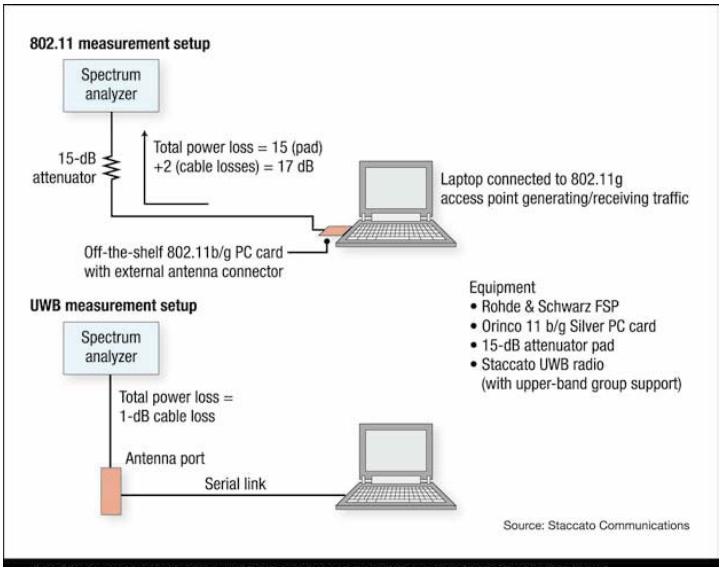
High Speed Bluetooth testing raises concerns

By Roberto Aiello and Siddharth Shetty

The Bluetooth Special Interest Group is preparing its specifications for the next generation of Bluetooth. The High Speed Bluetooth specification will support high-speed file transfers and video streaming applications. Initially, the Bluetooth SIG selected only WiMedia ultra-wideband (UWB) technology to enable the new protocol. Recently, however, it announced the option of using 802.11 as an interim solution, piggybacking Bluetooth protocols on existing Wi-Fi radios in portable devices.

This means that now WiMedia UWB and 802.11 are candidate alternate MAC/PHYs (AMPs) for the High Speed Bluetooth release. The principle is to allow the existing Bluetooth technology to be used in consumer devices while achieving faster throughput via a secondary radio. However, many in the industry are concerned about the known interference issues that will result between the 802.11 radio in the Bluetooth device and other IMT-2000 services operating in adjacent frequencies, such as WiMax, LTE, UMTS and wideband CDMA. The concern is that if consumers have a poor user experience with the initial implementation of High Speed Bluetooth using the 802.11 AMP, the long-term risks to the success of the technology could outweigh any short-term time-to-market gains. Bluetooth already has a high-profile position in the consumer marketplace (last year the SIG welcomed its 9,000th member), and rushing time-to-market with an interim technology is risky.



Measurement setup to determine potential interference from the 802.11 AMP (top) and UWB AMP (bottom).

Usage models

Wireless LANs and IMT-2000 do not typically operate simultaneously, because they both provide access to the network infrastructure. High Speed Bluetooth and IMT-2000 services, however, will support independent applications, and they will often be operating simultaneously. This means that if the High Speed Bluetooth device is using the 802.11 AMP, it is likely to be running in an environment with IMT-2000 services operating in nearby frequency bands. To illustrate this point, consider the following usage models.

In the first one, two multiradio handsets are located close to each other. One is making a voice call over WiMax, the other is transferring a file to a PC with 802.11-based High Speed Bluetooth. The voice-over-WiMax call will drop when the other handset transfers a file to the PC, even at a distance of several meters. Similarly, when a handset is making a voice call with WiMax and at the same time printing using High Speed Bluetooth, the handset needs to wait for the end of the call before printing without dropping the call. Alternatively, it would not be able to receive a call if the print job already started.

In both of these usage models, any interference between the Bluetooth system and the WiMax or cellular services would be extremely detrimental to the end user's experience. The reality is that consumers expect to be able to use multiple technologies simultaneously, without interference.

Spectrum allocation

One of the initial reasons for concern regarding interference between the Bluetooth 802.11 AMP and IMT-2000 services is that they operate in adjacent parts of the spectrum. The concern is that the use of 802.11 as a high-speed option for Bluetooth would have severe detrimental effects on other services operating in adjacent licensed frequency bands.

In addition, even though the Bluetooth SIG intends to limit the 802.11 AMP to file transfer applications, once this high-speed radio >>22

about the authors

Roberto Aiello is co-founder and CTO of Staccato Communications. A recognized leader in the UWB community, he is actively involved in regulatory and standards-setting committees and is the author of more than 20 patents on UWB technology.

