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Henrique Ajuz Holzmann
(Organizador)

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Técnicas de Processamento de Sinais e Telecomunicações

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APRESENTAÇÃO

A obra Técnicas de Processamento de Sinais e Telecomunicações está organizada de maneira a atender a temas atuais sobre a área de telecom e processamento de sinais de maneira sucinta e otimizada, sendo dividido em 17 capítulos sequenciais.

A transmissão de dados juntamente com suas vertentes representa um dos principais pilares para o progresso econômico de uma nação e para o atendimento de inúmeras necessidades da humanidade, estando presente nos mais diversos setores. Desenvolve-la de maneira eficiente é uma busca constante de grandes empresas e pesquisadores, buscando otimizar e agilizar o processo de troca de informações.

Produzir conhecimento nestas áreas é de extrema importância, a fim de gerar desenvolvimento e ampliar possibilidades nos mais diversos campos. Desta forma um compendio de temas e abordagens que facilitam as relações entre temas referentes a comunicação e processamento de sinais em diferentes níveis de profundidade em pesquisas, envolvendo aspectos técnicos, científicos e humanos é trazido nesta obra.

Boa leitura!

Henrique Ajuz Holzmann

SUMÁRIO

CAPÍTULO 4

ON-CHIP KOCH FRACTAL ANTENNA ARRAY FOR 60 GHZ ISM BAND APPLICATION

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ABSTRACT: The Industrial Scientific and Medical band in 60 GHz (57 GHz to 64 GHz) is being proposed to high data rate wireless transmission requiring antennas with efficient design. In this paper we present an on-chip array aperture couple antenna, using Koch fractal geometry. The proposed antenna is composed by a transmission feed line, an aperture and patch element built in aluminum with 2 micrometers of thickness lying on two layers of silicon with height of 200 micrometers. Those dimensions were calculated according to the effective wavelength for resonance frequency at 60 GHz in order to match at 50 Ohms. The proposed antennas have been simulated using the ANSYS software, and the results show an omnidirectional radiation pattern, with half power beamwidth greater than 124 degrees, gain of 16.7 dBi, and polarization close to the circular polarization with axial ratio less of 2.22.
KEYWORDS: *Antenna; Design ISM Simulation.*

1 I INTRODUCTION

The increasing use of the electromagnetic spectrum for various technologies has implied the necessity of more bandwidth resulting in to research the utilization of higher frequency bands, especially in the millimeter wave range (30 - 300 GHz). Industrial scientific and medical

(ISM) band in 60 GHz range (57–64 GHz), normalized by Federal Communication Commission (FCC) have bandwidth of 7 GHz for high data rate wireless communication (NIKNEJAD e HASHEMI). Services in the ISM 60 GHz include technologies like Wireless Fidelity (Wi-Fi), wireless personal local area network (WPAN), and communication of fifth generation (5G) (ZHAO e REYNAERT).

Allied to these new systems, there is the necessity of device's portability, and the development of broadband antennas in Silicon at 60 GHz has the advantage to permit their utilization inside integrated circuit. Considering this scenario, the mutual interference and electromagnetic coupling, and the standards indicated for each technology, aperture-coupled antennas appear to be a good solution since it promotes gain with compact structures (NIKNEJAD e HASHEMI), (ZHAO e REYNAERT), (ZHANG, LI e LIU), (KHAM et al).

This paper presents the development of an on-chip array Koch fractal aperture-coupled antenna, operating in ISM application at 60 GHz band, built in silicon and aluminum. The rest of the paper is divided as follows. Section II shows the basic structure of aperture-coupled antennas. Section III shows the antennas proposed and the materials and methods used. Section IV presents the different results achieved, and finally conclusions are drawn in section V.

