Designing for WLAN Integration into Handhelds

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The demand for high performance, multifunction handheld devices such as mobile phones, PDAs and smartphones continues to grow. The merging of multiple technologies into a device that fits in the palm of your hand as well as your pocket has, and will, continue to generate and drive this demand. We have seen the beginning of the Bluetooth wireless headset craze which will eliminate the wire between the mobile phone earpiece and the mobile phone itself. Display resolutions will continue to improve along with the quality of audio systems while memory size, CPU speed, and overall performance continue to increase, enabling new applications such as video phones, VoIP over WLAN in the enterprise and home, high-resolution video streaming, and high speed Internet while still having ubiquitous mobile phone coverage.

With the power and weight constraints set by today's compact handsets, designers face significant challenges in adding new technologies to next-generation products without increasing their size. What may not be as apparent is that as multiple technologies converge into these handheld devices, a whole new set of electromagnetic interference issues arise. In addition to the small form factor and low power requirements, the wireless subsystems must be designed to tolerate or co-exist with one another rather than harm each other. This article delves into how these new requirements and challenges are overcome to engineer the next generation of high-performance and high-functionality wireless handheld devices.

As an example, some next generation handheld products will contain GPS, WLAN and Bluetooth as well as 2.5G and 3G cellular technologies. They will have multiple transceivers and may easily operate in up to five or six bands. The standards committees that set each of these standards do not specify receiver requirements assuming that the device will be within 10 cm of two or three other transmitters. To make these devices functional design teams must calculate new requirements for transmit spectrum power levels as well as receiver adjacent channel rejection requirements, so that the device's tendency to self-interfere is eliminated.

Before discussing the engineering details let's take a quick look at why integrating the wireless systems into one handset is so important. While the other gadgets in their lives may come and go a surprisingly large number of consumers have grown accustomed to having their mobile phone with them at all times, being able to place a call at any time and be reached any time. Because cellular is the one technology capable of providing ubiquitous coverage for the foreseeable future it will most likely be the enabling infrastructure for automatic, anywhere, anytime connections as they extend from voice to Internet data services.

Fig. 1: Cellular Is The Enabling Infrastructure For Different Systems

WLAN technologies, usually in the form of IEEE 802.11 (WiFi) systems, have huge market growth and penetration in three key areas: home, offices and hot spots in hotels, coffee shops, convention centers and airports. WLANs typically enjoy very high speed and excellent in-building penetration making them a natural for use in office settings. The cost for WLAN service is often free of per-minute-billing and the network capacity is tens, and in the future even hundreds, of Mbit/s. WLANs should soon be able to also deliver high-speed video, video conferencing, audio, and VoIP.

Bluetooth is finding its niche in these devices and will be the key enabling wireless technology for the wireless headsets that we now see people walking around with over their ears. It is also an ideal technology for low-speed and power-sensitive devices such as wireless keyboards and mice which do not require high bandwidths. And, of course, the Bluetooth hot sync of calendars and e-mail will persist.

GPS is not just for airplanes anymore and as GPS subsystem costs lower, this technology is finding its way into handsets as a navigational aid and as an emergency location service, such as E911.

The design of a product with all of these wireless systems generates a multi-dimensional problem. Each system has its own transmit spectral characteristics and will require its own custom receiver adjacent channel rejection capabilities. We will take a look at this problem from the perspective of the WLAN subsystem specifically looking at IEEE 802.11b (11 Mbit/s) for simplicity, although the next generation systems will be based on IEEE 802.11g (54 Mbit/s.)

The design philosophy for every wireless subsystem must adhere to “do no harm” and “be robust to interference,” with the first piece meaning that the transmit spectral mask must not significantly raise the noise floor in the passband of the other wireless systems. Of course these other systems are in the same handheld device, so isolation between antennae of 20 dB - at best - can be assumed, so with a thermal noise floor at -114 dBm/MHz it is desirable that the WLAN system transmit no more than -94 dBm/MHz in the passband of other devices. In practice some margin added to this requirement has insignificant impact to the other systems. An alternate method is to bound the out-of-band transmit power such that the sensitivity degradation of other wireless systems is limited to a specified value.

