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Microstrip Antenna Design for Pulsed Radio Frequency Energy and Pulsed Electromagnetic Field Applications

Zafer Emre Albayrak [1], Çetin Kurnaz [2]

PhD Student, Department of Electrical and Electronic Engineering, Ondokuz Mayıs University, Kurupelit Samsun, Turkey[1]

Associate Professor, Department of Electrical and Electronic Engineering, Ondokuz Mayıs University, Kurupelit Samsun, Turkey[2]

ABSTRACT: The therapy of wounds, pain and edema in the human body can be shortened with pulsed radio frequency (PRFE) or pulsed electromagnetic field (PEMF). The Federal Communications Commission (FCC) has allocated 13.56 MHz, 27.12 MHz and 40.68 MHz frequencies as medical use bands for PRFE and PEMF applications. In this study, three different microstrip antenna operating at 13.56 MHz, 27.12 MHz and 40.68 MHz frequencies were designed using Computer Simulation Technology (CST) program. The dimensions of the designed antennas are as follows respectively; 600 mm x 400 mm, 340 mm x 130 mm and 300 mm x 150 mm. The antenna designed for 13.56 MHz operating frequency has an S_{11} value of -13.6 dB. The other antennas designed for 27.12 MHz and 40.68 MHz frequencies, the S_{11} values are -13.4 dB and -11.9 dB. The directivity values of the antennas are -30 dBi, -20.8 dBi and -18.9 dBi for 13.56 MHz, 27.12 MHz and 40.68 MHz frequencies respectively. The designed microstrip antennas generate 0.169 V/m, 0.517 V/m and 0.702 V/m electric field with 50 W input power. These microstrip antennas, which are designed by changing the input power values, can be easily used in PRFE and PEMF applications.

KEYWORDS: Microstrip Antenna, Pulsed Radio Frequency Energy, Pulsed Electromagnetic Fields, CST.

I.INTRODUCTION

The International Telecommunication Union (ITU) has reserved a portion of the radio frequency spectrum globally for industrial, scientific, and medical (ISM) applications [1]. ISM bands can be used without requiring a license by complying with a certain output power limitation. Center frequencies of 13.56 MHz, 27.12 MHz, 40.68 MHz, 5.8 GHz, and 24.125 GHz within the ISM band are used globally. In 1947, the Federal Communications Commission (FCC) determined 13.56 MHz, 27.18 MHz, 40.68 MHz frequencies for medical uses [2]. Pulsed electromagnetic fields (PEMF) and pulsed radio frequency energy (PRFE) accelerate the wound healing process [3]. 27.12 MHz and 40.68 MHz frequencies are widely used in PRFE and PEMF clinical applications [4]. Patents have been obtained for devices operating in these frequency bands for medical applications [5]. There are many studies in the literature on tissue damage treatment using these frequency bands. A study [6] showed that 27 MHz PRFE application shortened the healing processes of wounds on mouse skins. In the study conducted by [7] the reduction of the wound area and the reduction of pain intensity in diabetic foot and venous foot patients were examined with the application of 27 MHz PRFE. [8] investigated the effects of 27 MHz PRFE application on diabetic mice. [9] stated that it is possible to remove wrinkles on the skin tissue with radio frequency therapy. [10] stated that electromagnetic waves have a relaxing effect on low back pain. In addition, there are many studies in the literature on antenna designs operating at frequencies of 13.56 MHz, 27.18 MHz, and 40.68 MHz. Some of them are as follows;in a study on mice, an amplifier was designed for 27 MHz electromagnetic field therapy [11]. Coil antenna design has been made for the effects of low energy 27 MHz PEMF applications on wound healing [12]. A wearable antenna has been designed for PRFE applications [13]. Coil antenna designs were made at 13.56 MHz and 40.68 MHz frequencies and SAR on human tissue was examined [14]. By designing antenna circuits operating at 13.56 MHz and 40.68 MHz frequencies, wireless pacemakers were designed for heart rhythm disorder [15]. In the study conducted by [16], regulations and standards for radio frequency based wireless devices developed for medical applications are specified.

