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# Horn antenna design for BAN millimeter wave on-body communication

Solofo Razafimahatratra, Julien Sarrazin, Aziz Benlarbi-Delai

Laboratoire d'Electronique et d'Electromagnétisme  
Sorbonne Universités, UPMC Univ Paris 06,  
UR2, L2E, F-75005  
Paris, France  
solofo.razafimahatratra1@etu.upmc.fr,  
julien.sarrazin@upmc.fr, aziz.benlarbi\_delai@upmc.fr

Philippe De Doncker

Wireless Comm Group - OPERA Dpt.  
Université libre de Bruxelles

Bruxelles, Belgique  
pdedonck@ulb.ac.be

**Abstract**—In this paper, a 60-GHz H-plane horn antenna is designed and studied in the context of Body Area Network (BAN). Targeting both size reduction and bandwidth widening, we obtain an optimal design that meet a good tradeoff between compactness, matching, bandwidth and multimode propagation. The study of return loss is conducted considering the dimensions of the horn antenna.

## I. INTRODUCTION

The 60-GHz band is attractive for Body Area Networks (BANs) application for its high atmospheric attenuation, low interference with other networks, component compactness, large available bandwidth and low human body skin penetration [1] [2]. However, as far as we know, there is no accurate propagation model characterizing on-body communication at 60 GHz. To establish such a model, we need realistic measurement which requires low profile antenna.

In this paper, a planar H-plane horn antenna is considered. An H-plane horn antenna has a high directivity in the H-plane of the antenna and is loosely wide beam in the E-polarization [3]. Using such antenna is suitable to make measurement for on-body BANs without requiring unsafe high level of emitted power. Our study deals with matching, band widening, compactness and reduction of multimode propagation. Resonance and matching were evaluated using CST Microwave studio by means of horn dimensions study.

## II. THEORY AND DESIGN

The simulated geometry of the antenna is illustrated in Fig. 1. and Fig. 2.

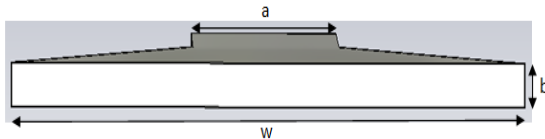


Fig. 1. Antenna geometry : face view.

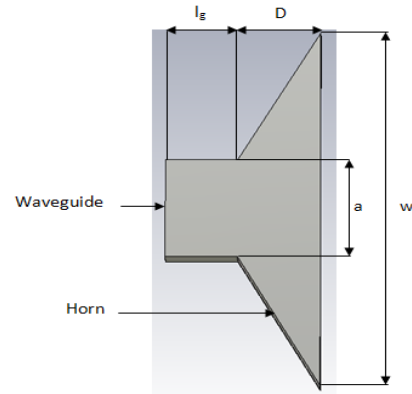


Fig. 2. Antenna geometry : top view.

The relation between a mode  $TE_{mn}$  cutoff frequency  $f_c$  and waveguide dimensions [4] is given in (1).

$$f_c = \frac{1}{2\pi\sqrt{\mu_0\epsilon_0}} \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2} \quad (1)$$

The  $TE_{10}$  mode cutoff frequency is chosen under 50 GHz. Considering a dielectric constant of air, we can infer from (1) the following waveguide dimensions: width  $a = 3.2$  mm, thickness  $b = 0.7$  mm. The thickness  $b$  is set to standard value. The horn dimensions ( $D$ ,  $w$ ) are discussed in the next paragraphs.

## III. PARAMETER STUDIES

The horn antenna return loss can be regulated by either varying the length  $D$  of the horn, for resonance issue, or varying the horn aperture width  $w$  to achieve matching to the air. This paper presents a horn antenna design evaluating the influence of these two dimensions. The concepts are verified by simulating the design with different dimensions with CST Microwave Studio.

To widen the bandwidth centered at 60 GHz, many solutions involving different values of  $D$  and  $w$  are possible and

one must define the optimum couple of  $D$  and  $w$ . In the following paragraph, we study the impact of  $D$  and  $w$  on the performance of the antenna.

### A. Dependence on horn length

The length enables to adjust the reflection. As shown in Fig. 3, central frequency decreases with the horn length  $D$ . The return loss is better than -10 dB throughout 5 GHz. It is due to resonance phenomenon.

The best performance in terms of S11 is obtained for  $D = 2.3$  mm.

