Title

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Single-Feed Highly-Directive Fabry-Perot Cavity Antenna for 60 GHz wireless systems: Design and Fabrication

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Abstract

In this paper, a prototype Fabry-Perot Cavity (FPC) antenna is designed and fabricated at millimeter-wave frequencies, aiming at designing directive antennas for 60 GHz wireless systems. A prototype FPC antenna is designed to have 17 dB gain at 42.8 GHz with 600-700 MHz 3dB-pattern-bandwidth and it is designed in order to be mounted on a wafer (chip). Measurement tools at millimeter frequencies and also antenna integration possibilities lead us to design an efficient feeding network for this kind of antenna. The antenna is fabricated on a quartz wafer (very low loss dielectric especially at millimeter-wave frequencies) which is coated by a thin layer of gold on each side. All the simulations on the reflection coefficient, gain and the radiation pattern of the antenna are done and compared using two most powerful EM simulators, Ansoft HFSS and Zeland IE3D and they are also compared with some measurement results for the prototype antenna.

Introduction

The FPC antenna, which represents a class of leaky wave antennas, is a promising design to get highly directive radiation with a single feed and very low loss. The idea is based on excitation of leaky-wave using a cavity covered by a Partially Reflective Surface (PRS) and it has been improved and studied over years [1-7]. In the late 60s, Von Trentini used this concept for the first time, not to produce radiation but to improve it [1]. Later on, Jackson et al in [2] showed gain enhancement using a multilayer dielectric as a superstrate. FPC antennas can be designed by using a PRS made by either periodic slots or patches [3, 4]. Also, this antenna can be excited using multi-element array feed as shown in [5]. Recently, [6, 7], this type of the antenna has been analyzed at millimeter-wave frequencies, at 60 GHz, because of its potentials for wireless applications due to low losses and ease of fabrication which will be discussed in this paper.

In this work, we show the feeding line and the fabrications process. The basic design is made at 60 GHz but due to the fabrication and material constraints, we have designed and fabricated our first prototype at 42.8 GHz. Finally preliminary measurement results are provided in comparison with simulated ones.

Antenna Design

The design procedure of FPC antennas is discussed in [6 and 7]; here the main focus will be on the feeding design and also the fabrication process. In order to

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have the mechanical stability, the most challenging task is to find a way to mount the PRS layer over the ground plane in order to form the Fabry-Perot cavity. On the other hand, the large conduction loss at millimeter-wave frequencies, leads us to design a PRS layer made of periodic slots instead of periodic patches. The two mentioned reasons guided us to design our FPC antenna on the quartz substrate as the cavity which is coated by a thin layer of gold. The quartz material has been measured in Broadcom Corporation at millimeter-wave frequencies and the measured permittivity is 4.37 with a very low dielectric loss tangent. Using the design procedure mentioned in [6, 7], the FPC antenna is designed at 60 GHz with the slot dimensions equal to 1.1 mm by 0.24 mm in order to provide 17 dB gain. The resonance height of the cavity can be calculated using the method proposed in [6, 7] which for the mentioned antenna is equal to 1.1385 mm. Fig.1 illustrates the feeding network of the designed antenna which is divided in three sections; section one is the back-gap for the CPW line which is designed for ease of probing. Section two is a 50-Ohm CPW line at the central frequency of the antenna and finally, section three is the half-wavelength slot at the central frequency of the FPC antenna. The simulations results of the reflection coefficient and the broadside gain of the antenna at 60 GHz simulated by HFSS and IE3D are shown in Fig.2.

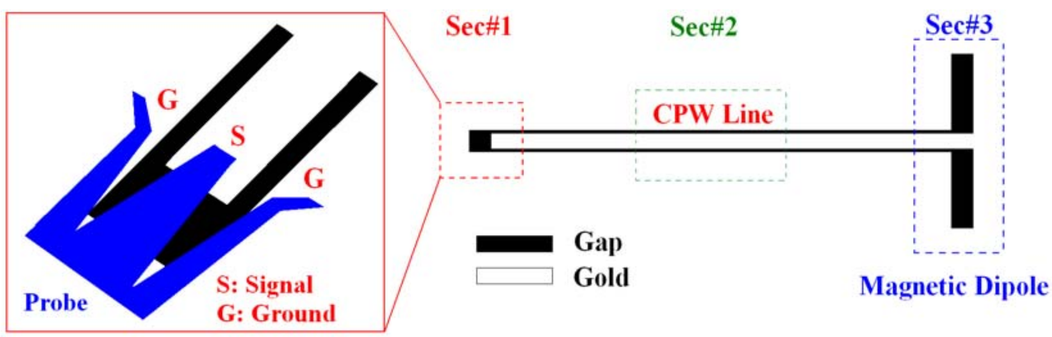

Fig.1 the feeding network of the antenna.

