

Antenna myths for base station antennas

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Contents


Introduction	3
Myth 1: Antenna parameters are invariable	3
Horizontal beamwidth example	4
Front-to-back ratio example	4
Myth 2: A panel antenna has the same pattern as its radiating elements	5
Panel antenna construction	6
The array factor	6
Myth 3: Multiple input ports mean multiple arrays inside	7
Solution with common tilt control	7
Solution with separate tilt control	7
Diplexing and PIM risks	7
Graphical notation	8
Myth 4: Multibeam antennas have multiple arrays inside	8
The Butler Matrix	8
Myth 5: Beam steering requires active antennas	10
Beam steering with non active antennas	10
Beam steering vs. MIMO	11
Conclusion	11

Introduction

Base station antennas are like closed boxes that we rarely get a chance to look inside. They can't be opened without getting damaged and their size and weight makes it difficult for display inside offices. Despite evolving throughout the years, we still see only the same shaped box from the outside. This could be one of the reasons behind many misperceptions surrounding their technology, which have turned into myths over time. In this white paper, we explore some of the most common myths related to these mysterious boxes, revealing a few of the industry's best-kept secrets.

Myth 1: Antenna parameters are invariable

Radio planners initially select their base station antennas by **gain, beamwidths, supported bands** and **input ports**. Most datasheets would list some of these values in their headers and summaries. However, there are two factors that might affect these specifications' values—wide operating bandwidth and electrical tilt.



CCV4PX310.11R
Argus® multiband antenna, 2x 790–960 and 4 x 1695–2960 MHz, 65° horizontal beamwidth, internal electrical tilt with manual override. Bands cascaded SRET.

- Integrated internal remote electrical tilt (RET), with independent control of electrical tilt with manual override on all arrays
- All internal RET actuators are connected in “cascaded SRET” configuration

Electrical Specifications

Frequency band, MHz	790–862	880–960	1695–1880	1850–1990	1920–2180	2300–2500	2500–2690
Gain, dBi	15.8	16.4	16.7	16.8	17.4	18.1	18.1
Beamwidth, horizontal, degrees	73	62	63	66	67	62	64
Beamwidth, vertical, degrees	8.9	8.2	7.6	7.0	6.6	5.5	5.2
Beam tilt, degrees	0–10	0–10	0–10	0–10	0–10	0–10	0–10
USLS (first lobe), dB	18	18	18	18	18	18	17
Null fill, dB	-22	-22	-22	-22	-22	-22	-22
Front-to-back ratio at 180°, dB	35	34	33	38	38	39	40
Isolation, intersystem, dB	28	28	28	28	28	28	28
VSWR return loss, dB	1.5 14.0	1.5 14.0	1.5 14.0	1.5 14.0	1.5 14.0	1.5 14.0	1.5 14.0
PIM, 3rd order, 2 x 20 W, dBc	-150	-150	-150	-150	-150	-150	-150
Input power per port, maximum, watts	300	300	250	250	250	250	250
Polarization	±45°	±45°	±45°	±45°	±45°	±45°	±45°
Impedance	50 ohm	50 ohm	50 ohm	50 ohm	50 ohm	50 ohm	50 ohm

Figure 1: A CommScope antenna data sheet showing frequency range effect

Antennas are analogous to audio speakers. We've noticed how low end models exhibit different performance across our human audible range (20 Hz to 20 kHz). For this, equalizers are inserted to boost bass and treble ranges for example. Similarly, wide-bandwidth antennas, if not properly designed, might show different performance across their supported spectral ranges and e-tilts.

Let's have a deeper look into this by plotting some planet pattern files for a **CommScope antenna**, comparing it to **two other brands**.

Horizontal Beamwidth example

Usually three-sectored sites deploy 65° half power horizontal beamwidth antennas. The neighboring sites' azimuth and locations are designed accordingly over simulation tools. In case the actual HPBW is less than the specified one, we get coverage holes. And, if it is more, we observe unnecessary interferences and increase in soft handovers.

