EXPERIMENTS ON THE OPTIMIZATION OF A NOVEL M.I.C. SYMMETRICAL THREE-PORT CIRCULATOR

P. de Santis
F. Pucci

Selenia S.p.A., Research Department
Via Tiburtina Km.12,400
00131 Rome (Italy)

Abstract

The results are reported of feasibility and optimization studies on a novel type of M.I.C. symmetrical, three-port, X-band circulator based on "edge guided waves" propagation.

Introduction

Recently a great deal of attention has been devoted by microwave scientists to the physical characteristics and the application potentialities of a novel type of unidirectional guided wave propagation, having the following characteristics [1-6]: a) it takes place in ferrite structures perpendicularly to the direction of the applied magnetic bias Ho; b) it is electromagnetic in character in as much as both the r.f. electric and magnetic fields contribute in the propagating wave and is theoretically predicted by an "exact" analysis (as contrasted to quasi-static analyses); c) it is guided by the r.f. conductor's edge in a ferrite microstrip configuration and by the ferrite-dielectric interface in a partially loaded parallel plate configuration; d) the amplitude of the associated field components reactively decays in a direction perpendicular to the guiding contour; e) in a lossless model it exists for $\mu_{eff}<o$ (μ_{eff} is the relative effective permeability for plane wave propagation perpendicular to Ho) as well [4] as for some values of $\mu_{eff}>o$; f) it is unidirectional, e.g. for a given orientation of Ho it has a given sense of propagation which is inverted by inversion of Ho (see fig.1)

Although this type of propagation has been called in many different ways depending upon the geometry of the guiding structure, in the present work we shall adopt the term "edge - guided wave" (E.G.W.) propagation as proposed by M.E. Hines [1]. Exploiting the E.G.W. propagation M.E. Hines [2,3] has recently realized a new class of microstrip distributed isolators operating in the 5 - 8 GHz and 8 - 12 GHz bands. M. Lemke [5] reported the construction of the same type of isolator operating in the 12 - 18 GHz band. Chiron et al. [6] published the performance data of an E.G.W. isolator in a parallel plate configuration operating between 3 and 12.6 GHz. E.G.W. phase-shifters as well as multiport circulating structures were also derived from the basic structure of the isolators. A true symmetrical three-port circulator however has not as yet been realized.

In the present work we show that exploiting E.G.W. propagation, the construction of a novel type of symmetrical, three-port microstrip circulator is feasible.

Experimental studies

Based on the results obtained in the studies [4] of E.G.W. propagation along straight contours, various types of M.I.C. three-port, symmetrical circulators were constructed.

Fig.2 is a photo of the r.f. circuit (gold) deposited by photoetching techniques on a ferrite substrate, for an X-band circulator. The substrate is a YIG (ε_f=16, $4\pi M_S$=1780 Oe) disk, flattened out in correspondence to the three r.f. connectors, with a circular hole at the center. The diameters of the disk and of the central hole are 22mm and 3mm respectively. The thickness of the gold overlay and of the ferrite substrate are 35 μ and 0.6mm respectively. In the desired mode of operation E.G.W. are launched along the periphery of the r.f. circuit by three taper sections. The central hole helps in eliminating unwanted ferrite volume modes. Fig.3 shows the performance data for such a circulator in the 10.5 - 12.5 GHz band, when the applied d.c. magnetic field is 3800 Oe. Fig.4 shows the performance data over the 9 - 12 GHz band, when Ho=3150 Oe.

At the moment, research work to optimize above circulator is in progress along the following lines: 1) optimum matching conditions are being investigated between a 50 Ω line and a perpendicularly magnetized ferrite

microstrip line for $|\underline{Ho}|$ close to the circulator's operation values. Preliminary results indicate that matching conditions that are optimum at $\underline{Ho} = o$ yield reasonably acceptable values of VSWR also when $\underline{Ho} \neq o$; 2) a broadbanding of the device is under study by application of dielectric loading techniques. Ferrite-dielectric layered structures as well as lateral dielectric loading [3] are being investigated both theoretically and experimentally; 3) spurious mode propagation effects due to ferrite volume modes as well as to unwanted direct couplings are being analized.

Details on above subjects will be given in the full paper.

Conclusions

Some preliminary results on the optimization of an experimental three-port, symmetrical, M.I.C., E.G.W. circulator, have been reported. Although the performance characteristics which have been presented are inferior to the ones of the traditional Y-junction M.I.C. circulators, the results so far obtained seem to be fairly promising to motivate further research in this area.

Acknowledgements

The authors wish to express their gratitude to Drs. C. Borghese, G. Cicerchia, C. Misiano and R. Roveda for their contributions during this program.

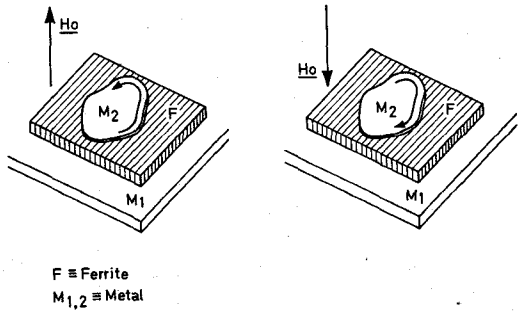

FIG. 1 RELEVANT TO THE UNIDIRECTIONAL CHARACTER OF E.G.W.

