

DESIGN AND DEVELOPMENT OF DIRECTIONAL COUPLER FOR RANGING TRANSPONDER OF IRNSS AT 3.4 GHZ

Vaidehi R. Patel¹, Nimesh M. Prabhakar², A.K.Sisodia³

¹Department of Master Engineering In Communication System Engineering,
LJIET, GTU, Ahmedabad, Gujarat,

²Asst. Prof. of Master Engineering In Communication System Engineering,
LJIET, GTU, Ahmedabad, Gujarat

³Prof. of Master Engineering In Communication System Engineering,
LJIET, GTU, Ahmedabad, Gujarat

ABSTRACT

Directional couplers are used in RF and microwave signal routing for isolating, separating or combining signals. They find use in a variety of measurement applications: Power monitoring, Source levelling, Isolation of signal sources. But Directional couplers are operating at different frequency band for different application. We will design Directional coupler at 3.4GHz frequency in Ranging Transponder of IRNSS system using Microstrip Technique. Design of Directional coupler is done by using Advance Design System (ADS). By using lumped components (Inductive or capacitive compensation techniques) or multi section technique or different designs, results can be achieved as per the specifications. Here, 3-dimensional directional coupler technique is used to get results as per the specifications. Our target specifications met with the fabricated results but the frequency is shifted. This could be happened because of fabrication problem: material permittivity may be changed compared to simulation material, tangent constant may be different.

Key Words:- Coupler; ADS software; Isolation; Directivity; IRNSS

1. INTRODUCTION

The term microwaves may be used to describe electromagnetic (EM) waves with frequencies ranging from 300 MHz to 300 GHz, which correspond to wavelengths (in free space) from 1 m to 1 mm. The EM waves with frequencies above 30 GHz and up to 300 GHz are also called millimeter waves because their wavelengths are in the millimeter range (1–10 mm). The millimeter wave spectrum at 30MHz-300 GHz is of increasing interest to service providers and systems designers because of the wide bandwidths available for carrying communications at this frequency range. Such wide bandwidths are valuable in supporting applications such as high speed data transmission and video distribution.

Directional couplers are general purpose tools used in RF and microwave signal routing for isolating, separating or combining signals. They are used in a variety of measurement applications: Power monitoring, Source leveling, Isolation of signal sources, Swept transmission and reflection measurements. Directional coupler also providing taps for cable distributed system such as cable television, separating transmitted and received signals on telephone lines.

Directional couplers are passive reciprocal networks. It is a four-port network where all four ports are ideally matched and lossless. Directional couplers can be realized in microstrip, stripline and waveguide. Directional couplers are used to sample a signal, incident and reflected waves. When two transmission lines are close together, because of the interaction of the electromagnetic fields of each line, power can be coupled between the lines.

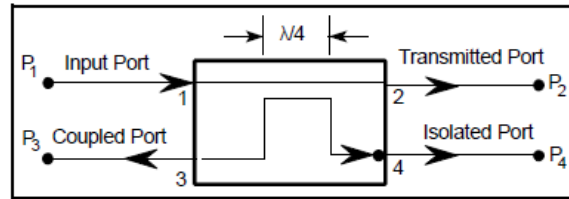


Figure 1 - Directional Coupler

1. A portion of the wave traveling from port 1 (input) to port 2 (output) is coupled to port 3 (forward coupled), but not to port 4.
2. A portion of the reflected wave traveling from port 2 to port 1 is coupled to port 4, but not port 3.
3. A portion of the wave incident on port 4 to port 3 is coupled to port 2, but not port 1; and a portion of the wave incident on port 3 is coupled to port 1, but not port 2.

2. IRNSS

Indian Regional Navigational Satellite System (IRNSS) is a regional satellite navigation system owned by the Indian government. The system is being developed by Indian Space Research Organization (ISRO).

There are two types of transponder is used in IRNSS:

- (i) Navigation transponder (ii) Ranging transponder.