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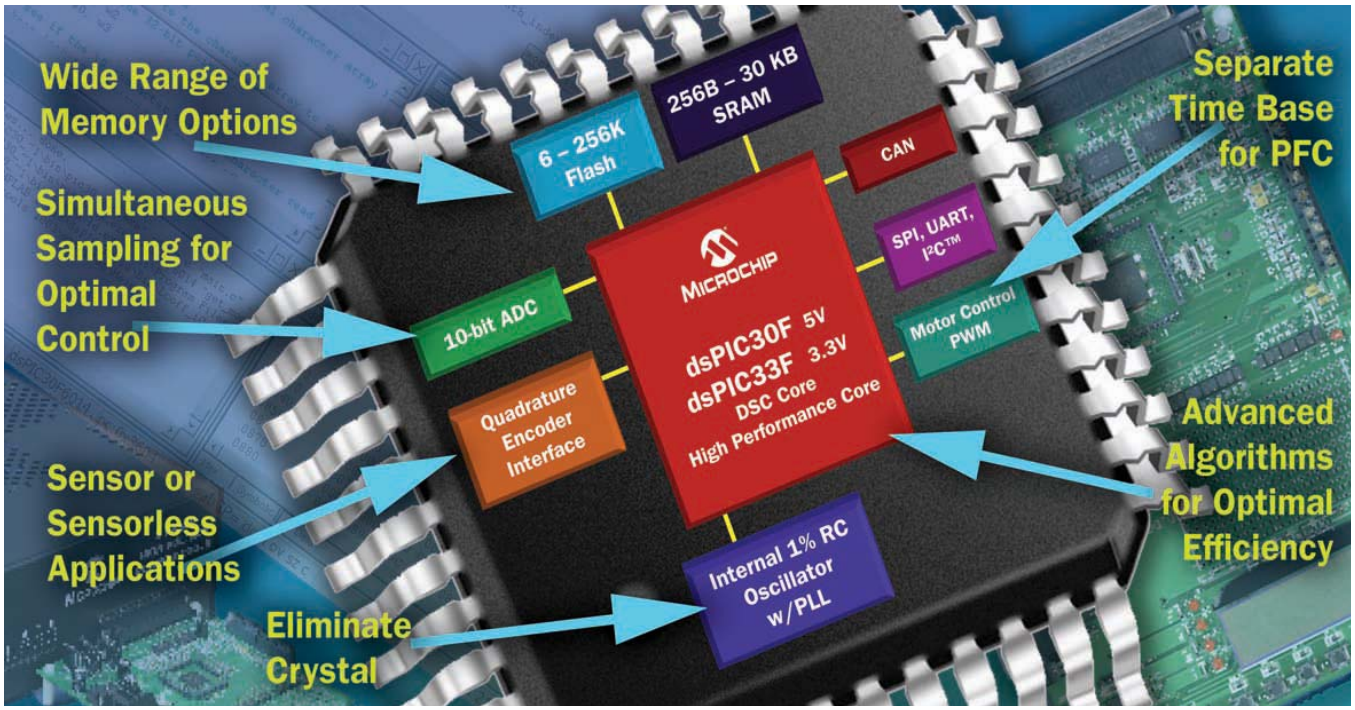

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<<20 **BLUETOOTH** functionality exists, users may decide to use it for video streaming (as described by Bluetooth press materials). Because of their continuous nature, these streaming applications over an 802.11 AMP will have an even higher potential for interference than will file transfers.

Desensitization

With multiple services in use simultaneously in a multimode device (as in the usage scenarios above), a Bluetooth 802.11 AMP may interfere with the operation of the other radios, leading to desensitization or even blocking of reception. If any of the blocked services are transmitting time-critical content, such as conversational audio or streaming media, the user experience can be poor. As an illustration, we will consider the use of WiMax in conjunction with an 802.11 AMP.

In the United States, the 2.5- to 2.7-GHz range is licensed for use by WiMax systems. Given its proximity to the 2.4-GHz spectrum, WiMax has little isolation from the out-of-band emissions originating from an 802.11 radio, which could dramatically hinder high-reliability WiMax operation. Interference to WiMax is being taken very seriously by designers for reasons that can be understood better from an interference study report published by the European Electronic Communications Committee (ECC) in February 2005. The report, "The Protection Requirements of Radiocommunications Systems Below 10.6 GHz from Generic UWB Applications" (also known as Report 64), includes IMT-2000 services operating between 2.5 and 2.7 GHz as among the "victim" services of interest.

