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A Configuration of Ultra-Wideband Planar Antenna Comprises Band Suppression at 5~6 and 3.3~3.7GHz

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Abstract: Two-slits in a UWB planar antenna in the means of suppressing the frequency bandwidths for 5~6 and 3.3~3.7GHz are studied. Frequency bandwidths for 5~6 and 3.3~3.7GHz are known as the Wireless Local Area Network (WLAN) and Worldwide Interoperable for Microwave Access (WIMAX), respectively. Both are coexisted with the UWB frequency bandwidth that is allocated between 3.1 and 10.6GHz. Coexistence between these frequency bandwidths have potentially caused interferences such as signal disruption and data lost in the respective systems. Two-slits are etched in the conductor elements in the means of generating the notched-band characteristics by producing impedance mismatched in the proposed antenna. Band notching are generated for the frequency bandwidths 5~6G and 3.3~3.7GHz, respectively. Band notch peaks are desired to achieve higher than -5dB. Slits are etched in the elliptical element and ground plane for band notching at the frequency 5~6 and 3.3~3.7GHz, and optimized proposed antenna's peak of the reflection coefficient S_{11} are given -3 and -4dB, respectively. Slits parameters are studied in order to recognize the dominant parameters that affect the notched-band characteristics. It is shown that the two-slits have engendered the notched-band characteristics in the UWB planar antenna and slits parameters could be exploited in order to influence the notched-band characteristics accordingly.

Keywords: Ultra-wideband, band notching, WLAN, WIMAX

1. Introduction

Ultra Wideband (UWB) communication system is widely known for its advantages as discussed in [1]. Ultra Wideband (UWB) communication system comprises of a wide frequency bandwidth. The prominent advantage of UWB is significantly for its ability to carry large amounts of data in short pulses. The Federal Communication Commission (FCC) has established the UWB communication system since February 14th, 2002. UWB frequency bandwidth is allocated between 3.1 and 10.6 GHz. According to the FCC, UWB is defined as any radio frequency or a minimum of 500 MHz and that meets the power limits assigned by the FCC. Maximum output power allowed by the FCC regulation is 0.0001mW/MHz. UWB antennas are designed such as in rectangle, square, ellipse, circle, triangle, ring and many other shapes in order to meet certain design requirements in terms of polarization, bandwidth and gain. UWB communication systems are utilized in various engineering fields [1-2]. UWB has the capability to convey substantial media annals

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between handy apparatus, servers and kiosk. The devices such as media players, printers, external mass storage and real-time displays are the examples for the UWB applications. Products that utilized the UWB communication systems such as universal serial bus (USB) [3], sensor network and radar [4], vision systems, automobile radar coordination and transmission, and quantify systems [5], consumer and business data communication [6], and wireless body area network (WBAN) [7]. Detection and sensor are applied using UWB in CMOS, medical monitoring application, human body and pre-authentication in WIMAX application [8-12]. Instead of its ability in carrying large amount of data, UWB can be utilized in low data transfer in a long range communication [13].

The disadvantage of UWB communication system is when co-existed communication systems for Wireless Local Area Network (WLAN) and Worldwide Interoperability Microwave Access (WIMAX) have allocation in the UWB frequency bandwidth. Interferences occurrence between co-existed communication systems are unavoidable. Communication systems interference could have affects to the signaling or apparatus such as data loss, malfunction or buzzing sound [14-21].Thus, elimination between co-existed communications has become essential. Band rejection methods are studied and proposed in [22-28]. Band notch characteristics can be realized by parasitic element, complimentary split ring resonator (CSRR), electromagnetic band-gap (EBG), tuning stub and conductor element etching. Generally, the band notching methods are used in the means of achieving the impedance mismatched in the proposed antennas. Usually, the parasitic element, tuning stub and CSRR are designed located in the radiator element. EBG is designed usually very close to the strip line in the means of interrupting with the strip line current distribution. Etching in the conductor element used shapes such as alphabetical and structures in the means of generating impedance mismatched in the conductor element. Method to realize band notch in an antenna design could increase the complication and size. Etching method used for band notching are considered simple, low profile and compact. Most etching designs are considered as complicated and increase calculation time. Simple design and low profile is most desired in an application. Thus, a simple and novel single slit is designed for simplicity to generate a band notching.

UWB planar antenna with two-slits in the conductor elements to suppress the frequency bandwidths for 5~6 and 3.3~3.7GHz are presented. Dual slits are etched in the elliptical-shaped radiator and ground plane. A single band notch is realized by each slit by generating impedance mismatched in the elliptical element and ground plane. Slits are designed in horizontal considering the surface current distribution is vertically polarized. Thus, it is considered that the surface current polarity is disrupt by the slits and eventually impedance mismatched is realized in the proposed antenna. A solitary slit is carved in the elliptical-shaped element and the ground element is utilized to characterize the notched band between 5 to 6 GHz and 3.3 to 3.7 GHz, respectively. Thus, co-existed communication system that is WLAN and WIMAX is eliminated from the UWB frequency bandwidth. Reference and UWB planar antenna comprises two-slits in the conductor elements are discussed in section 2. Result and summary of the reference and the UWB planar antenna comprises two-slits in the conductor elements are described in section 3 and 4, consecutively. Parametric study for the slit parameters are presented in section 3.2. Slit parameters such as length l, width w and slope angle θ are modified and the band notch characteristics are compared. The comparisons are investigated in the means of determining the correlation between band notch characteristics such as center frequency f_c, frequency bandwidth f_{bw} and peak of reflection coefficient S_{11} with the slit parameters and are described in section 3.2.1, 3.2.2 and 3.2.3, consecutively.

