Design of Small Integrated Antenna for Peer to Peer Wireless Communication

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ABSTRACT

In this paper, a small integrated antenna also called as microstrip patch antenna has been designed to investigate the effect of different array combinations of rectangular microstrip patches on the directivity and radiation pattern. The purpose of this work is to obtain an small, efficient and economical integrated antenna that can work effectively for peer to peer wireless communication such as for bluetooth devices. Since, the operating frequency for such devices lies between 2.4 GHz to 2.484 GHz and uses 80 channels with 1 MHz channel spacing, thus, the results were observed for the frequency within its allocation. The results obtained had showed better improvement in the directivity and radiation pattern by increasing the number of combinations for microstrip patch arrays.

KEYWORDS

Rectangular microstrip patches, circularly polarized, directivity, radiation patterns.

1. INTRODUCTION

An antenna is a key element for wireless communication as it transmits and/or receives electromagnetic waves [1]. During a decade, several antenna designs have been developed and their application depends on the physical parameters of its output. Due to recent trends of the communication system requirements in portable devices, it is necessary to design a light, compact, portable and an efficient antenna [2]. Several researchers are still developing optimum designs to reduce the size and weight of multiband antennas while keeping good performances [3–5]. An integrated antenna is among the one that is being preferred due to several practical applications, because of to its light weight, small size, easy and cheap realization. A small integrated antenna, also called, microstrip antenna has significant applications in the area of wireless communication and is used for several microwave applications. Small integrated antenna technology came into subsistence in the late 1970s but was well established in 1980s. The construction of microstrip antenna is easy as it requires a thin patch on one side of a dielectric substrate. The other side of substrate has a plane to the ground [6]. The patch is generally made of conducting material like Copper or Gold and may be in any arbitrary shapes like rectangular, circular, triangular, elliptical or some other shape [7]. For practical applications, the most common used microstrip patches are rectangular and circular patch antennas. In wireless communication, small integrated antennas are preferred than other radiating systems, due to their

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light weight, reduced size, low cost, conformability and ease of integration with communication devices [8]. Electromagnetic waves are significant as it radiates due to fringing fields between the edges of microstrip patch and the ground plane. The small integrated antenna can be mainly fed by either of the two methods, i.e., contacting and non-contacting methods. In contacting method, the RF power is fed directly to the radiating element having another connecting element such as a microstrip line or probe feed. In the non-contacting method, there is no physical contact between the elements. An electromagnetic field coupling is done to transfer power between the microstrip line and the radiating pact that includes proximity feeding and aperture feeding [9]. According to the radiation pattern configurations, a well polarized microstrip antenna can be classified as left-handed circularly polarized (LHCP) or right-handed circularly polarized (RHCP).

In this paper, a microstrip based patch antenna has been designed to get the resultant parameters by varying the arrays of microstrip patches to obtain the optimum output parameters. Finally, the comparison has been done with the theoretical parameters of short range peer to peer wireless communication devices.

2. BLUETOOTH

Bluetooth is a low power wireless communication device and is used for transfer of both data and voice signals. It is effective for a short range communication of upto 100 meters only. It is a wireless communication technique between two devices. During literature survey, it has been found that the bluetooth device is named after Viking Kin Harald Bluetooth. It was invented by Ericsson in 1994, in a hope that it would unite a world as Harald Bluetooth united Norway and Denmark and thus the device has named after Harald Bluetooth [10]. Bluetooth technology provides a 10-meter personal bubble that supports simultaneous transmission of both voice and data for multiple devices. Up to 8 data devices can be connected in a piconet, and up to 10 piconets can exist within the 10-meter bubble. Each piconet supports up to 3 simultaneous full duplex voice devices (CVSD). Theoretically, the data transfer rate is 1Mb/s, but the existing data rates are 432 Kbps for full duplex transmission, 721/56 Kbps for asymmetric transmission, and 384 Kbps for TMS 2000 transmission [11]. The protocol splits that bandwidth to support both voice & data communication. Bluetooth can support an asynchronous data channel, up to three simultaneous synchronous voice channels, or a channel, which simultaneously supports asynchronous data & synchronous voice [12]. Each voice channel supports a 64 Kbps synchronous (voice) link. The asynchronous data channel can support an asymmetric link of up to 721 Kbps in either direction, while permitting 57.6 Kbps in the return direction or a symmetric link up to 432.6 Kbps.

