White Paper

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Active Antennas: The Next Step in Radio and Antenna Evolution

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1 INTRODUCTION

In this white paper we examine the evolution of cell site architectures from legacy systems to active antennas. We outline the market trends and requirements that are driving this transition and describe the technological innovations being introduced to meet these requirements. We then describe the benefits of the active antenna architecture over traditional implementations and demonstrate the benefits to the operator from a total cost of ownership. We also describe a family of active antenna architectures that can be adapted to meet specific requirements from an end customer. Finally, we describe the evolution of active antennas arrays from simple linear arrays to more complex multi-band, multi-column arrays.

2 RADIO ARCHITECTURE EVOLUTION

Several key factors are driving the evolution of cell site architectures. The primary drive is the increasing demand for bandwidth and capacity. This demand is being address by i) new radio technologies like HSPA and LTE, ii) deployment of new frequency bands for cellular radio transmission, and iii) increase in the number of carriers and channels (bandwidth).

While new 3G and 4G technologies like HSPA+ and LTE are being introduced there is also a need to continue to support legacy technologies like GSM and CDMA for the foreseeable future. Consequently, radio networks are being required to support multiple technologies (GSM, UMTS and LTE or CDMA, WiMAX, and LTE) in multiple frequency bands simultaneously. Therefore, there is a growing need to integrate the electronics and hardware in a typical base-station to minimize site footprint and lower costs.

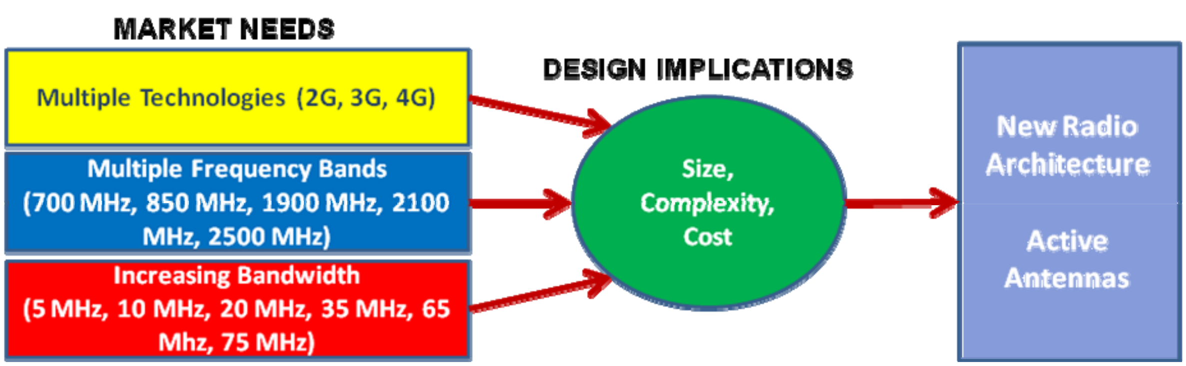

Figure 1: Market trends and resulting radio architecture evolution.

Over the last decade, cell site architectures have been evolving from the legacy cell site architecture where large radios are located remote from the antennas, to an architecture wherein a separate RF portion of the radio can be located more closely to the antenna. This separation of the digital radio, BBU (Base Band Unit), from the analog radio, RRH (Remote Radio Head), allows for a reduction of the equipment foot print at the site and for a more efficient operation of the network. A digital fiber optic link provides the connection between the BBU and RRH.

