

## **ADVANTAGES OF PSEUDO-OMNI ANTENNAS FOR C-RAN/DENSIFICATION APPLICATIONS**

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### **EXECUTIVE SUMMARY**

This paper will examine the advantages of the Pseudo-Omni antennas used in deployment of modern, wireless, infrastructure systems, by reviewing the challenges facing the wireless operators today, a review of key performance characteristics of the modern wireless infrastructure antennas, why omnidirectional antennas are key to ongoing wireless deployment and densification, and how the advantages of the Pseudo-Omni antennas provide an attractive solution to wireless carriers seeking to meet the deployment challenges of today and the future. The macro RAN will be densified by the undergirding of the new micro RAN (40 feet and lower) and pico RAN (“street level”) which bring access points (AP’s) closer with lower power, increased bandwidth, and lower latency, where antenna choice is critical to success.

### **INTRODUCTION**

The need for ubiquitous wireless coverage, along with gigabit speeds, is driving a new wave of wireless infrastructure deployments. Generically referred to as small cell, C-RAN (Cloud-Radio Access Network), D-RAN (Distributed-Radio Access Network) or distributed node deployments, the common goal of these infrastructure deployments is to provide cloud based network improvements available in 4G Advanced and developing 5G standards such as network “breathing” (redeployment of radio assets where needed), faster data speeds, applications slicing for IOT/Autonomous Vehicles (amongst others), and lower data latency. A key method of enabling these enhancements, is through network densification. Essentially,

network densification is the deployment of radio access nodes closer to the mobile customer, hence the descriptor “Small Cell”, and the recent boom in small cell needs and applications. Since small cell deployments are more numerous, and closely spaced to one another, these type of sites or access points (AP’s) have a smaller coverage radius and therefore allow for lower radiated power service. At the same time as these new radio nodes are being installed, new radio and access technology advancements are being deployed today that would have been unthinkable or unavailable just a few years ago. These advancements include multi-carrier/multi-band radios, carrier aggregation, use of unlicensed frequency bands as capacity offload, or in conjunction with carrier aggregation to increase data speeds, expansion of MIMO functionality from simple 1x2/2x2 arrays to 2x4/4x4 or 4x8/8x8, on-site or remote optimization of the antenna RF radiation pattern in both elevation and azimuth, or even beam shaping by 8x8 or more “massive” and beam selective MIMO antenna architectures at frequencies <6GHz.

## **CARRIER CHALLENGES**

Innovation and change have always had a home in the wireless industry, and unless you have been living in a cave for the last few years, it is very clear the pace of change and innovation, is only accelerating. Today, carriers are faced with a head-spinning array of network infrastructure choices, from cloud/data, virtual data, link-application, layers/split options, to configuration/deployment options within the physical layer. As indicated, earlier carriers are also planning for 5G deployments, which is driving the move to breathable/scalable cloud based virtual networks. This direction is being pursued, both for performance improvement in today’s 4G networks, but will also become the backbone for the 5G network just on the horizon, to allow for CAPEX and OPEX savings, as the network scales up to meet the needs of the 5G network. Put simply, carriers can no longer afford to deploy completely new infrastructure (hardware and software) with each new generation of wireless standards. This fact also extends to the physical layer Radio Access Network (RAN), including the choice densification antenna.

## **ANTENNA REVIEW**

While not the primary focus of this paper, some history and application of the macro panel antenna is necessary to understand the contrasts with omnidirectional antennas in the small cell/densification application. After all, understanding history enables better preparation and reaction to the future.

High gain directional panel antennas have long been used in the cellular infrastructure space for macro site applications. These panel antennas can be seen on the macro tower site as off-white, or gray rectangular panels, in a typical three (120° per sector) arrangement. These antennas typically provide 33, 65 or 90 degree horizontal beamwidth (HBW), remote electronic tilt (RET) capability, and gains generally ranging from 12-18dBi for 4, 6 and 8 foot panel heights, dependent upon array gain/vertical beam width (VBW), determined by panel height and number of array elements, and HBW. In general the more concentrated the RF energy from the antenna in the elevation, (VBW) plane, the taller the antenna becomes, and likewise, the narrower the antenna is in the HBW plane the wider the antenna physically becomes for a given frequency. This larger physical size is necessary both to accommodate larger number of elements but also to decrease HBW for a given number of elements for a given frequency, both factors working to focus the RF energy within tighter vertical and horizontal beamwidths. Therefore, for a given HBW and frequency, antenna height will grow as VBW becomes narrower. Likewise, for a given panel height and frequency a 65° horizontal beamwidth antenna will be physically wider than a 90° antenna; likewise a 33° HBW antenna will be wider physically than a 65° HBW antenna for a given frequency. (We should note that another factor is how many arrays are in the same antenna. For example, a 90 degree antenna with more ports, can be narrower than a 65 deg antenna with less number of ports.)