2 I APPERTURE-COUPLE ANTENNAS

Aperture-coupled antennas are compact broadband antennas composed by two or three layers used in many applications and technologies [5-8]. Generally, these layers are the transmission feed line, aperture, patch elements, and in some cases, one parasite patch element, separated by dielectrics with different permittivity. According to (STUZMAN e THIELE, 2013), layers with different permittivity can be used to filter spurious radiations. The association of more one layer with a radiating element upper, but smaller than the lower layer patch, promotes the union of the two resonant frequencies close it is yield a broadband effect.

In the model of the aperture-coupled antennas, the transmission line is feed generating an electromagnetic field through the substrate to the slot layer, concentrating part of the power through the aperture, illuminating the patch in the higher layer (STUZMAN e THIELE, 2013), (KIM), (PACHI, KAMARKAR e LAW). Fig. 1 shows structure of aperture-coupled antenna with three layers.

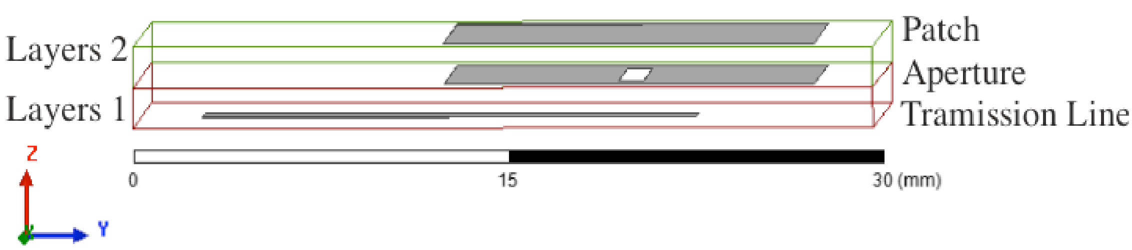

Fig. 1. Strcure of aperture-coupled antenna.

In (BERNARDO et al) was compared aperture-coupled patch antennas operating in industrial scientific and medical band at 60 GHz (57 – 64 GHz), with square and circular shapes, the square patch presented a more compact structure with dimension less than 1.55 mm. The conception of patch antennas, coupled with the use of low cost dielectric and radiating element, such as silicon and aluminum, enables a versatile antenna design. From results of (BERNARDO et al), this paper presents a Koch fractal aperture-coupled antenna array for ISM band at 60 GHz.

3 I MATERIALS AND METHODS

From a mathematical point of view, a fractal is a set in Euclidean space with specific properties, such as self-similarity or self-affinity, simple and recursive definition, irregular shape, and natural appearance (FALCONER, 2003). Fractal geometry is the study of sets with these properties, which are too irregular to be described by calculus or traditional Euclidian geometry language (SULLIVAN, 2000), (MANDELBROT, 1982). The Koch fractal is used, generally, in patch antenna, to increase the perimeter of the radiating element and consequently decrease the resonance frequency in a smaller area that implies a reduction of gain and greater current density.

Fractals are resort to conventional classes, such as geometrical fractals, algebraic fractals and stochastic fractals (FALCONER, 2003). Two common methods used to generate mathematical fractals are Iterated Function Systems (IFS) and Lindenmayer Systems (FALCONER, 2003), (MANDELBROT, 1982).

Antenna array is used to alter or improve parameters such as bandwidth and gain [5]. In this work, antennas with identical dimensions but different shapes are used to increasing antenna gain in the operating frequencies.

The first dimensions of the designed aperture-couple are related to the effective wavelength, λ_{eff}, at 60.5 GHz resonant frequency. From simulations in the ANSYS software it was possible to optimize the dimensions taking the λ_{eff} given by

$$\lambda_{eff} = \frac{c}{f_0\sqrt{\frac{\varepsilon_r + 1}{2}}}, \qquad (1)$$

where c is the light speed in vacuum, f_0 is the resonance frequency in Hz, and ε_r is the relative permittivity of the material.

The aperture-coupled patch antennas were designed using silicon as dielectric material, with thickness of 200 μm, and dielectric permittivity, ε = 11.9, loss tangent of 0.001, and radiating elements of aluminum, with thickness of 2 μm.

