POSSIBILITY TO THE REMOTE SENSING APPLICATION OF THE SIX-PORT TECHNOLOGY

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Abstract: The six-port technology and its many useful applications are now being recognized once again in modern society. Since the six-port based wave-correlator (SPC) technology is well known for its unique ability to accurately measure the complex wave ratio (amplitude and phase difference between two waves), many applications of the SPC have been extensively investigated including a SPC based vector network analyzer (SPC-VNA).

In this paper, we start with the basic concepts and fundamentals on both the six-port based reflectometer and the six-port based wave-correlator. Next, we introduce one of the best microwave applications of the six-port technology, i.e. a prototype SPC-VNA using a developed MMIC of the SPC. Finally, we will discuss about possibility to the remote sensing technology as an alternative application of the developed MMIC SPC.

1 INTRODUCTION

The six-port technology and its many useful applications are now being recognized once again in modern society, and are published in book form. The six-port based wave correlator (SPC) technology is well known for its unique ability to accurately measure the complex wave ratio (amplitude and phase difference between two waves), besides many applications including a SPC based vector network analyzer (SPC-VNA). The SPC-VNA is very interesting for us, however, it is important to understand a basic theory firmly first of all.

In this paper, we start with the basic concepts and fundamentals on both the six-port based reflectometer and the six-port based wave-correlator. Next, we introduce one of the best microwave applications of the six-port technology, i.e. a prototype SPC-VNA using a developed MMIC of the SPC. Finally, we will discuss about possibility to the remote sensing technology as an alternative application of the developed MMIC SPC.

2 SIX-PORT FUNDAMENTALS

2.1 Six-Port Refrectometer

As an alternative measurement technique for the complex reflection coefficient Γ of a device under test (DUT), the six-port reflectometer was proposed by Engen and Hoer in the 1970s.The six-port reflectometer comprises a signal source port, a measurement port, and four sidearm ports to which power detectors are connected as shown in Fig. 1.

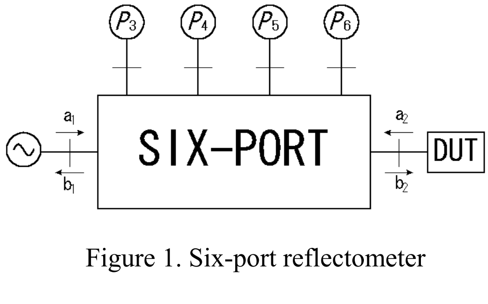

Figure 1. Six-port reflectometer

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The incident and emergent scattering variables at the measurement port are denoted by a_2 and b_2 respectively. When the DUT of reflection coefficient $\Gamma = a_2 / b_2$ is connected to the port, the four sidearm port power readings P_h, (h=3, 4, 5, 6) may be written as

$$P_h = \alpha_h \left| A_{hi} a_2 + B_h b_2 \right|^2 = \\ = \alpha_h \left| b_2 \right|^2 \left| A_h \Gamma + B_h \right|^2, \qquad (1)$$

where A_h and B_h are complex constants depending on the six-port reflectometer and α are the power conversion parameters of the power meter connected to the sidearm ports. If we denote an arbitrary sidearm port by subscript h, and one of the other four ports by i,

i=3, 4, 5, 6, $i \neq h$,

then the power ratio ${}_hP_i \equiv P_i / P_h$ with port h as reference port can be expressed as

$${}_hP_i \equiv \frac{P_i}{P_h} = \left| \frac{A_i \Gamma + B_i}{A_h \Gamma + B_h} \right|^2 = {}_hK_i \left| \frac{1 + k_i \Gamma}{1 + k_h \Gamma} \right|^2, \qquad (2)$$

$$= \mathrm{b} + \mathrm{c}$$

where ${}_hK_i$, k_i, and k_h are calibration parameters of the six-port reflectometer which should be determined in advance.

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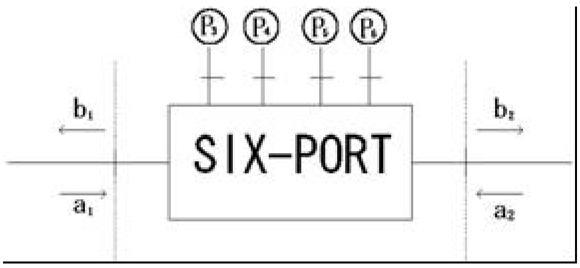
2.2 Six-port Wave Correlator

