

Keysight Technologies

Solutions for Millimeter Wave Wireless Backhaul

Designing and Testing E-Band Backhaul
Using Effective Network Analysis, and
Signal Generation and Analysis Solutions

Application Note

Overview

The backhaul plays a critical role in the telecommunications network, comprising the intermediate links between the core, or backbone network, and the small subnetworks at the edge of the entire network. In microwave mobile or wireless networks, there are three types of backhauls: macrocell, small cell and femtocell. Femtocell backhauls normally use a broadband access technology and are not covered in this application note. Small cell backhauls transport traffic between the outdoor small cell site and either the node connecting to a macrocell backhaul network, or the node connecting to the Wide Area Network (WAN)/Internet/metro network. It comprises equipment at both ends, along with any mesh or serial equipment in between.

Today, operators have a number of different backhaul technologies to choose from, one of which is called E-band. It presents a particularly enviable option due to its high capacity and potential economic benefits. Available worldwide, E-band point-to-point, line-of-sight microwave radios—also known as millimeter wave (mmWave) radios—operate in the unlicensed 57-64 GHz frequency band at data rates up to 1 Gbps, and in the lightly licensed 71-86 GHz frequency band and 92-95 GHz frequency band at data rates up to 10 Gbps. Such functionality makes them ideal for dense urban environments (less than 1 km), as well as, industrial suburban environments (2-5 km). And, it's a key reason why analysts project a significant jump in the mmWave backhaul market in coming years, driven largely by the increased use of mmWave for Long Term Evolution (LTE) small cell backhauls.

Problem

There are a number of reasons why today's operators might want to migrate to an E-band backhaul. Such solutions offer more bandwidth in higher frequency bands and feature an antenna beam that is very directional and easy to control. Additionally, the frequency bands in which E-band radios operate, namely 60 GHz and 70-90 GHz, are now open to commercial services and products.

Despite these advantages, there are also a number of design and test challenges that can be expected as this transition occurs. For example, the extremely narrow beam width of E-band leaves the signal potentially vulnerable to building sway and atmospheric interference. It also makes aligning systems very difficult. And, E-band is very susceptible to degraded performance caused by the rain and oxygen absorption. The rain essentially interferes with the E-band's radio wave transmission, forcing it to repeatedly transmit data to achieve a reasonable level of service. It even has the potential to cause an interruption in service. On top of this, the cost of testing E-band backhaul solutions is extremely high.

Solution

With advances in mmWave technology triggering the shift from using traditional backhaul (e.g., optical and microwave links) to E-band point-to-point links, having appropriate, cost-effective test and measurement instruments in place is now more important than ever. Such solutions are critical to ensuring proper operation of the E-band backhaul, while also addressing the challenges previously outlined.

An effective mmWave test and measurement strategy must comprise both network analysis for mmWave component test and calibration, as well as, appropriate signal generation and analysis to properly test and measure communication links (e.g., the transmitter, signal path and receiver). The network analysis solution must provide a single-sweep measurement capability, enable full mmWave port power control and support for true differential measurements. The signal generation and analysis solutions, on the other hand, should offer fast measurement times and switching speeds, scalability to enable the tools to be tailored to the users changing test needs and flexibility to ensure they support both current and future formats.

One group of instruments meeting this criteria is Keysight Technologies, Inc.'s mmWave product portfolio. The portfolio features both a mmWave network analyzer solution, as well as, one for signal generation, signal analysis and signal path emulation. The network analyzer solution is ideal for mmWave device characterization, modeling and parameter extraction in coaxial or on-wafer, while the signal generation/analysis solution is well suited for testing mmWave communications links.

mmWave Network Analysis Solution

Keysight's N5251A single sweep, 10 MHz to 110 GHz vector network analyzer solution employs a mmWave test controller and a combination of broadband frequency extenders that provide a male 1.0 mm test port output connector. The N5251A is available as a single product solution. However, it can also be configured using the PNA or PNA-X network analyzer for a lower cost solution. Existing N5227A PNA and N5247A 67 GHz PNA-X users simply need to add the N5261A/N5262A test controller and broadband frequency extenders to be able to cover single sweep 10 MHz to 110 GHz measurements.

The N5251A mmWave solution is the only broadband solution with integrated tri-axial bias tees, which provide accurate control of the device bias through its force/sense ability. Its broad frequency enables superb time-domain resolution and enables accurate leveled power to be applied to the device being measured, allowing users to sweep the power at the 1.0 mm port. Additionally, the N5251A features a range of calibration choices for coax, in-fixture and on-wafer devices.

