Rezaul AZIM[1], Mohammad Tariqul ISLAM[1], Ahmed Toaha MOBASHSHER[2]

Institute of Space Science (ANGKASA), Universiti Kebangsaan Malaysia, Malaysia (1)
School of Information Technology and Electrical Engineering, The University of Queensland, Brisbane St Lucia, QLD 4072, Australia (2)

Ultra-wideband Antenna with Band-notches for Lower and Upper WLAN

*Abstract. A compact rectangular printed antenna with dual band-notches is proposed for ultra-wideband (UWB) applications. The dual band-notch characteristics have been realized by etching one **C**-shaped parasitic element and rectangular split ring resonator above the ground plane. The proposed antenna can achieves a wide bandwidth from 2.9-11 GHz with the dual notched bands centred at 5.25 GHz and 5.8 GHz. Compared to the other designs, the proposed antenna has a simple structure to achieve the dual band-notched characteristics to avert the potential interference between UWB and existing WLAN system.*

Streszczenie.** W artykule przedstawiono kompaktową, prostokątną antenę drukowaną o podwójnym wycięciu pasmowym, w zastosowaniu do aplikacji Ultra WideBand. Dzięki wykorzystaniu opisanej technologii produkcji, antena posiada zakres częstotliwości 2.9-11GHz, a jej prosta struktura pozwala wyeliminować potencjalne zakłócenia pomiędzy UWB i siecią WLAN. (**Antena Ultra WideBand z pasmowym wycięciem dla WLAN o niższej i wyższej częstotliwości)

Keywords: UWB; Notched band; WLAN.
Słowa kluczowe: UWB; pasma wycięte; WLAN.

Introduction

Ultrawideband (UWB) technology has become one of the most promising technologies in indoor communication due its advantages such as high data transmission rates, high precision ranging, low complexity, low cost, low spectral power density, and simple hardware configuration over the conventional wireless communication systems. After the released of frequency band of 3.1 - 10.6 GHz as an unlicensed band for UWB radio communication by the US the Federal Communications Commission in 2002, antennas with ultra-wide bandwidth have been widely investigated by both industry and academia [1-5]. In UWB frequency band there are some other existing narrow band services such as wireless local area network (WLAN). In USA most WLAN are designed to operate in 5.15 - 5.35 GHz (Lower WLAN) and 5.72- 5.825 GHz (Upper WLAN) frequency band. These existing narrow band may cause electromagnetic interference with the UWB systems. One possible way to suppress the interfering signals is to use a spatial filter such as a frequency selective surface above the antenna. However, this approach will increase the system complexity and cost, and requires more space when integrated with other RF circuitry. Another way is to use antennas that are capable of filtering the frequency bands that are used by WLAN from UWB frequency band. Therefore, it is necessary to design antennas that are capable of notching the frequency band from 5.15 - 5.35 GHz and 5.72 - 5.825 GHz in UWB systems to avoid possible interference between UWB and existing WLAN system.

Many UWB antennas have been proposed to overcome interference problem using frequency band notched design [4]. Many techniques have already been applied to design band-notched antennas. For example an isolated slit inside a patch, two open-end slits at the top edge of a T- shaped stub, two parasitic strips and a square ring resonator embedded in a tuning stub have been reported to design band notched antenna. Embedding of various thin slots on the antenna surface, such as L-shaped slot, U-shaped slot, square-shapes slot, T-shaped slot, pi-shaped slot, H-shaped slot and fractal slot have also been reported for achieving notched bands [6-14]. By adding either a split-ring resonator (SRR) or a multi-resonator load in the antenna structure, the undesired frequencies can be stopped with better system performance [15, 16]. However, some of these designs need a complex structure to produce and control the notched-band function. Moreover, some of the proposed band-notched designs for WLAN completely rejected the entire 5 - 6 GHz frequency band. However, the needed notched band is from 5.15 - 5.35 GHz for lower WLAN and 5.72 - 5.825 GHz for the upper WLAN band. Hence, any useful information contained in the frequency bands of 5.0 - 5.15 GHz, 5.36 - 5.71 GHz and 5.826 - 6.0 GHz will also be lost, which resulting in the degradation of received information and thus a shorter range of coverage and lower signal quality.

