AN EDGE-GUIDE MODE MICROSTRIP ISOLATOR WITH TRANSVERSE SLOT DISCONTINUITY

Robert C. Kane* & Thomas Wong**

*Motorola Inc., Schaumburg, Il. 60176
**Illinois Institute of Technology
Dept. of Electrical & Computer Engineering
Chicago, Il. 60616

ABSTRACT

A new configuration edge-guide mode isolator is described. The new device utilizes a transverse slot, located at one edge of the upper conductor, to effect the isolation function. Results are reported on a series of experiments which confirm operation of the device. Considerations for optimizing performance are detailed and supporting experimental data is included. A modified distributed lossy-termination Hines type isolator is also considered.

INTRODUCTION

Magnetostatic devices which employ the edge-guided mode of propagation have been described in the literature. In particular, methods for realizing effective edge-guide circulators and isolators have been detailed (1,2,3). These previously described devices utilize either distributed lossy terminations or a distributed short located at the isolation port to achieve the desired isolator operating characteristics. Araki, in his paper referenced above, describes experimental results which indicate that, although an edge-guide isolator with a distributed short termination is realizable, comparable performance utilizing an open-circuit termination is not achieved.

The edge-guide mode device described in this paper considers an alternative method of realizing isolator characteristics without the need for a termination of any kind. The new configuration provides for utilization of this type of device in circumstances requiring a strictly planar construction or one where a lossy, distributed termination is not practical.

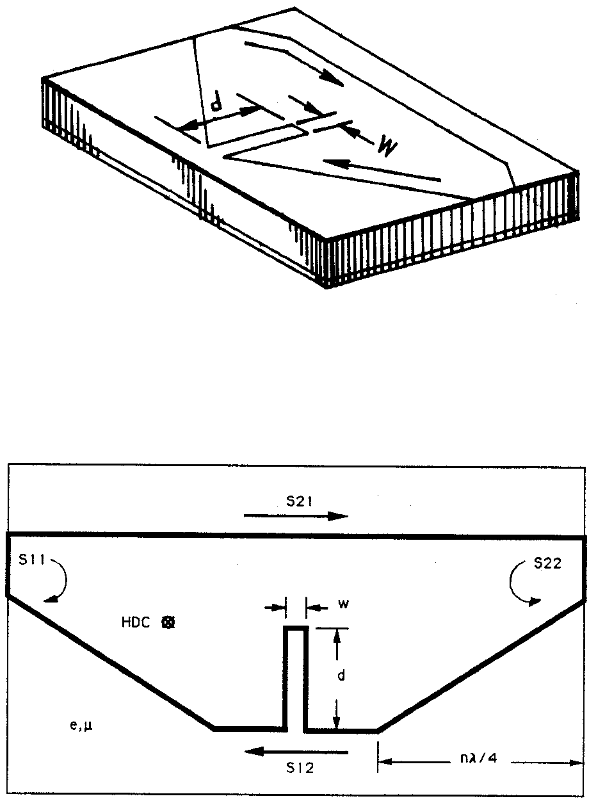

FIGURE 1

DEVICE FABRICATION

The new device is constructed with an upper conductor pattern as shown in Figure 1. Notice that no provision has been made for a termination along either edge as has been the case in prior embodiments. In this instance a transverse slot is located at one edge of the upper conductor. The transverse slot is, in fact, an open-circuit termination for the edge-guide mode isolator.

Impedance transformations, at either end of the device, are employed to match the associated external circuitry to the relatively low impedance of the isolator.

For the device under consideration we have:

Substrate:	Trans-Tech TT1-1500 1.00" x 1.00" x 0.030" <40 μ-inch surface $4\pi Ms = 1500$
Transformers:	0.238"
Isolator section:	0.40" conductor width 0.324" length
Slot:	0.24" depth 0.030" width

The biasing field is supplied by using a $SmCo_5$ magnet (0.75" dia. x 0.25" high) which resides on an insulating spacer. Spacer height is selected to provide the desired bias field strength.

