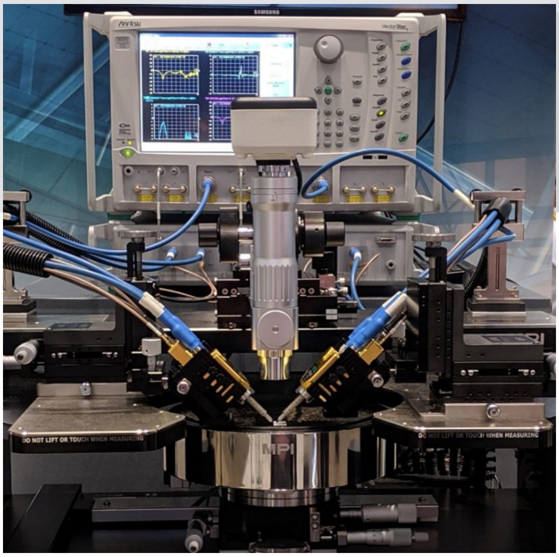
On-Wafer Biasing Using Anritsu Kelvin Bias Tees on VectorStar™ ME7838x Broadband Systems



VectorStar ME7838G 70 kHz to 220 GHz Broadband VNA

VectorStar ME7838x broadband VNA systems perform measurement sweeps from 70 kHz to 110, 125, 145, and 220 GHz through a single output port. A typical application for this is on-wafer measurements through a probe. Often there is a need to bias an active device through the probe and, for optimum accuracy, the biasing is performed using a Kelvin bias tee located as close to the device under test (DUT) as possible. This application note describes how to bias an active device up to 220 GHz using a Kelvin bias tee with the Anritsu VectorStar ME7838x broadband system.

DUT Biasing with a VNA

Typical DUT biasing at RF and microwave frequencies is often performed through a connector located on the front or rear panel of the VNA (Figure 1).

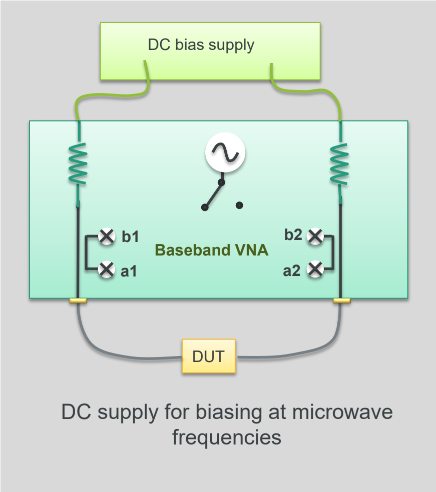


Figure 1. Device biasing through a front or rear panel connection

For cases when accurate biasing is critical, an external bias tee can be used to locate the DC supply point close to the DUT. To further improve accuracy, a Kelvin bias tee with force/sense terminals attached to a source measure unit (SMU) instrument will significantly improve DC biasing control (Figure 2).

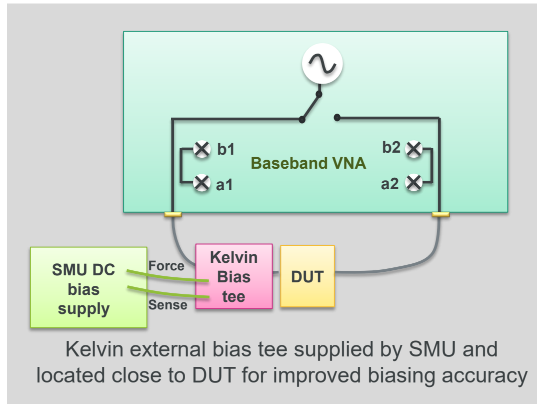


Figure 2. Biasing with a Kelvin bias tee

Kelvin Biasing with a Broadband VNA

Broadband VNAs are defined as baseband VNAs (usually up to 70 GHz using V [1.85 mm] connectors) with waveguide band modules that have 1 mm or smaller connectors in order to support millimeter-wave (mmWave) bands. Biasing devices at mmWave frequencies using broadband VNAs present similar goals regarding accurate biasing with Kelvin control, especially for on-wafer measurements. The architecture of the broadband VectorStar VNA is based on a combination of the baseband VNA, in this case a VectorStar MS4647B 70 GHz solution, with the Anritsu non-linear transmission line (NLTL) modules and broadband test set. The unique design of the NLTL module provides a DC path between the baseband VNA and the DUT (Figure 3).

