A Polyvalent Coplanar Coupler on the Ferrite Thin Films with Improving the Dimensioning and Performance

Rahmouna EL Bouslemti,, Faouzi Salah-Belkhodja

Abstract. Couplers are widely used as combiner or power dividers. A different form of CPWG coplanar coupler structures is proposed in this work with a wideband performance. The HFSS is used to optimize the device and to check the transmission characteristics at operating frequency. In this analysis, the coupler studied is a co-directional (COD) at a 2.8 GHz and a transdirectional (TRD) at 2 GHz. The proposed couplers demonstrate noval operating characteristics and non-reciprocal of a clasic coupler which have not been demonstrated before. In this operating mode, the operating frequency of the proposed polyvalent coupler can be selected as desired. All coupler ports can be adapted to a load impedance of 50 Ohm. In addition, the best impedance match on all ports is maintained at all center frequencies. The coupler demonstrates a coupling level of 3 dB with a reflection level of 22 dB and a non-reciprocal isolation level as 20 dB. The polyvalent CPWG coupler have compact sizes of 19×23 mm, with impedance Z0 is 49 Ω.

Keywords: Microwaves, Microwave Theory, Ferrite Thin Films,

I. INTRODUCTION

All During the eighties ; a miniaturization of civilian and military devices has imposed itself, particularly in the field of aeronautics and telecommunications, and has continued ever since. The devices must therefore be developed miniaturized, low-cost products, while operating at higher frequency ranges and multiple-band operation mode [1]-[2].

Many researchers have studied the transmission characteristics of the CPW couplers whose work [3]-[4], and other authors have given a general baseline for all models of the directionel coupler shape microstrip [5, 6, 7] and coplanar couplers [8]-[9]-[10].

In this analysis the Polder tensor is used to describe the tensor permeability of the ferrite. Though, a coupler with coplanar waveguide (CPWG) structure is well suited to microwave integrated circuits because line and ground (GND) are located in the same plane and are easily patterned. Wen in [8] is the first who has studied and developed the theory of coplanar waveguide (CPWG). A few researchers have been studied and realized the coupler with a CPWG structure. recently, M. A. Abdlla in [9] and [10] was studied and developed this device with a ferrite substrat.

In our previous paper, a new CPWG coupler was proposed and its transmission characteristics were analyzed using an Ansoft HFSS.

The main purpose is to create a meandeer coupler with YIG (ferrite of 1mm thick), which works as a co-directional (COD) at an frequency and contra-directional (CTD) at another frequency. The component that will be used to develop must be having a low insertion loss, a high isolation and reflection levels at all ports.

II. THEORY

The device type is determined according to the relative location of the isolated port to the input port, directional couplers are categorized to three types, as shown in Fig. 1, namely, co-directional (COD), contra-directional (CTD), and transdirectional (TRD) [5]-[11].

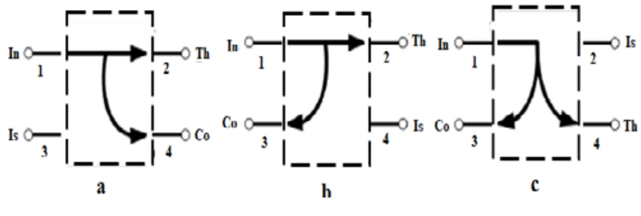

Fig. 1. Three types of directional couplers. (a) COD coupler. (b) CTD coupler. (c) TRD coupler with Input, through, isolation and coupled port.

$$S_{41} = \frac{\sqrt{1-k^2}}{\sqrt{1-k^2}.\ \cos\vartheta + j\sin\vartheta} \quad (1)$$

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$$S_{31} = \frac{jk \sin\vartheta}{\sqrt{1-k^2}.\cos\vartheta + j\sin\vartheta} \quad (2)$$

