Every manufacturer seemingly wishes to add some form of wireless capability into new and existing mobile, household, industrial, scientific, and medical product. This trend toward the “Internet of Things” is in full swing and with it comes problems with EMI. That is, EMI from the product itself, that interferes with sensitive telephone, GPS/GNSS, and Wi-Fi/Bluetooth receivers. This is called “platform interference” and it’s a big problem for manufacturers.

Most digital-based products create a host of on-board radio frequency “noise” (electromagnetic interference), that usually won’t bother the digital circuitry itself, but the harmonic energy from digital clocks, high-speed data buses, and on-board switch-mode power supplies can easily create interference well into the 700 to 950 MHz mobile phone bands, causing receiver “desense” (reduced receiver sensitivity). In order to use the various mobile phone services (Verizon, ATT, Sprint, T-Mobile, and others in the U.S.), manufacturers must pass very stringent compliance tests according to CTIA standards. This on-board digital noise often delays product introductions for weeks or months.

My last three clients all had platform interference issues that kept their products off the market until major redesigns were done. In this article, I’ll show what this noise looks like, how to measure it and suggest some remediations.

**Examples**

First, let’s take a look at a typical product. The details will remain general for confidentiality purposes. This board includes a USB port whose data ultimately gets transmitted via various mobile phone systems, depending upon the factory configuration.
There are two common types of high frequency harmonic plots; narrow band and broadband. Figure 2 shows the difference. Typically, DC-DC converters or data/address bus data will appear as a very broad signal with several resonant peaks (violet trace in Figure 2), while crystal oscillators or high
speed clocks will appear as a series of narrow spikes (aqua trace in Figure 2). Unless the product is designed for EMC compliance, both these types of signals can radiate or conduct high frequency energy well into the mobile phone bands.

Figure 3 - Measuring the noise generated by an on-board DC-DC power converter. The radio module is at the far right end of the board.

Figure 4 - Measuring the noise from a DC-DC power converter located adjacent to the radio module.

Types of Measurements

There are generally two types of measurements I suggest. The first helps characterize the general
noise profile of an area of the board (DC-DC converters, clock buses, processors, RAM, and any other potential high frequency device. This measurement is taken from least 1 to 1000 MHz, in order to characterize the general spectral profile and to see whether any energy extends into the receiver passband of concern (Figure 5). For other mobile phone and/or GPS/GNSS, you’ll need to look as high as 2 GHz. For Wi-Fi, you’ll need to look as high as 2.5 or 5.4 GHz. Max Hold mode is used with the analyzer to build up a maximum spectral amplitude.

Figure 5 - In this example, we’re looking from 30 MHz to 1.5 GHz to generally characterize the spectral emissions profile of a couple of on-board DC-DC converters. Both will potentially cause interference to mobile phone bands in the 700 to 950 MHz region. The one with the violet trace is over 30 dB above the ambient noise level.

The next measurement I suggest is to look at just the receiver (downlink) band. You’ll probably need an external broadband preamplifier of at least 30 dB gain in order to clearly observe the encroaching noise, if any. I generally turn on the 20 dB built-in preamplifier as well. I use the Beehive Electronics external amplifier, with frequency range of 100 kHz to 6 GHz, but there are many other companies, such as Aaronia, Rohde & Schwarz, and Keysight that sell high-gain broadband preamplifiers with low noise figure. You’ll probably need to make these measurements inside a shielded room in order to exclude other mobile phone transmissions from disrupting your measurements. Examples are shown in Figures 6, 7, and 8.
Figure 6 - Measurement of two noisy sources (aqua and violet traces) within the receiver passband of a mobile phone band. The yellow trace is the ambient measurement.

Figure 7 - Ethernet harmonics within the receiver pass band (violet trace).
Figure 8 - In this case, the noise (violet trace) was pulsative and captured using Max Hold mode on the spectrum analyzer. It’s 10 dB higher than the ambient noise level.

Remediation Checklist

As I mentioned, the product design must be developed with EMC in mind and no corners should be cut. This will consist of:

- A near perfect PC board layout
- Filtering of DC-DC converters
- Filtering of any high frequency device
- Filtering of the radio module
- Local shielding around high noise areas
- Possibly shielding the entire product
- Proper antenna placement

The PC board layout is critical and is where most of your effort should reside. An eight or ten layer stack-up will provide the most flexibility in segregating the power supply, analog, digital, and radio sections and provide multiple ground return planes, which may be stitched together around the board edge to form a Faraday cage. Care must be taken to avoid return current contamination between sections. The power plane for the radio section should be isolated (except via a narrow bridge) from the digital power plane. This can provide up to 40 dB of isolation between the digital circuitry and radio.

It is vital that the power and ground return planes be on adjacent layers and 3-4 mils apart at the most. This will provide the best high frequency bypassing. Clock, or other high speed traces, should avoid passing through too many vias and should not change reference planes.

Power supply sections should be well isolated from sensitive analog or radio circuitry (including antennas). Be aware of primary and secondary current loops and their return currents. These return currents should not share the same return plane paths as digital, analog, or radio circuits. remember
that return currents want to return directly under the source trace.

The book, *Platform Interference in Wireless Systems*, by retired Intel engineers, Kevin Slattery and Harry Skinner, is very useful in providing ideas for measurement and remediation. For general product design guidelines, the book, *EMI Troubleshooting Cookbook for Product Designers*, by Patrick André and Kenneth Wyatt, describes several basic design concepts to reduce EMI.

*Note: This will be my last EMC Blog posting, as I’m moving on as senior technical editor for another magazine. Hopefully, we’ll be able to find one or two authors to continue this series. I’d like to thank Martin Rowe for his sponsorship for these nearly three years, as well as the support of Janine Love, Suzanne Deffree, and all the others behind the scenes at UBM Canon. I’d especially like to thank all my readers for their special insight and encouragement.*

**References**