IRNSS is an independent Navigation Satellite System providing services in the Indian Region. IRNSS is being implemented by the Indian Space Research Organization. The project is being managed by the lead center viz., ISRO Satellite Centre, Bangalore with support from the other work centers viz., Space Application Centre, Ahmedabad, ISTRAC. IRNSS provides fairly good accuracy and the whole constellation is seen all the time. IRNSS system provides the Dual frequency user with a targeted position accuracy less than 20 meters in the coverage area.

3. DESIGN APPROACH

Parameter	Values
Coupling	-20 dB
Return loss	<20 dB
Insertion loss	0.4 dB
Isolation	30 dB
Directivity	20 dB

Table 1 – Target Specification

A. Microstrip Coupled Line Design

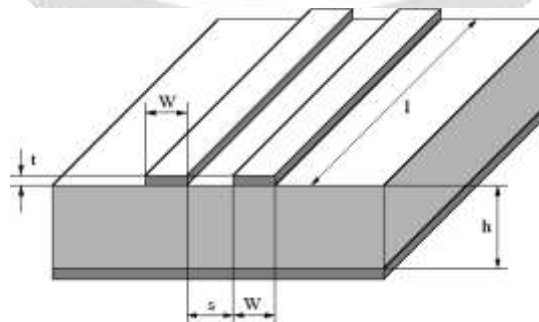


Figure 2 – Coupled line structure

Coupling and the operational frequency are known parameters at beginning of the design. Based on the known parameters, the proposed procedure has the following steps.

Parameter	Value
Coupling, C	20 dB
Centre frequency, f	3.4 GHz
Substrate name	FR4
Substrate permittivity, Er	4.6
Substrate thickness, h	1.6 mm
Copper thickness, t	0.035 mm
Tan δ	0.002
Characteristic Impedance, Zo	50 Ω

Table 2 – Design Specifications

B. Find Even- and Odd-Mode Impedances

$$Z_{oe} = Z_o \sqrt{\frac{1 + 10^{\frac{C}{20}}}{1 - 10^{\frac{C}{20}}}}, \quad Z_{oo} = Z_o \sqrt{\frac{1 - 10^{\frac{C}{20}}}{1 + 10^{\frac{C}{20}}}}$$

Z_o is 50 Ω. After calculations the even and odd mode impedances, Z_{oe} and Z_{oo} are 55.277 Ω and 45.226 Ω respectively.

C. Find Physical Dimensions w/h and s/h

Calculation of w/h ratio

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

Where,

$$R = \frac{Z_{oe}}{Z_o} \quad \text{and} \quad R = \frac{Z_{oo}}{Z_o}$$

Now,

$$\left(\frac{w}{h}\right)_{se} = \left(\frac{w}{h}\right) \Big|_{R = \frac{Z_{oe}}{Z_o}}$$

And

$$\left(\frac{w}{h}\right)_{so} = \left(\frac{w}{h}\right) \Big|_{R = \frac{Z_{oo}}{Z_o}}$$

The corrected term is given by,

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

The shape ratio for the coupled line is,

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

Where,

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

and

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

Calculation of spacing ratio s/h

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

D. Find Physical Length l

The physical length of the directional coupler is obtained using:

$$l = \frac{\lambda}{4} = \frac{c}{4 f \sqrt{\epsilon_{eff}}}$$

Where, $c = 3 * 10^{11}$ mm/s and f is operational frequency in hertz.

4. SIMULATION

ADS(Advance Design System) software is used here for simulation.

Various techniques are used to improve directivity.

1. Coupler with lumped element compensation (Inductive or capacitive compensation techniques)
2. Multi-section coupler
3. N-sectional structure

Here conventional technique is used for design of directional coupler.

