Vol 57, No 2—May 2023

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™
AnalogDialogue

Revolutionizing Wireless Coverage: The Power of Cellular DAS Integrated Solutions

Hamed M. Sanogo, End Market Specialist for Communication and Cloud

Abstract

Commercial buildings and sports venues require quality cellular coverage, but these environments pose signal reception challenges. This article presents a comprehensive solution for distributed antenna systems (DAS), which are essential for extending cellular coverage and capacity within building structures. It will outline the benefits of highly integrated system designs that include an RF transceiver coupled with a bidirectional amplifier (BDA) or remote access unit (RAU) equipment. By exploring this solution through the proposed block diagrams, readers can better understand how these elements work together.

Introduction

Modern environments such as commercial buildings and sports venues often require improved cellular coverage to provide seamless connections. However, the thick steel, concrete, and energy efficient glass walls in today's large commercial buildings, hospitals, and sports venues can easily prevent cellular signals from reaching occupants' mobile phones. In other words, the fortified construction and highly tinted windows, among other construction materials, make buildings act like an RF shield.[1] Also, high rise structures may experience high levels of RF interference from nearby cellular towers, which can further degrade service. Overcapacity is yet another cause of poor mobile phone reception when too many people occupy a small space. These factors combined cause poor cellular phone reception. An integrated, DAS solution is essential to enabling quality cellular service and accelerating the future growth of wireless networks.

What Is a DAS?

A DAS is an in-building wireless enhancement system that provides building occupants with reliable mobile phone coverage. A DAS is a network of spatially separated antenna nodes that expand the cellular range and boost signal strength to achieve a superior cellular level of connectivity in high density indoor or outdoor venues. Although no two DAS implementations are the same, a typical deployment may involve direct connections between a donor antenna, an RF signal BDA or booster, a wireless carrier's base transceiver station (BTS), a fiber distribution head-end, RAUs, and many in-building strategically placed ceiling antennas. In some cases, multiple BTSs are installed; one for each carrier.

Often, multiple RF feeds are combined and then passed to the head-end, which is the master distribution unit. The donor antenna, placed on the roof of the building, sends and receives signals from a cell carrier and brings the wireless signal into the building through an optimally located RF signal BDA. The head-end equipment then feeds the RAUs via a variety of fiber optic cabling. The RAUs in turn feed the antenna systems via coax cables. Multiple ceiling antennas can be fed from a single RAU. This provides voice and data services to mobile devices inside the building much like a cell site provides coverage in a cellular network. Figure 1 shows a typical fully DAS architecture.

The two main trends of improving in-building wireless coverage are using only an RF booster or BDA products, which are simple repeaters for signals (also known as passive DAS), or using a full active DAS system, as shown in Figure 1. Both passive and active DAS signal distribution systems are used to improve wireless coverage and capacity inside a commercial building depending on the situation. A hybrid DAS is when a distribution system has aspects of both passive and active types.

