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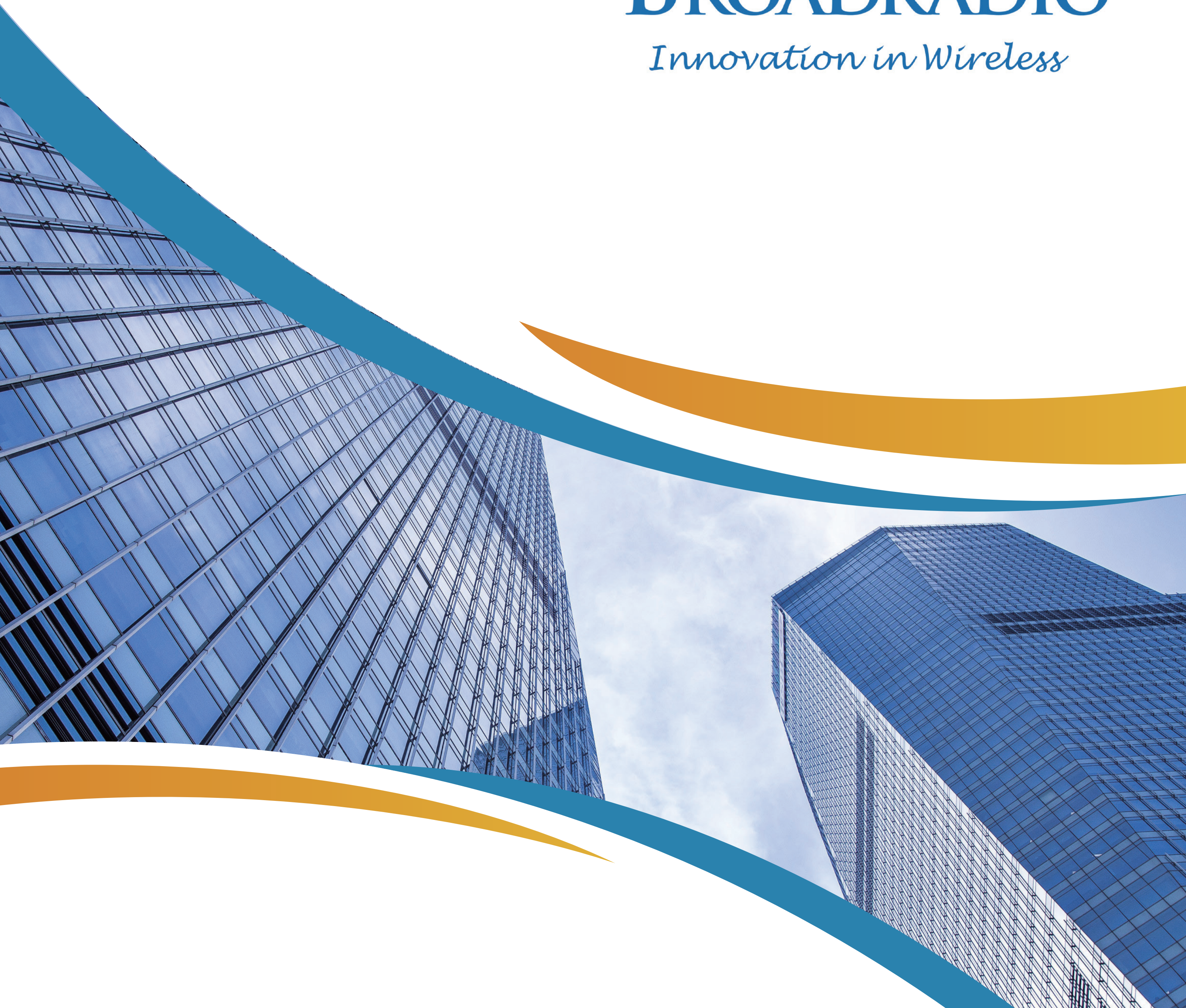
Innovation in Wireless



Multi-Beam Technology Adds Immediate Capacity without Additional Antennas

[01 INTRODUTIO]

By the Growing number of smart phone users, the demand for year-on-year increases in voice and data capacity in cellular systems is a problem faced by every operator worldwide and it will not disappear with the advent of new technologies and spectrum. The extraordinary growth in wireless data traffic such as video conferencing, media streaming and mobile-TV continually increase the demand for capacity in the cellular.

