PRACTICAL APPLICATION OF TIME DOMAIN IN THE DESIGN OF MICROWAVE COMPONENTS TO 50 GHz

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HEWLETT PACKARD

ABSTRACT

This paper describes a HP8510B Network Analyzer measurement system that has been configured with 2.4mm coaxial connectors to take advantage of higher resolution time domain measurements achievable by sweeping .045 to 40, or 50 GHz. High resolution provides improved ability to accurately identify closely spaced discontinuities, which is critical to the successful design of next-generation broadband components.

A comparison of measurement results is shown using the 2.4mm and K connector to 40 GHz, and with the 2.4mm connector to 50 GHz.

AUTHOR

Julius Botka was born and educated in Hungary. He joined HP in 1966 and has worked on the development of microwave components and standards for the HP 8407, HP 8755, HP 8505, and HP 8510A/B Network Analyzers. Recent achievements include the design of the .045-26.5 GHz Directional Bridge for the HP 8513A and HP 8515A test sets, the concept of the 2.4mm connector family, and the HP PSC Precision Slotless Connectors in type N, 3.5 and 2.4mm. Julius is currently R&D Project Manager for Microwave Components and Standards at HP's Network Measurements Division, Santa Rosa, California.

title

PRACTICAL APPLICATION OF TIME DOMAIN IN DESIGN OF MICROWAVE COMPONENTS TO 50 GHz

7101

Broadening continuous frequency capability in network measurements is making high resolution time domain a reality. This paper will give an overview of the capability and how it may be used in the design of the next generation of microwave components.

AGENDA

- The 2.4 mm Connector
- A 40/50 GHz 8510B
- The use of high resolution time doman in design
- Summary

7102

The paper is divided into four sections. The first section talks about the 2.4 mm connector, used on most 40/50 GHz HP instrumentation. The second section shows HP's 40/50 GHz Network Analyzer. The third section shows measurement results using the analyzer. The fourth section summarizes the advantages of the new HP 40/50 GHz Network Analyzers.

Picture of Conn (photo)
nuts done as 3.5 mm 5/16
torque 8"/#
this is slotless contact

SECTION 1

THE 2.4 mm CONNECTOR

- Total solution to 50 GHz
- Optimized without SMA matability constraints
- Outperforms the K, works to 50 GHz
- Nearly Indestructable

7103

The three interconnectable members of the 2.4 mm family provide a cost-effective solution to all three requirements of use. Production grade for component and internal instrument use, instrument grade for test port and other instrumentation requirements and metrology grade PSC-2.4 for use on traceable calibration and verification standards and female connectors used as test ports on network analyzers.

Advantages of the 2.4 mm connector
(slide)

THE PRODUCTION GRADE 2.4 mm CONNECTOR

- Good performance
- Low cost, similar to SMA
- Male solders onto .086 inch diameter semi-rigid cable similar to SMA solder connector. Cost effective some instruments have up to 40 connector pairs
- Life: up to hundreds of connections internal connections only

7104

This is the version of 2.4 mm connector to use for components for use in systems or for cabling inside instruments.

THE INSTRUMENT GRADE 2.4 mm CONNECTOR

front panel Connector

- Better performance than production grade
- Cost similar to 3.5 mm target front panel connector in same QTY
- Excellent repeatability gold plated contact pins
- Life: more than 5,000 connections tested slotless connectors to 30-40K

7105

This connector grade is recommended for high performance components and as user accessible connectors on instruments and systems.

THE METROLOGY GRADE PSC-2.4 CONNECTOR

traceable thru mech measurements

- Best performance
- Highest cost, only required for standards and female test ports
- Slotless female contact
- Excellent repeatability (10 dB better than instrument grade)
- Life: more than 5,000 connections

7106

This grade was developed for standards and female test port use where the female contact's impedance has to be calculable (cylindrical and slotless) and its impedance needs to be independent of the male pin diameter it is mated to. Only the PSC connector has traceable electrical performance through mechanical dimensions to NBS.

AVAILABILITY

- Production grade: Omni Spectra OS-50
- Instrument grade: Amphenol Corporation
- Metrology grade PSC-2.4, on products: Hewlett-Packard Company

7107

It is anticipated that shortly Amp Corporation and Maury Microwave Corporation will also provide connectors and standards, respectively, in 2.4 mm. It is also expected that both Omni-Spectra and Amphenol will produce both production and instrument grade 2.4's. Hewlett-Packard is producing the metrology grade PSC-2.4 connector.

AVAILABLE KITS

Two Introductory 2.4 mm Connector Kits Are Available

- A general kit for 2.4 mm interconnection and cabling
- A kit for building a test fixture or microcircuit housing with hermetic 2.4 mm launchers

7108

These kits are available off the shelf, from Omni-Spectra MACOM at reasonable cost. Both kits are comprised of production grade 2.4 mm connectors and the necessary tools to install them.

PROBLEMS WITH SLOTTED CONNECTORS SUCH AS K

- Female pin diameter depends on male pin diameter
- Z_o over slots is not 50 ohms due to reasons metal in slots. Also current flowing around slots is out of phase w/ rest of length of inner connection. Z is not calculable & very difficult to compensate for

7109

These are the two reasons that the PSC connectors in N, 3.5, and 2.4 mm were developed at Hewlett-Packard. The PSC connectors have cylindrical 50 ohm Zo contacts.

FEMALE SLOTLESS CONTACT STABILITY ON STANDARDS

Provides following for female DUT's:

- Measurement related to true 50 ohms
- Traceability
- Cascadable S-parameters

7110

Slotless female standards provide the only means of measuring an unknown with a female connector in relation to true 50 ohm.

