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Design of multiband microstrip patch antenna with bandwidth enhancement for wireless communication system

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ABSTRACT

This research work presents analysis of multiband rectangular microstrip patch antenna for globalsystem for mobile communications at 0.9455GHz and 1.7595GHz and wireless local area Network at 2.4635 GHZ and 5.15 GHz and WiMAX at 3.5745GHz and international mobile telecommunications (IMT) at 4.46 GHz . An antenna is designed using FR4-(epoxy) substrate material with thickness1.6 mm and dielectric constant of 4.3. The microstrip antenna has a patch dimension of 83.33mm×45mm. The antenna has minimum return loss of - 32.563 dB at 0.9455GHz, -27.226 dB at 1.7595 GHz, -29.136 dB at 2.4635GHz, -31.621 dB at 3.5745GHz, -36.531dB at 4.46 GHz, -25.613 at 5.15 GHz. In this antenna designed the maximum gain of 2.20 dB at 0.9455GHz, 3.17 dB at 1.7595 GHz, 5.68 dB at 2.4635GHz , 7.04 dB at 3.5745 GHz, 6.08 dB at 4.46GHz, 5.26 dB at 5.15 GHz. The simulation of the design antenna is done using the software computer simulation technology CST.

Introduction

present and upcoming technology tendencies in wireless communication must increase the request for microstrip antennas that can effort at many bands with appropriate bandwidth . Microstrip antennas are one of the elementary components vital for wireless communication .In the new years there has been a fast and incessant development in wireless communication [1] .There are dissimilar profiles of antenna contingent on its application. Generally, the microstrip antenna has many unique and beautiful characteristics.. These properties comprise low profile, light weight, being compact and conformable to mounting structure, easy fabrication and integration with solid-state devices [2,3]. These properties donate to the successful application of microstrip antennas not only in the military, such as aircraft, space craft, missiles, but also in the commercial areas, terrestrial cellular communications ,such as mobile satellite system, global positioning system and broadcast satellite system [4] .

Fig. 1: microstrip antenna applications [5]

A suitable patch structure can be made to operate at different frequencies wide apart at the same time thereby avoiding use of multiple antennas. Multiband can be achieved by many techniques like slotting, notching, lumped element loading, shorting posts, parasitic and fractal elements [6]. The advantage of multiband antenna frequencies is evident in mobile phones . The designers of phones always need more space for many different antennas and other among the solutions they have the use of one antenna operates in numerous frequencies instead of using the antenna for each frequency and this is what we call the multiband frequency which opened the way for wireless evolution [5] . The frequency all occasions of interested wireless systems, (GSM: 0.915–0.96 GHz), (GSM: 1.71–1.785 GHz), (GSM: 1.85–1.99 GHz), (WLAN)) (2.4–2.4835 GHZ), (5.15 – 5.35 GHZ) (IMT) (4.4-49 GHz), WiMAX (3.4-3.69GHZ) [7]. In this paper multiband, microstrip antenna at six resonant frequencies of 0.9544 GHz , 1.7595 GHz ,2.4635 GHz , 3.5745 GHz , 4.46GHz and 5.15 GHz it was designed. More characteristics of the proposed antenna and analysis results were presented done by using (CST) program.

Theoretical

Antenna parameter

Radiation pattern of an antenna is a graphical representation of the variation of electromagnetic power radiated by antenna in space, observed in far field region of antenna. It actually represents the field strength, radiation intensity, power flux density, directivity, or polarization of the field radiated by the antenna [8].

Input impedance is defined as the impedance presented by an antenna at its terminals or the ratio of the voltage to current at a pair of terminals .

The bandwidth of an antenna is defined as the range of frequencies over which the antenna can properly radiate or receive energy [9] .

$$B.W = f_H - f_L \qquad (1)\ [10]$$

f_H : The highest frequency corresponding to -10 dB the return losses .

f_L : The lowest frequency corresponding to -10 dB the return losses .

$$FBW = \left(\frac{f_H - f_L}{f_c}\right) \times 100\ \% \qquad (2)\ [11]$$

FBW : Fractional bandwidth

f_c : Resonant frequency

Gain shows how efficiently the available power at input terminals of antenna is transmitted . The unit of gain is dB , if taken considering the isotropic antenna then it is represented in dBi [12].

