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Designs and Analysis of Ultra-Wideband (UWB) Antenna with Band-Notched Characteristics operates on UWB band (3.1 to 11.3 GHz) while rejecting the full U-NII band (5.06 to 5.85 GHz)

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***Abstract*— The UWB pulses are very short, thus they have very strong temporal and space resolving ability, Low electromagnetic radiation because of low radio power pulse less than -41.3 db and low energy consumption which enables the usage of long life battery operated devices. Within the UWB range there are various wireless standards namely WLAN (5.15 to 5.85 GHz) for U-NII band, WiMax (3.3 to 3.85 GHz) & (8.5 GHz). Apart from this the lower portion of X-band also falls within UWB range and if these bands are in use at the same time than there is a chance of interference of signals. In addition to this, to avoid the interference between standards one could either use UWB antenna with band notched characteristics or a fixed frequency or band antenna may be used. Therefore in designing of an UWB antenna with band notched characteristics presented in this dissertation first a primitive UWB antenna was simulated by the use of partial ground and bevelled corners and then with the help of two rectangular notches the U-NII band for WLAN especially was rejected. The proposed design is compact in size and can be fabricated easily for comparison of results. In this paper, a UWB antenna with band notched characteristics was proposed which is simulated on software tool CST Microwave Studio 2011. The proposed antenna operates entirely on UWB band (3.1 to 11.3 GHz) while rejecting the full U-NII band (5.06 to 5.85 GHz). The peak return loss in nearly -30 dB and VSWR is less than 2 for entire operating band except for U-NII.**

***Index Terms*— UWB (ultra wideband antennas); U-NII band (5.06 to 5.85 GHz), wireless LAN; WiMax frequency 3.1 GHz to 10.6 GHz; CPW-fed planar antenna; broadband impedance matching; wireless LAN.**

I. INTRODUCTION

This ultra-wide band antenna with band notched characteristics is presented. The proposed design operates in frequency band ranging from 3.07 to 11.45 GHz with a band rejection from 5.06 to 5.85 GHz (U-NII). The overall dimension of this antenna is (27.00 × 32.42 × 1.67) mm3. For enhancing the bandwidth of the antenna partial ground plane along with beveled corners on the radiating patch are utilized. Beveling corners are used only on lower two corners of the patch on micro strip fed side. As the design achieved the ultra wide bandwidth then two identical rectangular notches are inserted on the radiating patch for U-NII band rejection. All the parameters of this proposed designed are simulated and optimized by a software tool CST Microwave Studio 2011.

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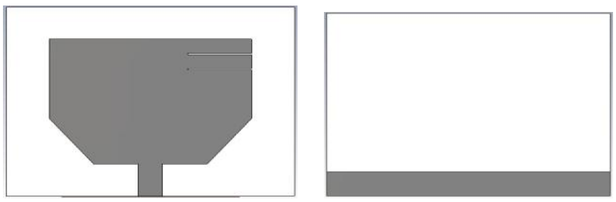
A. Development of Design

The designing of the proposed structure is divided into three steps. In the first step the simple microstrip patch antenna with partial ground plane is used. After the partial ground, two identical beveled corners are used on the radiating patch to make the proposed design suitable for UWB applications which is shown in second step. In the last step two identical rectangular notches are inserted on the radiating patch for the desired band rejections. Now let us discuss

B. Addition of Two Identical Rectangular Notches on Radiating Patch

As we have obtained the ultra-wide band antenna which is operating efficiently in frequency ranging from 3.1 to 10.6 GHz in step-II; now for reducing interference we require band notching. As two identical rectangular notches are inserted on radiating patch the band rejection characteristics is obtained. The dimension and position of these notches directly affects the center frequency and the bandwidth of the band rejection characteristics. The reason behind the use of two identical rectangular notches is that a single notch is not giving the desired bandwidth for band rejection. When only one rectangular notch is inserted then the U-NII band was not fully rejected therefore two rectangular and identical notches are utilized for the purpose. The geometry of the structure obtained after step-III is shown in figure given below



Addition of two identical rectangular notches on radiating patch

C. Geometry of the Proposed Design with Optimized Parameters

The top view and bottom view of the proposed antenna is shown in figure (a) and (b) respectively. The overall dimension of proposed antenna is 22×32.42×1.67 mm3. The proposed structure is easy to fabricate and less complexity which is the key feature of this design. The design was simulated by using FR-4 ($\varepsilon r = 4.3$, $\tan\delta = 0.02$) with 1.6 mm thickness which is low cost material and easily available. In this design the thickness of the radiating patch and the ground plane is not omitted such that the simulated design becomes similar to the fabricated antenna. This design can also be used for lower X-band applications along with Ultra-Wide band. The optimized value of the designing parameters is given in table.

