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ADI SDR Transceivers Enable Amateur Space Communication

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Radio amateurs recently received another way to provide uninterrupted worldwide radio coverage. By means of a new geostationary satellite, it is now possible to reliably cover one-third of the Earth in just one hop. In order to contact the satellite, it is necessary to use dedicated equipment because the access frequencies are different from the ones used to bounce radio signals from the ionosphere. The new software-defined radio (SDR) approach to radio transceivers offers multiple advantages, such as flexible reconfiguration and the capability to observe the whole band of interest at a glance, just to name a few.

This article begins with an overview of this satellite, the story behind it, the areas covered, and how it can be accessed. Then the realization of a practical radio station by using the ADALM-PLUTO SDR, based on one of the ADI SDR transceivers, will be presented.

The Satellite

Launched in 2018 from Cape Canaveral, the Es'hail-2 communication satellite of the Qatar satellite company Es'hailSat provides television, voice, internet, corporate, and government communication services across Europe, the Middle East, Africa, and beyond. It has been operational since February 2019 and has been positioned above central Africa in a geostationary orbit. From a height of 36,000 km, it covers an area spanning from Brazil to Malaysia, from the Faroe Islands to Antarctica, as shown in Figure 1.

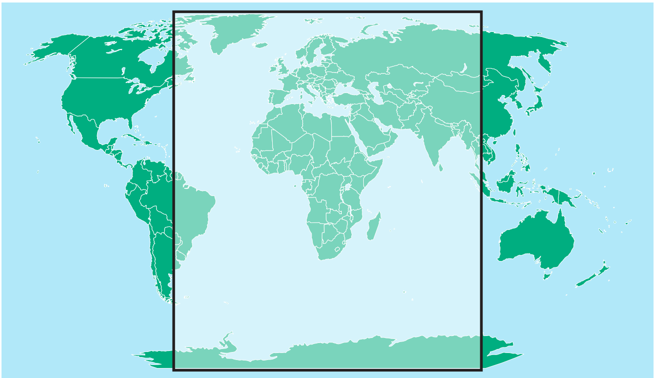


Figure 1. The Earth seen by Es'hail-2.

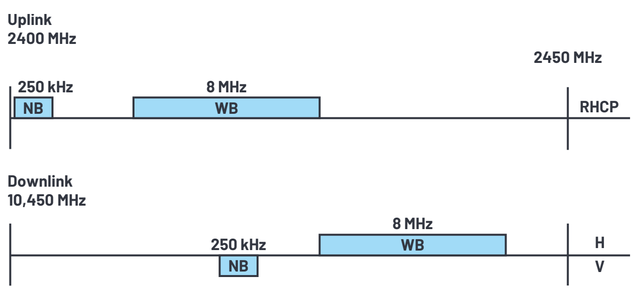
Es'hailSat was established in 2010. Based in Doha, Qatar, the company owns and operates satellites to serve broadcasters, businesses, and governments. In order to promote and foster space technology development in Qatar, Es'hailSat initiated the development of new technology for the Qatar Amateur Radio Society (QARS), a national nonprofit organization for amateur radio enthusiasts, together in partnership with Amateur Satellite Corporation (AMSAT), another global nonprofit organization. AMSAT designs, builds, arranges, launches, and operates satellites carrying amateur radio payloads. AMSAT affiliated national organizations exist in various countries, including AMSAT Germany (AMSAT-DL), which became involved on behalf of QARS in December 2012. This collaboration has made it possible to equip the Es'hail-2 satellite with two dedicated transponders, providing the first amateur radio geostationary communication capability that connects users across the visible globe in a single hop and in real time.

