DEVICE PERFORMANCE USING MAGNETIC WAVES AT X BAND*

by

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Abstract

The development of samarium cobalt magnets, high quality epitaxial yttrium iron garnet (YIG) films, and a better understanding of surface magnetic waves have resulted in a new class of signal processing devices at X band.

Summary

Signal processing at X-band frequencies and higher is limited to a few technologies which are all inherently lossy. Figure 1 represents the propagation loss typically encountered. The use of bulk acoustic waves in YAG, which is currently favored, has two inherent disadvantages: a transduction loss usually greater than the propagation loss and the inability to tap out energy in a coded fashion. Coaxial and surface acoustic waves, which do not have these disadvantages, are impossibly lossy at high frequencies. Surface magnetic waves in films and bulk[1] YIG appear to be the only devices available for use in complex coding at X-band and higher frequency.

Although bulk YIG has a lower loss than epitaxial YIG (0.7 Oe vs 4.5 Oe at 9 GHz) the epitaxial YIG film can be used to obtain a nonmonotonic dispersion.[2] A typical example of this dispersion is shown in Figure 2. In the +y direction, two regions exist which are of particular interest to the rf signal designer. The first region, about 2.2 GHz on the graph, is centered around a point of inflection. This implies a region which can be used to compress a linear chirp, or, with the use of frequency inversion, produce a passive pulse compression system. At higher frequency a region occurs where $dt/df \approx 0$, approximately 2.3 to 2.5 GHz on the graph, and nondispersive tapping can be used to produce coded waveforms. Thus, a single technology, epitaxial YIG films on a dielectric layered structure, can be used to produce both dispersive and nondispersive delay lines. Since the dispersion characteristic depends predominantly on the structure used, the center frequency of operation can be varied by simply changing the bias field. With the introduction of samarium cobalt magnets, large bias fields can be obtained with magnets of quite modest dimensions.

The bandpass response of a single YIG film in a dielectric layered structure is dominated by loss at opposite ends of the dispersion characteristic. At long wavelengths (short time delays) the wavelength of the magnetic wave exceeds the width dimensions of the film/dielectric structure and suffers cutoff similar to a microwave signal in a waveguide beyond cutoff. At short wavelengths (large time delays) the loss goes as $38.2\,\Delta H \cdot t$ (db) where ΔH is the linewidth in oersteds and t is the time delay in μsec. The resultant bandpass response tends to center on the nondispersive portion of the dispersion as shown by the device results of Figure 3. This device has a 125 nsec delay at 8.45 GHz with a -3 db bandwidth of 45 MHz and a total insertion loss of 20 db.

To obtain a bandpass response necessary for dispersive operation a multiple layered structure with more than one film is used in a magnetic field with a normal gradient. In this structure the dispersion of one film will be perturbed by the dispersion of the other. The result will be that energy is coupled between the two films, giving rise to a wave propagating with the average velocity of the two waves traveling independently. Hence, the resultant dispersion will be the average of the two independent dispersions, and the insertion loss will also be averaged. A dispersive delay line using two films, naturally occurring on opposite sides of a gadolinium gallium garnet seed grown by liquid phase epitaxy, is shown in Figure 4. This device has a linear dispersion of 300 MHz centered at 9.1 GHz with an insertion loss of 25 db. Figure 5 shows the waveforms associated with pulse compression in this device. A compressed pulse of less than 9 nsec with sidelobe suppression of -20 db was obtained. The estimated compression ratio is 30:1. Figure 6 is a photograph of this device compared to a dime. The use of samarium cobalt magnets provides the necessary 2300 Oe bias field and yet keeps the size down to dimension necessary for microstrip applications.

References

1. J.B. Merry and J.C. Sethares, "Low Loss Magnetostatic Surface Waves at Frequencies up to 15 GHz," presented at 1973 Intermag Conference, Washington, D.C.

2. W. L. Bongianni, "Magnetostatic Propagation in a Dielectric Layered Structure," J. Appl. Phys., Vol. 43, No. 6, June 1972.

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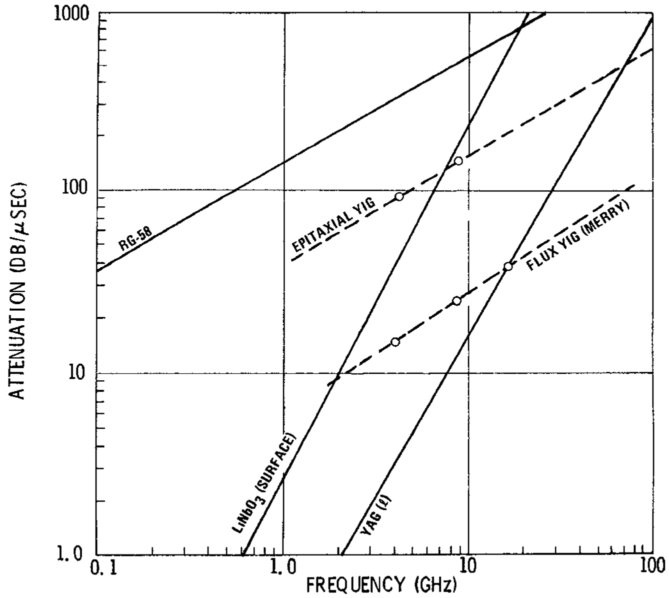