Macro sites fundamentally differ from small cell/densification sites, in that the key objective of a macro site is to provide a minimal level of coverage, over a very wide area, often 1 mile or larger in diameter. As many users are connected to any given macro site sector, these users can be interspersed anywhere within the sector coverage range, some are near and under the main antenna boresight; some are far, meant to be in the antenna boresight. Hence, the macro sector is typically designed to provide a statistically acceptable user experience at cell edges under normal sector load conditions. Within the macro sector, the quality of radio link to (downlink) and from (uplink), the user can vary dramatically,

dependent upon distance from site, technology being utilized, antenna design (downtilt/gain/VBW/HBW), obstructions in the way such as foliage, buildings, etc., and last but definitely not least), the quantity of users utilizing the radio resources within a given sector.

Therefore, the drive towards network densification is not by accident. It is based upon the need to place the radio resource closer, (much closer in fact), to the user; ergo, the requirement for micro and pico RAN network enhancements. This is not only to divide the native capacity for a given frequency/bandwidth/technology into smaller and smaller coverage radii for improved capacity, but also to enhance the user experience for faster and faster data speeds. Extensive elaboration could be provided here, but for the purposes of this paper, the reader should be aware that faster data rates require higher orders of modulation (256 QAM for example), wider modulation bandwidths and/or carrier aggregation, (a defacto wider bandwidth pipe for data to be transferred over). Communication theory dictates that wider bandwidth channels, have a higher receiver noise floor, making high speed/long distance links impractical. In summary, the higher data speeds, higher capacity, higher user experience, have more or less become mutual requirements of the modern wireless infrastructure networks. In short, a larger quantity of radio nodes, each capable of optimized coverage over shorter distances over multiple frequency bands is required.

## **SMALL CELL OMNI-DIRECTIONAL ANTENNAS**

Although macro panel antennas have many positive attributes, they are overkill for the small cell application, both in terms of gain (given small radio node coverage radius), physical size of the macro panel antenna and cost. In terms of aesthetics, imagine multiple 4, 6 or 8' panel antennas atop of a lamp post, or telephone pole in a city center? Or the cost associated with deploying multiple macro antennas in a small cell application? One attribute of the macro panel antennas that can be carried over to the small cell space, is multiple accurate, frequency band sculpted coverage (more about that later). There exists a need for an aesthetically appealing, cost effective, multiband antenna structure, to be used for cellular network densification applications.

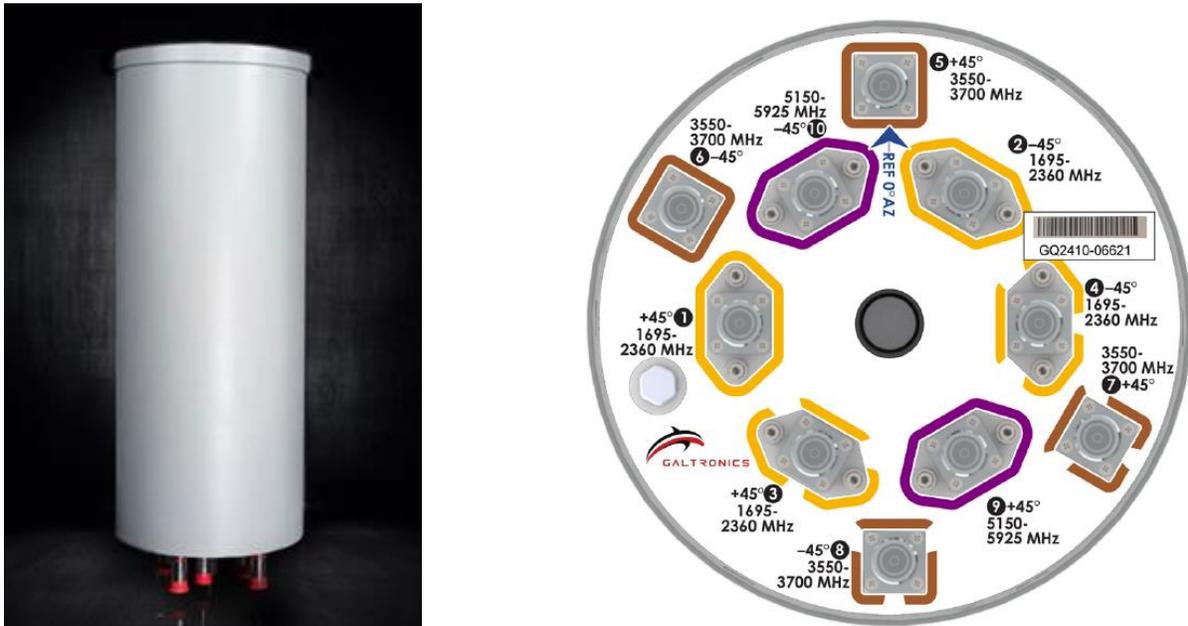
The choice of the small cell antennas provides the RF Engineer, an opportunity to optimize coverage (gain, HBW, VBW), band coverage, aesthetics and CAPEX and OPEX spend discussed earlier. Greater quantities of cell sites deployed in urban areas and elsewhere can allow for lower transmit (downlink to UE) powers to be utilized to prevent cross-cell carrier pollution, and in fact is a desired attribute as radio access nodes become more densely deployed and another reason why high (double digit) levels of antenna gain are not generally necessary. Given the fact that many densification sites are deployed with lower transmit (downlink) RF power often in the range of a few 100 milliwatts to <20 watts per carrier, the RF Engineer *can* be tempted to consider the use of a simple dipole, or even iDAS omni directional antenna for deployment.

