



# WHITE PAPER: **Eight Parameters for Optimal DAS Performance**

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# Executive Summary

Investing in a Distributed Antenna System (DAS) is not an easy decision. It requires in-depth evaluation with many parameters playing a big role in the process. Any investment in a data-driven 4G solution must be measured by the value and data volume it yields, not the up-front CAPEX. The need for better coverage and, more importantly, the data capacity of the solution, should be the top priority. The investment must be evaluated based on the volume of data it can produce on both downlink (DL) and uplink (UL).

The ability to handle an ever-increasing volume of data is often the focus of an evaluation process; therefore, it is important to ensure that the investment in a DAS yields the highest data capacity

possible, both for now and the foreseeable future. It is a known fact that data traffic grew 50 percent from Q3 2015 to Q3 2016, and that voice traffic has more or less stagnated (Figure 1).

Predictions show that the data volume produced in mobile networks will increase by a factor of 8 from 2016 to 2022. At the same time, Annual Revenue per User (ARPU) is falling in the mobile network, which is the main challenge we face in the mobile industry today.

The conclusion is that you need to invest in a DAS that provides the best level of data performance per investment, and that can be upgraded easily in the future with additional bands and features to support growth. Evaluating an investment

in a DAS by focusing only on brute downlink power is insufficient, and does not take into consideration the true performance of its data production.

Unfortunately, most DASs are assessed on downlink performance only. This is a big mistake. The “DL Level KPI” is important, and both the DAS and the design should comply with that KPI. However, the benchmark parameter should be the data capacity delivered by the DAS. Both the downlink and uplink data production per investment must be evaluated. After all, the motivation for implementing a DAS is a need for more data capacity with less investment. There could be a big disconnect between the signal level and the data capacity, depending on the quality of the DAS. The following paper introduces the key parameters to consider:

- Making the DAS investment as efficient as possible

- Ensuring maximum performance
- Providing low total cost of ownership (TCO)

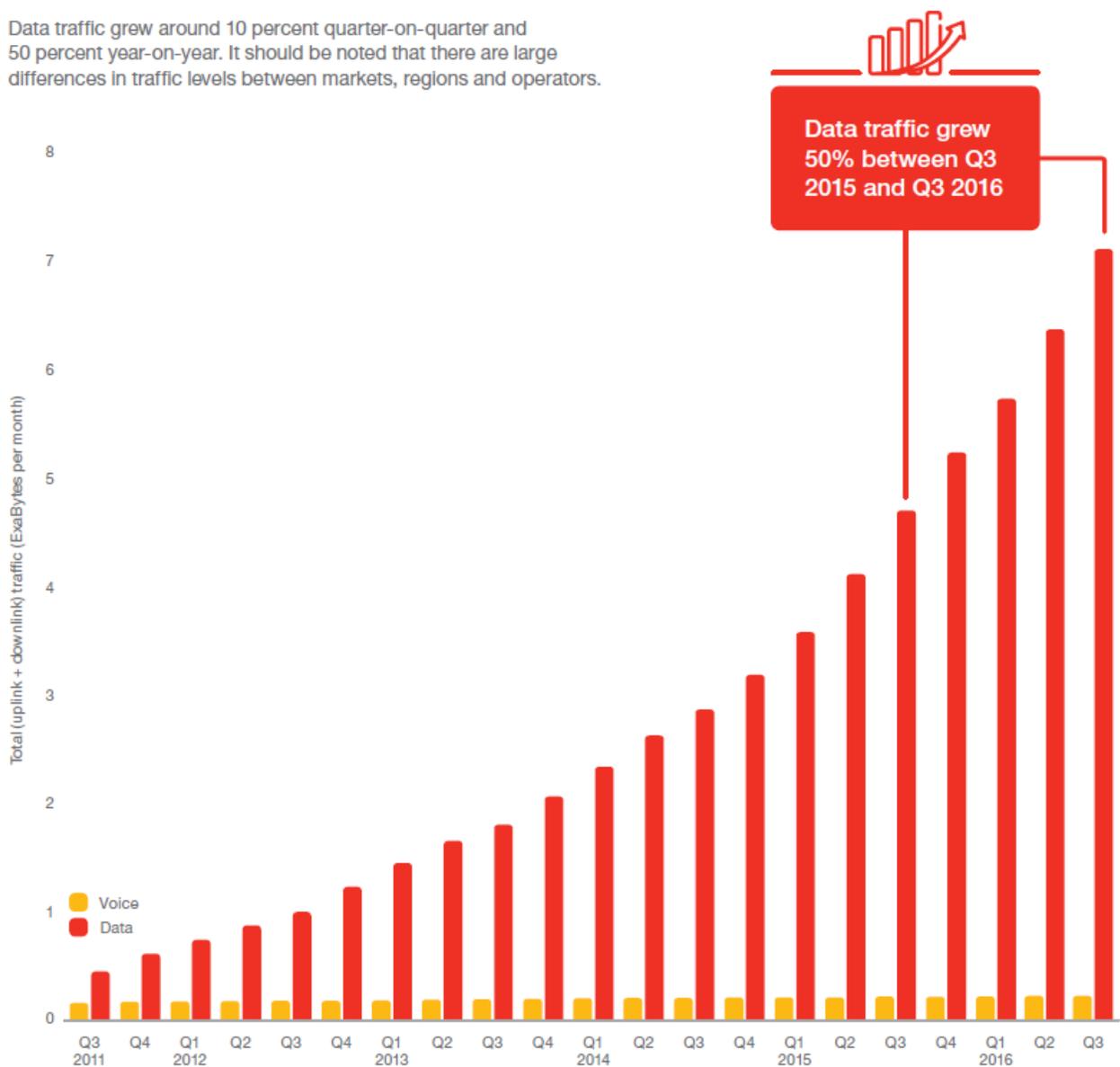
### *Facts*

- Mobile operators will need to **produce more data for less.**
- Mobile operators work with fixed RF spectrum, so they need to drive **as much data over the spectrum as possible.**

Only a high-quality DAS with transparent RF performance can ensure maximum data transport to the user. This provides the best business case for mobile operators.

In this document, we will discuss some of the main parameters of RF performance, and their impact on a network’s throughput and efficiency.

Data traffic grew around 10 percent quarter-on-quarter and 50 percent year-on-year. It should be noted that there are large differences in traffic levels between markets, regions and operators.



Source: Ericsson traffic measurements (Q3 2016)

<sup>1</sup> Traffic does not include DVB-H, Wi-Fi, or Mobile WiMAX. VoIP is included in data traffic

Figure 1: Global data and voice traffic 2011-2016.

## The Basic RF Performance of the DAS Really Matters

Data is the driver and main reason for new, more efficient solutions, while the most valuable asset of the mobile operator is its frequency spectrum and the RF bandwidth it licenses.

The “data challenge” (Figure 1) is the main reason to migrate from 2G, 3G, 4G, and MIMO, apply carrier aggregation, and support LTE, LTE-Advanced to produce more data volume over the same RF spectrum at a lower cost.

You need to maximize the volume of data and earned revenue of the investment. Each mobile operator must

maximize spectrum efficiency, by ensuring that network capacity is ample and efficient, as well as demonstrating a significant return on investment (ROI).

**Any mobile operator's main asset is its allocated RF spectrum, and assuring the highest possible data throughput over the limited spectrum range is the most important parameter when evaluating a DAS supplier.**

## Evaluating the Basic RF Performance is Important

If we focus on the essential function of a DAS we can conclude that:

The purpose of the DAS is to transport RF signal on both the downlink and uplink with minimum signal degradation, ensuring high data throughput to all users. In other words, the DAS must be as transparent as possible.

The RF performance information presented in datasheets is important, but sometimes hard to compare and evaluate. Below are a few key points to keep in mind:

- The performance of the DAS on both uplink and downlink is critical. High quality ensures high capacity and a more compelling business case.
- The impact of noise figure, degradation, distortion, and delay must be evaluated and minimized.
- Be sure to evaluate the actual performance of your DAS equipment (some datasheets can be difficult to decipher).
- Remember that “3GPP compliant” is not a measure of quality.
- Ask for real operational RF power, EVM, NF numbers and test reports.
- Avoid relying on terms such as “typical,” “maximum,” and “better than,” which cannot be quantified.

