Anritsu Advancing beyond

TERAOPTICS MSCA-ITN Training Event – Madrid – uc3m | Universidad Carlos III de Madrid

70 kHz to 220 GHz Broadband Vector Network Analyzer

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RF & uW Business Development & Field Applications
Anritsu EMEA – Engineering & Technology

November 30th, 2021

Education:

Sapienza University of Rome
B.Eng. Biomedical Engineering 2005 – 2009
M.Sc. in Nanotechnology Engineering 2010 – 2012

Johannes Kepler Universität Linz
Ph.D. Physics 2014 – 2016
Main investigation area: "Technology integration of microwave imaging and Scanning Probe Microscopy for nanoscale electrical characterization".

Work:

Anritsu - RF & Wireless Business Development & FAE; 2017 – Present - EMEA

Agilent / Keysight Technologies - R&D Engineer; 2013 – 2017 - Linz, AT

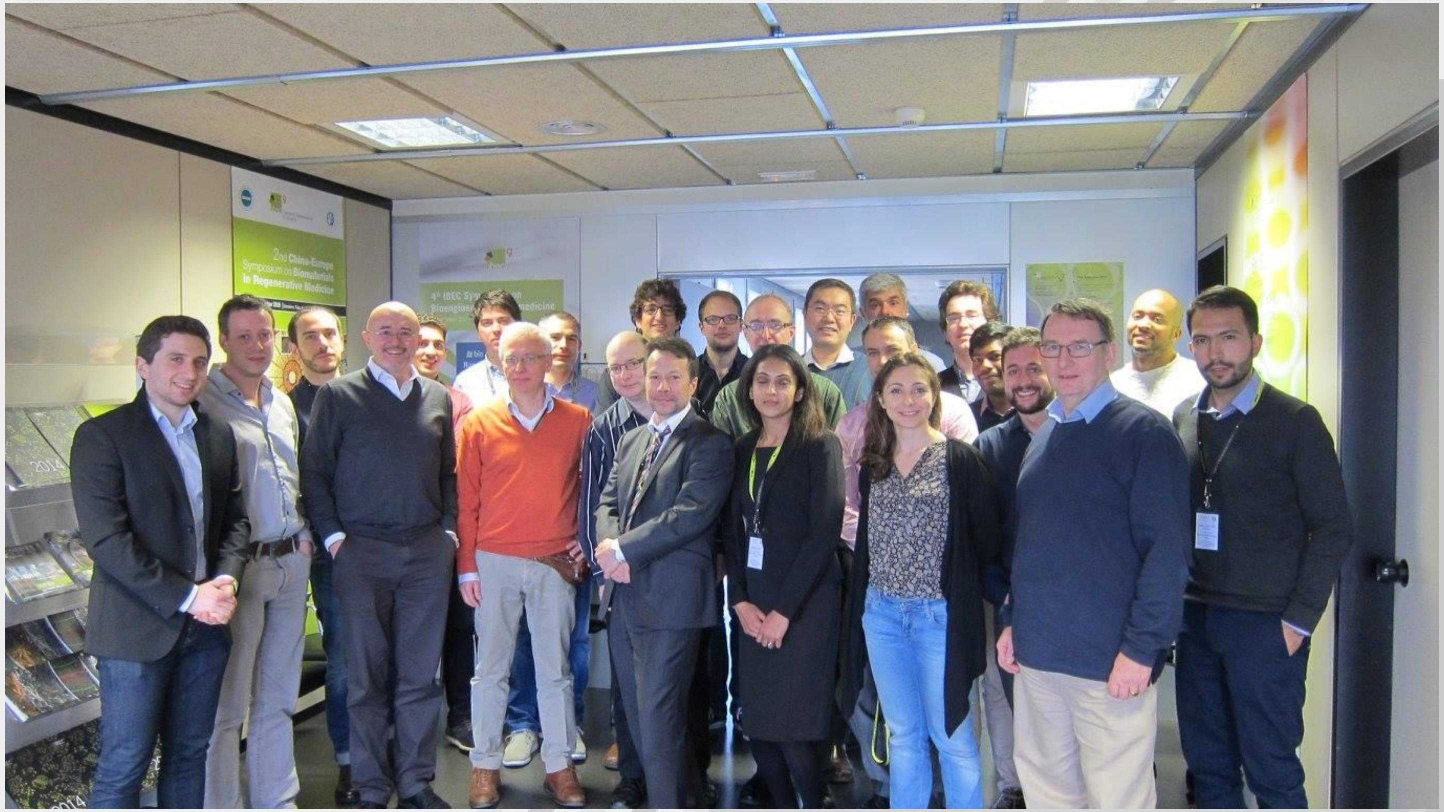
Philips - Internship; 2012 - Eindhoven, NL

Nanomicrowave MSCA ITN

Nanoscale Microwave Technologies and related emerging applications.

Consortium:

- Agilent --> Keysight (Linz, Austria)
- STMicroelectronics (Lille, France)
- Bio-Nano-Consulting (London, UK)
- IBEC (Barcelona, Spain)
- CNRS (Lille, France)
- University of Genoa (Genoa, Italy)
- CNR (Roma, Italy)
- University College London (London, UK)
- Johannes Kepler University (Linz, Austria)
- Queen Mary University (London, UK)



PhD years can be like…

PhD years can be like…

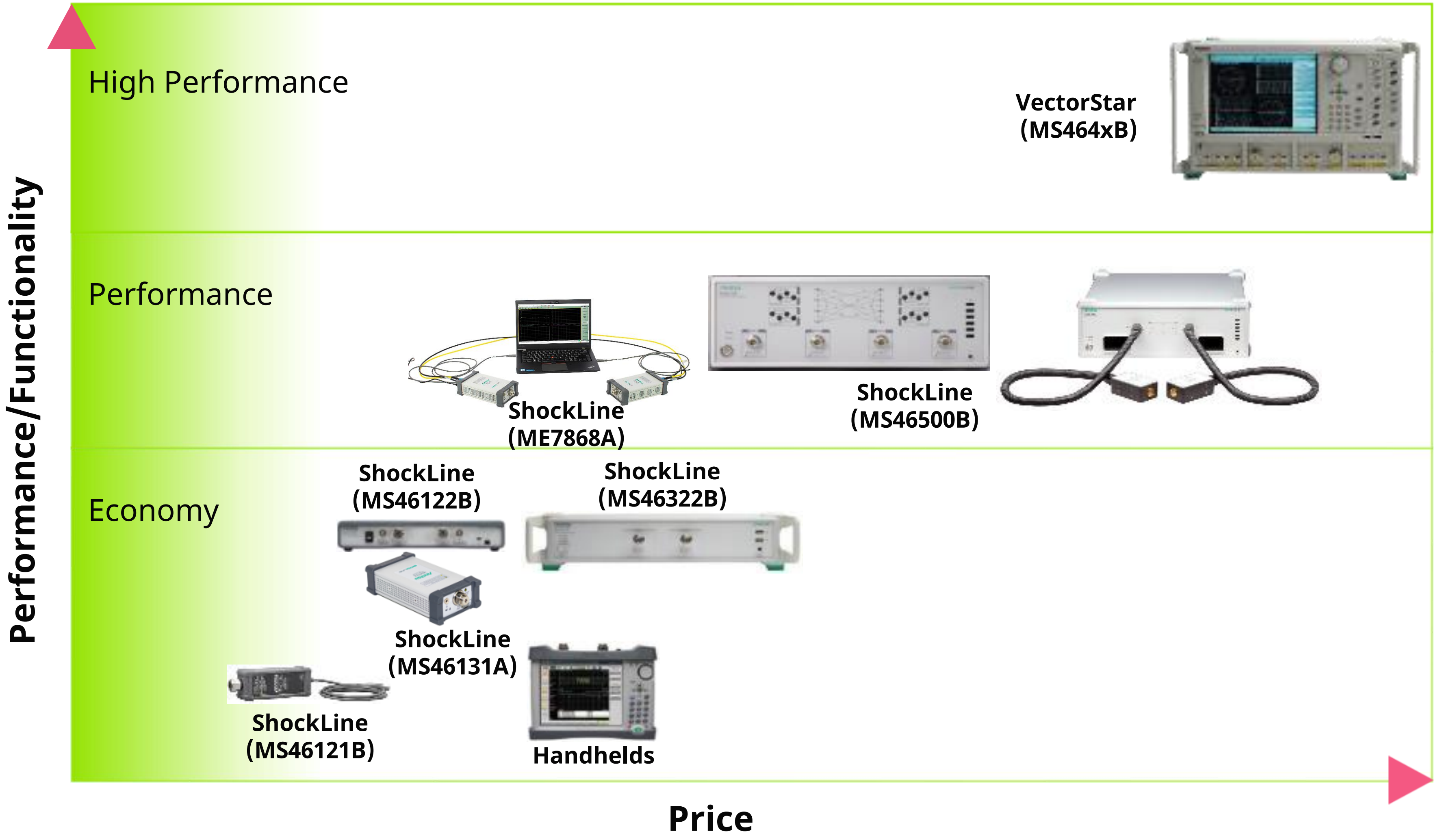
But also, PhD years be like…

70 kHz to 220 GHz Broadband Vector Network Analyzer

Agenda

1. VNA today: a wide range of solutions
2. Inside a VNA: the architecture
3. Broadband: why?
4. 220 GHz Broadband VNA
5. Demo Videos

Anritsu VNA Portfolio Overview



ShockLine™ VNA Family

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MS46522B
- 2-port **Performance** VNA
- 50 kHz to 8.5/20/43.5 GHz
- N(f), K(m) connectors

MS46131A / ME7868A
- 1-, 2-port **Modular** VNA
- 1 MHz to 8/20/43.5 GHz
- N(f), K(m) connectors

MS46121B
- 1-port **USB** VNA
- 150 kHz to 6 GHz
- N(m) connector

SmartCal
- 2-, 4-port **SmartCal** auto calibration units
- 8.5 GHz, 20 GHz models
- N(f), K(f) and other connector options

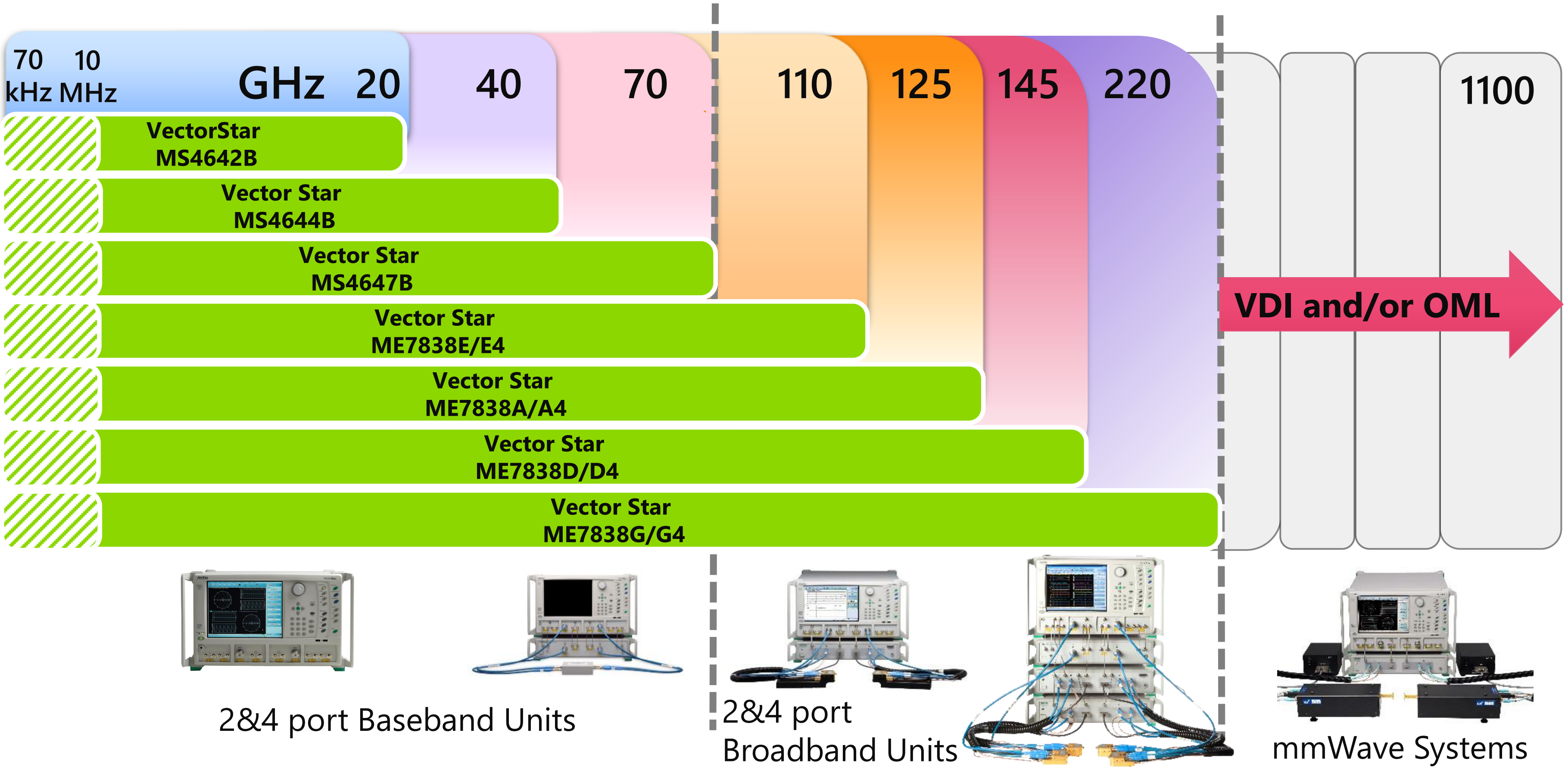
MS46524B
- 4-port **Performance** VNA
- 50 kHz to 8.5/20/43.5 GHz
- N(f), K(m) connectors

MS46522B
- 2-port **Performance** E-band VNA
- 55 GHz to 92 GHz
- WR12 waveguide

MS46322B
- 2-port **Economy** VNA
- 1 MHz to 8/20/43.5 GHz
- N(f) and K(m) connectors

MS46122B
- 2-port **USB** VNA
- 1 MHz to 8/20/43.5 GHz
- N(f) and K(m) connectors

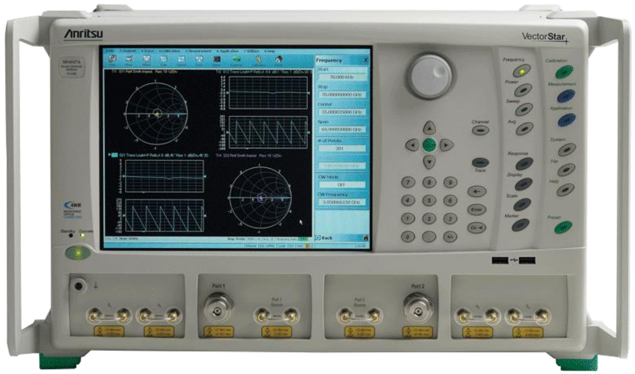
VectorStar™ VNA Family



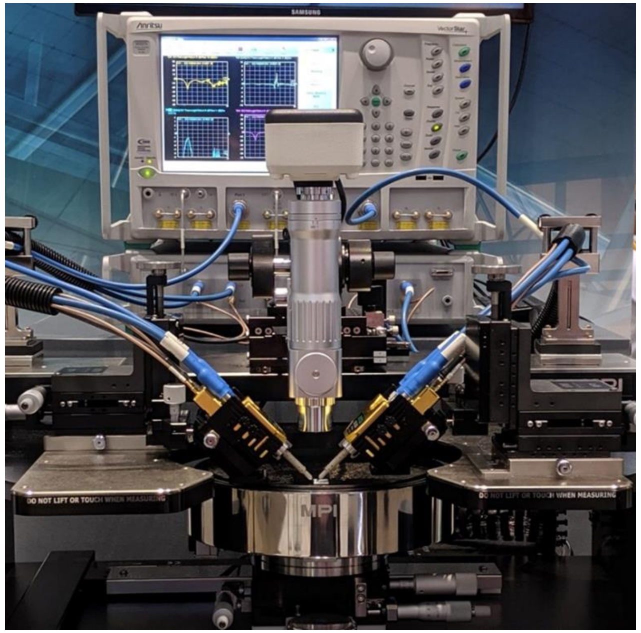
VectorStar Overview

VectorStar®

- Industry-leading **performance with flexibility**
  - VectorStar family flexible upgrade approach
- **70 kHz start frequency**
  - Accurate time domain characterization
  - Better models means better circuit simulations
- Single connection S-Parameters, Gain Compression, and IMD
- **Best broadband system** for on-wafer device characterization
  - Widest frequency range with best stability, dynamic range, leveled power sweep range, and smallest form factor
  - 70 kHz to 220 GHz industry-first performance
- **Best pulse measurement performance** for radar systems and components
  - 2.5 ns resolution with 100 dB dynamic range
- **Cost effective, highly accurate, optoelectronic measurements** to 110 GHz
- **Best differential measurement performance for signal integrity analysis**
  - Lowest start frequency for best modeling accuracy and eye diagram measurement
  - Best true mode stimulus performance for Signal Integrity measurements
  - Best TDR measurements



VectorStar Target Markets & Applications



- **Broadband On-Wafer Device Characterization**
    - mmW MMIC design, active device testing where port biasing is required
- **Radar**
    - Pulsed S-Parameters, T/R module testing, RCS
- **Active Device Measurements**
    - S-Parameters, Gain Compression, Noise Figure, Differential Noise Figure, Pulse, Differential, IMD
- **Signal Integrity**
    - S-Parameters, Differential True Mode Stimulus
- **Antenna Measurements**
    - Independently drive RF and LO signals remotely, Pattern characterization
- **Multiple Waveguide Bands**
    - If multiple waveguide bands (e.g. W and E band) are developed/manufactured
- **Frequency Translation**
    - S-Parameters, Conversion loss, Isolation, port match
- **E/O, O/E and O/O**
    - Transfer function

VectorStar | Flexible Configuration for Different Applications

Option	Name	Description
MS4640B-002	Time Domain	
MS4640B-007	Receiver Offset	Independent Source & Receive, Multiple Source Control, NxN
MS4640B-021	Universal Fixture Extraction	
MS464xB-031	Dual Source Architecture	
MS464xB-032	Internal RF Combiner	
MS4640B-035	IF Digitizer	
MS4640B-036	Extended IF Digitizer Memory	
MS4640B-041	Noise Figure	
MS4640B-042	PulseView™	
MS4640B-043	DifferentialView™	
MS4640B-044	IMDView™	
MS4640B-046	Fast CW	
MS4640B-047	Eye Diagram	
MS4640B-048	Differential Noise Figure	

VectorStar | Flexible Configuration for Different Applications

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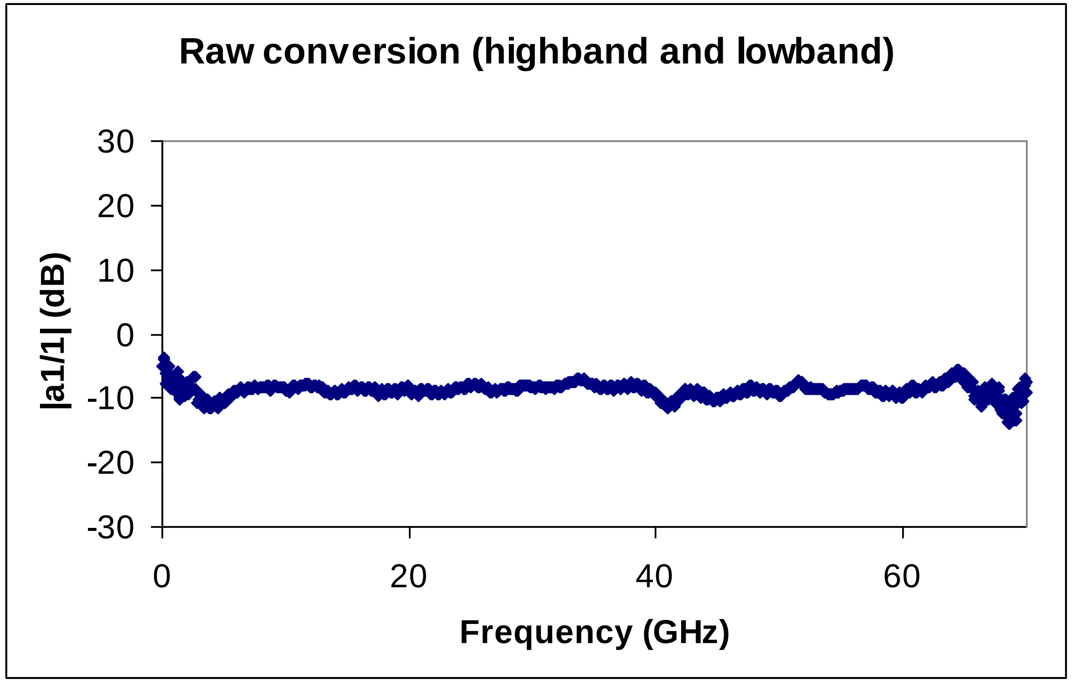
Option	Name	Description
MS464xB-051	Direct Access Loops	
MS4640B-053	External ALC	
MS464xB-061/062	Active Measurements Suite	2 or 4 step attenuators, direct access loops, bias tees, and gain compression
MS4640B-070	70 kHz Low Frequency Extension	
36585K/V	Precision AutoCal	2-port, 40/70 GHz
MN4765B	O/E Calibration Module	

VectorStar | Unique Hybrid VNA Architecture

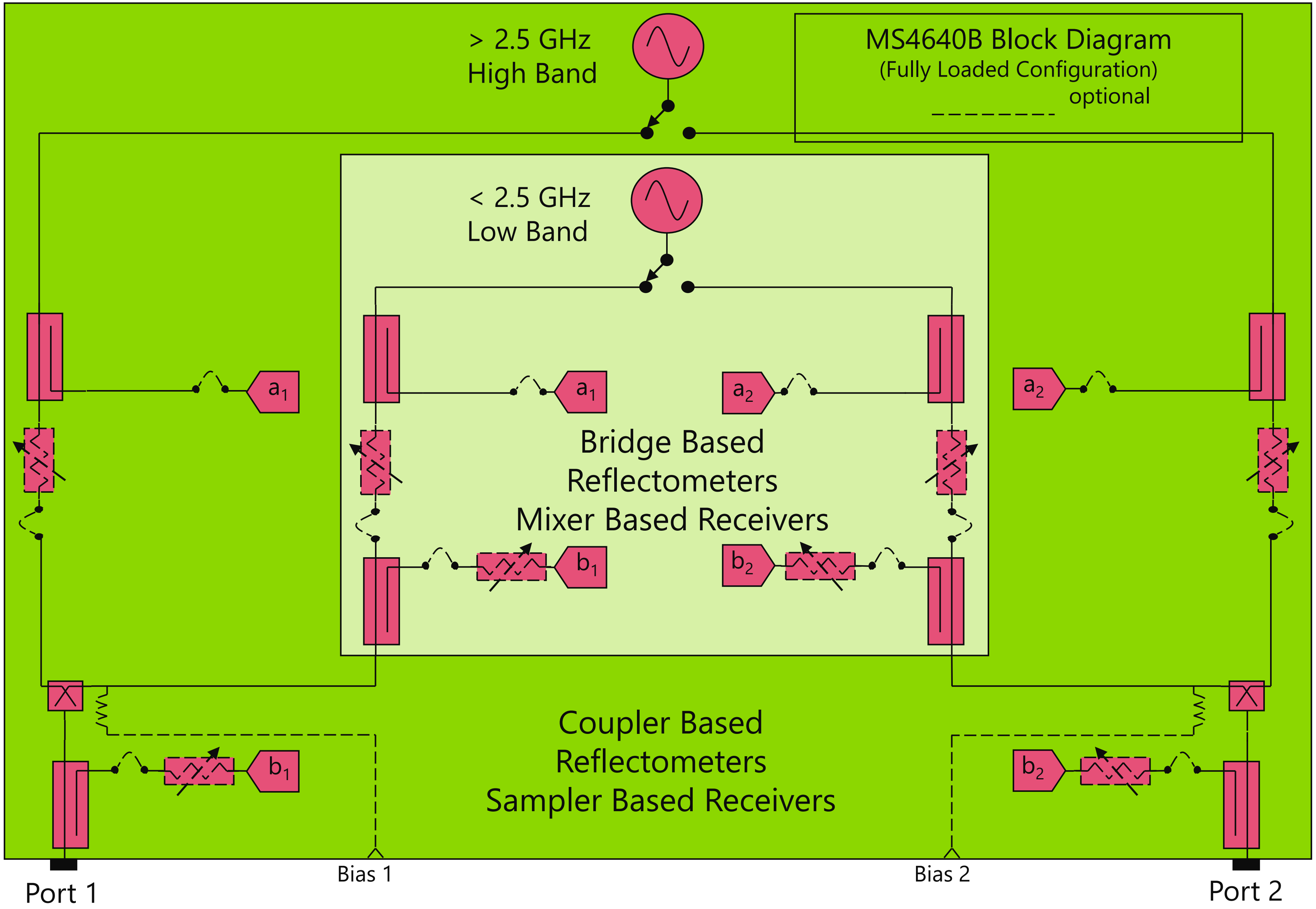
Two VNAs in parallel: The only way to get 6 decades of coverage (from kHz to GHz)

- Each receiver technology (sampler or mixer) used in its best range
- Each coupling technology (coupler or bridge) used in its best range
- Both share a common IF path and fully synthesized source



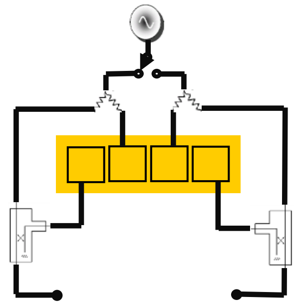
VectorStar™

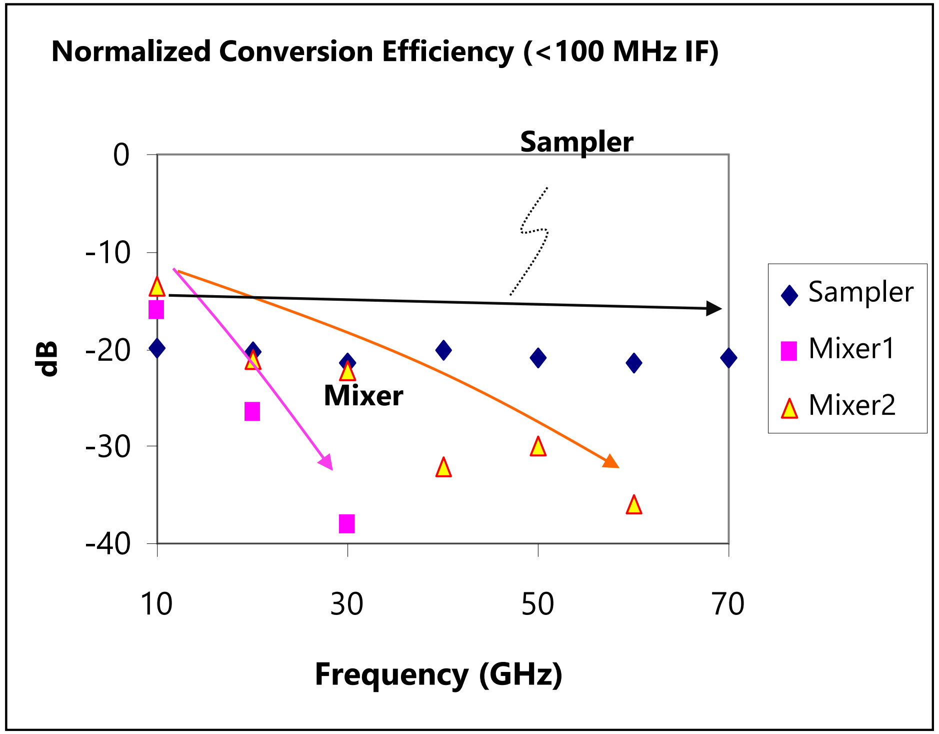
VectorStar Architecture | Two VNAs in One!

