INTEGRATED FIN-LINE 6-PORTS FOR MM-WAVE NETWORK ANALYZERS

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Abstract

The design and performance of an integrated 6-port mm-wave reflectometer is presented. The design uses Fin-Line technology and beam lead diode detectors in a Ka- full-band application. The high precision measurement capability of the 6-port device has been tested successfully in an automated 6-port network analyzer setup.

Introduction

Network analyzers (NWA) on the basis of the 6-port measurement scheme offer an attractive alternative to the well known mixer/sampler equipted NWA's. Despite it's generally poor performance as real-time measurement system a 6-port NWA may be constructed to form a relatively low-cost, light weight, compact and precise "quasi-real-time" measurement system when high speed data acquisition and computing devices are employed (1, 2).
One of the important advantages of the 6-port measurement concept is that only the power detection devices (6-ports) have to be changed when the 6-port NWA is modified to be used in another band of interest, e.g. from MHz-range to several hundreds of GHz. A one octave operation of these detection devices can be achieved up to 18 GHz (3).
For millimeter-wave, high precision measurements dielectric and various standard waveguide 6-port setups have been reported (e. g. 5). No compact, integrated 6-port realization above 18 GHz is actually known to the authors. To reduce system size and cost and to achieve premises for industrial application in cm- and mm-wave ranges a planar, integrated 6-port reflectometer design has been evaluated.

The 6-port reflectometer design

This paper reports the design and application in Ka-band of a fully integrated 6-port detecting module using E-plane Fin-Line technology in a split-block housing.

The Fin-Line design (fig. 1) consists of a symmetrical ring 5-port combined with a 10 dB distributed parallel-Fin-Line directional coupler.As power sensors beam lead silicon Schottky-diodes are implemented either in series (for low reflection at the 5-port) or in parallel (for high detector voltage at the coupler). By this design concept a dense concentration of all high frequency circuitry is achieved resulting in a compact 6-port detector with a footprint of 10 cm by 15 cm.
It has been shown earlier that a 6-port with power detecting points "q_i-points" equally distributed in the complex power plane represents an optimum configuration for 6-port measurement application. One Fin-Line ring 5-port together with the directional coupler gives a practical realization according to the 6-port requirements: Matching at all ports and 120 degree phase condition between adjacent arms of the 5-port. The coupler, the ring-5-port and the detector circuits have been designed and optimized using computer simulation. After this optimization a usable operation bandwidth of the full (Ka-)waveguide band has been achieved: Measured input reflection S_{AA} and transmission S_{AB} of the coupler is shown in fig. 2 with a beam-lead detector diode at arm D. The coefficient S_{AD} represents the transmission of the 10 dB coupler path before mounting the diode. Figures 3 and 4 give an overview over the 5-port operation with three detector diodes at arm 2, 4 and 5 as sketched in fig. 1.
Input reflection under -10 dB can be observed, which is sufficient when an appropriate error correction and calibration scheme (7) is applied in the measurement procedure.
It can be deduced from fig. 2, 3 and 4 that good matching under -15 dB and transmission of -6 dB has been achieved with our Fin-Line design over a wide operating bandwidth.
The simple detector circuits with Fin-Line matched loads operated with a Tss= -50 dBm (zero-bias, Siemens diode), conversion k = 200 ÷ 400 mV/mW and an input reflection under -15 dB in Ka-band.

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The figures 5 and 6 demonstrate the 6-port operation with two commonly used calibration standards (matched waveguide load, waveguide short) connected to the test-port 3. The measurement of the short (fig. 6) visualizes the 120 degree phase difference between the three power readings at the 5-port, which thus is ideally conditioned for the 6-port calibration and measurement scheme.

6-port NWA application and performance

A dual 6-port Ka-band NWA setup operating with our new Fin-Line integrated devices has been tested in Ka-band (fig. 7). It consists of a sweep generator with power leveling loop, a counter with phase-locking capability, two switches, isolators, the two 6-port modules and a data accquisition/computer unit (DAC). All microwave equipment is controlled by a IEEE 488 bus. The two switches allow for our self-calibration technique for dual 6-port NWA's published earlier (7). The DAC unit consists of a high speed relais multiplexer (scanner), a 14 bit A/D-converter unit and a 16/32 bit CPU with single user system enviroment which yields a quasi real-time display of measurement data on an integrated grafic monitor.
Table 1 summarizes the relative and absolute accuracy.
These data reveal the same degree of measurement accuracy that can be achieved with 6-port setups constructed by bulky and expensive standard waveguide components.