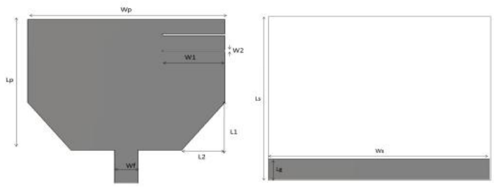


Fig. (a) Geometry of the proposed structure (top view)

(b) Geometry of the proposed structure (bottom view)

TABLE Optimized Dimensions of The Proposed Structure

Parameters	Dimensions (mm)
W_S	32.42
L_S	27
W_p	22.8
L_p	17.8
W_f	2.75
L_1	5
L_2	6.5
L_g	3.55
W_1	7.2
W_2	0.2
h	1.6
mt	0.035

D. Return Loss and VSWR curve of the Proposed Antenna

The return loss or S11 plot of the proposed structure is shown in figure given below. It shows that the antenna fairly operates over entire ultra-wide band and some portion of lower X-band while rejecting the complete U-NII (Low), U-NII (Mid), U-NII (Worldwide) and U-NII (High) bands. The proposed antenna operates entirely on UWB band (3.1 to 11.3 GHz) while rejecting the full U-NII band (5.06 to 5.85 GHz). There are two peaks in return loss curve of about -29 dB nearly at 4.2 GHz and 8.9 GHz frequencies approximately.

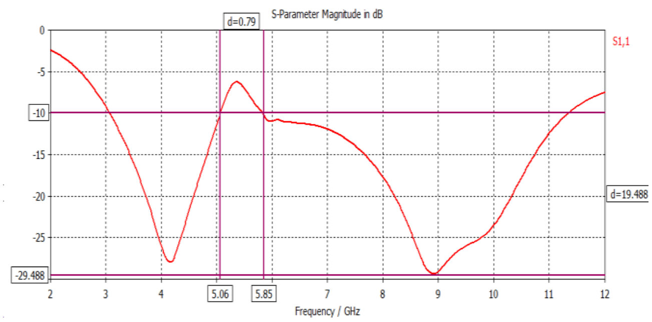


Fig. Return Loss Curve of the Proposed Antenna

The voltage standing wave ratio (VSWR) curve of the proposed design is shown in figure 5.10. The entire plot is less than 2 except for U-NII band which means that the U-NII band is completely rejected and the interference from this band is removed to a certain extent.

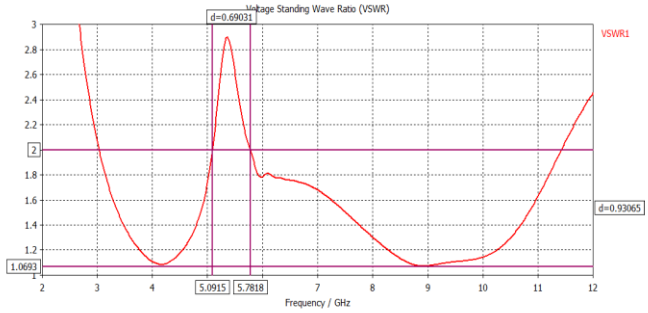


fig .-Voltage Standing Wave Ratio (VSWR) Curve of the Proposed Antenna

E. Parametric Study of Designing Parameters by Parameter Variation

In this section the parameter variation method is described for all the designing parameters involved in this structure one by one. In this study each parameter is optimized while keeping other parameter constant. Parameter variation gives an idea about the optimal values of variables or parameters to achieve desired results.

.1 Variation of Parameter W_S

The variation of width of substrate 'WS' is shown in figure given below. The figure clearly shows that as the width of the substrate is increased the peak return loss decreases and the band rejection increases very slightly; therefore the optimal value of 'WS' is chosen to reject whole U-NII band compromising for decrease in peak return loss.

