Design and Analysis of Quad-Band Grid Array Microstrip Antenna at UWB and ISM Channel Frequencies for WBAN Operations

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Abstract

In this paper, we present design and simulation of a compact grid array microstrip patch antenna. In the design of antenna a RT/duroid 5880 substrate having relative permittivity, thickness and loss tangent of 2.2, 1.57 mm and 0.0009 respectively, has been used. The simulated antenna performance was obtained by Computer Simulation Technology Microwave Studio (CST MWS). The antenna performance was investigated by analyzing its return loss (S_{11}), radiation pattern, voltage standing wave ratio (VSWR) parameters. The simulated S_{11} parameter has shown that antenna operates for Industrial, Scientific and Medical (ISM) band and Wireless Body Area Network (WBAN) applications at 2.45 GHZ ISM, 6.25 GHZ, 8.25 GHZ and 10.45 GHZ ultra-wideband (UWB) four resonance frequencies with bandwidth $\geq$ 500MHz ($S_{11} \leq$ -10dB). The antenna directivity increased towards higher frequencies. The VSWR of resonance frequency bands is also achieved succesfully less than 2. It has been observed that the simulation result values of the antenna are suitable for WBAN applications.

1. Introduction

In recent years, the wireless communication systems related researches are increasing in the field of small size, multiband and ultra-wideband (UWB) antennas. A pivotal component of wireless communication is the antenna which is replaced of cable [1-3].

The miniaturization of sensors, wireless communication systems and other integrated electronic technologies has made personal portable electronic devices an important part of life [4-6]. Due to compact size of the microstrip antenna, it can easily integrate into wireless communication devices. Recently there has been intensive focus on portable personal wireless network system which is called personal area networks (PANs) or body-area networks (BANs). Wireless body area network (WBAN) is a network designed to wirelessly connect various sensors and devices within or around the human body [7-13]. In general, WBAN systems are divided into two parts as wearable systems and implantable systems [11]. Wearable systems can communicate wirelessly with in-body implant devices, other on-body wearable devices, and external network systems.

WBAN has potential applications in different areas such as medical, personal entertainment and military [2, 14]. WBAN health monitoring systems provide real-time remote monitoring of health parameters of the elderly, patients, athletes and astronauts. Many health parameters such as basal body temperature, respiratory rate, heart rate, blood pressure, glucose level and electro cardo gram (ECG) waveforms are transmitted wirelessly (off-body mode) to remote stations via an external network [15]. Thus, doctors can make early diagnosis and give patients more effective advice for their health [16]. In the wireless health monitoring systems, because of the more efficient use of energy, an efficient and high-capacity connection is required [17]. Requirement of multi-functional WBAN systems with low-cost, low-power have led to the development of UWB technology [18]. UWB and 2.45 GHz industrial, scientific and medical (ISM) band signals are allocated in the unlicensed Federal Communications Commission (FCC) approved frequency ranges of 3.1–10.6 GHz and 2.4–2.5 GHz respectively. UWB offers many advantages such as higher bit rates, lower power consumption, smaller size antennas and less complexity on the transmitter side, over other traditional narrowband systems, [13, 17]. UWB antennas in WBAN applications provide a very attractive advantage to extend the battery life of wireless devices due to its low power consumption feature. [11-13]. These antennas also reduce exposure to electro-magnetic (EM) radiation, which can be dangerous for human tissues [12]. However, for wireless communication terminals, the antennas must be compatible with multiple frequency band applications. However, the disadvantage of this situation that is increasing the number of frequency bands causes more design complexity of antennas [19]. Microstrip antenna is generally preferred in order to fulfill the requirements of UWB antenna design in WBAN applications [18]. Microstrip antennas are a competitive solution with the inherent advantages of low profile, light weight, low cost, easy to manufacture and easy integration into a compact system [19, 20].

In this paper, we present design and analysis of a compact grid array microstrip patch antenna on RT/duroid 5880 substrate. A similar grid array structure has been studied for the millimetric wave length in [21] before that. Computer Simulation Technology Microwave Studio (CST MWS) simulation program has been used for design and analysis in this study. This program analyzes using finite integration technique (FIT) method. Simulated results consisttently show that this antenna is multiband and to work at ISM band and UWB channel frequencies.

2. Antenna Design

Fig. 1 shows the geometry of the front, back and side views of the proposed antenna with dimensions. RT / duroid 5880 substrate was chosen in the antenna design due to some advantages such as cost, availability and its low dielectric tolerence, loss and low moisture absorption. Dimensions, dielectric permittivity ε_r and tangential loss Tanδ of RT / duroid 5880 Substrate are 38 mm x 50 mm x 1.57 mm, 2.2 and 0.0009, respectively. Annealed copper conductor whose thickness is 0.02 mm were used for the antenna patch and ground plane. The geometry of radiating patch on the front surface of antenna shown in Fig. 1(a) where there are 10 grids array. Microstrip line feeding technique is used in antenna feed line. We selected the values of the feedline width Wf=4.85 mm and height Lf=10 mm for the 50 ohm line impedance. The ground plane of antenna is designed two steps Fig. 1(b) shown that first step ground plane (Wg=38 mm, Lg=17.2 mm) without slot and there are only a resonance band of antenna. Fig. 1(c) represents the modified second steps ground plane with slot. The slot dimensions are 3.9 mm x 4.7 mm. This slot increased the number of resonant bands of the antenna. Thus, the antenna design has been completed and antenna simulation results analysis will be given in the next section.

