Performance and Modeling of Saw Tooth Edge Mode Isolators

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Abstract **This paper presents modeling and results of a novel edge mode isolator. The new isolator can be optimized to increase isolation or to reduce insertion loss. This is achieved by introducing a saw tooth edge at the lossy periphery. Reduction of the insertion loss by about 0.3 dB is observed. In another simulation, an increase of isolation by about 3 dB compared to conventional edge mode isolator.**

I. INTRODUCTION

There has been a renewed in broadband isolators. Broadband isolators can be found in the form of a terminated Y-junction circulators. Y junction circulators have low insertion loss (less than 1 dB). However, the bandwidth of Y-junction circulators is limited to about 3:1. On the other hand, commercial edge mode isolators with up to 5:1 bandwidth have been demonstrated but with insertion loss of 2 dB and isolation of about 20 dB.

The concept of edge mode isolation was introduced in 1971 by Hines [1](Fig.1a). In this device, the asymmetry in current distribution is used to achieve nonreciprocal insertion loss. In one direction of the propagation, the current primarily flows on the short straight edge resulting in low insertion loss. In the opposite direction, the current flows on the long edge with lossy material resulting in high insertion loss. The structure received a lot of interest due to its broadband [2-5]. At low frequency just above resonance, the non-reciprocity is high due to strong magnetic properties. As frequency increases, magnetic properties of the ferrite start to diminish as the elements of Boulder tensor starts to be less anisotropic. However the electrical length of the isolator increases as frequency increases which compensates for the loss in anisotropy. This may explain the extra-ordinary bandwidth of edge mode isolators. It has been shown [5] that there is a trade off between insertion loss and isolation. For high isolation more of the conductor has to be covered with lossy material, which increases insertion loss.

In 1990 Kane [2] et al, introduced the concept of using a transverse slot to replace the lossy material. The slotted edge mode has shown low insertion loss than a similar Hines edge mode. However, the bandwidth was compromised. Other work proposed the use of shorting pins on one side (the lossy edge) of the isolator [4] resulted in a similar loss of bandwidth.

This paper presents a new approach where a saw tooth is used at the lossy edge to increase isolation especially at high frequency (Fig. 1b) and (Fig. 1c). The lossy material covers only the saw tooth to reduce insertion loss. The saw tooth can be either optimized for higher isolation or low insertion loss. Using small saw tooth generally results in low insertion loss and medium isolation. On the other hand large saw tooth increases both insertion loss and isolation.

This paper presents HFSS simulations in Section II. The results are compared to verify the effects of the new geometry and the paper is concluded in Section III.

II. RESULTS

Fig. 2 shows the performance of typical Hines obtained using HFSS simulator. The material used is Trans-Tech TT1-1500, Magnesium ferrites ($4\pi M_s$=1500 G). The dimensions of the substrate are 1”x1”x.03”. The applied magnetic field is assumed 700 Oe. The matching section tapers from a 50 ohms line (0.02” width) to a 0.4’’ inch wide section with impedance of about 5 ohms. The length of the taper is approximately 0.24” and the length of the isolator section is approximately 0.32”. The lossy material was assumed to have μ_r=10, ε_r=11, σ=100 mhos. The dimensions of the lossy material are 0.4”x0.15”x0.01”. Figure 2 shows an insertion of about 2.2 dB and an average isolation of about 24 dB. The lossy material covers about 0.07” of

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the conductor. It should be noted that the present results of the basic Hines edge mode isolator is in a reasonable agreement with the experimental results presented in Ref [2]. No data regarding the lossy material parameters and the DC bias were provided in that reference.

When a small saw tooth edge was added to the lossy side as shown in (Fig. 1b), the performance at the high end was recovered as shown in Fig. 3. The average insertion loss was about 1.90 dB with an isolation of about 23.44 dB. The isolation is comparable to Hines basic edge mode configuration while the insertion loss is lower. Another saw tooth edge with a tooth size of 0.07”x0.07” as shown in (Fig. 1c) gave about 2.0 dB insertion loss and about 27 dB of isolation as shown in (Fig. 4). These results show an improved figure of merit for the new isolator.

In summary, table 1. shows a comparison of the average Insertion loss and the isolation of different models used in simulations.

