Design, Simulation and Development of Wideband Directional Coupler at S Band

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***Abstract* - Directional Coupler is a four port passive device, used in the field of radio technology. It couples a defined amount of the electromagnetic power from the primary transmission line to the secondary transmission line depending on value of coupling factor. Its performance is evaluated based on certain parameters like coupling, directivity, isolation, insertion loss. This paper focuses on designing two line microstrip directional coupler for IRNSS application at S band (2.5 GHz centre frequency) by using ADS software. By using multisection coupler, the performance of the coupler can be improved. The directional coupler is fabricated by using FR4 substrate.**

***Index Terms* - Coupling, Directivity, Isolation, Insertion loss, ADS Software.**

I. INTRODUCTION

It is a four port passive device [9] used in the field of radio technology. It couples a defined amount of the electromagnetic power from primary to secondary transmission line. An essential feature of directional coupler is that it only couples power flowing in one direction. The coupled output from the directional coupler can be used to obtain the information (frequency and power level) on the signal without interrupting the main power flow in the system.

Directional couplers often are formed as waveguide, stripline, or microstrip directional couplers..Directional couplers are most frequently constructed from two coupled transmission lines set close enough together such that energy passing through one is coupled to the other because of the interaction of electromagnetic field. Such a coupler is stripline or microstrip coupler.

In this paper, the design of three section microstrip directional coupler is presented. The center frequency is 2.5 GHz, which is suitable for IRNSS application. The substrate is FR4 and its thickness is 120 mil. The coupler is simulated by using ADS software.

II. THEORETICAL BACKGROUND

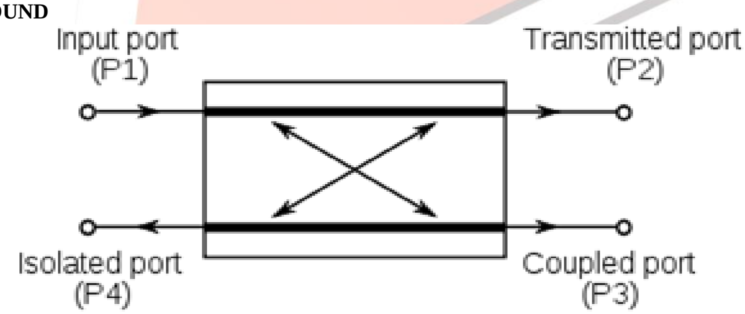


Figure 1 Schematic diagram of directional coupler [9]

Directional couplers have four ports as shown in Figure 1. Port 1 is the input port where power is applied. Port 3 is the coupled port [9] where a portion of the power applied to port 1 appears depending on coupling factor. Port 2 is the transmitted port where the power from port 1 is outputted, less the portion that went to port 3. Directional couplers are frequently symmetrical [9] so there also exists port 4, the isolated port.

Waveguide couplers are forward wave couplers (co - directional couplers), whereas the coupled line couplers like stripline or microstrip couplers are backward wave couplers (contra – directional couplers). Since, the conventional two line microstrip is inhomogeneous medium [5] (partially dielectric, partially air) as shown in Figure 2, it suffers from poor directivity [10], since even

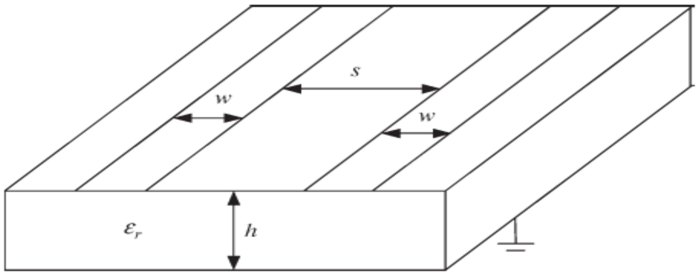


Figure 2 Schematic diagram of two line microstrip coupler [1]

and odd mode phase velocity [5] is different. Various techniques are used to improve that.