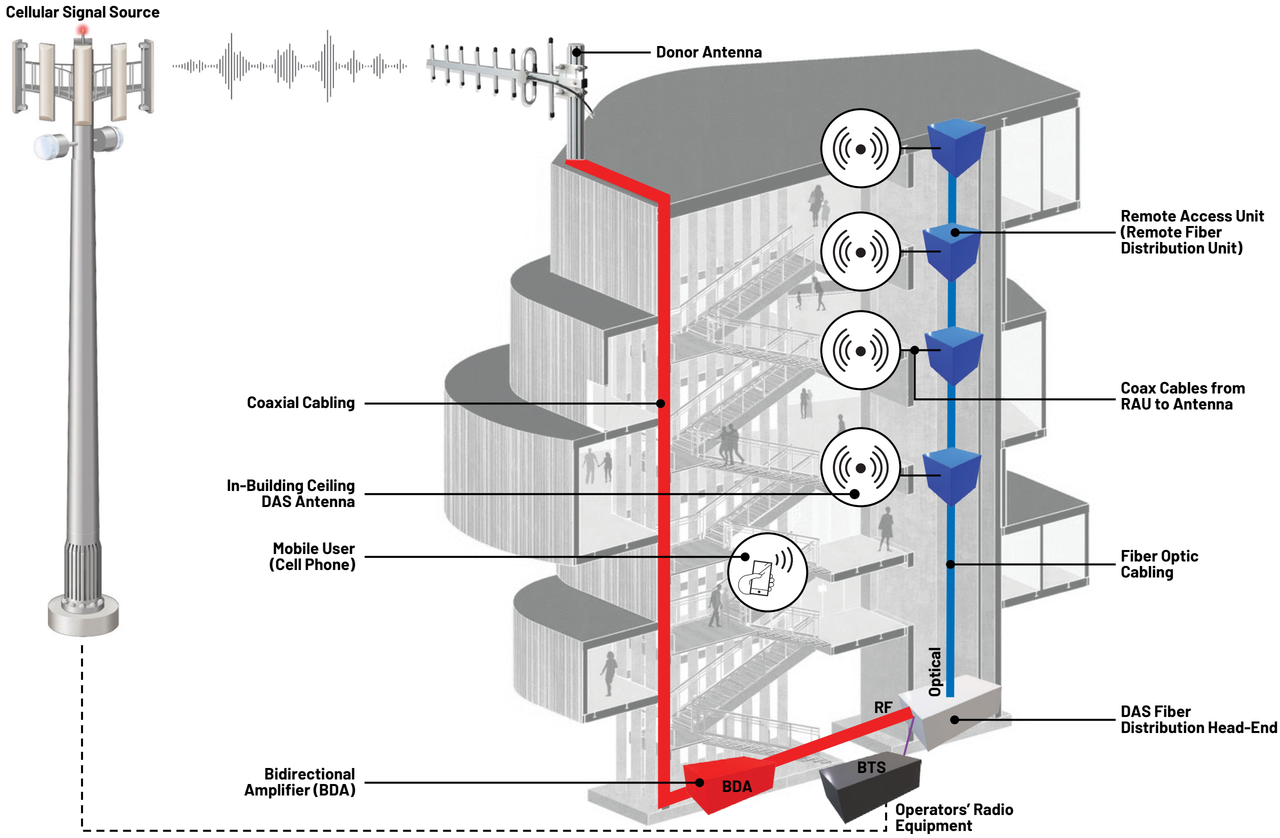

Figure 1. A hybrid DAS architecture.

The Bidirectional Amplifier

As the RF signals travel a farther distance from the donor antenna, they will continue to grow weaker and weaker from the attenuation presented by the long coaxial cabling. To avoid or mitigate this, a passive DAS offers a wide variety of multiband RF repeaters to increase or amplify and redrive the signals. The BDA front-end consists of a filtering, low noise amplifier (LNA) and sometimes an automatic gain control (AGC) circuit. The AGC components are designed to limit the RF power level as well as to protect the BDA from damage or distortion. The BDA amplifies the radio frequency signals in two directions simultaneously. They do not modulate, modify, or otherwise distort the actual radio signal. Their main purpose is to keep the RF signal strong throughout the building. Most BDA modules are designed to amplify multiple carriers at the same time and their use does not require an agreement with the carriers. Figure 2 shows the high level block diagram with the suggested electronic components of a BDA for RF signal amplification and rebroadcasting.

The DAS Remote Access Unit

The DAS head-end equipment performs analog-to-digital conversions and can convert RF signals from single or multiple carriers. This is why carrier approval is usually needed from each provider to install an active DAS. Digitizing the RF signal and placing it on high bandwidth fiber optic cabling allows the signal to be transported at high bandwidth and at full strength over much longer distances with minimal losses to all the RAUs strategically placed on each floor throughout the commercial building.[1] With this process, signals are much less susceptible to interference.

