NEW EDGE GUIDED WAVE ON FERRITE STRIP

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ABSTRACT

Electromagnetic wave propagation along ferrite strip whose cross section is square immensed in D.C. magnetic field is investigated experimentaly. The existence of the mode similar to edge guided mode in ferrite substrate microstrip line was discovered. This mode may be useful for nonreciprocal circuit in millimeter and optical integrated circuit.

Introduction

In this paper, the authors would like to present a new result concerning wave propagation along magnetized ferrite strip, which is suitable for making millimeter and optical integrated nonreciprocal circuit.

Researches and developments of millimeter integrated circuit (MMIC) are very active. As far as the authors know, however, nonreciprocal circuits of MMIC have never been proposed.

Another active area is the researches on optical integrated circuits (OIC). In this field, some nonreciprocal circuits have been proposed[1 2]. The principal idea of an isolator in OIC is due to TE to TM mode conversion. In the proposed configurations of the isolator, the magnetic material like YIG is used. Other than this magnetic material, anisotropic material like $LiNbO_3$ is also utilized to maintain the phase matching of TE and TM modes in film or in YIG film. This fact makes the circuit fabrication very difficult.

Several years ago, M.E.Hines presented a paper on edge-guided mode (EGM) on ferrite substrate strip or microstrip line[3]. This EGM is suitable for making nonreciprocal devices in microwave frequency region. Transmission line like strip or microstrip line, however, is not applicable in MMIC or OIC, because conductors cause a large loss. But anyway the wave propagation form like EGM is suitable for making nonreciprocal devices. Considering the present status of MMIC and OIC, the authors just happened to ask whether the conductors in ferrite substrate strip line or microstrip line is essential to support the EGM or not. If it were not, that is, if magnetized ferrite strip itself could support EGM like wave, this mode could be used in MMIC or OIC as nonreciprocal circuits. And if so, there would be no need to use anisotropic material like $LiNbO_3$ in order to make nonreciprocal devices.

Experimental Results

It is well known that ferrite strip without D.C. magnetic field can support surface waves like HE_{11}, EH_{11} mode. In order to examine whether EGM like wave can exist on magnetized ferrite strip or not, any frequency could be used. There is no problem principally to make an experiment in 10GHz and not in millimeter or optical frequency. If there could be such EGM like in microwave frequency would occur in case of HE_{11} mode, The same EGM like wave in optical frequency would occur in case of EH_{11} mode, because in microwave frequency the character of ferrite can be expressed through $\tilde{\mu}$ tensor and in optical frequency, through $\tilde{\varepsilon}$ tensor.

Fig.1 shows the experimental setup. The size and saturation magnetization of the ferrite are $20\times4\times500^{mm}$ and 2300 Gauss, respectively. To excite HE_{11} mode, the electromagnetic horn was used as usual. Field distribution was measured by a dipole antenna.

Fig.2 is one of experimental results. From this figure, we can say

(1) HE_{11} mode is well excited when Hdc=0.
(2) The field distribution changes according to D.C.
(3) Changes of the field distribution is nonreciprocal.

Fig.3 shows another result when Hdc is large. In this figure, the position of the peak of the distribution is on the edge. In case of Fig.2, however, the peak is not on the edge. This fact shows the difference between this wave propagation and EGM in ferrite substrate microstrip line. In Hines' case, the peak is always on the edge regardless of the value of Hdc.

At certain value of Hdc, the field distribution is quite strange as shown in Fig.3. From small value of Hdc to 1.2 Koe and from 2.0 Koe to higher , the peak is on the left edge. But at 1.6 Koe, the field distribution is quite different from others.

Fig.4 shows the field distribution along the propagation direction. At 1.6 Koe, the field is decaying along the direction. At other Hdc, the field distributions along the propagation direction are just usual standing-wave. From these, it will be said that at 1.6 Koe the field is radiating to the space.

It is sure that the change of the field distribution with Hdc is due to the existence of the off-diagonal part of the $\tilde{\mu}$ tensor.

Simple Theoretical Investigation

To analyze the characteristics of the proposed ferrite strip is very difficult. Instead of the ferrite strip, let's consider the ferrite slab line in Fig.5.

