ADJUSTABLE MAGNETOSTATIC SURFACE WAVE DIRECTIONAL COUPLER

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ABSTRACT

This paper describes a new magnetostatic surface wave (MSSW) component : an adjustable MSSW directional coupler. This device, similar to the surface-acoustic-wave (SAW) multistrip coupler[1], has been realized on an yttrium iron garnet (YIG) film. A 100% power transfer from one track to the other has been obtained at 2.5 GHz. The unidirectional coupling has frequency filtering characteristics due to the dispersion of MSSW. The device presents a feature very important for applications : the coupling is continuously adjustable by an applied magnetic field, a variation of about 50 Oe being necessary to switch the power from one track on to the other.

Introduction

The adjustable directional coupler considered here is presented schematically in fig.1. The structure of

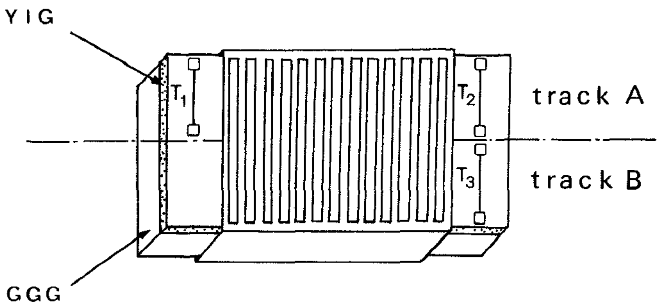

Fig.1- Configuration of an adjustable magnetostatic surface wave directional coupler.

this new MSSW component is similar to that of the SAW multistrip coupler[1]. It consists of a grating of parallel metallic strips on a YIG film. The shorted bar grating is connected to the metallic film deposited on the bottom face of the substrate. Referring to fig.1, if a MSSW, with a wave vector k perpendicular to the strips, impinges on one half of the structure (along track A for instance), a current is set up in the loop constituted by a strip and the metallic film under the YIG. This current also appears in track B where it generates a new MSSW. As in the case of the SAW coupler, the behavior of the MSSW coupler can be described in terms of a symmetric and an antisymmetric modes having different propagation constants. The power of the MSSW goes back and forth from one track to the other as a consequence of the interference of these two modes. The frequency dependent coupling constant K is given by $K = \frac{(k_a - k_s)}{2}$ where k_a and k_s are the wavenumbers of the antisymmetric and symmetric modes respectively. The power transferred from track A to track B is given by $P_B(L) = P_o \sin^2(KL)$ where P_o is the input power and L the coupling length. A total power transfer is obtained for $L_T = (2n+1)\frac{\pi}{2 \cdot K_n}$ where $n = 0,1,2,...$

The results reported in this paper include the variation of the coupling with frequency and with number of coupling strips. The measured coupling constant is compared to that calculated from the experimental values of the symmetric and antisymmetric mode wavenumbers. Taking into account the results of this work, a new device has been implemented and tested.

Experimental Results

First experiments are carried out on the coupler-transducer configuration shown in fig.2. The MSSW are

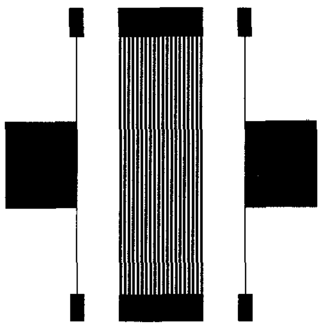

Fig.2- Coupler-transducer pattern of the first device.

