# Twin-Beam Antenna

## A Cost Effective Way to Double LTE Site Capacity

Upgrade 3-Sector LTE sites to 6-Sector without incurring additional site CapEx or OpEx and by combining twin-beam antenna with the latest LTE interference mitigation technology

By Haig Sarkissian | January 2019

EXECUTIVE SUMMARY

A critical challenge facing 4G LTE fixed wireless operators is how to cost-effectively increase site capacity. Although there are many options available, sectorization is one of the most cost effective, expedient and practical means of doubling site capacity.

A new Twin–Beam Antenna by Alpha Wireless allows FWA operators to replace the antennas of a traditional 3-sector site, add the necessary eNB radios and instantly double the site capacity of their FWA LTE deployments. The Twin-Beam Antenna looks identical to a single beam antenna in physical size, weight and wind loading but accommodates two narrow beams. Therefore three Twin-Beam antennas will convert a 3-sector site into a 6-sector site without incurring additional costs and delays associated with site approval. Because the site appearance stays identical, incremental ongoing site rental expenses are usually avoided.

6-sector deployments can utilize a 2x2 antenna configuration or a 4x4 antenna configuration in each sector. New multi-channel RRU's enable radio upgrades without occupying additional space on the tower. In a 2x2 deployment, an operator can use three 4x4 RRU's and connect each RRU to a twin beam antenna, thereby creating a 6-sector 2x2 site. In a 4x4 deployment, an operator can use three 8x8 RRU's and connect each RRU to a twin beam antenna, thereby creating a 6-sector 4x4 site.

6-sector sites can be deployed with n=1 or n=2 frequency reuse configurations, each with its own advantages and challenges. Traditionally, interference between adjacent sectors at an LTE site had limited performance at the sector edge. With n=2 frequency reuse, network designers can virtually eliminate adjacent sector interference but requires the operator to own double the spectrum bandwidth, or to obtain additional spectrum at potentially significant cost. Innovations in LTE interference mitigation algorithms such as CoMP (Co-ordinated Multi-Point) and eICIC (enhanced Inter-Cell Interference Coordination) enable n=1 frequency reuse, which makes efficient use of spectrum resources while delivering uniform throughput to all users—independent of their position relative to the sector edges.

3-sector n=1 | 6-sector n=2 | 6-sector n=1

In this white paper, Wireless 20/20 examines the technical drivers and economic motivations of multi-sector deployments. The analysis is backed up with field test results that demonstrate the importance of interference mitigation in achieving optimum results. The Wireless 20/20 WiROI Tool is used to quantify key performance indicators (KPI's), such as cost per GByte and CapEx per Subscriber as well as Network OpEx per Subscriber in order to enable comparison with alternate solutions.

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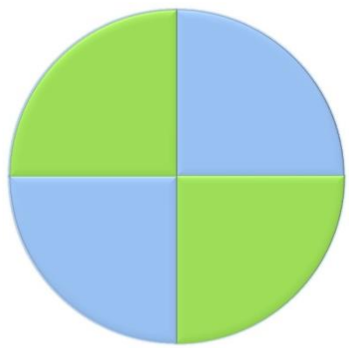
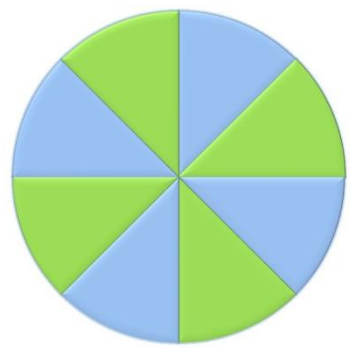
## Twin Beam Antenna in Four Sector Deployments

Some fixed broadband wireless operators deploy networks with 4 sector base stations using n=2 frequency reuse. The Alpha Twin Beam antenna can be used in these situations to convert a 4 sector base station into an 8 sector base station by replacing the original 90 degree antenna with Twin Beam antennas. The antenna configuration will look identical from the size, weight and wind loading point of view. By using additional RRU's to light up the four additional sectors, the operator instantly benefits from the added capacity offered by the eight-sector base station.