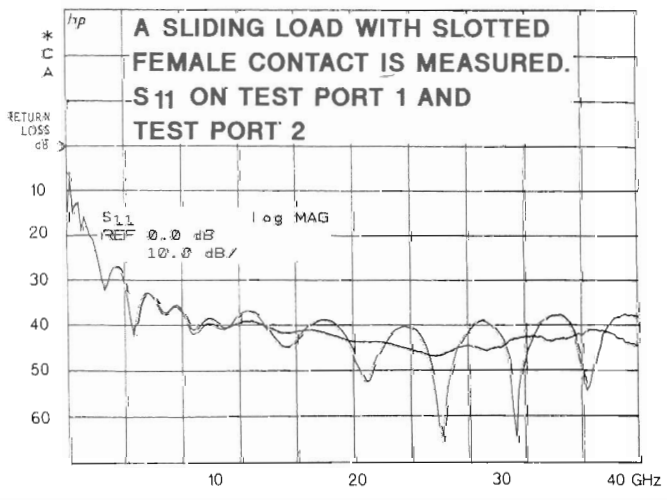
FEMALE SLOTLESS CONTACT STABILITY ON TEST PORTS

Provides following for male DUT's:

- Measurement related to true 50 ohms
- Traceability
- Cascadable S-parameters

7111

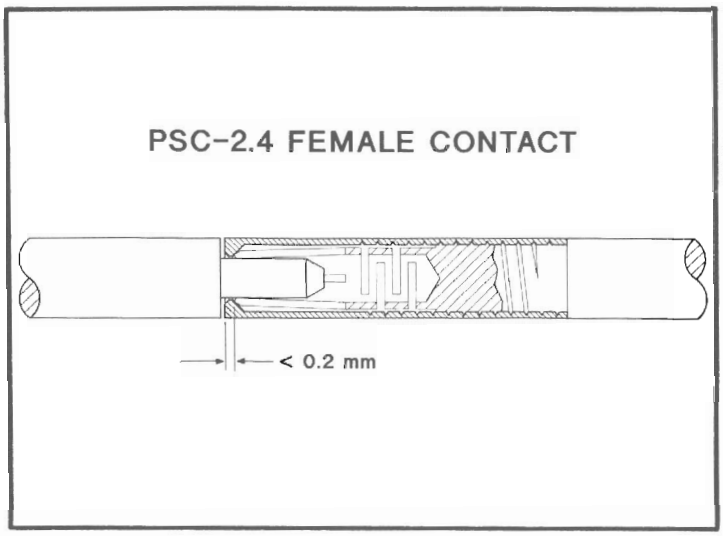
If the test port's female connector changes impedance between calibration and the measurement of the devices under test, the same unaccountable error is encountered as resulted from the change of the slotted female standards. Only the PSC-2.4 female connector provides the test port with the male pin diameter independence required.



7112

A sliding termination with slotted female connector is measured on two test ports, both test ports were calibrated by the same calibration standards. The only difference was the male pin diameter. They differed by 0.01 mm (0.0004"), well within the permitted connector tolerances. Great care was taken to eliminate all other variables such as the test port pin depth differences.

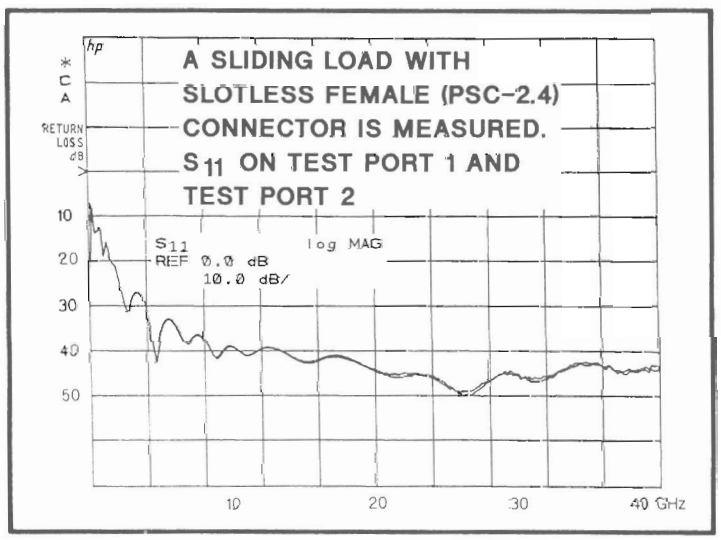
this is slotless load
Calibration done w/ slotless cal std



7113

This slide shows the construction of the PSC-2.4 female contact.

Contact is made within the first 0.2 mm (.008") from the front of the female pin to the male pin. Parasitics are a fraction of what they are on a slotted female contact.



7114

A sliding termination with a slotless female connector (PSC-2.4) is measured on two test ports. Both test ports were calibrated by the same standards. Only the male test port pin diameters were different by 0.01 mm (0.0004"), permitted by the tolerances. The small difference seen is due to the connector repeatability of ≥55 dB at 40 GHz.

