Novel feed high gain microstrip patch antenna array design for 5.8 GHz applications

HÜSEYİN AKMAN, MESUD KAHRİMAN*

Engineering Faculty, Electronics and Communication Eng., Suleyman Demirel University, 32260 Isparta, Turkey

New novel fed 2x2 antenna array operating within the 5.8 GHz frequency band for biomedical sensor is presented. The proposed design is optimized for return loss below -16 dB. Antenna is designed to receive chest movements during breath exhaust and inhauls. Antenna array is fed through an antenna and it makes this antenna array shape novel. It meets the requirements by -16 dB return loss and 5dB gain. Our designed antenna is a low cost antenna. FR4 epoxy material which has a 4.25 relative permittivity and 1.5 mm thickness was used as a substrate. Because of this subtract material antenna is so cheap and readily available.

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1. Introduction

Microstrip patch antennas are used in modern communication systems especially in industry, TV, broadcast radio, mobile systems, global positioning system (GPS), radio-frequency identification (RFID), multiple input multiple-output (MIMO) systems, vehicle collision avoidance system, satellite communications, surveillance systems, direction founding, radar systems, remote sensing, biological imaging, missile guidance, due to their low cost, lightweight, and low profile, planar configuration, easy of conformal, superior portability, suitable for arrays, easy for fabrication, and easy integration with microwave monolithic integrate circuits [1]. On the other hand microstrip antennas have three basic disadvantages: narrow bandwidth, low gain, and relatively large size [2]. Moreover to design mini systems using in telecommunication systems many miniature antenna designs reported in literature. For most of these designs planar antennas are used because of their applicability to mobile systems [3]. For wireless communication are very different frequencies used [4-6]. For this work is ISM 5.8GHz frequency selected.

For microstrip antenna some feeding techniques developed like microstrip line feed, coaxial feed, proximity-coupled microstrip feed and etc. We feed the array through an array element and investigate the return loss and gain at 5.8 GHz working frequency. We found that, with this type of feeding array meets the requirements and array can be used for 5.8 GHz applications. As we know this is a novel feeding.

Like us, M. T. Islam et al. designed a novel feeding strip. They used U-shaped feeding strip for the 150 mm X 150 mm microstrip patch antenna working on both 2.45/5.8 GHz. They achieved 10.1 dBi gain and 31.9 dB return loss for 5.8 GHz [7]. T. S. Ooi et al. studied a 60 mm X 60 mm compact dual band circularly polarized patch antenna working on 2.45/5.8 GHz ISM frequencies. They designed the antenna by using two FR4 patches with size reduction. They achieved 7.34 dB gain and 12.8 dB return loss [8]. Lin Peng et al. designed a 64 mm X 62 mm asymmetric M-shaped patch antenna for 2.45/5.8 GHz ISM bands. They achieved ~-15 dB return loss and 6.32 dB gain for 5.77 GHz [9]. Pingan Liu et al. designed a 23 mm X 36.5 mm compact CPW-fed tri-band printed antenna using FR4 working at 2.4/5.8 GHz ISM bands. They tried Y shaped patches have different dimensions and achieved -15 dB return loss and 2.5 dB gain for 5.8 GHz [10].

First of all as we want to use designed antenna for planar movement detection we selected patch antenna design because of its low cost, little dimensions and easy fabrication. Then we calculated single patch dimensions for an array element. After that we started to design according to our aims like less than 10 dB return loss and 2 or 3 dB gain using HFSS. After simulation was finished we fabricated the antenna and measured its return loss. As we know and researched our feeding was novel and caused no bad results. We conclude that our antenna can be used at 5.8 GHz applications.

2. Antenna feeding methods

An antenna can be fed by various techniques. Major techniques are coaxial feed, microstrip planar feed, proximity-coupled microstrip feed, aperture-coupled microstrip feed and coplanar waveguide feed [11].

2.1. Microstrip line feed

This is the most basic and easy technique which antenna excited by microstrip transmission line [12]. In this technique bandwidth is limited, increased thickness of substrate are the disadvantages while easy modelling are the advantages [13].

