A microstrip cavity type transmission line having a lossy center conductor provides attenuation and reflection coefficient information in response to the disturbing effects of proximate conducting surfaces or plasma. Equivalent conductance and susceptance of the plasma and the proximity of conducting surfaces can be determined by using such information to solve standard transmission line formulas.

1 Claim, 4 Drawing Figures
MICROSTRIP PLASMA PROBE

BACKGROUND OF THE INVENTION

The communications blackout that occurs during reentry of space vehicles into the earth's atmosphere is a major problem in manned space flight. Although the cause of the communications blackout is known to be the buildup of a plasma layer at the surface of the space vehicle, the precise nature of such plasma layer is not well understood. Since the design of a communications system capable of continuous operation during space vehicle reentry is necessarily predicated upon a thorough knowledge of the electrical and physical parameters and properties of the plasma layer, considerable effort is being made to provide suitable plasma diagnostic equipment. Of particular interest is the general electrical nature of the plasma; its conductance and susceptibility and other gross parameters from which an equivalent circuit can be hypothecated. Weight and power economies dictated by Spacecraft Specifications require that diagnostic equipment for determining such parameters be lightweight low power devices. It is also necessary that they be rugged, simple and reliable for operation in extremely adverse environmental conditions. The present invention is directed toward a novel probe that achieves these and other ends.

SUMMARY OF THE INVENTION

The diagnostic probe comprehended by the present invention is in essence a modified microstrip line whose fringing fields are sensitive to and a measure of certain parameters of proximate disturbing influences such as plasma or metal plates or the like. The ground plane of the microstrip line is configured to form a cavity whose dimensions permit wideband operation. The center conductor of the microstrip line is made lossy to damp out oscillations and to provide means for measuring attenuation. This modified microstrip line provided with a matched load and is supplied by a signal generator. Means are also provided for the measurement of input, output and reflected signal power. The measured values together with the known resistance value of the lossy center conductor can be used to solve standard transmission line formulas for susceptance and conductance.

It is a principal object of the invention to provide a diagnostic probe of the type described that is lightweight, rugged and reliable.

It is another object of the invention to provide a diagnostic probe of the type described that is broad band and has minimum power requirements.

These, together with other objects, advantages and features of the invention, will become more apparent from the following detailed description when taken in conjunction with the illustrative embodiment in the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of one presently preferred embodiment of the invention;

FIG. 2 is a top view (with the top cover removed) of the microstrip cavity components of the invention;

FIG. 3 is a sectional view of the microstrip cavity of FIG. 2 taken at 3–3; and,

FIG. 4 is another sectional view of the microstrip cavity of FIG. 2 taken at 4–4.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The principle of operation of the present invention is based on the fact that the fringing fields of a lossless microstrip cavity that extend beyond the cavity itself are sensitive to and a measure of certain parameters relating to outside disturbances such as the presence of plasma or the proximity of a metal plate. For example, the placing of a metal plate in the near proximity of the top of the microstrip cavity illustrated by FIGS. 2 through 4 (assuming the center conductor to be lossless) would have the effect of adding a capacitance $C_p$ in parallel with the microstrip cavity capacity $C_m$. The total of these two capacitances lowers the characteristic impedance of the cavity. The closer the metal plate is moved to the cavity the lower the characteristic impedance of the cavity becomes. It is a feature of the invention to provide a lossy center conductor for the microstrip cavity. This provides a known line resistance $R$, and also effectively dampens any possible oscillations in the device. That is, there is thus introduced a measurable parameter that permits the simultaneous solution of standard transmission line equations. When the line carries a TEM mode the electromagnetic wave propagating thereon is represented by standard transmission line equations:

$$\alpha = \sqrt{R} \Re\left[ \sqrt{1 + j \omega C} \right], \text{ and:}$$

$$|\rho| = \sqrt{\frac{R}{Z_0}} - \left( \Re\left[ \sqrt{1 + j \omega C} \right] + j \\imaginary\left( \sqrt{1 + j \omega C} \right) \right)$$

$$\frac{R}{Z_0} + \left( \Re\left[ \sqrt{1 + j \omega C} \right] + j \\imaginary\left( \sqrt{1 + j \omega C} \right) \right)$$

wherein:

$\rho$ is the reflection coefficient of the cavity

$\alpha$ is the attenuation constant

$R$ the line resistance

$Z_0$ is the characteristic impedance of the cavity

$G$ is the conductance, and

$C$ is the cavity capacitance.

By measuring the loss in the line and the reflection coefficient and knowing the line resistance $R$, equations (1) and (2) can be solved simultaneously to determine $G$ and $C$.

The block diagram of FIG. 1 illustrates microwave cavity 6 in combination with the appropriate apparatus for making such measurements. Signal generator 7 delivers a low power (milliwatts) amplitude modulated signal to the transmission line of microstrip cavity 6. The frequency of the signal is not critical and will in general be determined by other design considerations. However, frequencies in the 400–800 megahertz range have been found to be effective. Load 10 is matched to the characteristic impedance of the transmission line. Directional coupler 8 permits measurement by detector 11 and amplifier-indicator 14 of the input signal power and simultaneously the measurement by detec-
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3. Directional coupler 9 provides for measurement by detector 13 and amplifier-indicator 16 of transmitted power. The various components of the device shown in FIG. 1 are connected by appropriate microwave transmission lines such as waveguides, striplines or coaxial cables.

Microstrip cavity 6 is illustrated in detail by FIGS. 2, 3, and 4, reference to which is now made. Ground plane conductor 17 is configured to form a cavity whose major dimensions are less than a significant percentage of the operating frequency wavelength. Input and output coaxial transmission lines 22 and 23 are connected to the cavity by means of coaxial cable connectors 23 and spacers 24. Strip transmission line 20 is connected to the input at output coaxial transmission lines by means of coaxial line to strip transmission line connectors 19. Strip transmission line 20 can be any suitable lossy line of known resistance. Commercially available metal film fiberglass plastic resistance cards have been found to be effective and practical. The cavity is filled with a filler 18 of dielectric material. A top cover 21 also of dielectric material is provided for protection against the adverse environmental condition of space flight. Such a cover of course reduces the sensitivity of the device and its thickness must necessarily be an engineering design compromise. When the device is used as a space plasma diagnostic probe it is most advantageously flush mounted on the space vehicle nose cone with top cover 21 exposed.

While the invention has been described in its preferred embodiment it is understood that the words which have been used are words of description rather than words of limitation and that changes within the purview of the appended claims may be made without departing from the scope and spirit of the invention in its broader aspects.

What is claimed is:

1. A diagnostic probe for measuring the physical parameters of plasma in the earth's plasma layer comprising

a section of microstrip transmission line having a lossy center conductor said center conductor having a discrete predetermined resistance value, a ground plane configured to define a microwave cavity, said microwave cavity having dimensions that support the propagation of TEM mode electromagnetic waves therein, and an input and an output,
a signal generator,
a first directional coupler,
input signal measuring means,
reflected signal measuring means, said first directional coupler connecting said signal generator, said microstrip transmission line input, said input signal measuring means and said reflected signal measuring means,
a second directional coupler,
a load matched to the characteristic impedance of said microstrip transmission line, and
output signal measuring means, said second directional coupler connecting said microstrip transmission line output, said load and said output signal measuring means.

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