The RAUs convert the digital fiber signals back to analog RF and feed them to the DAS ceiling antennas. The RAU is connected to the remote ceiling antennas via coaxial cables providing more coverage and range, which allows all users to experience a superior cellular level of connectivity. Figure 1 shows the optical fiber cabling between the head-end and all the RAUs.

The main and very key function in a DAS is the RAU, which facilitates the expansion of RF capacity. The RAU's main purpose is the digital-to-RF and RF-to-digital conversions. ADI's highly integrated and agile RF transceiver solutions, like the ADRV902x family, are the fundamental integrated circuit components that enable the RAU to take on complex tasks.

Figure 3 shows a high level block diagram of a typical DAS RAU. Table 1 lists a few proposed part functions and numbers. Even though the diagram makes several specific part proposals for the platform, the rest of this article will only focus on the RF transceiver, ADRV9029, and a few of the attached power components.

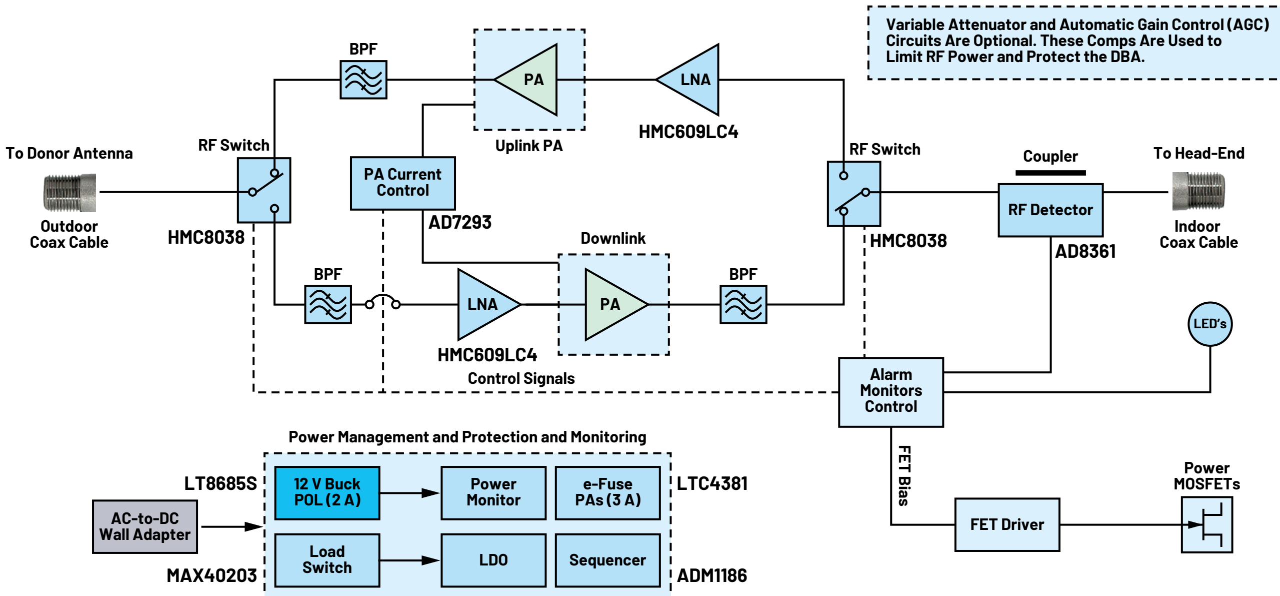

Figure 2. A BDA/RF booster block diagram.

