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MAGNETOSTATIC VOLUME WAVE DELAY LINES WITH STEPPED GROUND PLANES

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SUMMARY

A magnetostatic forward volume wave delay line was divided into sections each with a different ground plane spacing. The length of each section was optimized so that the total group delay, i.e., the summation of the delay in each section, showed a minimum phase error from a quadratic phase with frequency characteristic. Using this technique a delay line with 600 MHz bandwidth, 50 nS differential delay and phase error < ± 16° has been demonstrated at X-band.

INTRODUCTION

Potential applications of MSW delay lines in compressive receivers (1) and in variable delay units for phased array antennas place close tolerances on the deviation, or error, from a quadratic phase (linear delay) with frequency variation. A phase error of < ± 5° over a 1 GHz bandwidth and a differential delay of 100 nS is a typical goal. Various approaches to modify the intrinsic MSW dispersion have been investigated, but best results in terms of bandwidth low insertion loss and phase error have been achieved with simple delay lines (3). Here a simple technique is described which allows the variation of one parameter of the delay line along the path length to be optimized and thus yield a minimum phase error.

The delay versus frequency characteristics of simple delay lines, comprising a YIG film spaced from a ground plane, are dependent upon the saturation magnetization, bias field, YIG film thickness, and ground plane spacing. Improvement in the degree of delay linearity with frequency of a surface wave delay line has been demonstrated (4) and was achieved by adjusting the variation in the magnetic bias field along the length of the YIG film by a series of iron screws. However, a study of the effects of different parameters on the delay characteristics of forward volume waves indicated that a controlled variation of the ground plane spacing would be most effective in the synthesis of linear delay with frequency characteristics (3). This technique has also been successfully applied to magnetostatic surface wave delay lines (5).

STEPPED GROUND PLANES

In this investigation it was assumed that the delay line comprised several (n) sections each with different ground plane spacings (t_n) as shown in Figure 1a. Fixing the ground plane spacings, the group delay was calculated as the summation of the group delay in each section and the length of each section (ℓ_n) was optimized so as to obtain a minimum delay error from a linear delay versus frequency characteristic. The minimum phase error obtained is dependent to some extent upon the choice of ground plane spacings for each section, the number of sections and the bandwidth over which the optimization is performed.

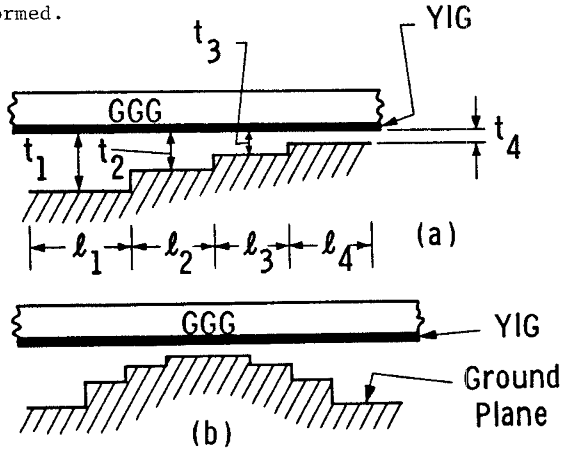

Figure 1. Stepped ground plane with YIG film as used in a) calculation, b) experiment.

Calculated results with a YIG film 32 µm thick and 0.5 cm wide are shown in Figure 2 for a delay line with four sections and the dimensions shown in Table 1. The deviation from a linear variation of delay with frequency in Figure 2 is less than 0.5 nS. The calculated phase error over the same bandwidth is shown in Figure 3 and is less than ± 7°.