Conclusion

With our design concept presented and the successful practical realization an integrated 6-port reflectometer for mm-wave Network Analyzer applications has been achieved. The design goal has been met with a compact, cheap planar Fin-Line circuit. The measurement accuracy in an automated, error corrected 6-port NWA is equal to results achieved with NWA's utilizing waveguide 6-ports.

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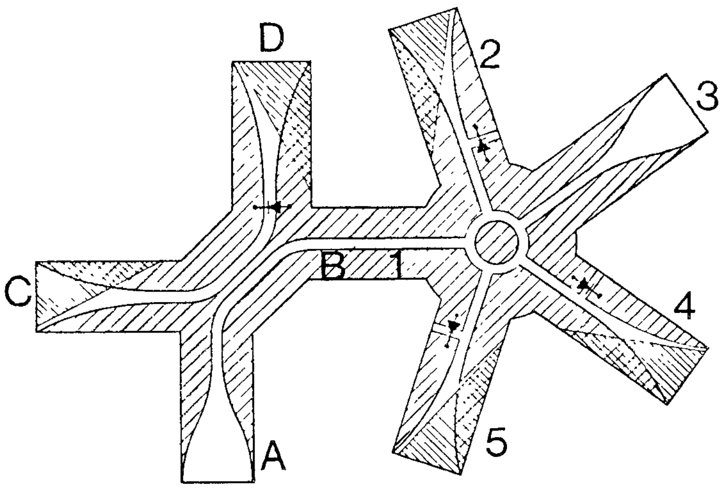

