Ensuring Greater Confidence in Signal Analysis at 110 GHz and Beyond

Introduction

As you reach terahertz frequencies, it's easy to underestimate the challenges that arise in design simulation, measurement, and analysis. Compared with baseband, radio frequency (RF), or microwave signals, those at 30 GHz, 300 GHz, and 1 THz behave quite differently. Propagation losses in the atmosphere are high at wavelengths of 10 mm, 1 mm, or 0.3 mm, especially at the resonant frequencies of oxygen, water, and carbon dioxide molecules. It is also difficult to generate power and make calibrated and over-the-air (OTA) measurements at those frequencies and wavelengths.

Keysight leveraged decades of millimeter-wave (mmWave) test expertise to develop off-the-shelf tools that address these challenges. Our latest instruments and software applications put those capabilities at your fingertips, and specialized application engineers are ready to work with you. These signal analysis solutions will help you succeed at 110 GHz and beyond.

Working at the Intersection of Technology and Demand

Millimeter-wave technology has been in use for decades, primarily in aerospace, defense, and backhaul applications, where the benefits have justified the high costs of development, manufacturing, and support. In recent years, advancements in the fabrication of mmWave devices have reduced the cost of extremely high-frequency (EHF) devices, making them more viable in commercial and consumer applications.

For example, complementary metal-oxide semiconductor developers now produce devices with frequencies greater than 500 GHz, and some are aiming to push this cost-effective technology into the 1.0 to 1.5 THz range.

Emerging applications

Keysight is also pursuing groundbreaking component-level research and development (R&D) at extremely high frequencies. One example is an in-house next-generation indium phosphide (InP) process that supports transistor switching frequencies above 300 GHz. This research opens up higher bandwidths in integrated circuits and end products, such as our high-performance oscilloscopes that deliver breakthroughs in real-time and equivalent-time specifications (Figure 1).

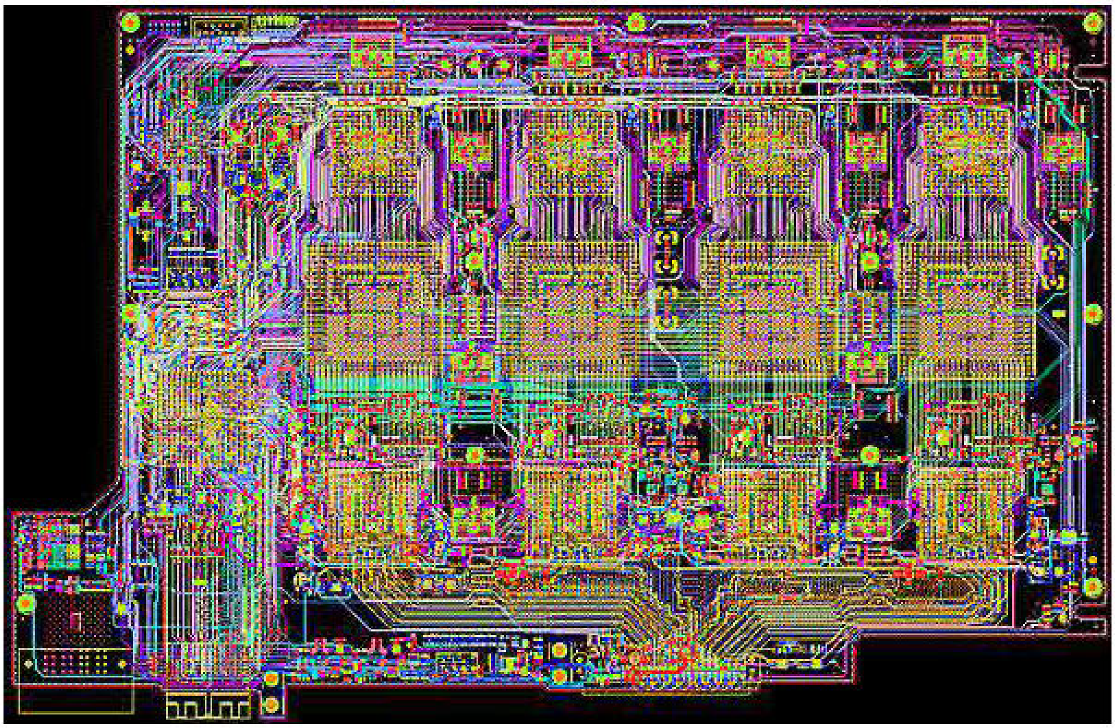

Figure 1. The Keysight high-performance oscilloscope acquisition system, shown here, earned a PCG Technology Leadership Award from Mentor Graphics

Millimeter-wave technologies such as 802.11ad are already on the market. The 802.11 standard is evolving to incorporate 802.11ay, a follow-up to 802.11ad, and 802.11be, a follow-up to 802.11ax.