Omnidirectional antennas have long served as the backbone for a variety of radio services from personal, commercial to government/military applications, since the early days of radio communication, now well over 100 years ago and spanning three centuries. The first antennas designed by Henrich Hertz, were dipole types, used for both transmitting and receiving, (reciprocity) placed at the focal point of a parabolic reflector (his published his work in [\*Annalen der Physik und Chemie\*](#) (vol. 36, 1889)). Advantages of the ¼ wave stub or dipole style omnidirectional antenna designs are simplicity, full omnidirectional in azimuth orientation and low cost.

As a simple structure, the omni-directional dipole antenna provides for low cost in a small size which is attractive from the CAPEX and OPEX perspectives, but also has the additional benefit of minimal impact/degradation to site aesthetics when simply connected up to the RF ports of a radio. Despite these “first glance” benefits of these antennas, there exists a need for RAN optimization beyond the capabilities of the simple dipole antenna. These include optimization per band (downtilt, gain, VBW), wide bandwidth coverage to satisfy the needs of new, modern multiband radios, and multi-band MIMO (2x2 or 4x4, up to 8x8) support. Enter the Pseudo (Quasi) Omni antenna.

## THE PSEUDO-OMNI ANTENNA

The Pseudo-Omni antenna, utilizes the best attributes of the macro panel antenna (wideband, multi-band coverage, polarization diversity), while providing 360° horizontal coverage. An example of a 10-port Pseudo-Omni antenna is shown in figure 1 below:



**Figure 1: Pseudo-Omni “Canister” Antenna, Galtronics GQ24210-06621 10-Port Example Shown (not to scale)**

Also referred to as a “Quasi-Omni” antenna, the Pseudo-Omni antenna integrates multiple panels antennas and elements, oriented in a 360° pattern along with internally integrated combiners to feed transmit RF to, and derive receive RF signals from, individual antenna elements, so that common antenna ports can service a complete 360° azimuth pattern surrounding the antenna. Antenna elements are optimized so that gain, downtilt and vertical (elevation) beamwidths, are all optimized to meet specific customer requirements. Figure 2 below is a comparison of key performance attributes between ¼-wave, vertically polarized and pseudo omnidirectional antennas, with detail of each attribute following.

PARAMETER	ANTENNA TYPES		
	1/4-Wave Stub	Vertically Polarized Dipole	Pseudo-Omni Antenna
Number of Available Ports	1	1	Up to 24 (or more), 2-8 per band typically supported
Multi-Band Coverage	Wideband single element	Wideband single element	Multiple elements - sub-band optimized
Gain	Lowest (0-2dBi), Ground Plane Dependent	Higher (2-6dBi), Ground Plane Dependent	Highest (6-12dBi), Height Dependent
Horizontal (Omni) Pattern	Good (with ground plane, without obstructions)	Good (with ground plane, without obstructions)	Fair to Good (without obstructions)
Bandwidth Capability	Very narrow (50-100MHz typical)	Can be designed very wide (500-1000MHz)	Inherently wideband (500-1000MHz)
Multi-Band Capability	Single band only (at most)	Single or dual band	Available in dual, triple and quad bands from 600MHz to 6GHz
Polarization Diversity	None - Single Polarization Only	None - Single Polarization Only	Dual Slant (+/-45°)
Vertical BW/Downtilt Options	None - Fixed	Limited, Custom Designs Possible	YES, Sub-band optimized (FET, MET, RET)
Azimuth Shaping	None	None	Can be implemented in design
MIMO Support	No for single antenna	No for single antenna	Yes (2x2, 4x4, 8x8)
Return Loss	Worst (7-10dB over moderate bandwidths)	Better (8-14dB over 500-1000MHz bandwidths)	Best (>14dB over wide bandwidths)
Power Handling	Low (≤ 5 watts)	Higher (≤ 50 watts)	Highest (>80 watts per port)
Aesthetics/Size	Very Good (small physical size)	Very Good (small physical size)	Good/Fair (dependent upon size/color match)
Environmental/IP65 Capability	Yes	Yes	Yes
Cost Per Port	\$ (very low)	\$\$ (low)	\$\$ (low)