Same experiment w/ slotless sliding load

2 Slots

THE PSC-2.4 CONNECTOR ELIMINATES TWO ERRORS OF A SLOTTED FEMALE CONTACT

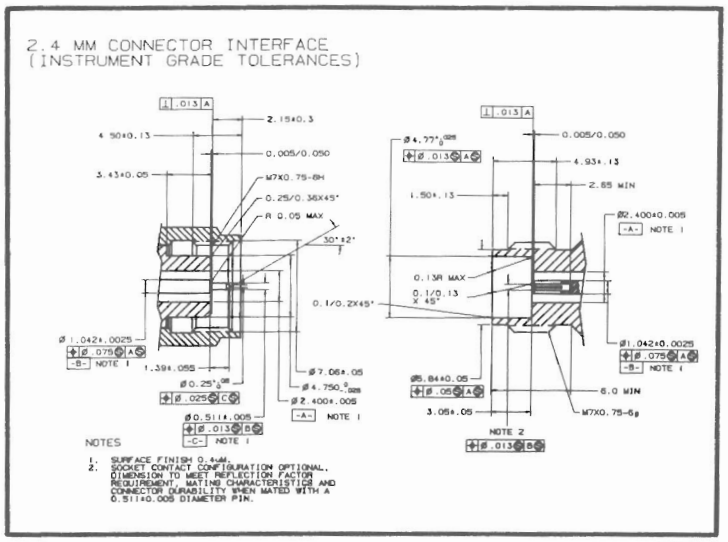
1. A -36 dB R.L. error @ 40 GHz due to $Z_0 \neq 50$ ohms at slots
2. A -40 dB R.L. error @ 40 GHz due to Z_0 dependency of the slotted fingers on the male coupling pin's diameter

7115

The presence of slots on female standards and female test ports results in the single largest error in a network analyzer utilizing a slotted connector such as the K.

allows 20 dB more range in return loss. 40-50 dB measurements w/ same accuracy as 20 dB measurement before.

total error vector about 34 dB

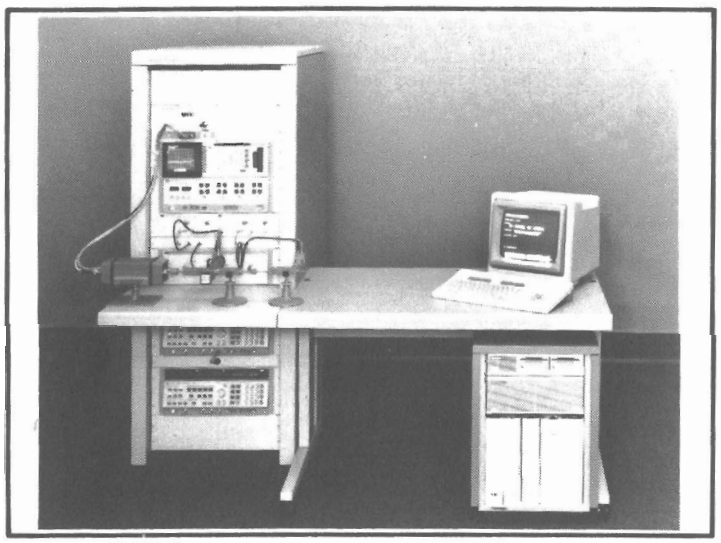


7116

Early in the 2.4 mm connector program, HP, Amphenol, and Omni-Spectra agreed to make the interface public. This makes it easy for users and other manufacturers to produce a compatible product.

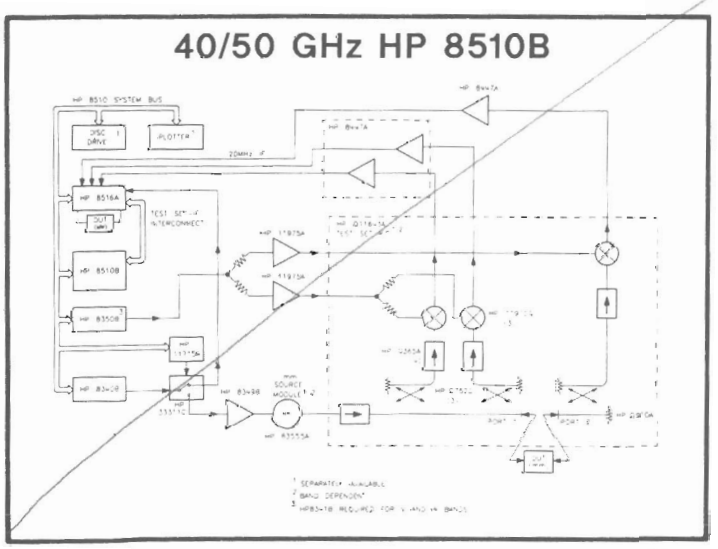
avail on request
see FE

SECTION 2



7117

The 8510B/8516A, 40 GHz Network Analyzer System, makes measurements from .045 to 40 GHz a snap. Combining it with an 8510B Q-Band Waveguide System allows the ultimate in time domain resolution not obtainable in any other manner.



7118

One 8510B system with a 40 GHz 2.4 mm 8516A test set and the equipment shown on this system diagram for Q-Band waveguide measurements provides measurement capability from .045-50 GHz.

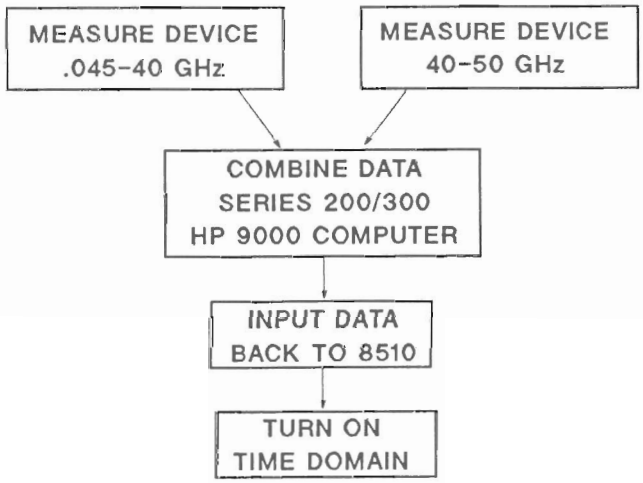
TO MEASURE UP TO 50 GHz

- Calibrate both 2.4 mm test ports, one on the 8516A and the other on the Q-band to 2.4 mm waveguide adapter with the same calibration standards (only 2.4 mm 85056A calibration standards work to 50 GHz)
- Measure on both test ports
- Combine and display data