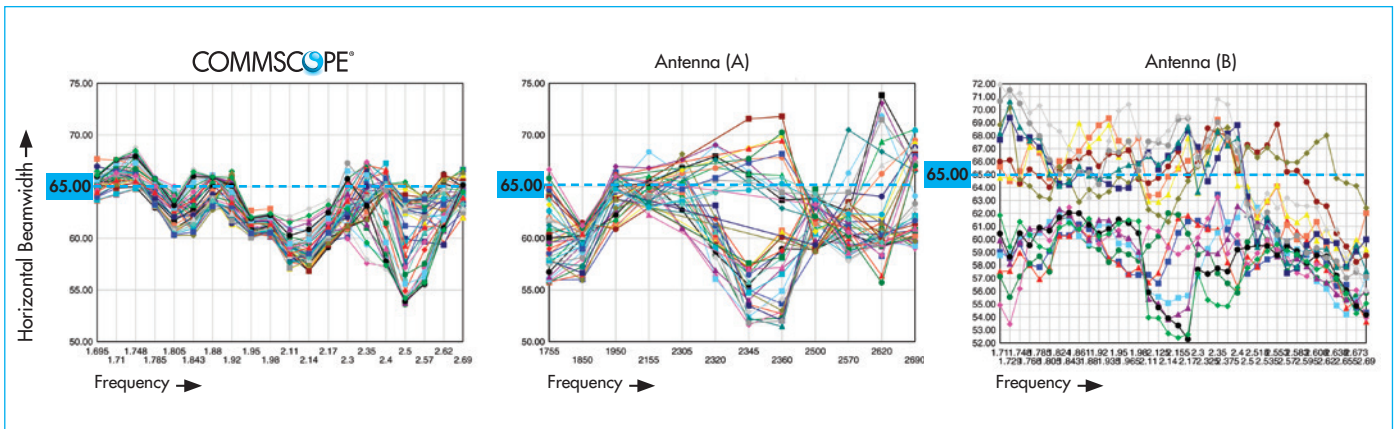


Figure 2: Horizontal beamwidth variation with frequency¹

Looking at Figure 2 above, each plotted line represents a frequency at a specific e-tilt. It is very clear that the **HPBW varies across the antenna's supported bands and tilts**—reaching as high as 75° and as low as 52° in the low end antenna manufacturer's case. Note that the CommScope antenna, on the left, shows much less variations than the other two.

Front-to-back ratio example

Another example is an antenna's front-to-back ratios. Again each line represents a different frequency with a specific e-tilt. Values' dispersions are shown in the histogram (Figure 3). Such dispersion can also be misleading during antenna selection based on specifications provided in datasheets.

