2B1-4

An active transmitter antenna with beam scanning and beam shaping capability for 60GHz application

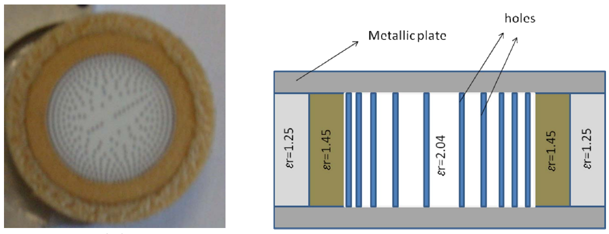
O. Lafond, M. Himdi [1], #H. Merlet, and P. Lebars [2]
[1] Institute of Electronics and Telecommunications of Rennes, UMR CNRS 6164, University Of Rennes I, Rennes Cedex 35042, France, Olivier.lafond@univ-rennes1.fr
[2] Canon Research Center France SA,
35517 Cesson-Sévigné Cedex, France, herve.merlet@crf.canon.fr

1. Introduction

For 60GHz indoor communication systems [1], there is a remarkably large range of frequency allocated for unlicensed wireless telecommunications around 60 GHz (typically 59–66GHz). In Europe, the frequency ranges 62–63 GHz and 65–66 GHz are reserved for wideband mobile networks (Mobile Broadband System). In Japan, the 59–67 GHz band is reserved for wireless communications. In indoor operation, as the link between transmitter and receiver can be shadowed because of human body interposition for example, implementing beam-scanning antennas is needed to carry out high bite rate communications. Some solutions are conceivable to achieve beam-scanning antennas, for example phased arrays [2] but it does not allow for scanning the beam over a large angle and it induces losses due to phase shifters. It is the same limitation for switched antenna arrays based on a Butler matrix [3]. Homogeneous lenses may allow the obtention of a wide scan antenna [4] but bring about a problem of retro-diffusion from the lenses to the sources. Luneburg lens avoids this problem because it presents a dielectric gradient index lens whose relative permittivity ε_r varies radially according to the law given by [5]. Moreover, this inhomogeneous lens offers the particularity to have infinity of focus points. So, it becomes possible to achieve a very wide scan antenna. Practically, inhomogeneous lens can be manufactured either from materials with varying effective dielectric permittivity [6] or by assembling a finite number of concentric homogeneous dielectric shells [7]. This kind of inhomogeneous spherical lens antenna has demonstrated off-axis performances by moving one source around the lens [8] and a beam shaping capability by associating several sources below the lens [9]. In this paper, we study a plate Luneburg lens to obtain a narrow beam (10°) for azimuth plane and a wide beam (70°) for elevation plane. First, a new mixed solution is chosen to manufacture the lens by using holes in a Teflon sheet (ε_r=2.04) and external foam crowns (ε_r=1.45 and ε_r=1.25). Secondly, the principle of the beam-scanning and beam-shaping antenna is matched by using one MMIC power amplifier behind each ridged source waveguide. Finally, a transmitter active reconfigurable antenna at 60 GHz is tested by measuring the received power and the radiation patterns for different configurations.

2. Design and characterization of plate Luneburg lens

We decided to design a plate Luneburg lens using holes in the central region (Teflon, (ε_r=2.04)) and additional Divinycell foam dielectric crowns (ε_r=1.45 and ε_r=1.25) for the external region (Fig. 1). The total diameter of the lens is 28mm to respect the narrow beam specification in azimuth plane. The diameter of the heart of Teflon is 17.5mm and the diameters of the two crowns are respectively 23mm and 28mm. To achieve the good beam width for the elevation plane (70°), the thickness of the lens is 3mm and two metallic plates are added under and above it.



(a) (b)

Fig. 1. (a) Lens after manufacturing with holes in the Teflon heart and two crowns of foam, (b) Cutting plane of design

The measured radiation patterns in azimuth and elevation plane are respectively given in Figs. 2a and 2b. The beam width is between 9.5° and 10° in the azimuth plane. The cross-polarization level compared to the main beam is lower than -22dB. For the elevation plane, the measured beam width (60°) is very close to predicted one (65°) and the cross polarization level is also very low (<-22dB). The measured gain (15/16dBi) is in good accuracy with directivity (16dBi). These results show a very good efficiency for this lens antenna.