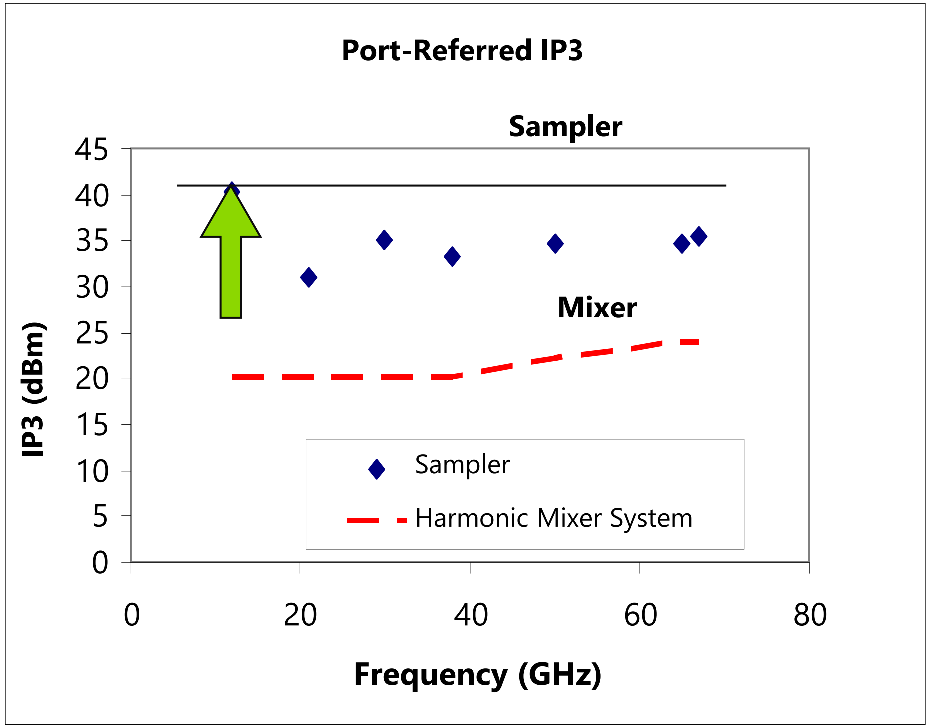


VectorStar | Receivers

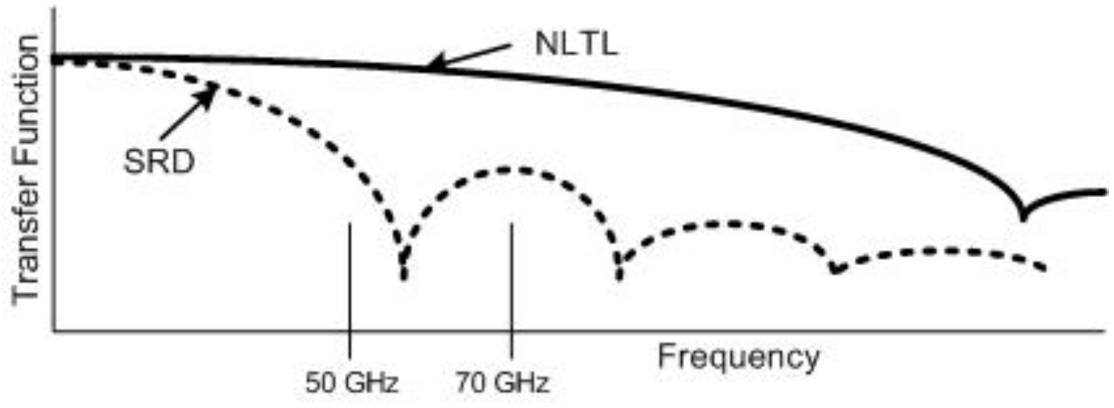
- Mixers used at lower frequencies, samplers used at higher frequencies
- Harmonic mixing approaches tend to have significant roll-off at higher frequencies compared to samplers
- New sampler and impulse technologies (MMIC-based)
  - Higher LO frequencies for lower noise figure and better dynamic range
  - Conversion loss does not noticeably increase until well beyond 110 GHz
  - Inherent symmetry of sampler structure allows improved linearity (higher IP3)



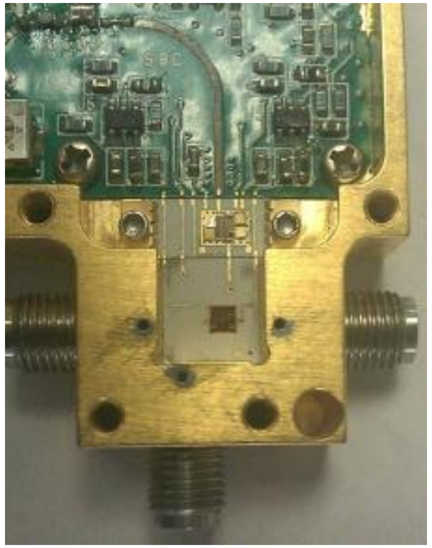




VectorStar | NLTL Harmonic Sampler Technology

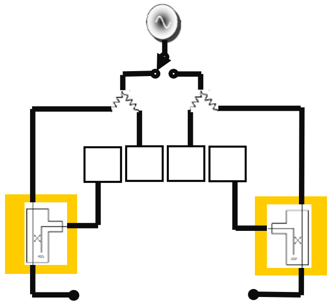


NLTL ShockLine VNA (ASIC)

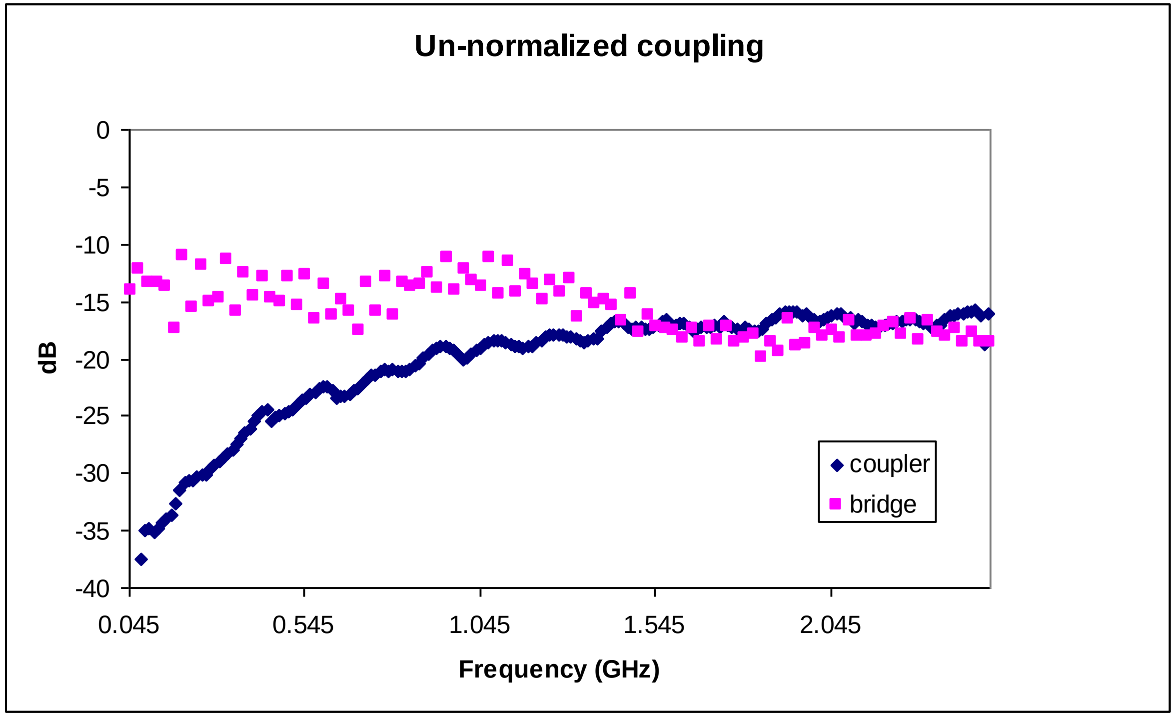


- VectorStar MS4640B uses NLTL harmonic samplers for better dynamic range
- Step Recovery Diodes (SRD) Transfer function tends to drop off by 50 GHz
- Non-Linear Transmission Line (NLTL) technology offers a higher comb frequency with less drop off in performance at high frequency
- Results in excellent dynamic range up to 70 GHz in the VectorStar VNA without the need for increased amplification. Less amplification results in better stability.
- High levels of monolithic integration results in reflectometers that are miniature in size

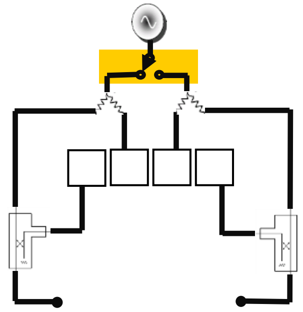
VectorStar | Reflectometers



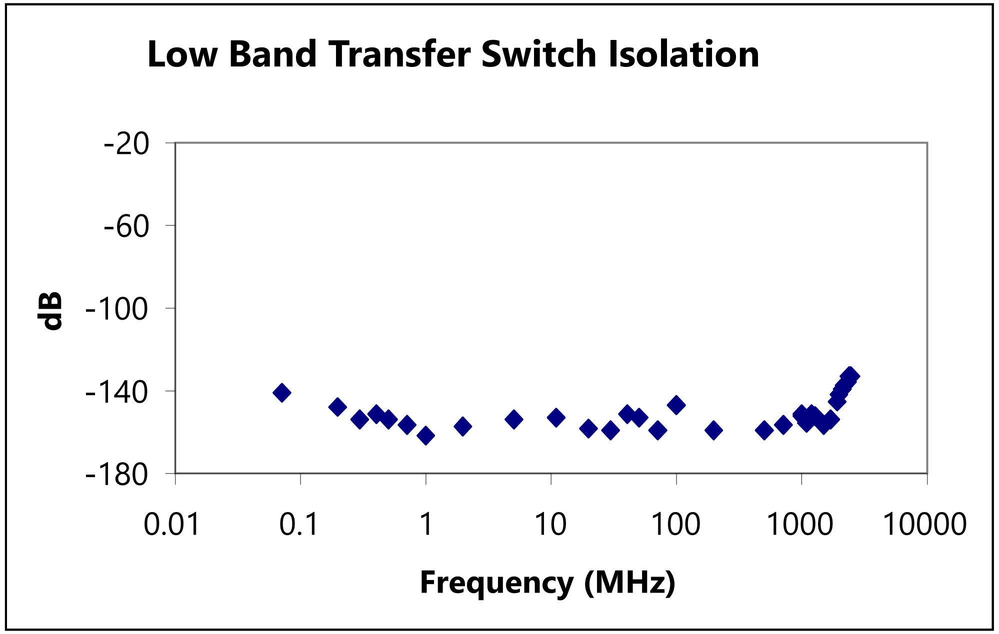
- Bridges used at lower frequencies, directional couplers used at higher frequencies
- Bridges do not rely on wavelength-related physical lengths to provide coupling, thus, extending down to much lower frequencies
- Directional couplers roll-off severely at lower frequencies, impacting dynamic range and high-level noise. Their physical dimensions also increase prohibitively at very low frequencies.

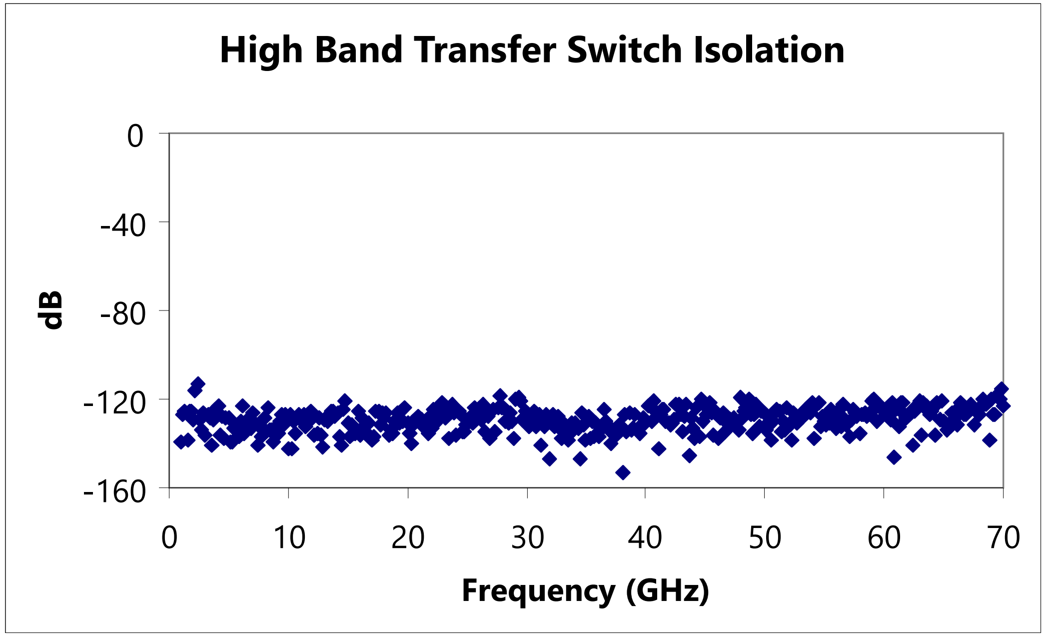


VectorStar | Transfer Switch



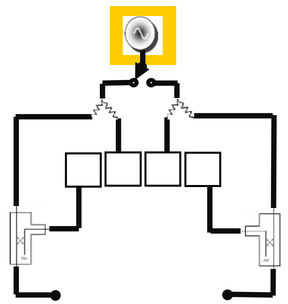
- High-isolation switch technology
  - Originally developed for multiport VNA test sets: 120 dB isolation at 70 GHz with relatively low insertion loss
  - Different switch technologies used (FET low frequency, PIN high frequency) for best insertion loss, isolation, and compression performance
  - Leads to low leakage and better dynamic range

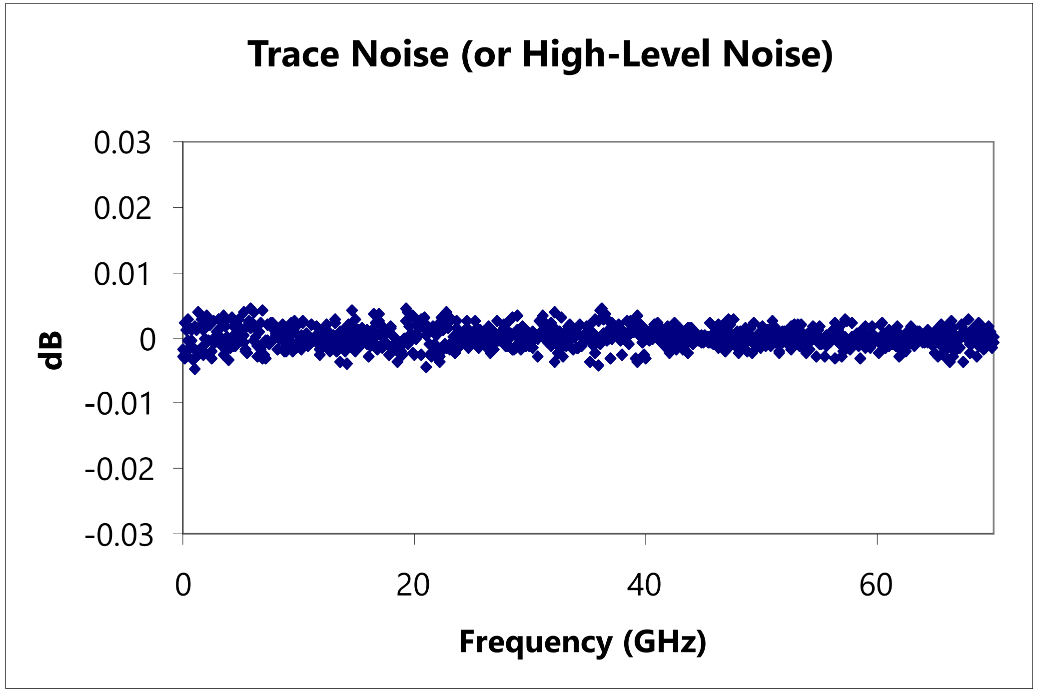




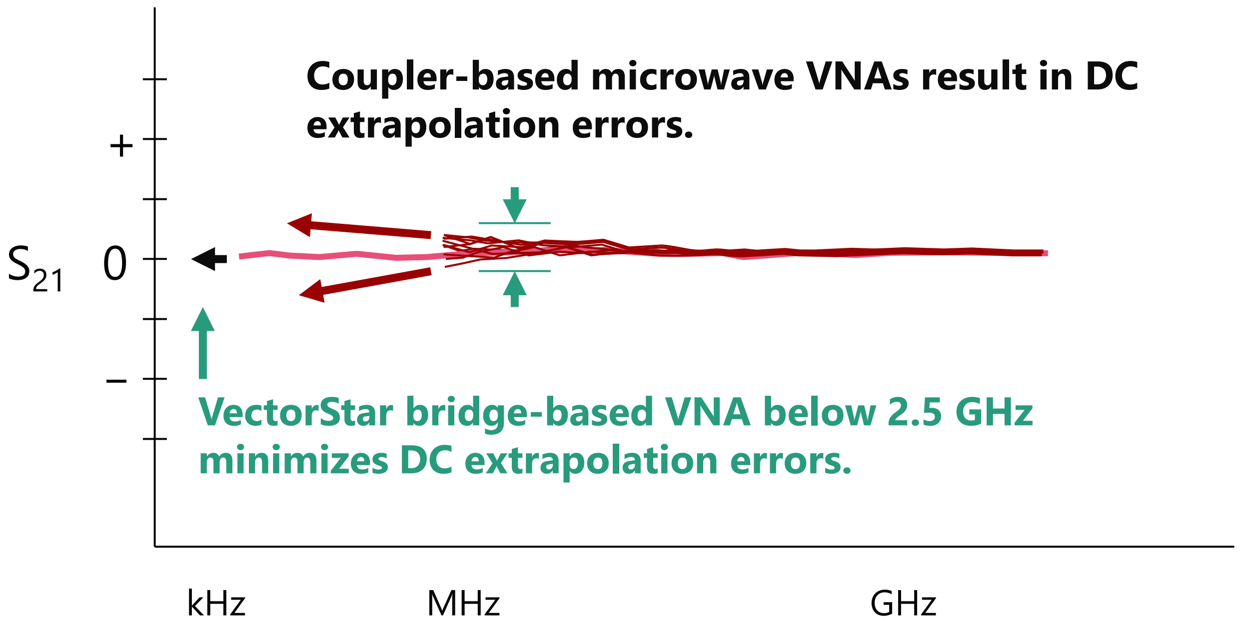
VectorStar | Sources

- Designed for optimum combination of speed and spectral purity (phase noise)
- Locally synthesized, no locking required through IF
  - Allows source and receiver LO to be at different frequencies
- Phase noise directly impacts high-level noise

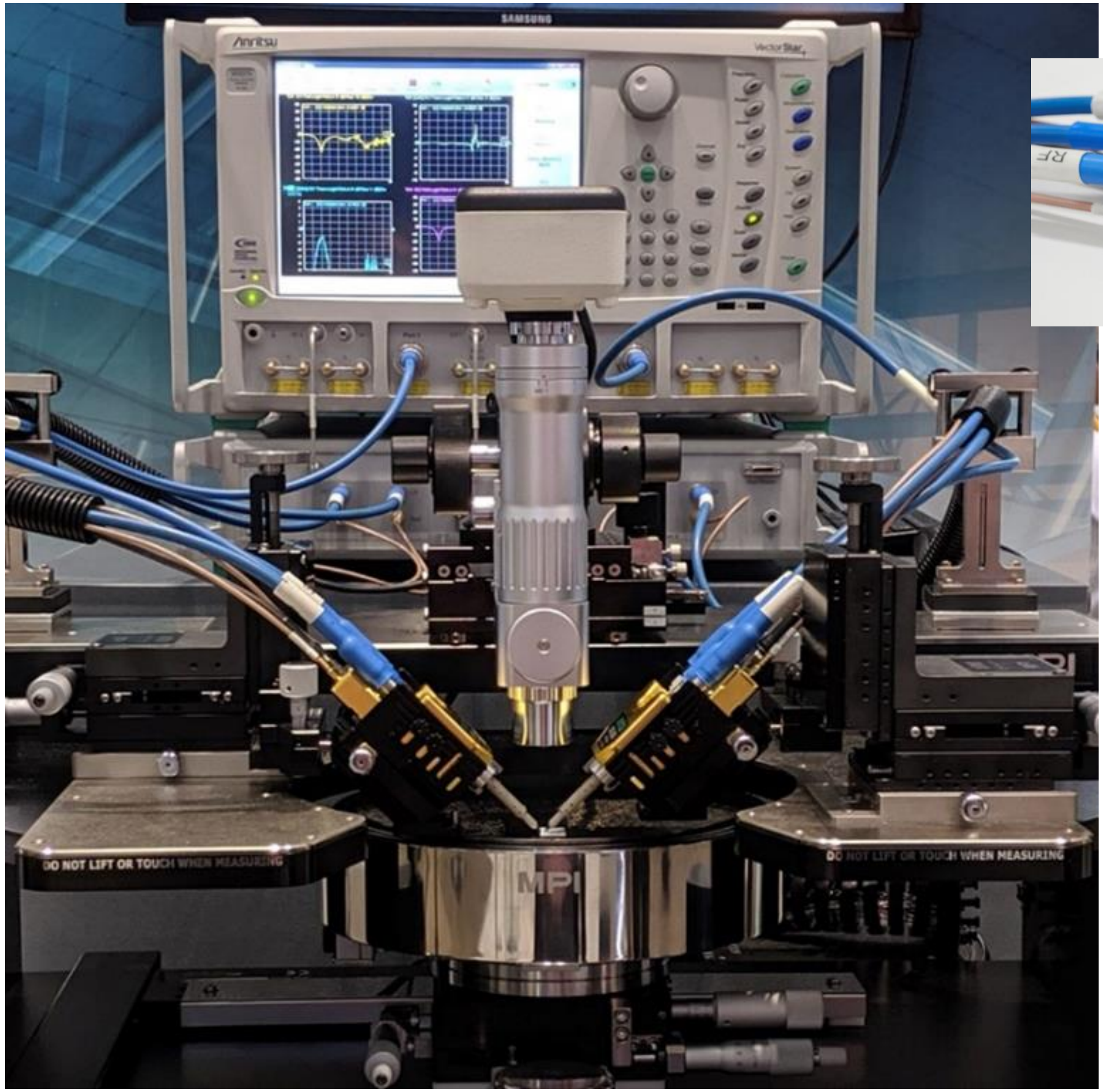




DC accuracy is determined by signal to noise ratio at low frequency and proximity of pointing vector

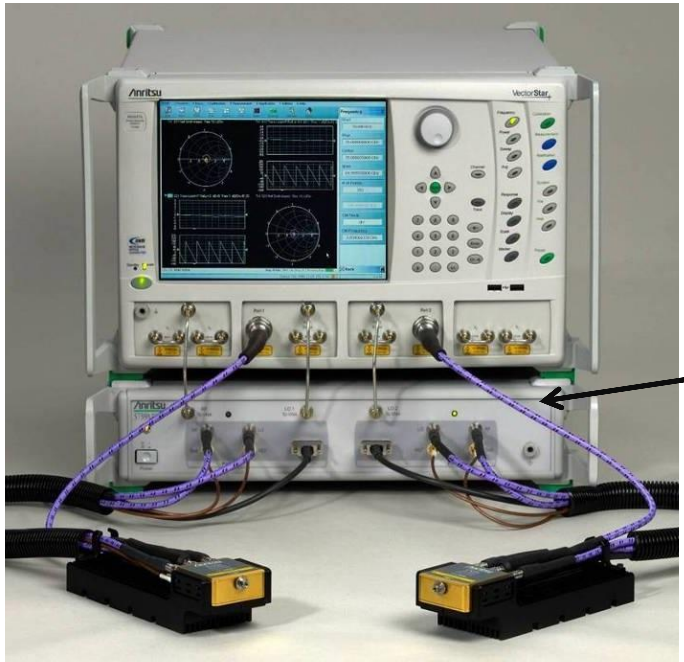


VectorStar | Industry-First and Industry-Leading 125, 145, and 220 GHz Broadband VNAs



VectorStar | Flexible Upgrade Architecture | 2-Port Broadband VNA

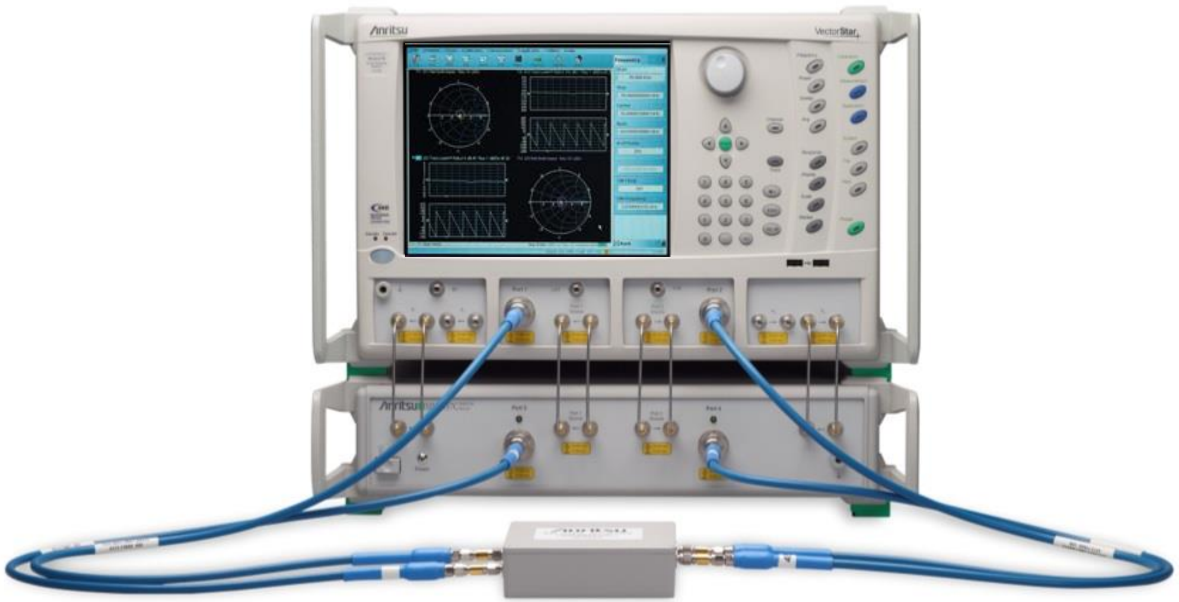
- For applications >70 GHz VectorStar in ME7838A (110 GHz) or ME7838D (145 GHz) or ME7838G (220 GHz) configuration is the highest performing Broadband VNA on the market
- 3743A (110 GHz) or MA25300A (145 GHz) or MA25400A (220 GHz) modules are the smallest on the market
- Anritsu is the only equipment manufacturer offering a broadband solution up to 220 GHz
- Flexible upgrade path
  - User does not have to choose between platforms, number of ports, or frequency option with future needs in mind



3739C controls ports 1 and 2

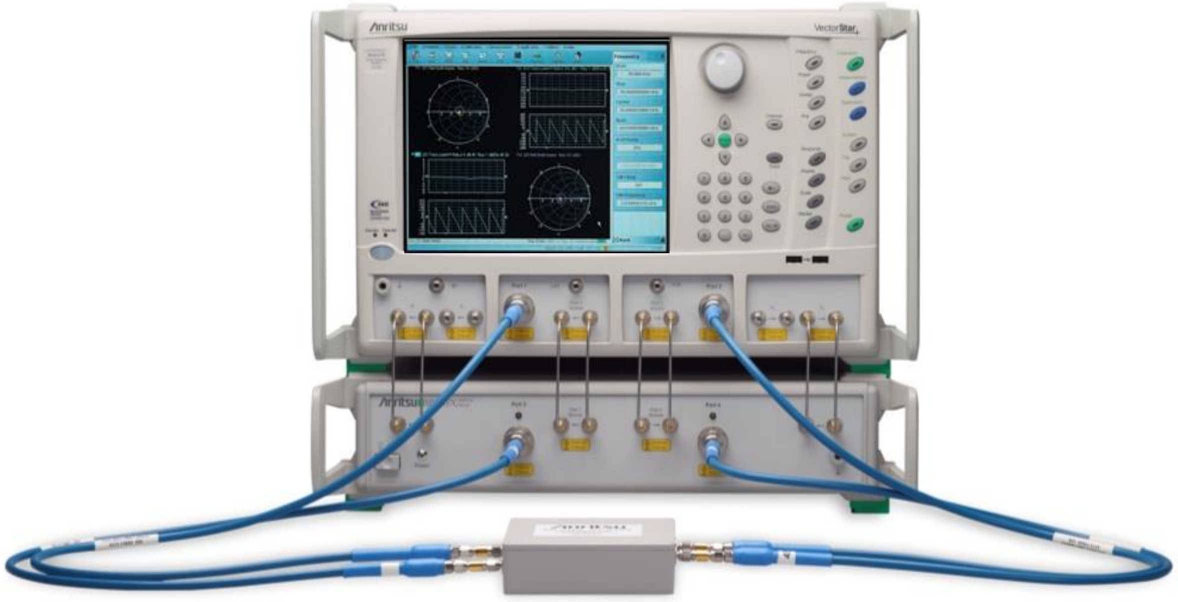
VectorStar | Flexible Upgrade Architecture | 4-Port VNA

- Many Signal Integrity (SI) applications include differential devices
- Use MN469xC to configure 4 port measurements
- Supports Option 31 Dual Source Architecture
- Supports Option 43 DifferentialView (True Mode Stimulus)
- 4 port power calibration
  - Provides accurate differential device analysis
- Dual source power sweep



VectorStar | Flexible Upgrade Architecture | 4-Port VNA

- External test set offers easy upgrade capabilities – buy what you need when you need it
- Use configuration without Options 031 and 043 for measuring single ended multiport components (couplers, mixers, etc.)
    - Passive, linear active devices
- Broadest frequency balanced/differential measurements in the market
- MN4694C
    - 70 kHz to 20/40 GHz
- MN4697C
    - 70 kHz to 50/70 GHz



VectorStar | Flexible Upgrade Architecture | 4-Port Broadband VNA

ME7838A/D/E/G Broadband VectorStar with two additional ports:

- 3736B master test set
- MN4697C multiport test set
- Two additional mmW modules
- Majority of benefits from 2 port system also apply to 4 port

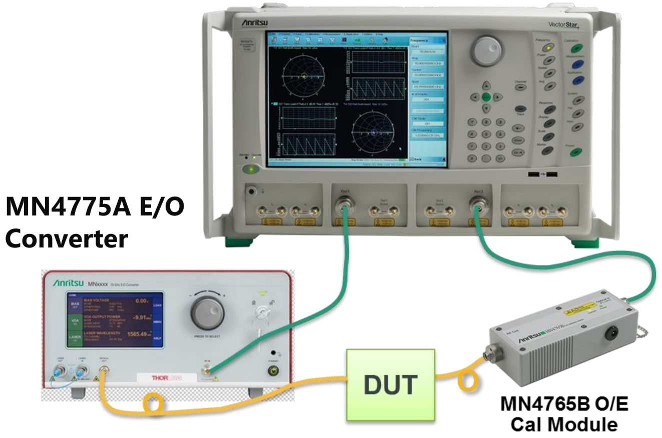
MN4697C requires no modifications and provides the baseband frequencies up to 54 GHz

3736B is the master test set and controls ports 3 and 4

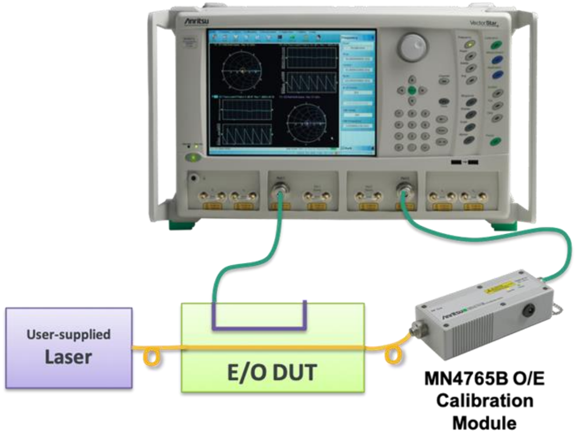
3739C controls ports 1 and 2

VectorStar | Flexible Upgrade Architecture | Optical VNA (ONA)

- The ME7848A Opto-electronic Network Analyzer (ONA) combines VectorStar with an Anritsu MN4775A E/O converter and the MN4765B calibration module creating a complete opto-electronic VNA measurement system
- Announcement at ECOC show September 23, 2019
- New ME7848A-0200 series system combines VectorStar with the Anritsu E/O converter and O/E calibration detector
- After calibration the system is capable of measuring E/O, O/O and O/E devices with specified performance
- The ME7848A-0100 system includes the O/E detector calibration module without a converter
    - This offers the same configuration options as 0200 except without qualified TDS referenced specifications
- Different converter options will allow customers to add MN4765B and MN4775A modules for expanded wavelength measurement capabilities



ME7848A-02xx



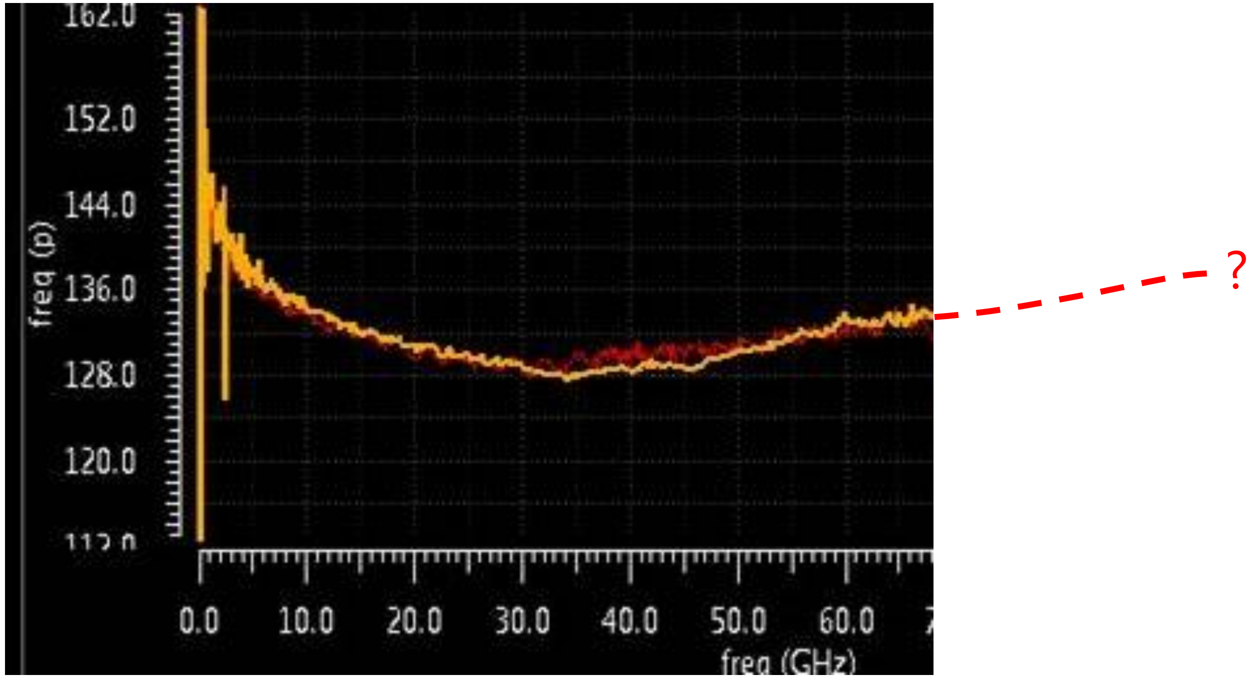
ME7848A-01xx

Why is a broadband VNA required?