FIG. 1. PROPAGATION LOSS FOR COAX, ACOUSTIC AND MAGNETIC WAVES

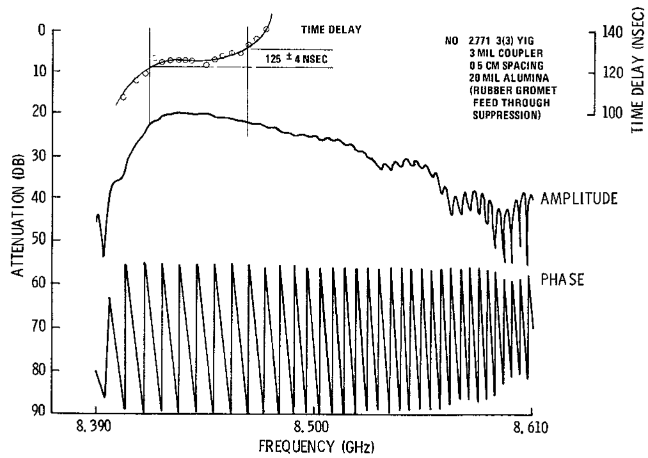


FIG. 3. NONDISPERSIVE DELAY LINE

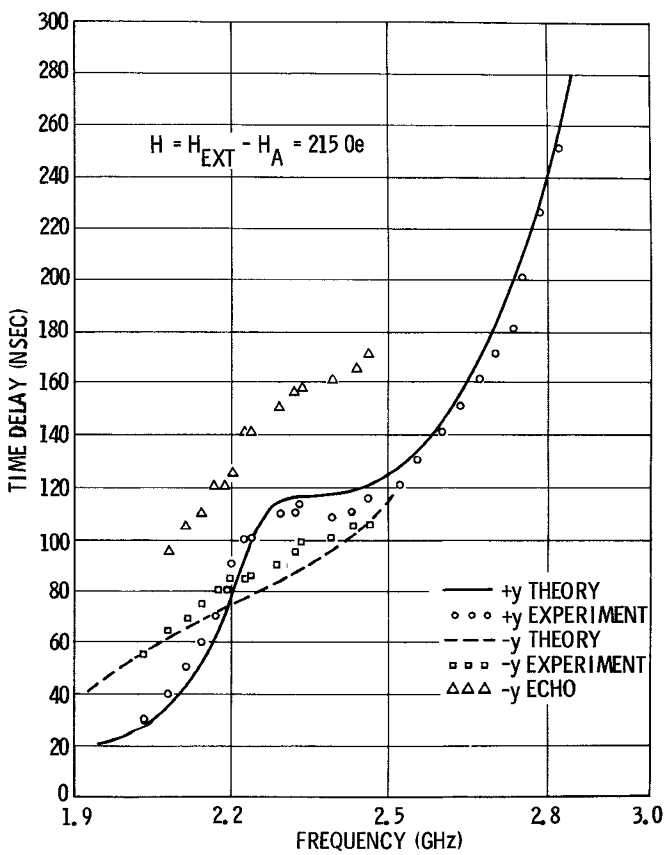


FIG. 2. MAGNETOSTATIC MODE FOR A 10 μ YIG FILM SEPARATED FROM THE GROUND PLANE BY A 125 μ GLASS DIELECTRIC

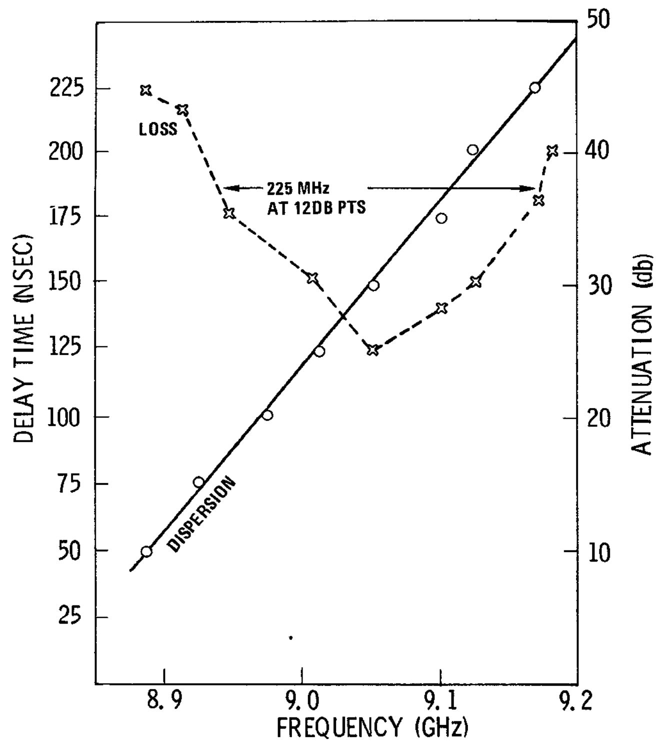
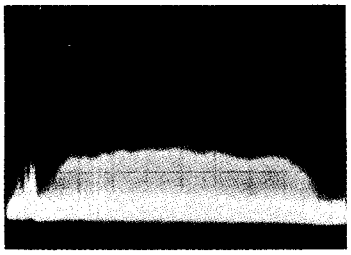