7119

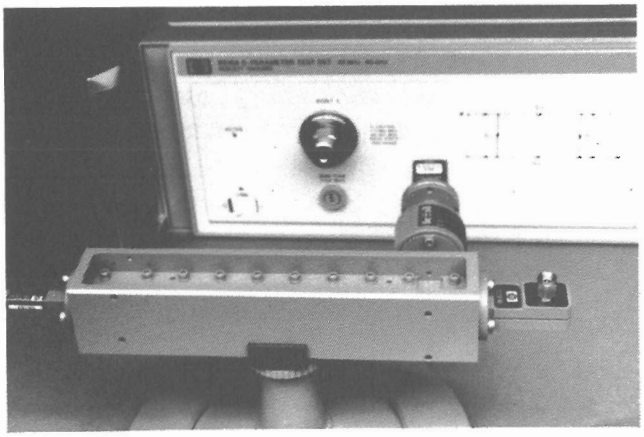
This slide shows steps required to make measurements to 50 GHz.

Cal kit picture



7120

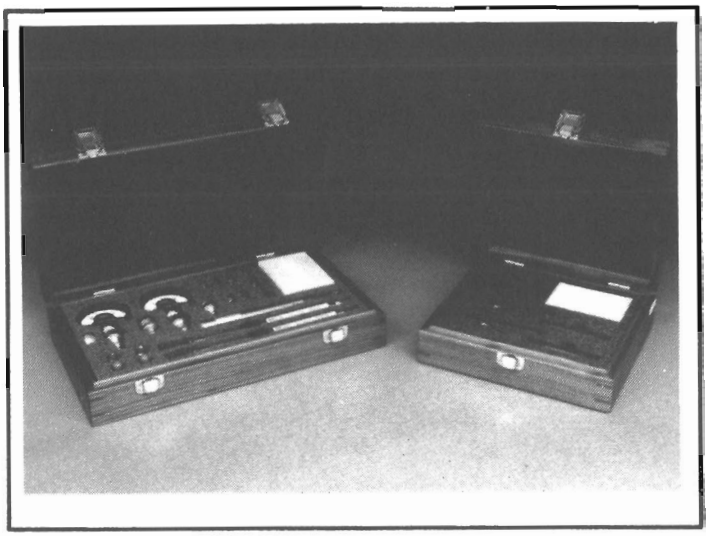
The software is not supported by HP, but since the source code is provided, no problem for the customer is anticipated. The software has been used at HP in product development since 1985.



7121

The use of HP's new 2.4 mm connector provides very good performance all the way up to 50 GHz. The PSC (Precision Slotless Connector) metrology grade provides NBS traceable performance for the whole 2.4 mm connector family.

Port cal kit picture here



7122

Both the calibration and the verification standards as well as female test port connectors utilize the PSC 2.4 mm connector. The same calibration standards are used to calibrate the HP8516A and the 2.4 mm test port of the Q-Band test set, to provide continuous measurement coverage to 50 GHz.