Device Characterization

- Device characterization is the on-wafer measurement process of sweeping devices such as transistors, capacitors, etc. with a broadband VNA to generate device models using modeling software such as IC-CAP.
- There are often additional application measurements to be made on the same wafer. Device characterization is the application that determines the VNA **must** be a broadband analyzer.
- Modelers recognize the need for 220 GHz and higher VNA measurements for accurate models. They may decide to migrate later to 220 GHz because of immediate budget constraints.
- After frequency, the next decision is the number of ports. If differential devices are to be measured, they will need a 4 port BB VNA. Again, the decision may be to upgrade later.
- Flexible upgradability is a valuable benefit to users.

Device Characterization: Turning S-Parameters into Extracted Parameters



Fundamental band device characterization provides a glimpse of the device in the primary frequency range of operation.

There is a need to look beyond the fundamental frequency and into the harmonic region of operation.

- Devices such as capacitors, inductors and transistors need characterization beyond fundamental operating range for accurate circuit simulation and performance.

Device Characterization: Turning S-Parameters into Extracted Parameters

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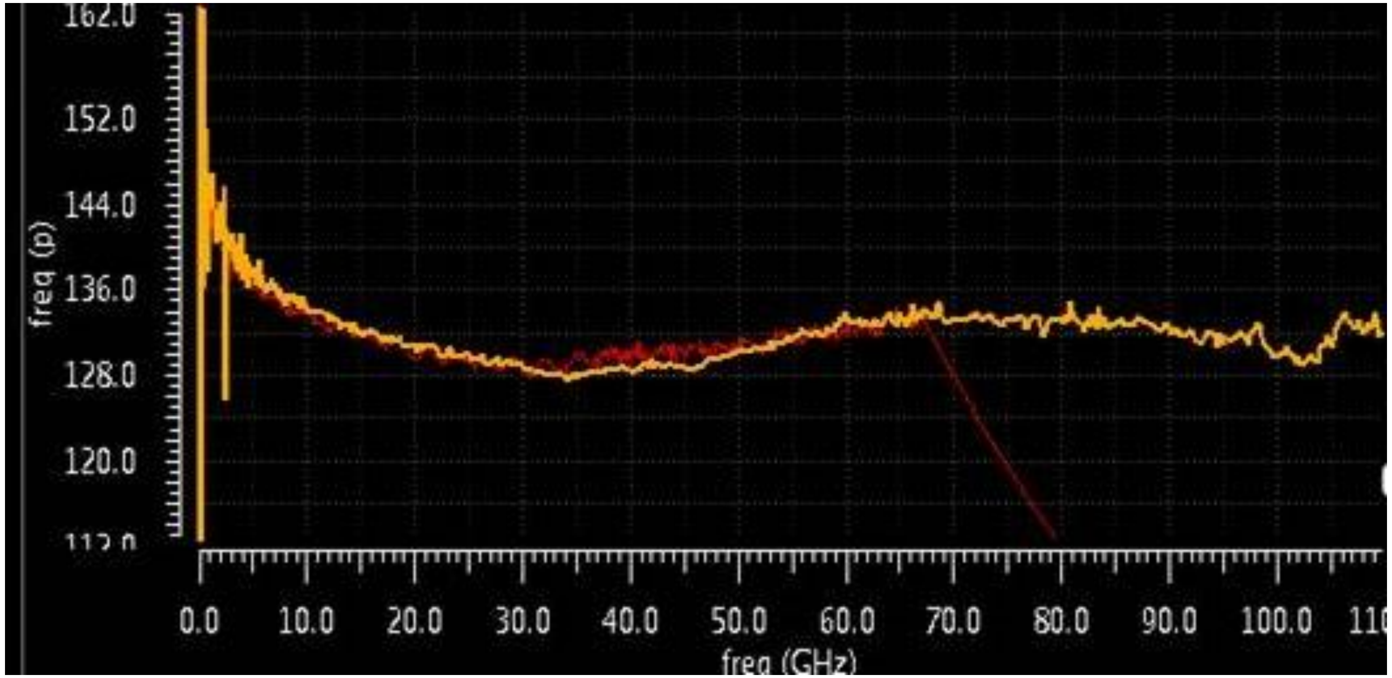
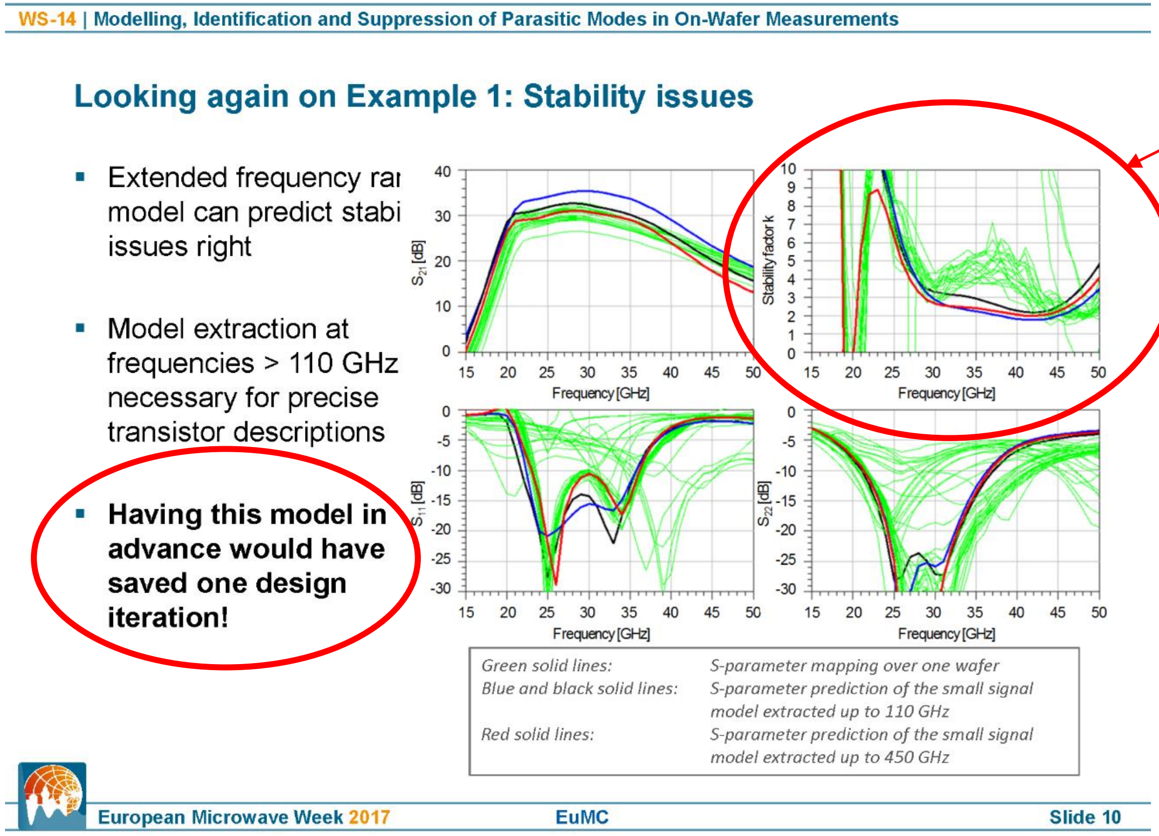


Sweeping up to 110 GHz is the first tier of analysis. Allows predicting how things will work at the basic level, make sure there is no resonances, etc.

But, in terms of device characterization, more is required to get a full view of what's going on.

- Typical applications need characterization well above 70 GHz baseband VNAs. Characterization to the 2nd, 3rd and even 5th harmonic ideal.

Device Characterization

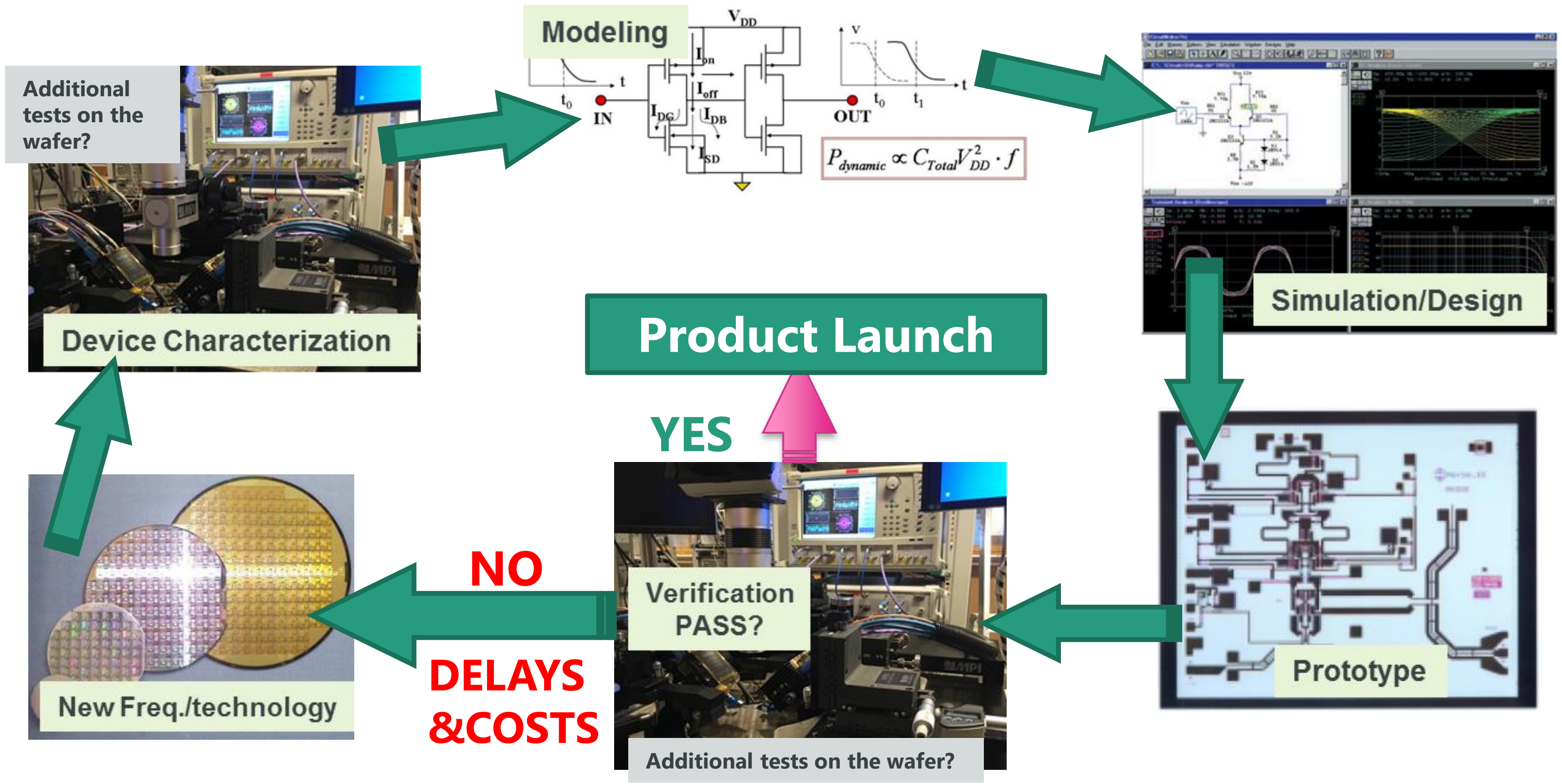


[Loz17] R. Lozar, et al. "On the importance and difficulties of planar on-wafer measurements at submillimeter frequencies". Workshop presentation WS-14, EuMW 2017

Designing a 40 GHz amplifier

- Blue and black lines are S-parameter and K factor simulation predictions based on 110 GHz measurements
- Green lines are actual performance. 110 GHz data did not predict 20 GHz instability.
- Red lines are simulation predictions based on 450 GHz measurements.
- Broadband characterization beyond 110 GHz improves device models and circuit simulations.

Components Testing: need for Broadband Characterization



- Wafer design cycle requires VNA measurements during device characterization and verification stages.
- If the verification fails is it due to inaccurate device models (resulting in inaccurate circuit simulations) or unsuccessful design? Wide broadband systems offer opportunities for best-optimized models.
- Additionally, when multiple devices, components, and sub-systems are combined on the same wafer, an ultra-wide broadband system enables measurement of the entire wafer with a single setup.

VectorStar Broadband System Setup

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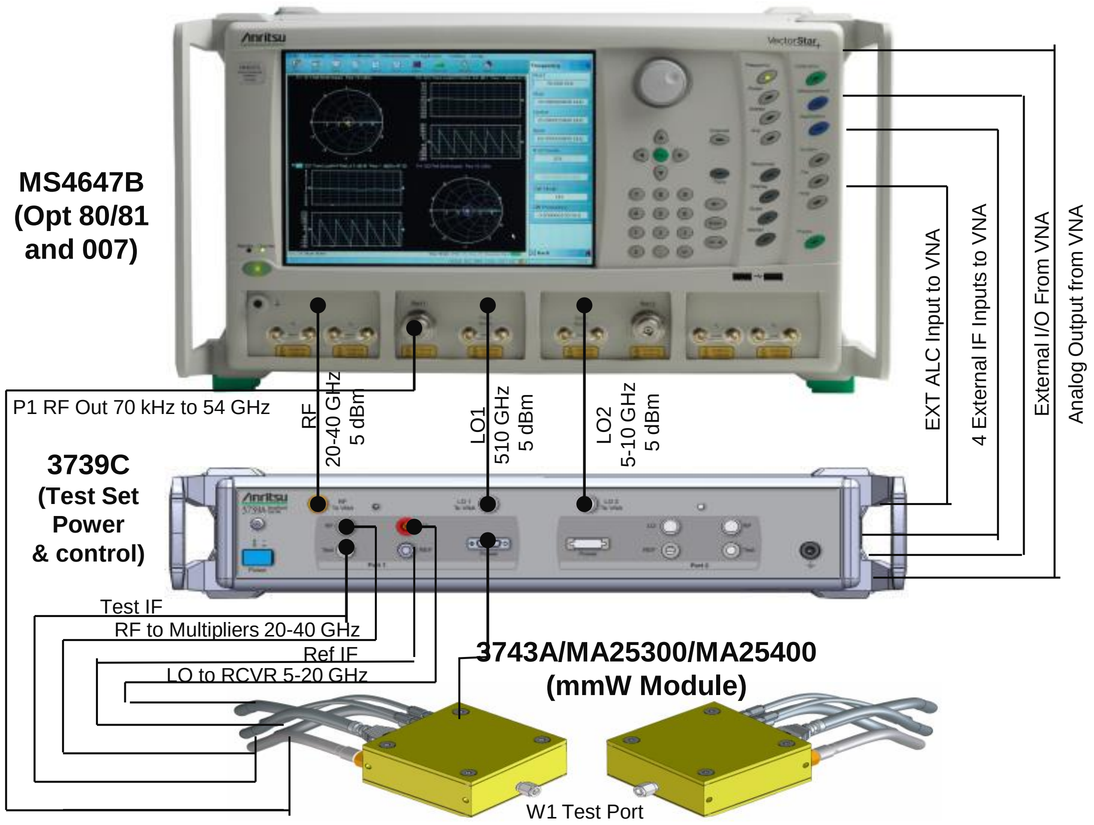
This system architecture eliminates various external components (external synthesizers, MUX combiner, mmW module) reducing the number of system components that have impact on overall system stability.

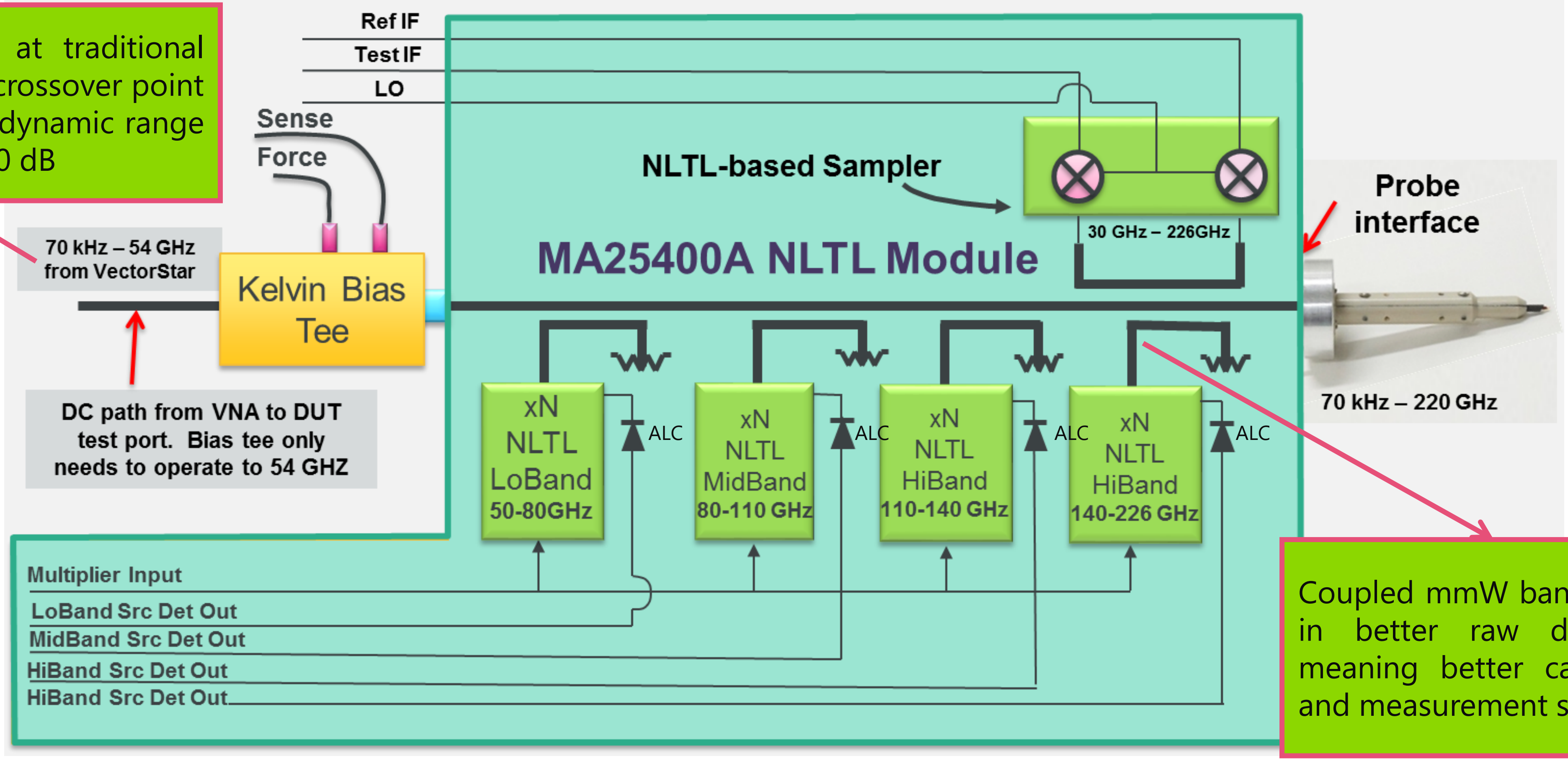


The mmW modules also reduce the size and foot-print when compared to classical waveguide designs.

VectorStar 70 kHz-110/145/220 GHz Module

- DC path in NLTL module enables biasing from the backside of the module.
- While using the DC path, a 70 GHz bias tee provides biasing up to 220 GHz.
- mmW ALC is done at the module level.
- Direct connect from millimeter-wave module to probe provides maximum dynamic range – no lossy 1 mm cable required, and better raw directivity.

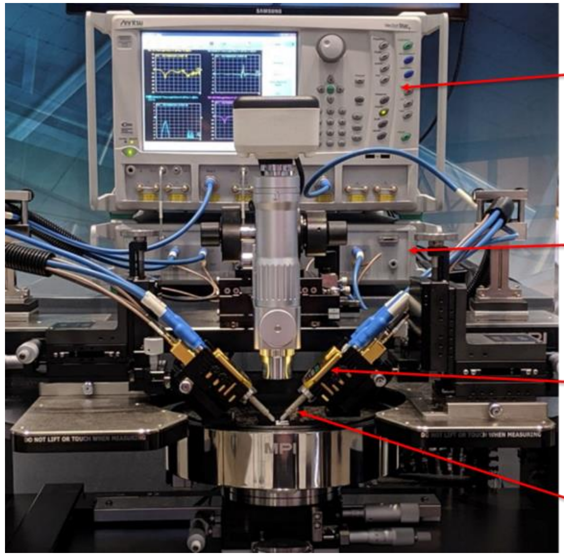
Avoids high loss at traditional coax/WR10 band crossover point of 67 GHz, where dynamic range can drop to mid 80 dB



DC path back to VectorStar

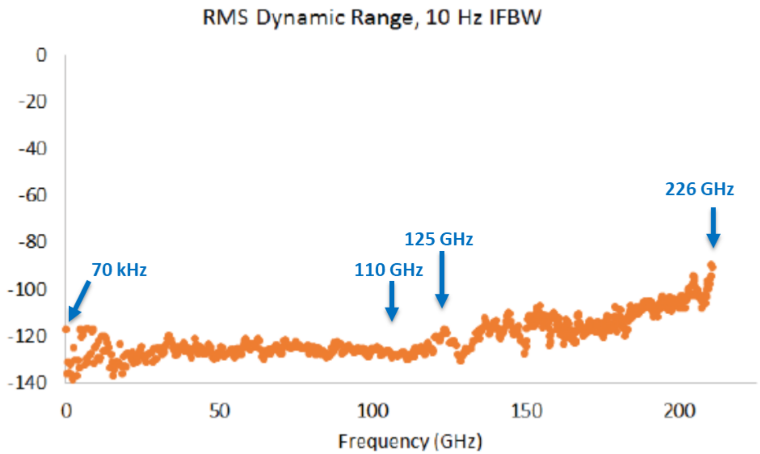
Coupled mmW bands result in better raw directivity, meaning better calibration and measurement stability

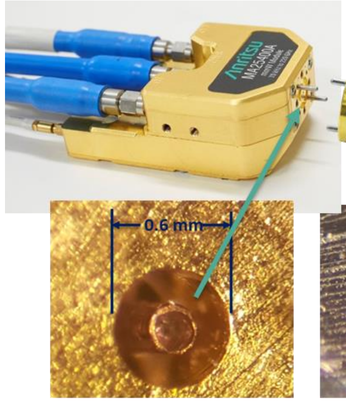
220 GHz single-sweep VNA



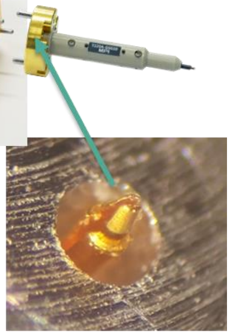
If the verification fails, is it due to inaccurate device models (resulting in inaccurate circuit simulations) or unsuccessful design?

A 220 GHz broadband system enhances the opportunity for improved device models and improved circuit simulations.



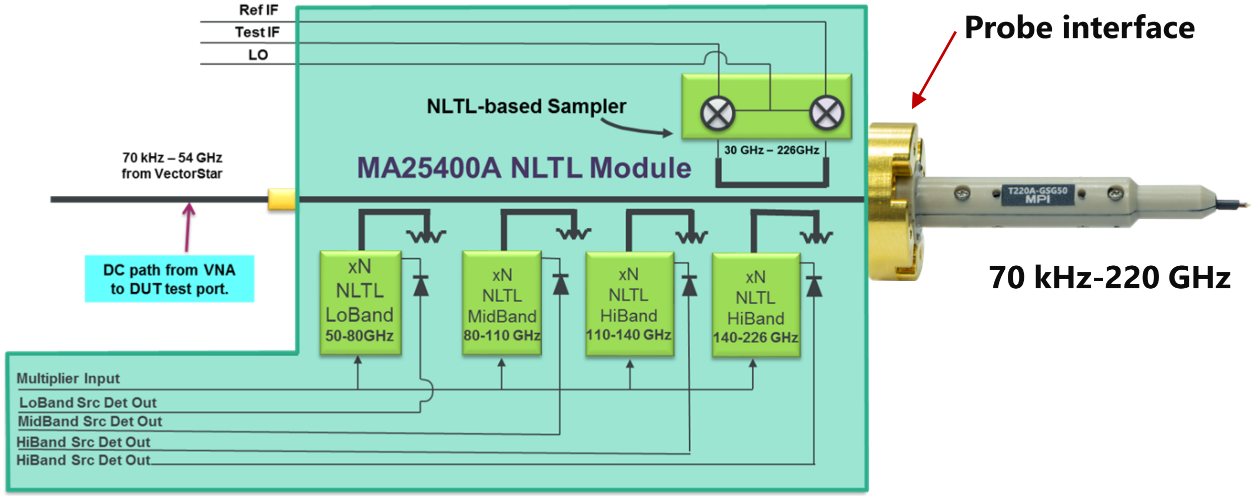


Slot-less <0.4mm female center conductor



Slotted <0.4mm male pin center conductor

- NLTL module offers a DC path from the VNA to the test port and excellent mmWave noise floor receiver sensitivity (-119 to -104 dBm) for wide dynamic range.
- Allows very low drive levels before the noise floor dominates the measurement.
- Compact module with optimal conversion efficiency and noise floor performance.
- RF and LO signals are supplied by the system test set
- Source bands are coupled to the main transmission line through substrate couplers
- NLTL harmonic sampler converts test and reference signals to IF from 30 GHz to 226 GHz and located close to the DUT port.
- Electronic ALC control provides up to 50 dB of power level control.



On-Wafer Test Challenges

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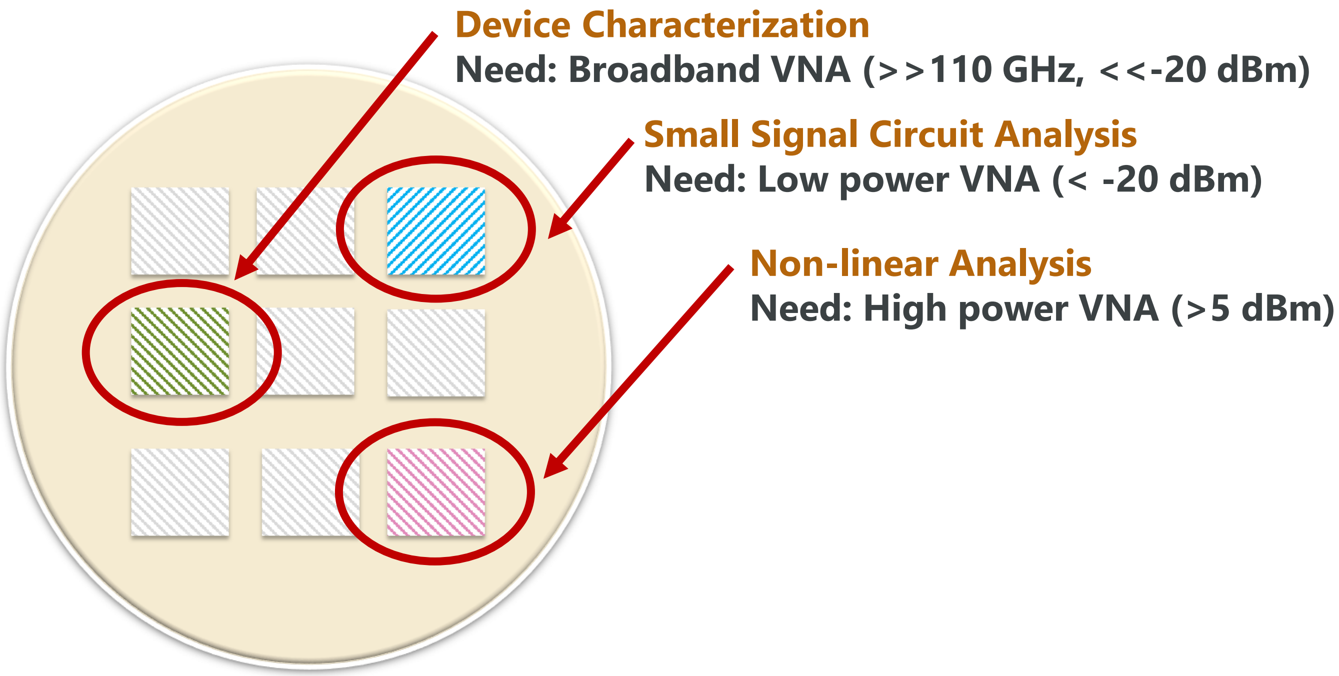
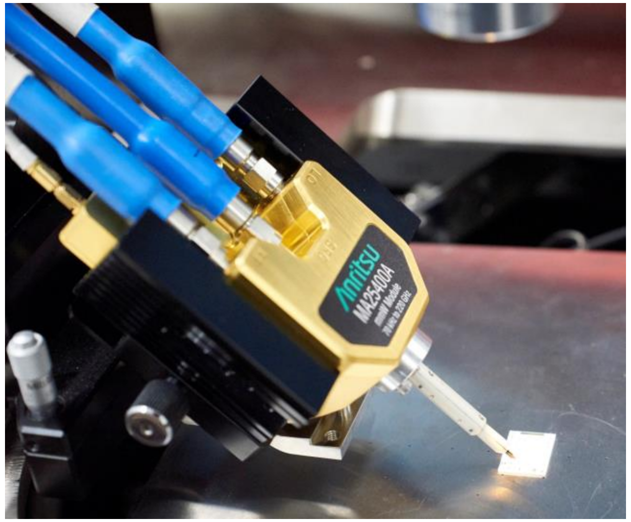


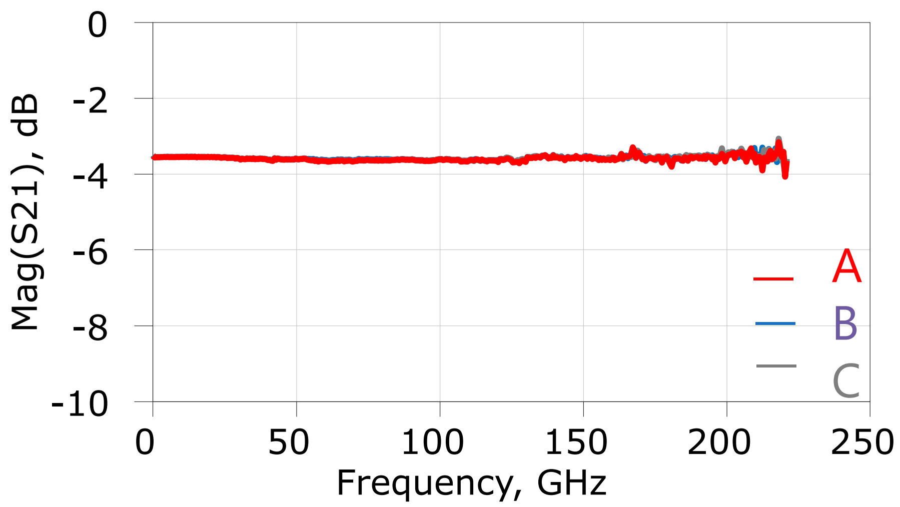
- On-wafer measurements typically require a wide range of VNA measurements due to its highly populated nature.
- A broadband VNA is a must for device characterization and is desirable for linear small signal measurements, since multiple bands often exist on the same wafer (reduces the need to reconfigure VNA).