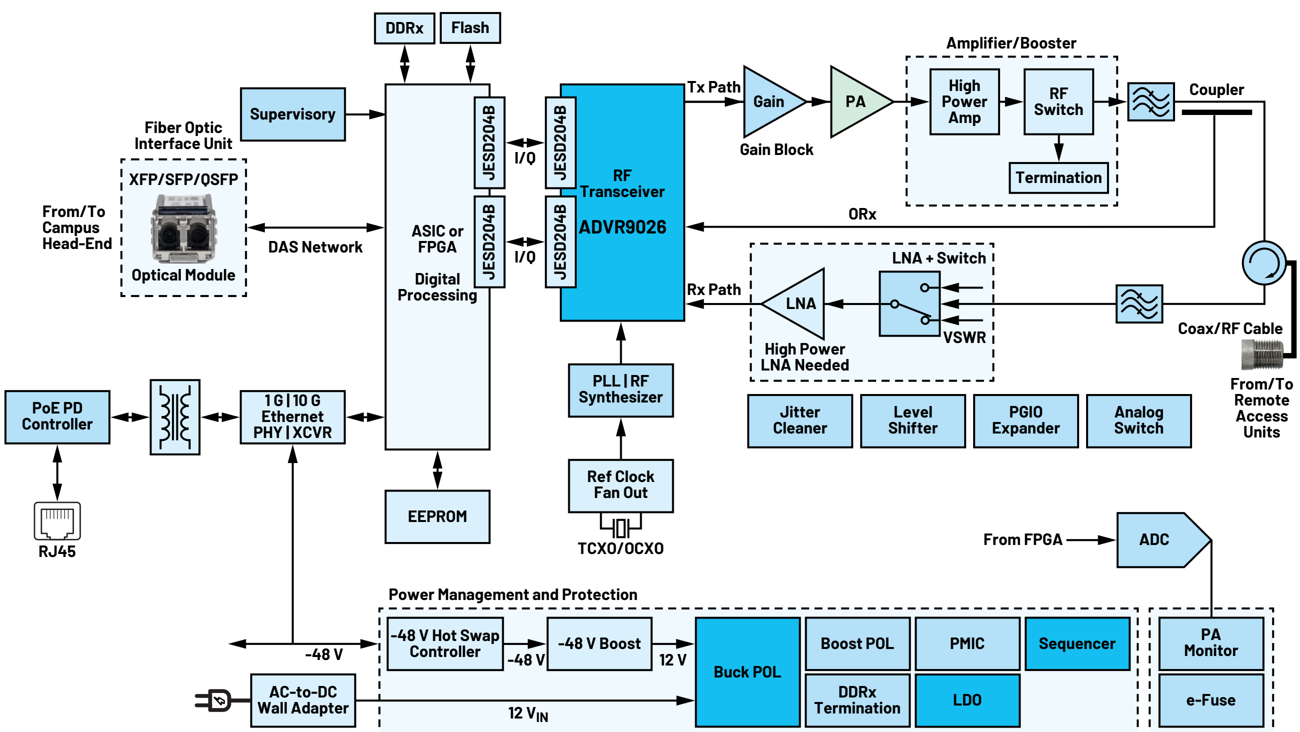

Figure 3. A block diagram of a typical RAU with the ADRV9029 RF transceiver.

Table 1. Proposed Components of the RAU Design

Function	ADI Part Number
Gain Block	HMC788A
RF Transceiver	ADRV9029
RF Switch	ADRF5160
PLL/VCO	ADF4351
Clock Jitter Cleaner	AD9528
Buck POLs	LT8625S, LT8627SP
LDOs	LT1761, ADM7172
PMIC	ADP5055
Sequencer	ADM1166
PA Monitor, e-Fuse	AD7393, LTC4381
PoE PD Controller	MAX5969A

A Highly Integrated Zero-IF Sampling Analog Transceiver: ADRV9029

The ADRV9029 is a highly integrated zero-IF sampling analog transceiver, capable of synthesizing and digitizing wideband signals. The device can be programmed for usage in both frequency division duplex (FDD) and time division duplex (TDD) applications. The device provides the performance demanded by DAS cellular infrastructure applications, especially with the RAU. The device includes two key functions as part of its digital front-end block that separates it from the competition. These functions are the digital predistortion (DPD) adaptation engine and crest factor reduction (CFR) engine. For cases where the DAS system has stringent latency requirements, the CFR can be bypassed. The functional block diagram of the ADRV9029 is shown in Figure 4.