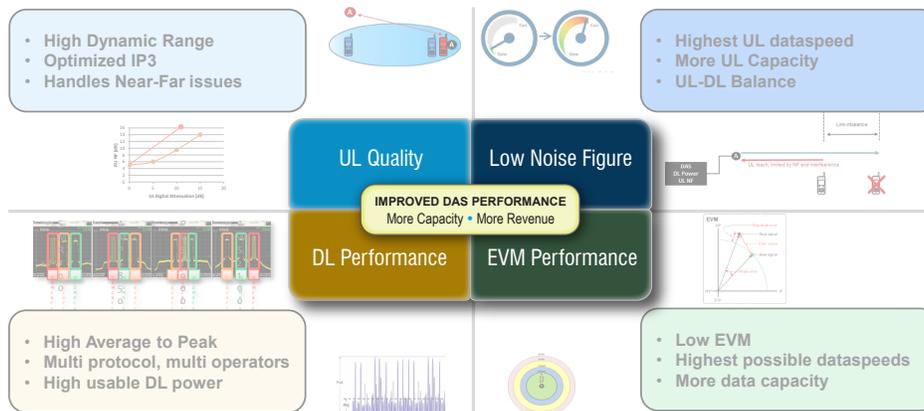


Figure 2: The four quadrants of DAS performance: low noise figure, error vector magnitude (EVM), downlink (DL) performance, and uplink (UL) quality.

# 1. Noise Figure

When considering mobile services, we need to make sure there is balance between the downlink and uplink service range of the DAS. It does not make sense to have good service on the downlink if the uplink struggles to meet the demands of the user base.

More and more, we see a fifty-fifty split between the data-loads on the UL and DL. However, for some venues, even more data is passed on the uplink than on the downlink, mainly caused by users uploading pictures and videos to social media.

## 4G Uplink Example

With any DAS, you face the challenge of noise figure (NF). NF is degradation of the signal-to-noise ratio (SNR) caused by signal loss on passive DAS components. Increased NF will impact the uplink service range. The more NF, the shorter the UL range, the less users the DAS can support. In such a scenario, more antennas are needed to support users (leading to more loss, more NF, etc.).

The basis for the RF link budget is an evaluation of the UL and DL performance. Even the most common RF planning tools do not consider the UL in the planning process. However, this is critical since the UL capacity needs to be balanced against that of the DL.

**Keep in mind that signal loss on passive DAS components = noise figure. The greater the loss, the higher the NF, and the greater the degradation of the service range on the UL from the DAS antennas.**

In the following example (Figure 3), we estimate the UL service range per DAS antenna in a 4G/2100 MHz system on a 10 MHz LTE carrier. We evaluate how many antenna locations are needed to cover a standard office building with a semi-open environment. Obviously, it is a generalized estimation, and more detailed planning would be needed for an actual case, but it clearly shows the impact of NF within a DAS.

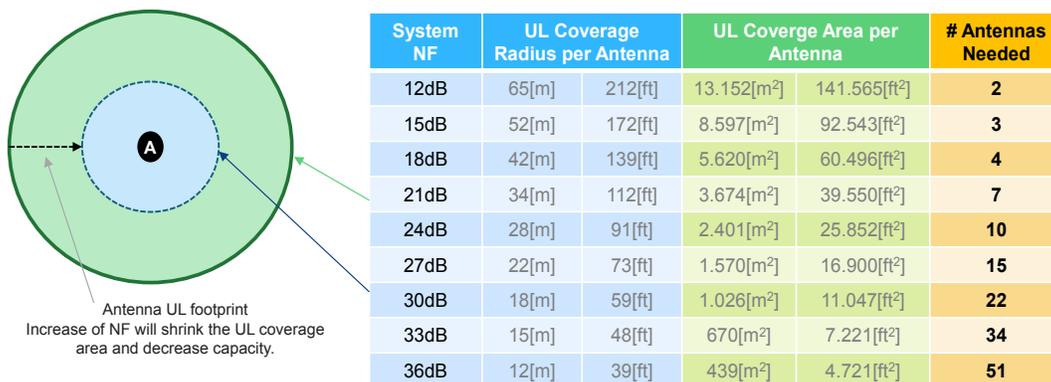


Figure 3: 4G-LTE uplink estimation of DAS antennas needed / service range from a typical DAS in a 200,000ft<sup>2</sup> / 18,800m<sup>2</sup> office building versus the NF / loss of the DAS.

The example above covers NF/passive losses from 12 through 36dB, showing the UL footprint in both distance and area. As a standard, 20 percent overlap between the antennas is included.

We can see from the example that the difference between 21dB and 30dB of NF limits the range from 34 m to 18 m, or about half the distance. But keep in mind that the coverage area goes from 3674 m<sup>2</sup> to 1026 m<sup>2</sup>. This is a 27 percent decrease in the original service area, so a factor of 3-4 is needed in the number of antennas to compensate (and more antennas lead to increased NF).

**Downlink coverage is useless if there is no UL service. It only serves as a source of interference.**

### Did you know:

- **Passive losses increase the NF and limit the data-throughput on the uplink.**
- **This limitation will impact the business case of the solution.**
- **You should ask your supplier for the complete end-to-end noise figure of the system.**
- **There needs to be balance between the UL noise figure and the DL power of the system, to ensure balance between UL and DL coverage and services.**

### JMA Wireless Low Noise:

- **Highest possible data rates on the uplink**
- **More data users serviced per investment**
- **High uplink capacity**
- **Less antennas needed to balance the link**
- **More antennas can be connected to one sector, maintaining high UL performance (passive loss = noise figure)**



## 2. Near-Far Optimization

Distributed antenna systems are deployed at different types of venues. One common challenge facing different DAS implementations is the fact that some mobiles are very close to antennas, while others are at the fringe of the coverage area.

The challenge, especially on the uplink, is the ability to handle both the close and distant mobile phones, sometimes referred to as the “near-far” challenge.

### The Near-Far Challenge

The DAS and base station face the challenge of multiple mobile devices transmitting at the same time within the same RF band of service. The base station must selectively identify the mobile in service while at the same time ignore the signals from other mobile devices.

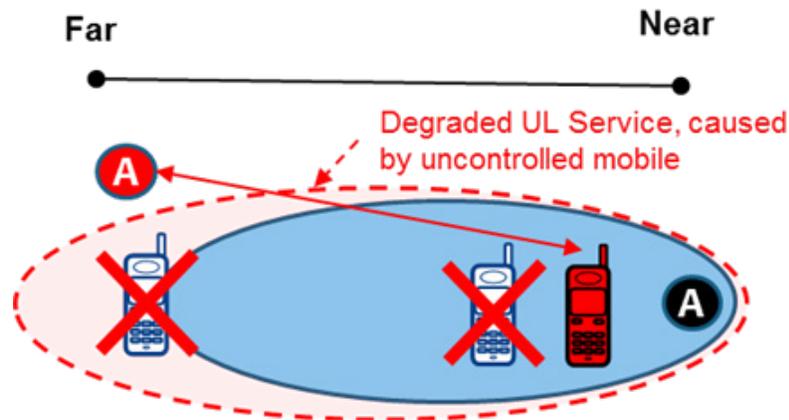


Figure 4: A simplified scenario in which a mobile (red) is close to the DAS antenna (black) servicing mobile phones in the blue area. The service area will shrink from the intended area (red dashes) due to the increased noise introduced by the “alien” / non-controlled mobile device, causing loss of service to the intended customers (blue mobile devices). In extreme cases this may even collapse the UL footprint of the DAS service area, not only for the local antenna or remote units, but for the whole cell connected to that antenna.

The main challenge is that the mobile devices near the servicing antenna will reach the DAS system at much higher signal levels than more distant mobile devices. Power control that adjusts the transmit power from the mobile phones will, to some extent, compensate for the difference in the link-loss of mobile phones near the DAS antenna and mobiles farther away from the antenna. However, there are limitations:

- Mobiles might be so close to the DAS antenna that they “saturate” the power control, thereby preventing UL transmit power from being adjusted any lower.
- Mobile phones that are not in power control are at a high risk of degrading the service of the whole sector connected to the DAS.
  - This could be caused by mobiles serviced by other cells within your own network. In this case, there is no free capacity to “hand over” to the DAS cell.
  - It could be that mobiles cannot be handed over to the DAS cell if there are missing neighbor relations.
- The biggest risk is often “alien mobiles,” mobile devices that operate in the same frequency band, but are serviced by another mobile operator.
  - A worst-case scenario is when operators are not serviced well inside a building while on the same DAS.
  - In this case, the “alien mobile” uses high power to reach the distant outdoor base station located just under your DAS antenna, causing noise and degradation of your UL service on that sector.