**Figure 2: 1/4-wave Stub, Dipole vs. Pseudo-Omni Antenna Comparison**

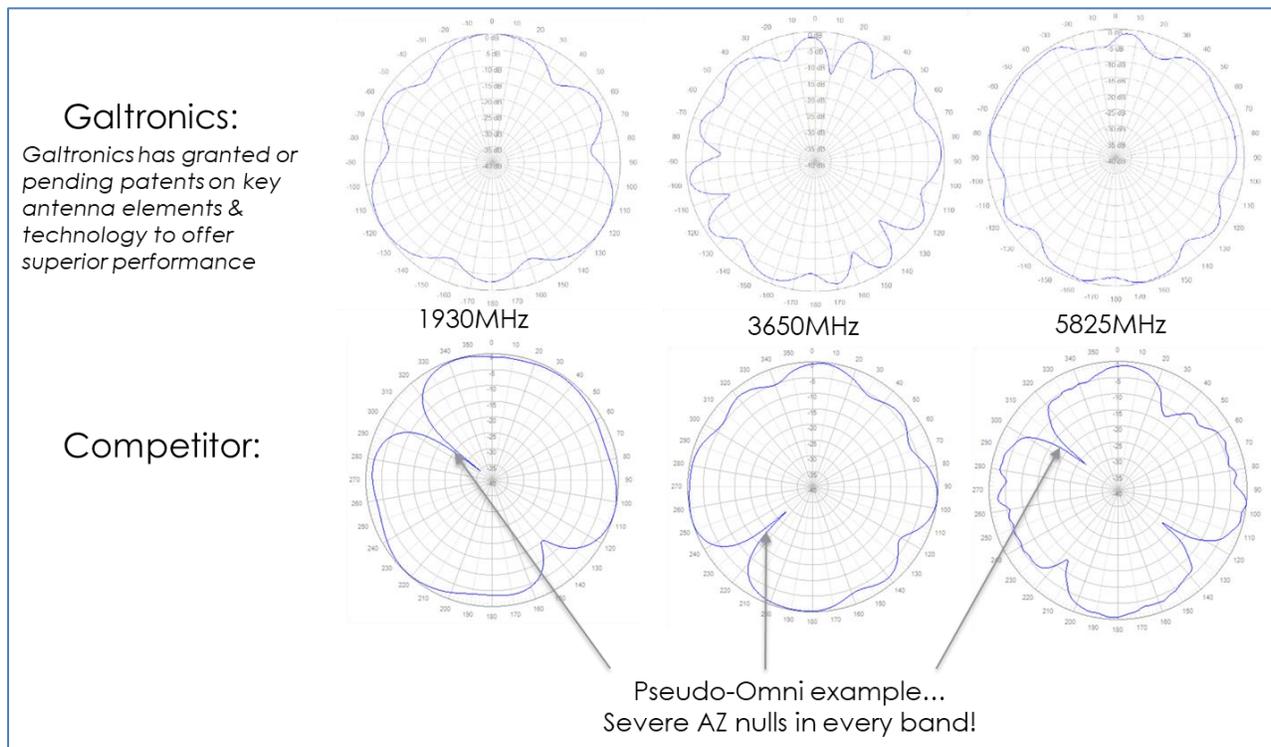
**Number of Available Ports:** Of course, the pseudo-omni antenna is a multiple element array, so in a sense it is unfair to compare single port omnidirectional antennas against the pseudo-omni, however, the point being made here, is that even if multiple 1/4-wave or dipole omni antennas were to be deployed, there would exist no polarization diversity, no practical ability to set or control downtilt, limited bandwidth and other limitations of the simpler omni directional antennas. The pseudo-omni solution provides a clear advantage.

**Multi-Band Coverage:** Both 1/4-wave stub and dipole designs provide for a limited number of bands that can be supported within the 600-6000MHz frequency range. The Pseudo-Omni antenna in contrast, can support multiple bands through advanced designs that minimize physical dimensions of height and diameter in a single, integrated, carrier aggregation-ready assembly.

**Gain:** As stated previously, densification requirements in general, require moderate (7-10dBi) levels of gain. Simple omnidirectional designs cannot approach such gain levels, and are limited in gain to 0-5dBi generally by definition.

**Horizontal (Omni) Pattern:** The ¼-wave and dipole omni antenna performance in the category can be quite good, assuming necessary reference ground plane is provided. The Pseudo-Omni antenna in contrast is comprised of multiple panels, if not designed correctly can lead to gain ripple in azimuth.

**GALTRONICS ADVANTAGE** Galtronics owns or has pending multiple patents related to Pseudo-Omnidirectional antennas to achieve the best possible azimuth coverage given the inherent nature of a pseudo-omni antenna. A comparison of Galtronics vs. competitor in azimuth patterns within 3 bands is shown in figure 3 below. In each band the competitor’s antenna contains a severe gain null in the azimuth pattern.