Fig. 2 shows the proposed on-chip Koch fractal aperture-coupled array antenna, with Koch fractal level 0 (square) Fig. 1(a), Koch fractal level 1 Fig. 1(b), array Koch fractal level 1 Fig. 1(c), and structure antenna Fig. 1(d).

Fig. 3 shows the dimensions in function to λ_{eff}, of Koch level 0 (square shape) Fig. 3(a), Koch level 1 Fig. 3(b), and array Koch level 1, Fig. 3(c), and antennas in the chip of area of 1 cm^2. Koch fractal level 1 has been built with insertion of square of 1/3 of total dimension of central element, in borders of the patch antenna. This promotes an 1/3 increase in total structure of patch element. In fractal geometry applied to antenna project there is an increase of the electrical perimeters and reduction of resonance frequency, thus, the Koch level 0 (square) was projected with central frequency of 70 GHz, λ_{eff} = 1.6875. In the case of Koch fractal level 1, it was used a central frequency at 60.5 GHz with λ_{eff} = 1.9611 mm, increasing the perimeter of 33.33%.

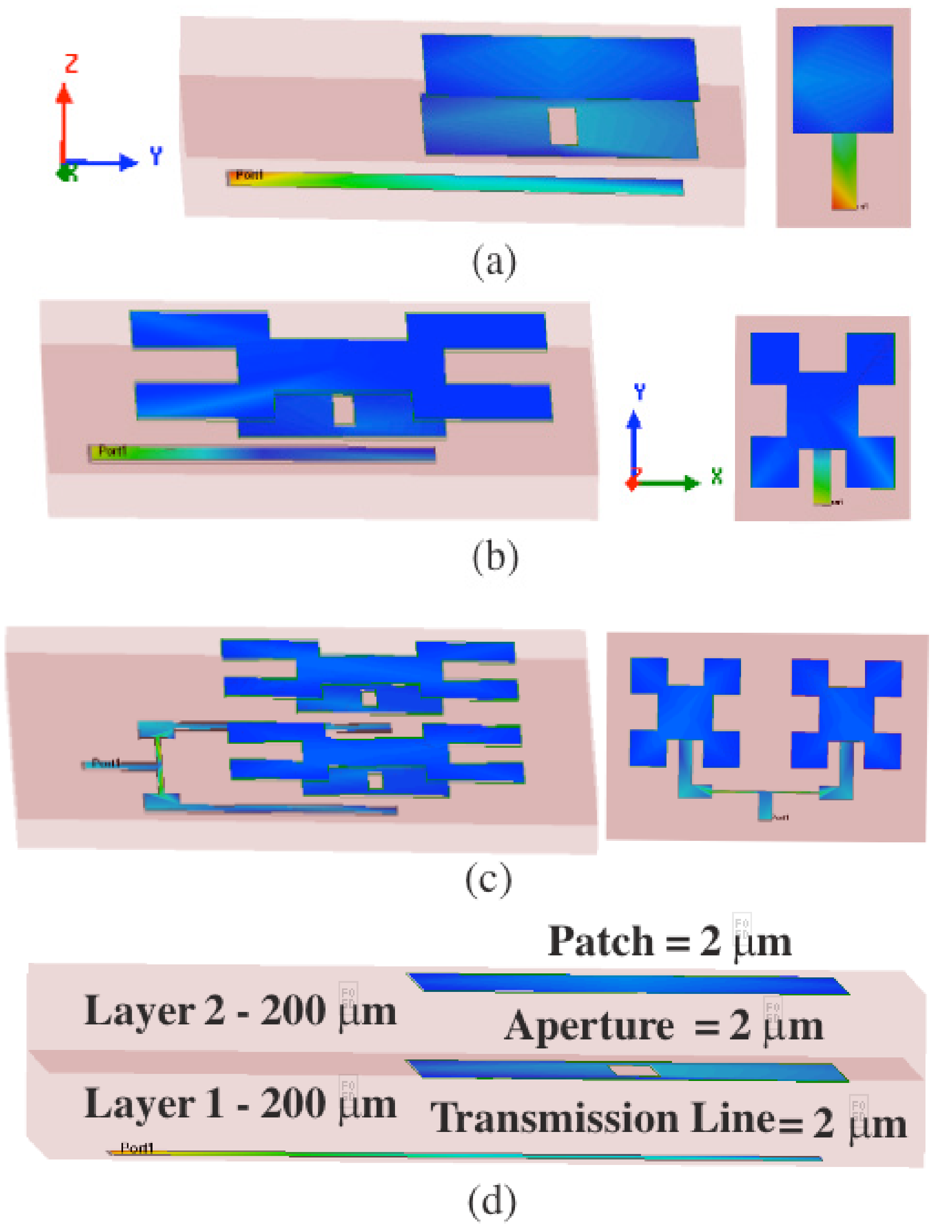

