A Dual Band Microstrip Patch Antenna for WLAN and WiMAX Applications

P. Krachodnok

Abstract**—**In this paper, the design of a multiple U-slotted microstrip patch antenna with frequency selective surface (FSS) as a superstrate for WLAN and WiMAX applications is presented. The proposed antenna is designed by using substrate FR4 having permittivity of 4.4 and air substrate. The characteristics of the antenna are designed and evaluated the performance of modelled antenna using CST Microwave studio. The proposed antenna dual resonant frequency has been achieved in the band of 2.37-2.55 GHz and 3.4-3.6 GHz. Because of the impact of FSS superstrate, it is found that the bandwidths have been improved from 6.12% to 7.35 % and 3.7% to 5.7% at resonant frequencies 2.45 GHz and 3.5 GHz, respectively. The maximum gain at the resonant frequency of 2.45 and 3.5 GHz are 9.3 and 11.33 dBi, respectively.

Keywords**—**Multi-Slotted Antenna, Microstrip Patch Antenna, Frequency Selective Surface, Artificial Magnetic Conduction.

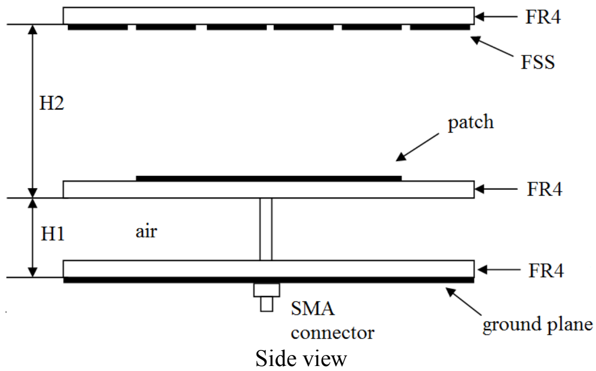
I. Introduction

THE patch antenna has inherent advantages of small size, low profile, lightweight, cost-effect, and its ease of integration with other circuits. It is very suitable for applications in wireless communication systems. For today's wireless communications, multi-band and wide-band patch antennas will become the requirements for accurately transmitting the voice, data, video, and multimedia information. However, the most serious problem of a patch antenna is its narrow bandwidth because a patch antenna on a dielectric substrate has surface wave losses. Therefore, the enhancement of the patch antenna bandwidth and frequency band has become an important issue in the antenna design field.

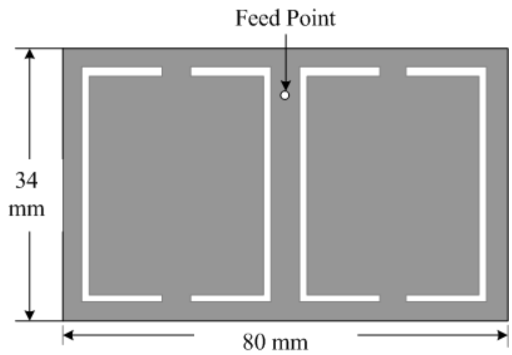
The frequency selective surface (FSS) structure has a phenomenon with high impedance surface that reflects the plane wave in-phase and suppresses surface wave. A patch antenna with one FSS structure can improve its radiation efficiency, bandwidth, and gain, moreover, the FSS reduces the side lobe and back lobe level in its radiation pattern. The FSS has been widely applied in antennas, filters, reflectors, polarizers, absorbers, propagation, and artificial magnetic conductors (AMC) for more than four decades [1]-[6]. Typical FSS geometries are designed by dipoles, rings, square loops, fractal shapes, etc. The transmission or reflection characteristic of a FSS depends on the shape, size, periodicity, and geometrical structure of FSS elements.

