A BROAD BAND STRIPLINE OR COAXIAL 'RESOLVER' FOR THE ACCURATE MEASUREMENT OF COMPLEX REFLECTION COEFFICIENTS USING THE 6 PORT MEASUREMENT CONCEPT

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ABSTRACT

A broad band stripline or coaxial network is described which allows for the accurate determination of complex reflection coefficients over multi-octave bandwidths from the measurement of two referenced power levels.

Introduction

Recently, a compact waveguide 'resolver' has been described which enables Γ to be accurately determined from the measurement of two referenced power levels.[1,2] It is, however, limited to waveguide bandwidths. The question arises as to whether there is an analogous stripline or coaxial device which operates over multi-octave bandwidths. The description of such a unit is the purpose of this contribution.

With a resolver Γ is determined in a five port mode of operation as indicated schematically in figure 1. The basic resolver is a four port device with an input port 1, an output port 2, and two secondary ports 3, 4 for detectors. The conditions previously derived for the optimum resolver are that: 1) the signal divide with equal amplitude and phase from ports 1 and 2 when feeding secondary port 3, 2) the signal divide with equal amplitude but a 90^o phase difference from ports 1 and 2 when feeding secondary port 4, 3) the coupling to ports 1 and 2 from the secondary ports be weak.[2] These conditions are suggestive as to how a broadband stripline or coax resolver might be built. Condition 1) can be met by using a divider at port 3 while condition 2) can be met by using a 90^o hybrid at port 4. The weak coupling to the mainline ports 1 and 2 can be accomplished with broadband coupled line couplers as in figure 2. The coupler for the reference detector can also be of this type and can be made an integral part of the unit.

A Practical Realization in Coax

A practical realization of this device which covers the double octave 2-8 GHz has been built and a picture of it is given in figure 3. The five coupled line couplers are constructed in 7 mm line whereas the divider and 90^o hybrid are in stripline. In spite of the double octave bandwidth, the couplers are only single section. This is because ideal performance can be achieved if the coupling as a function of frequency is the same for all five. There is no requirement on coupling flatness as a function of frequency. The actual coupling is about 27 dB at mid-band falling off to about 30 dB at the band edges. The unit was calibrated in a manner similar to that for the waveguide resolver and the calibration stored in a file on a floppy disk for subsequent use. The principle correction that must be made is for amplitude unbalance from the main line ports when feeding the hybrid port 4. This unbalance can be as much as ±1 dB.

To demonstrate the accuracy of this unit, the measurement of some VSWR standards over the double octave 2-8 GHz will be given. In Table 1 the results of the measurement of an APC7 Maury Microwave 1.50 VSWR standard are summarized. The measurement was made by first taking a reference reading with an APC7 Wiltron load and then measuring the standard using a calibration previously stored in a file on a floppy disk. The detection equipment used and measurement procedure have been described previously. The measured result of 1.50±.04 indicates that both the standard and load must be very good. A repeat measurement of the load indicates that the system repeatability for a VSWR measurement is <1.003. A second measurement was made with a 1.20 SMA VSWR standard constructed by inserting a special small diameter center conductor into an SMA sliding load. With an APC7 to SMA adapter on the output of the resolver, a reference reading was taken while sliding the SMA load. The special center conductor was then inserted and a second measurement made while sliding the load. The results are summarized in Table 1 and correspond to a VSWR of $1.20^{+.005}_{-.025}$.

Six Port Modes of Operation

The five port mode of operation has the advantage that dual channel scopes with the IEEE interface buss, which are made commercially by several manufacturers, can be used directly without modification. The reference detector must be connected to the reference channel while detectors 1 and 2 are connected to channels A and B respectively. This particular resolver can be used in a 6 port mode of operation, if that is desired, simply by connecting a third detector at the other output port of the hybrid as in figure 4. If $\overline{P}_1$, $\overline{P}_2$, and $\overline{P}_3$ are the referenced power levels measured by the three detectors, then for the ideal circuit the Smith Chart parameters $|\Gamma|\sin\Theta$, $|\Gamma|\cos\Theta$ will be given by

$$|\Gamma|\sin\Theta=\frac{\overline{P}_2-\overline{P}_3}{4}\ ,\quad |\Gamma|\cos\Theta=\frac{\overline{P}_1}{2}-\left(\frac{\overline{P}_2+\overline{P}_3}{4}\right)\ . \tag{1}$$