2. Structure for the UWB Planar Antenna Comprises Two-Slits in the Conductor Elements

The reference and UWB planar antenna comprises two-slits in the conductor elements are depicted in Fig. 1. Dielectric substrate FR-4 is used for the reference antenna. Substrate permittivity ε_r and the electric tangent delta δ is 4.4 and 0.019, respectively. Elliptical and the ground elements are placed in the single sided of the substrate. Length and width of the substrate is $L_d + L_g$ and W_g, respectively. Minor and major radius of the elliptical part and length of the ground plane are L_1, L_2 and L_g, correspondingly. Feed point is soldered in the centre edge of the elliptical-shaped radiator at the lowest part. Space between the ground plane and the elliptical-shaped radiator is given as, F. Variables of the reference antenna and slits are tabulated in Table 1.

Table I - Variables for reference antenna and slits

Parameter	Dimension (mm)
L_d	21
L_g	24
W_g	21
L_1	16
L_2	12.8
h_s	0.76
h_c	0.035
F	0.4
l_1	8.3
θ_1	0°

w_1	0.13
l_2	12.3
θ_2	52°
w_2	0.5

Conductor elements are placed one-sided on the substrate of the FR-4 with half-ground plane. Slits are horizontally located in the conductor elements. Slit structures are outlined in Fig. 2. Slit for the elliptical-shaped radiator and the ground part are placed in horizontal with the slanting slope θ_1 and θ_2, respectively. The maximum reflection coefficient S_{11} is determined by the slits slope angle, θ. Slit slope angle θ is considered to interrupts vertically polarized surface current distribution. UWB frequency bandwidth is achieved by adjusting the radiuses of the elliptical-shaped radiator L_1, L_2 and the feed gap F. Eccentricity e of the elliptical element is described in Equation (1).

$$e = \sqrt{1 - \frac{L_2^2}{L_1^2}} \qquad (1)$$

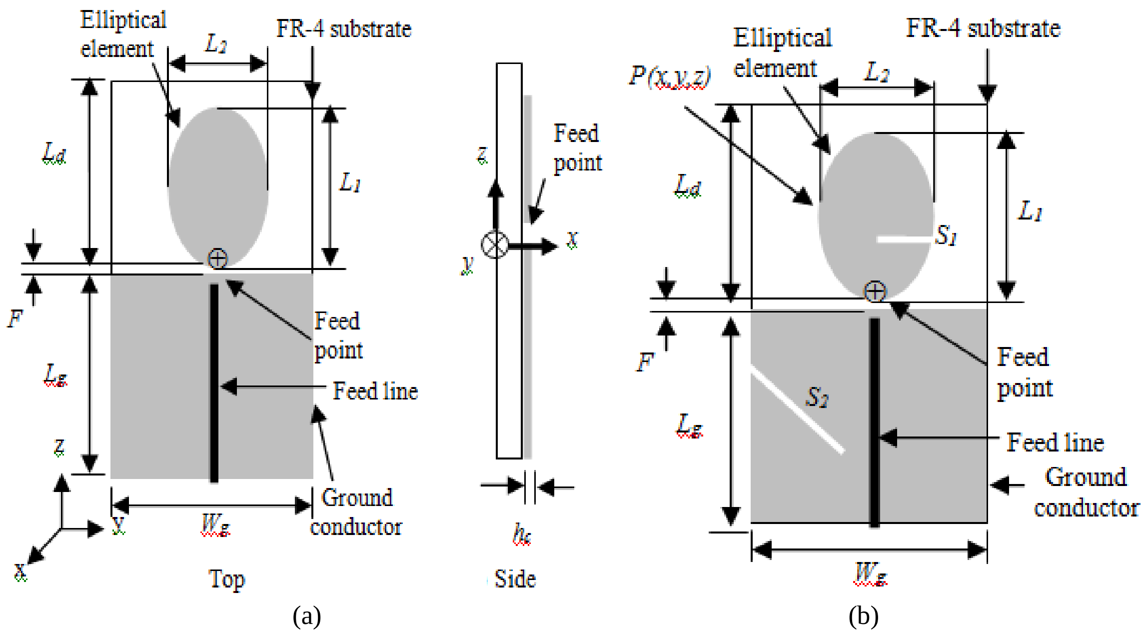


Fig. 1 – (a) reference; (b) UWB planar antenna comprises two-slits in the conductor elements

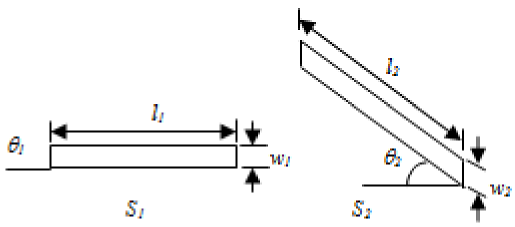


Fig. 2 – Two-slits formations (a) S_1 ; (b) S_2

3. Antenna Performances for Reference and UWB Planar Antenna Comprises Two-Slits in the Conductor Elements

Antenna performances for the reference and UWB planar antenna comprises two-slits in the conductor elements are simulated from 3 to 11GHz within an open boundary condition with 0.0001 Convolution Perfect Match Layer to minimize the reflection. Simulation is carried out in the Computer Simulation Software (CST) using the Microwave module by Transient solver analysis. Simulated and measured results for the reference and UWB planar antenna with two-slits are evaluated. It is implored that the disparity between the reference and UWB planar antenna with two-slit performances are negligible. Hence, it is regarded as the two-slit are not affected the distinctive antenna performances. Performances for the reference and UWB planar antenna with notched band are described for reflection coefficient S_{11}, surface current distribution, gain *G*, and radiation efficiency e_{ff} in section 3.1, 3.2, 3.3 and 3.4, consecutively. Slit S_1 and S_2 parametric study are conferred in section 3.5, respectively.