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In this study, three different microstrip antenna designs operating in 13.56 MHz, 27.12 MHz, and 40.68 MHz frequency bands allocated by the FCC for medical applications were made. After this point, in the coming parts of the paper, the 13.56 MHz frequency microstrip antenna will be called Antenna-I, the 27.12 MHz antenna will be called Antenna-II, and the 40.68 MHz frequency antenna will be called Antenna-III. The dimensions of the antennas designed using the CST program, the radiation patterns, and the electric and magnetic field values due to the same input power were obtained and comparisons were made.

II. SYSTEM MODEL AND ASSUMPTIONS

First of all, to design a microstrip antenna, the antenna's resonance frequency (f_r), coefficient of electrical conductivity (ε_r) and the height of the dielectric material (h) are determined. Then, the patch width (W) of the microstrip antenna is calculated as shown below.

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \tag{1}$$

Here c is the speed of light.

The effective value of the permeability coefficient (ε_{eff}) of the insulator and change in patch length (ΔL) is calculated as given in the equations below [17].

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad , \ {}^{W}\!/_{h} > 1 \tag{2}$$

$$\Delta L = 0.412\,h\,\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \tag{3}$$

The dimensions of the patch can be given by the equation (4) [17].

$$L_{eff} = L + 2\Delta L \tag{4}$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \tag{5}$$

The three-dimensional view of the rectangular microstrip antenna is given in Fig. 1.

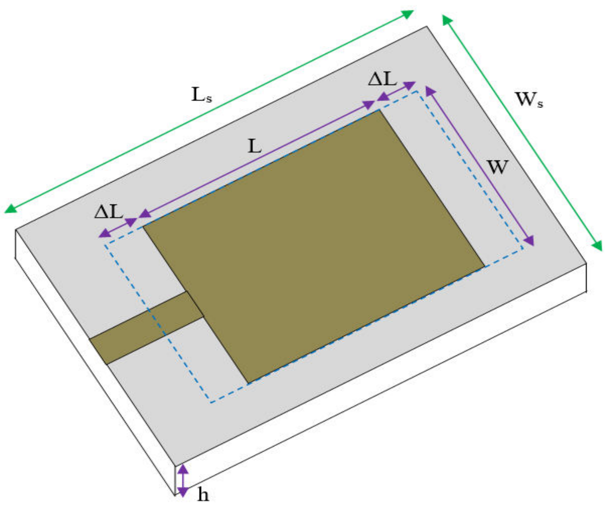

Fig. 1 Three-dimensional view of microstrip antenna

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The relationship between the thickness of the dielectric layer and the wavelength in free space (λ_0) is given by the equation (6) [17].

$$0.003\lambda_0 \leq h \leq 0.05\lambda_0 \tag{6}$$

The relationships between the width and length of the dielectric layer and the width and length of the patch are as given by the equations (7) and (8) [17].

$$W_s = W + 6h \tag{7}$$

$$L_s = L + 6h \tag{8}$$

Structures of three different microstrip antennas (Antenna-I, Antenna-II and Antenna-III) operating in 13.56 MHz, 27.12 MHz and 40.68 MHz frequency bands by using CST program are shown in Fig. 2. Antenna dimensions have been reduced by arranging patch, ground and dielectric (substrate) geometries with the formulas used to determine microstrip antenna dimensions. The ground layers of the designed microstrip antennas are 1 mm thickness copper material, the dielectric layers are 1 mm thickness FR-4 material and the patch is 1 mm thickness copper material

