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SIMULTANEOUS PULSE SEPARATOR

Pradeep Wahi and Zygmond Turski
Litton Systems, Inc., Amecom Division
5115 Calvert Road
College Park, MD 20740

ABSTRACT

Simultaneous signals in EW/IFM receivers escape unnoticed, thus lowering the probability of intercept. Propagation of these signals through a highly dispersive delay line should separate them in time domain. Magnetostatic waves are inherently dispersive and, therefore, offer great promise for correcting the simultaneous signals problem directly at microwave frequencies. A simultaneous pulse separator using a dispersive delay line is proposed, and the experimental results of an MSW dispersive delay line are reported.

INTRODUCTION

Continuously increasing signal density in the EW environment increases the probability of their simultaneous appearance in the input to the receiver. Furthermore, simultaneous signals can be deliberately transmitted as an effective ECCM technique.

Channelized receivers are quite effective in such an environment since the simultaneous signals will excite different frequency channels and will be processed separately. It is mainly the large size and high cost that limits their deployment.

In the presence of simultaneous signals, an inexpensive IFM receiver will at best measure the parameters of the strong signals, totally ignoring the weaker one and thus lowering the probability of intercept.

Since the simultaneous signals differ in frequency, a time domain dispersion could remedy the problem. For instance, a highly dispersive delay line preceding the IFM receiver would differentially delay the signals depending upon their respective frequencies and thus separate them in time domain (Fig. 1). Wideband microwave dispersive delay lines can be fabricated using bulk or planar structures. Delay line media with highest dispersion are sought to obtain maximum time domain separation in small size.

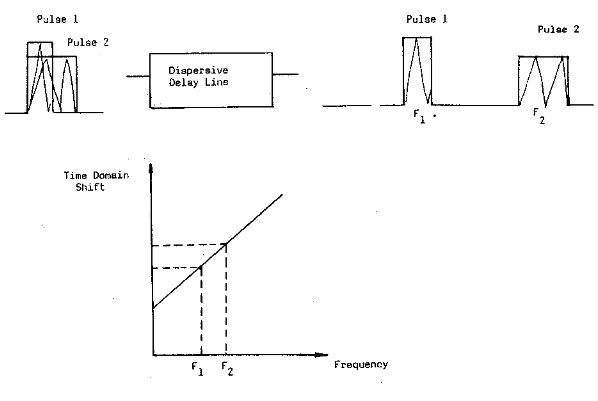

Figure 1: Dispersive Concept for Time Domain Separation

SIMULTANEOUS SIGNAL SEPARATOR

An advanced IFM receiver containing the simultaneous signal separator is depicted in Figure 2. In addition to a traditional IFM receiver, it contains the simultaneous signal detector (SSD), two switches, dispersive delay line, and a compensating non-dispersive delay line. The SSD, originally designed to flag the presence of simultaneous signals close in amplitude beyond system's discrimination capability, will be readjusted to flag every simultaneous signal occurrence. Such an SSD controls the two switches routing only the simultaneous signals through the dispersive delay line for time domain separation. The non-dispersive delay line L_C compensates for the time elapsed due to propagation through SSD and associated switches. The key element of the pulse separator is the dispersive delay line. A number of non-TEM transmission structures and propagation media were studied to identify the parameters maximizing dispersion. For this application linearization of dispersion is clearly not necessary.

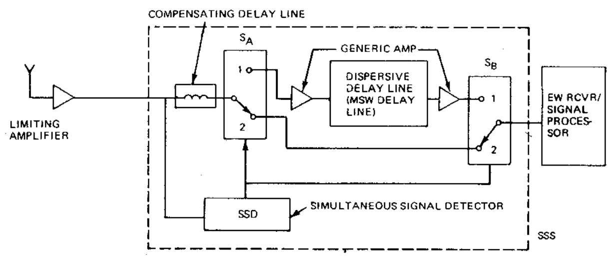

Figure 2: Simultaneous Signal Separator

DISPERSION ON DIELECTRIC SUBSTRATES

Asymmetric structures such as microstrips, slotlines or coplanar waveguides propagate non-TEM modes and, therefore, exhibit dispersion. Since the dispersion needs to be at least such that two simultaneous signals in C-band separated by 100 MHz will disperse in time domain by 30 nsec, it implies certain dispersion sensitivity $S = \Delta Vp/\Delta l$, if the delay line length is fixed. Although investigated, in a simple microstrip case dispersion sensitivity is insufficient in order to fabricate a delay line of reasonable length. A layered dielectric medium enhancing the dispersion was studied. Experimental results showing increased dispersion were reported earlier (1). The dispersion increases appreciably when a layered dielectric medium is arranged so that the dielectric constant increases from top to bottom layer (Figure 3). Dispersion increases with the ratio of the lowest to the highest K value, with the thickness of the lower dielectric layer and when the change in the dielectric constants between the layers is gradual. The overall dielectric constant or the size of the delay line is, however, determined by the lowest k value associated with the top layer substrate. Thus, there exists an upper limit on the achievable reduction in length of the delay line for a desired

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dispersion; simple calculations showed that, typically, a delay line length of 80 meters would be required to separate simultaneous signals 100 Mhz apart by 30 ns in time domain (1).