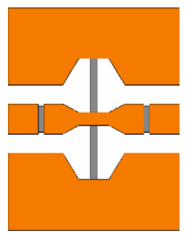
- For on-wafer measurements the ME7838G is calibrated using probes and a calibration impedance standard substrate (ISS).
- The ME7838G can be calibrated using common calibration algorithms such as LRM, ALRM, and multiline TRL.
- May use internal VectorStar calibrations, MPI's QAlibria or WinCal.
- A 220 GHz calibration ISS from MPI is available and support pitches from 50 to 100 um.
- The CS-5 GGB calibration ISS provides 220 GHz calibrations and supports SOLT, LRL and LRM calibrations with pitch range from 75 to 250 um.



Three Measurements, Consistent Results

Here, we have the transmission coefficient of a symmetrical 3dB verification attenuator measured with three probe touchdowns, A, B and C.

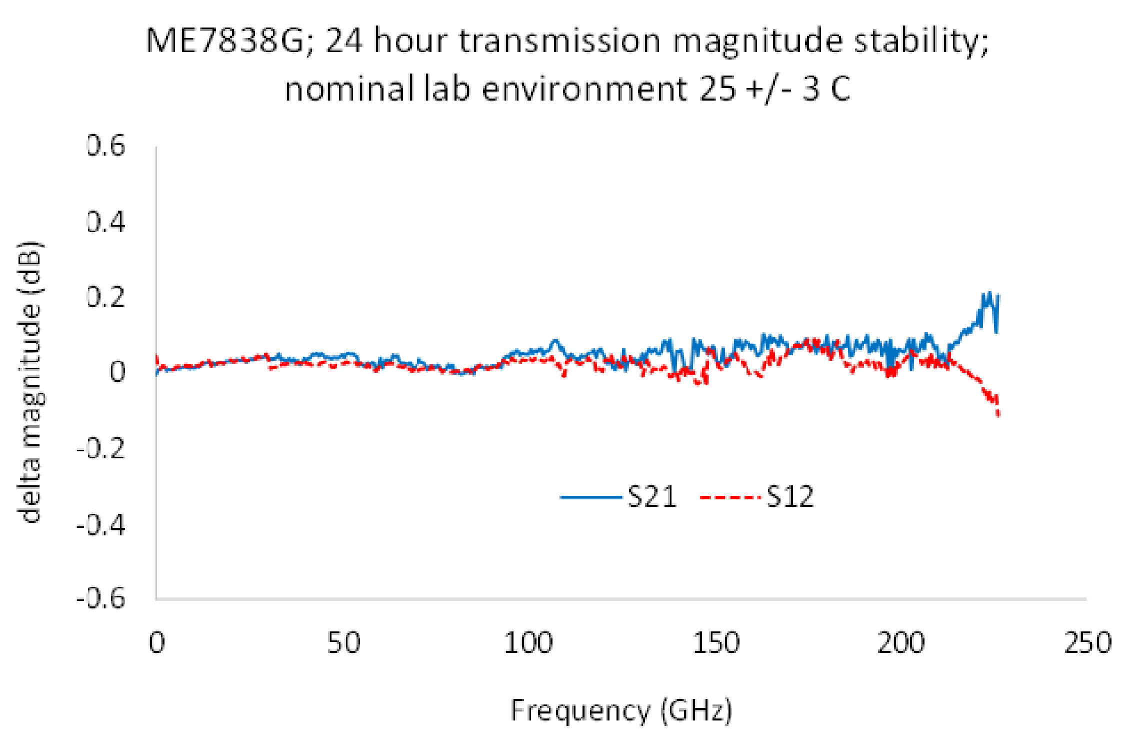


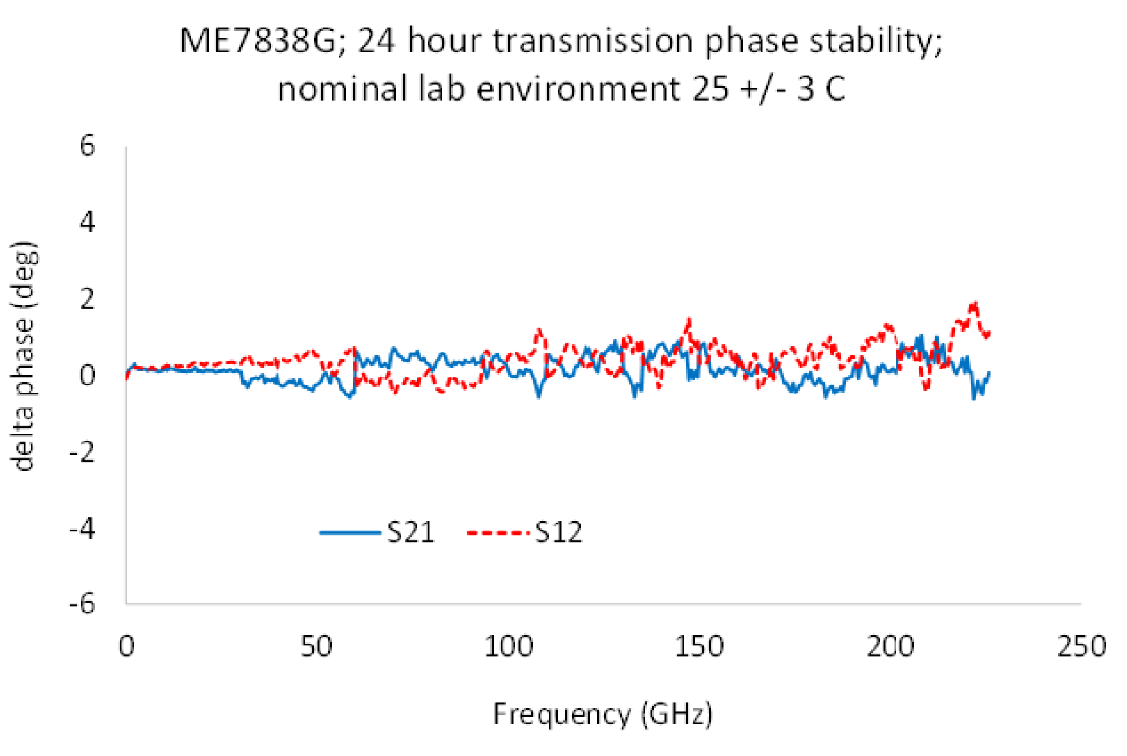


3 dB matched attenuator

The average attenuation was as expected. And consistency of the data is impressive!
As you can see, it is hard to distinguish three measurement series from each other. So, we looked at the vector difference between traces, normalizing the last two of them, the traces B and C to the first series A.

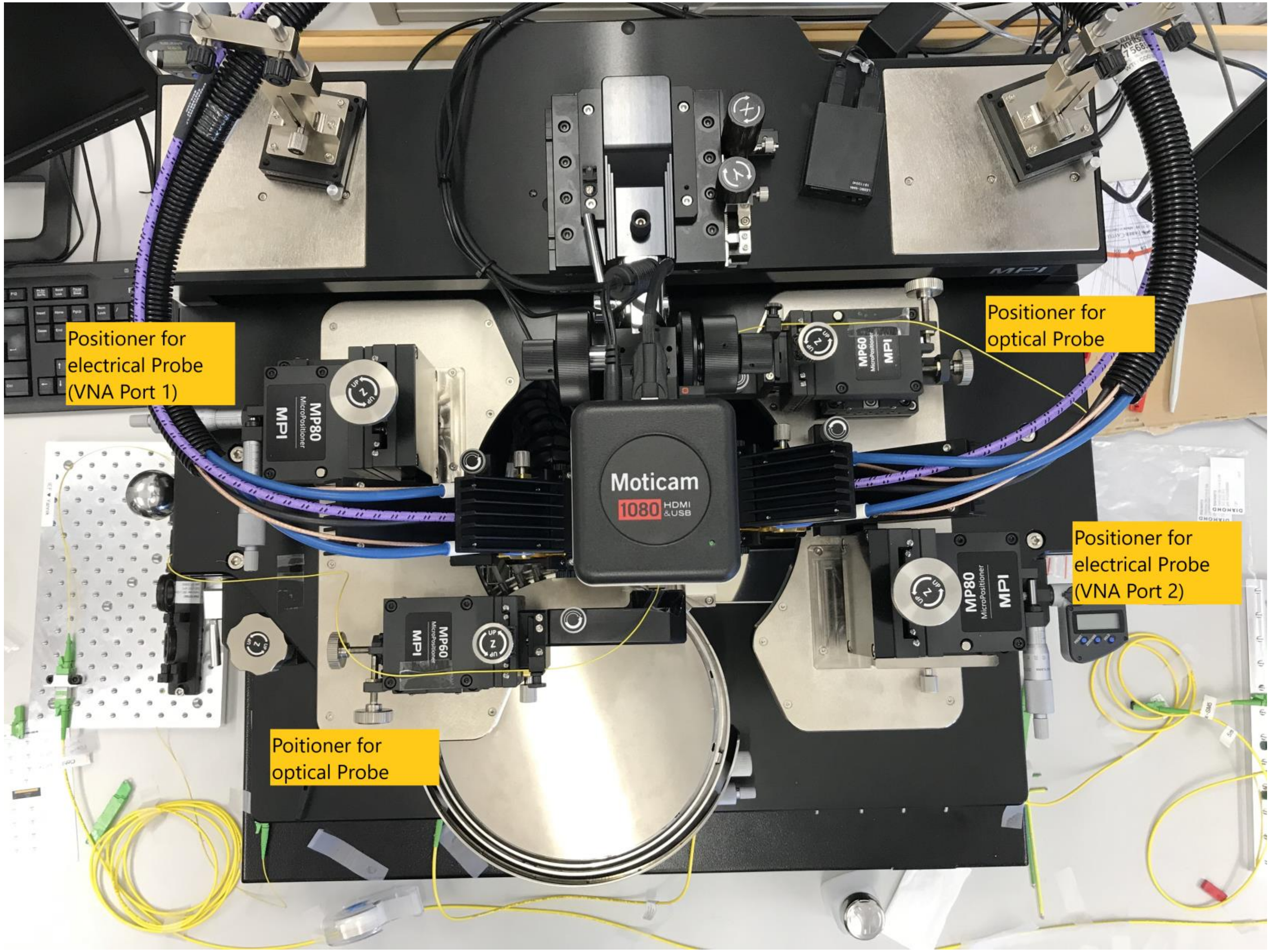
Measurement Stability 220 GHz ME7838G



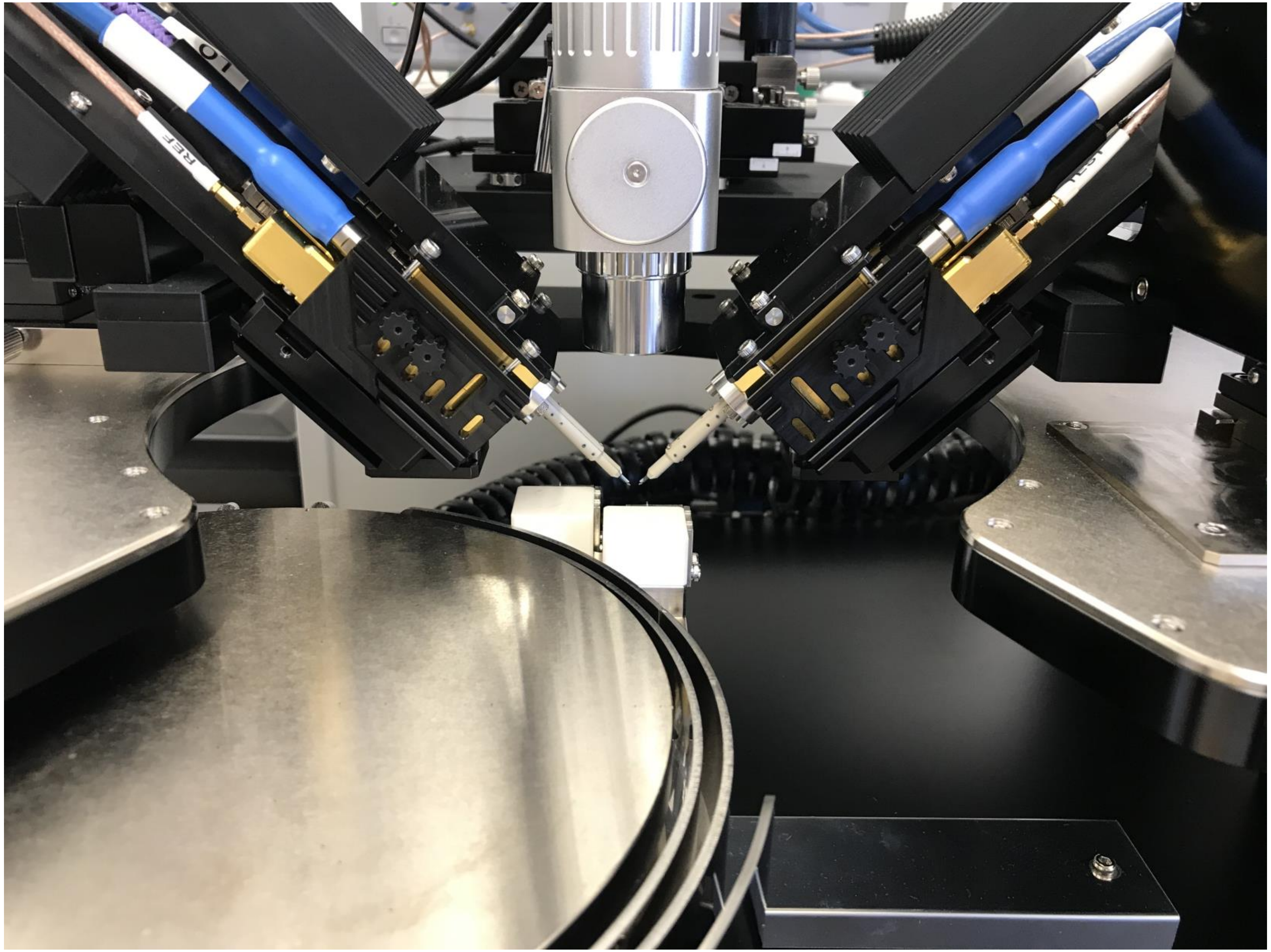


- Tightly integrated NLTL modules continue to offer excellent stability

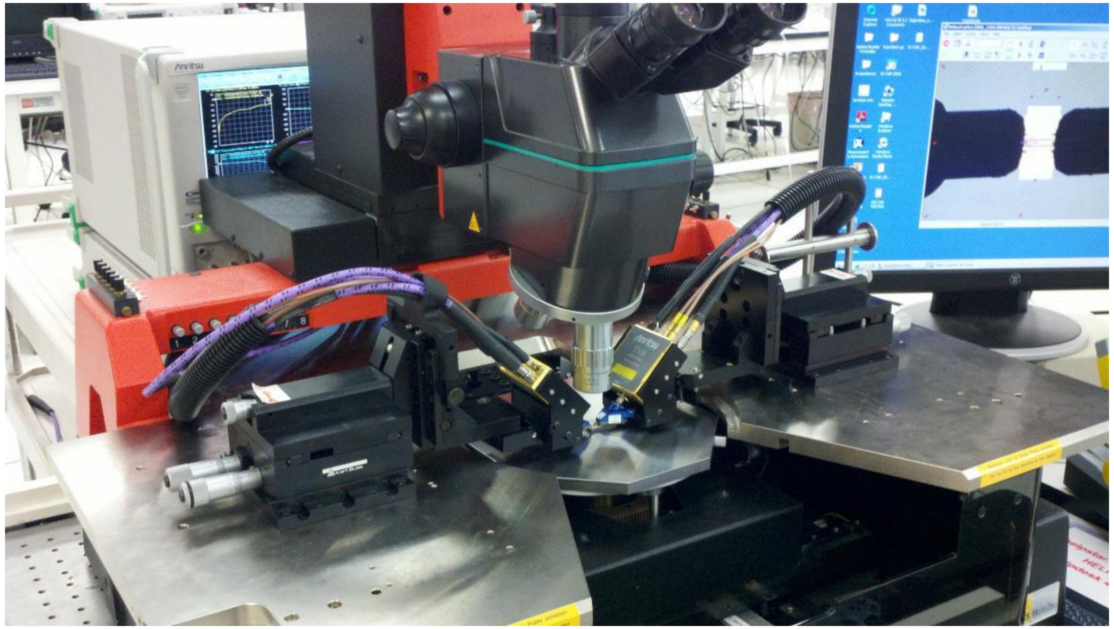
Combined optical/electrical setup



Module Mounting with MPI brackets and holders



On-wafer calibrations above 70 GHz



- SOLT no longer optimum accuracy due to lower termination performance
- LRM variant often the better calibration choice for on-wafer above 70 GHz

Calibration choices for VNA measurements

Cal Algorithm	Description	Advantages	Limitations
SOLT (short-open-load-thru)	Common for coax. Useable up to 40/70 GHz on-wafer	Simple, redundant standards, not band limited	Need well-defined standards. Limited to lower frequencies on-wafer
SSLT (short-short-load-thru)	Often used in waveguide	Simple, redundant standards	Lower accuracy at higher frequencies and band limited
SSST (short-short-short-thru)	Waveguide and high frequency coax	Better accuracy at higher frequencies than SOLT	Band limited. Needs well defined standards. Difficult for on-wafer.
SOLR/SSSR (similar to above but with 'reciprocal' instead of thru)	Similar to SSST but when a good thru not available	Does not require a well defined thru	Accuracy degradation due to less defined thru.
LRL (line-reflect-line. Also called TRL when L1 is 0)	High performance coax, waveguide or on-wafer	Highest accuracy. Minimal standard definition	Requires very good transmission lines. Band limited
LRM (line-reflect-match) when one line is a match	High performance coax, waveguide or on-wafer	Highest accuracy. Minimal standard definition. Not band-limited due to load.	Requires very good transmission lines. Less redundancy.
ALRM (advanced line-reflect-match) include load models and two reflection types	Relatively high performance	High accuracy. Only one line length.	Requires load definition. Reflect standard may require care.

On-wafer calibrations:

- SOLT up to 40 or 70 GHz if standards provide required performance
- LRx up to 110 or 145 GHz

LRM Setup Panel

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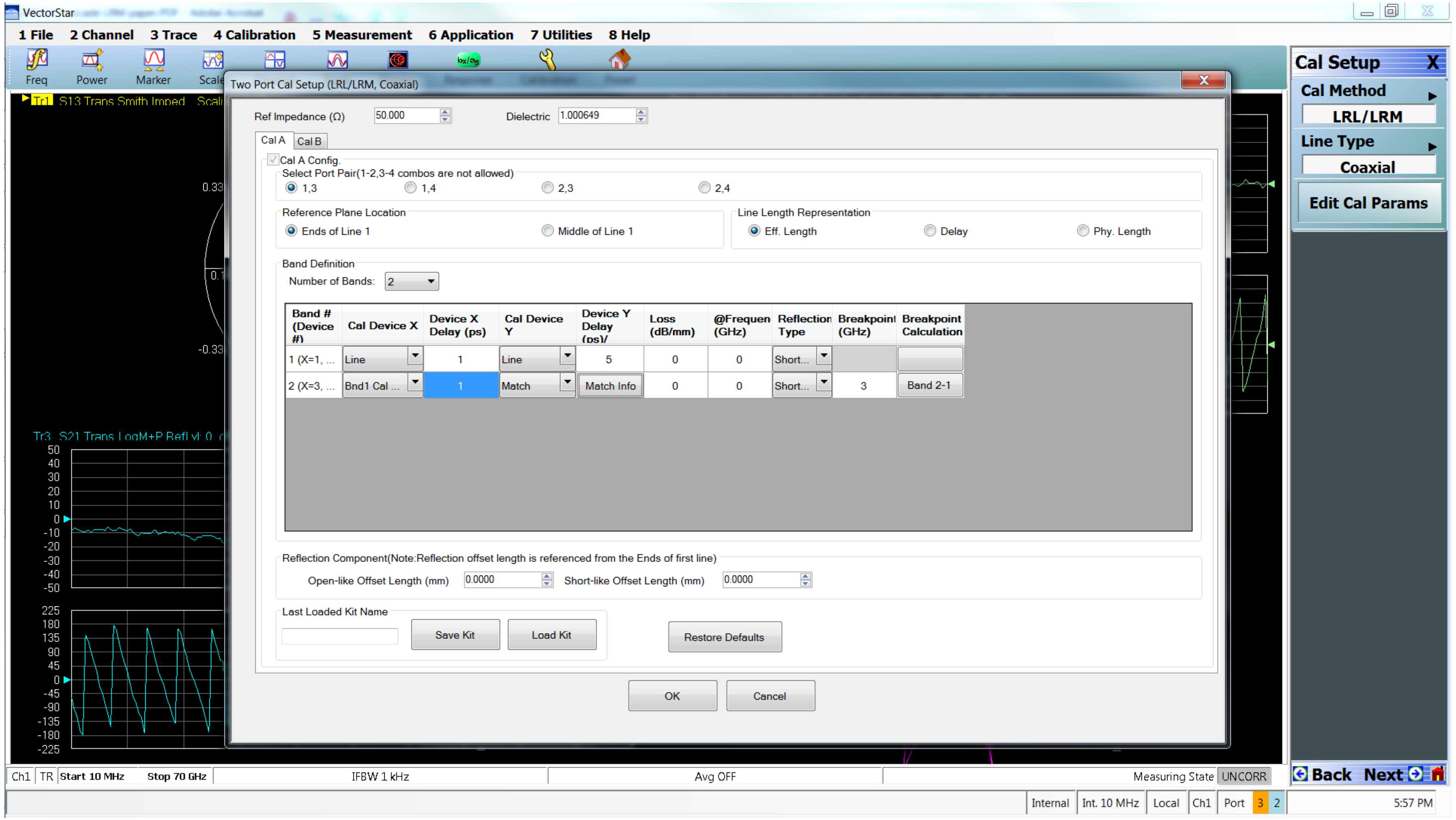
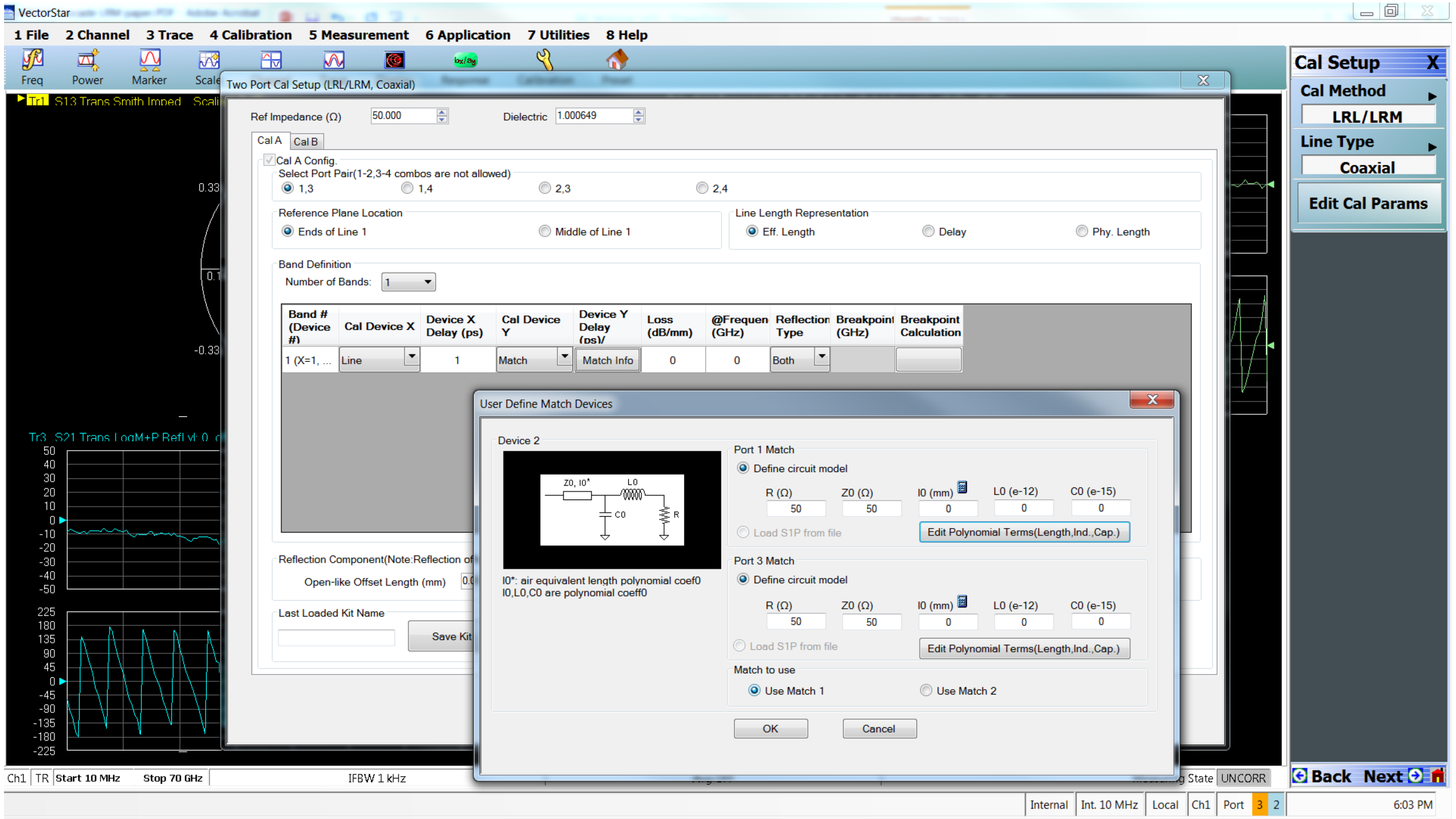


- Specify end of line or middle of line for test port location. Middle of line can be used to position test port at the DUT plane.
- Input effective line length or delay.

