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An Rectangular Patch Antenna for ZigBee at 2.4GHz

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Abstract: ***ZigBee belongs to the Personal Area Network task group, which operates at a modest rate. It's a form of home networking technology. A technical standard known as ZigBee was developed for managing and identifying the network. The need for low-power, low-bit rate devices at a reasonable price point was met by a protocol called ZigBee for short-range wireless communication. An antenna that can transmit and receive radio waves is called a ZigBee antenna, and it is defined by the IEEE 802.15.4 standard. They are essential for the functioning of ZigBee's wireless personal area networks, which use little power. Therefore, a 2.4GHz patch antenna is constructed with a 39x47.8 mm2 area, a 1.6 mm substrate composed of FR-4(Lossy), and a copper patch. At VSWR of 1.06, 110.25 MHz bandwidth, and 2.76 dB gain, a return loss of -29.77 dB is attained. All directions are covered by the radiation pattern. Quite a bit of agreement exists between the computed values and the predicted results.***

Keywords—ZigBee, ISM band, Patch antenna, ZigBee application, Return loss, Bandwidth, Directivity, VSWR, Gain

I. INTRODUCTION

Our dependence on wireless technology is growing by the day [1]. The most prevalent and ubiquitous network in wireless communication is the WPAN. Most significant frequency of the ISM radio band, for Wireless Local Area Networks is 2.4GHz [2]. WiFi technology is becoming an integral component of our regular lives. It aids in reducing automobile congestion in public areas [3]. Bluetooth, on the other hand, improves low-cost offerings by increasing data capacity and providing a broader bandwidth. It also eliminates congestion among wireless services, offers a safe internet connection, and facilitates connectivity [4]. Zigbee network features minimal latencies, a versatile network layout, and can accommodate up to 65,000 nodes.

An 802.15.4-based communication device, that is probably widely exploited in wireless networks [5]. The Zigbee protocol, also known as IEEE 802.15.4, is extensively deployed to link sensor networks, that are specially intended for lower-level communication, with minimal intricacy, low energy consumption, and lower data rates [6]. Wireless and, Media access protocols, for PAN devices are described in the IEEE 802.15.4 standard [7].

ZigBee protocol offers three communication topologies: “Point-to-point, Point-to-multipoint, and Mesh topologies” with a single device, acting as coordinator [8]. Many important improvements and attention have been made to the ZigBee platform in consecutive years following License-free ISM frequency spectrum, for commercial purpose of communications. Continuous surge of wireless application, along with a higher level of downsizing and, greater frequency of operation, has heightened attention in constructing high-performance antenna kinds [9].

Printed antennas or patch antennas had performed a significant role in creation of antennas, with diverse frequencies, and bands. Typical patch antennas are composed of patch on one side of a Dielectric substrate, and a ground plane on the other side, both of which are supplied via a microstrip line/coaxial probe. MPAs possess numerous benefits over standard antenna systems, including low- profile, light in weight, cheap cost, ease of fabrication, and ease of integration, with Monolithic Microwave Integrated Circuits-(MMICs). They also show intrinsic resonance performance and excellent narrow bandwidth operation [10].

As a consequence, this article proposes a Rectangular Shaped Patch Antenna, designed for Zigbee applications, resonating at 2.4GHz. The shape, overall size, and material grade of the MSP antenna are all factors that limit its performance.

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II. ANTENNA DESIGN

Patch antenna is a form of microstrip antenna, that is generally deployed in wireless communications, due to its low profile, light in weight and ease of integration into a system. The antenna has a rectangular patch of flat metal, that is affixed, over a ground plane. Patch is usually a conductor such as copper or gold and, is placed on a dielectric substrate, to provide electrical insulation between patch and ground plane. The thickness of the substrate, and the dimensions of the patch determines, the Resonant frequency of the antenna. To generate the EM waves, the patch antenna is fed by coaxial cable or Microstrip line, which is usually linked to center of the patch. The wave is then radiated into the environment through patch and the ground plane. The model design of patch antenna in shown in Figure 1.

