White Paper

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Study:
Simplify The Evolution to 5G Networks with Active-Passive Antennas (APA)

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Executive Summary

The 5G world is almost upon us and with it will come new applications such as virtual reality, augmented reality, self-driving cars, digital healthcare, robotics, and massive use of the Internet of Things (IoT), all of which will affect our daily lives. However, to achieve these capabilities, there are still numerous technical and economic challenges facing the industry that must be solved.

Massive multiple input multiple output (mMIMO) antenna and radios systems are a key enabler of the Advanced LTE (4.9G) and 5G ecosystem. While these systems will be used for both small cell and macro sites, one of the challenges for mobile network operators (MNOs) is how to deploy these systems on already crowded and constrained macro sites.

RFS is developing Active-Passive Antenna (APA) systems that address this challenge. APAs are systems in which mMIMO systems and the passive antennas used in 4G systems are tightly integrated through shared electronics, radio frequency (RF) components and chassis. RFS will feature a prototype APA at Mobile World Congress Barcelona in February 2018. While development challenges remain, a fully developed system offers the following benefits. It:

- Simplifies adding and deploying mMIMO systems on existing crowded macro sites
- Minimizes visual impact and total cost of ownership (TCO) for towers by reducing wind load
- Shares some components between the mMIMO and passive antenna structures to lower the initial cost and weight compared to other options
- Requires no additional antennas in a sector
- Uses passive antenna volume and a mechanical frame to enable an efficient thermal management system, resulting in a more robust and reliable system
- Minimizes additional operating expenditure (OPEX) and site negotiation requirements

Understanding a 5G World

The main goal for infrastructure providers is to reduce the cost/bit/sec/Hz

The 5G world that we are creating is full of promise. When 5G is fully implemented, it will enable new applications and services that will continue to change our lives and our business environments. Virtual and augmented reality, self-driving cars, digital healthcare, robotics, and massive use of the Internet of Things (IoT) are just some of the potential game-changers. However, before we can realize this new world, the telecom industry must solve numerous technical and economic challenges. Even with the partial completion of 3GPP Release 15 in December 2017, there are still major issues to tackle, including the definition of a millimetre wave-based (mmW) radio access network (RAN) that will enable MNOs to design and deploy workable, optimized and profitable mmW networks on a large scale. With these challenges in mind, senior telecom executives and analysts are warning against “5G hype”, strongly reminding us that the main target for infrastructure providers is to drive down the cost/bit/sec/Hz of their network.

Site acquisition for active antennas will be a major challenge

5G networks will not replace 4G networks; the two will coexist. LTE-based systems will continue to evolve and MNOs will have to build 5G infrastructure alongside, or on top of, existing and evolving 4G RANs. As a result, the “telecom site nightmare” is far from over. Acquiring new sites has become almost impossible in most dense urban areas. And adding new antennas that support new frequency bands for macro sites and small cell sites can generate very long, painful and expensive negotiations with site owners. The deployment of massive multiple input multiple output (mMIMO) active antenna systems (AASs), a key enabler of Advanced LTE (4.9G) and 5G, will be another major challenge for MNOs. When using mmW, which operates at frequencies higher than 28 GHz, MNOs will have to find ways to deploy dense small cell networks at street level. When using frequencies below 6 GHz, MNOs will need to find ways to add new radios on already crowded towers, rooftops and other structures.

APAs are the best solution to simplify site negotiations and decrease TCO for active antennas

Each MNO will have different deployment strategies, influenced by the spectrum they own, local regulations, and go-to-market priorities. While 5G architectures will include small cells, there will be cases where active antenna systems will be added to already crowded macro sites. In these situations, all MNOs will face the same constraints regarding the total number of antennas they can deploy on any given site. As a result, they will all ask their hardware vendors the same question: “Can we somehow integrate these new 5G active antenna systems with the passive base station antennas we use for 4G? “

Active-Passive Antennas (APAs) will greatly simplify MNOs’ evolution toward 5G. Integrating mMIMO systems with passive multi-band antennas, without dramatically changing their form factor and performance, can potentially solve multiple issues. APAs do not increase site antenna counts and they require only a minimal size increase, so they simplify and reduce site negotiations and the related operating expenditures (OPEX). APAs also help solve some of the technical challenges faced by mMIMO radios, such as thermal dissipation, which could help to offset or decrease capital expenditures (CAPEX).

