International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 10 Number 01 (January-2022)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2022.1001.001

Coplanar Asymmetric Plasmon Gap Isolator

A. Ouzer Nabil[1*], O. B. Arafat[1], A. Abderahim[2] and Y. Mariam Dahabaye[3]

[1]*Department of Electrical Engineering, National Institute of Science and Technology of Abeche, CHAD*
[2]*Department of Science and Technology, University of N'Djamena, CHAD*
[3]*National School of Information and Communication Technology, N'Djamena, CHAD*

**Corresponding author*

Abstract

New challenges of electronic technology require on chips integration of numerous passive components. The miniaturization of components used in integrated circuits of radio frequency systems and the optimization of their performance is becoming more and more essential. The coplanar isolator is one of non-reciprocal passive devices that contain magnetic materials for power sources protection. The Plasmon Gap Isolator component is designed to have a low insertion loss (around 1 dB) and an isolation greater than 20 dB.

Article Info

Received: 12 December 2021
Accepted: 15 January 2022
Available Online: 20 January 2022

Keywords

Isolator, Ferrite, Plasmon, Insertion loss, ENR.

Introduction

To meet the current growth needs of scientific applications in the telecommunications field, microwave specialists are required to:

design communication circuits operating at high frequencies;

miniaturize these circuits and implement higher performance, highly integrated and very low-cost technologies for commercial applications.

This context makes us look at this domain based on some research works that have led to the realization of coplanar isolators (Vincent D. Al, 2005; Kirouane and Al, 2009; Ouzer Nabil A. Al, 2014; Eric D. Al, 2020). These components are all localized planar components, used in the field of electronics, microwave and telecommunications. They are fabricated by stacking thin layers of magnetic and metallic on a substrate.

The isolator is a passive component and a quadrupole formed by 2 ports. Its function is to let the signal pass from port 1 to port 2 and to block it in the opposite direction. The first coplanar ferrite rods isolator was proposed in 1969 by Wen. This device worked close to gyromagnetic resonance, but despite proper isolation, the insertion losses in this prototype were still too high for commercial application.

Its applications can be, for example, decoupling between a source and a load to avoid signal return in case of mismatch, combining transmitters for multiplexing in telecommunication field, etc. (Ouzer Nabil, 2016). Coplanar isolators always have losses that are due to magnetic and dielectric materials, losses in the conductor, the influence of skin effects and radiation losses (Capraro S. Al, 2007; Krupka and Gabelich, 1999; Sivukhin, 1957; Caloz et T. Itoh, 2006).

A gap plasmon is an electromagnetic wave that propagates in a gap between two metal surfaces (Landy and al, 2013; Fabrice Pardo and al, 2011; Patrick Bouchon and al, 2011).

These waves have been studied by a classical description of noble metals, but the corresponding model has limitations and shows unnatural behaviour of sub-nanometric gaps.

In designing compatible isolators with monolithic integrated circuits, preferred structure is the coplanar structure, because of the simplicity of its connection to other components. This device has an operating range close to gyromagnetic resonance; and although isolation seemed to have been achieved, the insertion loss was still too high.

A new design of Plasmon Gap Isolator, consisting of an asymmetric coplanar waveguide on a ferrite substrate, a lower ground plane and a plasmon gap placed on the asymmetric plane will be proposed in this paper.

Design of asymmetric coplanar isolators

First step for the fabrication is the design and simulation of the new structure. The simulation tool used is HFSS (High Frequency Structure Simulator), which is an electromagnetic simulation software (Ansoft, 2009).

This step allows the optimization and sizing of the structure to be designed. To realize a coplanar slot isolator with low insertion losses (less than 1 dB) and an isolation of more than 20 dB, it is necessary to study the different component parameters.

The study was based on old structures, as shown in Fig. 1, which are made of a coplanar guide, with a ground plane on the bottom of the substrate not connected to the upper ground planes and slots. (Aly and El sharawy, 2002; Sauviac, 2013).

A bias magnetic field is applied perpendicular to the structure. The ferrite substrate (made of YIG - Yttrium Iron Garnet) (Waldron, 1964; Goldman, 2006; Ibrahim *et al.*, 2000) is 1 mm thickness. The properties of the ferrite used are summarized in Table 1. This material is used in the X-band (8-12 GHz). (Clerjon *et al.*, 1999b). In Fig.2, (Ouzer Nabil, 2016) compared simulation results of an asymmetric isolator with a ground plane on the whole surface of the YIG, with that of (Kirouane and Al, 2009), having a ground plane only on one side of the YIG (Fig. 1(a)). For these two structures already fabricated, we observe on the simulation results a low isolation of 7 dB (Fig. 2(a)) and an acceptable isolation of 12 dB ((Fig. 2(b)).

