Low Profile Circularly Polarized Antenna with Large Coverage for Multi-Sensor Device Links Optimisation

Mohamad Majed, Youssef Sbeity
University of Limoges
ENSIL-ENSCI
Limoges, France
E-mail : mohamad.majed@etu.unilim.fr
youssef.sbeity@etu.unilim.fr

Michele Lalande, Bernard Jecko
University of Limoges
XLIM Lab
Limoges, France
E-mail : michele.lalande@xlim.fr
bernard.jecko@xlim.fr

***Abstract*-Multi-sensor devices are well connected to each other and to the microcontrollers via wireless links. This technology introduces the interfacing problems not only in terms of signal processing, but also in the Electromagnetic (EM) links to perform Multi-sensor, Sensor arrays, Identification, Localization, Tracking, and Multiple Input Multiple Output (MIMO) Radar applications. Because of the unpredictable sensor positioning, the link antennas must work in circular polarization, have large coverage and a small thickness to be located on walls, ceilings, platforms, etc. To satisfy these conditions, this paper presents a new kind of low profile antenna with circular polarization able to cover a large area. The use of Electronic Band Gap Low Profile Metamaterial (LP-EBG) satisfies all these specifications together.**

Keywords-Sensor; Radar; Circular Polarization; Antenna; Miniature; Larger Aperture Angle.

I. INTRODUCTION

Today, multi-sensors are extensively used for many applications including: temperature control in a building, identification, localization, tracking, remote sensing, and MIMO radars.

All these wireless technologies need reliable links with microcontrollers, base station and other links for ad-hoc sensors techniques. Such applications involve link antennas with circular polarization because the sensor positions cannot be mastered. In addition, they need antennas with large coverage to minimize the number of sensors and the cost. Large coverage means a large aperture angle but of a small gain. There is no problem by the gain decrease because of the radiated power, which is always limited by the Equivalent Isotropic Radiated Power (EIRP) specifications. Hence, the decrease of the working band must be controlled.

These antennas will be located on Printed Circuit Board (PCB), walls, ceilings, Internet of Things (IoT) boxes, etc. Consequently, they must have a low profile. To achieve these characteristics together, an original antenna based on the Electronic Band Gap (EBG) antenna concept [1] was designed in this paper. This is a low profile antenna with a thickness around $\lambda/10$ and transversal dimensions usually included between 1.5λ and 0.1λ. This antenna can work in a linear or circular polarization and it is possible to multiply the space coverage by 2 or 3 times in its miniaturized form.

The rest of the paper is structured as follows. Section 2 describes a small low profile antenna design, followed by the circular Pixel characteristics in Section 3. Antenna miniaturization to increase the aperture angle is explained in Section 4 and Section 5 sheds light on the Radio Frequency Identification (RFID) application and ground coverage. The work is concluded in Section 6, followed by references.

II. SMALL LOW PROFILE ANTENNA DESIGN

A Low Profile EBG antenna [2] is a resonant high gain air cavity (Figure 1.a) inserted between a ground plane and a semi-reflective surface usually a Frequency Selective Surface (FSS). A small antenna is built with the same characteristics (see Figure 1.b) by introducing vertical walls in such structure. This small antenna is called "Pixel" because it has already been used in its square shape as Pixel in the Agile Radiating Matrix Antenna (ARMA) concept [3].

The new air cavity antenna (Pixel) is fed by a patch that is printed on a dielectric slab or by any other probe being located on the cavity (Figure 1.c). The dimensions of the final structure with a square shape [3] can be chosen to be between 1.5λ and 0.1λ, and other shapes can be used besides a circular one, as shown further in the paper.