The directivity of an antenna is defined as the ratio between the radiation intensity in a given direction to the radiation intensity averaged over all directions [13].

The input impedance of the antenna should be matched to the source impedance. If both the impedances are not matched then some part of the transmitted power will be reflected back. This reflected power relative to input or incident power is called the return loss of the antenna. In general the threshold for return loss is -10 dB which means 90% of incident power should be transmitted [14,15].

CST, Computer Simulation Technology, is a 3D simulation tool for electromagnetic design and analysis. It is user friendly and allows the optimization of devices in practically limited applications as claimed by the software guarantees. For this work, CST is ideal to design and optimize the antenna element and array over the desired frequency range GHz. It also allows the simulation of the feed network along the antenna structure. The software has two main solvers that can be used for antenna design and simulation: the time domain solver also known as the transient solver or the frequency domain solver [16] .

Antenna design

Figure 2 shows the geometries of the proposed antenna shorted λ/4 at 0.9 GHz frequency, has the same resonance frequency as that of a λ/2, with half the area [17]. with rectangular patch fabricated on the FR4 substrate with relatively permittivity ε_r=4.3 and thickness 1.6mm. In Figure 1, the rectangular patch fed by microstrip line has been cut with rectangular slot The proposed antenna, rectangular patch with size of 83.33mm × 45mm. The multiband characteristics can be achieved by using big rectangular and put a side column to change the distribution of the current to add frequency 2.4635 GHz and 3.57 GHz and 5.15 GHz and cut tow triangles from the corners to get the frequency 1.7595 GHz, parasitic elements on the ground plane for tuning Frequency 2.4635 GHz and improve return losses, impedance matching. The results of the designed antenna are done using "CST" program.

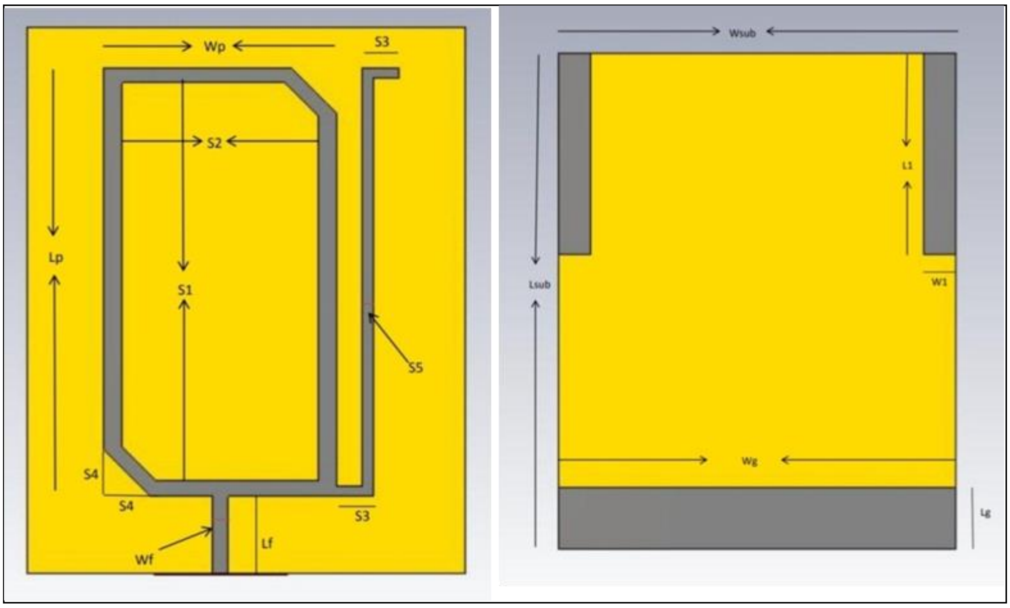


Fig. 2: Structure of the proposed Antenna

Table 1: list of design parameters of the designed Antenna

dimension	Lsub	Wsub	Lg	Wg	Lp	Wp	Lf	Wf
value	106	85	15	85	83.33	45	17	3
dimension	S1	S2	S3	S4	S5	L1	W1	h
value	77.33	38	7	9	2	43	7	1.6

All dimensional are measured in mm .