The two isolation peaks are observed in the magneto static zone (between 8 GHz and 9 GHz), that is close to the gyromagnetic resonance (Vaart, 1970), which is between 6 GHz and 8 GHz, where the μr permeability is very high.

In conclusion of their studies, we can tell that the second structure presents usable results but not sufficient.

Design of the new plasmon gap isolator structure

In order to optimize the performance of already fabricated coplanar isolators that we presented in the previous paragraph; we propose the new structure of Fig. 3. All dimensions and the polarizing magnetic field are identical, so only the plasmon gaps have been added.

Simulation results

Studies carried out in simulation show better results compared to the old structures considering the dimensions and the number of small gaps given in Table 2.

Simulations under HFSS were performed under an excitation field (Hi) of 160 kA/m and a frequency band from 5 to 12 GHz. The results are presented in Fig. 4.

The isolation performances obtained with this new structure show a peak of isolation in the band of magneto static waves appearance, at the right of the gyromagnetic resonance zone which is between 6 and 8 GHz.

The isolation is about 24 dB and insertion losses of 1.03 dB. We note a clear improvement over previously studied coplanar isolators (Kirouane and Al, 2009; Ouzer Nabil, 2016). In this configuration, non-reciprocal propagation is clearly evident in the X-band at 8.36 GHz.

Table.1 Magnetic properties of YIG substrate.

Type	ϵ_r	μ_r	$\tan\delta$	Ms (Gauss)	DH (A/m)	Hi (kA/m)
Y101	15,3	1	2.10^{-4}	1840	50	160

Table.2 Geometrical parameters of the new slot insulator structure.

Name	Dimensions (µm)
Alumina Substrate	635
YIG Substrate	1000
Line Thickness	5
Line Width	400
Slot	200
Gap plasmon length	500
Plasmon Gap Width	50
Component length	10 000
Component width	4000
NumberofPlasmon Gap	09

Table.3 Variation of the excitation field H.

Field strength (kA/m)	160kA/m	180kA/m	200kA/m
PI (dB)	-1.03	-1.16	-1
IS (dB)	-23.56	-26.8	-29.35
NRE (dB)	22.53	25.64	28.35
Reflection (dB)	-14.93	-20.2	-13.22
Frequency (GHz)	8.36	9	9.6

Fig.1 Asymmetric isolator with ground plane on: (a) asymmetric side; (b): any ferrite surface. (Kirouane and Al, 2009; Ouzer Nabil, 2016)

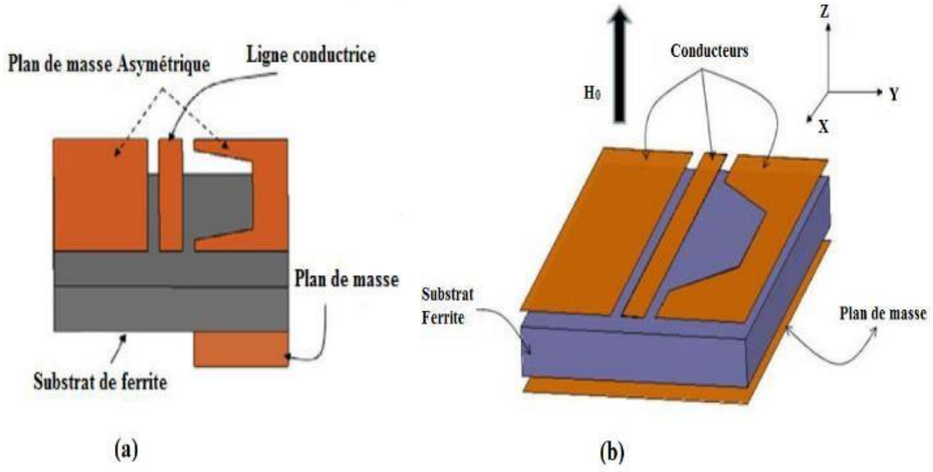
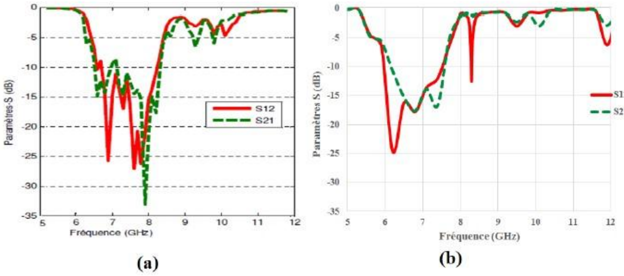