Digital Predistortion Function

A DPD function or capability allows a wireless system to drive its power amplifiers (PAs) closer to saturation (without having the power amplifier saturate), enabling a higher efficiency power amplifier while maintaining linearity. This means that the DPD function enables RAUs to achieve higher power amplifier efficiency by extending the linear operating region of the PA, while still meeting adjacent channel leakage ratio (ACLR) requirements in the transmit signal chain. A PA in the remote DAS node also helps to reduce its overall power consumption. The ADRV9029's observation receiver paths connect to the DPD actuator and coefficient calculation engine to help the system's PAs run with high efficiency.

The ADRV9029's DPD algorithm supports a carrier bandwidth of up to 200 MHz. The integration of the DPD function into the ADRV9029 results in significant system-level cost, space, and power savings when compared to a discrete implementation that used an RF transceiver with an FPGA-based DPD solution. And when a specific application calls for it, the DPD engine in the ADRV9029 can be completely bypassed through GPIO control.

An ACLR, the ratio of the transmitted power on the assigned channel to the power leaked in the adjacent radio channel, performance improvement following the application of DPD to a 20 MHz LTE signal baseband data is captured in Figure 5. These power spectral density plots illustrate how the out of band nonlinearities, caused by intermodulation products of the LTE 20 MHz signal, are reduced by 15 dB to 20 dB after the application of DPD.

Crest Factor Reduction Block

Due to the inherent nature of the current technologies used for wireless systems, especially for multicarrier waveforms such as orthogonal frequency division multiplexing (OFDM), the signal can have a high pick-to-average power ratio (PAPR) that can adversely impact the efficiency of the PAs. The main reason is that the signal has peaks that exceed the PAs' linear operating range. A crest factor reduction (CFR) scheme ensures that the range required by the signal is within the power amplifier linear range and helps to mitigate or even eliminate the effects of PAPR in a system.

The ADRV9029 comes with a CFR engine on board that is used to help reduce the PAPR. With reduced PAPR, the RAU's PAs can operate at a higher output power, which increases its power amplifier efficiency in the transmit line up. The device comes equipped with three CFR engines. In short, this well-controlled monolithic platform provides a DPD engine that is preassisted by a CFR block. It is this combination of work on signals on a chip that separate the ADRV9029 from the competition in performing the task of keeping PAs linear.

Note that the ADRV9029 implements CFR using a variation of the pulse cancellation technique by subtracting a precomputed pulse from the detected peaks to bring the signal within the power amplifier linear range. Therefore, a pulse needs to be generated and loaded for each carrier combination. For these and other reasons, the CFR block adds latency. In most cases, DAS systems have stringent latency requirements. When this is the case, the CFR function can simply be bypassed. The ADRV9026 is a member of the product family without DPD and CFR.

Power Supplies

After doing everything right to achieve the highest possible error vector magnitude (EVM) and adjacent channel leakage ratio (ACLR) static transmitter performance metrics, ignoring the RAU's system power supply design could place all the good RF design and simulations work done in jeopardy. During operation, supply currents with the ADRV9029 can vary significantly, especially if operating in TDD mode. When noise from the supply is not controlled, it could even affect the JESD204B/JESD204C link performance.

ADI has developed the innovative switch mode power supply and packaging technologies necessary to support all its RF transceivers and other 5G RF SoC parts, like the ADRV9029. The Silent Switcher® 3 family of ICs features exceptionally low frequency output noise, fast transient response, low EMI emissions, and high efficiency. The LT8642S, LT8625S, and LT8627SP are recommended for the RAU, as shown in the block diagram in Figure 3. The complete portfolio of Silent Switcher devices can be found at analog.com/silentswitcher.