In this paper, the multiple U-slotted microstrip patch antenna on AMC is presented for enhancing gain. In addition, a dual-band FSS is used to study its impact on the bandwidths at operating frequency near 2.45 and 3.5 GHz. The frequency bands of 2.4-2.485 GHz and 3.4-3.6 GHz are regulated by IEEE 802.11b/g and 802.16a for WLAN and WiMAX applications, respectively. In simulations, the characteristics of the proposed antenna were obtained by using the CST software. Furthermore, the prototype of the proposed antenna is constructed and tested.

P. Krachodnok is with the School of Telecommunication Engineering, Suranaree University of Technology, Nakhonratchasima 30000, Thailand (e-mail: priam@sut.ac.th).



(a)



(b)

Fig. 1 (a) The proposed antenna geometry and (b) U-slotted patch antenna

II. Antenna Structure

The dual band antenna is shown in Fig. 1. This geometry consists of three main components, which are multi U-slotted patch antenna composed of a rectangular patch with four identical U-shape slots, FSS superstrate, and AMC ground plane and two alcove parts, a rectangular ground plane and air substrate. The thickness of the airsubstrate is adopted to be H1= 6 mm. A copper plate has dimensions of 120mm×120mm and thickness of 0.035 mm, where is used as the ground plane.

The patch is symmetrically designed and the feed point in the central line is 12 mm. The patch uses copper as material and the thickness of it is 0.035 mm. The dimensions of a U-slotted patch antenna are 120mm*120mmand the thickness of the substrate is 1.6mm.The four identical U-shape slots are placed symmetrically and the width of them is 2.5 mm. The dimensions of the rectangular multiple U-slot radiator patch are 80mm×34mm. The length and width of the U-slot are 28 mm and 11mm, respectively. In our studies a coaxial line with a characteristic impedance of 50 ohms is used as the feed of the U-slotted patch antenna. The inner conductor of the coaxial line is attached on the top patch going through the dielectric substrate, and the outer conductor is shorted to the metallic plate on the other side of the patch antenna. The FR4 material is used for the dielectric substrate with a thickness of 1.6 mm. The relative dielectric constant and electrical loss tangent of the substrate are 4.4 and 0.02 at frequencies 2 to 4 GHz. Fig. 1 (a) illustrates the geometry of the proposed patch antenna. The antenna has a very simple structure and thus it is easy to be manufactured. Fig. 1 (b) shows the novel shape and four U-shape slots, along with probe feeding, contributed to the enhanced performance of the antenna.

The AMC ground plane is designed by using FR4 material with a thickness of 3.2 mm, which the dielectric constant is 4.4 and the optimal value of parameters are W1=29.2 mm, W2=2.5 mm, W3=21mm. Fig. 2 (a) shows the AMC ground plane, which is placed on PEC. In addition, the FSS constructed with double square loops ring and one square loops elements as shown in Fig. 2 (b), which is used to improve the bandwidth and the gain of the U-slotted patch antenna. The thickness of the top metallic patch, the FSS, and the bottom metallic plate is 0.035 mm. Detail dimensions of the double square loops ring and one square loops element are P1=29.2 mm, P2=24.2 mm, P3=21 mm, P4=18 mm,P5=16 mm, and H2=30 mm. In optimizing the onsets of two resonant frequencies of 2.45 GHz and 3.5 GHz, the change of geometrical parameters P1, P2, P3, P4, P5 and H2 can be used to find the best bandwidth.

III. Results and Discussion

The simulated results are carried out by the help of CST Microwave Studio. The schematic diagram and return loss of the conventional antenna are illustrated in Fig. 3. This structure is designed by using double side 1.6 mm broad thickness FR4. In conventional antenna return loss found of about -29.62 dB at resonant frequency of 2.325 GHz and corresponding bandwidth of 27 MHz, it is narrow bandwidth. For the U-slotted patch antenna resonant frequency is 2.45 GHz with the return loss of -23.52 dB. The simulated 10 dB bandwidth is 40 MHz. Hence introduce multiple U-slot not only can enhance the antenna bandwidth but also improve the gain at the single frequency band.