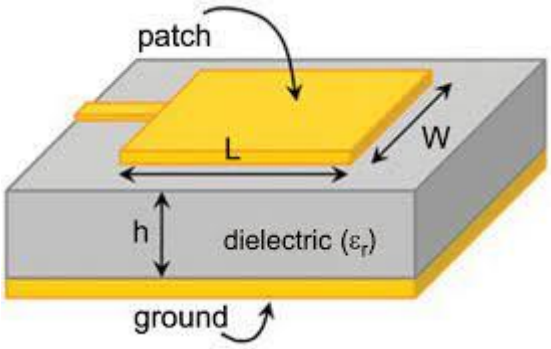

Figure 1: Patch antenna model

This study designs an MSP Antenna with a frequency range of 2.4GHz. Substrate is made of FR-4(Lossy), with 4.4 as Dielectric constant and, copper-(pure) as a patch. Since antenna shouldn't be substantial, the height-(h) of substrate is critical. Insert feed is adopted, as it has perfect Impedance match. The three key parameters required to construct an MSP Antenna are operating frequency-(fo), Substrate's dielectric constant-(εr), Substrate's height-(h). The dimension of the antenna is depicted in Figure 2.

A. WIDTH- (W)

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \quad (1)$$

B. (ε_{eff})-Effective Dielectric constant

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{\frac{1}{2}} \quad (2)$$

C. Effective length-(L_{eff})

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} \quad (3)$$

D. EXTENSION OF LENGTH-(ΔL)

$$\Delta L = 0.412 \times h\,\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (4)$$

E. Actual patch's length -(L)

$$L = L_{eff} - 2\Delta L \quad (5)$$

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$$L = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} - 0.824h\left(\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}\right) \quad (6)$$

F. Ground Plane's lenght -(L_g)

$$L_g = 6h + L \quad (7)$$

G. Ground Plane's Width -(W_g)

$$W_g = 6h + W \quad (8)$$

H. Microstrip feedline Width

$$w = \frac{7.48 \times h}{e^{\left(Z_0\frac{\sqrt{\varepsilon_r + 1.41}}{87}\right)}} - 1.25 \times t \quad (9)$$

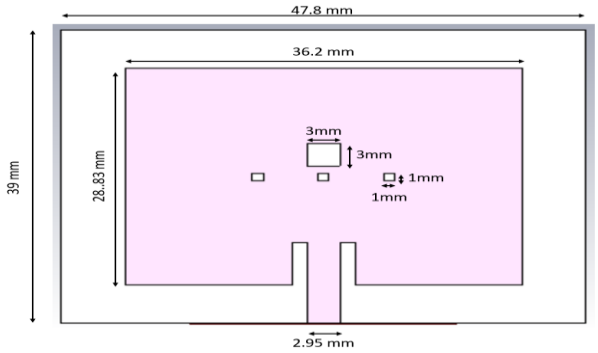

Figure 2: Antenna's Dimension

III. RESULTS AND DISCUSSION

The Patch Antenna Has Been Sketched In "Cst Studio Suite" And Antenna Parameter Are Been Analyzed. Cst Studio Suite Is A Software Package For Electromagnetic Simulation. It Provides Tools For Designing, Simulating, And Analyzing The Behaviour Of Electromagnetic Systems, Such As Antennas, Microwave Circuits, And High-Frequency Electronic Devices. Its User-Friendly Interface, Which Allows Users To Easily Create And Analyze 3d Models Of Their Electromagnetic Systems. The Software Also Includes A Range Of Tools For Post-Processing And Visualizing Simulation Results, Such As Plotting And Animation Tools, As Well As The Ability To Export Data To Other Formats For Further Analysis.

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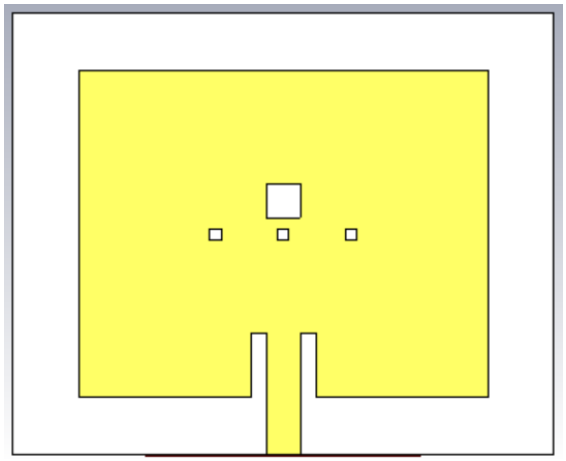

Figure 3: Antenna Designed In Simulation

The Patch Antenna's Essential Characteristics Are The “Ground Plane, Substrate, And Patch”. The Foundation Is Laid Initially In Software's Associated Workplace, Followed By Substrate And, The Patch Layer, Based On The Dimensions Considered. Using Coordinate Data, The Msp Antenna Can Be Simply Built In The Workspace. At Last, Feed Is Given To The Msp Antenna. The Intended Antenna Has Been Built, As Illustrated In Fig.3. The Following Criteria Must Be Considered When Examining The Planned Msp Antenna: “Return Loss, Bandwidth, Vswr, Directivity, And Gain” Are All Aspects.