A piconet is a set of devices that is connected through bluetooth technology for temporary phase. A piconet starts with two connected devices, such as a portable PC and cellular phone, and may grow upto eight connected devices [13]. All bluetooth devices are peer units and have identical implementations. However, while establishing a piconet, one unit will act as a master and the other(s) as slave(s) for the duration of the piconet connection. Bluetooth technology has no line-of-sight requirements making it a potential replacement for infrared ports. Portable PCs can be connected wirelessly to printers, transfer data to desktop PCs or PDAs, or interface with cellular phones for wireless WAN (Wide Area Networking) access to corporate networks or the Internet.

3. ANTENNA DESIGN

The fundamental design of the microstrip patch antenna is shown in Fig. 1. 'L' signifies the length of the transmission line between the slots, 'W' is the width of the patch and 'h' is the patch height.

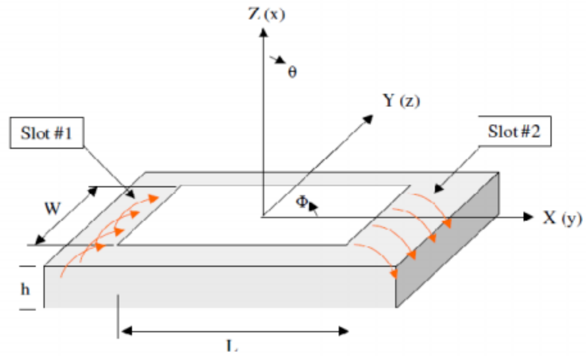

Fig. 1 Geometry of rectangular microstrip patch

A careful estimation is required for the antenna design to achieve the optimum results. In order to design a small integrated antenna for peer to peer communication devices, the resonant frequency of 2.45 GHz is selected which is very well inside the frequency range of bluetooth, i.e., 2.4 GHz to 2.5 GHz [14]. In this paper, the resonant frequency used is 2.45 GHz. The dielectric material of the substrate (E_r) selected is N4000-13 with a value of dielectric constant 3.430. The particular use of a dielectric material is an important design parameter. Low dielectric constant is employed in the prototype design as it gives better efficiency and higher bandwidth, and low quality factor Q. The low value of dielectric constant helps in rising the fringing field at the patch periphery and thus increases the radiated power. In this proposed design, patch size is independent of dielectric constant. Substrate thickness is also an important design parameter. Thick substrate increases the fringing field at the patch periphery like low dielectric constant that increases the radiated power. The height of dielectric material (h) of the microstrip patch antenna with coaxial feed is to be used. In this design, the height of dielectric material employed is 1.6 mm.

4. PHYSICAL PARAMETERS OF ANTENNA

Some important antenna parameters can be calculated by the transmission line method [1] [15] and is explained as below.

A. Width of the Patch

Numerically, the width of the microstrip patch can be calculated using the equation as [16]

$$w = \frac{c}{2 f_0 \sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

B. Length of the Patch

The length of the patch can be calculated only if the effective dielectric constant is known [8], and the effective dielectric constant can be calculated as

$$E_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{1/2}$$

E_{reff} = Effective dielectric constant

ε_r = Dielectric constant of substrate

h = height of dielectric substrate

w = width of the patch

The dimensions of the patch is extended on each end by a distance ΔL and is calculated by

$$\Delta L = 0.412h\frac{(E_{reff} + 0.3)(\frac{w}{h} + 0.264)}{(E_{reff} - 0.258)(\frac{w}{h} + 0.8)}$$

The actual length L of the patch is given as

$$L = \frac{\lambda_0}{2} = 2\Delta L$$

C. Input Impedance

The input impedance can be obtained by the equation [17]

$$X_f = \frac{L}{\sqrt[2]{E_{reff}}}$$

Where X_f is the desired input impedance of the coaxial cable and E_{reff} is the effective dielectric constant. Similarly, the admittance can be found using the equation

$$Y_f = \frac{w}{2}$$

D. Ground Dimension

For practical design, it is necessary to have some finite ground plane. For optimum design of small patch antenna, it is required that the ground plane should be greater than the patch dimensions by approximately six times the substrate thickness all around the fringe [18]. Hence, the ground plane dimensions would be given as

$$L_g = 6h + l$$
$$W_g = 6h + W$$

The above quoted physical parameter equations for antenna design is used to set the input parameters of the microstrip patch antenna. Table 1 shows the proposed input design parameters of microstrip patch antenna. By using these input parameters, the antenna was simulated using Phased Array Design Toolbox [19]. We simulate the antenna by varying the number of microstrip patches and the effect was observed on the directivity and radiation pattern. The microstrips were in the form of m x n array elements, where, m is the number of elements in x-axis direction and n corresponds to the number of elements in y axis.

