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Design and Concept of Broadband Dual Directional Coupler

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ABSTRACT- *Design and concept of broadband dual directional coupler is under developed. The -24dB fixed coupling dual directional coupler is using transmission line transformer technique. The directivity should be better than 20 dB for 10 to 80 MHz frequency. The design and estimation should ensure more than 100 W with minimum insertion loss.*

KEYWORDS* - *Dual directional coupler, Ferrite transformer, Directivity, Coupling

INTRODUCTION

Directional coupler are four port passive devices that are used mostly in the area of radio frequencies technology. They couple a defined amount of the electromagnetic power in a transmission line to a port enabling the signal to be used in another circuit.

Thus, it is like impossible to measure the power without directional coupler. [1]

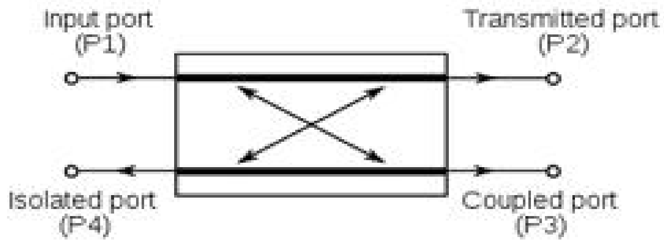

Fig 1: Directional coupler

A. Performance parameters

Coupling: It is defined as the ratio of coupled to the input power which is given by

$$C_{3,1} = -10 \log \frac{P_3}{P_1} dB \qquad (1)$$

Isolation: It is defined as the difference in signal level between the input and the isolated port when other two port are terminated by matched load which is given by

$$I_{4,1} = -10 \log \frac{P_4}{P_1} dB \qquad (2)$$

Directivity: It depends upon the cancellation of two wave components which is given by

$$D_{3,4} = -10 \log \frac{P_4}{P_3} dB \quad (3)$$

Also,

$$D_{3,4} = I_{4,1} + C_{3,1} \quad (4)$$

Insertion loss: It is defined as the ration of transmitted power to the input power which is given by

$$L_{i2,1} = -10 \log \frac{P_2}{P_1} dB \quad (5)$$

B. Ferrites

A ferrite is a type of ceramic compound composed of iron (III) oxide (Fe_2O_3) combined chemically with one or more additional metallic elements. They are both electrically nonconductive and ferromagnetic [2] & [3].

Fig 2: Ferrite transformer and ferrite

MOTIVATION

At low frequency lumped component are used and at high frequency distributed component are used.

At 10 MHz, $\lambda = \frac{c}{f} = \frac{3*10^8}{10*10^6} = 30m$ (6)

At 80 MHz, $\lambda = \frac{c}{f} = \frac{3*10^8}{80*10^6} = 3.75m$ (7)

Here, the size of waveguide will be too large so to get reduced size directional coupler we go for directional coupler using transmission line transformer technique.

MATHEMATICAL ANALYSIS

A. Coupling Vs. Insertion loss

For a perfect(lossless) coupler,

Pin = Pout + Pcoupled

ML (main-line loss in dB) = 10 log (Pin / Pout)

CPL (coupling in dB) = 10 log (Pin /Pcoupled)

TABLE 1

Sr. No.	Coupling(dB)	Insertion Loss	Pout for Pin =100W
1.	3	3	50.11
2.	6	1.25	74.99
3.	10	0.458	89.99
4.	20	0.0436	99
5.	24	0.01732	99.60
6.	30	0.00435	99.90

TABLE 2

Sr. No.	Coupling (dB)	Input power (W)	Pc Coupled power (W)	Vp-p= $\sqrt{8PcR}$ R=50Ω
1.	-24	1	4m	1.26
2.	-24	3	0.03	3.46
3.	-24	10	0.01	34.64
4.	-24	50	0.19	8.71
5.	-24	100	0.39	12.64

SIMULATION

TINA (Toolkit for Interactive Network Analyzer) software is used which is powerful circuit simulator for analyzing, designing and real time testing of RF, Communication, a mixed electronic circuit and their PCB layout [4], [5] & [6].

