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Adaptation by Schottky Contact Coupled Lines for Planar Antennas on Photonic Bandgap

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Abstract: The antennas manufactured on photonic crystal used as substrate, are multi-bands and are by consequent not adapted always well to the lines which feed them. It is often necessary to resort to geometrical modifications on the drivers to cure with the problem of the loss of adaptability line-antenna. We propose a device of adaptation by Schottky contact coupled lines on semiconductor which makes it possible to modify the parameters of the feeders of antenna by the means of the tension.

Key words: Adaptation, photonic crystal, Schottky, antenna, multi-bands

INTRODUCTION

The photonic crystals invest moreover in more the field of the millimeter-length and micrometric waves. The applications extend to the planar antennas, to the delay lines and the nonreciprocal devices. Photonic crystal used as substrate for planar antennas prohibited the back radiation in the substrate and reinforces it in the air, which represent an enormous advantage compared to the traditional substrates. Implementation of the concept of a planar antenna in a monolithic integrated circuit was considered for the first time by Brown *et al.* (1993). The structure (Fig. 1) consists of an area with photonic crystal consisted gallium arsenide GaAs semi-insulating substrate. A dipole antenna deposited on this crystal, is supplied by a coplanar line. This type of antenna can be used in the band of the millimeter-length waves.

Under operation multi-bands, the problem of the adaptation of the antenna to the coplanar line, can to be posed and the recourse to geometrical modifications on the line is necessary. We propose a device where the coplanar line is replaced by two lines with Schottky contact (Fig. 2).

The adaptation of the antenna, without changing geometrical configuration of the structure, is theoretically possible. Modification electric parameters would intervene electronically by change of the tension applied. This structure can offer in more the advantage of confining the electric field in the depletion layer under drivers, to minimize of them the losses in substrate and to allow the radiation of it only level of the dipole antenna on the photonic crystal.

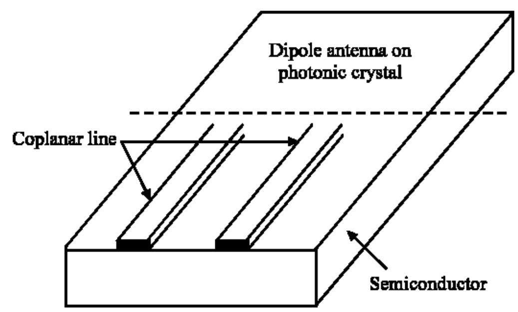

Fig. 1: Dipole antenna supplied with coplanar line

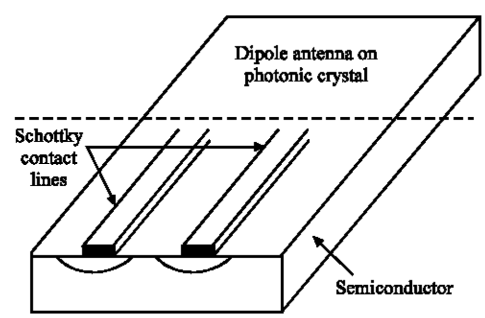

Fig. 2: Dipole antenna supplied with Schottky contact lines

THEORY

The behavior of the lines in metal semiconductor contact, in weak signals, results in one dependence of the propagation parameters due to applied tension (Tom, 1965; Jager and Rabus, 1973; Gary and Richard, 1975). The Green's function technique is used to evaluate, by taking account of the edge effects, the 2D profile of

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the depletion layer under the Schottky contact strips. The electric potential which obeys the Poisson's equation in inhomogenous medium can be written as follows (Chang, 1973).

$$\nabla^2\phi = \begin{cases} 0 & y > 0 \\ -\dfrac{\rho}{\varepsilon} & y \le 0 \end{cases} \tag{1}$$

Where:

$$\rho = \begin{cases} q_j & \text{on the jth strip} \\ -qN_D & \text{on the depletion layer} \\ 0 & \text{elsewhere} \end{cases} \tag{2}$$

And:

$$\phi = \begin{cases} V_{ji} - V_{bi} & \text{on the jth strip} \\ 0 & \text{on the depletion layer boundary} \\ 0 & \text{elsewhere} \end{cases} \tag{3}$$

The condition on the boundary depletion layer force the potential and thus the electric field to cancel itself outside this zone in the semiconductor substrate.