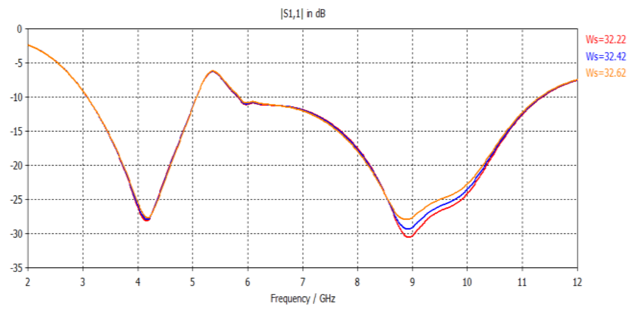


Fig. 5.11. Variation of parameter 'WS'

2 Variation of Parameter LS

The variation of length of substrate 'LS' is shown in figure given above. As the value of 'LS' is increased the band width increases and peak return loss decreases.

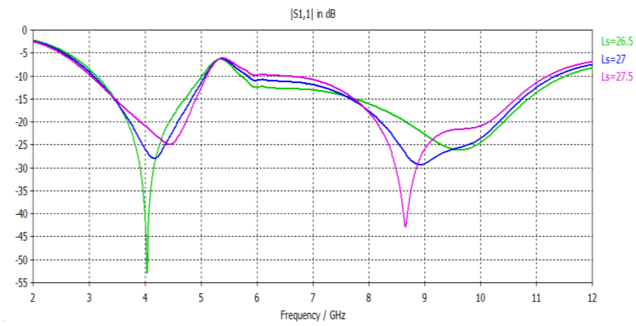


Fig. 5.12. Variation of parameter 'LS'

3 Variation of Parameter Wp

The variation of width of patch 'Wp' is shown in figure given below. The higher frequency shifts towards lower side reducing the bandwidth of the structure with the increase in the width of the patch. The same can be seen in the figure given below.

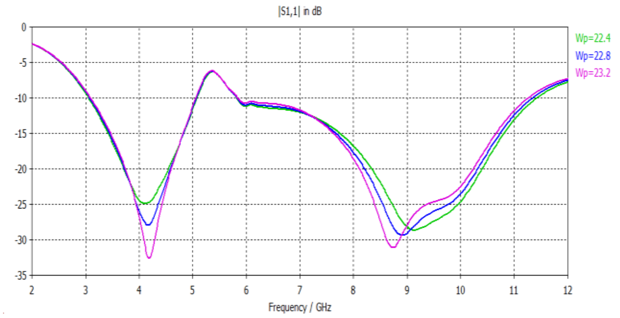


Fig. Variation of parameter 'Wp'

4 Variation of Parameter Lp

The variation of parameter 'Lp' i.e. length of the radiating patch is shown in the figure given below. The return loss peak at lower frequency is sensitive to the positive variation in 'Lp' i.e. it increases with the increase in length of patch; whereas the higher frequency peak is sensitive to negative variation in the length of the patch.

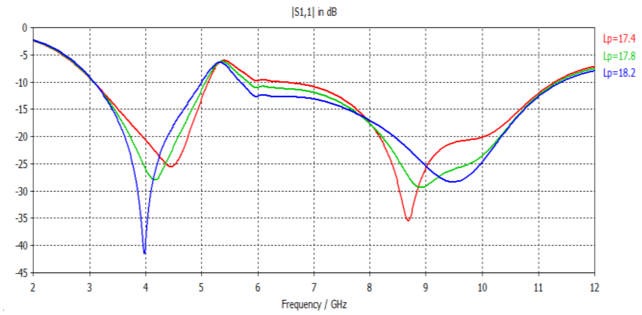


Fig. Variation of parameter 'Lp'

5 Variation of Parameter Wf

The variation of parameter 'Wf' i.e. width of the microstrip fed line to radiating patch is shown in the figure 5.15 given above. Although fed line width depends upon the impedance of patch which is to be matched to 50 Ω sources but still its variation is given above for instance. As the width of microstrip fed line increases the peak value of return loss curve increases at higher frequency whereas it reduces at lower ones which can be easily observed from the plot given above.

