A SECOND GENERATION DUAL SIX-PORT NETWORK ANALYSER

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Abstract.

A new technique in dual six-port reflectometry is proposed. This new technique is known as Biphase-Bimodulation and eliminates mechanically precise phase shifters and attenuators; a requirement of current designs. Calibration is simple, requiring only five standards in a Thru-Delay and Match technique.

This new reflectometer system promises measurement performance approaching that of heterodyne analysers though at a much reduced hardware cost.

Introduction.

A conventional dual six port reflectometer is illustrated in fig 1.0. The development of this system was lead by Engen(1) and Hoer(2). Current systems are burdened by the computer control of mechanical phase shifters and attenuators.
The new reflectometer design is illustrated in fig 1.1.
The mechanical phase shifters and attenuators have been removed and replaced with a Biphase-Bimodulation element. This element consists of a simple directional coupler and two PIN diode modulators. The performance of the Biphase-Bimodulation element is not critical to successful calibration and measurement, indeed its performance is defined during calibration.

The remaining hardware appears similar to that of current reflectometers. The power meters however are more complicated. The Biphase-Bimodulation impresses two audio tones f_1 and f_2 upon the microwave carrier. Detection is achieved by a conventional square law detector followed by a filter network. This filter network distinguishes between the audio signals f_1 and f_2 by means of two "high Q" bandpass filters. This provides two outputs at f_1 and f_2 , the magnitudes off these two signals may then be processed by a microcomputer to evaluate the S matrix of the device under test.

Figure I A current state of the art dual six port reflectometer.

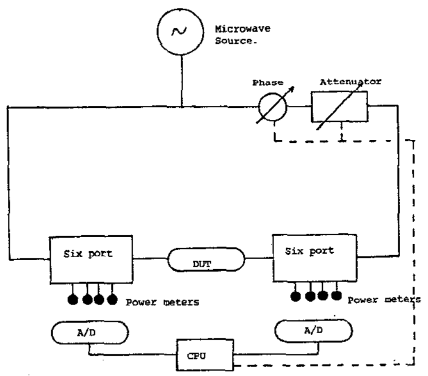
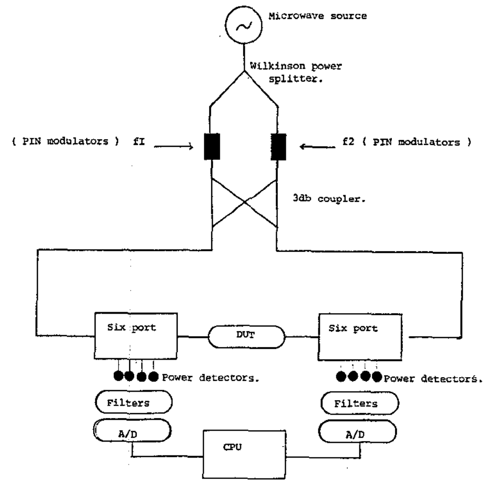


Figure 2 A second generation reflectometer.



System operation :- an overview.

Essentially the Biphase-Bimodulation element introduces a microwave carrier to the dual reflectometer that consists of two components. For the lhs six-port the microwave carrier consists, ideally, of a 0^0 phase shift labelled with the audio tone f_1 and a 90^0 phase shift carrier labelled with the audio tone f_2. The microwave carrier entering the rhs six-port consists of a 0^0 phase shift labelled with the tone f_2 and a 90^0 phase shift labelled with the tone f_1.

This labelling of the microwave carrier components, introduces a degree of independency that allows each six-port to be considered as two individual reflectometers labelled by f_1 and f_2. The Biphase information allows the recovery of the thru S parameters exhibited by the device under test. The technique has been christened Biphase-Bimodulation since two phase's and two modulation frequencies are impressed upon the microwave carrier.

Measurement proceeds by measuring four pseudo-reflection coefficients pertaining to the four "independant" reflectometers. These pseudo-reflection coefficients are :-

for the LHS reflectometer,

$$\Gamma_{11} = \left.\frac{b_1}{a_1}\right|_{f_1} \qquad -1a$$

$$\Gamma_{12} = \left.\frac{b_1}{a_1}\right|_{f_2} \qquad -1b$$

for the RHS reflectometer

$$\Gamma_{21} = \frac{b_2}{a_2}\Big|_{f_1} \qquad -1c$$

$$\Gamma_{22} = \frac{b_2}{a_2}\Big|_{f_2} \qquad -1d$$

Where a_1,a_2,b_1 and b_2 are the incident and emergent waves at the left and right measurement planes. These four complex quantites are regarded as pseudo-reflection coefficients and measured in a manner akin to that of a single reflectometer measurement of a reflection coefficient.

Equations 2,3a and 3b describe the behaviour of the two port network and the performance of the Biphase-Bimodulation element.

$$\begin{bmatrix} b_1|_{f_1}+b_1|_{f_2} \\ b_2|_{f_1}+b_2|_{f_2} \end{bmatrix} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \begin{bmatrix} a_1|_{f_1}+a_1|_{f_2} \\ a_2|_{f_1}+a_2|_{f_2} \end{bmatrix} \qquad -2$$

and,

$$\frac{a_2}{a_1}\Big|_{f_1} = R \qquad -3a$$

$$\frac{a_2}{a_1}\Big|_{f_2} = \frac{1}{\bar{R}} \qquad -3b$$

Where for a perfect directional coupler R = j. In general R is complex and determined during calibration. Straight forward algebraic manipulation of eqns 1,2,and 3 leads to the S-matrix of the device under test as :-

$$s_{11} = \frac{\Gamma_{11}}{R} + \frac{\Gamma_{12}.R}{R-\frac{1}{\bar{R}}} \qquad - 4a$$

$$s_{12} = \frac{\Gamma_{11}}{R-\frac{1}{\bar{R}}} - \frac{\Gamma_{12}}{R-\frac{1}{\bar{R}}} \qquad - 4b$$

$$s_{21} = \frac{\Gamma_{22}}{R-\frac{1}{\bar{R}}} - \frac{\Gamma_{21}}{R-\frac{1}{\bar{R}}} \qquad - 4c$$

$$s_{22} = \frac{\Gamma_{22}}{R} + \frac{\Gamma_{21}.R}{R-\frac{1}{\bar{R}}} \qquad - 4d$$

An important feature of this dual six-port analyser is that since the reflectometers may be regarded as independent, the scattering matrix of the DUT is evaluated directly from just one set of power readings.

Calibration.

The introduction of the Biphase-Bimodulation element allows the dual reflectometer to be considered as four single independant reflectometers. Calibration follows a methodology similar to that developed by Judah(3)or other schemes(5) for the calibration of a normal single six-port reflectometer.

A simple five standard Thru-Delay and Match (tdm) is required to completely characterize this new dual six-port reflectometer.

Conclusion and points of application.

This paper presents a new Biphase-Bimodulation technique that eliminates mechanical phase shifters and attenuators from the conventional DSPNA. This technique allows dual reflectometers to perform quasi-real time evaluation of scattering parameters in a swept frequency measurement system.

References.

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