A six-port wave-correlator is shown in Fig. 2. In this case, the six-port wave correlator is operated as a two-channel wave receiver. Two ports incident waves are denoted by a_2 and a_1, and defined their complex wave ratio W= a2/a2, then the four sidearm port power readings P_h, (h=3, 4, 5, 6) may be written as same formulas as (1) and (2),



.Figure. 2. Six-port wave correlator

$$P_h = \beta_h \left| C_h a_2 + D_h a_1 \right|^2 = \\ = \beta_h \left| a_1 \right|^2 \left| C_h W + D_h \right|^2, \qquad (3)$$

$${}_hP_i \equiv \frac{P_i}{P_h} = \left| \frac{C_i \Gamma + D_i}{C_h \Gamma + D_h} \right|^2 = {}_hT_i \left| \frac{1 + t_i W}{1 + t_h W} \right|^2, \qquad (4)$$

where β are the power conversion parameters. C_h and D_h are complex constants, and ${}_hT_i$, t_i, and t_h are calibration parameters f the six-port wave-correlator which should be determined in advance. Although the choice of h is wholly arbitrary, we set h=4 (i=3,5,6) in harmony with Engen's notation.

Then, (4) can be rewrite,

$${}_4P_i = {}_4T_i \left| \frac{1 + t_i W}{1 + t_4 W} \right|^2, \qquad (5)$$

where real ${}_4T_3$, ${}_4T_5$, ${}_4T_6$ and complex t_3, t_4, t_5, t_6 are the system parameters of the wave correlator, and W is the correlation ratio of the two incident waves a_2 and a_1. By expanding (5) into quadratic form, we have three circles in the complex W plane with the centers zi and radii Li described as

$$z_i = -\frac{t_4\,{}_4P_i - t_i\,{}_4T_i^{\;2}}{{}_4P_i - {}_4T_i}, \qquad (6)$$

$$L_i = \left| \frac{t_4 - t_i}{{}_4P_i - {}_4T_i} \right| \sqrt{{}_4T_i\,{}_4P_i}.$$

Since the locus of each circle represents the possible values for W, the complex W is the intersection of three circles as shown in Fig. 3.

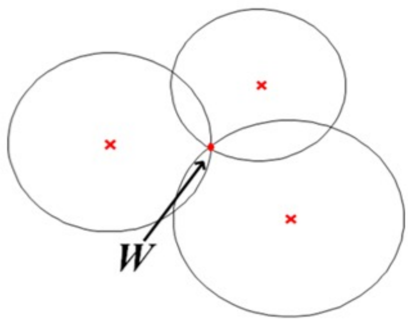


Figure. 3. Complex W plane

3 ALTERNATIVE VNA BASED ON MMIC SPC

A Prototype MMIC six-port correlator based VNA to measure the scattering parameters of a two-port DUT is shown in Fig. 4. This configuration is composed of directional couplers, switches, isolators, circulators, and matching loads.