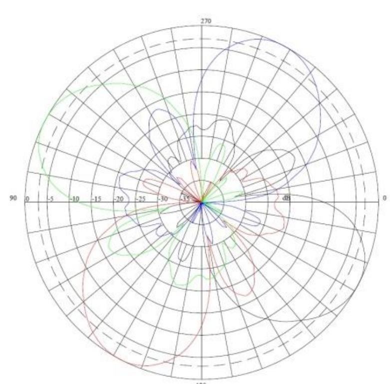


4-sector n=2

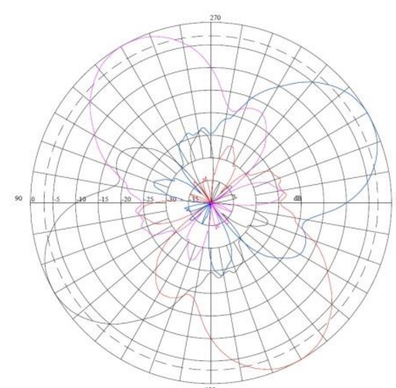


8-sector n=2

One of the main reasons to deploy a network with n=2 frequency reuse is to avoid intersector interference, which has traditionally caused tremendous support issues for fixed BWA operators. Using n=2 frequency reuse, the operator pays a higher price of using more spectrum but benefits from provisioning uniform service across its coverage area. Households that are located at the sector edge enjoy the same performance as households located at the center of a sector. By moving to an 8-sector deployment, all of the benefits of lessened interference offered by n=2 are still enjoyed while a gain of 2x of capaciity is realized due to sectorization.



4-sector antenna pattern for f1



4-sector antenna pattern for f2

As seen in the antenna pattern graphs above, there is great separation of antenna gain between the 4-sectors using frequency f1. Similarly, there is great separation of antenna gain between the four sectors using frequency f2. In an 8-sector configurations, these patterns overlap in order to enable an 8-sector deployment.

For information on the Alpha Wireless Twin-Beam antenna, visit [www.alphaantennas.com](http://www.alphaantennas.com)

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## Motivations for Sectorization

As consumption increases, MNOs need to provide more capacity.

Since wireless spectrum is a shared resource, sectorization offers a way to reuse spectrum multiple times within a single site. Compared to other methods, such as cell division or small cells, sectorization is more cost effective for outdoor deployments.

There are primarily three methods for increasing outdoor cellular network capacity:

1. Additional Spectrum
2. Additional Cell Sites
3. Additional Sectors

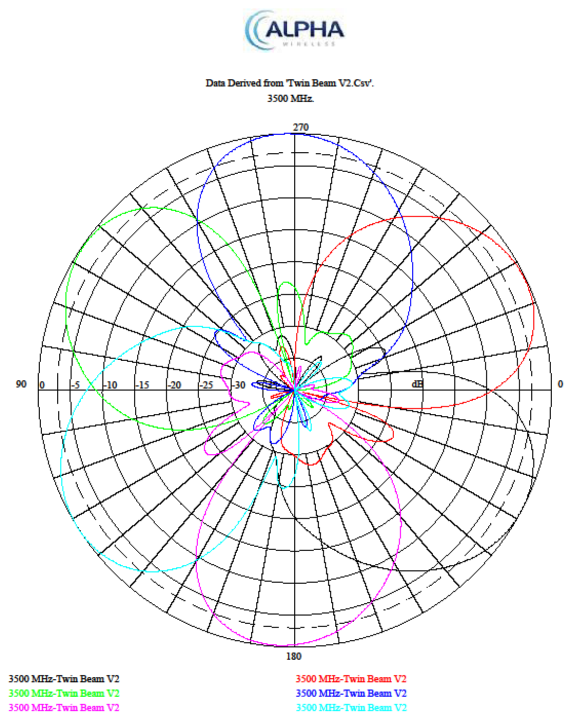
Additional spectrum is often the most preferred way in increasing cellular network capacity, especially when sufficient additional spectrum is available at a reasonable price. This however is often not the case since there is more demand for spectrum than supply, especially in wide-enough channels. For fixed wireless use, spectrum blocks are best utilized if they come in 20MHz blocks. Furthermore, the cost of spectrum measured in $/MHz-Pop continues to increase much faster than the rate of inflation. Thus, prudent cellular operators try to maximize the utilization of their existing spectrum assets in order to derive the maximum capacity from it.

