A MAGNETOSTATIC FORWARD VOLUME WAVE DIRECTIONAL COUPLER WITH A GUIDING SLOT STRUCTURE

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ABSTRACT

A new configuration of a magnetostatic forward volume wave (MSFVW) directional coupler has been proposed. It should be noticed that a slot line structure is adopted. The propagation of MSFVW along the structure has been confirmed experimentally except around the lower limit of MSFVW band. A directional coupler with adjacent guiding slots has been fabricated on an epitaxial yttrium iron garnet (YIG) grown on a gadolinium gallium garnet (GGG) substrate. A nearly 100 % power transfer from one slot line to the other has been demonstrated. The directivity was measured to be above 20 dB except around the lower frequency limit.

INTRODUCTION

Waveguides for magnetostatic wave (MSW) are of interest because of potential usefulness(1,2). Guiding MSW may be used to increase delay time on a given size sample, or to make a ring resonator(3). Furthermore, the controlled coupling between adjacent waveguides will make it possible to obtain signal routing devices such as adjustable directional coupler.

Previously, the directional coupling of magnetostatic surface wave (MSSW) has been studied(4,5). However, MSSW propagation is highly anisotropic and is not feasible to make waveguide bends. Furthermore, below 4.2 GHz, MSSW saturates due to non linear effect at lower power level than MSFVW. On the other hand, MSFVW can propagate in any direction in the plane. So a new type of waveguide has been proposed and examined. The structure consists of a slotted metallic layer deposited on a YIG film. Thereafter a directional coupler with two adjacent slot structure has been fabricated by a conventional photolithography technique and tested.

EXPERIMENTS SHOWING A GUIDING PROPERTY OF A SLOT STRUCTURE

A slot structure gives us the intuition that it may have a guiding ability of MSFVW because a metalized YIG film holds MSFVW of higher phase velocity than non metalized one. On top of this, an idea that the slot structure is very useful for a directional coupler from a feasible fabrication point of view has a temptation which leads us to check if the slot is able to guide the MSFVW modes. The structure for testing the guiding ability is depicted in Fig.1. Aluminum is deposited on an alumina substrate by

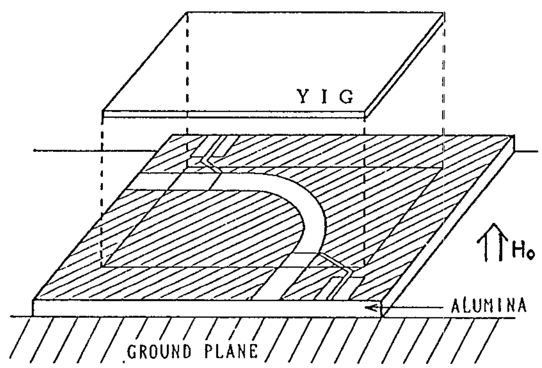

Fig.1. Geometry of waveguide for MSFVW.

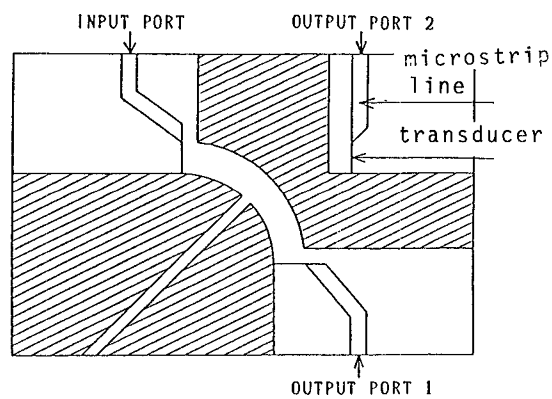

Fig.2. Mask pattern of MSFVW waveguide.