Fig.2. Structure of on-chip Koch fractal aperture-coupled antennas array: a) Koch fractal level 0 (square); b) Koch fractal level 1; c) Koch level 1array.

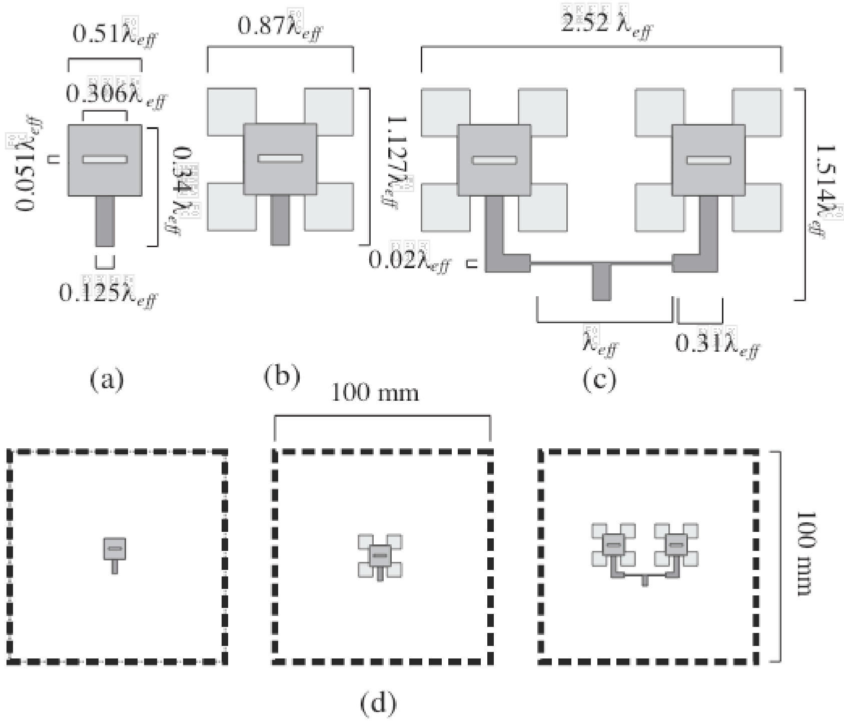

Fig.3. Structure of on-chip Koch fractal aperture-coupled antennas: a) Koch fractal level 0 (square); b) Koch fractal level 1; c) array Koch level 1.

4 I ON-CHIP ARRAY ANTENNA WITH KOCH FRACTAL GEOMETRY

Fig. 4 shows IS_{11}I values for Koch fractal aperture-coupled antennas from 50 GHz to 90 GHz. Table I presents values of first resonance frequency, f_1, second resonance frequency, f_2, central resonance frequency, f_0, bandwidth, BW, and return loss of simulated antennas.

It can be observed that the on-chip Koch fractal antennas level 1 obtained variation in resonance frequency of 14.28%, and bandwidth of 34.95%, covering part of ISM 60 GHz (57 – 64 GHz). The greater bandwidth has been observed in Koch fractal level 1, with small difference in resonance frequency between Koch fractal level 1 and array Koch fractal level 1 of 1.11%.

