MICROWAVE INTEGRATED IMPATT DIODE RADIATOR

by H. W. Cooper, C. Moskowitz, M. R. Natale,
T. Andrews
Westinghouse Electric Corporation
Aerospace Division
Baltimore, Maryland

Microwave integrated circuits, coupled with the capability of microwave power generation in bulk and junction semiconducting devices, have opened the possibility for constructing economical integrated beacons in which the entire package, including the prime power source, is of the order of a cubic inch. In order to realize the economy and efficiency inherent in these devices, it is necessary to abandon the concepts of distributed elements which have proved so useful in conventional propagating structures and adopt and develop instead means of determining the characteristics of extremely small integrated structures having generally low impedance levels characteristic of semi-conductor power generators. These techniques are described and developed for use in designing the integrated source-radiator. The device described in this paper consists of an X band dipole which is vapor deposited on an alumina substrate and integrally connected to an IMPATT oscillator thru an impedance transforming network together with an r.f. decoupled bias network.

The geometry or concentration profile of the active element used in this development is that of the true Read structure consisting of a well defined double diffused N-P junction into an epitaxially grown intrinsic region. Fabrication of the device is such that the resulting structure is completely planar and oxide passivated which contributes to its ruggedness and freedom from surface instabilities. From measurements of the gain of a negative resistance amplifier using the IMPATT diode as the active element and slotted line measurements to determine the reactive component, an equivalent circuit for the device was determined. The measurements were made with the semiconductor packaged in a miniature microwave cartridge terminating a 50 Ω coaxial line. The measured cartridge impedance was then subtracted from the measured values to obtain the impedance of the semiconductor oscillator alone. The average equivalent series impedance is a negative three ohms and a capacitive reactance of about 60 ohms. For design purposes, the statistical spread covers a region of about $\pm$ 30% in each value. This spread defines a sectoral region on the Smith chart which in turn defines the active device as a circuit element. It is well known that the condition for oscillation of a negative resistance device occurs when it is terminated in an impedance which is the negative of itself. Consequently, it is necessary to transform the antenna impedance to the value required by the oscillation condition.

Since there is no data available concerning the driving point impedance and effective antenna length, these parameters had to be measured. The structure shown in figure 1 was prepared for this purpose. By the principle of images the impedance of the monopole radiating into half space is doubled to obtain the impedance of a dipole radiating into all space. Using techniques of metal deposition, through a mask, monopoles such as that of figure 1 were deposited on the edge of an alumina wafer (0.02 x 0.5 x 1 inch) and fastened to a ground plane fitted in the rear with a 50 Ω coaxial connector for fastening to a slotted line. The results of these impedance measurements for one monopole length is shown in figure 2.

To provide the desired 2 to 4 ohm impedance level required by the IMPATT oscillator, a dipole length of 0.340 inch (at 95 GHz) shunted across the driving point by an inductance of 0.22 nh and a series capacitance of 0.83 pf is required. This L-section provides the necessary impedance transformation as well as the means for bias application to the active element. Details of the final structure are shown in figure 3. The series capacitance is provided by an open circuited section of line approximately 3/16 λ long. Because this line is unshielded, there will be some radiation from the gaps. However, the pattern is such that it does not seriously affect the major pattern of the dipole.

A broad band, high input impedance structure is used for the bias leads thru the use of alternate high and low impedance quarter wavelength sections and then terminating the common junction with a beam lead or MOS lumped capacitor. This technique, coupled with the use of the series inductance of the gold wire bonds to the diode and antenna, ensures that the cross polarized energy radiated from the bias lines is maintained 30 db below that from the dipole.

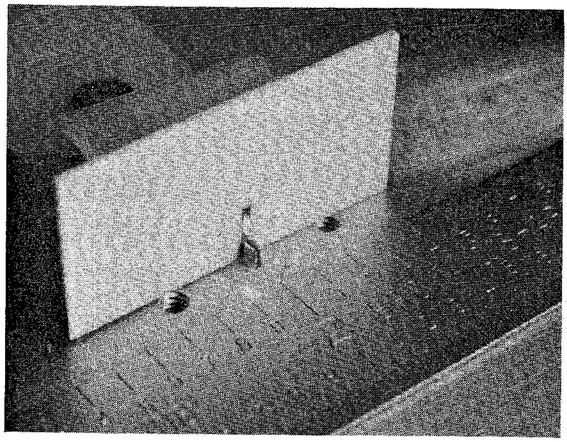

Figure 1. X Band Monopole - For Driving Point Impedance Determination.

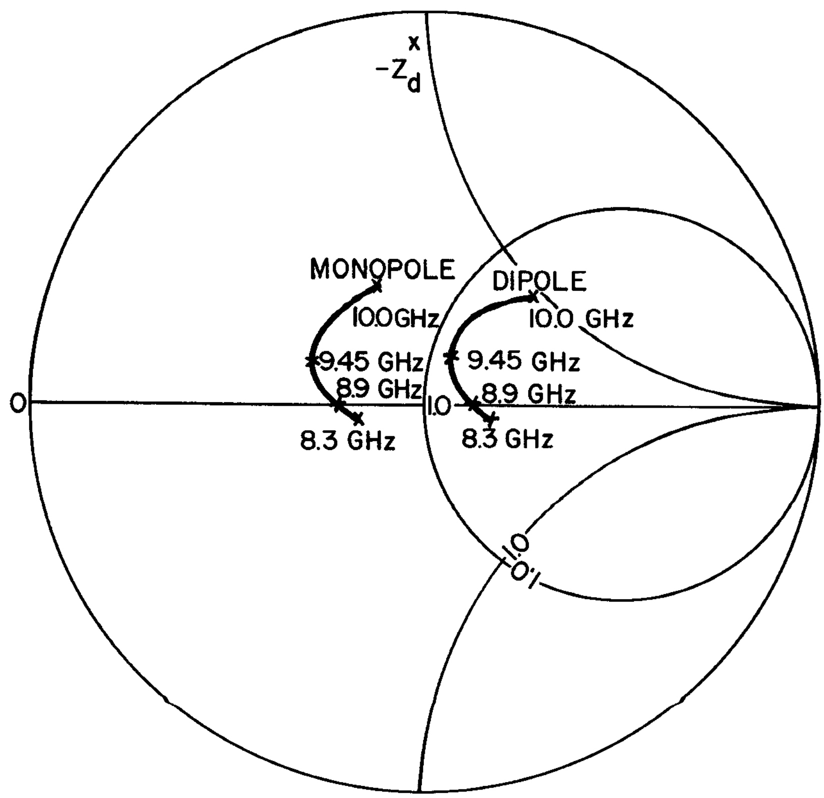

Figure 2. Monopole Impedance and Measured IMPATT Device Impedance

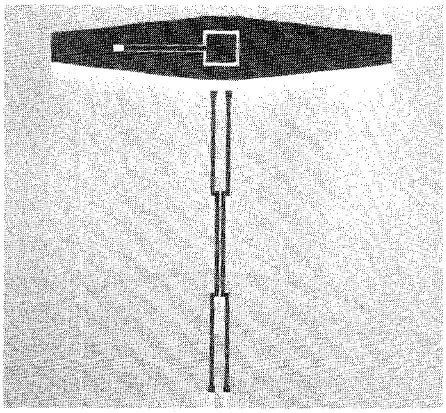

Figure 3. Integrated Radiator Showing L Section and Bias Coupling

BENDIX RESEARCH LABORATORIES
Southfield, Michigan 48075

Advanced Microwave Components, Networks, Antennas, and Instruments