III. FIGURES

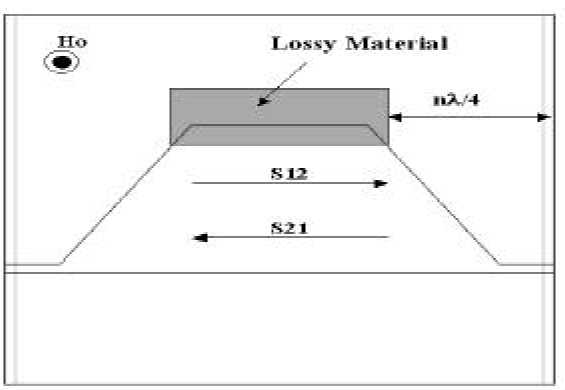

Fig. 1a

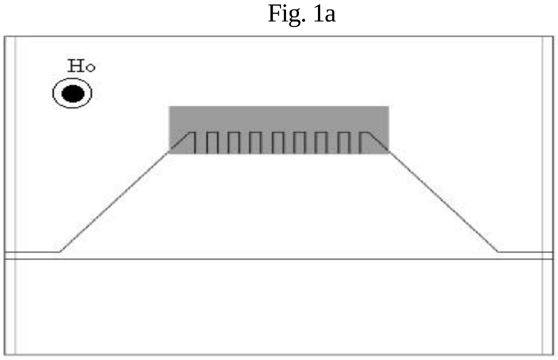

Fig. 1b

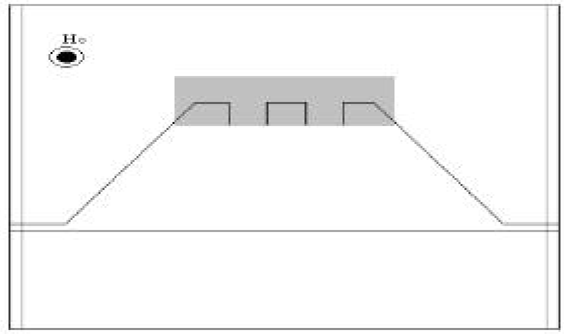

Fig. 1c

Fig. 1 Geometry of Different Edge mode Isolator including saw tooth edge

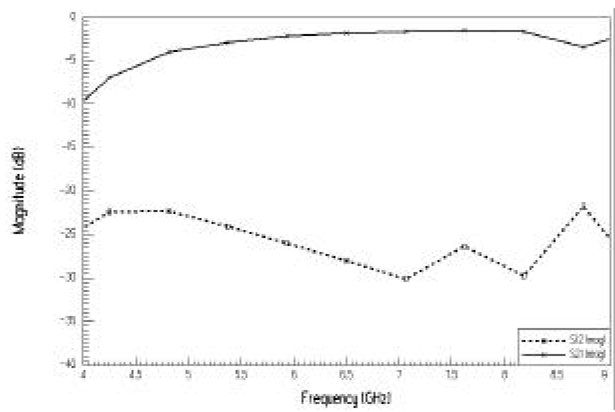

Figure 2 Insertion loss and Isolation versus frequency of Hines edge mode Isolator

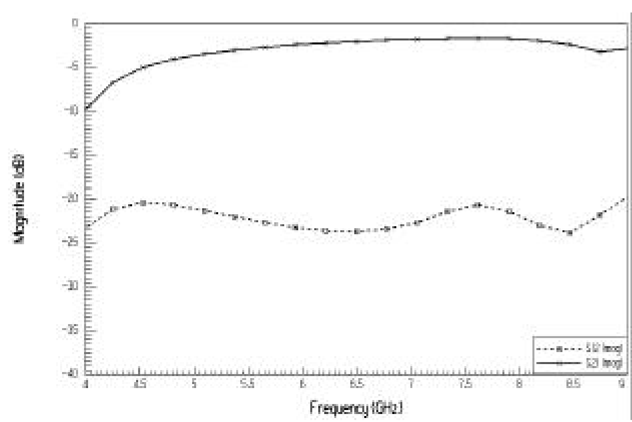

Fig. 3 Insertion loss and Isolation versus frequency of edge mode Isolator with small saw tooth edge.

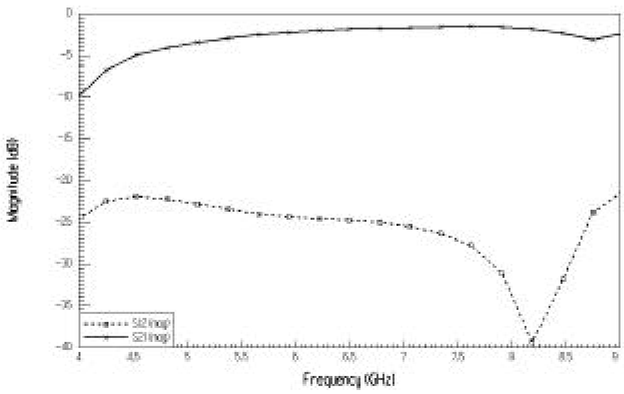

Fig. 4 Insertion loss and Isolation versus frequency of edge mode Isolator with large saw tooth edge.

Geometry	Average Insertion Loss(dB)	Average Isolation (dB)
Hines Model	2.20	24
Small saw tooth model	1.90	23.44
Large saw tooth model	2.00	27

Table (1) Comparison of average Insertion loss and isolation of different models used in the simulations

IV. CONCLUSION

This paper presents a novel edge mode isolator to improve figure of merit. Higher isolation was observed for the same insertion loss and lower insertion loss can be obtained for the same isolation.

ACKNOWLEDGEMENT

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REFERENCE

1- M.E. Hines, " Reciprocal and Nonreciprocal Modes of propagation in Ferrite Stripline and Microstrip Devices". IEEE trans. Vol. MTT-19, pp.442-451: May 1971.

2- Robert C. Kane, Thomas Wong, " An Edge-Guide Mode Microstrip Isolator with Transverse Slot Discontinuity" . IEEE MTTS. pp. 1007-1011: 1990.

3- Joseph Helszajn. "Ferrite phase shifters and control devices " , McGraw-HILL Book company, 1989.

4- K. Araki,"Reflection problems in a ferrite stripline ," IEEE Trans., pp 491-498. August, 1976

5- Elshafie, J. Abeles, E. Elsharawy," full wave analysis of edge mode isolators," IEEE part H., Dec. 1997.