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A CPW Fed Star Shaped Patch Antenna For WSN Applications

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Abstract: This paper proposes a miniature antenna for wireless sensor network application in 2.45 GHz. A coplanar waveguide fed star shaped patch antenna is designed using electromagnetic solver, IE3D. A CPW feed is designed for 50ohm impedance matching .The antenna for WSN should be low powered, low cost and easy to fabricate. These can be achieved using small antennas. The small antenna size gives reduced node size and reduced battery power. An experimental prototype antenna of 30 mm (length) x 35 mm (width) was fabricated on 1.6mm thick FR4 substrate .Various numerical analysis were made by adjusting the arms of the star patch and the proposed structure show an improvement in return loss .The antenna has -14.5dB return loss at the operating frequency of 2.4 GHz, the VSWR is of 1.3, it has Omni -directional radiation pattern. The Impedance bandwidth of the antenna is 120 MHz. The measured results are appreciably in good agreement with the simulated one.

Indexterms : *Coplanar waveguide feed, Omni-directional, Patch antenna, return loss, Wireless sensor network.*

I. INTRODUCTION

A wireless sensor network consists of so many sensors scattered in an environment. These sensors are tiny sized sensors. Tiny sensor is one which has computational capability and sensing functions [1]. Each tiny sensor can sense physical phenomenon like temperature, Vibration, light, electromagnetic strength and humidity etc…, these data collected are forwarded to central node called sink node which has the processing capability. The data is transferred from tiny sensor to sink node through some intermediate node. This WSN find its vital application in areas like military affairs, patient healthcare, environmental inspection etc..[2]. The communication between the tiny sensor and sink node is a wireless communication.

The Wireless communication is mainly concentrated on the antenna size. The reduced antenna size results in small sensor node and low power consumption [3]. So the antenna can be a low profile, low powered and high frequency micro strip antenna. The antenna size is proportional to 1/ $\sqrt{\xi r}$ [4]. Small antenna concept is the one which uses planar antenna and by adjusting the electrical size the desired centre frequency can be obtained.

There is a great demand in wireless communication system applications. Microstrip patch antennas are widely used because of their several advantages [7] such as light weight, low volume, low fabrication cost and capability of dual and triple frequency operations. It is simple and inexpensive to manufacture using modern printed circuit technology. It is mechanically robust when mounted on rigid surfaces, compatible with MMIC designs[8] .And when the particular patch shape and mode are selected, they are very versatile in terms of frequency, polarization, pattern and impedance.

WSN can also be used in Road traffic management and real time traffic data Collection. WSN antenna with meander line is designed with 150×150 mm^2 dimension to generate horizontally polarized radiation pattern. The operating frequency is chosen at 433 MHz (ISM band) in order to avoid much higher demanding traffic in 2.4 GHz and to cover a larger area. The return loss obtained for this frequency is -21dB [4,5]. The antenna size reduction is made by means of the increasing electrical length and dielectric substrate.

In another paper, two rectangular-printed-spiral antenna with U-strip that operates at 433 MHz.The antenna structure is flat to install on the road. Both spiral and U-strip configurations can increase the electrical length. Thus, the antenna possesses small size, easy fabrication and low cost. The antenna radiates Omni -directional pattern The measured return loss is -12.435 dB at 433 MHz with 5.455 % Impedance bandwidth (428-452 MHz)[6] . A coplanar waveguide (CPW)-fed microstip antenna is a compact antenna. The antenna size is minimized by loading of inverted L-strip over the conventional monopole patch antenna to lower the height of the antenna. The prototype with overall size of 25 × 25 × 1.6 mm^3 achieves a bandwidth of 2.6-13.04 GHz (10.44 GHz). Good impedance matching, constant gain, stable radiation patterns and better return loss are observed.[7].

In this paper, an antenna is proposed for wireless sensor network .It is Star shaped micro strip patch antenna using CPW feed. In general, PCB antennas can be designed with different feed mechanism like probe feed, CPW feed, Micro strip Feed. CPW (Coplanar Wave guide) feed is used in proposed antenna.CPW feed is chosen to achieve good bandwidth, good impedance matching, low radiation leakages and ease of integration with active or passive devices in microwave monolithic integrated circuits [13]. The coplanar waveguide antenna has two parallel slots cut into a copper surface, which act as transmission line feed to radiating element of the antenna.

In this work FR4 substrate is used to achieve size reduction and cost reduction.. The antenna is designed using IE3D software [12]. Different Numerical analysis has been performed to achieve reduced size than its defined size of half the wavelength to meet the frequency of 2.4GHz. This frequency find its application in Bluetooth, wireless body area network (WBAN), wireless personal area network (WPAN), and ZigBee etc..This also provides worldwide standard for personal area networks (PANs) or short-distance wireless networks for low data rate solutions with long battery life and very low complexity [9] .Further the design of proposed antenna, the simulation and measured results are discussed under section II, Section III, Section IV respectively.