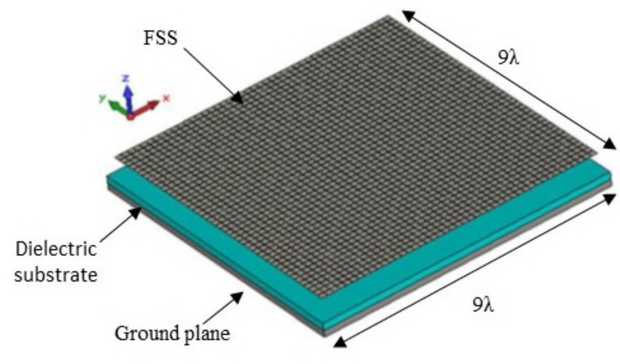

Figure 1.a EBG Antenna

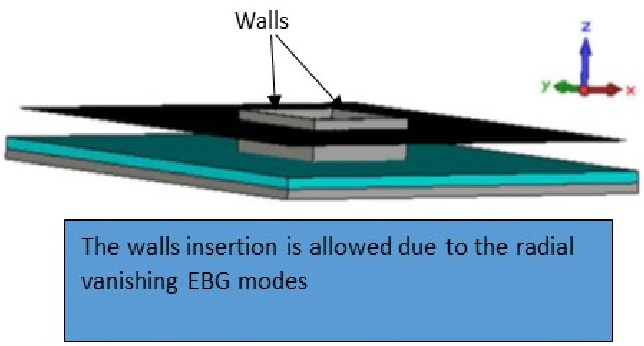

Figure 1.b Walls limited cavity antenna

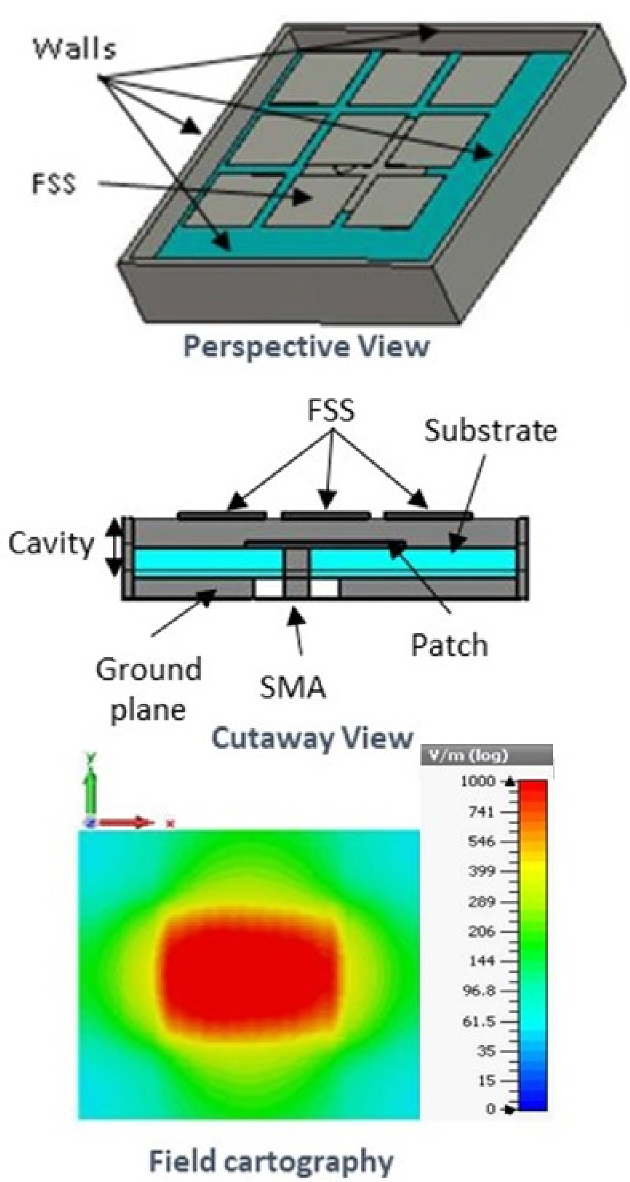

Figure 1.c Final antenna with its corresponding radiating surface ES field cartography

III. CIRCULAR PIXEL CHARACTERISTICS

To show the main characteristics, a circularly shaped Pixel antenna with a λ/2 diameter fed by a circular patch is designed (Figure 2). The antenna is fed by four ports [4] polarization circuit in order to obtain a good circular polarized radiation pattern.

