# Thin Film Isolators Utilizing MSSW Transducers

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## Abstract

This paper presents a novel concept of ferrite isolators. The new type of isolator is comprised of a nonreciprocal surface wave transducer in the form a miniature strip line mated with a finite ground plane. The transducer is constructed on a thin YIG film grown on a GGG substrate. Since thin magnetic films can be grown on GaAs or Si, the present isolator can be built and integrated on the same chip with other passive and active devices. A 250 microns x 2000 microns version of the new structure gave a 6 dB insertion loss and about 30 dB of isolation at 7.8 GHz. The return loss was more than 20 dB.

## 1. Introduction

Theoretical and experimental work on magnetostatic surface wave (MSSW) transducers was initially presented by Ganguly and Webb [1]. Further work included edge effects of the transducer [2] and ferrite film width [3]. Magnetostatic approximations have been employed in these papers. Both the fully electromagnetic and the simple magnetostatic solutions [4] reveal that magnetostatic surface waves (real and complex) can be highly nonreciprocal [5] in the presence of a ground plane. However, to date MSSW transducers have not been used as isolators or circulators for the following reasons :

1. High insertion loss. The air-guided MSSW are slow. So, for a given loss in dB per sec., the insertion loss is usually high (10 dB or more).
2. Low isolation due to
   a. Electromagnetic coupling between the strips.
   b. The excitation of MSSW in the opposite direction at the ferrite-dielectric surface as show in Fig. 1(a).

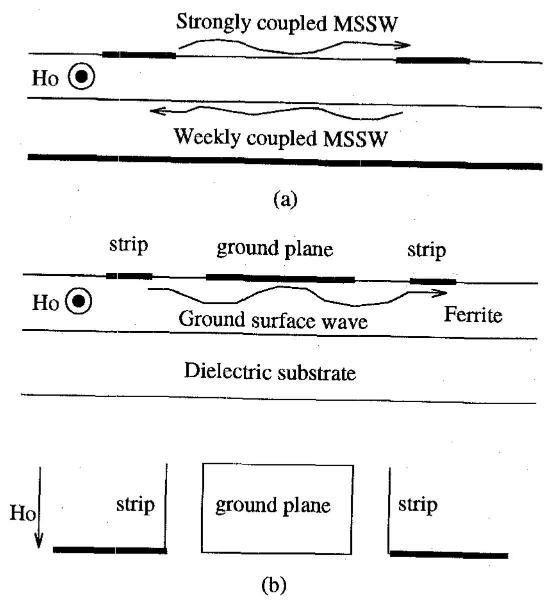


**Figure 1** *(a) Conventional MSSW transducers. (b) Thin film MSSW isolator.*

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Although the oppositely propagating surface waves may be weakly coupled, it can have a significant effect on the isolation as well as the isolator insertion loss.

This paper presents a new concept to utilize MSSW nonreciprocity. The present structure is constructed of a strip line mated with a finite ground plane as shown in Fig. 1(b). The ground surface waves have different bandwidth, dispersion, and coupling to the line from ferrite-air surface waves. Therefore, over the ground guided MSSW bandwidth, the insertion loss will be nonreciprocal. The presented isolator is expected to have the following advantages:

1. Ground-guided MSSW are very fast. Therefore, for a given loss per sec., ground-guided MSSW will have low loss.

2. The bandwidth of ferrite-dielectric surface wave is

$$\gamma\sqrt{H_0(H_0+4\pi M_s)} \le f \le \gamma(H_0+2\pi M_s) \qquad (1)$$

whereas the bandwidth of ground-guided MSSW is given by

$$\gamma\sqrt{H_0(H_0+4\pi M_s)} \le f \le \gamma(H_0+4\pi M_s) \qquad (2)$$

Therefore, over the upper bandwidth of ground-guided MSSW, air and dielectric-guided MSSW are cutoff. Thus, there is no coupling or loss due to oppositely propagating surface waves.

3. The ground plane will diminish the electromagnetic coupling between the input and the output.

4. Since the ground plane is in the same plane as the transducers, there is no restrictions on the strip line width, ferrite layer thickness. These can be made thin to make the device more compatible with MMIC GaAs wafers.

In addition to the significance of meeting the above size requirements, an improvement in the performance of ferrite isolators can be achieved. While bulk ferrite substrates, used in conventional isolators, have a line width of tens or even hundreds of Oersteds [7], thin magnetic films grown on matched substrates can have a line width of less than one Oersteds [8]. Low values of line width will improve coupling to the leaky magnetostatic surface waves in the backward direction [4]. Therefore, high values of isolation can be obtained.