The 802.11b standard specifies that the transmit spectrum shall be 50 dB down from the power in the passband at frequencies greater than 22 MHz from the center frequency. The maximum transmit power in the passband is typically 12 dBm/MHz so that translates into a requirement of -38 dBm/MHz outside the passband, a far cry from "do no harm." Regulatory agencies may place further constraints on the out-of-band transmit power but even those additional constraints may not be enough to guarantee that adequate performance is achieved, an example that shows additional specifications are required for the WLAN subsystem to make sure it does not harm to other wireless subsystems.

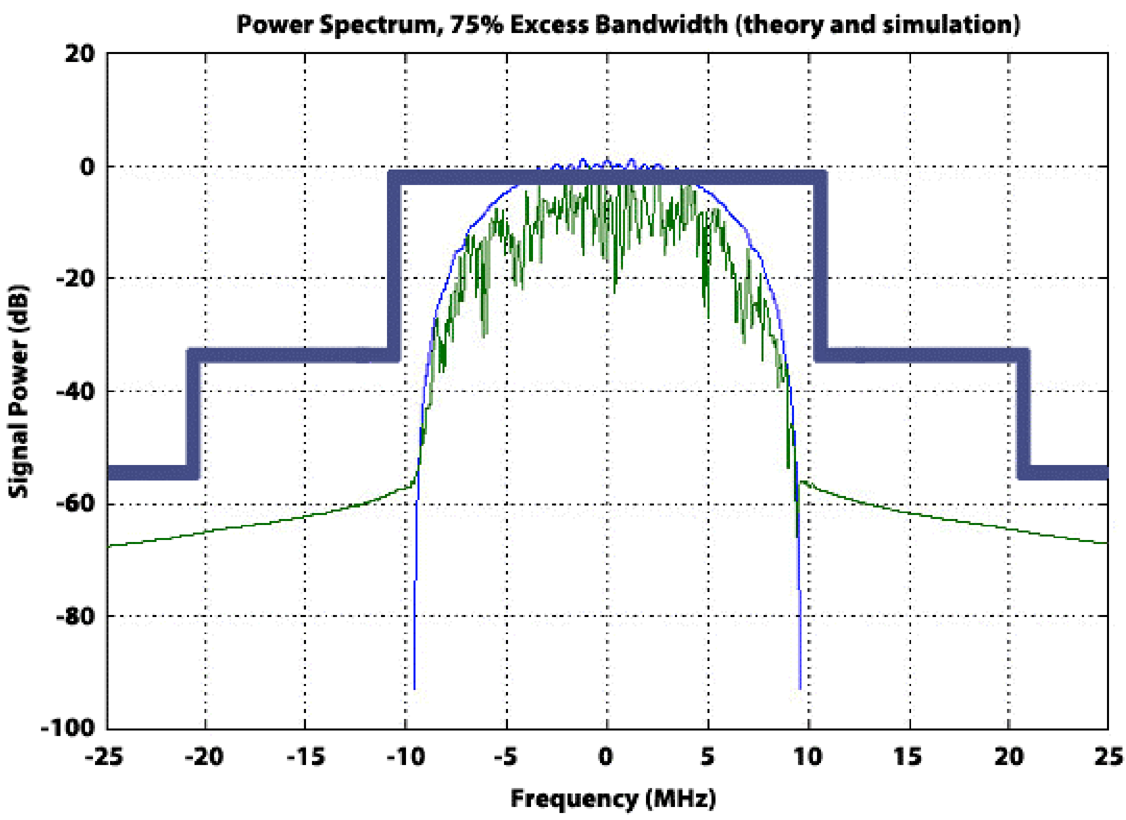

Fig. 2: 802.11b Spectral Passband Requirements

Likewise the WLAN subsystem must "be robust to interference." In a handheld device this has a whole new meaning. While in a WiFi-equipped laptop the distance to other wireless transmitters is measured in meters, if not tens of meters, the distance in the handset is again in centimeters. The number of interferers that must be tolerated vary in transmit power from 0 dBm to +30 dBm and vary in frequency separation from 0 to 1600 MHz from the WLAN system. A few examples are shown in the table below.