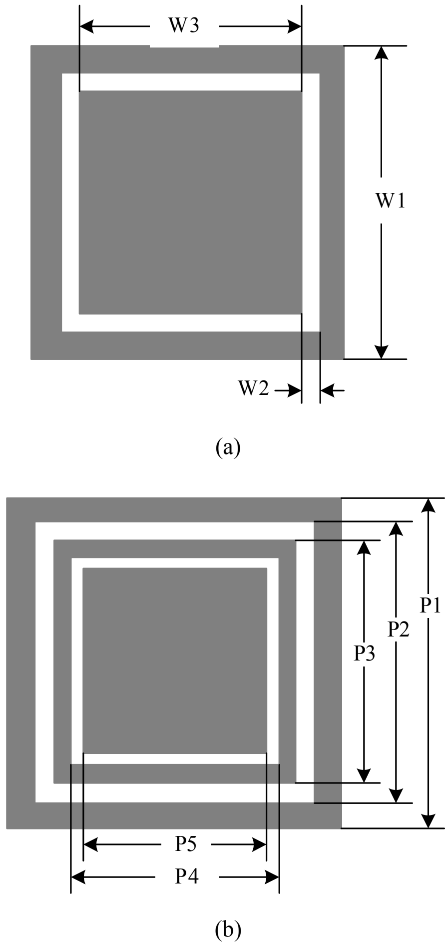


Fig. 2 (a) Unit cell of AMC Ground Plane and (b) unit cell of FSS superstrate

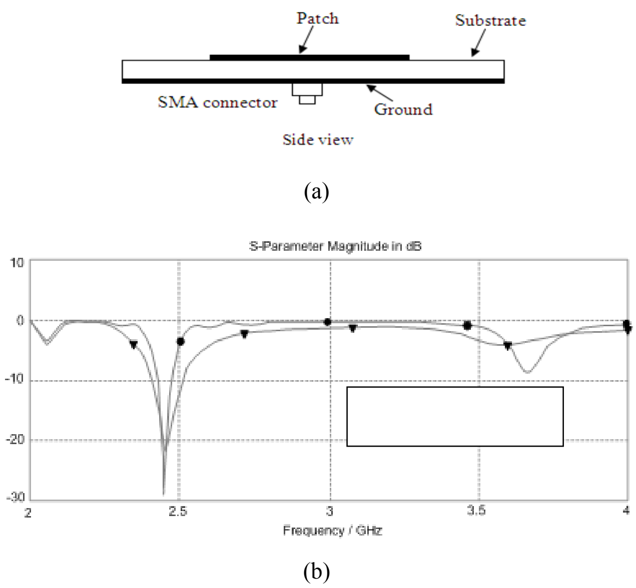
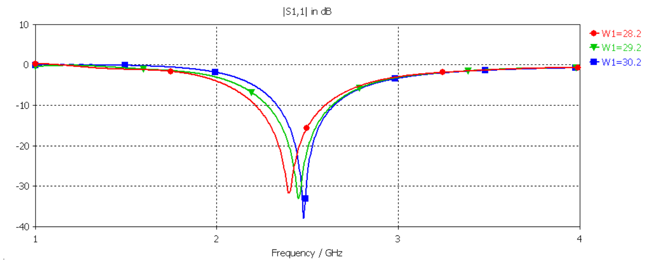
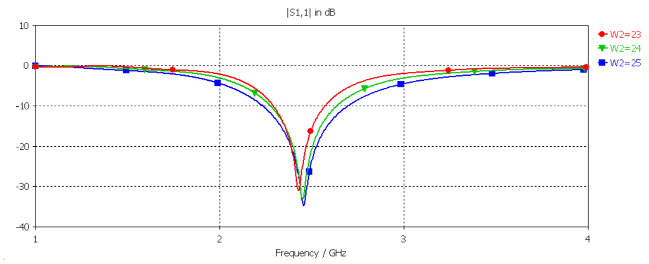