Table 1. Input parameters for design of microstrip patch antenna

Input Parameters	**Units**
Power	6.90 mW
Impedance	71.00 Ω
Current	13.00 mA
Admittance	219.00 mho
Frequency	2.45 GHz
Input voltage	1.00 V
Patch Length	4.114 cm
Patch Width	3.259 cm

5. RESULTS

The performance of the antenna has been investigated by varying the number of microstrip elements in the antenna array. In this paper, we have shown the results for a single, 2 x 2, and 4 x 4 antenna array elements and the effect on the directivity and scattering pattern is observed. Fig. 2 shows the 3D geometry for a single antenna element whereas Fig. 3 and Fig. 4 shows the 3D geometry for 2 x 2 and 3 x 3 antenna array elements respectively. The corresponding scattering patterns for a single, 2 x 2 and 4 x 4 antenna array elements is shown in Fig. 5, Fig. 6 and Fig. 7 respectively. Similarly, the 3D radiation pattern is shown in Fig. 8, Fig. 9 and Fig.10, respectively.

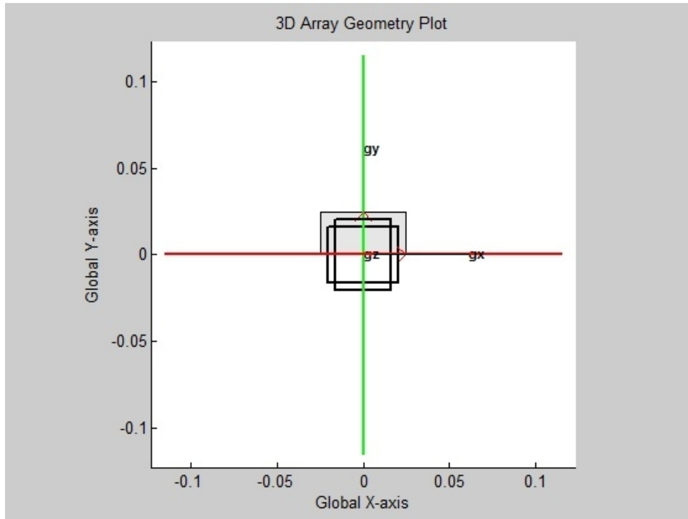

Fig. 2. 3D Geometry of a single microstrip antenna

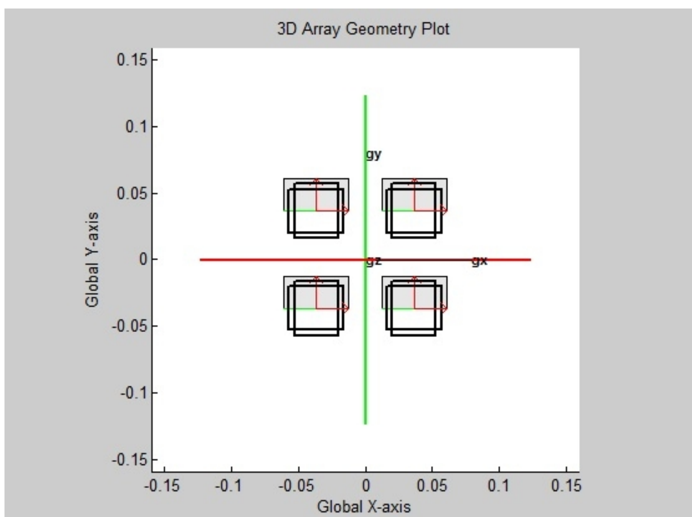

Fig. 3. 3D Geometry of a 2 x 2 microstrip antenna

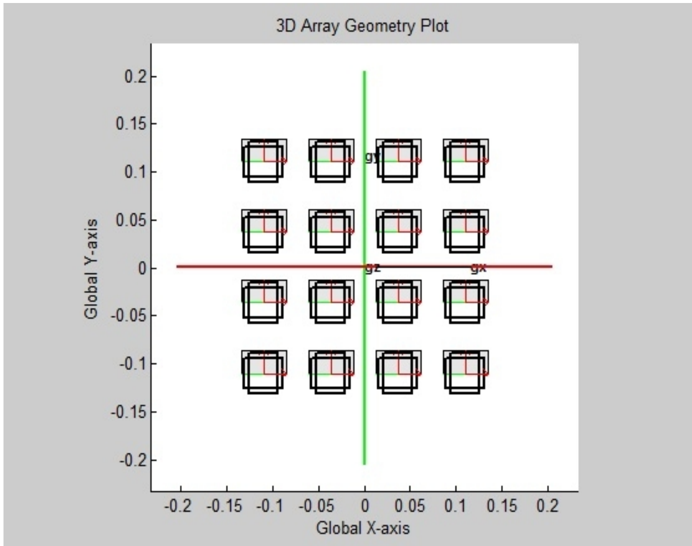

Fig. 4. 3D Geometry of a 4 x 4 microstrip antenna

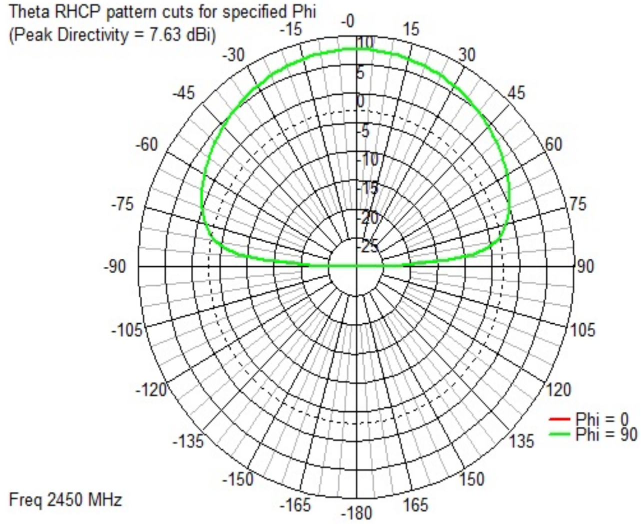

Fig. 5. Radiation pattern for a single microstrip patch antenna

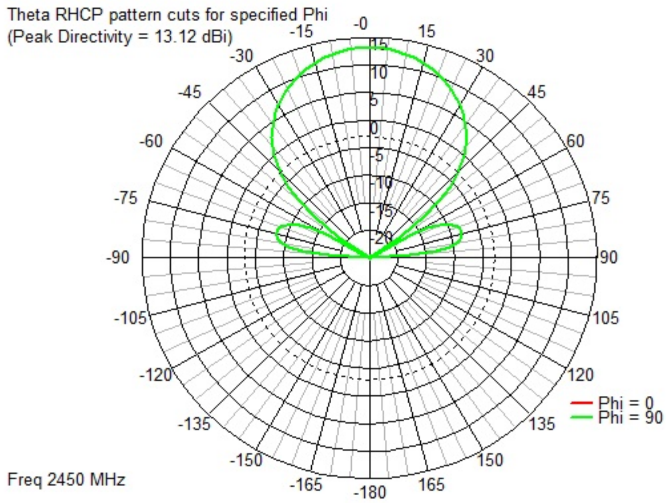

Fig. 6. Radiation pattern for 2 x 2 microstrip patch antenna

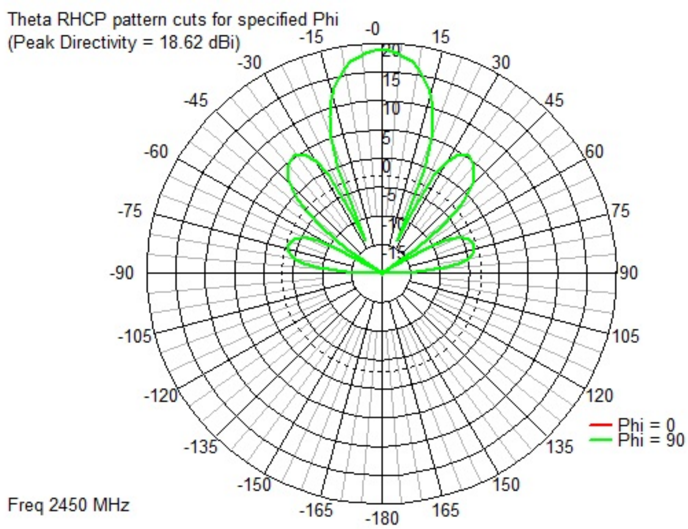

Fig. 7. Radiation pattern for 2 x 2 microstrip patch antenna

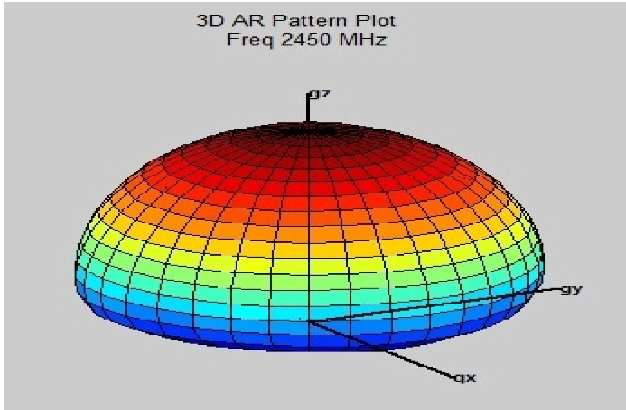

Fig. 8. 3D radiation pattern of a single microstrip antenna

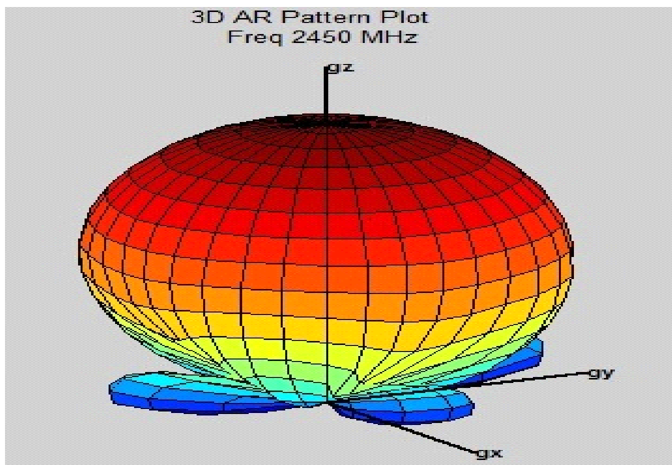

Fig. 9. 3D radiation pattern of a 2 x 2 microstrip antenna

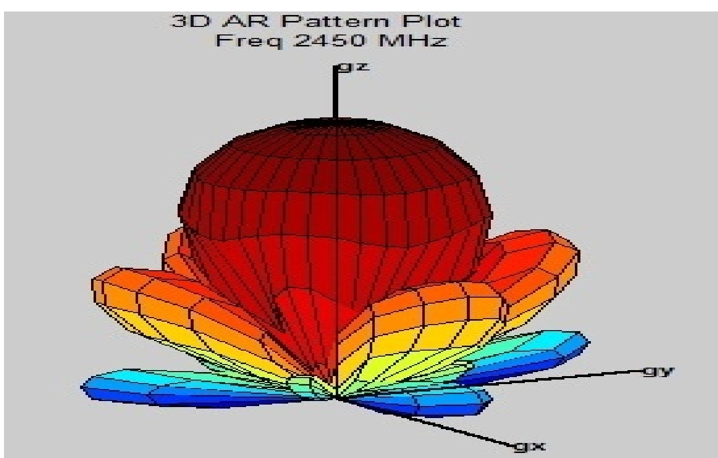

Fig. 10 3D radiation pattern of a 4 x 4microstrip antenna

6. CONCLUSION

We designed 3 different configurations of microstrip based patch antennas by setting the input operating frequency of Bluetooth devices, i. e. 2.45 GHz. The directive gain of a single, 2 x 2, and 4 x 4 antenna arrays is observed to be 7.63 dB, 13.12 dB and 18.62 dB. The results showed that 4 x 4 rectangular microstrip antenna array can work as an efficient microstrip antenna as it shows improved directive gain and radiation pattern. Moreover the patch area is very small as compared to conventional antenna and the directivity is high 18.62 dB as compared to the conventional antenna. Hence the antenna can operate well at the frequency 2.45 GHz as is required for operating the Bluetooth devices. It may be concluded that this antenna shows high directivity with reduced size. Due to increase in the directivity, it may be possible that this antenna can work for bluetooth devices upto 100 meters in a more efficient manner than the available conventional antennas.

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