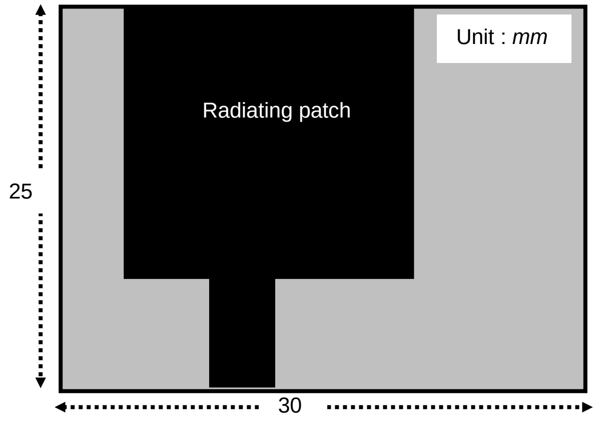
In this article, a novel compact dual band-notched antenna with increased bandwidth is proposed. To improve the bandwidth, the top edge of the partial ground plane is modified by introducing triangular shape slots to form a symmetrical sawtooth shape [17]. The dual band-notched characteristic is obtained by placing a ***C***-shape parasitic strip and a rectangular split ring resonator above the partial ground plane. The proposed antenna has a simple structure and is easy to fabricate.

Antenna geometry

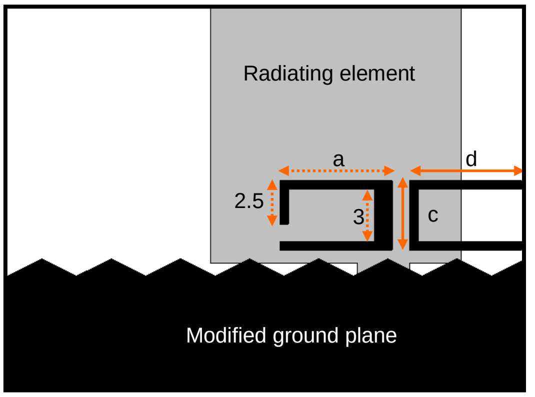
The configuration and dimensions of proposed dual band-notched antenna is depicted in Fig. 1. The antenna comprises of a rectangular radiating patch and partial ground plane. The ground plane is modified by introducing triangular shape slots on its top edge to achieve a broad impedance bandwidth [18]. The antenna is fabricated on 1.6 mm-thick FR4 substrate of relative permittivity 4.6 and loss tangent 0.02. The rectangular shape radiating patch fed by a microstrip feed-line is printed on the one side of dielectric substrate of 30 × 25 *mm,* while the modified partial ground plane is printed on the other side. The length of the microstrip feed line is fixed at 7.25 *mm* to achieve a 50 Ω characteristics impedance.

To realize the proposed UWB antenna with dual band-notch characteristics, one ***C***-shape parasitic element and a rectangular split ring resonator are placed on the back side of the substrate and couple to the ground plane. The length and width of the ***C***-shape strip are *c* and *d mm* respectively. The width of the split ring resonator is *a* and has a side lengths of 2.5 *mm and* 3 *mm*. Both the strip and resonator have a thickness of 0.5 *mm*.

At the notch frequency, the current flows are more dominant around the parasitic elements and they are oppositely directed between the parasitic elements and the radiating patch as shown in Fig. 2. Therefore, the resultant radiation fields cancel out and high attenuation near the notch frequency is proposed. Hence, the antenna at that frequency does not radiate efficiently.



