FIN LINE FERRITE ISOLATOR FOR INTEGRATED MILLIMETERWAVE CIRCUITS

Adalbert Beyer and Klaus Solbach
Department of Electrical Engineering
University of Duisburg
Bismarckstrasse 81
D-4100 Duisburg
Fed.Rep. of Germany

ABSTRACT

The realisation of a field displacement isolator in fin line technique is described. Fin line distributions allow application of the principle of operation known from rectangular metal waveguide isolators. Encouraging first experimental results are reported.

Introduction

In recent years fin lines have emerged as a usefull medium for integrated millimeterwave circuits. Filters and couplers[1], detector and mixer circuits[2] and even semiconductor oscillator configurations[3] sucessfully have been realized in the frequency range of 8-170 GHz using fin lines. Although nonreciprocal circuit elements like circulators and isolators are highly usefull building blocks in millimeterwave subsystems so far no efforts have been made to realize such circuits in fin line technique.

This contribution describes the concept and a first experimental realization of a fin line ferrite isolator at a modell frequency (f=11 GHz).

The Concept

Several studies of fin line dispersion and characteristic impedance have been published[4-6] but no field distributions have been given. Since a concept for a ferrite isolator would have to be based on an understanding of the fields of fin line, field distributions have been calculated using the field-theoretical method described in[6].

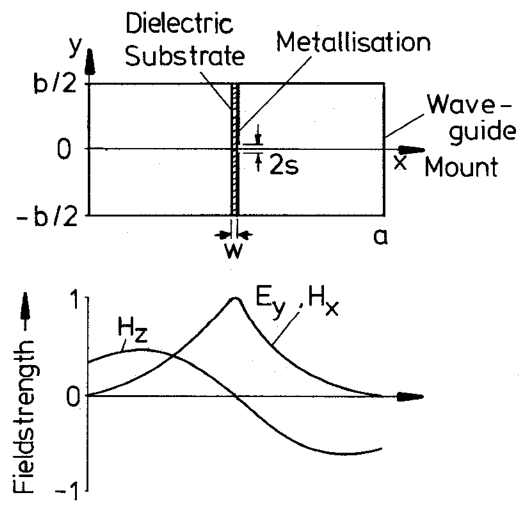

Fig.1: Fin line structure with calculated E_y, H_x and H_z-field strengths (X-band mount with a=22.86mm and b= 10.16mm, w=0.25mm, 2s=3.0mm).

In Fig. 1 the cross-sectional view of a unilateral fin line is shown together with the E_y, E_x and H_z-field-strengths calculated in plane y=0 at 11 GHz. The fin line structure employed here had a slot width of 2s=3 mm, substrate thickness w=0.25 mm, ε_r=10.5, with a characteristic impedance of Z_0=185 Ω. The fin line mount used here was a standard X-band waveguide[6,8].

From the field distributions it can be seen that the propagating wave is concentrated in the neighbourhood of the slot. Circularly polarized magnetic fields ($|H_x|=|H_z|$) exist in a plane closer to the center of the waveguide than in unloaded metal waveguide.

It is known that a magnetized ferrite slab placed in a plane of circularly polarized magnetic field exhibits differential phase shift and attenuation for both directions of propagating waves. Resonance isolators exploiting this phenomenon employ very thin slabs of ferrite to make use of the marked resonance characteristic of the ferrite effective permeability for one direction of the propagation.

Field displacement isolators on the other hand employ thick ferrite slabs to exploit the difference in the ferrite permeability tensor for the two directions of propagation. The position of the slabs has to be chosen near the plane of circularly polarized magnetic field and the applied static magnetic field can be chosen so that a condition exists where the field distributions differ very much for both directions of propagation. Under such a condition appropriately positioned absorbing material inside the waveguide will discriminate between the direction of propagation and thus attenuate waves in one direction (isolation) while the waves in the opposite direction (transmission) are hardly affected[7].

Since the field displacement isolator principle is known to be more effective and broadband as compared to the resonance isolator principle it was decided to make use of it in the design of a fin line device. The application of the principles of operation known from metal waveguide isolator structures is straight foreward since from Fig.1 it is clear that similar conditions concerning the magnetic fields exist in the fin line structure.

Experimental Isolator

Fig.2 shows a photograph of the fin line structure designed to prove the feasibility of a field displacement isolator in fin line technique.