Especially for the stadium, square and other places which are crowded with smart phone users, the demands for capacity in voice and data are extraordinary. To request more capacity, the service providers are exploring several ways to expand the network capacity.

1) Adding Cell Sites is an effective but expensive approach to add capacity. In general adding new real estate is time consuming and increasingly prohibitive. With median inter-site distances dropping from 5km to 2km and recently to less than 200m in dense urban areas, the operator has less choice in selecting affordable property. Doubling the number of cell sites approximately doubles the network capacity and the throughput per user (assuming the user density stays constant), and greatly improves the peak user and the aggregate throughput per km2.

2) Adding Carriers (or more accurately, bandwidth) directly adds to capacity. The LTE standard is particularly adept at utilizing increased bandwidth. In addition, in the USA, the FCC permits increasing radiated power with the bandwidth in the PCS, AWS, and lower 700 MHz bands providing improved penetration and coverage. Doubling bandwidth at least doubles throughput.

3) Reducing noise. In 3G and 4G LTE networks, noise containment in the RF path is critical. External noise from a variety of sources — including multi-path reflection, environmental noise and interference from adjacent or nearby cells — can significantly decrease receiver sensitivity at the base station. As noise within the sector increases, mobiles increase their signal power levels, creating more uplink interference. Noise within the RF path is also problematic, with thermal noise and passive inter-modulation (PIM) being the major culprits.

4) Increasing frequency reuse. Another way to increase the capacity is to create more opportunities for frequency reuse through higher order sectorization.

5) Among a number of strategies shown above, the traditional way of adding cells and purchasing of additional spectrum both presents significant cost and time issues. Normally, site acquisition and site construction can be taken up to 2-3 years. And the total cost is more than 0.2 million USD due to the acquisition, construction and commission. And for adding more spectrums, if it is available, can be easily cost billions of dollars.Small cell deployment is also being touted as an excellent way to add network capacity. However, it could not satisfy service providers' immediate need for more capacity.

[02 TRADITIONAL SECTORIZATION]

In order to avoid interference in channelized systems, frequency channels need to be separated geographically. With sectorization the number of sectors (cells) subject to interference is reduced as the power of the sector focused forward.

In the last 50 years, wireless capacity has increased by a factor of about 1,000,0006. This growth has come from better spectral efficiency, more spectrum and more cells/sectors. Since the 1990s, one of the most popular and effective strategies for increasing site and network capacity has been sectorization.

The first sectorized systems replaced standard 360-degree omni-directional antennas with three separate directional antennas. The most commonly deployed configuration uses three antennas, each with a nominal azimuth beamwidth of 65-degrees. While the antennas within a sectorized cell share a common base transceiver station (BTS), each is managed and operated independently with its own power level, frequencies and channels.

The use of three directional sector antennas versus one omni-directional antenna substantially reduces co-channel cell interference and triples the opportunity for frequency reuse. As a result, the service providers realize significant gains in capacity.

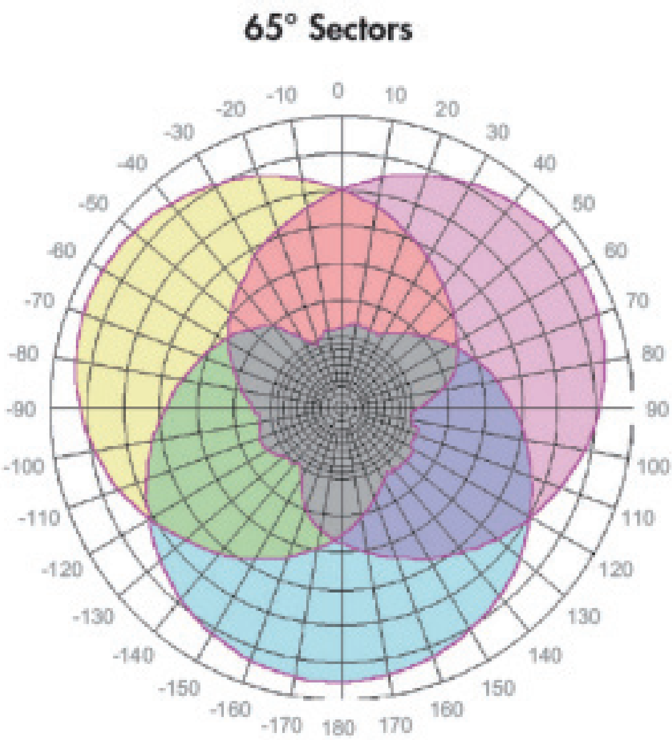
[03 HIGH ORDER SECTORIZATION]