References

1. Hines M.E., A new microstrip isolator and its application to distributed diode amplification, IEEE G-MTT 1970, International Microwave Symposium, Newport Beach (Cal.), Digest of papers, pp.304-307.
2. Hines M.E., Ferrite phase shifters and multiport circulators in microstrip and strip line, IEEE G-MTT 1971, International Microwave Symposium, Washington (D.C.), Digest of papers, pp. 108-109.
3. Hines M.E., Reciprocal and nonreciprocal modes of propagation in ferrite strip line and microstrip devices, IEEE Trans. on Microwave Theory and Techniques, Vol. MTT-19, no.5, pp. 442-451, May 1971.
4. De Santis P., Roveda R., Magnetodynamic boundary waves, Proceedings of the 1971 European Microwave Conference, Vol. 2, pp. C 5/2 : 1 - C 5/2 : 4.
5. Lemke M., Low noise microslot and microstrip mixers on ferrite substrates for Ku band frequencies, Proceedings of the 1971 European Microwave Conference Vol.2, pp. C 3/3 : 1 - C 3/3 : 3.
6. Chiron B. et al., Nouveaux dispositifs non réciproques à très grande largeur de bande utilisant des ondes de surface électromagnétiques, L'onde électrique, Vol. 51, Fasc. 9, pp. 816-818, Oct. 1971.

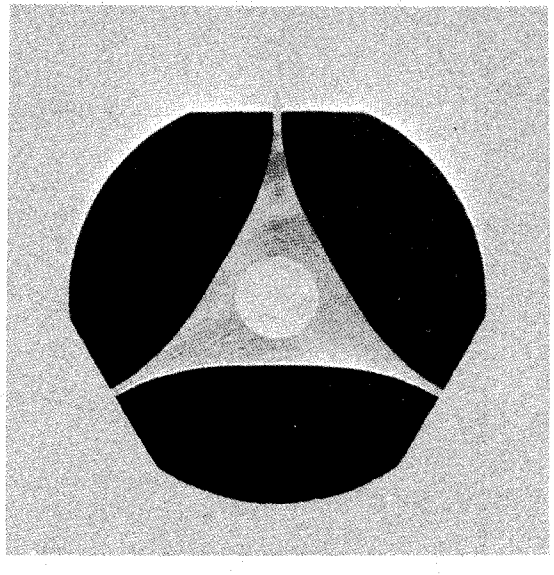

FIG. 2 THE R.F. CIRCUIT OF THE CIRCULATOR.