## 2. Experimental Results

The isolator under test is shown in Fig. 2. Fig. 2(a) shows the short-short type isolator with parallel magnetization where transducers 1 and 2 are shorted to the ground plane. The dimensions of the ground plane are

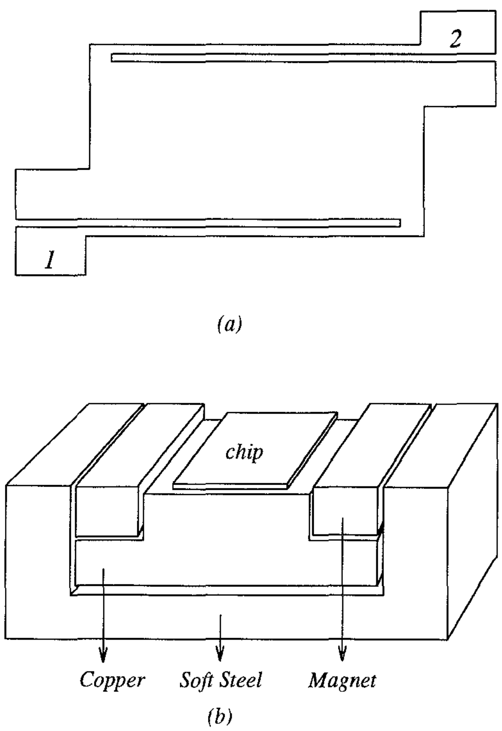


**Figure 2** *(a) Thin film isolator.*
*(b) Fixture that's been built.*

250 microns x 2000 microns and the transducer width is 40 microns. The substrate is a 46 microns YIG ($4\pi M_S$=1800 G) grown on a 500 microns GGG substrate. A fixture was built to produce the magnetic field and hold the chip, as shown in Fig. 2(b). The value of $H_0$ varied between 2700 Oe at the magnet to 1500 Oe at the chip. The structure was placed on a four probe cascade station for experimental testing. The HP-8510 network analyzer was used to measure the s-parameters of the chips. The measured results are shown in Figure 3. An insertion loss of about 6 dB and 30 dB of isolation were obtained at 7.8 GHz. The bandwidth was about 1 GHz. This bandwidth corresponds to

$$\gamma(H_0 + 2\pi M_s) \le f \le \gamma(H_0 + 4\pi M_s) \qquad (3)$$

assuming $H_0$=1500 Oe. The return loss was about 22 dB at center frequency.

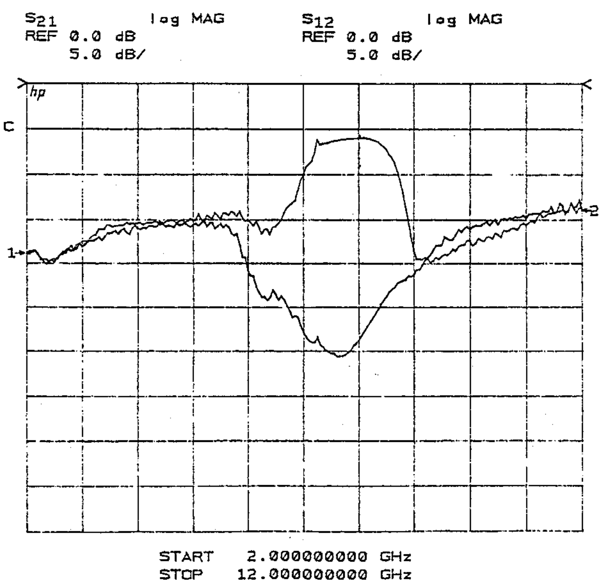


**Figure 3** *Insertion loss of thin film isolator.*

Several isolators with wider ground plane width have been built and tested. Results of isolation, return loss and insertion loss for short-short type isolator with ground plane width $w_G$=250, 500, 1000 and 2000 microns are compared and shown in Fig. 4. Here the transducer width $w_T$=40 microns and slot width $s$=30 microns are kept the same.

Isolators with open-short and open-open terminations have been built and tested. The insertion loss was consistently 4 dB more than that of short-short type ones with the same ground plane width. This has been found to be due to the mismatch at the open-circuited transducers. Therefore, the short-short type was the only structure that gave low insertion loss.

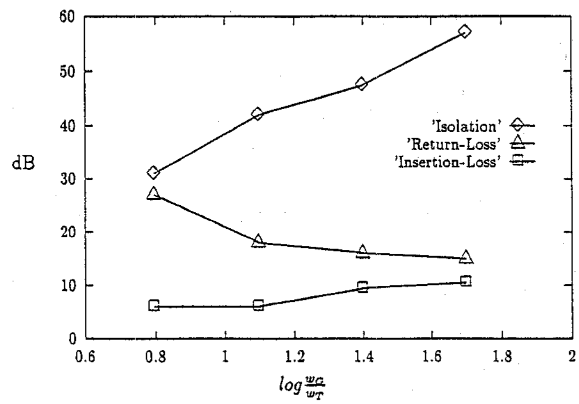


**Figure 4** *Experimental results for isolation, insertion loss and return loss.*

From Fig. 4 we conclude that the insertion loss will decrease when the ground plane width decreases. Thus, a narrower ground plane is required for a low insertion loss isolator. Reducing the insertion loss can also be achieved by increasing the film thickness or increasing the $4\pi M_S$. Since, the isolation will decrease as the ground plane width decreases, there will be a trade-off between low insertion loss and high isolation.

## 3. Conclusion

Thin film isolator employed the concepts of MSSW transducers was described in section 1. Experiments had been done to verify the isolator that worked well and a 6 dB insertion loss had been obtained. Future work will include optimizing the insertion loss and isolation by developing a theoretical electromagnetic simulation. Modifying the isolator to function as a circulator is also under way.

## 4. References


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