II-8. A YIG Delay Line for Use at Microwave Frequencies

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The application of yttrium iron garnet in microwave devices has been associated with electronic tuneable filters and low-level power limiters. The characteristics of YIG exploited in these components is the extremely narrow linewidth of the material in the region of ferromagnetic resonance.

Recent experimental investigations of the microwave acoustic properties of single crystal yttrium iron garnet have suggested many novel rf device applications that should prove useful to the system designer.

The work of Spencer *et al*[1] triggered a sequence of experiments with YIG that clearly demonstrate the realization of a new class of solid state device. The first application of YIG as a delay line was reported by Eggers and Strauss[2] in the uhf band. The use of permanent magnets with an L-band delay line was first described by Sparks and Higgins.[3]

In this paper, the results of using single-crystal YIG bars for microwave delay lines up to 4 Gc/sec are discussed. Also, the design considerations for light-weight, low-power, non-cryogenic microwave memories are reviewed using yttrium iron garnet as the delay medium and permanent magnets for the biasing field.

The device operation is based on the conversion of rf energy to elastic vibrational energy so that the delay obtainable is proportional to the crystal length and the velocity of propagation of sound in YIG. Figure 1 shows the ex-

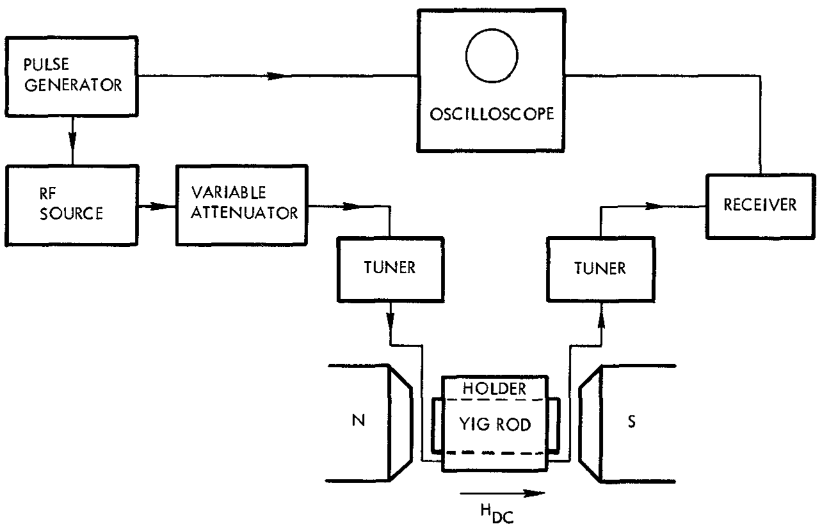

Fig. 1 Experimental arrangement used to excite microwave phonons in YIG.

perimental arrangement for the generation and detection of microwave phonons in yttrium iron garnet. The YIG rod, mounted in a holder, is placed in a dc magnetic field of sufficient magnitude to bias the end faces near ferromagnetic resonance.

When excited by an incident electromagnetic pulse, the short-circuited end of the input coaxial center conductor produces a large oscillating magnetic field which is transduced by a magnetostrictive process to a circularly polarized acoustic shear wave in the YIG. The acoustic wave propagates down the rod and a fraction of the energy is transmitted via the output antenna. The balance of the energy is reflected back to the input.

The energy in the transmitted wave is transduced to electromagnetic energy by a process inverse to that described earlier.

The reflected pulse continues to traverse back and forth in the YIG rod until all the energy is transmitted, or dissipated by scattering and sonic absorption processes.

The output signal is observed as a train of pulses, damped exponentially and spaced in time an amount corresponding to the round trip distance in the medium. Figure 2 is a photograph of a pulse train obtained with a permanent magnet yttrium iron garnet delay line using a crystal oriented in the [100] direction. The frequency of operation in this case was 1100 Mc/sec and the horizontal scale was 5 microseconds per division.

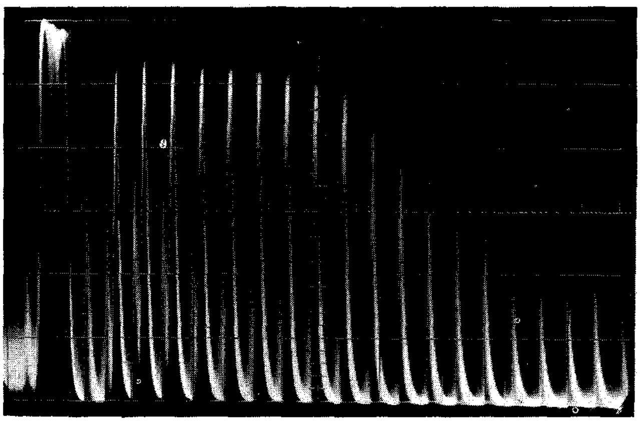

Fig. 2 Pulse train setup in [100] oriented YIG crystal.

Figure 3 is a photograph of an "in-line" coaxial YIG delay line that employs a cylindrical type permanent magnet. The small YIG crystal that serves as the delay medium is shown in the foreground.