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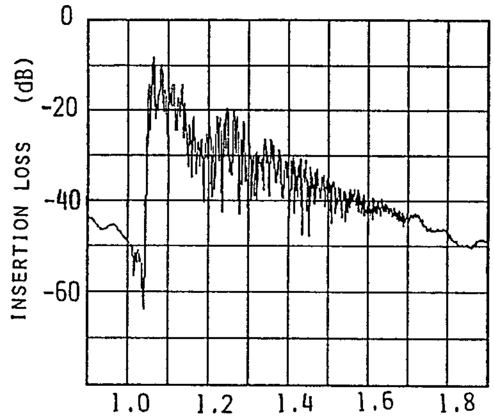
evaporation and etched to construct a guiding slot by a conventional photolithography technique. On the structure YIG/GGG composite is fittingly placed. The point is that the slot is curved to show the guiding ability clearly and besides a transducer is set on the port 2 to catch the leakage, if any, as shown in Fig.2. The hatched part in the figure is metalized and grounded. The dimensions are given in detail as follows: the slot is 2 mm wide and 11 mm long. YIG has a rectangular shape of 12 mm width, 20 mm length and 18.5 μm thickness. The alumina substrate is 20 mm wide, 30 mm long and 1 mm thick. Each transducer is 2 mm long and 75 μm wide. The input and output ports are connected with microstrip line of which the characteristic impedance is 50 Ω. An additional slot is made to suppress electromagnetic breakthrough, as illustrated in Fig.2.

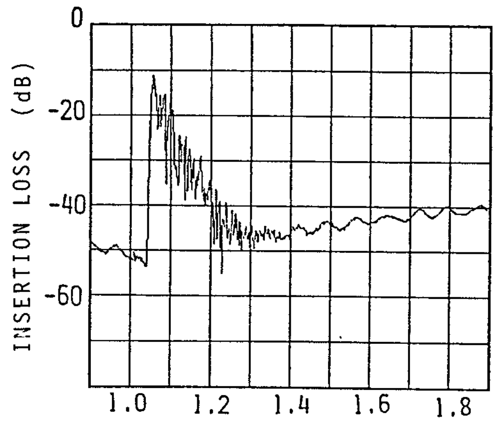
The output power on the ports 1 and 2 in the case when the dc biasing magnetic field of 500 Oe is applied are shown in Fig.3. Collating Fig.3(a) persuade us that the MSFVW are guided along the slot. On the other hand, it can be seen from Fig.3(b) that some leakage are received on the port 2, although they are restricted only in the narrow frequency band near the lower cutoff frequency of the MSFVW mode.

DIRECTIONAL COUPLER USING GUIDING SLOT STRUCTURE

Fig.4 shows a directional coupler using a slot structure which has been assured to have a guiding property in the previous section. The slot width is 0.7 mm and two slots with the 2.5 mm long coupling section is separated by 50 μm. Each transducer is 0.7 mm long and 50 μm wide. The epitaxial YIG film was 18.5 μm thick grown on a 0.4 mm thick GGG substrate and was cut out to be a rectangle of 12 mm × 20 mm. The input and output characteristics of this MSFVW directional coupler are shown in Fig. 5 for the case when the dc internal magnetic field of 430 Oe is applied. It can be easily understood from these figures that the device works effectively as a directional coupler. The results in Fig.5 say that if the port 1 is the input port, the output on the port 2 shows the peaks at 1.30 GHz, 1.55 GHz and 1.70 GHz, while the output on the port 4 shows the dips at each corresponding frequency and besides that when the output on the port 4 takes the maximum values at 1.4 GHz, 1.65 GHz and 1.85 GHz, the output on the port 2 becomes minimum at the corresponding frequencies. These facts tell us that the MSFVW goes back and forth from one slot



(a)



(b)

Fig.3. Insertion losess of MSFVW waveguide a) for output port 1 and b) for output port 2 with internal biasing magnetic field of 520 Oe.

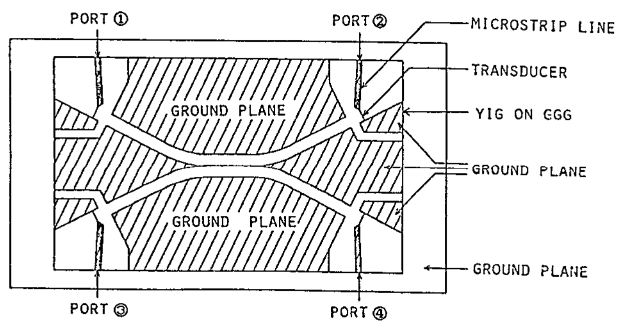
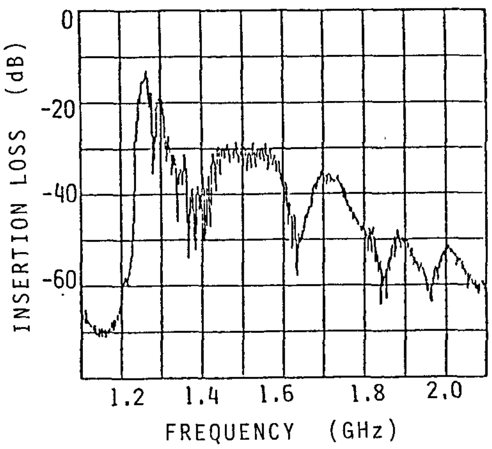
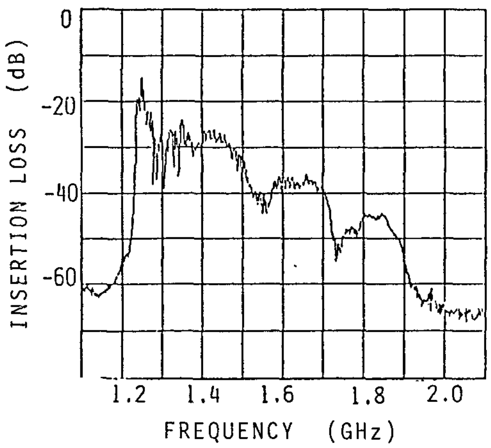