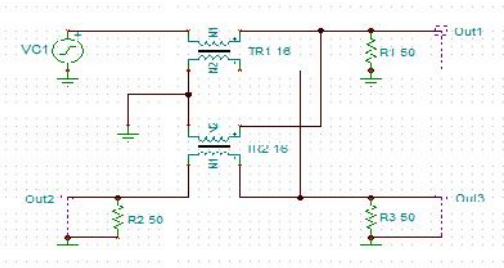

Fig 3: Circuit diagram of directional coupler

A. Working principle

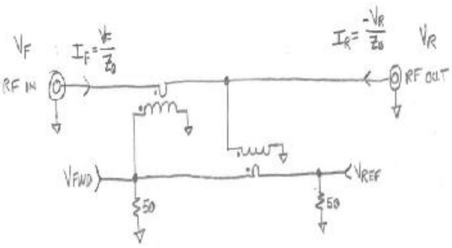

Fig 4: Layout of directional coupler

Transmission line voltage: $V = V_F + V_R$

Transmission line current: $I = I_F + I_R$

$$I = \frac{VF - VR}{Z0} \quad (8)$$

Sensing line current:

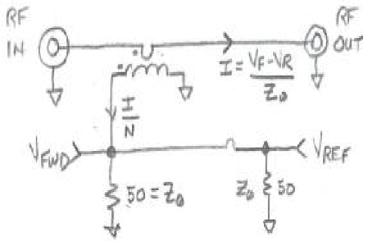

Fig 5: Layout of current transformer

$$V_{FWD}' = V_{REF}' = \frac{I}{N} * \frac{Z0}{2} \quad (9)$$

$$= \frac{VF - VR}{Z0} * \frac{Z0}{2N} \quad (10)$$

$$V_{FWD}' = \frac{VF - VR}{2N} = V_{REF}' \quad (11)$$

Sensing line voltage:

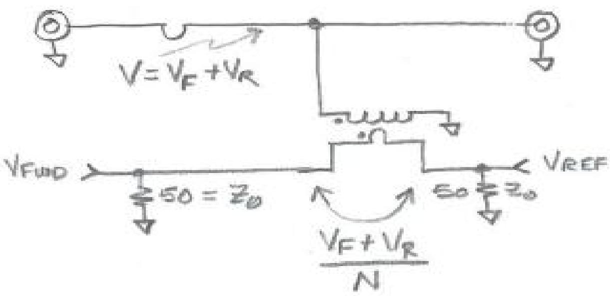

Fig 6: Layout of voltage transformer

$$V_{FWD}'' = \frac{VF + VR}{2N}$$

$$V_{REF}'' = -\frac{VF + VR}{2N}$$

$$V_{FWD} = V_{FWD}' + V_{FWD}'' = \frac{VF - VR}{2N} + \frac{VF + VR}{2N} = \frac{VF}{N} \quad (12)$$

$$V_{REF} = V_{REF}' + V_{REF}'' = \frac{VF - VR}{2N} - \frac{VF + VR}{2N} = -\frac{VR}{N} \quad (13)$$

