Radiation and Switchable characteristic of a Microstrip Antenna with Hall-effected Doped Semiconductor Substrate

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Abstract

Radiation characteristic of a tunable or switchable microstrip planar array of rectangular patch antenna printed on doped (n-type) semiconductor substrate with a magnetic bias field perpendicular to the electric field of the patch are described. The screening effect of the charge carriers on the transverse component of the electric field is observed to be negligible for an intrinsic semiconductor substrate but gradually approaching that of a metallic conductor as the doping level reaches 10^{18} cm-3. The magnetic bias field apply to the doped semiconductor substrate makes the situation of Hall-effect which provide resistance or normal situation to the working of antenna. Now if we stop the magnetic biasing, the Hall-effect is removed and the extrinsic characteristic of doped substrate is reappear, then the propagation between patch and ground is shorted and the antenna stop the working. By varying the doping concentration, we can adjust the cutoff magnetic biasing and by controlling the magnetic field from zero to cutoff range we can control the Radiation characteristic of antenna.

1. Introduction

Microstrip Antennas are widely used in wireless communication because of there compatibility, low profile, low cost etc. In recent years a considerable amount of research is being carried out on various aspects of ferrite based microstrip antenna and arrays, such as radiation and scanning characteristics, design consideration, impedance calculation, RCS measurements of switchable antennas and generation of circularly polarized radiation from these antennas [1-3]. Wave propagation along semiconductor structure has been a subject of investigation since the early days of integrated circuit development. As the speed of semiconductor devices continues to increase, both distributed effects and charge transport phenomena need to be accounted for in a realistic description of the propagation of signals in high frequency circuits and antennas systems. Recent investigations on MIS and coplanar waveguides on semiconductor substrate have taken into consideration nonlinear effects [6- 9].

Here we proposed a rectangular patch antenna on a semiconductor substrate which is doped with extrinsic impurity and biased with magnetic field which represents the Hall Effect. This antenna has some advantage as follow:

a. Antenna has comparatively better bandwidth.
b. Antennas have comparatively high radiation due to non-ferromagnetance property.
c. For the switchable and tunable characteristic patch not destroy the power in mechanical lattice vibrations which provide high efficiency.

2. Principle

In the limit of vanishing carrier concentration, this structure may be viewed as a simple dielectric, for which the guided modes, fringing field are well documented. On the other extreme is the case when the semiconductor is heavily doped so that it can be accounted for by its surface impedance, given in terms of its bulk conductivity. We can examine the variation of resistance against to biasing magnetically field by given fig: 1.

It is the purpose of this study to examine the nature of Hall Effect for semiconductor substrate with doping level between these extremes and to develop a theory and formula of Radiation Power P_{Rad} for the rectangular patch antenna structure so that building blocks with fully accounted for physical bases may be obtained to aid in the analysis and simulation.

List of Symbols

a = length of patch
b = width of patch
H = bias field
λ = wavelength
h = height of semiconductor substrate
k_o = $2\pi / \lambda$
I = current supplied for patch
R = Hall-effect constant
V_H = Hall voltage
R_H = Hall coefficient
J = current density
σ = conductivity, such that $\sigma E = J$
ρ = $1/\sigma$ = resistivity
e = charge of the electron
n_i = intrinsic carrier concentration
n_h = holes carrier density
n_e = electron carrier density
N_a = acceptor impurity concentration
N_d = donar impurity concentration
V_o = edge voltage between slots of rectangular patch

