Application Note

Local Oscillator Substitution in Satcom Testing Applications

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Low-Earth orbit (LEO) satellite systems are being deployed for mission-critical use cases at an accelerating rate. This brings associated critical test requirements that, if not performed accurately, could lead to degraded system performance. This whitepaper will focus on how the technique of local oscillator (LO) substitution is used to evaluate or fault-find up and down conversion chains. For simplicity and brevity, ground station applications will be featured. However, the same technique applies to both user terminals and satellite payloads.

There are many types of satellite deployment, ranging from those in geostationary orbit (GEO) to those in low-Earth orbit as shown in Figure 1.

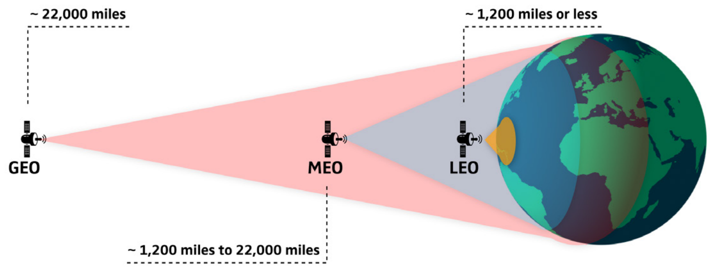

Figure 1: GEO, MEO, and LEO deployment altitudes.

Deployments of LEO satellites are happening at an ever-increasing rate. For example, the SpaceX Starlink system currently has approximately 3,500 satellites in low-Earth orbit, and, in December 2022, the FCC approved deployment of 7,500 next-generation satellites[1]. Due to the reduced latency of LEO systems, they are becoming the system of choice for both civil and military applications including, but not limited to, 5G and military battlefield communications. Ukrainian use of the Starlink system is a recent example of the latter. Use of LEO systems for these types of operation leads to a requirement for high accuracy testing to ensure reliable operation.

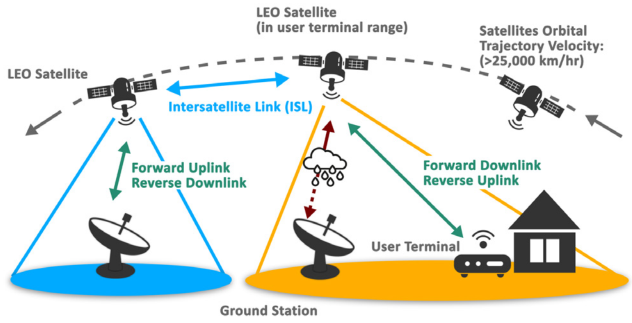

Figure 2: The typical architecture and the various elements of a LEO system.

Ground stations, also referred to as gateways when connecting to the terrestrial network, are a key element of up and downlink operation as shown in Figure 2. The various modules comprising the up and downlink paths require a variety of tests to ensure reliable operation. Such testing may be performed during development and production of the modules, during integration, as part of fault-finding, and operational monitoring. Figure 3 shows a simplified block diagram of the RF and microwave paths in a gateway and examples of where test equipment would be used to assess physical layer performance. For the purposes of this whitepaper, we'll focus on the green-shaded areas where signal generators are used as LO substitutes during evaluation or fault-finding associated with the up and down conversion paths. More information on the other test applications may be found in a recent article[2] by the author.

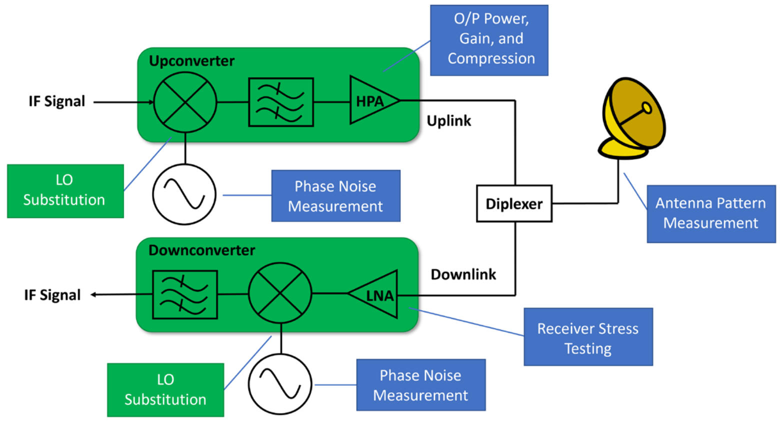

Figure 3: A gateway block diagram that shows examples of RF and microwave path testing.