SECTION 3

CONTINUOUS MEASUREMENT

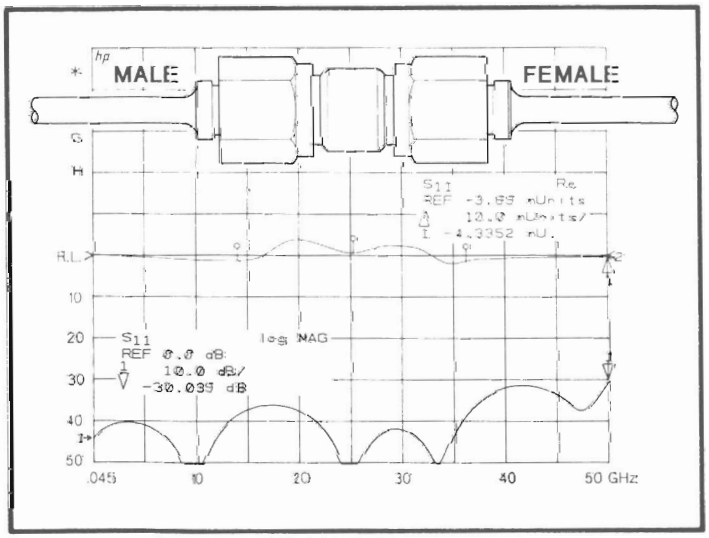
COVERAGE TO 40 OR 50 GHz

PROVIDES HIGH RESOLUTION

TIME DOMAIN REPRESENTATION

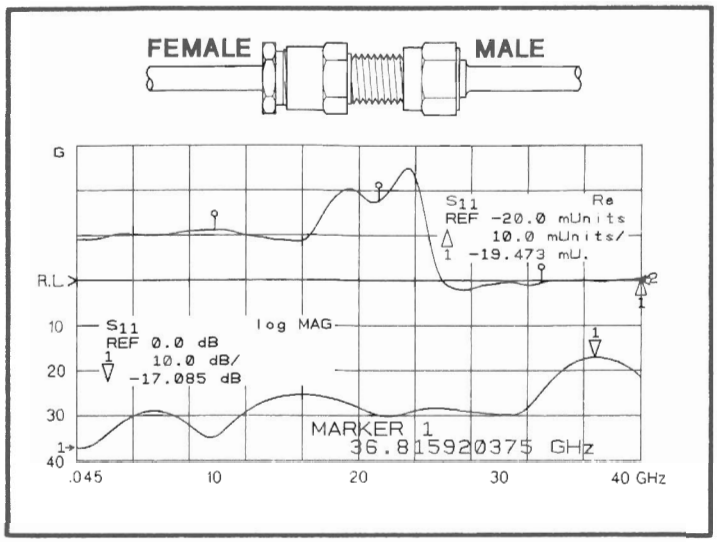
7123

In the development of the new generation of high frequency (40 GHz and above) components, the availability of an HP8510B 50 GHz time domain system is of great help. High resolution requires taking data in the frequency domain over the highest possible bandwidth.



7124

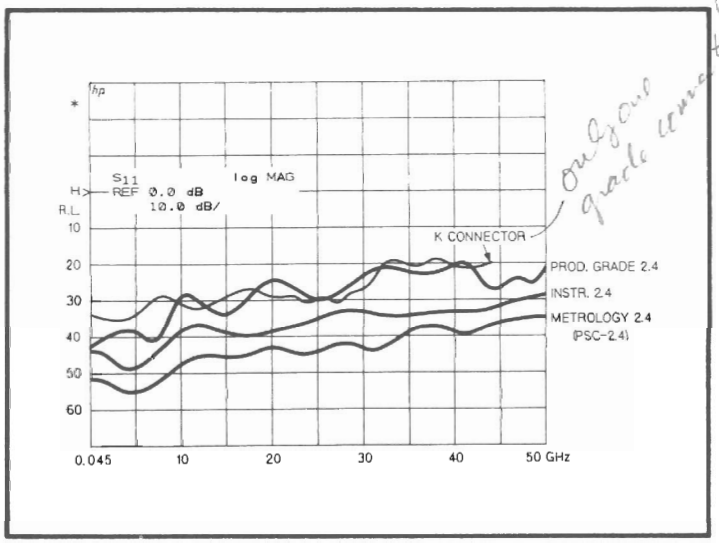
This slide shows a pair of the cable (.086" diameter) installed 2.4 mm production grade connectors, and the performance. The upper trace is time domain the lower is return loss, both to 50 GHz.



7125

This slide shows a pair of K factory installed cable (.100" diameter) connectors and the performance. The upper trace is time domain the lower is return loss.

Comparible grade as last slide



7126

This slide shows performance comparison of the three types of 2.4 mm connector pairs to a pair of K connectors.

Only compare the K connector to 44 GHz, it was not designed to work to 50 GHz.

MISMATCHES CAN NOW BE

PINPOINTED WITHIN 1.0 mm

(40 THOUSANDS OF AN INCH),

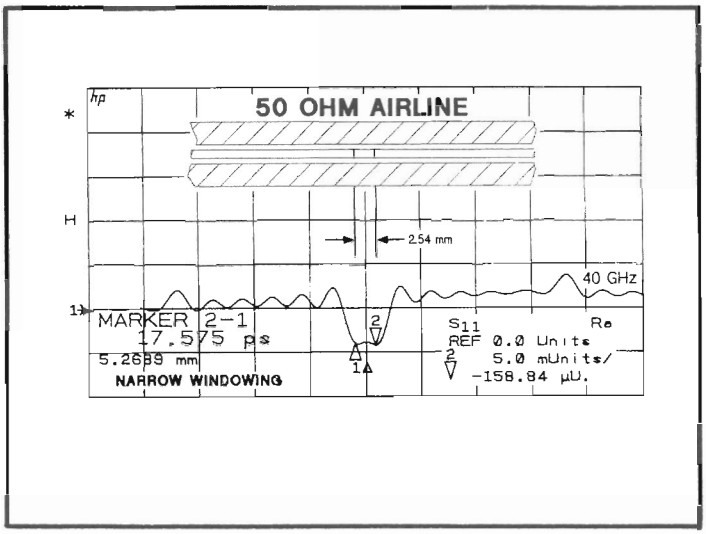
APPROXIMATELY

1/8 WAVELENGTH AT 40 GHz

7127

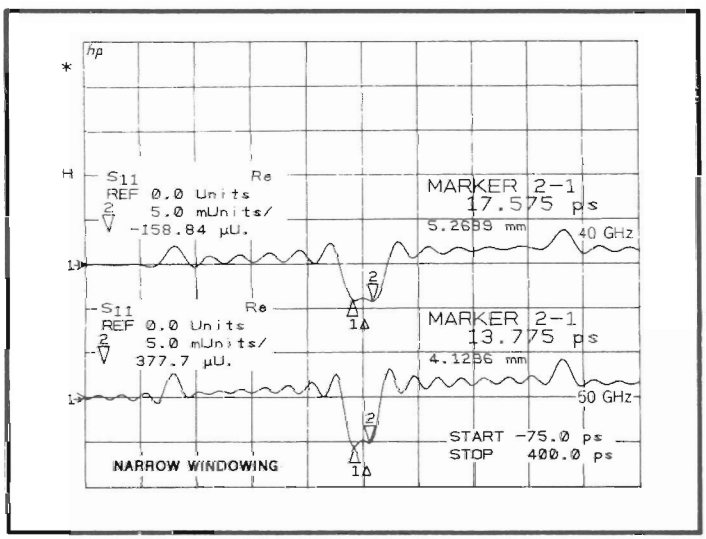
Many of the new generation microwave components are required to work over multi-octave bandwidths. Locating discontinuities accurately is very important so they can be compensated for within 1/8 wavelength at their highest operating frequency.