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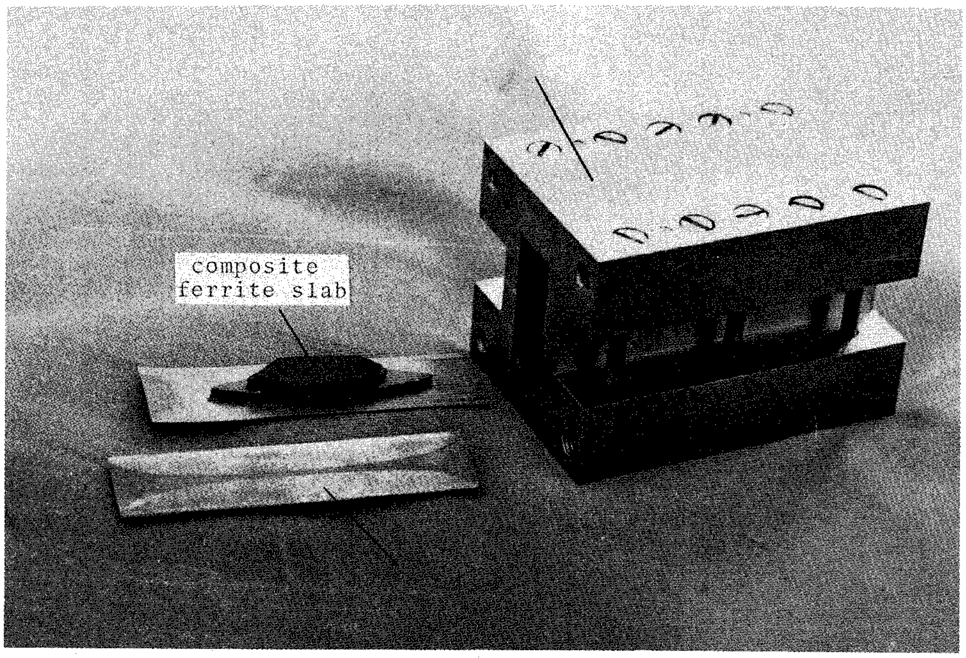

Fig.2: Photograph of the experimental fin line isolator.

A section of fin line with tapered transitions for insertion into a waveguide measurement set-up[8] is layered on its back side with a composition of a dielectric spacer, a ferrite slab and an absorbing sheet. The ferrite, spacer and absorber are tapered at the ends to enhance the match to the fin line. The cross-sectional view of the loaded fin line structure is given in Fig.3 together with the desired field patterns to achieve isolator action.

For waves propagating in the transmission direction it is supposed that the electromagnetic fields are shifted away from the ferrite slab, while for waves in the opposite direction it is supposed that the fields are strong near the ferrite slab. Thus the absorber sheet dissipates a large portion of the energy travelling in the isolated direction (shaded area in Fig.3b) while only little energy is absorbed in the transmission direction (shaded area in Fig.3c).

Since no theoretical investigation was carried out to determine the optimum thickness and spacing of the ferrite slab, the best permittivity of the dielectric spacer and the optimum of the absorber some of these parameters were checked experimentally. So, in a series of experiments the permittivity and the thickness of the dielectric spacer and the dimensions of the absorber were varied. Best results with a figure of merit around 25 were achieved using a low permittivity spacer (ε_r = 2.33) of thickness t_1 = 0.79 mm and a ferrite slab ($4\pi M_s$ = 1650 Gauss) of thickness t_2 = 1.28 mm while the absorber (Ferrosorbepoxy sheet) had a thickness of t_3 = 1 mm. The length of the composite slab structure was 22 mm including 11 mm for both tapered ends. The applied magnetic field was 3500 Gauss to operate slightly below ferromagnetic resonance.

In Fig.4 the measured isolator characteristics are plotted for this design. The achieved isolation bandwidth still is small, but it was found that this can be increased using a more effective absorber load. On the other hand the minimum transmission loss of 0.9 dB is encouraging since it includes a measured 0.5 dB insertion loss for the unloaded fin line section.

Very much larger bandwidths have been achieved using a tighter coupling of the ferrite slab to the fin line (spacer thickness t_1 = 0) at the expense of increased transmission attenuation. This mode of operation also has been employed in a slot line isolator in the past[9].