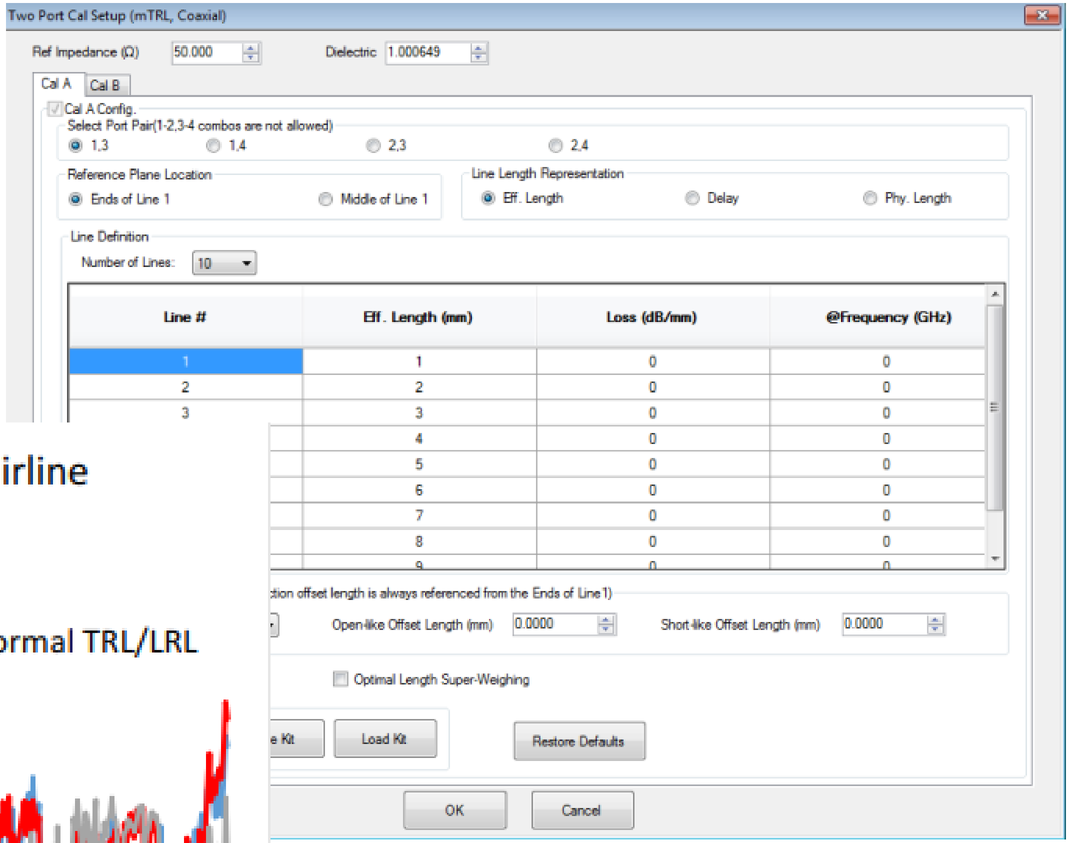
ALRM Setup Panel

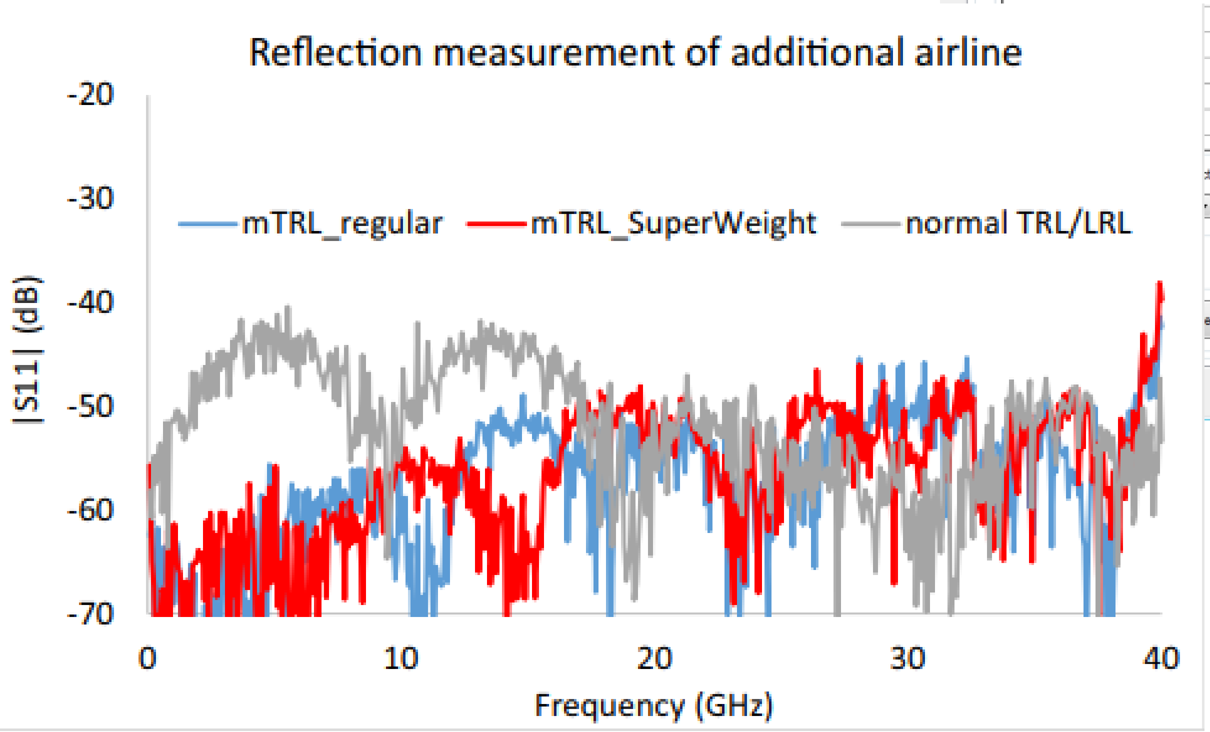


- Selecting both reflection types initiates ALRM.
- In addition to using two reflect types the load model is automatically populated with suggested values based on previous measurements. Or the user can edit as preferred.

mTRL (Multiline TRL)

- mTRL can use up to 10 calibration lines
- Relative contribution determined by algorithm
- Non optimal line lenghts are de-emphasized





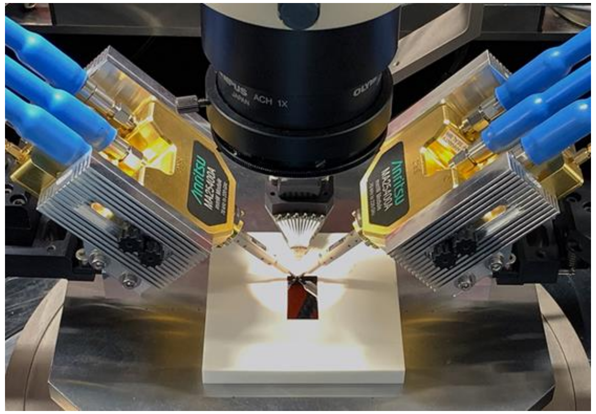
New probe station installations

145 GHz 2 port installation at Chalmers University on MPI TS200 station

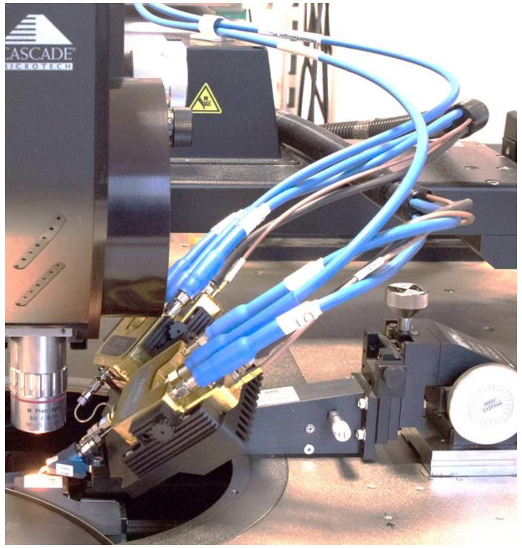
220 GHz 2 port installation at NIST on MPI semi-automatic TS2000-THZ station

Customer-owned probe stations

Fraunhofer Installation
Customer-designed brackets



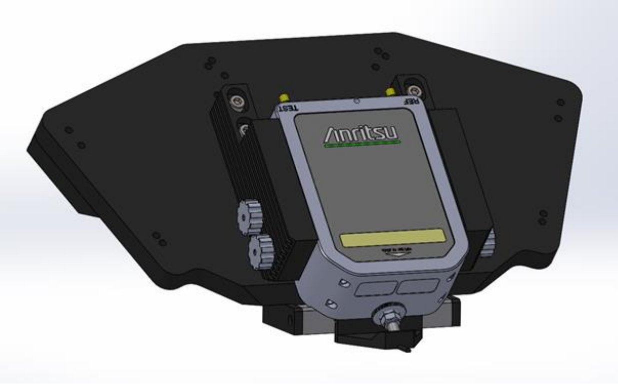
Ferdinand Braun Installation
Customer-produced brackets based on our drawings



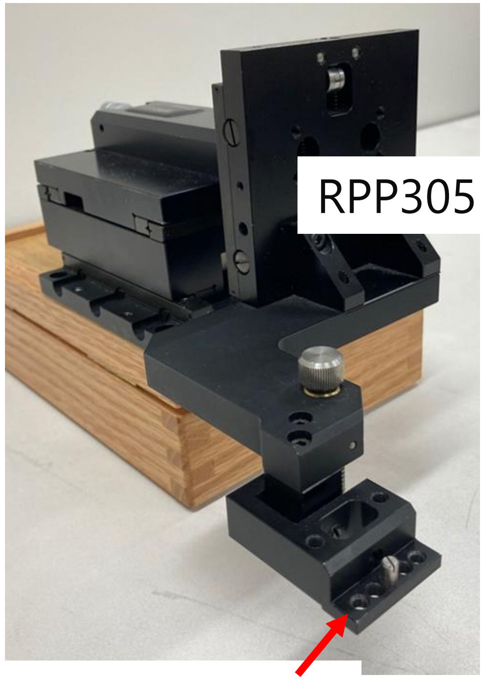
Minatec/CIME Installation
Anritsu-supplied brackets

- For VNA opportunities on an existing probe station, Anritsu-provided module brackets mounted on existing positioners is one possibility.
- Alternatively, customer may install the system using their own designed module brackets or modify one of our bracket designs.

Anritsu Installations

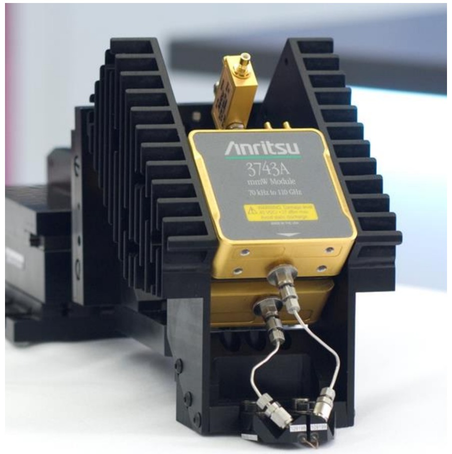


- Anritsu-designed module brackets available for single-ended or differential installations.
- Designed to fit on existing RF probe holder positioners such as the FormFactor RPP305



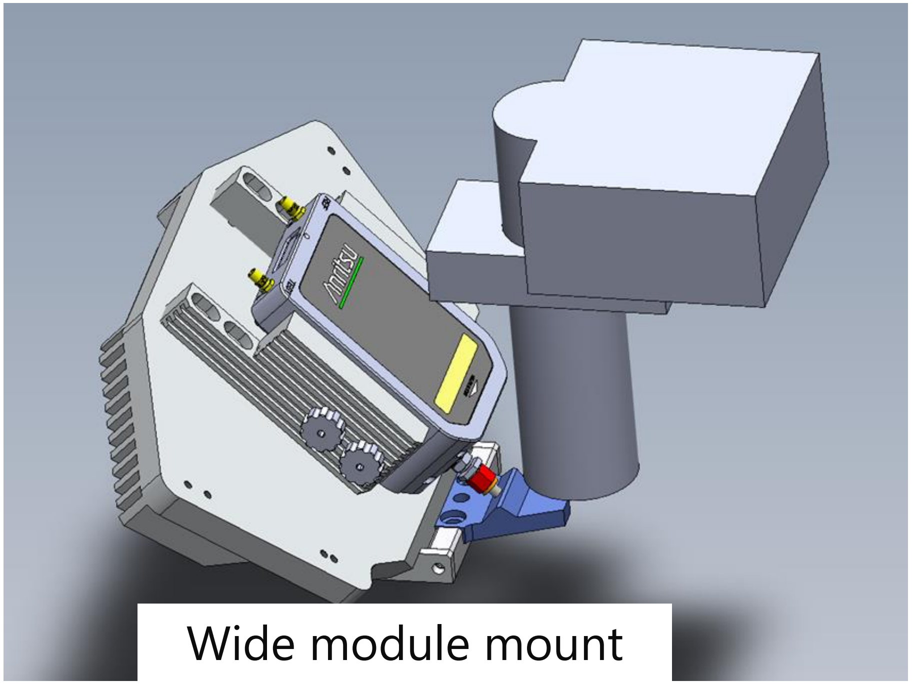
RPP305 positioner

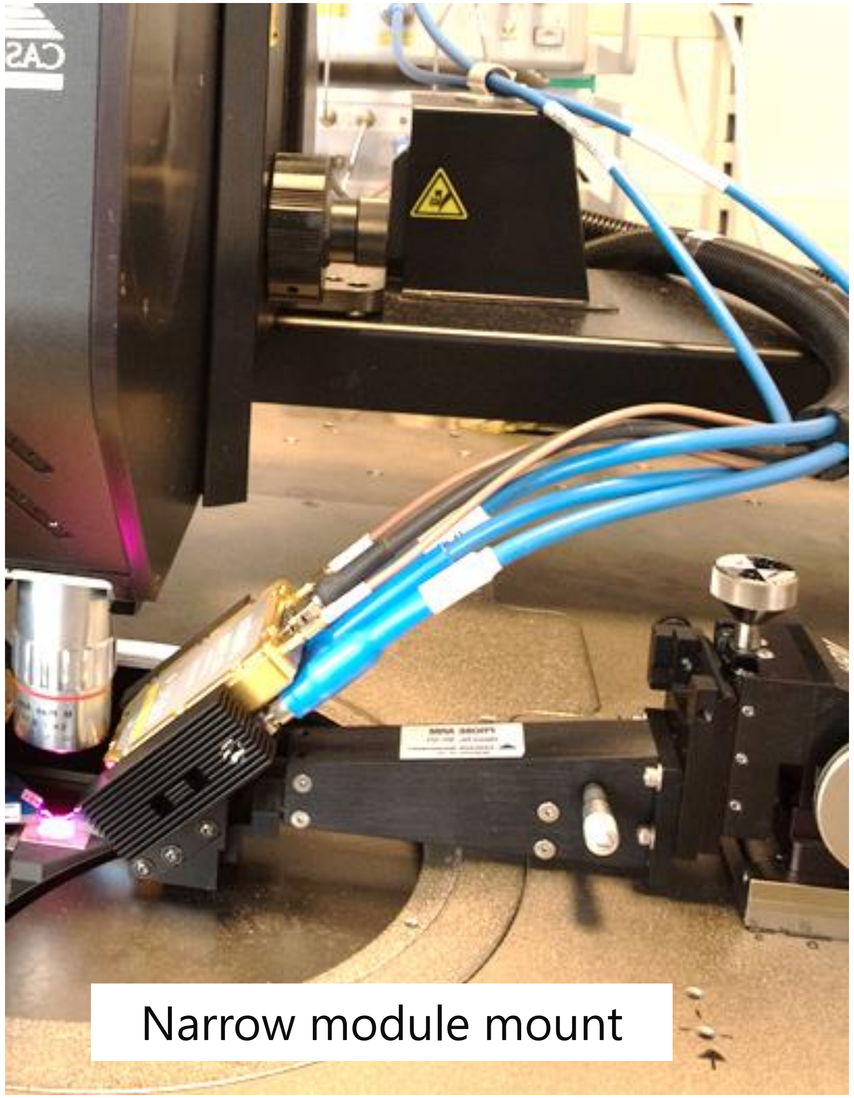
RF probe holder



Narrow vs Wide single-ended module mount

Narrow mount best for small platen openings.

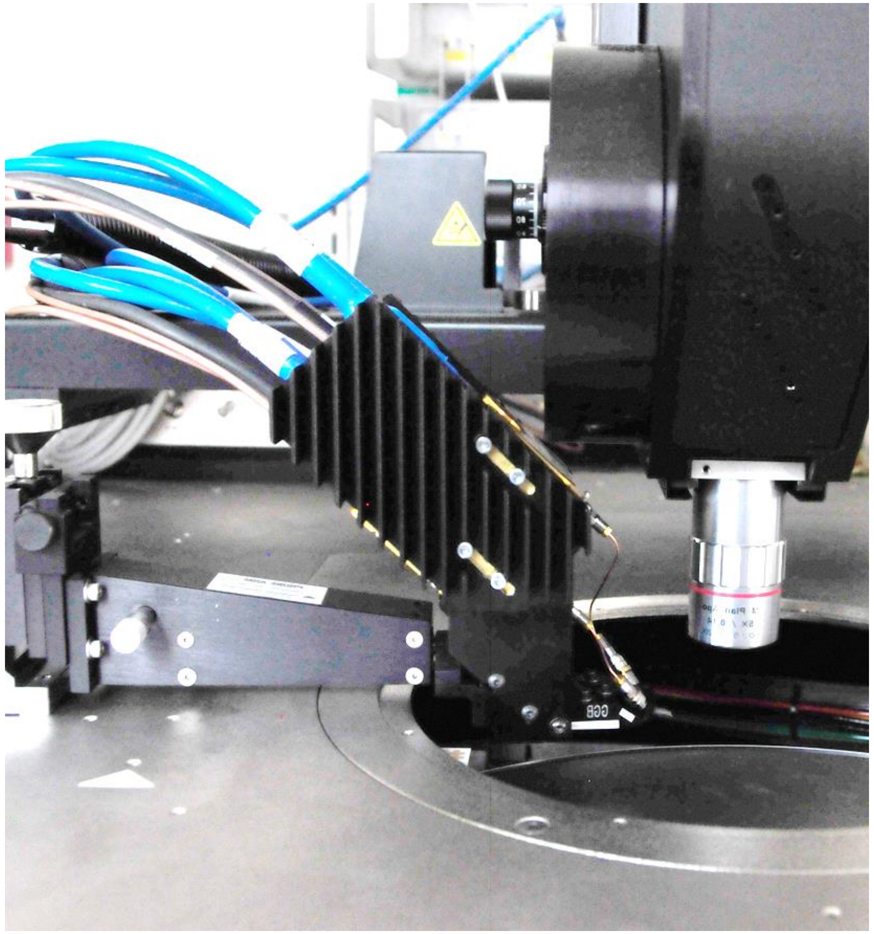


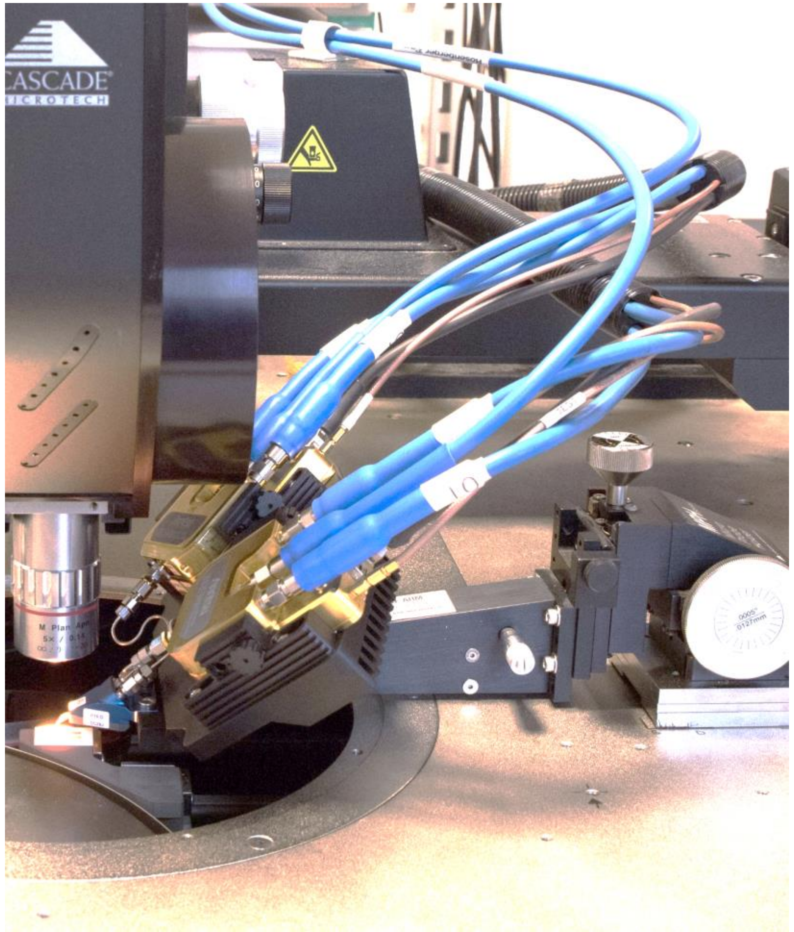


Considerations:

- Opening in platen accessing the chuck
  - Need about 20 cm
- Scope clearance to module
  - Focus distance to wafer (~35 mm)
  - ½ width of lens (~20mm)

Narrow vs Wide differential module mount





- Differential installation considerations: Platen opening and clearance to microscope.
- **Note magnetic positioners.** Alternative to mounting on platens when positioner mounting holes are not available. Using magnetic positioners on Summit 12000 probe station a good example.

Narrow single-ended module mounting variations

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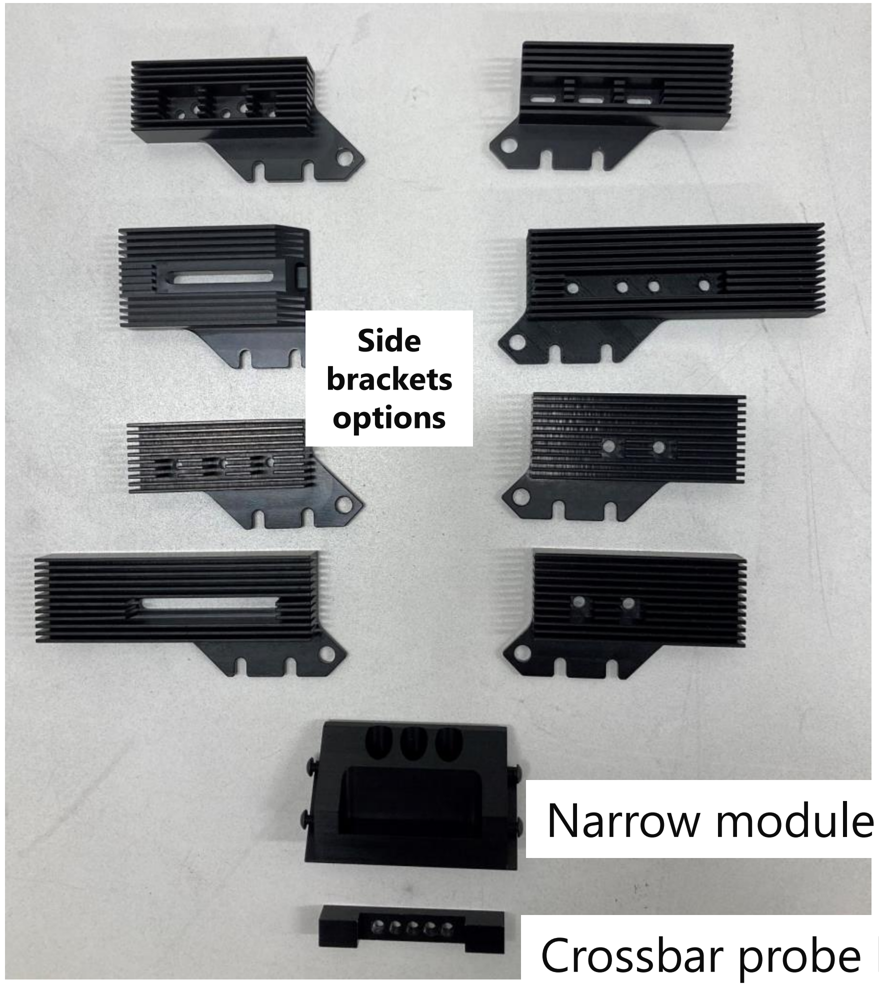


Narrow module mount

Crossbar probe holder

Same module mount and crossbar for all side brackets

Side brackets for narrow mounts

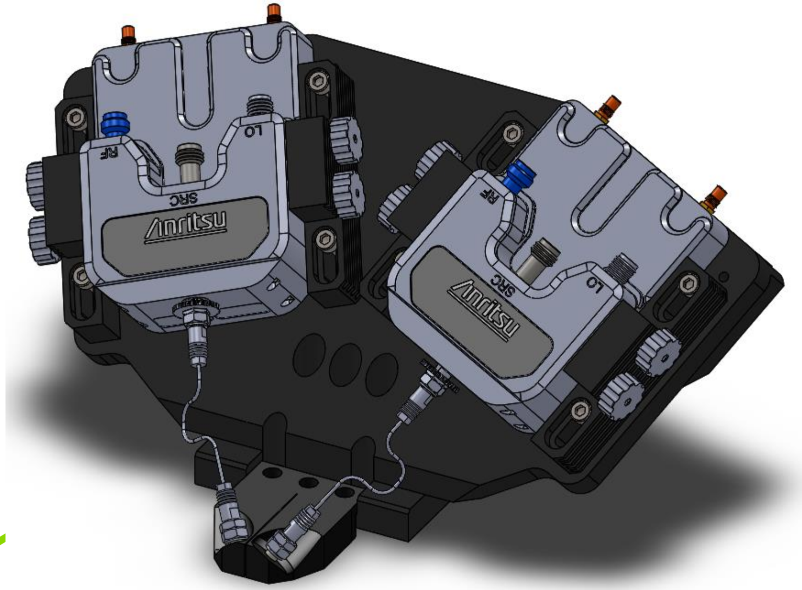
- Variations for :
  - Different frequency modules
  - Different probes due to different probe tip lengths
    - FormFactor Infinity
    - GGB Picoprobe
  - Combination of Infinity and GGB
  - Combination of 0.8mm and 1mm probes (same module using different adapters).
  - Combination of 110 GHz and 145 GHz modules (2 and 3 hole modules)

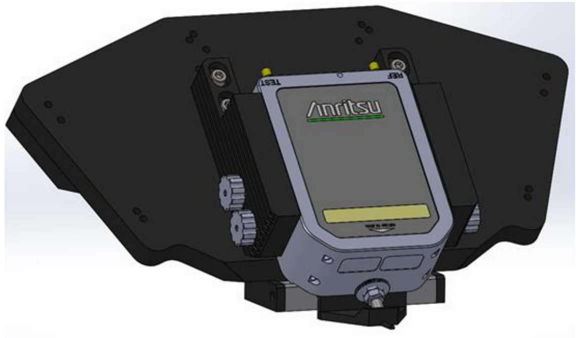
Infinity

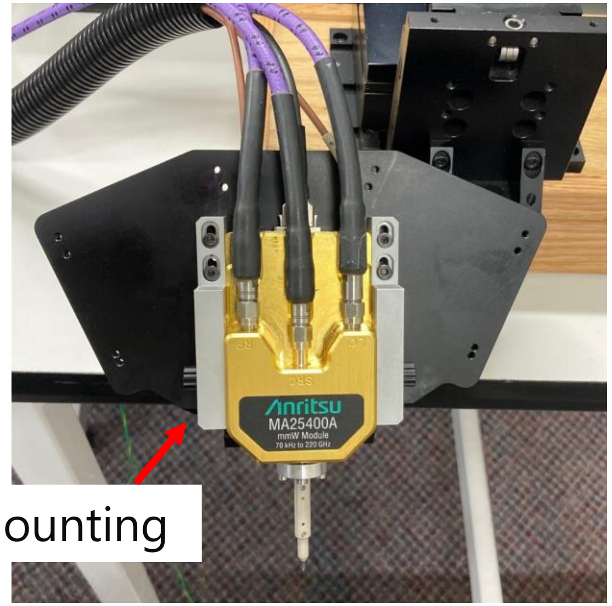
GGB

Anritsu wide module brackets

- Wide bracket for mounting 2 or 4 modules for single-ended or differential.
- Wide mounting bracket plate uses different side brackets for different frequencies and provides improved lens clearance, especially for differential.
- Range of side bracket options similar to narrow mounts.
- Will need correct set of cables per probe brand for differential measurements.
- Side brackets available for 220 GHz modules. Differential up to 145 GHz.

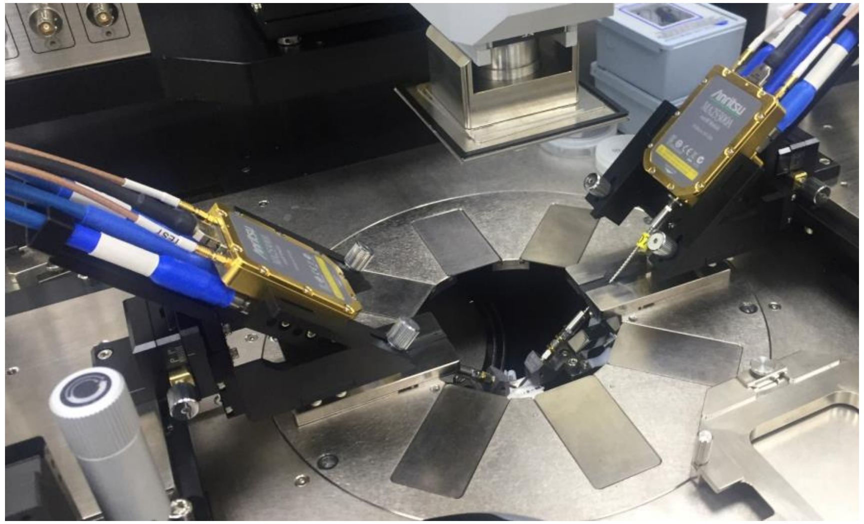




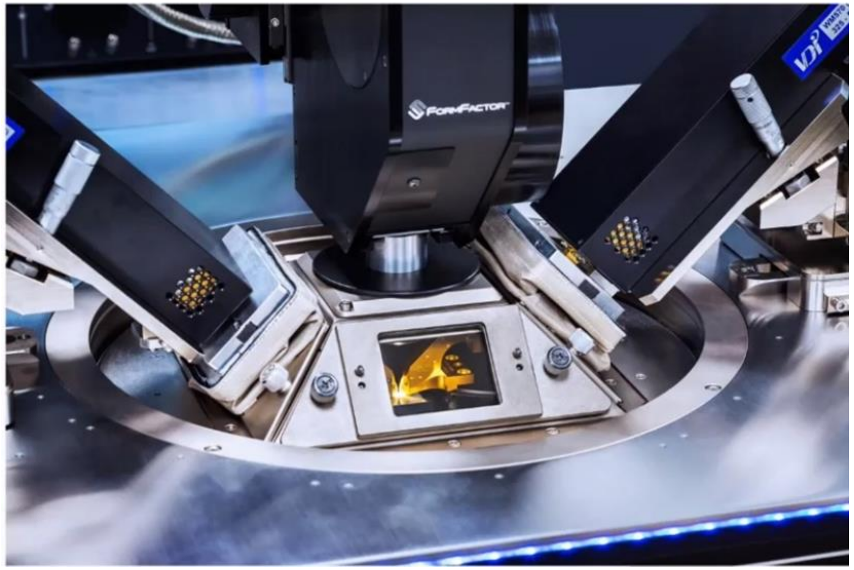


220 GHz mounting

Installation on heat chamber probe stations



MPI chamber (top hat removed)



FormFactor chamber

- Heat chamber used for temperature characterization of devices.
- Need cables to connect to probe through heat chamber window

Demo Video: Installation

Demo Video: Calibration

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Anritsu ME7848A
Optical Vector Network Analyzer

Enrico Brinciotti, Ph.D.