3.1 Reflection Coefficient S_{11}

Reference antenna has generated the frequency bandwidth between 3 and 11 GHz. Reflection coefficients S_{11} for the eccentricity *e* and measured result for reference antennas are depicted in Fig. 3 and 4, consecutively. The reflection coefficient S_{11} is higher in the lower and high frequency region for eccentricity $e=0$. UWB frequency bandwidth is not satisfied for eccentricity $e=0.9$. Thus, UWB is reasonably achieved for eccentricity $e=0.6$. The results are reasonable. Reference antenna has determined for $e=0.6$ and $F=0.4$, respectively. Simulated finalized reflection coefficient S_{11} for the reference and UWB planar antenna comprises two-slit in the conductor part is represented in Fig. 5.

Notched band between the frequency 3.3 ~ 3.7GHz and 5 ~ 6GHz were determined above the level -10dB which emphasized that below this level, is the operating frequency of an antenna. Simulated and measured reflection coefficient S_{11} are operated below -10dB level and has satisfied the UWB frequency bandwidth allocation spectrum of which the operating frequency is between 3.1~10.6GHz. The result agrees well. Band notch characteristics are duality and band notches are located between the frequency 3.3~3.7 and 5~6GHz. The centre frequency f_c for the band notch between 3.3~3.7 and 5~6GHz is 3.5 and 5.5GHz. The maximum reflection coefficient S_{max} is *-4* and -3.4 dB with frequency bandwidth given as 0.3 and 1 GHz, respectively.

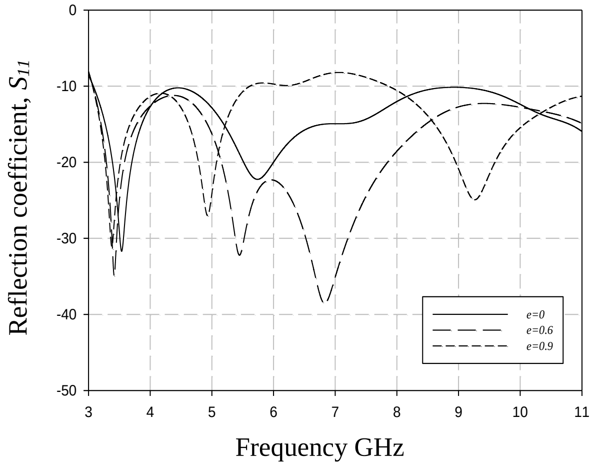


Fig. 3 - Reflection coefficient for eccentricity *e*

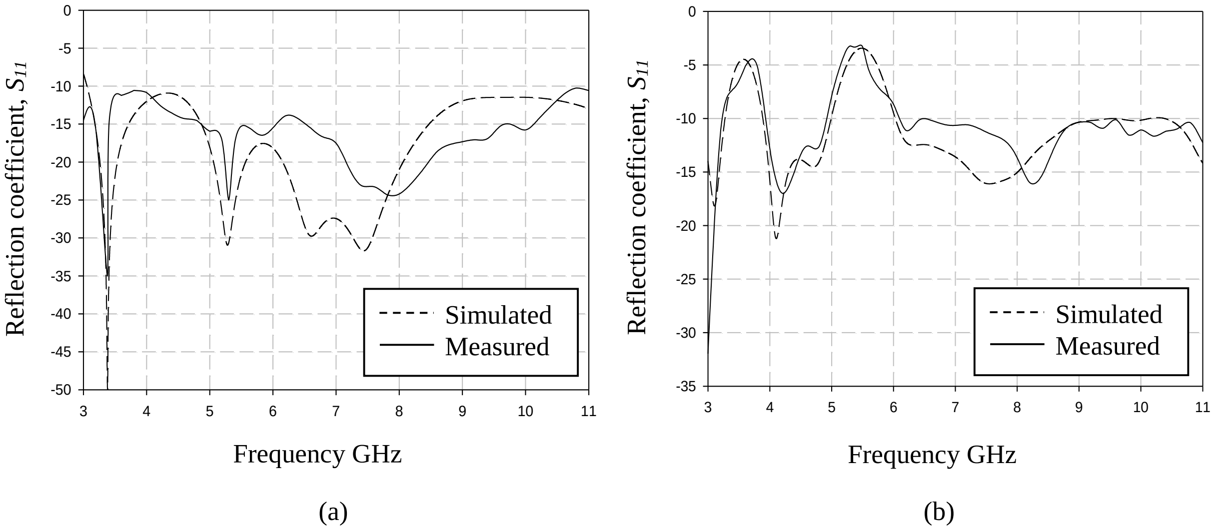


Fig. 4 – Measured reflection coefficient S_{11} for (a) reference antenna; (b) UWB planar antenna comprises two-slits in the conductor elements