In most cases, the third-generation ADI Silent Switcher devices eliminate the need for an LDO, even in most supply-noise sensitive applications such as phase-locked loop and LNA designs. When an LDO is required, the ADM7172 and LT1761 are recommended. The ADRV9029 also requires a specific power-up sequence to avoid undesirable power-up currents, and the ADM1166 has been proposed as a solution.

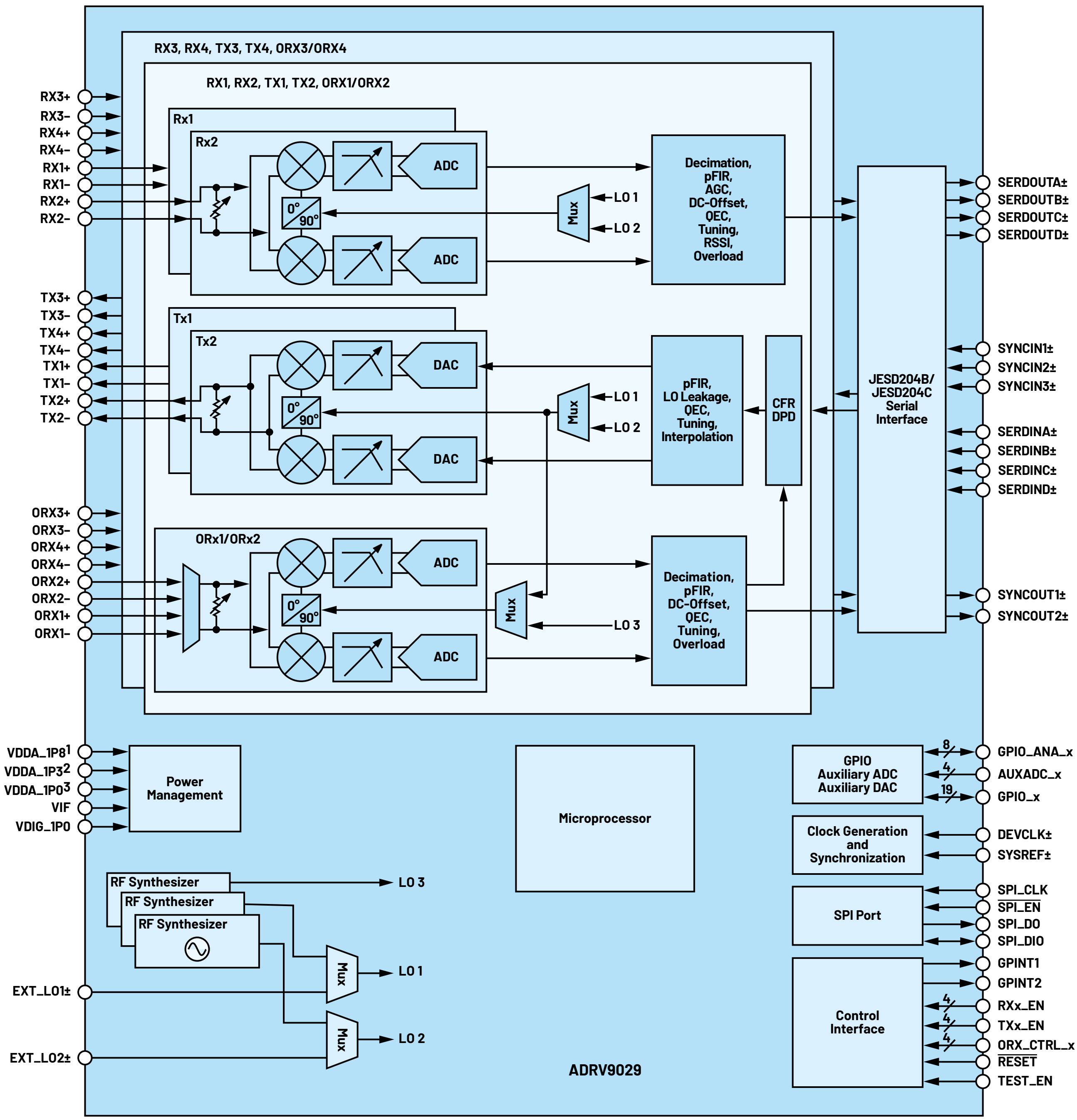

Figure 4. An ADRV9029 functional block diagram.