Resolution



7128

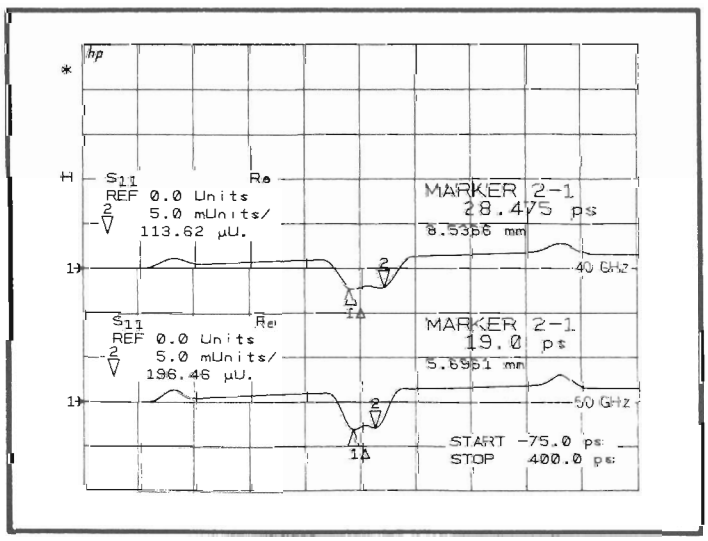
Two 0.1 mm (0.004") diameter wire rings were placed on the center conductor of a 50 ohm 2.4 mm airline. They can be easily seen as separate capacitive discontinuities when the separation is 2.54 mm, less than 3/8 wavelength at 40 GHz. An additional 25% resolution can be achieved by measuring to, and displaying time domain to 50 GHz.



7129

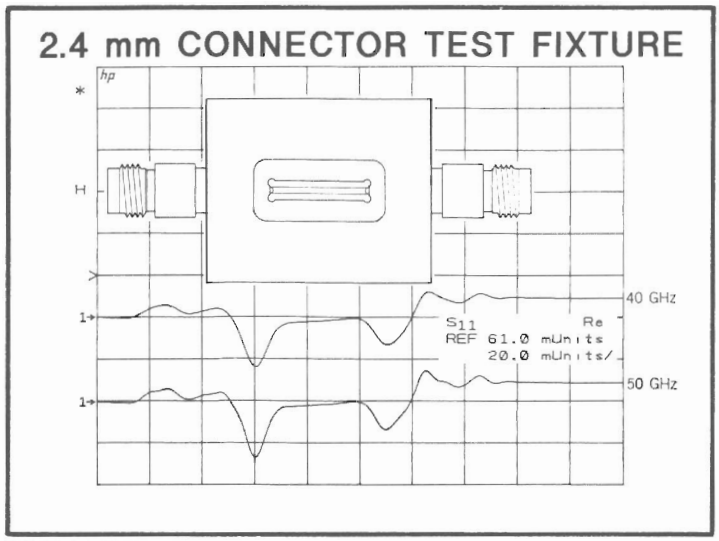
This slide shows the same two discontinuities set 2.54 mm (upper trace) and 2.0 mm apart (lower trace). This is the minimum distance they can be resolved separately. The upper trace was taken to 40 GHz the lower to 50 GHz. The 2.0 mm spacing would show up as only a single capacitive discontinuity when measured to 40 GHz.

Can now resolve 2 mm
Ripple is due to narrow window



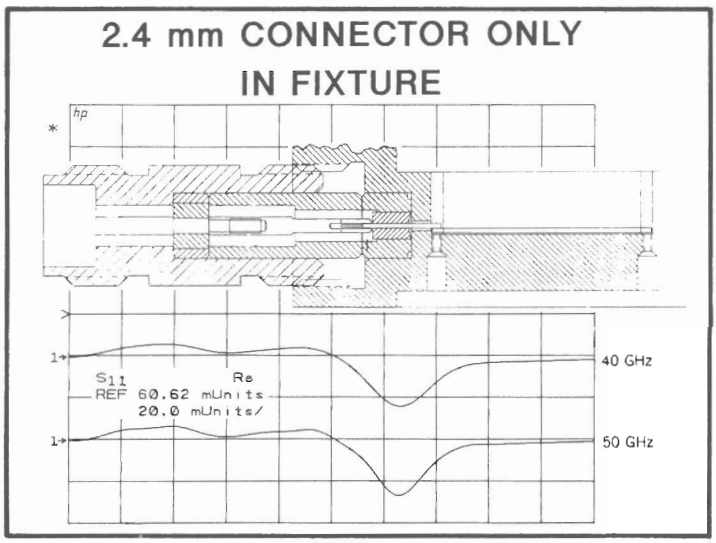
7130

If the ripple seen in the previous slide obscures wanted detail, then the normal windowing function has to be used. In that case, the closest resolvable distance is 3.75 mm when measuring to 40 GHz (upper trace) or 3 mm when measuring to 50 GHz. Sometimes displaying the time domain with the normal windowing function first is useful in identifying major discontinuities before switching to minimum window width.



