

Millimeter-Wave Component Characterization With Vector Network Analyzer

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Abstract: The N5291A measurement solution for mmwave network analysis is a distributed system composed of a vector network analyzer (VNA), a test set controller, and frequency extenders. A distributed system is made up of separate components that communicate together to act as one system. The frequency extenders interface with the device under test (DUT) and are the only pieces of the system that operate at mmwave frequencies. This allows us to test mmwave devices without having to completely rebuild VNAs to handle higher frequencies. The frequency extenders connect to a test set controller, which interfaces with the test set of the VNA. This gives the VNA a new maximum frequency of 120 GHz so it can test modern mmwave devices.

Keywords: Vector network analyzer, frequency extenders, single-connection.

1. Introduction

The adoption of millimeter wave have evolved significantly over the years and can be placed into 2 major application spaces:

The commercial application space:

The earliest commercial applications of millimeter wave have been in Wireless Gigabit communication systems example of this would be 60GHz wireless HDMI.

Then in around early 2010 we saw the start of millimeter waves frequencies adoption for automotive radar applications at 77GHz. This started with the initial implementation of park assist and collision avoidance radar and evolved now to applications of multi-channel radar systems for autonomous vehicle control.

More recently there has been a significant drive for more data and faster wireless communications systems. This has driven the wireless communication markets to utilize the 60–90GHz frequencies for 5G applications.

Aerospace and defense:

This industry has for a very long time lead the application of millimeter wave frequencies for several of their solution needs. The millimeter wave band has always offered them the secure satellite and ground communication systems.

Secure communication systems demand for complex encryption of large amounts of data and millimeter wave frequencies worked well for them. This has driven development of ultra-wideband military communication solutions that use millimeter wave frequencies.

As environmental phenomena challenged the use of optical/thermal imaging for EW system. There has been increase in the need of EM field imaging methods at millimeter wave bands. These Doppler radar imaging systems have driven the need for the A/D RADAR systems to take advantage of millimeter wave frequencies.

Finally, we have security imaging, which is one place we all are familiar with where the application of millimeter wave is used.

All these applications present unique challenges in their testing and application. Error sources such as cable losses, connector repeatability, and phase shifts that might have been mostly negligible at radio frequencies are amplified at higher frequencies. High-end vector network analyzers typically have maximum frequencies of 67GHz , so many of these applications require testing beyond the limits of most hardware.

The most convenient solution is a VNA with a single-connection/multiple-measurement (SCMM) architecture. As implemented in the Keysight PNA-X network analyzers, you can measure passive or active devices with one set of connections: S-parameters, noise figure, gain compression, THD, IMD, and more. For even greater measurement versatility, the SCMM capability supports the spectrum analysis measurement application. The measurement solution for mmwave network analysis is a distributed system composed of a vector network analyzer (VNA), a test set controller, and frequency extenders. Keysight's distributed solution is based on the *N5295AX03* modular frequency extension. The *N5295AX03* can be added to an existing compatible network analyzer (PNA or PNA-X with a maximum frequency of 26.5GHz or higher), reducing the cost of test by upgrading instead of replacing. The frequency extenders connect to the *N5292A* test set controller, which interfaces with the test set of the VNA.

The frequency extenders up-convert the 26.5GHz output from the test set to test devices at

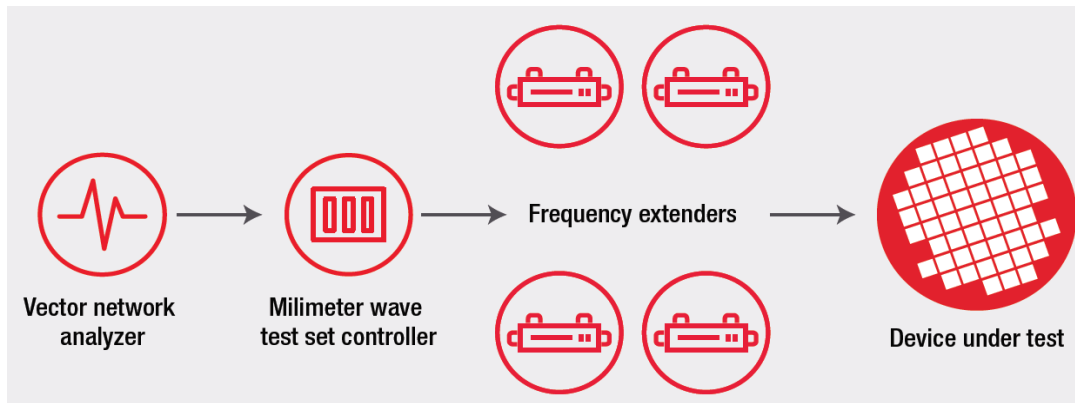


Figure 1: High level block diagram of the mmwave VNA system



Figure 2: N5291A mmwave measurement system

millimeter-wave frequencies. The block diagram of the *N5295AX03* frequency extender shows the conversion circuitry. There are three multiplier chains available, which can mix the RF input

to produce frequencies as high as 120GHz . This frequency is well within the millimeter range and provides accurate characterization of cutting-edge millimeter-wave devices.