II. ANTENNA DESIGN

The geometry of the proposed Star shaped Coplanar wave Guide fed patch antenna operating at 2.4 GHz is shown in Fig.1. In this study, the dielectric substance (FR4) with thickness of 1.6 mm with relative permittivity of 4.4 is chosen as substrate to facilitate printed circuit board integration .The outline of the antenna was printed on a dielectric substrate that has a thickness of 0.4 mm, dielectric constant of 4.4, and loss tangent of 0.02. This geometry allows a large electrical length that aids in performing miniaturization. The total size of the antenna is 30 mm×35 mm×1.6 mm. The antenna is fed using a vertical metal strip, which has the input impedance of about 50 Ω. The proposed antenna is designed using IE3D software and the electrical size and shape of the antenna is adjusted to achieve operating frequency of 2.4GHz .Due to the Star shaped structure there is a size reduction of 81% than the λ/2 size of the antenna to achieve the 2.4 GHz frequency.

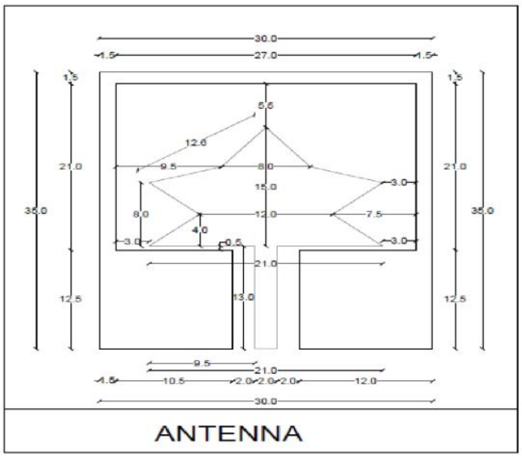

Fig. 1. The Geomentry of 2.4GHZ Star Shaped Tuning Stub Antenna (mm).

III. SIMULATION RESULTS

The analysis and performance of the proposed antenna is explored by using IE3D for the better impedance matching. The analysis of the antenna is carried out by varying one parameter and keeping other parameters constant. The optimal parameter values of the antenna are listed in the Table 1.

Table 1. Antenna Parameters (mm)

Description	Optimal value(mm)
Width of tuning stub	15
Length of tuning stub	21
Feed gap distance	0.5
Overall width	35
Overall length	30

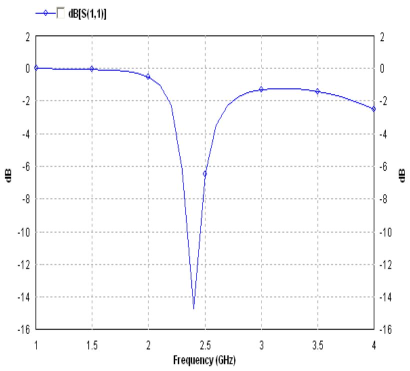

Fig.2.ReturnLoss.

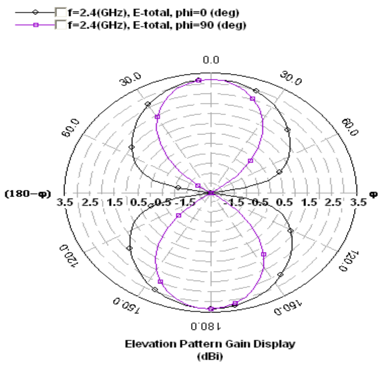

Fig. 3. 2D Radiation Pattern.

The structure is a star shaped patch antenna with the dimension 30mm×35mm×1.6mm.The feeding mechanism is coplanar wave guide feed. The patch size is adjusted to get the center frequency of 2.4 GHz, The return loss is -14.5 dB, shown in Fig. 2. The simulation impedance bandwidth of the antenna for less than - 10 dB return loss is 120 MHz (2.25– 2.45 GHz). The radiation pattern of the antenna is Omni-directional shown in Fig. 3. The VSWR bandwidth is within the permissible value given by Fig. 4. The gain values can be effectively adjusted if we appropriately design the shape. For instance, In simulation, we can observe adjusting the length L of the structure improves the gain of the antenna. This proves that length and width plays an important role in this type of antenna offering in some situations more gain and bandwidth.

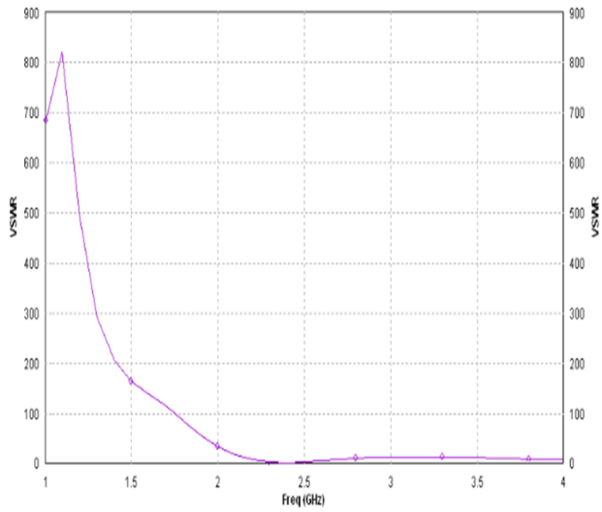

Fig. 4. VSWR Characteristics.