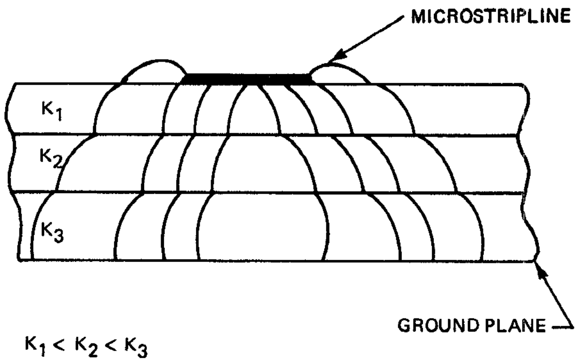

Figure 3: Layered Dielectric Medium Microstripline

MAGNETOSTATIC WAVE DELAY LINE

Magnetostatic waves (MSW) are relatively slow (3-300 Km/Sec) and inherently dispersive. Improved growth techniques for YIG film on Gadolium Garnet (GGG) substrates have revived the interest in MSW (2,3). The low phase velocity and inherent dispersion along with frequency tunability up to 20 GHz make MSW ideal for wideband microwave dispersive delay lines. Typically, time delays and dispersion of 100 ns/cm and losses less than 20 dB/usec are achievable with available YIG films. Preliminary MSW dispersive delay lines for a simultaneous pulse separator were fabricated. Although experimental results measured for magnetostatic surface wave mode indicate acceptable magnitude of dispersion, an optimization of parameters continues. In a surface mode, $\vec{H} \times \vec{n}$ is parallel to the propagation vector, $\vec{k}$, where $\vec{n}$ is the unit normal to the plane of the YIG film as shown in Figure 4. Energy is primarily confined to the surface of the YIG film.

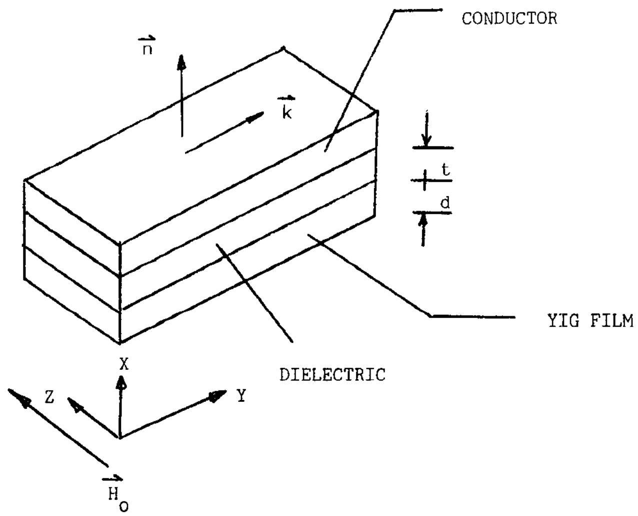

Figure 4: MSSW Coordinate System

In a limiting case when the ground planes are far removed from the film, the dispersion relation is given as (4):

$$e^{-2|k|d} = 1 + 4\Omega_H + 4\Omega_H^2 - 4\Omega^2 \qquad (1)$$

where:

- d is thickness of the film
- Ω is $\omega/\omega m$
- Ω_H is $\omega c/\omega m$
- ωm is the frequency corresponding to the saturation magnetization, $4\Pi M_s$, of the YIG
- ωc is the gyromagnetic angular frequency.

Dispersion can be modified with the thickness of the film, the spacing of the ground planes, and the magnetic bias field. The theoretical and experimental results for modifying thickness are shown in Figure 5.

