NEW NONRECIPROCAL DEVICES IN A COPLANAR WAVEGUIDE

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ABSTRACT

Some new nonreciprocal magnetic devices in a coplanar waveguide, using the edge-guided mode, is proposed. The structure of these devices are suitable for application to microwave integrated circuits, because of a plane configuration. Experimental resulats on some types of coplanar structures with ferrite material are described.

Introduction

The edge-guided mode on ferrite substrate stripline has been proposed [1] as nonreciprocal magnetic devices for microwave integrated circuits. Since then, the characteristics of this mode have been investigated the characteristics of this mode and many good results have been obtained.

On the other hand, a coplanar waveguide is also suitable for the fabrication of microwave integrated circuits, because this configuration permits easy shunt connection of other elements. Low-loss dielectric substrates with high dielectric constants may be employed to reduce the longitudial dimension of the integrated circuits, because the characteristic impedance is relatively independent of the substrate thickness. Not much attention has been given to nonreciprocal devices of coplanar type [2].

Here we will treat the nonreciprocal circuits of coplanar type. A coplanar waveguide may be regarded as one modification of microstrip, so it will be expected that the edge-guided mode will exist in a coplanar waveguide. If it's so, this mode could be applied to make nonreciprocal devices, such as isolators, circulators and differential phase shifters.

Experimental results show the field displacement effect, that is, wave energy propagates along one slot larger than the other. This field displacement effect is reversed for the opposite direction of wave propatation. As a practical application, a simple isolator was made and measured.

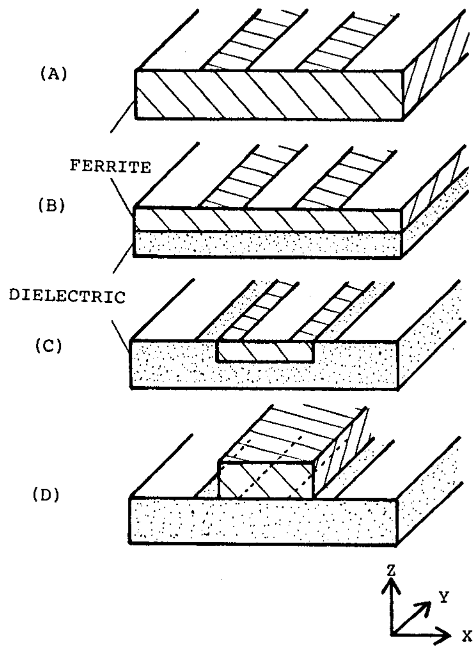


Fig.1. Coplanar waveguide configurations.

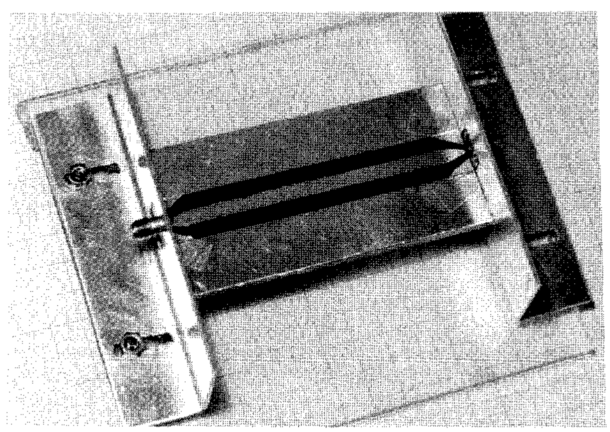


Fig.2. Actual view of a coplanar waveguide.

Experimental Results

Fig.1 shows some of the cross sections of coplanar waveguide structures which were measured in our experiments. (A) is constructed with ferrite substrate, whereas (B), (C) and (D) are constructed with both ferrite and dielectric materials. One typical coplanar waveguide is shown in Fig.2.

Experiments were performed by using YIG, with a saturation magnetization $4\pi Ms = 1800G$, $\Delta H = 70Oe$ and a relative dielectric constant of 16. A DC magnetic field perpendicular to the ground plane is required to provide appropriate bias conditions. The RF magnetic field intensity was measured just above the surface of the coplanar waveguides with a small loop antenna (its diameter : 4mm) picking up only a magnetic field.

The field distribution in the transverse plane were measured. Fig.3 shows the field distribution of (B) the dimension of which is illustrated in this figure. The relative dielectric constant of the dielectric slab is 16. + or - indicates the direction of the DC magnetic field along Z axis and a wave propagates +y direction. Fig.4 shows the field distribution of (C) the dimension of which is illustrated in this figure. Both Fig.3 and Fig.4 show the field displacement effect and this effect charges for the two opposite directions of the DC magnetic fields.