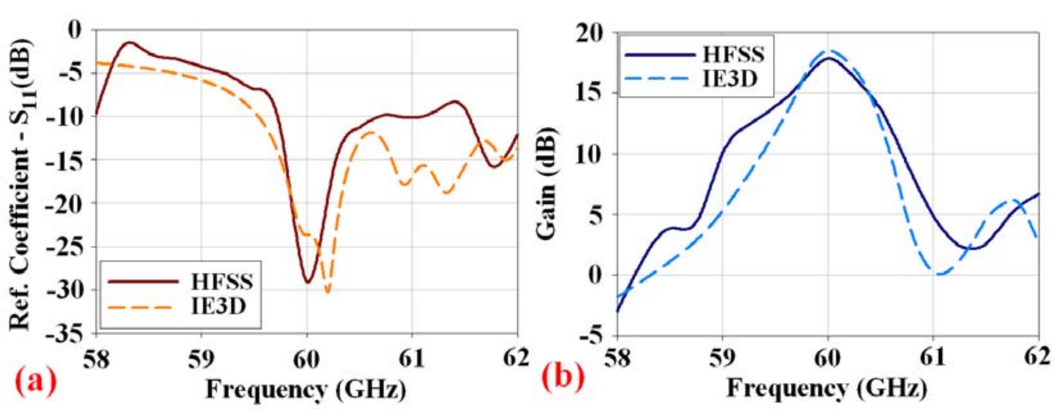

Fig.2 (a) the reflection coefficient, (b) the broadside gain of the FPC antenna at 60 GHz.

Due to restriction on the quartz thickness, it was decided to fabricate a prototype of the design at a lower frequency at which the quartz thickness is available commercially. The quartz is thus selected with the thickness equal to 1.5875 mm

(1/16th inch). This thickness is equal to the resonance height of the FPC working at 42.8 GHz, which would also radiate with 17 dB gain. The slot dimensions in order to have 17 dB gain at 42.8 GHz, are designed equal to 1.2 mm by 0.5 mm. The feeding network of this antenna is the same as what shown in Fig.1 and it is redesigned to work at 42.8 GHz. Fig.3 shows the measurement setup and the fabricated FPC antenna at 42.8 GHz. The antenna is fed by a GSG probe with 200 μm pitch-to-pitch. As discussed in [6, 7], the design procedure of the FPC antenna is based on the infinite PRS layer. After the ideal design, based on formulas in [5], the infinite PRS layer is truncated transversely in order to be able to fabricate a finite size antenna. In this work, the antenna is simulated using Zeland IE3D for an infinite ground plane and also HFSS in order to investigate the edge effect. Fig.4-a shows the simulation result of the reflection coefficient of the fabricated antenna in comparison with the measurement results. As expected, the antenna shows the resonance behavior almost at the designed frequency; the 0.5 GHz frequency shift is due to fabrication inaccuracies in our first prototype. The ripples in both HFSS simulations and the measurements are caused by the edges of the antenna. The broadside gain of the fabricated antenna is simulated with both mentioned softwares as shown in Fig.4-b. Both results have their maximum roughly at the designed frequency and the 3dB pattern bandwidth of the HFSS results is around 600 MHz whilst the one predicted by IE3D simulations is equal to 700 MHz.