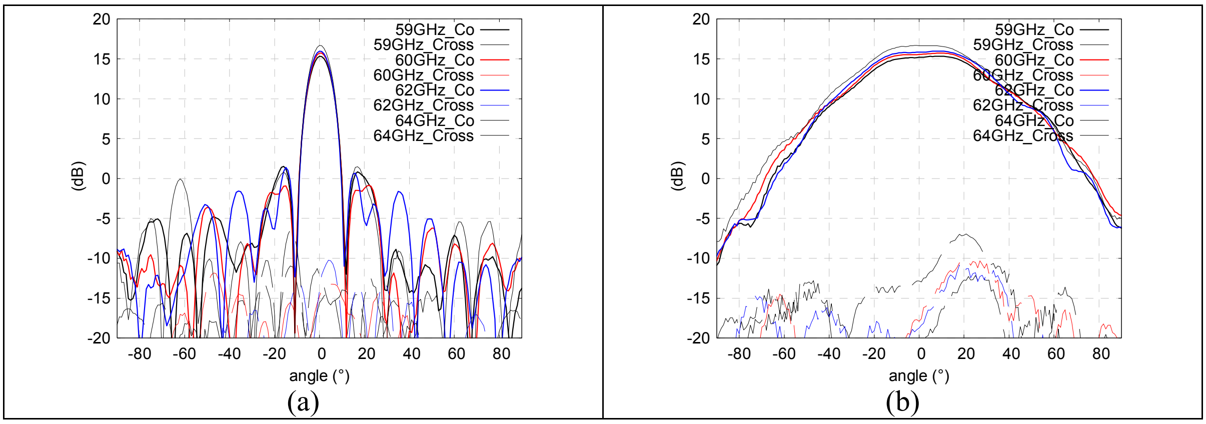
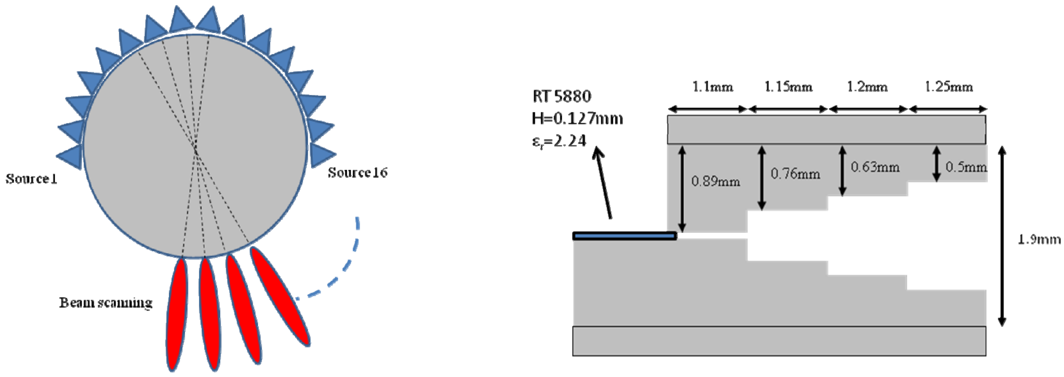


Fig. 2. Plate Luneburg lens fed by a classical open-ended waveguide – (a) Measured radiation patterns in azimuth plane and (b) in elevation plane