2.2. Coaxial feed

In Coaxial feeding, inner side of coaxial cable touches to antenna patch through the substrate and the outer side connects to the ground plane. In this technique it is easy to fabricate, easy to match and has low spurious radiation from the feed line [13].

Techniques mentioned above are direct feeding techniques and in these methods a connecting element is used to feed RF power directly to the radiating patch. Commonly used indirect feeding techniques are proximity-coupled microstrip feed, aperture-coupled microstrip feed and coplanar waveguide feed techniques and in these techniques electromagnetic field coupling is done to transfer power between the Microstrip line and the patch. These types of feeding are used when there is no actual contact between the patch and the input radiating material [12].

2.3. Proximity-coupled microstrip feed

For this type of feeding, two dielectric substrates are used and the feed line is positioned between these substrates and the radiating patch is on top of the upper substrate. Because of the increase of the antenna's thickness spurious feed radiation is eliminated. Also antenna provides very high bandwidth.

2.4. Aperture-coupled microstrip feed

The radiating patch and the microstrip feed line are separated by the ground plane and the coupling between them is made through a slot or an aperture in the ground plane.

2.5. Antenna array

Single microstrip patch antenna has some disadvantages like low gain, low efficiency, low directivity ant etc. These disadvantages can be overcome by implementation of more than one patch antennas in array configuration. It is observed that more patch elements means improvement in performance [14]. Atas et.al. showed that S11, directivity and gain can be better when antenna number increased [15].

3. Antenna design

In this letter an antenna which was designed to planar movement detection system operate at 5.8 GHz. Our aim was design an antenna which is low cost, light-weight, easy for fabrication and acceptable S11 (below -10dB) and an acceptable gain.

Theoretical value of the single element is 16 mm × 11 mm and fabricated is 16.5 mm × 10.5 mm. After comparison with simulated and fabricated values it is seen that results are approximate values and fabricated dimension is appropriate. The equation (1-4) below is used to calculate the dimension of patch.

$$L = \frac{C}{2f\sqrt{\varepsilon eff}} - 2\Delta l \tag{1}$$

$$\varepsilon eff = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{w}\right)^{-1/2} \tag{2}$$

$$\Delta l = \frac{0.412\ h(\varepsilon eff + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon eff - 0.258)\left(\frac{w}{h} + 0.8\right)} \tag{3}$$

$$w = \frac{2}{2f\varepsilon r}\sqrt{\frac{2}{1+\varepsilon r}} \tag{4}$$

Where;

L= the length of the patch antenna
w = the width of the patch antenna
εeff = effective substrate
Δl = fringing field of the antenna [8].

Beside that analysis and performance prediction should be simply. For these, we chose FR4 epoxy (εr = 4.25 and height of 1.5 mm), rectangular patch and microstrip line feeding. Then antenna simulated using ANSYS HFSS Antenna Design Software. The designed antenna configuration is shown in Fig. 1.

After simulation microstrip patch antenna is fabricated using FR4 epoxy as chosen before. After all antenna is measured with Rohde & Schwarz FSH6 Spectrum Analyzer. Finally measured values are compared with the simulated values at the same graphic. For the purpose, antennas were referred to 50 Ω.

The fixed antenna dimensional parameters for shown in Fig. 1, are given in Table 1. The fabricated antenna is given in Fig. 2.

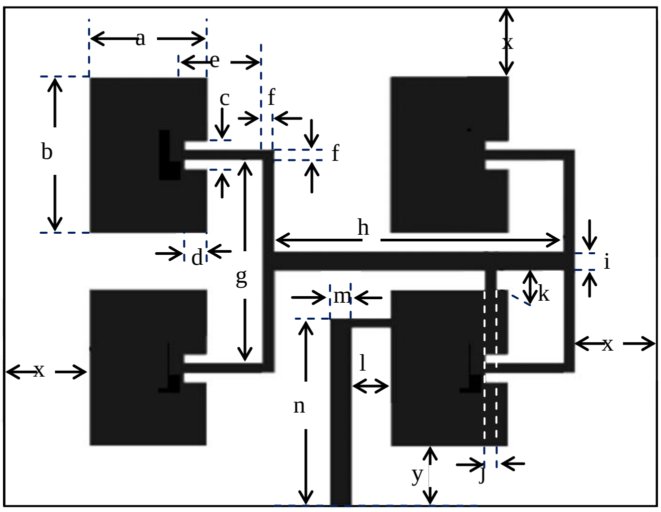

Fig. 1. The dimension of our novel fed antenna.