Many amateur satellites receive an OSCAR (orbiting satellite carrying amateur radio) designation. These satellites can be used free of charge by licensed amateur radio operators for voice and data communications. So far, they have been launched into low Earth orbits (LEOs) and into highly elliptical orbits (HEOs), and what all of them have in common is that it is necessary to track them with antennas when they appear above the horizon for just a few minutes. Once they disappear below the horizon, the communication is no longer possible. Satellites on a geostationary orbit have the advantage that, as observed from Earth, their positions do not shift in the sky. Although the antennas on Earth do not have to move to access them, the big distance of 36,000 km sets new challenges in terms of free space power loss, antenna pointing accuracy, and latency—about 250 ms for a trip from one ground-based transmitter to the satellite and back to another ground-based transmitter. The nickname given to Es'hail-2 is OSCAR100 because it is the one hundredth satellite to carry an amateur radio payload.

Access to Es'hail-2

Radio amateurs have worked with satellites for many years. Traditionally, this has been done using analog downconverters and upconverters that shift the received and transmitted signals to and from the amateur bands where transceivers operate. The uplink (from Earth to satellite) and downlink (from satellite to Earth) frequencies used by satellites are sometimes beyond the capabilities of available transceivers. Es'hail-2 has two transponders: one for narrow-band (NB) transmissions and one for wideband (WB) transmissions. In this section, we will talk about the narrow-band transponder. Since, on this transponder, the available bandwidth is only 250 kHz, to accommodate multiple channels it is necessary to use appropriate modulation techniques. The types of analog modulation that are most commonly used are telegraphy (Morse code, also called continuous-wave (CW)) or telephony (voice, also called single sideband (SSB)).

Uplink is at 2.4 GHz (13 cm band) in right hand circular polarization (RHCP) and downlink is at 10.45 GHz (3 cm band) in either horizontal (H) or vertical (V) polarization. Radio amateurs have the privilege to transmit in the 13 cm band (2300 MHz to 2310 MHz and 2390 MHz to 2450 MHz) as licensed radio operators for satellite communication with sufficient power and high gain antennas. This band overlaps with the civilian radio allocation 2400 MHz to 2500 MHz, which is part of the industrial, scientific, and medical (ISM) bands. One of the most popular unlicensed emissions on the ISM band is wireless LAN. The transponders are detailed in Figure 2.



	Uplink (MHz)			Downlink (MHz)			BW (MHz)
	Pol	Begin	End	Pol	Begin	End	
NB	RHCP	2400.05	2400.3	V	10489.55	10489.80	0.25
WB	RHCP	2401.5	2409.5	H	10491	10499	8

Figure 2. Transponders of Es'hail-2.

The Innovative SDR Approach

The change that came with the introduction of SDR in its many variants also impacted the amateur radio world. Even though most transceivers still have the same controls of the older analog ones, many of them incorporate digital signal processor (DSP) technology after the mixer, at the intermediate frequency level. Some of them are also able to directly sample the whole shortwave portion of the spectrum (dc to 30 MHz). One advantage of the SDRs is that their performances do not degrade with time, since many critical analog components are partially replaced by digital algorithms. Another advantage is that the same performances that require expensive components in analog radios, like mixers or filters, can be obtained in a more cost-effective way by complementing them with different elements like analog-to-digital converters (ADCs) and DSPs. The integration of multiple blocks, such as image rejection mixers, oscillators, and ADCs, in the same silicon device has made feasible new receiver architectures that are very critical to implement with discrete technology. One example is devices like the AD9363/AD9364 RF agile transceivers that combine all RF front-end, mixed-signal, and digital blocks in a single device for both receiving and transmitting. When paired with an FPGA that manages the digital data flow into and out from the device, the elements remaining to build a complete station are the antennas, the power amplifier, and the software algorithms running on a computer.

ADI offers the ADALM-PLUTO SDR to demonstrate the capabilities of the AD9363, shown in Figure 3. This is a cost-effective hardware tool that can be used by engineers to develop applications where radio is involved based on the new SDR approach. The AD9363 has a receive and transmit bandwidth of 20 MHz and it can easily receive both the narrow and wide downlink transponders of the Es'hail-2, once they are downconverted externally to its frequency range of 235 MHz to 3.8 GHz. It can transmit on the uplink frequencies without any external upconverter. Another beneficial feature, when compared to devices of the same class and price, is that it has two connectors for receive and transmit, so it supports full-duplex operation. The normal amateur radio interaction is half-duplex (you either talk or listen), but the ability to receive your own transmission in real time allows you to understand whether you are modulating in a clear way, or whether you need to increase/decrease the transmitted power. It also helps to have the ability to point the transmit antenna to the sky once the receive antenna has been adjusted.