To make S-parameter measurements up to 1.1 THz, a variety of easily configurable banded mmWave solutions configured from the PNA and PNA-X network analyzers can be used. The 2- or 4-port OML-based banded waveguide system features the PNA-X and frequency extenders from OML Incorporated that cover a range of 50 GHz to 500 GHz. It may be configured with or without a test set controller depending on the measurements required and the frequency extenders being used. Specific

measurements that can be made include true mode, time domain, power, power sweep (single frequency), power spectrum, intermodulation distortion, and noise figure, among others. The 2- or 4-port PNA/PNA-X VDI-based banded waveguide system is used for THz imaging and is configured using frequency extenders from Virginia Diodes Incorporated (VDI) that extend the frequency range to 950 GHz.

These banded mmWave solutions use built-in firmware to leverage software between the PNA and PNA-X Series network analyzers. Regardless of the frequency range of the measurements being taken, the instruments can be manually controlled from the front panel. A mouse can also be used to access simple pull-down menus. Using the firmware interface, it is easy to switch between frequencies for measurements.

Network Analyzer Measurement Example

To gain a better understanding of how a measurement might be taken with the mmWave network analyzer solution, consider a N5251A solution that has been configured from a 4-port PNA network analyzer and allows single-sweep measurements from 10 MHz to 110 GHz (Figure 1). The N5251A has the ability to control and use receiver leveling to set the power accurately at the 1.0 mm test port. Also, it supports measurement applications like true differential measurements, pulsed measurements and scalar mixer measurements, and has the flexibility to enable a single touchdown for on-wafer components that completely characterizes the behavior of the device being measured.

With the N5251A's ability to accurately control power, gain-compression measurements at mmWave frequencies are much simpler. As an example, Figure 2 shows a power sweep being used to perform a 110 GHz buffer amplifier measurement, while also doing a traditional S-parameter measurement.

Mixer measurements and power spectral measurements can also be easily made with this configuration of the N5251A. Figure 3a shows the PNA performing a LO power sweep of a 75 to 110 GHz down converter mixer at a continuous wave of 75 GHz. Power spectral measurements are made using the PNA's built-in IM spectrum option. Figure 3b shows the measurement of the input and output spectrum of a 110 GHz buffer amplifier measured across the frequency range from 10 MHz to 110 GHz.

FIGURE 3b.
Shown here is
input/output of an
amplifier at 77 GHz.
With the PNA's IM
spectrum option,
all spectral power
components can be
measured across the
10MHz to 110 GHz
frequency range.

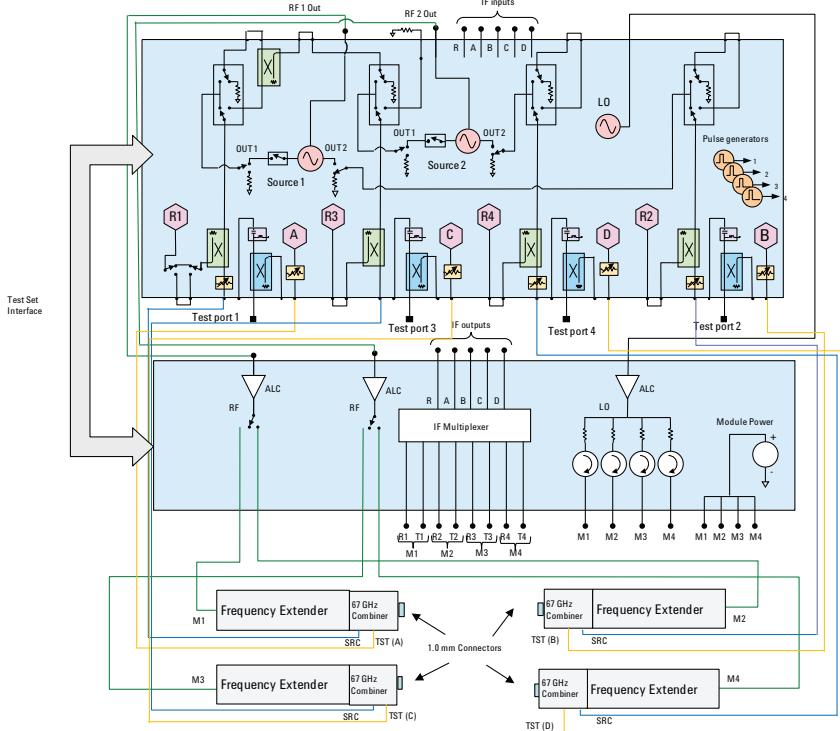


FIGURE 1. Shown here is the block diagram for the 4-port 110GHz N5251A mmWave network analyzer based on the N5227A PNA.