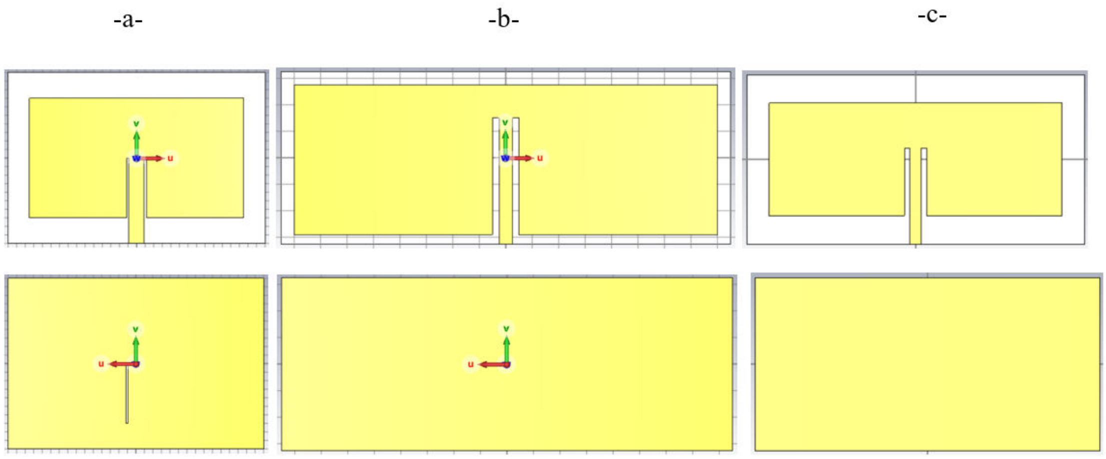

Fig. 2 Front and back views of the designed microstrip antenna for a) Antenna-I, b) Antenna-II, c) Antenna-III

The dimensions of the designed antennas Antenna-I, Antenna-II and Antenna-III are given in Fig. 3. Dimensions of Antenna-I are 600 mm x 400 mm, Antenna-II and Antenna-III, dimensions are 340 mm x 130 mm and 300 mm x 150 mm respectively.

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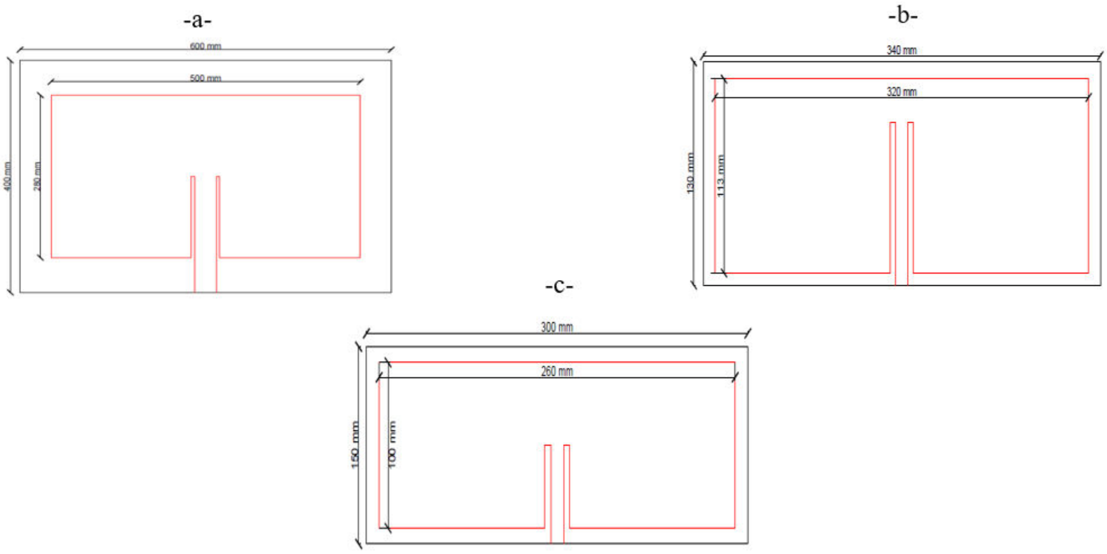

Fig. 3 Dimension of designed antenna for a) Antenna-I, b) Antenna-II, c) Antenna-III

III.RESULT AND DISCUSSION

The reflection coefficients (S_{11}) of the microstrip antennas designed via CST program are given in Fig. 4. The S_{11} value of the Antenna-I is -13.4 dB at this frequency. It is -13.4 dB for Antenna-II and -11.9 dB for Antenna-III. The S_{11} value at the operating frequency is below -10 dB for each designed antenna.