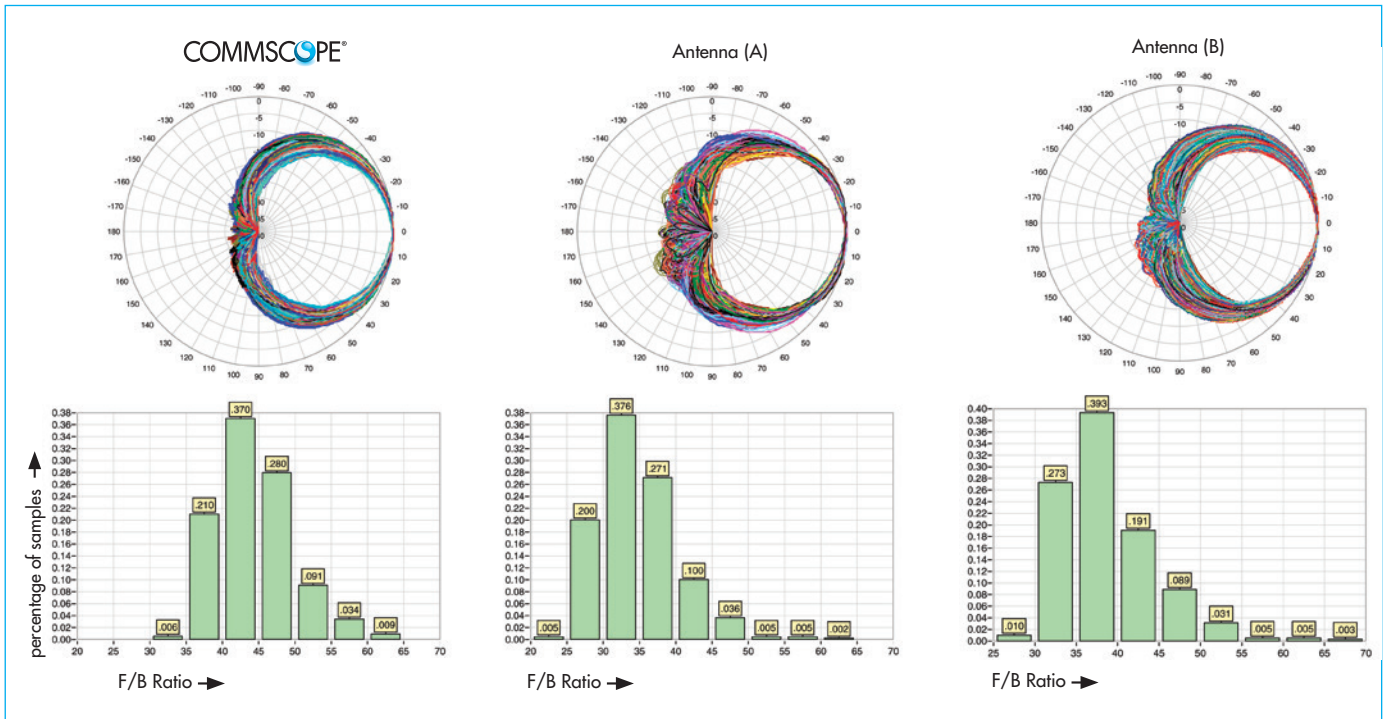


Figure 3: Front-to-back ratio dispersion with frequency'

It is very common that engineers, comparing manufacturers' antennas datasheets, observe **identical parameter values** with **unjustified price differences**. However, bearing in mind that **antennas parameters' invariance is a myth**, a better antenna will always be the one with **the fewest dispersions** from the datasheet values—across its entire operating band and e-tilts range.

Myth 2: A panel antenna has the same pattern as its radiating elements

We are all familiar with panel antennas patterns and electrical tilting, in the horizontal and vertical planes. There is however a misperception about how the panel's overall pattern is shaped.

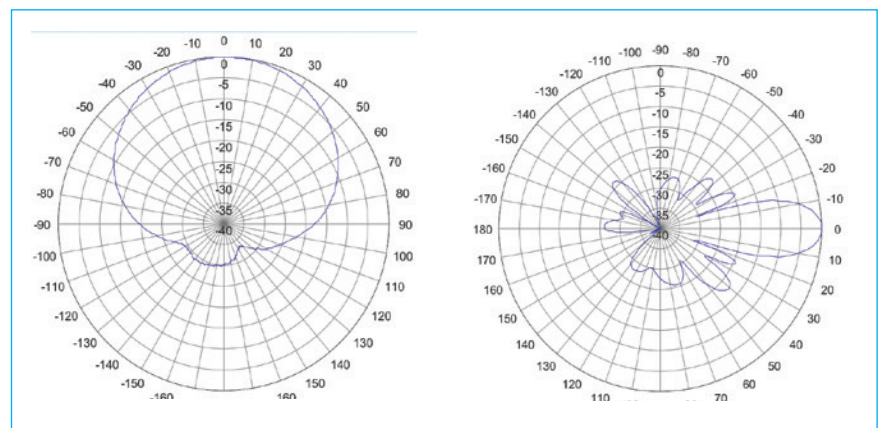


Figure 4: Typical antenna horizontal and vertical patterns

Panels antenna construction

A panel antenna comprises a number of radiating antenna (AE) elements' arrays, for high and low bands. Low band elements dipoles are larger in size (bigger $\lambda/2$) and require more isolation distances in between than high-band ones. It is, thus, logical that more of the high-band arrays can fit into the same antenna radome.

For example, Figure 5 below shows a panel antenna with a single low-band array between two high-band arrays.