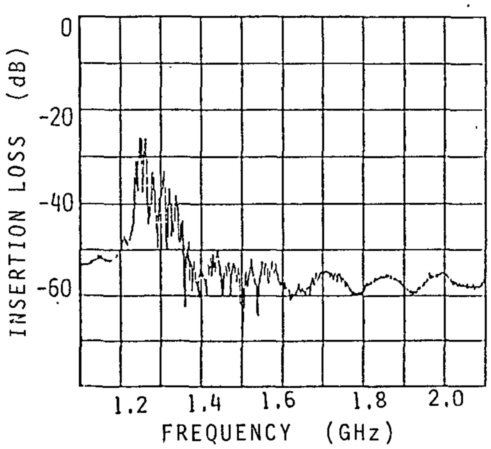
Fig.4. Pattern of MSFVW directional coupler.



(a)



(b)



(c)

Fig.5. Input-output characteristics of MSFVW directional coupler a) between ports ① and ②, b) between ports ① and ④ and c) between ports ① and ③ for internal biasing field of 430 Oe.

to the other. In other words, a nearly perfect coupling occurs within the path of less than 2.5 mm.

The output on the port 3 should not be observed as an ideal function of directional coupler, if the MSFVW is launched at the port 1. However, not a little output power is observed at the port 3 at a certain range near the lower cutoff frequency of the MSFVW. This is not desirable, but it is clearly due to the fact that the slot structure loses its guiding ability over the frequency range.

Three parameters to represent the characteristics of a directional coupler is given at a few frequencies in Table 1. Directivity of 20~25 dB is obtainable over the frequency range of some 300 MHz. These would be considered a promising figures from a practical point of view. Coupling factors show that nearly a perfect coupling is performed in this

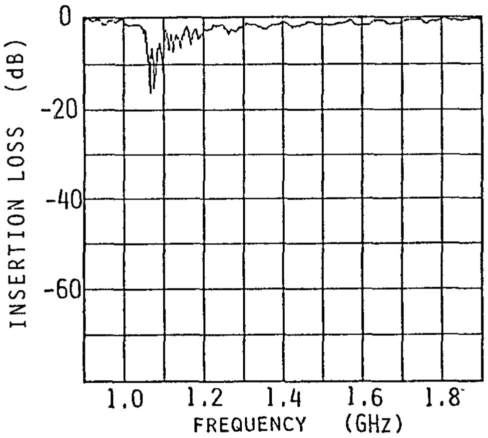


Fig.6. Return loss of MSFVW directional coupler.

device. On the other hand, we can see that insertion loss is too much to be practical. The authors, however, do not take it as a serious problem since the high insertion loss comes up from mismatching between a transducer and a microstrip line. Return loss was measured at the port 1 at 380 Oe of biasing magnetic field. The mismatching is quite clear except the narrow frequency range near the lower cutoff, as shown in Fig.6.

FREQUENCY (GHz)	1.40	1.65	1.85
COUPLING (dB)	28	38	45
DIRECTIVITY (dB)	25	20	10
INSERTION LOSS(dB)	45	50	60

Table 1. Coupling, directivity and insertion loss of the directional coupler

CONCLUSIONS

Firstly the authors assured that a slot structure is useful for the waveguide for MSFVWs. Secondly they have demonstrated a new coplanar type of a MSFVW directional coupler using the guiding slot structure. The proposed directional coupler was shown to perform its function effectively, although it has the problem that it doesn't work over the narrow frequency range near the lower cutoff of MSFVW mode.

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