A MAGNETOSTATIC DELAY LINE OSCILLATOR

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Abstract

A single mode X-band oscillator has been built using a magnetostatic delay line as the frequency stabilization element. Experimental data are presented.

Introduction

One of the more promising devices to appear in surface wave technology in recent years is the surface acoustic wave delay line oscillator.[1] Present photolithographic techniques limit the upper useful frequency of this device to about 2 GHz. The magnetostatic surface wave delay line[2] (MSWDL), on the other hand, is capable of operating from approximately 2 GHz up to 18 GHz. An X-band oscillator using this delay line is the subject of this paper.

Theory

The conditions required for oscillation in a feedback loop oscillator are that the path length around the loop be $2\pi N$ radians, where N is an integer, and that the loop gain exceeds unity at the operating frequency. The block diagram of the MSWDL oscillator is shown in Figure 1 below.

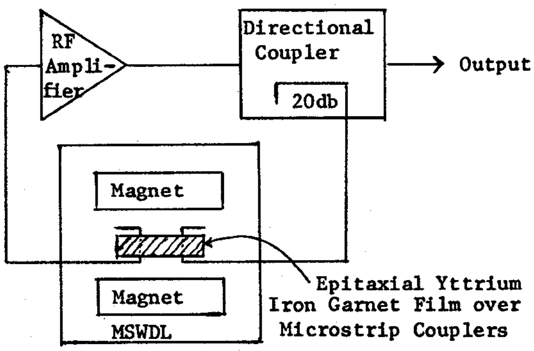

Figure 1. MSWDL Oscillator Block Diagram

The signal path length through the MSWDL is many wavelengths long (~300). By phase considerations alone this would give rise to a comb of frequencies spaced @ 30 MHz intervals, but the amplitude passband of the MSWDL (see Figure 2) and the nonlinear nature of the traveling wave tube amplifier select one frequency from the possible comb.

When power is applied to the amplifier, oscillations build up in amplitude until limited by nonlinear elements in the loop. Unlike its acoustic counterpart the MSWDL oscillator can be readily tuned. This is achieved by varying the strength of the applied magnetic bias field either by moving the permanent magnets or inserting the device into a solenoid. Other methods of tuning are possible which involve changing the electrical path length around the loop. Varactor phase shifters, line stretchers and possibly the application of semiconductor overlays[3] are examples of this second method.

Experimental Results

The amplifier used in the experimental setup was an Alfred 563A T.W.T. amplifier, with adjustable gain.

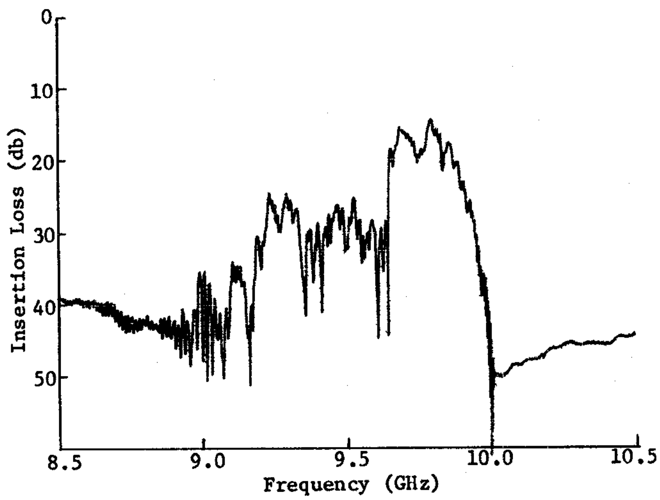

Figure 2. MSWDL Bandpass Response

The MSWDL is shown in Figure 3. The YIG film, 22μm thick, on a gadolinium gallium garnet substrate, is placed face down on two microstrip coupling arms. The coupling arms are separated by 0.47×10^{-2} meters which corresponds, for this sample, to a delay of 32 ns.

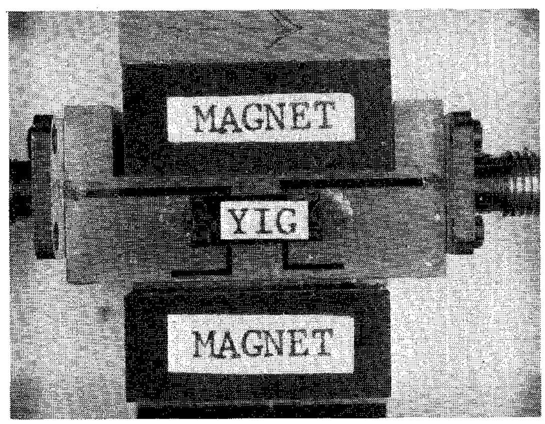

Figure 3. The MSWDL

This yields a velocity of 1.47×10^{5} meters/second. At 9.7 GHz, therefore, the wavelength in the YIG is 15μm and the total path length through the YIG is a little over 300 wavelengths.

The operating frequency of this particular oscillator was between 9.6 and 9.8 GHz, depending on the laboratory temperature and stray magnetic influences on the test bench (no attempt was made to magnetically shield the oscillator). The temperature drift measured was 5 MHz/°F and during the course of the temperature run the oscillator was observed changing modes. The results of this test are presented in Figure 4.