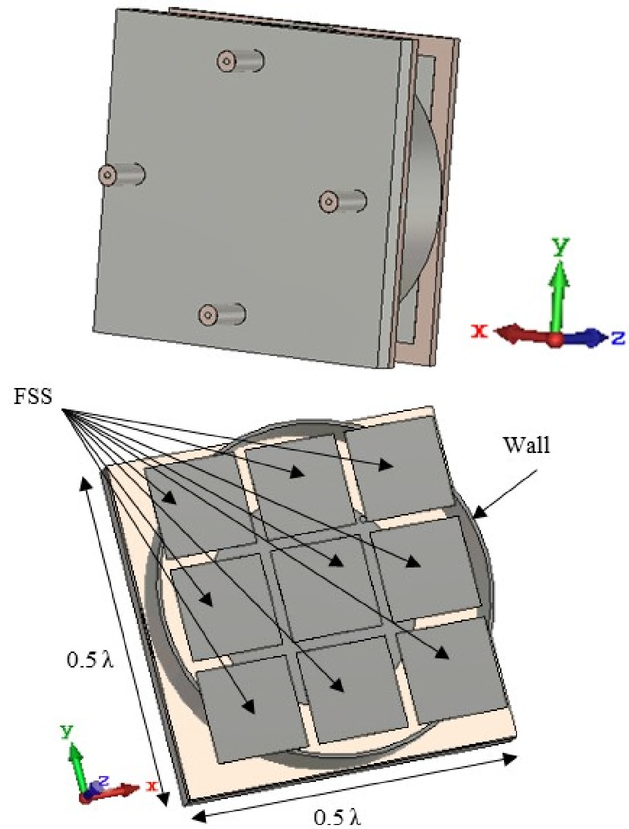

Figure 2.a Circularly shaped Pixel antenna above a square ground plane

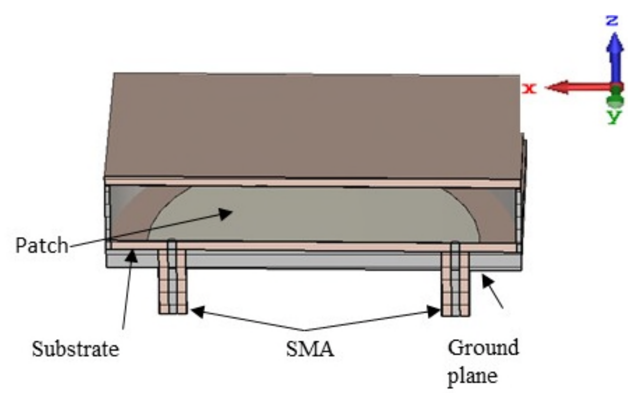

Figure 2.b Cut view: plane containing two feeding coaxial cables.

The Return Loss S_{11} parameter evolution as a function of the frequency (Figure 3.a) shows a large bandwidth: 18% but the aperture angle is only about 103° (Figure 3.b) with a $\lambda/2$ diameter of the "Pixel". The axial ratio is presented in Figure 3.c.