Prototype designs for YIG delay lines have been established which considerably reduce the magnet size and incorporate a matching section as an integral part of the device as depicted in Fig. 4. Figure 5 illustrates a delay line employing a small cylindrical magnet with the TNC connectors threaded directly into the pole pieces. Investigations are now in progress to determine the optimum pole-piece configuration to enhance the field strength and uniformity in the center gap.

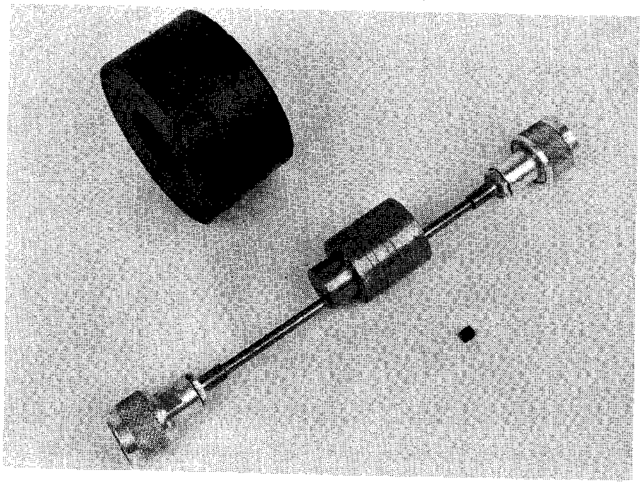

Fig. 3 Permanent magnet, coaxial assembly and YIG crystal for delay line applications.

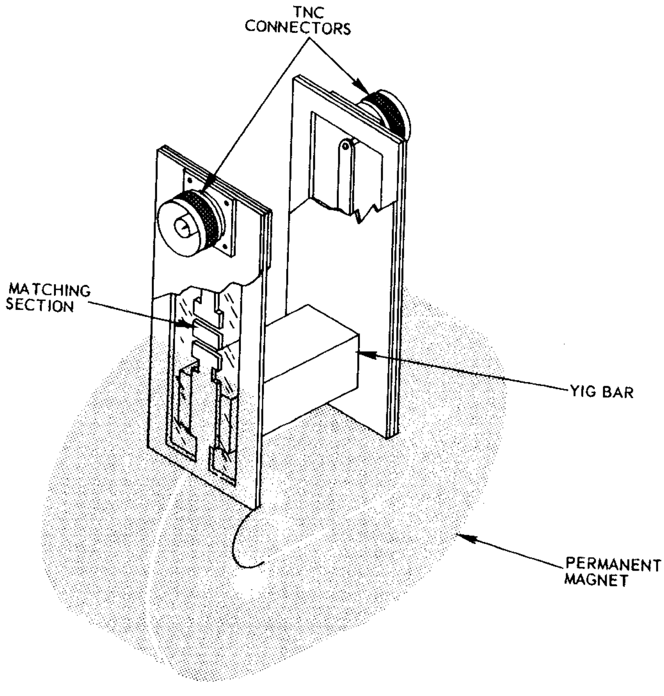

Fig. 4 Prototype design of permanent magnet yttrium iron garnet delay line.

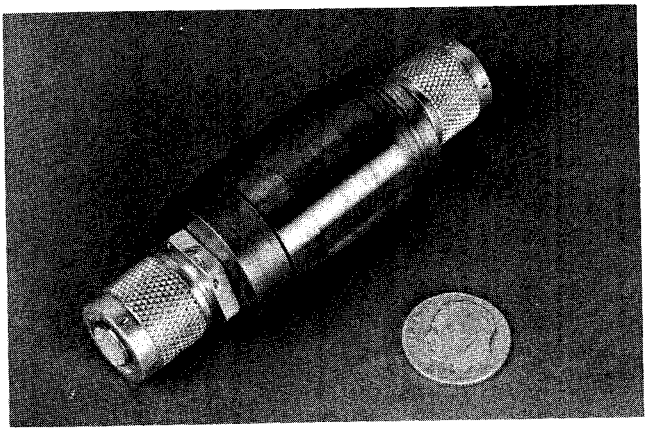

Fig. 5 YIG delay line with cylindrical magnet and pole pieces.

Insertion loss measurements have already been made up to 4 Gc/sec, and are being extended to X-band. Further work is necessary to improve the dynamic bandwidth and insertion loss of the permanent magnet devices. Preliminary investigations of the rf probe configuration have suggested significant design improvements in this area.

REFERENCES

1. E. G. Spencer, R. T. Denton and R. P. Chambers, "Temperature Dependence of Microwave Acoustic Losses in Yttrium Iron Garnet," *Phys. Rev.*, Vol. 125, pp. 1950–1951 (March 15, 1963).
2. F. G. Eggers and W. Strauss, "A UHF Delay Line Using Single Crystal Yttrium Iron Garnet," *J. Appl. Phys.*, Vol. 34, Pt. 2, pp. 1180–1181 (April 1963).
3. R. A. Sparks and E. L. Higgins, "An L-Band Permanent Magnet Type Yttrium Iron Garnet Delay Line," Paper E-7, *Digest of Ultrasonics Symposium*, December 6, 1963.