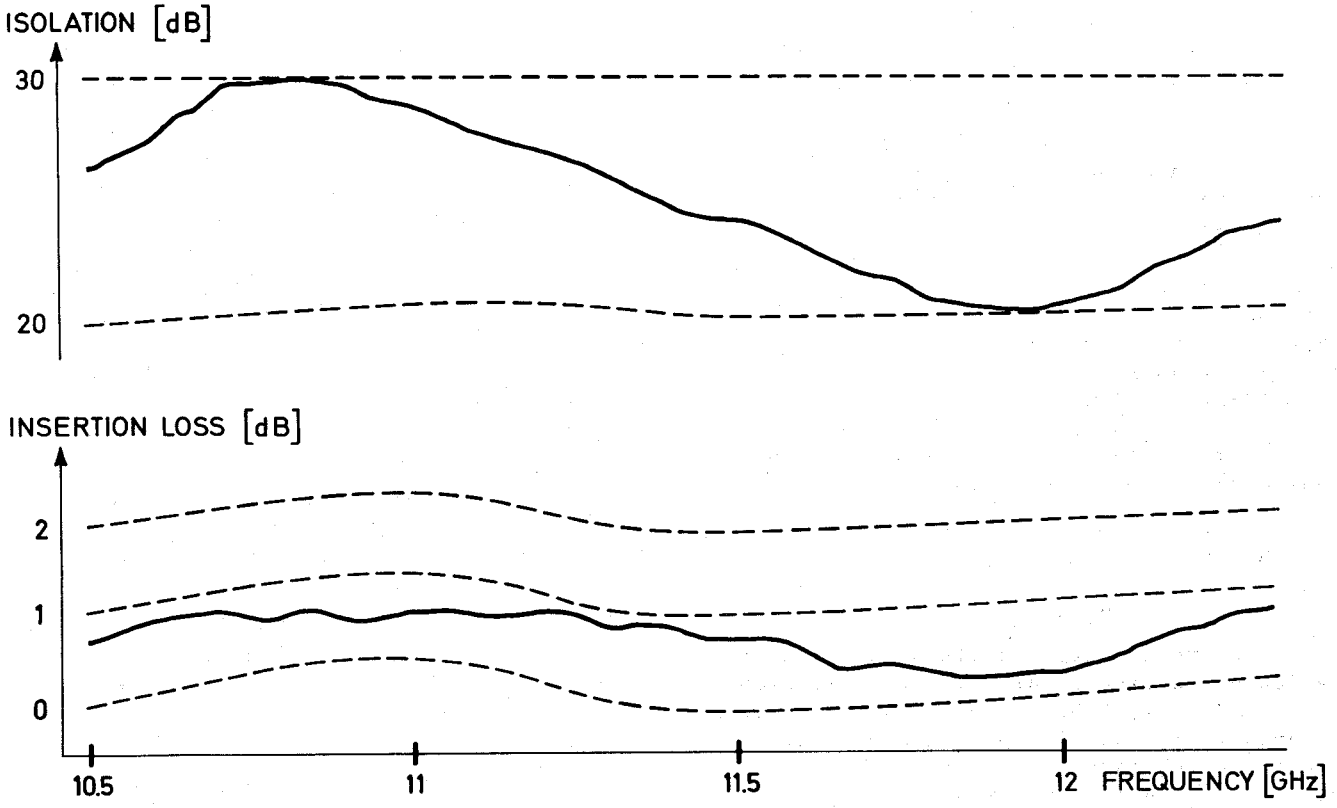

FIG. 3 PERFORMANCE CHARACTERISTICS AT H_o = 3800 G.

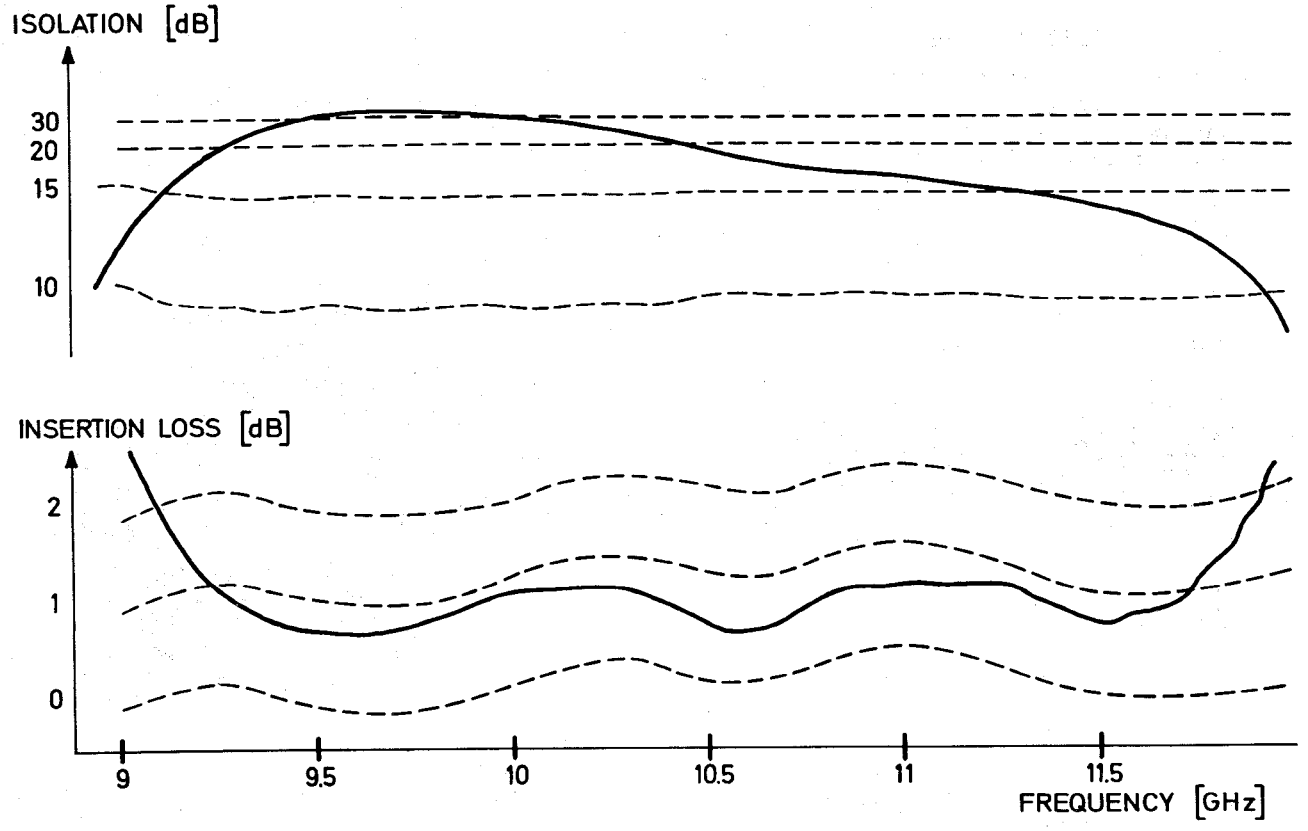

FIG. 4 PERFORMANCE CHARACTERISTICS AT Ho= 3150 G.