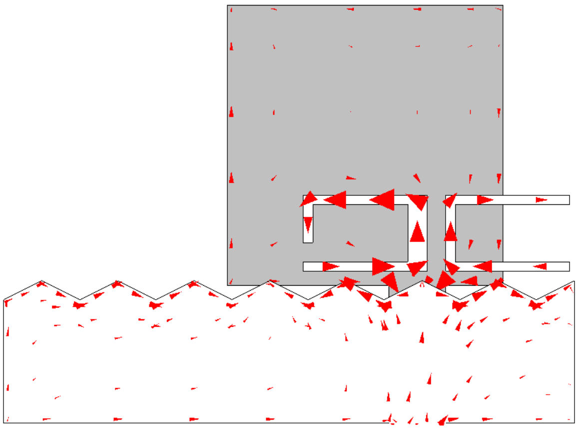
(a) Top view



(b) Bottom view

Fig.1. Geometry of the proposed antenna

(a)



(b)

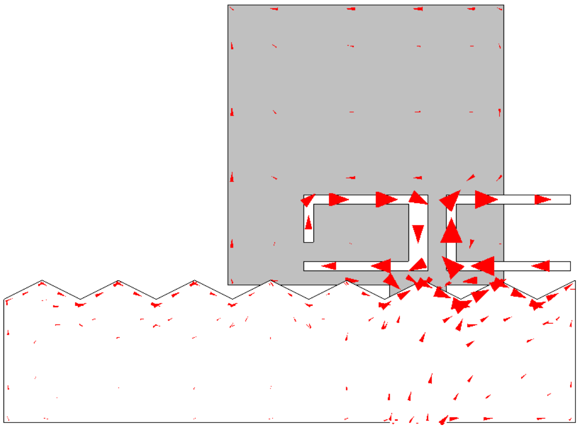


Fig. 2. Current distribution at (a) 5.25 GHz and (b) 5.8 GHz

To gain some insights into the band notching technique, the input impedance characteristics of the proposed antenna is compared with that of antenna without band notch structure and is shown in Fig. 3. It is observed that the input impedance of the band notch design is similar to that of antenna without band notch structure except at notch frequency bands. At notch frequency bands the input impedance is far from 50 Ω, which means that the input impedance is mismatched to 50 Ω resulting in generation of notched bands at these frequencies.

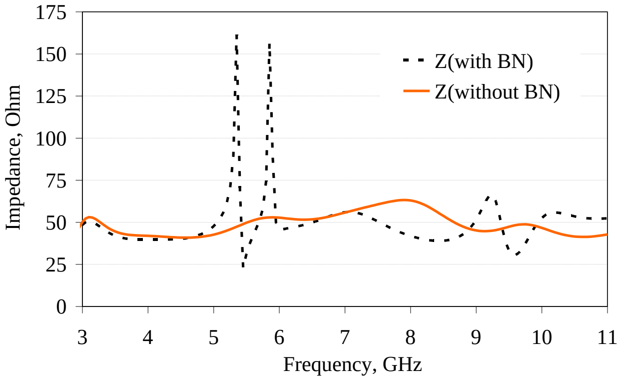


Fig. 3. Simulated input impedance of the proposed antenna

Results and discussion

The performances of the proposed antenna are performed using full-wave electromagnetic simulator IE3D from Zeland. A parametric study of proposed antenna is carried out in order to investigate the effects of strip and split ring resonator on band-notched characteristics. Since the strip and split ring resonator are the main factor in achieving band notched characteristics, there three parameters *a*, *c and d* are selected to perform the sensitivity study. The effects of parameters *a*, *c* and *d* on band-notched characteristics are simulated and shown in Figs. 4-6 respectively.