It's important to note that although this study focused on UWB as the interferer, the analysis was based purely on transmit power spectral density (PSD), and it made no assumptions about the transmitter's signal characteristics. Hence, any interfering energy with PSD higher than the protection limit specified in this report was concluded to have the potential to interfere with IMT-2000 client stations.

> Some propose that a coexistence mechanism be added to 2.4-GHz Bluetooth so it does not transmit during WiMax operation.

The protection limit was derived in the following manner. The maximum allowable interferer power level at the receiver of the IMT-2000 subscriber unit (without causing degradation) was found to be –115 dBm/MHz. For the use case where a protection distance of 36 cm is considered, a free space path of approximately 30 dB (at 2.5 GHz) results in transmit PSD protection limit of –115+30 = –85 dBm/MHz to provide adequate protection to the IMT-2000 client station.

Note that in the above example, the ECC determined that a separation distance of 36 cm was appropriate to take into account a foreseen frequent scenario in which an operating UWB device may be on a desk in an office environment, not far from a potential victim IMT-2000 mobile station.

This analysis can be validly extended to the coexistence requirement between WiMax and the Bluetooth AMP. In the United States, 802.11 radios are allowed to transmit up to +20 dBm within 2.4 to 2.484 GHz, while it can transmit up to –41 dBm/MHz in the adjacent bands allocated to IMT-2000 services. This means that to avoid interference at 36-cm distance, the 2.4-GHz 802.11 AMP device would need to limit the emission levels to –85 dBm/MHz in the adjacent WiMax bands. (Note that the WiMedia UWB AMP will be operating above 6 GHz.)

In light of the above observations, industry leaders are now suggesting that a coexistence mechanism be added to 2.4-GHz Bluetooth so that it does not transmit during WiMax operation. If next-generation WPANs use the 802.11 AMP to link desktop peripherals, the results will dramatically exacerbate the interference situation. For example, if a user receives a streaming video WiMax transmission on a mobile handset, and the nearby desktop connections start transferring a file to an iPod (or a printer), the WiMax video connection will stop, and the user will be staring at a blank screen.

Measurements

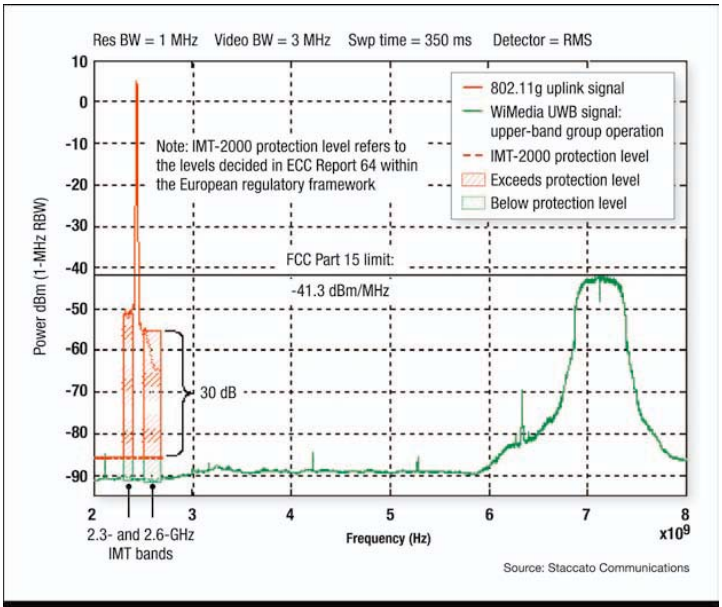
A set of measurements was performed in Staccato Communications' lab to quantify the interference effect.

All measurements were performed in a lab environment using conducted cables. The spectrum analyzer (SA) settings were held constant for >>24

Frequency band (MHz)	Services	Duplexing
2,300 - 2,400	Wireless Communications Service (WCS) band in U.S./ Canada, WiMax (WiBro in Korea); also chosen as an additional International Mobile Telecommunications (IMT) band at WRC'07	TDD
2,400 - 2,484	Industrial, scientific and medical (ISM) band—used by unlicensed radios such as 802.11, Bluetooth	TDD
2,500 - 2,570 (uplink) 2,620 - 2,690 (downlink)	IMT-2000 band for 3G services such as UMTS, W-CDMA, LTE	FDD
2,570-2,620	IMT-2000 band for 3G services such as UMTS, W-CDMA, LTE	TDD

Source: Staccato Communications

Bluetooth 802.11 AMP and IMT-2000 services operate in adjacent parts of the spectrum.