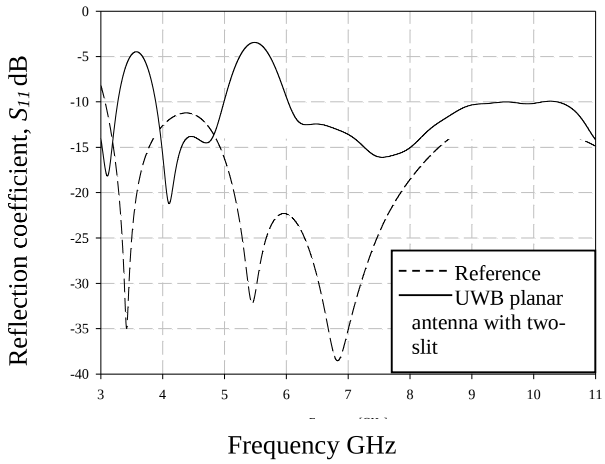


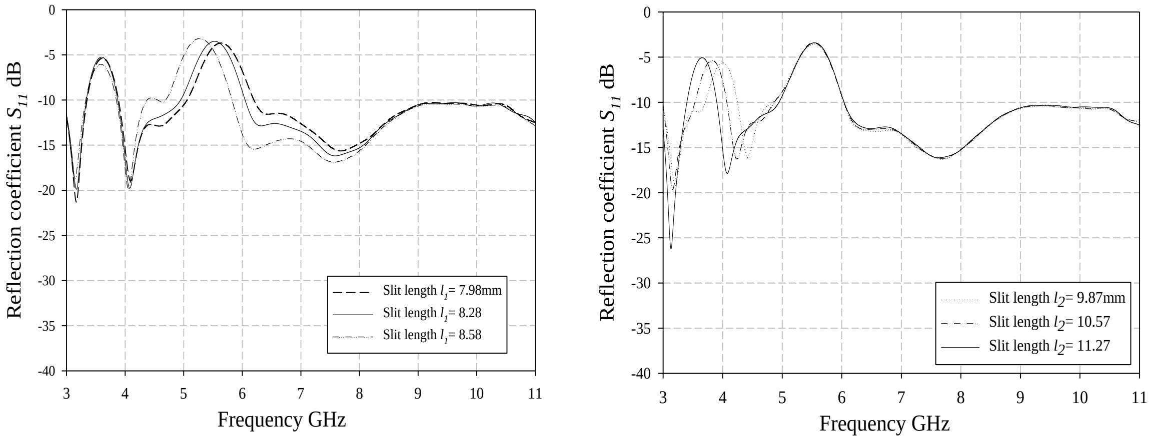
Fig. 5 – Simulated reference and UWB planar antenna comprises two-slits in the conductor elements

3.2 Two-Slits Parametric Studies

Slit parameters are categorized for slit length *l*, width *w* and slope angle θ. Slit lengths in the elliptical and ground parts are acknowledged as slit length l_1 and $l_{2.}$, correspondingly. Slit widths and slope angles in the elliptical and ground parts are identified as w_1, w_2, θ_1, and θ_2, respectively. Slit S_1 is located in the elliptical part which has engendered the suppression between 5~6GHz and characterized by the parameters l_1, w_1 and θ_1. Slit S_2 is placed in the ground plane that has generated band notch between 3.3~3.7GHz and described by the parameters l_2, w_2 and θ_2. Slit parameters are considered in the means of investigating its influence to the band notch characteristics, accordingly. Dominant slit parameter that could be used to affect the band notch characteristics are identified and manipulated in the means of achieving the desired band notch characteristics. Furthermore, slit parameters that influenced the band notch characteristics significantly could be modified in the means to control the band notch characteristic. Correlation between slit parameters, length *l*, width *w* and slope angle θ, that significantly affects the band notch frequency bandwidth f_{bw}, center frequency f_c and peak of reflection coefficient S_{max} could be determined. Hence, covet band notch is possible to exemplified consequently. Band notch characteristics are categorized as centre frequency f_c, frequency bandwidth f_{bw} and reflection coefficient peak value S_{max}. Band notch features that are influenced by the slit variables length *l*, width *w*, and slope angle θ are discussed in sub-section 3.3.1, 3.3.2 and 3.3.3, consecutively.

3.2.1 Slit Length l_1 and l_2

Reflection coefficient S_{11} for UWB planar antenna comprises two-slits that are corresponded to slit length l_1 and l_2 alterations are portrait in Fig. 6(a) and (b), respectively. Slit length l_1 and l_2 are prolonged gradually for 0.3 and 0.7mm, respectively. The values are preferred as the reflection coefficient S_{11} has presented substantial transformations. Band notch centre frequency f_c, are relocated in the lower frequency region for prolonged length of slit l_1 and l_2. Band notch frequency bandwidths f_{bw} are approximately unaffected when slit length l_1 and l_2 are altered. Band notch peak values S_{max} are considerably amplified for prolonged slit length l_1 and l_2. Band notch characteristic for frequency bandwidth between 3.3 and 3.7GHz is considerably unchanged when slit length l_1 is altered and otherwise.