## The JMA Wireless Solution to the Near-Far Challenge

One of the advantages of the JMA Wireless TEK0 DAS platform is the ability to control the gain and attenuation at different stages throughout the DAS, allowing it to be more resistant to potential near-far UL problems, impacting only the system NF while still maintaining a high IP3.

This will ensure that the JMA Wireless TEK0 DAS solves the near-far challenge by preventing any degradation of the base station, and avoiding any negative impact to the DAS remote caused by high UL RF power.

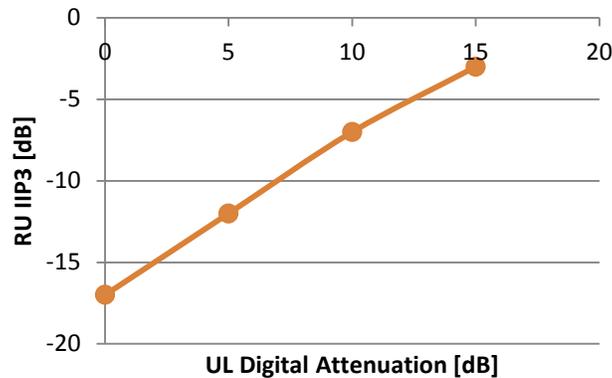


Figure 5: The JMA UL digital attenuation will improve the “blocking point” (IP3) of the remote unit, allowing the system to handle high-level UL signals without creating noise and service degradation.

A crude way of improving near-far performance is to focus on the DAS before the front-end of the remote unit. The problem with this approach is made clear in Figure 4. This will have a 1:1 direct impact on the noise figure of the system and will limit the UL data speed.

In Figure 5, we see that JMA Wireless TEK0 DAS can be adjusted in digital UL attenuation up to 15dB, thereby, improving the blocking point upto a very strong signal of -3dBm, without impacting the system NF 1:1 as shown in Figure 6.

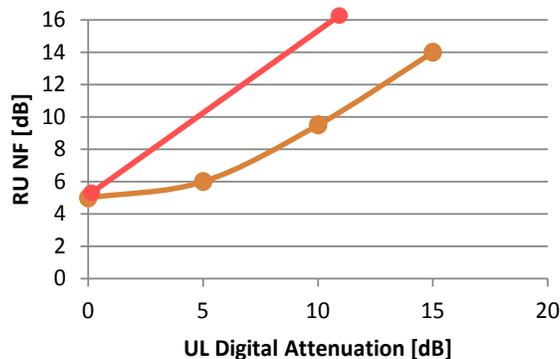


Figure 6: With the traditional method of applying UL attenuation to improve the IP3 (red line), there is a 1:1 impact to the front-end of the system and the system NF. The JMA Wireless TEK0 DAS (brown line) has a limited impact on the NF when applying attenuation. The brown line shows that an extra 5dB of UL attenuation increases the NF by only 1dB, not 5dB as in the traditional configuration.

**DAS solutions are installed in the real world, not in a lab. Near-far issues are a real concern, and the DAS should be able to handle them with a minimum impact on system performance.**

### JMA Wireless Optimized UL Performance

In Figure 6, it is evident that the optimized tuning of the JMA Wireless TEKO DAS allows for improvement of IP3 with only limited degradation of the system NF. This allows the only remote unit affected by strong UL signals to be optimized (as shown in Figure 7) and to handle the issue with a minimum impact on its UL footprint.

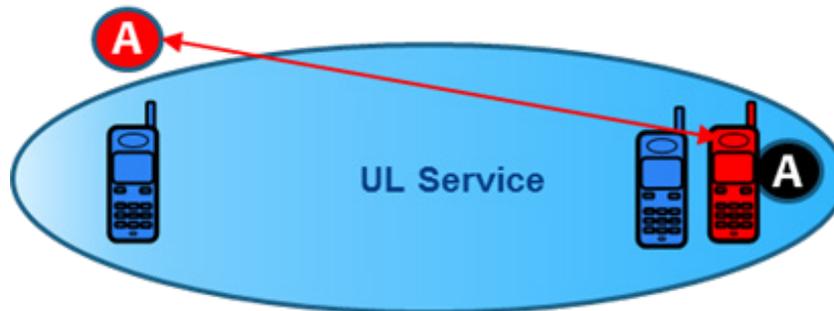


Figure 7: Thanks to the optimized IP3 tuning of the JMA Wireless TEKO DAS, the system is very resilient to strong “alien” signals (red mobile) without compromising the system NF (unlike other DAS vendors).

### UL Performance is Critical

We have already addressed the challenge of a UL data load increase within a network, and the ability to support maximum UL performance due to the JMA Wireless low noise figure, which is essential. In addition, the ability to handle the near-far challenge without compromising the system NF is crucial.

These DAS solutions are installed in the real world, not in a lab, and near-far issues are a real concern. Once you block the UL of your remote unit, the noise increases at the risk of “collapsing” the entire cell, resulting in a loss of service not only to the users associated with that particular antenna and remote units, but to the whole cell connected to the DAS.

**There is only one solution to the near-far challenge: an optimized IP3 with minimum impact on the system NF.**

It is also important to realize that once high UL signal starts distorting your system, the noise will be “in-band” of your intended service; therefore, it is not possible to apply a filter later in the stage to cure the problem. There is only one solution to the near-far challenge: an optimized IP3 with minimum impact on the system NF.

## Did you know?

- Uncontrolled mobiles can impact the performance of a DAS if it cannot cope with the “near-far” issues.
- Other mobiles from other operators are often the biggest challenge since they might be in the same band, transmitting high power to reach their own system, close to your antennas.
- A multi-operator approach will ensure that all mobiles are on the same system, using the same UL transmit power, thus limiting the “near-far” problem.
- Adding an attenuator in-front of the remote unit is a “typical” solution to handle “near-far”, but this will increase the NF, decrease the throughput and limit the businesses.

## JMA Wireless Near-far Optimization:

- Ensures high performance in venues where some mobiles are close to antennas
- Prevents uncontrolled mobiles from increasing the noise in the whole DAS cell
- Optimizes IP3 with limited impact on system NF
- Produces stable connections, with no dropped calls due to “RF blocking”
- This is very important in areas such as:
  - Shopping centers
  - Stadiums
  - Metro systems
  - Other large venues



### 3. Error Vector Magnitude (EVM)

Since the advent of 2G mobile systems, 3G and 4G are utilizing more complex adaptive modulation schemes to maximize the throughput over the given bandwidth. This is known as “spectrum efficiency.”

In Figure 8, we can see the relation between the signal-to-interference-plus-noise ratio (SINR) and the used quadrature amplitude modulation (QAM) step and Master Coding Scheme (MCS). The better the link quality, the higher the throughput.

**The better the quality of the DAS, and the signal to noise of the RF link, the higher the data speed over the RF channel.**

#### DAS Performance is Much More than the Signal Level

As mentioned earlier, the biggest mistake when selecting DAS types and designs is evaluating on the downlink signal level only.

Far too often, this is the only KPI given serious consideration. This is a flawed strategy since DAS is commonly implemented to improve data coverage, and to provide users with higher data speeds, thus reducing the “production cost” per Mb and increasing network revenue.

The network evaluates the quality of the radio link, applying the highest-possible modulation format given the actual radio link quality, thereby maximizing throughput over the same spectrum in steps, based on the actual SINR (Figure 8).

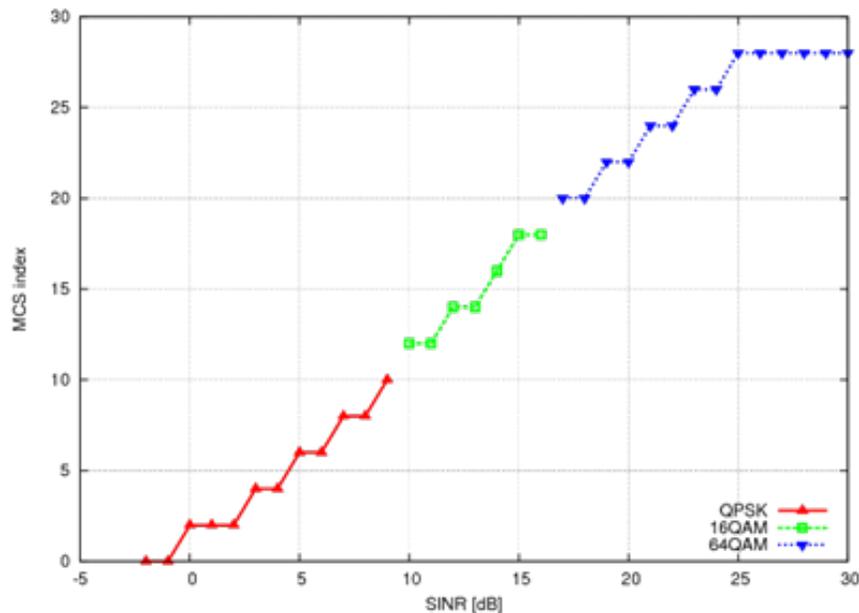


Figure 8: As seen in the graph above, the LTE system will step up and down between various modulation formats, depending on the signal-to-interference-plus-noise ratio (SINR). Please also note that there are “sub steps” within the three QAM steps.