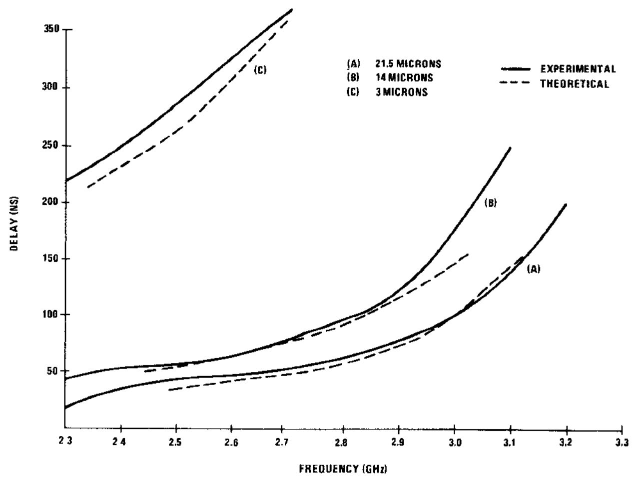

Figure 5: YIG Film Thickness Effects

The thinner films are more dispersive and, therefore, should be suitable for pulse separator application. This permits use of the modified bubble memory YIG films where the device technology is well documented. Figure 6 shows the separation of simultaneous signals, 150 MHz apart, by at least 40 ns using 3 micron thick film. The ultimate bandwidth is controlled by the MSSW passband between propagation frequencies f_l and f_h:

$$f_l = \gamma (h^2 + H.4\Pi M_s) < f < \gamma(H + 2\Pi M_s) = f_H \qquad (2)$$

where:

- H is the internal bias field
- γ is the gyromagmetic radio, 2.8 MHz/Oe.

A wider instantaneous frequency band is obtained by staggering delay lines with different center frequencies.

Shorted narrow microstrip couplers were used for an efficient transduction onto the YIG film. Attachment of a simple microwave matching network designed using the S parameters substantially improved the return loss. Most of the films available for microwave applications are limited to one inch diameter. Separation of signals, 100 MHz apart, by at least 40 ns was achieved by cascading two 1.2 cm long 14 micron thick YIG film delay lines.

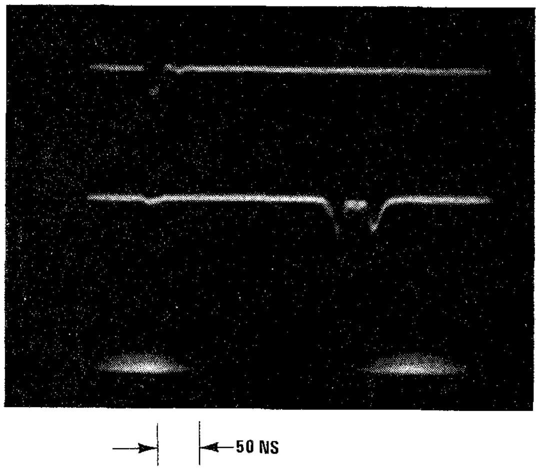

Figure 6: Simultaneous Signals at 2.4 and 2.55 GHz Using 3 Micron Thick 1.2 Cm Long YIG Film

The effect of temperature was empirically investigated and shown to be similar to that of changing magnetic bias field. This indicates the possibility of compensating for temperature ch~nges by varying the magnetic bias field.

It appears that the intrinsic dispersion of MSW can be further modified and enhanced by reflective arrays similar to those used in surface acoustic wave devices.

CONCLUSIONS

A dispersive simultaneous signal separator in conjunction with an inexpensive IFM receiver should improve the probability of intercept in a dense EW environment. Work conducted to date on MSW dispersive delay lines results in 40 ns separation of simultaneous signals in frequencies as close as 2.4 and 2.55 GHz. It is anticipated that further optimization of dispersion, mainly by the means of SAW-like arrays, will enable IFM performance in pulse environment close to that of a channelized receiver, at a fraction of the cost and size.

ACKNOWLEDGEMENT

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REFERENCES

1. Wahi, P.K. and Turski, Z. "Dispersion in Microstrip Lines Comprising Layered Dielectric Media" Electronics Letters Vol. 17, No. 21, p. 785-786, 1981.
2. Sethares, J.C. "Magnetostatic Wave Devices and Applications" 27th Annual Conference on Magnetism and Magnetic Materials, paper DB-1, Atlanta, Nov 10-13, 1981.
3. Collins, J.H. and Owens, J.M. "Magnetostatic Wave and Saw Devices - Similarities, Differences and Trade Offs" 1978 IEEE Ultrasonic Symposium Proceedings, IEEE cat CH1358-1/78 p. 536-540.
4. Bongianni, W.L. "Magnetostatic Propagation in Dielectric Layered Structure" J. Appl. Phys. Vol 43, p 254-2548, June 1972.