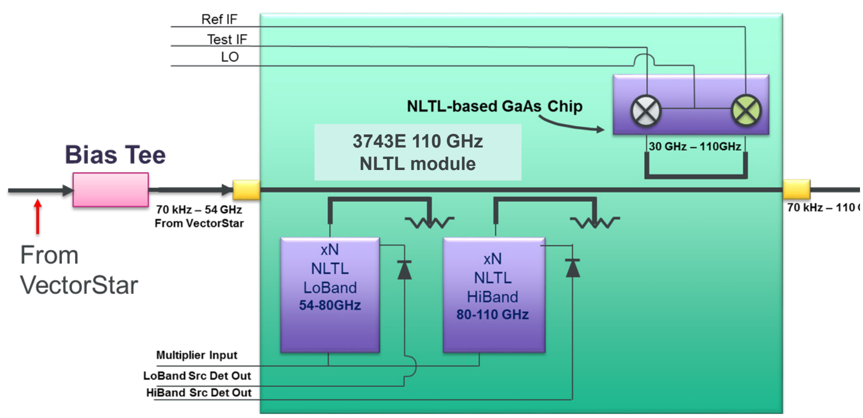


Figure 3. Anritsu NLTL module providing a DC path to the DUT

For on-wafer biasing, this architecture provides the opportunity to insert an external bias tee on the VNA side of the module while avoiding the need for the bias tee to carry a mmWave signal through the carrier transmission line above 54 GHz (Figure 4). An additional benefit of this approach is that the bias tee can be changed for different designs when higher voltage or current requirements are needed.

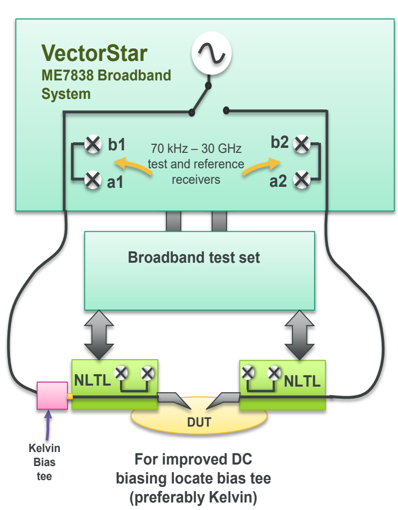
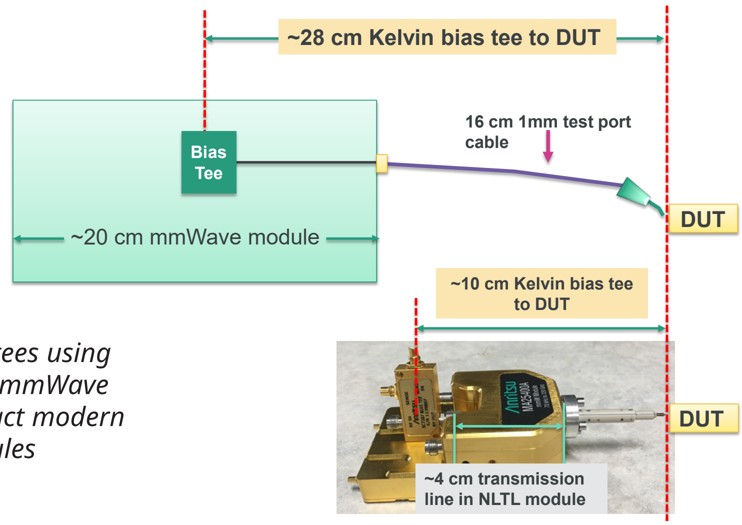


Figure 4. DC path within the NLTL modules allow connection of the Kelvin bias tee at the input of the mmWave module

As previously described, for optimum bias control, it is best to locate the force and sense ports of the Kelvin bias tee as close to the DUT as possible. In the case of broadband mmWave measurements, that means locating the bias tee inside or next to the mmWave module. Since the NLTL mmWave module is compact, it is possible to mount an external bias tee at the input connector of the module and still locate the force and sense lines close to the DUT. The larger, traditional mmWave modules, especially where 1 mm cables are needed to connect them to the probe, result in locating the bias tee further from the DUT (Figure 5). Where possible, always be aware of options available to shorten the distance between the bias tee and DUT, such as using shorter test port cables or eliminating test port cables altogether.