### 3GPP Specification on EVM is Insufficient

Please note that an ideal DAS will have a very low EVM, ideally close to or below one percent distortion. If not, data throughput is impacted, the spectrum efficiency drops, and your revenue potential over the spectrum drops. 3GPP allows up to 12 percent EVM. Be aware that being “3GPP compliant” is not good enough, and that the base station, passive equipment, and radio channel will add to the EVM distortion.

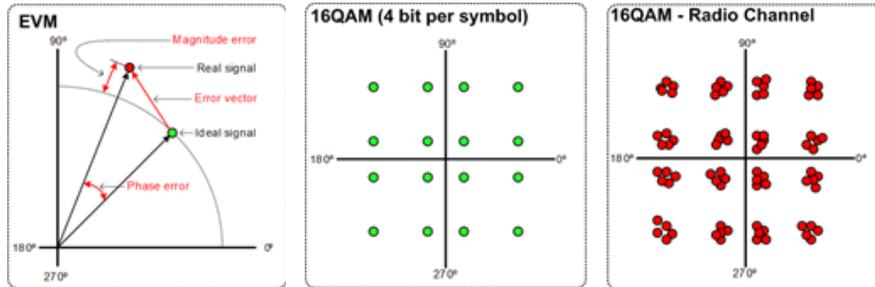


Figure 9: One example of the error vector magnitude (EVM), the ideal theoretical modulation constellation shown in green for a 16 QAM signal. After transport through distribution equipment and air interface, we experience the “real” constellation in red, and the EVM is the discrepancy in phase and level between the theoretical (green) and the real (red) location of the information bits.

In Figure 9, we see the principle of EVM illustrated. The strict maintenance of low EVM in a DAS is important since it reflects on the “data production” of the implemented solution, thereby making its business case. Remember that any EVM degradation of the DAS is added to the EVM error already present in the system. Do not take “3GPP compliant” as a measure of quality; low EVM is a much better way of improving the performance and business case of the network.

Any radio channel will perform better when the margin between the signal and the noise is improved. Modulation accuracy and transparency of the signal (modulation) must be maintained.

### EVM Will Impact Your Business Case

Like the other key parameters for DAS equipment, EVM plays a big role in the “production cost” per Mb of data produced. The better the EVM, the more throughput per investment, resulting in a better business case.

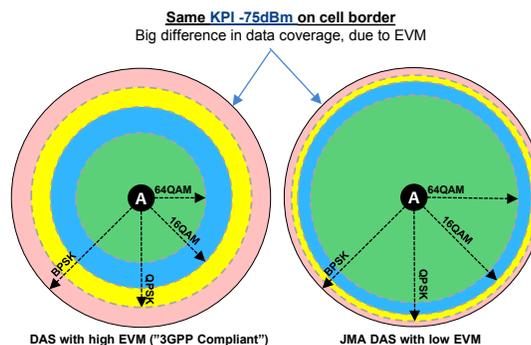


Figure 10a: One example of the Error Vector Magnitude (EVM), the ideal theoretical modulation constellation shown in green for a 16 QAM signal. After transport through distribution equipment and air interface, we experience the “real” constellation in red, and the EVM is the discrepancy in phase and level between the theoretical (green) and the real (red) location of the information bits.

An example of the principle of the EVM performance impact is made clear in Figure 10a, showing two DAS solutions feeding an antenna. Both systems provide the same DL KPI of -75dBm signal level, but the JMA Wireless TEKO DAS exhibits a low EVM; thus, the 64 QAM coverage area is significantly larger, servicing more data capacity in the same footprint.

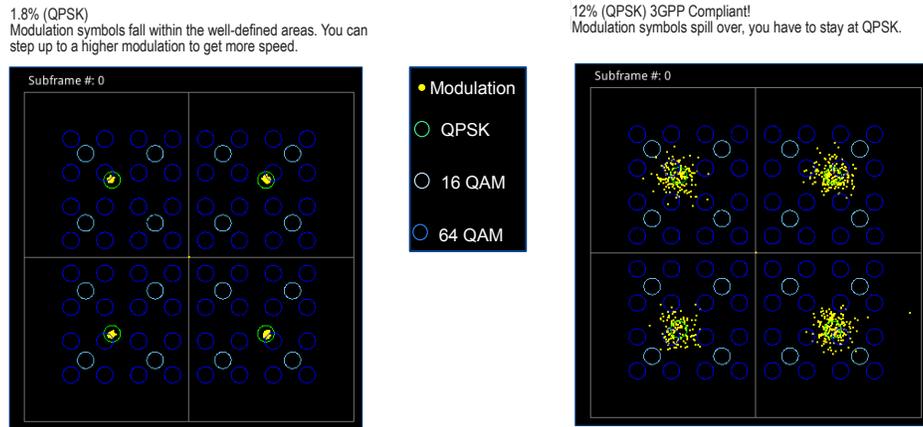


Figure 10b: EVM measurements of an actual DAS, using QPSK constellations. These charts also show the ideal locations of QPSK (green circles), 16 QAM (light blue circles) and 64 QAM (dark blue). Clearly, the 1.8% EVM is close to the ideal locations, but the 12% EVM (still 3GPP compliant) will never step-up to higher modulation and will limit throughput.

In Figure 10b it is evident that the 12% 3GPP EVM chart on the right will prevent the system from achieving higher modulation rates, thus limiting the data-speed. So even if the signal level is compliant with the KPI, the lack of EVM quality limits the throughput, negatively impacting the business case.

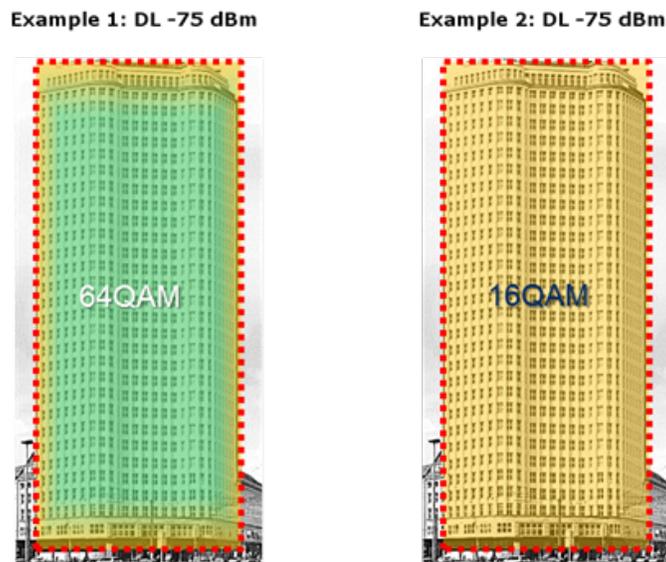


Figure 11: This illustration demonstrates a simplification of the EVM performance impact on the data production in a building. The same building, with the same DL KPI (-75dBm) is depicted. However, Example 1 shows the JMA Wireless TEKO DAS performing at 64 QAM (green) throughout most of the building, impacted only at the perimeter due to interference from macro signal (orange), where the mobile system steps down to 16 QAM. Example 2 depicts a low-cost DAS, which distorts the signal so much that it cannot regenerate to 64 QAM, but instead distributes only 16 QAM throughout the entire building.

**Bad EVM will increase the noise on the link. Combined with noise from other sources of interference, typical nearby cells will degrade SINR and degrade the data speed, resulting in less users served and increased cost per Mb.**

### What Happens When EVM is Bad?

When EVM is rising, and the performance degrades, the result is increased noise on the RF link, resulting in a decreased SINR. When the SINR decreases, the mobile system steps down in modulation scheme as per Figure 8, resulting in lower throughput, decreased data speed, and less data production in the coverage area, which means less users serviced.

Let's review the example in Figure 11 and apply some typical numbers (10MHz, 4G LTE carrier).

