Integrating Functions Inside Base Station Antennas; Past, Present and Future

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Over the past 20 years, base station antennas have become ubiquitous, visible almost anywhere on the globe the human race calls home.

While there are tradeoffs between performance and appearance, the driving force in base station antenna design has been, and continues to be the need to achieve greater functionality inside the aperture and volume. The most significant advances in base station antennas have involved integrating more and more features into the standard and accepted form factors.

When cellular sector base station antennas, then commonly referred to as "panel" antennas, first appeared in large numbers in major cities in the US and Europe, the antennas appeared on towers of various heights and designs; building sides and roof tops; water towers; high voltage power transmission towers; and anywhere a cellular operator could lease a location that provided the height and location required by that that cell.

While governments, industry, businesses and communities have grudgingly accepted certain minimum antenna shapes and sizes, traditional cellular frequencies covering 806 to 960 MHz require widths around 1 foot and heights ranging from 4 to 8 feet. This creates antenna gains ranging from 14 dBi to 18 dBi for azimuth 3 dB beam widths of 60 to 90 degrees. Once the gain and azimuth beam width are fixed, the vertical 3 dB beam width, number of elements, element spacing and hence the height of the antenna are easily determined. Personal Communication Services (PCS), Universal Mobile Telecommunications Systems (UMTS) and Advanced Wireless Services (AWS) frequencies covering 1710 to 2170 MHz require antennas about half the size, about 6 inches wide, and 2 to 4 feet in height.

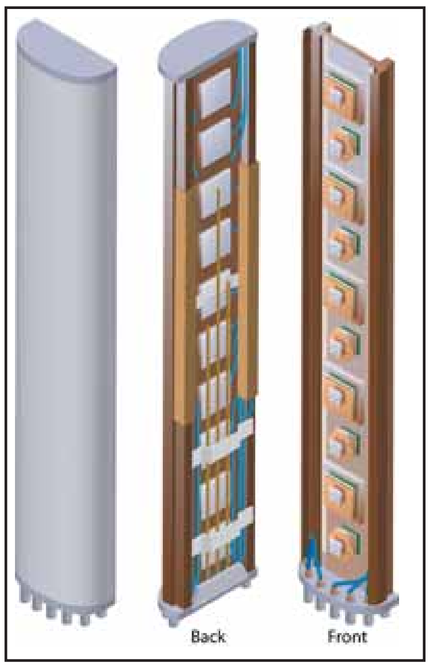

Figure #1

However, in the future, people worldwide will essentially see antennas of the same size and shape. While the outside dimensions have, and will remain nearly constant, what has changed, and will continue to change, is what's going on inside.

In the late 80s cellular systems were built around receive diversity achieved through horizontal separation of about 10 wavelengths, or 12 feet at cellular frequencies. It then quickly became apparent that many locations were difficult or impossible to accommodate the 10 wavelength separation, particularly in Europe with pressure to create cell sites with minimum visual impact. The early 90s saw the development of dual polarized antennas. Rather than two vertically polarized antennas separated in space, antennas using two orthogonal polarizations were used to process two low correlation signals. Since vertical polarization was the common type, the first dual polarized antennas used vertical and horizontal polarization. The problem with these early dual polarized antennas was the difficulty in creating azimuth patterns of the same shape and beam width. This problem was solved with the introduction of dual slant 45 polarized antennas that inherently create identical or nearly identical horizontal patterns.

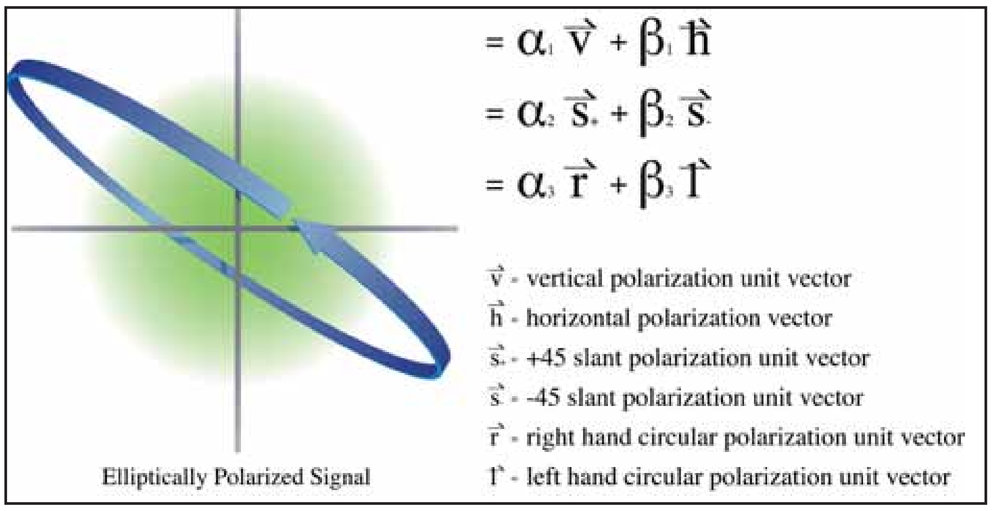

Figure #2

Integrating more function is not without additional requirements and considerations. Even today some operators prefer to use single vertically polarized antennas to avoid the trade offs and additional requirements of more complicated antennas.