Connecting bias tees using traditional large mmWave modules or compact modern NLTL modules

Figure 5. Small compact NLTL modules mounted directly to the probe provide the opportunity to locate the Kelvin bias tee close to the DUT

Choices in Kelvin Bias Tees

Since the architecture of the Anritsu NLTL mmWave module provides a DC path between the DUT and the baseband VNA, the bias tee can be attached to the RF input side of the mmWave module. When attaching an external bias tee at the RF input port of the mmWave module, the design of the bias tee needs only to support RF frequencies up to 54 GHz (the typical band-switch point between the VectorStar system and mmWave module).

An important benefit of this architecture is that when the bias tee is readily accessible, the characteristics of the bias tee can be changed without having to modify the mmWave module. For example, higher current bias tees will often have higher low-end frequency limits due to the inductor size. If lower frequency with lower current is desired, it is very easy to switch the bias tee. It is also convenient to change the characteristic of the bias tee network for situations where a potential resonance between the bias tee network and the DUT might exist.

Kelvin DC biasing using Anritsu NLTL mmWave modules

All Anritsu NLTL mmWave modules provide a DC path between the baseband VNA and the DUT. This means that the external Kelvin bias tees available from Anritsu can be used for DUT biasing up to 220 GHz without the need for them to transport the mmWave frequency. The two commonly used Kelvin bias tees are the SC8215 and SC7287 with the following characteristics.

Anritsu Kelvin Bias Tee	Frequency Coverage When Mounted to Anritsu NLTL Module	Frequency coverage when bias tee is not mounted to Anritsu NLTL module	V	A	Bias Leakage Current (mounted on NLTL module) (avg, typ temp)	Resistance to ground
SC8215	70 kHz – 110/125/145/220 GHz	70 kHz – 70 GHz	16 VDC	100 mA	16 pA	0.91 – 1.11 Teraohm
SC7287	100 MHz – 110/125/145/220 GHz	100 MHz – 70 GHz	50 VDC	500 mA	50 pA	0.91 – 1.11 Teraohm

Both Kelvin bias tees have V (1.85 mm) connectors at the input and output of the component. The low-end frequency limit is determined by the bias tee network, and the upper frequency limit is determined by the NLTL module when the bias tee is attached. When operating independently and not connected to the NLTL module the upper frequency limit of the bias tee is useable to 70 GHz. If needed, alternative designs with higher current capabilities or different network structure are available.

Kelvin biasing up to 145 GHz

The VectorStar MA25300A NLTL broadband mmWave module provides the ability to sweep from 70 kHz to 145 GHz through the Anritsu-designed 0.8 mm coaxial connector. The architecture of the module is similar to the other Anritsu modules with a DC path so connection of the bias tee is similar. While the transmission line of the 110/125 GHz modules is approximately 55 mm in length, the MA25300A transmission line path has been reduced to approximately 30 mm in order to reduce signal loss. Shortening the transmission line to 30 mm results in a stepped module housing design to accommodate both the mmWave circuitry and the additional electronics. The internal transmission line with the 0.8 mm test port connects directly to the probe for best performance of dynamic range and raw directivity. Consequently, the shorter side of the module will be facing down during on-wafer measurements. Thus, proper connection of the bias tee to the input V connector of the module will need to be considered due to the orientation of the module to the positioner and bracket (Figure 6).

