I and T-Shaped Printed Antennas for a Wireless Sensor Network Operating at 5.7 GHz

#Mazlina Esa, and Evizal
Faculty of Electrical Engineering, Universiti Teknologi Malaysia,
81310 UTM Skudai, Johor, Malaysia, mazlina.esa@ieee.org

1. Introduction

The wireless sensor network (WSN) is a combination of sensing, computation, and communication into a single tiny device [1], as depicted in Fig. 1. A sensor network consists of an array of numerous sensor networks of diverse types interconnected by a wireless communication network [2]. Sensor data is shared between these sensor nodes and used as input to a distributed estimation system. The system extracts relevant information from the available data. Fundamental design objectives of sensor networks include reliability, accuracy, flexibility, cost effectiveness, and ease of deployment. Each node has at least a sensor with an embedded processor, and low power radius. It acts as information source, sensing and collecting data samples from the environment. Node can also act as information sink, receiving dynamic configuration information from other nodes or external entities. The end portion of a node can be an antenna. A chosen configuration is the microstrip structure which allows for planar circuitry to be integrated with the WSN node.

WSNs use small, low-cost embedded devices for a wide range of applications. They do not rely on any pre-existing infrastructure. The WSNs need not communicate directly with the nearest high-power control tower or base station, but only with their local peers. Each sensor or actuator becomes part of the overall infrastructure. Peer-to-peer networking protocols allow mesh-like interconnect for transferring data between thousands tiny embedded devices in a multi-hop manner. The flexible mesh architectures envisioned dynamically adapt to support introduction of new nodes or expand to cover a larger geographic region. Additionally, the system can automatically adapt to compensate for node failures [1]-[3]. The concept of WSN is based on a simple block sensing. Potential applications include medical monitoring, vehicle monitoring, industrial, ship, security system and control system. Example applications are shown in Fig. 2.

2. Design of Printed WSN Antenna

Several related designed WSN antennas are available in references [4]-[9]. The design reported in this paper starts with the conventional rectangular microstrip patch antenna configuration operating at 5.7 GHz. Upon achieving good resonance, the rectangular patch is modified into two compact configurations of geometrical alphabetical shapes. Hence, the I-shaped, and T-shaped microstrip patch antennas are proposed for use in the WSN of industrial application. The modified configurations are obtained through systematical transformation, maintaining the surface area of the rectangular radiating element. The work is presented in detail in reference [10].

The geometry of the antenna is depicted in Fig. 3. The radiating element is of length L and width W. The board size is of length L_g and width W_g. The coaxial feeding technique is chosen. The computation of the geometrical parameters is described. The width is computed as [4], [6], [10]:

$$W = \frac{c}{f_0}\left(\sqrt{\frac{\varepsilon_r + 1}{2}}\right)^{-1} \qquad (1)$$

and the corresponding length of the patch is:

$$L = L_{eff} - 2\Delta l \qquad (2)$$

Using equation (1), W =17.78 mm. Then, the effective relative permittivity is computed, ie ε_{eff} = 3.0255. This gives ΔL = 0.722 mm. Next, L is computed as 13.69 mm using equation (2). Figs. 4 and 5 show the transformation from the rectangular geometry into I- and T-shaped configurations.

3. Performances of Rectangular, I- and T-Shaped Antennas

A conventional rectangular microstrip antenna designed on a single layer of dielectric susbtrate was first simulated as basis to the modified configurations. The simulated RL response in Fig 6(a) showed excellent return loss of -38 dB at 5.7 GHz. The bandwidth achieved is 200 MHz, however, an identical layer of dielectric is then added for bandwidth enhancement feature. Hence, a double layer is designed and simulated. The simulated RL response is shown in Fig 6(b). It can be inferred that the double layer basic rectangular antenna resonates well at the desired 5.7 GHz frequency of operation with excellent RL of approximately -37 dB. This indicates that minute reflection of signal exists at the input. The corresponding reflection coefficient and VSWR are 0.0147 and 0.129, respectively. The reflection bandwidth has increased from 178 MHz to amazing 3554 MHz of (7.445 GHz – 3.891 GHz or 3554 MHz) or 62.4 % that fulfills desired specification. Hence, adding the second layer of dielectric has improved the reflection bandwidth.

The first proposed antenna configuration is the I-shaped. The simulated RL is shown in Fig 7(a). It can be inferred that the antenna resonates well at the desired 5.7 GHz frequency of operation with sufficient RL of -10.83 dB at 5.8 GHz resonance. This indicates minute reflection of signal exists at the input. The reflection bandwidth is narrow (5.82 GHz – 5.76 GHz or 60 MHz) and agrees well with theory. Similar to the basic rectangular patch, a double layer I-shaped antenna is designed and simulated. The simulated result is depicted in Fig 7(b) with 3.4215 GHz reflection bandwidth and excellent RL = -33 dB at 5.7 GHz.