Dual slant polarized antenna challenges include port-to-port isolation, polarization purity and proper representation of the antenna front to back ratio. These issues simply do not occur for simple vertically polarized antennas.

Isolation between the two ports is important to prevent adversely high levels of transmit signal from coupling into the orthogonal port, and to maintain polarization purity. As polarization purity degrades, correlation increases, reducing the effectiveness of polarization diversity. Besides high isolation, low cross polarization levels are needed over the entire sector and slightly beyond. This requirement led to development of new dual polarized elements that maintain high cross polarization levels not just on bore sight, but over the entire field of view.

An additional challenge with dual slant polarized antennas is interpretation of front to back. With vertically polarized antennas, the definition of front to back is straightforward, the relative level in dB between the peak of beam and the highest pattern level in a defined region in the rear hemisphere. The problem with dual slant is how antennas are typically measured on a test range. The illuminating antenna is kept at a constant polarization, say plus 45 slant when viewed from behind the source antenna, and the antenna under test (AUT) is rotated through the pattern. The back hemisphere is actually measuring mostly cross polarization. There are various methods to correct for this inconsistency, including specifying total power front to back, measuring and processing two orthogonal components to maintain co-polarization and cross-polarization, however an industry standard has never evolved.

With two vertically polarized antennas spaced horizontally, isolation is not an issue, nor is purity of polarization (only to the extent there will be a certain level of polarization loss).

So as dual polarized fixed tilt antennas gained popularity in the mid-90s, wireless system designers needed to deal with these additional considerations.

The next major innovation to provide more function in the same volume was the variable beam tilt antenna, first introduced in the mid-90s, but not generally accepted until the early 2000s. These antennas are found in two broad categories, mechanically electrical beam tilt (MET) and remote electrical beam tilt (RET).

MET refers to the use of a mechanism operated by hand along with an indicator to change the vertical beam peak position over a range of beam tilts, typically between 1 and 1.5 times the vertical beam width of the antenna. RET refers to an electronic means to perform this adjustment, either locally at the antenna or remotely from the shelter, or even from a remote office or network operations control (NOC). Most, but not all, RET base station antennas conform to the Antenna Interface Standards Group (AISG), which issues standards for interoperability among manufacturers.

Prior to variable beam tilt antennas, system designers had to choose the fixed beam tilt when deploying the antennas. If a different beam tilt was desired, the choice was to switch to a different antenna or use mechanical tilt. Mechanically tilting the antenna has several drawbacks. For example, some locations do not allow the antenna to be tilted. For aesthetic reasons the antenna needs to be flush against the wall or structure to which the antenna is attached. Electrical tilt provides more consistent performance than mechanical tilt. When the vertical beam peak is electrically tilted, the entire pattern -- forward, side and back -- is tilted analogous to an umbrella. With mechanical tilt, the forward pattern tilts down, the back of the pattern tilts up, and the sides of the pattern remain fixed. This creates a distortion in the constant tilt, or conical cut, that becomes severe when accommodating for more than a few degrees of tilt.

Variable beam tilt antennas must also trade off performance for function. The vertical pattern of a fixed tilt antenna can be optimized for that tilt, producing the desired upper and lower side lobe levels and null fill. Variable tilt antennas compromise the vertical pattern performance to achieve a balance at various tilt angles. Also the element spacing must avoid grating lobes at the highest tilt positions, requiring smaller element spacing and higher cost.

In the late 90s as capacity limitations grew and operators began utilizing multiple frequency bands, for example GSM 900 and GSM 1800, the need arose for multi-band antennas including dual-band and triple- band antennas. Early versions of dual band antennas placed columns of low band and high band side by side, but several companies have developed innovative techniques to overlay low band and high band in the same aperture. These interleaved approaches have had strong success and large deployments have occurred over the last five years, replacing single band antennas with same or similar sized dual and triple band antennas **(See Figure #1)**.

Again performance must be balanced with functional requirements. Return loss, variation in azimuth pattern and cross polarization degrade with interleaved designs. The aperture-coupled patch has proven to be an excellent choice and is more amenable to interleaved approaches.