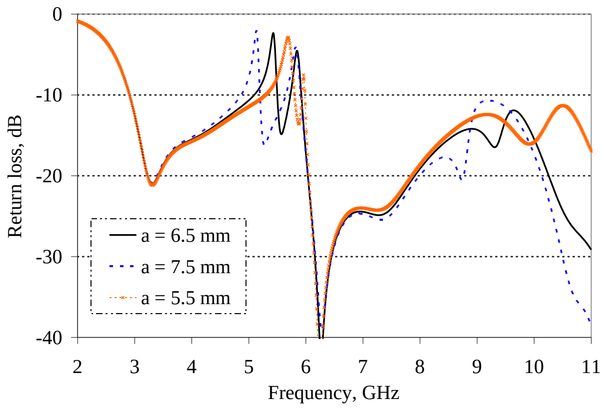


Fig. 4. Return losses for different values of *a*

Figure 4 shows the return losses for different values of *a* while the other parameters are kept constant. As the values of *a* increases from 5.5 to 7.5 *mm*, the centre frequency of the first notched band for lower WLAN moves towards lower frequency edge. It is also observed that, the bandwidth of the first notched frequency band is decreases with increasing *a*. From these results, it can be concluded that the first notched band for lower WLAN band is controlled by the rectangular split ring resonator and has very small effect on second notched band for upper WLAN. It is also concluded that the centre frequency as well as the bandwidth of the first notched band for lower WLAN can be adjusted by properly selecting the value of *a*.

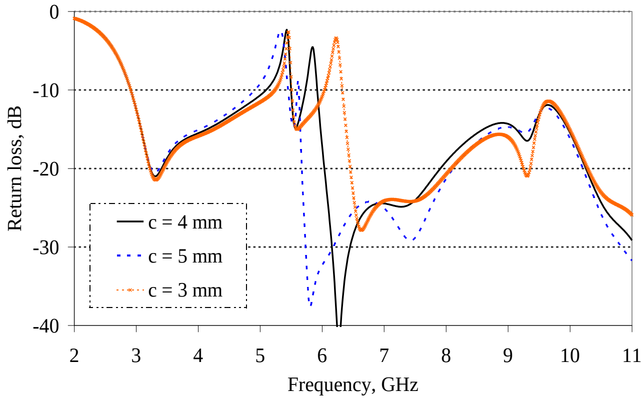


Fig. 5. Return losses for different values of *c*

The return loss curve for different values of length *c* of the ***C***-shape parasitic element is depicted in Fig. 5. As the values of *c* increases from 3 to 5 *mm*, the centre frequency of the second notched band for upper WLAN is shifted from 6.24 to 5.62 GHz. It can also be seen that the bandwidth of the notched band is decreases with *c* where as the first notched band almost remain unaltered. Fig. 6 shows the return loss values of the proposed antenna for different values of width *d*. For *d* = 5.5, 6.5 and 7.5 *mm* with other dimensions are fixed and *a* =6.5 *mm, c* = 4 *mm*, the centre frequency of the second notched band moves towards lower frequencies and bandwidth of the notched band is decreases. It can also be observed that *d* has very little effect on first notched band for lower WLAN. Therefore, from Figs. 4-6 it can be concluded that, the first notched band for lower WLAN is controlled by the rectangular split ring resonator where as the second notched frequency band for upper WLAN is obtained by properly selecting the values of ***C***-shaped parasitic strip.