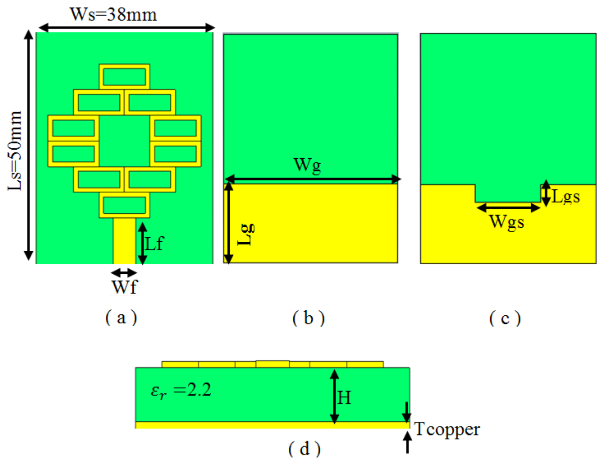


Fig. 1. Geometry of proposed antenna a) Front patch plane view b) first back ground plane view (without slot) c) second back ground plane view (with slot) d) bottom side view.

3. Simulation Results

There are parameters which determine antenna performance such as return loss, radiation pattern, voltage standing wave ratio (VSWR), etc. Return loss parameter graph is considered for the design and simulation. Other parameters were evaluated after obtaining the optimum return loss parameter graph. The return loss graph includes the resonance cutoff frequencies of the antenna, the bandwidths, the number of bands, and the resonance frequency maximum return loss information. The first step structure shown in Fig. 1 (a,b,d) is designed and simulated using the CST MWS software program.

As a result of the simulation, the return loss (S_{11} -parameter) versus frequency graph shown in Fig. 2 is obtained. As shown in the graph, only one resonance frequency at 5.43 GHz. This graph shows that maximum return loss is -26.727 dB and resonance frequency band is between the 5.11 GHz – 5.75 GHz (Band Width is 640 MHz). Our target is to design a multi-band antenna, so this result is not an appropriate. The ground plane of antenna was modified due to this situation. A part of ground plane was removed to make slot as shown in Fig. 1(c).

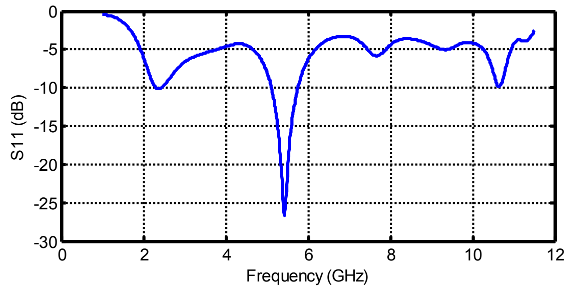


Fig. 2. Return loss for first design antenna (without slot).

Slot size was determined to obtain the optimum return loss parameter graph. Return loss parameter graph was shown in Fig. 3 for various values of slot size. Increasing the length ground slot (Lgs) and width ground slot (Wgs) values cause new resonance frequencies and frequency shift in this graph, respectively. Lgs = 3.9 mm and Wgs= 4.7 mm were determined as the optimum value and four resonance frequency bands were obtained for these values.

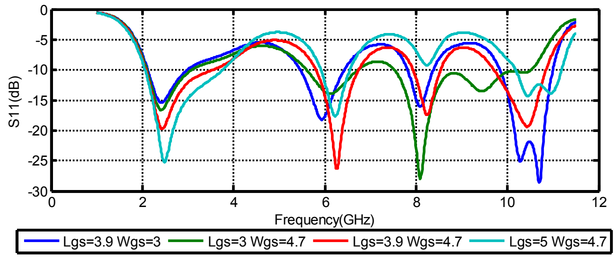


Fig. 3. The effect of varying the ground plane slot size on the return loss.

Fig. 4 shows return loss versus frequency graph for the obtained values. There are total of four frequency bands, at resonance frequencies of 2.45 GHz ISM band and 6.25 GHz - 8.25 GHz and 10.45 GHz UWB band regions, which can be used in WBAN applications. The 2.45 GHz resonance frequency in the graph covers the entire ISM band with 1470 MHZ (2.075-3.545 GHz) band width (≤-10 dB) and the maximum return loss is -19.759 db. Other resonance frequencies have bandwidths 940 MHz (5.800-6.740 GHz), 620 MHz (7.915-8.535 GHz), 1145 MHz (9.700-10.845 GHz) and maximum return losses -26.334 dB, -17.417 dB, -19.377 dB respectively. As mentioned by FCC, UWB ≥ 500 MHz is desired and band width values we found are suitable for UWB ≥ 500 MHz.