Adding additional cell sites has been a well-accepted means to increase network capacity. This process increases frequency reuse by segmenting the area covered by an existing cell site into small cells. The primary motivation of adding more cells is to reuse the spectrum assets and increase capacity. This, however, comes with the cost and associated delays of new site acquisition, which may include lengthy approvals, as well as site erection and backhaul provisioning expenses. An additional disadvantage of adding new cell sites is the increase in the recurring monthly operating expenses associated with the added sites. These include monthly rental and maintenance, which usually increase annually.

Sectorization is the process of adding new sectors to an existing cell site. Typically, an existing cellular cell site has three sectors covering the 360 degree area around the base station tower. By increasing the number of sectors at a given site from three to six, one theoretically can double the capacity of a site. In theory, three-sector sites can be increased to six sectors, or nine sectors or even twelve sectors if antenna dimensions can be managed. Another by-product of adding more sectors is interference between adjacent sectors, also known as Self Interference.

## Self-Interference

Self-interference is the phenomenon where the RF signal from an antenna beam overlaps that of the beam of its adjacent sector. Typically, the wider the beam width, the more the overlap it will have onto its neighboring sector. Narrowing the beam-width typically sharpens the side lobes of an antenna and thereby allows for a reduction in overlap. But overlap of beams of adjacent sectors cannot and should not be eliminated in order to provide continuous coverage.



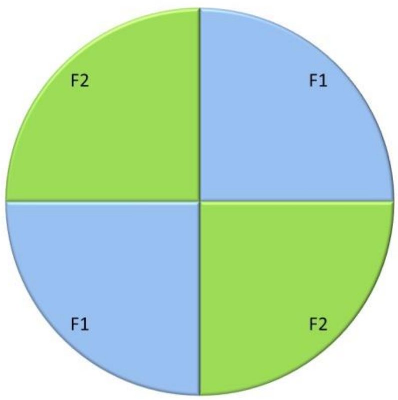

As we increase the number of sectors from 3 to 6, the number of overlap areas, also known as sector edges, also increases. Users who end up in the overlap area usually suffer from interference because their antenna can pick up signals from more than one base station sectors.

Without interference mitigation techniques, the benefits derived from increased sectorization have been negated by the loss from increased self-interference.

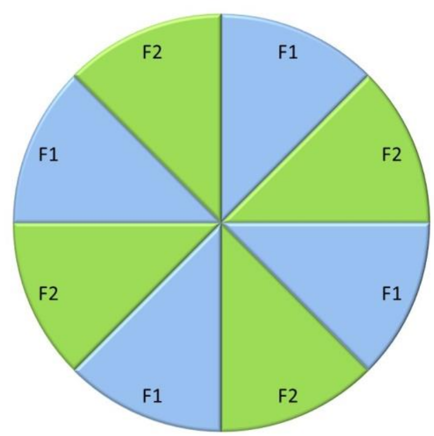
There are two principal frequency allocation approaches in dealing with self-Interference. One approach is Interference Avoidance by using frequency reuse of n=2. The second approach is by Interference Mitigation which uses advanced algorithms to identify the root cause of interference and finds clever ways to deal with it.

## Interference Avoidance with n=2 Frequency Reuse

When operators have sufficient spectrum resources, they can resort to n=2 frequency reuse, whereby the cell site would have an even number of sectors. In n=2 configuration, typically 4 sectors are used with a single-beam antenna in each sector, covering an area of 90 degrees radially as shown below. With n=2 the sectors have frequency separation by virtue of alternating the specific frequency channel used so that no two adjacent sectors use the same exact frequency band. A key attribute of n=2 frequency reuse is simplicity.




