MILLIMETRIC NON-RECIPROCAL COUPLED-SLOT FIN-LINE COMPONENTS

L.E. Davis and D.B. Sillars

Department of Electrical and Electronic Engineering
Paisley College of Technology, Paisley, Scotland

ABSTRACT

Promising preliminary results are presented for an isolator and a 4-port circulator in novel fin-line structures in the frequency range 26.5 - 40.0 GHz. The basic configuration is a ferrite-loaded coupled-slot fin-line with the ferrite magnetised parallel with the direction of propagation. It is suggested that such structures would also be suitable for higher frequencies.

INTRODUCTION

For traditional non-reciprocal devices operating at millimetre-wave frequencies, a strong magnetic bias or an anisotropic ferrite would normally be required together with a ferrite sample which is physically small and machined to close tolerances. Non-reciprocal fin-line structures are reported here in which (a) rectangular fin-line structures are magnetised longitudinally enabling saturation to be achieved from weak magnetic fields due to the small demagnetising factor, (b) hexagonal ferrites are not required, and (c) non-reciprocity is developed with a 'large' slab, i.e. over several wavelengths, rather than a fraction of a wavelength as in traditional junction devices.

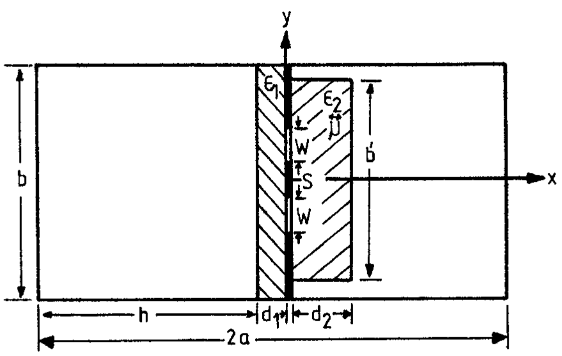

Fig.1: Ferrite-loaded coupled-slot fin-line.
$a=b=3.556$mm, $b'=3.0$mm, $\varepsilon_1=2.22$, $\varepsilon_2=13.0$
$d_1=0.127$mm, $d_2=0.5$mm, $h=3.4925$mm, $M_s=4000$A/cm

ISOLATORS

Results for a coupled-slot fin-line isolator have recently been described (1). It was reported that when a coupled-slot fin-line loaded with a ferrite slab (Fig.1) and supporting only the odd mode was magnetised parallel to the direction of propagation, a displacement of the field from one slot to the other occurred. One application of this phenomenon is in an isolator, produced by placing a piece of resistive card over one slot. It should be noted that the odd mode of the unmagnetised isotropic ferrite-loaded fin-line is defined as having the electric field E_y an even function of y with respect to the x-axis.

The investigation was extended to study the effects of placing two ferrite slabs on the coupled-slot fin-line separated by a piece of resistive card. Non-reciprocity was produced by magnetising the ferrites with anti-parallel magnetic fields, achieved by placing a bar magnet alongside each ferrite region. The small longitudinal field produced by each magnet was sufficient to saturate the ferrite slabs. Fig.2 shows the structure with the ferrites and resistive card tapered at each end to help reduce losses. Preliminary results for insertion loss, return loss and isolation loss are shown in Fig.3. Here a maximum isolation of 41.5 dB is observed with a 20 dB isolation bandwidth of 6.75 GHz (18.4%). Insertion losses of between 3.5 - 6.0 dB and return loss better than 16dB over the 20 dB isolation bandwidth are produced.

4-PORT CIRCULATOR

Investigations have also been carried out on a non-reciprocal 4-port fin-line coupler. With suitable location of a longitudinally-magnetised ferrite slab on the coupled-slot section (Fig.4), non-reciprocal coupling occurs, i.e. circulation. A dielectric overlay was placed on top of the ferrite to improve the isolation by concentrating the field within the ferrite slab (2), (3). S-parameter curves of the non-reciprocal coupler are shown in Fig.5a and Fig.5b where 4-port circulator behaviour is clearly evident. Fig.5a shows that a 20 dB isolation bandwidth of 3.6 GHz was produced at the coupling ports (S_{12},S_{34}) with between 2.5 - 3.5 dB losses produced at the transmission ports (S_{14},S_{32}). The return loss (S_{11}) was measured to be better than 15dB. The direction of circulation is reversed by reversing the applied field, as expected.

OPERATION ABOVE 40 GHz

This non-reciprocal coupled-slot fin-line configuration has a number of features that will be useful at frequencies above 40 GHz. These are:-

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(a) the closer mechanical tolerances are associated with the fin-line circuit (where they are more easily controlled) rather than with the ferrite slab,

(b) the ferrite slab is several wavelengths long which makes grinding and handling easier,

(c) the applied field is low despite the high frequency,

(d) the need for hexagonal materials is less urgent,

(e) broad bandwidths appear to be possible.

