A Design of PCB Antenna for Application Based Wireless Sensor Node

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ABSTRACT: In this paper, an antenna has been designed and implemented for wireless sensor node. The antenna element of the proposed node is based on Omni directional PCB (printed circuit board) patch antenna. It uses meandering connecting strip which is optimized to have frequency band operation, between 2.40 to 2.49 GHz for |S11| ≤ -10 dB. This work is a part of development of the wireless sensor node for a specific application. We have designed a dipole antenna suitable for the specific application using FR-4 epoxy glass laminate material, and have presented the simulated result obtained from NEC 4.0V simulation tool. This design has a better power handling capacity. Further, we have implemented this for the wireless sensor node as well.

KEYWORDS: WSN Antenna, Patch Antenna, Antenna Design, PCB antenna

I. INTRODUCTION

The antenna is a key constituent in a wireless communication system. The main objective of an antenna is to transform electrical signals into RF electromagnetic waves. The electromagnetic waves are then propagated into free space (transmit mode) and are transformed into electrical signals (receive mode). A characteristic antenna is basically an air core inductor of definite wavelength. The AC current through an inductor or conductor lags the voltage by approximately 90 degrees so the maximum power is delivered at ¼ wavelengths. If wavelength is λ then the λ/2 dipole produces most power at the ends of the antenna with little power in the center of the antenna. The other similar work with different geometry and application of antenna are cited in articles [1,4].

II. DESIGN THEORY

There are diverse types of antenna for the better output power, sensitivity and antenna gain. Reducing its frequency by a factor of 2 doubles its range (line of sight). Lowering the operating frequency also signifies that the antenna increases in size. When choosing the operating frequency for a radiodesign, the available board space must also accommodate the antenna. So the choice of antenna, and the size available should be considered at an early stage in the design.

\[ \lambda \text{ in meters} = \frac{2.99792458 \times 10^8 \text{ m/sec}}{f(\text{GHz})} \]

Moritz Von Jacobi’s maximum power theory states that maximum power transfer happens when the source resistance equals the load resistance. For complex impedances, the maximum power delivered from a transmission line with impedance \( Z_0 \) to an antenna with impedance is \( Z_a \). It is important that \( Z_0 \) is properly matched to \( Z_a \). If a signal with amplitude \( V_{IN} \) is sent in to the transmission line, then only apart of the incident wave will be transmitted to the antenna if \( Z_0 \) is not properly matched to \( Z_a \) then it is.

\[ Z_0 = Z_a^* \]

The complex reflection coefficient (Γ) is defined as the ratio of the reflected waves’ amplitude to the amplitude of the incident wave. Γ can be calculated from the impedance of the transmission line and the impedance of the antenna, as shown in the equation:
The reflection coefficient is zero if the transmission line impedance is the complex conjugate of the antenna impedance. Thus if \( Z_0 = Z_a ^* \) then the antenna is perfectly matched to the transmission line and all the applied power is delivered to the antenna. Antenna matching typically uses both; the Return Loss and the Voltage Standing Wave Ratio (VSWR) terminology. VSWR is the ratio of the maximum output (Input + \( \Gamma \)) to the minimum waveform (Input – \( \Gamma \)) shown in following equation. This means that a specific geometry can be made about half the size of a required patch (area of interest). Their input impedance levels have much the same dependence as that for the required patch. By selecting the required position to obtain as good a match as possible to with a connector and the VSWR bandwidth was computed. It can be seen that the bandwidth varies if there is change in patch size [2].

\[
VSWR = \frac{V_{\text{max}}}{V_{\text{min}}} = \frac{V_{\text{input}} + V_{\text{reflected}}}{V_{\text{input}} - V_{\text{reflected}}} = \frac{1 + |\Gamma|}{1 - |\Gamma|}
\]

The power ratio of the reflected wave to the incident wave is called Return Loss. This indicates as to by how many decibels is the reflected wave power below the incident wave return loss for the same port. It can be seen that a very good impedance match (\( |S_{11}| \) less than -20 db) is achieved for each desired level of miniaturization [3].

\[
S_{11} = 20 \log |\Gamma| = 20 \log \left( \frac{V_{\text{SWR}} - 1}{V_{\text{SWR}} + 1} \right)
\]

Antenna design, VSWR and Return Loss are measures with which we can find out how well the antenna functions. The mismatching of the antenna is one of the largest factors that reduce the total RF link budget. To avoid unnecessary mismatch losses, it is recommended to add a pi-matching network so that the antenna can always be matched. If the antenna design is adequately matched then it just takes one zero ohm resistor or DC block cap to be inserted into the \( \pi \)-matching network. There are a numerous issues to consider when selecting the antenna:

