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**Meta Description:** Learn about new AISG v3.0 features and how the MAX11947 modem with a built-in 4:1 MUX can help a system designer.

**Abstract:** With the introduction of the new AISG v3.0 standard in 2019, many new use cases were implemented for antenna line communication. While these changes had little to no impact on the physical layer of operation, one systematic change was obvious: every RF connection on the cellular tower would now require AISG communication to service the ping function. This article summarizes changes on the hardware level and demonstrates how features of an AISG modem with a 4:1 multiplexer, can help system designers implement the new standards requirements with fewer components and less development overhead.

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# Designing with a Physical Layer Modem for AISG v3.0 Compatibility

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## Introduction

The proliferation of cellular networks and handsets over the past decade has resulted in an exponential need for electronics to support the mobile communications infrastructure. A simultaneous demand for more bandwidth is also pushing network providers to continuously expand their coverage while increasing cell density; in turn, this has boosted the need for infrastructure hardware.

Over 15 years ago, manufacturers began to standardize interoperability of cellular radio equipment, allowing more variation in assembling cellular base stations with antenna gear, amplifiers, etc. This communication standard was first established by the Antenna Interface Standards Group (AISG) in 2003 and 2004[1]. The AISG standard continues to evolve with market expansion. Several features are considered to meet the inter-operable communications needs of today and the future.

## AISG v2.0 and the Physical Layer Modem

Integrated modulator-demodulators (modems) were introduced in 2009 to provide a complete, focused solution for translating between the ubiquitous RS-485 interface and a 2.176MHz OOK signal, defined by the communication standard riding on the same cable as the cellular RF band.

The IC solution allowed for a much more compact system design, saving space, power, and hardware. In addition, the integrated modem provided the reliability of a simple, proven, factory-tested device in one small package.

## New AISG v3.0 Standard

An upgrade to the successful standard was put forth by the AISG in 2019. This evolutionary step was built upon the success of previous generations with the intent to add new features, while maintaining the core interoperability of primaries and their managed antenna line devices (ALDs).

The new AISG v3.0 feature set includes device discovery, connection mapping, and multi-primary control. While a system designer can find the new standard to be a helpful upgrade for many higher-level functions, the physical (PHY) layer remains unchanged from v2.0 to v3.0 [2][3]. Consequently, all modems originally introduced with v2.0 are still fully compatible with the new AISG v3.0 standard.

#### Need for More than One AISG Channel

Although the step from AISG v2.0 to v3.0 had very little impact on the physical layer of the system, the new v3.0 standard does require the ability to initiate and detect a ping packet on all the connected RF channels. This requirement facilitates the mapping of cable connections, allows the end user to identify multiple primaries and secondaries, and provides a tool for fault detection during initial assembly and maintenance. Although the need for each channel to have awareness of AISG helps the end user, it places a large burden on the hardware designer to include communication capabilities on all possible RF channels, where previously it was only necessary for one.

Trying to convert an AISG v2.0 architecture directly into a v3.0 compatible application could require over twice as many modems as previous generation designs; going from six modems (grey blocks in Figure 1) to 15 (grey plus red blocks).



Figure 1. Shows an example application of AISG v2.0 vs v3.0.

In the above example, two modems remain for each antenna pair to maintain compatibility across base station providers. However, seven or eight modems are required on the tower mounted amplifier (TMA): four listening on the ports running to the antenna array (up-stream) and four used on the down-stream ports to broadcast a ping to the base station. The base station requires additional modems: one for the original AISG channel and three more to receive ping packets from the TMA on other ports.

More than 15 or 16 modem ICs is excessive and inefficient and can be reduced using bypass circuits or RF switches to share AISG signals between RF ports. The traditional bypass circuit was helpful in a v2.0 system when only a single RF channel was expected to carry the AISG commands, allowing a tapping off of the signal while still passing it up or down the cable. However, since ports needed to be individually identified, the designer needed to separate the up-stream and down-stream branches. This was much more difficult using the former bypass architecture in a new v3.0 design.

