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MAGNETOSTATIC-WAVE PROPAGATION IN A FINITE YIG-LOADED RECTANGULAR WAVEGUIDE*

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Abstract

The propagation of magnetostatic waves (MSW) in a waveguide partially loaded with a low-loss YIG slab is investigated theoretically. Using the integral equation method, the dispersion relation is found to be an infinitely large determinant equal to zero. Proper truncation of this determinant and numerical analysis to find its roots are carried out in this work. It is noticed that there exists a trade off between the time delay and the device bandwidth and maximization of one property leads to a poor value in the other. Thus some design compromises should be made. It is also observed that the frequency range of operation of the device can be adjusted by an external magnetic bias field. This flexibility in tuning the device to operate in any frequency range adds an extra dimension of flexibility to the operation and also design of these devices.

Introduction

Magnetostatic-wave propagation in a YIG slab in free space on an infinite ground plane or bounded by two infinite parallel ground planes or completely filling a waveguide has been reported in the literature.[1-3] Some results pertinent to the design and construction of delay lines and filters were also given.[4-6] The theoretical analysis carried out by all these previous works are based on the method of separation of variables, whereby a closed form for the dispersion relation may be obtained.

In this paper, the propagation of magnetostatic waves in a rectangular waveguide partially filled with a YIG slab is studied theoretically. The dc external magnetic field is parallel to the slab and perpendicular to the direction of propagation. The slab is placed inside and along the guide but not necessarily in contact with the waveguide walls. Figure 1 shows a cross section of the configuration. To simplify the analysis, the slab is assumed to be thin, so that approximate numerical solution becomes feasible.

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The introduction of a gap length (x_o) is motivated to account for the loose contacts between the YIG slab and the waveguide walls and to provide a general structure for the design of delay lines. For the configuration shown in Figure 1, if the gap length x_o is zero, conventional mode analysis may be used to solve for the dispersion relation.[7] However, when x_o is nonzero, numerical analysis based on the integral equation formulation appears to be the only means.

Based on the integral equation method the problem of magnetostatic-wave propagation in a YIG slab of finite width inside a waveguide (see Fig 1) is analyzed and the magnetic potential function in the YIG region is expressed in terms of an integral equation. Assuming the slab to be thin, an approximate numerical solution to the integral equation can be obtained. Based on the approximate numerical solution for the dispersion relation, some computer results obtained in a certain frequency range is plotted. The results obtained from the approximate numerical solution for the general case, when it is reduced to special cases, is in good agreement with the existing published results.

Theoretical Analysis

As noted earlier, when the width of the slab is less than the width of the waveguide, that is when $x_o \neq 0$ (see Fig 1), the mode analysis technique appears to be fruitless and the integral equation method seems to be more appropriate. In this method an unknown magnetic potential function denoted by $\phi(x,y,z)$ at a point (x,y,z) inside the YIG slab is assumed to exist. Assuming a time dependence of the form $e^{j\omega t}$ and wave propagation in the y-direction, the y-variation would be therefore of the form e^{-jky} where ω, t and k are the frequency of operation, the time parameter, and the wave number respectively. In this manner the magnetic potential function in the YIG region, $\phi(x,y,z)$, can be written as $\tilde{\phi}(x,z)e^{-jky}$. Based on $\tilde{\phi}(x,z)$ and with the help of proper permeability tensor,[8] fictitious "magnetic sources" can be obtained in terms of $\tilde{\phi}(x,z)$. The density of magnetic sources consists of two parts a) the magnetic volume charge density (ρ_v) and b) the magnetic surface charge density (ρ_s). Considering a uniform guide cross section and combining the obtained magnetic sources with an appropriate Green's function, an integral expression for the magnetic potential function $\tilde{\phi}(x,z)$ in the YIG region (except for the common factor e^{-jky}) can be written as:

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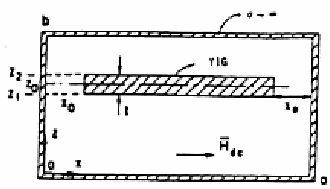

FIG. 1 DEVICE CONFIGURATION.

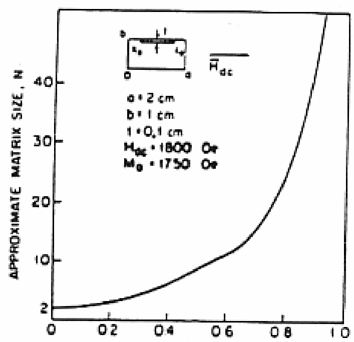

FIG. 2 RELATIONSHIP OF THE WALL GAP (x_0) AND THE CUT-OFF POINT (N).

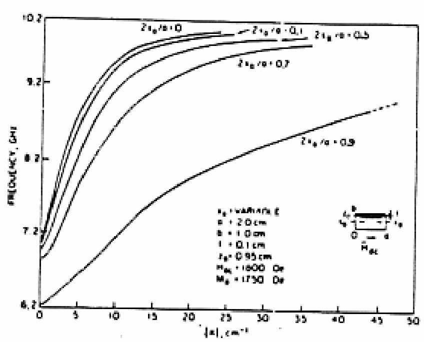

FIG. 3 EFFECT OF INCREASING THE AIR GAP (x_0) ON THE DISPERSION CURVE.

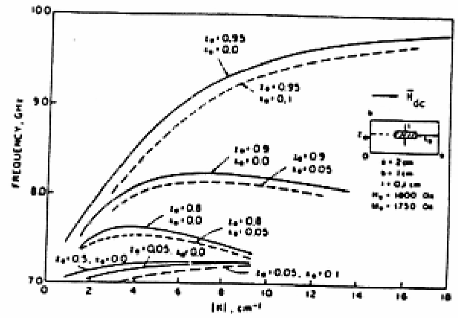

FIG. 4 COMBINED EFFECT OF POSITION AND WIDTH OF THE SLAB ON THE DISPERSION CURVES.

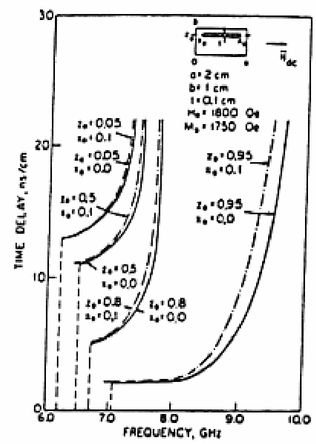

FIG. 5 EFFECT OF SLAB WIDTH AND POSITION ON TIME DELAY/UNIT LENGTH.

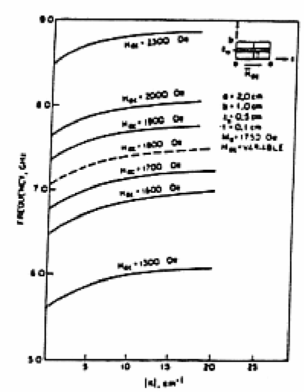

FIG. 6 EFFECT OF MAGNETIC BIAS FIELD