Critical Local Oscillator Specifications

Before looking at LO substitution, it's necessary to consider what's important in terms of local oscillator specifications. There are many factors that contribute to the performance of satellite up and downlinks and several of them, such as the signal purity of the local oscillators, impact bit errors. Excessive phase noise increases error vector magnitude (EVM) and can lead to symbol and hence bit errors because the position of the constellation points on the I-Q diagram cross over symbol decision boundaries as shown in Figure 4.

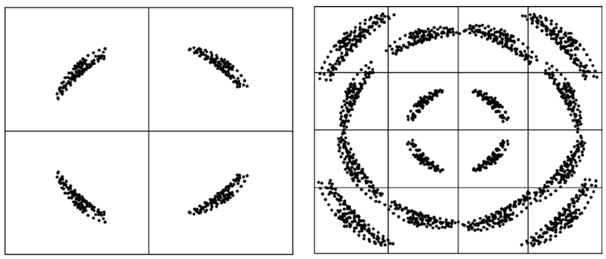

Figure 4: QPSK is resilient to phase noise, whereas the same level of phase noise (angular rotation) causes symbol errors in higher-order modulation schemes.

LO Substitution

LO substitution is an important technique when testing up and downconverters in communications systems. It enables design engineers and technicians to evaluate signal chains without their performance being masked by the characteristics of the designed-in LO or to determine if the LO is the source of issues when the system is not performing properly. When choosing a synthesizer as an LO substitute, it is important to choose one that has high signal purity so that the test equipment is not itself the cause of poor phase noise and hence errors as shown to the right in Figure 4.

Figure 5 shows the Boonton SGX1000 signal generator being used as an LO substitute along with Boonton RTP5000 peak power sensors for evaluation of the high-power amplifier (HPA) in the upconverter chain.

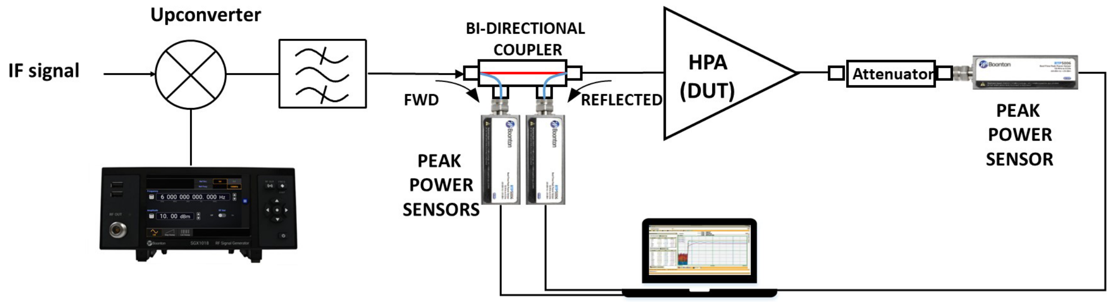

Figure 5: A setup using LO substitution to test a satellite upconverter HPA, featuring the Boonton SGX1000 Series as the LO substitute.

There are various stages in a satcom system's lifecycle where a signal generator would be used as part of the test setup. Table 1 shows these stages and relevance to ground station, user terminal, and satellite payload testing.

	Ground Stations/Gateways	User Terminals	Satellite Payloads
Development	✓	✓	✓
Manufacture	✓	✓	✓
Troubleshooting	✓	✓	✓
Installation	✓		
Maintenance	✓	✓	

Table 1: Lifecycle phases where a signal generator may be used.

Signal sources are available in various formats, the most common being a signal generator with a single RF output port. However, if wishing to generate the up and downlink LO frequencies from a single box, a multi-channel synthesizer may be more practical. Examples of these form factors from Boonton and sister brand Holzworth are shown in Figure 6.

Figure 6: A single output signal generator is on the left and a multi-channel synthesizer is on the right.

Beyond LO Substitution

Signal generators have satellite communications applications that go beyond LO substitution. In some systems, particularly military satcom systems, there can be a continuing need to evaluate new waveforms or to emulate interferers. In such applications a signal generator is used to upconvert the waveforms created by an arbitrary waveform generator. In these cases, it is again phase noise that is an important parameter.

Summary

In this whitepaper, we've touched on the importance of phase noise, the use of signal generators as LO substitutes, and even their application for ongoing waveform validation. The Boonton SGX1000 range of signal generators covering the frequencies from 10 MHz to 18 GHz has been used as an example along with the Holzworth families of synthesizers. Gateway examples have been used; however, all the same principles apply to user terminals and satellite payloads.

Endnotes

1 https://www.fcc.gov/document/fcc-partially-grants-spacex-gen2-broadband-satellite-application

2 Buxton, Bob. Testing satellite uplink and downlink chains. *EE World Test and Measurement Handbook*, June 2023, pp 31-33

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