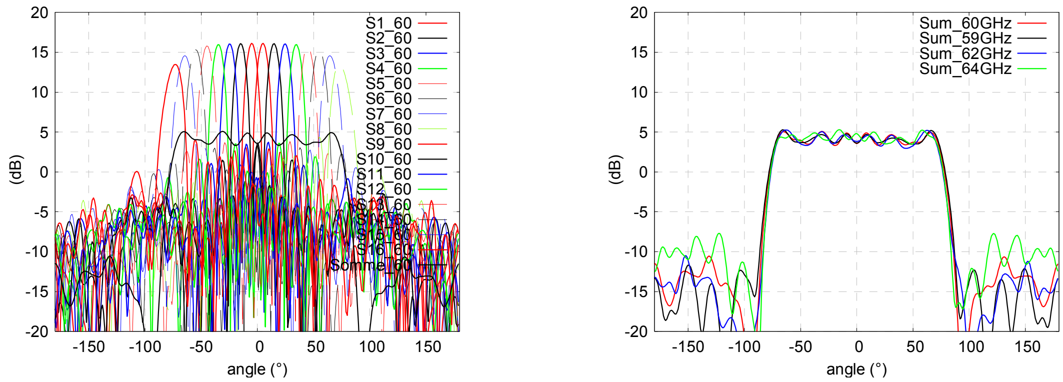
3. Principle of reconfigurable antenna

The principle of the active reconfigurable antenna is described in Fig. 3a. The design is based on the plate Luneburg lens fed by several sources (16) [10]. Depending of the number of active sources behind the lens, it is possible to obtain a beam scanning antenna or a beam shaping antenna. To put a lot of sources just behind the lens, the width of each source must be small (<2.5mm) and this source must radiate in a end-fire configuration to illuminate the lens, so a ridged waveguide fed by microstrip line has been chosen (Fig. 3b). In Fig. 4a are given the simulated radiation patterns (CST Microwave Studio Software) when the sixteen sources feed the lens sequentially at 60 GHz. In Fig. 4b are given the simulated radiation patterns when the sixteen sources feed the lens simultaneously.



(a) (b)

Fig. 3. (a) Sources + lens – The beam scanning angle depends of the feeding source, (b) the ridged waveguide fed by microstrip line.



(a) (b)

Fig. 4. Sources + lens – (a) Simulated radiation patterns (co-polarization) at 60 GHz when the sixteen sources feed the lens sequentially, (b) Simulated radiation patterns (co-polarization) when the sixteen sources feed the lens simultaneously.

4. Active reconfigurable antenna at 60 GHz

The first aim is to design a steerable antenna by choosing with switches one beam. In this case, only one source antenna feeds the lens and a tilted beam is obtained depending of which source is pushed ON. The others sources are pushed OFF. The second aim is to modify the shape of the radiation pattern by pushing ON several sources simultaneously. The complete antenna must be matched whatever the number of excited sources. The FMM5715X MMIC amplifier [11] can be used as a switch and the input impedance (S11) is matched in ON and OFF states. That simplifies the feeding line network which feeds all the sources and allows the match of the global antenna on a wide bandwidth. One MMIC power amplifier is positioned behind each open-ended waveguide to control its excitation. This amplifier realizes a 15dB gain and an isolation better than 45dB. As this amplifier keeps a correct matching level whatever its state, the EIRP of our global antenna will not change as the number of feeding sources changes because the input power will be always divided between the 16 MMIC amplifiers. A photo of the active demonstrator antenna is given in Fig. 5a. The millimeter-wave anechoic chamber of IETR is set to measure antennas in receiving configuration. Nevertheless, we tried to measure our active transmitter antenna by inverting the millimeter-heads of the measurement setup. Firstly, we measured three independent beams (9 to 12) of the antenna in azimuth plane to demonstrate the beam-scanning capability. A 10° beam width is achieved for these configurations at 62GHz. Secondly, these three beams n°9 to 12 have been excited simultaneously to widen the radiated beam and a 30° beam width is obtained. In Fig. 5b, the four individual beams are presented too with the real radiated power level for each one. The measure proves the stability of the EIRP whatever the number of excited beams as it explained.

