Optimal printed antenna for 60 GHz short range impulse communication systems

Rahma Abdaoui[1], Martine Villegas[1], Genevieve Baudoin[1], Antoine Diet[2]
[1] Université Paris-Est, ESYCOM, ESIEE Paris, Cité Descartes, 2 Bd Blaise Pascal, 93162 Noisy-le-Grand Cedex
[2] L2S-DRE UMR8506 (Université Paris Sud-11CNRS, Supélec,). Supélec, Plateau du Moulon, Gif sur Yvette

***Abstract-* A printed antenna with good time domain performances for 60 GHz short range impulse communication is presented in this paper. The antenna was simulated and optimised using Agilent software Momentum and EMpro. The antenna presents a maximum gain of 7.4 dBi, 4 GHz bandwidth and short delay spread. The influence of the antenna on the transmitted pulse is analyzed and demonstrates the superior antenna performances with an antenna fidelity reaching up to 84%.**

Key words: 60 GHz, printed antenna, antenna fidelity, impulse architectures

I. INTRODUCTION

With the increasing (demand) concerning high data rates wireless applications satisfying additional requirements such as low-cost and power consumption, new radio solutions have being developed in the 60 GHz band. These solutions make profit of the advantages of this band especially after the allocation of about 9 GHz of the [57GHz-66GHz] band to unlicensed use in Europe for example [1][2]

In our study we focus on short range indoor applications such as kiosk downloading or very high speed wireless connections for mobile devices. These applications don't require directive antennas. Therefore, onboard integrated antennas with a sufficient trade-off gain and Half-power beam width can be appropriate candidates. In this paper, a new 60 GHz printed antenna, designed for impulse radio communications, is presented. The antenna effect on the transmitted and received pulse was also analyzed in different points in the space.

II. ANTENNA DESIGN AND CHARACTERISATION

Figure 1 shows the geometry of the proposed antenna. A50 Ω feed line is used for the excitation followed by a slot .The structure is also characterized by steps on both sides of the patch. The antenna is designed on RT/duroid 5880 substrate with 0.254 mm thickness (ε_r =2.2, tanδ=0.0009 at 10 GHz) [1].The choice of a substrate with a low dielectric constant was made in order to maximize the antenna radiation. The substrate length is 6.6 mm and the width is 3.8 mm.

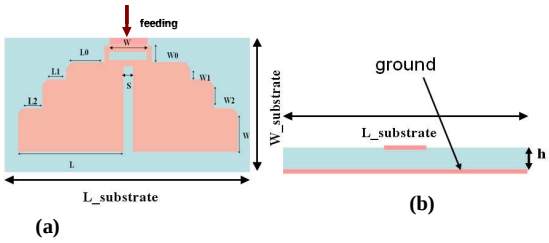

Figure1. Configuration of the proposed antenna: (a) front view (b) left view

TABLE I
ANTENNA DIMENSIONS

L_substrate	6.6 mm
W_substrate	3.8 mm
W	0.8 mm
L	2.2 mm

III. SIMULATIONS AND RESULTS

Antenna performances are estimated using simulations on Agilent software Momentum and EMpro. Its return loss is below -10 dB from 58 to 62 GHz (4 GHz bandwidth), as shown in figure 2. This antenna presents a maximum gain of 7.4dBi at 59 GHz and a Half-power beam width of 90° .

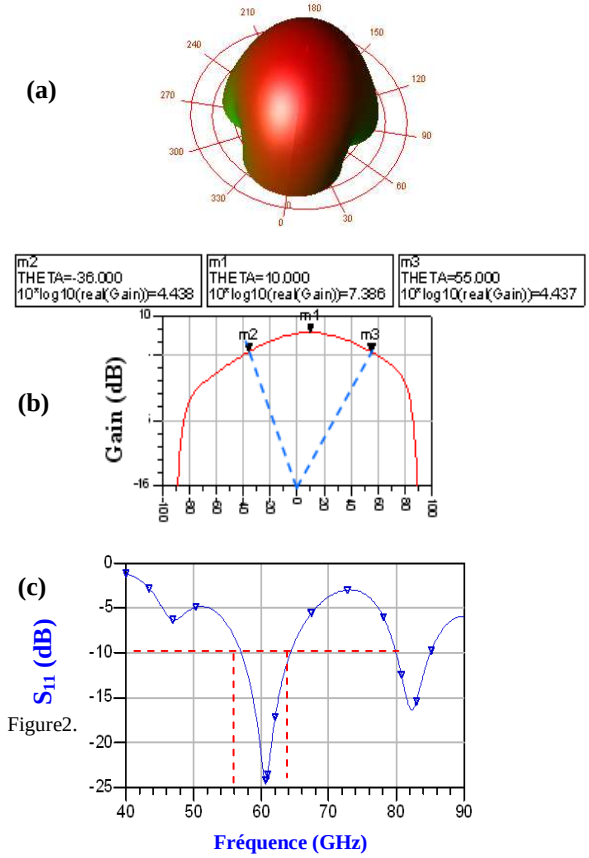

Figure2.