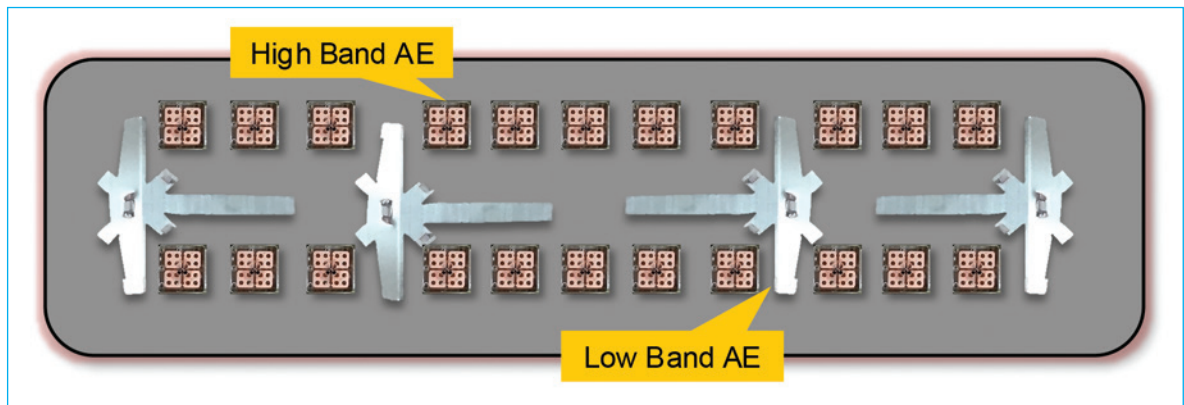


Figure 5: CommScope antenna from the inside

The array factor

Yet **the panel antenna pattern is quite dissimilar from its radiating antenna element pattern.**

This is the result of multiplying the antenna elements (called column pattern) and the array factor patterns. The latter's shape is based on its antenna elements spacing, phase shifts and amplitude variation.

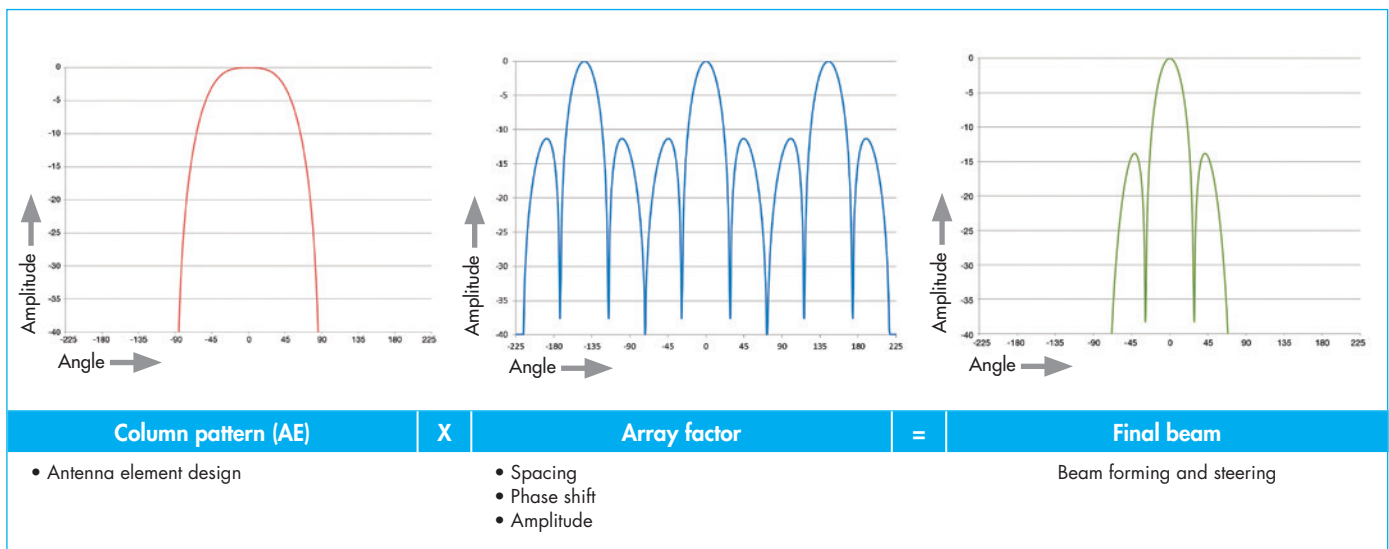


Figure 6: Forming a panel antenna pattern²

Figure 6 above further depicts this concept. It is also worth noting that changing the AE's phase shifts and amplitudes result in an electrical beamforming of the array factor—and, consequently, the final overall beam shape. This same concept is also applicable for e-tilt applications.

Myth 3: Multiple input ports mean multiple arrays inside

The number of input ports and independent electrical tilt controls is an important RF planning parameter. More ports mean less combiner losses with better VSWR and PIM performance. The independent e-tilt controls also reflect more optimization flexibility between the connected systems.