DEVICE OPERATION

Figure 2 depicts the transverse electric-field for the edge guide mode which may be expressed as:

$$E_z = A\exp^{[-ax]} \qquad (1)$$

$$a = {}^{K}/_{\mu}\,\omega(\mu\ )^{1/2} \qquad (2)$$

This is commonly referred to as the 0th-order mode. This mode is established by introducing a biasing magnetic field (H_{DC}) normal to the plane of the ferrite substrate. Notice that this mode exponentially decays in the x direction and is effectively zero at large x when a wide upper conductor is used. This transverse characteristic is employed to effectively separate oppositely propagating components in the isolator region. The preferred edge for each of the separate propagating components is determined by the direction of the applied biasing field.

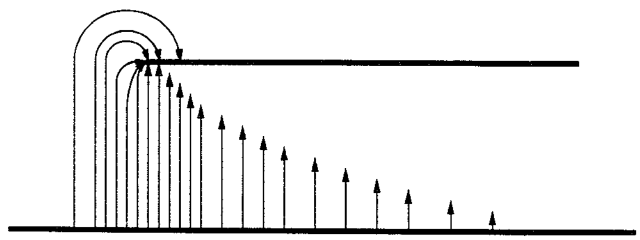

FIGURE 2

For a properly biased device with a transverse slot along one edge, energy propagating from port 1 toward port 2 will do so unimpeded. However, energy propagating from port 2 to port 1 will encounter the slot discontinuity. This discontinuity is an effective open-circuit and propagation beyond the slot, along this edge, is attenuated. The reflection, which typically occurs at a mis-match, is not observed. The energy component not transmitted beyond the slot does not appear at the incident port (port 2) due to the anisotropy in the ferrite substrate. Since the reflected component may not propagate it will dissipate in the substrate material.

This means of effecting the isolator function is in contrast to the Hines' device which employs a distributed lossy termination to attenuate the energy propagating in one direction. The transverse slot isolator is effectively the dual of Araki's distributed short termination where he describes the attenuation mechanism as mode conversion.

EXPERIMENTAL RESULTS

The transverse-slot edge-guide isolator, described above, has been constructed and evaluated. Figures #3 and #4 show the performance of this device.