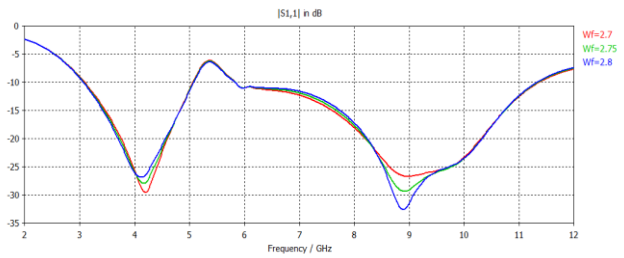


Fig. Variation of parameter 'Wf'

6 Variation of Parameter L1

The variation of parameter 'L1' i.e. length of beveled corners on radiating patch is shown in the figure given below. Although on increasing the length of beveled corners the bandwidth increases but the value of peak return loss decreases at the same time which is due to the fact that the gain bandwidth product is constant. Therefore appropriate value of 'L1' is chosen to reject only the band between 5 to 6 GHz.

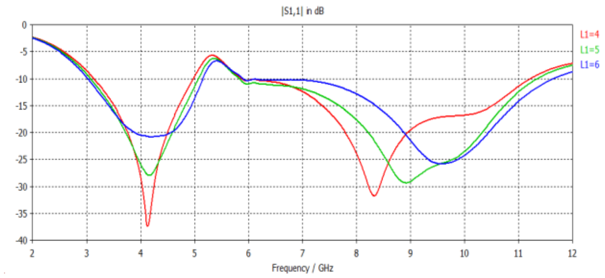


Fig.. Variation of parameter 'L1'

II. Radiation Patterns

The radiation pattern depicting far field Gain at three different frequencies viz. 3.5 GHz, 4.5 GHz, 7.5 GHz, 9 GHz and 10 GHz are shown in figure The radiation pattern is a measure of field strength transmitted or received by an antenna. The antenna shows slightly bidirectional radiation pattern at the frequency of 3.5 and 4 GHz.