Parameter	Values
Frequency	3.4 GHz
Coupling	20 dB
Dielectric constant of substrate	4.6
Thickness of substrate h	1.6 mm
Microstrip couple line thickness t	0.035 mm
Microstrip couple line Width w	2.86 mm
Interval s between two Microstrip lines	2.18 mm
Microstrip line length l	11.82 mm

Table 3 - Parameters values used in simulation

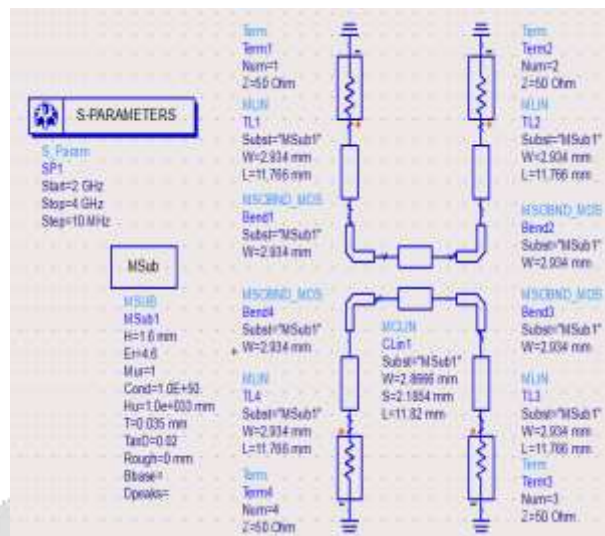


Figure 3- Schematic of Directional Coupler

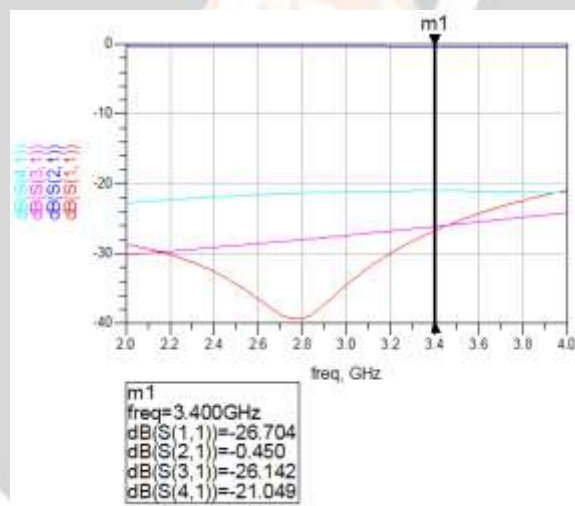


Figure 4- Simulation Results of Schematic

After doing design in schematic, further I will design in layout in ADS. In the layout part, if I want Return loss(S11) than I will give input at port 1 and other ports will be terminated. Same like that, if I want coupling(S31) than input will be given at port 1 and output will be taken from port 3, other ports will be terminated. Same in other cases for S41, S21, S33, S44.

Layout output results will be lost slightly compared to schematic results.

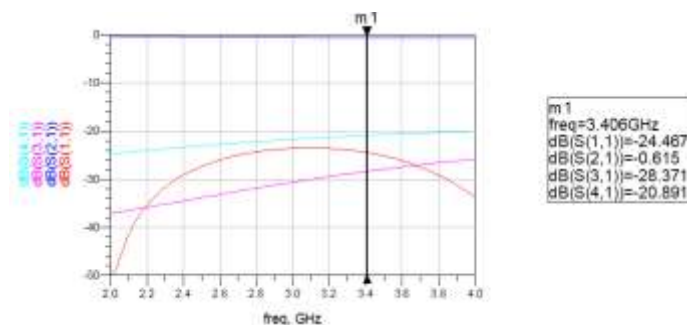


Figure 5- Simulation Results of Layout

Note here, In all the simulation outputs:
 S11-Return Loss, S21-Insertion Loss, S31-Isolation, S41- Coupling.

Parameters	Results
S11-Return Loss	-24.467 dB
S21-Insertion Loss	-0.615 dB
S31-Isolation	-28.371 dB
S41-Coupling	-20.891 dB

Table 4 – Measured Results

Using multisection technique we can improve the parameters. Here, I have used 3-dimensional directional coupler.