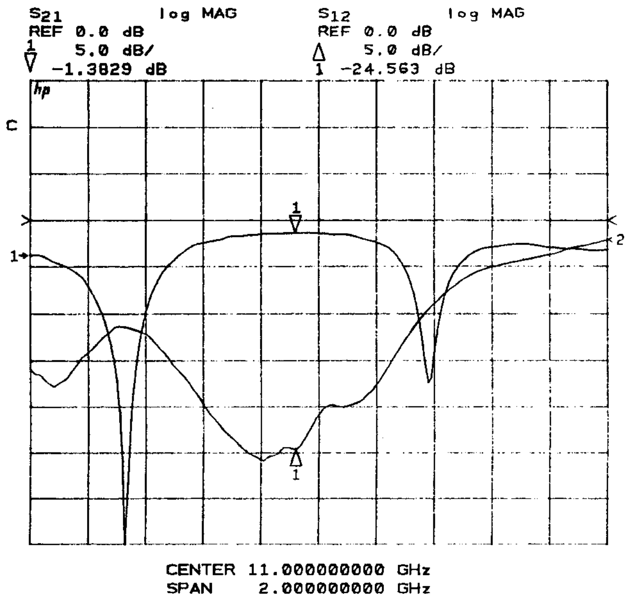

FIGURE 3

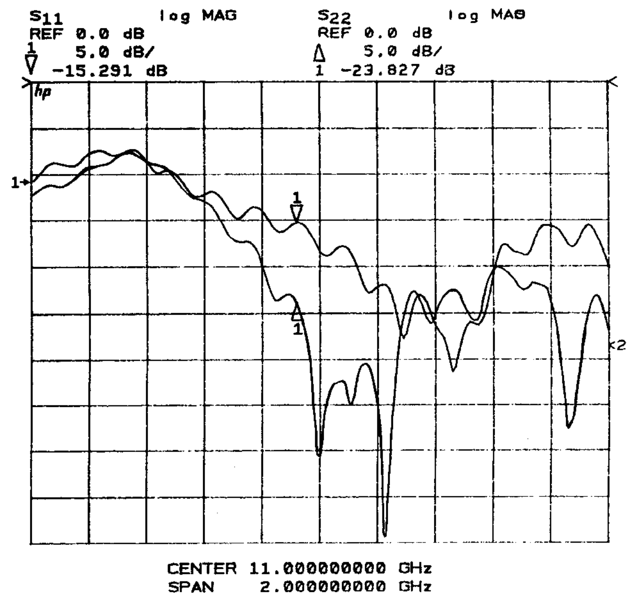

FIGURE 4

S_{21} Bandwidth ($\lvert S_{21}\rvert < 1.5$dB)		2.0GHz
S_{12} Bandwidth ($\lvert S_{12}\rvert > 18$dB)		3.6GHz

Notice that the insertion loss (S_{21}) is entirely co-incident with the isolation band (S_{12} <-18dB).

An edge-guide device of Hines' configuration, as depicted in Figure #5, was constructed and performance is shown in Figure #6. The lossy termination shown is realized as a deposited thick-film of R_S = 100Ω.

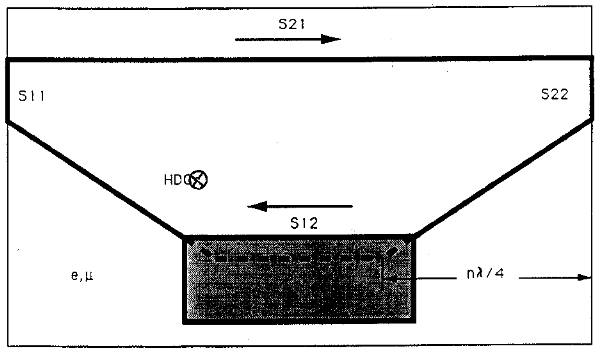

FIGURE 5

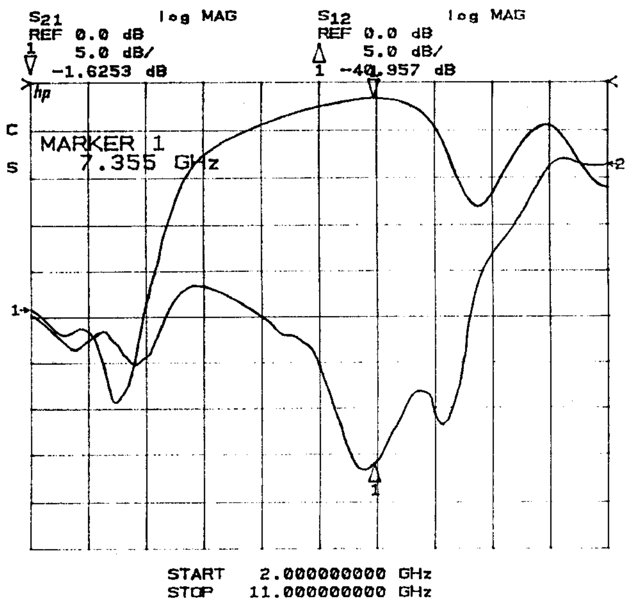

FIGURE 6

Comparing the performance of the transverse slot isolator to that of either the Hines' device or the results reported in the Araki paper, referenced earlier, we observe that the usable insertion loss bandwidth of the transverse slot isolator offers an improvement. Further, the magnitude of the minimum insertion loss is similar for all three structures.