propagated in a 20 µm thick YIG film grown by liquid phase epitaxy on a gadolinium gallium garnet (GGG) substrate. A magnetic field H = 288 Oe is applied in the plane of the film perpendicular to the propagation direction of the waves. The coupler consists of 20 aluminum strips, 9 mm long, 75 µm wide and separated by 75 µm. The coupler and three microstrip transducers (T_1, T_2, T_3), 3 mm long by 30 µm wide are etched in a 5 µm thick aluminum film deposited on the YIG surface. Microwave energy is applied at T_1 and output signals are detected at transducers T_2 and T_3. The insertion loss between T_1 and T_2 ($I_{1 \to 2}$) and between T_1 and T_3 ($I_{1 \to 3}$) are measured as a function of frequency and number of coupling strips. This number N in the coupler is varied by chemical etching. Fig. 3 shows the frequency dependence of coupling between 2.4 GHz and 2.7 GHz for devices without strip grating (N=0; fig.3a) and with a 18 strip array (N = 18; fig. 3b). The coupling between the two tracks is observed at 2.49 GHz for N = 18. The insertion loss $I_{1 \to 3}$ at this frequency are 20 dB while they are 35 dB for N=0. As can be seen in fig.3b, coupling is a periodic function of MSSW frequency. This has been previously shown in the case of the coupling between two distinct YIG films[2], because the MSSW are strongly dispersive, the coupling constant changes with frequency. When the two tracks are coupled, the high insertion loss observed is due to the reflection of the MSSW by the metal plate deposited between transducers T_2 and T_3. The variation of $I_{1 \to 3}$ vs number of coupling strips has been measured for different frequencies. An example at 2.45 GHz is given in fig. 4. $I_{1 \to 3}$ is a periodic function of N, the periodicity in the given example is 975 µm corresponding to a coupling constant $K = 3.2\ mm^{-1}$. K has been measured for different frequencies. The results are summarized in table 1.

The symmetric mode when propagating through the periodic structure generates a current in the parallel metallic strips. No current is generated by the antisymmetric one. In consequence, the propagation constants of these

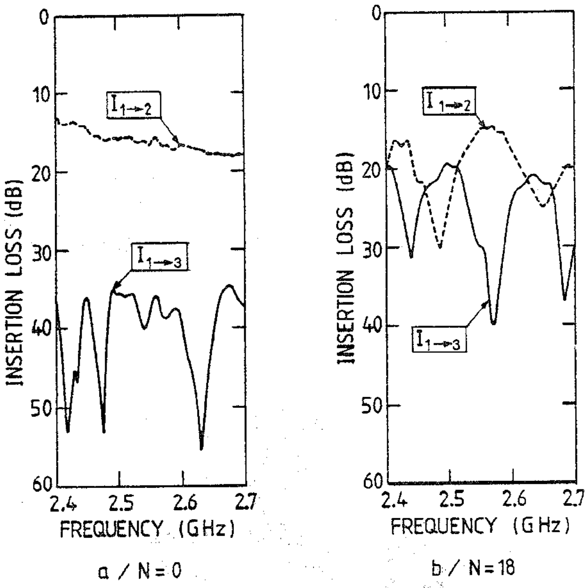

Fig.3- Frequency dependence of directional coupling for the first coupler.

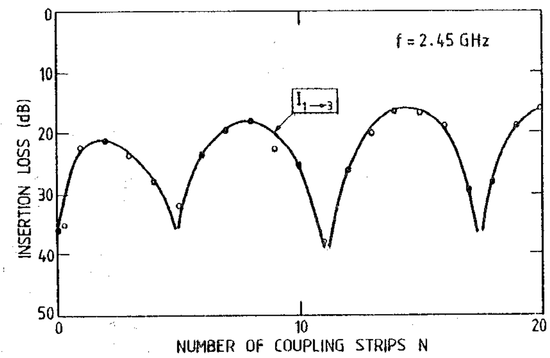

Fig.4- Variation of insertion loss $I_{1\to3}$ vs number of coupling strips

f (GHz)	K (mm^{-1})	K' (mm^{-1})
2.45	3.2	1.9
2.50	3.7	2.3
2.55	4.2	2.8
2.60	4.6	3.3
2.65	4.6	3.8
2.70	4.9	4.4
2.75	5.2	5.0
2.80	6.0	5.6
2.85	6.0	6.3
2.90	6.3	7.1
2.95	6.8	8.0
3.00	8.6	8.9

Table 1. Comparison of the coupling constant K obtained from variation of insertion loss versus number of coupling strips and K' deduced from the variation of phase versus frequency for the symmetric and antisymmetric modes.