Fig. 3 (a) Schematic diagram and (b) return loss of the conventional microstrip patch antenna without air substrate

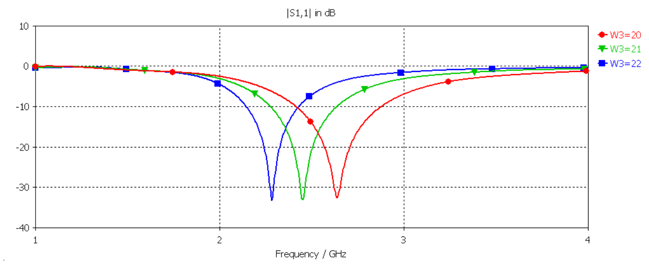
The AMC with high impedance surface characteristics has achieved development to support dual band antenna which make great advancements as ground plane in low-profile antenna. It has to enhance the radiated gain, in the meantime reducing the near-field coupling to the environment. In a proposed design, the resonant frequencies of the AMC composite for directivity enhancement are dominantly controlled by choosing the resonant length, W2 and W3, and the gap between the patch and AMC, H1, and can be tuned by the U-slot length and width of the patch. Next, we design a dual band FSS composite for the specified operating bands of a U-slotted patch antenna based on the knowledge of the characteristics of the unit cell, and then it are used as a superstrate for the U-slotted patch antenna to assess the level of improvement on its bandwidth. Figs. 4-6 show the simulated return loss of the AMC, dual band FSS, and dual band antenna without superstrate, respectively, the resonant frequencies are shifted away from the band due to the effect of its parameter. In Fig. 6, the H1 value has an effect on the frequency band number of the antenna.



(a)

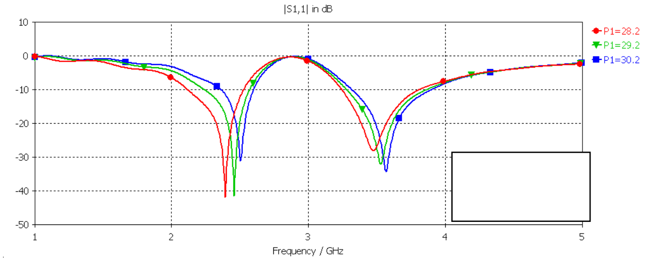


(b)

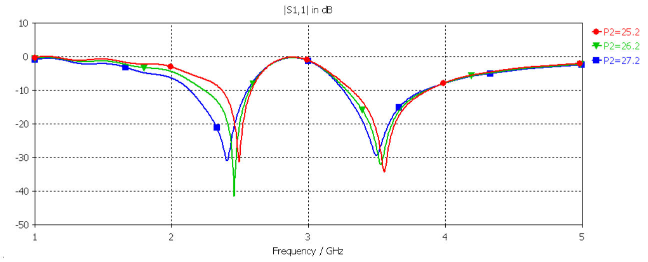


(c)

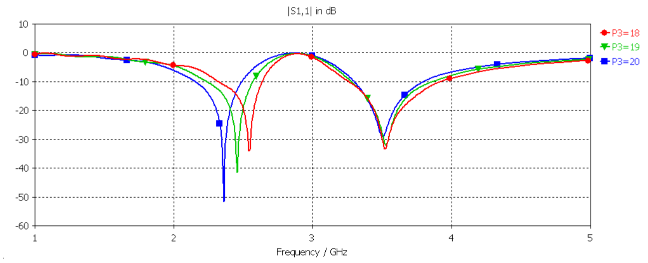
Fig. 4 Simulated return loss of AMC for varied value of W1, W2, and W3