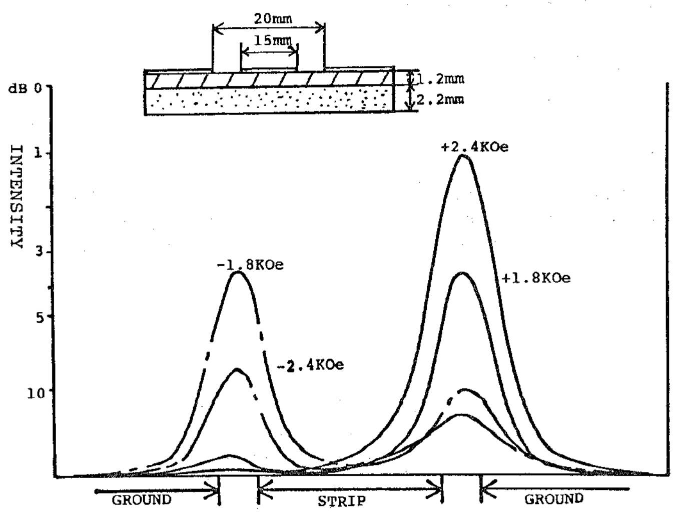


Fig.3. Field distribution of (B);f=7GHz.

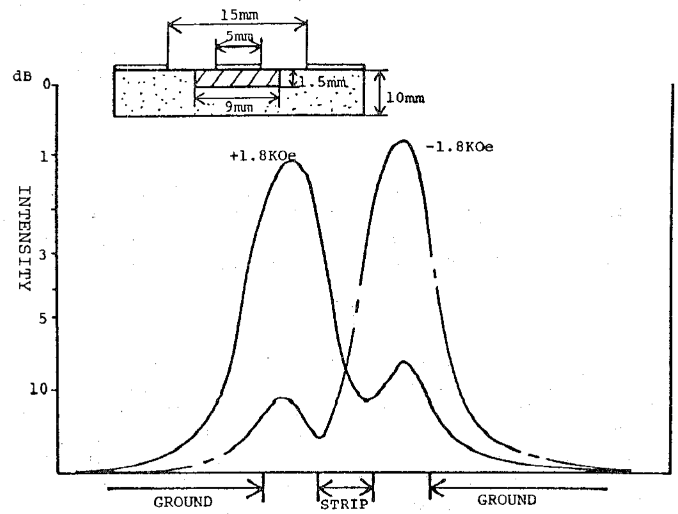


Fig.4. Field distribution of (C);f=7GHz.

From the results, it is concluded that the edge-guided mode exists in a coplanar waveguide. In addition, the direction of the field displacement effect is different between the two figures (B) and (C). When the DC magnetic field is applied in +z direction, (B) shows the displacement effect in +x direction, and (C) in -x direction. Another structure of (B) with a ferrite layer thickness of 5mm and a dielectric layer thickness of 10mm showed the same direction of the displacement effect with that of (C). The field displacement of (C) and (D) is just the same with that of the edge-guided mode in ferrite substrate microstrip proposed by M. E. Hines [1]. The reason why so is now under investigation.

Fig.5 shows the magnetic field intensity in the two slot regions of (C) structure illustrated in Fig.6 versus the strength of the DC magnetic field. The other structures showed much the same tendency as this figure. The performance of nonreciprocal effect is the largest near the saturation magnetization about 1.8KOe.

Fig.6 shows the magnetic field intensity at the two edges of the ferrite rod of (D) structure versus the RF frequency. The level difference is about 10dB from 7.0 to 8.0GHz. This structure is the most desirable one because it can be made only by putting a ferrite rod on a coplanar waveguide.

As one application of this effect, we made a simple isolator. We covered the half of the surface of (B) structure with resistive sheet. Fig.7 shows the forward and backward loss. The measured isolation is the largest from 6.5 to 7.0GHz. The level is about 30dB. The backward loss is affected by the position of resistive sheet.

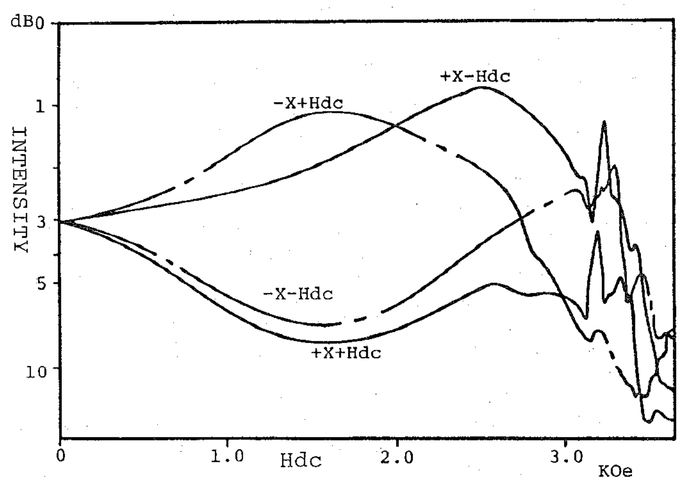


Fig.5. Field intensity in slot regions;f=7GHz.

