A TEMPERATURE STABILIZED MAGNETOSTATIC WAVE DEVICE

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ABSTRACT

A narrow band magnetostatic volume wave delay line with rare earth cobalt bias magnets has been constructed whose center frequency of nominally 7.58 GHz drifts by less than 2 MHz over the temperature range 25°C to 70°C.

Introduction

An important factor to be considered in the design and application of epitaxial YIG magnetostatic wave devices is the variation of the device center frequency and delay time with changes in temperature. Techniques previously described which achieved temperature stabilized operation relied either on a special $Y_3La_{3-x}Fe_5Ga_{5-y}O_{12}$ garnet film composition[1] or used a separate temperature stabilizing component in the permanent magnet assembly.[2] This paper describes the application of commercially available rare earth cobalt[3] permanent magnets to achieve temperature stabilization of the center frequency of an epitaxial YIG magnetostatic volume wave delay line. The delay line is for use in an experimental microwave delay line stabilized oscillator.[4]

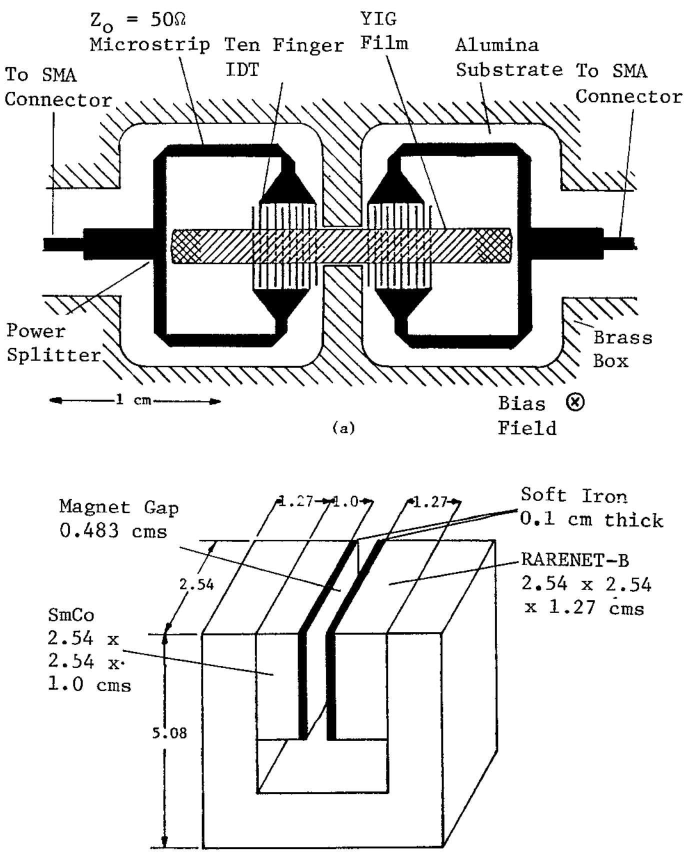

Figure 1. Narrow band delay line construction: a) shows microstrip circuits, transducer structures and YIG film. The magnetic bias field is applied normal to the YIG film plane. b) shows permanent magnet structure used to achieve temperature stabilized operation at 7.58 GHz. All dimensions are in centimeters.

Device Construction

The delay line construction is shown in Figure 1. Figure 1a shows the YIG film, the transducer structures and microstrip circuit. Figure 1b shows the permanent magnet. Magnetostatic waves were transduced using a pair of ten finger interdigital structures[5] as shown in Figure 1a. The interdigital transducers (IDT) produce a narrow band approximately (sin x)/x response, where $x = \pi (k_o-k)/k$, $k_o = \pi/p$, p is the center to center spacing of adjacent fingers and k is the magnetostatic wave number. The finger length in each transducer was 5 mm, finger width 50 μm and center to center spacing, p, of 0.33 mm. Microwave signals are applied to the IDT by microstrip lines and a power splitter. The YIG film used in these experiments was grown by LPE on a <111> GGG substrate, was 10.6 μm thick, width 2 mm and length 20 mm. The ends of the film were ground at an angle of approximately 1/2° in order to prevent reflections from the end of the film. The YIG film was spaced from the transducers by 120 μm so that the input impedance approximated 50Ω at $k = k_o$. The permanent magnet structure, Figure 1b, comprised a soft iron yoke and two rare earth cobalt pole pieces. Soft iron plates were attached to the pole faces so as to improve the field uniformity. Using this structure, fields of up to 5 k Oe, uniform to within one oersted over an area of 3.5 cm^2 have been achieved in the gap.