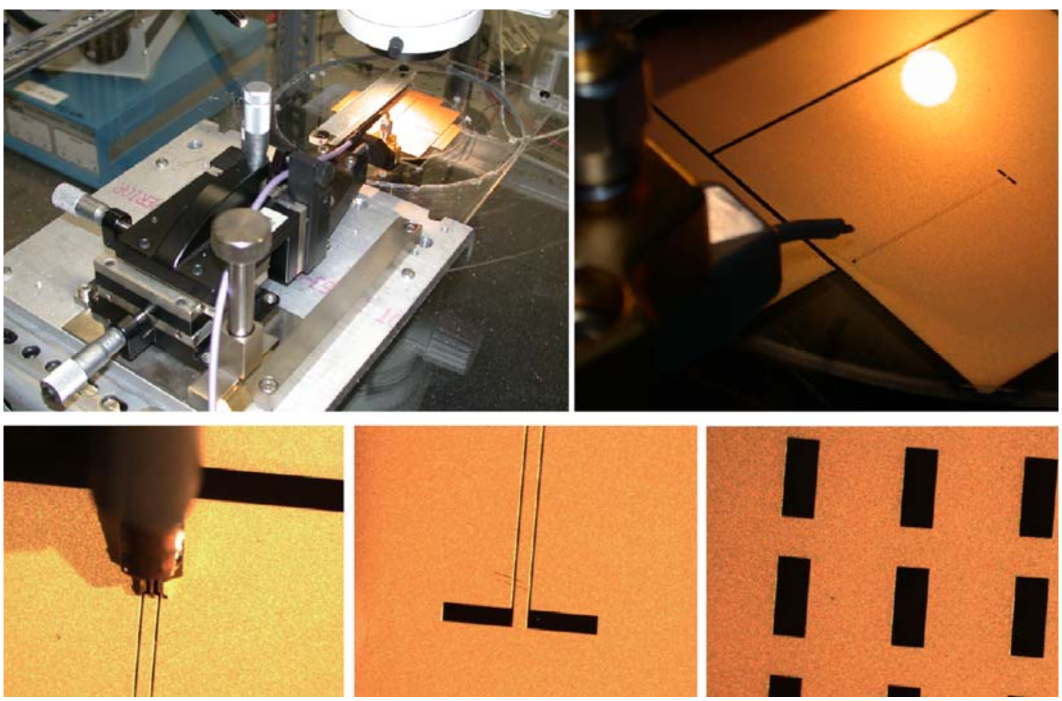

Fig.3 The measurement setup and the fabricated FPC antenna.

Conclusion

In this paper, the FPC antenna is designed and fabricated at millimeter-wave frequencies, 42.8 GHz, as an intermediate step to fabricate and measure a 60 GHz antenna. The antenna is planar and requires a single feed, which limits losses associated to the feeding network, and our design provides a gain of 17dB.

Acknowledgment

The Authors acknowledge Zeland Corporation (IE3D) and Ansoft HFSS for providing us their simulation tools that were instrumental in the whole design process.

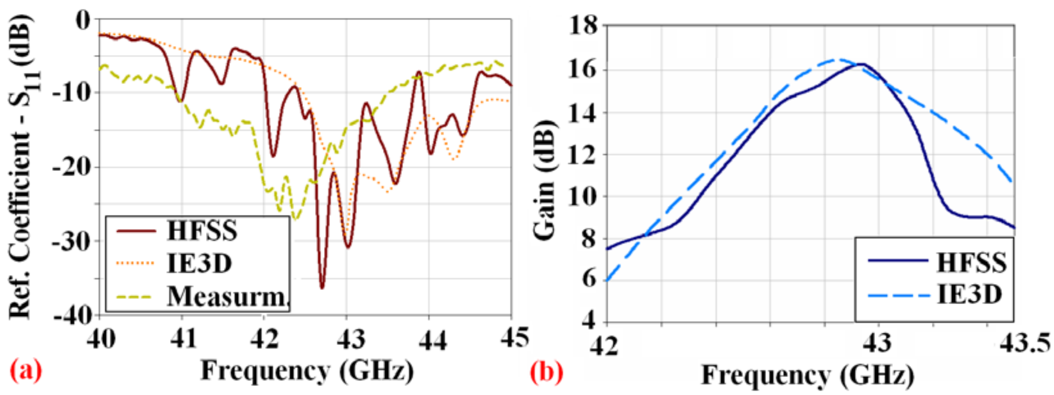

Fig.4 (a) Reflection coefficient, and (b) broadside gain of the FPC antenna at 42.8 GHz.

References

[1] G. V. Trentini, "Partially reflecting sheet arrays," *IRE Trans. Antennas Propag.*, vol. AP-4, pp. 666–671, 1956.

[2] D. R. Jackson, and N. G. Alexopoulos, "Gain Enhancement Methods for Printed Circuit Antennas," *IEEE Trans. Antennas Propag.* , vol. AP.33, no. 19, Nov. 1985.

[3] Tianxia Zhao, David R. Jackson, Jeffery T. Williams,Hung-Yu David Yang, and Arthur A. Oliner," 2-D Periodic Leaky-Wave Antennas—Part I: Metal Patch Design," *IEEE Trans. Antennas Propag.* , vol. 53, no. 11, Nov. 2005

[4] T. Zhao, D. R. Jackson and J. T. Williams "2-D Periodic Leaky-Wave Antennas—Part II: Slot Design," *IEEE Trans. Antennas Propag.* , vol. 53, no. 11, Nov. 2005

[5] R. Gardelli, M. Albani and F. Capolino, "Array Thinning by Using Antennas in a Fabry–Perot Cavity for Gain Enhancement," *IEEE Trans. Antennas* Propag. , vol. 54, no. 7, Jul. 2006

[6] S. Ali Hosseini , Filippo Capolino , and Franco De Flaviis, " Design of a single-feed 60 GHz planar metallic Fabry-Perot cavity antenna with 20 dB gain", *iWAT2009,* Santa Monica, CA, USA, March 2-4, 2009.

[7] S. Ali Hosseini , Filippo Capolino , and Franco De Flaviis, " Design of a Single-Feed All-Metal 63 GHz Fabry-Perot Cavity Antenna Using a TL and a Wideband Circuit Model," *2009 IEEE AP-S,* SC, USA, June 1-5, 2009.