1. Coupler with lumped element [3] compensation (Inductive [2] or capacitive [3] compensation techniques)
2. Multi-section coupler [4, 7, 8]
3. N-section tandem structure [6]

In this paper, multisection coupler technique is used to improve the performance of the coupler.

III. Two Line Microstrip Coupler Design

A. Single section coupler design[1]

The design equations for single section coupler are as follows:

1. Calculation of even and odd mode impedances:

$$Z_{0_e} = Z_0 * \sqrt{\frac{1+C}{1-C}} \tag{1a}$$

and

$$Z_{0_o} = Z_0 * \sqrt{\frac{1-C}{1+C}} \tag{1b}$$

2. Calculation of shape ratio (w/h) :

The w/h ratio for single microstrip line is

$$\frac{w}{h} = \frac{8\sqrt{\left[\exp\left(\frac{R}{42.4}\sqrt{(\varepsilon_r+1)}\right)-1\right]\frac{7+(4/\varepsilon_r)}{11}+\frac{1+(1/\varepsilon_r)}{0.81}}}{\left[\exp\left(\frac{R}{42.4}\sqrt{\varepsilon_r+1}\right)-1\right]} \tag{2}$$

Where,

$$R = \frac{Z_{oe}}{2} \quad \text{or} \quad R = \frac{Z_{oo}}{2}$$

Now,

$$(w/h)_{se} = (w/h)\Big|_{R=\frac{Z_{oe}}{2}} \tag{3a}$$

And

$$(w/h)_{so} = (w/h)\Big|_{R=\frac{Z_{oo}}{2}} \tag{3b}$$

The corrected term is given by,

$$\left(\frac{w}{h}\right)'_{so} = 0.78\left(\frac{w}{h}\right)_{so} + 0.1\left(\frac{w}{h}\right)_{se} \tag{4}$$

The shape ratio for the coupled line is,

$$\left(\frac{w}{h}\right) = \frac{1}{\pi}\cosh^{-1}(d) - \frac{1}{2}\left(\frac{s}{h}\right) \tag{5}$$

Where,

$$d = \frac{\cosh\left[\frac{\pi}{2}\left(\frac{w}{h}\right)_{se}\right](g+1)+g-1}{2} \tag{6}$$

$$g = \cosh\left[\frac{\pi}{2}\left(\frac{s}{h}\right)\right] \tag{7}$$

3. Calculation of spacing ratio (s/h) :

$$s/h = \frac{2}{\pi}\cosh^{-1}\left[\frac{\cosh\left[\frac{\pi}{2}\left(\frac{w}{h}\right)'_{so}\right] + \cosh\left[\frac{\pi}{2}\left(\frac{w}{h}\right)_{so}\right] - 2}{\cosh\left[\frac{\pi}{2}\left(\frac{w}{h}\right)'_{so}\right] - \cosh\left[\frac{\pi}{2}\left(\frac{w}{h}\right)_{se}\right]}\right] \quad (8)$$

4. Calculation of physical length (l) :

$$l = \frac{\lambda}{4} = \frac{c}{4f\sqrt{\varepsilon_{eff}}} \quad (9)$$

B. Three section coupler design

ADS layout of three section microstrip directional coupler is shown in Figure 3.