RF & uW Business Development & Field Applications
Anritsu EMEA – Engineering & Technology

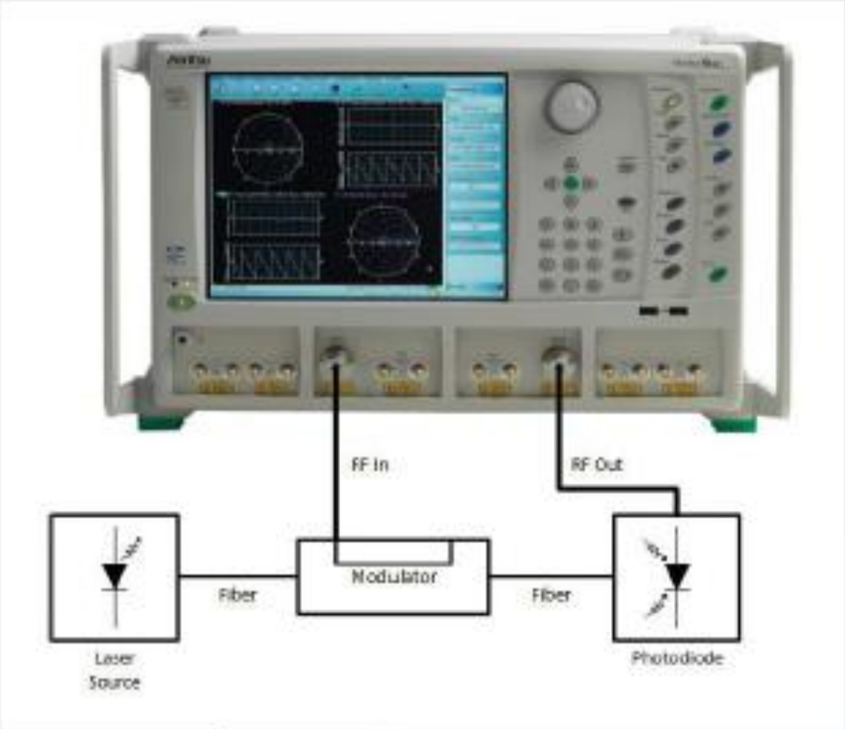
November 30th, 2021

Anritsu ME7848A Optical Vector Network Analyzer

<u>Agenda</u>

1. Optoelectronic (E/O & O/E) Measurements
2. Anritsu Optical VNA
3. Demo Video

Optoelectronic (E/O and O/E) Measurements



Target Markets

- The ME7848A Optical Network Analyser system addresses the needs of the E/O and O/E component manufacturers that need to characterize components in R&D and manufacturing
- Also targets module integrators and manufacturers of optical transmitters, receivers, and transceivers

Optoelectronic (E/O and O/E) Measurements

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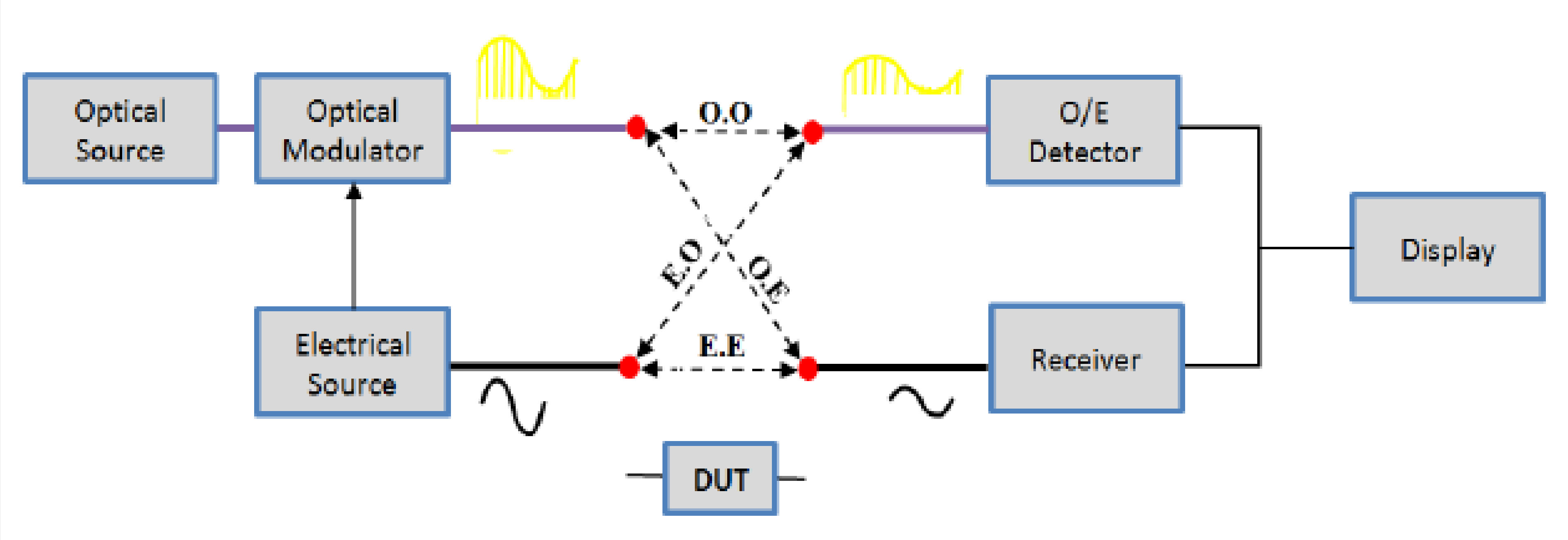


Our Solution allows the measurement of all 4 domains simply and easily with our Standard Optical measurement Software on Vectorstar VNAs

1) Optical Input – Electrical Output (O/E) (Photodetector)
2) Electrical Input – Optical Output (E/O) (Optical Modulator)
3) Electrical Input – Electrical output (E/E) (Any RF component)
4) Optical Input – Optical Output (O/O) (An optical Cable/Component etc.)

MN4765B O/E Calibration Module (850, 1060,1310 and 1550 nm)

- Characterized optical front end for VectorStar VNAs

- Protected from physical and static damage
- Bias regulation
- Temperature stable
- NIST derived characterization from 70 kHz to 110 GHz (magnitude & phase)
- Battery backup
- Improved uncertainties

MN4765B O/E Calibration Module (850, 1060,1310 and 1550 nm)

- Characterized optical front end for VectorStar VNAs

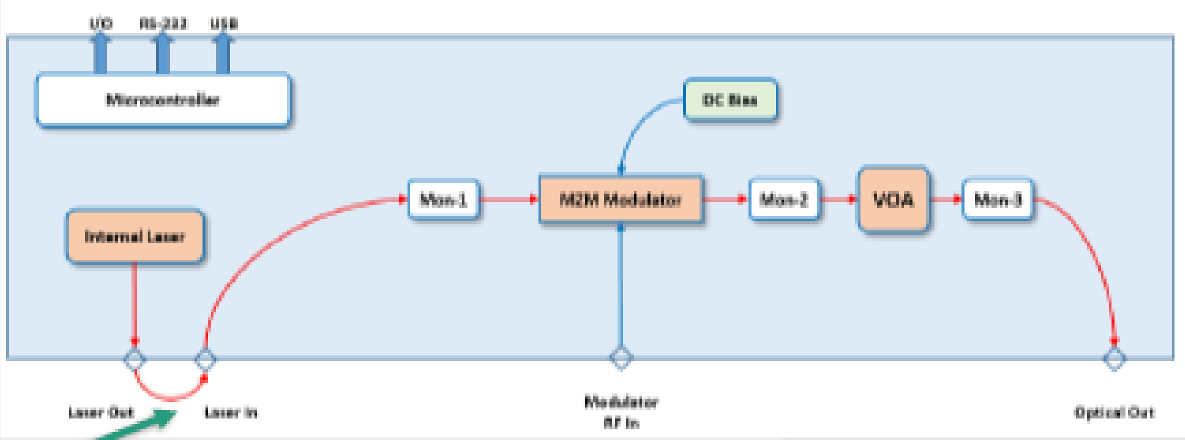
MN4765B-0070 (Option 70): 70 GHz at 1550 nm
MN4765B-0071 (Option 71): 70 GHz at 1310 nm
MN4765B-0072 (Option 72): 70 GHz at 1310/1550 nm
MN4765B-0110 (Option 110): 110 GHz at 1550 nm
NEW **MN4765B-0111 (Option 111): 110 GHz @ 1310 nm**
MN4765B-0112 (Option 112): 110 GHz @ 1310/1550 nm
MN4765B-0040 (Option 40): 40 GHz at 850 nm
MN4765B-0042 (Option 42): 40 GHz at 850/1060 nm
MN4765B-0043 (Option 43): 40 GHz at 850/1060/1310/1550 nm

- Protected from physical and static damage
- Bias regulation
- Temperature stable
- NIST derived characterization from 70 kHz to 110 GHz (magnitude & phase)
- Battery backup
- Improved uncertainties

MN4775A Electrical to Optical Converter

- Modulator stabilized by fully automatic bias controller
- Internal tunable laser source
  - Or fixed wavelength source
- Can couple external laser to Optical Input
- Touchscreen or remote via RS-232

- MN4775A-0040 40 GHz 850nm E/O Converter
- MN4775A-0070 70 GHz 1550 nm E/O Converter
- MN4775A-0071 70 GHz 1310 nm E/O Converter

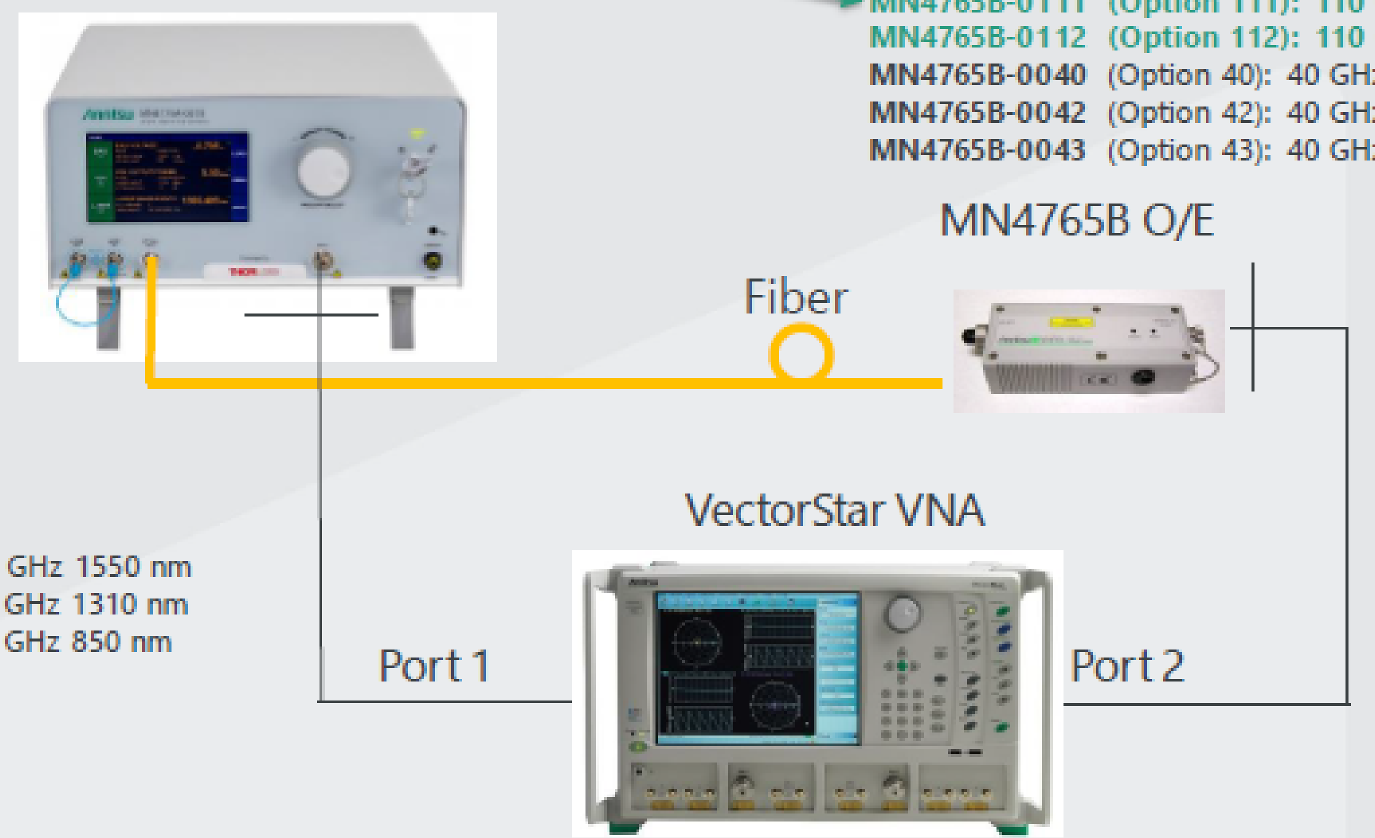


Loop not present on MN4775A-0040

ME7848A Opto-Electronic VNA (850, 1060, 1310 or 1550 nm)

MN4765B-0070 (Option 70): 70 GHz at 1550 nm
MN4765B-0071 (Option 71): 70 GHz at 1310 nm
MN4765B-0072 (Option 72): 70 GHz at 1310/1550 nm
MN4765B-0110 (Option 110): 110 GHz at 1550 nm
NEW → **MN4765B-0111 (Option 111): 110 GHz @ 1310 nm**
MN4765B-0112 (Option 112): 110 GHz @ 1310/1550 nm
MN4765B-0040 (Option 40): 40 GHz at 850 nm
MN4765B-0042 (Option 42): 40 GHz at 850/1060 nm
MN4765B-0043 (Option 43): 40 GHz at 850/1060/1310/1550 nm

MN4775A E/O



MN4775A-0070: 70 GHz 1550 nm
MN4775A-0071: 70 GHz 1310 nm
MN4775A-0040: 40 GHz 850 nm

ME7848A ONA (Optical Network Analyser)

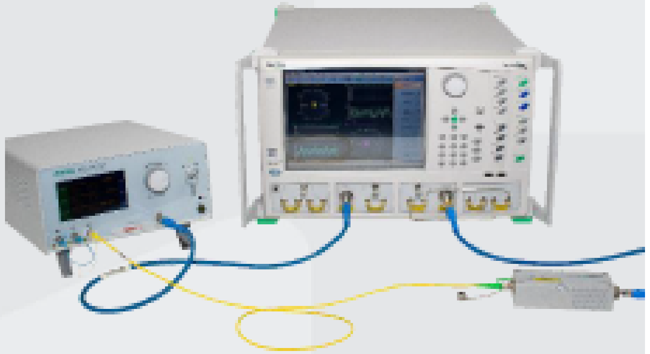
The ME7848A-02XX series system contains the following:

- MS464xB Vector Network Analyzer with option 51
    - (option 61 or 62 optional)
- MN4765B-0040/0070/0071 O/E Calibration Module
- MN4775A-0040/0070/0071 E/O Converter
- Accessory Kit:
    - 2000-1957-R for 40 GHz systems
    - 2000-1958-R for 70 GHz systems

The ME7848A-01XX series system contains the following:

- MS464xB Vector Network Analyzer with option 51
    - (option 61 or 62 optional)
- MN4765B-0040/0070/0071 O/E Calibration Module
- Accessory Kit:
    - 2000-1957-R for 40 GHz systems
    - 2000-1958-R for 70 GHz systems

ME7848A ONA



Two versions of the accessory kits are available depending on the frequency coverage:

- 2000-1957-R accessory kit for 40 GHz systems
  - Two 1m RF K connector test port cables (806-304-R, 36", m/f)
  - One 33KFKF50C K connector f/f adapter
  - 1m single mode patch cord (808-20-R, 850 nm), (FC/PC-FC/APC)
  - Two semi-rigid K cables for front panel reverse coupler configuration optimizing S21 performance (2000-1963-R).
  - Fiber connector cleaning kit

- 2000-1958-R accessory kit for 70 GHz systems (1310 or 1550 nm operation)
  - Two 1m RF V connector test port cables (806-209-R 36" m/f)
  - One 33VFVF50C V connector f/f adapter
  - 1m single mode patch cord (808-21-R, 1310/1550 nm), (FC/PC-FC/APC)
  - Two semi-rigid V cables for front panel reverse coupler configuration optimizing S21 performance (2000-1964-R).
  - Fiber connector cleaning kit

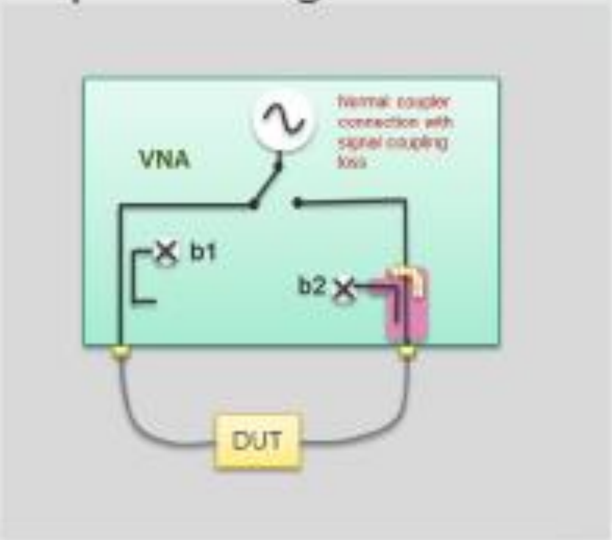
ME7848A ONA

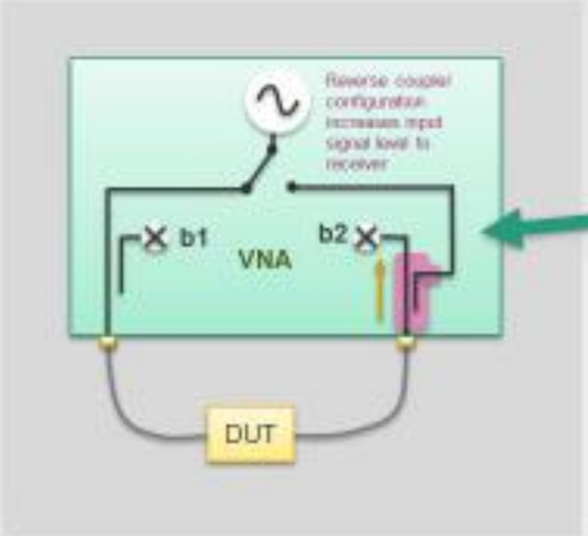
Accessory kit RF cables

- The output of the MN4765B O/E calibration module is male so a female-to-female RF cable is needed for the O/E module to VectorStar connection.
- The supplied 806-304-R (K connector kit) and 806-209-R (V connector kit) cables are male/female.
    - Thus, a female/female adapter is included for connection.

ME7848A ONA

Reverse coupler configuration





- Results in reduced S12 performance

- ME7848A includes the use of access loops (opt. 51, 61 or 62)
- Accessory kits provide semi-rigid cables for reverse coupler configuration.
- Reverse coupler configuration maximizes receiver sensitivity for optimal noise floor and dynamic range performance.

ME7848A ONA

Configuring for reverse coupler operation

- Accessory kit includes two front panel cables to construct the reverse coupler orientation for frequencies above 2.5 GHz.
- Standard rear panel loop cables can be used to configure for reverse coupler operation below 2.5 GHz.
- Reverse configuration optimizes performance of noise floor for E/O and O/E measurements.
- Noise floor specified in ME7848A TDS is expressed in terms of dBm and W/A (Watts/Amps, for E/O measurements) or A/W (Amp/Watts, for O/E measurements).

ME7848A Optical Network Analyzer

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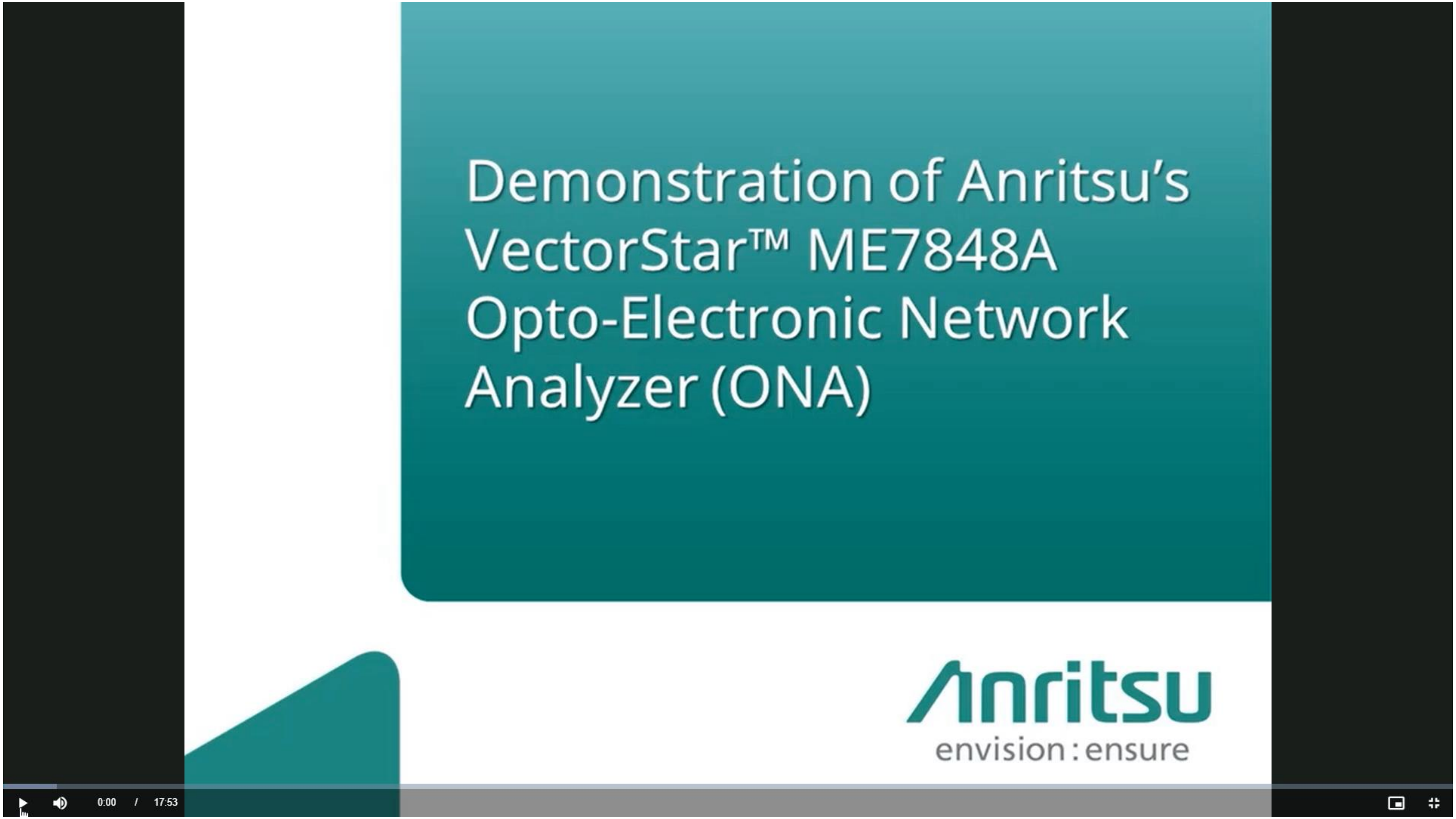
Reverse coupler operation summary

- It is recommended to include an access loop option if a VectorStar is expected to be configured for optical measurements in the future.
- The benefit of the reverse coupler configuration is primarily for 850 nm measurements to help minimize the lower source level of the 850 nm MN4775A-0040 converter.
- If a VectorStar VNA does not have access loops it can still be configured for Opto-electronic measurements with very good performance in the 1310 and 1550 nm range.
- The ME7848A TDS provides specifications for both 'normal' and 'reversed' configuration to help specify performance of VectorStars without the loop options.


Demonstration of Anritsu's VectorStar™ ME7848A Opto-Electronic Network Analyzer (ONA)
Anritsu
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ShockLine™ ME7868A Distributed 2-port VNA

Enrico Brinciotti, Ph.D.

RF & uW Business Development & Field Applications
Anritsu EMEA – Engineering & Technology

November 30th, 2021

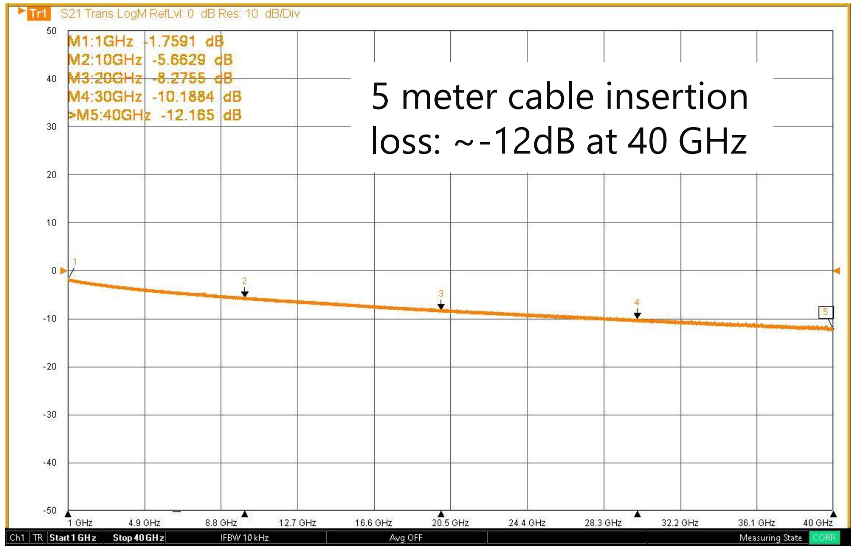
ShockLineTM ME7868A Distributed 2-port VNA

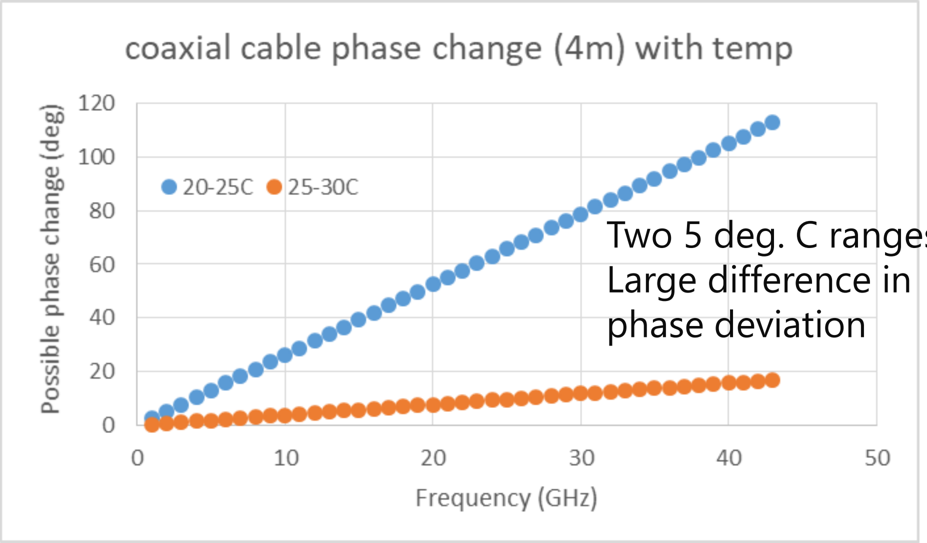
Agenda

1. Key cable effects on microwave S-parameter measurements
2. Managing cable effects on µW VNA measurements
3. A New VNA architecture solution
4. ShockLineTM ME7868A distributed 2-port VNA
5. Target use cases and key advantages
6. Summary

Key Cable Effects on Microwave S-Parameter Measurements

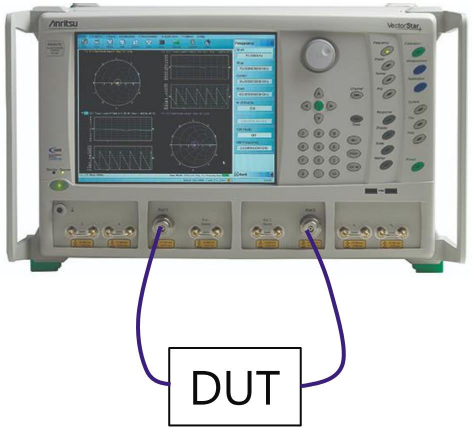
- **Cables introduce signal losses between DUT and VNA port**
    - Cable insertion loss (IL) reduces effective VNA measurement dynamic range
    - Higher frequencies and longer lengths = higher losses
        - Typical microwave cable might have ~1 dB loss per meter at 4 GHz
        - Loss grows to ~2-4 dB per meter at 40 GHz
- **Cable phase uncertainty**
    - Small deviations in cable electrical length cause deviations in phase measurement results
    - Length affected by changes in environmental temperature and cable movement





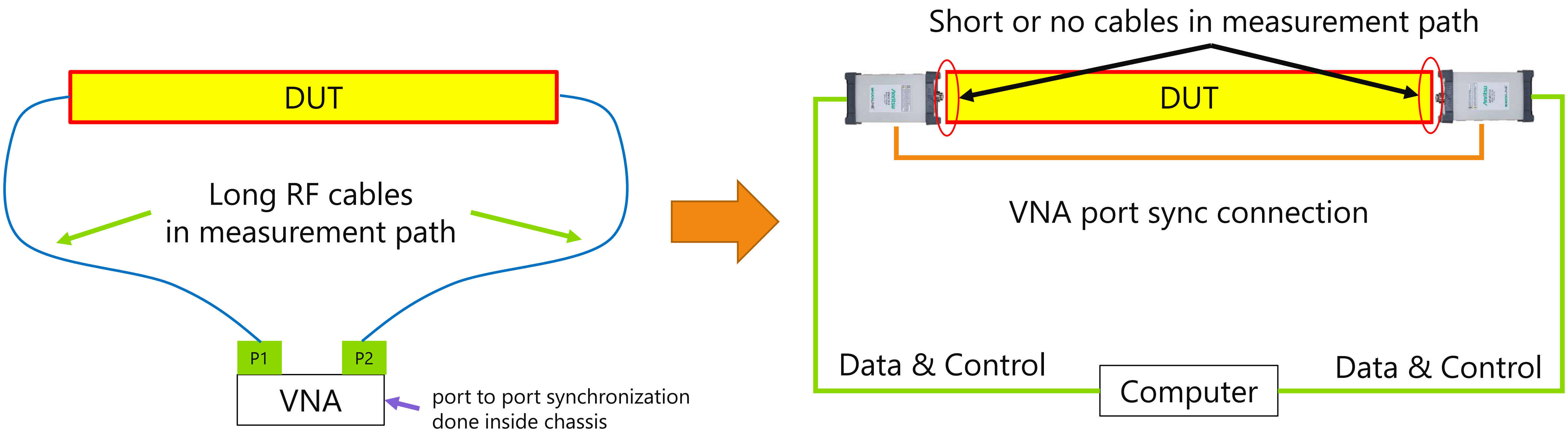
Typical Methods for Managing Cable Effects on µW VNA Measurements

- **Keep cables as short as possible to minimize insertion loss**
  - Benchtop applications can normally keep cable lengths <1 meter
  - Many DUTs are small enough to interface with short cables
- **Control test environment**
  - Careful calibration and test techniques can minimize phase uncertainty from cable movements
  - Temperature regulation reduces any phase deviations due to changes in cable electrical length
- **Remove cable effects from DUT test results**
  - De-embedding techniques rely on cable characteristics staying constant after calibration
  - VNA must have enough dynamic range performance to overcome cable insertion loss
- **Standard techniques do not apply to some common VNA applications**
  - S-parameter measurements over long distances
    - Larger OTA chamber applications
    - Outdoor antenna range testing
    - Large vehicle shielding and propagation characterization
  - Applications requiring movement or physical measurement placement



A New VNA Solution for Long Distance S-Parameter Applications

- **Address cable IL and phase issues by eliminating the test port cables altogether**
- **Requires:**
  - Portable VNA ports for easy placement at DUT eliminating long test port cables
  - Independent source and measure circuitry in each port module
    - Independent source and measure circuitry in each port module
    - High frequency measurement signals stay localized to port
  - Long distance port to port synchronization to enable vector s-parameter measurement