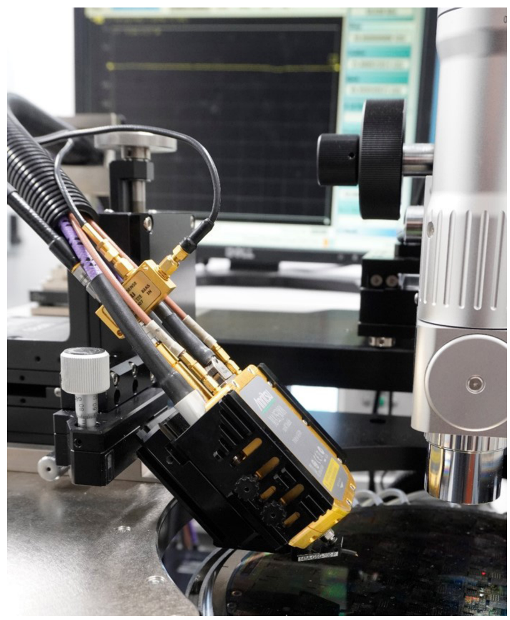


Figure 6. Kelvin biasing up to 145 GHz using the VectorStar MA25300A NLTL module

To best address the physical design of the MA25300A module, an extension line, such as the Spinner V connector coaxial line (PN# BN533499), is recommended. The Spinner coaxial line positions the bias tee away from the NLTL module body, and allows for mounting on the on-wafer positioner and brackets (Figure 7) with low loss.

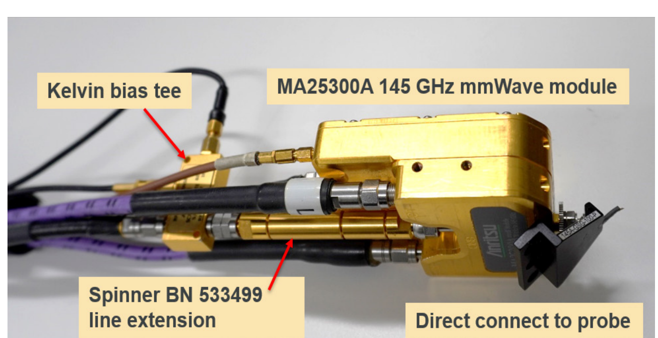


Figure 7. Kelvin biasing to 145 GHz using the MA25300A NLTL module

Kelvin biasing up to 220 GHz using the MA25400A NLTL module

As with the 145 GHz MA25300A NLTL module, in addition to the DC path between the baseband VNA and DUT (figure 8), the MA25400A broadband mmWave module also provides a reduced transmission path of 30 mm for signal maximization.

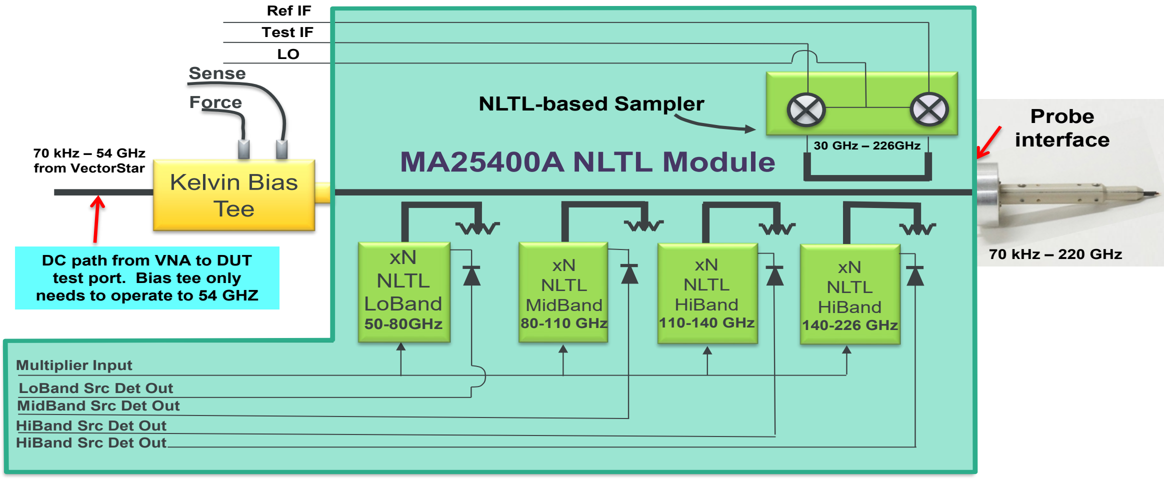
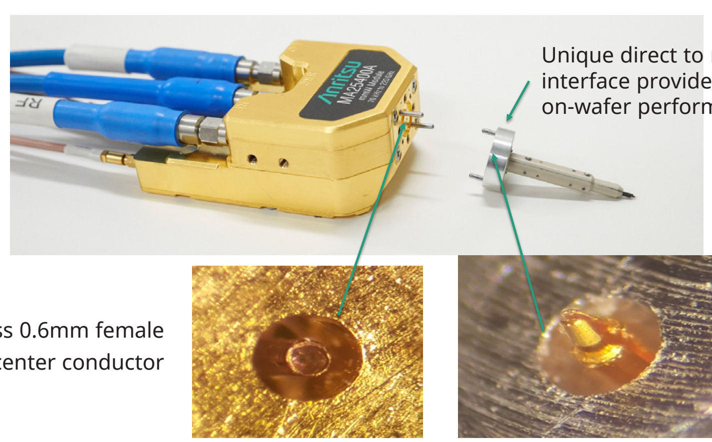