Example: same building (20.000 m<sup>2</sup>), same signal level, same base station and backhaul.

**JMA Wireless TEKODAS** performs 64 QAM in 80 percent (60 Mbps) of the building, 16 QAM in 20 percent (15 Mbps)

- 16.000 m<sup>2</sup> @ 60 Mbps
- 4.000 m<sup>2</sup> @ 15 Mbps
- Average 51 Mbps

**Another vendor** performs at only 16 QAM throughout the entire building

- Average 15 Mbps

WEB browsing is 0.5 Mbps in average load

- JMA Wireless can support  $51/0.5 = 102$  users
- Other supplier  $15/0.5 = 30$  users
- JMA Wireless is 340% more efficient in capacity and traffic production on the same investment in base stations and backhaul with the same signal level KPI.

### Tier 1 Operators Demand Better EVM than 3GPP

Key mobile operators are focused on maximizing the data production in their DAS and typically will demand better EVM performance than specified by 3GPP to ensure a solid business case and future-proof system.

The key requirements for UL and DL EVM are:

- EVM preferably better than 3 percent at 256 QAM for LTE/A support
- EVM at or below 7.5 percent (at full power) on all bands

## No Chain is Better than its Weakest Link

Keep in mind that the SINR and EVM will also be affected by the EVM from the source to the DAS, so the EVM from the base station is added to the EVM of the DAS. The increased SINR due to the EVM from the base station is added to the potential interference from other cells, degrading total performance. Bad EVM will raise the noise on the link and degrade the capacity and throughput. Some DAS vendors are at 6-12 percent EVM, but are still “3GPP compliant”. You should ask your DAS vendor for EVM test reports, and do not accept “3GPP compliant” as an indication of quality.

## Did you know?

### EVM performance is often more important than the signal level.

- Two systems with the same signal level will provide different data-rates, depending on the EVM performance.
- EVM will be even more important in future systems once 256 QAM is applied.
- You should ask your vendor for real EVM measurement reports. The 3GPP specification alone is not sufficient.
- Once the EVM is determined to be poor, there is no remedy, no matter the signal level.

### JMA Wireless Low System EVM:

- Transparent transport of RF signal
- Maximum data speed on UL and DL
- JMA Wireless is better than 1 percent EVM



## 4. Downlink Power from the Remote Unit

Over the years, mobile networks have migrated from supporting basic voice service and narrow bandwidth to much higher data speeds over the same RF spectrum. To support this migration, more complex modulation schemes are being used, from 2G to 3G, and now 4G.

A DAS is often shared among several service providers (Figure 12), using the same band to operate their services, sometimes with a mix of different services on the same remote unit.

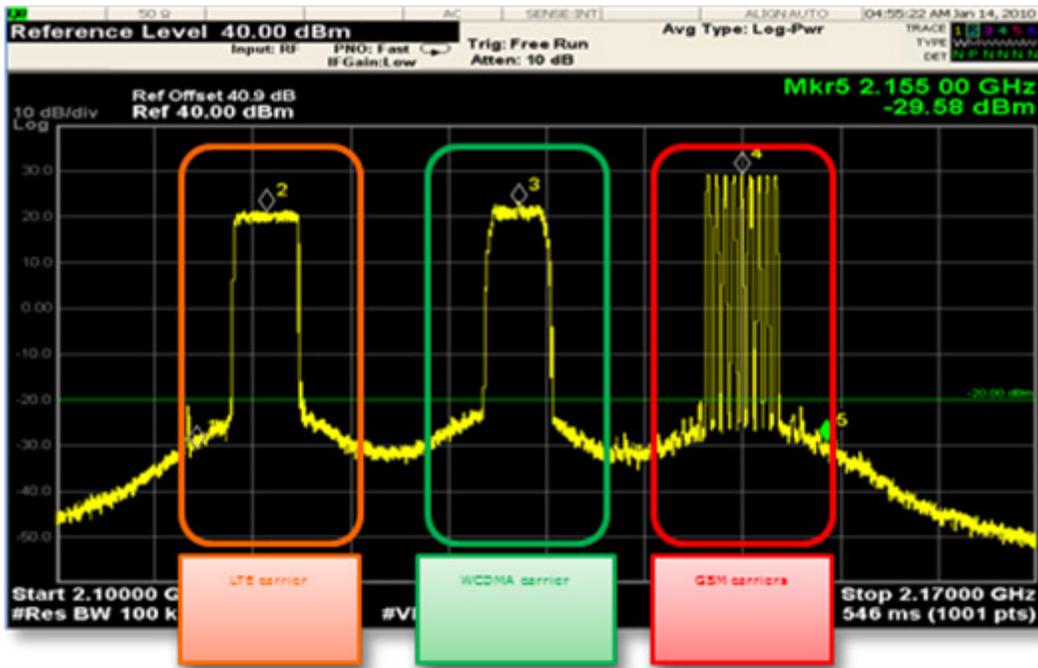


Figure 12: One example of sharing the same spectrum: in this case, the 2100MHz band between 2G, 3G, and 4G services on the same DAS remote unit.

The RF amplifiers in remote units must have enough headroom to support the average to peak difference of the modulation.

### Mixing Services on the Same Band Requires High Quality, Linear Amplifiers

When you modulate an RF signal, you will have a variation in the power transmitted from the amplifier depending on the modulation type. You will have the average load of the amplifier, but also peaks that the amplifier must be able to support while transmitting the modulated signal.

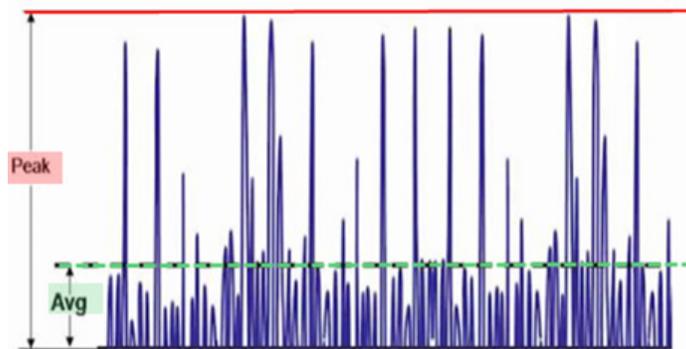


Figure 13: Example of the load (power) that the RF amplifier (remote unit) must support when transmitting a modulated signal.

## Watch out for the Power Levels on the Data Sheets

The amplifier needs to have the same high performance throughout the band end-to-end.

Watch out for the RF transmit power rating when comparing vendors. It is difficult to compare vendors if they do not use the same metrics and same PAR (peak-to-average power ratio) values. Some vendors provide compression (non-linear P1dB) power performance information, which is not useful as it relates to servicing users. You should ask your DAS vendor to provide the useable RF transmit power level, not the P1dB. Also, ask for the PAR.

## Did you know?

- You should compare the different vendors using the same RF power metrics.
- It is very important the amplifiers have headroom to cope with the LTE modulation (PAR).
- You should ask your vendor for PAR performance, and operational RF power (not P1dB compression value).

## JMA Wireless High Quality Remote Support:

- 2G, 3G, and 4G support at the same time, on the same band
- Simultaneous operation, even in a “mixed” environment
- 9-12 dB of “headroom” to cope with modulation peaks, while some other vendors state the “peak” power in their datasheets
- Customers can actually use the power figures provided by JMA Wireless
- Results in more DL capacity (supports more bandwidth)



## 5. Link Balance and Delay

Any radio link must be well-balanced. DL coverage has no purpose if there is no UL signal (Figure 14). As addressed earlier in this white paper, the JMA Wireless TEKO DAS ensures highly useable DL power, with low EVM. The JMA Wireless TEKO DAS low noise figure and near-far capability ensures maximum performance in all types of deployments.

### Balancing the Link

Be careful both when evaluating the performance of your DAS vendor and when designing the DAS solution. Introducing imbalance will only cause problems with interference, noise, and erroneous offset of power control. These problems will most likely not only impact the performance of the DAS, but the adjacent network as well.