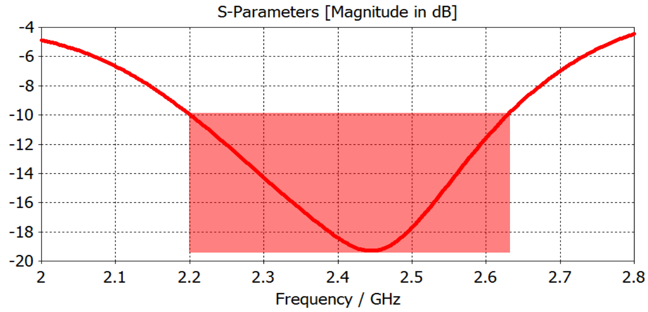

Figure 3.a S11 parameter as a function of the frequency

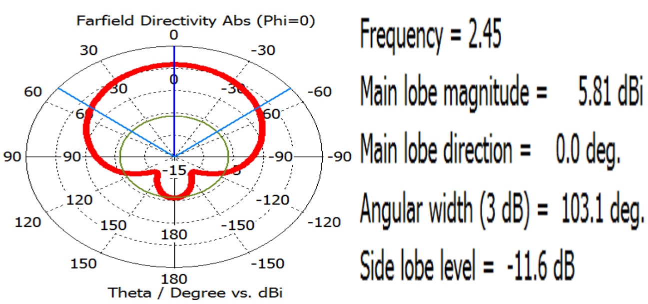

Figure 3.b Antenna gain evolution

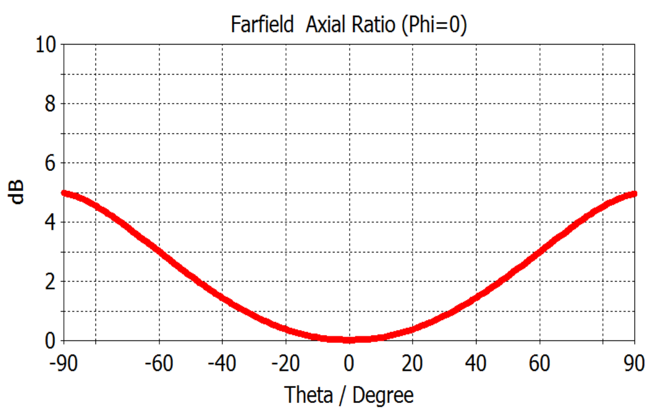

Figure 3.c Axial ratio

Axial Ratio: <3 dB for +-60 degrees. This indicates that the deviation from circular polarization is less than 3 dB over the specified angular range.

IV. ANTENNA MINIATURIZATION TO INCREASE THE APERTURE ANGLE

To increase the aperture angle of the antenna, the diameter of the Pixel antenna is reduced to 0.2λ (Figure 4). Consequently, the feeding patch dimensions must be highly reduced by introducing a new substrate with a high permittivity Ɛ = 10 (Arlon). This new antenna is called Mini Antenna "MINA" and the characteristics are demonstrated in a linear polarization design as seen in Figure 4.

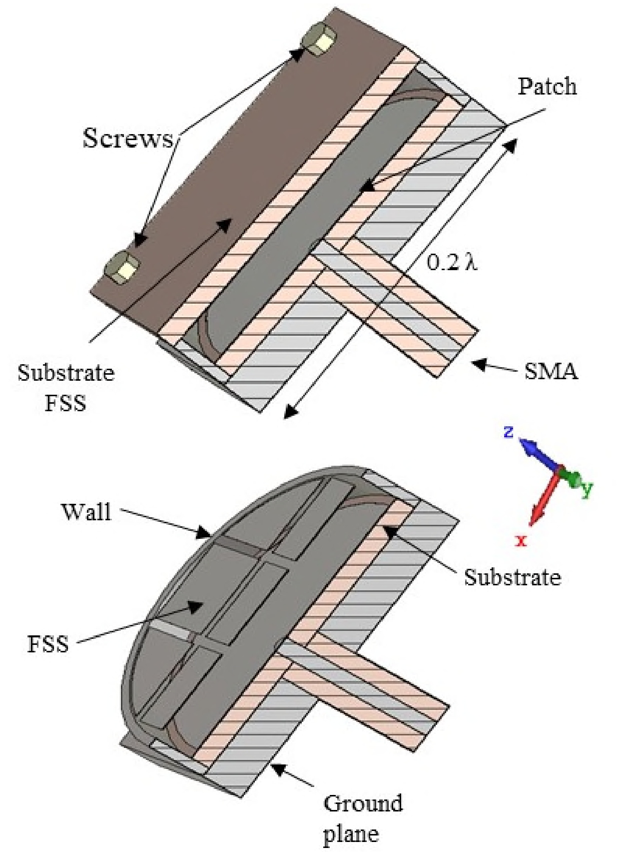

Figure 4. Half cut-view of the MINA (with and without the FSS substrate).

Concerning these conditions, the bandwidth is strongly reduced as shown in Figure 5.a: 0.5% (should be improved to match with the application bandwidth) but the aperture angle is large, as expected (Figure 5.b).