Most RF planners believe that buying an antenna with different connectors and separate tilt controls means more integrated antenna elements arrays inside. It will then be safer for PIM and VSWR. But could this be another myth?



Figure 7: 10-port antenna with five e-tilt controls

As we explained in Myth 2, low-band elements dipoles are larger in size (bigger $\lambda/2$) and require more isolation distances in between. Consider, then, an RF planner who needs to run GSM 900MHz and LTE 800MHz on separate antenna ports. This imposes doubling the antenna widths. But doubling the width is highly discouraged because of tower wind loading and general appearance constraints.

Solution with common tilt control

A solution is to diplex the G900 and L800 signals before the antenna ports, and then use a normal single-array antenna of normal width. The diplexer can even get embedded inside the antenna radome, with separate input ports from the outside.

But then your optimizers might complain about the impossibility of tuning GSM and LTE tilts separately. This was a big drawback for this technique, and a better approach was required.

Solution with separate tilt control

The solution, deployed today by many antenna manufacturers, was to use diplexers behind each antenna element. Each signal (G900 and L800 in our example) will then have its own path until reaching an AE where both are diplexed. Here we can have separate input ports with separate e-tilt controls—but, of course, with the additional diplexers' complexity cost.

Diplexing and PIM risks

The concept works pretty well but planners have to be aware of the PIM (passive intermodulation) risks involved in diplex'ing bands on the same antenna elements.

Not all bands combinations' can be safely diplexed over the same antenna elements without risking PIM. CommScope has a tool with a GUI for such a purpose. It can be downloaded for free here: <http://www.commscope.com/Resources/Calculators>

Graphical notation

Figure 8 shows a graphical notation commonly used to indicate antennas' construction. In this example a double-width antenna (500 mm) with two low-band and two high-band arrays is depicted. The first low-band array (R1/R2)—shown as diagonally split rectangle—has four input ports that are internally diplexed to the same AE's. The second low-band array (R3) is an ultra-wideband array with two ports. Finally, the high-band AE's (Y1 and Y2) are interleaved inside their respective low-band arrays. The standard AISG color codes are used for the respective bands.³

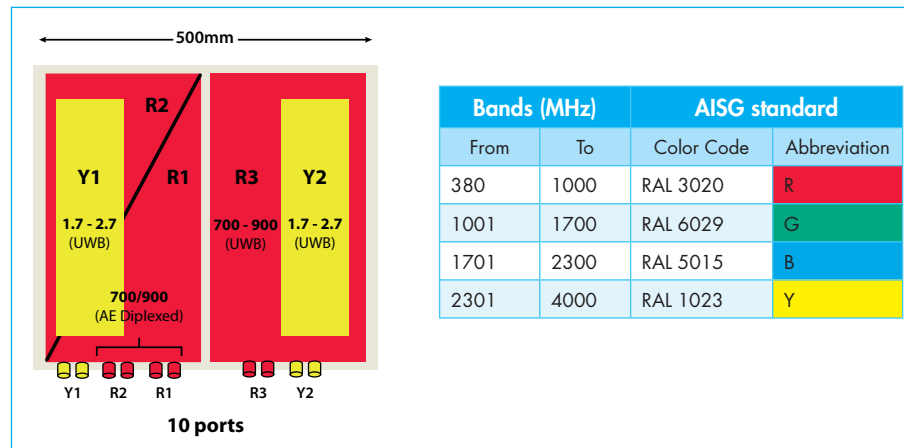


Figure 8: Antenna elements and ports notations

This then proves our third myth, which is another important item to look after when buying antennas.

Myth 4: Multibeam antennas have multiple Arrays inside

When twin beam or multibeam antennas are mentioned, the first idea that jumps to mind is a combination of two or more arrays, carefully positioned to radiate in different directions. Or can you think of ways? Let's look at two techniques deployed by CommScope.

The Butler Matrix

Going back to the second myth, the array factor is dependent on its antenna elements' spacing, phase shifts, and amplitude variation.

Since the AE's can't be moved, we are left with only phase and amplitude variations to electrically change pattern shapes.

The Butler Matrix—first described by Jesse Butler and Ralph Lowe in a 1961 paper—is one of the classical techniques to achieve this. It is built out of hybrid combiners and phase shifters (Figure 9) such that each antenna element sees different shift and amplitude combinations of the input ports (1R, 2L, 2R and 1L). In the below figure, feeding the input signal from a different input port, results in a different beam direction.