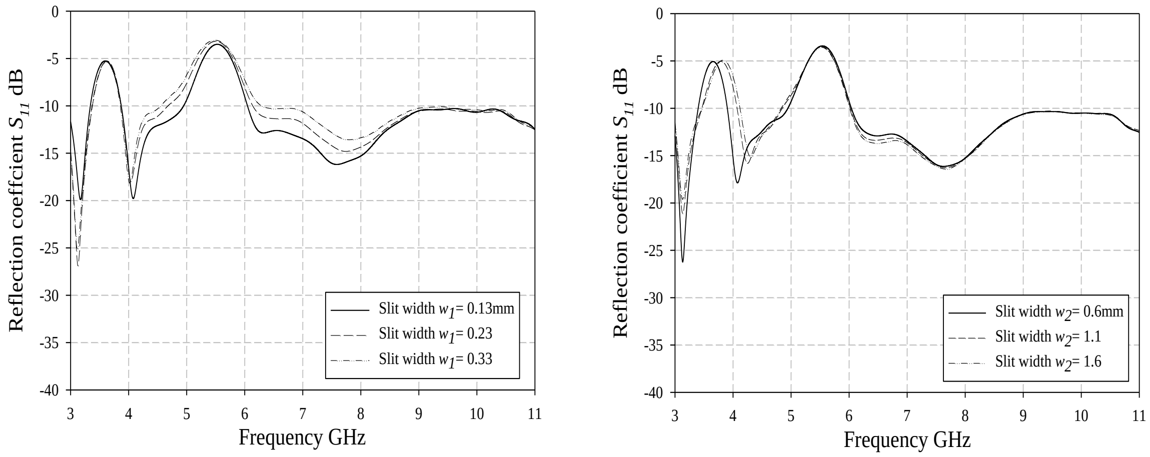


(a) (b)

Fig. 6 – Reflection coefficient S_{11} correspond to slit length (a) l_1 ; (b) l_2

3.2.2 Slit Width w_1 and w_2

Slit width w_1 and w_2 are amended and the band notch features are illustrated in Fig. 7(a) and (b), correspondingly. Slit width w_1 and w_2 are expanded for 0.1 and 0.5mm, correspondingly. Band notch frequency bandwidth f_{bw}, are generally affected by the alteration of slit width w_1 and w_2 whereas centre frequency f_c and band notch peak value S_{max} are trivially affected. Band notch frequency bandwidth f_{bw} are broadening for wider slit width w_1 and w_2. Centre frequency f_c is relocated in the lower and higher frequency region for broader slit width w_1 and w_2, respectively. The band notch peak value S_{max}, are slightly unaffected for slit width w_1 and w_2 alterations. Band notch characteristic for the frequency bandwidth 5~6 and 3.3~3.7GHz are merely determined due to the adjustment of the certain slit S_1 or S_2.

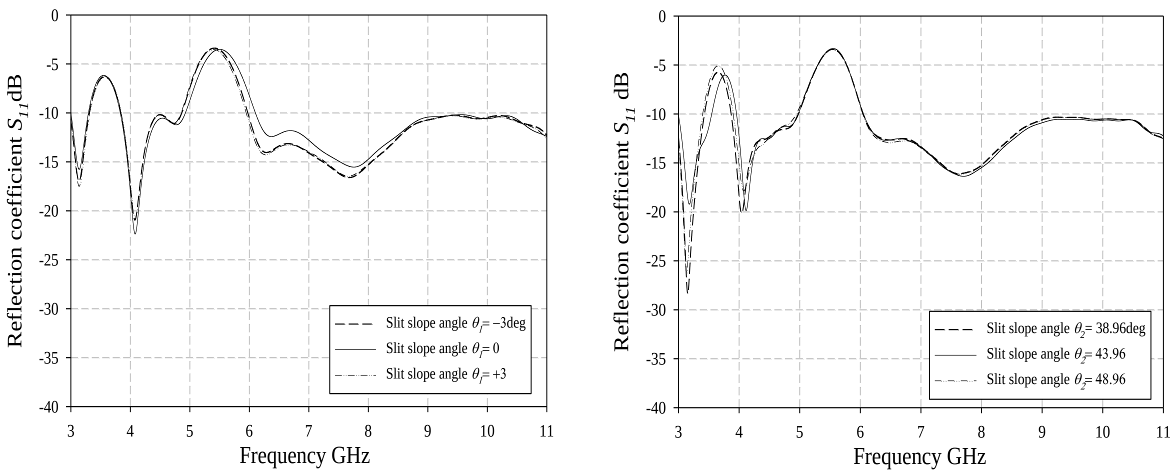


(a) (b)

Fig. 7 – Reflection coefficient correspond to slit width (a) w_1 ; (b) w_2

3.2.3 Slit Slope angle θ_1 and θ_2

Slit slope angle θ_1 are regulated for ± 3 degree from the origin and θ_2 is proportionally + 5 degree. Band notch characteristic due to slit slope angle θ_1 and θ_2 are depicted in Fig. 8(a) and (b), respectively. Band notch centre frequency f_c and frequency bandwidth f_{bw} are slightly changed by the alteration of slit width w_2. Band notch peak is generally affected by the slit width w_2 alteration. Band notch peak between the frequency bandwidth 3.3~3.7GHz is higher for deepen slanting angle θ_2. Slit slope angle θ_1 is altered from the origin in the elliptical element. Hence, it is considered that the band notch characteristics for slit slope angle θ_1 for ± 3 degree are duplicated. Nevertheless, band notch frequency bandwidth f_{bw} for slit slope angle θ_1, when 0 degree is somewhat bigger than when it is set for θ_1 for ± 3 degree.