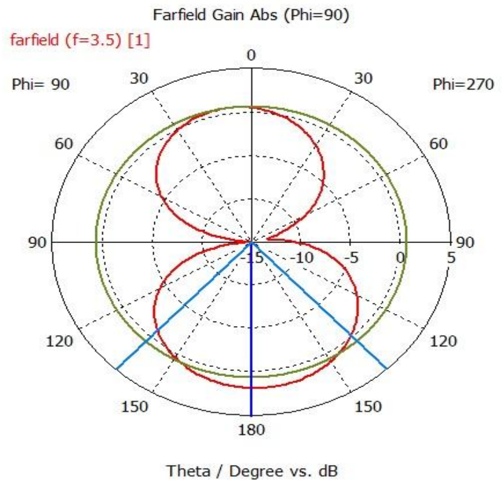


Fig.Radiation pattern at 3.5 GHz

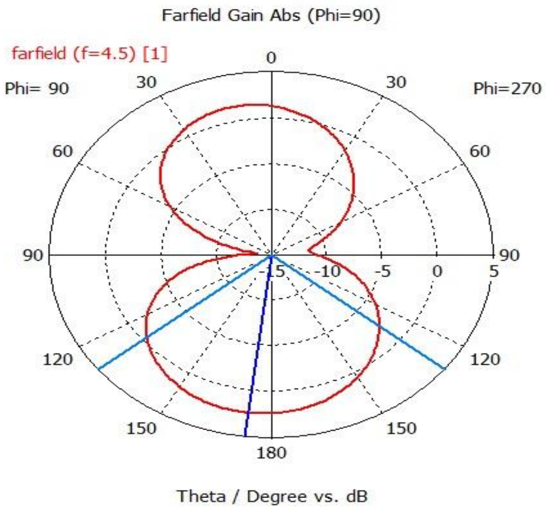


Fig. Radiation pattern at 4.5 GHz

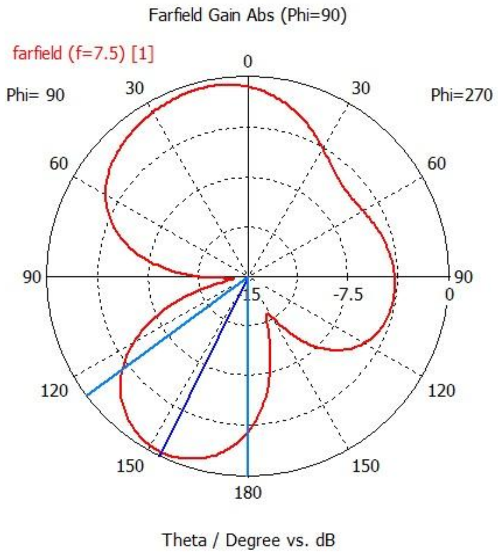


Fig.Radiation pattern at 7.5 GHz

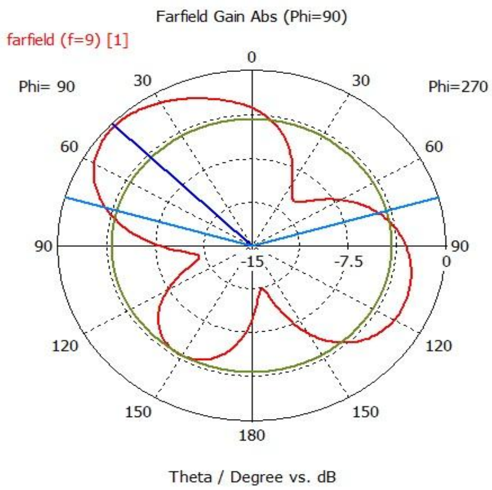


Fig.Radiation pattern at 9 GHz

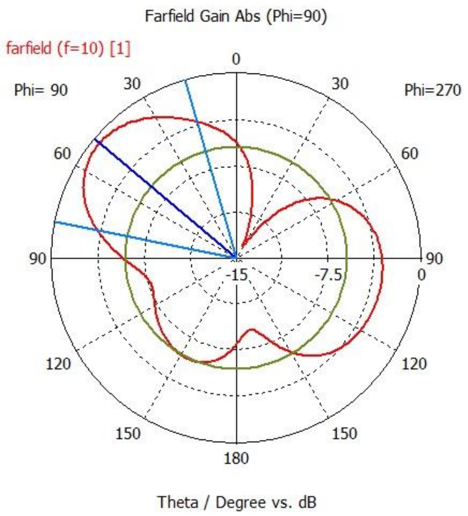


Fig. Radiation pattern at 10 GHz

A. Radiation pattern (three dimensional)

Radiation pattern (three dimensional) In figure through 5.30 the three dimensional radiation patterns are given. The value of gain at frequency 3.5, 4.5, 7.5, 9 and 10 GHz are 1.818 dB, 2.354 dB, 4.382 dB, 5.142 dB and 4.953 dB respectively.