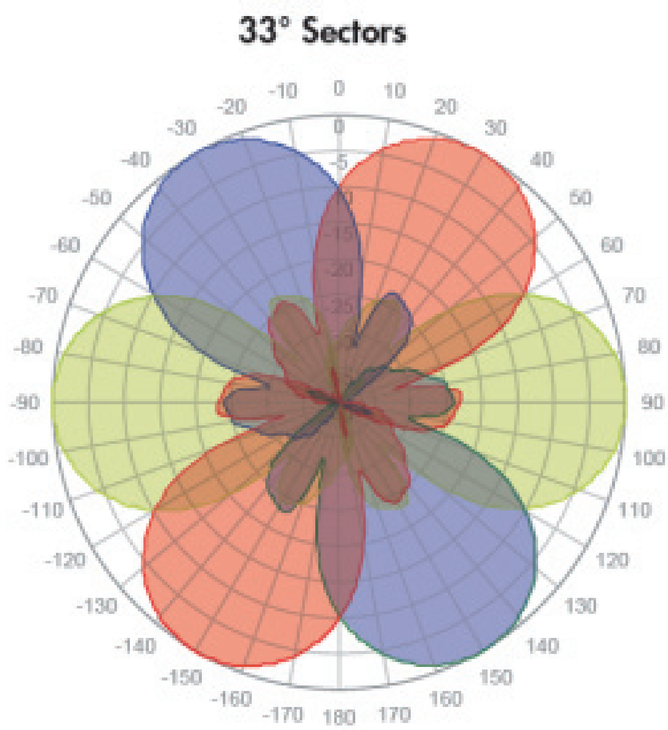
More than ten years ago, the service providers began to explore the capacity potential with higher order sectorization, which is splitting the conventional three-sector system into six-sector system. A six-sector deployment is using two 33° narrow beams to replace one 65° beam sector antenna. Due to the narrow azimuth beamwidth, higher order sectorization reduces not only the overlap interference, but also the soft hand-off area to improve the frequency reuse efficiency.

Comparing the 33° narrow azimuth beam antenna with normal 65° sector antenna, the narrow azimuth beam antenna provides rapid roll-off pattern, better sidelobe and backlobe suppression. Moreover, when a 120 ° sector is split into two small sectors equally by replacing one normal sector antenna with two narrow beam antennas, two split sectors can be controlled independently to optimize the network and customize the footprint of the cell site.

Figure 1 illustrates the significant reduction of inter-sector overlap in switching from a 65-degree to a 33-degree antenna. Reducing the overlap decreases the soft handoff area and provides additional capacity gains.

For the six-sector deployment, two crossover level points between split sectors can be optimized to -6 to -10 dB, which is good crossover level to handover between sectors for 2G, 3G and LTE systems.





[04 THE DRAWBACK OF HIGHER ORDER SECTORIZATION BY NARROW BEAM ANTENNAS]

The traditional way of deploying six-sector site is to replace three 65° sector antennas with six narrow beam panel antennas, which means double the number of antennas when using higher order sectorization. The increasing number of antennas means double the costs including purchasing, packaging, transportation and deployment cost.

Normally, a 33° narrow beam antenna is much wider in size than a 65° panel antenna due to its physical requirement for an additional antenna array to provide a narrower azimuth beam width. So the wider in size creates a lot of visual impact for the site. Moreover, the large surface of panel antenna creates significantly more wind loading comparing with the 65° panel antenna. Besides that, the larger narrow beam antenna also adds more weight to the tower than the 65° panel antenna.