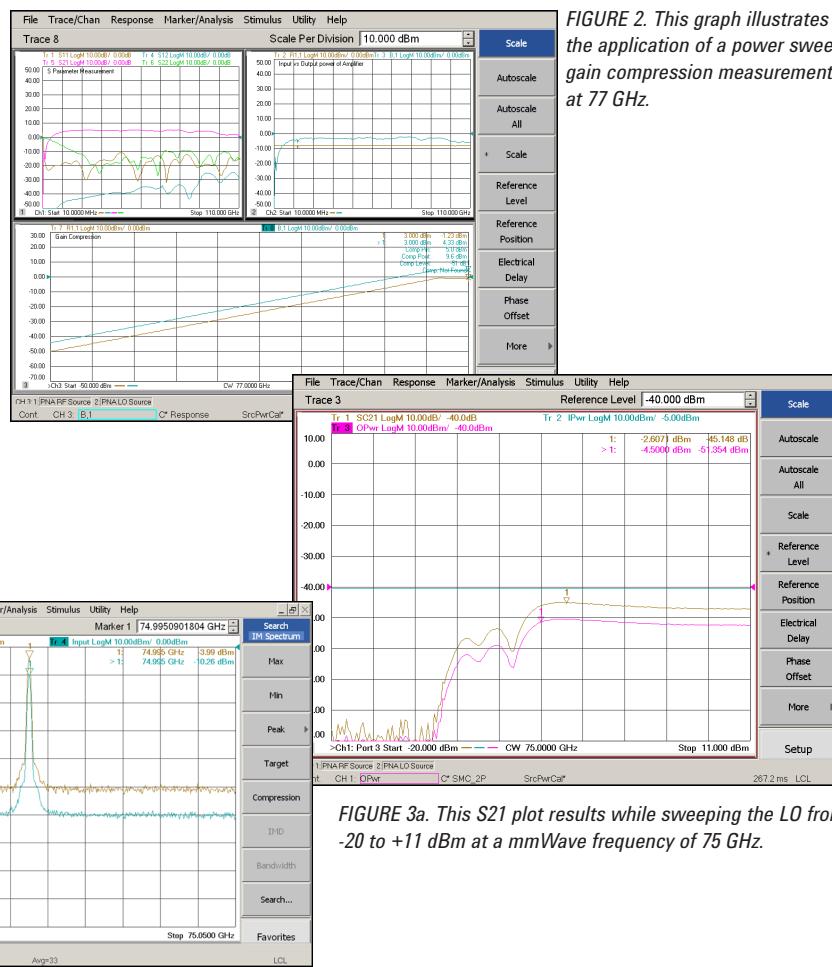


FIGURE 3a. This S21 plot results while sweeping the LO from -20 to +11 dBm at a mmWave frequency of 75 GHz.

FIGURE 2. This graph illustrates the application of a power sweep gain compression measurement at 77 GHz.

mmWave Signal Generator and Analysis Solution

mmWave signal generation and analysis, as well as, signal path emulation, is possible using Keysight's M8190A wideband arbitrary waveform generator (AWG), PSG signal generators, PXA/EXA spectrum analyzers, and high-performance Infinium Series oscilloscope with the 86901B vector signal analysis software (Figure 4). Consider, for example, the evaluation of a transceiver. Testing the transceiver requires a simulated transmitter and/or a simulated receiver. Ideally, both should be flexible enough to generate real world distortions on the source side and compensate for them on the sink side. With the M8190A high-performance arbitrary waveform generator working at 12 bit and 12 GSa/s or at 14 bit and 8 GSa/s, users have the ability to create these types of waveforms to use as a test source. The vector PSG signal generator acts as an external I/Q modulator. On the analyzer side, an Infinium oscilloscope is used with its support for up to 63 GHz of real-time frequency bandwidth. The PXA and/or EXA with 160-MHz RF analysis bandwidth, together with a Keysight smart mixer could also be another choice—depending on the signal bandwidth and frequency. The test solution also includes software consisting of MATLAB support for customized signal creation, Signal Studio support for specific signal formats such as LTE, and the 89601B software for signal analysis.

During actual measurement of the transceiver, a signal would first be generated by the M8190A AWG or Signal Studio, up-converted with a Keysight E8267D vector signal generator and/or external third-party upconverter, and then transmitted to the Device Under Test (DUT), in this case, an 86 GHz link. Next, it would be down-converted by an external device, such as a Keysight smart mixer or third-party downconverter, and analyzed by the Infinium oscilloscope, or PXA/EXA using 89601B vector signal analyzer software (Figure 5).