Stages	w	s	l
1	2.68 mm	1.54 mm	3.5 mm
2	2.68 mm	2.71 mm	3.5 mm
3	2.68 mm	2.78 mm	3.5 mm

Parametr of transmission line and bens are same as the conventional structure. The simulation results are as follows: Return loss, Insrtion loss, Coupling and Directivity respectively.

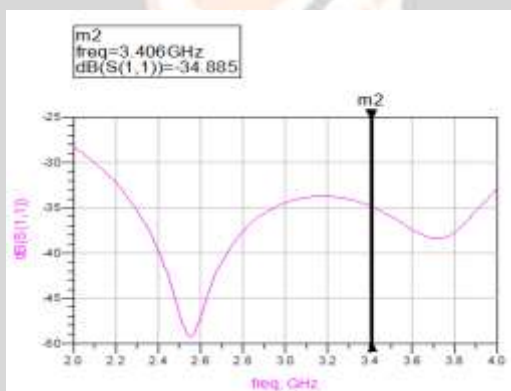


Figure 6- Return loss

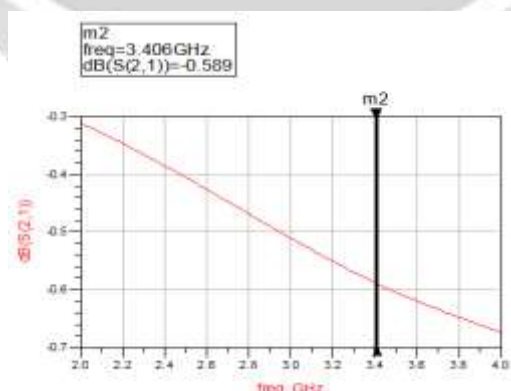


Figure 7- Insertion loss

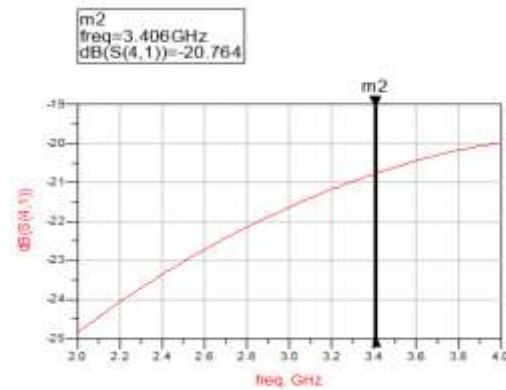


Figure 8- Coupling

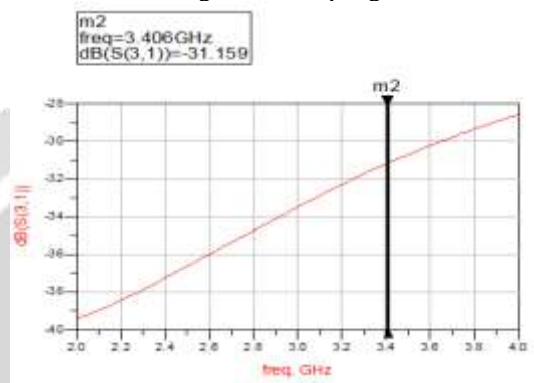


Figure 9- Isolation

Target Specifications are achieved in 3-dimensional directional coupler. Figures - 6 to 9 are simulation results of layout.

5. CONCLUSION

It can be concluded that the best method for design of directional coupler at 3.4 GHz frequency is microstrip technology among stripline technology, microstrip technology and waveguide technology. By using lumped components (Inductive or capacitive compensation techniques) or multi section technique or different designs, results can be achieved as per the specifications. Here, 3-dimensional directional coupler technique is used to get results as per the specifications. At center frequency 3.4GHz, return loss S_{11} is greater than -20 dB and insertion loss is greater than -5 dB. Coupling is 20 dB and Isolation is more than 30 dB. Directivity is about 10 dB. The specifications of this project have been met.