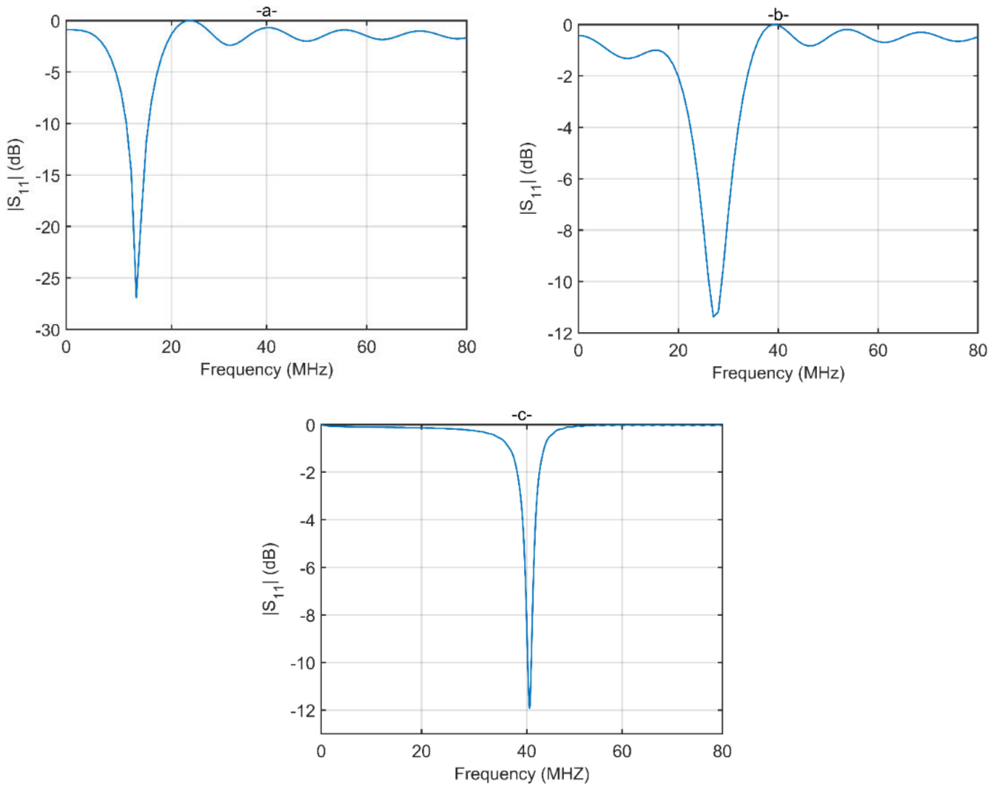

Fig. 4 The S_{11} value of designed antenna for a) Antenna-I, b) Antenna-II, c) Antenna-III

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The directivity value of the designed antennas is given in Fig. 5. The highest directivity value of Antenna-I is -30 dBi, and Antenna-II and Antenna-III have -20.8 dBi and -18.9 dBi value respectively.

-a- -b- -c-

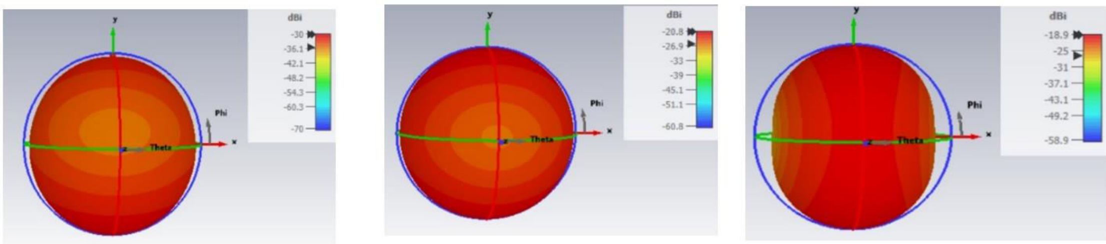

Fig. 5 Directivity value of the designed microstrip antenna for a) Antenna-I, b) Antenna-II, c) Antenna-III

When microstrip antennas supplied 50 W input power, the electric field (E) and magnetic field (H) changes that occur around them are given in Fig. 6 and Fig. 7. When the antenna-I was supplied with 50 W input power, the highest 0.169 V/m electric field and 0.000448 A/m magnetic field value were measured around the antenna. These values are 0.517 V/m and 0.00137 A/m for Antenna-II and 0.702 V/m and 0.00186 A/m for Antenna-III. In low-frequency microstrip antenna applications, antenna efficiency and antenna gain decrease along with the smaller antenna sizes.In this case, the antenna radiation is also low. This is basically the reason why low value electric and magnetic fields are formed around the antennas when they are fed with a constant 50 W.