CONCLUSIONS

Isolator and circulator behaviour have been demonstrated with coupled-slot fin-line structures loaded with ferrite slabs magnetised parallel to the direction of propagation. It has been shown that in the frequency range 26.5 - 40.0 GHz reasonable isolation is achieved with very low values of applied magnetic field. The results have implications for similar components at higher frequencies and theoretical and experimental work is in hand to extend and improve the performance of these promising devices.

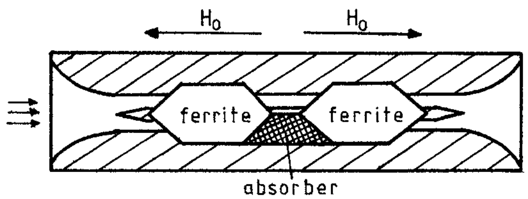

Fig.2: Twin ferrite coupled-slot fin-line isolator.

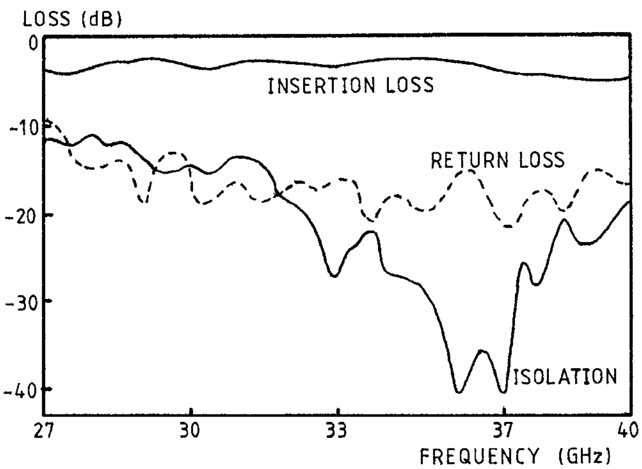

Fig.3: Performance of twin ferrite coupled-slot fin-line isolator. W=S=0.5mm, ferrite length = 20mm, H_o=160A/cm.

ACKNOWLEDGEMENTS

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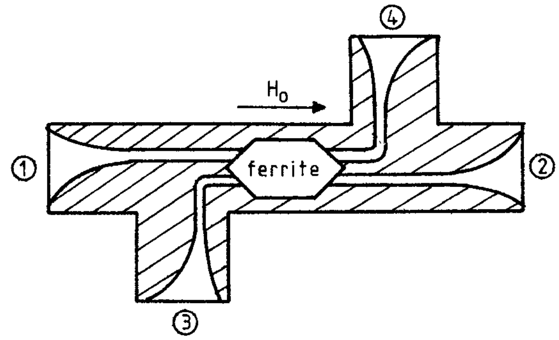

Fig.4: Ferrite-loaded 4-port fin-line coupler.

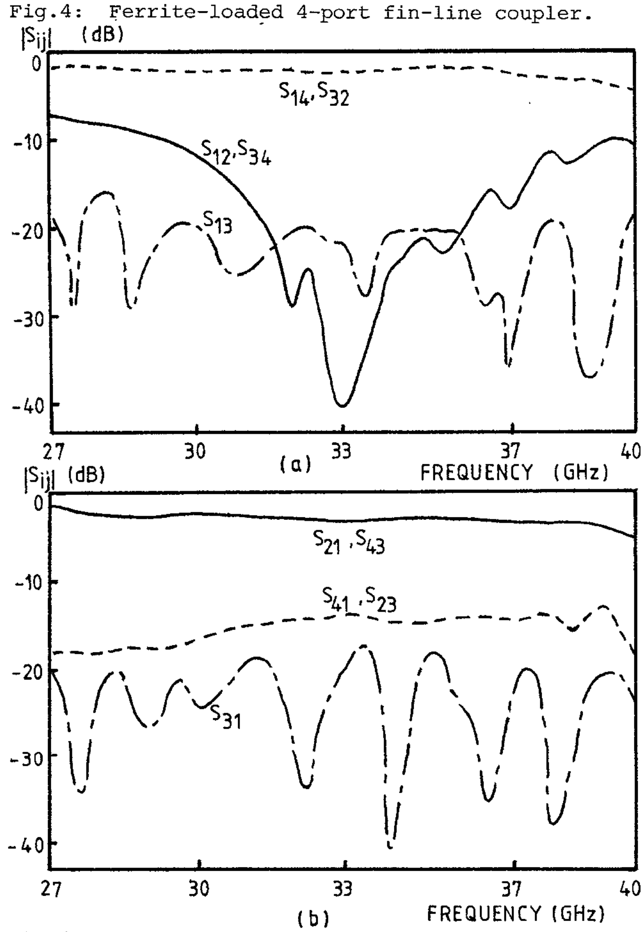

Fig.5: Non-reciprocal transmission and coupling characteristics. W=0.2mm, S=1.0mm, ferrite length=30mm, coupling length=35mm, H_o=160A/cm