The electric potential is then written:

On the strips:

$$\phi_i(x,y) = \sum_{j=1}^{n} \int_{x_{j1}}^{x_{jn}} q_j(x',h_j).G_{11}(x,y|x',h_j)dx' + \int_{ZD} qN_D.G_{12}(x,y|x',h_j)dx'dy' = V_i - V_{bi} \tag{4}$$

On the boundary depletion layer:

$$\phi(x,y) = \sum_{j=1}^{n} \int_{x_{j1}}^{x_{jn}} q_j(x',h_j).G_{21}(x,y|x',h_j)dx' + \int_{ZD} qN_D.G_{22}(x,y|x',h_j)dx'dy' = 0 \tag{5}$$

The neutrality of the electric charges is written:

$$\sum_{j=1}^{n} \int_{x_{j1}}^{x_{jn}} q_j(x',h_j)dx' + \int_{ZD} qN_D dx'dy' = 0 \tag{6}$$

With:

- n : Number of drivers
- • : Potential in a point of the structure
- V_{bi} : Diffusion potential
- N_D : Doping
- • : Volume charge density
- q_j : Charge distribution on the jth conductor
- qN_D : Charge distribution in the depletion layer
- ZD : Depletion layer
- x_{jk} : kth point on x axis, jth strip.

Equation 4-6 are then transformed and standardized. The exact solution of the equations is not possible, it can thus be only approximate.

Moments method (Roger, 1968) applied to these equations allows to obtain a system of non-linear equations. This system can be solved using an optimization method. We developed a program of optimization based on the Vignes method (Vignes, 1980).

This program allows the calculation of loads on the strips and the evaluation specifies profile of the depletion layer. Electric parameters structure are then calculated.

NUMERICAL RESULTS

The results for a structure with two lines show a good conformity with those of (Brito *et al.*, 1986) (profile boundary depletion layer, linear parameters of the structure).

We took lines of 100 μ of width, spaced 0.5 mm; the conductivity being of $3.5*10^{7}$ • •^{1}.

For the semiconductor of dielectric permittivity of 12; we took a resistivity of 1• • cm: Corresponding to a doping $N_D = 5.1*10^{15}$ cm^3; then a resistivity of 1• • cm: Corresponding to a doping $N_D = 8.8*10^{16}$ cm^3, one obtains for each doping the following characteristic impedance:

For $N_D = 5.1*10^{15}$ cm^3, the real and imaginary part of the characteristic impedance are respectively (Fig. 3 and 4).

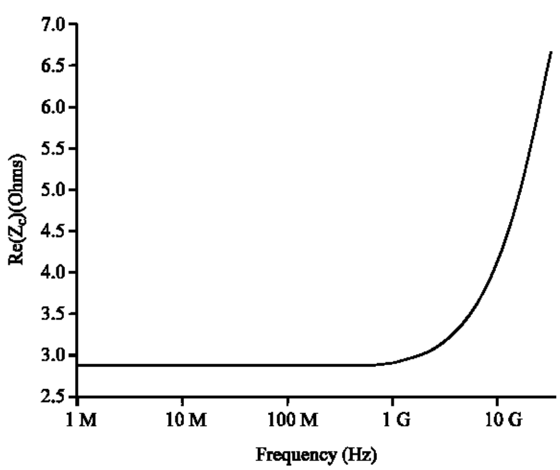

Fig. 3: Re(Z_C) versus frequency; ($N_D = 5.1*10^{15}$ cm^3)

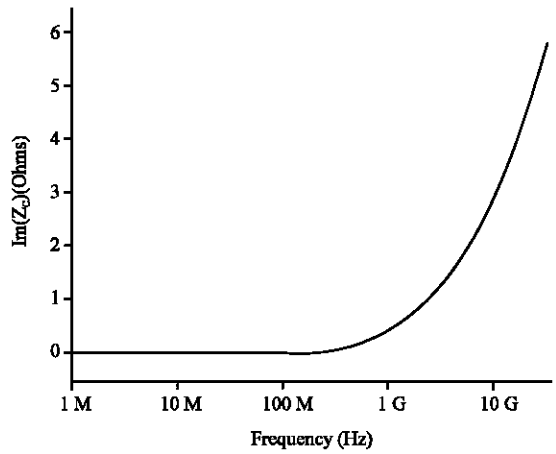

Fig. 4: $Im(Z_C)$ versus frequency; ($N_D = 5.1*10^{15}$ cm^3)