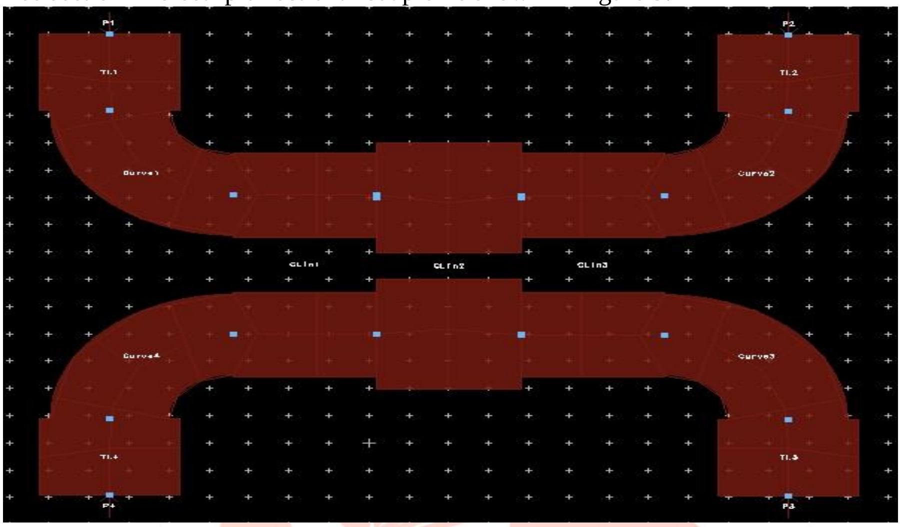


Figure 3 ADS layout of three section coupler

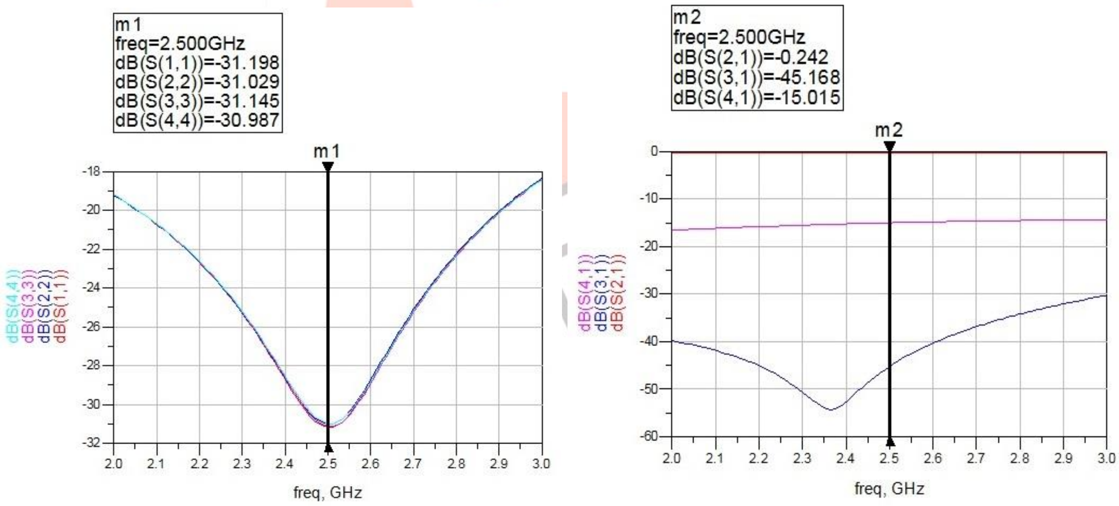


Figure 4 Layout results of three section coupler

Figure 4 shows the layout results of the three section coupler. The return lossat port1, port2, port3 and port4 are -31.198 dB, -31.029 dB, -31.145 dB and -30.987 dB respectively, insertion loss is -0.242 dB, isolation is -45.168 dB and coupling is -15.015 dB at the center frequency.

Figure 5 shows the fabricated three section coupler using FR4 substrate material.