- Antenna placement
- Ground planes for \( \frac{3}{4} \) wavelength antennas
- Undesired magnetic fields on PCB
- Antenna mismatch (VSWR)
- Objects that alter or disrupt Line of Sight (LOS)
- Antenna gain characteristics
- Antenna bandwidth
- Antenna Radiation Efficiency

### III. Proposed Design Dimension

There are several antenna types to choose from while deciding what kind of antenna to be used in an RF product. Size, cost and performance are the most vital factors to be kept in mind at the time of choosing an antenna. The three most commonly used antenna types for short range devices are; PCB antennas, chip antennas and Segment antennas, all of which have their own pros and cons. Here, we have focused on PCB antenna since they are very cost effective, easy to implement and have better performance at more than 868 MHz. Also, a small size PCB antenna at high frequencies can be design as per the application requirement.

The antennas discussed in this paper are for the license frequency worldwide band 2.4000 GHz - 2.4900 GHz band and the all the standard frequency bands at sub 1 GHz. For the sub 1 GHz bands; there is usually a “low” sub 1 GHz band and a “high” sub 1 GHz band. Our ambition is to provide excellent antenna designs for our application with Omani directional radiation.
Total area covered by the antenna is shown in fig 1 and physical dimension on each strip of antenna are described in fig 2. Total length of track $c/c = (270+150x6+145) = 1645$ mils. The width of track is 20 mils and its spread area is 260x280. The length of $L_{tips} = 165$ mils (Segment D strip in fig 2), PCB thickness is 31 mils, Cap track (segment E) is 273 mils, The capacitance track below segment is 273 mils forthickness of PCB 0.08mm. This assembly can maintain the capacitance of around 0.22pF. The material used for the PCB is FR-4 epoxy glass which is laminated with HTE Copper of thickness of 0.0032 inches ± 10%. Aim of the proposed algorithm is to maximize the network life by minimizing the total transmission energy using energy efficient routes to transmit the packet. The proposed algorithm is consists of three main steps.

![Figure 1: Required patch area and layout](image1)

![Figure 2: Design dimensions for proposed geometry](image2)

After carrying out the design calculations of the proposed antenna we reach Fig 2, which consists of 16 segments. Thedimension details for creating this image in simulation software are given in the following table in geometrical absolute coordinate system.
Table 1: Feeding dimensions for simulation

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<td>Y1</td>
<td>Z1</td>
<td>X2</td>
<td>Y2</td>
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<td>T-h</td>
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<td>6*w+h</td>
<td>T</td>
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</table>

w=0.00143 m; T=0.007112 m; h=0.00381 m

IV. SIMULATION RESULTS

As an outcome of our data, we get the simulated antenna image similar to Fig 3. This antenna design falls in a dipole antenna category with loading effect. In this antenna feed is offset, but it is not a monopole structure unlike most of the antenna. It is wire base meander based antenna. In order to reduce the vertical height, we have applied the meander shape as loading. The power handling capacity will be up to +60dBm as shown in Fig 5.
focus. It shows impedance is 35 ohm. The co-polarize pattern is around -12dB down. The entire antenna factor is better the other tried samples and pattern.

![Figure 5 Result](image1)

![Figure 6 Result](image2)

This fig 5 shows the max gain is 1.6 dB in elevation plane the result obtained from the simulation tool which is based on SLOVER IS MOM. The fig 6 shows the Omni directional pattern which obtained in elevation plane. The pattern axis is shifted in H plane, which is due to loading.

V. IMPLEMENTATION RESULTS

After analyzing the result of above work we fabricated the same patch antenna on the PCB of the wireless sensor node* and got the result on lab successfully are going to test on real tile field soon along with the application need and required rules of communication. Due to the loading the impedance is modified from 73 ohm, the reactive part is too high to suppress the antenna efficiency the antenna factor is low. To match this specification impedance matching circuit is employed. The PCB layout of this antenna is shown in fig 7 and the impedance matching circuit is shown in fig 8. The values of the capacitance and inductance can be selected as per the actual impedance after fabrication of PCB and require gain.
From above result discussion we would like to state that the PCB base antenna is better cost effective solution for wireless sensor node for a typical application. It shows the better performance than inverted F antenna [1].

REFERENCES.


BIOGRAPHY

Sham Naysie is a Research Student of Dept of Computer Science of SantGadge Baba Amravati University, India. He received Batchelor and Master Degree in Electrical and Electronics from Govt. College of Engineering Amravati. He is working in IT industries and associate with engineering academic. His area of research is WSN and its effective deployments.

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