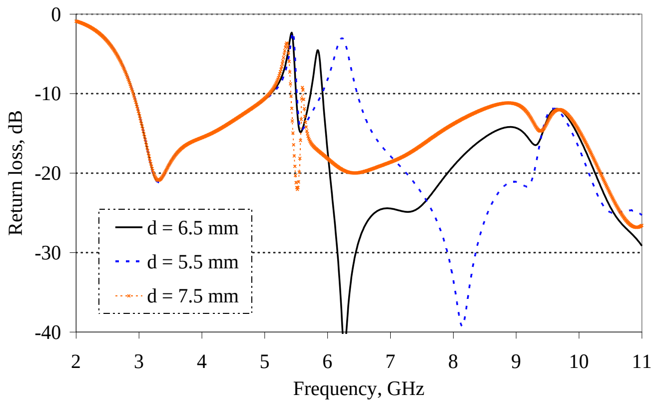


Fig. 6. Return losses for different values of *d*

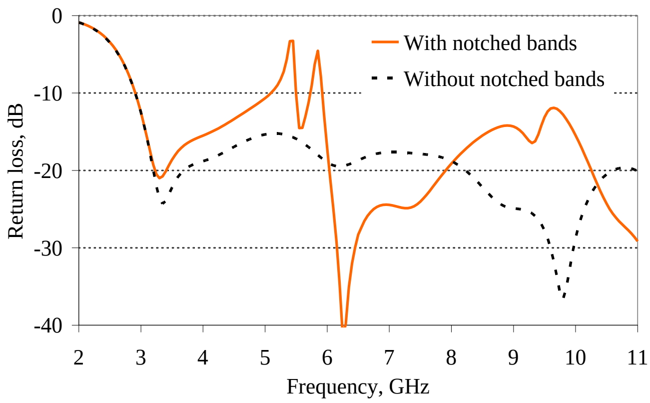


Fig. 7. Return losses with and without notched elements

Figure 7 shows the performance of the proposed antenna with and without band notched elements. Sharp frequency band-notched characteristic are observed at the desired centre frequency of 5.25 GHz and 5.8 GHz when a ***C***-shape parasitic element and a rectangular split ring resonator are placed above the partial ground plane. It is seen that the designed antenna with band-notched elements can exhibits two notched bands of 5.1-5.5 GHz and 5.72-5.9 GHz with an ultra-wide bandwidth of 2.9-11 GHz. These notched bands can efficiently minimize the potential interference between WLAN and UWB.

Figure 8 depicts the peak gain of the proposed antenna along with the gain of the antenna without notched bands. At the notched frequency bands sharp decrements in the gain are observed which clearly indicates the effects of notched elements. Other than the notched bands, the gain of the proposed antenna is almost similar to that antenna without notched bands. However, at the frequency of 9.5 GHz the antenna gain slightly varied because of the low matching of that antenna in that frequency. Other than the notched frequency band, antenna gain with a variation of less than 1 dBi is achieved.

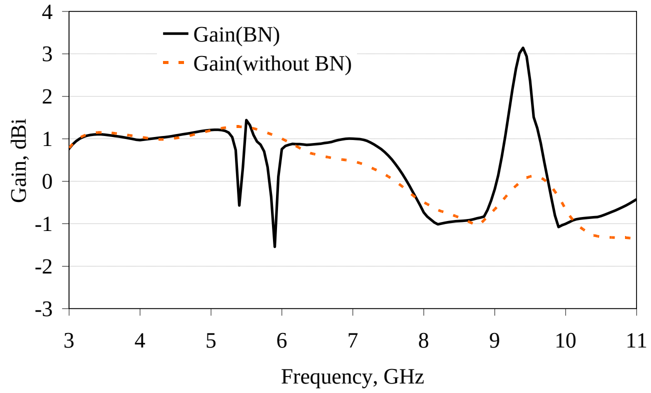


Fig. 8. Peak gain of the proposed antenna

Figure 9 shows the radiation patterns of the proposed band notch antenna at three frequencies of 3.3 GHz, 5.5 GHz and 6.3 GHz. It is observed that at lower frequencies both the *E*- and *H*-plane field patterns are approximately bidirectional and the antenna has a main beam in the broadside direction. As the frequency increases, higher order current modes are excited and the radiation patterns becomes slightly directional. However a stable and symmetric the radiation patterns are observed over the entire operating band of the proposed antenna which is similar to a typical monopole antenna [18].

Conclusion

A compact rectangular printed antenna with dual band-notched characteristics is proposed. The antenna comprises of a rectangular radiating patch and modified partial ground plane, and designed on an inexpensive FR4 dielectric substrate. By placing a ***C***-shaped parasitic element and a rectangular split ring resonator above the partial ground plane, dual notched bands are achieved. The results show that the compact antenna with a size of 30 × 25 *mm* not only achieved an ultra-wide bandwidth but also dual-notched band characteristics with stable radiations patterns.