Figure 8. Combining an external Kelvin bias tee with the MA25400A NLTL module for DC biasing from DC to 220 GHz

In order to support VNA measurements above 145 GHz, the MA25400A module provides a 0.6 mm coaxial connector for mode-less VNA measurements beyond 220 GHz (Figure 9). The unique interface uses a UG-387-type flange to align the 0.6 mm male/female pins instead of threads for added durability and precision.

UG-387 flange provides alignment for 0.6mm coaxial male/female pin connection eliminating the need for a threaded connector.



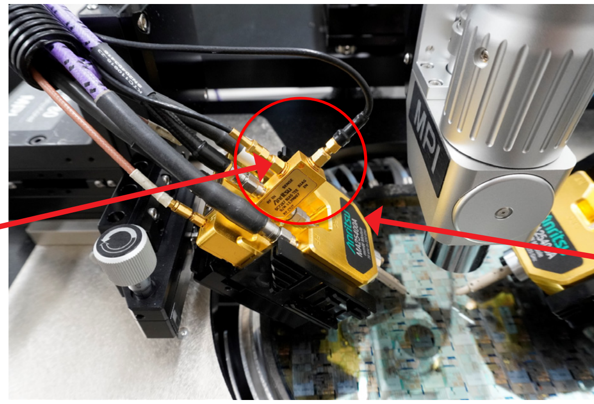
Slot-less 0.6mm female center conductor

Slotted 0.6mm male pin center conductor

Figure 9. Anritsu developed 0.6 mm coaxial connector with UG-387 style flange for precise orientation and connection

Since the module interface is optimized for on-wafer measurements, the orientation of the module may be in either direction (Figure 10). Thus, the Kelvin bias tee in this case can be mounted directly to the input of the module and not affect mounting on the positioner.

SC8215 Kelvin
Bia Tee



MA25400A 220 GHz
NLTL Module

Figure 10. Anritsu MA25400A NLTL module with direct connect to the Kelvin bias tee and on-wafer probe for VNA analysis from 70 kHz to 220 GHz with Kelvin DC biasing

Summary

The VectorStar ME7838x series of broadband systems covers a range of 70 kHz to 110/125/145/220 GHz. The distinctive architecture of the Anritsu NLTL mmWave modules offer a DC path between the baseband VNA and the DUT through the module. This beneficial design offers the opportunity to switch between the baseband VNA for non-broadband applications and the mmWave module for on-wafer broadband measurements. An additional benefit is the ability to attach a Kelvin bias tee to the input side of the module for DC Kelvin biasing. This unique ability offers the opportunity to optimize Kelvin bias tee performance for the application and DUT characteristics as needed without having to perform major design changes within the mmWave module as found in other designs.

NOTES

Anritsu envision : ensure

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