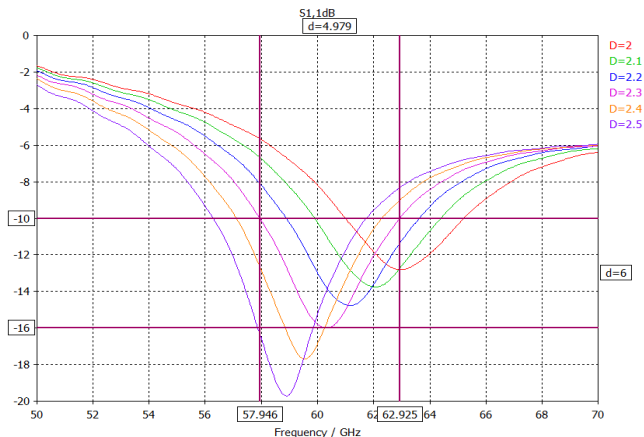


Fig. 3. Return loss  $|S_{11}|$  for different horn lengths  $D$  in mm, waveguide width  $a = 3.2$  mm, height  $b = 0.7$  mm, horn aperture width  $w = 11.2$  mm, waveguide length  $l_g = 2$  mm.

### B. Dependence on horn aperture width

The width is varied to obtain a good matching at the horn front edge to the air. Fig. 4 shows the return loss for different aperture widths. The central frequency decreases with the horn aperture width  $w$  due to impedance at the horn edge. The best performance in terms of S11 is obtained for horn aperture width  $w = 11.3$  mm. We converge to the final dimensions of the horn : width  $w = 11.2$  mm and length  $D = 2.3$  mm.

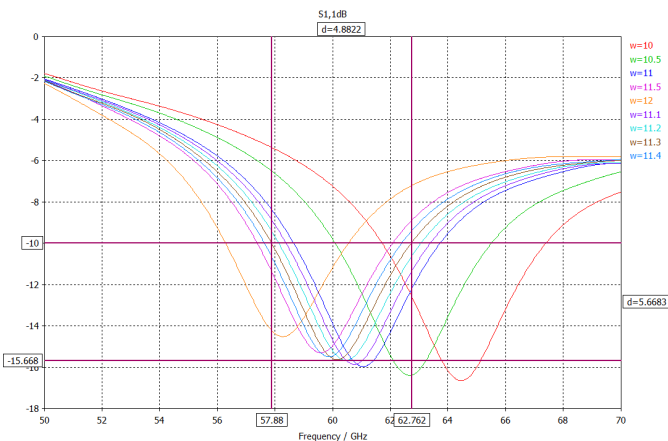


Fig. 4. Return loss  $|S_{11}|$  for different horn aperture widths  $w$  in mm, waveguide width  $a = 3.2$  mm, height  $b = 0.7$  mm, waveguide length  $l_g = 2$  mm, horn length  $D = 2.28$  mm

Therefore, the overall dimensions of the horn antenna are  $11.2 \times 3.8 \times 0.7$  mm<sup>3</sup>.

### C. Reducing higher mode

According to theory and simulation, the presence of mode TE30 persists at 60 GHz for width  $w$  above 7.5 mm. However, the TE10 mode is dominant for  $w < 9$  mm. We propose the following design in Fig. 5 to reduce TE30 mode amplitude.

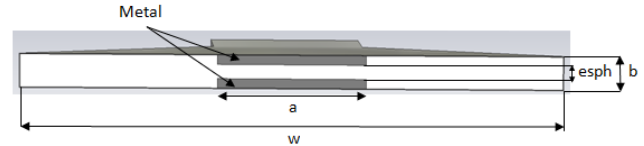


Fig. 5. Antenna design with metal pieces inserted in the middle of the cross section for TE30 mode reducing.

After simulation, the rejection ratio between TE10 and TE30 is reduced of about 13 dB for metal spacing equals to 0.3 mm for a width  $w$  equals to 9 mm. With metals, we deteriorate return loss performance by means of magnitude and bandwidth.

## IV. CONCLUSION AND FUTURE WORK

A 60-GHz horn antenna was designed and studied. The optimal design, with regard to bandwidth and matching is obtained by varying horn dimensions. The resulting antenna size is  $11.2 \times 3.8 \times 0.7$  mm<sup>3</sup>, which is compatible with applications dealing with BAN context. The 10-dB bandwidth is around 5 GHz centered at 60 GHz. At this center frequency the matching is maximum and equal to -16dB. TE30 mode overlaps to TE10 at the horn front edge to the air for horn width above 7.5 mm. However, we can keep the TE10 mode dominant.

This paper presents a conventional horn antenna where compactness and matching issues are undertaken. For the conference, we will also analyze the equivalent Substrate Integrated Waveguide (SIW), the horn taper design and human body influence on matching and radiation patterns.

## ACKNOWLEDGEMENT

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