Another issue by using two narrow beam antennas to replace the 65° panel antenna is alignment errors during deployment. Two narrow beam antennas need to be aligned precisely to replace a 120° sector for optimizing overlapped area, intra-sector interference, and cross-over level points.

For the reason mentioned above, the six-sector site by using narrow beam antennas is not gained much attention in telecom market.

[05 BI-SECTOR ARRAY TECHNOLOGY MAKES SIX-SECTOR DEPLOYMENT MORE PRACTICAL]

Leveraging the latest in phased array technology, Broadradio's Bi-Sector Array offers a new and innovative solution for service providers to implement 6-sector sites and hence increase capacity using existing site infrastructure and spectrum at a fraction of the cost of introducing additional cell sites.

Broadradio creates a better narrow beam shape using phased array technology. By optimizing the phase and amplitude of each horizontal array elements, the phased array network control outer-edge roll-off and inner edge overlap which results in asymmetrical beam pattern. By using a sector-sculpting Butler matrix, the single array projects two asymmetrical beams to create optimal RF coverage for new higher order sectorization sub-sectors.
The key feature:

- Supporting 2 x 2 or 4 x 4 MIMO
- Single array panel design supporting two sector beams
- Optimized asymmetrical Left-Hand (LH) and Right-Hand (RH) sector RF patterns with interference reducing roll-offs between sectors and between beams
- High performance horizontal and vertical side lobes and vertical nullfill
- High gain array approach
- Small adjacent sector overlap reducing softer handovers
- Better match of original tri-sector coverage

The architecture of the sector-sculpting Twin Beam antenna, shown in Figure 2, uses a Butler matrix to split the input power and feed each of the four independently controlled column arrays. Aperture coupled array elements are connected to the air-substrated stripper line butler matrix. Also with Broadradio's distributed phase shifter network and Remote electrical tilt technology, we present the most advanced bi-sector array antenna in telecom market.

The bi-sector array antenna has shown its potential in capacity through extensive testing in different networks, environments, spectrum allocations and user densities. It is been approved that full six-sector deployment can increase the capacity up to 2.1 times. Also decrease drop call rates and increase traffic carried.

Applications for the Bi-sector include 3G, 4G and 5G. High-band, low-band and dual-band models support all major mobile technologies in the 698–960 MHz, 1710–2690 MHz and 3300–4200 MHz bands

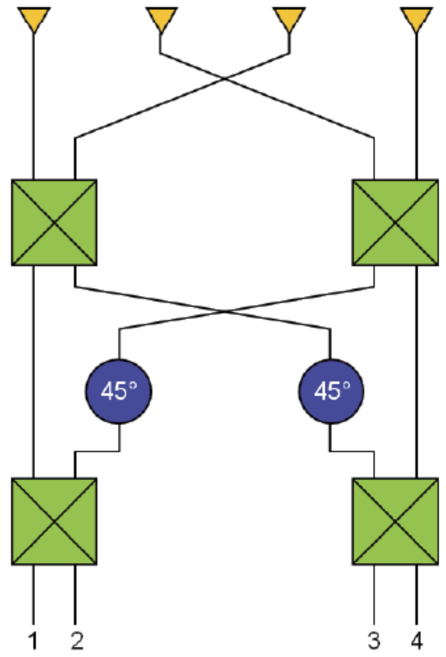
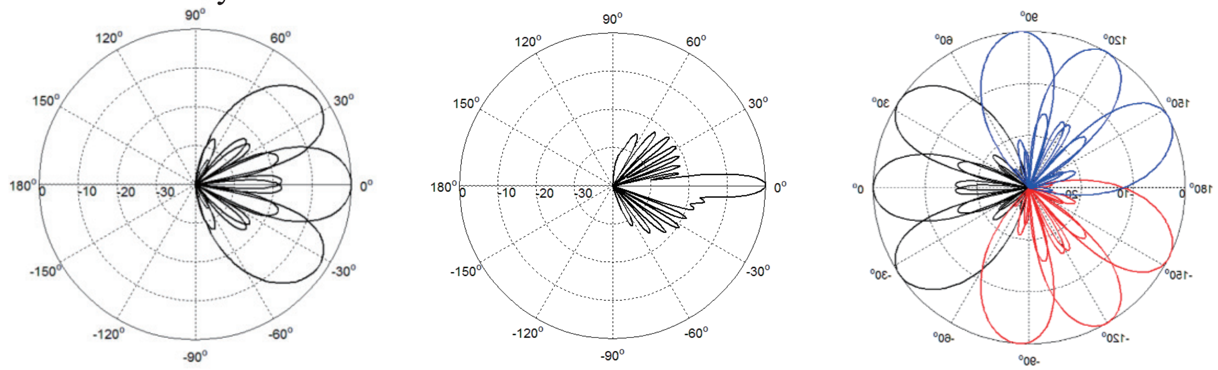