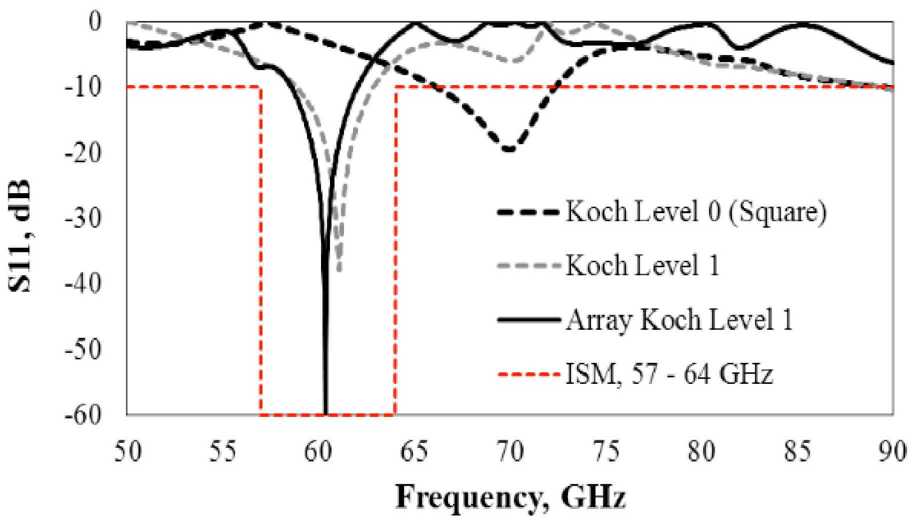

Fig.4. Comparison of S_{11} parameter of simulated on-chip Koch fractal aperture-coupled antennas.

Antenna	f_0 (GHz)	f_1 (GHz)	f_2 (GHz)	Bandwidth (GHz)	Return Loss (dB)
Koch 0	70	66.20	72.35	6.15	-19.50
Koch 1	61.06	58.85	62.85	4.00	-36.15
Array Koch 1	60.38	58.60	62.00	3.40	-59.67

Table 1 Results of On-Chip Koch Fractal Aberture-Coupled Atennas

From axial ratio shown in Fig. 5, it can be noticed that the Koch fractal level 1, in resonance frequencies have polarization close to circular polarization Fig. 4(b), i.e., results of axial ration close to 1, indicating that the antenna can receive/transmit signals with low polarization losses, regardless of its position. This result can be associated to the relation of antenna dimension and aperture.