A further modification which leads to a particularly simple form for the above equations is achieved by replacing the divider with a 180^o hybrid as in figure 5. If two detectors are now connected at the two outputs of the 180^o hybrid, then the equations take on the particularly simple form

$$|\Gamma|\sin\Theta=\frac{\overline{P}_3-\overline{P}_4}{4}\ ,\quad |\Gamma|\cos\Theta=\frac{\overline{P}_1-\overline{P}_2}{4} \tag{2}$$

i.e. the Smith Chart parameters are proportional to the normalized voltage differences at the outputs of the two hybrids.

Advantages of This Configuration for Reflectometer Measurements

The resolver (or 6 port) just described has several potential advantages over other 6 port structures-particularly for reflectometer measurements. Only one critical component namely one 90^o hybrid is used whereas other 6 ports use as many as four or five. The coupling to the detectors is about -30 dB. For a typical input power of +10 dBm, there will be -20 dBm at the detectors. This is at the upper end of the linear region of most crystal detectors. On the other hand, the measured voltage is large enough not to be

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noisy. Because of the weak coupling the device calibration is essentially independent of detector match and detector tracking provided that a single calibration reading with a good load is made before measurements begin. The insertion loss is quite small so that full power from the generator is incident on the device under test. Finally the output port match is very good (VSWR <1.10 from 2-8 GHZ for this unit) which is often desireable.

References

1) G.P.Riblet,"A Compact Waveguide 'Resolver' for the Accurate Measurement of Complex Reflection Coefficients using the Six-Port Measurement Concept" in IEEE MTT-S 1979 International Microwave Symposium Digest, May 1979, pp.60-62.

2) G.P.Riblet,"A Compact Waveguide 'Resolver' for the Accurate Measurement of Complex Reflection and Transmission Coefficients using the Six-Port Measurement Concept", IEEE Transactions on MTT, Vol.MTT-29,pp.155-162, February 1981.

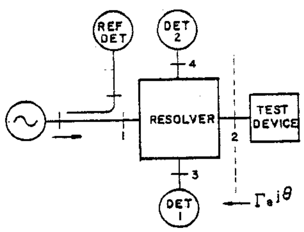

FIGURE 1: SCHEMATIC DIAGRAM OF AN EXPERIMENTAL ARRANGEMENT FOR THE MEASUREMENT OF Γ WITH A FIVE-PORT.

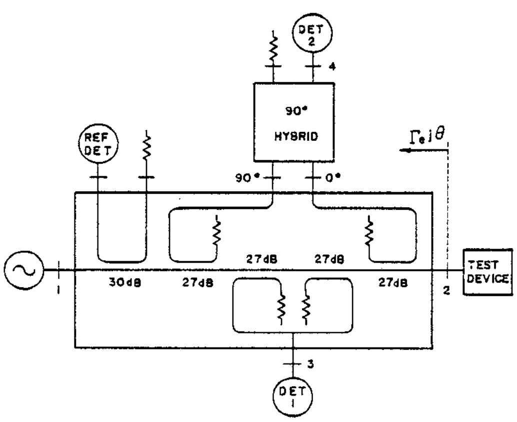

FIGURE 2: SCHEMATIC DIAGRAM OF A MULTI-OCTAVE RESOLVER USING COUPLED LINE COUPLERS.