Achieving the promise of 5G will depend on the successful use of wider bandwidths in the allocated spectrum in frequency range 2 (24.25 to 52.6 GHz) and unlicensed spectrum in the 57 to 71 GHz band. Other communications applications include mmWave line-of-sight backhaul systems and satellite-to-satellite links.

Another emerging application is imaging, which leverages the resolution made possible by 1 mm wavelengths. Examples include analysis of pill coatings in pharmaceutical production, physical measurements of content and texture in food production, and medical imaging that produces distinct spectral signatures for healthy and diseased tissues.

Weighing the Advantages and Challenges of mmWave Signal Properties

Developers of mmWave-based systems may encounter difficulties beyond propagation losses in the atmosphere. For example, when compared with RF and microwave designs, signal losses are greater through transmission lines such as coaxial cable and waveguide.

As frequencies increase, physical dimensions decrease. Thus, all the associated hardware becomes smaller and more fragile, and manufacturing tolerances become much tighter, making it more difficult to fabricate and assemble delicate mmWave devices.

Despite the challenges, EHF signals come with significant benefits. For example, antenna dimensions can be tiny compared with microwave antennas, resulting in compact transmitter and receiver systems. The antennas also can be highly directional with small beamwidths.

With wavelengths ranging from 1 to 10 mm, mmWave signals exhibit absorption properties that may seem problematic but can be advantageous. For example, in terrestrial applications, these signals rapidly absorb as they propagate through the atmosphere.

Given these attributes, mmWave signals are most useful for short-range communications. Some of these, such as automotive radar (77 to 81 GHz), point-to-point radios, wireless backhaul links, and high-altitude radioastronomy arrays, rely on areas of low absorption.

Others use high absorption as a way to reduce interference between users. For example, the 802.11ad (WiGig) standard for high-speed audio and video links operates in the unlicensed 60 GHz band. Unlike typical Wi-Fi signals, this frequency provides a range of about 40 feet (about 12 meters), attenuated by wood, stone, and glass, making it a good choice for home entertainment installations in apartments, condominiums, or townhomes. Coupling high-absorption properties with highly directional antennas also enables the creation of secure communication systems that minimize the chances of eavesdropping.

Focusing on the Measurement Challenges

Guiding signals and generating power presented even greater challenges in developing commercial, off-the-shelf test equipment with accurate, repeatable results.

For example, the waveguide must be close to perfect for the proper internal operation of any mmWave instrument. Working in the 100 GHz to 1 THz frequency range requires the use of different waveguide bands. At millimeter wavelengths, any skew in a flange connection can cause unwanted reflections that degrade signal quality and power.

Generating adequate signal power is a challenge. It is difficult to simultaneously maintain amplifier efficiency and linearity at these frequencies, limiting the top-end power that a signal generator or network analyzer can produce. Related to this, the availability of wider contiguous bandwidths, a benefit associated with mmWave, introduces more noise into the instrument and raises the noise floor. The net effect: lower maximum power and a higher noise floor will reduce the available dynamic range in wideband spectrum measurements.

Precision required

Once you get past these difficulties, the next challenges come from the instrument calibration and test setup. Accurate calibration of power levels at extremely high frequencies is difficult, but precise control of power is essential to ensure measurement accuracy and avoid damage to the device under test (DUT).

Making measurements is quite different at these frequencies, prompting even the most experienced engineers to set aside trusted methods and adjust their expectations. The instruments, cables, and accessories must be right at every stage, from spectrum analysis and the assessment of distortion or spectrum emission mask to network analysis and the characterization of passive (S-parameters) or active devices (X-parameters). That requires clean connections and upconversion of output signals, precise downconversion of incoming signals, low-level internal spurious signals, and well-managed internal harmonics.

Finally, there is one more critical difference to note. In some cases, the connection between the instrument and the DUT occurs OTA rather than through cables or the waveguide. If OTA, you must control and calibrate the radiated environment around the test setup. You also need a way to consistently control or lock down any directional element in the DUT to ensure repeatable measurements.

Extending Signal Analysis to mmWave Frequencies

Keysight offers off-the-shelf test solutions for designs that operate at extremely high frequencies. The flagship Keysight UXA X-Series signal analyzers — the latest version, the N9042B UXA, and the V3050A signal analyzer frequency extender — focus on meeting three key challenges in mmWave signal analysis: sensitivity, frequency range, and analysis bandwidth.