-a- -b- -c-

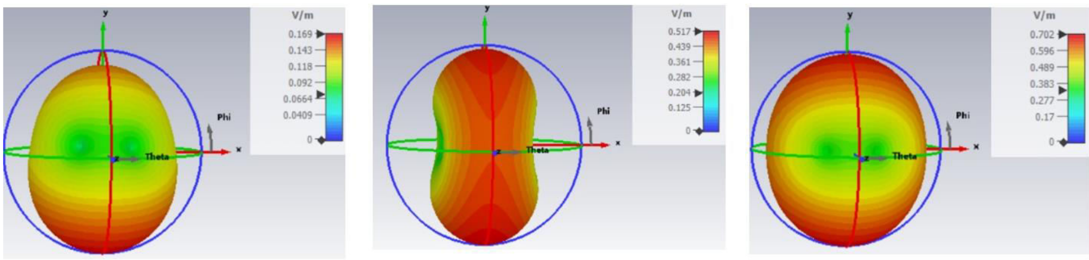

Fig. 6 Three-dimensional electric field radiation simulation result of the designed microstrip antenna for a) Antenna-I, b) Antenna-II, c) Antenna-III

-a- -b- -c-

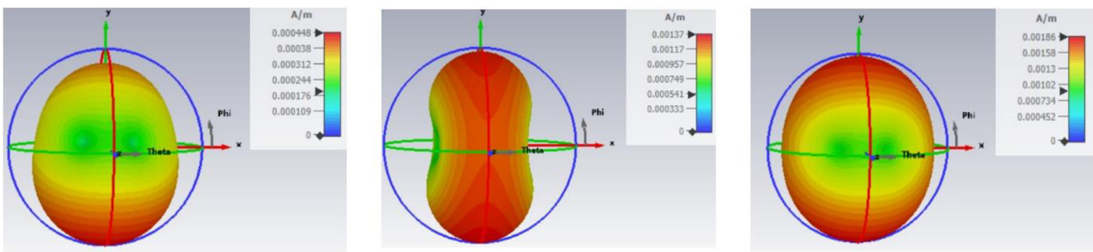

Fig. 7 Three-dimensional magnetic field radiation simulation result of the designed microstrip antenna for a) Antenna-I, b) Antenna-II, c) Antenna-III

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One-dimensional electric field radiation simulation results of the designed microstrip antennas are given in Fig. 8 and magnetic field radiation simulation results are given in Fig. 9. Electric and magnetic field radiation direction is 90 degrees for Antenna-I, electric and magnetic field radiation direction is 91 degrees for Antenna-II, and electric and magnetic field radiation direction is 89 degrees for Antenna-III.