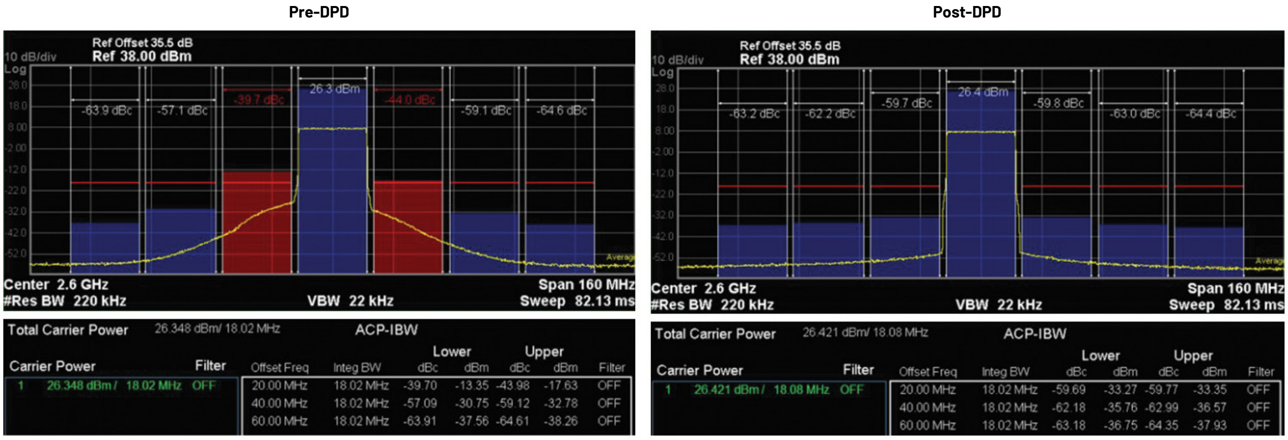

Figure 5. Power spectral density showing improvement in ACLR after application of DPD for a 20 MHz LTE signal.

Conclusion

A DAS helps deliver effective RF coverage and capacity, which facilitates seamless connectivity to meet today's high demand for reliable voice and data. This article discussed how a BDA (also known as passive DAS) or a full active DAS solution can improve cellular signals within building structures to ensure that occupants have robust wireless connections throughout the facility. The RAU is an integral part of a full active DAS communication solution the same way the ADRV9029 is for the DAS node. ADI offers the reference design, user guides, firmware libraries, and other design collaterals to support engineers with their design effort. For more detailed information about the ADRV9026 RF transceiver and design collaterals or to purchase the complete radio evaluation board, please visit here.

References

[1] "Designing Distributed Antenna Systems (DAS)." Advantage Business Media, 2016.

About the Author

Hamed M. Sanogo is an end market specialist for cloud and communications in Analog Devices' Global Applications Group. Hamed graduated with an M.S.E.E. degree from the University of Michigan-Dearborn and later earned an M.B.A. degree at the University of Dallas. Following graduation, Hamed worked as a senior design engineer at General Motors and a senior staff electrical engineer and Node-B and RRH baseband card designer at Motorola Solutions before joining ADI. Hamed has spent the last 17 years in different roles, including FAE/FAE manager, product line manager, and currently an end market specialist for communications and cloud.

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

For regional headquarters, sales, and distributors or to contact customer service and technical support, visit analog.com/contact.

Ask our ADI technology experts tough questions, browse FAQs, or join a conversation at the EngineerZone Online Support Community. Visit ez.analog.com.

©2023 Analog Devices, Inc. All rights reserved. Trademarks and registered trademarks are the property of their respective owners.

VISIT ANALOG.COM