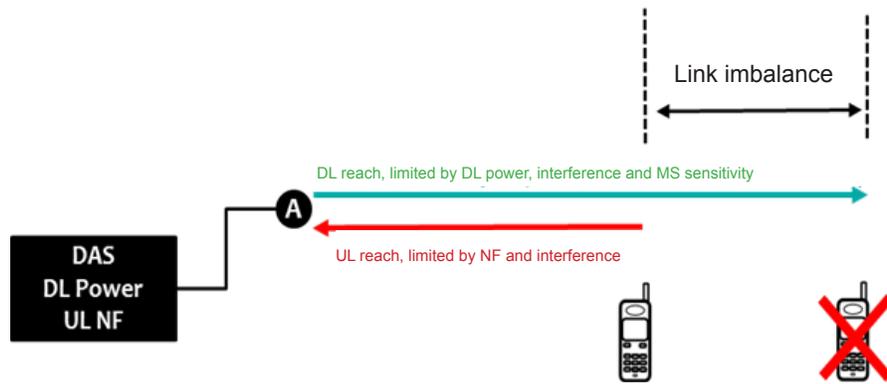


Figure 14: When designing mobile coverage, you need to ensure a balance between the downlink and uplink.

**Downlink coverage is useless if there is no uplink service. It will only be a potential source of interference.**

### Delay Impact

In mobile systems, there is a limitation of the service range due to the propagation delay over the air interface. Introducing additional delay in the link between the network and the mobile will limit the effective cell range.

Commissioning of DAS platforms should not be complicated. In the JMA Wireless TEKO DAS, you can rely on automatic gain features over the optical links that will compensate for any loss over fiber, and the variation of this loss. Other manufacturers rely on a time-consuming measurement and calculation of fiber loss that will not compensate when these losses change over time.

Delay over optical fiber is approximately a factor of 0.7 compared to the speed over the air. This means that a 2G cell, capable of reaching about 32 km will be limited to  $32 \times 0.7 = 22.4$  km. You can then “use” 20 km for fiber, and the last 2.4 km as service distance over the air as a simplified example.

### Delay over the Fiber and in the DAS, is a Real Limitation

Even though you still might have headroom in your optical link budget, delay over fiber is a concern.

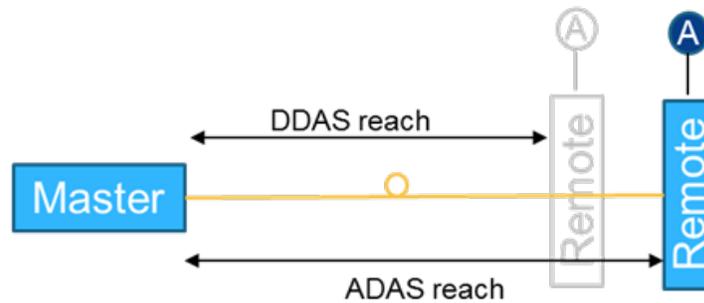


Figure 15: Although digital transport over fiber can increase an optical link budget, you need to keep in mind that the delay due to digital signal processing will limit the usable reach below that of the optical link budget.

**Digital delay in the DAS will limit the cell range, especially on TDD.**

### Digital DAS Adds More Delay and Limitations in the Reach

Digital processing in “Digital DAS” (DDAS), where analog RF signals are converted into digital streams over the fiber link, introduces more delay compared to analog transport (ADAS) as seen in Figure 15. This will add even more delay to the already present delay over the optical fiber itself, resulting in a typical 25 percent reduction in reach over the fiber, compared to analog transport. In addition, DDAS conversion and transport are limited by RF bandwidth when compared to analog.

### Concerns for Time Division Duplex (TDD) Systems

The timing and framing of TDD systems are particularly sensitive to delays. TDD uses the same RF spectrum to transmit and receive offset in time. So, the shorter the delays between “transmit and receive” the more capacity you can pipe down the radio-link. Having to leave “space” in the timing structure to handle the delay of the DAS will cannibalize the capacity and lower the efficiency of the DAS for TDD services.

### Did you know?

- **Digital signal processing adds delay. This will affect the maximum distance over fiber.**
- **You should focus on both DL and UL performance, and balance the link.**
- **Automatic compensation of variations on the optical link is critical for continuous optimum performance.**

## JMA Wireless Optical Transport:

UL Quality	Low Noise Figure
IMPROVED DAS PERFORMANCE More Capacity + More Revenue	
DL Performance	EVM Performance

- **JMA Wireless DAS uses a robust, reliable optical link**
- **Auto adjustments of gain, when there is variance on the link**
- **Up to 10dB of optical link budget**
- **Up to 20 km over the fiber**
- **No digital delay, so less impact on TDD systems**
- **The JMA Wireless C-DAS application can concentrate significant RF bandwidth over single-fiber cores**

## 6. Supporting Carrier Aggregation for LTE-Advanced

### Carrier Aggregation Basics

Carrier Aggregation (CA) is the ability to combine several LTE Air Channels into one data pipe, to support very high data rates to the users.

- Carrier Aggregation will support a wider RF bandwidth, resulting in more data recourses for the individual user.
- This will improve network performance, and benefit the business case.
- Both DL and UL will benefit, can be implemented “asymmetrical”, and FDD and TDD CA is possible.
- 600 Mbps+ with 4CA, 2x2 MIMO, 64 QAM.

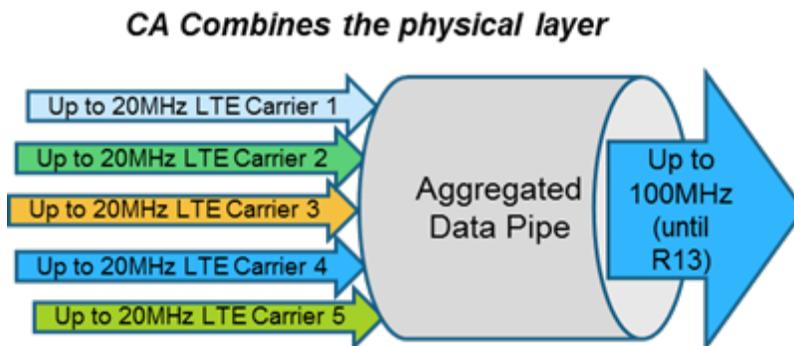
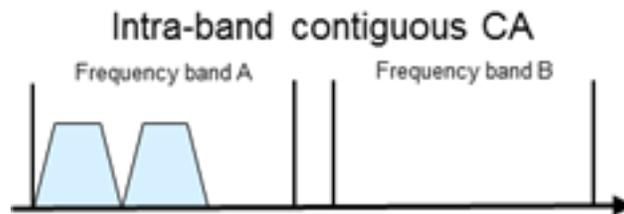


Figure 16: Utilizing Carrier Aggregation, LTE-Advanced combines several physical LTE radio channels into one data stream. After Release -13 even more than 5 individual 20MHz channels.

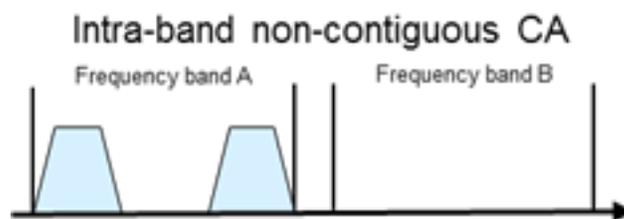
**Carrier Aggregation can be supported across continuous or fragmented spectrum. You can utilize Carrier Aggregation within the same frequency-band on adjacent channels, on the same band using non-adjacent channels, across several frequency bands as demonstrated below.**

The UL and DL do not need to have the same CH bandwidth, and you can implement Carrier Aggregation on both FDD and TDD systems.

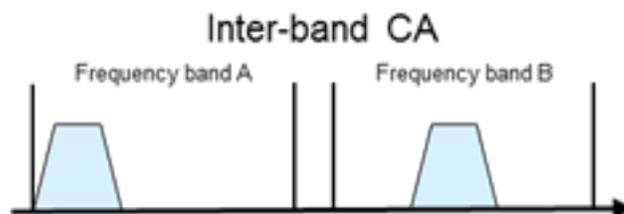
- Intra-band contiguous spectrum where adjacent LTE CH is aggregated.



- Intra-band non-contiguous where non-adjacent LTE CH on the same band is aggregated.



- Inter-band CA, where LTE CH from different frequency bands are aggregated.



### **Carrier Aggregation will be Effective Throughout the Cell**

Carrier Aggregation will be effective throughout the footprint of the cell, and will yield 1:1 performance increases as per the number of LTE CH that are aggregated as seen in Figure 17.

Obviously, performing higher data rates with higher modulation schemes, MIMO, S/N conditions, etc.