However, the ability to share aperture is limited. At a given frequency a signal from a mobile device can have any elliptical polarization. This elliptically polarized signal can be received and decomposed into any two orthogonal polarizations, for example vertical and horizontal, or slant plus 45 and slant minus 45, or even right hand circular and left hand circular polarization, but no more than two (**See Figure #2**). Using a traditional aperture you cannot create four polarizations without the subsequent loss in power, negating any advantage. The consequence of this is if more than two signals are required, for example 4 by 2 multiple input multiple output (MIMO), a larger aperture cannot be avoided. This creates a major obstacle to deployment of more than 2 by 2 MIMO as apertures larger than the accepted standards must be used.

Another area of product development over the past twenty years has been the use of the volume behind the antenna's radiating aperture to house components. These include Tower Mounted Amplifiers (TMAs), bias T's that provide DC power to TMAs, filter combiners or diplexers, to combine or separate different operating bands, and RET to control the variable beam tilt. These aesthetically pleasing approaches are found in single sector versions and round canister versions housing two or three sectors in a single unobtrusive housing (**See Figure #3**).

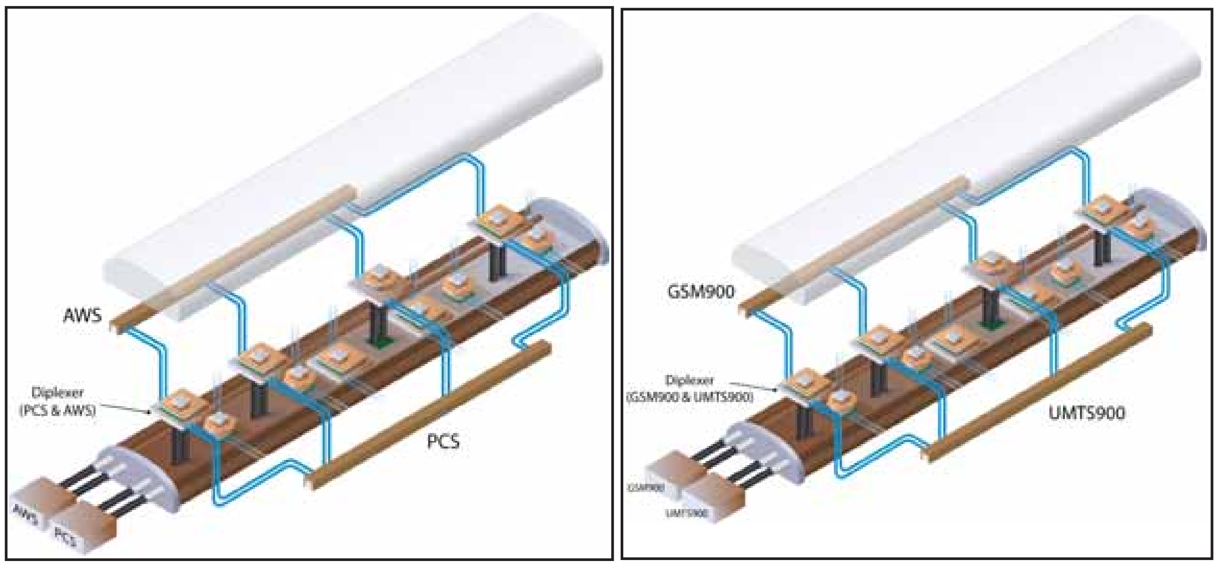

Figure #4a and #4b

This brings us to the current state of the art and what we can expect to see in antenna design over the next twenty years. Base station antennas are inherently broadband devices. Today dual band antennas cover 806 to 960 MHz (850/900 band) in the lower band and 1710 to 2170 MHz (1700/2100) in the upper band. Wireless systems are being deployed in increasing numbers in the 2300 to 2700 MHz spectrum and 3300 to 3800 MHz spectrum. Aperture sharing of various frequencies simultaneously up to now has been achieved through overlaying the 806 to 960 MHz band with the 1710 to 2170 MHz band. There is also a growing need to create overlays with the 2300 to 2700 MHz and 3300 to 3800 MHz band. This presents new challenges, and unlike the cellular and PCS networks, overlaying 1710/2100 with 2300/2700 requires techniques that work when the gap between the two bands is a small fraction of the required bands.

Figure #3

Another major challenge today is how to overlay narrowly spaced separate frequency bands. Examples include GSM 900 with UMTS 900 or the US AWS band with US PCS band. For fixed electrical tilt, where the same constant pattern performance is acceptable, a common antenna can be used with a filter combiner at the base station transceiver (BTS) to separate the two bands. The problem occurs when there is a need to have separate beam control of the two bands. For example, a fixed tilt GSM 900 is acceptable, but the UMTS antenna requires vertical pattern control. One solution is to provide separate aperture for GSM and UMTS, but this creates a significantly wider antenna and the increased difficulty of installing into existing sites.