**Figure 3: Pseudo-Omni Pattern Comparison – Galtronics GQ2410-06621 to Competitor**

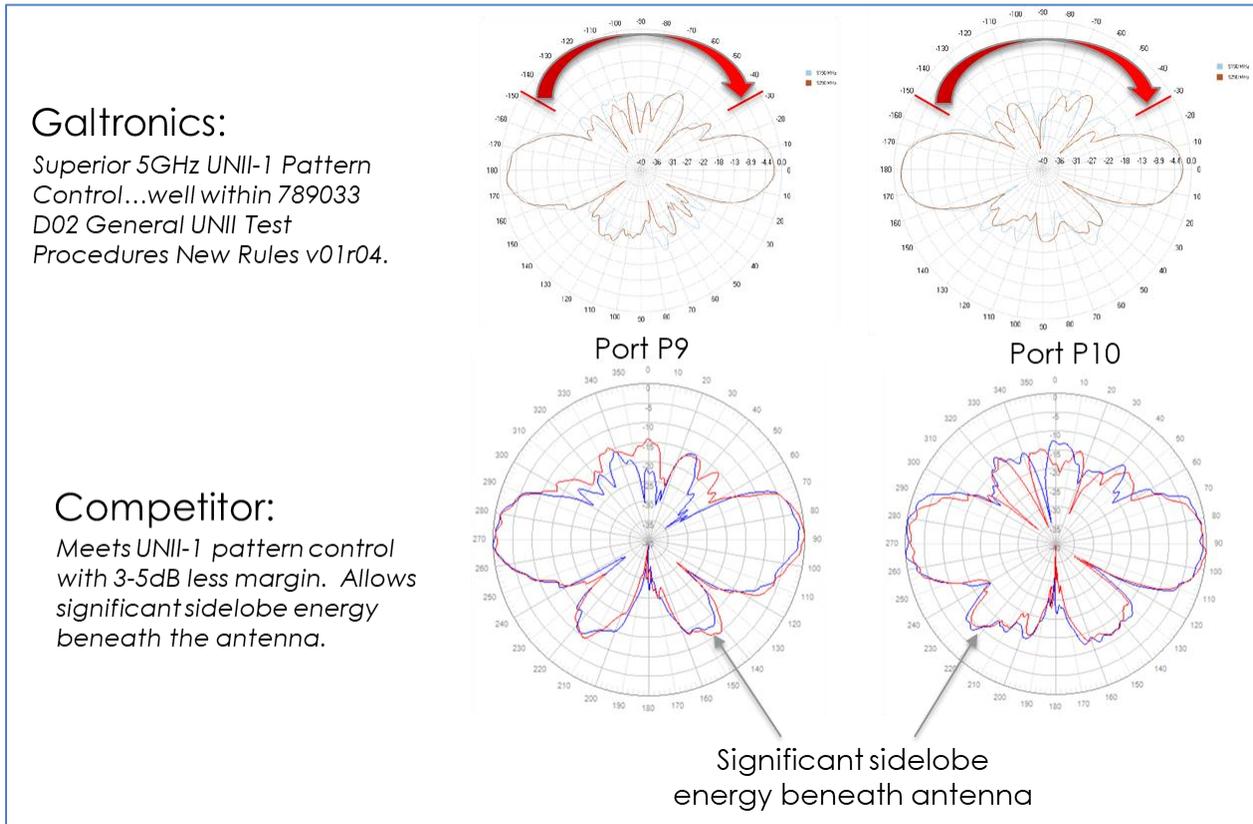
**Bandwidth Capability:** The  $\frac{1}{4}$ -wave stub antenna has the worst performance in this category, generally relegated to a simple narrowband resonance, in return loss of 50-100MHz. Vertically or horizontal polarized dipole elements can be designed for return loss and gain performance over fairly wide ranges, for example 1695-2690MHz. Pseudo-Omni antennas, can also be designed for very wideband return loss and gain performance. The fact that there are different ports covering different bands in the same antenna, makes these antennas cover the whole cellular bands.

**Multi-Band Capability:** As the pseudo-omni antenna is comprised of multiple antenna elements in a single space, it can easily support 2 or more frequency bands, basically providing a “one stop RF coverage shop” opportunity for lowband 600MHz through 6GHz.

**Polarization Diversity:** Single port omnidirectional antennas can only provide polarization in one axis (typically vertical), while pseudo-omni antennas provide cross polar (dual slant  $\pm 45^\circ$ ) polarization, so each set of 2x2 radio feeds benefit from polarization diversity, and hence diversity gain. This is maintained over all bands supported by the pseudo-omni antenna.

**Vertical Beamwidth & Downtilt Options:** There are options to compress the vertical beamwidth in a omnidirectional dipole (none with a  $\frac{1}{4}$ -wave stub), and multiple elements can be implemented with a phase shifter, to provide a narrower vertical beamwidth with downtilt, if necessary with growth in the Z (height) dimension, however the pseudo-omni antenna can also provide options for vertical beamwidth while also providing advantages in many other ways that are being illuminated here such as number of bands supported, higher gain, polarization diversity, better return loss, etc. still provide for a superior densification omni antenna solution.

**GALTRONICS ADVANTAGE- 1** Galtronics pseudo-omni antennas, that contain 5GHz capability for outdoor applications, are all UNII-1 pattern and gain compliant, and provide superior pattern control with greater UNII-1 pattern margin. (We could have a separate section on FCC in UNII-1, and how quasi-omni antennas meet those spec. Also, highlighting the fact that we need pattern shaping to meet FCC requirement, which is not easily possible with the other two antennas (1/4 Wave stub and vertical dipole) )



**Figure 4: Pseudo-Omni 5GHz Vertical Pattern Comparison – Galtronics GQ2410-06621 to Competitor**

**GALTRONICS ADVANTAGE - 2** Galtronics will soon be introducing small cell panel antennas with Manual Electrical Downtilt (MET). This will allow the user to select the level of vertical downtilt, on a site by site basis as deployed.