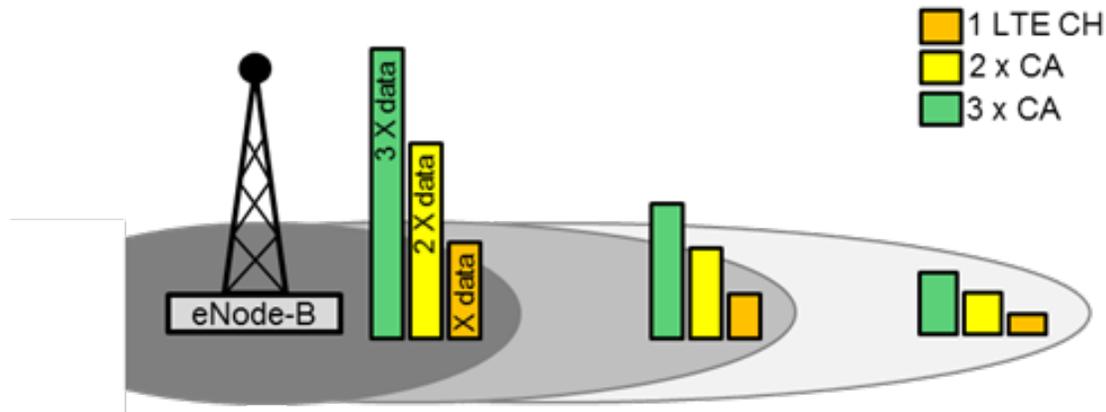


Figure 17: Carrier Aggregation is effective throughout the cell's footprint.

**The RF performance of the DAS is CRITICAL when supporting wide band LTE carriers, especially multiple carriers / multiple bands as needed in CA.**

We must assure that the DAS is able to handle the challenge of Carrier Aggregation, like we already covered previously in this paper:

#### **Wide-band support of non-contiguous spectrum**

- It is very important that the DAS supports end-to-end, across multiple bands with full performance across the total bandwidth on all bands.

#### **High peak-to-average power across full bandwidth**

- The amplifiers must be able to handle the peak to average dynamics of the LTE modulation over multiple carriers on the same band, at the same challenge.

#### **Low EVM, at 256 QAM across the full spectrum**

- If the DAS compromises the EVM on the radio-link, the data throughput will drop dramatically, and this cancels the benefit of Carrier Aggregation.

#### **Low intermodulation across the full spectrum**

- There are literally thousands of sub-carriers to handle at the same time. Intermodulation is a big challenge. A quality DAS is needed, and high isolation between the bands in the RF path is critical, both the RF and optical path.

## Did you know?

- The DAS should support low EVM to truly benefit from Carrier Aggregation.
- The amplifiers need to have high peak-to-average performance, across the full bands to support maximum Carrier Aggregation.
- Each LTE CH consists of hundreds of sub-carriers. The DAS needs to ensure low intermodulation across both the RF and optical part to avoid intermodulation degradation.

## JMA Wireless Supports Carrier Aggregation:



- The high quality transport of the RF on both DL and UL will assure carrier aggregation and LTE-A support throughout the bands
- Especially, the low EVM and 256 QAM performance is critical to maintain high throughputs
- The capabilities of high RF performance on our quality amplifiers will assure headroom to handle the high peak-to-average load when implementing Carrier Aggregation on multiple carriers within the same band

## DAS Performance Really Matters

We have briefly looked at the key RF parameters of a DAS. Although this is “basic RF metrics” they are all very important for the performance of the mobile services, on both the downlink and the uplink. The uplink/downlink balance is important particularly in the design phase. High DL power makes no sense with bad UL performance. A DAS is quite an investment, and high performance is important to ensure you get the most value from that investment.

# 7. DAS Degradation due to Passive Intermodulation

## The 3G and 4G PIM Issue

With the implementation of spread spectrum systems like UMTS, and in particular with multi-carrier systems like 4G, the focus on Passive Intermodulation (PIM) is more important as compared with more “simple” 2G systems. In Figure 18, we can see the principle behind PIM. The example shows the effect of non-linearity due to quality issues on the passive side of a DAS. The result of PIM is two carriers,  $f_1$  and  $f_2$ , will mix and create unwanted products as a function of their fundamental frequency. The amplitude of these products is related directly to the quality of the passive device and the bandwidth of the PIM increases with the higher order of the PIM. The better quality of the passive device and connectors, the less amplitude of these unwanted signals. PIM is measured in dBc with reference to the carrier power of  $f_1/f_2$ , with the aim to be as low as possible, often below -155dBc.

Remember that a 4G carrier consists of hundreds of sub-carriers, all these are candidates for creating inter carrier PIM, and especially if they hit the UL of any band it will degrade the services. 3G and 4G systems are primarily implemented to drive data at high efficiency through the mobile networks. PIM will severely degrade the throughput of data, making the network less efficient and data speed will decrease and thus impact the business case of the network.

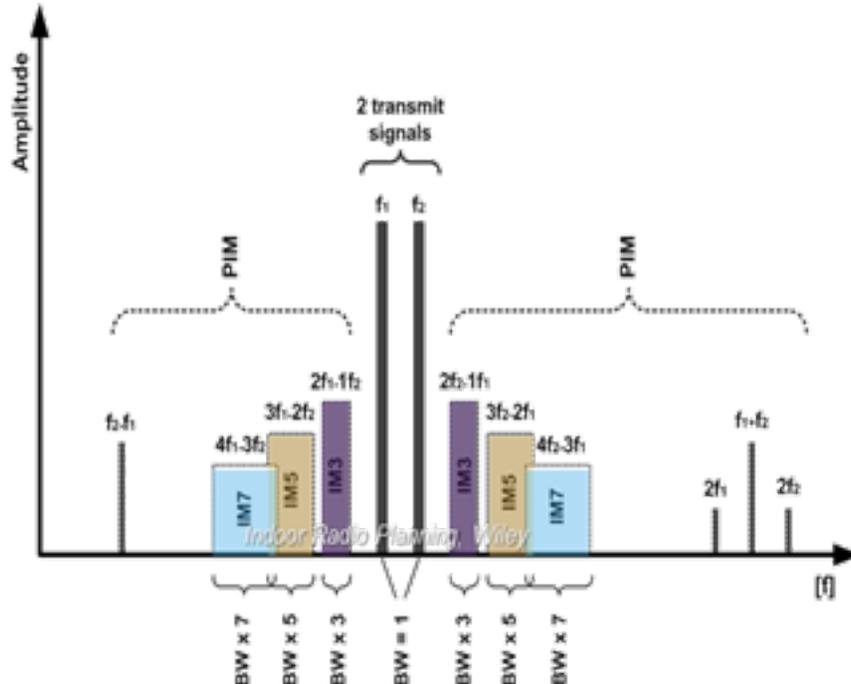


Figure 18: Principle of PIM, the two carriers,  $f_1$  and  $f_2$  mixes in nonlinear passive components and generates unwanted interfering signals.

It is important to remember that the higher power density in the DAS and the wider spectrum in the system, the higher the PIM risk will be. Multi-operator and 4G systems; therefore, are especially prone to PIM. It is very important to rely on the low PIM DAS Point of Interfaces and low PIM connectors and jumpers that JMA Wireless produces.

### The PIM Impact on 4G Performance

The impact of PIM on the UL noise in the cell and the traffic volume is evident in Figure 20. This is real 4G network statistics from a live indoor DAS sector. It is clear that the “uplink idle noise” in the cell prior to solving the PIM issue is high and that impacts the traffic volume in the cell.

After solving the PIM issue, the noise falls up to 10dB and the volume of data produced in the cell really picks up. The increased noise also resulted in a high drop rate on the traffic in the cell.

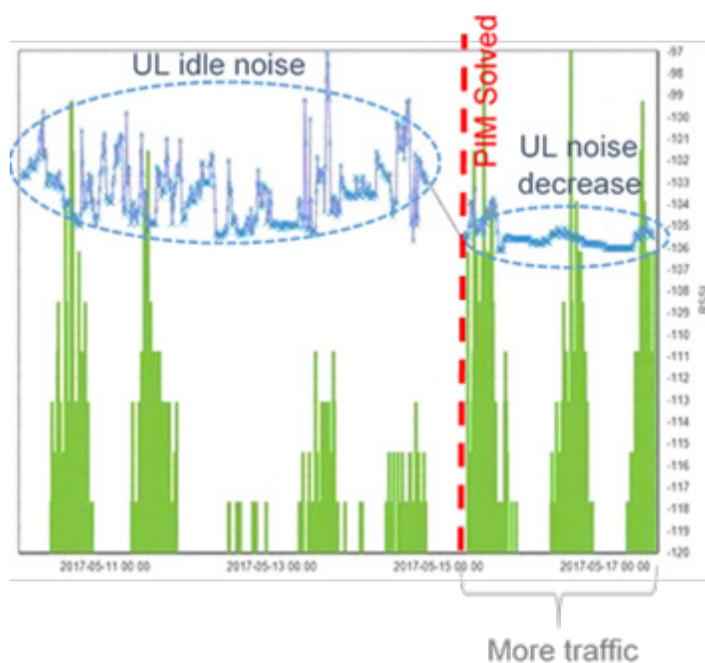


Figure 19: The impact of PIM in a DAS from a real 4G network. Prior to resolving the PIM issue, there was a high level of “idle noise” due to the PIM noise. This problem decreases after solving the PIM and the traffic volume in the cell raises.