(a) (b)

Fig. 8 – Reflection coefficient S_{11} correspond to slit slope angle (a) θ_1 ; (b) θ_2

3.3 Surface Current Dispersions

Surface current dispersions for the frequency *f=3.5, 5.5* and *9.5*GHz are presented in Fig. 9. Surface currents are saturated in the feed point and the edges of ground plane for low and middle frequency region for the reference antenna. However, surface current is distributed in the feed point, and the edges of the elliptical element and ground plane for higher frequency region. Thus, slits are positioned in elliptical and the ground part to cause the impedance mismatched and consequently initiated the notched band between the covet frequencies. Surface current saturations are in symmetric because of the symmetric feature of reference antenna. Saturation of surface current in the conductor planes for the UWB planar antenna with two-slit is observed in Fig. 9(b). Slit in the conductor planes are etched to realize the band notch frequency bandwidths between 5~6 and 3.3~3.7 GHz. Surface current is saturated in slit at the centre frequency of *f*=3.5, 5.5 GHz, respectively. Impedance mismatched has occurred by the slits in the conductor planes.

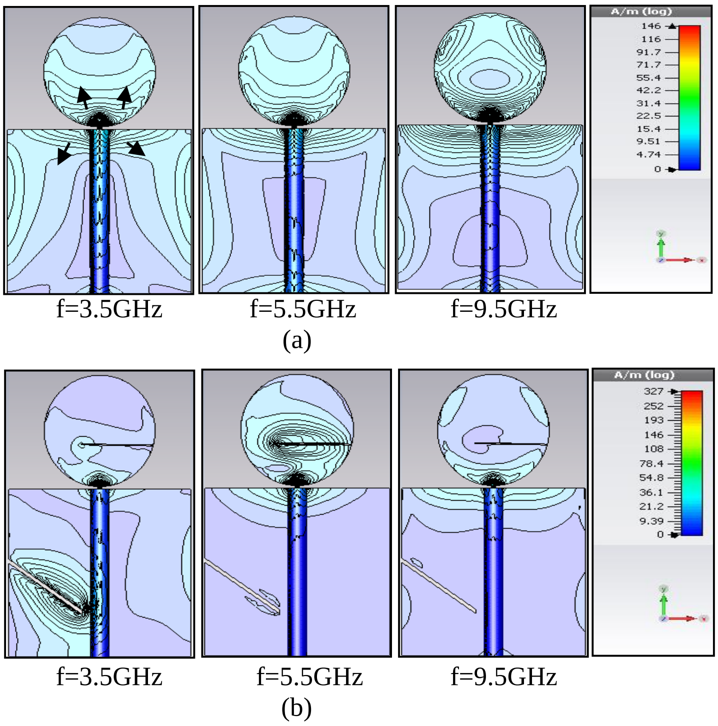
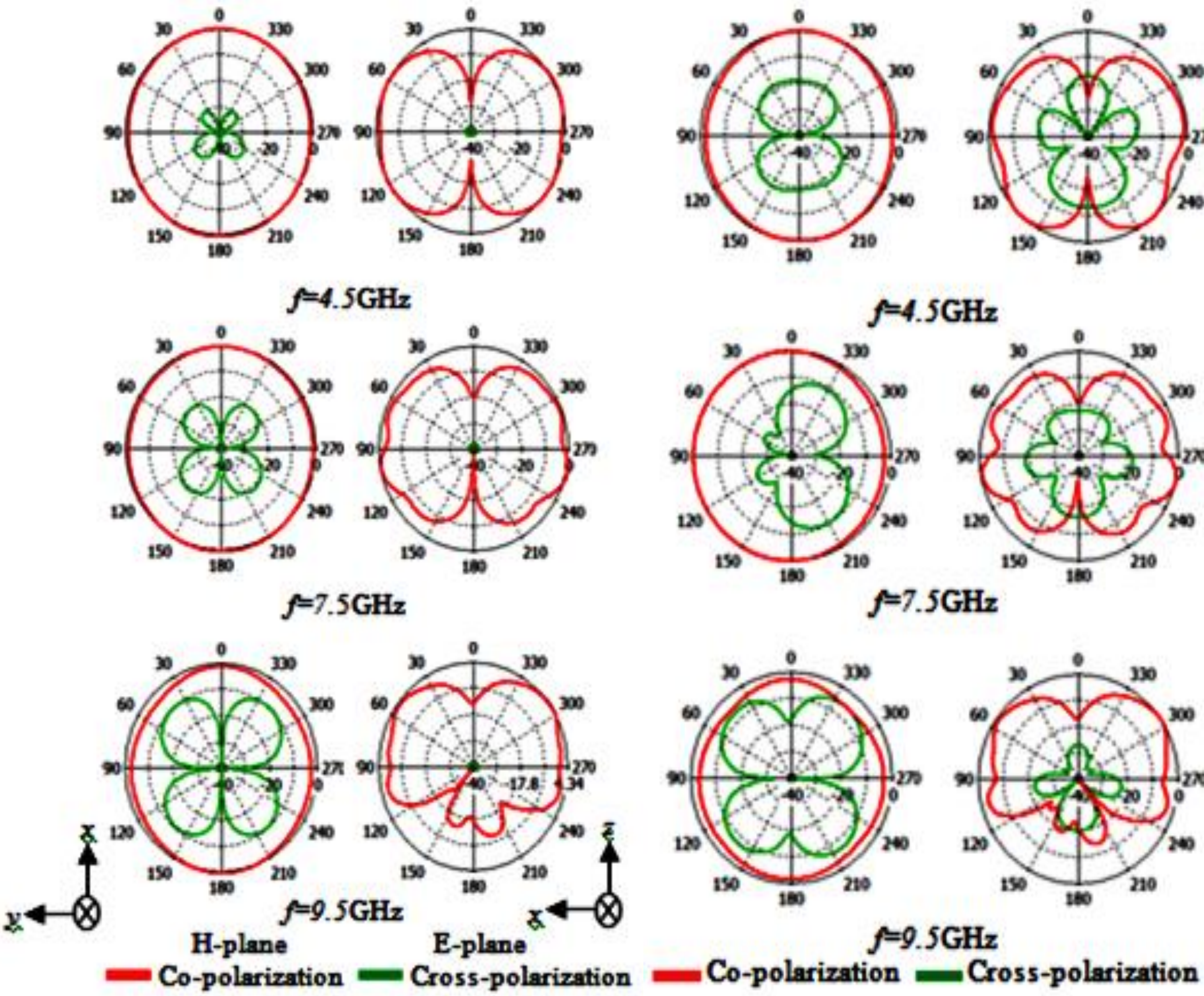