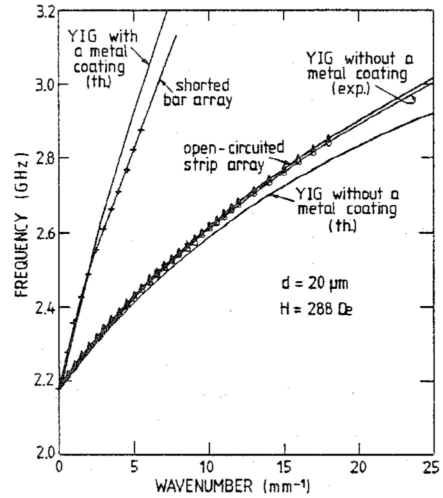

Fig.5- Theoretical and experimental dispersion curves for the studied configurations.

two modes are different. k_a has been obtained by measuring the variation of phase versus frequency of a MSSW propagating under an open-circuited strip array whereas for k_s the strips were electrically shorted. Fig.5 represents the experimental dispersion curves of these modes and the dispersion after the periodic structure has been removed. Also shown on this figure are theoretical variation of wave number with frequency of MSSW propagating on a ferrite slab without and with a metal coating. These results show that in the case when the metal is removed, there is a difference between the theoretical and experimental dispersion curves. This difference is attributed to a small variation of the magnetization ($4\pi M$ = 1750 Oe for the calculated curve). The antisymmetric mode dispersion curve is close to that for a single film showing that this mode is practically unperturbed by the periodic grating. The symmetric mode, on the other hand, is perturbed by this structure. From those results, the coupling constant K' and its variation with frequency can be deduced. Values of K obtained from variation of insertion loss $I_{1\to3}$ versus coupling strip number and K' are compared in table 1. The agreement is satisfactory for frequencies above 2.7 GHz. The discrepancy observed for frequencies below 2.7 GHz is explained by the MSSW wavelengths which, at those frequencies, are ranging about the coupler size.

Taking into account these results, a new MSSW coupler has been designed. The coupler schematic is shown in figure 6. The 45 period "shorted bar" grating is etched in a 3 µm thick aluminum film deposited on the surface of a 19 µm thick YIG film. The array microstrips are 4 mm long, 10 µm wide and separated by 10µm. The three aluminum microstrip transducers, 1.8 mm long by 30 µm wide, are 1.5 mm distant along the propagation direction. The frequency response between 2.4 GHz and 2.8 GHz of this structure for an applied magnetic field H = 220 Oe is shown in fig.7. A quasi perfect power transfer from track A to track B is obtained at 2.528 GHz. At this frequency, the insertion loss is 9 dB between T_1 and T_3 whereas it is 52 dB between T_1 and T_2. This figure shows that the coupling constant changes with frequency, as already shown. The coupler length is 0.89 mm corresponding to a coupling constant K_o= 1.8 mm^{-1} and K_1 = 5.3 mm^{-1}. K also depends of the value of the applied magnetic field as can be seen on fig.8 showing the magnetic field dependence of directional coupling. Owing to this property, the power transfer

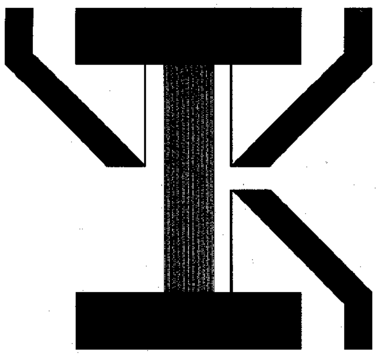

Fig.6- Coupler-transducer pattern of the second device.