Conclusions

It has been shown that fin line isolators are feasible. Improvements of the present design are expected from the use of resistive card absorbers and further matching of the ferrite loaded fin line to the unloaded fin line.

Great advantages of the described isolator structure could be that it is easily integratable into fin line circuits by simply loading a suitable section of fin line with a composite ferrite slab. Furthermore it could be made extremely compact since the magnet needed to supply the static magnetic field could be integrated into the metal waveguide mount without seriously disturbing the propagating waves, since it is possible to concentrate the propagating waves in the neighbourhood of the slot (low-impedance fin lines).

This contribution is intended to trigger further work, particularly field-theoretical investigations of the ferrite loaded fin line. This could yield data needed for a more rigouros optimization of the many parameters in the fin line and the composite ferrite slab.

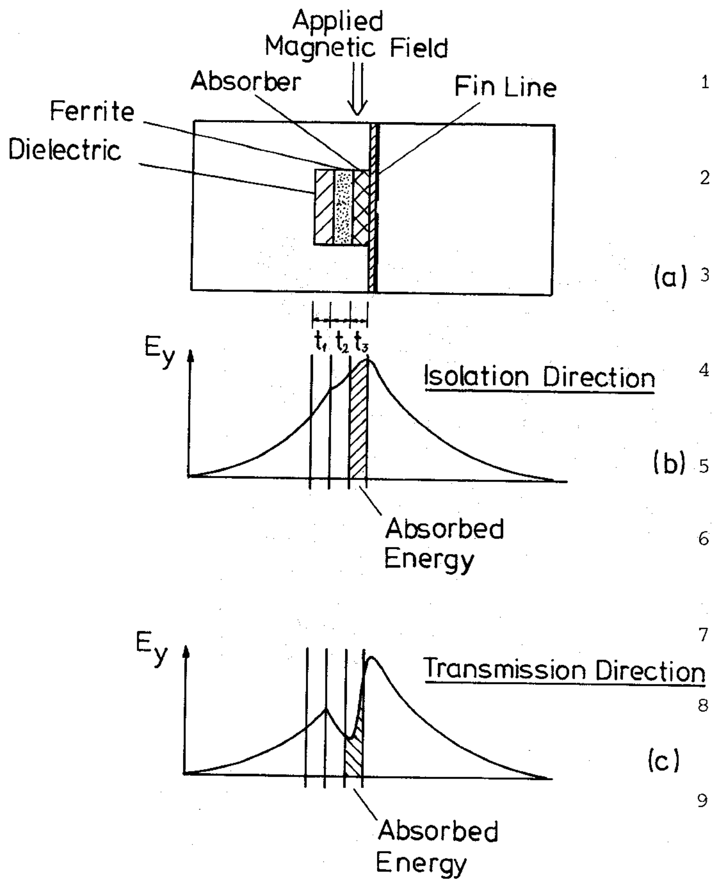

Fig.3: Cross-sectional structure of the investigated isolator (a) with the desired field distribution for the isolated direction (b) and for the transmission direction (c).

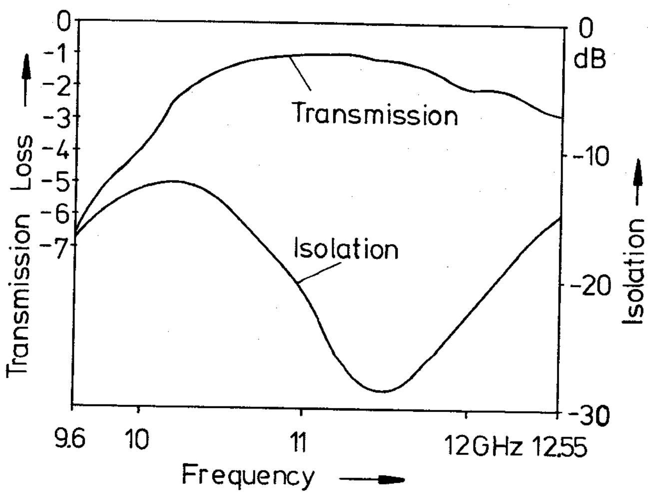

Fig.4: The measured isolation and transmission loss of the experimental fin line isolator.

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