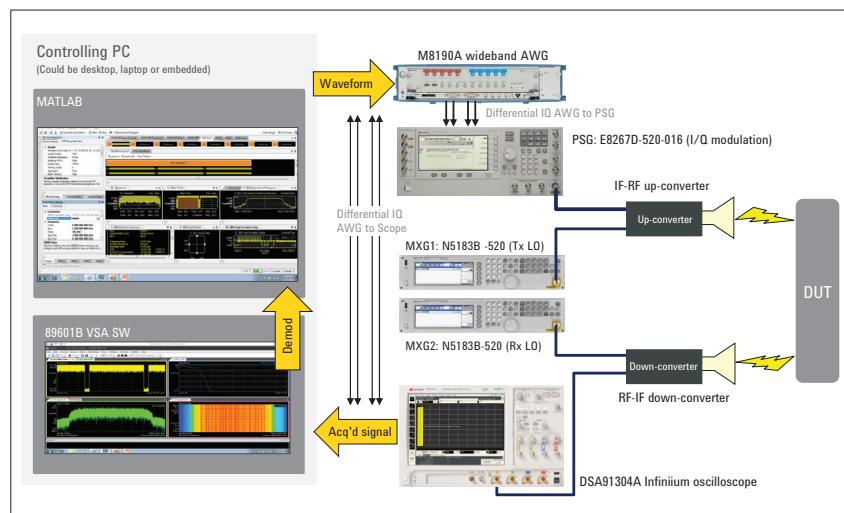


FIGURE 4. This block diagram depicts the overall modulated signal generation and analysis solution that can be used for mmWave backhaul measurements and analysis.

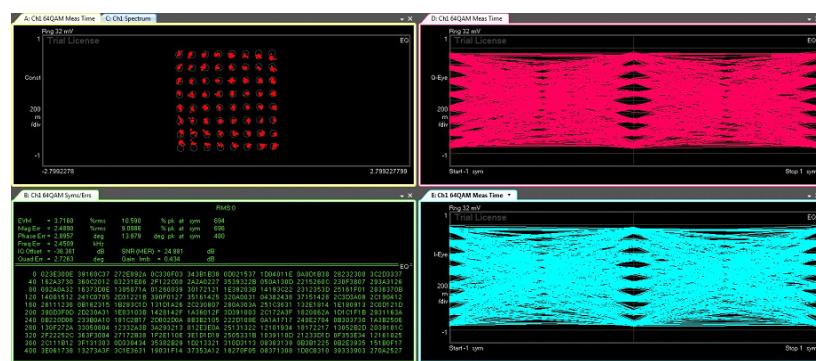


FIGURE 5. Analysis of the transceiver produces a 64-QAM constellation with 3 GSymbols/s and a Q-eye and I-eye diagram on a 86 GHz communication link.

Summary of Results

Ongoing advances in mmWave technology are helping to shift backhauls away from traditional technology and toward more economical, high-capacity E-band point-to-point links. Unfortunately, the challenges associated with these links further complicate an already difficult design and test process. Fortunately, the N5251A mmWave network analysis solution for component test and the mmWave signal generation and analysis solution for testing communication links, are helping to make these challenges much less formidable. As a result, they are now providing today's engineers with a critical tool for ensuring the proper operation of E-band backhaul, and in turn, helping the technology's continued proliferation.

The Power to Accelerate Wireless Design and Test

Keysight is a leader in wireless test, focused on the highest-performance design and test of wireless devices and networks, with application-focused platforms optimized for existing and emerging standards. Adding to this optimal R&D and field support, Keysight allows engineers to better understand the intricacies of the continuously evolving wireless industry so you can accelerate your development of products.

To learn more about Keysight's suite of test and measurement products please visit:
www.keysight.com/find/powerofwireless

Related Applications

- mmWave S-parameter measurements
- WiGig testing
- Microwave and millimeter signal measurements

Related Keysight Products

- Infiniium 90000 Series Oscilloscopes & InfiniiMax Series Probes
- E8267D PSG Vector Signal Generator
- E8257D PSG Analog Signal Generator
- N5183B MXG X-Series Microwave Analog Signal Generator
- N9030A PXA Signal Analyzer
- N9010A EXA Signal Analyzer
- 89601B VSA Software
- Signal Studio Software
- M8190A 12 GSa/s Arbitrary Waveform Generator
- Smart Harmonic Mixers
- PNA Network Analyzers
- Millimeter Wave Frequency Extenders
- from Virginia Diodes Inc. for the PSG
- Signal Generators
- Millimeter Wave Source Modules from OML, Inc. for the PSG Signal Generators

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