Figure2. Simulated antenna characteristics

(a) Radiation pattern (b) Gain and Aperture at -3dB

(c) Bandwidth

Effects of the antenna on transmitted and received pulse have an important impact on the performances of impulse architectures in the case of a correlation receiver with high delay spread antenna for example, risks overlapping, which limit data rates , as well as frequency [3] [4]. Fidelity of the radiated and received pulse has to be taken into account while designing the antenna.

The fidelity factor of an antenna characterised the distortion introduced by the antenna on the transmitted pulse. So it describes the similarity degree between the transmitted pulse and the received pulse at the direction (θ, φ). The expression of the fidelity factor is given as follows:

$$FF = \max_{\tau}\left[\frac{R_{xy}(\tau)}{\sqrt{R_{xx}(0)R_{yy}(0)}}\right]$$

Where - x is the transmitted pulse

- y is the received pulse at the direction (θ, φ)

Considering a modulated Gaussian pulse at 59 GHz, with duration of 142 psec in order to cover the entire allocated band between 57 GHz and 64 GHz, for the excitation, the fidelity factor of the antenna is calculated in many directions for two configurations scenarios.

In the first scenario (figure we focus on the similarity between the radiated pulses in many directions and the transmitted pulse.

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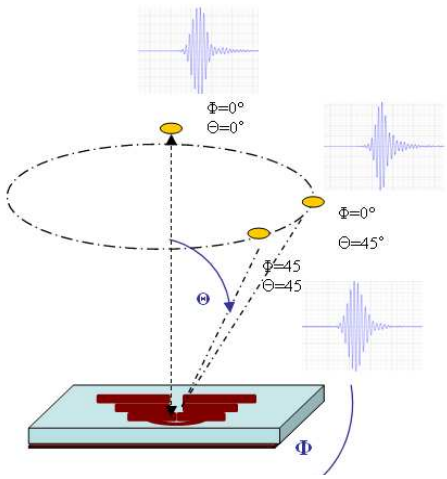

Figure 3.Antenna Fidelity : scenario 1

The following Table shows some calculated values of the antenna fidelity factor for some specific directions .It reaches 84% in the case of ($\theta = 45°, \varphi = 45°$) for the radiated pulse which can be considered as excellent.

TABLE II
ESTIMATED ANTENNA FIDELITY

thêta	phi	FF
0	0	80.2%
45	0	79.7%
45	45	84.1%

The same antenna is used in the second scenario for the reception (Figure 4). The antenna fidelity is then estimated at the out put of the second antenna. It reaches in this case 61%.

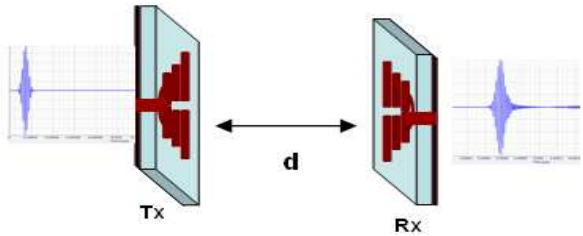

Figure4. Antenna Fidelity: scenario 2

Figures 5 and 6 show the transmitted and received pulses.

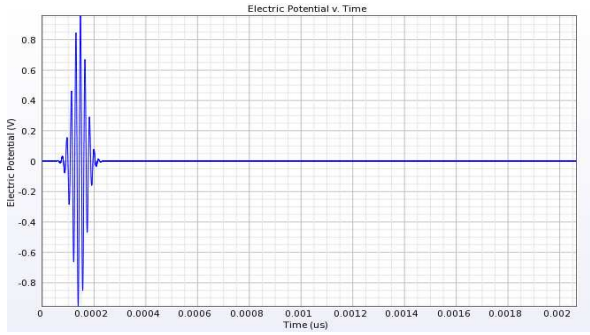

Figure5. Input pulse

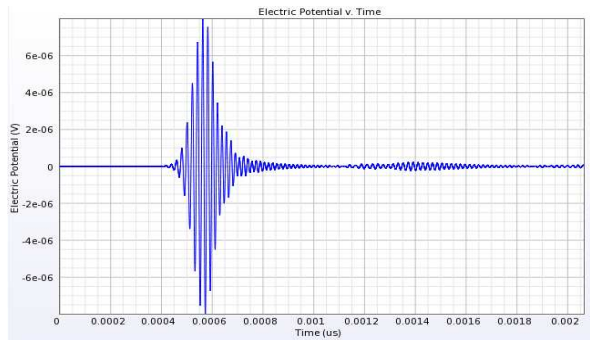

Figure6. Received pulse

The received pulse is the second derivative Gaussian excitation pulse. As a result, the received pulse is similar to the input pulse with some distortion. This distortion is acceptable since it didn't exceed one third of the pulse duration to avoid

inter symbols interferences in the case of pulse series transmission and guarantee high data rates.