### PIM Will Degrade the Business Case of the Network

As documented in Figures 19 and 20, PIM will have direct impact on the data volume, quality and dropped calls in the network.

A single connector in a DAS can degrade the whole DAS, not only the performance in the branch of antennas connected to that specific part of the DAS, but the quality of the whole cell is degraded. Sometimes even the adjacent cells and network can be impacted.

A lot of resources are spent on testing PIM in the mobile networks for the reasons above. No doubt this is important, but would it not be better to avoid the PIM issues whatsoever!? This can be achieved by using quality, low PIM passive components, antennas and connectors.

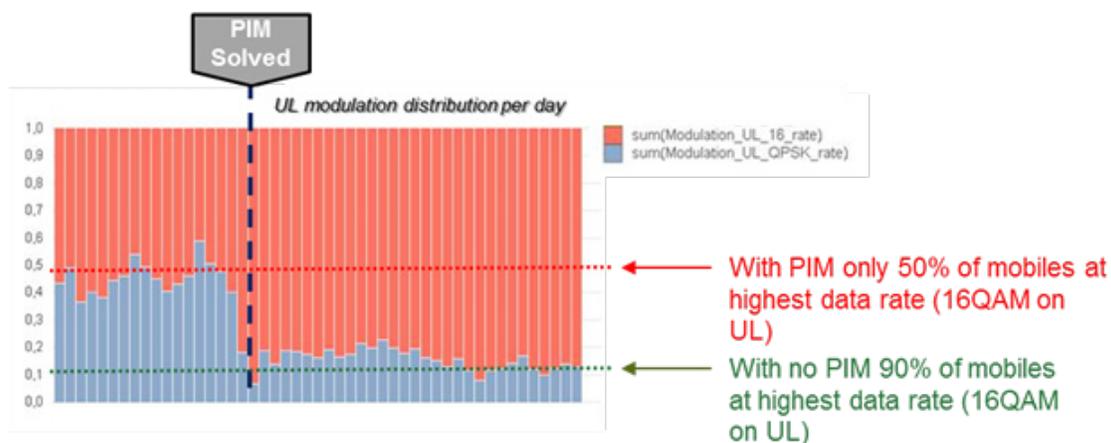


Figure 20: The impact of PIM is also clear on the EVM, thus the efficient throughput in the cell. This has a direct impact of the network economy as shown. There is a clear increase of the utilization of higher order modulation after the PIM has been solved.

Figure 20 shows the same cell with the same PIM issue, but now the KPIs from the network GUI are showing the distribution of the UL adaptive modulation. In this cell, only mobiles that supports up to 16QAM are used and after solving the PIM problem, the utilization of the highest modulation rate rises from 50 percent to 90 percent in the cell.

Future classes of mobiles will apply even higher modulation rates that rely on modulation schemes higher than 16QAM; therefore, the effect will be even more evident and important in the future

### Avoid PIM with JMA Wireless DAS and Connectors

Rest assured that the Point Of Interface of the JMA Wireless TEKO DAS is capable of handling the input from multiple high power base stations without any PIM issues. Make sure to use quality jumpers and connectors between the base stations and the TEKO DAS as well as low PIM connectors, jumpers and antennas throughout the DAS.

The JMA Wireless connector solutions and the simple, automated procedure of mounting the connectors ensures that you can avoid any PIM issues. This is very important, since a DAS typically has up to hundreds of connectors, and a single bad connector is enough to degrade the services as just documented in Figures 20 and 21.

The low PIM JMA Wireless connectors, jumpers, antennas and DAS will ensure you the highest possible data rates, higher throughputs, less dropped calls and better revenue from your DAS.

# 8. The Impact on the Business Case

All these parameters are important in maximizing the RF and data performance, ultimately providing maximum data performance per investment and lowering the total cost of ownership (TCO).

**A high RF performance DAS is the foundation of a best-in-class RF transport system that offers the most value (data speed) per investment, now and in the future.**

The modularity and upgradability of the JMA Wireless TEKO DAS represents a future-proof system with low TCO, the ability to integrate a Multi-Band Spectrum Analyzer that logs, monitors and alarm triggers the performance KPIs, and the ability to feed power to remote units over thin copper cables like CAT5/6. All these advantages are provided in addition to the “basics” of a high RF performance DAS. That is the foundation for a best-in-class RF transport system.

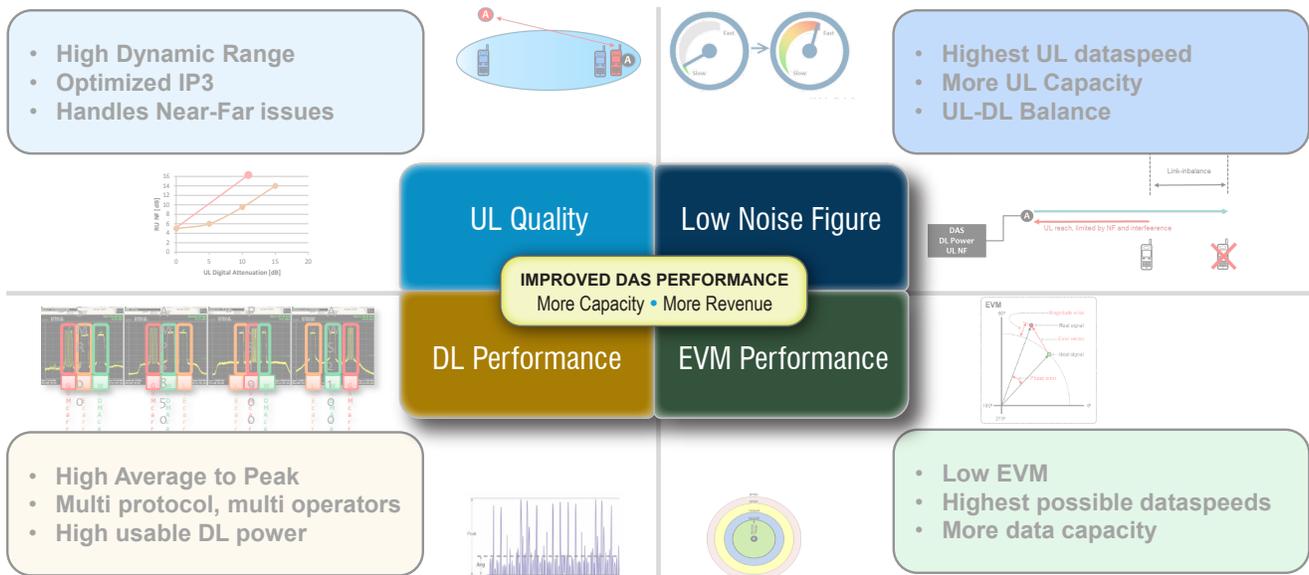


Figure 21: The four quadrants of DAS performance: noise figure, error vector magnitude (EVM), downlink (DL) power and headroom, and uplink (UL) performance of the complex RF environment.

## JMA Wireless High-Performance TEKO DAS:



- **JMA Wireless supplies a transparent high-performance DAS**
- **Assures best-in-class downlink and uplink quality**
- **Offers the best possible data throughput and performance**
- **Supports Carrier Aggregation for LTE-A**
- **Ensures the best value for the investment**
- **JMA near-far optimization will**
  - Ensure high performance in venues where some mobiles are close to antennas
  - Provide stable connections and no dropped calls due to “RF blocking”
  - Perform well in enclosed areas like metro systems
- **JMA Wireless low system noise figure means**
  - Highest possible data rates on the uplink
  - Good UL/DL link balance
- **JMA Wireless low system EVM means**
  - Transparent transport of the RF signals
  - Maximum data speed on UL and DL
  - Bad EVM will raise the noise on the link and degrade the capacity
  - Performance is better than one percent EVM
- **JMA Wireless fiber transport means**
  - Longer reach over the fiber (no additional delay)
  - Continuous auto calibration of fiber loss



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