One of the key benefits of using n=2 configuration is that the cell edge users will not experience interference from adjacent sectors. An FWA operator can provision uniform SLAs, independent of whether a user is located at the cell edge or at the cell center. Simplicity is achieved by using all-in-one eNodeB's which combine an RRU with a BBU. These units do not need to coordinate with their adjacent eNB's and therefore no complex coordination algorithms are necessary. These eNB's are typically less expensive and are in existence from a variety of vendors. Installation and operation is also simplified as long as the alternating pattern of frequency reuse is maintained. Of course, the largest drawback for this approach is the efficiency of spectrum utilization.  Realizing the need to increase the efficiency and thereby the total capacity of such a site, Alpha Wireless has designed its Twin Beam antenna to allow FWA operators to upgrade their 4 sector cell sites to 8-sector sites. while maintaining the n=2 frequency reuse configuration. The Alpha Wireless Twin Bean antenna has the same form factor, weight and wind loading of a single 90 degree beam antenna, but it contains two narrower beams capable of splitting a 90 degree space into two. By using the twin beam antenna, an operator can easily upgrade to an 8-sector configuration, thereby doubling the total capacity of a cell site. Of course, four additional eNB radios are necessary in order to light up the new sectors. This is a small price to pay, considering the alternative of site acquisition. Best of all, in most cases, the monthly site rental fee is minimally impacted since the number of physical antenna elements stays the same. The resulting site will have the configuration shown below.




n=2 frequency reuse can be implemented until appropriate mitigation techniques are proven by equipment vendors.

## Interference Mitigation with n=1 Frequency Reuse

Sometimes FWA operators do not have sufficient spectrum resources to allocate for n=2 frequency reuse configurations, while maintaining sufficient channel bandwidth in each sector. These operators are interested in maximizing their channel bandwidth in order to achieve higher peak speeds, while utilizing all of their spectrum resources in every sector. In order to maximize spectrum utilization, these operators have resorted to using n=1 frequency reuse configuration while realizing the interference challenges that result from it. Thanks to LTE advanced feature, interference can now be mitigated using a variety of techniques.

One means of improving spectral efficiency is by reducing the noise seen by a user, thus increasing the signal-to-noise ratio. This can be done by mitigating or cancelling interference, where interference is defined by noise introduced by adjacent communications occurring simultaneously. One key source of interference is from Cell Specific Reference Signals (CRS) that are transmitted in every LTE resource block. When noise is reduced, the EU is able to decode signals with higher modulation schemes, such as QAM64, thereby increasing spectral efficiency.

Inter-cell interference may be encountered near cell edges, especially as the number of sectors per site increases. Interference avoidance schemes such as CRS muting can be combined with advanced scheduling algorithms in order to help avoid or minimize such interference. Also, enhanced Inter-cell Interference Coordination (eICIC) techniques have been defined in later versions of the LTE specification, enabling UEs to avoid interference.

The implementation of these schemes comes with a cost associated with additional resource block (RB) allocation from neighboring cells, especially in heavily loaded sectors. By borrowing RB's from a neighboring sector in order to serve a cell edge user with a higher quality signal, an LTE eNodeB is reducing the time slots available for the neighboring sector. By using a twin beam antenna, where each beam is connecter to an eNodeB, a cell site can double the number of RB's available in each sector. Therefore borrowing a small percentage of the RB's from a neighboring sector in order to provide a signal with high signal to noise ratio increases the total spectral efficiency of each sector.

LTE interference mitigation and scheduling coordination algorithms, combined with a twin beam antenna, can be a powerful tool for performance differentiation by both service providers and base station manufacturers.