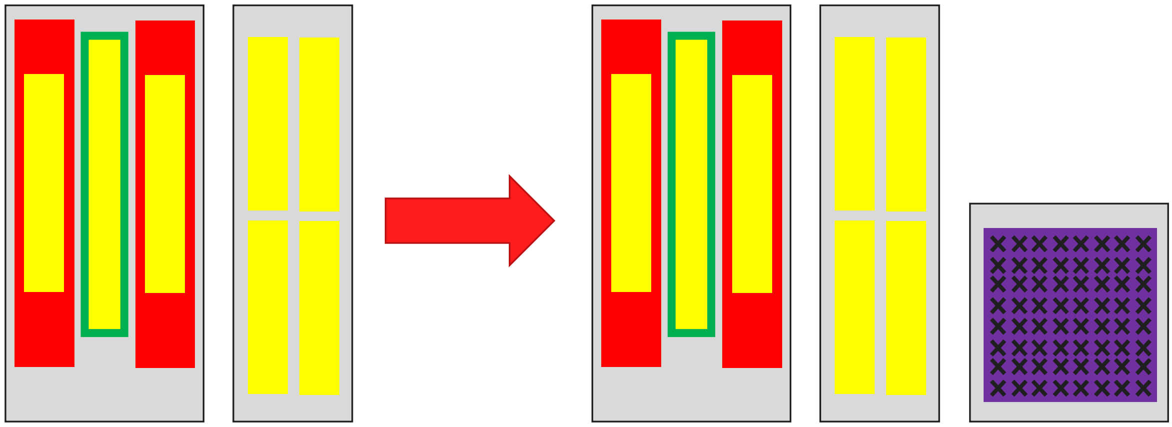
Options for Adding mMIMO to Existing Macro Sites

The ideal scenario for an MNO is to simply add an mMIMO system to an existing macro site without increasing antenna count, size, or cost, and without reducing coverage footprint, performance, or ease of deployment. Understanding that we do not live in a perfect world, the question becomes which architecture provides the best balance of trade-offs and takes us closest to this ideal scenario?

The following scenarios provide example options that MNOs should consider. In these scenarios, the MNO has a site with two passive antennas in a sector — two low-band (LB) arrays and seven mid-band (MB) 2x2 MIMO arrays — and wants to add an mMIMO active antenna at 3.5 GHz. At least four options are possible, each with pros and cons that need to be carefully evaluated before a decision is made.

Scenario 1

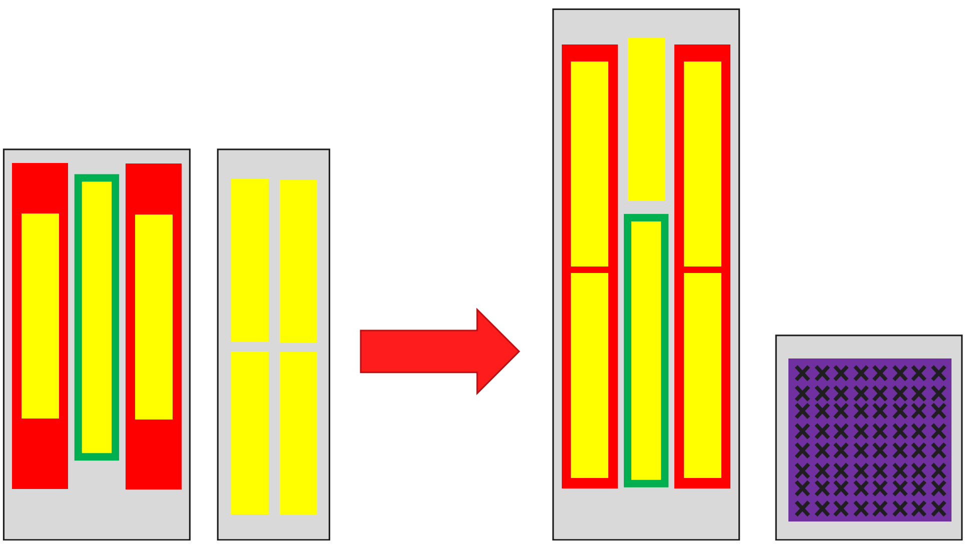
The easiest way to add an mMIMO system for either 5G New Radio (NR) or LTE is to deploy a standalone system because it does not require modifications to legacy passive antennas.