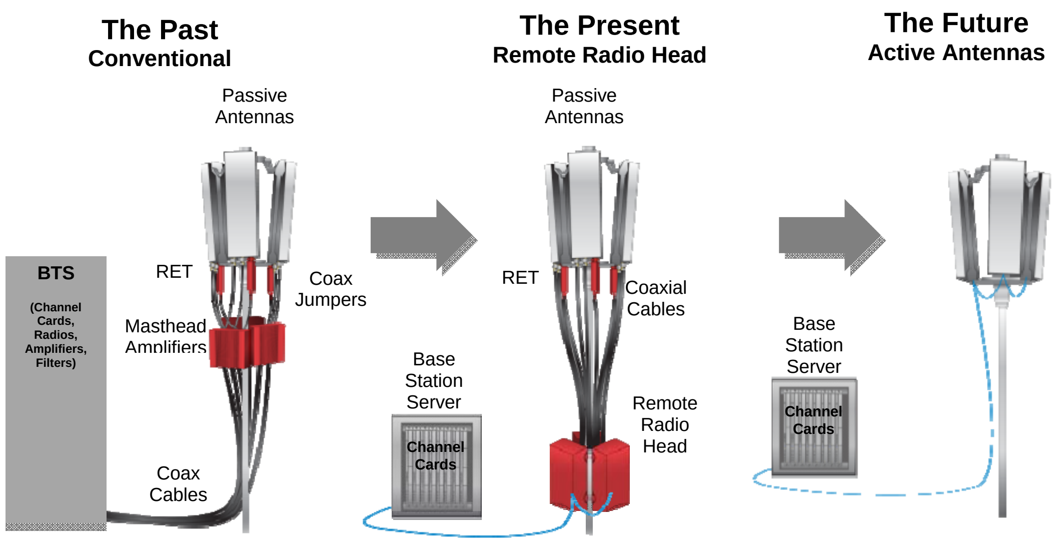

Figure 2: Cell site architecture evolution.

The next stage in the evolution of the site architecture is the actual integration of the radio into the antenna and the distribution of the radio functionality across the antenna elements. This is an active antenna.

3 ACTIVE ANTENNA SYSTEM (AAS) ARCHITECTURE

A single sector architecture for an LTE active antenna system that supports 2x2 MIMO is depicted in Figure 3. For comparison, the equivalent implementation using an RRH is also shown.

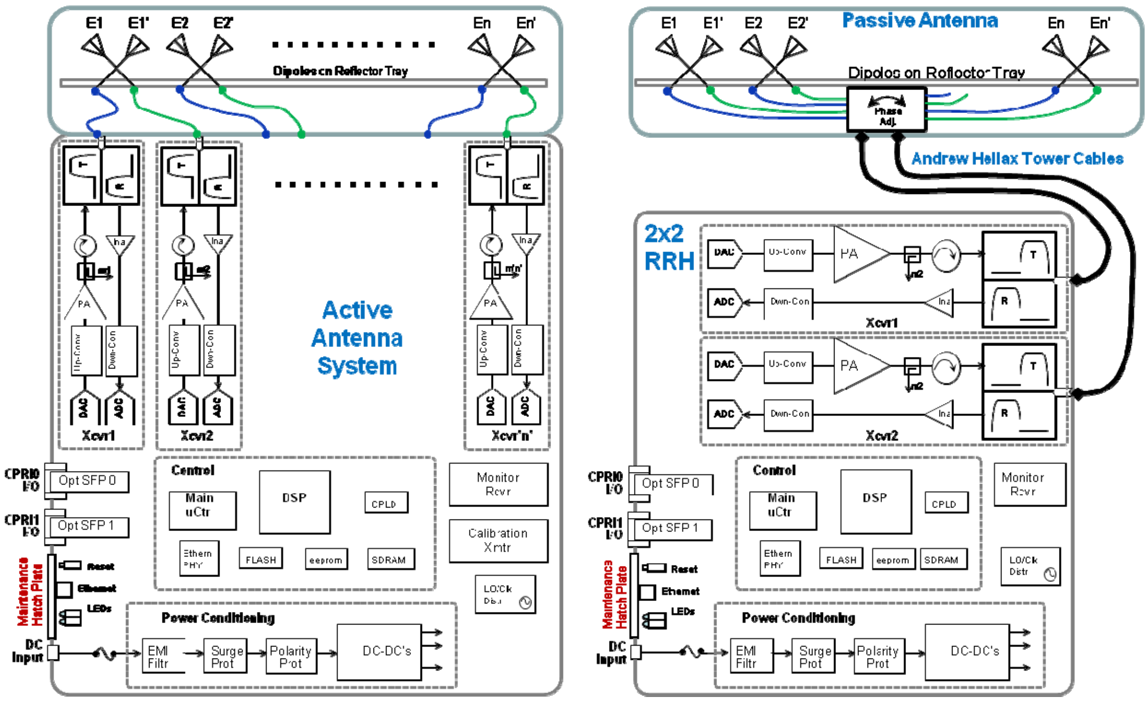

Figure 3: Active antenna architecture compared with a remote radio head plus antenna.