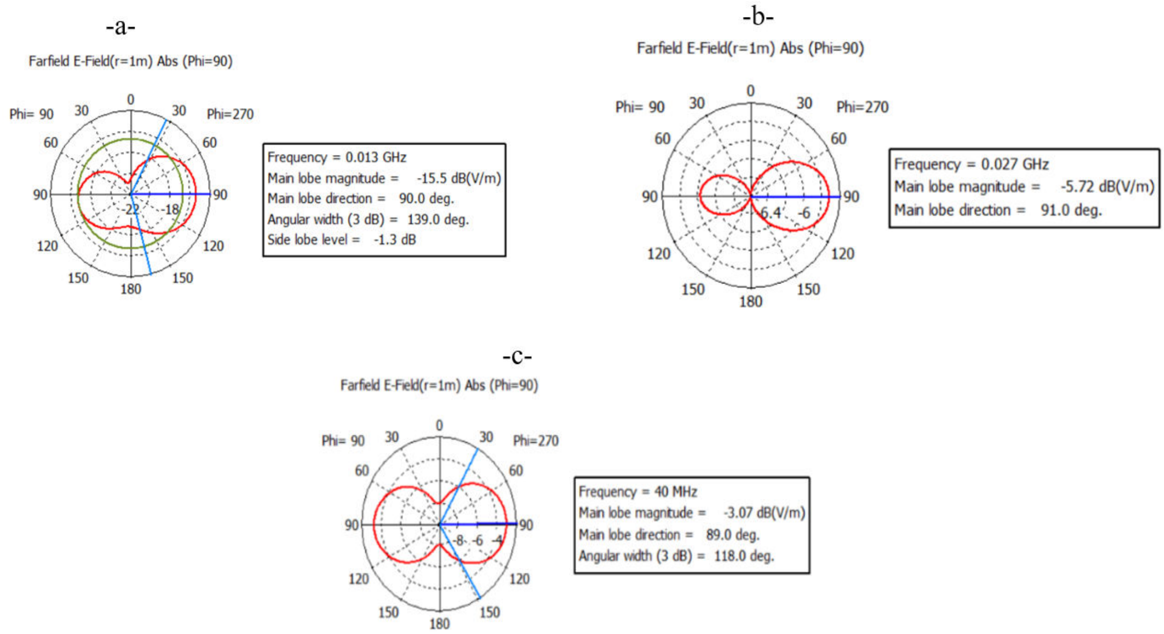

Fig. 8 One-dimensional electric field radiation simulation result of the designed microstrip antenna for a) Antenna-I, b) Antenna-II, c) Antenna-III

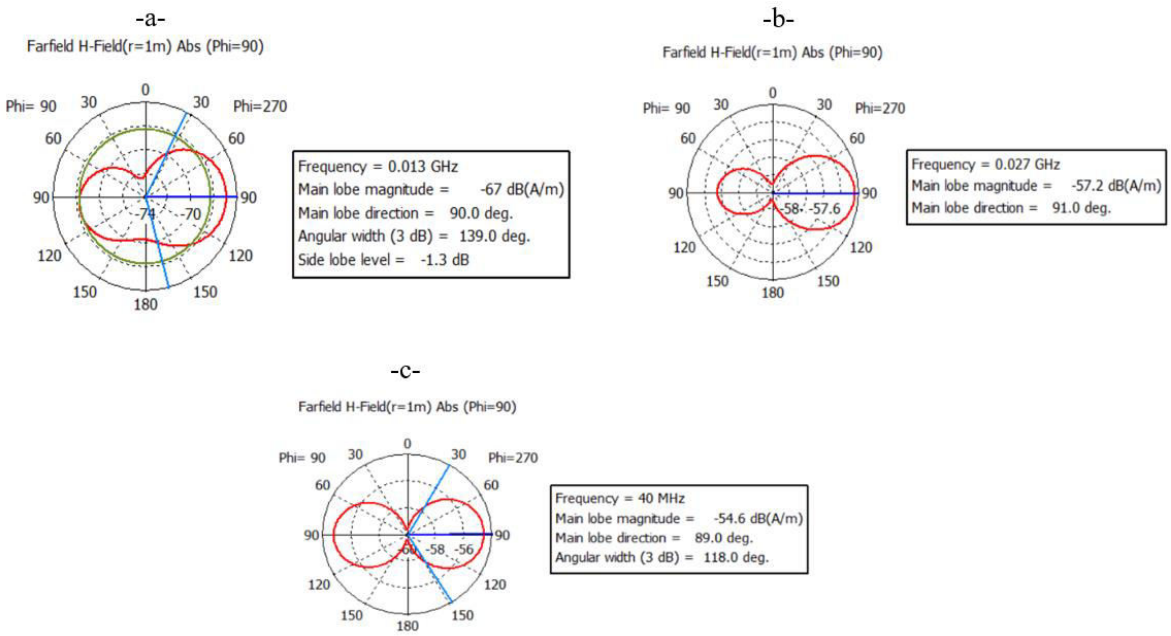

Fig. 9 One-dimensional magnetic field radiation simulation result of the designed microstrip antenna for a) Antenna-I, b) Antenna-II, c) Antenna-III