The main drawback of this option is the impact of adding an additional antenna system. Even if space is available — which will rarely be the case in most dense urban areas — it will require renegotiation with the landlord and might involve new civil work with the associated building permits, as well as additional OPEX. Also, the visual impact of this new antenna will have to be considered and may be met with public disapproval.

Scenario 2

Another option is to continue using two antennas and combine all of the passive arrays under a single radome.

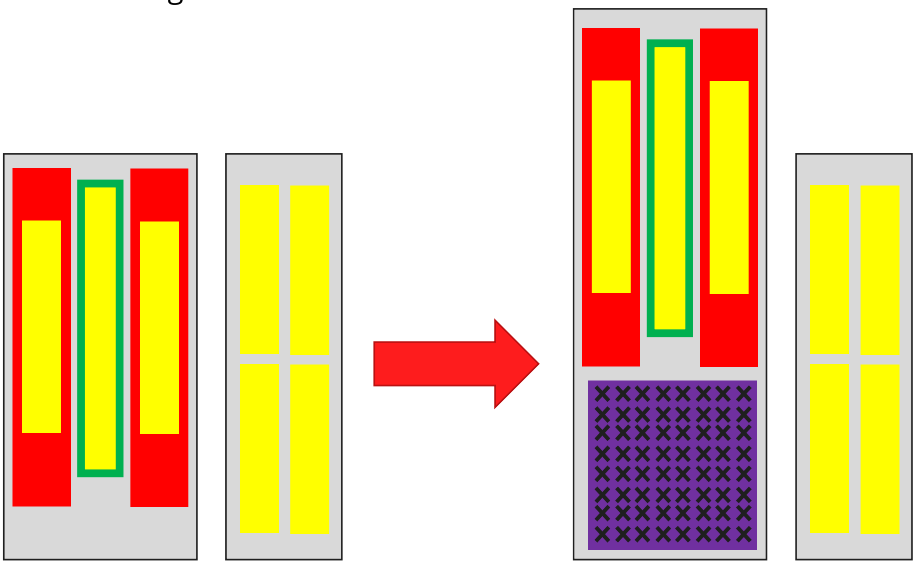


Options for Adding mMIMO to Existing Macro Sites

This advantage of this configuration is that the overall antenna count per sector does not increase. The main disadvantages are the increased height of the passive antenna system or a reduced coverage footprint due to the constrained number and dimension of arrays in this stacked architecture. This scenario also requires the MNO to re-optimize the existing network, which can be quite challenging.

Scenario 3

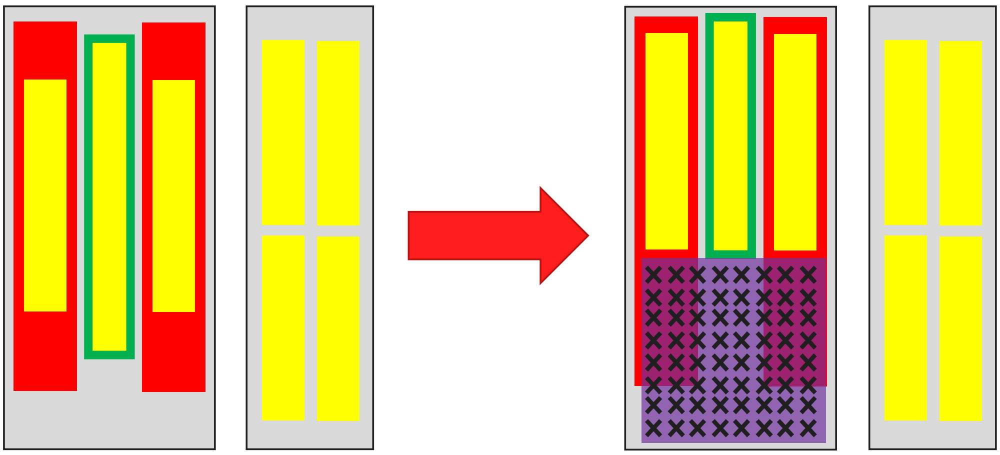
A third option is to add the active antenna to one of the passive antennas in a stacked architecture, although depending on the frequency bands, a side-by-side structure might be more appropriate. In this case, the new active antenna is largely an independent system with limited shared components aside from common housing.