The second proposed antenna configuration is the T-shaped. Simulated RL response of the single layer T-shaped antenna is shown in Fig 8(a). It can be inferred that the single layer T-shaped antenna resonates well at the desired 5.7 GHz frequency of operation with good RL of -19.36 dB at 5.7 GHz resonance. This indicates minute reflection of signal exists at the input. However, the reflection bandwidth is narrow (5.74 GHz – 5.66 GHz or 80 MHz) and agrees well with theory. Similar to the I-shaped patch, a double layer T-shaped antenna has been designed and simulated for bandwidth enhancement feature. The performance is depicted in Fig 8(b). It can be seen that excellent RL = -34 dB at 5.7 GHz is obtained with 3.7589 GHz broad reflection bandwidth.

The corresponding radiation patterns of the double-layer I- and T-shaped antennas are depicted in Fig. 9. It can be seen that the double-layer I- antenna exhibits broad HPBW of 102.7^{o}. This is broader than the broad 67.7^{o} HPBW of the double-layer basic rectangular antenna, which agrees well with theory. However, the double-layer T-shaped antenna exhibits narrow HPBW of 23.6^{o}. This differs from previous designed antennas. This could probably due to the configuration itself.

4. Conclusions and Future Work

The paper presents the design of 5.7 GHz antennas suitable for WSN application. Three configurations of microstrip patch antennas have been designed and investigated. These are the basic rectangular, I-shaped, and T-shaped antennas. The design starts with a single layer dielectric. Due to bandwidth limitation, double layer of dielectric was employed for bandwidth enhancement feature. The basic rectangular antenna has dimensions of 17.78 mm x 13.69 mm. The single layer basic rectangular antenna was found to resonate well at the desired 5.7 GHz frequency of operation. It exhibits very narrow reflection bandwidth of 90 MHz. The double substrate layer employed enhanced the antenna bandwidth tremendously. It was found that all antennas operate well at 5.7 GHz with over 3 GHz broad reflection bandwidths. The T-shaped double layer antenna is the smallest in size and performs optimally.

Acknowledgments

The authors acknowledge the support of Universiti Teknologi Malaysia and Fundamental Research Grant Scheme Vote 78024, Ministry of Higher Education, Malaysia.

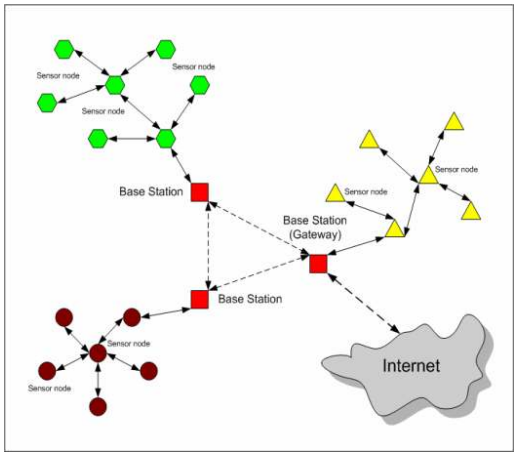


Fig 1. Basic concept of WSN [1]-[3].

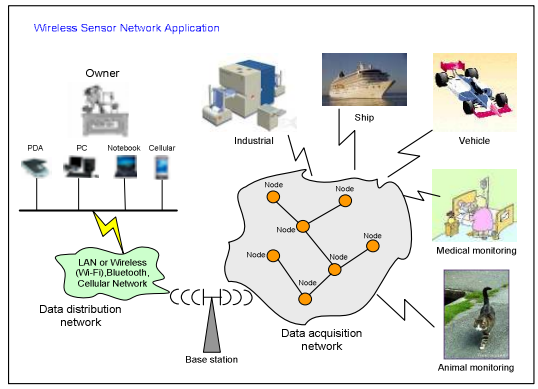


Fig 2. Application examples of WSN [1]-[3].

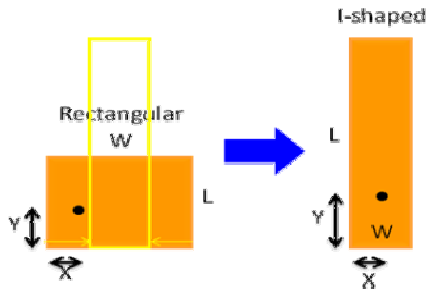


Fig 4. Transformation into I-shaped antenna.