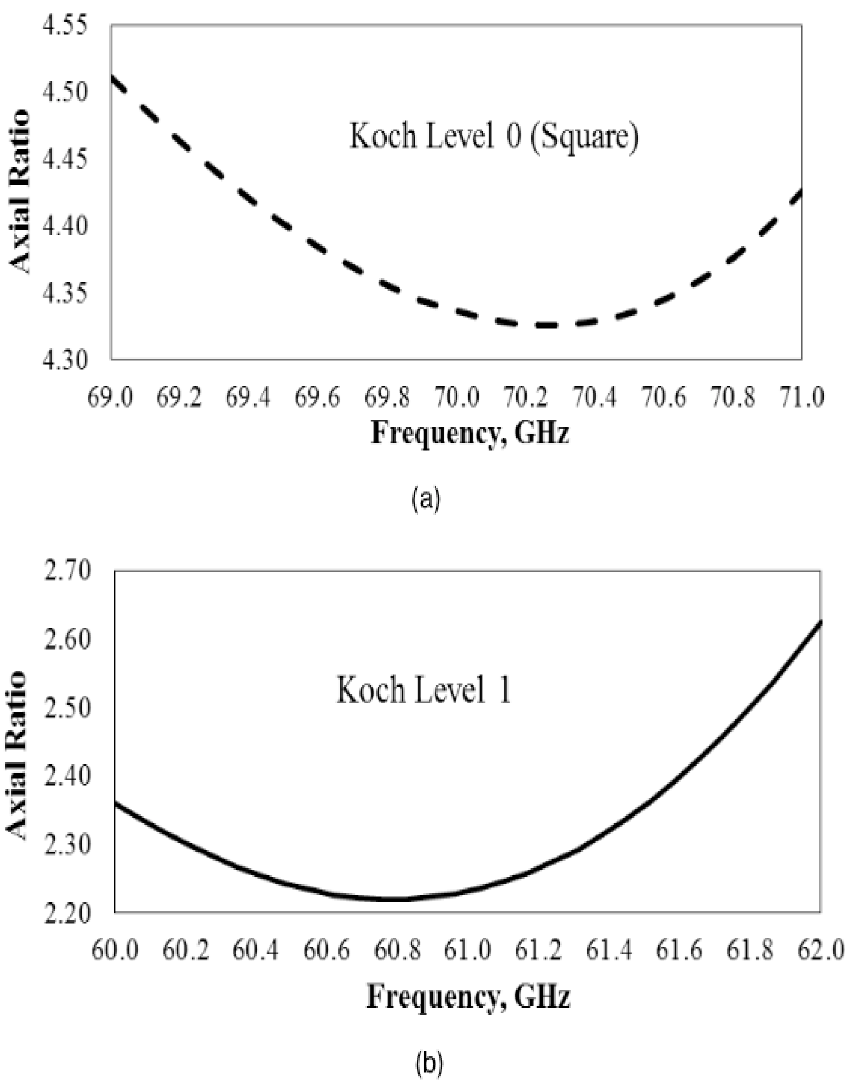

Fig.5. Axial ratio of aperture-coupled antenna: a) Koch level 0; b) Koch level 1.

Fig. 6 shows Gain (dBi) curves in resonance frequency of on-chip Koch fractal antennas. According to [11], there is a relationship between the quantity of metal in the radiating element and the gain in the patch antennas. Thus, the array Koch fractal level 1 achieves gain of 16.7 dBi, presenting an increase of 10.66 dBi (142.9%) and 8.63 dBi (106.9%) compared to the Koch fractal level 0 and the Koch fractal level 1, respectively.

Radiation pattern, with HPBW indications in resonance frequencies of Koch fractal aperture-coupled antennas are shown in Fig. 7. Antennas presents omnidirectional radiation pattern, with greater variations for electric fields (j = 0º), magnetic fields (j = 90º), and half power beamwidth (HPBW) for array Koch fractal antennas of 46.15%, Fig.7(c), compared to Koch fractal 1, demonstrating that array Koch fractal level 1 presented more illumination area that Koch fractal level 0 (square) and Koch fractal level 1.

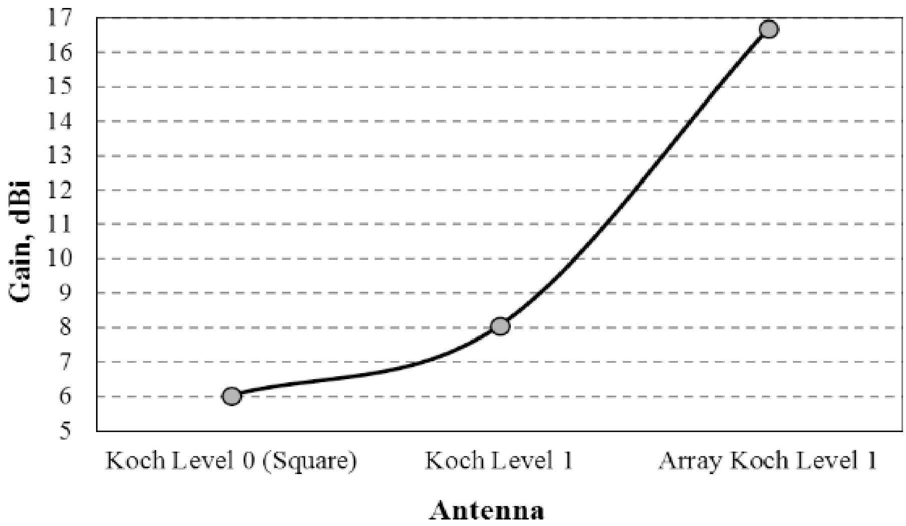

Fig.6. Comparison of gain of on-chip Koch fractal aperture-coupled antennas and array.