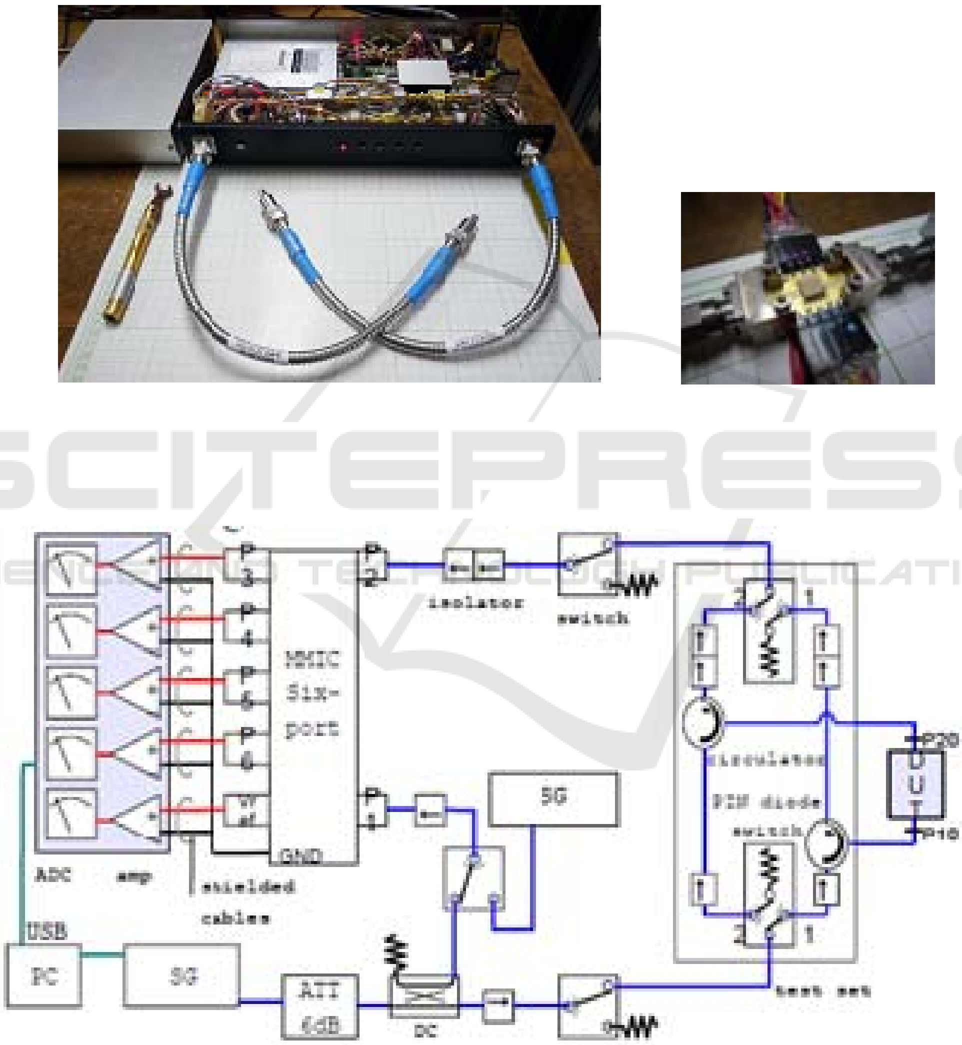
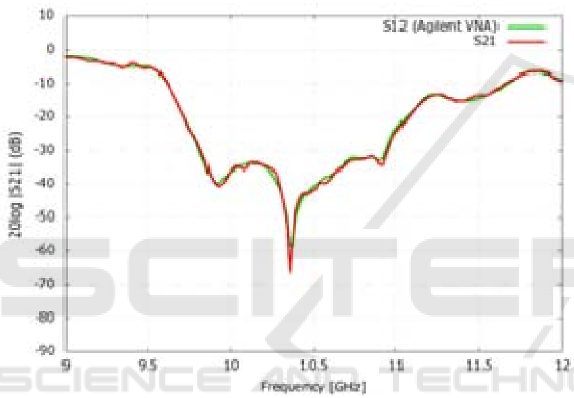


Figure. 4. Scheme of the MMIC six-port correlator based vector network analyzer

For determining the system parameters of the six-port correlator, three lines of different length are used as standards for measuring the transmission S-parameters, and three shorts with different length are used as standards for measuring the reflection S-parameters. The system performance was evaluated by measuring various two-port passive components. Figure 5 illustrates the measured S-parameters of a UWB filter. The measurement is conducted from 9 to 12 GHz with 151 points. For comparison, the measured results using a commercial VNA (Agilent N5230C) are also shown in the same figure. One can see the agreement between the two measured data is very good up to the dynamic range of 60 dB for S21. The measurement results of S11 are also in very good agreement.



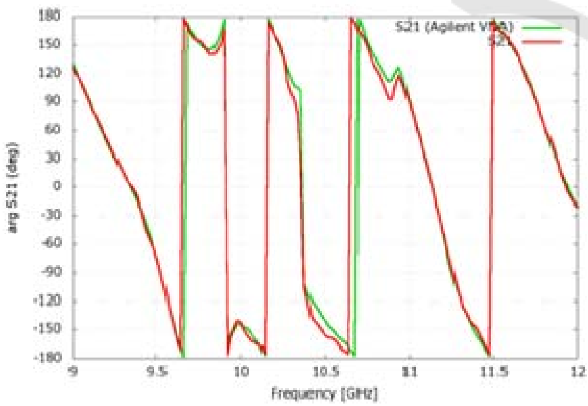


Figure. 5. S-parameters of a UWB filter measured by the developed six-port VNA and a commercial VNA

4 CONCLUSIONS AND A POSSIBILITY TO THE REMOTE SENSING OF MMIC 6PC

In this time, we introduce the six-port based wave-correlator (SPC) technology. With our improved its calibration theory, our developed MMIC SPC has a good ability to accurately measure the complex wave ratio (amplitude and phase difference between two waves). That is why we are studying and developing an alternative VNA using the SPC. Now, we are developing a compact and MMIC PSC-VNA for high frequency student experimental equipment with reasonable price as education support. In near future, we will pursue possibility of the application to the remote sensing.

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