θ=β*l* denotes the electrical length of the coupler and k is given by :

$$k = \frac{Z_{Oe}-Z_{Oo}}{Z_{Oe}+Z_{Oo}} \quad (3)$$

where Z_{0e} and Z_{Oo} denote the characteristic impedance of the even-mode ans odd mode of symmetrical coupled lines respectively, which verify this condition [7] :

$$Z_{Oe}Z_{Oo} = Z_O{}^2 \quad (4)$$

We can write Z_{0e} /Z_{0o} in terms of a voltage coupling coefficient *k* as [7]:

$$\frac{Z_{Oe}}{Z_{Oo}} = \frac{1+k}{1-k} \quad (5)$$

If the coupling from port 1 to port 3 is given as *C* dB (where *C* is a positive quantity), then *k* is related to *C* as [7]:

$$k = 10^{-C/20} \quad (6)$$

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III. STRUCTURE'S CHARACTERISTICS

The design parameters are the characteristics of the magnetic material, the polarization and the circulation frequency of the device, this characteristics are given in Table 1.

Table 1. Characteristics of the Coupler's Parts

Ferrite « YIG »	
Relative dieclectric « ε_f »	15.3
Diecltric loss tangent « tangδ »	10^{-4} at 9.8 GHz
Saturation magnetization « M_s »	178 mT
Internal fiel « H_i »	447 kA/m
Copper	
Conductivity « σ »	41.106 S/m
Relative permeability « μ »	0.999991

A magnetic bias field (H_i) must be applied in a direction perpendicular to the solid layer of ferrite to assure the transmission caracteristic of the coupler ; the signal is transmitted in one direction and attenuated in the reverse direction.

We can also determine the resonant frequency the expression, given in [12]:

$$f_{mn} = \frac{c}{2\sqrt{\varepsilon_r}}\left[\left(\frac{m}{w_g}\right)^2 + \left(\frac{n}{l_g}\right)^2\right]^{0.5} \quad (7)$$

Where c is the velocity of light, w_g and l_g are the width and the length of the ground patch, respectively, and m and n are integers, the mode indexes.

IV NUMERICAL STUDY OF CPWG COUPLER

IV.a. STRUCTURE

In this paper, we have specified the CPWG topology (Coplanar Waveguide with Lower Ground Plane) to design a novel waveguide polyvalent coupler, shown in Fig. 2.

The principle of operation of our proposed coupler is to utilise the dispersive onset of high permeability and the Low electrical connectivity to set up the upper cut-off frequency of a magnetic component based *on a* ferrite rearward to get an TRD operation and forward to get un COD operation with almost equal power division in its operation bandwidth. Low coercivity of the ferrite is exploited to reverse their magnetic characteristics and their magnetic field.

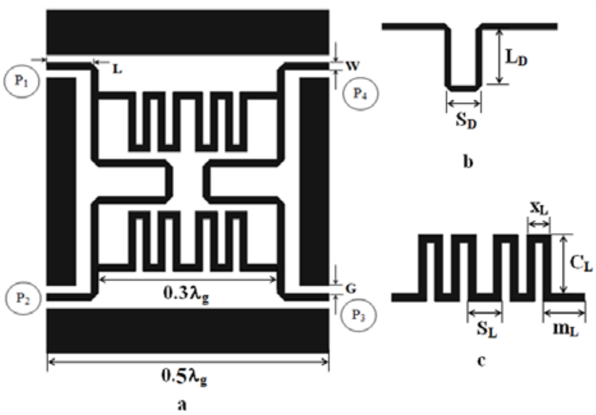


Fig. 2. Structure of a directional coupler with CPWG structure and the detailed dimensions of the specific elements.

a/ Details of the CPWG and rectangle ferrite : 0,5.λ_g=19 mm, L=3mm, W=0.5 mm, G=0.5 mm
b/ Details of the meandered pole : S_D=2 mm, L_D=4.5mm
c/ Details of the meandered line : S_L=1 mm, m_L=2 mm, X_L=0.5 mm, C_L=4 mm.

where λ_g is the guide wavelength of the TEM wave in the transmission line medium at the design frequency f_0 and ε_r is the dielectric constant of the substrate [7], $\lambda_g = 38.34mm$ at 2.8 GHz.

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_r}} \quad (8)$$

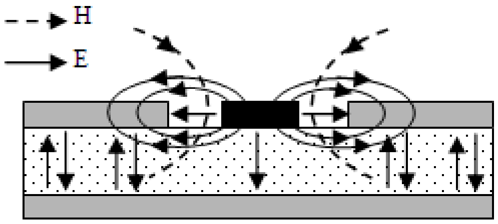


Fig. 3. Electromagnetic configuration of the CPWG coplanar line.