Figure (3) shows the reflection coefficient against frequency of the designed antenna . The return loss -32.563 dB at 0.9455GHz and -27.226 dB at 1.7595GHz and -29.136 dB at 2.4635GHz and -31.621 dB at 3.5745GHz and -36.531dB at 4.46 GHz and -25.613 at 5.15 GHz.

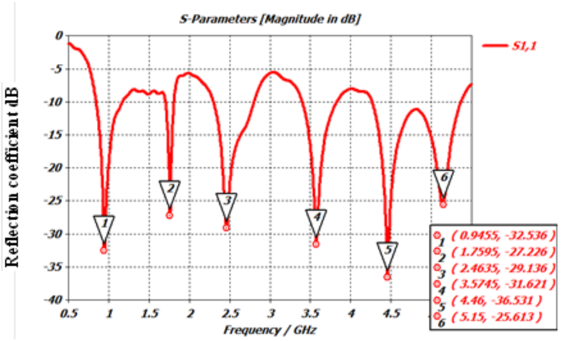


Fig. 3: Reflection coefficient

Figure (4) shows the voltage standing wave ratio (VSWR) of the antenna at operating frequencies is closed to 1, which represents the ideal value for getting very good impedance matching at six resonant frequencies, This is indicates that the reflected signals are very small .

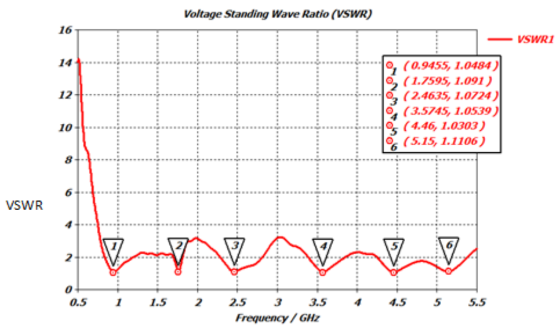


Fig.4: VSWR

Figure (5) shows the antenna gain and directivity as a function of frequency. It is clear from the figure that the gain takes positive values at the six resonance frequencies .

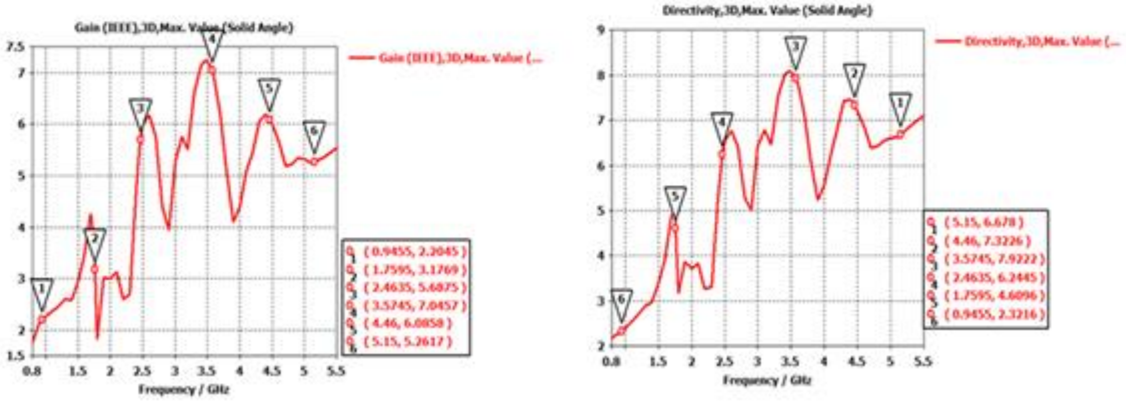
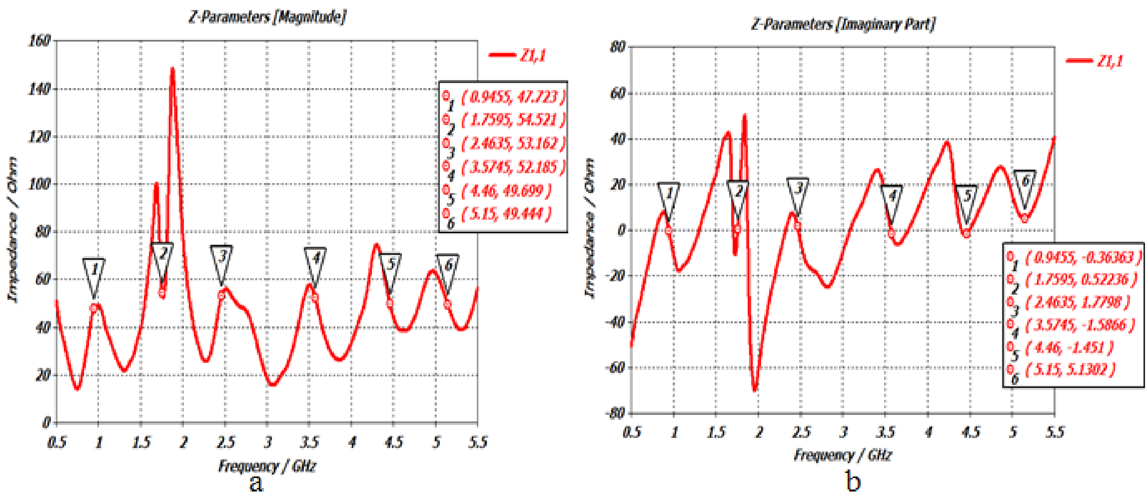