Table 1. Ground Plane Spacings and Lengths for a Four-Section Delay Line

Section No., n	Ground Plane Spacing, t_n (cm)	Section Length, ℓ_n (cm)
1	0.0032	0.180
2	0.0045	0.369
3	0.0075	0.155
4	0.0136	0.296

Experiments were performed with the ground plane machined as shown in Figure 1b. Here sections 2, 3, and 4 were each divided to give the symmetrical structure shown. Measurements of group delay and phase error as a function of frequency are shown in Figures 4 and 5 respectively over a 600 MHz bandwidth. Note that a bias field higher than that used in the calculations was applied so that the frequency scales of Figures 2 and 3, and 4 and 5 do not coincide. The differential delay was 50 nS and the phase error shown in Figure 5 was $< \pm 16°$. This phase error is double that predicted from the calculations but will be reduced when device construction techniques are improved and the wave reflections from the steps properly understood and compensated. A three centimeter long device has also been constructed which exhibited 150 nS differential delay with $< \pm 50°$ phase error over an 800 MHz bandwidth. Calculations have been performed which show the feasibility of achieving a $< \pm 5°$ phase error over an 800 MHz bandwidth with a > 100 nS differential delay using this technique.

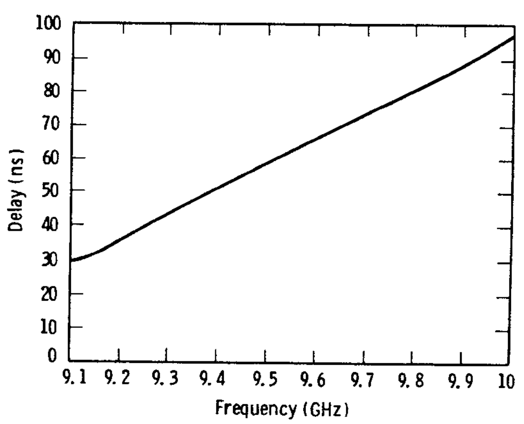

Figure 2. Calculated variation of group delay with frequency.

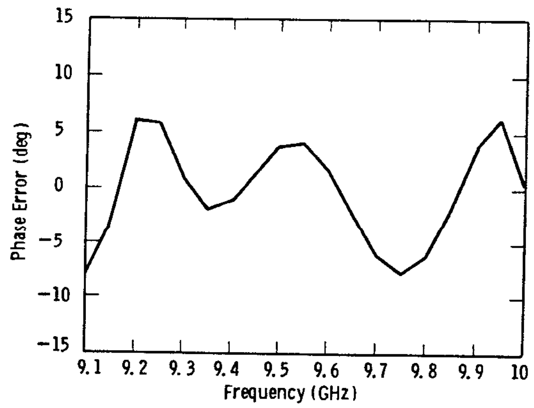

Figure 3. Calculated phase error from a quadratic phase with frequency variation.

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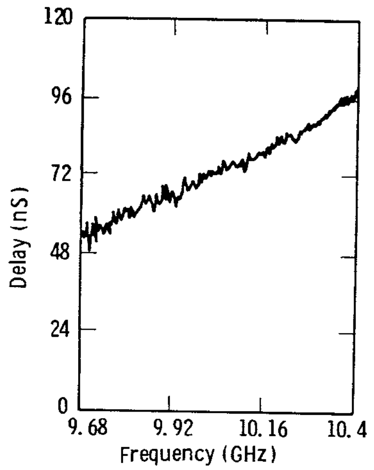

Figure 4. Measured group delay of a forward volume wave delay line.

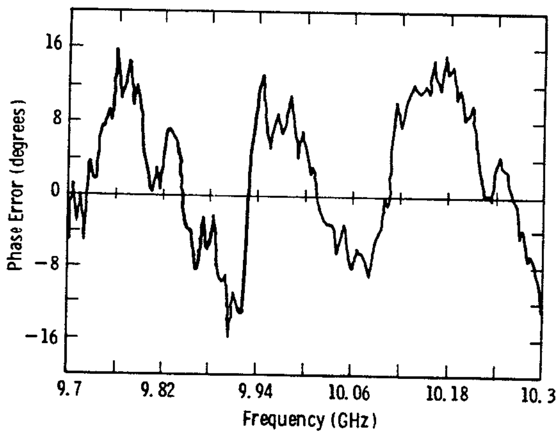

Figure 5. Measured phase error of a forward volume wave delay line.