The CPWG proposed coupler is symmetrical in design. The dimensions of these specific elements with the dimensions of the CPWG are chosen to satisfy the desired design objective. The dimensions of the CPWG are chosen in such a way that the input impedance of the feeding of the each port becomes equivalent to 49 Ω.

The final desired design was obtained through optimisation of geometrical parameters for different ferromagnetic resonance (FMR) line width ΔH values to developed in order to improve the performance of the coplanar coupler and achieve an almost 3 dB backward coupling level for all the studied cases.

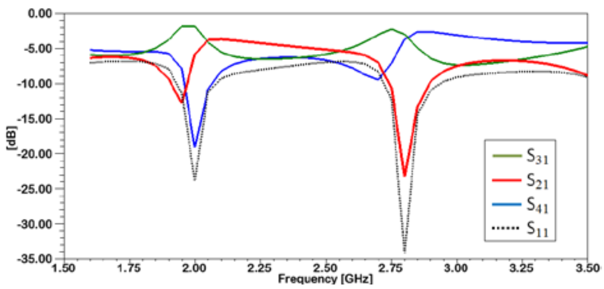
IV.b NUMERICAL RESULTS

The theoretical calculation result was confronted to the value obtained by numerical simulations of static mode of the coupler using the Ansoft HFSS. These simulations allowed to calculate the coupling, isolation , directivity, and the reflection coefficients.

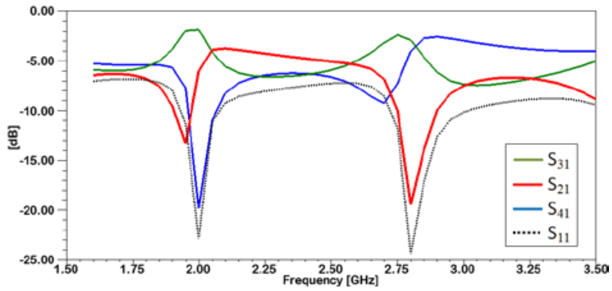
The applied magnetic field polarization H_i=477KA/m is assumed to be uniform in all the studied cases and it must be applied in a direction perpendicular to the solid layer

The characteristics of the CPWG coupler was simulated for different ΔH magnetic values of 45, 100, and 150 Oe.

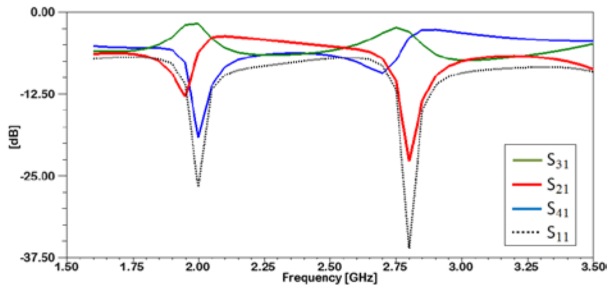
Although the proposed coupler was designed to achieve a 3 dB power division for both operating frequencies at 2 GHz and 2.8 GHZ. , representing a matched and lossless coupler. The high lossy nature of the ferrite can be influence the dispersive characteristics of a transmission line. Consequently, the equal power division level is around 4 dB at 2 GHz and 3 dB at 2.8 GHz.



(a)



(b)



(c)

