ABSTRACT

Spectrum and cell/switch equipment are expensive. How can wireless carriers stay more competitive while minimizing capital expense for more capacity and better service quality?

GENESIS OF NEW ERA OF ANTENNA OPTIMIZATION!

TriPhase™ antenna that shines a new light in a dark tunnel to guide a way out

Wireless operators often face the challenges of antenna optimization because of the physical limitations of the antenna size and weight for regulatory and structural requirements. To achieve higher gain antenna to maximize the coverage, the size of antenna gets bigger and taller resulting in an increase of the structural loading on the tower and becoming less attractive to regulatory committees and tower owners. Also, if a different horizontal beam width, downtilt, or azimuth is required for better optimized network, it typically requires multiple tower climbs and replacement of antennas until optimization goals are met. This conventional optimization technique is not only very time consuming to get the necessary approvals from the zoning committee, tower owner, and/or landlord, but also increases the service downtime and operating capital expense for antenna replacements.

However, antenna optimization shouldn’t be this much of a painful and expensive process. The genesis of a TriPhase™ antenna from KMW shines a new light in a dark tunnel to guide a way out. KMW’s TriPhase™ proprietary antenna technology employs both electrical and mechanical means to achieve desired antenna flexibility without sacrificing the size and weight requirements.

This white paper is to provide an overview of the KMW’s patented TriPhase™ antenna technology designed to help wireless operators to maximize the cell capacity and manage antenna configuration as the network environment changes while maintaining high quality of service (QOS).
CAPACITY OR COVERAGE?

In a typical wireless network, the forward link (base station to mobile) has larger coverage than the reverse link (mobile to base station) and the reverse link has higher maximum capacity than the forward link. Therefore, the coverage sectors are limited by the reverse link and can be extended by the use of tower-top-amplifier (TTA). The capacity sectors, however, are limited by the forward link and thus sectors should be designed for sufficiently low operational path losses such that the maximum forward link capacity can be realized with a finite base station transmit power.

The coverage challenges can be mitigated using the following options to reduce path loss: 1) increase antenna gain, 2) lower feedline cable loss, 3) raise antenna height on the tower, 4) use tower-top-amplifier, 5) use repeaters or in-building systems, and 6) build a new coverage cell site.

On the other hand, generally the capacity challenges can be mitigated using the following options: 1) manage sector-to-sector overlap (such as reducing soft(er) handoff overhead in CDMA network), 2) add additional sector(s) (such as sectorizing an omni site or adding beyond the conventional 3 sectors), 3) antenna optimization (such as downtilt adjustment to control the interference or beamwidth adjustment or azimuth change for traffic load balance), 4) smart antenna deployment, 5) carrier/channel add, and 6) cell split with new capacity cell site add.

CAPACITY PLANNING: IS ANTENNA OPTIMIZATION A LAST RESORT?

Normally, wireless carriers tend to focus more on the cell level and system level capacity planning rather than a sector level capacity planning because of their relatively easier and quicker implementation processes. The replacement of the existing antennas for optimization is more cumbersome, time-consuming, and unpleasant because of the necessary government, city, and landlord approvals that are required every time any of the antenna configuration is changed or replaced. Because of these reasons, antenna optimization for capacity improvement is typically considered as a last resort unless the spectrum is exhausted or the network has a severe interference problem due to improper downtilt, azimuth or beamwidth.

However, it has been proven that proper selection of downtilt, azimuth, and beamwidth depending on each of the sector traffic loading for a cell site can significantly improve the cell capacity which is much more economical solution than adding expensive channel elements and carriers or building new traffic offload cell sites.

It is strongly recommended that the carrier adds should be considered as a last resort of the capacity mitigation technique in order to grow the overall cluster system at the same growth rate of the busiest sector in that cluster.
INCREASING CELL SITE TRAFFIC EFFICIENCY

In a typical wireless network, the distribution of the subscriber traffic is not uniform for a given geographical area. Predicting the sector traffic load prior to the construction of the new cell site is a difficult and time-consuming task. Depending on the antenna azimuth configuration, the sector traffic may present a huge traffic imbalance between the sectors within a cell site. This results in the under-utilized sectors in the air-link capacity because of the finite transmit power per sector to support users covered by the sector.

The following charts depict a typical cell site with traffic imbalance and a well optimized cell site with balanced traffic.

As shown in the left chart above, the capacity of the cell site with highly imbalanced traffic is mainly dictated by the busiest sector triggering an expensive carrier add or a new traffic offload cell site while the other two sectors still have significant remaining capacity to grow into.

The chart on the right, however, shows a very well balanced cell site carrying the same amount of the traffic as shown on the left while maintaining additional capacity room to grow until a carrier add or a traffic offload cell site. This well balanced site can delay the expensive carrier add or the construction of a new traffic offload cell site nearby until all three sectors are fully utilized.

TRAFFIC LOAD BALANCE WHILE MAINTAINING CELL SITE COVERAGE

The sector traffic load balancing can be achieved by using different horizontal beamwidth antennas and azimuth on each sector at the cell site in order to redistribute the number of users covered by the cell site evenly between the sectors.
CHANGING HORIZONTAL BEAMWIDTH, DOWNTILT, AND AZIMUTH WITHOUT EXPENSIVE ANTENNA REPLACEMENT AND TOWER CLIMB

Up to date designing a smart antenna to control the various antenna pattern characteristics such as horizontal beamwidth, electrical downtilt, and boresight point angle has been mainly limited by the antenna size for structural and regulatory requirements as well as the associated manufacturing cost for such complex antenna.