Dynamic range effect of long test port cables

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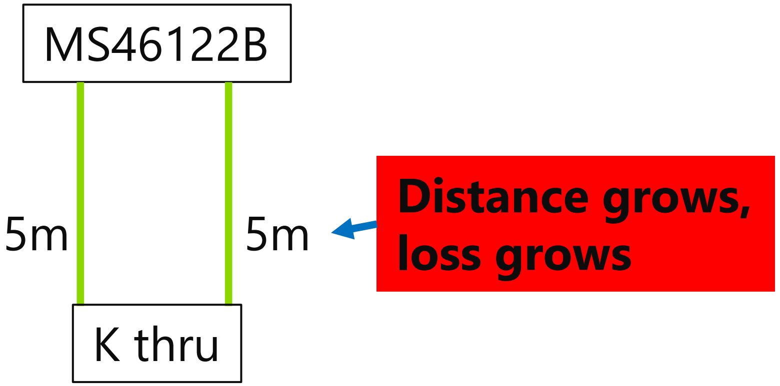
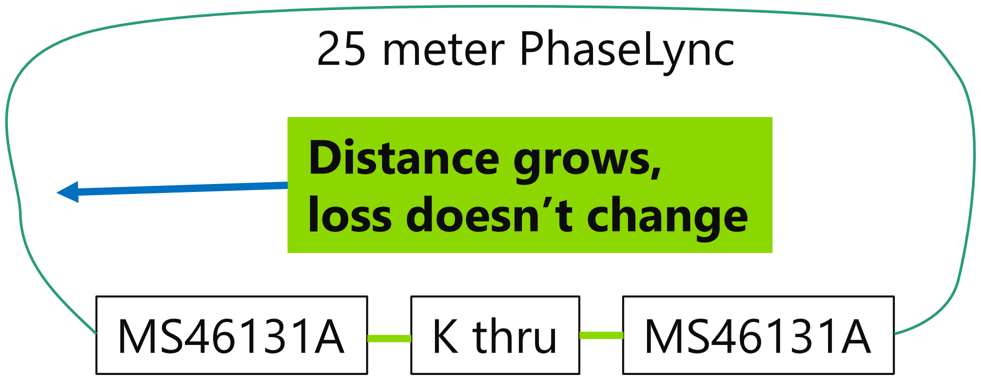
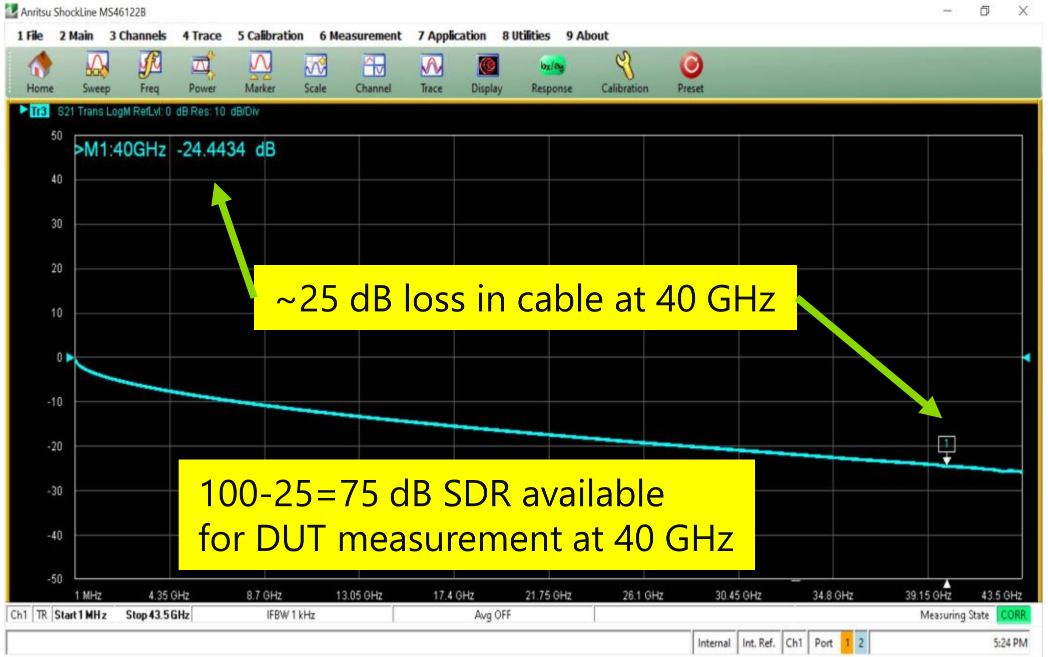
Single chassis VNA with long test port cables

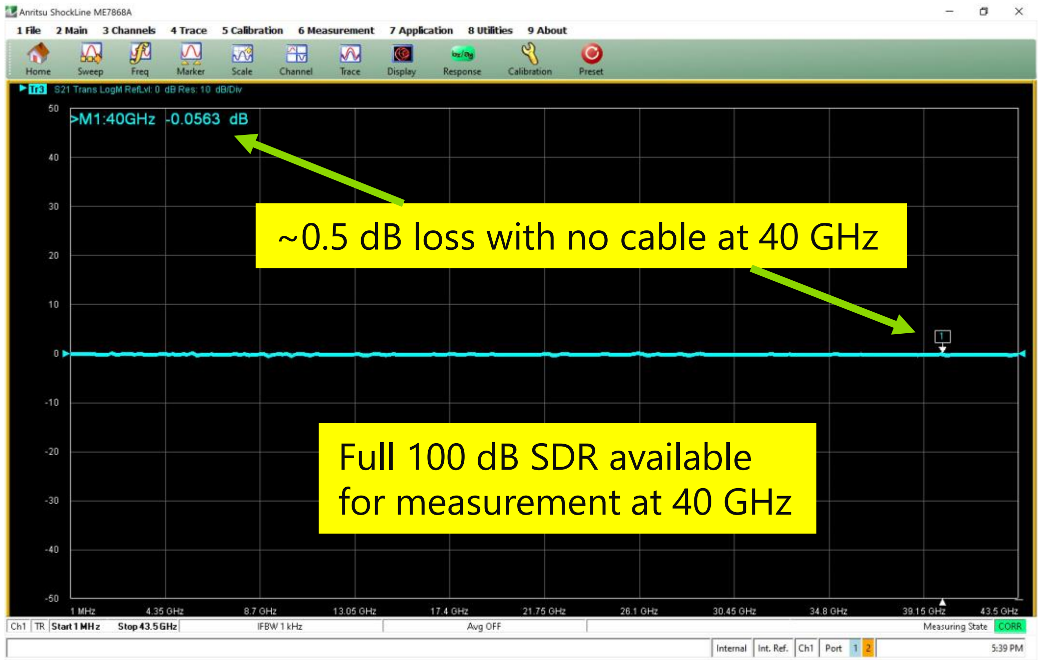


ME7868A VNA with no test port cables



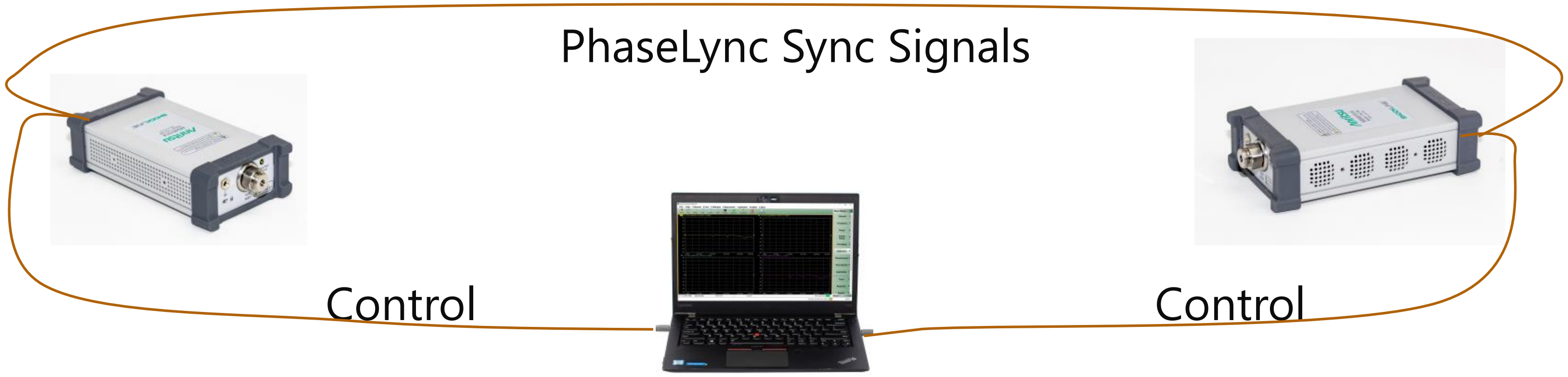


S21 Plots

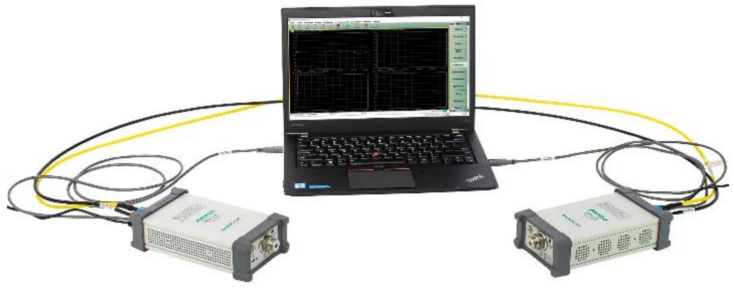


ShockLine ME7868A Distributed 2-Port VNA

- **2-port VNA uses two ShockLine MS46131A 1-port VNAs as port modules**
- **8/20/43.5 GHz models**
- **Supports fully reversing 2-port S-parameter measurements**
- **Groundbreaking PhaseLync™ technology enables vector synchronization over wide distances**
    - Provides frequency reference to both units
    - Measurement handshaking and acquisition control
    - Maintains system synchronization over long distances (tested to 100 m)
- **User provided PC controls VNA ports via USB**



ME7868A Block Diagram



ME7868A

Requirements for Synchronizing Ports on a 2-port VNA

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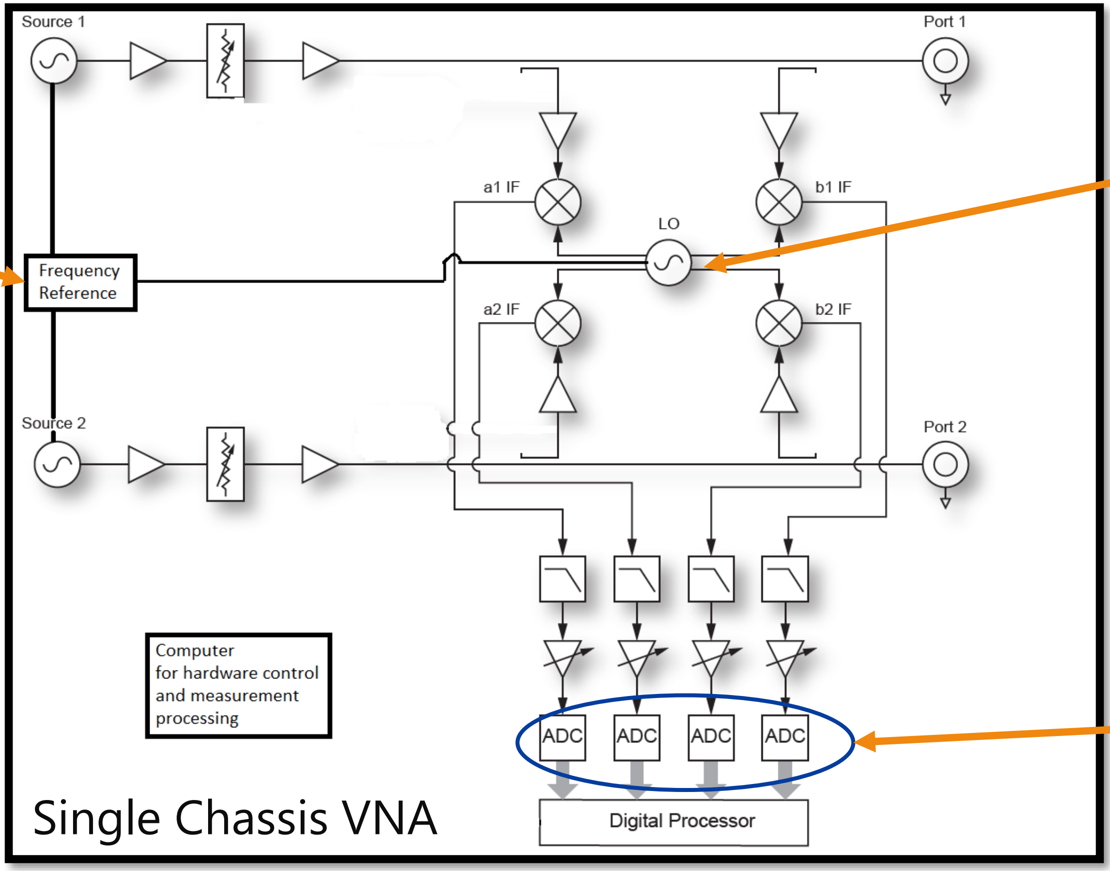
- Must be controlled from the same PC to coordinate hardware setups between ports
- A common LO must be provided for both transmit and receive modules
- A frequency reference must be shared between the modules so the ADC clocks can be synchronous
- Typical single chassis VNAs accomplish synchronization easily

Shared Frequency reference

common LO for TX, RX



Synchronous ADC clocks

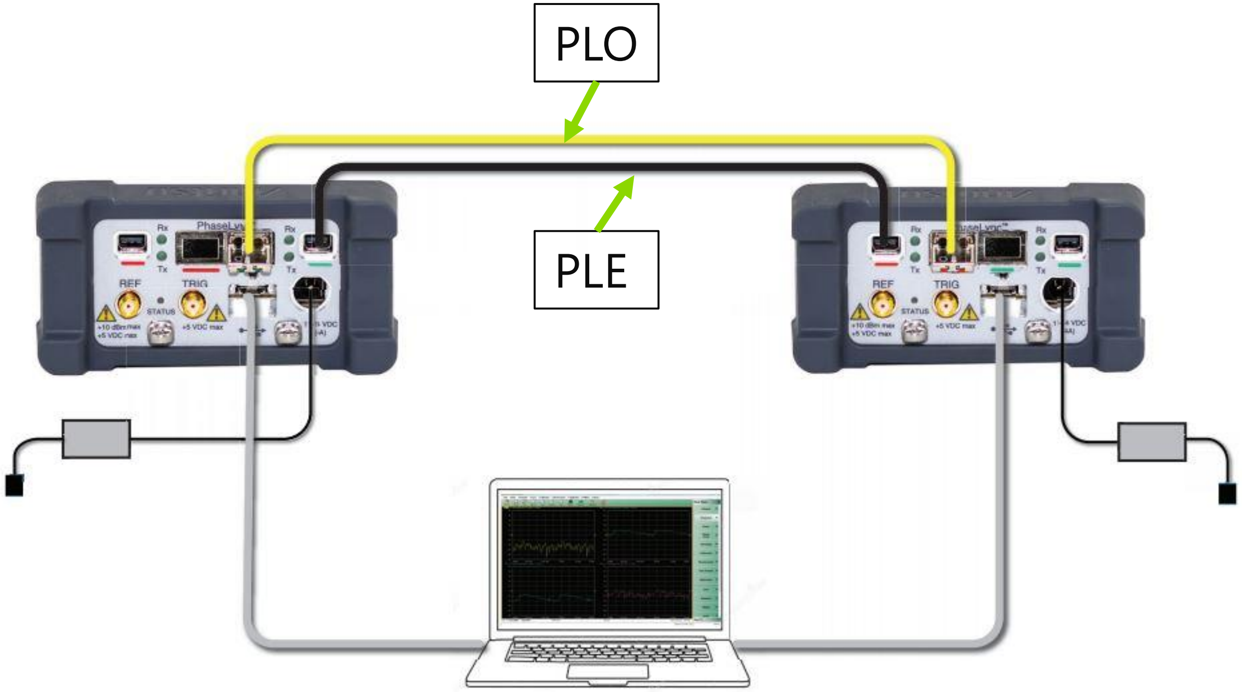
Synchronizing 1-port VNAs in the ME7868A

- PhaseLync option (option 12) includes hardware in each MS46131A 1-port VNA
- System option architected to share reference clock and LO between 1-port VNAs
- PhaseLync has two cable connections
  - PhaseLync electrical (PLE) cable
  - PhaseLync optical (PLO) cable

Bottom Panel without Phase Lync

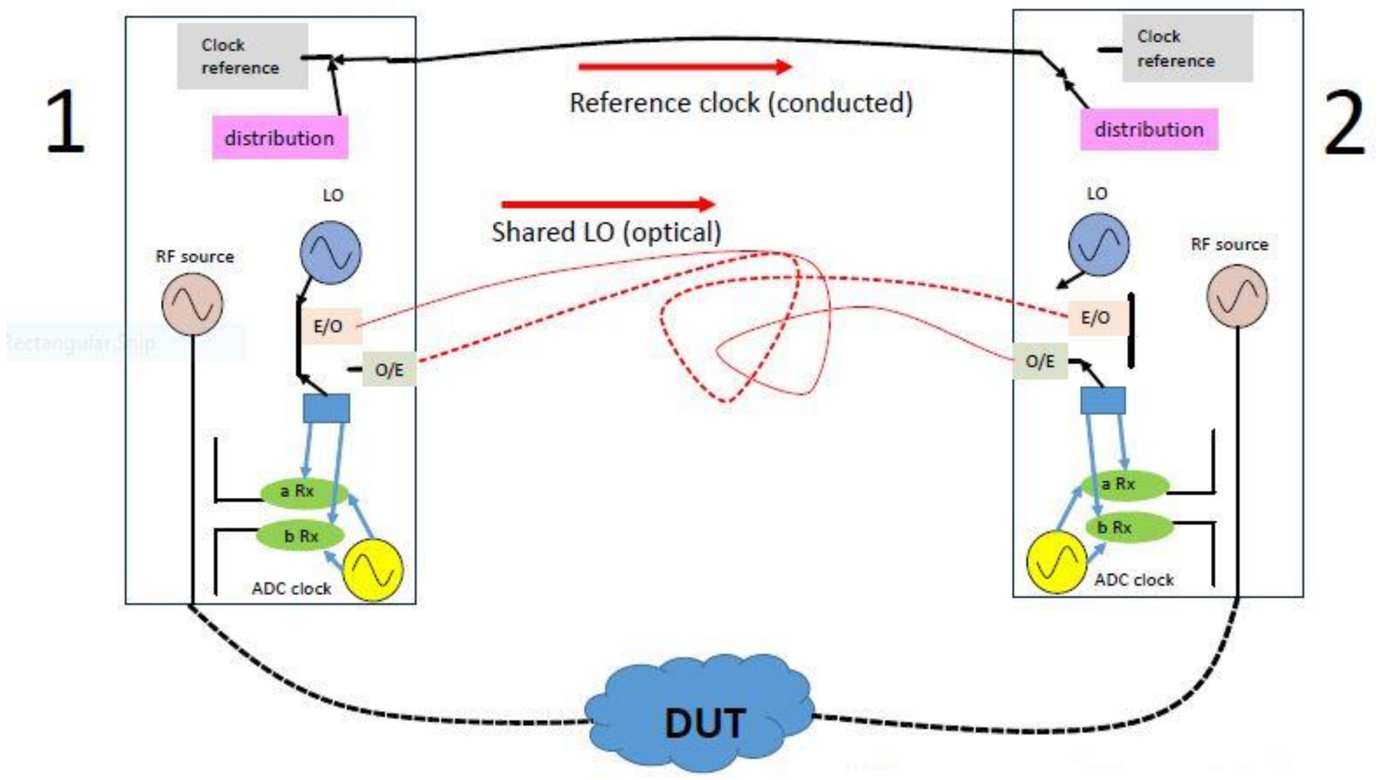
Bottom Panel with Phase Lync

PhaseLync hardware & connections

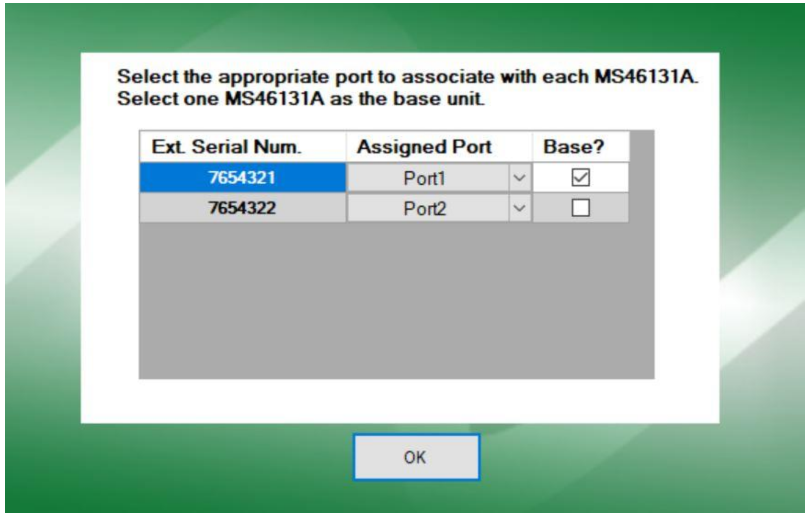


ME7868A Synchronization

- PhaseLync Optical connection carries the shared LO
- PhaseLync Electrical connection carries the shared reference clock
- Base MS46131A unit selected at startup, sources the reference clock
- Unit sourcing LO signal is determined by software setup



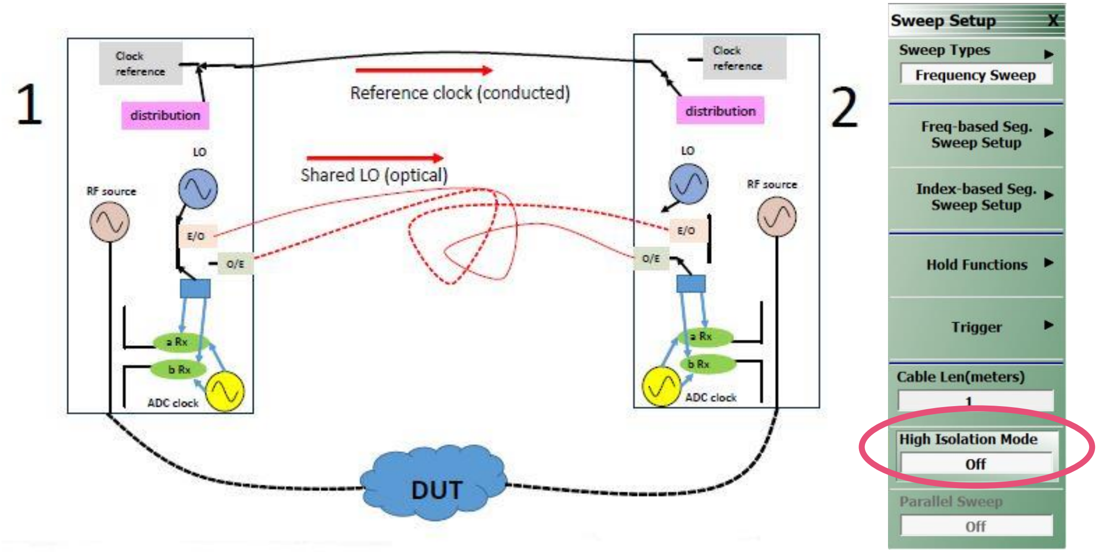
Simplified block diagram showing normal mode LO sharing with port 1 driving



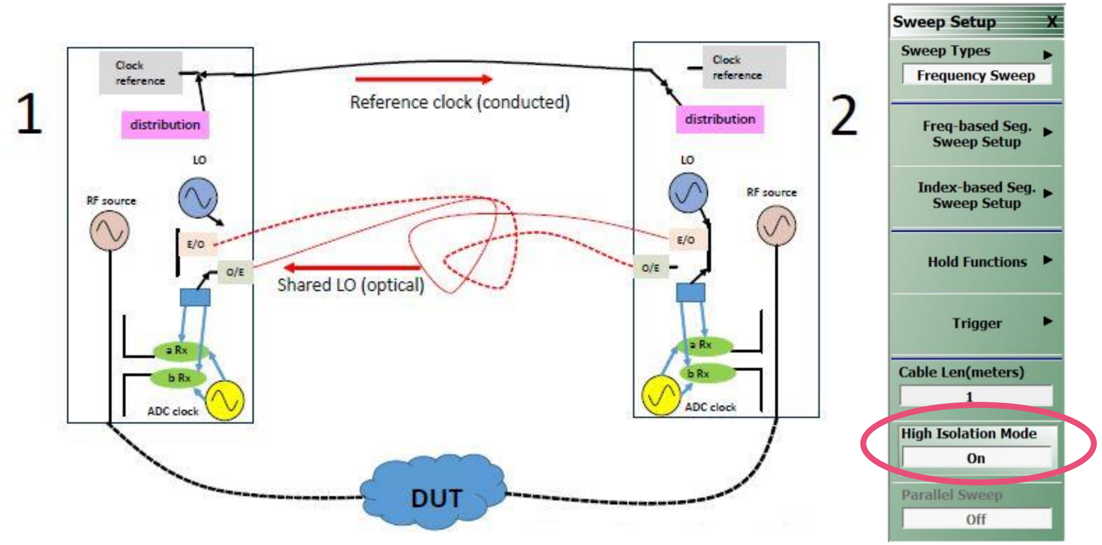
Startup menu assigns port, selects base unit

LO Sharing modes in ME7868A

- Normal LO sharing mode
  - LO sourced from driving port
  - Improves trace noise, degrades isolation
- High Isolation LO sharing mode
  - LO sourced from the port not driving
  - Improves isolation, degrades trace noise
- Static LO sharing mode
  - For SOLR, LRL/M, TRL/M calibrations and measurements
  - LO always sourced on port 2
  - High Isolation mode automatically disabled
  - S12, S21 noise floor not symmetrical



Port 1 sourcing, Normal mode LO sharing



Port 1 sourcing, Hi Isolation mode LO sharing

High Isolation mode effect on noise floor in ME7868A

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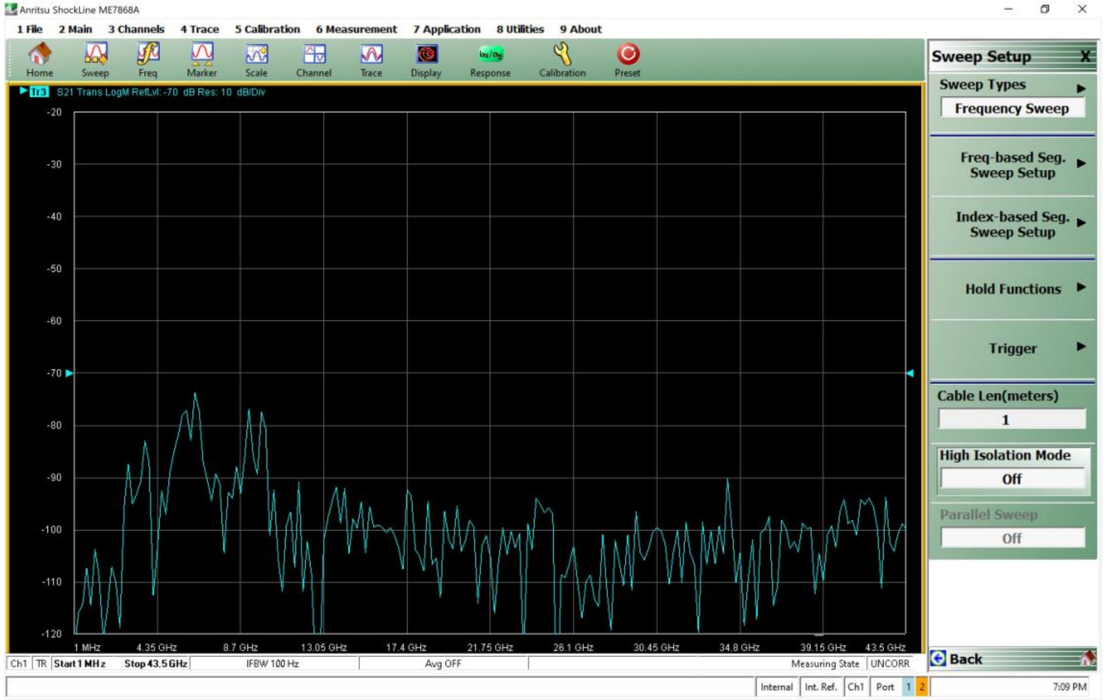
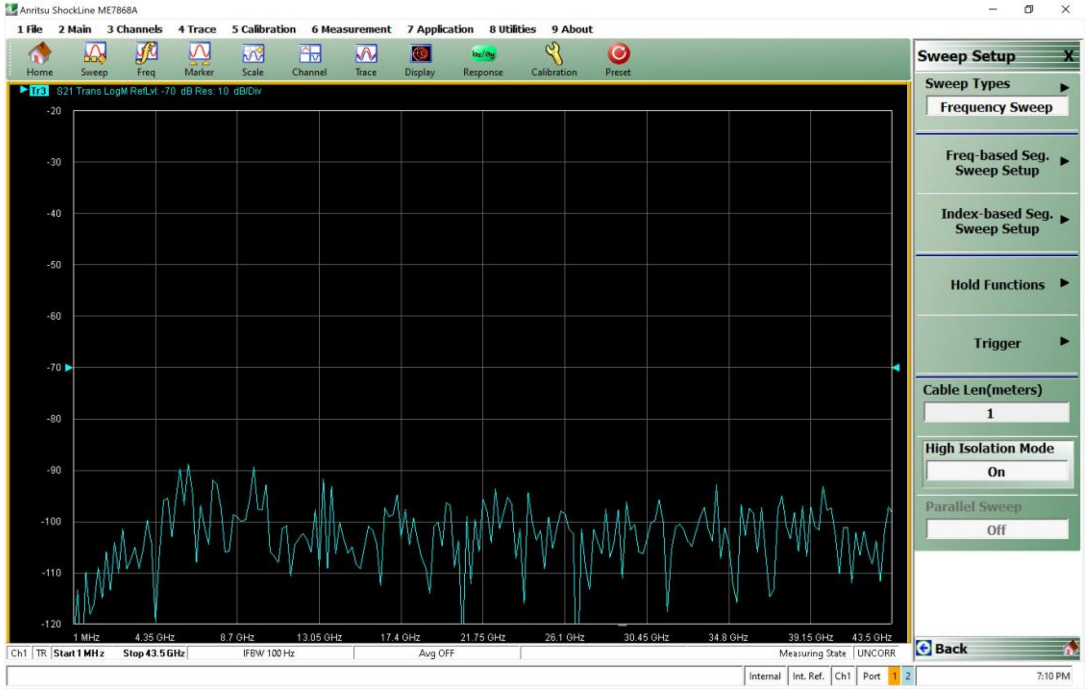


Normal mode terminated noise floor (S21)



