Radiated Performance Testing of WiMAX Mobile Devices

Given the potential cost of higher network densities, wireless carriers need to be concerned about the RF performance of mobile devices on the network.

WiMax Forum™ Radiated Performance Tests

Objects typically found near the radiating elements (human head, hands, and body, table tops, etc.) can all have a significant effect on the resulting radiated performance. To address these issues, the WiMAX Forum has developed a set of radiated performance tests to evaluate the performance of mobile WiMAX devices, helping network operators ensure that WiMAX certified devices will operate reliably.

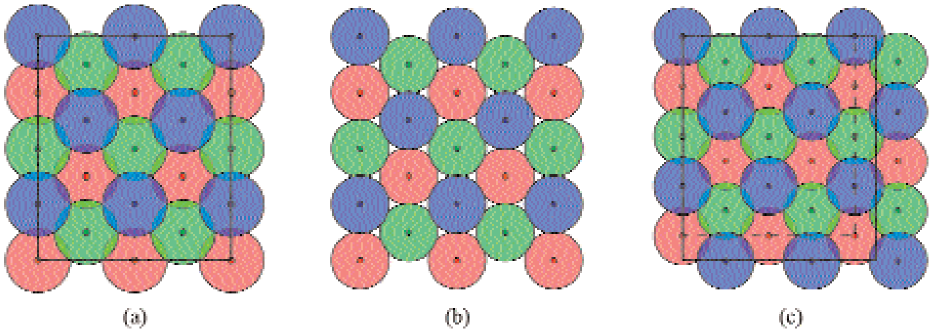
Editor's Note:

*A list of references containing additional details on the WiMAX Forum's set of radiated performance tests can be found at www.wirelessdesignmag.com.

By Dr. Michael D. Foegelle, ETS-Lindgren, L.P.

The Technical Working Group (TWG) of the WiMAX Forum™ recently and resoundingly approved a new test plan, *WiMAX Forum™ Radiated Performance Tests (RPT) for Subscriber and Mobile Stations.* This test plan marks a distinct departure from the previous work of the Forum's certification program, which until now had focused primarily on verifying conformance of WiMAX radio designs to the 802.16e standard, and interoperability of various WiMAX network components. For those who have not been directly involved in the events leading up to this development, it may not be clear why this type of performance testing is so important to both the Forum and the industry as a whole.

The primary goal of these radiated performance tests is to provide a metrological way of evaluating "edge-of-link" performance of WiMAX mobile devices without resorting to the "Can you hear me now?" criteria of network "drive testing", where mobile devices are taken along defined paths within a well defined network to determine when the signal drops out. To be sure, drive testing is an important part of network evaluation, but by moving to a laboratory environment to determine mobile device radiated performance we can remove a wide range of variables and obtain traceable quantitative results that allow for detailed product evaluation and comparison. This information is of great use to network operators, who can use it to determine when a product is likely to provide a less than optimum user experience, in the form of lost connections or low data rates, over their entire network. With the relative youth of WiMAX network implementation, the adoption of RPT at this early stage will also provide network designers with a better indication of expected device performance that can be applied throughout the network buildup to help ensure uniform coverage without over-building the network.



(a) (b) (c)

Figure 1. Illustration of a typical cellular network arrangement (a) showing the result of an 11% reduction in range length (b) and the corresponding increase in base station density (c) required to provide the same amount of coverage.

The Value of a dB (or two)

Network operators use the concept of "link budgets" to plan network layout/density. The range of communication between two wireless devices is a function of the power radiated by one device and the receiver sensitivity of the other, and vice-versa. It's easy to think of it in terms of how "loud" the one device can "talk" and how well the other device can "hear". The RF link breaks when the two devices get too far apart, such that one can no longer "hear" the other. It can also break due to either device having poor transmit (talk) or receive (hear) characteristics. Thus, in defining a link budget, certain assumptions are made about the RF performance of the devices that will be used on the network. Network designers have complete control over the base stations used to lay out the network, but providing the user the flexibility to use whatever mobile device they choose, while still maintaining network integrity, can be considerably more difficult. While network link budgets are typically designed with a certain amount of safety margin, any loss in RF performance of the system components can result in "dead spots" on the network. Poor RF performance can result in customer complaints, product returns, and even low customer retention. So how can the network operator address this when designing their network?

RF engineers typically represent power levels in dB, a logarithmic representation of a ratio of two power quantities. A loss of 3 dB in signal level corresponds to half the power, while an increase of 3 dB doubles the power. Typical link budgets between a base station and a mobile device are typically on the order of 80 to 100 dB or more. For radio propagation in free-space, electromagnetic fields fall off in a $1/r$ relationship, where r is the distance from the transmitter. Thus, in free space, the path loss in dB between a source and receiver increases as $20 \log(r)$, allowing a link budget in dB to be represented in terms of a maximum separation distance. Given the log ten definition of a dB, a 10x increase in distance would result in 20 dB of additional path loss. Thus, if the received signal strength at 10 meters from a source was 0 dBm, then at 100 meters, it would be -20 dBm, and at 1000 meters it would be -40 dBm.