A. Return Loss

Return Loss, Also Known As Reflection Coefficient, Is A Amount Of Efficiency Of An Antenna In Transmitting A Radio Frequency (Rf) Signal To The Intended Receiver. “It Represents Ratio Of The Power Carried To Load, To Power Reflected Back To The Source, And Is Expressed In Decibels (Db).” Return Loss Is An Important Metric For Estimating The Performance Of An Antenna And For Optimizing Its Design. A Low Return Loss Means That Most Of The Power Is Being Transmitted To The Receiver, While A High Return Loss Indicates That A Significant Amount Of Energy Is Being Reflected Back To The Source, Reducing The Overall Transmission Efficiency. The Return Loss Must Preferably Be Lower Than -10db. Figure 4 Shows The Return Loss At 2.4ghz.

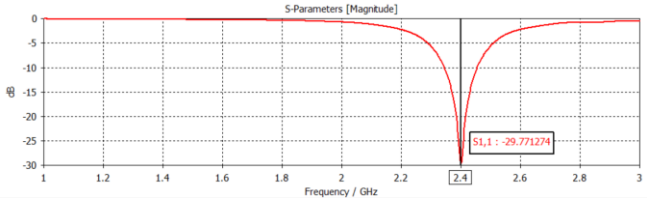

Figure 4: Return Loss

B. Vswr

“Voltage Standing Wave Ratio-(Vswr)” Is A Quantity Of The Effectiveness Of An Antenna In Transmitting Radio Frequency (Rf) Signals. “It Represents The Ratio Of The Maximum To Minimum Voltage In A Standing Wave Pattern, That Can Occur On A Transmission Line, Linked To The Antenna.” Vswr Of 1:1 Specifies Perfect Match, Between The Impedance Of The Antenna And, The Transmission Line, With No Reflected Energy And No Standing Wave Pattern. A Vswr Higher Than 1:1 Means That Some Energy Is Being Reflected Back To The Source, Indicating An Impedance Mismatch Between The Antenna And The Transmission Line. The Higher The Vswr, The Greater The Amount Of Energy Being Reflected, Reducing The Overall Transmission Efficiency And Potentially Causing Interference. Figure 5 Shows The Antenna Vswr At 2.4ghz.

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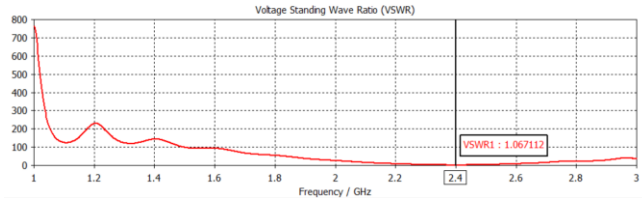

Figure 5: Vswr

C. Bandwidth

Bandwidth Is An Important Characteristics And States That Range Of Frequencies, Over Which The Antenna Is Able To Effectively Transmit Or Receive Radio Frequency (Rf) Signals. Bandwidth Of An Antenna Is Concluded By Its Resonant Frequency And The Frequency Range Over Which Its Input Impedance Remains Constant And Close To Characteristic Impedance Of The Transmission Line.

Bandwidth = 2.455072 - 2.344823
= 0.110249 Ghz
= 110. 25mhz

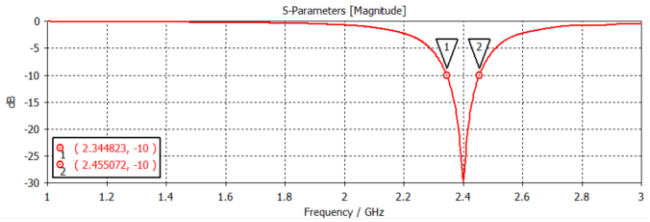

Figure 6: Representation Of Bandwidth At 2.4ghz

D. Gain

Antenna Gain States An Antenna System's Capacity, To Focus Radiated Power, In A Given Direction Or, Contrary Absorbs Power Effectively Arriving From A Certain Direction. The Gain Of An Antenna Is Measured In Decibels (Db) And Is Defined As 10 Log10 (Pout/Pin), Where Pout Is The Power Of Antenna's Output Signal In The Direction Of Maximum Gain, And Pin Is The Power Of The Input Signal. Figure 7. Shows The Gain Of 2.76db At 2.4ghz.