B. Simulated results

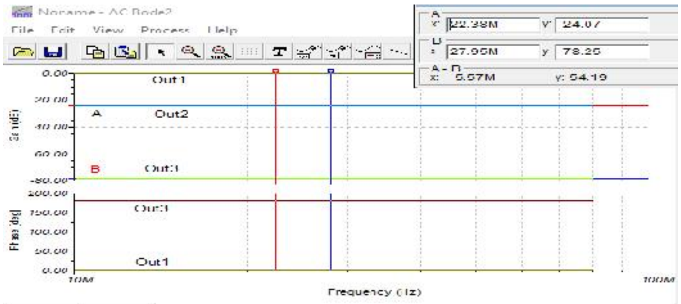

Fig 7: Simulated results of broadband directional coupler

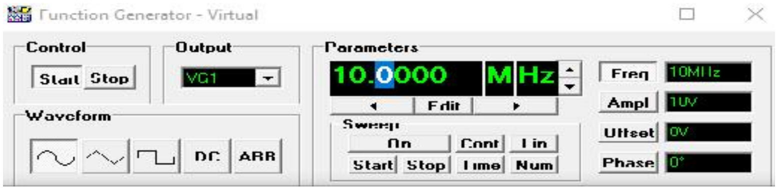

Fig 8: Simulation using function generator

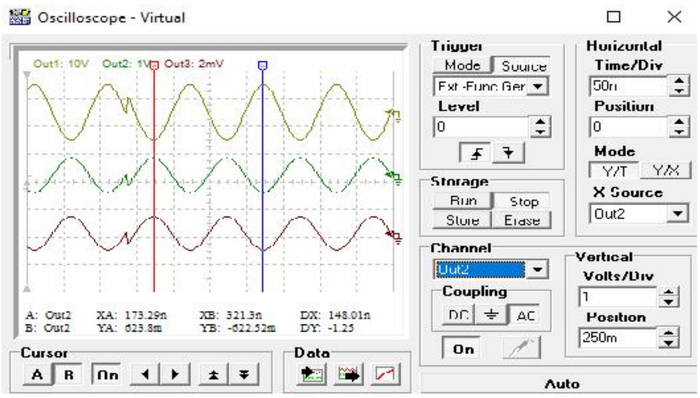

Fig 9: Simulation using Oscilloscope

Here, input voltage(peak-peak) = 20V

Out1, Insertion loss= I = 20log $\frac{19.92}{20}$ = -0.03dB (14)

Out2, Coupling, C = 20log $\frac{1.25}{20}$ = -24.08 dB (15)

Out3, Isolation, I = 20log $\frac{1.75m}{20}$ = -81.15 dB (16)

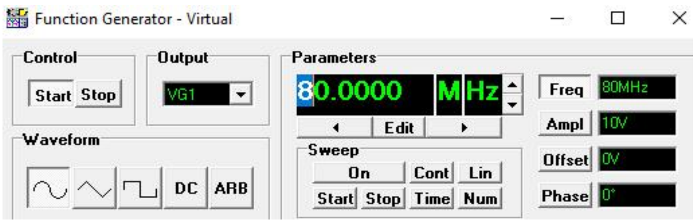

Figure 10: Simulation using function generator

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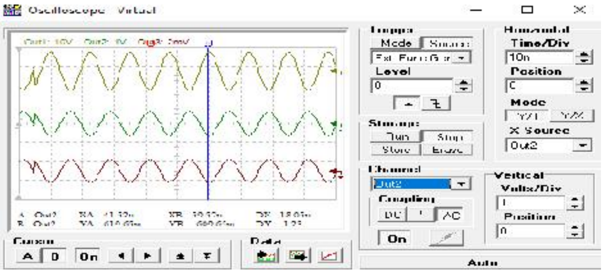

Figure 11: Simulation using function generator

So, for 10 to 80 MHz frequency range performance parameters remains same therefore it is broadband directional coupler.

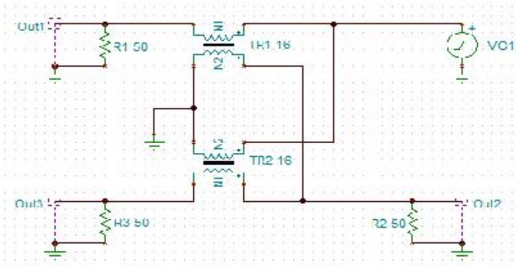

Figure 12: Circuit diagram of directional coupler

By interchanging port 1 and port 2 we will get the same results. Thus, it satisfies the dual operation of the directional coupler [9] & [10].

C. Applications

1. It covers all ISM band application under 100 MHz

2. In Helicon Double Layer, ion thruster is a prototype spacecraft propulsion engine which uses a 13.56 MHz transmission to break down and heat gas into plasma. RF power is coupled into a specially shaped antenna & then it excites a helicon wave in the plasma, which further heats the plasma.

CONCLUSION

By using the transmission line transformer technique, the performance parameters get improved. Also, the size of the directional coupler gets reduced.

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