**Azimuth Shaping:** In an increasing number of deployment scenarios, it is desirable to contour the omnidirectional pattern coverage, to something other than a 360° omnidirectional shape. Examples are single beam, dual beam (peanut, heart) or even triple beam (clover) azimuth patterns. These patterns allow antenna placement and patterns to be optimized based upon man-made structure location and/or

the RF environment the antenna is to be placed into. For example, a null in azimuth coverage may be placed at the location of competitor's antenna across the street to provide additional RF selectivity assistance to the radio. The pseudo-omni antenna has a clear advantage, with its ability to have azimuth shape contoured for omni or other types of optimization. See "Variations of the Pseudo-Omni Antenna" page 14 for additional information.

**Supports MIMO:** Whether for maximizing capacity, increasing data throughput, or both, antenna Multiple Input/Multiple Output (MIMO) capability is of critical importance in optimizing these capabilities. Whether 2, 4 or even 8-branch MIMO (or massive MIMO at frequencies >1GHz), having multiple spatial paths including polarization diversity allows for higher link probability and data stream weighting/combining (diversity gain) that the user can "feel" as an overall improved experience. This paper will not dive into the details and significance of MIMO enhancement, however the fact that the pseudo-omni antenna provides a minimum of 2-branch MIMO and polarization diversity per band, with 4 and even 8-branch options available, the pseudo-omni antenna, again, provides a clear advantage of the simple, low cost omni antennas cannot.

**Return Loss:** Return loss, is a simple measurement of the quality of the impedance match, between antenna and the radio or other feed system components. When a mismatch exists in the RF transmission system (antenna, feedline, combiners, radio, etc.), RF power applied to an antenna from radio will be reflected back to the radio. The worse the mismatch, the greater the amount of power will be reflected. This mismatch measurement can also be expressed as VSWR (voltage standing wave ratio), which is another measurement of the quality of the match (ratio of total voltage on the transmission line, applied and reflected, to the voltage applied) . The pseudo-omni antennas are optimized for superior return loss over very wide bandwidths, 617-960MHz, 1695-2690MHz, 3400-3800MHz and 5150-5925MHz or part of each sub-band depending on application. A typical return loss specification for a pseudo-omni antenna is 14dB minimum (VSWR specification of <1.5:1), which equals to less than 4% power loss due to power mismatch/reflection. Compare this to the capability of the omnidirectional stub and dipole antennas in the 7-12dB range, it is clear the pseudo-omni antenna has the advantage here.

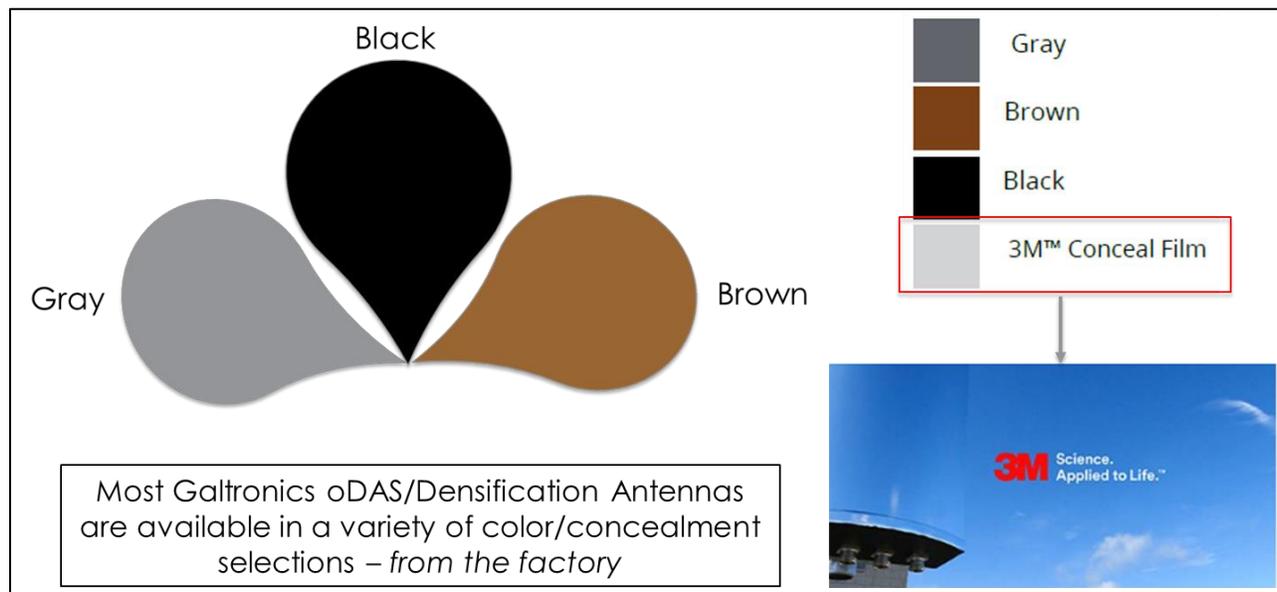
**Power Handling:** As you might expect, being a derivative of macro cellular antenna panels with very high RF power handling capability, the pseudo-omni antenna structure also can handle similar high levels

of power. The condition to this statement, is that more internal heat is developed within the pseudo-omni antenna, as the RF signals are split from primary source to antenna elements. Therefore, specifying RF power handling for a pseudo-omni antenna is more than simply calculating the breakdown voltage of critical internal elements/structures and backing off by a comfortable safety factor. Heat dissipation sources need to be factored into the RF power rating specification. This, effectively serves to de-rate all internal components from PCB's to DC and RF/coaxial cables to plastics as internal temperatures can climb quite high given the sealed nature of the pseudo-omni antenna (whether IP24 or IP65 sealed). Net-Net, when properly designed, the pseudo-omni antenna can handle higher levels of average and peak RF power than the simpler stub and dipole antenna structures.