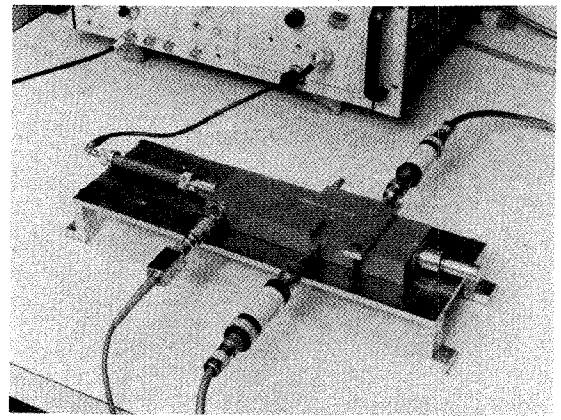

FIGURE 3: THE PICTURE OF A 2-8 GHZ COAXIAL RESOLVER CONSTRUCTED IN 7mm LINE.

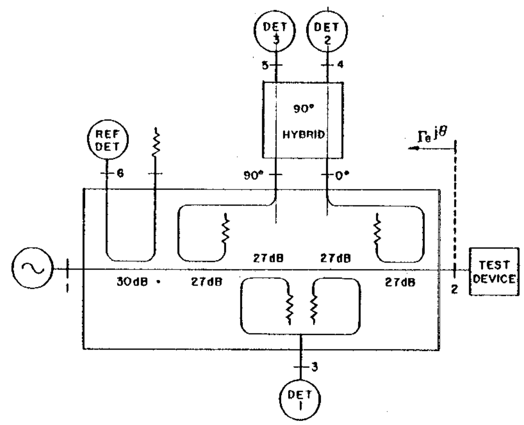

FIGURE 4: A SIX-PORT VERSION OF THE MULTI-OCTAVE RESOLVER.

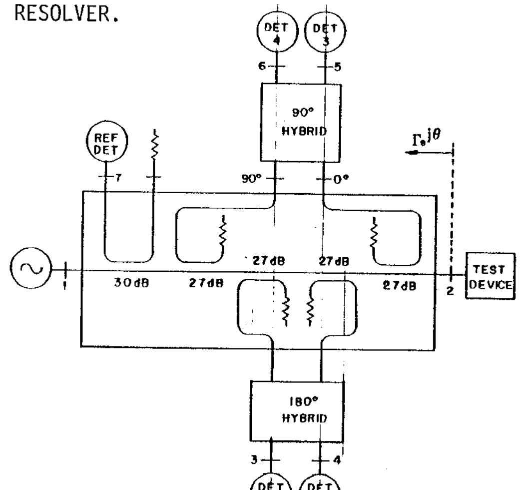

FIGURE 5: A SIX-PORT VERSION OF THE MULTI-OCTAVE RESOLVER WHICH YIELDS PARTICULARLY SIMPLE EXPRESSIONS FOR THE SMITH CHART PARAMETERS $|\Gamma|\sin\theta$, $|\Gamma|\cos\theta$ IN TERMS OF REFERENCED POWER LEVELS.

Table I

Measurements of 1.50 APC7 and 1.20 SMA VSWR standards using 2-8 GHZ resolver.

MAURY 1.50 VSWR STANDARD

FREQ.(MHZ)	VSWR
2000	1.478
2200	1.517
2400	1.534
2600	1.513
2800	1.51
3000	1.502
3200	1.527
3400	1.5
3600	1.504
3800	1.487
4000	1.491
4200	1.489
4400	1.487
4600	1.481
4800	1.512
5000	1.493
5200	1.489
5400	1.519
5600	1.479
5800	1.517
6000	1.505
6200	1.508
6400	1.543
6600	1.508
6800	1.53
7000	1.513
7200	1.509
7400	1.509
7600	1.498
7800	1.513
8000	1.48

MDL 1.20 VSWR STANDARD (SMA)

FREQ.(MHZ)	VSWR
2000	1.178
2200	1.199
2400	1.199
2600	1.199
2800	1.196
3000	1.203
3200	1.191
3400	1.196
3600	1.189
3800	1.193
4000	1.19
4200	1.194
4400	1.184
4600	1.193
4800	1.177
5000	1.19
5200	1.183
5400	1.178
5600	1.176
5800	1.178
6000	1.172
6200	1.186
6400	1.181
6600	1.183
6800	1.184
7000	1.178
7200	1.178
7400	1.175
7600	1.172
7800	1.177
8000	1.174