The field distribution of the ferrite slab line is a little different from the one of the ferrite strip; the field distribution of the ferrite strip is concentrated in both x and y directions but that of the ferrite slab is concentrated only in y direction.

The analysis for the ferrite slab line is very simple, and there have been some papers published[4]. In case of TE mode, the position of the peak of the field distribution changes with the Hdc.

Ex component in the ferrite can be presented as eq.(1).

$$Ex = C\cos\{q(y-\frac{b}{2}) + \Phi_x\} \qquad (1)$$

when Hdc=0, Φ_x=0. The value of Φ_x shows the amount of the change of the peak position.

In case of ferrite slab, this Φ_x can be calculated easily. The dotted line in Fig.6 shows the Φ_x value. K means the off diagonal component of $\tilde{\mu}$ matrix. The measured values in case of ferrite strip is shown with the solid line. In both cases, Green's formula was used to estimate the value of K[5].

The tendency coincides. But quantitatively, there are big differences between them.

The authors are investigating the theoretical work further.

Conclusion

From above results, it became clear that on ferrite strip there exists a certain electromagnetic wave of which distribution in cross section changes with Hdc magnetic field nonreciprocally.

This mode might be of use in millimeter and optical integrated circuits. Theoretical investigations and much more works in microwave and optical regions are now being carried.

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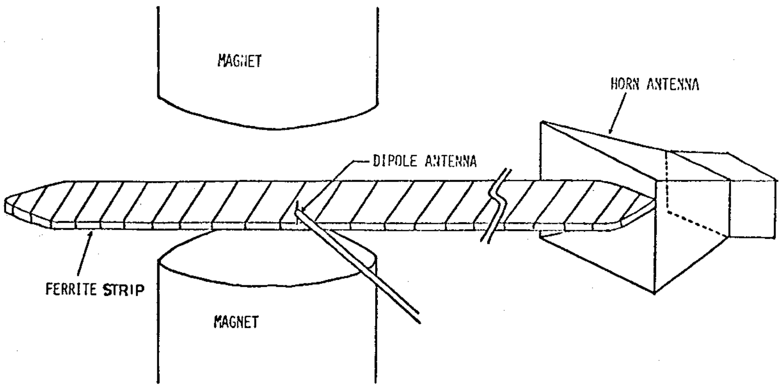

FIG.1 SCHEMATIC DRAWING OF EXPERIMENTAL SETUP.

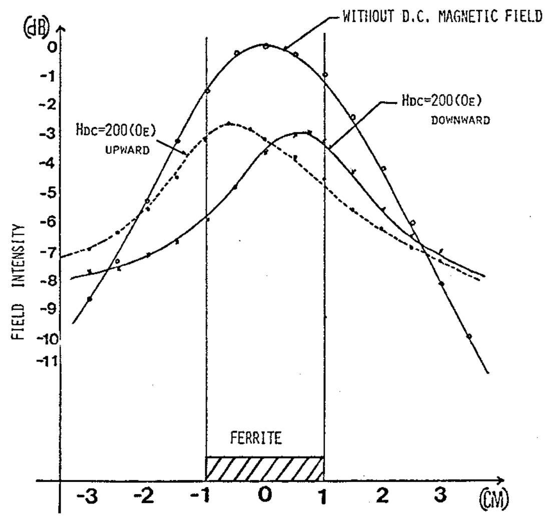

FIG.2 FIELD DISTRIBUTION (AT, HDC=200 OE)