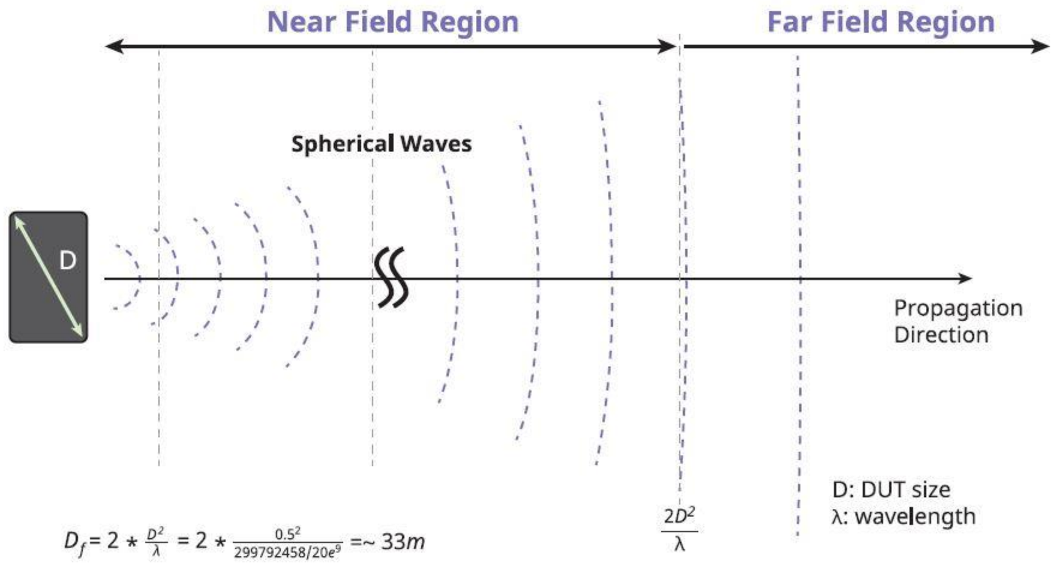
High isolation mode terminated noise floor (S21)

High Isolation mode is ***on by default*** (V2020.10.1 and later software) for better noise floor performance

OTA Antenna Chamber Applications Over Wide Spans

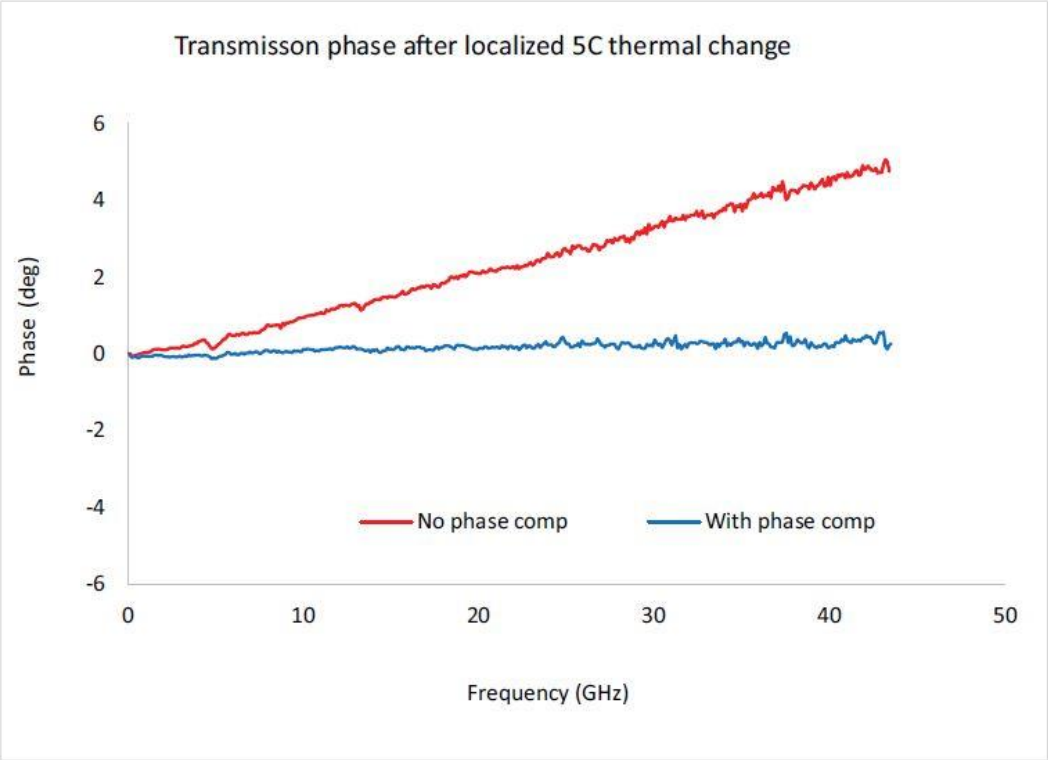
- **Larger OTA chambers are required for far field antenna testing**
  - Antenna testing generally done in the far field region
  - Fraunhofer distance (d_f) equals the start of the far field

    $d_f = 2{*}D^2 / \lambda$ (where D=largest dimension of the antenna, λ = wavelength)
  - Examples
    - 28 GHz: D=0.5 m, λ=0.010707 m, d_f =~46.7 meter
    - 39 GHz: D=0.5 m, λ=0.007687 m, d_f =~65 meter
- ***Long cables* needed to cover distance between VNA ports and antennas *add significant IL***
- **Antenna pattern testing *moves cables creating phase instability***



Phase Compensation Correction

- Consider a 5 degree C change on the PLO
- Compare a S21 measurement of a transmissive device before and after the temperature change
- Phase compensation algorithm reduced the apparent distortion
  - ~5 degrees at 43 GHz without compensation
  - <<1 degree at 43 GHz with compensation
- length, scales roughly linearly with frequency



ME7868A phase stability video showing phase compensation in action:
ShockLine ME7868A 10m Phase Stability Demo

ME7868A Advantages for OTA Chamber Applications

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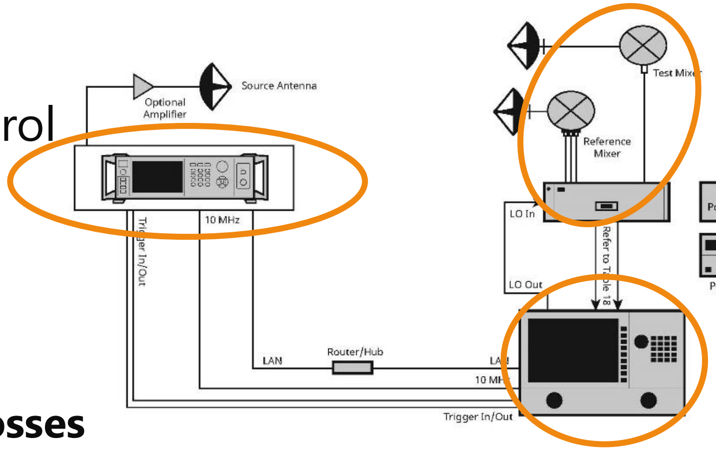
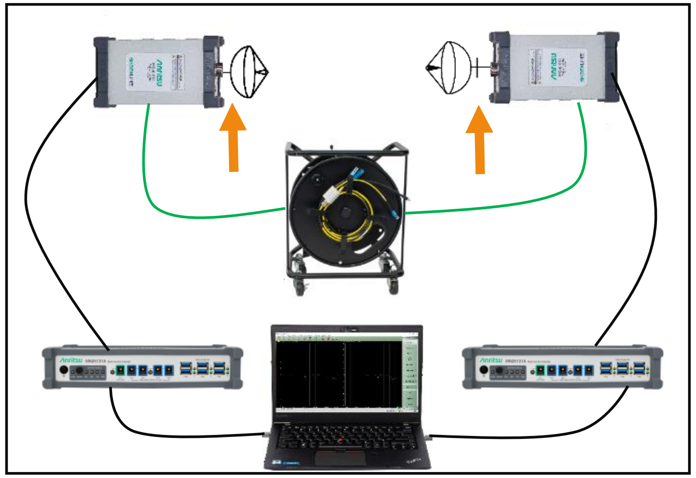
- **Typical microwave OTA antenna test setup requires:**
  - High performance VNA for dynamic range and complex hardware control
  - Signal generator for remote sourcing at test source antennas
    - Eliminates long cable from VNA source port with very high insertion loss
    - Requires complex triggering, reference, and measurement control
  - Mixers for reference and antenna under test (AUT)
    - **Down converts measurement signals to lower frequencies, lowering losses**
    - **Requires additional LO and IF distribution hardware for mixer control**
    - **High end VNA must supply LO, IF, and control signals for mixers**
    - **Mixers limit measurement bandwidth**
- **ME7868A simplifies equivalent OTA antenna test setup**
  - VNA ports connect near or directly to test antennas
    - **Full wideband measurement sweeps**
    - **No down conversion required**
    - **Eliminates cable insertion loss, full VNA SDR applies to measurement**
    - **Improves phase stability over temperature and movement**
  - Improves overall measurement uncertainty
    - Less hardware required
    - Calibration and de-embedding simplified
- **Much more cost-efficient solution**



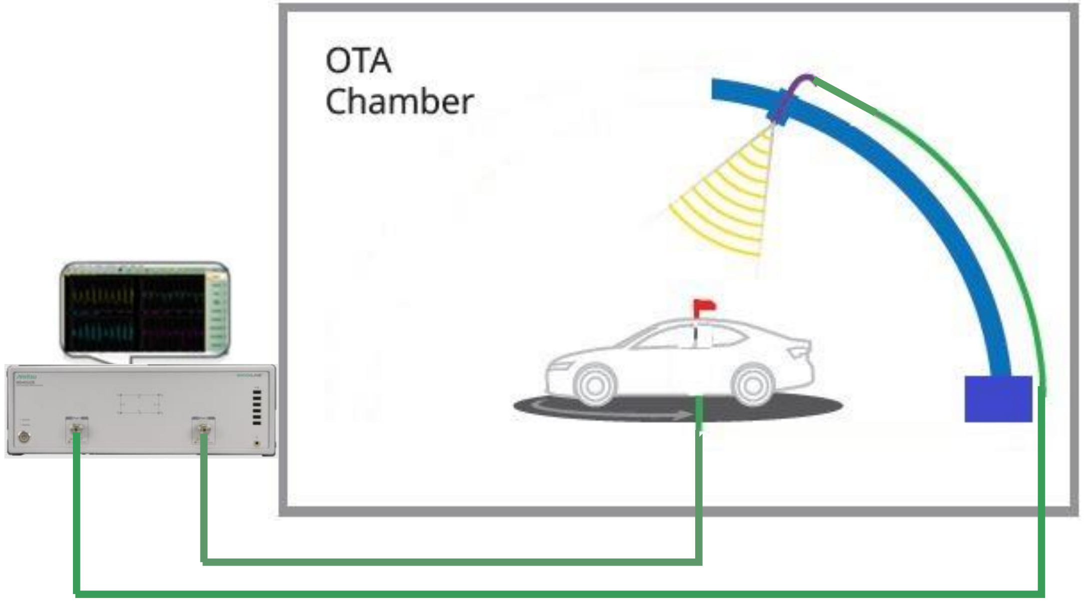
Typical large OTA Chamber Setup

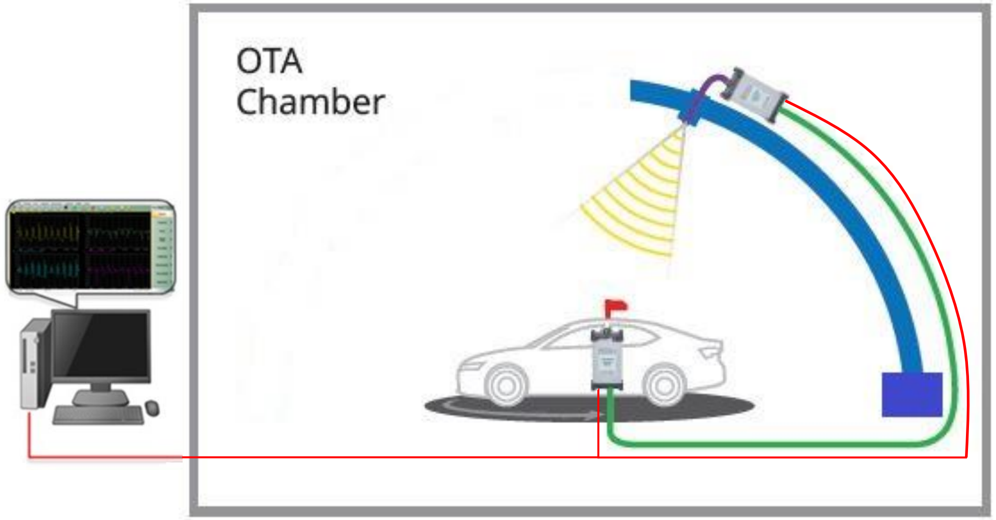


Equivalent ME7868A Chamber Setup

Example Large OTA Chamber Configuration with ME7868A

- **Automotive antenna testing**
  - Auto rotates turntable, test antenna on arched positioner enabling 3D pattern scans
  - Tests include antenna gain, directivity, beamwidth, efficiency



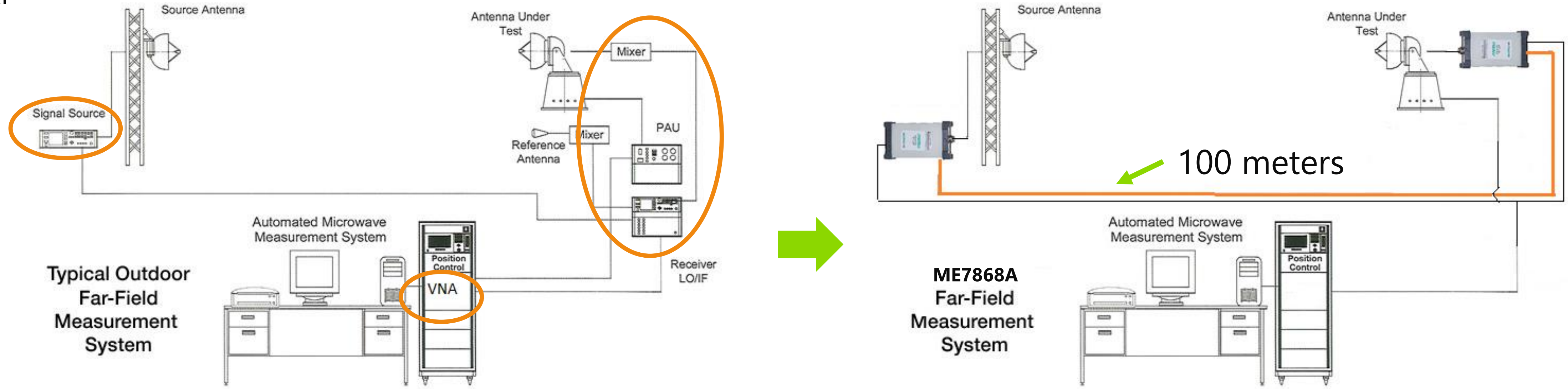


Standard VNA setup
- Long port cables required (>~25 meters)
- Reduced measurement dynamic range due to cable insertion loss
- Cables add phase measurement uncertainty

ME7868A setup
- Ports directly interface to DUT and test antennas
- Full VNA dynamic range applied to measurement
- Less measurement uncertainty with no long cabling

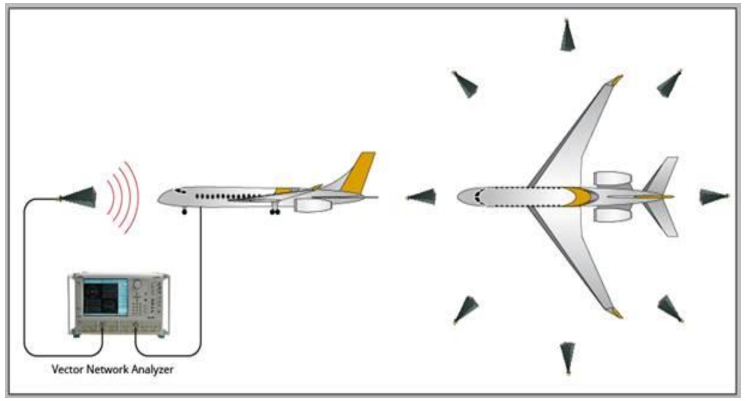
Outdoor Antenna Test Range Use Case

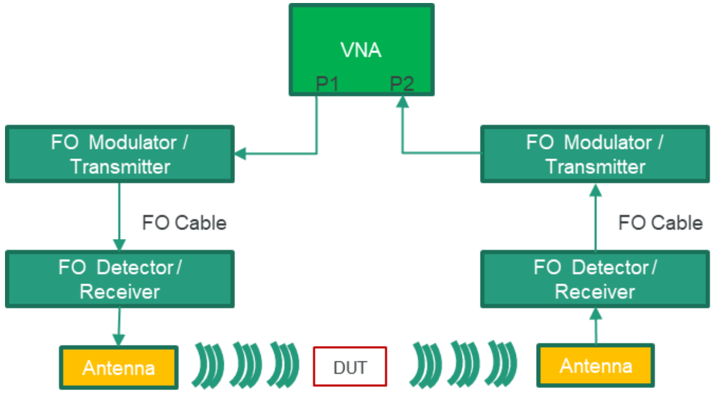
- **Outdoor antenna ranges use similar hardware to large OTA Antenna chambers**
  - High performance VNA for dynamic range and complex hardware control
  - Signal generator for remote sourcing at test source antenna
  - Mixers and support hardware for reference and antenna under test (AUT) signal paths
  - Hardware must work over longer distances (50+ meters)
- **ME7868A PhaseLync technology advantages in long distance setups**
  - ***Ports can be setup 100 meters apart, simplifying outdoor range setups***
  - ***Eliminate Long RF cable runs to either transmit or antenna under test***
  - ***Improved amplitude and phase stability***
  - No coupling into RF cables
  - Flexible Configurability



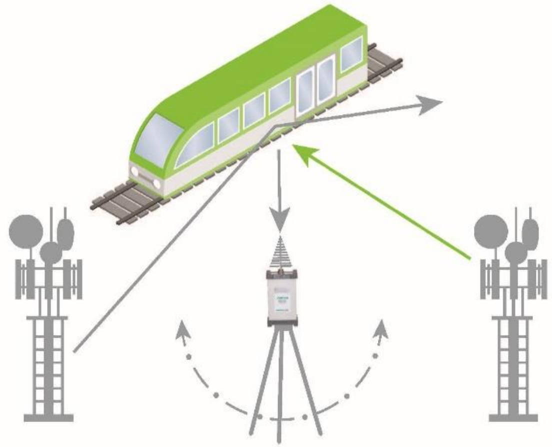
ME7868A and Large Vehicle Testing

- **Issues measuring large vehicles**
  - Multiple test setups with significant cable movement required around the vehicle
  - Wide outdoor temperature variation affecting cables
  - Very complex O/E, E/O hardware used to enable distances between VNA and test antennas
    - Required for wide band measurements
    - Less affected by temperature
- **ME7868A advantages**
  - **Easy to setup multiple measurement positions**
  - **Direct connection to antennas improves test dynamic range**
  - **Better temperature and phase stability**
  - Supports standard calibration, de-embedding
  - More cost-efficient test solution



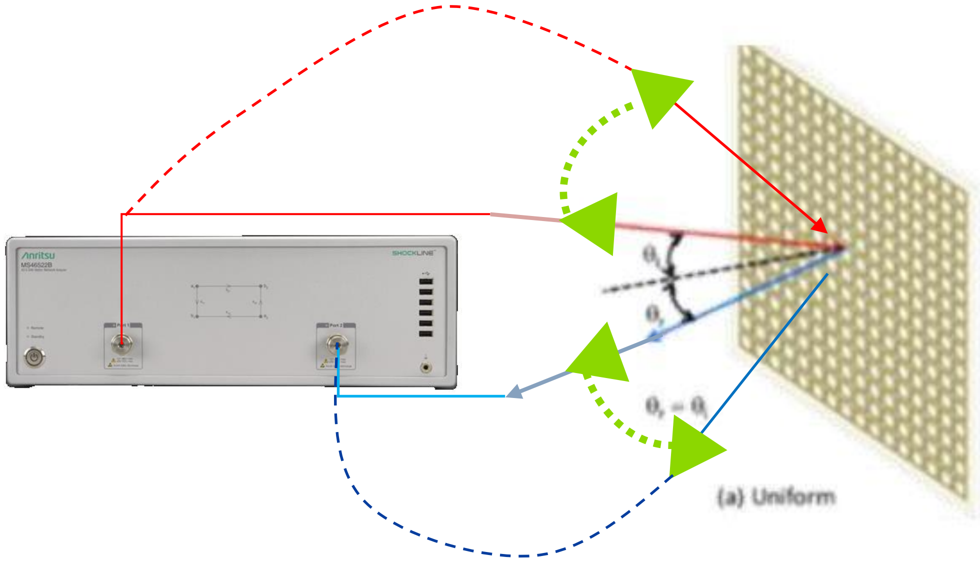


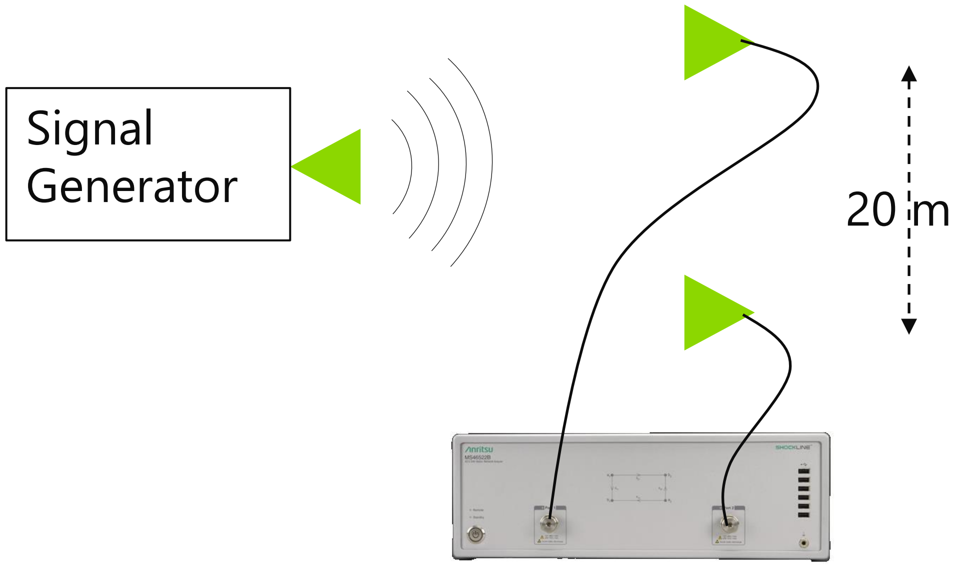
O/E, E/O Long Distance Extension Setup



VNA Applications with Positioning Requirements

- **Applications requiring measurement positioning**
  - Characterization of 5G smart surfaces
    - Antennas need to be positioned at some distance to measure reflection angle from surface
    - Measuring multiple reflection angles requires moving cables creating phase instability
  - Measuring relative phase between radar antennas
    - Measurement between antennas requires long cables adding significant insertion loss
    - Cable movement during setup introduces significant phase uncertainty
  - Cable characterization in large vehicles





Measuring Reflection Angle with ME7868A

- E2IP produces 5G smart surface signal reflector / diffuser
- Measure frequency (24 to 28 GHz) and angle of reflection from smart surface
- ME7868A port mobility enables direct beam direction testing

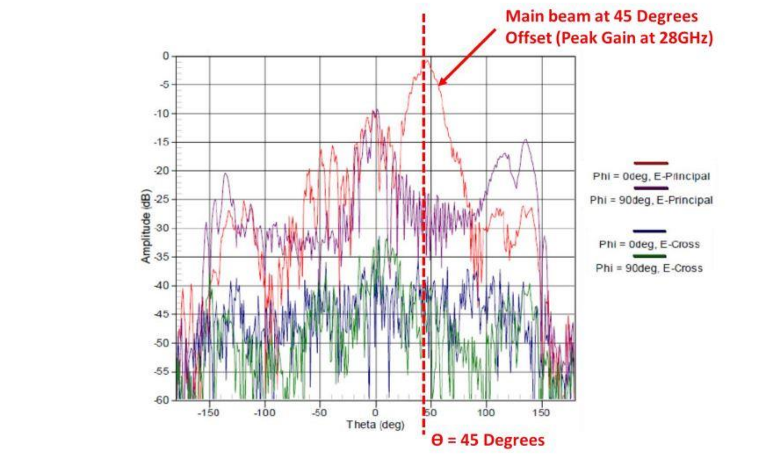
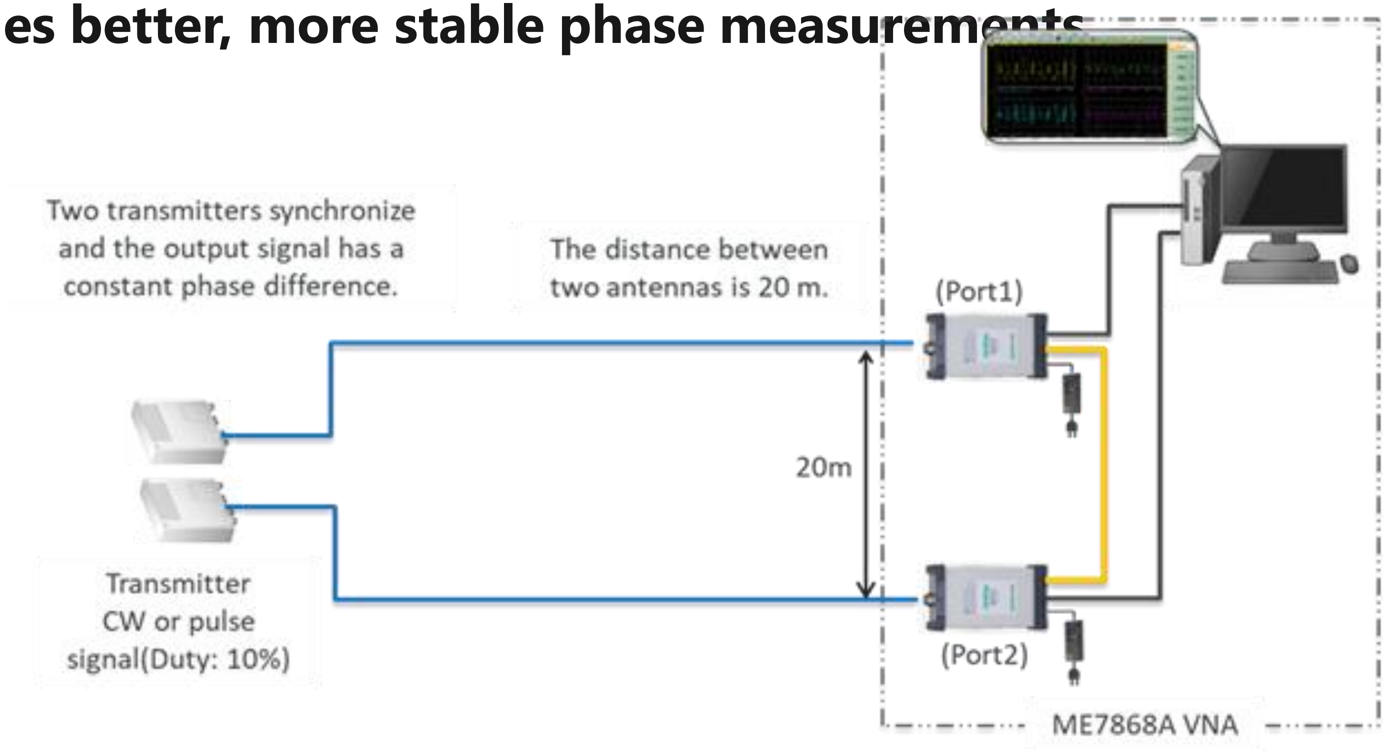


Figure 2 Peak signal strength demonstrated for a 5G Smart Surface designed to reflect a 45 o signal source

Sample Measurement

Relative Phase Measurement Application

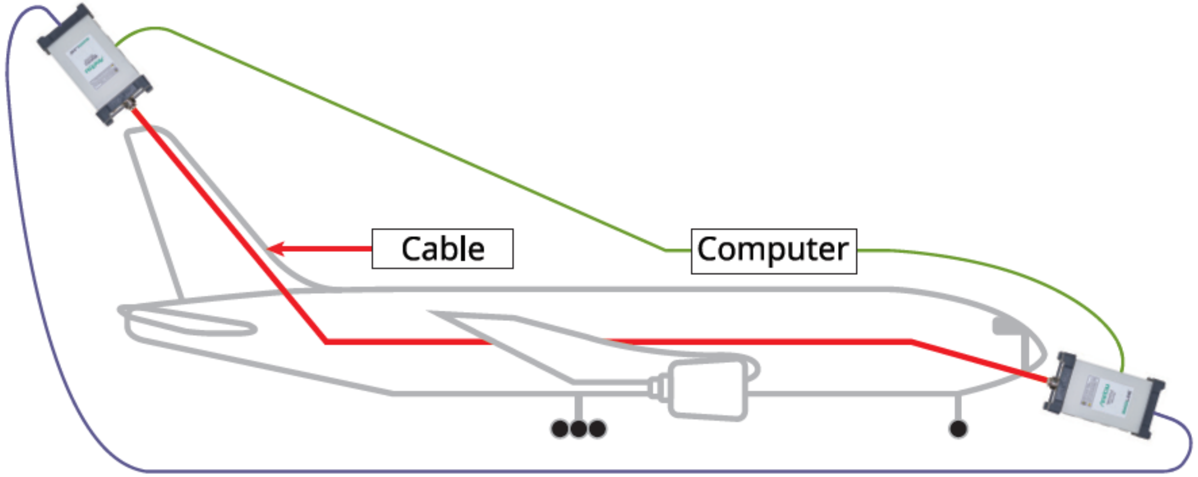
- ***Port power off feature* enables both ME7868A ports to be in *receive only mode***
- **No port sourcing enables measurement of signals broadcast from two external transmitters**
- **Relative phase measured with B2/B1 non-ratioed parameter (NRP)**
- **Architecture enables better, more stable phase measurements**



Example ME7868A Relative phase measurement on a radar system with two antennas separated by 20 meters.

Large Vehicle Cable Characterization

- **VNA measurements not necessary for all installed cables**
  - Distance to fault, scalar insertion loss tests do not require full VNA capabilities
  - Other solutions provide less expensive scalar measurements for these types of tests
- **Cable measurements needing phase require VNAs**
  - Cable S-parameter data at install saved for future use
  - Phase matched cable tests
- **ME7868A Architecture enables better, more stable phase measurements**
  - No long port cables between VNA and end of cable under test
  - Better stabili



Example ME7868A Setup for Cable Testing in Aircraft

Summary

- **ShockLine ME7868A is a groundbreaking 2-port VNA**
    - Solves cable insertion loss and phase stability issues by moving the ports to the DUT site
    - Simplifies long distance OTA applications
        - Less hardware required than existing VNA solutions
        - Better dynamic range without test port cable insertion loss
        - Lower measurement uncertainty without long cables in measurement path
        - Much lower cost
    - Supports VNA applications with measurement positioning requirements
        - Measuring reflection angle from smart surfaces
        - Relative phase between distant radar antennas

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Advancing beyond