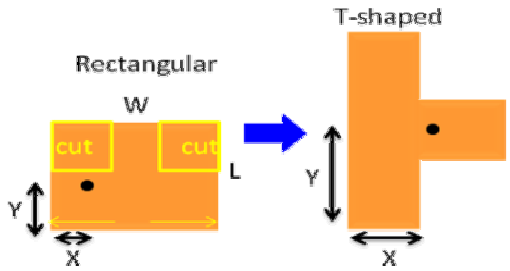
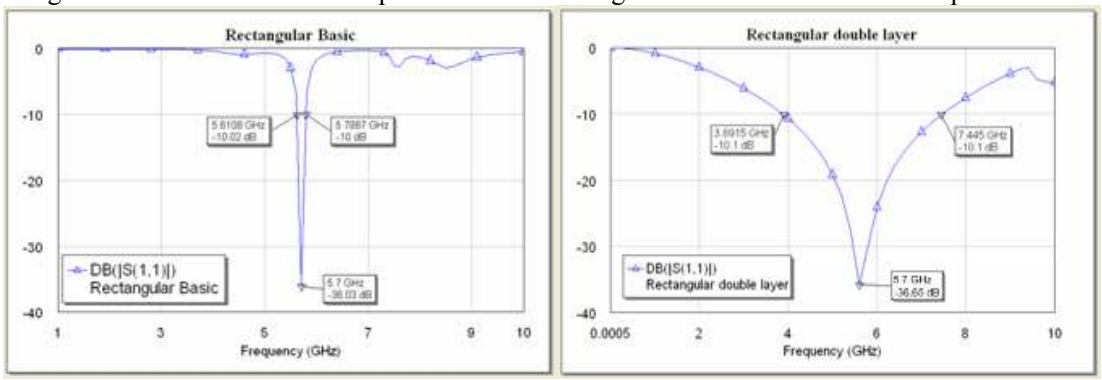
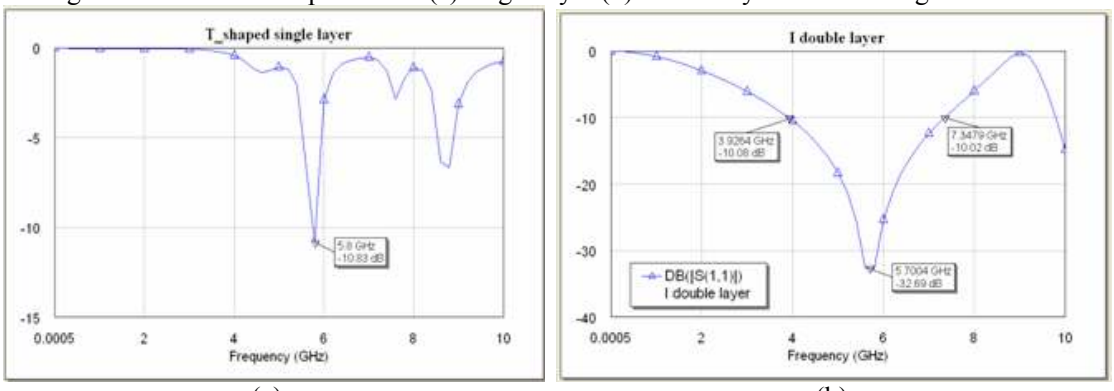


Fig 5. Transformation into T-shaped antenna.



(a) (b)

Fig 6. Simulated RL response of a (a) single layer (b) double layer basic rectangular antenna.



(a) (b)

Fig 7. Simulated RL response of (a) single layer (b) double layer I-shaped patch antenna.

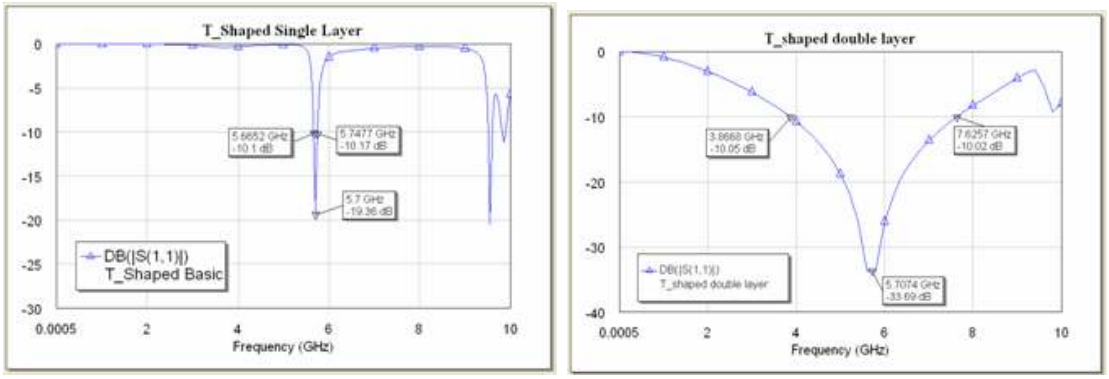


Fig 8. Simulated RL response of (a) single layer (b) double layer T-shaped patch antenna.