Table 1. Antenna physical parameters

Parameter	a	b	c	d	e	f	g	h
mm	10.5	16.5	3	2	7	1	21.5	26
Parameter	i	j	k	l	m	n	x	y
mm	2	1	2	3.5	2	22	10	8.5

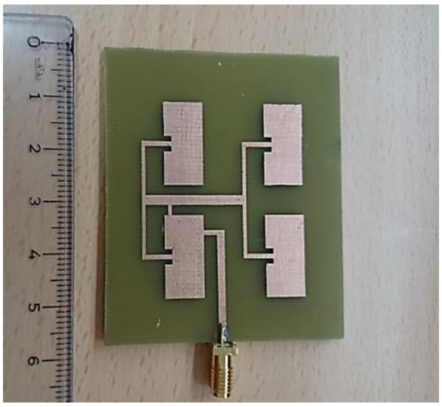

Fig. 2. Fabricated 2x2 array Microstrip patch antenna

4. Simulated and experiment results

Fig. 3 shows the simulated and measured return loss of the proposed 2×2 microstrip patch antenna array. The 10-dB bandwidth is from 5.73 GHz to 5.89 GHz about 160 MHz. It is clearly seen that results are so close.

The Fig. 4 shows the simulated 3-D radiation pattern for proposed antenna. The achieved max gain for proposed antenna is 5.06 dBi. When Fig. 4 analyzed it is seen that radiation direction is perpendicular to the antenna plane as desired. Also radiation is almost zero at the ground plane.

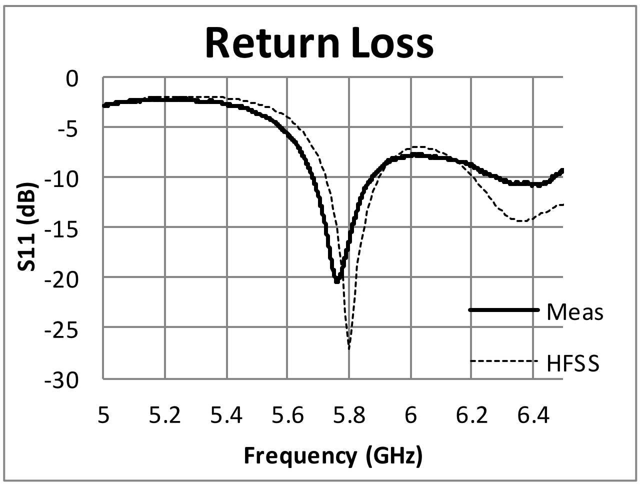

Fig. 3. The simulation and test results of return loss

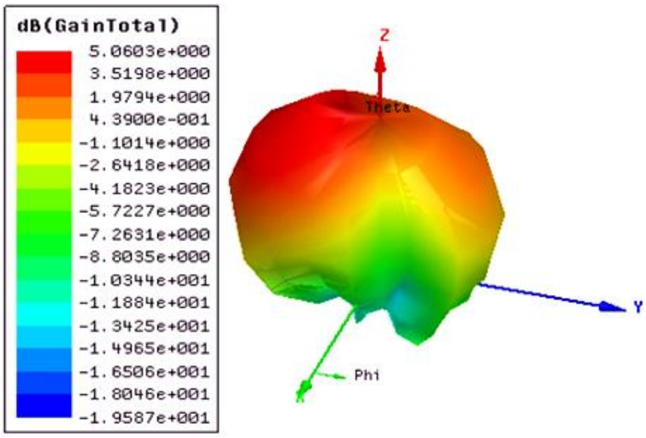

Fig. 4. Simulated 3-D radiation pattern of the proposed 2x2 array Microstrip patch antenna

The simulation result gives a return loss of -27dB at 5.8 GHz while the measurement result gives a return loss of -16 dB at the same frequency and -20 dB at 5.76 GHz.