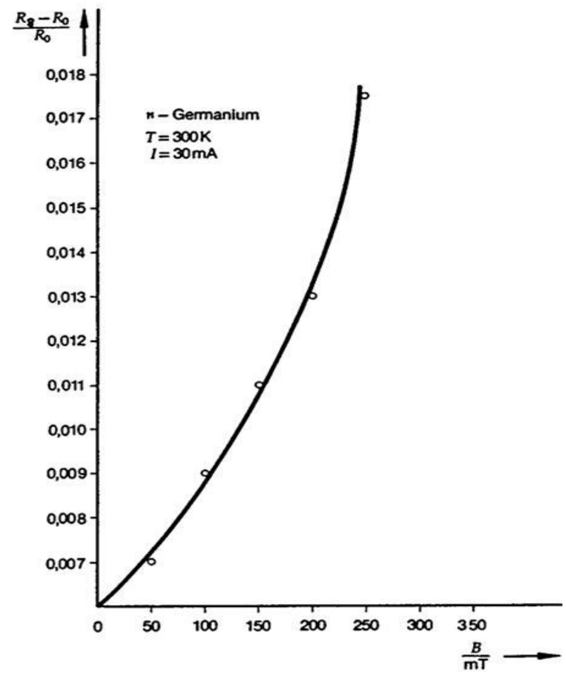


Fig: 1 Change of resistance as a function of the magnetic flux density

3. Numerical calculation

To consider numerical calculation lets assume semiconductor doped with n-type of impurity. For a particular constant value of k_o, b and θ equation

$$\left[P_{Rad} = A\,\frac{H}{V_H}\right] \qquad (1)$$

Where

$$A = \frac{V_o^2 I}{240\pi^2 b\, e\, N}\int_0^{\pi} sin^2\left(\frac{k_o\, b\, cos\theta}{2}\right)\, tan^2\theta\, sin\theta\, d\theta \qquad (2)$$

As we can see from equation (1) that Radiation Power P_{Rad} depend on H and V_H while V_H have mutual dependence on magnetic field H, so we can say that the power of radiation is depends on magnet biasing field H. We can vary the radiation power (P_{Rad}) and magnet biasing field (H) relation by change the constant Z by vary doping concentration (N) and antenna biasing voltage (V_o).

4. Antenna structure

The microstrip patch antenna geometry on semiconductor substrate backed by ground is shown in Fig: 2. The length, width and height of patch are a, b and h respectively. Here we are taking n-type germanium crystal as substrate which is doped with carrier concentration N. The patch is magnetically biased with field H as shown in fig 2.

The side view of patch is also present in Fig: 3 which help to understand the numerical calculation of switchable and tunable characteristic of proposed rectangular patch antenna which varies with the biasing field and impurity doping concentration.

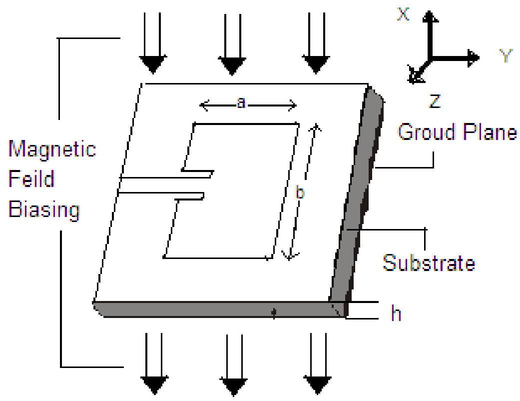


Fig: 2 Diagram of magnetically biased microstrip rectangular antenna

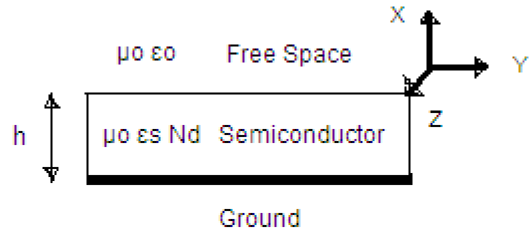


Fig: 3 Side view of Patch substrate

5. Working

The working process of this antenna is based on the concept as of the Hall-Effect. Here the magnetic field applies which reduce the skin effect in substrate or creates resistance between the patch and the ground plane and provide normal environment as of the substrate without doping for working of an antenna.

When the field is not applying, the patch has high bulk conductivity due to impurity which makes the antenna in nearly OFF situation. When the ac signal apply to patch which is magnetically biased as shown in fig: 2 then for the first half cycle the electric field (E_{-Y}) generate across the patch length (a) to nullify the effect of Lorentz Force (F) which arise their due to effect of magnetic field (H) and current velocity (v). Again for the second half cycle of ac signal, the electric field (E_Y) generates across the patch length (a) but in opposite direction of the previous electric field (E_{-Y}) generated for the first half cycle.