Fig. 1 Schematical layout of the integrated Fin-Line 6-port

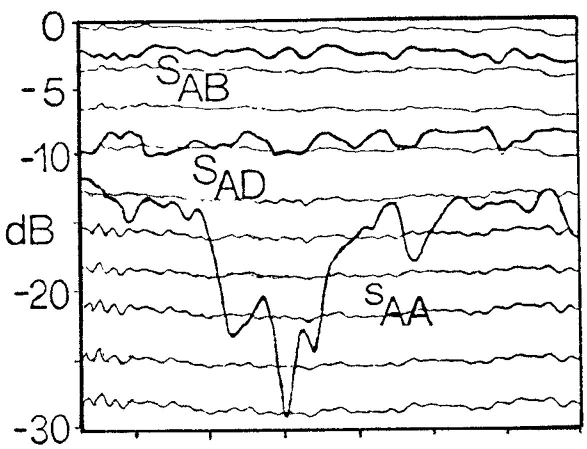

Fig. 2 Input reflection, transmission of 10 dB coupler with detector diode

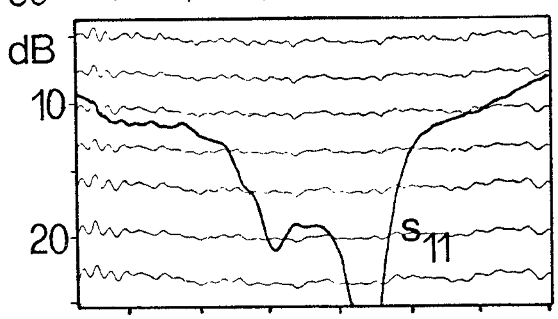

Fig. 3 Input reflection of 5-port with three detector diodes

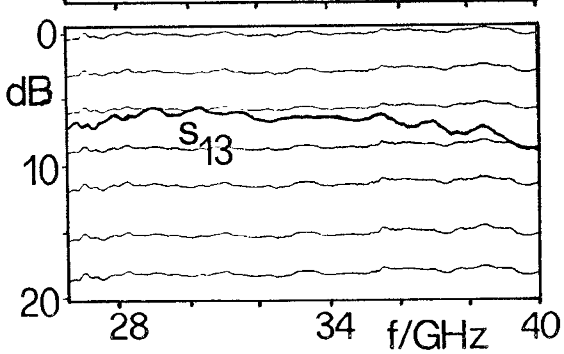

Fig. 4 Transmission of the ring 5-port

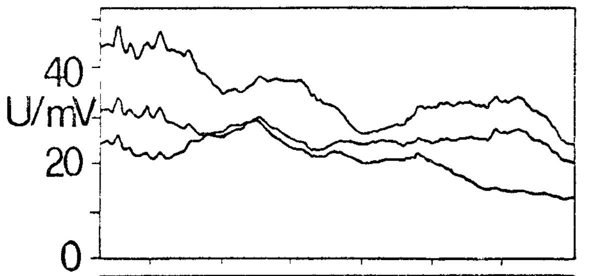

Fig. 5 Detector voltages, matched load at port 3

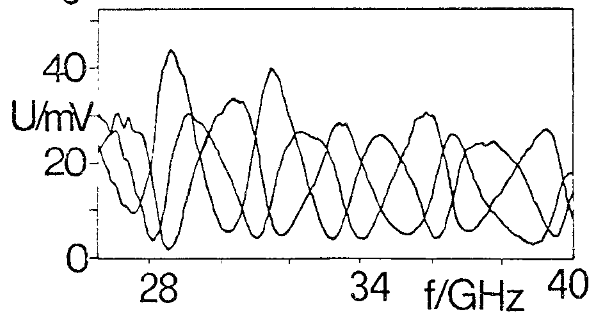

Fig. 6 Detector voltages, short at port 3

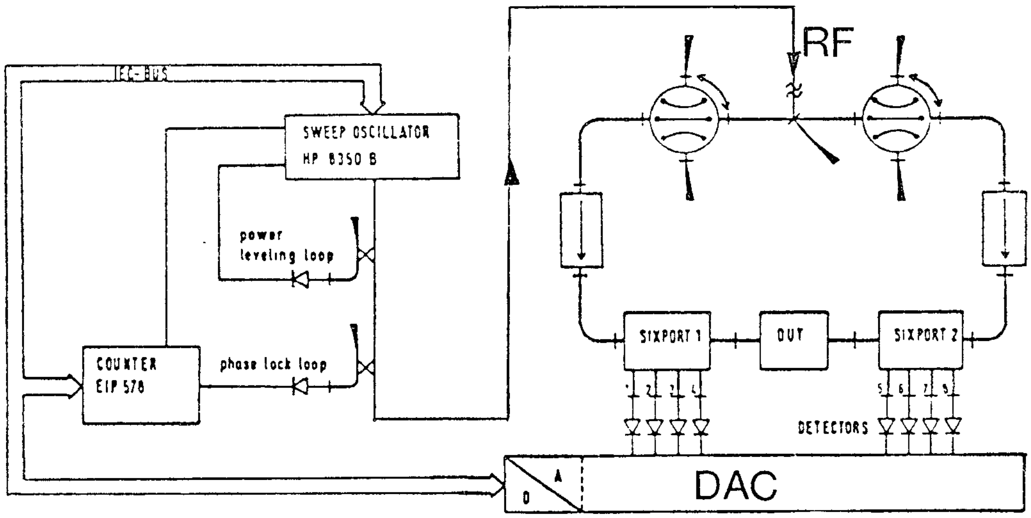

Fig. 7 Dual 6-port Networkanalyzer Configuration

	X-Band	Ka-Band
Transmission (Sik):		
--System Directivity:	>45 dB	>40 dB
--Relative Error ampl.:	<.05 dB <.2 dB	<.1 dB at /Sik/=0dB <.4 dB at /Sik/=-10dB
angle:	< 1 deg	<3 deg
Reflexion (Sii) :		
--System Directivity:	>40 dB	>35 dB
--Relative Error ampl.:	<.05 dB	<.1 dB at /Sii/=0dB
angle :	<1 deg	< 2 deg

Generator power level: 0dBm

Table 1
Dual 6-port NWA performance
Ka-band, compared to X-band Waveguide setup data