Wireless networks are typically designed with a number of fixed base stations distributed so that the ranges corresponding to their link budgets overlap. Moving too far from one base station allows roaming to the next one before the link is lost with the first. Figure 1(a) illustrates a typical cellular arrangement that provides this overlap. If we assume free space path loss as described above, then reducing the performance of the mobile station by 1 dB would reduce the available range of the link budget by 11%, resulting in "holes" in the network as illustrated in Figure 1(b). In order to eliminate these holes and account for the reduced performance of the mobile, the base stations would have to be placed closer together as shown in Figure 1(c). Thus, where originally sixteen base stations were sufficient to cover the indicated area, now twenty are required, solely because the mobile station performance is one dB below that expected in the original link budget. Now, to be fair, on a real network we typically don't see true free-space propagation. The effect of the earth, trees, buildings, etc. increases the path loss typically seen on a wireless network, so that the effect of a single dB of path loss on the range of the wireless network is reduced. There have been many studies to determine the behavior of real wireless networks, and the available models tend to range from 35 to 45 dB of path loss per decade as opposed to the 20 dB per decade of the free space model. If we pick a point in the middle and assume an average of 40 dB per decade, that corresponds to a 2 dB reduction in performance producing the same 25% increase in base stations shown in Figure 1.

Whether we are talking about one or two dB or even ten, there is always some point where the available link budget would be insufficient to provide overlapping coverage between base stations. More importantly, once the network has been designed, it is impractical to move base stations closer together to try to address shortcomings in the link budget. Instead, to address these issues from the network side, it becomes necessary to go back and add more base stations to fill in the gaps, as shown in Figure 2. Patching holes in a network by adding base stations could easily double or, in the case of Pico-cells, even triple the required number of base stations. Not only does this cost more in terms of infrastructure and backhaul, but it also requires more spectrum, since the new cells have to overlap the original planned spectrum re-use map.

Given the potential cost of higher network density and the prohibitive cost of increasing network density once installed, it becomes readily apparent why wireless carriers need to be concerned about the RF performance of the mobile devices that are used on their networks. Once a network is designed for a given level of mobile device performance, allowing an unsuspecting user to bring a device with lower performance onto the network would result in a less than ideal user experience due to the reduced link budget. At that point, who is the user likely to look to in order to resolve their problems?

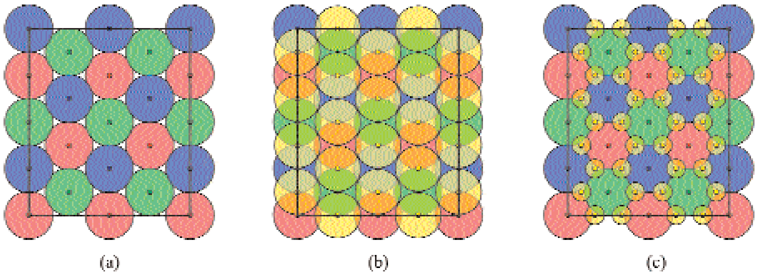

(a) (b) (c)

Figure 2. Illustration of possible ways to address network "holes" by adding more base stations (b) or Pico-cells (c).

The Antenna Assumption

By now it should be apparent that it is important for the network operator to have some assurance of the RF performance of any mobile station that will be used on their network. Ask most wireless radio design engineers and they'll tell you that the average radiated performance of the device is just the conducted performance (transmit power or receiver sensitivity) of the radio (in dBm) plus the efficiency of the antenna that is attached to it. While this is the basic concept taught in any antenna class, unfortunately it doesn't hold completely true when talking about today's compact wireless electronics.

The first assumption that tends to break down is that a wireless device radiates the same way that the antenna used within the device radiates. The goal for a mobile wireless device is typically to generate an omnidirectional dipole-like pattern, and often the embedded element by itself may be able to do so. However, once an antenna is embedded in a device, the platform in which it is embedded can have a significant effect on the radiation pattern of the antenna. To mitigate the impact of this effect, custom antenna designers will often perform passive antenna pattern measurements of their antenna already installed in the target platform. However, it's never possible to completely eliminate the impact of a transmit cable attached to the embedded antenna, nor to eliminate all effects of mismatch and standing waves. For electrically small devices, the cable can have a very significant impact on the radiation pattern.

At the other end of this assumption is the radio to which the embedded antenna will be attached. While conducted tests can determine the ideal performance of the radio under a variety of simulated conditions, these tests are all performed in a 50Ω conducted environment and don't address the impact of the antenna or platform on the overall device performance. While a radio may perform well into a well matched 50Ω load, a mismatch can cause non linear behavior (overheating, etc.) that would not be detected in the conducted test. Moreover, the embedded radio is rarely in an electrically quiet environment. The platform typically has CPU clocks, displays, etc. all of which produce RF noise that, once the embedded antenna is attached to the radio, make their way into the receiver. This platform interference was not present during the conducted test, but is likely to always be present during normal operation of the device. Thus, typically the only way to determine the impact of this interference is to test in a radiated environment with the antenna attached.

In addition to the impact of the platform, there are usually a number of near-field impairments that must be accounted for. Objects typically found near the radiating elements (human head, hands, and body, table tops, etc.) can all have a significant effect on the resulting radiated performance. Thus, when we talk about determining radiated performance, we need tests that can account for all of these effects.

The Radiated Performance Test

To address these issues, the WiMAX Forum has developed a set of radiated performance tests to evaluate the performance of mobile WiMAX devices. The details of this testing is beyond the scope of this article, but is available elsewhere.* The results of these tests will help network operators ensure that WiMAX Certified devices will operate reliably on their networks. In addition, through the use of the RPT requirement the effect of changes to the platform, including the embedded antenna(s), can be evaluated without having to repeat other certification tests on an embedded radio that has already been certified as a "compliant portion". In this way, certification of device "variants", where basic components like CPU or display may be changed, is streamlined without concerns as to the impact on device performance.

WDD

About the Author

Dr. Michael D. Foegelle is the Director of Technology Development at ETS-Lindgren in Cedar Park, TX. He can be contacted at (512) 531-6444 or foegelle@ets-lindgren.com.