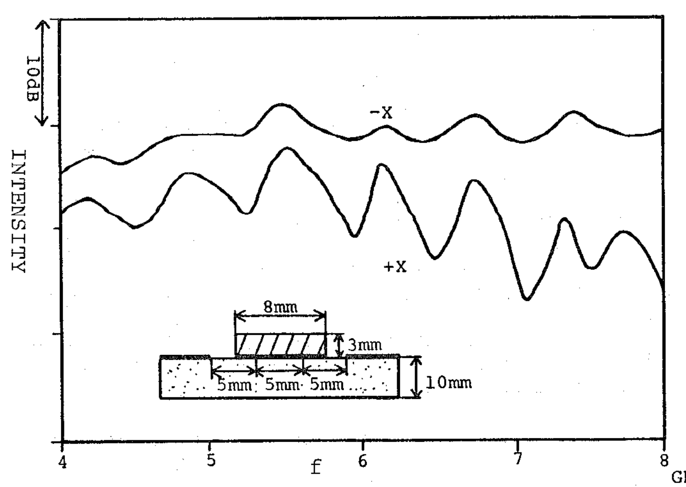
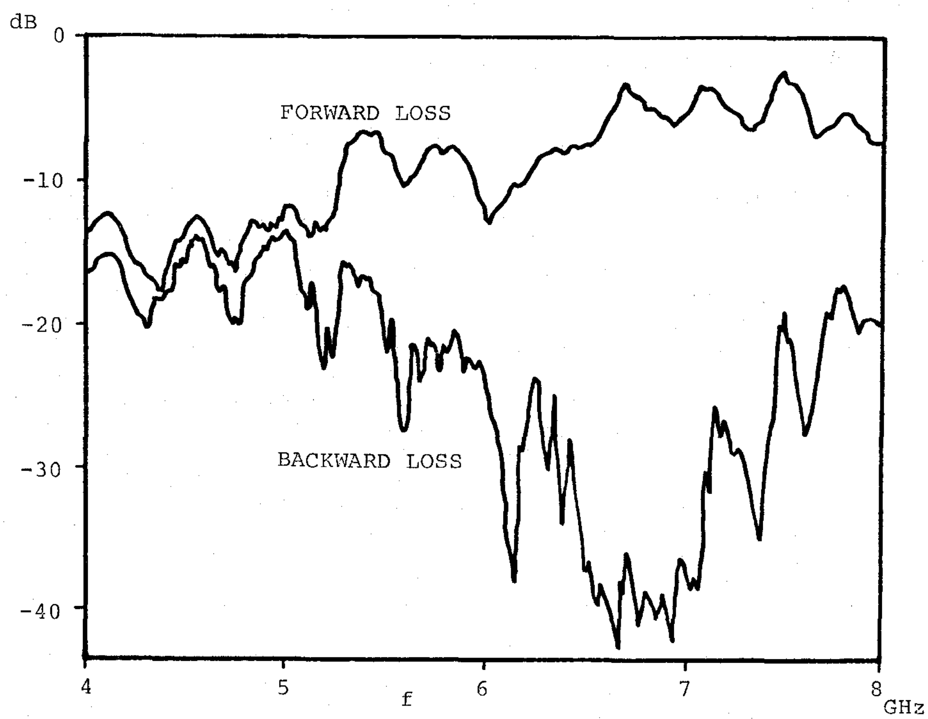


Fig.6. Characteristics of (D) structure; Hdc=1.8KOe.



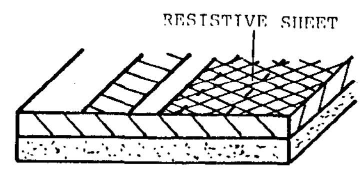


Fig.7. Characteristics of a coplanar type isolator;Hdc=1.8KOe.

Conclusion

With these experiments, it is concluded that the edge-guided mode exists in a coplanar waveguide. This could be used to construct nonreciprocal circuits in a coplanar waveguide. Further experimental works and theoretical investigations are being done.

References

[1] M.E.Hines, "Reciprocal and non-reciprocal modes of propagation in ferrite stripline and microstrip devices," IEEE Trans. Microwave Theory and Tech., vol.MTT-19, pp.442-451, May 1972

[2] C.P.Wen, "Coplanar waveguide: a surface strip transmission line suitable for nonreciprocal gyromagnetic device applications," IEEE Trans. Microwave Theory and Tech., vol.MTT-17, pp.1087-1090, December 1969