Both the AAS and RRH are connected to a baseband unit with a high-speed serial link as defined by the Common Public Radio Interface (CPRI), Open Base Station Architecture Initiative (OBSAI), or Open Radio Interface (ORI). The high speed serial link is used to transport the Tx and Rx signals from the BBU to the RRH or AAS. In an RRH, the downlink (Tx) signal is digitally upconverted and amplified on the downlink path. Correspondingly the analog uplink (Rx) signal is processed by a low noise amplifier (LNA), downconverted and digitized. The duplexed outputs from the RRH feed a passive antenna array via a corporate feed network with RET support. The RRH comprises two transceivers, one for each MIMO path. Each transceiver incorporates an upconverter, an amplifier, an LNA, a downconverter, and a duplexer.

In an active antenna, each element in the antenna array is connected to a separate transceiver element. A typical AAS system may therefore have multiple transceivers (for example 8-16). Since there are many more transceivers/amplifiers in an AAS, each amplifier in an AAS delivers a much lower power when compared to an amplifier in an equivalent RRH.

4 AAS BENEFITS

The benefits of an active antenna architecture over an RRH based site architecture are many. First, there is a potential to significantly reduce the site footprint. Second, the distribution of radio functions within the antenna results in built-in redundancy and improved thermal performance, which can result in higher system availability (lower failure rates). Third, distributed transceivers can support a host of advanced electronic beam-tilt features that can enable improvements in network capacity and coverage; hence, it has the potential to lower capital and operational costs. Each of these features shall now be described in the following sections.

4.1 Site Footprint

The first obvious benefit with the integration of the radio within the antenna is the elimination of several components like cables, connectors, and mounting hardware and an overall reduction in the physical tower space required. By integrating the remote radio head functionality into the antenna, the aesthetics of the site can be improved and wind load reduced. The following table compares the hardware required for a three sector BTS using an RRH-based solution with an Active Antenna System (AAS). As can be seen from the table, there is a significant reduction in the number of components in an AAS.

	RRH + Passive Antenna	Active Antenna
High Power RF Cables	**6**	**-**
Mounting Brackets	**6**	**3**
RET Controller	**3**	**-**

Table 1: Typical components in a three-sector, single-band, cell site.

In addition to the cost benefits due to reduction in the number of components, further savings can be potentially achieved with lower tower leasing costs and lower installation costs.

4.2 Improved System Availability

Due to its inherent architecture, an AAS can offer significant improvements in system availability over an RRH based system. The increase comes about because of two factors:

i) Improved thermal margin

The active antenna architecture can eliminate a substantial portion of the power losses in the RF feeder cables when compared to a conventional BTS. Though an RRH can provide a similar benefit, the AAS goes further by eliminating the need for even a short jumper cable between the RRH output and the antenna. Additionally, the active antenna can support an electronic beam tilt without requiring a Remote Electrical Tilt (RET) feeder network. This further reduces the power loss for an AAS when compared to an RRH with a RET. In most configurations this can increase the power delivered to the antenna when compared with an RRH. The additional margin can be used to lower the overall thermal dissipation in the amplifiers.

Further, with the radios integrated directly into the antenna housing, and with replacement of a small number of large amplifiers with many small amplifiers, the heat is spread over the larger antenna structure as opposed to the smaller RRH or amplifier shelf. This availability of higher surface area for heat dissipation results lower temperature rises in the components, which results in improved thermal margins and better reliability.

ii) Redundancy with Graceful Degradation and Self-Healing

The distributed and redundant architecture of the AAS, wherein each antenna element is fed by its own transceiver, provides reliability benefits as the failure of one transceiver does not cause a critical failure. The system is intelligent and can sense a transceiver failure. When a transceiver does fail, the amplitude and phases on the remaining elements are automatically adjusted digitally to compensate for the elevation beam distortion and the reduction of EIRP on the horizon. With the appropriate sizing of the amplifiers and intelligent readjustment of the amplitudes and phases, the AAS can be designed to have minimal or no loss in coverage performance with a single transceiver failure and minimal degradation with two transceiver failures. Since the likelihood of more than one transceiver failing in a single AAS is minimal, very high system availabilities can be achieved.