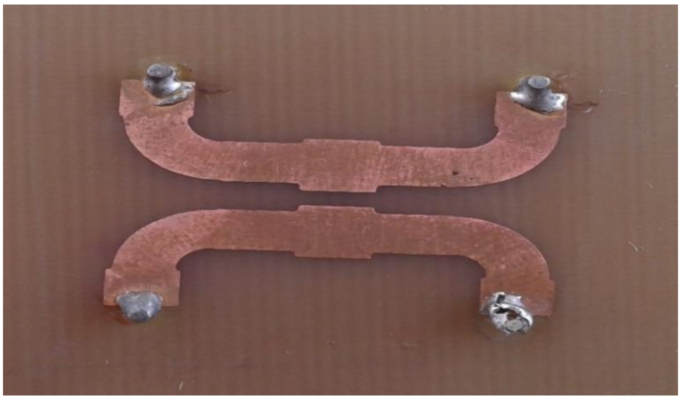
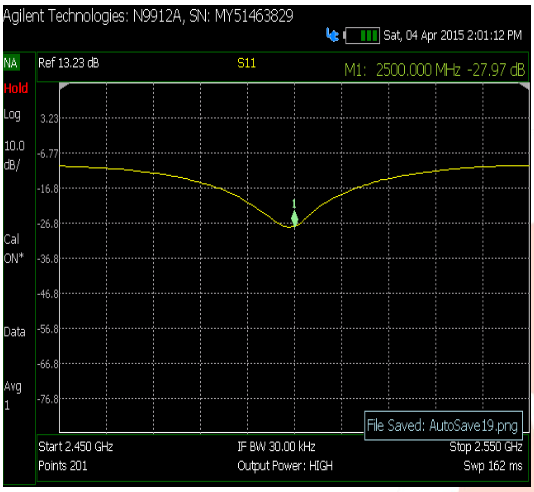
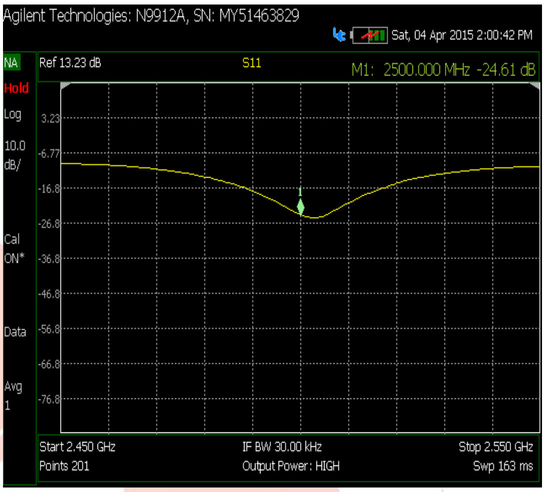


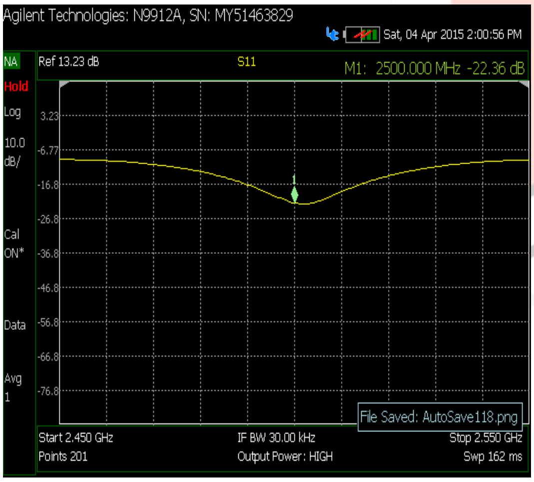
Figure 5 Fabricated three section coupler