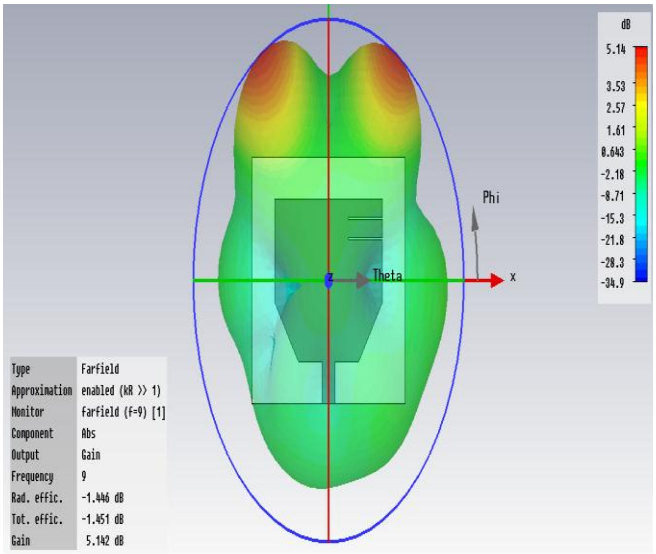


Fig. Radiation pattern (three dimensional) at 9.0 GHz

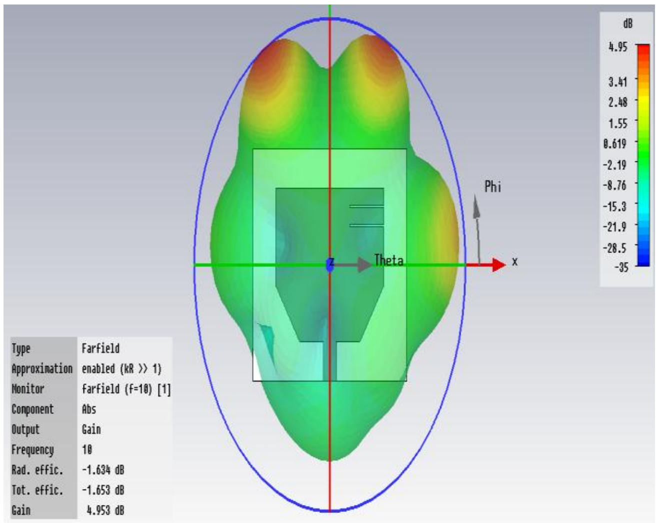


Fig.Radiation pattern (three dimensional) at 10.0 GHz

B. Smith Chart

A Smith chart was developed by Phillip H. Smith in 1940's. The Smith chart is a method that graphs the reflection coefficient and impedance and is also used to examine the relationship between them. Since smith chart is defined only for the input and output reflection coefficient parameters (S11, S22), it represents that how the antenna impedance varies with frequency. It shows the complex reflection coefficient in polar form for arbitrary impedance. The center of the smith chart circle corresponds to reflection coefficient (Γ) which when equals to zero means a perfect impedance match. Thus the plot of Γ should be as close as possible to center of the smith chart. Figure shows that the circle is close to VSWR =2 circle in the smith chart.

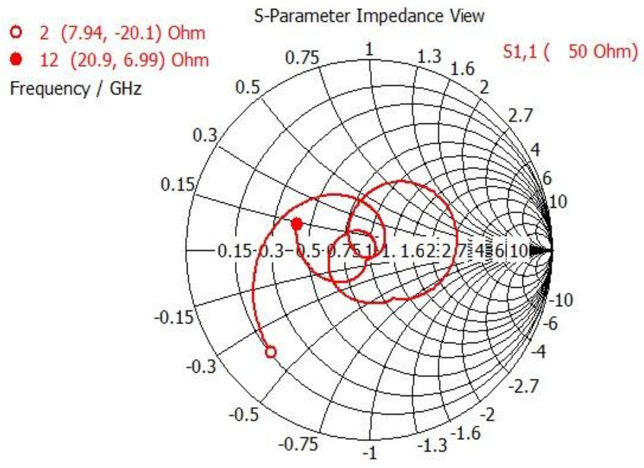


Fig.Smith chart of the proposed antenna

III. CONCLUSION

In this dissertation, an ultra-wide band antenna with band notched characteristics for U-NII band rejection is presented. In designing the antenna structure three issues were addressed. These issues were namely, simplicity of the structure, compactness of the antenna and frequency interference from the existing wireless standards like WLAN, WiMax and lower X band applications. The simulation of the proposed structure is conducted on software tool CST Microwave Studio 2011TM. In this design microstrip line fed is used. Ultra-wide bandwidth is achieved by the combined use of partial ground plane and two identical beveled corners on the radiating patch whereas to obtain band notched characteristics two identical rectangular notches are utilized. The dimension of the proposed structure is 22×32.42×1.67 mm3. Most of the UWB antenna don not operate over entire specified ultra-wide band specified by US-FCC i.e. 3.1 to 10.6 GHz. This proposed design operates over entire ultra-wide band with some lower X band rejecting only U-NII (Unlicensed National Information Infrastructure) band. U-NII band includes U-NII (Low) ranging from 5.15 to 5.25 GHz, U-NII (Mid) ranging from 5.25 to 5.35 GHz, U-NII (Worldwide) ranging from 5.47 to 5.725 GHz and U-NII (Upper) ranging from 5.725 to 5.825 GHz with a maximum power limit of 1 W for indoor and outdoor applications. The proposed antenna has a peak return loss of -29 dB approximately. This design has the ability to reject the signals from 5.06 to 5.85 GHz which is whole U-NII band.

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