Beam Steering Monopole Antenna for Low Power Wireless Communication in WSN

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Abstract. Antenna for wireless sensor networks (WSN) application need to satisfy a number of additional properties like antenna efficiency. Since there are many WSN nodes, the use of low cost and high efficient antenna is highly important. Therefore, in this paper, a beam steering antenna resonate at 2.4 GHz with monopole element by using parasitic array technique is proposed. The parasitic array element is introduced to achieve a better gain and acts as a reflector to steer the beam to the desired degree of angles. The structure of the proposed design consists of monopole antenna as the radiating element, and to parasitic patches with the same dimension of monopole are placed next to the radiating patch. Two switches (PIN diode) are used and embedded at the back of the structure. By activating and deactivating of the switches (ON or OFF), the parasitic is either grounded or disconnected from ground. Consequently, depending on the switches configuration, the beam pattern can be steered two direction angles which ±25º left or right. The simulated and measured results are presented to demonstrate the performance of the proposed antenna.

1. Introduction

Nowadays, wireless networks are one of the most promising technologies that current been used in the industries and one of the technologies that always fits well with all the wireless network type is wireless sensor network (WSN). WSN are distributed system compromising of a number of nodes and each node consists of sensors, battery, microprocessor, radio chip and antenna [1]. There are several requirements in designing the antenna for WSN which are low cost, flexible, high efficiency and low power. In reliability aspect, there are challenges in making sure the system is sufficiently reliable and in the same time increase the lifetime of the sensor nodes.

However, high energy efficiency of WSN being a big problematic issue that leads to low performance of WSN [2], [3]. Life span of WSN decreasing when it is cannot consume enough power. The radiation signals of WSN’s antenna on sensor node become a waste of power because it radiated all directions not only toward the user [4]. Moreover, the power radiated in all directions will be having interference by other users. In order for the sensor nodes to consume enough power for the continuous life span, it needs to exchange the battery regularly which is really not practical and causing high cost. Not enough energy will also lead to sensor failure which is will reduce to low accuracy of the data. Improvisation of the data transfer on the sensor is said can be a solution to recover this problem. By using beam steering antenna, the direction of the beam can be changed to the desired position, making more effective communication link due to higher gain and interference reduction [5].

Therefore, the aim of the project is to design the beam steering antenna with monopole as a driven element and parasitic array technique for tilting. The switching of the beam pattern will be
accomplished by inserting two switches and manipulating the parasitic array which acts as a reflector of the designed antenna. The same concept of reconfigurability has been proposed in [6],[7], but this works focusing on using omni directional type of antenna as a driven element and less complexity.

2. Antenna design and reconfigurations.

The geometry of the monopole antenna with parasitic element is shown in Figure 1. This antenna is designed on FR-4 substrates with a dimension of 105mm x 90mm, height, h= 1.6mm and permittivity, $\varepsilon_r=4.3$. On the top of the substrate, the patch of the driven element ($L_p \times W_p$) and both parasitic elements are placed, and the partial ground plane (dimension of $k \times W_g$) is located at the back of the design. The dimension of feed line is $w_f \times L_f$ mm. The dimension of the driven and parasitic element is almost identical, and parasitic is positioned at a gap of $g_p$ from the driven. Patch and ground plane are made up by the copper which is the thickness, $t = 0.035$mm. Two PIN diode switches are placed in between the two shorting copper pin behind both parasitic elements and the ground plane. The shorting copper pin is inserted at the centre bottom of the parasitic patch. For the activation of the PIN diode, the antenna structure is modified and integrates with biasing circuit, includes biasing line, biasing cable and RF components. Three RF inductors with a value of 27 nH are placed as a bridge and provide blocking of the dc current to flow through dc biasing wire. The cathodes of the diodes are connected to the dc biasing wire (positive terminal), while the anodes are soldered to the partial ground plane (connected with negative terminal). The direction of the pattern is changed to the left or right depending on the switch configurations. When the switch is ON, one of the parasitic patches is grounded via shorting pin and switch, and acts as reflector to reflect the energy and pattern to the opposite side, and vice versa.

A photograph of the prototype antenna using PIN diode is shown in Figure 2. The dimensions of the proposed antenna are as follows (unit in millimeters): $L_p= 21.5, W_p= 31, k= 47, W_g= 105, w_f= 3, L_f= 48, g_p= 3, r_p= 13.6$. 

![Diagram](image-url)
3. Result and discussion

The preliminary works has been done by using ideal diodes for proof of the concept. Before the parasitic plane has been placed on the antenna, the antenna was design as monopole antenna with single patch and feed at the front and half ground plane at the back of the antenna. Figure 2(a) and (b) shows the simulated reflection coefficient result of the monopole antenna without and with parasitics, respectively.
Figure 3. Simulated S11 for the monopole antenna (a) without parasitics and (b) with parasitics.