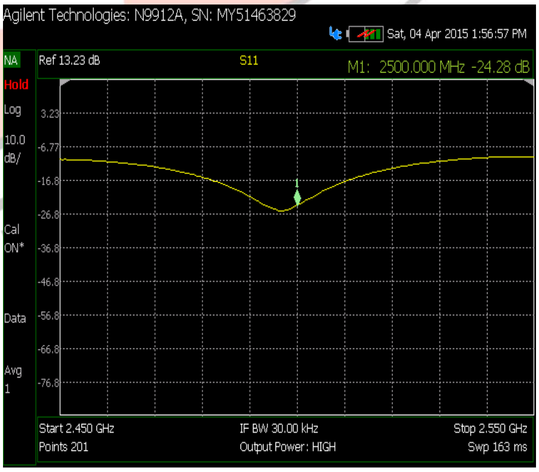
(a) S_{11}



(b) S_{22}

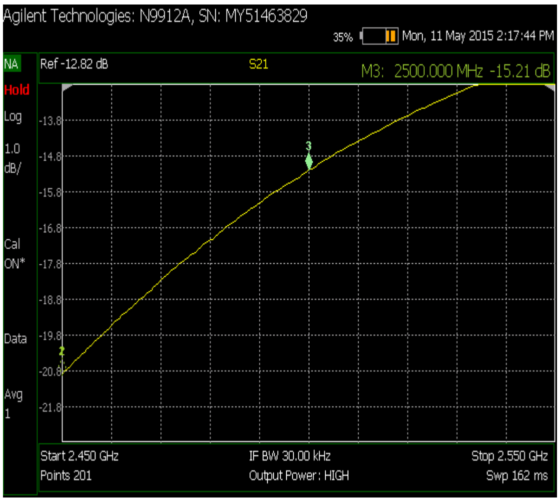


(c) S_{33}

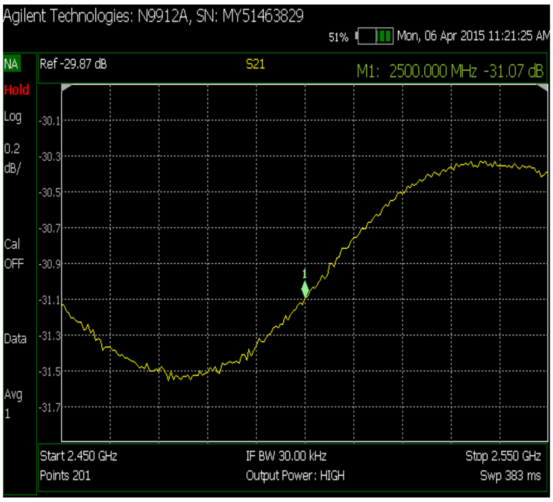


(d) S_{44}

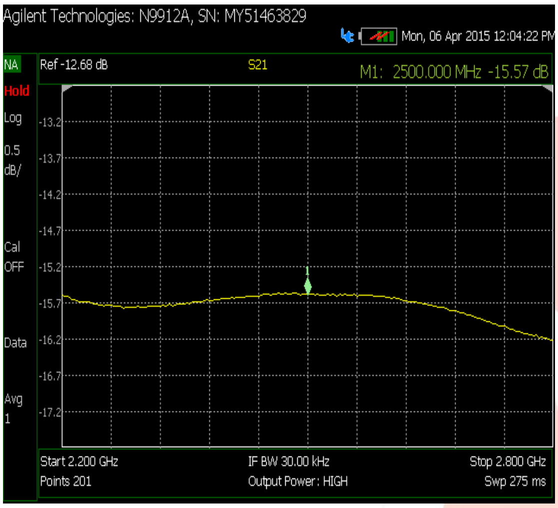
Figure 6 Fabricated coupler results



(e) S_{21}



(f) S_{31}



(g) S_{41}

Figure 6 Fabricated coupler results (Cont…)

Figure 6 shows that for fabricated three section coupler, at the center frequency, return loss at port1, port2, port3 and port4 are -27.97 dB, -24.61 dB, -24.28 dB and -22.36 dB respectively, the insertion loss is -15.21 dB, the coupling is -15.57 dB and the isolation is -31.07 dB. The losses of the cables are -7.306 dB and -7.300 dB at 2.5 GHz, which are used for measurements.

IV. CONCLUSION

Many reference papers for directional coupler have been studied. Since, the objective is to design the directional coupler for IRNSS receiver where the received power is in terms of mW, microstrip coupler is selected. but two line microstrip coupler suffers from poor directivity and smaller bandwidth. Various techniques are used to improve these parameters like multisection coupler. From review papers and simulation results, we can say that three section coupler gives better results compared to single section coupler.

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