In the both cases the electric field remains across the patch length (a) which create the situation as of the simple semiconductor substrate which is necessary for the fringing field to the radiation of an antenna

6. Results

For frequency 9 GHz with dielectric constant = 2.2 and height h = 0.254 of substrate with the parameters given below. After evaluating the value of A put it in equation (2) for differ –differ value of H/V and get the result which is linear in nature as shown in table 1.

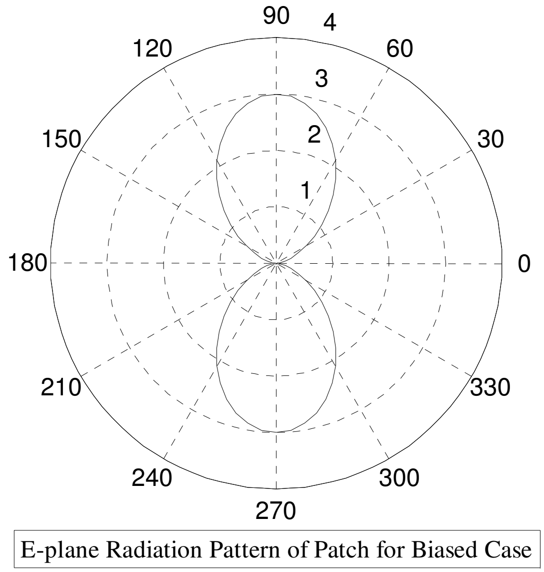
Substrate Sample	Ge crystal n-type
Electron charge (e)	1.6×10^{-19} C
Patch Length (a)	1.11 cm
Patch Width (b)	1.31 cm
Antenna current (I)	8×10^{-3} A
Antenna Voltage (V_o)	5 V
Magnetic Field (H)	1000 Gauss
Hall Coefficient (R_H)	33×10^3 cm^3/C
Hall Voltage (V_H)	53×10^{-3} V
Doping concentration (N)	2.4×10^{17} per cm^3

$$A = \frac{V_o^2 I}{240\pi^2 b\, e\, N} \int_0^\pi \left\{ \frac{sin^2\left(\frac{k_o\, b\, cos\theta}{2}\right)}{tan^2\theta\, sin\theta\, d\theta} \right\}$$

Table 1: radiation Power according to values of H/V

H/V	Radiation Power
1500	46.650
1400	43.540
1300	40.430
1200	37.320
1100	34.210
1000	31.100
900	27.990
800	24.880
700	21.770
600	18.660
500	15.550
400	12.440
300	9.330
200	6.220
100	3.110
0	0

The radiation patterns of E-plane for the biased and unbiased cases are shown in fig 4. We can evaluate the variation from the figure for biased and unbiased situation.



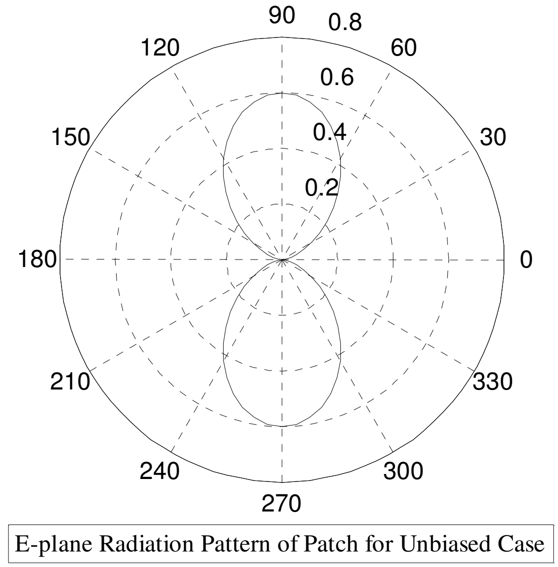


Fig: 4 Radiation Pattern of E-plane for Biased and Unbiased Cases

7. Conclusions

From the table 1 we can see that variation of increasing radiation power of antenna with respect to increasing magnetic biasing or (H/V), is linear. A microstrip patch antenna using this structure and technique capable of changing radiation power from zero (switch off) to max using magnetic field biasing. This antenna can be use in defense purposes for radar operation, for detecting devices etc.

8. References

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