The direction of the radiation pattern seems to be changed when the parasitic is just placed only on one side. First, the parasitic was placed on the right side of the patch and the result of the simulation shows the changes in the direction of the radiation pattern, as shown in Figure 4(a). It goes direct toward the left of the antenna, about 25° to the left. On the other hand, the direction of the pattern in steered on the opposite direction when the parasitic patch was placed on the left side, as demonstrates in Figure 4(b). When both of the diodes is either ON or OFF state, the ‘butterfly shaped’ pattern is achieved, as presented in Figure 4 (c) and (d). This type of shape is very important to indicate the function of parasitic in coupling the energy. The switching configuration with simulated tilt angle is summarized in Table 1.

Table 1. Switching configuration of proposed antenna

| State of the switch | Angle tilt (°) | Realized Gain (dBi) |
|---------------------|----------------|---------------------|
| Right (Switch 1)    | Left (Switch 2)|                     |
| ON                  | ON             | 0°                  | 1.23                |
| OFF                 | ON             | -25°                | 2.51                |
| ON                  | OFF            | +25°                | 2.41                |
Figure 4. Simulated of the beam steering antenna when (a) switch 1 is ON, (b) switch 2 is ON, (c) both switches are ON and (d) both switches are OFF

The fabricated antenna is then measured using the Rohde & Schwarz ZVL network analyzer (VNA) to measure the S – parameter of the antenna. Figure 5 shows the comparison results of simulation and measurement for all configurations. Based on this figure, it clearly can be seen that the measured antenna is slightly different with the simulated result. This is occurred maybe due to the fabrication tolerance that might affect the results. In addition, via copper used to connect the parasitic patch and the pin diode need to be embedded properly with exactly the same dimension of the simulation. However, due to the limitation of size of hole saw of the drill in our lab, the hole dimension is not exactly match with the size in the simulation. This will disturbs the dimension of the overall patch, and consequently affect the reflection coefficient result.
Figure 5. Reflection coefficient comparison of simulation and measurement result for (a) both switches OFF, (b) both switches ON, (c) right switch ON and (d) left switch ON

4. Conclusion
This paper proposed a design of beam steering antenna for low power wireless communication in WSN application. The beam steerable antenna is realized by using two PIN diodes. The parasitic array technique is applied on the proposed design, by placing two identical parasitic patches next to the radiating element. The antenna is successfully steering the beam with presence of the parasitic element. The direction of the beam pattern is capable to be changed in two directions which are in a degree of ±25°. The antenna is fabricated on the FR4 substrate and the simulation and measurement results is compared and analyzed.

5. References
[1] A. Kundu and S. Roy, “Performance of Smart Antennas in Wireless Sensor Networks,” Int. J. Comput. Appl., vol. 957–888, no. 1, pp. 3–6, 2012.
[2] E. Network, A. Computing, P. Putra, and M. Campus, “Power Consumption Optimization Analysis Based on Berkeley-Mac Protocol Using,” vol. 88, no. 2, pp. 295–302, 2016.
[3] M. Elshaikh, M. N. B. M. Warip, O. B. Lynn, R. B. Ahmad, P. Ehkan, F. F. Zakaria, and F. A. Fuad, “Energy consumption optimization with Ichi Taguchi method for Wireless Sensor Networks,” 2014 2nd Int. Conf. Electron. Des., pp. 493–498, 2014.
[4] L. Catarinucci, S. Guglielmi, L. Patrono, and L. Tarricone, “Switched-Beam Antenna for
Wireless Sensor Network Nodes,” *Prog. Electromagn. Res. C*, vol. 39, no. April, pp. 193–207, 2014.

[5] J. Ahn, K. Kim, Y. Yoon, and K. Hwang, “Pattern reconfigurable antenna for wireless sensor network system,” *Electron. Lett.*, vol. 48, no. 16, pp. 984–985, 2012.

[6] T. Sabapathy, M. F. Jamlos, R. B. Ahmad, M. Jusoh, M. I. Jais, and M. R. Kamarudin, “Electronically reconfigurable beam steering antenna using embedded RF PIN based parasitic arrays (ERPPA),” *Prog. Electromagn. Res.*, vol. 140, pp. 241–261, 2013.

[7] M. Jusoh, T. Sabapathy, M. F. Jamlus and M. R. Kamarudin,”Reconfigurable four-parasitic-element patch antenna for high beam switching application, *IEEE Antennas and Wireless Propagation Letters*, vol. 13, pp. 79-82, 2014.

**Acknowledgments**

The author would like to acknowledge the support from the Fundamental Research Grant Scheme (FRGS) under a grant number of 9003-00608 from the Ministry of Higher Education.