Letters to the Editor

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A Solid-State Microwave Amplifier and Oscillator Using Ferrites

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A MICROWAVE amplifier and oscillator has been built using, as the active element, a piece of magnetized ferrite at room temperature. The operation of this device is based on the proposal by Suhl[1] in which microwave power at one frequency produces, through nonlinear coupling in the ferrite, amplification of a lower frequency microwave signal. Theory predicts that such a device should be a low-noise amplifier.

Suhl proposed that a ferrite sample be placed in a cavity which is simultaneously resonant to two signal frequencies f_1 and f_2. At the position of the ferrite, the field configuration at one of these frequencies must have a magnetic field component along the direction of an applied dc magnetic field, and the field configuration at the other frequency must have a component perpendicular to this direction. A high-power "pumping" field of frequency f_1+f_2 is applied perpendicular to the dc magnetizing field which is adjusted for gyromagnetic resonance at this frequency. Under these conditions amplification or oscillation should be observed at the signal frequencies f_1 and f_2.

In our experiment the pumping frequency was 9000 Mc/sec and, in order to simplify the circuitry, the two signal frequencies were made approximately equal to the subharmonic, 4500 Mc/sec. The signals were capacitively coupled by a coaxial probe to a resonant circuit consisting of a half-wavelength shielded strip line with a Q of 500, as shown in Fig. 1. Two disks of single-crystal manganese ferrite, 0.125 in. in diameter and 0.050 in. thick were placed on top and bottom of the strip at the center point. The pumping power was applied through a dominant-mode wave guide running at right angles to the strip line. The dc magnetic field was applied in the plane of the strip and was directed at an angle of approximately 45° to the strip line so that components of signal field existed both parallel and perpendicular to the dc field.

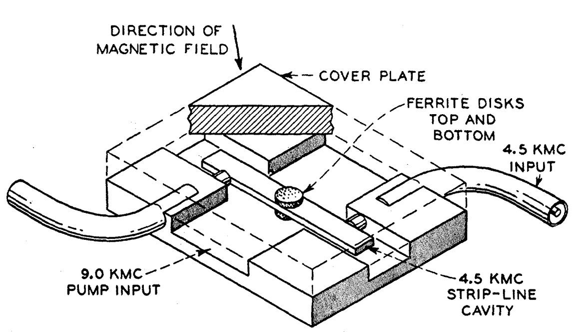

FIG. 1. Cavity configuration for ferrite microwave amplifier.

With a pumping pulse of 20 kw peak power and of 3 μsec duration, a pulse of oscillations at 4.5 kMc/sec was observed having an output power of 100 watts. We have not yet measured how much of the pumping power was actually absorbed in the ferrite.

By reducing the pumping power below the threshold value required for oscillation, a range of amplification could be observed. Thus, by reducing the 9-kMc/sec drive about one db below the oscillation threshold, a gain of 8 db was observed at 4.5 kMc/sec. As the signal was detuned from 4.5 kMc/sec, its image, f_2, was displaced from f_1 and beats could be observed.

Another experiment was made in which f_1 and f_2 were 4.0 and 4.8 kMc/sec, respectively, with the resonant circuits consisting of a shielded strip-line cross. Frequency conversion and oscillations were observed at 4.0 and 4.8 kMc/sec. The oscillations had a peak power of 50 microwatts and were jittery in amplitude for reasons not yet clear.

I wish to thank A. G. Fox, H. Suhl, and E. H. Turner for many helpful discussions and F. A. Dunn for very competent technical assistance.

[1] H. Suhl, Phys. Rev. **106**, 384 (1957).

Ultrasonic Attenuation by Free Carriers in Germanium

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RECENTLY, Blatt[1] gave some discussion to the attenuation of ultrasonic shear waves to be expected in multivalley semiconductors due to the presence of free carriers. It is the purpose of this note to point out the close relationship between this process and the acoustoelectric effect, and to use the observed[2] magnitude of the acoustoelectric effect to predict the amount of attenuation to be expected (which is somewhat different from that predicted in reference 1).

Since the ultrasonic wave carries a flux of momentum equal to $1/c$ times the flux of energy (c being the wave velocity), a loss of wave energy must be accompanied by a proportional loss of momentum; this loss of momentum appears as a dc force exerted on the