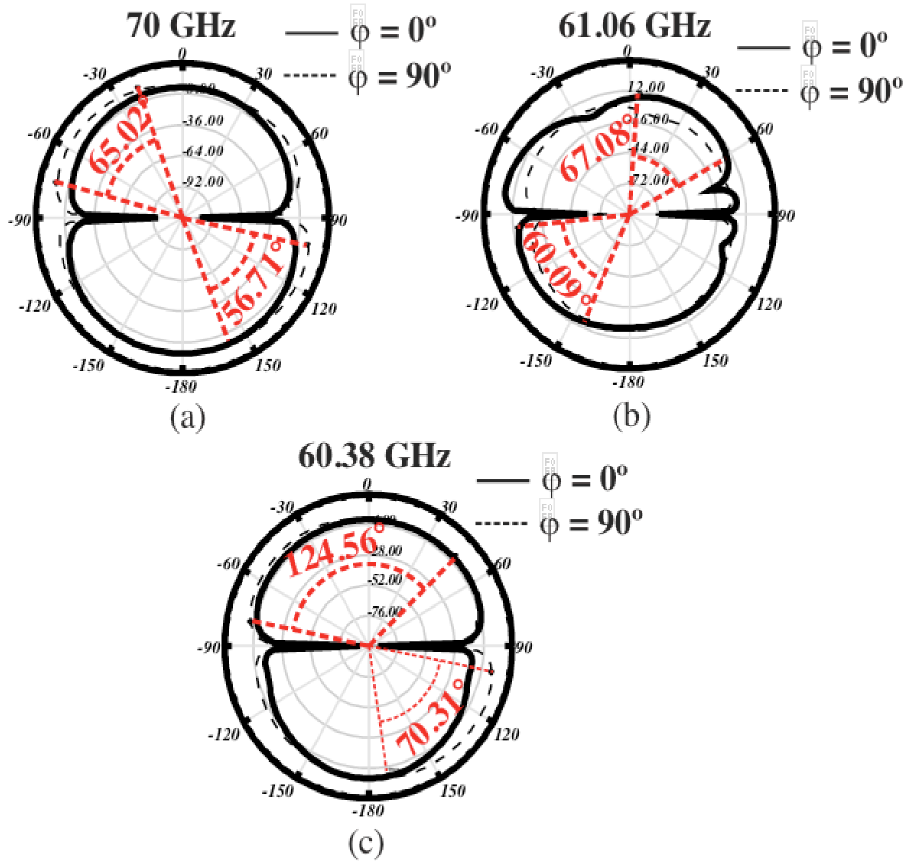

Fig.7. Radiation patterns of on-chip aperture-coupled antennas: a) Koch fractal level 0 (square); b) Koch fractal level 1; c) array Koch level 1.

5 I CONCLUSIONS

In this paper, it was presented the simulation of an on-chip array Koch fractal aperture-coupled antennas operating in industrial scientific and medical band at 60 GHz (57 GHz to 64 GHz). The proposed aperture-coupled antennas were designed with patch element built in aluminum with 2 micrometers, on two layers of silicon with 200 micrometers. All dimensions were calculated according to the effective wavelength for resonance frequency at 60 GHz to match to 50 Ohms. The use of Koch fractal and array Koch fractal allowed the development of aperture-coupled antennas of greater perimeter with more metal in patch elements promoting increase in the gain. Gain of array Koch fractal level 1 observed was of 16.7 dBi, increasing of 142% compared to the Koch fractal level 0 (square), with bandwidth operating in ISM Band, polarization closeto the circular polarization with axial ratio less of 2.22, and half power beamwidth greater than 124 degrees in resonance frequencies.

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