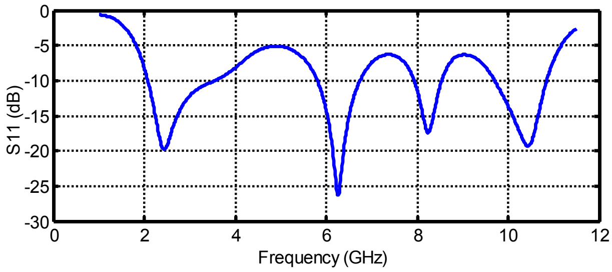


Fig. 4. Return loss of final proposed antenna (Lgs= 3.9 mm Wgs= 4.7 mm).

The voltage standing wave ratio (VSWR) is an indication of how good the impedance match of the antenna is. Fig. 5 shows

VSWR ≤ 2 for antenna resonant frequency bands (≤-10 dB). That is, the impedance of the antenna is matched to the operating frequency bands.

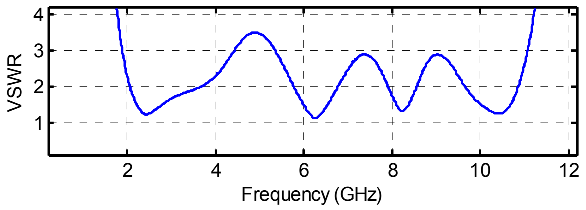
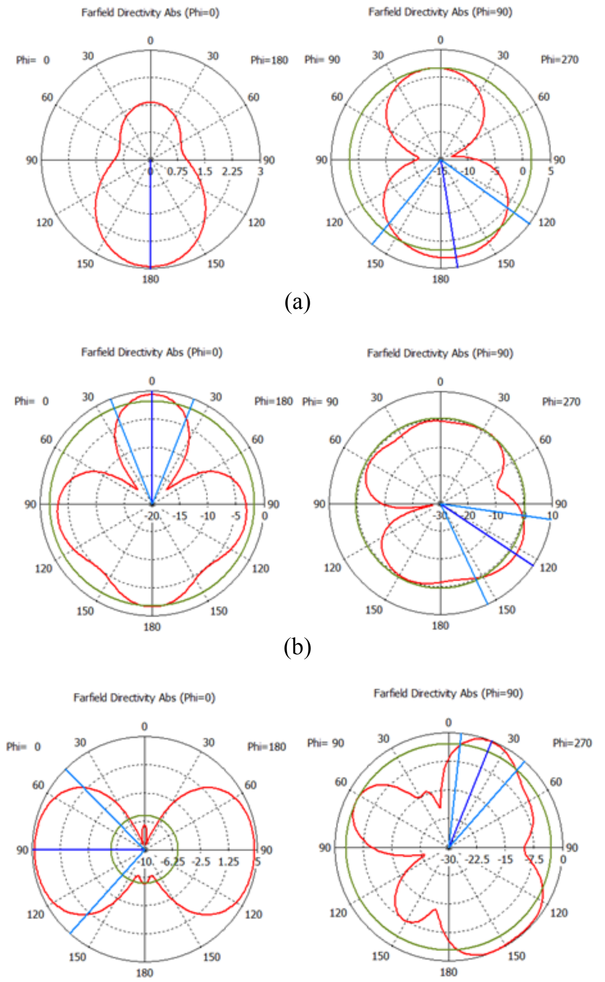


Fig. 5. Graph of VSWR for proposed antenna.

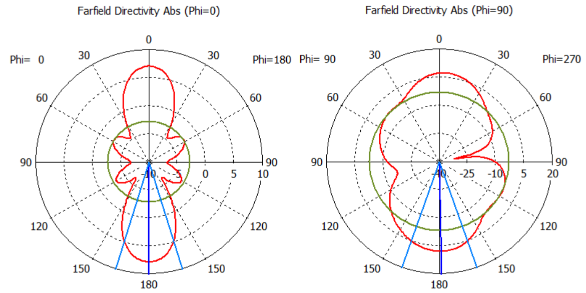
Fig. 6 shows the simulated antenna 2D radiation patterns. Radiation pattern shows how the antenna directs the energy. The antenna directivity is 3.086 dB, 4.380 dB, 4.541 dB, 7.80 dB for maximum return loss frequencies respectively and it increases for higher frequencies.



(a)

(b)

(c)



(d)

Fig. 6. Radiation pattern at different frequencies (a) 2.45 GHz (b) 6.25 GHz (c) 8.25 GHZ (d) 10.45 GHZ.

4. Conclusions

In this study, a multi-band grid array microstrip antenna was designed and simulated. The simulated antenna performance obtained by CST MWS have been analyzed. The proposed antenna is compact and multi-frequencies UWB bandwidth. UWB microstrip antenna is widely used due to consuming low power and compact in WBAN applications. Four spectral frequency bands have been obtained for WBAN applications with appropriate return losses and bandwidths (One in the ISM three in the UWB zone). Each of these frequency bands can communicate with different devices or can be used together to increase bandwidth. In future works, we plan to use these values in WBAN antenna production and measurement.

5. References

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