Fig. 5: gain and directivity

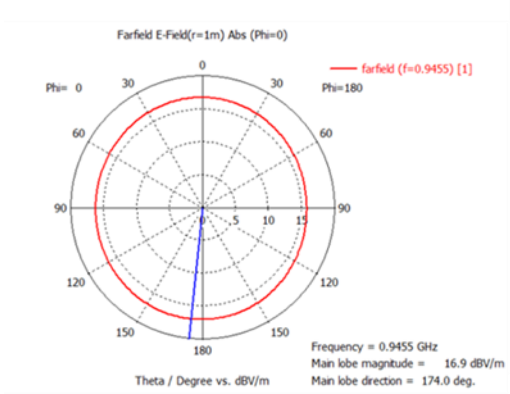
Figure (6) shows the real part and the imaginary part of the impedance with the frequency, it is clear from the figure that the resistance of the proposed antenna has impedance approximating the ideal value the real part is close to 50Ω and the imaginary part approaches 0Ω at the six working frequencies 0.9455 GHz and 1.7595 GHz. And 2.4635 GHz and 3.5745GHz and 4.46GHz and 5.15 GHz .

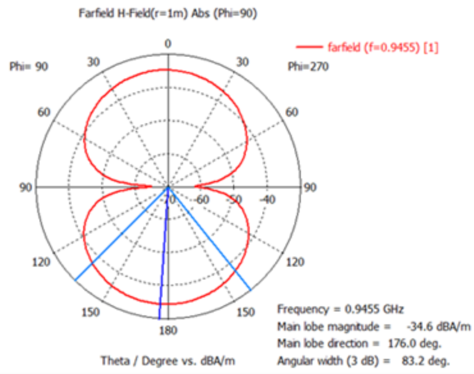


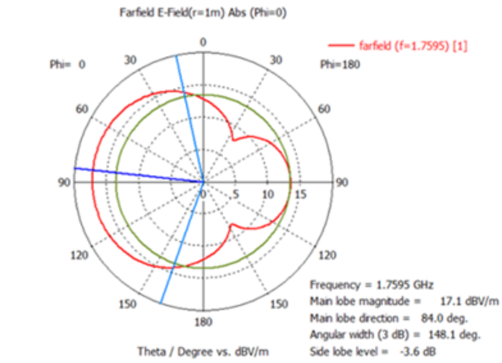
a- Real part b- imaginary part

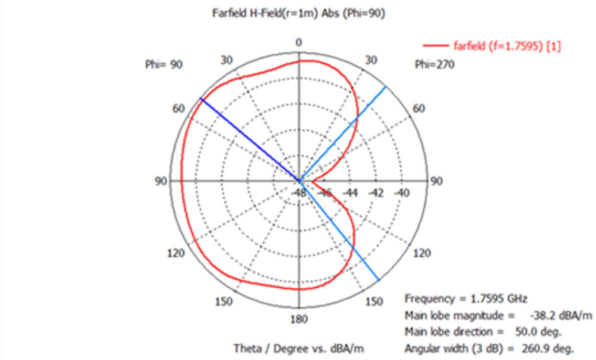
Fig. 6: Impedance versus frequency

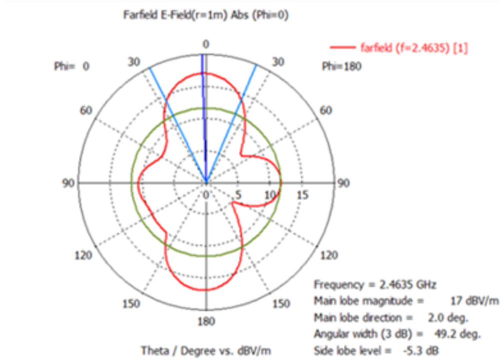
Figure (7) shows Radiation pattern in the xz and yz plan for the proposed antenna at the six resonant frequencies, we can build a precise analysis of our antenna and the impact of the technique used on its structure through the radiation pattern of an antenna which makes it possible to visualize the lobes in two or three dimensions, in the horizontal plane (phi = 0°) or in the vertical plane (phi = 90°) including the most important lobe.

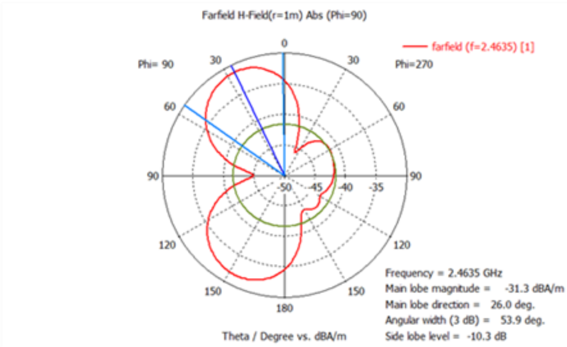

Farfield E-Field(r=1m) Abs (Phi=0)
farfield (f=0.9455) [1]
Phi= 0
Phi=180
Frequency = 0.9455 GHz
Main lobe magnitude = 16.9 dBV/m
Main lobe direction = 174.0 deg.
Theta / Degree vs. dBV/m

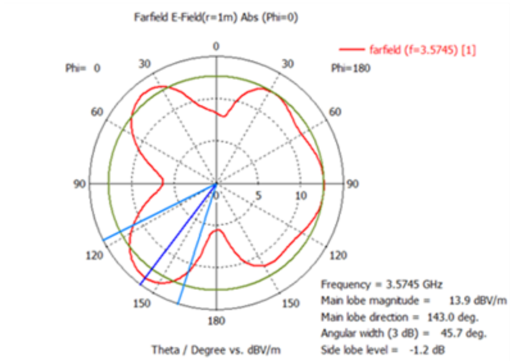

Farfield H-Field(r=1m) Abs (Phi=90)
farfield (f=0.9455) [1]
Phi= 90
Phi=270
Frequency = 0.9455 GHz
Main lobe magnitude = -34.6 dBA/m
Main lobe direction = 176.0 deg.
Angular width (3 dB) = 83.2 deg.
Theta / Degree vs. dBA/m

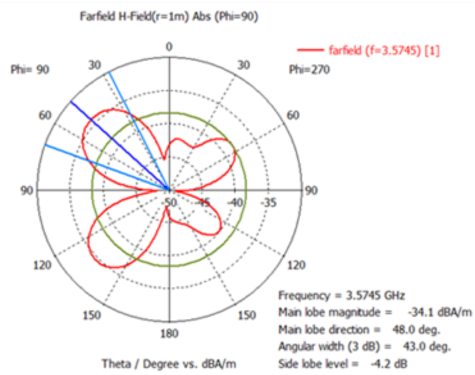

Farfield E-Field(r=1m) Abs (Phi=0)
farfield (f=1.7595) [1]
Phi= 0
Phi=180
Frequency = 1.7595 GHz
Main lobe magnitude = 17.1 dBV/m
Main lobe direction = 84.0 deg.
Angular width (3 dB) = 148.1 deg.
Side lobe level = -3.6 dB
Theta / Degree vs. dBV/m