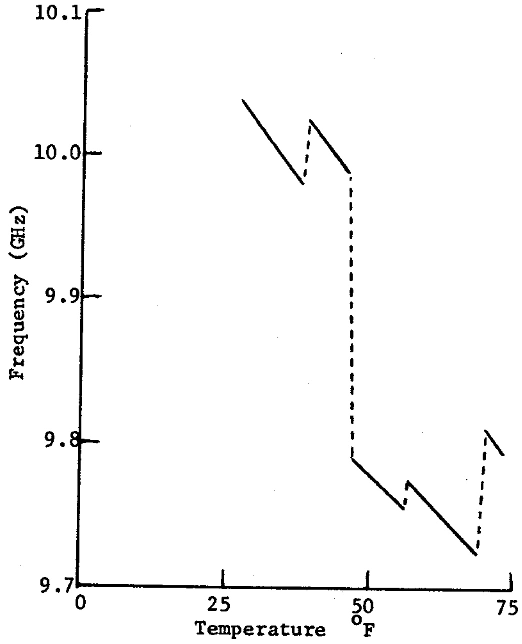

Figure 4. Temperature Drift Characteristics

The power spectrum 3db points were separated by approximately 40 kHz--this measurement was made using a Watkins-Johnson low noise traveling wave tube, part number WJ-424 (Fig. 5), and a microwave counter registered less than 7 kHz/second frequency shift. The frequency shift is fairly steady and is thought to be thermal in nature. No spurious modes were observed above the noise floor of the spectrum analyzer (55db below the signal except for those generated in the test instrument (Fig. 6).

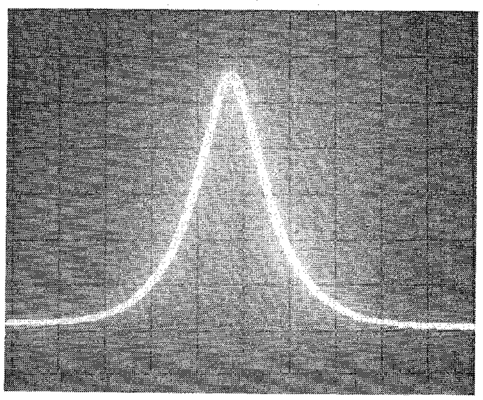

Figure 5. Magnetostatic Oscillator Power Spectrum

Center Frequency	9.199 GHz
Horizontal	100 kHz/div
Vertical	10db/cm

Electromagnetic tuning was achieved using a single layer solenoid 7.6×10^{-2}m diameter and containing 26 turns of #22 wire closely wound. For a 3 ampere current this coil yielded a field of approximately 12 gauss at its center. From 0 to 3A change of current

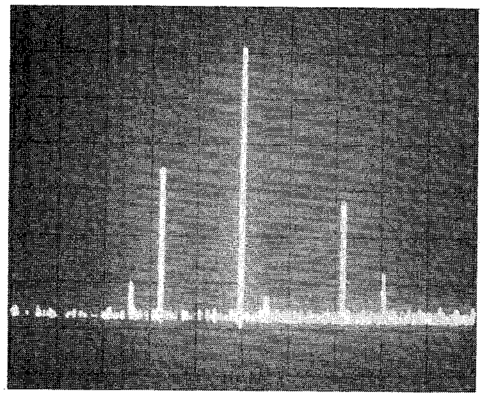

Figure 6. Spurious Mode Spectra

Horizontal - 200 MHz/cm
Vertical - 10db/cm
All apparent spurious modes were shown to be generated in the spectrum analyzer.

through the coil the frequency was observed to shift from 9.6888 GHz to 9.7163 GHz yielding approximately 2.3 MHz/gauss tunability. The same coil was connected to a 2 MHz source and the resulting modulation recorded on a spectrum analyzer (Fig. 7).

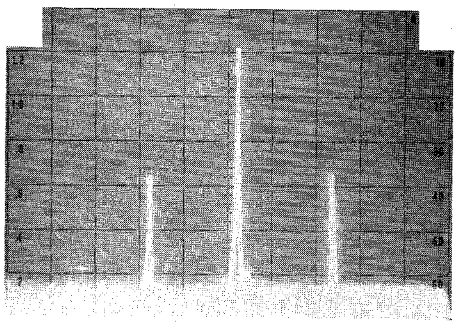

Figure 7. Modulation Spectrum

Center Frequency - 9.68 GHz
Horizontal - 1 MHz/cm

Summary

The MSWDL offers a new method of stabilizing microwave oscillators over the frequency range of 2-18 GHz. It is compatible with present microstrip R.F. integrated circuitry and miniaturization could be achieved using solid state amplifiers. Temperature drift is excessive at the present state of the art but can possibly be compensated for by using gallium substituted YIG and varactor compensated amplifiers.

References

1. Lewis, M. F., "Surface Acoustic Wave Devices and Applications. 6. Oscillators - The Next Successful Surface Acoustic Wave Device?" Ultrasonics, May 1974, 115-123.
2. Bongianni, W. L., "Device Performance Using Magnetic Waves at X-Band," IEEE G-MTT International Microwave Symp., Colorado, June 1973.
3. Masamitsu, et al., "Magnetostatic Surface Waves in Ferrite Slab Adjacent to Semiconductor," IEEE-MTT, Feb. 1974, 132-135.