The ADALM-PLUTO is supported for both transmission and reception by some free software packages, often written by radio amateurs themselves. One example is the SDR Console by Simon Brown (amateur radio callsign G4ELI). This software manages the interaction between the user and the transceiver, and implements demodulation and modulation in software.

An SDR Satellite Station

Radio amateurs are well known for building their own hardware and repurposing existing equipment to fit their needs. With receive antennas and downconverters, the cheapest alternative is an ordinary satellite dish for commercial satellite television and a low noise block (LNB). The LNB contains the waveguide and the downconverter that translate the incoming downlink signal at 10.450 GHz to less than 1 GHz, which falls inside the receivable band of the SDR. Narrow-band modulation types such as CW (a few tens of Hz) or SSB (less than 3 kHz) mandate highly stable local oscillators to avoid continuous retuning, which is less critical in wideband modulation types such as the ones used by broadcast television (some MHz). In modern digital communications, compensation for frequency offset and long-term drift due to thermal issues is built into the standards and implemented by everyone. Unfortunately, this is not standardized, or not implemented, for many narrow-band modulation schemes implemented by amateur radio operators, and the expectation is that PLL or sample rate accuracy and drift either in the LNB or baseband signals is perfect. To ensure this assumption is correct, sometimes high precision/low drift reference clocks are used. Since many amateur radio operators are more comfortable swapping a reference clock than implementing complex digital signal processing techniques, many will recommend this easy fix.