Farfield H-Field(r=1m) Abs (Phi=90)
farfield (f=1.7595) [1]
Phi= 90
Phi=270
Frequency = 1.7595 GHz
Main lobe magnitude = -38.2 dBA/m
Main lobe direction = 50.0 deg.
Angular width (3 dB) = 260.9 deg.
Theta / Degree vs. dBA/m


Farfield E-Field(r=1m) Abs (Phi=0)
farfield (f=2.4635) [1]
Phi= 0
Phi=180
Frequency = 2.4635 GHz
Main lobe magnitude = 17 dBV/m
Main lobe direction = 2.0 deg.
Angular width (3 dB) = 49.2 deg.
Side lobe level = -5.3 dB
Theta / Degree vs. dBV/m


Farfield H-Field(r=1m) Abs (Phi=90)
farfield (f=2.4635) [1]
Phi= 90
Phi=270
Frequency = 2.4635 GHz
Main lobe magnitude = -31.3 dBA/m
Main lobe direction = 26.0 deg.
Angular width (3 dB) = 53.9 deg.
Side lobe level = -10.3 dB
Theta / Degree vs. dBA/m


Farfield E-Field(r=1m) Abs (Phi=0)
farfield (f=3.5745) [1]
Phi= 0
Phi=180
Frequency = 3.5745 GHz
Main lobe magnitude = 13.9 dBV/m
Main lobe direction = 143.0 deg.
Angular width (3 dB) = 45.7 deg.
Side lobe level = -1.2 dB
Theta / Degree vs. dBV/m


Farfield H-Field(r=1m) Abs (Phi=90)
farfield (f=3.5745) [1]
Phi= 90
Phi=270
Frequency = 3.5745 GHz
Main lobe magnitude = -34.1 dBA/m
Main lobe direction = 48.0 deg.
Angular width (3 dB) = 43.0 deg.
Side lobe level = -4.2 dB
Theta / Degree vs. dBA/m