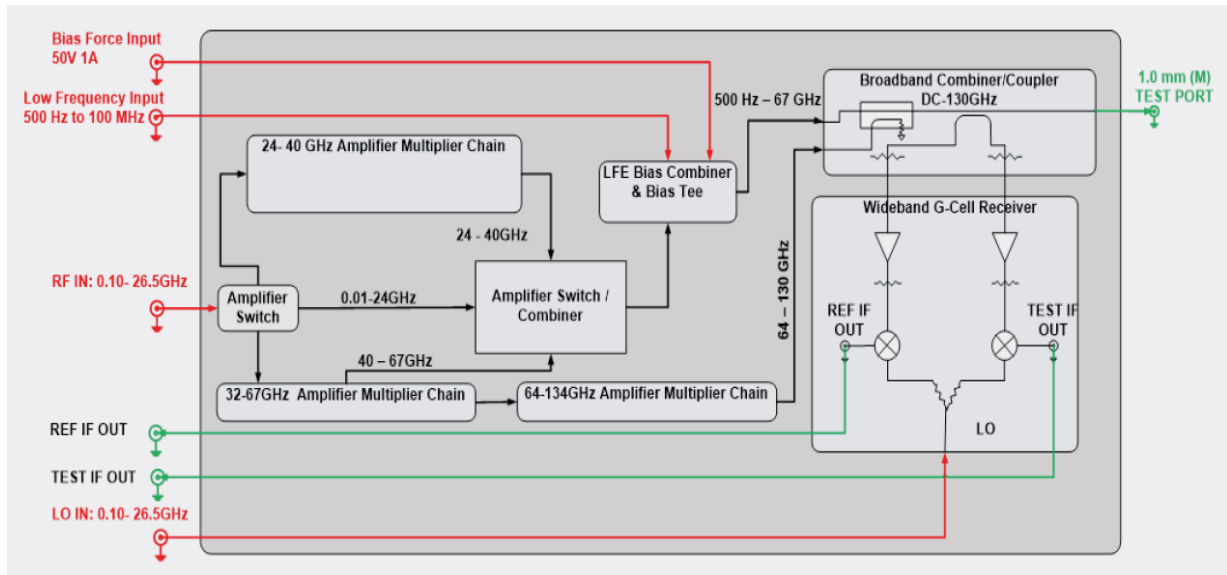


Figure 3: N5295AX03 frequency extender block diagram

The test set controller amplifies the network analyzer's local oscillator (LO) signal to drive the frequency extenders' mixers across their entire frequency range. The controllers also error correct and condition the frequency extender output to be at the IF of the VNA. The controller simplifies the measurement setup by providing RF, LO, and intermediate frequency (IF) signals to the frequency extenders over a single cable.

To test monolithic microwave integrated circuits (MMICs), which contain many components that operate in different frequency ranges, one should have a measurement system enabling measurements from low frequencies to mmwaves. This is implemented in VNA low-frequency extension test set, allowing measurement down to 900Hz .

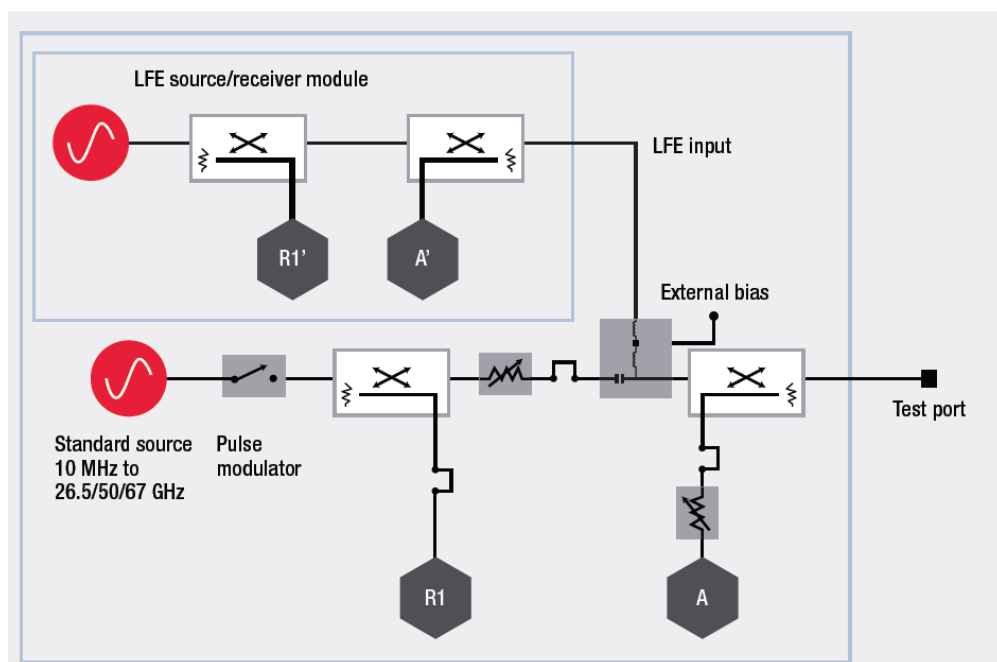


Figure 4: LFE implementation

2. Conclusion

The single-connection/multiple-measurements (SCMM) distributed architecture VNA measurement system allows to confidently characterize and optimize new-generation mmwave devices.

The key advantages are:

1. Single sweep, traceable measurements with minimum measurement uncertainty from 900Hz to 120GHz due to standardized 1 mm coaxial connector.
2. Typical dynamic range $>110\text{dB}$ up to 110GHz , $>100\text{dB}$ up to 120GHz .
3. Temperature stability due to separate frequency extension modules with convection cooling.

References

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