Analysis and Design of Multi-Band Sector Antenna for Mobile Wireless Communication Systems

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Abstract

There are different shapes of the antennas in mobile communication system. But we are interested in analysis and Design of Sector antenna for mobile wireless communication in three bands. This kind of antenna can be largest applied for cell phone base-station sites.They are also used for other types of mobile communications, for example in Wi-Fi networks. This antenna is fed by microstrip line and composed of three radiating element which resonant in three frequencies and covers (4GHz-8GHz) frequency bands. In this paper, we present several steps of designing the sector antenna then a comparison with a rectangular antenna in literature. High Frequency Structure Simulator (HFSS) software is used to compute the gain, input impedance, radiation pattern, and return loss S11 of proposed antenna. Based on the designed sector antenna, many phased arrays will be simulated using HFSS. The impact of distance between element, number of element and phase will be checked. Obtained results are analyzed and compared with literature.

I. Introduction

Mobile wireless communication has increased popularity in a recently years. Due to enhancement in this popularity, the design of the antenna used for mobile wireless communication devices have to be small, lightweight and low profile and simple structure in order to assure reliability, mobility and high efficiency. A sector antenna is very simple in fabricates using a conventional microstrip fabrication technique [1-5]. The main reflector screen is produced from aluminum where internal parts are covered by the fiberglass in order keep its operation stable regardless of the weather conditions.Ground also is very important in return path of electric current.

There are different shapes of the antennas depending on the application of it, but rectangular configurations are the most commonly used. In our study we are interested in sector shape, the largest use of these are, cell phones, base transceiver stations and mobile communication. In addition of their small size compared with other shapes like the rectangular and circular patch antennas and provide circular polarization which is desired in wireless communication. Rectangular patch antenna will be introduced as reference and its performance will be compared with sector antenna. The chosen of the sector antenna is designed by Pozar in [1]

In this study, several designs of sector patch antennas arrays are presented. We will compare single element of both shapes, then array of sector antenna will be designed using theory of array factor. Moreover, these designs are simulated using HFSS. Based on the simulation results, we can see that a sector antenna achieve good results once we make comparison with the IEEE 802.11 a/n for the verification of the simulation results. This band contains frequency ranges that are used for many satellite communications transmissions, some Wi-Fi devices, some cordless telephones, and some weather radar systems.

This paper is divided into four sections: the first section is devoted to give an overview of the sector antennas and a preface of the important parameters in single element designs. Second section discusses the sector antenna deigned based on HFSS. Third section presents a comparison between sector antenna and IEEE 802.11 a/n application. Finally, a brief conclusion is presented in the fourth section.

Theory

A. Sector circular antenna

It is one of the common antenna which has sector shaped radiation pattern. The basic shape is shown in figure 1 below, in geometric sense some portion of the circumference of a circle measured in different degrees (60^0 , 90^0 or 180^0) depends on the coverage area. It is widely used in cell phone base station as well as mobile communication. Directional antennas focus energy in a particular direction. Directional antennas are used in some base station applications where coverage over a sector by separate antennas is desired. Point to point links also benefit from directional antennas.

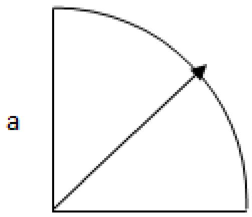

Figure1. radius sector antenna

The expression for calculate radius is given by [3]

$$a = \frac{k_{mn} C}{2\pi f_r \sqrt{\varepsilon_r}}$$

B. Radiation pattern.

It is defined as "a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far-field region and is represented as a function of the directional coordinates. Far fields means power radiated in a large distance, for the transmitting antenna, the power radiated is calculated as

$$W(\theta, \Phi) = \frac{G(\theta, \Phi)}{4\pi r^2} P_t$$

C. Return Loss

Mathematically, RL is the ratio of the light reflected back from a device under test, to the light launched into that device, usually expressed as a negative number in dB. Normally, RL consider as the loss of signal power resulting from the reflection caused at a discontinuity in a transmission line. RL can be summarized in the following equation below;

$$RL(dB) = 10 \log_{10} \frac{p_i}{p_r}$$

Where;

RL is the return loss in dB

p_i is the incident power and p_r is the reflected power.

II. Antenna Design

The architecture of the proposed antenna is depicted in figure 2. The overall dimensions are a little shorter and it is circular antenna which fed by the microstrip line. and fabricated on an FR4 epoxy substrate of dielectric and thickness h=0.127 cm. The antenna and microstrip feeder is printed on the positive side of the substrate and earth plate on the other side.the angle and radius of circular sector patch are $a = 1cm$ and $\alpha = 90$.

Dimension of the earth plate is 40mm×40mm; Width of the Microstrip feeder is S1 and length is L1 + d; Size of the rectangular radiation patch is W×R2; The length of the rectangular-ring patch is L2. The resonant frequency of the circular shaped radiation patch has a frequencies band from (4-8) GHz. These three radiation patches is connected by a printed patch of length is L2. By changing the size of this radiating element we can adjust the resonant frequency of the antenna very flexible and convenient.

