6.3 ELECTROMAGNETIC PROPERTIES OF WEAKLY IONIZED ARGON

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The electromagnetic properties of a rectangular dielectric slab enclosed in waveguide has been previously analyzed and reported.[1,2] A complex transmission coefficient, τ, may be written for the slab as

$$\tau = {}^{E_t}/_{E_i} \tag{1}$$

and

$$\frac{1}{\tau} = {}^1/_2 \left(\frac{\gamma_\epsilon}{\beta_o} + \frac{\beta_o}{\gamma_\epsilon} \right) \sinh \gamma_\epsilon L + \cosh \gamma_\epsilon L \tag{2}$$

where E_t is the complex voltage transmitted through the slab
E_i is the complex voltage incident on the slab
γ_ϵ is the complex propagation constant for the dielectric equal to $\alpha_\epsilon + j\beta_\epsilon$ where α_ϵ is the attenuation constant and β_ϵ is the phase velocity constant.
β_o is the phase velocity constant for free space and
L is the thickness of the slab.

The use of a microwave bridge circuit allows time resolved measurement of the phase and attenuation of the transmitted signal relative to a reference signal. Use of equations (1) and (2) permits computation of α_ϵ and β_ϵ, from which the electromagnetic properties of the plasma including (1) electron density, (2) electron collision frequency, (3) conductivity and (4) reflection coefficient may be determined.

The plasma studied is shock heated using a conventional shock tube. A volume of ionized gas passes through narrow slots in the side walls of X-band waveguide (Fig. 1). Flow internal to this section is constrained to original flow streamlines by the knife edge walls and ceramic windows brazed into the waveguide. External flow is diverted into an expansion section by the wedge design of the microwave housing. The ceramic windows are made one-half wavelength at 10 kmc resulting in less than 1% reflection. Radiation losses from the slots are negligible.

A block diagram of the microwave apparatus is shown in Fig. 2. Figure 3 is a representative oscillograph of a test run. The upper curve is the crystal voltage output of the magic T sum arm; the lower curve is the crystal voltage output in the magic T difference arm. These deflections are converted to microwave input levels using static crystal calibration curves. The blanking marks are used for accurate time correlation of the two sweeps and occur at 10 μsec intervals.

Electron densities of 10^{10} - 10^{13} electrons cm^{-3} have been measured at 10 kmc using this system. Reduced data for the electromagnetic parameters as a function of distance behind the shock front for low Mach number shocks are presented. Measurement and calibration techniques and the limitations and accuracy of measurements are also discussed briefly.

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[1] F. J. Tischer, Measurement of the Wave Propagation Properties of Plasma in the Microwave Region, Ohio State University Report 941-1, August 1959, Diamond Ordnance Fuze Laboratories, Ordnance Corps, Contract DA-49-186-502-RD-816, pp. 17.

[2] F. L. Tevelow and H. D. Curchack, Shock Tube-Microwave Propagation Measurements Using the Dielectric Slab Approximation, Presented at 2nd Magnetohydrodynamics Symposium, March 1961, Philadelphia, Pennsylvania.

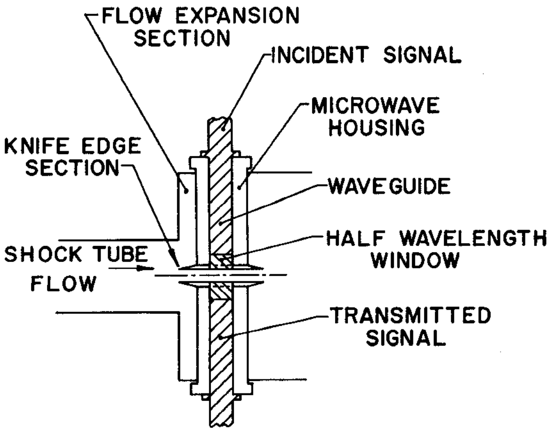

Figure 1 - Shock Tube-Microwave Test Section (Schematic).

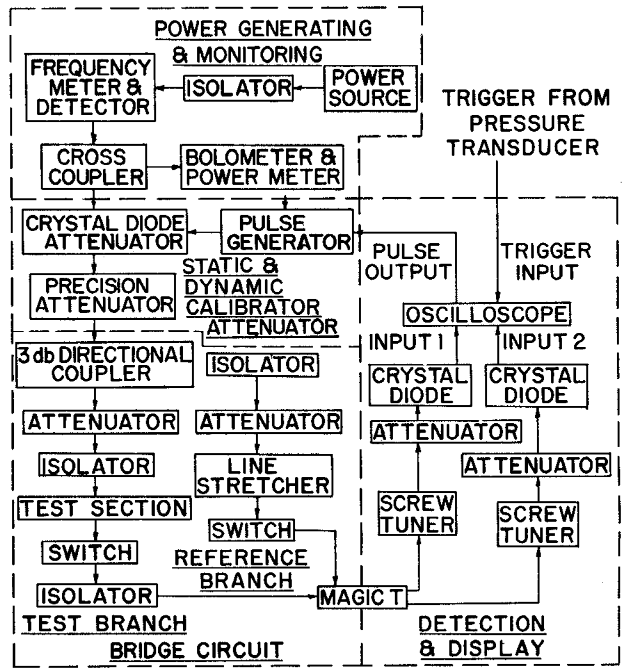

Figure 2 - Microwave Circuitry (Block Diagram).

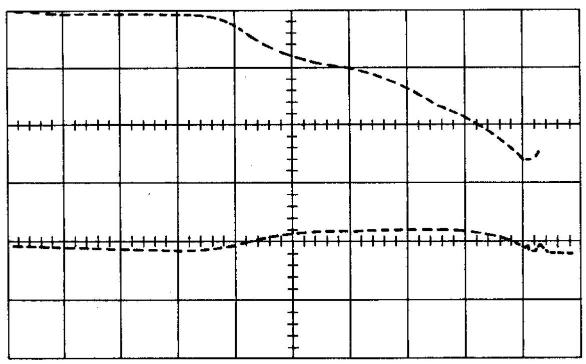

Figure 3 - Magic T Crystal Diode Voltage Outputs.