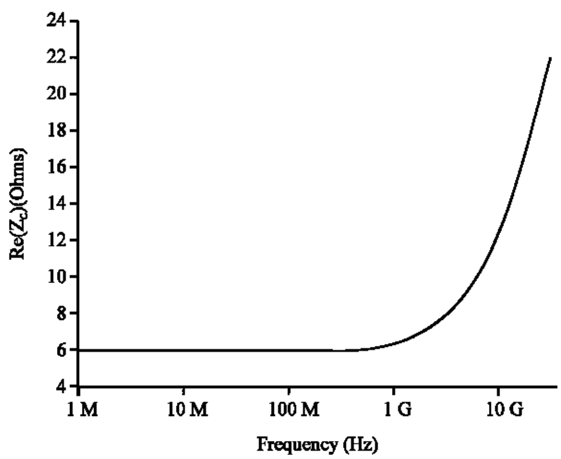

Fig. 5: $Re(Z_C)$ versus frequency; ($N_D = 8.8*10^{16}$ cm^3)

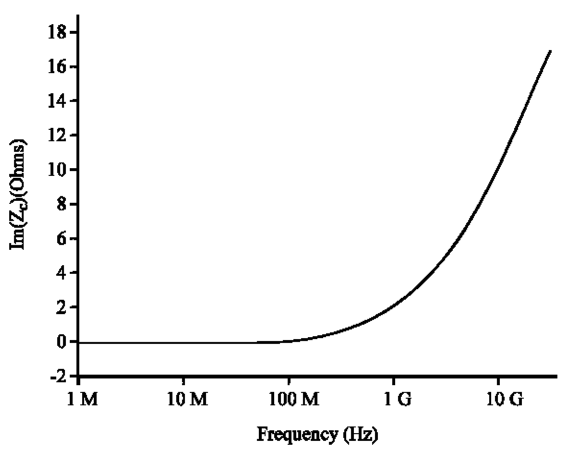

Fig. 6: $Im(Z_C)$ versus frequency; ($N_D = 8.8*10^{16}$ cm^3)

For $N_D = 8.8*10^{16}$ cm^3, the real and imaginary part of the characteristic impedance are respectively (Fig. 5 and 6).

We treated lines of micronic widths, our program can however treat lines of millimeter width dimensions and even of submicronic width dimensions.

GREEN'S FUNCTIONS

The Green's function G(x, y|x•, y•) which is the potential at the point (x, y) due to a charged line located at the point (x•, y•) can be calculated using the image method. The Green's functions in the case of studied structure are written:

For y • 0 and y• • 0:

$$G_{11}(x,y|x',h_j) = -\frac{1}{4\pi\varepsilon_1}\left\{\begin{matrix} \ln\left[\left(x-x'\right)^2+\left(y-y'\right)^2\right] \\ -\frac{\varepsilon_2-\varepsilon_1}{\varepsilon_1+\varepsilon_2}* \\ \ln\left[\left(x-x'\right)^2+\left(y-y'\right)^2\right] \end{matrix}\right\} \quad (7)$$

For y • 0 and y• • 0:

$$G_{12}(x,y|x',h_j) = -\frac{1}{4\pi\varepsilon_1}\left\{\begin{matrix} \frac{2\varepsilon_1}{\varepsilon_1+\varepsilon_2}* \\ \ln\left[\left(x-x'\right)^2+\left(y-y'\right)^2\right] \end{matrix}\right\} \quad (8)$$

For y • 0 and y• • 0:

$$G_{21}(x,y|x',h_j) = -\frac{1}{4\pi\varepsilon_2}\left\{\begin{matrix} \frac{2\varepsilon_2}{\varepsilon_1+\varepsilon_2}* \\ \ln\left[\left(x-x'\right)^2+\left(y-y'\right)^2\right] \end{matrix}\right\} \quad (9)$$

For y • 0 and y• • 0:

$$G_{22}(x,y|x',h_j) = -\frac{1}{4\pi\varepsilon_2}\left\{\begin{matrix} \ln\left[\left(x-x'\right)^2+\left(y-y'\right)^2\right] \\ +\frac{\varepsilon_2-\varepsilon_1}{\varepsilon_1+\varepsilon_2}* \\ \ln\left[\left(x-x'\right)^2+\left(y-y'\right)^2\right] \end{matrix}\right\} \quad (10)$$

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