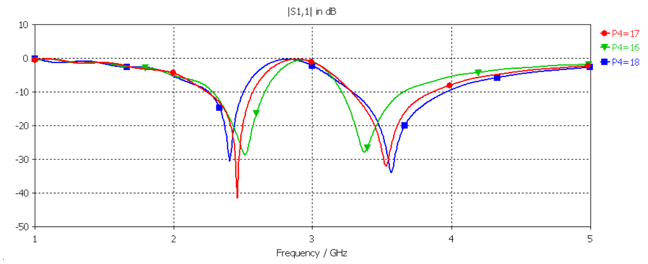
(a)



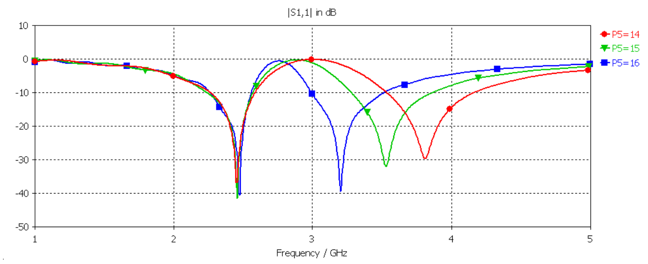
(b)



(c)



(d)



(e)

Fig. 5 Simulated return loss of FSS for varied value of P1, P2, P3, P4, and P5

The resonant frequencies for the U-slotted patch antenna implanted with and without a FSS consisting of double square loops ring and one square loops elements are found to be near 2.45 and 3.5 GHz for the impedance matching with better than -10 dB return loss as yielded in Fig. 7. From simulation results, it is found that the bandwidths have been improved near the operating frequencies of 2.45 and 3.5 GHz for the U-slot patch antenna implanted with a new FSS; however, the operating frequencies of 2.45 and 3.5 GHz of the U-slot patch antenna implanted without a FSS are not in the frequency bands of 2.4-2.485 and 3.4-3.6 GHz regulated by IEEE 802.11b/g and 802.11a.For further improvement on the performance of the U-slot patch antenna, a FSS consisting of new parameters in the double square loops ring and one square loops elements was proposed to improve the performance of the U-slot patch antenna. It is demonstrated that the FSS consisting of new parameters of the double square loops ring and one square loops can successfully be used to improve the bandwidths, gains, and onsets of operating frequencies for the U-slot patch antenna, respectively. After implanting the new FSS in the U-slot patch antenna, it is found that the bandwidths have been improved at resonant frequencies. We note that the input impedance does not seriously affect the performance of the FSS antenna at H2=30 mm and only the higher operating frequencies of the patch antenna slightly shift upward. The bandwidths have been improved when the thin FSS is placed above them.

In Fig. 8, the prototype antenna was fabricated from FR4 substrate with the same dimension parameters as we had explained previously. It is characterized in term of return loss, radiation pattern, and gain using HP8722D Network Analyzer, is perform in anechoic chamber. The simulated results compared with a measurement of prototype at resonant frequencies show in Figs. 9 and 10. This designed technique could be confirmed by a measurement results from prototype antenna that agree with simulation results.

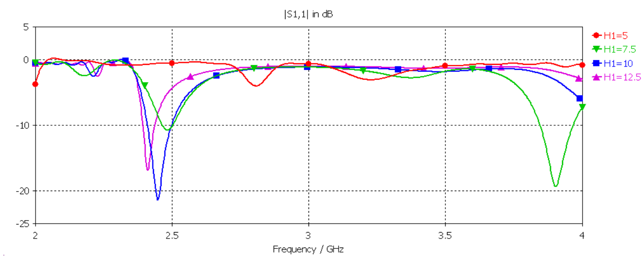


Fig. 6 Simulated return loss of dual band antenna with varied H1

Fig. 9 shows the simulated and the measured return loss of the proposed antenna at resonant frequency of 2.45 GHz and 3.5 GHz are -25.4 dB and -29.2 dB, respectively. The impedance bandwidth at -10 dB return loss is from 2.37 GHz to 2.55 GHz and 3.4 GHz to 3.6 GHz. It seems that the bandwidths have been improved from 6.12% to 7.35 % and 3.7% to 5.7% at resonant frequencies 2.45 and 3.5 GHz, respectively. Moreover, the radiation patterns at frequencies 2.45 and 3.5 GHz are acceptable as illustrated in Fig. 10. The maximum gain appears at 2.45 and 3.5 GHz are 9.3 and 11.33 dBi, respectively. The unidirectional radiation patterns could be obtained at dual frequencies and currents induced by external vertical linearly polarized electric fields.