6. ACKNOWLEDGMENT

The author thanks Prof. A. K. Sisodia & Asst. Prof. Nimesh M. Prabhakar from L. J. Institute of Engineering and Technology for technical discussion & processing support without whom this paper would never be completed.

7. REFERENCES

- [1] Eden Corrales, Alex Baldomero, Pedro de Paco, "A Dual-Band 180-Degree Hybrid Coupler Based on Coupled-Line Sections" IEEE Microwave and Wireless Components Letters, VOL. 25, NO. 4, April 2015, p.p. 211-213, ISSN: 1531-1309.
- [2] M.Karthick, Vineet Kumar Dad, Shilpi Soni, Chinmoy Saha, Deepak Ghodgaonkar, "Design and Implementation of a Miniaturized Dual Band Quadrature Hybrid at S and C-Band for SATCOM Application", 2014 IEEE, ISBN: 78-1-4799-6986-9.
- [3] Venkata Sudheer Nune, B Surendra Babu, "DESIGN OF A 6DB DIRECTIONAL COUPLER USING DEFECTED GROUND STRUCTURE", International Journal of Engineering Sciences Research -IJESR, Vol.04, Issue 02; July 2014, p.p. 541-546, ISSN: 2320-976; e-ISSN-2277-2685.

- [4] N.S.Murthy Sarma, M.Chakrapani, P.parvathi "Design and Verification of Strip Line Directional Couplers for Various Applications in RF and Microwave Communication Systems", International Journal of Computer Science and Information Technologies (IJCSIT), Vol. 2 (2), 2011, p.p 871-875, ISSN: 0975-9646.
- [5] CHEN Peng, CAI Jinyan, "Design and Simulation of Dual-band Composite Right/Left-handed Transmission Lines Directional Coupler", 2011 IEEE, p.p. 1400-1404, ISBN: 978-1-4577-0321-8.
- [6] Yu-na Su, Geng Li. "A Design Method of Microstrip Directional Coupler with Multi-Elements Compensation", IEEE International Symposium on Radio-Frequency Integration Technology, Nov. 30 - Dec. 2, 2011, p.p. 221-225, ISBN: 978-1-4577-0520-5.
- [7] Seungku Lee, Yongshik Lee, "A Design Method for Microstrip Directional Couplers Loaded With Shunt Inductors for Directivity Enhancement", IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 58, NO. 4, APRIL 2010,p.p. 994-1002, ISSN: 0018-9480.
- [8] Vinit Kumar Gupta, Punam P Kumar, C V N Rao, "A Novel Miniaturized, Wideband, High Directivity Microstrip Coupler on FR4", 2013 IEEE, ISBN: 978-1-4799-2174-4.
- [9] Tomas Shejbal, "Directivity Coupler with a Very Low Coupling Coefficient", 2013 IEEE, p.p. 109-113, ISBN: 978-1-4673-5513-1.
- [10] Wu Xing, Li Zhongyun "Analysis and Optimization of a Ka-Band Directional Coupler", 2012 IEEE, p.p. 001-004, ISBN: 978-1-4673-2185-3.
- [11] Mr. Brijeshkumar G. Chhatrola, Mr. Nimesh M. Prabhakar, "Design, Simulation and Development of Wideband Directional Coupler at S Band", International Journal of Engineering Development and Research (IJEDR), Volume 3, Issue 2, p.p. 989-994, ISSN: 2321-9939.
- [12] Vijayan T, "Performance of Microstrip Directional Coupler Using Synthesis Technique", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 2, Issue 3, March 2013, p.p. 761-767, ISSN: 2278 – 8875.

Books-

- [13] David M. Pozar, "Microwave Engineering", Third Edition, Wiley Student Edition.
- [14] Samuel Y. Liao, "Microwave Devices and Circuits", Third Edition, Pearson.
- [15] K Lal Kishore, "Electronics Devices and Circuits", B S Publication.
- [16] M.H.Rashid, "Power Electronics Handbook", Second Edition, Academic Press.