This advantage of this configuration is that the overall antenna count per sector does not increase, and it could have minimal impact on the existing network. The main disadvantage is that the size and weight of the stacked unit could be considerable, making the system difficult to deploy if these aspects are not optimized.

Scenario 4

In this option, the active antenna system is highly integrated into a passive antenna with an interleaving architecture. It is referred to as an interleaved APA. In this example, the 3.5 GHz mMIMO radiating layer is interleaved with the low-band arrays and shares some common electrical and RF components as well as the structure of the passive antenna to improve the mMIMO thermal management system.



Options for Adding mMIMO to Existing Macro Sites

The main challenge of this option is to design an interleaved architecture that does not affect the RF performance of any frequency band. As shown in Table 1, this configuration is closest to the ideal scenario.

	Site negotiations and related costs	Visual Impact	Trade-offs on RF Performance
Scenario 1: Standalone mMIMO using three antennas	--	--	++
Scenario 2: Standalone mMIMO using combined passive antennas	-	-	+
Scenario 3: Stacked APA	-	-	+
Scenario 4: Interleaved APA	++	++	+

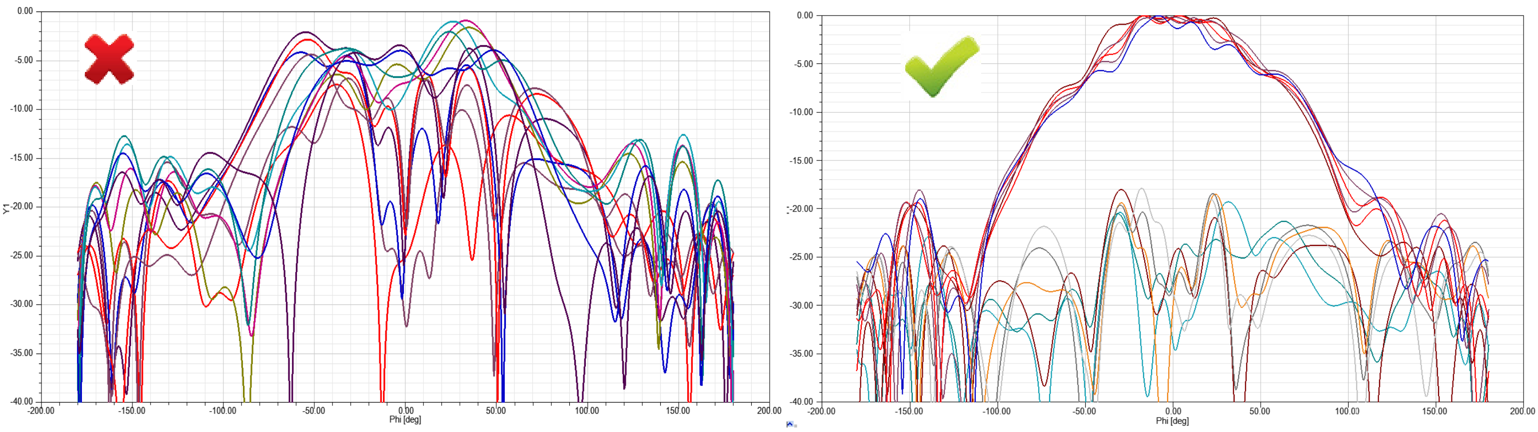
Table 1: Scenario comparison

Solving the Interleave Challenge

An effective and well-performing antenna system (passive or active) requires a highly efficient and well-designed radiating layer. In the case of mMIMO antennas, even digital processing and algorithms cannot fully compensate for the weak antenna radiating performance that results from a poorly designed radiating layer. This is even more critical in a multi-band or multi-radio access technology (RAT) environment.