Experimental Results

The transmission loss of the delay line is shown in Figure 2, over the frequency range 7.75 GHz to 8.15 GHz. Also shown is the transmission phase in the vicinity of the transmission peak at $k = k_o$ (7.912 GHz). In this measurement the bias field of 4.356 k Oe was supplied by the permanent magnet. Identical results were obtained using a 12" electromagnet. Measurements of the

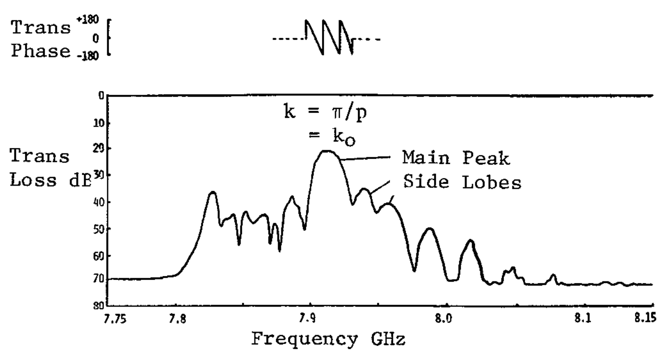

Figure 2. Transmission loss of the narrow band delay line at a magnetic bias field of 4.35 k Oe. The transmission phase response in the vicinity of the main transmission peak at $k = k_o$ is also shown.

center frequency ($k = k_o$) of the (sin x)/x transmission response were made using either a network analyzer or by measuring the frequency of oscillation when the delay line and a TWT were connected as a delay stabilized oscillator. First, the temperature dependence of the center frequency of the YIG device, in a constant bias field, was measured as +9 MHz/°C. This corresponds to a change in effective internal field of +3.2 Oe/°C or, if the bias field is 4.25 k Oe, to a change in bias field of +0.075%/°C. Next the bias magnets were designed to produce a bias field of 4.25 k Oe at 25°C with a temperature dependence of -0.075%/°C, Figure 1b. The two materials[3] used in the construction of the bias magnets were SmCo with a specified temperature coefficient of remanence of -0.04%/°C and RARENET B with a coefficient of -0.09%/°C.

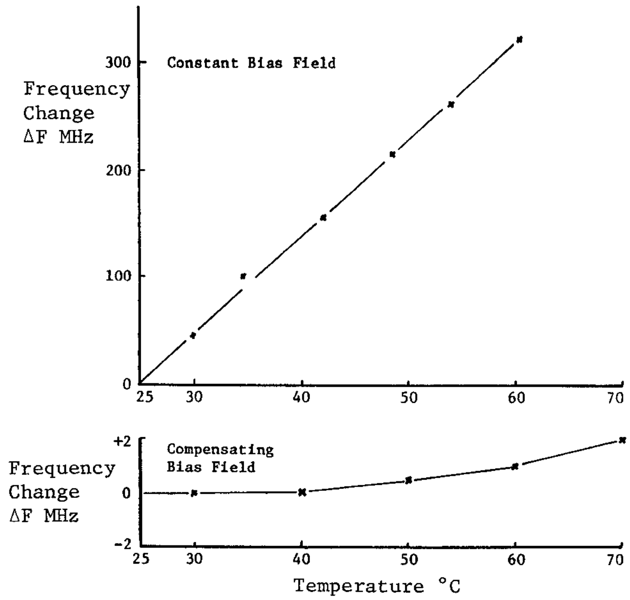

Figure 3. Shows variation of delay line center frequency with temperature. ΔF = 0 corresponds to 7.58 GHz. Upper portion gives temperature variation of the delay line in a constant bias field. Lower portion shows frequency drift characteristics of the delay line when the compensating permanent magnet structure is used.

The variation (ΔF) of the device center frequency with temperature obtained using this permanent magnet is shown in Figure 3. ΔF = 0 corresponds to 7.58 GHz and the temperature range is from 25°C to 70°C. The compensated magnet has kept the center frequency constant to within 2 MHz over a 45°C temperature range. By fine tuning the magnet dimensions the temperature stability can be improved further. Also shown, for reference, in Figure 3, is the temperature variation obtained with the same device in a constant bias field.

Conclusions

It has been demonstrated that good temperature stability can be obtaned over a 45°C temperature range in narrow band magnetostatic wave devices without ovening. The frequency stability achieved is equivalent to approximately 6 ppm/°C. Through the use of SmCo and RARENET B or similar rare earth transition metal permanent magnets[5] it is possible to temperature compensate the center frequency of narrow band magnetostatic volume wave devices throughout the microwave range. The techniques outlined here are also applicable to magnetostatic surface wave devices.

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