Fig.2 Isolator length slot 8-6 mm width 1 mm, with lower ground plane, (a): on one side of the YIG, (b): on the whole surface of the YIG. (Kirouane, 2010; Ouzer Nabil, 2016)



(a) (b)

Fig.3 Design of the new Plasmon Gap Isolator

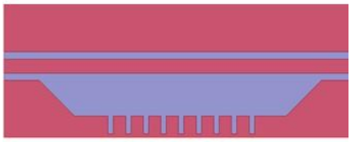


Fig.4 Plasmon Gap Isolator with Hi = 160kA/m (S_{12}: transmission or insertion loss; S_{21}: insulation)

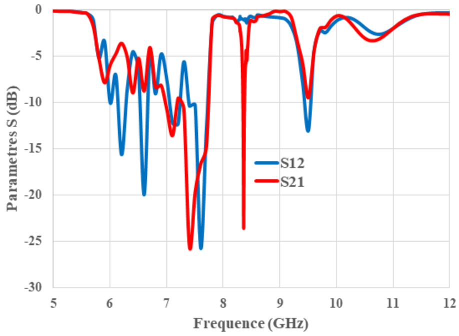
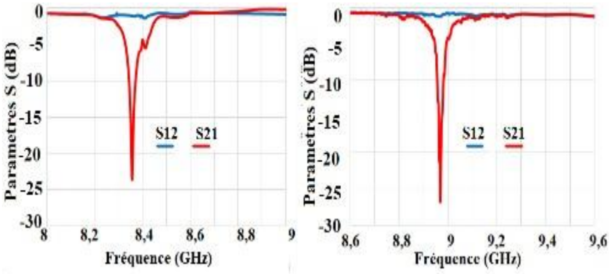
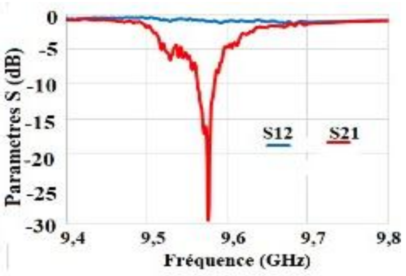


Fig.5 Variation of the H field: (a) H=160 kA/m, (b) H=180 kA/m, (c) H=200 kA/m

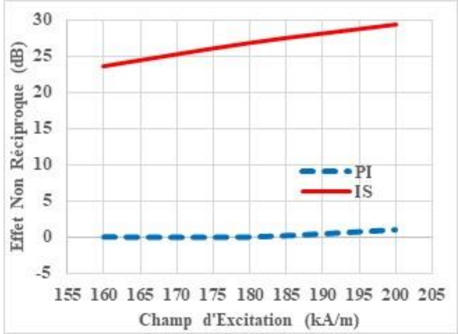


(a) (b)



(c)

Fig.6 Non-reciprocal effect as a function of the excitation field H



Excitation field variation H

The excitation field is varied from 160 to 200 kA/m, while keeping other parameters, in order to observe the influence of the field on the component.

From the results, the variation of the excitation field affects the non-reciprocal effect frequency (difference between insertion loss and isolation). We observe this effect at the frequency of 8.3, 9 and 9.6 GHz for fields of 160 KA/m, 180 KA/m and 200 KA/m respectively.

The S_{12} transmission (insertion loss) remains constant in the three cases considered, but the frequency and the isolation peak amplitude increases with the excitation field (see Table 3).

We can also see that the increase of the H field leads to an increase of the gyromagnetic zone, i.e. a decrease of the disturbance or attenuation zone of the signal. We present in Fig. 6 the evolution of non-reciprocal effect as a function of the applied Hi field. We notice that with this new isolator configuration, the isolation is improved and always remains above 20 dB, while the increase in field strength has little influence on the insertion loss.

Table 3 shows data for the three cases studied. The reflection remains acceptable for all three applied Hi field, however, this new structure gives better results with a field strength of 180 KA/m.

Isolators are non-reciprocal passive microwave devices, whose main function is to prevent the propagation of reflected waves due to the mismatch between the transmitter and the receiver.