Figure 2 The architecture of the sector-sculpting Twin Beam antenna

[06 ADVANCED ARRAY TECHNOLOGY MAKES TRI-BEAM ARRAY AND NINE-SECTOR SYSTEM COME TRUE]

Further request by the service providers for exploring the capacity expansion, Broadradio's engineer design the first 3-way Butler matrix and present the first triple-beam array antenna and nine-sector system in telecom market.

The triple-beam antenna provides very stable crossover level points approx. 8dB between sub-sectors across the frequency band, which is suitable for intra-sector handover for GSM, 3G and LTE. As shown in Figure 3, by optimizing the 5 x 6 array, the antenna provides excellent beams performance including horizontal sidelobe suppression below -15dB across all frequencies band, excellent upper sidelobe suppression below -18dB. Due to the high performance of the antenna array, the gain of the center beam can easily reach up to 22dBi with the length of antenna is approx. 1200mm, which can reduce the visual impact on site comparing with other panel antenna and it is an ideal antenna for urban and high density area coverage. The architecture of the sector-sculpting Triple Beam antenna, shown in Figure 5, uses a 3*3 Butler matrix to split the input power and feed each of the 3 independently controlled column arrays.



Azimuth **Elevation** **9 sectors**

Figure 3 patterns of triple beam antenna

Figure 4   triple beam antenna

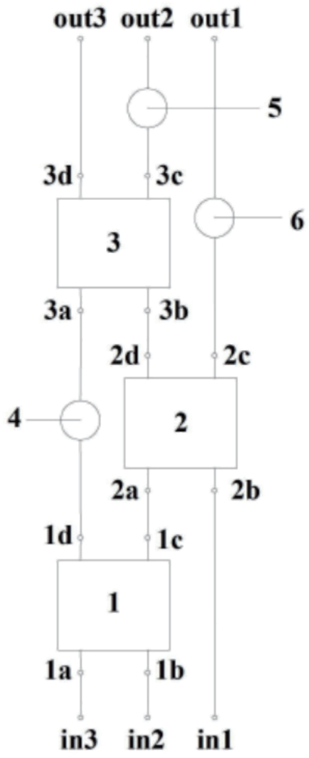


Figure 5   The architecture of the sector-sculpting Triple Beam antenna

The unique shape of the triple-beam antenna allows for a single sector to be upgraded without requiring any changes to the surrounding sites: the triple-beam antenna matches the existing coverage without changes to other sites. Expanding the triple-beam antenna to all nine-sector sites results in a more efficient upgrade strategy for 3G and LTE network as shown in Figure 6, the triple-beam antenna offering the following advantages:

- No increase in the number of antennas required: a minimum of three tri-beam antenna are required for a 9-sector site.
- No change in the antenna mounting requirements: the tri-beam antenna directly replaces the existing antennas and reuses these mounts.
- No change in the lease requirements of the site or the need for re-approval of the site.
- No change to the surrounding sites reducing the optimization requirements and costs.
- Ability to upgrade single sector or multiple sectors as traffic demands.