In an interleaved APA, the high density of mid-to-high-band radiating elements, along with their close proximity to low-band arrays, can lead to RF pattern distortions in all bands, adversely affecting system performance. If the interleaving structure is not properly designed, it results in severe degradation of RF performance, including gain and side lobe performance, leading to an inefficient use of costly radiated power. Using our expertise in antenna design, RFS has expanded upon solutions and techniques that significantly reduce field coupling and interactions among radiating elements.

Figure 1 below shows two examples of radiation patterns generated by a 3.5 GHz mMIMO 8x8 array interleaved with a low-band array and compares the distortions in a poorly designed system to the RFS system.

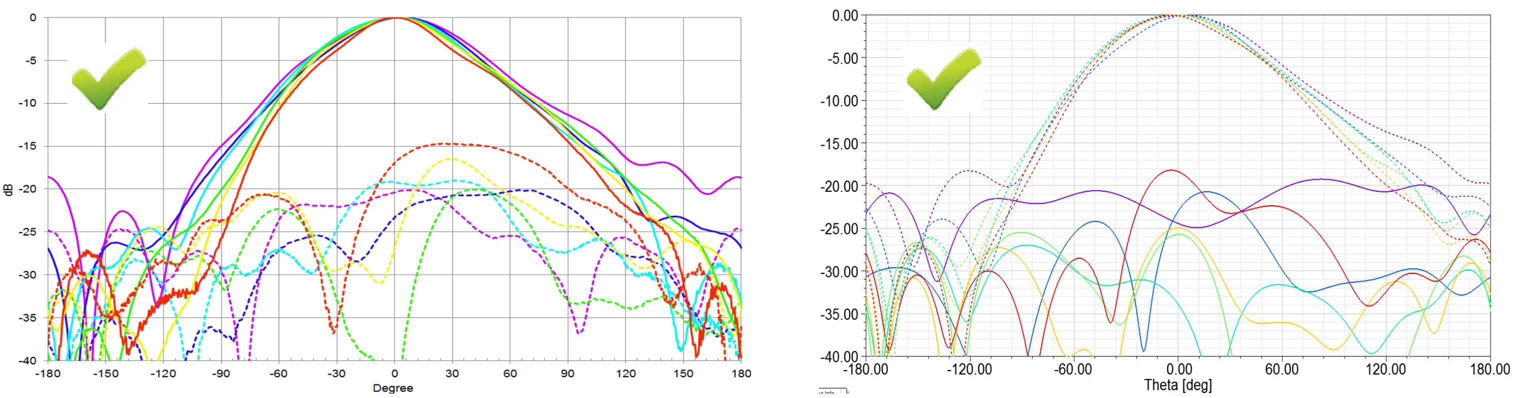


Poor Design

RFS Design

Figure 1: 3.5 GHz mMIMO interleaved radiation patterns with a poor design versus the RFS design

It is equally important to ensure that low-band array performance is not significantly impacted when interleaved with the 3.5 GHz array. Figure 2 shows the radiation patterns of the low-band array on its own and when interleaved. When interleaved, there is very limited, if any, degradation and only a slight decrease in gain.



LB Alone

LB Interleaved with 3.5GHz

Figure 2: Low-band radiation patterns with and without interleaving

The Benefits of APA

A key benefit of an interleaved APA is the simplification of deploying a new layer of active antennas in dense urban areas where site constraints are very often MNOs' first challenge. In addition, tightly integrating an active antenna with a passive antenna in the same enclosure provides the opportunity to reduce several other sources of design complexity as well as CAPEX and OPEX. These benefits raise questions about the viability of the business case for active antennas.

To illustrate, let's focus on thermal management. Thermal dissipation — removing excess heat originating from electronics — is one of the most important technical challenges as we move toward the mass deployment of mMIMO. An efficient thermal management system is one where temperature differences between the environment and sensitive electronic components, along with heat flux (W/cm^2), are minimized. This is necessary to ensure that all components work safely within their thermal boundaries so that reliability is not adversely affected or compromised. The mMIMO radio systems developed today largely achieve this, but only by using massive and heavy heatsinks (heat exchangers) or by using fans for forced convection.

Within an APA, the passive antennas already have metallic structures with significant surface area and sufficient thermal mass. If these structures are incorporated in a clever manner, and the chimney effect is maximized, they can be used as part of the heat exchanger in an mMIMO system without fans or additional bulk. This reduces the weight of the overall system and enables a much more efficient and robust system. In addition, the available volume in a passive antenna can be efficiently used to separate electronic boards, such as the digital and power supply boards, and to prevent a concentration of heat generation close to sensitive components such as power amplifiers.