Figure 2. The Keysight N9041B UXA X-Series signal analyzer (left) and N9042B UXA X-Series signal analyzer, paired with the V3050A signal analyzer frequency extender, reach into the mmWave range with continuous sweeps up to 110 GHz

The advanced front-end circuitry of the N9041B UXA achieves low loss and efficient mixing for a displayed average noise level (DANL) as low as -150 dBm/Hz when characterizing wideband modulated signals in the mmWave band.

Both UXAs — the N9041B and the N9042B — come with two input connectors. A robust and economical 2.4 mm input connector covers measurements up to 50 GHz, and a dedicated 1.0 mm input connector, machined to exact tolerances, ensures continuous sweeps and the best DANL up to 110 GHz. Unlike solutions that use banded measurements, the UXA enables you to sweep the entire range with full sensitivity. This capability lets you investigate unknown or unexpected signals with high sensitivity and provides greater confidence that you're seeing problematic signals, not artifacts from the analyzer.

The N9042B UXA uses the V3050A frequency extender to enable unbanded and preselected swept power spectrum from 2 Hz to 110 GHz without the need to manage band breaks and images.

A flexible solution

For coverage to 110 GHz, choose the N9041B UXA single box or move the measurement plane directly to the DUT with the N9042B UXA and the V3050A as a remote head. You have full flexibility to adapt your measurements to suit your test configuration.

Regardless of the UXA choice, calibration at the measurement plane to remove the magnitude and phase errors associated with cables and fixtures in the test setup is essential for accuracy at these frequencies. The Keysight U9361 RCal receiver calibrator allows you to minimize the linear errors of the test receiver system using the ultra-stable reference and repeatable results, with precision factory calibration data.

Learn more about external mixing, extending frequency range, and measurement plane in the white paper Tackling Millimeter-Wave Signal Analysis Challenges.

Enabling Deeper Analysis of Complex Signals

Tight integration between the analyzer and Keysight software puts advanced analysis and fresh insights at your fingertips — literally. The instrument touch-enabled X-Series applications provide general-purpose, ready-to-use measurements and specific applications for standards compliance. By capturing Keysight measurement expertise and delivering repeatable results, the applications make it easy to see and understand the performance of devices and designs.

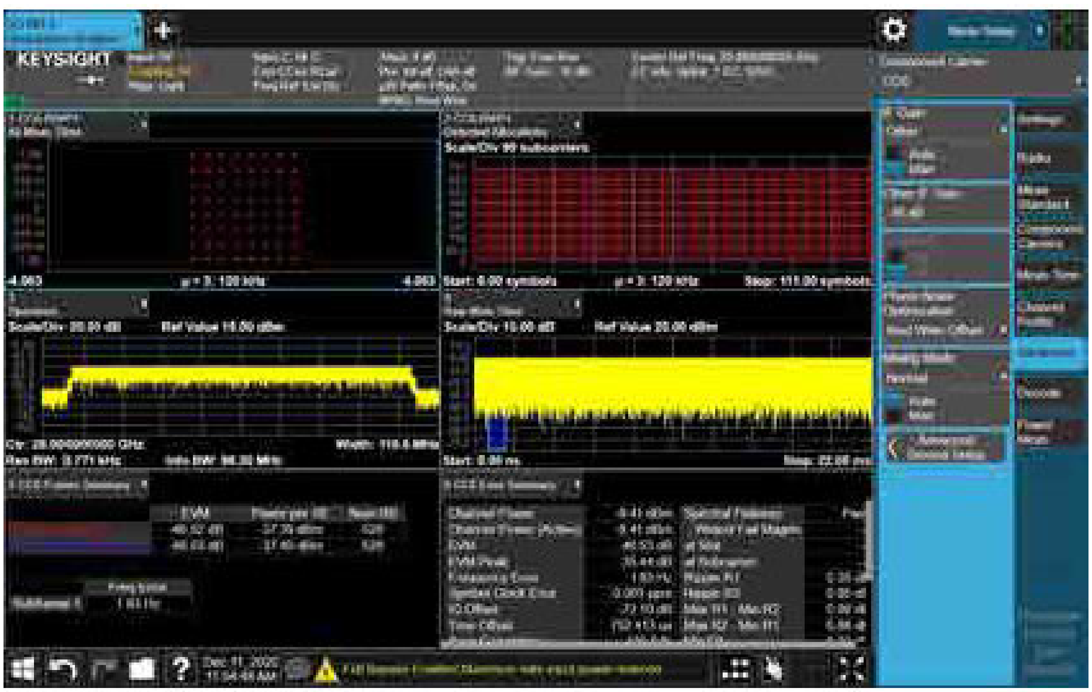

Figure 3. Configurable windows allow you to quickly characterize this 5G 28 GHz 1CC signal

Keysight 89600 VSA software is a comprehensive set of tools for demodulation and vector signal analysis. To help pinpoint the root cause of signal problems, the 89600 VSA also provides capture and playback capabilities that enable detailed post-processing analysis with advanced triggering and post-capture tune-and-zoom measurements (Figure 4). These tools let you explore virtually every facet of a signal and optimize your most advanced designs.