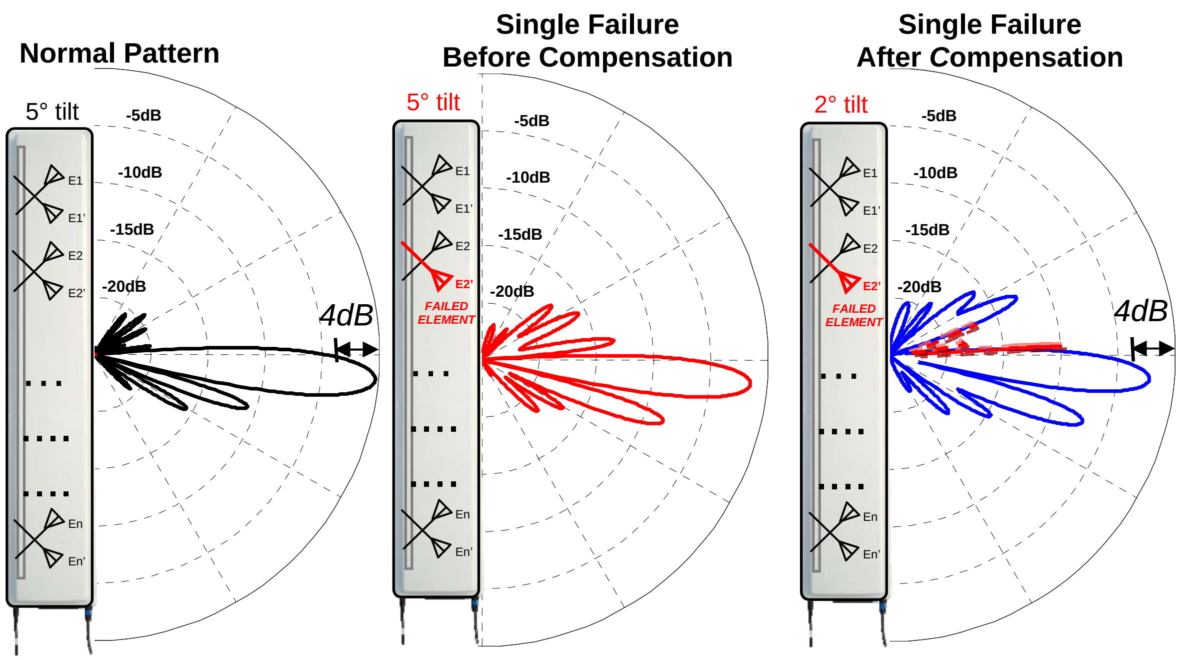

Figure 4: Self-healing of beam patterns for improved system availability.

Since the AAS can be designed to have minimal loss in performance with a single transceiver failure, repairs and site upgrades for failed units can be delayed and scheduled. For a site with several sectors and bands, multiple unscheduled repair visits (as would be the case for an RRH based system) can be replaced by a single scheduled visit that is less frequent. This can significantly reduce the operational costs for operators.

4.3 RF Planning with Advanced Antenna Tilt Features

Another critical benefit of an AAS is the unique ability to electronically tilt elevation beams by having independent baseband control of the phase, amplitude, and delay of individual carriers on each antenna element. This supports multi-mode systems where different carriers in the same frequency band, with different air interfaces, may require different tilt orientations. The flexibility with tilt control in AAS enables advanced RF planning features, much of which can potentially reduce the cost to operators by reducing the number of sites required. Several versions of tilt control are described in the following sections.