**GALTRONICS ADVANTAGE** Galtronics has tested one of our latest pseudo-omni models with 320 watts of average RF power applied across multiple ports, external ambient temperature of +122F/+50C for a period of 1 hour while measuring VSWR on each port to measure performance during internal heat rise. At the conclusion of the test, RF parameters were tested, and physical condition of the antenna observed, and found all to pass production acceptance levels.

**Aesthetics/Size:** Without question, the simple stub and dipole designs can provide the user with very small, compact omnidirectional antenna package sizes, which aids in site aesthetics. Consider however, multiple stub or dipole antennas connected directly to radios, performance of all, compromised by the close proximity of each to each other, on the radio, as well as lack of conformal ground plane, as well as all radios for each band being placed high on top of a pole or tower. The net result, is severely compromised RF coverage, and a new set of aesthetic issues. Pseudo-omni antennas, while physically larger than the simple omni antennas, consolidate multiple bands within a single radome, while also providing the benefits elaborated upon within this paper. Modern pseudo-omni antennas utilize radome material, that can be readily painted, either at the factory by the supplier, or in the field by the customer, to blend in better to the pole, tower, or nearby surroundings, in a more aesthetically pleasing way.

**GALTRONICS ADVANTAGE** Galtronics offers a wide selection of color/concealment options for most pseudo-omni antennas, see figure 5 below. Further color customization per RAL or FED STD colors are available for high volume urban deployments.



**Figure 5: Galtronics Color/Concealment Options for Pseudo-Omni Antennas**

**IP65 Capability:** Traditional high gain multi-band macro panel antennas in the 4' to 8' range, have historically employed drain holes at the bottom of the antenna, to allow internal condensation a place to exit the antenna. This traditional approach works well for large physical structures, and has been successfully used for decades in the wireless industry. Issues with this approach arise, however, when the antenna structure is compressed into increasingly smaller and smaller sized assemblies. Most macro panel antennas are rated to only IP24, which prevents an object >12.5mm in size from passing through the drain hole and allows for “splashing” water applied to the antenna. Obviously a drain hole in the 10-12mm size range can, and does, allow ingress of small flying or crawling insects, and other environmental contaminants such as dust and ash. IP65 compliance is much more stringent with respect to moisture and environmental ingress, and is important for outdoor small cell antennas, as antenna performance

can be much more adversely impacted in smaller sized antennas, such as pseudo-omni antennas in the 1' to 4' range.

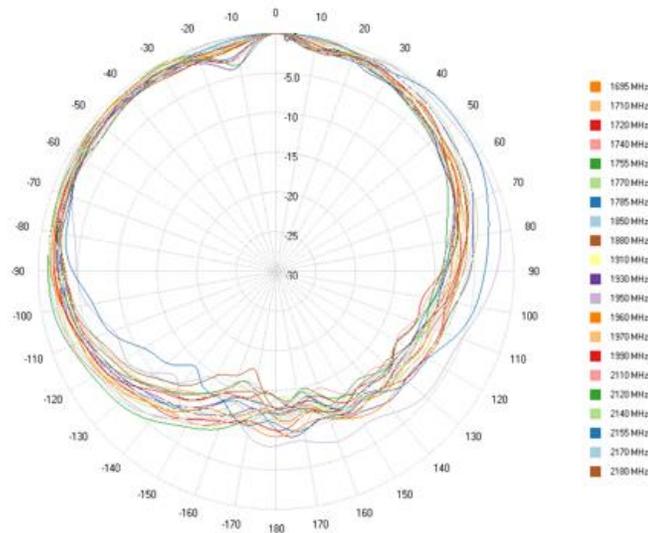
**GALTRONICS ADVANTAGE** Galtronics latest generation Pseudo-Omni antennas are IP65 capable. To be IP65 compliant the antenna must not allow water leakage when water jets are directed at the antenna during 3 minute test period, through 6.3mm nozzle at a rate of 12.5L per minute and pressure of 30kPa at distance of 3 meters.

**Cost:** As simple structures, you would be correct in assuming the single port  $\frac{1}{4}$ -wave stub and dipole antennas are less costly than the pseudo-omni antenna structure. The pseudo-omni antenna assembly, contains many more physical antenna elements and is larger physically than the simple single port omni antennas. Essentially, integrating multiple omnidirectional antennas over multiple frequency bands, polarization diversity and other advantages explained above, the value of the pseudo-omni antenna in small cell/densification extends beyond a simple expansion of number of physical ports. (Again not sure if we can show that the capacity improvement, number of ports, cost/bit might not be as bad to defend the cost increase.)