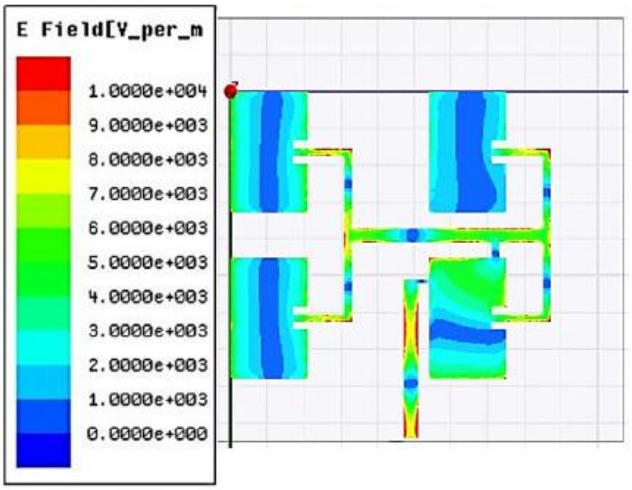

Fig. 5. Electric field distributions of proposed antenna

Fig. 5 shows the simulated electric field distributions of proposed antenna at 5:8 GHz. As seen from this figure maximum electric field on our antenna is 10.000 V/m. It is seen that E-field is distributed uniform along X-direction.

To indicate the excitation mechanism of the antenna obviously, in Fig. 6, the simulated surface current distributions of the proposed antenna are illustrated at 5.8 GHz. Current is homogeneously distributed on the antennas and intensified at the center area of the antennas.

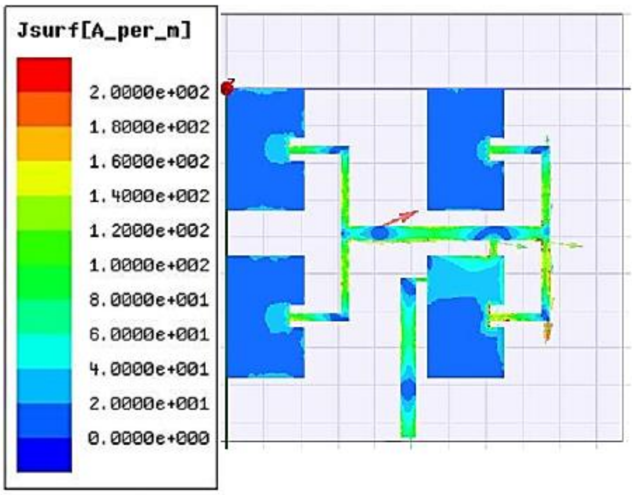

Fig. 6. Surface current distributions of proposed antenna

The comparsation of performance analysis from proposed antenna, with previous works is given in Table 2. The performance analysis of antennas is maked on, return loss, antanna gain and dimensions. Table 2 shown, that the proposed antenna have not a great dimensions and have a enough gain.

Table 2. Antenna Comparison with previous works

Return Loss (dB) @5.8GHz	Gain (dBi)	Dismensions (mm)	References
-31,9	10,17	150 × 150	[7]
-12,8	7,34	60 × 60	[8]
-15	6,32	64 × 62	[9]
-15	2,5	23 × 36.5	[10]
-16,44	5,06	63.5 × 57.5	This work

5. Conclusion

The simulated and measured result shows that the return loss of the antenna is within the designed 5.8 GHz frequency band. This 2×2 antenna array can be fabricated easily and cheaply. Also because of its little dimensions it can be integrate into devices. As it mentioned before our designed antenna has sufficient values of gain and return loss at 5.8 GHz and so it can be used at this frequency wherever want to use. As it feeded through an antenna, to our knowledge, it has a novel feeding.

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*Corresponding author: mesudkahriman@sdu.edu.tr