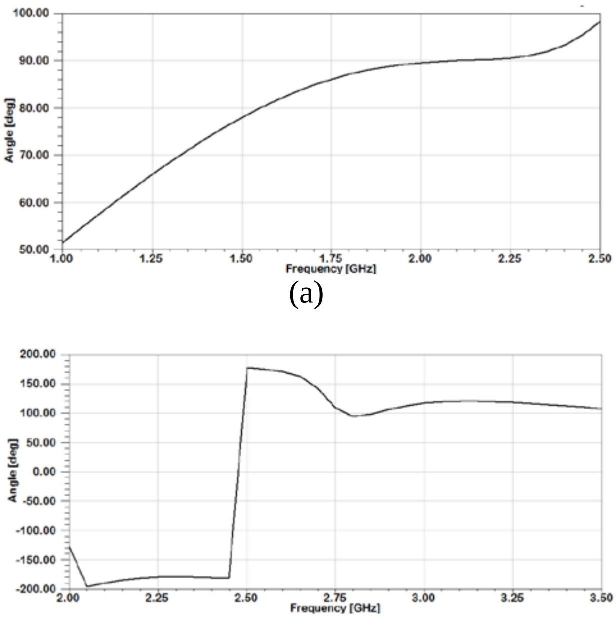
Fig. 4. **S**hows the S-parameter results of the proposed coupler for different values of ΔH, (a) for ΔH=45 Oe, (b) for ΔH=100 Oe and (c) for ΔH=150 Oe.

For the case of ΔH= 45 Oe, the difference between S_{31} and S_{21} is 4.03 dB at 2 GHz and phase difference is 89.88°, that for a TRD operation; the difference between S_{31} and S_{41} is 0.25 dB at 2.8 GHz and phase difference is 92.25°, that for a COD operation, this simulated result are shown in Fig. 4. a.

For the case of 100 Oe, The coupling and through results, shows those values are 6.04 dB and 1.80 dB, respectively, the return loss is 22.82 dB and isolation performance is 19.81dB at 2 GHz, for a TRD operation; and The values of these same parameters are given respectively 3.55 dB, 3.65 dB, 24.33 dB and 19.42 dB, at 2.8 GHz, that for a COD, this resultant scattering parameters shown in Fig. 4.b.

Finally, the last case of 150 Oe, The coupling and through results, shows those values are 6.15 dB and 1.82 dB, respectively, the return loss is 26.72 dB and isolation performance is 19.11 dB at 2 GHz, for a TRD operation; and The values of these same parameters are given respectively 3.58 dB, 3.43 dB, 35.95 dB and 22.74 dB, at 2.8 GHz, that for a COD, this resultant scattering parameters shown in Fig. 4.b.

The phase differences of simulated result for the three cases studied the is shown in Fig. 5.



(a)

(b)

Fig. 5. Phase of proposed coupler for (a) of S_{21} and S31 at 2 GHz, (b) of S_{41} and S_{31} at 2.8 GHz.

Table 2. S Parameters of Proposed CPWG Coupler for ΔH=150 Oe.

		Operating frequency	
		2 (GHz)	2.8 (GHz)
S-Parameter (dB)	S31	1.82	3.58
	S41	19.11	3.43
	S21	6.15	19.42
	S11	22.82	24.33
Phase difference		89.88°	92.25°
Size (mm)		19×23	

Analyzing the Table 2 above, the CPWG proposed coupler fulfill the essential conditions of coupler design. This device cap operate at 2 GHz or 2.8 GHz as a transdirectional (TRD) coupler or a a co-directional (COD) coupler, with a coupling level around the 3 dB and 4 dB successively. we can say that this coupler has a polyvalent function.

So the input at port 1 is equally divided at port 2 and port 3 with a phase difference of 89.88°for the first case and it achieve a 3 dB power division for the second case.

From the simulation results, the proposed 3 dB CPWG coupler has a better result with a reduced size for different operation but it has a disadvantage of a bandwidth becomes narrower, it is calculated from this formula [5]-[7].

$$\text{relative bandwidth} = \frac{f_2 - f_1}{f_0} 100\% \qquad (9)$$

Bandwidth percentage of TRD coupler at is approximately 5% and 6.07 % for the COD coupler.

V. CONCLUSION

A new polyvalent 3 db coupler is presented in this work. The structure, the geometric dimensions and the different characteristics transmissions were presented. The results obtained from the simulation in HFSS show the functioning of the coupler. The 3D simulations made it possible to demonstrate the overall magnetic behavior of the component

These studies have shown that the coupler under the proposed conditions can function as a TRD and COD coupler for different frequencies. This work made it possible to highlight the feasibility of a device

From the above analysis, we can conclude that the use of the ferrite substrate material can improve the performance of the component. A practical study will be put in place to verify the veracity of this model.

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