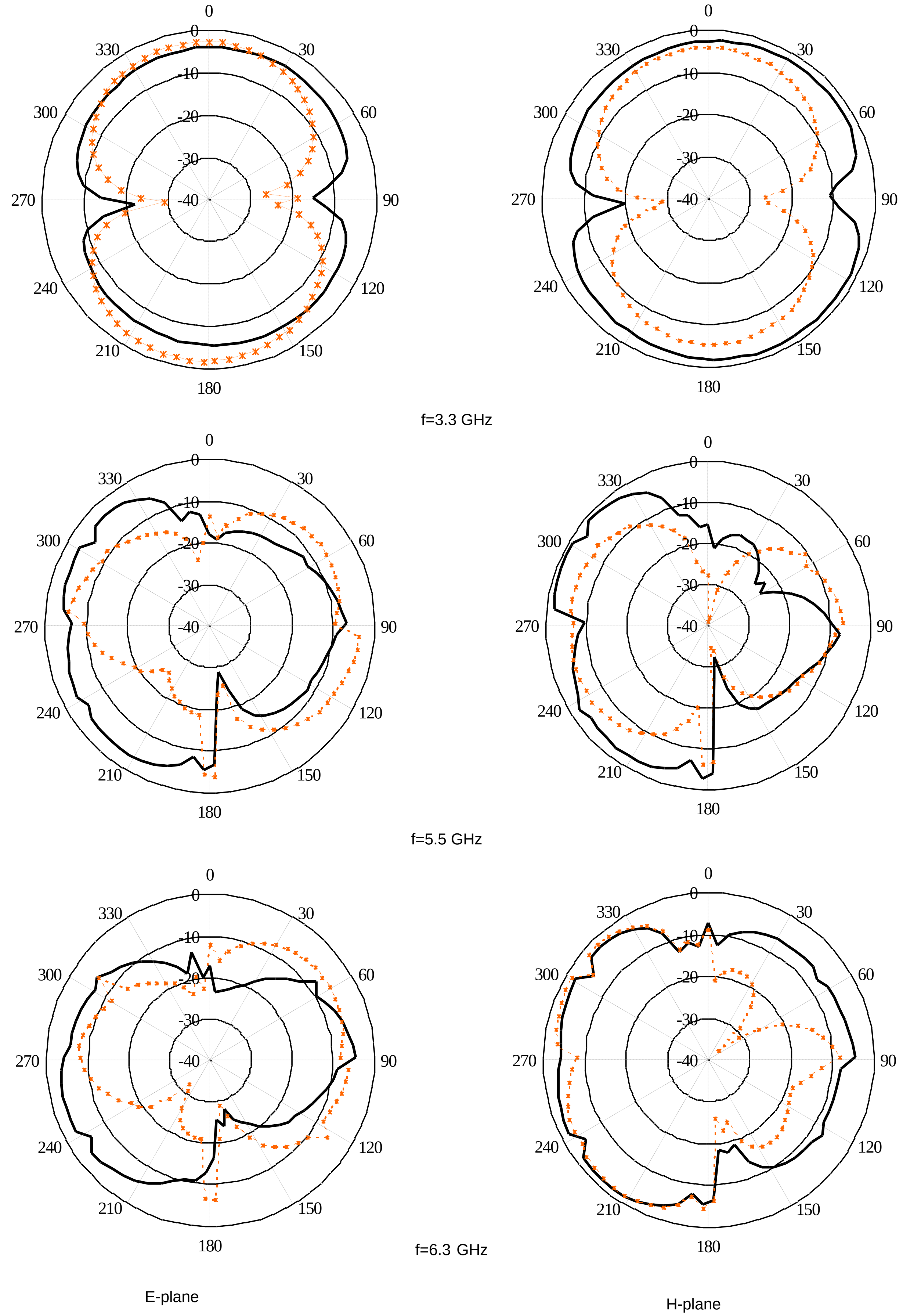


Fig. 8. *E*- and *H*- field patterns at different frequencies [Copolarization, Crosspolarization]

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***Authors**: Dr. Rezaul Azim and Professor Dr. Mohammad Tariqul Islam are with the institute of Space Science (ANGKASA), Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor Darul Ehsan, Malaysia, E-mail: rezaulazim@yahoo.com; titareq@yahoo.com. Mr. Ahmed Toaha Mobashsher is with the School of Information Technology and Electrical Engineering, The University of Queensland, Brisbane St Lucia, QLD 4072, Australia, E-mail: i_toaha@yahoo.com.*