Significant improvements in the minimum insertion loss have been observed as a result of improving the substrate surface finish. The devices reported here were constructed with surface roughness of approximately 40 micro-inch. A series of experiments, conducted with TT1-1500 ferrite of varying roughness ranging to less than 10 microinch, have shown loss improvements of as much as 0.5dB. An improvement of this magnitude incorporated into the transverse-slot isolator considered here would yield an insertion loss of less than 1.0dB over the usable bandwidth.

The slot geometry has been determined experimentally and is found to yield optimum performance when the length is one-fourth wavelength of the propagating energy. Similarly, slot width affects isolator performance with a slot width of approximately 0.030in. found to be optimum.

A device, constructed with multiple slots, has been evaluated. It was anticipated that the multi-slot technique should yield proportionately improved performance. This improvement was observed as an increase in isolation. Future work will consider bandwidth improvements which may be realized by employing multi-slot devices where the slots are of dis-similar length.

An alternative lossy termination device is shown in Figure #7 where the lossy material resides beneath the upper conductor of the isolator and directly on the ferrite substrate. Performance data is shown in Figure #8

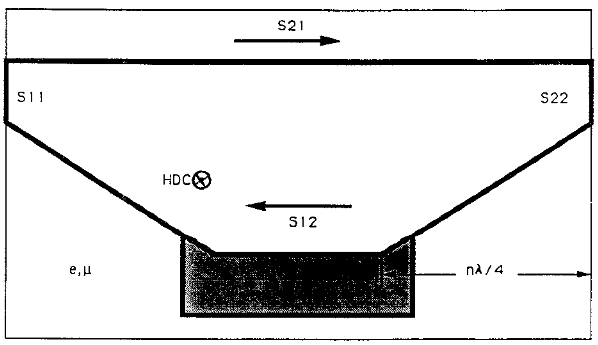

FIGURE 7

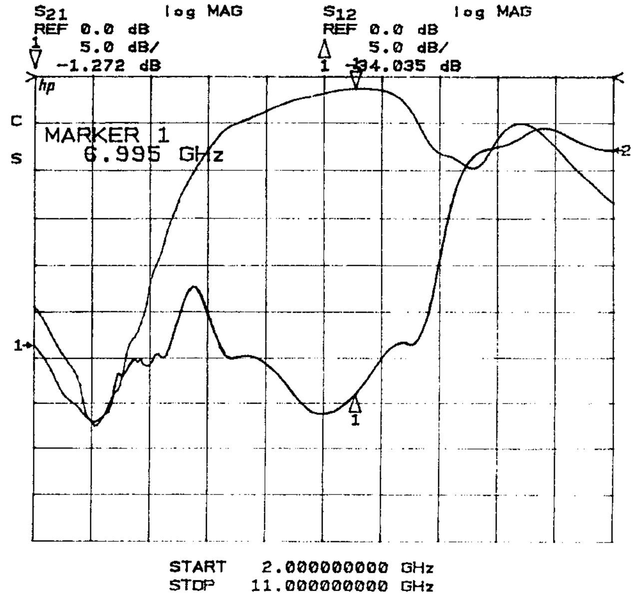

FIGURE 8

The experimental results indicate that no appreciable advantage is derived from this approach. The performance suggests that in the edge-guide mode, with the electric-field concentrated near the edge of the upper conductor, fringing fields are significantly greater than is the case in conventional microstrip or stripline.

CONCLUSION

The transverse-slot edge-guide mode isolator has been described and evaluated. Device performance is found to be comparable to alternative geometry edge-guide isolators. Since the transverse-slot device is strictly planar and requires no lossy termination, it may be realized as a simple metallization on appropriate substrate with only the attendant biasing magnet required to complete the operable circuit function.

REFERENCES

(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) K. Araki et al, "Reflection Problems in a Ferrite Stripline", IEEE Trans. Vol. MTT-24, pp. 491-498:Aug. 1976.

(3) M. Dydyk, Edge-Guide: One Path To Wideband Isolator Design" Parts I and II, MICROWAVES, Jan. & Feb. 1977.