NEW BEAM STEERING BASE STATION ANTENNA USING EBG MATERIAL

H. Boutayeb (2), J.P. Daniel (4), F. Gadot (1), P.Y. Garel (3), A. de Lustrac (1), K. Mahdjoubi (2), P. Ratajczak (3), K.Sayegrih (4), A.C. Tarot (2)

(1) IEF, Université Paris XI,UMR 22 du CNRS, Bât. 220
91415 ORSAY, FRANCE
andre.delustrac@ief.u-psud.fr, frederique.gadot@ief.u-psud.fr

(2) IETR, Université de Rennes 1, Bât 11C, Campus de Beaulieu
35042 RENNES, FRANCE
halim.boutayeb@univ-rennes1.fr, kouroch.mahdjoubi@univ-rennes1.fr, anne-claude.tarot@univ-rennes1.fr

(3) France Telecom R&D, Antenna Department, Fort de tete de chien
06320 LA TURBIE, FRANCE
philippe.ratajczak@francetelecom.com, pierreyves.garel@francetelecom.com

(4) ADVANTEN, Germanium, 80 avenue des Buttes de Coësmes
35700 RENNES, FRANCE
jean-pierre.daniel@advanten.fr

1. INTRODUCTION

The purpose of this paper is to present the results obtained through a collaborative project named "BIP"[1], between French Industry and Academic Research in the frame of the RNRT (National Research Network for Telecom). In this project, the main purpose was to manage the coverage (single beam or multi-beam) of a base station for mobile communications with a reconfigurable EBG material. The use of this kind of structure for this application needs to solve different problems like:

- the design of a wide or multi-band controllable EBG material
- the capabilities to control the radiation over 360° in the azimuth plane (the maximum of radiation in the elevation plane stays in the 90° direction),
- the matching of the antenna

The RNRT project started in 2001 with 5 partners:

- 2 french universities laboratories:
  - IEF (Institut d'Electronique Fondamentale),University of PARIS XI
  - IETR (Institut d'Electronique et de Telecommunication de Rennes), University of RENNES 1,
- Antenna Department of France Telecom R&D,
- ADVANTEN: Advanced Antennas & Radio Applications Company.

2. BEAM STEERING PRINCIPLE : A RECONFIGURABLE EBG MATERIAL

For this application, the EBG structure must have the same electromagnetic behavior for a large frequency band including GSM, DCS and UMTS. In order to control the EBG material and to manufacture the structure, a lattice of metallic wires has been choosen; it has a wide Electromagnetic Band Gap starting from 0 GHz to a frequency depending on the geometrical parameters of the lattice.

2.1. A reconfigurable EBG material

To manage the radiation of the antenna, we choose to control the behavior of the EBG material between two complementary states like a lattice of long metallic wires without transmission in the frequency range 0 to 20 GHz and a lattice of discontinuous metallic wires with transmission in the same band.

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If diodes are inserted between the discontinuous wires , the state of the EBG structure can be controlled as we can see on the **Figure 1**

- when the diodes are on: the discontinuous metallic wires are equivalent to long wires thanks to the low impedance and capacitance of the diodes, and the lattice is like a reflector in the frequency range 0-15 GHz
- when the diodes are off: the wires stay discontinuous because the diodes have high impedance and the lattice is transparent in the frequency range 0-5GHz

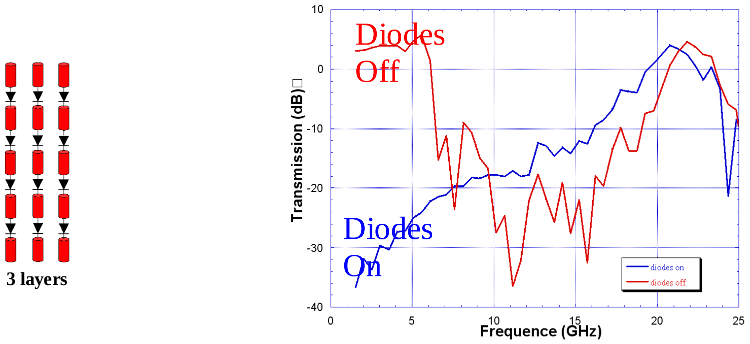

Figure 1 : FDTD simulations of a controllable EBG material

The bandwidth of the controllable EBG material is depending on the geometrical parameters of the lattice and the length of the discontinuous part of the wires that must be small toward wavelength. The choice of PIN diodes was made in order to obtain a very low impedance and capacitance when the diodes are on.

