at the start of the design process.

If you are concerned that the radio you are prototyping does not comply with local regulations such as FCC rules and it may cause unacceptable interference, you should consider operating the prototype in a screened room or applying for an experimental license until development &#151 and compliance &#151 is completed.

Radio Modules
A modular approval allows you to avoid re-approving the radio for each revision of the host circuitry. The module is considered a separate device that complies with all of the relevant radio regulations on its own, regardless of the host in which it is installed.

Modules carry unique design considerations. They need to meet the appropriate radio regulations on a standalone basis, with the antenna selected for use. They may need shielding over the radio circuitry, and filtered and buffered modulation and data inputs. In order to ensure stable operation of the radio in the presence of abnormal behavior by the host device, modules can require on-board DC regulation. Planning on a modular approval at the start of development can be an investment that pays off later by letting you re-use the same radio design again and again without re-approval.

Software/Firmware
Software/firmware development should include test suites. If software is designed with compliance testing in mind, it can be easily modified later when abnormal modes of operation are required. Control of output power, duty cycle and modulation are frequently useful during compliance testing. It may also be necessary to configure the transmitter to operate without any input signals to simulate worst-case conditions.

Board Layout and Shielding
Board layout is critical to a successful radio design. Traces can be efficient antennas, not only for the wanted signal but also for noise. Locate noise sources away

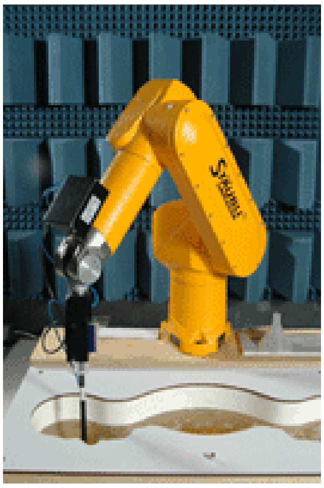


Figure 2. SAR testing robot at work.

from I/O ports or the power circuitry, to reduce conductive coupling to cables which in turn behave as antennas, or to the power distribution system where it can leak into other sections of the device. It is important to ensure that traces do not have resonant lengths for the unwanted frequencies present. Shorter traces are generally better than longer ones &#151 a long trace or jumper wire to a far-off section of board can cause radiated coupling nightmares. Shielding over the sensitive RF circuitry can mitigate this problem.

The equipment enclosure can provide shielding to reduce RF emissions or improve immunity, only if the enclosure is conductive (metal or plastic) and preserves the continuity of a conductive path around the electronic circuitry inside. Any seams or holes in the enclosure must be sufficiently small to attenuate electromagnetic disturbances that could enter or exit. Small openings (see Figure 1) can be tolerated, depending on the frequencies of concern. In this chart the dimensions of 1 cm and 10 cm represent the diameter of a circular opening, the diagonal of a rectangular opening, or the length of a thin slit or seam. Non-conductive enclosures provide good protection from electrostatic discharge (ESD) but afford no shielding.

PC boards with multiple ground layers can be used to provide shielding around traces that need isolation. Filters can then be used to prevent signals from leaking parasitically into other sections of the device. Harmonic RF emissions are a common source of test failures for transmitters, and special care should be taken to filter the antenna port to reduce them.

Pre-Compliance Testing

In cases where the product development uses modules or subassemblies that have not been previously evaluated for radio or EMC, or where marginal radio or EMC performance of the product is suspected, it is prudent to perform some pre-compliance testing &#151 so there are no surprises at the end of the development program. Where antenna port conducted tests are specified, measurements can be made anywhere. Radiated emission tests require a reasonable 3m (typical) site, but a 1 m pre-compliance site can be set up in most facilities. This can only provide approximate results but could reveal problems at an early stage when the corrections can be made quickly and cost-effectively.

If the developed product has been tested on an accredited test site and failed (or even passed), the accredited test results can be used to correlate with results on a pre-compliance site to decrease the uncertainty of the pre-compliance results.

Testing for Regulatory Compliance
Transmitter testing typically includes measurements of output power or field strength, occupied bandwidth, and spurious emissions from the chassis, antenna port, and AC input. Duty cycle may be taken into account. Low power radios operating on some frequencies may require a frequency stability test over voltage and temperature variations, to show that the carrier won’t drift into an adjacent channel or band. Multi-tone transmitters will often have to be tested for spurious intermodulation products generated by the multiple carriers. Higher power transmitters may be subject to requirements for frequency and power stability within a few milliseconds of keying or releasing, and are often tested for adjacent channel power leakage during all aspects of operation.

Other common transmitter tests include emissions masks which ensure that modulation sidebands are attenuated at specific frequency offsets from the carrier, or spectral density for wideband modulations to verify that the power is spread over a wide frequency range. Frequency-hopping radios require the number of frequency hops to be tested. Analog voice modulation is tested for output bandwidth limiting as voice pitch or volume increase.

It’s easy to forget the receiver portion of a transceiver, but receivers need testing too. Regulatory limits on spurious radiated or conducted emissions are common. In some cases, additional receiver tests are required such as sensitivity, blocking, and co-channel rejection.

Access Protocols
Newer transmitter standards specify a &quotlisten before talk&quot functionality to increase spectrum re-use. A receiver of sufficient sensitivity and bandwidth monitors the intended channels of operation for use; programming selects an open channel and avoids using the occupied channel for a predetermined interval. Channels are usually checked periodically before and during operation.

RF Exposure
Radio transmitters can heat nearby skin and body parts. To assess the potential for permanent damage, RF exposure evaluations can range from calculations to computer modeling or even SAR (Specific Absorption Rate) testing, where a probe maps the power density in a fluid-filled &quotphantom&quot simulating the shape of the human body or head. Existing regulatory limits for RF exposure are similar but not identical, and the designer needs to know the differences and which devices are exempt. Multiple co-located transmitters may need to show RF exposure compliance of all transmitters simultaneously, possibly leading to a requirement for reduced output power of each individual transmitter.

If the designer or design team takes the time to understand the technologies and the regulatory constraints up front, and then measures prototype performance as the project progresses, the transmitter development cycle can proceed toward a successful goal with no nasty surprises &#151 or delays. The payoff is a product that fits into the &quotwindow&quot for market share and profitability. If the radio can be approved as a module, it can be used over and over again with no added engineering or approval costs.

About the Author

Roland Gubisch is chief EMC and Telecom engineer, roland.gubisch@intertek.com; and Nicholas Abbondante is EMC project engineer, nicholas.abbondante@intertek.com.

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[1] http://www.wirelessdesignmag.com/sites/wirelessdesignmag.com/files/legacyimages/0802/wd802cs_1_lrg.gif