Fig. 9 Surface current distribution for (a) reference antenna;
(b) UWB planar antenna comprises two-slits in the conductor elements

3.4 Radiation Patterns

Simulated co- and cross-polarization, and measured radiation pattern for the reference antenna at the frequency *f=4.5, 7.5* and *9.5*GHz are characterized in Fig. 10(a) and 11(a), accordingly. Co-polarizations are portrayed in omni-directional in H- and bi-directional and E-plane, respectively which takes the characteristic of monopole antenna. Cross-polarization in the E-plane is very small and negligible. The maximum gain for the frequency of interest is at frequency *f=9.5*GHz in the E-plane. The direction is in +*z*-axis. The maximum gain is $G_{max}=4.28$ dB. The simulated and measured results are reasonable. Measured radiation patterns for the UWB planar antenna with two-slit are presented in Fig. 10(b) and 11(b), respectively and compared with the simulation. Co-polarizations of the reference and UWB planar antenna comprise two-slits are in omni-directional. Cross-polarizations for the H- and E-plane of the UWB planar antenna comprises two-slits in the conductor elements are slightly bigger than the reference antenna. Slits in the conductor planes are deliberated to increase the cross-polarizations.



(a) (b)

Fig. 10 – Simulated radiation patterns for (a) reference; (b) UWB planar antenna comprises two-slits in the conductor elements