2.2. The beam steering

The usual square lattice of the controllable EBG material has been transformed to a cylindrical one in the center of which have been placed a omni-directional probe . The control of the coverage is made through the bias of the diodes. The Figure 2 shows the electric field in different cases of angular sector of diodes off. We can see that:

- when the diodes are on: the angular sectors are like reflectors,
- for the other sectors where the diodes are off, the EBG material is transparent,
- we can choose the azimuth angle, the beamwidth and manage single or multi-beam coverage.

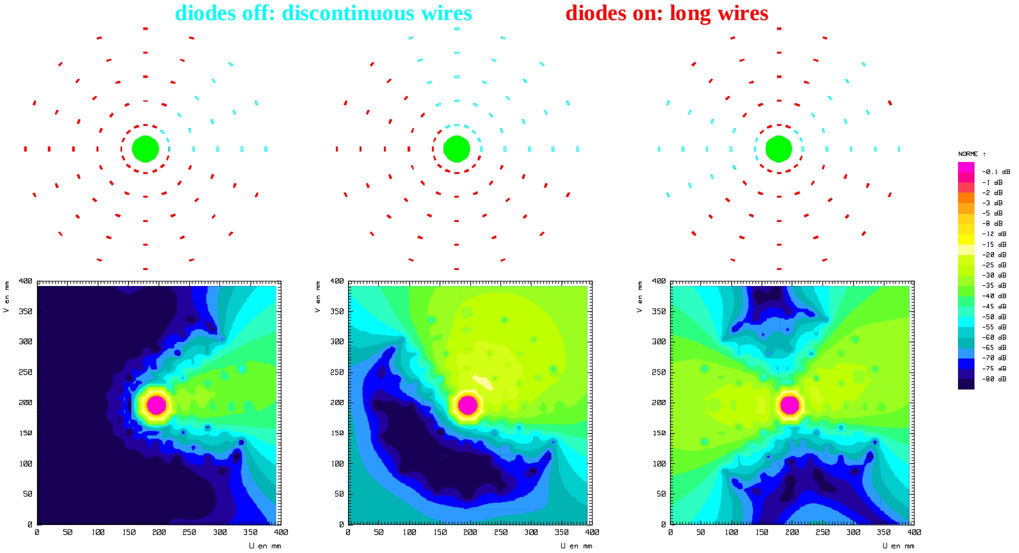

Figure 2 : FDTD simulations of a controllable EBG material

The cylindrical EBG material associated with an omni-directional probe in the center leads to difficulties for a proper matching; the EBG structure acts as a reflector, when the diodes are on, and reflects the radiation of the probe. So the radiation goes back towards the probe and gives a mismatch of the input impedance of the antenna. The distribution of the cylindrical lattice has been optimized **[3]** taking into account that the number of cylindrical layers is fixed by the beam shape, the level of back radiation and the input impedance of the antenna.

3. EVALUATION OF THE PERFORMANCES

In order to estimate the electromagnetic characteristics of the EBG structure to control the coverage of the base station antenna, we develop two breadboards:

- the first one to evaluate the control principle with the EBG material by the design of a single layer of discontinuous metallic wires with diodes
- the second without electronically control but with a four layers of EBG structure of continuous metallic wires to evaluate the EM performances: input impedance, capabilities of the single or multi-beam coverage.

3.1. Performances of the control principle

The breadboard has been realized in Advanten's metallized foam technology.

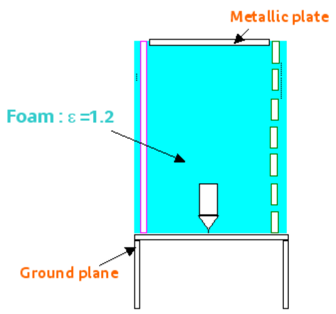

Figure 3:Technologic breadboard

The probe is a monopole on a ground plane (Figure 3) inserted in a foam cylinder of 100 mm radius and a ε_r = 1.2 with a metallic plate on the top. The discontinuous wires with 6 diodes are placed on the external face of the cylinder and spaced by 15°, this number and this spacing have been optimized in order to keep the control and minimize the cost. So there are 144 diodes on this breadboard. The design of the antenna has been made with a FDTD code and Ansoft-HFSS

The radiation patterns at 1.7 GHz are presented (**Figure 4**) for different configurations of the diodes: 6 opened wires in the azimuth direction +90°, -90° and ±90°. The radiation patterns in E^θ and E^ϕ polarization are plotted in a 2D polar representation where the axis agrees to θ = 0° and the exterior circle θ = 180°. We can see a small dissymmetry on the back radiation between the +90° and -90° configuration certainly due to the manufacturing (soldering)