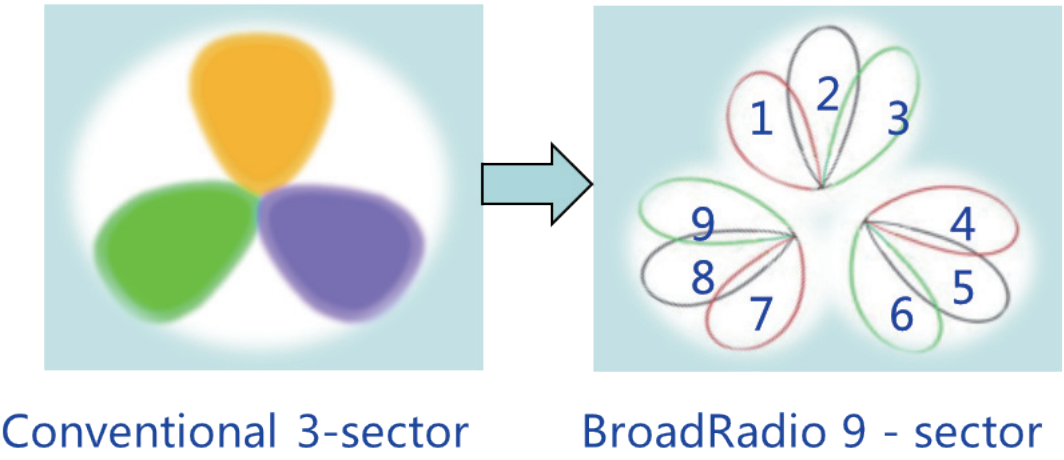


Figure 6 Conventional 3 sector and Broadradio 9 sector

[07 PENTA-BEAM AND NINE-BEAM ANTENNAS FOR EXTREMELY HIGH DATA TRAFFIC]

Multi-beam antennas are starting to be used in cellular networks where it is desired to increase capacity of existing cells. A single sector antenna can be replaced by two or more cell sectors. For this it is convenient to replace the single sector antenna with an antenna providing two or more beams in the horizontal plane.

A typical panel antenna for covering such a crowd is a cross polarized 9 column antennas (2x9 ports) to produce 9 sectors with dual branch receive as shown below in Figure 7. The left figure is for an array of 11x6 elements driven from a Butler matrix with 5 inputs forming the five beams shown and the right figure is from an array of 20x6 elements used to form 9 cross polarized beams. The architecture of the sector-sculpting Penta Beam antenna, shown in Figure 8, uses a 5*6 Butler matrix to split the input power and feed each of the 6 independently controlled column arrays.

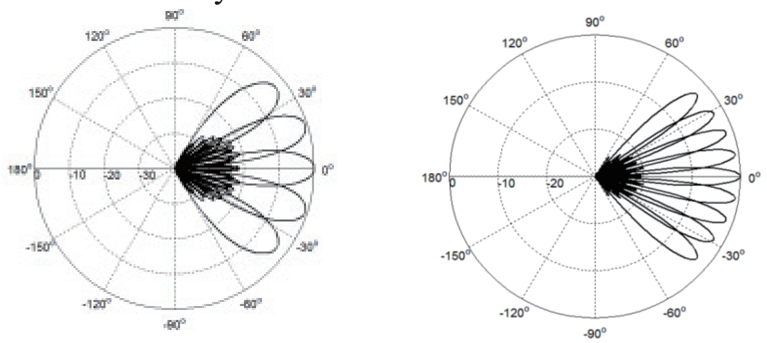


Figure 7 Multi-beam transmit patterns.