Source: Staccato Communications

In-band and out-of-band emissions for an off-the-shelf 802.11g card. The red slashed lines show where the card's emissions exceed the ECC protection level. The green line shows the performance of a WiMedia UWB radio operating above 6 GHz (which is where the UWB AMP will operate).

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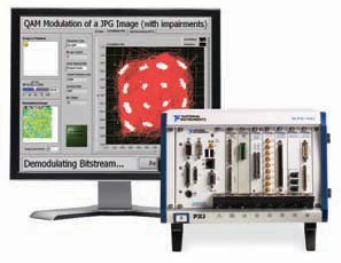

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<<22 BLUETOOTH both measurements to establish a common reference plane. A 15-dB attenuator pad was inserted in the 802.11 measurement to drive a lower signal level to the SA front end and hence get a lower noise floor reading by turning down the input attenuation on the SA.

Results show that 802.11 out-of-band emissions in the WiMax, UMTS and LTE bands exceed the protection limit by about 30 dB, while UWB emissions are 5 dB lower than the protection limit.

This means 802.11-based High Speed Bluetooth will interfere with IMT-2000 services unless they are located approximately 8 meters apart for 2.6 GHz and 16 meters apart at 2.3 GHz. If they are co-located in a single device, achieving this level of isolation between radios is unrealistic. Therefore, the most practical solution in such co-located cases would be to time-synchronize transmission and reception of different radios, i.e., one must be turned off for the other to operate. This could make receiving a WiMax call while using a High Speed Bluetooth feature impossible to achieve.

It was also observed that the UWB emission in the IMT-2000 bands is below the protection level and doesn't cause any interference. This means the WiMedia UWB AMP can be used in conjunction with IMT-2000 services, even co-located in the same device.

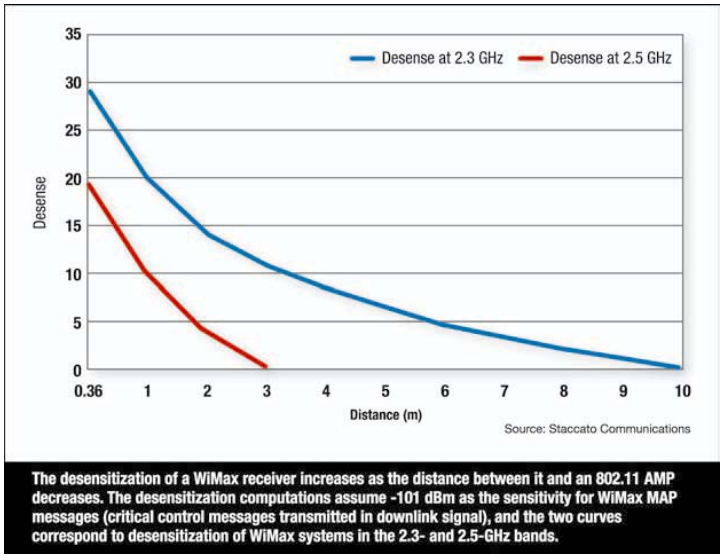
In general, the desensitization of a WiMax receiver increases as the distance between it and an 802.11 AMP decreases.

Recommendations

Analysis of real-world measurements shows that UWB AMP emission levels are sufficient to protect IMT-2000 services at 2.3/2.6-GHz bands per the protection requirements specified in ECC Report 64.

Real-world measurements show that 802.11 AMP radios have the potential to interfere with IMT-2000 systems at 2.6 GHz even at 8-m separation (assuming free-space loss and the –115 dBm/MHz maximum allowable interference PSD). For WiMax, out-of-band emissions from an 802.11 AMP can desense a client station sitting 10 meters away. Such effects can directly impact the capacity and functionality of these systems.

As an industry, we need to take these user experience issues seriously. The success of High Speed Bluetooth relies on the industry's understanding and addressing them before deploying them into the market. We also have a responsibility to protect licensed services from interfering with their proper operation. The appropriate next step would be to conduct adequate coexistence studies between 802.11-based High Speed Bluetooth and licensed services in 2.3/2.5-GHz bands. Subsequently, the industry should consider developing mutual interference mitigation mechanisms for High Speed Bluetooth using the 802.11 AMP, based on the results of the coexistence study. Alternatively, the industry should exclusively move operation of the 802.11 AMP to 5 GHz. ■



The desensitization of a WiMax receiver increases as the distance between it and an 802.11 AMP decreases. The desensitization computations assume -101 dBm as the sensitivity for WiMax MAP messages (critical control messages transmitted in downlink signal), and the two curves correspond to desensitization of WiMax systems in the 2.3- and 2.5-GHz bands.