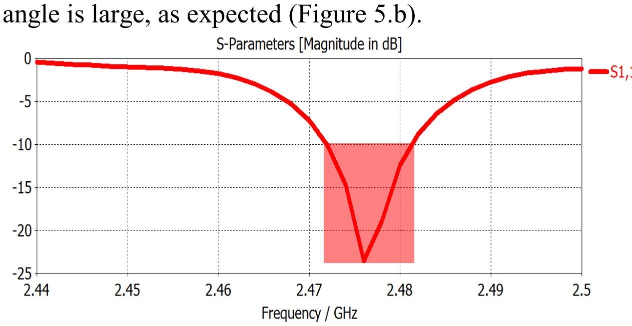

Figure 5. a S11 parameter as a function of the frequency

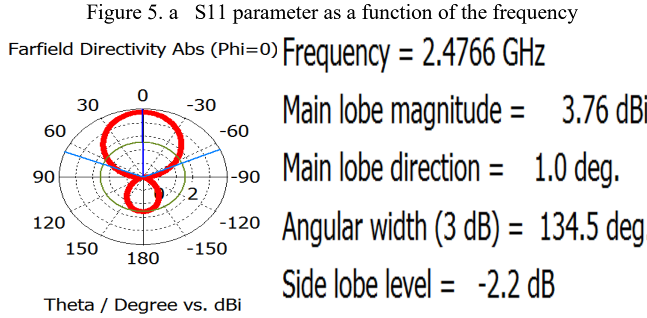

Figure 5.b Gain evolution as a function of the Θ angle for all the ϕ planes.

V. GROUND COVERAGE

To illustrate the operation, let us consider MINA as a reader antenna for a simple Radio Frequency Identification (RFID) application. It is located on the roof of a large shopping center area. The miniaturized MINA solution offers a coverage multiplied by four, as shown in Figure 6, when the 0.5λ and the 0.2λ structures are compared. Instead of using 4 readers, the number of the prepared tags is multiplied by 4 and only one reader is used.

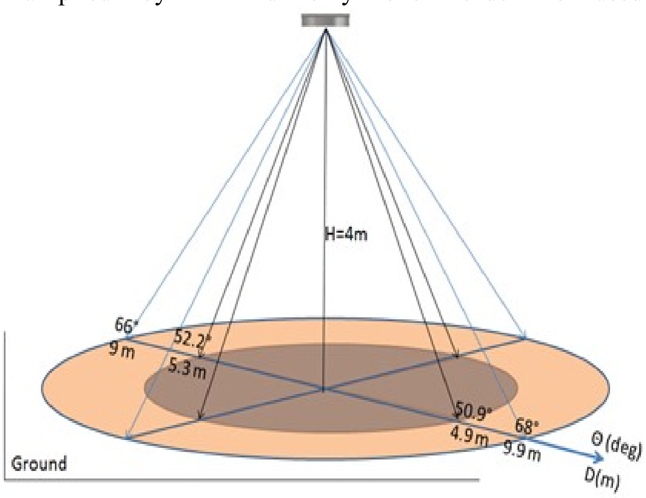

Figure 6. Ground coverage obtained with the 2 antennas: 0.5λ Pixel and the 0.2λ MINA.

VI. CONCLUSION

A new kind of low profile antenna was presented in this paper. The behavior is deduced from the usage of an EBG metamaterial, which allows to build planar antennas with large or small surfaces (1.5λ to 0.2λ).

For low frequency sensor-to-microcontroller links, the use of this solution is only limited by the antenna size and for high frequency solutions (sub millimeter ones) it is limited by the manufacturing technology. Such link antennas are particularly suitable for coverage of multi-sensor applications.

REFERENCES

[1] C. Menudier, M. Thevenot, T. Monediere, and B. Jecko "EBG Resonator Antennas: State of Art and Prospect" Antenna Theory and Techniques, 6th International Conference IEEE, pp.37-43. Sevastopol, Ukraine, September,2007.

[2] M. S. Toubet et al. "Wide Bandwidth, High-Gain, and Low-Profile EBG Prototype for High Power Applications," Antennas and Wireless Propagation Letters, IEEE , vol.10, no. 1362-1365, 2011.

[3] B. Jecko, E. Arnaud, H. Abou Taam, and A. Siblini "The ARMA concept: Comparison of AESA and ARMA technologies for agile antenna design.": Fermat Journal vol 20, pp.1-7, 2017.

[4] A. Siblini, B. Jecko, H. AbouTaam, M. Rammal, and A. Bellion "New Circularly Polarized Matrix Antenna for Space Applications" Wireless Telecommunications Symposium (WTS) IEEE, pp.1-4, London, 2016.

[5] A. Siblini, B. Jecko, and E. Arnaud "Multimode Reconfigurable Nano-Satellite Antenna for PDTM Application," Antennas and Propagation, 11th European Conference EUCAP, pp.542-545, Paris 2017.