For the impulse transceiver architectures, the time repetition of the pulse is a one of the important factors characterizing their performances .It is chosen to avoid inter-symbol interferences by respecting the following condition: $T_r > T_d + T_s$ where T_d is the channel delay spread and Ts is the pulse duration .So if the antenna introduced an important distortion in the transmitted pulse the previous condition could not be respected.

In this context, the presented antenna seems to be a good candidate for impulse architectures based on pulse energy detection.

IV. Non Coherent Receiver

The block diagram of a non coherent receiver is reported in the following figure .It includes an LNA, a band-pass filter bank, a square law device and a gate integrator. The receiver compares the energy of the received signal to a given energy threshold in order to make the decision.

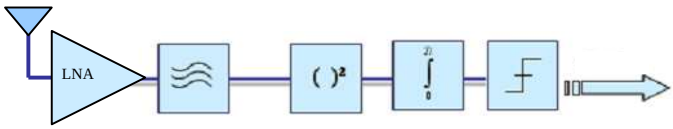

Figure7. Non coherent receiver architecture

Figures 9,10,11,12 show a train of pulses using OOK modulation at different stages of the receiver

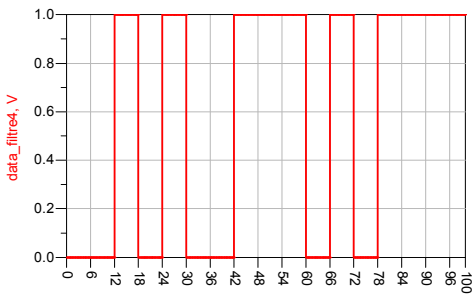

Figure9. Transmitted data

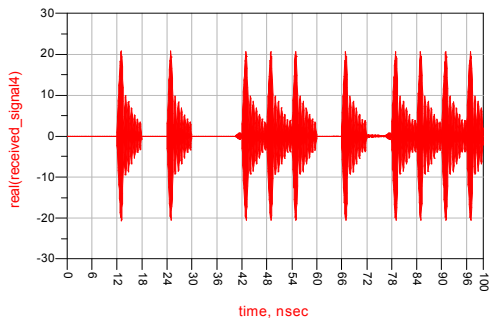

Figure 10 received train of pulses

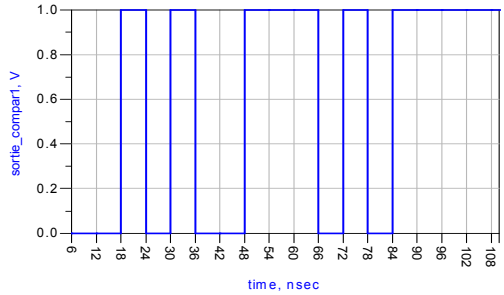

Figure 13 decision

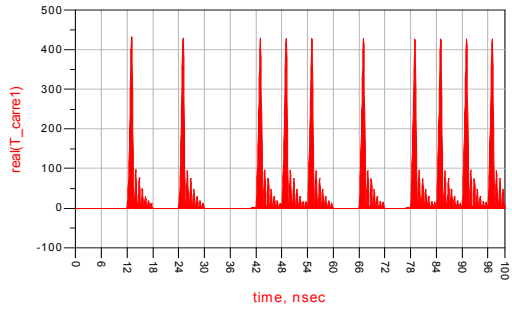

Figure 11 Squared pulses

The decision is done, respecting two hypotheses [5][6]:

$$H_0 : x = \int_0^T [n(t)]^2 \, dt \quad \rightarrow \quad \textbf{\textit{Bit 0}}$$

$$H_1 : x = \int_0^T [s(t) + n(t)]^2 \, dt \quad \rightarrow \quad \textbf{\textit{Bit 1}}$$

Where *s(t)* is the received noise and *n(t)* corresponds to the noise.

So, the receiver estimates the signal energy during the time integration period ($E = \int_0^{Ti} s_{received}(t)^2 dt$) and compares it to the estimated threshold which is greater than noise energy in order to decide the presence or the absence of a pulse during that period.

The non coherent receiver presents many advantages like its low complexity, easy implementation and the absence of synchronisation.

However, it has some limitations such as the signal to noise ratio SNR, which can affect the pulse detection in case of low SNR, and the time integration period limited by the channel delay, the time repetition of the pulse and the antennas distortion, and hence, the chosen antennas in the transmission and the reception should have high fidelity of radiated and received pulses to not limit the architecture performances.

The proposed antenna can be also a good candidate for multi band impulse transceiver architectures [4] where the time

repetition of pulses is a fundamental factor limiting the out put data rate of the transceiver.

V. CONCLUSION

A 60 GHz millimetre wave planar antenna with a trade-off gain band width and radiation pattern for impulse architectures is described. The reasonable distortion generated by the antenna on the pulse in transmission and reception is calculated. Therefore, the proposed solution can be considered as an optimal candidate for impulse architectures based on pulse energy detection.

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