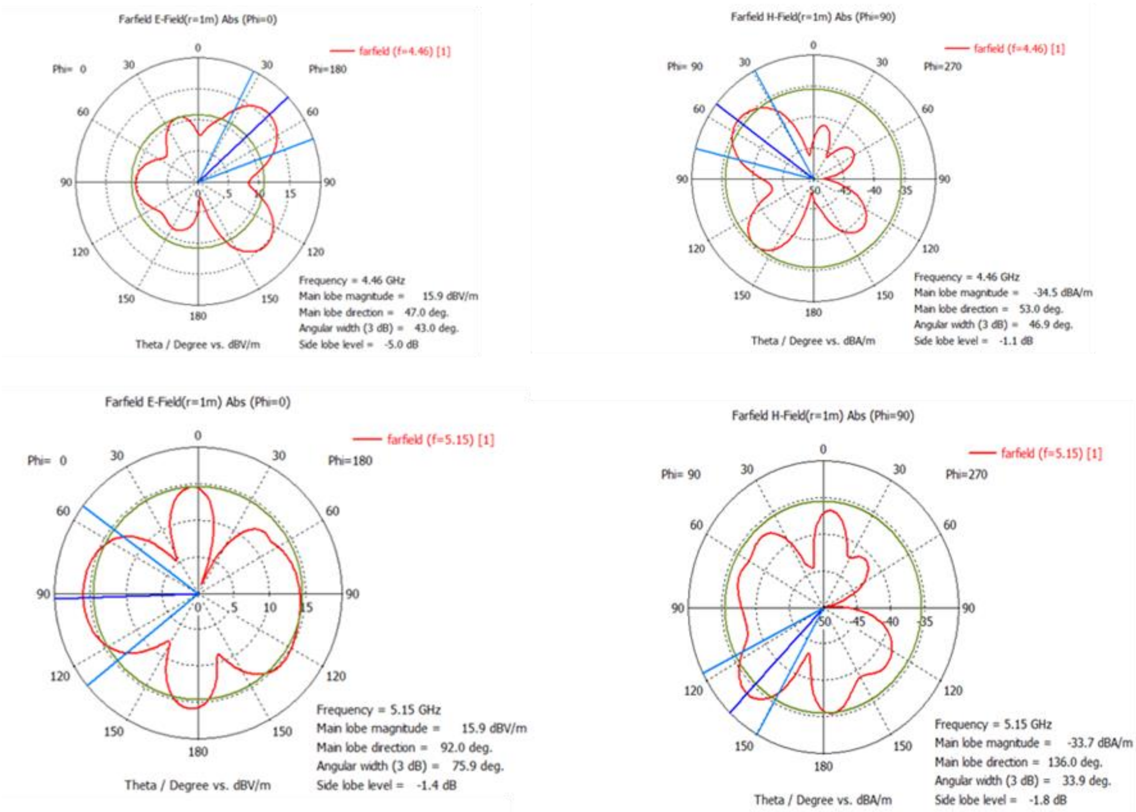


Fig. 7: Radiation pattern

Figure (8) shows Current distribution at the six resonant Frequencies , that the current take a different path with each frequency. Also the red parts appear to be responsible for that frequency .