Figure 3 shows a thermal simulation for one of our prototypes. Note that the number of hotspots is minimal and the maximum temperature difference between the structure and the ambient environment is within 40°C (104°F). Based on RFS estimates, this temperature elevation is at least 10 degrees lower than in a standalone active antenna.

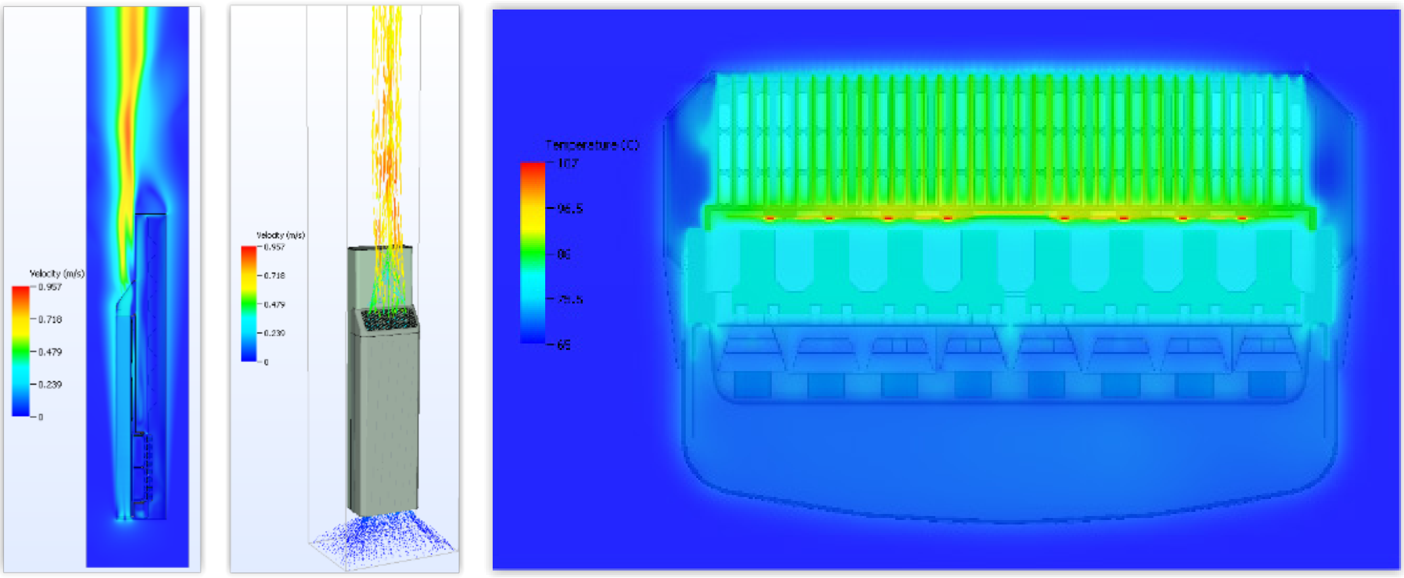


Figure 3: The efficiency of APA for thermal dissipation

Conclusion

- Simplify adding and deploying mMIMO systems on existing crowded macro sites
- Minimize visual impact and TCO for towers by reducing wind load
- Use shared components between mMIMO and passive antenna structures allows to lower the initial cost and weight compared to other options
- Require no additional antennas in a sector
- Use passive antenna volume and a mechanical frame to enable an efficient thermal management system, resulting in a more robust and reliable system
- Minimize additional OPEX and site negotiation requirements

ABOUT RFS

Radio Frequency Systems (RFS) is a global designer and manufacturer of cable, antenna and tower systems, plus active and passive RF conditioning modules, providing total-package solutions for wireless infrastructure.

RFS serves OEMs, distributors, system integrators, operators and installers in the broadcast, wireless communications, land-mobile and microwave market sectors. As an ISO compliant organization with manufacturing and customer service facilities that span the globe, RFS offers cutting-edge engineering capabilities, superior field support and innovative product design. RFS is a leader in wireless infrastructure.

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