MONOLITHIC ANTENNAS FOR MILLIMETER WAVE GaAs INTEGRATED CIRCUITS

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ABSTRACT

This paper describes millimeter wave GaAs dipole antennas whose radiation characteristics can be controlled during fabrication and/or operation. The physical layout of a monolithic semiconductor antenna compatible with the GaAs IC technology is also discussed.

This paper describes millimeter wave (MMW) GaAs dipole antennas whose radiation characteristics can be controlled during fabrication and/or operation. These antennas can be fabricated in various configurations compatible with the GaAs IC technology for various applications including high resolution airborne radar [1].

The use of conductivity-modulated semiconductor antennas in MMW ICs was first proposed by our group about a year ago [2]. Detailed calculations showing the characteristics of typical Si antennas on sapphire substrates were also recently reported [3]. This work presents theoretical plots for the performance of GaAs antennas. In addition, the physical layout of a monolithic GaAs antenna is discussed.

The radiation characteristics of a dipole antenna are determined by the distribution of current along its length. The use of high conductivity metallic coatings to fabricate conventional millimeter and submillimeter wave antennas such as micro-strip dipoles and patches provides little or no control over the current distribution through manipulation of material properties. In contrast the radiation and circuit characteristics of the proposed semiconductor antennas depend significantly on the value of conductivity and its variation along the antenna length. For example, a pure traveling wave type current distribution can be realized by suitably tapering the conductivity profile through controlled doping and/or during opera-

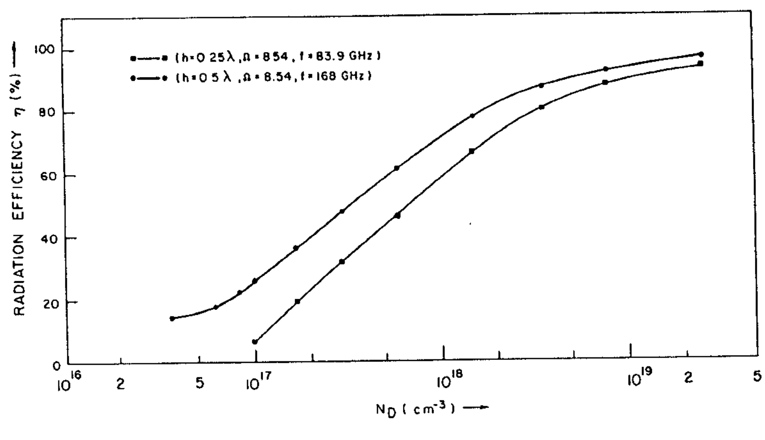

Fig. 1. Computed radiation efficiencies for tubular nGaAs dipole antennas as a function of doping concentration N_D. (Parameter $\Omega = 2\ \ln(2h/a)$; a is the radius and h is the half-length of the antenna.)

tion by selective manipulations of carrier concentrations.

Calculations based on the theoretical work of King, et. al., [4,5] are presented to evaluate the performance of nGaAs dipole antennas operating in the frequency range of 40-168GHz. Fig. 1 shows the radiation efficiencies (η) of uniformly doped nGaAs dipole antennas as a function of the doping concentration N_D. It is clear from these plots that efficient nGaAs antennas can be realized for MMW applications for doping concentrations in the range of 10^{16} - 10^{19} cm^{-3}. The doping profiles of traveling wave nGaAs antennas of half-lengths ranging from λ/2 to 2λ are shown in Fig. 2. All the antennas of Figs. 1 and 2 have a tubular geometry with a 2μm thick nGaAs coating over an insulating/high resistivity core of radius 23μ. The corresponding planar configurations for monolithic GaAs ICs can be determined using an equivalent radii technique [3,6].

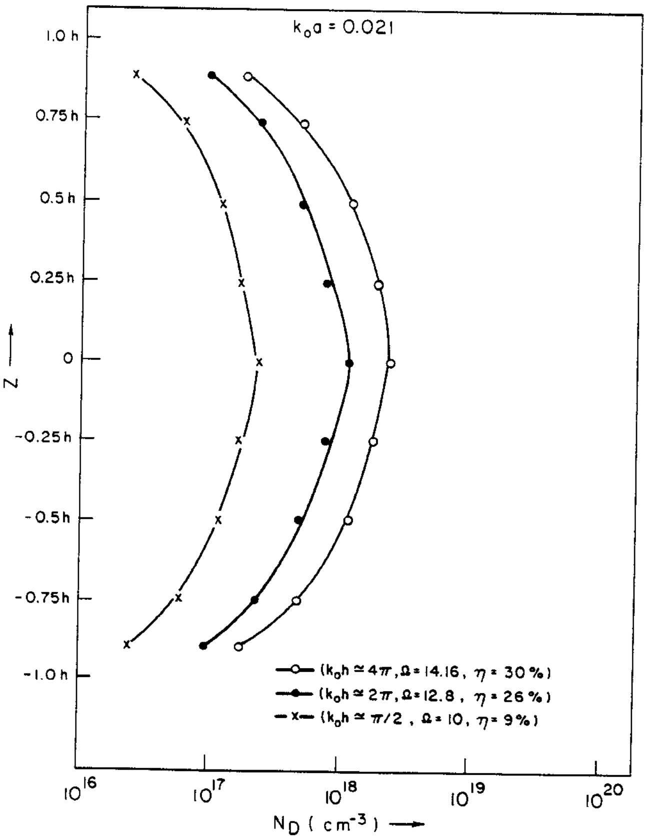

Fig. 2. Doping profiles of tubular traveling wave antennas.

The schematic of a monolithic nGaAs dipole antenna in the receiving mode is shown in Fig. 3. The detector diode (p^+-n) has been integrated between the n^+ feed lines. Typical dimensions for a full wave dipole operating at 168GHz will be: half-length h=890μm, width w = 100μm, and thickness t ≃ 2.5μm.

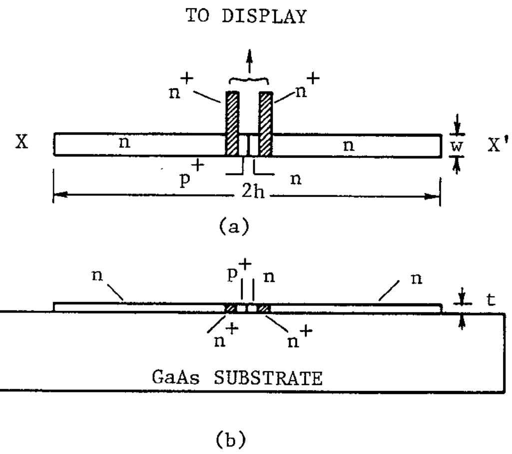

Fig. 3. A monolithic planar nGaAs dipole antenna structure with an integrated detector diode. (a) Top View, (b) Cross Section at XX'.

It is believed that the semiconductor antennas described here will provide the MMW circuit designer a new degree of flexibility in the realization of fully integrated radar sensors.

References

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