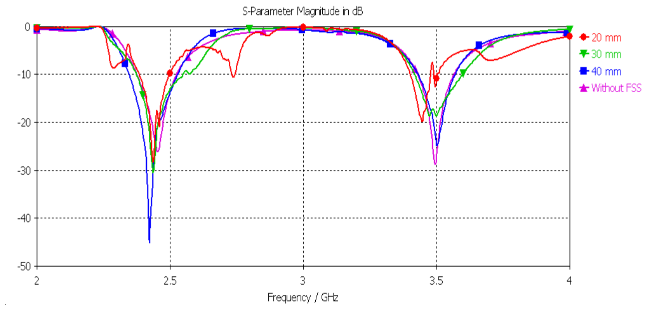


Fig. 7 The S_{11} of dual band antenna

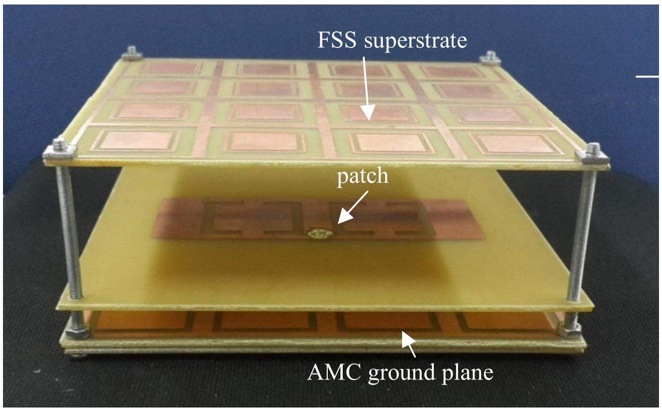


Fig. 8 The prototype antenna

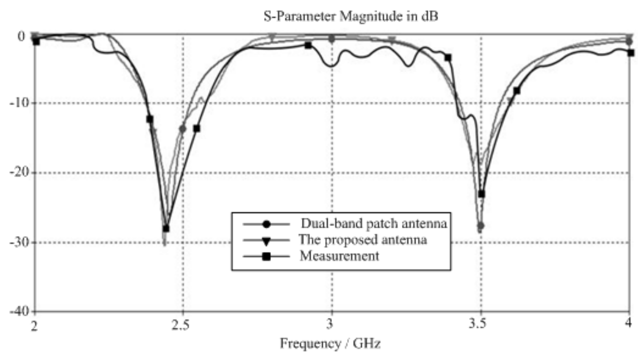
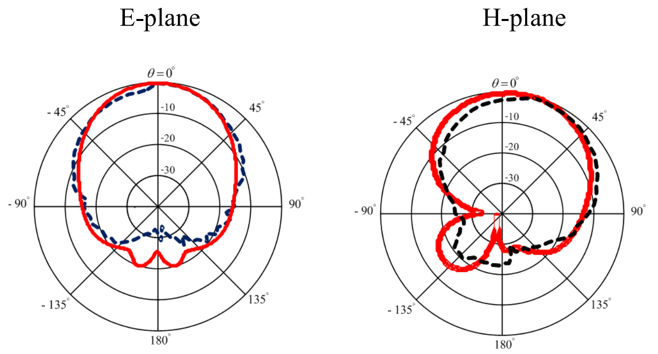


