Some Investigations on Simulated Plasma in K Band

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INTRODUCTION

Full paper can be accessed at the home page: http://www.dvgiri.com

This was work performed by D. V. Giri in partial fulfillment of a Master of Engineering Degree at the Indian Institute of Science in India. It was performed in 1969, the year in which he was admitted to continue his graduate studies at Harvard University. It consists of studying microwave propagation through an artificial dielectric. Recalling that this was done in 1969, when the term "meta material" did not exist, it should be noted that artificial dielectrics was an area of research at that time. His interest was to study propagation through a plasma medium. Due to lack of resources, in creating actual plasma medium, it was simulated by an artificial dielectric with an effective dielectric constant between 0 and 1. This is now a type of "meta material".

The study of electromagnetic wave propagation through various types of media such as air, ionosphere, troposphere etc., has been a subject of considerable importance with reference to transmission of messages and signals from one place to another. Modern communications require the use of microwave frequencies for sending information across. Blackout of signals during the reentry of a space vehicle was a motivating factor in choosing to work on this problem in the late 1960s. It was speculated that the failure of signal transmission during reentry was due to trapping or total reflection of the electromagnetic wave by the plasma layer formed due to thermal ionization arising out of the aerodynamic drag between the earth's atmosphere and the space vehicle. This can cause temperature rise of up to 6000 K. It was decided to study the propagation through the plasma medium as a function of the ion density. It is possible to create plasma medium in a bounded region in a laboratory by gas discharge. The plasma density can be controlled by the gas pressure. However, the study requires a) creation of a homogeneous plasma b) stable plasma and c) large dimension plasma tube to avoid diffraction effects of the plasma tube. Hence, it was decided to simulate the plasma medium by means of artificial dielectrics with a dielectric constant between 0 and 1. There were such artificial dielectrics at microwave frequencies (even in 1969) made of parallel plates and wire grid structures, whose propagation characteristics were studied in theory and in practice.

In the present study conducted in 1969, plasma medium has been simulated artificially by means of wire grid structures. We found that the construction is relatively simple, and crossed wire type can also be constructed to study either vertically or horizontally polarized incident wave. At first sight, the horizontal wires should not have any influence on a vertically polarized wave and vice-

versa. However, the experimental studies show that the horizontal wires have an appreciable influence on wave propagation even when the incident wave is vertically polarized.

In the experimental studies, the radiation patterns of a pyramidal horn have been measured with and without the artificial dielectric. Shifts in the location of the peak radiation, splitting of the major lobe into two lobes have been observed depending on experimental configurations. The shift of the major lobe can be correlated to the plasma density.

SUMMARY OF THE WORK:

1) A high-voltage regulated power supply unit to energize a K Band 2K 33 Reflex Klystron was built.

2) A square wave generator unit for modulating the reflector voltage of the Reflex Klystron was built.

   The above equipment was fabricated jointly with Squadron Leader. Lakhmir Singh who was deputed by The Indian Air Force to study for his M. Engineering Degree at the Indian Institute of Science.

3) K Band pyramidal horns, Crystal detector, waveguide adaptor for matching the output of the Reflex Klystron to the transmitting pyramidal horn was designed and built.

4) Single and crossed wire grid structures using 36 SWG copper wires have been constructed to simulate lossless, homogeneous Plasma medium.

5) Single and crossed wire grid structures using 36 SWG nichrome wires have been constructed to simulate lossless, homogeneous Plasma medium.

6) Pyramidal horn radiation patterns without the presence of the plasma medium was calculated.

7) From the known wire grid structures, the equivalent plasma parameters such as plasma frequency, density, effective dielectric constant, refractive index, propagation constant have been estimated.

8) Measurement and verification of the radiation patterns of the pyramidal horn without plasma and measurement of the radiation pattern with the plasma medium.

Keywords: Artificial dielectrics, propagation, K-band, simulated plasma, klystron