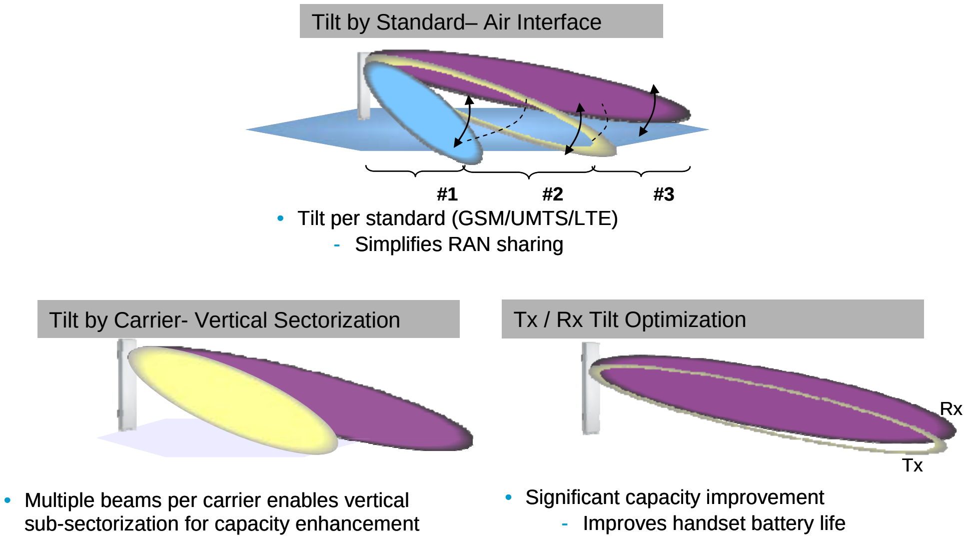

Figure 5: RF planning with advanced tilt features.

4.3.1 Tilt by Standard

In a legacy cell site, GSM/GPRS/EDGE or UMTS carriers may provide adequate coverage, but when an LTE carrier is newly introduced to the same site, it may need to be downtilted differently than the legacy carriers as the link budgets for LTE and UMTS may be different. This is feasible with AAS.

4.3.2 Separate Tx and Rx Tilt

The electronic tilt capability also allows for the separate beam tilting and optimization of the Tx (downlink) and Rx (uplink) paths. This might be critical when the link budgets for the Tx and Rx paths are unequal. It may also be used to optimize cell radii when the physical layer (modulation scheme) for the Tx and Rx paths is different, as is the case with LTE.

4.3.3 Tilt by Carrier

For maximum flexibility, tilt can be adjusted on a per-carrier basis. This has some interesting applications such as vertical sectorization in LTE and RAN sharing for UMTS.

4.3.3.1 Vertical Sectorization

In UMTS/LTE networks, adding sectors in the vertical plane have been proposed for improving system capacity. In a typical implementation, the first carrier may cover an inner sector whereas a second carrier covers an outer sector. For LTE, this has been shown in simulation to provide significant capacity benefits.

4.3.3.2 RAN Sharing

As multiple operators vie for precious real estate on tower tops, antenna sharing and RAN sharing amongst two or more operators has been proposed. In such a scheme a RAN that supports a multicarrier UMTS system is shared by two operators with each operator controlling/owning one or more of the individual carriers. Since the RF planning and site deployments are likely to differ among operators, each UMTS carrier may need to be tilted by different amounts in order for each operator to achieve optimal network performance.

4.3.4 Self Optimizing Networks (SON) and Advanced Beam-tilt Features

Looking ahead, optimizing beam tilt on a per-carrier basis based on active channel loading using advanced SON algorithms as envisioned in LTE can provide even higher network efficiencies.

5 FAMILY OF AAS ARCHITECTURES

The AAS architecture described in the preceding Section 3 describes an architecture that can support the full range of features outlined in Section 4. As such, an AAS may be designed to support a subset of the above features by adopting varying configurations. Some of these are described in the following sections.

5.1 Integrated RRH with Passive Antenna

The simplest AAS is a mechanical integration of the passive antenna with an RRH. This offers the benefit of reducing the site footprint and associated leasing/installation costs. The additional surface area afforded by the antenna can also offer some thermal benefits. Elimination of the RF jumper cables from the RRH to the antenna can offer some further benefits.

5.2 Distributed Amplifiers

Another variation that can be envisioned is an AAS with distributed amplifiers. Since the amplifiers are one of the highest power dissipating elements in the system, a distributed amplifier (one per antenna element) with a common up/down converter can offer some of the benefits of an AAS such as improved thermal design and incremental improvement in system availability due to the redundant amplifiers. Such a system cannot, however, support the full range of RF tilt controls.

5.3 Redundancy for Integrated RRH with Passive Antenna

As described in preceding sections, incorporating redundant subsystems with an intelligent failure recovery mechanism can improve the overall system availability. A similar concept can be applied to the Integrated RRH with Passive Antenna. Redundancy can be added to selective subsystems that have a high failure rate (for example, power supplies or amplifiers) to reap the benefits of a system with higher availability. Such a system can lower the site maintenance costs, at the expense of additional initial expense for the redundant systems.