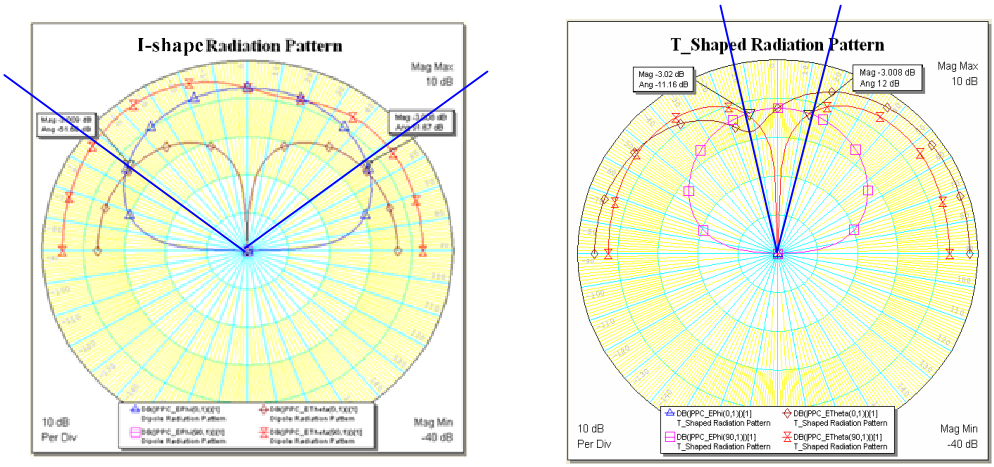


Fig 9. Simulated radiation patterns of double-layer I- and T-shaped antennas.

References

[1] Rajaravivarma, V., Yi Yang, Teng Yang, *"An overview of Wireless Sensor Network and applications,"* Proc. of the 35th Southeastern Symp. on System Theory, 16-18 March 2003, Page(s):432 – 436.

[2] Kim, Sang-Sik, Park, Ae-Soon, *"Mobility Support for Users in Wireless Sensor Networks,"* ISADS '07, Eighth Int. Symp. on Autonomous Decentralized Systems, 21-23 March 2007, Page(s):123 - 128.

[3] Li Zheng, *"ZigBee Wireless Sensor Network in Industrial Applications,"* SICE-ICASE, 2006. International Joint Conference 18-21 Oct. 2006, Page(s):1067 - 1070.

[4] Constantine, A. Balanis, *"Antenna Theory Analysis and Design,"* 3rd Edn, Wiley, 2005.

[5] Hong-Twu Chen, "*Experimental results of compact microstrip antennas,"* IEEE Antennas and Propagation Society Int. Symp., 1997 Dig. Vol. 2, 13-18 July 1997, Page(s):932 – 935.

[6] David M. Pozar, *"Microstrip Antennas,"* Proc. of the IEEE, Vol 80, No.1, January 1992.

[7] Zhang-Fa Liu, Pang-Shyan Kooi, Le-Wei Li, Mook-Seng Leong, and Tat-Soon Yeo, *"A method for designing broad-band microstrip antennas in multilayered planar structures, "*IEEE Trans. on Ant. and Propagat. Volume 47, Issue 9, Sept. 1999, Page(s):1416 – 1420.

[8] Duffy, S. M., "An enhanced bandwidth design technique for Electromagnetically coupled microstrip antennas," IEEE Trans. on Ant. and Propagat., Vol. 48, Iss. 2, Feb. 2000, Page(s):161 - 164.

[9] Deshmukh, A. A., and Kumar, G., *"Compact E and S-shaped microstrip antennas,"* Antennas and Propagat. Society Int. Symp., 2005 IEEE Vol. 3B, 3-8 July 2005, Page(s):389 - 392.

[10] Evizal, "Design of a 5.7 GHz for a Wireless Sensor Network", unpublished Master Thesis, Universiti Teknologi Malaysia, November 2007