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IV. CONCLUSION

In this study, three different microstrip antenna designs were made operating in the 13.56 MHz (Antenna-I), 27.12 MHz (Antenna-II), and 40.68 MHz (Antenna-III) frequency bands which allocated by the FCC for medical applications. The S_{11} value at the operating frequency for all three designed antennas is below -10 dB. The dimensions of Antenna-I, Antenna-II and Antenna-III are 600 mm x 600 mm, 340 mm x 130 mm and 300 mm x 150 mm. The directivity values of the designed antennas are -30 dBi, -20.8 dBi and -18.9 dBi respectively. When the antennas are supplied with 50W input power, 0.169 V/m electric field and 0.000448 A/m magnetic field value are obtained around Antenna-I. For Antenna-II and Antenna-III, these values are 0.517 V/m, 0.00137 A/m and 0.702 V/m, 0.00186 A/m respectively.

REFERENCES

[1] H. Çakmak,Ş. Tavman, "Radio Frequency System and its Applications in Food Industry," Gıda, vol. 36, no. 6, pp. 383-390, 2011.
[2] F. Marra et al., "Radiofrequency heating of foodstuff: Solution and validation of a mathematical model," J. Food Eng., vol. 79, no.3, pp.998-1006, 2007.
[3] H. Choi, et al., "Effects of pulsed electromagnetic field (PEMF) on the tensile biomechanical properties of diabetic wounds at different phases of healing,"PLoS One; vol.13, no.1: e0191074, 2018.
[4] N.D. Foley et al., "Pulsed high frequency (27MHz) electromagnetic therapy for persistent neck pain. A double blind, placebo-controlled study of 20 patients,'' Orthopedics, vol.13, no.4, pp.445-451, 1990.
[5] J. Palero, M. Baragona, "Device for Radio Frequency Skin Treatment. European Patent Specification," Patent No: EP 3 288 476 B1, 2018.
[6] M. Gümüşay et al.,"Comprassion of the Effect of PulsedElectromagnetic Field and Pulsed RadioFrequency Energy on Wound Healing in Rats,"TıpTeknolojileriKongresi,978-1-5090-2386-8/16, 2016.
[7] M. Maier, "Pulsed Radio Frequency Energy in the Treatment of Painful Chronic Cutaneous Wounds: A Report of Two Cases,"Pain Medicine, vol. 12, pp.829–832, 2011.
[8] Q. Li et al., "Pulsed radiofrequency energy accelerates wound healing in diabetic mice,"PlastReconstr Surg vol.127, no.6, pp.2255-2262, 2011.
[9] A. Araujo, "Radiofrequency for the treatment of skin laxity: mith or truth," An Bras Dermatol, vol.90, no.5, pp.707– 721, 2015.
[10] R. Andrade et al., "Pulsed electromagnetic field therapy effectiveness in low back pain: A systematic review of randomized controlled trials," Porto Biomedecial Journal, vol.1, no.5, pp.156-163, 2016.
[11] A. Kaya, M. Tuğlu, D. Kaya, "Design of Pulsed Electromagnetic Field Generatorand Applicator and the Effect of Wound Healing,"TıpTeknolojileriKongresi,978-1-5090-2386-8/16, 2017.
[12] M. Gümüşay, A. Kaya, "Effects of Low Energy Pulsed Electromagnetic Fields on WoundHealing,"' TıpTeknolojileriUlusalKongresi, 2014.
[13] K. Pandelisev, "Multiple Selectable Field/Currnet- Voltage Pads Having Individually Powered and Controlled Cells," European Patent Specification. Patent No: US 7,177,696 B1, 2007.
[14] K. Mohanarangam, Y. Palagani, J. Choi, "Evaluation of Specific Absorption Rate in Three-Layered Tissue Model at 13.56 MHz and 40.68 MHz for Inductively Powered Biomedical Implants," Appl. Sci. 2019, vol.9, no.6, 1125, 2019.
[15] H. Lyu et al., "Synchronized Biventricular Heart Pacing in a Closed-chest Porcine Model based on Wirelessly Leadless Pacemakers,"Scientific Reports, vol.10, no.1, 2020.
[16] P. Chadwick, "Regulations and standards for wireless applications in eHealth," Annu Int Conf IEEE Eng Med Biol Soc 6171-4, 2007.
[17] C.A. Balanis, "Antenna Theory: Analysis and Design: Willey-Inter Science," 2005.[3]