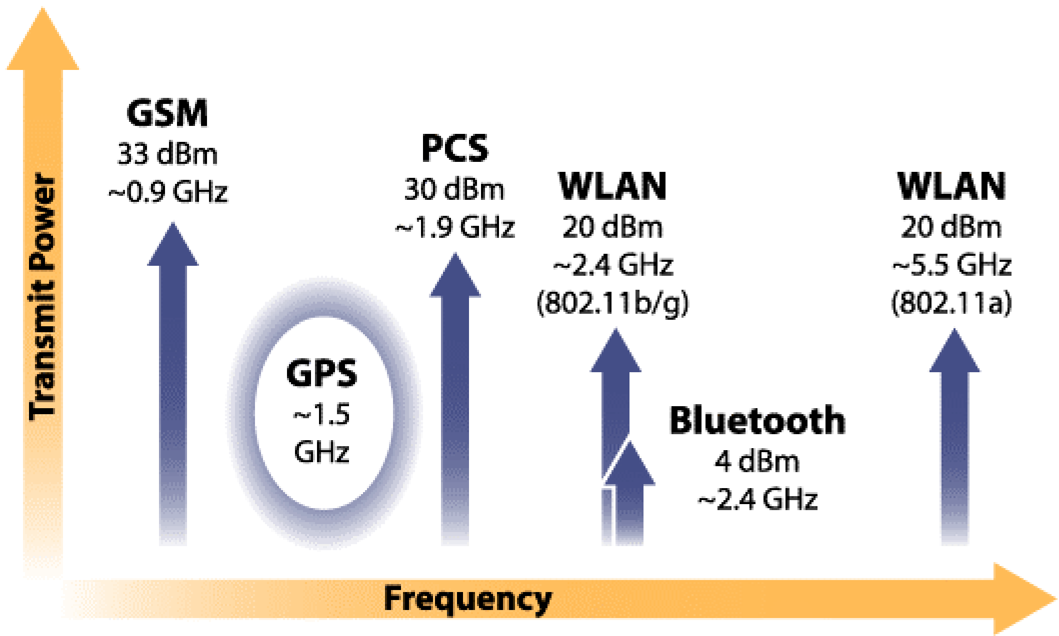

Fig.3: Possible Interference Sources In Handheld System

The 802.11b standard specifies that adjacent channel rejection must be at least 35 dB at 25 MHz from the center frequency of the receiver, and goes no further than that. There are no specifications on compression points for example. In addition the 802.11b standard specifies that the rejection is to be tested with respect to another 802.11b waveform. This might be expected, and is certainly needed, but it is inadequate for some purposes. For example this specification in no way guarantees the ability of the receiver to work properly in the presence of a PCS transmission from an antenna that is 5 cm away and is transmitting at +30 dBm. Additional design requirements must be added to make sure that both WLAN and Bluetooth, as well as other wireless systems, work in this type of close-proximity environment.

One particularly tough problem to solve is the coexistence of Bluetooth and WLAN in handheld devices. This problem is particularly difficult in handheld devices due again to the limited isolation between Bluetooth and WLAN antennae. The difficulty with Bluetooth and WLAN is that both operate in the 2.4-GHz ISM band so both systems are typically designed with a channel pre-select filter that captures the whole 2.4-GHz band. This makes rejection of interfering signals particularly difficult but there are multiple solutions to the problem.

One solution uses a TDM algorithm to avoid interference between the systems and adaptive frequency hopping is standardized in Bluetooth 1.2 solutions. However, even with this enhancement it may be difficult for WLAN and Bluetooth to simultaneously operate without techniques such as transmit power control. Although WLAN and Bluetooth coexistence is difficult, it has been solved so that the user still experiences simultaneous WLAN and Bluetooth operation, and key applications such as voice-over-Bluetooth are not affected.

The adjacent channel, transmit spectrum, size and power consumption requirements for WLAN devices in smart phones, mobile phones and PDAs are unique. Not every WLAN system can meet the performance requirements needed for these environments. In addition system designers must select products that have been specifically designed for these requirements, otherwise performance of the resulting products will not be satisfactory. The good news is that the requirements are achievable and are being implemented today in state-of-the-art WLAN systems and in reference designs for PDAs.

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