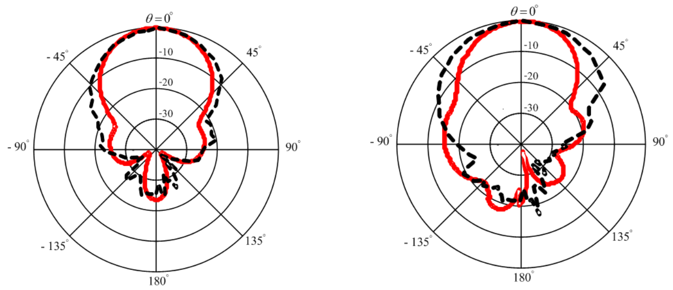
Fig. 9 Comparison of simulation and measurement return loss

IV. CONCLUSIONS

The high gain dual-band patch antenna on artificial magnetic conductors (AMC) ground planes is successfully designed for applications such as WLAN and WiMAX. The maximum gain at the resonant frequency of 2.45 and 3.5 GHz are 9.3 and 11.33 dBi, respectively. The impedance bandwidth at -10 dBi return loss is from 2.37 GHz to 2.55 GHz and 3.4 GHz to 3.6 GHz. It seems that the bandwidths have been improved from 6.12% to 7.35 % and 3.7% to 5.7% at the resonant frequencies of 2.45 and 3.5 GHz, respectively.



(a)



(b)

Fig. 10 Radiation patterns at (a) 2.45 GHz and (b) 3.5 GHz. (solid and dash line are the simulated and measured resulted, respectively)

ACKNOWLEDGMENT

This work was supported by Suranaree University of Technology (SUT) and by the Office of the Higher Education under NRU project of Thailand.

REFERENCES

[1] Dinesh Yadav, “L-Slotted Rectangular Microstrip Patch Anenna,” *Communication Systems and Network Technologies (CSNT)*, 3-5 June 2011, pp. 220 - 223
[2] Hsing-Yi Chen and Yu Tao, “Performance Improvement of a U-Slot Patch Antenna Using a Dual-Band Frequency Selective Surface With Modified Jerusalem Cross Elements,” *IEEE Trans. Antenna Propag,* Vol. 59, NO. 9, September 2011, pp. 3482-3486
[3] YongxingChe, XinyuHou, Peng Zhang, “Design of Multiple FSS Screens with Dissimilar Periodicities for Directivity Enhancement of A Dual-band Patch Antenna,”*Antennas Propagation and EM Theory (ISAPE),*29 November 2010-2 December 2010, pp. 319-322.
[4] JC Batchelor, E.A. Parker, B. Sanz-Izquierdo, J.-B. Robertson, I.T. Ekpo and A.G. Williamson, “Designing FSS for Wireless Propagation Control within Buildings,” *Antennas & Propagation Conference, LAPC 2009, Loughborough*, Vol. 39, No. 16-17 November 2009, pp. 14-17.
[5] Xiaoang Li, Chao Li, "Design of High Gain Multiple U-Slot Microstrip Patch Antenna for Wireless System," *Computational Problem-Solving (ICCP),* 3-5 December. 2010, pp. 256-259
[6] Y. Ranga , L. Matekovits , Karu P. Esselle and Andrew R. Weily , "Enhanced Gain UWB Slot Antenna with Multilayer Frequency-Selective Surface Reflector," *Antenna Technology (iWAT)*, 7-9 March 2011, pp. 176-179

Piyaporn Krachodnok graduated with the Bachelor Degree of Engineering in Telecommunication Engineering in 1996 from Suranaree University of Technology (SUT), Thailand, M.Eng. (Electrical Engineering), Chulalongkorn University, Bangkok, Thailand in 2001, and D.Eng.(Telecommunication Engineering), Suranaree University of Technology (SUT), Thailand in 2008 and had worked at this University for a year. Experiences & Expert are Electromagnetic Theory, Microwave Engineering, and Antenna Engineering.