5.4 Distributed Transceivers with Sub-arrays

A full featured AAS would require a transceiver at every antenna element. However, a compromise may be achievable where the number of transceivers is greater than that in an RRH but lower than the number of antenna elements. In this architecture, each transceiver feeds several sub-arrays that are linearly arranged to form the complete antenna array. Judicious design of the antenna and its sub-arrays can achieve all of the benefits of an AAS while minimizing system cost and complexity.

5.5 Antenna Combinations

As multiple bands and air interface standards are introduced, AAS architectures shall evolve from single-band active arrays to active-passive antenna arrays. An example of a high-band active-passive array is shown in Figure 6. In a typical active-passive configuration, the active array is used to deploy new (4G) services whereas the passive array is used to support legacy (2G, 3G) installations. The CommScope active-passive array borrows from our industry leading multiband antenna designs. Specifically, the passive array can be designed with broadband elements that can cover a highband as broad as 1710 – 2690 MHz.

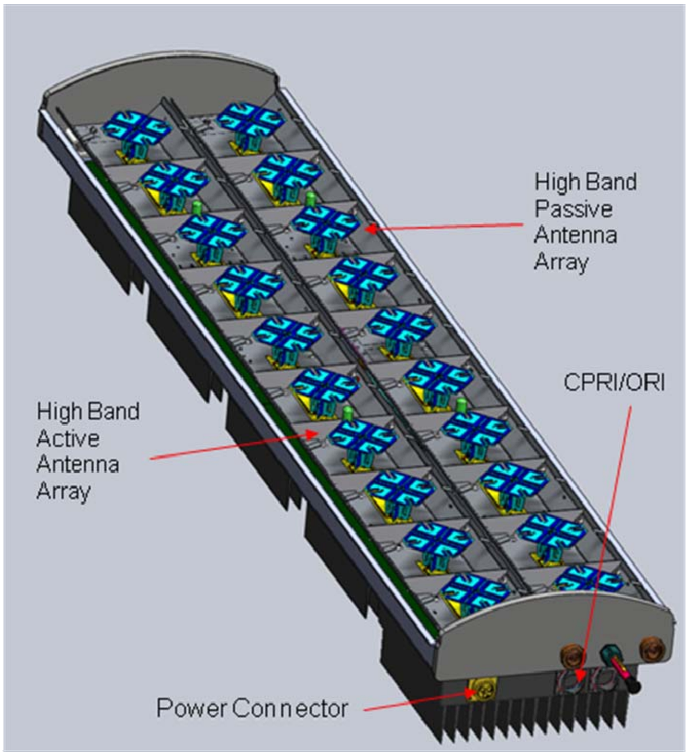

Figure 6: A high-band active-passive array.

As more legacy installations are upgraded to 4G (LTE), a dual column active-active array configuration can also be envisioned, with each active column supporting a separate band. Ultimately, multi-column active arrays that can support advanced beam pattern controls in azimuth and elevation shall be introduced.

6 SUMMARY

The key take-away from the discussions in the preceding sections is that AAS can lower the total cost of ownership for operators. The reduction in site footprint can lower capital expense, installation and maintenance costs. The improved system availability can reduce repair and maintenance costs, while simultaneously improving system up-time. The advanced tilt features can enable capacity and coverage improvements, resulting in lower network deployment costs. Ultimately, smart networks with AAS and SON can further improve network efficiencies.

CommScope has been conducting pioneering work on active antennas systems since 2001, when prototypes were built and tested in our corporate R&D labs in Richardson, Texas. Work continues today in CommScope’s radio and antenna R&D facilities. In 2007, CommScope initiated a joint development of active antennas with a partner, Ubidyne. (Ubidyne is a start-up company focusing on developing custom chips and transceiver systems for active antenna.) As part of this development CommScope has been manufacturing active antennas for various field trials over the last several years.

Figure 7: A 700 MHz active antenna developed by CommScope in partnership with Ubidyne.

With a long successful history of providing high performance, cost competitive antenna and radio products to the industry, as well as extensive experience in supplying fiber optic, coaxial, and twisted pair cables, CommScope is in a unique position to make active antenna solutions a success for our customers.