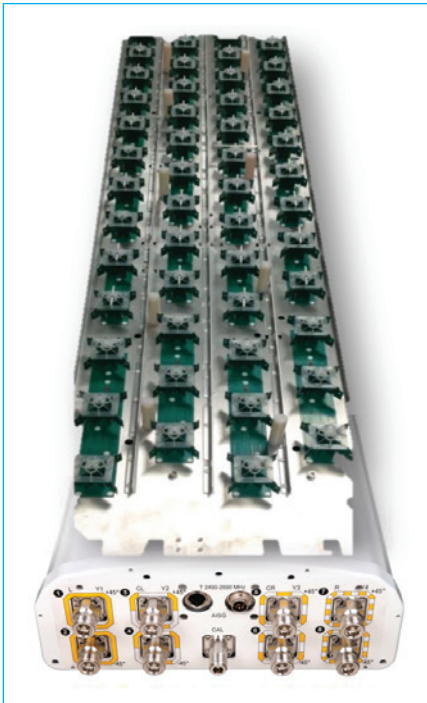


Figure 10: TTT65AP-1XR antenna

Myth 5: Beam steering requires active antennas

We have previously explored the Butler Matrix for electrical beam steering. Even though they are labeled “electrical”, these techniques might still need some mechanical actions to operate. A clear example is e-tilt that gets adjusted by mechanically pulling tilt control sticks.

Many believe that the only solution lies in active antennas—antennas with integrated radios. But these are still being debated in the industry. Despite reducing sites footprints they restrict future upgrades and harden maintenance. Yet one of the main long-term benefits is fully electrical beam steering and massive MIMO. That can’t be another myth, right?

Beam steering with nonactive antennas

Well, we are actually able to do full electrical beam steering over regular antennas with the support of the base station. Let’s take CommScope’s antenna **TTT65AP-1XR** as an example

- Planar array antenna, 2496–2690 MHz, 65° horizontal beamwidth, single internal RET
- Four columns of x-polarized arrays
- Tested for 0 and 30 degree beam steering

As seen in Figure 10, the TTTT has four x-polarized arrays with two input ports each. The antenna is designed for TDD-LTE with 0 degree and 30 degree beam steering directions.

The BTS radios are connected to the four column arrays. The radios apply specific amplitude and phase difference as per the antenna manufacturer-provided data.

The following table is an example of values provided to the BTS vendor for application at the antenna ports. There are mainly two beams that can be formed

- Broadcast beam: Changing phase and amplitude across ports
- Service (steered) beam: Changing phase only across ports

		Column 1	Column 2	Column 3	Column 4
65° broadcast	Phase ϕ	0	115	100	0
	Amplitude	0.81	1	0.73	0.6
Beam steering @ 0°	Phase ϕ	0	0	0	0
	Amplitude	1	1	1	1
Beam steering @ 30°	Phase ϕ	0	120	-120	0
	Amplitude	1	1	1	1

All this sounds reasonable, but there is always a challenge.

Beam steering vs. MIMO

For multi column antennas, such as the TTTT, the array factor is determined by the column spacing, phase and amplitude distribution.

The column spacing is the most debated factor here.

- If set to 0.5λ (narrow) we get the best beam steering with degraded MIMO.
- If set to 1λ (wide) we get the best MIMO but with larger steering grating lobes.

A balance needs to be made between the resulting grating lobe and MIMO performance. For example 0.65λ spacing.

Conclusion

It is now obvious that there are many myths surrounding base station antennas that have been cleared throughout the discussion.

In Summary...

- 1st cleared myth: *Antenna parameters can **vary** across supported bands and e-tilts.*
- 2nd cleared myth: *A panel antenna has a **different** pattern than its radiating elements.*
- 3rd cleared myth: *Multiple input ports **doesn't** mean multiple arrays inside.*
- 4th cleared myth: *Multibeam antennas **don't necessarily** have multiple arrays inside.*
- 5th cleared myth: *Beam steering can be implemented with **nonactive antennas**.*

Sources

¹ CommScope white paper: Connecting performance to measurable cost advantages, July, 2015

² Chuck Powell, RFS white paper: Beamforming vs. MIMO antennas, May 2014

³ AISG-Antenna Port-Colour Coding v3.1, May 2015

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