6.1 MICROWAVE INSTRUMENTATION FOR PLASMA RESEARCH*

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This instrumentation has been developed to make extensive microwave measurements on shock induced plasmas each of which exists for a small number of milliseconds. The over-all equipment can irradiate the plasma at two frequencies, one near 8 kmc, and the other near 60 kmc. The irradiation at 8 kmc propagates parallel to the glass shock tube axis, and the 60 kmc propagates perpendicular to the axis as shown in Fig. 1.

Metallic wave guide boundaries having circular cross section surround the cylindrical shock region. The wave guide components are designed for TE_{11} propagation at 8 kmc. The unloaded 2 3/8 inch inner diameter tube will support more than 9 wave guide modes. Consequently, a great deal of attention has been given to controlling the generation of unwanted modes.

The 2 3/8 inch metal tube is terminated in a manner permitting the shock induced plasma to propagate through a circular hole in the loading structure. Some details of this wave guide structure are given here. The reflections due to this termination are kept small. The reflection due to the plasma is the principal component of the reflected wave. It is separated from the input wave by a circulator and subsequently detected.

All the components are capable of withstanding 100 kilowatt peak power levels at 8 kmc. Average power levels at 8 kmc can be as large as 2 kilowatts.

The 60 kmc wave guide boundaries intersect the 8 kmc boundaries at right angles. Various launching structures have been investigated for crossing the 2 to 3 inch gap along a diameter of the 8 kmc wave guide boundary. Both the 8 kmc and 60 kmc receivers evaluate the magnitude and phase of the signals at their inputs. The 8 kmc signal samples are either from the reflection at the leading face of the plasma or the transmission through the plasma. The 60 kmc signal is either reflected from the plasma together with its glass boundary or is transmitted through the plasma and its glass boundary.

The 8 kmc source equipment, as shown in Fig. 2, includes a frequency offset generator which supplies a signal offset 30 megacycles, to be propagated in the plasma tube region. The original signal is also used as the local oscillator in the receiver. The entire transmission receiving system is, therefore, coherent. This permits significant measurements by phase detection.

The IF frequency used in the receivers is 30 megacycles. The IF amplifiers have extremely flat limiting over a 30 db range. Their bandwidth is 5 megacycles. Excursions of 30 db in the signal amplitude can be handled with phase errors of about 1 degree.

Magnitude measurements are carried out in a separate portion of the 30 mc receiver. For high sensitivity to changes in magnitude a differential magnitude measurement system is used.

The substantial bandwidth, 5 megacycles, is required by the high plasma velocity of about 2 millimeters per microsecond and also by the switching used in the sampling mode. In this mode the precision receiving system is sequentially switched among a group of microwave inputs. One of these is the signal reflected from the moving, leading surface of the plasma. The others (See Fig. 1) are a series of fixed probes distributed along the wave guide boundary. Sampling times of several microseconds are being used.

A single throw, five pole microwave switch is used in the sampling system. Five microwave output signals are all sampled in sequence. The single port output of the switch goes to the microwave receiver which is capable of recording both the magnitude and phase information as a series of microsecond pulse pairs.

The 60 kmc system (see Fig. 3) consists of two klystrons phase locked to each other with a frequency separation of 30 megacycles, The output of one is transmitted through the plasma, the other is used as the local oscillator of the receiver. In this way, a phase stable receiving equipment is obtained. The magnitude and phase measurements are made in the 30 megacycles and recording portions of the receiver. This portion of the receiver is identical with that used for 8 kmc.

The 60 kmc receiver has no microwave switching. It can be used on any one shock excited plasma run as either a reflection or transmission measuring equipment. Since the 60 kmc signal is propagated perpendicular to the direction of the plasma the significant data all comes in a very short period, of the order of 100 microseconds.

The entire equipment emphasizes high speed measurement of complex transmission or reflection coefficients. Simultaneous magnitude and phase measurements can be made in microseconds with good precision.

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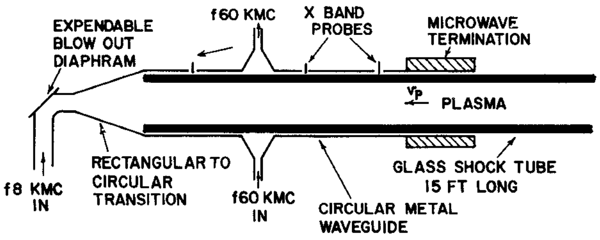

Figure 1 - Plasma Shock Tube-Waveguide System.

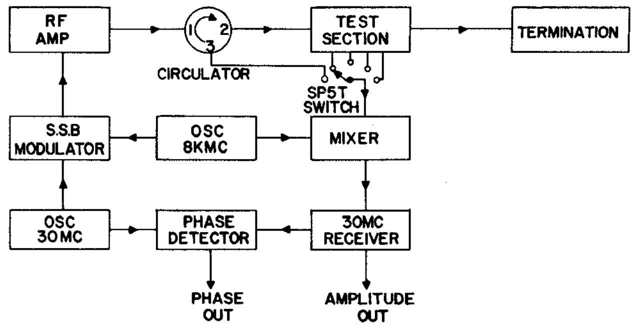

Figure 2 - "X" Band Irradiation and Measurement System.

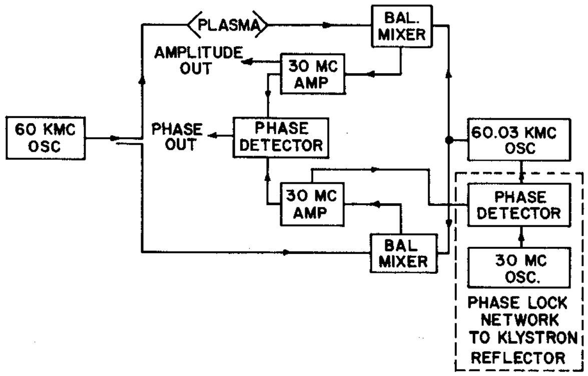

Figure 3 - Millimeter Wave Probing System.