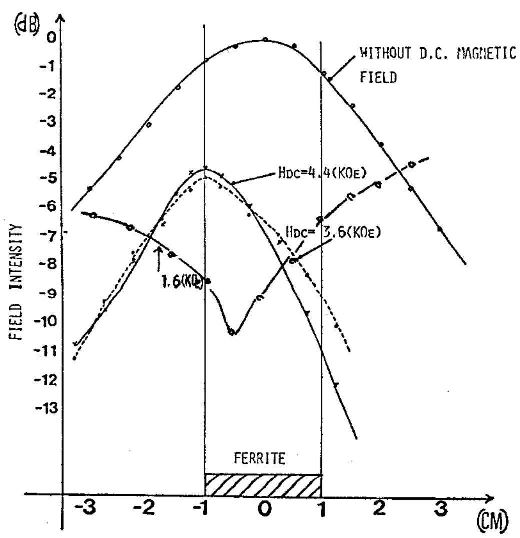

FIG.3 FIELD DISTRIBUTION

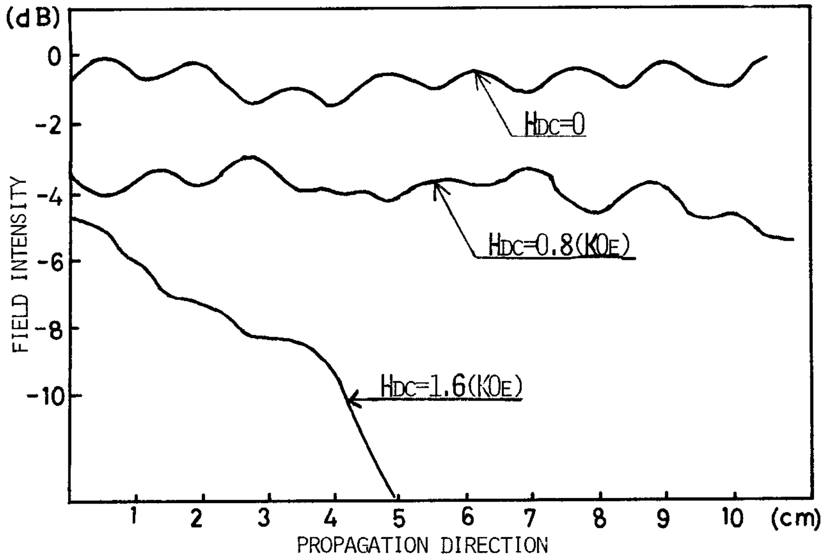

FIG.4 STANDING WAVE DISTRIBUTION.

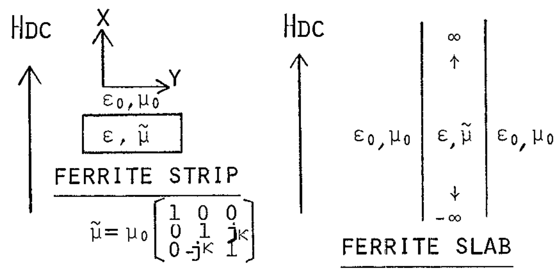

FIG.5 ANALYTICAL MODEL.

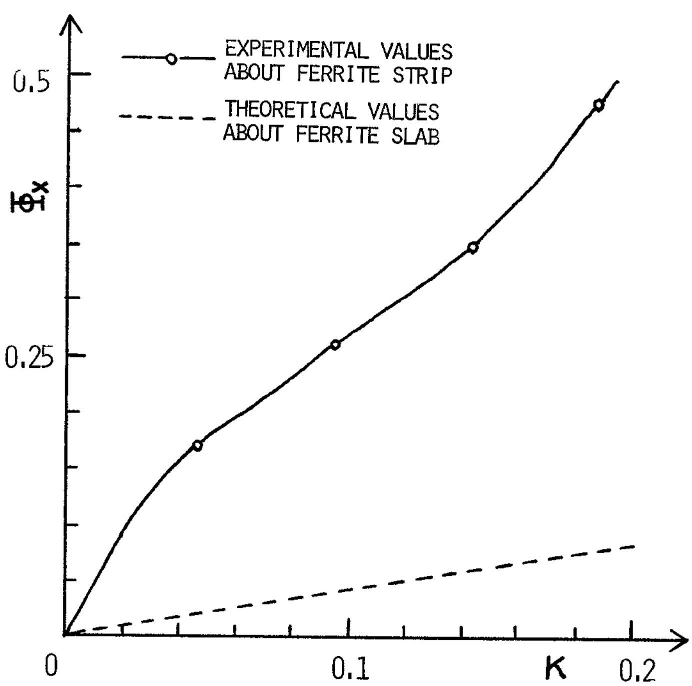

FIG.6 COMPARISON BETWEEN FERRITE STRIP AND FERRITE SLAB.