7131

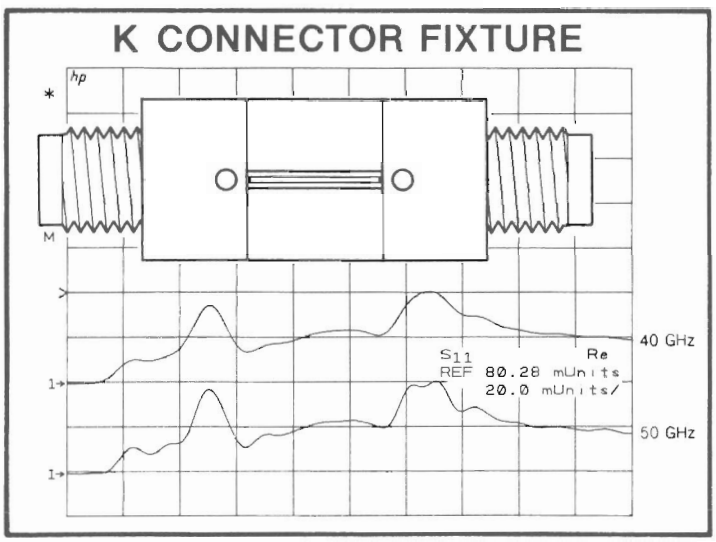
This slide shows a fixture with 2.4 mm connectors. This fixture was used in development of the connector-launch design to microstrip. The upper trace shows time domain to 40 GHz, the lower trace is obtained with the 50 GHz 8510B system. Notice additional detail visible on the 50 GHz plot. (circled)



7132

A cross section of the connector-launch to microstrip is shown. The drawing and the time domain traces below are lined up, so discontinuities show up below the corresponding components. Upper trace is 40 GHz, lower trace is 50 GHz. Both are normal windowing.

picture lined up w/ trace
picture scaled in X direction
according to ∈.

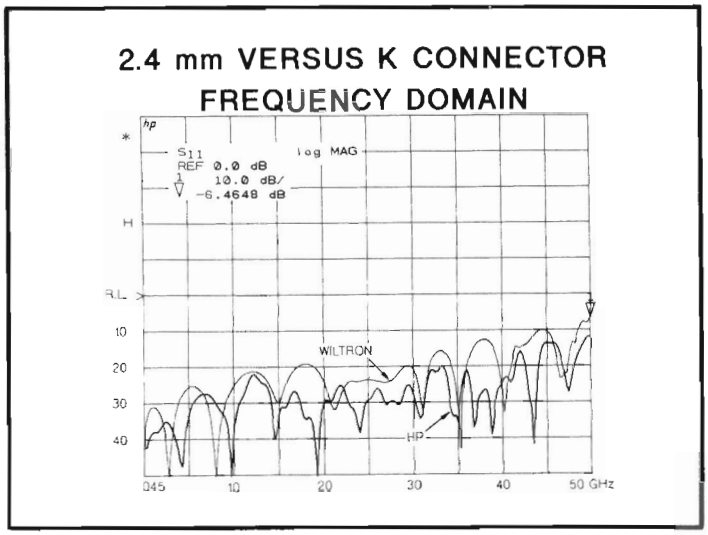


7133

The slide shows a K connector test fixture's performance in time domain. The upper trace is shown by the HP 8510B when measuring to 40 GHz, the lower trace is obtained when the upper frequency limit is expanded to 50 GHz.

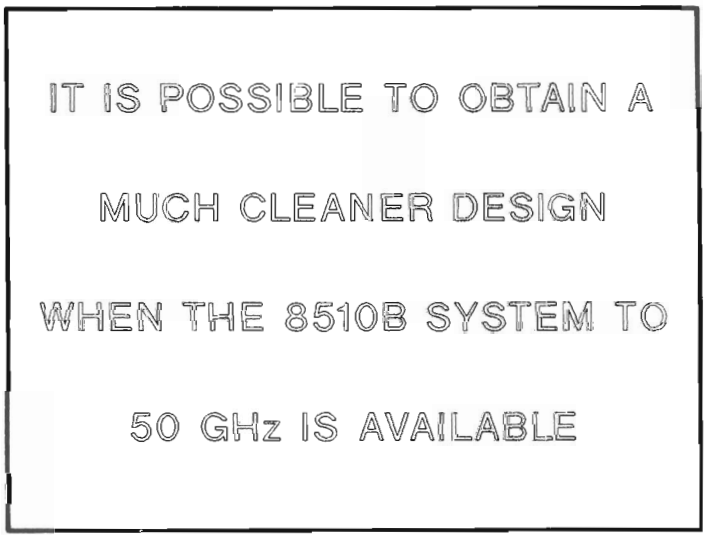
K-connector done last

same scale as last slide



7134

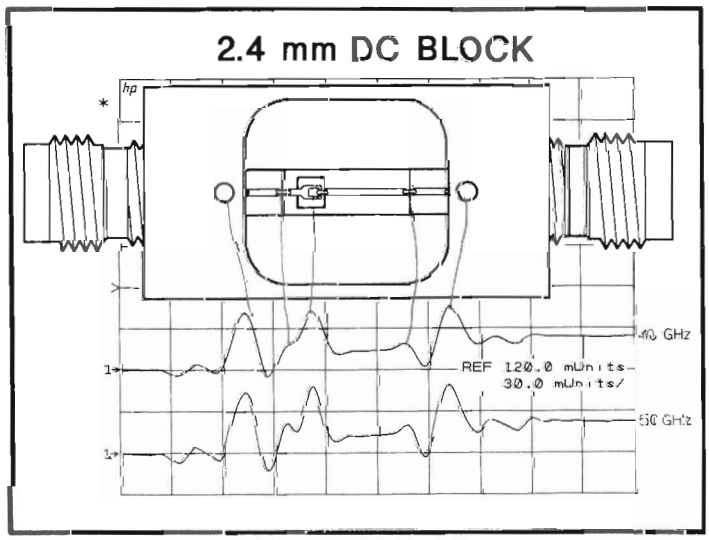
The slide shows the performance of a 2.4 mm test fixture (lower trace) used at Hewlett-Packard, and a commercially available test fixture with K connectors from Wiltron Company (upper trace). Part of the difference in performance is attributed to the availability of the 40/50 GHz time domain in development.



