Isolating Interference

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Find the key to (system design) happiness.

As wireless systems proliferate worldwide, the arch-enemy of wireless-system designers — uncontrollable interference — hampers capacity and limits the cost-effectiveness of new sites and system hardware. When you consider the fact that in five to seven years the planet will have more than 1.5 billion wireless users, it's clear that the ability to predict and control interference will be the single most important technical challenge to wireless usability. Fortunately, emerging packet-data-transmission formats will provide some tolerance to interference at the expense of delay. However, with the advent of data and Internet protocols over wireless, the RF emissions of co-channel and adjacent-channel users will continue to define the limits of quality and capacity in any wireless systems.

Numerous technological advances have taken aim at taming interference in practical cellular-system deployment. One major step was the development of CDMA technology, which actually induces interference among co-channel users between base stations and in neighboring cells. How can the introduction of more interference lead to the control of interference to the end user? The key is in the baseband processing of CDMA. By selecting a unique user code, simple circuitry at baseband can detect the desired user while spreading out the unwanted signals so that they appear as low-level noise. That CDMA actually improves capacity is borne out by the fact that most of the leading 3G technologies submitted for ITU approval use some of the ideas of CDMA.

Other methods, such as TDMA used in IS-136 and GSM, guarantee that only a specific user occupies a particular RF channel at any instant of time, thereby restricting the number of simultaneous users in a cellular system. When used with standard co-channel cell-system planning, it's possible for TDMA systems to provide a well-controlled interference environment, although the interference from users in neighboring co-channel cells is ultimately the limiting factor in capacity and quality.

Other multiple access and multilevel keying-modulation strategies, such as orthogonal frequency division multiplexing, offer various advantages and show promise for emerging broadband-wireless systems in a large multi-user interference environment.

No matter what the multiple access or modulation scheme, the rubber meets the road when service providers are forced to build out quickly, to keep up with consumer demand (capacity hot spots) and competing coverage areas. Here, frequency planning becomes difficult due to the rapid expansion, and all multiple-access technologies become stressed because of the higher levels of co-channel interference induced by new base stations, microcells and repeaters. The effect of adding just a single new base station in an urban core can create horrendous interference problems in a small area, or can render a control channel of an incumbent base station useless, due to bleedover. The filtering characteristics of subscriber phones, the specific radio-propagation characteristics for all radiating stations, and the effectsof inter-modulation harmonics in the base-station-transmitter chain all play into whether or not interference will occur. The great wireless build-out is happening around the world, but nowhere is the interference more acute than in the high-capacity urban cores, within and around metropolitan office buildings, airports and public arenas, which already are inundated with RF interference.

A secret weapon available to wireless-service providers in a rapid build-out mode is the ability to archive and simultaneously track the interference effects of every base station in their networks. By modeling the RF environment with a 3-dimensional representation of the physical world, it becomes possible to understand, predict and design around the RF environment that your own cell-system design creates. This use of knowledge is a crucial aspect in controlling interference.

**Real-Life RF Interference**

An example can be seen below, where a 1-by-1-mile urban core is modeled with six low-power IS-136 microcells and three taller macrocells in the U.S. 800MHz cellular band. The system has evolved over time, where each microcell is placed to serve users in a high-density urban environment. If each microcell has 57 RF voice channels, and three voice users are assigned per RF channel, then the system under study has nine base stations with 516 RF channels. The capacity of such a system easily can support thousands of simultaneous users with little blocking, but in major metropolitan districts such as Chicago, Hong Kong, Mexico City or New York, additional capacity may be needed. (See Figures 1 and 2.)

For example, say that an office building wished to install its own wireless-office-system (WOS) solution for its employees. Here is the dilemma: Already there's significant channel reuse in the urban core. What will happen if additional base stations and antennas are added within a building? This is where wireless-system-design software can help. Not only can computer-aided design tools help provide "what if" analysis of the interaction of new systems within an urban core, but they can simultaneously track the whereabouts of new RF equipment within the building, making it easy to locate antennas, leaky feeders and distribution systems in the future. (See Figure 3.)

This ability to archive and maintain a parts-list inventory for the service provider and building owner is a free bonus on top of the important ability of properly locating antennas and making judicious channel assignments. Figure 4 shows how the C/I is virtually unaffected on both the forward and reverse link by adding a 10th 57-channel base station in the building while positioning the omnidirectional antenna in the center of the building under test. An alternate design, using leaky feeders within the building of interest, further improves the co-channel interference ratio, while reducing some coverage in parts of the building.

**Scanning Frequency Use**

Still another way to understand and combat interference is to conduct a rapid scan of the frequency use around the building of interest. This allows the RF engineer to simply measure, in situ, the RF-interference environment, and then to design the in-building or campus system quickly. The article "Getting In" (Wireless Review, March 1, 2000), shows some simple methods of modeling the entire RF environment so that a reliable in-building design can be made. With this "measure and plan" technique, an RF engineer can be certain that the proper channel selection and antenna placements can be made. Again, having a computer-aided design tool that integrates measurements with 3D building data makes the job of interference control a snap.

Other methods for controlling interference include the use of adaptive frequency planning, where a careful scan of the entire frequency band is conducted for the purposes of measuring RF-interference levels everywhere throughout your market. Once the scan is completed, algorithms can process the measured data to determine how many channels, and which specific channels, are available in a particular market location (say within an office building). Research at Virginia Tech's Mobile and Portable Radio Research Group resulted in algorithms that could break down an existing channelization scheme throughout a cellular market, so that a specific channel listing could be defined at existing base stations. This concept of adaptive frequency planning allows service providers to re-adjust their existing co-channel cellular-system configurations to better optimize the RF channels at each transmitter. The value of such an approach allows a service provider to "reset" its market-wide channelization scheme to minimize interference, thereby making up for the lack of careful interference control during a high build-out phase. An example of a capacity study, which makes use of these concepts, appears in the January 1999 issue of the IEEE Vehicular Technology Transactions, where it was possible to predict the number of available channels throughout a skyscraper in a major U.S. city.

Other interference-control mechanisms act upon the leakage of adjacent-channel interference at the base-station receiver. By using new superconductive-filter technology, it's possible to manufacture very tight RF channel filters that help reduce adjacent-channel interference on the reverse link. With portable-phone users in skyscrapers, macrocells suffer huge amounts of interference on the reverse link unless in-building systems are used that force subscriber terminals to use very low power. This is yet another reason why in-building WOS is sure to evolve rapidly over the next few years.

One thing is certain about interference: It's difficult to completely design against. But with judicious channel-assignment schemes and deployment strategies that use knowledge of the physical 3D radio environment, it's possible to maximize capacity and the use of RF assets. Fortunately, new technologies in multiple access, filter design and computer-aided design and archiving are coming online to help engineers carry out the great wireless build-out more efficiently and accurately.

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