A solution that maintains the same aperture is to attach a diplexer at each element, and provide separate variable tilt feed networks for each service. This solution achieves the goal of keeping the same aperture size as the traditional antenna. A dual band GSM 900 and UMTS 900 can be housed in a volume about 1 foot wide and 8 feet high for a 65 azimuth beam width 18 dBi gain antenna. As an alternative, the same specifications for a dual PCS and AWS antenna can maintain the tradition PCS band size of about 6 inches wide by 4 feet high (**See Figure #4a and #4b**).

However, this is difficult to achieve, and while there is a need for an RF solution that will allow system designers to replace existing antennas with antennas of the same traditional size, the design techniques needed to produce such a solution do not exist today. Also, developing these solutions requires a careful balance in the design of the combiner. Acceptable trade offs between insertion loss, out of band rejection, filter directivity, weight, size and cost must be achieved.

Another solution that has been envisioned for years, but not yet available today due to technical and commercial hurdles, is the array of active elements. This is a simple concept that uses the traditional antenna size; housed within is an array of elements, each containing an RF front end and DSP to create a bit stream of data from that element at each frequency processed. This information is then used as required to form various beam patterns or MIMO schemes.

The hurdles to realize this type of product are considerable, but are not without precedence in other industries such as defense. Each element connects to an integrated transmit receive module (Tx/Rx) that provides amplification for both transmit and receive. At each element, RF is mixed to an IF frequency and finally to baseband and digital. All this must be housed in a robust reliable mechanical assembly, with allowances made for component failure and replacement. Reliability and MTBF must be such that tower climbs are the rare exception, not the norm. Designs must be modular and intuitive. Tower crews of the future will be no different from today. The steps to install, adjust, verify and repair must be as simple and straightforward tomorrow, as they are today. Again, as now, there will be a need to house this antenna in aesthetically pleasing configurations including canister configurations that can be concealed to appear as flag poles, street lamp stands and other objects to mask the true purpose.

Unobtrusive but powerful, enabling next generation communications while keeping a constant profile -- this is the base station antenna of the future.

About the Author:

Scott Wilson leads the Antenna Product Unit for Powerwave and is responsible for strategic direction and management of the base station antenna product portfolio, including remote electrical tilt (RET) and Clean Site concealment solutions. Scott holds four US Patents for antenna design. Scott holds Masters of Science degrees in Electrical Engineering and Physics, and a Bachelor of Science degree in Engineering Physics from University of Illinois, Champaign.

Powerwave Introduces Two New Dual Band Antennas

Company's next generation full-featured antenna product line expands with industry's first dual band i-RET antenna and i-Diplexer, dual band antenna with integrated diplexer

Powerwave Technologies, Inc., a global supplier of wireless infrastructure solutions, recently introduced two new dual band antennas at Mobile World Congress 2008.

The first offering is Powerwave's 2 m Dual Broadband Integrated Remote Electrical Tilt (i-RET) Antenna. Additionally, Powerwave also introduced its 1.4 m Dual Broadband Antenna with Integrated Diplexer.

Both antennas accommodate lower (824 to 960) and upper frequency (1710 to 2170) bands within the same housing, providing carriers with maximum flexibility for co-siting and capacity expansion.

The i-RET product is an industry first featuring an integrated remote electrical tilt antenna and is designed for operation in multiple bands. Separate RET modules for the lower and upper bands are integrated into a standard housing, providing the same length, width and depth as the equivalent antenna without RET. The antenna is the next iteration of Powerwave's i-RET antenna product line, which integrates remote electrical tilt functionality under the antenna radome, delivering maximized functionality and improved aesthetics, while eliminating installation and reliability issues that can occur with typical exterior RET modules.

Other benefits include manual tilt functionality, extended and shifted tilt range and maximum flexibility via support for 3GPP and multi-standard controls. Also included is absolute position sense, a feature that allows resumption of calibrated antenna tilt measurement and control after loss of power, without antenna recalibration.

Powerwave's new i-Diplexer antenna features a low loss and high power diplexer integrated inside the base station antenna. The antenna is designed for site architecture that allows combining the lower and upper frequency bands at the antenna, cutting in half the number of cable runs. This configuration eliminates the need for an exterior diplexer resulting in a more compact form factor without sacrificing performance. These benefits include improved reliability due to a reduction in the overall number of external parts, and a reduced need for cables and weatherproofing. The antenna is offered in either a MET version or with RET.

"These two new antennas are representative of Powerwave's continued efforts to integrate more functionality into the antenna with fewer separate components, to improve maintenance, installation, field service and upgrade," said Bill Vassilakis, vice president, Corporate Research and Advanced Development, Powerwave. "The result is antennas that are robust and reliable with fewer moving parts, all of which serves to lower operational costs."