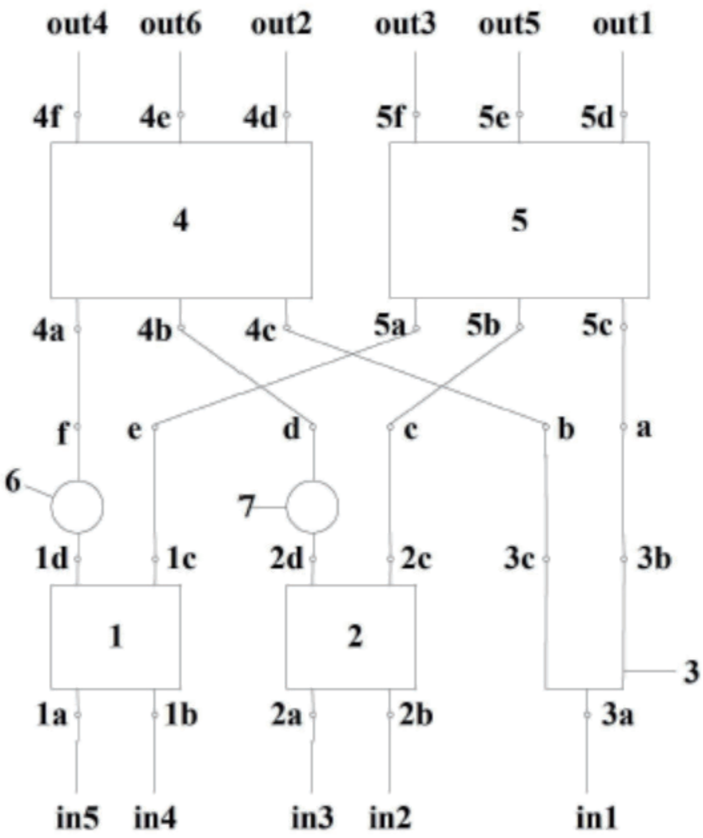


Figure 8 The architecture of the sector-sculpting Penta Beam antenna

The left figure corresponding to a penta-beam antenna array with a center beam gain of 23dBi; the right figure corresponding to an 9-beam antenna array has a center beam gain of 24dBi.

Twin-beam antennas have been implemented as RET antennas with the networks implemented in each row of the array. This is also possible with multi-beam antennas; however the complexity rapidly grows with the number of beams.

[08 HOW DOES THE MULTI-BEAM ANTENNA WORK]

The basic antenna consists of an array of dual-polarization columns fed from two Butler matrices so as to obtain a number of beams pointing at different azimuth angles. A Butler matrix is a microwave network with n input ports and n output ports allowing the forming of up to n beams when connected to the n port antenna. The input ports are all matched and isolated from each other as are the output ports. The network has the special characteristic that if a signal is applied to input port i (i=1,….n) then the output j (j=1….n) has phase 360 (j-1)(i-1)/n degrees, which means that feeding element i radiates a beam at azimuth of sin-1[λ/s*(i-1)/n] where s is the spacing of the columns.

[09 APPLICATIONS FOR PENTA-BEAM AND NINE-BEAM ANTENNAS]

One application is where an area with extremely high traffic density must be served from a single point. This frequently arises in the context of stadiums or open-air venues such as music concerts or sports events. Here, different sectors of the crowd are covered by separate narrow beams. Because music events and the like are often one-time or annual events, there is growing interest in high capacity cell-on-wheels systems with multi-beam antennas providing horizontally sectorized multiple cell coverage that can be moved in to cover the particular event.

Another application is using multi-beam antenna to cover urban area where has high density traffic or weak signal coverage. The multi-beam antenna has capacity up to 9 times and gain up to 24dBi, it is a most advanced and state-in-art product to provide high efficiency solutions. The deployment of penta-beam antenna for urban coverage is shown in Figure 9.

Figure 9 High density area using penta-beam antenna coverage

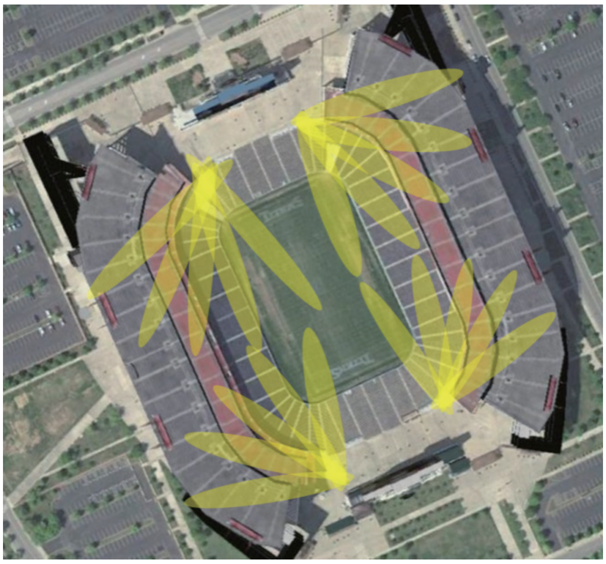


Figure 10 Stadium huge data solution with 4 penta beam antenna

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