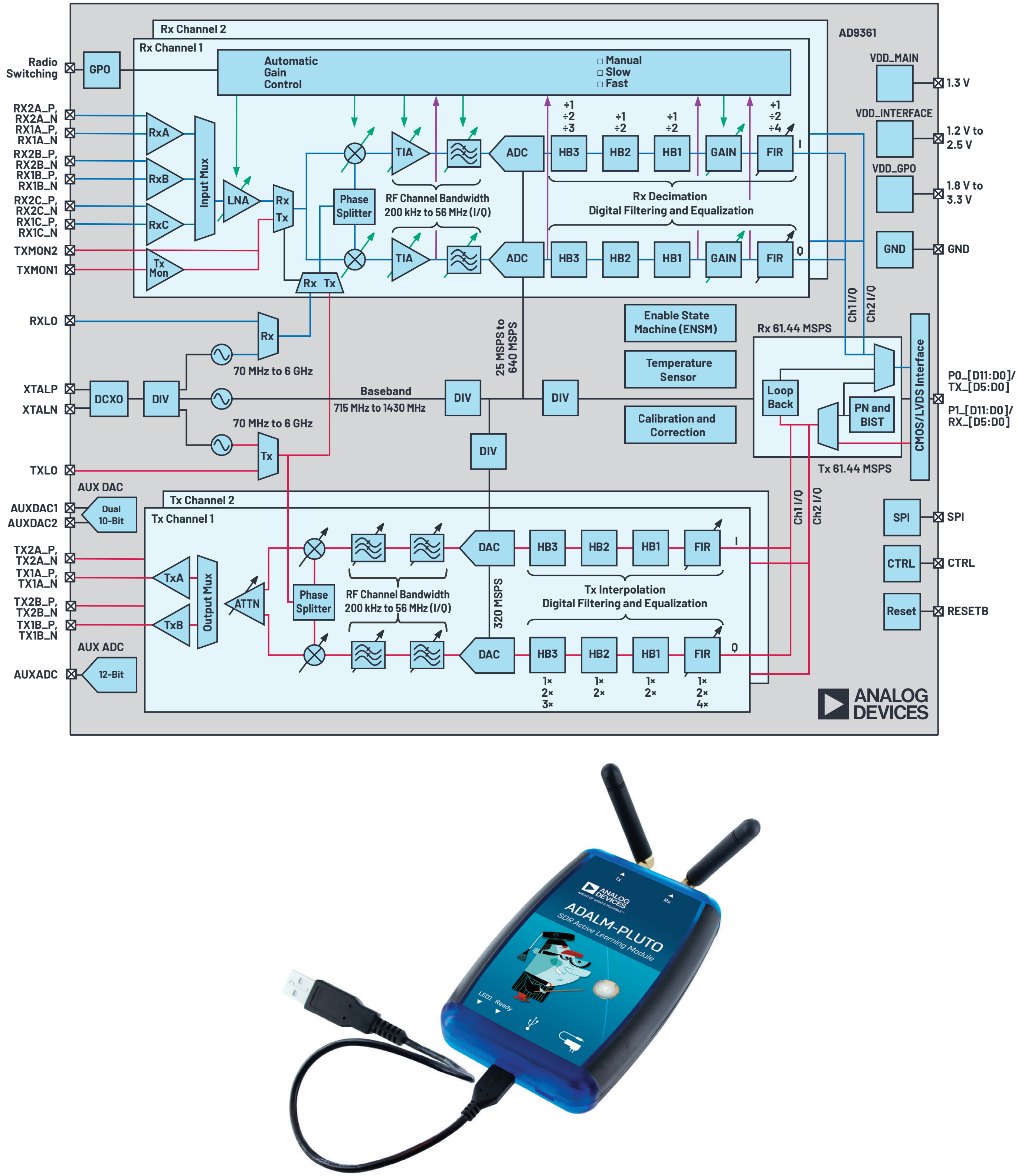


Figure 3. ADALM-PLUTO and its transceiver AD9363.

Since the uplink frequencies are within the WLAN 2.4 GHz band it is possible for licensed operators to repurpose existing WLAN equipment like power amplifiers and high gain antennae. The ADALM-PLUTO has about 5 dBm power output, which is insufficient to drive a power amplifier that has an output power of a few watts. The CN-0417 reference design, based on the ADL5606 20 dB power amplifier and powered by the LTM8045 SEPIC micromodule converter, yields enough power gain to overcome this limitation. Figure 4 shows how a communication station can be laid out. The station can also be rapidly deployed in the field to support emergency communication.

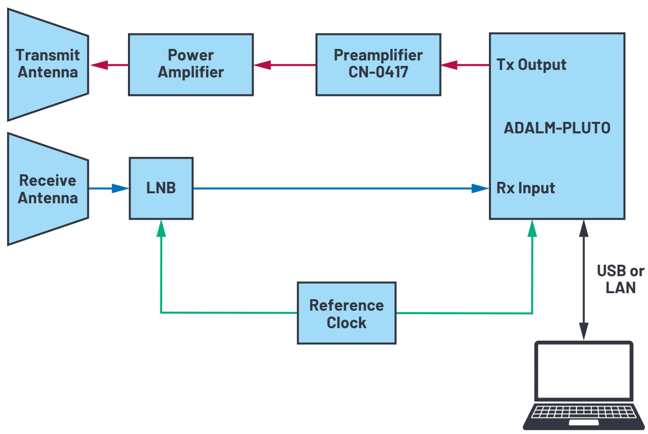


Figure 4. SDR satellite radio station.

Summary

In conclusion, we see a shift toward SDR technology in radio communication. This has been possible by integrating multiple analog and mixed-signal blocks in one device. Immediate advantages are cost-effectiveness, improved reliability, and reconfigurability.

Quoting the words of Drew Glasbrenner, KO4MA, AMSAT VP Operations, "May the 100th OSCAR satellite be the guide star to future amateur radio satellites and payloads to geostationary orbit and beyond."

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About the Author

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