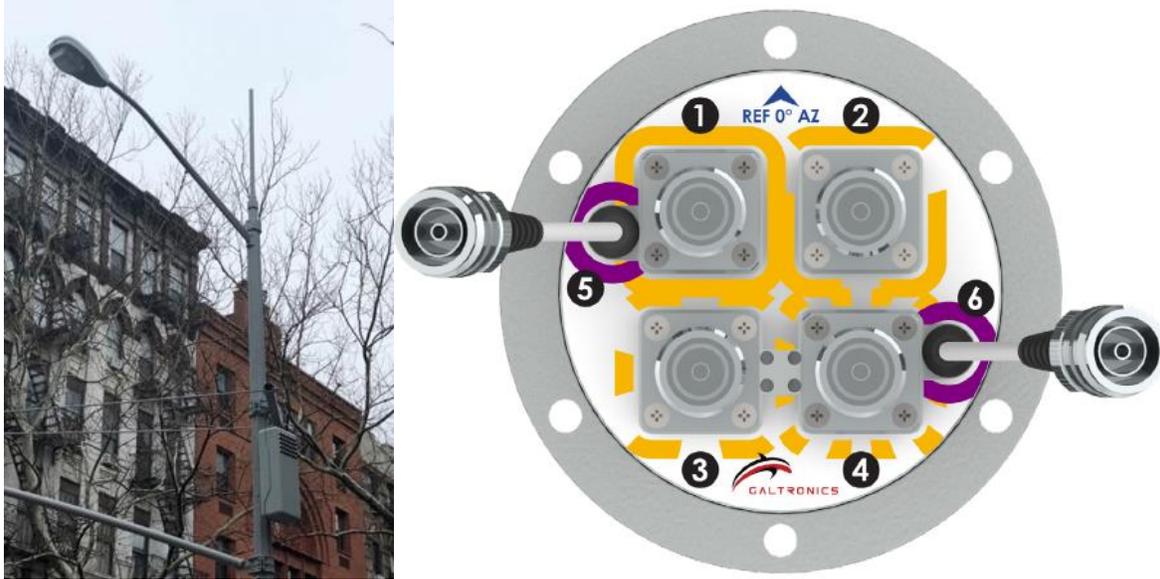
## VARIATIONS OF THE PSEUDO-OMNI ANTENNA

It is sometimes required, to deviate from a full 360° omnidirectional coverage pattern, in what would otherwise (externally) appear to be an omnidirectional antenna. Since the the native structure of the pseudo-omni antenna, is comprised of multiple antenna panels and elements combined together, these elements can be maipulated to offer beam shaped pseudo-omni antennas, that direct more radiational energy in one, or several azimuth orientations. As the outward physical appearance and dimensions of the antenna are the same or similar, the operator can deploy these customized omni antennas in the same city/jurisdiction as full 360° model pseudo-omni antennas. Only the operator needs to know the coverage differences! Such “sculpting” of the azimuth pattern allows the carrier to direct RF gain where needed, and less RF enegery where not.

Galtronics offers single, dual (peanut and heart shaped) and triple (clover) beam pseudo-omni antennas for such contingencies. This includes our smallest pseudo-omni 6-port “Whip” antenna model GO4806-06664. While the 6664 offers 360° horizontal (omni) coverage, variants have now been shipped that offer sculpted azimuth coverage patterns. Figure 6 below shows midband pattern sculpting of a 2” whip antenna representing 150° 3dB horizontal beamwidth, while Figure 7 shows typical urban installation of the GO4806-06664 and bottom side port access and configuration.



**Figure 6: Whip antenna midband azimuth pattern sculpting**



**Figure 7: Galtronics 2" Whip Antenna, GO4806-06664 shown (not to scale)**

## **SUMMARY**

The need, application and advantages, of the Pseudo-Omni antenna have been examined in this paper. While physical size, and cost of the Pseudo-Omni antenna, are greater than simple omni antenna structures, the wide range of benefits, such as multiband capability/consolidation, polarization diversity, MIMO support, and horizontal and vertical pattern control, and optimization amongst others, provide the carrier with clear advantages, that provide the user with a superior access, and data throughput experience.

## **ABOUT GALTRONICS**

Galtronics was created in 1978 and over the ensuing decades, has built a reputation for reliable wireless technology and innovative research and development. To date, Galtronics has manufactured over a billion antennas and helped build the data highways of the future. In a competitive niche market, Galtronics has proven its ingenuity and durability. Galtronics' parent company, Baylin Technologies, went public in 2013 and began trading on the Toronto Stock Exchange.

With global design and manufacturing facilities on two continents, Galtronics is one of the very few antenna companies in the world, with design capabilities in three key markets: DAS and Small Cell, Networking and Mobile. As content drives higher broadband requirements, more complex antenna systems are required to carry this increasing load. The fundamental design elements of antennas can only be satisfied by a limited number of companies in the world. Galtronics exceptional design capabilities, including its unique advantage of leveraging mobile antenna design to work within its distributed antenna systems, sets Galtronics apart from its competitors.

<https://galtronics.com/>