# Performance and Test Result

## Peak Speeds

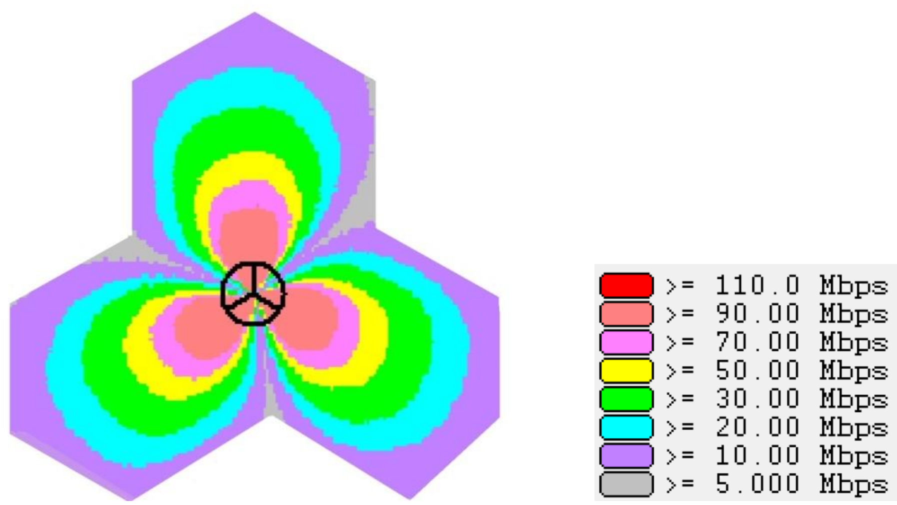
Peak downlink speed is one of the important parameters that wireless users measure. This is often the maximum speed seen by a user when no other users are actively receiving downlink information on a sector.  This is also the speed advertised by wireless marketers when they use the term "up to nn Mbps".

When measuring peak speeds on 4G LTE networks that do not incorporate interference mitigation, the peak speed achieved at the center of the sector is dramatically higher than the peak speed experienced by sector edge users. When a UE is located at the center of a sector and is close enough to have line of sight communication with the serving cell, it experiences little interference and its signal to noise ratio is the highest. These UE's usually receive signals modulation at QAM64 which allows them to achieve a high bit rate. As the UE moves further away from a site, its signal will weaken, and therefore the peak speed achieved will also decrease. But the larger decrease happens when the EU moves to the left or right of the center and enters the cell edge region, where the predominant degradation comes from interference from the adjacent sector.

With a 20MHz LTE bandwidth, typical cell center UE's will show downlink peak speeds of 90Mbps. Cell Edge UE's, on the other hand, will show peak speeds as low as 5Mbps speed as illustrated in the table below.

| | Cell Center Peak Speed (Mbps) | Cell Edge Peak Speed (Mbps) |
|---|---|---|
| 2x2 - No CoMP | **90** | **5** |

The following plot shows downlink peak bitrates for areas around a three sector cell site.



## Average Speed

The average speed experienced by an LTE UE is a function of its peak speed and the amount of resource blocks allocated to each UE. Since a wireless system is a shared resource, there are finite number of resource blocks in a given unit interval of time, which are shared by all the UE's connected to a sector. Therefore, a sector with 10 UE's all requesting downlink data simultaneously will share the total number of resource blocks typically equally between each user. If all the UE's are at the center of a sector, then the sector peak capacity will be 90Mbps, and each EU will experience 9Mbps average speed. If, on the other hand, all EU's are cell edge UE's, then the sector peak capacity will be 5Mbps and the 10 UE's will share the 5Mbps equally, and each will have an average speed of 0.5Mbps.

## Average Sector Throughput

Since UE's are typically distributed randomly around a cell site, the average sector throughput is a function of the average speeds of each of the UE's aggregated together. When a majority of UE's are located at the cell center, then the average sector throughput goes up. When the majority of EU's are located at the cell edge, then the average sector throughput goes down. Typically, 60% of the UE's are located in the center of the cell and the reaming 20% are located in each of the sector edges. The table below shows the average sector throughput of a 3-sector and a 6-sector site with randomly distributed UE's and an LTE channel bandwidth of 20MHz, with n=1 frequency reuse.