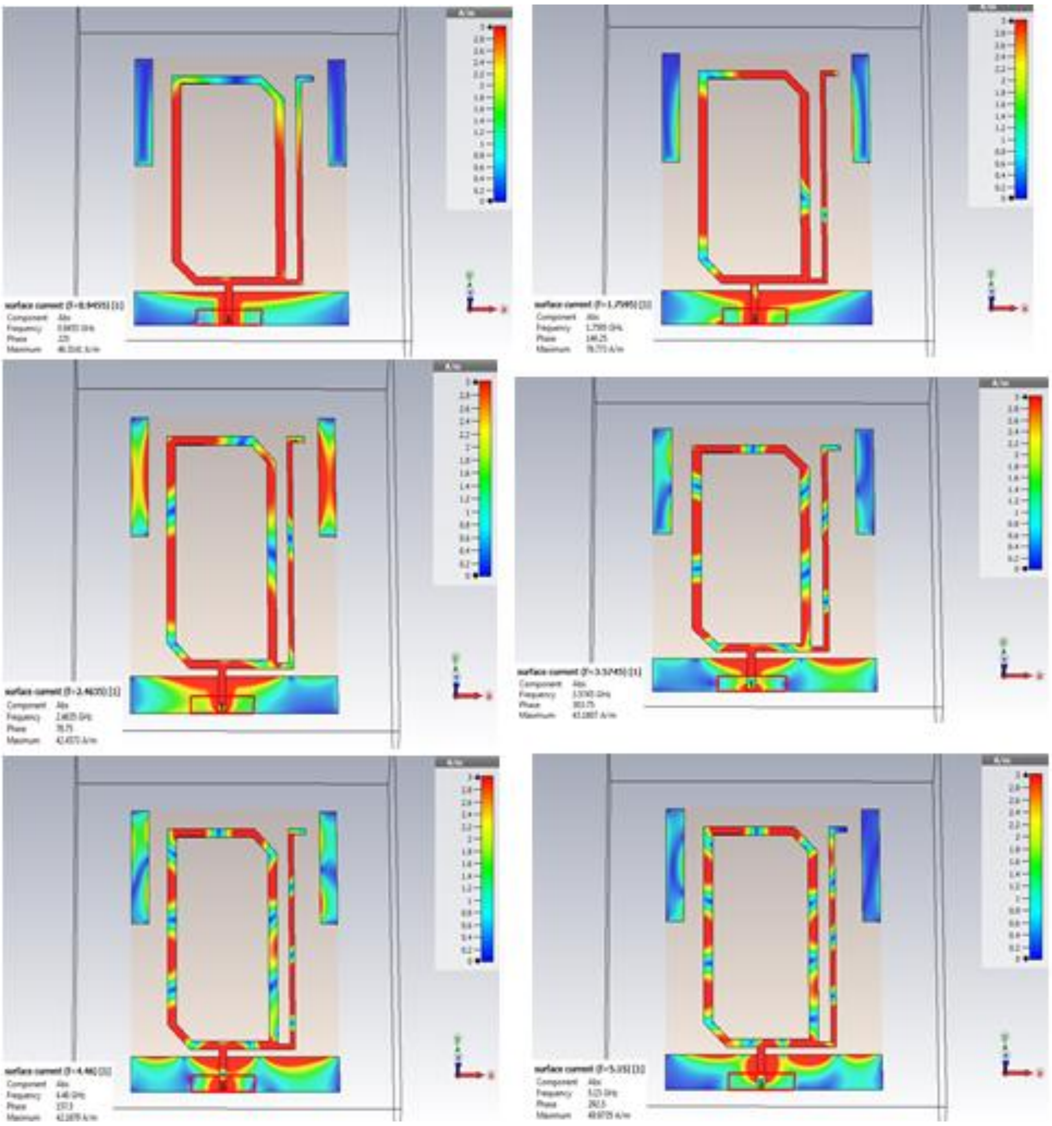


Fig. 8: Current distribution

The antenna characteristics can be summarized in the table (2)

Table 2: antenna characteristics at the six resonant frequencies

frequency GHz	Return loss	VSWR	B.W	gain dB	Directivity dBi
0.9455	-32.536	1.0484	326.42 MHz	2.20	2.3216
1.7595	-27.226	1.091	105.9 MHz	3.17	4.6096
2.4635	-29.136	1.0724	502.8 MHz	5.68	6.2445
3.5745	-31.621	1.0539	427.7	7.04	7.9222
4.46	-36.531	1.0303	1101 MHz	6.08	7.3226
5.15	-25.613	1.1106	1101 MHz	5.26	6.678

Conclusion

A multiband microstrip antenna is proposed in this paper, the design antenna is done using (CST) program. The multiband can be carried out by using big rectangular slots loaded in the patch of antenna and put a side column to change the distribution of the current to add new frequencies. The simulation results of the design antenna were good for each antenna parameters, return loss, VSWR, gain, directivity . and very good impedance matching .

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تصميم هوائي شريحة رقيقة متعدد الحزم مع تعزيز عرض الحزمة لأنظمة الاتصالات اللاسلكية

احمد عبد الكريم احمد[1] ، فارس صالح عطاالله[1] ، يسار عزالدين محمد علي[2]

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الملخص