E. Directivity

Directivity Is A Measure Of Capability Of An Antenna, To Direct Its Radiated Energy, In Specific Direction. It's A Ratio Of Power Density In The Direction Of Maximum Radiation, To Power Density Averaged Over All Directions. Greater The Directivity, The More Concentrated Or Focused An Antenna's Beam Is. Antennas With High Directivity Are Able To Concentrate Their Energy In A Specific Direction, Making Them Useful For Communication Over Long Distances. Figure 8. Shows A Directivity Of 5.28dbi At 2.4ghz.

F. Radiation Pattern

The Radiation Pattern Is A Graphical Illustration Of Distribution Of Its Electromagnetic Radiation In Space, Of An Antenna. The Pattern Shows How The Signal Strength Of An Antenna Varies With Direction And Provides Valuable Information About Its Performance In Different Scenarios. The Radiation Pattern Can Be Represented In Two Dimensions, Such As A Polar Plot, Or In Three Dimensions, Such As A 3d Polar Plot. The Radiation Pattern At 2.4ghz Is Depicted In Figure. 9 And 10.

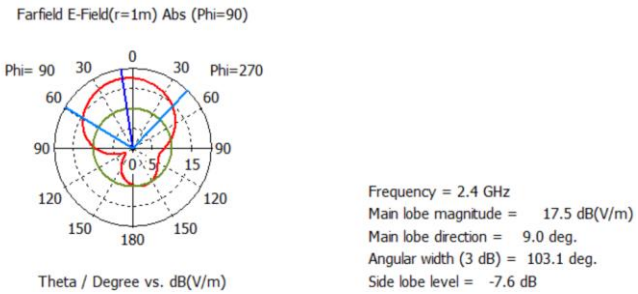

Figure 9: E-Field Pattern

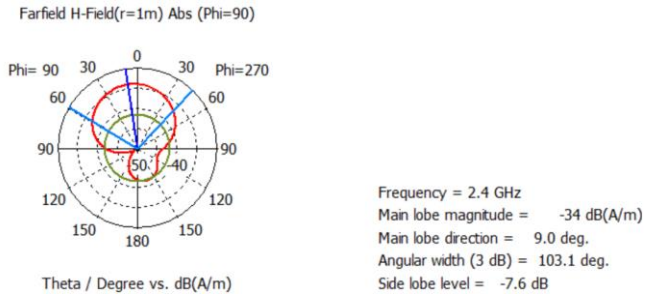

Figure 10: H-Field Pattern

Table I: Antenna Specifications

Parameters	Values
Return Loss	-29.77db
Vswr	1.06
Bandwidth	110. 25mhz
Gain	2.76 Db
Directivity	5.28 Dbi

This Research Describes A Miniaturized Zigbee Antenna. The Proposed Antenna Covers The 2.4ghz Of Ism Band, And The Simulated Results Accord Well. Table I Lists The Operational Parameters. This Antenna's Analysis Suggests That It Is Useful In Microdevices Devices, With A Simple Design And Compact Size As An Extra Benefit That May Easily Be Employed In Integrated Wireless System Implementations. The Influence Of Such Slots In Obtaining The Ism Band Was Demonstrated Using Surface Current Patterns.

CONCLUSION

Patch Antenna For Zigbee Applications Is Shown, In This Work. The Antenna Is 39 X 47.8 Mm^2 In Dimension, Has A Straightforward Design, And Is Compact. This Can Potentially Be Incorporated Into Smaller Devices. The Proposed Antenna Resonates In Frequency 2.4ghz, Where Observed And Simulated Results Correspond Well. Results And Study Of This Antenna Show That It Is Suitable For Small Devices, With A Basic Design And A Bonus Of Compactness. Thus An Omnidirectional Zigbee Antenna Is Achieved, Which Transmits And Receives Signals, In All Directions Around The Antenna's Longitudinal Axis, Which Is Ideal For Iot Applications.

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