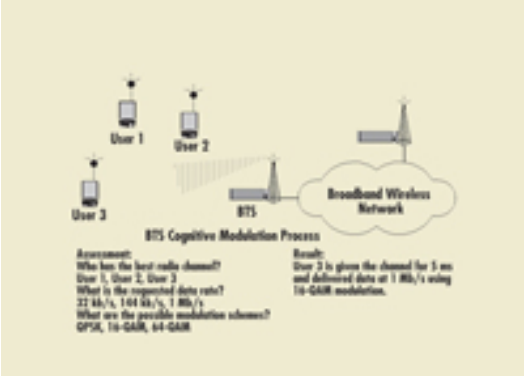
Improving the Utilization of RF Spectrum through Advancements in Radio Technology

By Joseph Bobier and Stuart Schwartz

As engineers develop new ways to deliver information wirelessly, policymakers and regulators seek to increase the availability and efficiency of RF spectrum. Last year, the U.S. General Accounting Office (GAO) provided a technical &quotwish list&quot for improving RF spectrum utilization, suggesting that the industry focus on:
&#149 Components capable of operating at &gt 100 GHz.
&#149 Advanced data compression algorithms that would reduce spectrum demand.
&#149 Software-defined radios capable of changing their operating parameters.
&#149 Spectrally-efficient waveforms.

To build on this dialogue, we offer two additional items that we regard as critical: *cognitive radio technology* and *spectrum multipurposing*. Further, we submit that many of these key building blocks are not futuristic; rather they are on the market or close to being so. One new technology &#151 xMax&#153&#151 provides evidence that true wireless broadband is closer than we think.



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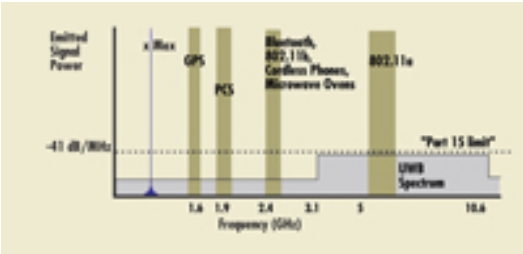
Cognitive Radio

So-called cognitive radio technology adapts its use of spectrum based on the real-time conditions of its operating environment &#151 a combination of artificial intelligence and radio technology. The process (see Figure 1) is conceptually simple. The network identifies which users need service, determines which users are operating in the best environment and fixes on the most efficient data transmission scheme to satisfy the user's request. Deliberately and continuously applied, this process results in significantly improved spectrum utilization.



[2]

This type of technology is the foundation of many of today's wireless standards, such as 3G mobile wireless technologies, W-CDMA High Speed Downlink Packet Access (HSDPA) and CDMA1x EvDO. Wireless LAN technology 802.11a and fixed wireless interface FLASH-OFDM employ similar processes.

Spectrum Multipurposing and the xMax Solution

The notion of *RF spectrum multi-purposing*&#151 exploiting spectrum &quotgray spaces&quot or unused regions of dedicated spectrum &#151 is a fairly significant departure from the single-use allocation scheme the FCC employs today. However, if technological advances enable spectrum dedicated for, say, an FM radio station to be used to simultaneously provide broadband wireless services without degrading the FM broadcast, the possibilities for wireless deployment would grow exponentially.

Ultra Wideband (UWB), with its low power transmission profile, is a step in the right direction. However, UWB's sideband emissions aren't completely interference-free, requiring the use of higher frequency spectrum (upwards of 3 to 10 GHz), which has limited propagation characteristics.

To meet this challenge, xMax modulation, a promising hybrid technology combining aspects of narrowband carrier systems and low powered wideband pulse position modulation (PPM), is being developed.

While existing wireless technology tries to move as much power as possible into the sidebands (where the information resides) and away from the carrier wave, xMax places more than 99% of the power in the carrier, keeping sideband energy emissions negligible. As shown in Figure 2, xMax is characterized by a spectrum utilization profile where adjacent channel spillover is so far below detectable levels it has no effect on neighboring users. The carrier is used to correlate with the information to enable reception.

The Wavelet Pass Filter is the key to xMax. This device allows the receiver to recover the weak information-bearing signal found amidst the narrowband interference and noise from legacy and neighboring users in the adjacent sidebands.

This results in a power spectral density substantially below that of UWB. The carrier itself occupies little bandwidth, while the information-bearing signal is spread over a 100 MHz sideband that is well below the noise floor. Because the spectral power is so low in the adjacent bands, legacy users experience no interference and are free to continue normal operation, thereby allowing for spectrum reuse.

Applications of the xMax Model

The xMax model holds multiple implications in the fixed wireless space. Using a 6 kHz voice channel for the carrier wave, a provider could deliver data rates on the order of megabits per second. And, by using lower frequency spectrum (xG's field-tested prototype uses a narrowband VHF paging channel), xMax can achieve greater signal distance &#151 minimizing access points or towers, lowering network costs and increasing margins.

Furthermore, the transmitters and receivers are not terribly complicated and there is no expensive synchronizing equipment necessary in this carrier-assisted system. In short, not only will the equipment be fewer and farther between, but far less expensive.

Conclusion

While the research and debate over optimal utilization of RF spectrum will continue, it is clear that significant progress is being made and that new, more efficient technologies may come to the marketplace imminently. Many of these technologies utilize the principles of cognitive modulation and employ better spectrum multi-purposing &#151 xMax is one such example. On this trajectory we can all feel optimistic about the future of wireless communication.

About the Authors
Joseph Bobier, original inventor of the single cycle modulation and demodulation

concept, is president of operations for xG Technology, LLC. Mr. Bobier formally trained in electronics and communications technology in the United States Navy. Since then he has received several patents in the fields of renewable energy, wireless networking and radio modulation technologies. Currently he heads the Fort Lauderdale, Florida technical offices for xG Technology.
Stuart Schwartz has been teaching and doing research in communications at Princeton for 39 years. He was chair of the department during the period of 1985 to 1994, and served as Associate Dean for the School of Engineering during the period July 1977 to June 1980. He has also held visiting academic appointments at Dartmouth, University of California, Berkeley, The Technion, Israel and the Image Sciences Laboratory, ETH, Zurich. His principal research interests are in signal processing for communications and image analysis.

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