The ultimate solution to managing AISG access across multiple ports, while not excessively increasing the electronics count, is to use a set of RF switches. These switches or a one-to-many multiplexer can route the OOK signal from a chosen port to fewer overall modems, while allowing the system to be reconfigured between standard AISG communications and ping operations.

#### Adjustable Transmitter Power

As with the older AISG designs, there was an inherent need to adjust the output level of the transmitter's power amplifier (PA). This capability was helpful whenever a power splitter was used for circuits, such as the bypass channel shown in the v2.0 TMA example of Figure 1. Signal power

adjustments were also useful if there was excessive attenuation in the 2.176MHz band from RF filtering or lossy connections. The original modems provided this adjustability through the selection of external resistor values. These resistors were used to set the PA bias point and could be adjusted for the modem to meet the AISG signal requirements (see Figure 2-A and 2-B). Although there was some flexibility built into the v2.0 modems, the output power of the PA was essentially fixed at the design stage, because the only means to adjust the power required replacing the bias resistors.



Figure 2. Transmit power and receive threshold.

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Similar to the transmitter power drop, the receiver threshold could also be affected by a power splitter, in-line filtering, or other attenuation factors on the RF channel. Unfortunately, unlike the adjustable PA power, there was no adjustability of the ON / OFF threshold in any of the original v2.0 modems.

### Power Saving Modes

Power savings is always high on a system designer's list of requirements. Often, there is a power budget constraint applying pressure on more critical design elements, especially as the ALD hardware is scaled to more channels while being forced into an ever more compact footprint. Having some flexibility in less critical circuits (i.e., the AISG modem) can give the designer more power budget for important blocks in the system.

One of the original AISG v2.0 modems on the market had a lower-power standby mode which would shut down the transmit circuitry to save a modest bit of power. Every milliamp helps, yet what would make for a better design is the ability to shut down, not only the transmitter, but the receiver block and other unused portions of the modem itself. In opposition to additional power down features, the modem would need to be flexible enough to balance other use models, such as reference sharing.

#### Sharing a Reference Oscillator

Every AISG modem requires a reference signal to generate the 2.176MHz carrier. This is typically provided with an 8.704MHz crystal and an integrated oscillator circuit. All existing AISG modems on the market can be architected with a primary/secondary (or master/slave) circuit within the system, saving crystals, and thus reducing BOM costs.

Each chip can act as the primary crystal oscillator (XO) for down-stream modems by buffering the signal through the SYNCOUT pin. This SYNCOUT signal is an open-drain output, which requires a simple external pull-up resistor to the analog supply so it can operate properly. This signal is then propagated to additional secondary modems downstream from the primary. The number of downstream modems is limited, but this reference sharing option is available.

Designing with this sharing architecture does have a drawback. Using any of the classic v2.0 modems, the primary would still need to burn as much power as any secondary modem. Thus, even though the system designer saves on components, there are no savings in their power budget.

#### **Spectral Emissions**

Finally, a primary requirement of the AISG standard for the PHY layer is the spectral purity of the modem's transmitter. The spectral performance is delineated in AISG v3.0.0.3, section 10.3.11 - Modular Characteristics. Strict requirements limit the PA's out-of-band spectral emissions, which tend to be very stringent. This is especially the case at the 30MHz knee where any harmonic noise must be below -67dBm in absolute power, and where the resolution bandwidth (RBW) settings of the test instrumentation are the harshest. The PA output spectrum also must be balanced with the overall power level (that is, the adjustable TX power), keeping within the absolute limits of the spectral mask. Increasing the PA power too much may cause a failure in the spectral mask.



Figure 3. AISG v3.0 standard modem spectrum emissions mask.

Since there is no change to the emissions mask, integrated modems available for the v2.0 market also meet the v3.0 standards, although they often only provide a narrow 1~4dB of margin at the 30MHz inflection point; thus, they limit the top end of the PA output power.