يقدم هذا العمل البحثي تحليل لهوائي الشريحة الرقيقة ذو رقعة مستطيلة متعدد الحزم يستخدم لتطبيقات النظام العالمي للاتصالات المتنقلة عند التردد GHz0.9455 وعند التردد GHz1.7595 وشبكة الاتصال اللاسلكية المحلية عند التردد GHz2.4635 وعند التردد GHz5.15 و WiMAX عند التردد GHz3.5745 وشبكة الاتصالات الدولية المتنقلة (IMT) عند التردد GHz4.46. المادة العازلة للهوائي المقترح هي FR4- (epoxy) ذات سمك mm1.6 وثابت عزل 4.3. تم حساب طو الرقعة المشعة بحيث يكون مساوي لربع الطول الموجي عند التردد GHz0.9 وكانت ابعاد الرقعة المشعة للهوائي 45mm83.33 × mm. تم تغذية الهوائي بتقنية الخط الشريطي الرقيق. خسائر العودة تأخذ القيم −32.563 dB عند التردد GHz 0.9455 و −27.226 dB عند التردد GHz 1.7595 و −29.136 dB عند التردد GHz 2.4635 و −36.531 dB عند التردد GHz 4.46 و −25.613 dB عند التردد GHz 5.15. في الهوائي المقترح تكون قيم الكسب 2.20 dB عند التردد GHz 0.9455 و 3.17 dB عند التردد GHz 1.79596 و 5.68 dB و GHz 2.4635 و 7.04 dB عند التردد GHz 3.5745 و 6.08 dB عند التردد GHz 4.46 و 5.26 dB عند التردد GHz 5.15 تم عرض نتائج المحاكاة باستخدام برنامج CST .

Table of acronyms	
GSM	Global System for Mobile communications
WLAN	Wireless Local Area Network
WiMAX	Worldwide Interoperability for Microwave Access
IMT	International Mobile Telecommunications
FBW	Fractional Bandwidth
VSWR	Voltage Standing Wave Ratio