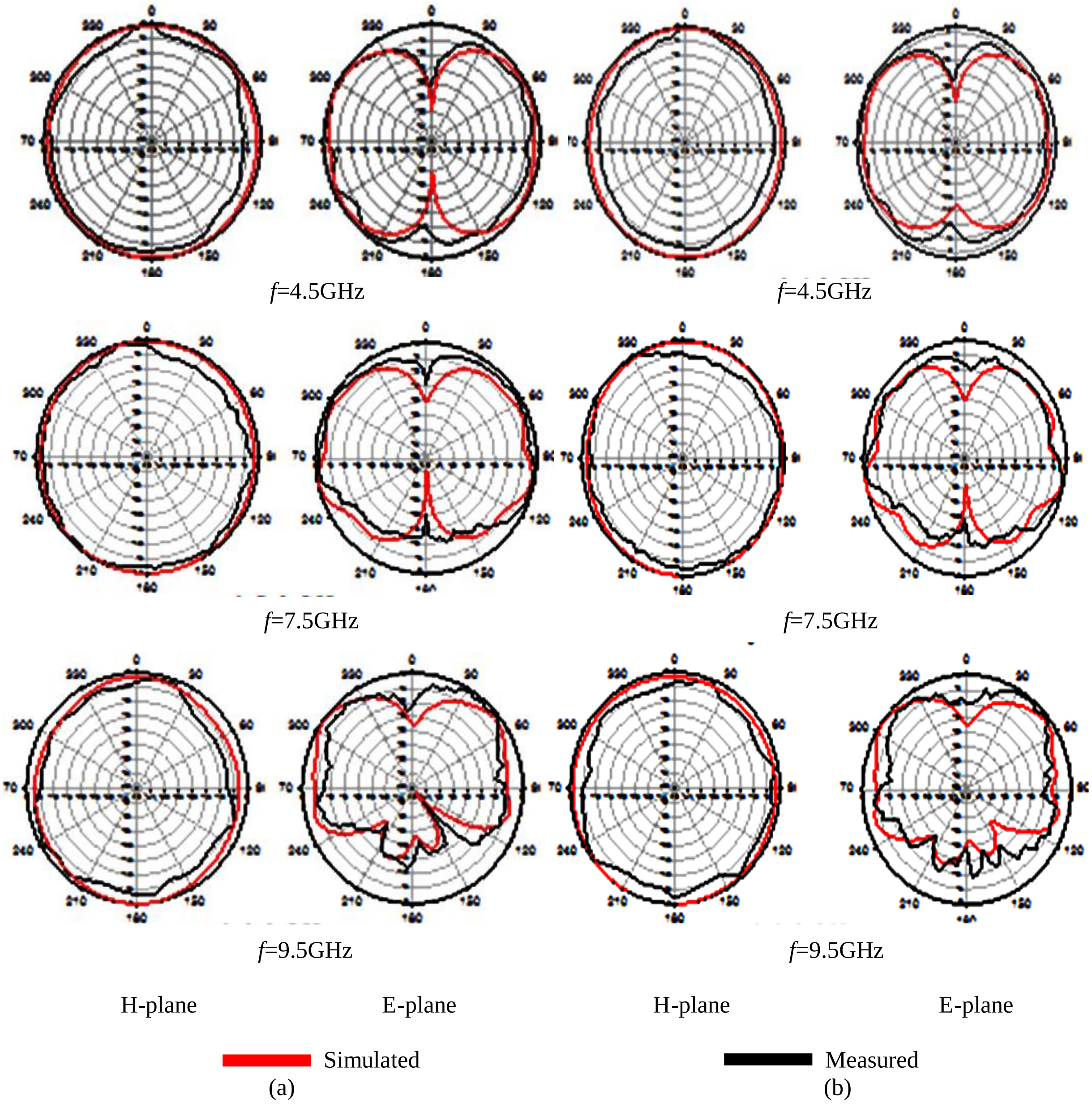


Fig. 11 – Measured radiation patterns for (a) reference; (b) UWB planar antenna comprises two-slits in the conductor elements

3.5 Gain *G* and Radiation Efficiency e_{ff}

Gains *G* and the radiation efficiency e_{ff} for the reference and UWB planar antenna with two-slit are compared in Fig. 12(a) and (b), consecutively. Generally, UWB planar antenna with two-slit has resulted better gain when referred to the reference antenna. Gain *G* slightly dropped at the band notch centre frequencies for the UWB planar antenna comprises two-slit in the conductor elements. Maximum gains G_{max} for the reference and UWB planar antenna comprises two-slit and reference antennas are given 5.2 and 5.4dB at the centre frequency f_c of 6.5 and 6.7GHz, respectively. Radiation efficiency e_{ff} for the UWB planar antenna comprises two-slit in the conductor elements has demonstrated steeps between the notched-band frequency bandwidth owing to the impedance mismatched. The steeps are at the centre frequency f_c 3.7 and 5.5GHz which are correspond to the 71% of radiation efficiency e_{ff}.

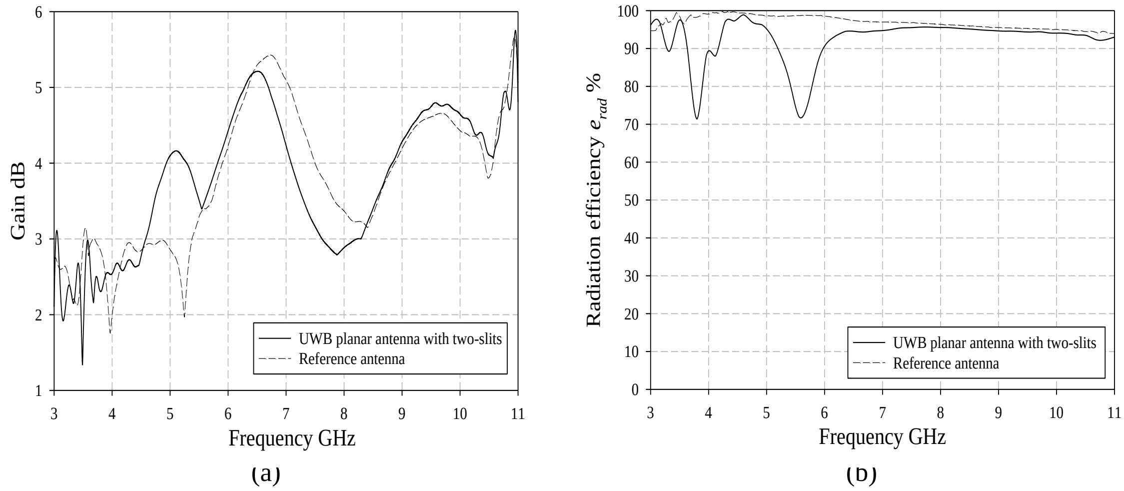


Fig. 12 – Simulated (a) Gain *G*; (b) Radiation efficiency e_{ff} for reference and UWB planar comprises two-slits in the conductor elements

4. Conclusion

UWB planar antenna comprises two-slit in the conductor elements is scrutinized to eliminate WLAN and WIMAX communication systems and slightly displays better performances comparing with the reference antenna. Slits in the conductor planes are considered to realize the band notch frequency bandwidths between 3.3~3.7 and 5~6 GHz and have achieved desired reflection coefficient S_{11} higher than -5dB. Measured radiation pattern for the UWB planar antenna with two-slits in the conductor elements are evaluated with simulation and are not precisely affected by the slits in the elliptical-shaped radiator and ground part. Band notch characteristics particularly can be influenced by the slits parameters alteration. Hence, specific slit parameters can be manipulated in the means of attaining a specific band notch characteristic.

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