Low Versus High Radio Spectrum

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Lower frequency bands are often described as "beach-front property." Many people believe that radio frequencies below 1 GH are ideal for mobile communications, but while lower frequencies provide some advantages, as the industry increasingly has to deploy capacity-constrained networks, the differences between low and high frequencies become much less significant. In capacity-oriented networks, all spectrum is highly prized and provides almost identical carrying capacity.

Lower frequencies do offer advantages, but my view is that these advantages are often overstated. Most usage of mobile broadband networks will occur within higher population densities in which networks will have to be designed for capacity rather than coverage. In these scenarios, low and high frequencies offer almost equivalent performance.

One advantage of lower frequencies is that the signals have better penetration, meaning they pass through objects such as walls with less attenuation. This effect results in better in-building penetration. Recall old broadcast TV signals that passed through concrete walls to bring "I Love Lucy" to television sets around the country. The primary advantage of lower frequencies, however, is that lower-frequency radio signals propagate farther in the environment. At the lowest end are systems to communicate with submarines operating in the extremely low frequency (ELF) band which ranges from 3 Hz to 300 Hz. Wavelengths at those frequencies are thousands of kilometers long, so antennas, which have to be huge, are a slight challenge.

In contrast, mobile communications systems used globally have frequencies much higher than this, ranging from 450 MHz to 2500 GHz, with most systems in the U.S. operating at either 850 MHz (cellular band) or 1900 MHz (Personal Communications Systems – PCS) band. In trying to cover an area with the minimum number of sites, using 1900 MHz takes somewhere between 2 to 4 times as many sites as 850 MHz. The exact ratio depends on multiple factors such as path loss, the link budget, cell tower height, and the geometry of the area being covered. Lower frequencies, such the 700 MHz band in which LTE is being deployed in the U.S. right now, requires even fewer sites than 850 MHz, though only slightly.

For rolling out a new "greenfield" mobile wireless network, fewer cell sites equates to a lower-cost deployment. For instance, it's less expensive to roll out a greenfield LTE nationwide network at 700 MHz than to roll out WiMAX at 2.5 GHz. Both use almost identical radio methods, namely orthogonal frequency division multiple access (OFDA) and 2X2 multiple-input-multiple-output (MIMO) smart antenna systems. The biggest difference is the frequency and the larger number of cell sites required for the higher frequency.

For that reason, a 700 MHz LTE deployment makes a lot of sense as an "underlay" network, a network built for coverage. But as pointed out in many of my papers, including "The Spectrum Imperative: Mobile Broadband Spectrum and its Impacts for U.S. Consumers and the Economy – An Engineering Analysis" (http://www.rysavy.com/Articles/2011_03_Spectrum_Effects.pdf) – even wireless networks that use the most advanced wireless technologies available, such as LTE, have extremely limited capacity. It only takes a handful of users simultaneously streaming video in a coverage area to consume sector capacity. For that reason, operators that have an underlay network will need to add capacity once they start loading their networks with subscribers.

A number of operators are planning to use their AWS licenses at 1.7 GHz (and eventually other frequencies) for exactly this overlay purpose. (Ultimately, cellular and PCS bands will also be refarmed for LTE.) It takes more sites to build out at 1.7 GHz, but the increased number of sites simultaneously translates to much greater capacity. So even if it were to take three times as many sites for 1.7 GHz as for 700 MHz, MHz for MHz, the 1.7 GHz network will have three times as much capacity as the 700 MHz network, and the overall LTE network now has four times the total capacity as it did with just the 700 MHz band. Of course, if an operator built out on higher frequencies, such as 1.7 GHz, 1.9 GHz, or 2.5 GHz in the first place, the operator would have a high capacity network from the beginning. As such, a network build at just higher frequencies would not ultimately cost any more to achieve comparable capacity.

Given that lower frequencies have such good propagation, one might wonder whether it might actually be a liability to use them in denser deployments with smaller cells. In other words, the signal in one cell might keep propagating into neighboring cells and cause excessive interference. Actually, an operator can prevent such excessive propagation by using down-tilt on the base station antennas. Thus the operator could ultimately build a high capacity network using lower frequencies and smaller cells.

The bottom line is that lower frequencies do offer advantages, but my view is that these advantages are often overstated. Most usage of mobile broadband networks will occur within higher population densities in which networks will have to be designed for capacity rather than coverage. In these scenarios, low and high frequencies offer almost equivalent performance.