A. Effect Of Width

The effect of bandwidth for different width of the patch , depicted in Fig. 5. which discloses the profiles of the impedance matching . While increasing the width the return loss S11 decreases and there is a shift in the resonance frequency, which implies poor impedance matching. Similarly if the length is decreased, there is a decrease in the return loss ‘S11’ and shift in the resonance frequency

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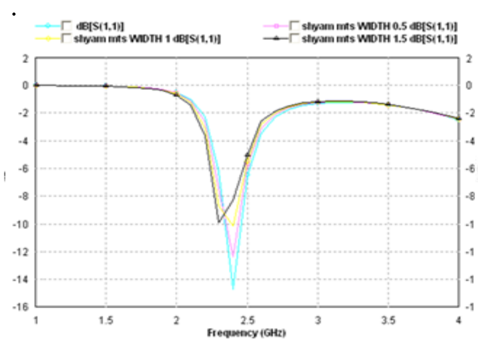

Fig. 5. Return Loss for various Widths.

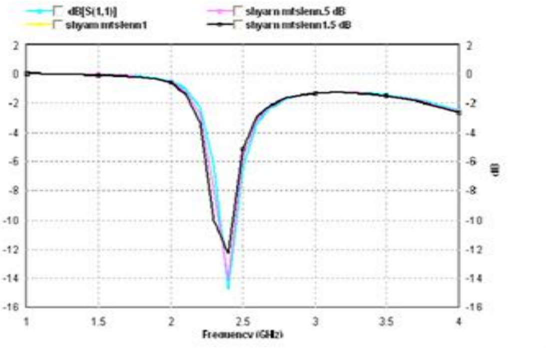

Fig. 6. Return Loss for various Lengths.

B. Effect Of Length

The effect of bandwidth for different length of the patch, depicted in Fig. 6. which discloses the profiles of the impedance matching . While increasing the length the return loss S11 decreases and there is a shift in the resonance frequency, which implies poor impedance matching. Similarly if the length is decreased, there is a decrease in the return loss ‘S11’ and shift in the resonance frequency.

C. Effect of Fedgap Distance

The effect of bandwidth for different band gap depicted in Fig.7. which discloses the profiles of the impedance matching. While increasing the feed gap the return loss S11 decreases and there is a shift in the resonance frequency, which implies poor impedance matching. Similarly if the feed gap is decreased the return loss decreases and shift in the resonance frequency.

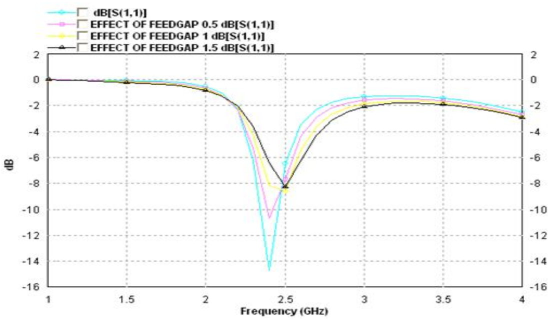

Fig.7. Return Loss for various feed gap distances.

Fig.8. Fabricated structure.

IV. MEASUREMENT RESULT

The antenna is fabricated using FR4 substrate and the measurement is done. The prototype of the proposed antenna was fabricated for different parameters with their optimal values and tested. All the measurements are carried out using Vector Network Analyzer (VNA). The actual construction of the 2.4 GHz CPW fed antenna with star shaped tuning stub or patch is shown in Fig.8. The total size, including of the antenna, is 30 mm x35 mm x 1.6mm. The simulated return loss is shown -14.5dB. The measurement in Fig.9. shows the center frequency is at 2.482GHz, return loss at -14.5dB.The impedance bandwidth of the antenna for a return loss less than -10dB is 120 MHz (2.25–2.45 GHz). The peak gain is 1.4 dBi, slightly better than the simulated result of 1.3 dBi. From Radiation Pattern, we can observe that this is an Omni-directional antenna.

Fig.9. Tested Result-return Loss.

V. CONCLUSION

In this paper, the proposed design has a planar configuration. It is a simple antenna structure with minimal antenna size and better impedance matching. It can be easily fabricated at low cost on the system substrate. Moreover, the proposed antenna can also be applied into practical WSN's products with of 30 ×35 mm^2. Due to the Star shaped structure there is a size reduction of 81% than the $\lambda/2$ size of the antenna to achieve the 2.4 GHz frequency. The computed time domain analysis of the designed antenna ensures the capability of the antenna working in the WSN environment. Good radiation characteristics of the proposed design can also been used for IEEE 802.15 applications. There is no ground plane for this antenna structure. The size is relatively small. The measured return loss is -14.5dB at 2.482GHz is efficient for many wireless applications especially wireless sensor networks.

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