FIG. 4. DISPERSIVE DELAY LINE USING LIQUID PHASE EPI-YIG 10.28 μ THICK (NRA 403B-3)

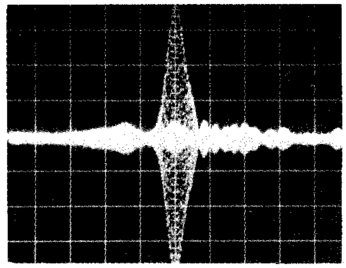


SPECTRUM OF INPUT CHIRP

10 db/ Div. Vert.

30 MHz / Div. Centered at
9. 10 GHz Horz.

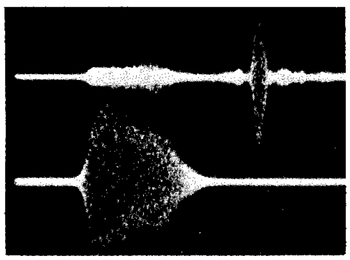
FIG. 5a. PULSE COMPRESSION IN AN X BAND MAGNETIC WAVE DISPERSIVE DELAY LINE



SIDE LOBE LEVEL
Double Exposure of Compressed Pulse With and Without 20 db. Attenuation

20 nsec/ Div. Horz.

FIG. 5d. PULSE COMPRESSION IN AN X BAND MAGNETIC WAVE DISPERSIVE DELAY LINE



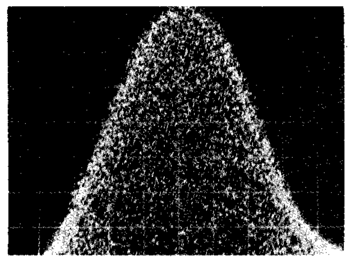
TIME DOMAIN

Compressed Pulse on Upper Trace

Input Chip on Lower Trace

50 nsec/ Div. Horz.

FIG. 5b. PULSE COMPRESSION IN AN X BAND MAGNETIC WAVE DISPERSIVE DELAY LINE

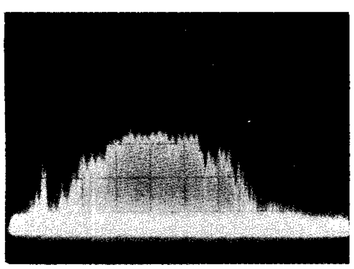


-4 db. POINTS

Expanded View of Compressed Pulse

2 nsec/ Div. With -4 db. Located at Center Line of Graticule. (~8 nsec)

FIG. 5e. PULSE COMPRESSION IN AN X BAND MAGNETIC WAVE DISPERSIVE DELAY LINE



Chirp Spectrum Weighted by The Dispersive Delay Line

10 db/ Div. Vert.
30 MHz/ Div., Centered at
9. 10 GHz Horz.

FIG. 5c. PULSE COMPRESSION IN AN X BAND MAGNETIC WAVE DISPERSIVE DELAY LINE

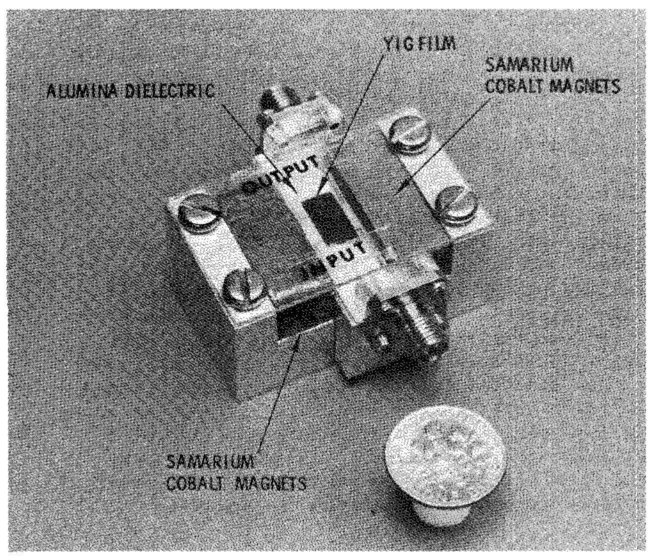


FIG. 6. X BAND DISPERSIVE DELAY LINE USING LIQUID PHASE EPITAXIAL YIG AND SAMARIUM COBALT MAGNETS