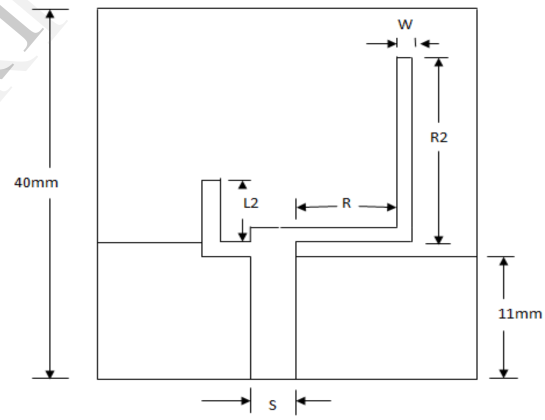

Figure2. Architecture of the proposed antenna

III. Results and discussion.

The proposed antenna in this paper is being designed and simulated by using HFSS and some optimized antenna parameter values are listed in table 1.

Table 1 Design Parameters of Proposed Antenna

parameter	Value(mm)
L2	23
R	2.8
W	5
R2	31
S	4

a. Radiation pattern and Gain

Radiation pattern in E-plan of sector antenna is traced in Figures 3 for two Microstrip line modes. We setting the solution type lump port since we use microstrip line, for values of theta and phi 5 is good(see figure 1) From the simulated results, it is shown that patterns of proposed antenna is directive. The gain of the studied antenna is about 5 dB and 5.7dB.However we can deduct the shape of the sector antenna and does not affect the gain.

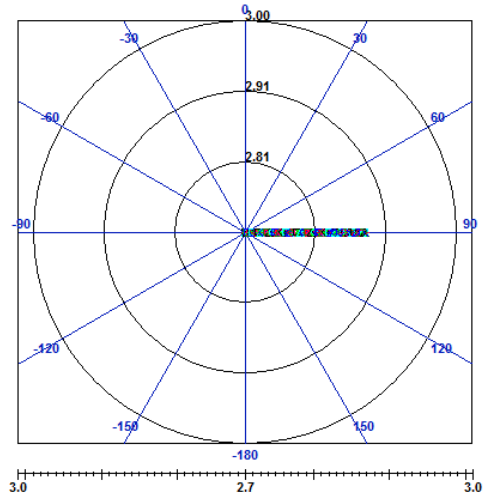

Figure 3.Radiation pattern of circular antenna.

b. Return Loss

Return Loss is the loss of the power signal resulting from the reflection caused by connector, broken optical fiber and creates multipath interferences in transmission or optical fiber .From Fig. 4, the fundamental resonance of the antenna occurs at 2.5-3.5 GHz with a return loss of S<10 dB. The relative impedance bandwidth is (3.249-2.789)/3=15.3% which meets the WLAN and BTS frequency coverage demand, thus it is very flexible and convenient to adjust the characteristic of the antenna at each frequency band. As can be seen from the graph that the antenna maintained good radiation characteristics in the entire frequency band since a match is good if the return Loss has got high but with the increase of frequency, the radiation pattern has begun to go bad, but still acceptable.

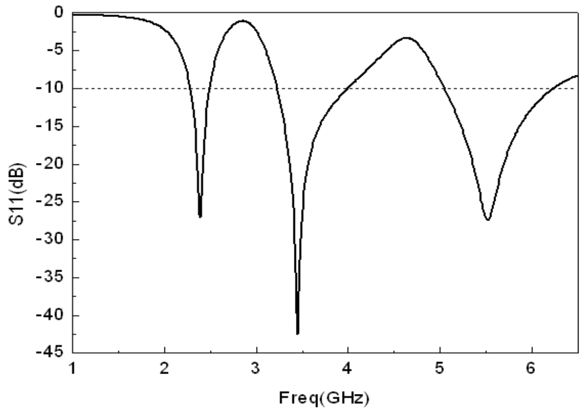

Figure4. Return Loss of the sector antenna

IV. Conclusion

In this paper, analysis and design of multi-band sector antenna for mobile wireless communication systems was presented. The simulation results showed that the antenna comply with the requirements of WLAN and BTS with bandwidth of (4-8) GHz .Moreover, We have seen that changing substrate and some parameters can modify the nature of the antenna: We switched from a broadband antenna with good reflection coefficient to a multiband frequency antenna that can be used to cover C-Band with reflection coefficient S11 < –10 dB.

In the second part of paper, were designed a sector antenna based on HFSS. Moreover we explained the facts that affect the antenna such as Return Loss and some parameters.

Radiation pattern refers to the direction of the electromagnetic waves radiates away from the antenna. It is calculated as the measure half power beam width in the E-plane and H-plane. Multiply them and invert and again multiply with 4*pi. The result will be approximate far field directivity. Now multiply directivity with efficient to calculate Gain. Where gain defined as the ratio of the power produced by the antenna from a far field source on the antenna beam axis to the power produced by a hypothetical lossless isotropic, which is equally sensitive to signal all directions. In addition there are two types of the fields (far and near field) but in antenna we only focusing on the far fields. The Sector antenna has been deployed in the Tianjin University of Technology and Education laboratory and has been demonstrated for 6 months also research must be continual in order to get better results for the future scientific research.

Acknowledgement

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