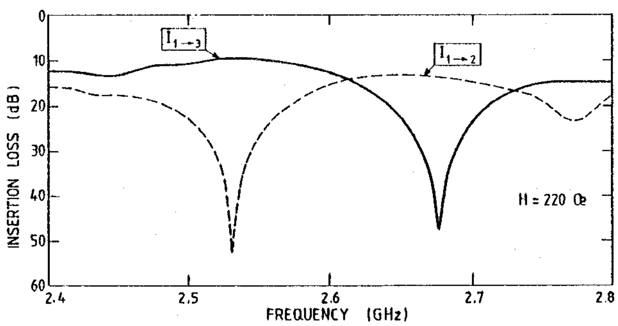

Fig.7- Frequency dependence of directional coupling for the second coupler.

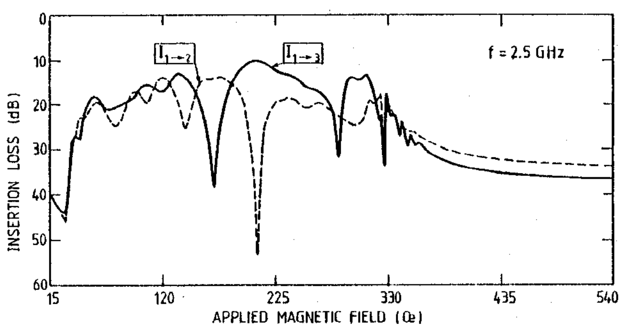

Fig.8- Magnetic field dependence of directional coupling for the second coupler.

between the two tracks is continuously tunable. In this case, a variation of about 50 Oe is necessary to switch the power from one track on to the other.

The following experiment has been performed to demonstrate the operation of the coupler : 10 μs wide microwave pulses are applied at transducer T_1 and output signals are detected at transducers T_2 and T_3. Oscilloscope traces of fig.9 have been registered for three different cases : no power transfer, half power transfer and full power transfer between the two tracks. The signal frequency for this experiment is 2.500 GHz.

Conclusion

A new adjustable microwave directional coupler using the propagation of magnetostatic surface wave in a YIG film has been performed. From the variation of the coupling with frequency and with number of coupler strips, the coupling constant has been deduced and compared to that obtained from the measurement of symmetric and antisymmetric mode wave numbers. The agreement is satisfactory between these two values. A full power transfer from one track to the other has been obtained at 2.528 GHz for an applied magnetic field H = 220 Oe. The coupling is continuously adjustable by an applied magnetic field; in the reported experiments, a variation of about 50 Oe is necessary to switch the power from one track on to the other. This feature makes this component very attractive and it can be used advantageously to design new microwave devices.

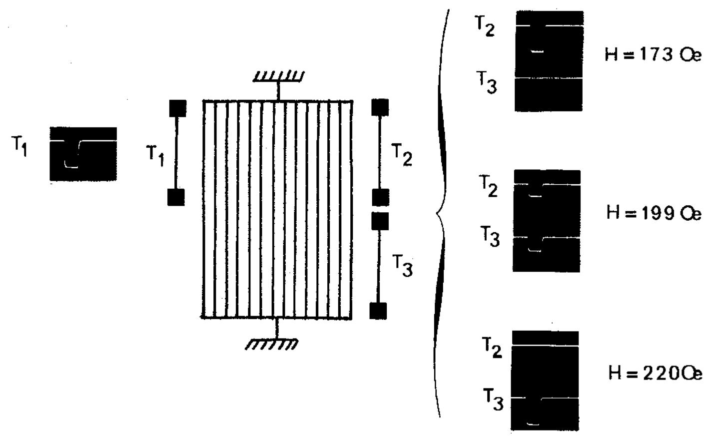

Fig.9- Transmission response of a multistrip coupler for 3 values of the applied magnetic field : 173 Oe, 199 Oe and 220 Oe corresponding respectively to no power transfer, half power transfer and full power transfer between the two tracks.

Acknowledgment

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