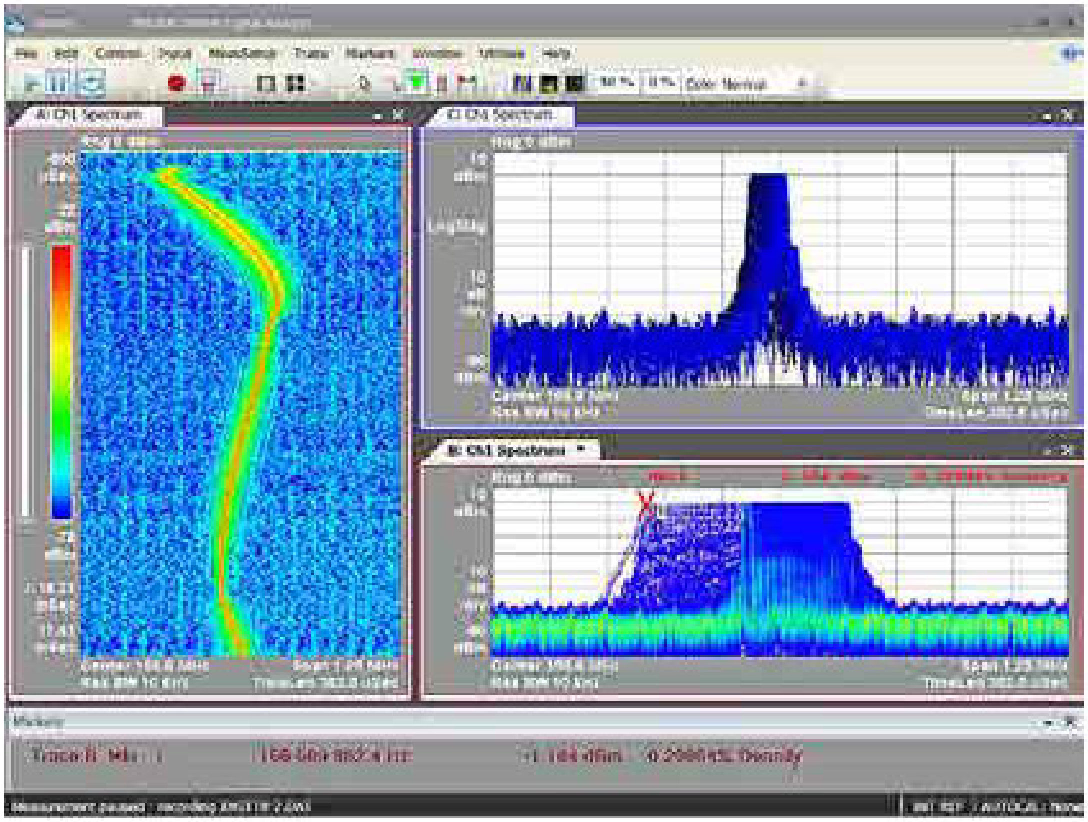

Figure 4. The 89600 VSA software provides visualization and measurement tools that can highlight subtle and transient events such as this radio turn-on event

Conclusion

You will encounter new design and test challenges creating next-generation devices that operate at millimeter-wave frequencies. We used our decades-long expertise to develop high-performance test solutions — the flagship UXA signal analyzer and software applications — to help you succeed at 110 GHz and beyond.

Related Resources

- Data Sheet: UXA X-Series Signal Analyzer, Multi-Touch, N9041B, publication 5992-1822EN
- Configuration Guide: UXA X-Series Signal Analyzer, Multi-Touch, N9041B, publication 5992-2112EN
- Data Sheet: N9042B UXA X-Series Signal Analyzer, publication 3121-1037.EN
- Configuration Guide: N9042B UXA X-Series Signal Analyzer, publication 3121-1036.EN
- Product: U9361 RCal receiver calibrator for improved receiver test system accuracy by 10X
- Brochure: Signal Analysis Solutions Catalog, publication 7120-1206.EN

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