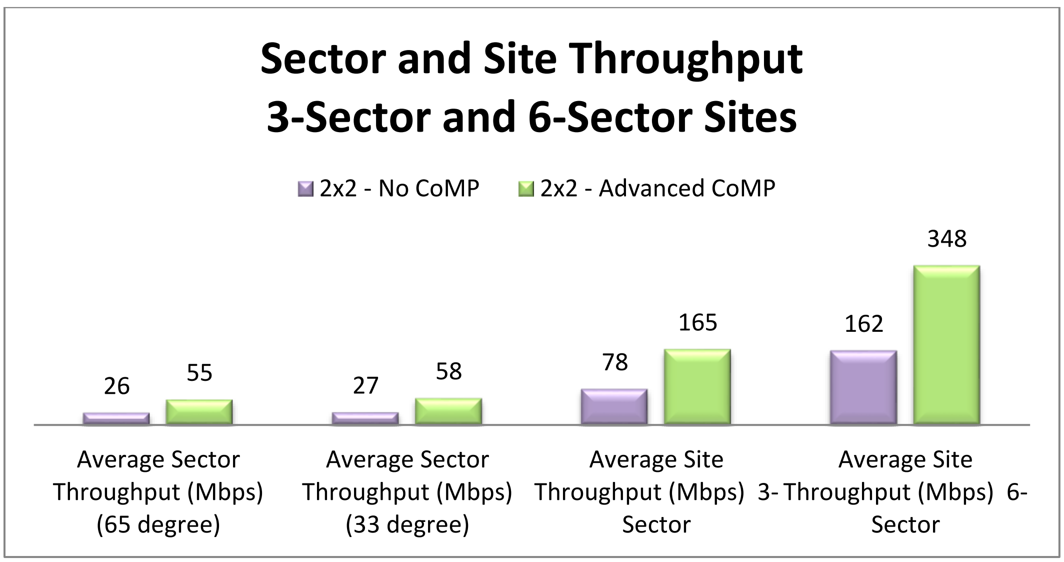
Notice that, the average sector throughput is about the same for a sector with a 65 degree antenna beam and a sector with a 33 degree antenna beam. Because an eNodeB is associated with each beam, the 3-sector site has a total of 3 eNodeB's and a 6-sector site has a total of 6 eNodeB's.

| | Average Sector Throughput (Mbps) (65 degree) | Average Sector Throughput (Mbps) (33 degree) | Average Site Capacity (Mbps) 3-Sector | Average Site Capacity (Mbps) 6-Sector |
|---|---|---|---|---|
| 2x2 - No CoMP | **26** | **27** | **78** | **162** |
| 2x2 - Advanced CoMP | **55** | **58** | **165** | **348** |

## Site Capacity

The total site capacity is a measure of the average sector throughput times the number of sectors per site. Since the average sector throughput is about the same for a 3-sector and a 6-sector site, 6-sector sites benefit from virtually doubling of site capacity. Site capacity is an important measure of the number of users that can be supported on a site. Assuming uniform distribution of users radially around a base station, congested 3-sector sites can divide the total number of users in each sector and hence allocate roughly half of the users to each of the new sectors of a 6-sector site.

Notice that when advanced CoMP interference mitigation techniques are employed, the sector capacity improves significantly. The amount of improvement depends on the specific technique used, as well as the robustness of the implementation of the CoMP algorithms by the eNodeB vendors. As the average sector throughput improves using CoMP, the total site capacity also improves. Sectorization techniques [using the Twin Beam antenna coupled with interference mitigation techniques translate to significantly higher site throughput, while offering uniform performance to all users regardless of their proximity to a cell center or a cell edge.