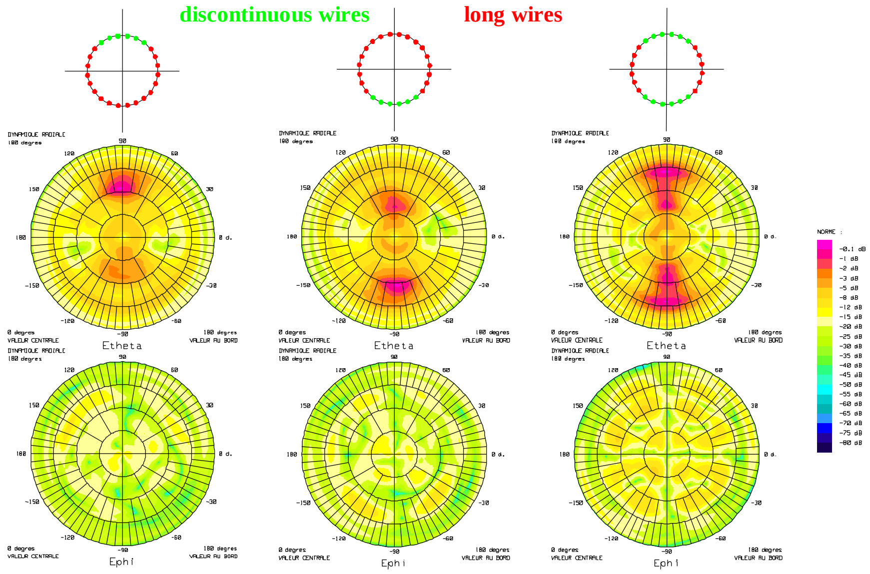

Figure 4 : Measured radiation patterns of the technologic breadboard- F = 1.7 GHz

The experiments show the capabilities of the beam steering with a cylindrical EBG material associated to a omni-directional probe in the center.

3.2. Performances of the beam steering base station

The base station antenna was design with SR3D **[4]**. The cylindrical EBG material is composed by 4 layers with a constant azimuthally step distribution. For this antenna, we didn’t take into account diodes in the EBG material. the structure is modelized with only continuous and discontinuous wires. For the experiment, we put and remove the long metallic wires depending the configuration of the EBG material, the discontinuous wires have not been manufactured. So in order to compare experiments and simulations, we have realized new simulations in the same geometrical configurations without discontinuous wires.

For the same aperture (60°) of the EBG material, the radiation patterns in the E^{θ} polarization are presented (Figure 5)at 0.9, 1.75 and 2 GHz. The comparison between experiment and simulation is excellent. the difference for the 2 GHz pattern is due to the frequency shift.

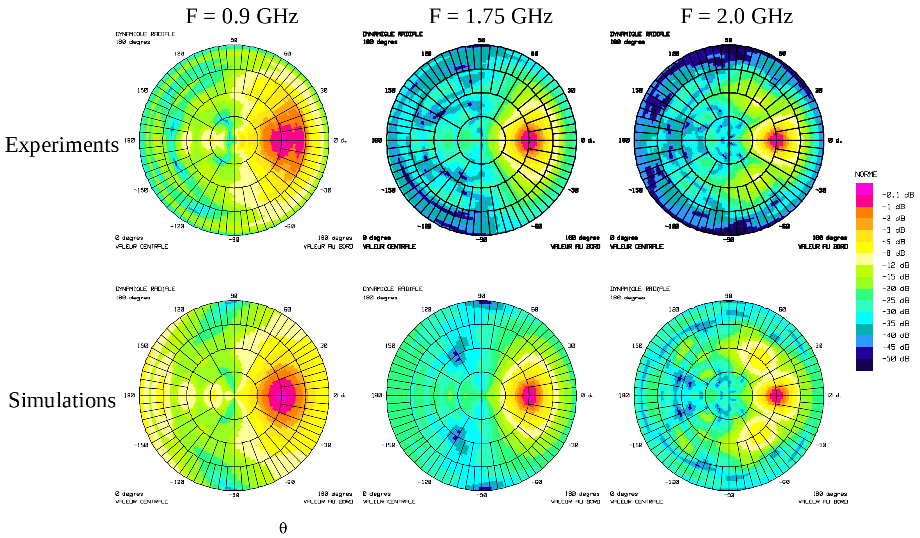

Figure 5 : radiation patterns comparizon of the base station antenna

4. CONCLUSION

The simulations and experiments show the capabilities of an azimuthally beam steering by a cylindrical EBG material controlled with PIN diodes associated to a omni-directional probe in the center.

The manufacturing of the complete structure with 4 layers of controllable EBG material will allow to validate the concept of this antenna and the use of this technology in term of electromagnetic performances (input impedance, radiation pattern, losses, ...) for the application of base station antenna.

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