7135

By being able to pinpoint and separate discontinuities better, it is now possible to improve performance of the new higher frequency components to levels previously only obtainable to 26.5 GHz. Even if the component is only used to 40 GHz, a better job can be done when measuring it up to 50 GHz.

even if design is used to 40



7136

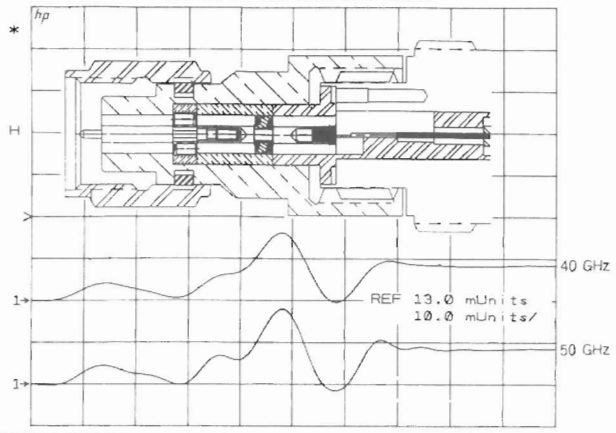
The slide shows a developmental prototype series blocking capacitor on the circuit and the inductive effect of the ribbon bonds from the two adjacent microstrip circuits. Upper trace 40 GHz, lower trace 50 GHz time domain.

drawing not to scale

lead lined up

HP DETECTOR TDR MEASUREMENT

40 GHz versus 50 GHz



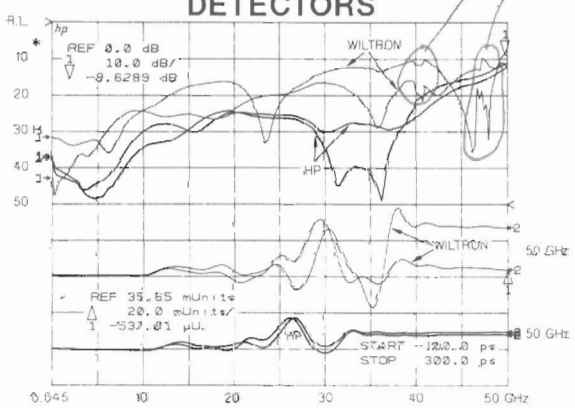
7137

This slide shows the time domain traces at 40 and 50 GHz of the .01-50 GHz broadband detector model HP 85025D.

this technique used extensively to design the 2.4 connector

HP AND WILTRON DETECTORS

due to resonance in K connector



7138

This slide shows the frequency domain return loss (S11) for two HP 85025D detectors to 50 GHz (lower traces), and the return loss of two Wiltron 40 GHz detectors (upper traces). The development of the HP detector was greatly helped by the high time domain resolution of the 40/50 GHz 8510B.

SECTION 4

WITH THE USE OF THE 8510B

40-50 GHz SYSTEM, IT IS EASY

TO DESIGN A SPECIAL

LAUNCHER OR COMPONENT

TO 50 GHz

7139

Being able to see and quantify discontinuities is absolutely necessary for a good and timely design.

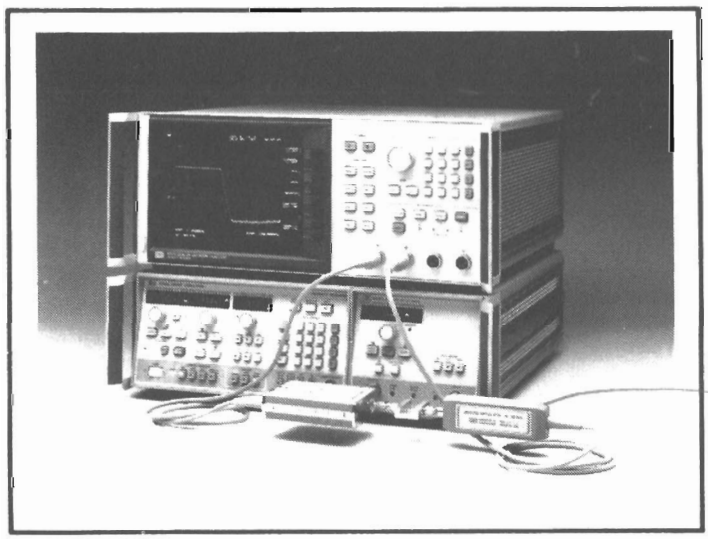
BY USING THE 2.4 CONNECTOR AND MEASURING TO 50 GHz, A WELL OPTIMIZED DESIGN CAN BE ACHIEVED, EVEN IF THE DESIGN IS ONLY USED TO 40 GHz

7140

At Hewlett-Packard, the combined 50 GHz 8510B system was used in development of all the internal microwave 40 GHz components for the 8516A test set and other equipment.

Consistent product quality, producibility, and the equipment's performance all benefit from this extra measure of capability.

8516 picture



7141

Last year, Hewlett-Packard introduced a complete line of 2.4 mm adapters, loads opens and shorts. At this time, with the 8516A 40 GHz Test Set and standards, HP is also introducing 50 GHz capability in Scalar Network Analyzers as well as a line of 50 GHz pads and other 50 GHz accessories.

this is a later data was shown for

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