The KMW’s patented TriPhase antenna technology provides wireless operators with all the flexibilities required for network optimization while providing more attractive solutions for easier structural and regulatory approvals with smaller and lighter antenna design.

The following antenna patterns show various antenna configuration scenarios for maximum sector performance from a single antenna without the need of antenna change/replacement or tower climb. All available patterns are configured via a remote controller either on site using a handheld controller or from a remote location using ethernet access.
CHANGING HORIZONTAL BEAMWIDTH, DOWNTILT, AND AZIMUTH WITHOUT EXPENSIVE ANTENNA REPLACEMENT AND TOWER CLIMB

With a use of either a hand-held Portable Antenna Controller (PAC) or a rack mounted Antenna Interface Control and Monitoring (AICM) unit, wireless operators can change any antenna configuration parameters (horizontal beamwidth, downtilt, and/or azimuth) without having any service interruption or having to wait until the service maintenance window.

The use of bias-injector installed in-line of the antenna feedline at the base of the tower, wireless operators do not have to install a separate control cable from the base of the tower to the antenna allowing quick, easy, and economic antenna installation. Also, the use of cross-polarization (+45/-45 degree slant) diversity reduces the number of antennas required per site by half resulting in less tower load and significant reduction in implementation cost.

ADAPTING TO DYNAMIC CHANGES OF THE SURROUNDING ENVIRONMENT

With the use of AICM, not only can wireless operators control the antenna parameters as needed to adapt to the changes in the surrounding traffic from a remote location at any time without the service interruption, but also can change the antenna configuration based on preprogrammed antenna parameter change schedule with the Time Of Day (TOD) feature.

Whether it's busy morning or afternoon commute hours, lunch time, unexpected traffic accident, or major sports events, KMW's TriPhase antennas can easily be reconfigured to ensure the optimal antenna configuration for maximum sector capacity at any situation without service interruption.
SECTOR LEVEL CAPACITY IMPROVEMENT CASE STUDY

RESULT

The following figures show an actual capacity improvement result measured from a commercial cell site using the KMW’s TriPhase antenna.

The baseline system employed 65 degree horizontal beamwidth at 50, 150, and 260 azimuth for alpha, beta, and gamma sector, respectively, while beta sector is carrying over 60% of the cell traffic.

<table>
<thead>
<tr>
<th>Baseline Weekday Busy Hour Average</th>
<th>Percent of Primary Traffic Erlang</th>
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<tbody>
<tr>
<td>Alpha</td>
<td>27.44%</td>
</tr>
<tr>
<td>Beta</td>
<td>12.41%</td>
</tr>
<tr>
<td>Gamma</td>
<td>60.16%</td>
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</tbody>
</table>

Load Balance Weekday Busy Hour Average

<table>
<thead>
<tr>
<th>Percent of Primary Traffic Erlang</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
</tr>
<tr>
<td>Beta</td>
</tr>
<tr>
<td>Gamma</td>
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To demonstrate the performance benefits of the KMW antennas, the KMW’s TriPhase™ antennas were also mounted at 50, 150, and 260 azimuth. The antenna beamwidths and azimuth angles were then remotely changed to 120, 35, and 90 degree horizontal beamwidth and 70, 180, and 230 azimuth for alpha, beta, and gamma sector, respectively. The new antenna configuration showed significant improvement on the redistribution of the sector traffic resulting in 24.46% capacity improvement measured by the following method.

- Traffic Peak Load
  = Busiest Sector Traffic Usage / Average Sector Traffic Usage
- Handoff Overhead
  = Total Traffic Usage Of The Cell Site / Total Primary Traffic Usage Of The Cell Site
- Erlang Utilization Improvement (%)
  = 100 x [(Baseline Handoff Overhead / KMW Load Balance Handoff Overhead) – 1]

<table>
<thead>
<tr>
<th>Traffic Parameters</th>
<th>Values</th>
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<tbody>
<tr>
<td>Baseline Traffic Peak Load</td>
<td>1.85</td>
</tr>
<tr>
<td>KMW Load Balance Traffic Peak Load</td>
<td>1.35</td>
</tr>
<tr>
<td>Baseline Handoff Overhead</td>
<td>0.99</td>
</tr>
<tr>
<td>KMW Load Balance Handoff Overhead</td>
<td>1.09</td>
</tr>
<tr>
<td>Erlang Utilization Improvement</td>
<td>24.46%</td>
</tr>
</tbody>
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SUMMARY

With the use of KMW’s remote controlled TriPhase antenna technology, wireless operators can easily and quickly reconfigure the antenna to accommodate the changes in subscriber traffic loading, time of day, seasonal adjustments and system growth and expansion, and also can maximize sector level capacity. Coverage and capacity adjustments can be made by changing horizontal azimuth, vertical downtilt, and/or horizontal beamwidth without expensive tower climb or antenna replacement. The remote access option allows wireless operators to reconfigure the antenna parameters at anytime and from anywhere as needed via a PC based control interface software.

- Choosing the right optimization technology to address network performance bottlenecks can be a difficult task without a proper strategy. A simple and proper choice of antenna selections can provide the drastic improvement over conventional antennas.

- Time of day (TOD) based cell optimization allows optimal cell capacity to address changes in the network environment during the day or week.

- Inter cell site load balance can be achieved using remotely variable downtilt adjustment feature between the neighboring cell sites in the cluster allowing maximum cluster performance.

- Actual field trials and commercial deployments with a major US carrier showed up to 34.54% capacity improvement over conventional baseline antennas while maintaining the quality of service (QOS) comparable to the baseline.