### Using a v2.0 Modem in New v3.0 System

All the features noted are available in a classic v2.0 modem. Since the PHY layer is essentially unchanged, each of the older modems meet the needs of an ALD system designer. Simply replicating existing AISG solutions detrimentally occupies more board space, impacts the system complexity, and may start to dominate the power budget, all while providing little to no improvement in performance and offering no feature upgrades. Fortunately, there is a new and improved alternative available for the AISG v3.0 market.

# Upgraded Features Available in a New AISG Modem

Maxim introduced the first AISG v2.0 modem to the market with the original MAX9947[4]. This device still provides a complete solution for interfacing between RS-485 and the defined 2.176MHz OOK signal, thus it remains fully compatible with the new AISG v3.0 standard. Even though the original modem can service the new standard, the expanded requirements in v3.0 provide an opportunity to enhance the existing design.

The new MAX11947[5] comes with several performance improvements and added features to address many of the shortcomings inherent in using older generation ICs in a newer system. The primary feature in the new modem is an integrated 4:1 multiplexer. This MUX effectively provides four modems in one chip and facilitates automatic scanning. This gives the developer a tool to interact with for up to four RF ports while using nearly the same PCB footprint compared to an original modem. This integrated switching capability greatly reduces the need to specify and test additional circuits, such as RF switches, while reducing BOM requirements.

As shown in the earlier example, what was six modems in the AISG v2.0 system and potentially 16 modems required for a v3.0-capable system is now reduced to just five modems when incorporating the integrated 4:1 MUXs (purple blocks in figure 1). The new modem/MUX combination also provides a code-free, non-microcontroller-based means to scan ports and identify a ping carrier signal with very little user intervention. The automatic port scanning feature helps to both map the hardware interconnects and find faults within the RF cabling system, completing the process with fewer IC components than is otherwise required.

A new SPI interface not only controls the MUX and modem but allows for the integration of features previously managed through external components. Parts like the PA power bias network (resistors) are now incorporated through a digitally adjustable transmit power. The modem also provides a new feature: an adjustable receive sensitivity threshold. Both adjustments help solve power splitting problems inherent in a bypass system, along with other inline attenuation issues. Not only can the TX output be adjusted from about -0.5dBm to about +7.0dBm in 0.5dB steps, but the new modem can also independently adjust the RX comparison level as well. This allows the carrier detection threshold to range from about -15dBm down to about -21.5dBm. The adjustable TX power and RX threshold can be modified on-the-fly, permitting the system designer to pass along this flexibility to the end user and allowing for improved system performance once installed in the field.

The new part also incorporates several power modes: operational, standby, and power-down. This gives the system designer many options to improve their power budget. The standby mode disables the transmitter circuitry like other classic modems from the v2.0 era, saving a typical 11mA versus the full operation mode. Even more savings is realized by disabling both the transmitter and the receiver circuitry with the power-down mode. This minimizes the power consumption (typically 20mA lower than operation mode) while still allowing the modem to act as a primary oscillator for others down-stream. If the SYNCOUT buffer is also shut down, the system designer can save over 23mA versus the operational mode.

This new modem exceeds the spectral compliance of the previous generation modems, now giving the system designer about 15dB of margin to the spectral mask at the 30MHz point, thus allowing more flexibility on the transmitter power setting.



Figure 4. Comparative spectral performance.

Finally, the new device has a unique feature related to the serial interface: all the classic modem signals are mirrored within the SPI registers. This means additional GPIO, UART, or other port pins are not required on a microcontroller to interface with the modem signals. By reading from and writing to the mirrored bit, both interface and control can be exercised through the registers. The system designer now has the option to use the modem as a bridge between an RF port and an MCU with minimal resources.

#### Conclusion

The MAX11947 is built with purpose to meet the needs of the new AISG v3.0 system designer. It provides added benefits and expands the role of the modem, while offering new built-in flexibilities that go beyond just saving design time and BOM costs.

More information on the new MAX11947 can be found on the Maxim web site at:

https://www.maximintegrated.com/en/products/comms/wireless-rf/MAX11947.html

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