The objective of this paper is to contribute to the improvement and miniaturization of a coplanar isolator for applications in various fields based on a coplanar line etched on ferrimagnetic material such as ferrite (YIG).

Based on our work results, we have selected a coplanar isolator design with nine (Fabrice Pardo and al, 2011) plasmon gap slots operating in the X-band. The insertion loss of this isolator is very low (1 dB) with an isolation strictly above 20 dB. As the excitation field increases, the non-reciprocal effect (NRE) becomes more important and the operating frequency of the isolator increases.

References

Aly, A. H. and E. B. El sharawy, « Modeling and optimization of parallel line edge mode microstrip isolator», IEEE Trans on Microwave Theory Tech Symposium, pp. 14796-1482, 2002.

Ansoft, An introduction to HFSS: fundamental principles, concepts and use, Ansoft LCC, 2009.

Caloz et T. Itoh, C. « Electromagnetic Metamaterials transmission line theory and microwave applications », John Wiley & Sons, 2006.

Capraro S. Al, Feasibility of an Integrated Self Biased Coplanar Isolator with Barium Ferrilte Films, IEEE Trans. On Components and Packaging Technologies, Vol. 30, No.3, 2007.

Clerjon S., Bayard B., Vincent D. & Noyel G. 1999b. « X-band characterization of anisotropic magnetic materials: application to ferrofluids». IEEE Trans. Magn., 35(1), 568-572.

Eric D. Al., Coplanar High Impedance Wire on ferrite substrate: Application to isolators, IEEE Transactions on Magnetics, Volume: 56, Issue: 10, Oct. 2020.

Fabrice Pardo and al., Light funnelling mechanism explained by magneto-electric interference, Physical Review Letters, vol. 107, Issue 9, 2011.

Goldman, A. « Modern ferrite technology », second edition, 2006 Springer Science, Business Media, Inc.

Ibrahim, B., C. Edwards, S. B. Palmer, « Pulsed laser ablation deposition of yttrium iron garnet and cerium-substituted YIG films », J. Magn. Magn. Mater. 220, pp. 183-187, 2000.

Kirouane, S. Al., "Simulation results on a new non symmetrical coplanar isolator structure using magnetic thin film", Progress in Electromagnetic Research (PIER), Vol. 8, (2009), pp. 161-170, 2009.

Kirouane, S., Conception et Réalisation d'un Isolateur Coplanaire en Bande X pour des Applications Télécoms, PhD Thesis, Université Jean Monnet de Saint-Etienne, 2010.

Krupka, J., S. Gabelich, « Comparison of split post dielectric resonator and ferrite disc resonator techniques for microwave permittivity measurements of polycrystalline yttrium iron garnet », Meas. Sci. Technol. 10 (1999) 1004–1008. Printed in the UK.

Landy and al., N., Homogenization analysis of complementary waveguide metamaterials, Photonics and Nanostructures – Fundamentals and Applications, vol. 11, pp 453-467, 2013.

Ouzer Nabil A. Al., Left-Handed Mode Propagation in Coplanar Isolator Based on Yttrium Iron Granet (YIG), META 2014 Conference, 20-23 May, SINGAPORE, 2014.

Ouzer Nabil A., Optimization of a coplanar field displacement isolator and magnetostatic waves operating in Xband, PhD thesis, Jean Monnet University of Saint-Etienne, 2016.

Patrick Bouchon and al., Total funnelling of light high aspect ratio plasmonic nano resonators, Applied Physics Letters, vol. 98, Issue 5, 2011.

Sauviac, B. « Meta-lines : Transmission line approach for the design of metamaterial devices », ch 2 of MetaLines : Transmission Line Approach for the Design of Metamaterial Devices, in Metamaterials and Wave Control (ed E. Lheurette), John Wiley & Sons, 2013.

Sivukhin, D. V. « The energy of electromagnetic waves in dispersive media », Opt. Spektrosk, vol. 3, pp 308-32, 1957.

Wen, C. P., Coplanar Waveguide: A Surface Strip Transmission Line Suitable for Nonreciprocal Gyromagnetic Device Application, IEEE Trans. Microwave. Theor. Technol. 17, 12, 1969.

How to cite this article:

Ouzer Nabil, A., O. B. Arafat, A. Abderahim and Mariam Dahabaye, Y. 2022. Coplanar Asymmetric Plasmon Gap Isolator. *Int.J.Curr.Res.Aca.Rev.* 10(01), 1-6. doi: https://doi.org/10.20546/ijcrar.2022.1001.001