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## Site Spectral Efficiency (Mbps/Hz/Site)

A standard industry metrics Spectral Efficiency (SE), which is expressed in Mbps/Hz, measures the throughput attained for each MHz invested. Extending this classical definition from SE to Site Spectral Efficiency, we add the dimension of a cell site and show site efficiency in the tables below. This new metrics is becoming a popular way to measure site efficiency is Mbps/Hz/Site. It is a measure of throughput attained for each MHz of spectrum invested at year site.

| | 3-Sector (n=1) Site Efficiency measured by Mbps/Hz/Site | 6-Sector (n=1) Site Efficiency measured by Mbps/Hz/Site |
|---|---|---|
| 2x2 - No CoMP | **3.9** | **8.1** |
| 2x2 - Advanced CoMP | **8.25** | **17.4** |

Site Spectral efficiency increases twofold when 6-sector sites are deployed. In addition, using advanced CoMP techniques improves sector efficiency, which in turn translates to an even more efficient site. The ideal solution would benefit from not only sectorization, but also from interference mitigation techniques to increase sector capacity and improve cell edge user performance.

When interference mitigation techniques are not available or are still being developed, n=2 frequency reuse with twin beam antennas offer a welcome relief for congested site. The table below shows site spectral efficiency improvements even with n=2 frequency reuse by taking a 4 sector site to an 8-sector site.

| | 3-Sector (n=1) Site Efficiency measured by Mbps/Hz/Site | 6-Sector (n=1) Site Efficiency measured by Mbps/Hz/Site | 4-Sector (n=2) Site Efficiency measured by Mbps/Hz/Site | 8-Sector(n=2) Site Efficiency measured by Mbps/Hz/Site |
|---|---|---|---|---|
| 2x2 - No CoMP | **3.9** | **8.1** | **5.8** | **11.6** |

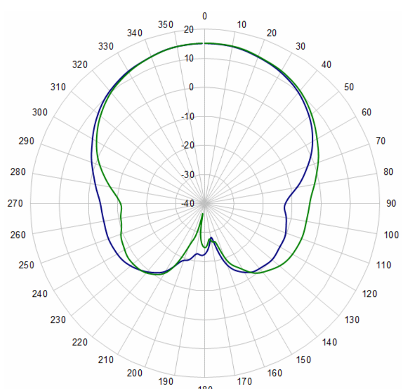
## Economic Considerations

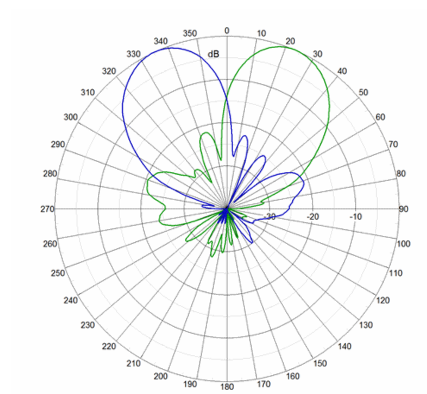
The Twin Beam antenna offers some compelling economic and practical benefits when single beam 3-sector sites become congested. These include CapEx and OpEx as well as time to market benefits.

From the capital expenditures point of view, adding a new site requires substantial site acquisition expenses, which may include delays due to lengthy approval cycles. The economic impact can be measured by comparing the site acquisition expense (typically $100K in the USA for a rural site) as well as new RAN equipment (antenna and eNodeB's) cost and installation. When a Twin Beam antenna is deployed to replace a single beam antenna, the added costs are those for the new RAN equipment, thereby saving an operator the cost of site acquisition. In addition to the CapEx savings, the operating expenses are also reduced since the monthly site rental and maintenance expenses of a second site are completely eliminated. These can amount for over $1K per month per site.

## Conclusion

A new Twin–Beam Antenna by Alpha Wireless allows FWA operators to replace the antennas of a traditional 3-sector site, add the necessary eNB radios and instantly double the site capacity of their FWA LTE deployments. The Twin-Beam Antenna looks identical to a single beam antenna in physical size, weight and wind loading but accommodates two narrow beams. Therefore three Twin-Beam antennas will convert a 3-sector site into a 6-sector site without incurring additional costs and delays associated with site approval. Because the site appearance stays identical, incremental ongoing site rental expenses are usually avoided.

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