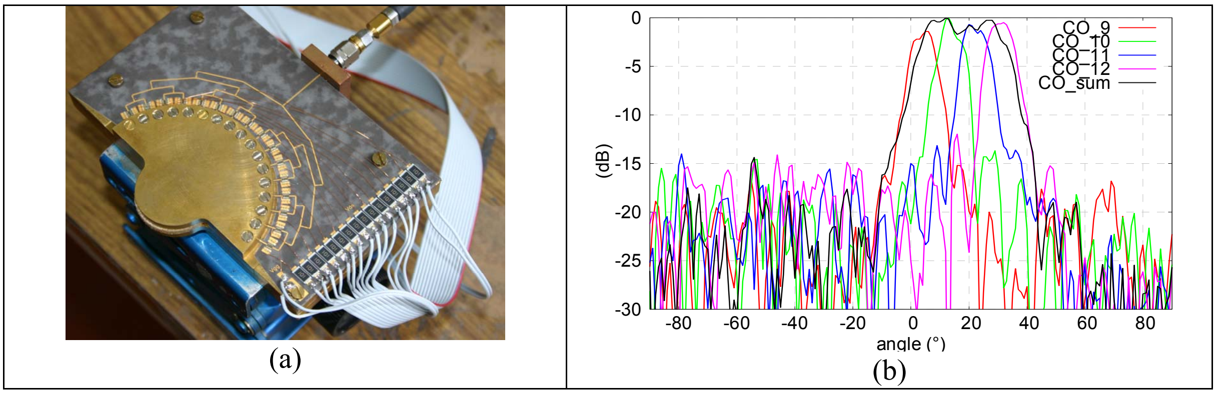


Fig. 5. (a) Active prototype antenna with MMIC amplifiers and DC bias elements, (b) Measured radiation patterns for several tilted beams and the sum of them.

5. Conclusions and perspectives

An active transmitter antenna has been demonstrated based on a plate Luneburg lens and fed by several sources to achieve beam scanning and beam shaping antenna. The EIRP is stable whatever the number of active sources because the MMIC amplifier used as a switch is always correctly matched whatever his state (ON or OFF). The future works will concern receiver antenna and the development of new integrated sources to simplify the design.

References

[1] Nan Guo, Robert C. Qiu, Shaomin S.Mo, and Kazuaki Takahashi.: '60-GHz Millimeter-Wave Radio: Principle,Technology, and New Results', EURASIP Journal on Wireless Communications and Networking, 2007, pp.1-8

[2] A. Adane, F. Gallee, C. person, V. Puyal, C. Villeneuve, D. Dragomirescu, '' Implementation of Broadband microstrip-U Coupled Patch Array on Si/BCB Membrane for Beamforming Applications At 60 GHz,''in Proceedings of the 5th European Conference on Antennas and Propagation, Rome, April 2011, pp. 1332-1336.

[3] C.-H. Tseng, C.-J. Chen, and T.-H. Chu, ''A low cost 60-GHz switched-beam patch antenna array with Butler matrix network," IEEE Antennas and Wireless Propagation Letters, vol. 7, pp. 432-435, 2008.

[4] B. Schoenlinner, X. Wu, J.P. Ebling, G. V. Eleftheriades, and G. M. Rebeiz, ''Wide-scan spherical-lens antennas for automotive radars,'' IEEE Trans. Microw. Theory Tech., vol. 50, no. 9, pp. 2166-2175, Sep. 2002.

[5] Zimmerman, ''Luneburg Lens and Method of constructing same,'' US patent 5 677 796, Oct. 14, 1997.

[6] S. Rondineau, M. Himdi and J. Sorieux, ''A sliced spherical Luneburg lens,'' IEEE Antennas Wireless Propag. Lett., vol. 2, pp. 163-166, 2003.

[7] Emerson&Cuming, Billerica, MA, ''Stepped-index Luneburg lenses : Antennas and reflective devices,'' 1960, Electronic Design.

[8] B. Fuchs, O. Lafond, S. Rondineau, M. Himdi and L. Le Coq, ''Off-Axis Performances of Half Maxwell Fish-Eye Lens Antennas at 77 GHz,'', IEEE transactions on Antennas and Propagation, vol. 55, n°2, Feb. 2007.

[9] O. Lafond, B. Fuchs, S. Palud, M. Caillet, M. Himdi, S. Rondineau and L. Le coq, "Reconfigurable antenna in mm-waves based on stratified lens and sources array," in proceedins of the 3rd European Conference on Antennas and Propagation 2009, Berlin.

[10] Patent n° 1121036.6 (UK), 07/12/2011, H. Merlet, P . Le Bars, O. Lafond, M. Himdi. "Manufacturing method of a dielectric material and its applications to millimeter-waves beam forming antenna systems".

[11] FMM5715X MMIC power amplifier, datasheet Eudyna.