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Design of a Tuning Fork type UWB Patch Antenna

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***Abstract*—**In this paper a tuning fork type structure of Ultra Wideband (UWB) antenna is proposed. The antenna offers excellent performance for UWB system, ranging from 3.7 GHz to 13.8 GHz. The antenna exhibits a 10 dB return loss bandwidth over the entire frequency band. The rectangular patch antenna is designed on FR4 substrate and fed with 50 ohms microstrip line by optimizing the width of partial ground, the width and position of the feedline to operate in UWB. The rectangular patch is then modified to tuning fork structure by maintaining UWB frequency range.

***Keywords*—**Ultra wide band, antenna, microstrip, partial ground plane.

I. Introduction

ULTRA Wideband is a carrier less short range communications technology which transmits the information in the form of very short pulses. This former military technology has gained a lot of popularity among researchers and the wireless industry after the FCC [1] permitted the marketing and operation of UWB. UWB has promised to offer high data rates at short distances with low power, primarily due to wide resolution bandwidth. The FCC in the USA has allocated a frequency band 3.1 GHz to 10.6 GHz for UWB transmission and released a mask which dictates the power levels to keep the narrow band incumbents spectrum free from interference. The UWB community is balkanized into three major groups; Multiband which is a consortium of companies led by Intel, Direct Sequence CDMA, pioneered by Freescale Semiconductor and C-Wave Technology, invented by Pulse Link. They are each racing to standardize their technology into an IEEE 802.15.3a standard. Compact and cheap ultra wideband antennas are needed for numerous UWB applications like wireless communications, indoor positioning and medical imaging. The printed planar monopole antennas are good candidates as they can be easily fabricated; they aid integration by being printed on the same board as transceiver and are low cost and light weight. There are several UWB planar antenna designs, including planar metal-plate antenna [2-3], half-disk antenna [4], and planar horn antenna [5], and many other structures [6-9], which have been reported.

In this paper an Ultra Wideband printed tuning fork structure antenna is proposed that shows acceptable return loss and bandwidth over most of the UWB frequency band. The rectangular patch is first designed by optimizing the ground plan, feedline width and position then modified to tuning fork structure. The performance of the antenna of the proposed antenna is obtained by simulation by using HFSS and results are presented.

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II. Antenna Geometry

The structure of the antenna is shown in Fig. 1. A rectangular patch of dimension 12.45 mm×16mm is on one side of an FR4 substrate of thickness 0.8 mm and relative permittivity 4.4 with the partial ground plane located on the other side. The dimension for the substrate is 32 mm×28mm.The antenna plate is fed by a microstrip of 50Ω feedline of width 'W' and placed 'L' distance from one edge of the substrate. The width of the partial ground is 'G'. The parameters 'W', 'L' and 'G' are optimized to operate the antenna within UWB range. The cut part is shown within the rectangular patch. The width of the cut part is 8mm and the length of the cut part is Lc, when Lc=14 mm, the rectangular patch becomes tuning fork type patch.

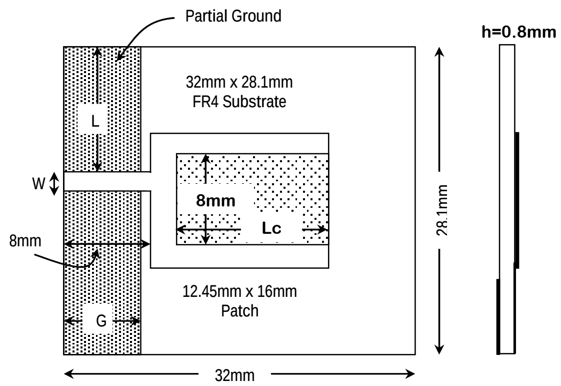

Fig. 1 Geometry of the rectangular patch antenna

III. Analysis and Discussions

The proposed antenna is optimized by using High Frequency Structure Simulator (HFSS) which is based on finite elements modeling (FEM). To design the UWB antenna, we have chosen three parameters (i) width of the partial ground, (ii) width of the feeding line and (iii) position of the feeding line from the edge of the substrate. By selecting these parameters, the proposed antenna can be tuned to operate within the frequency range 3.7–13.8 GHz.

The return loss of the propped UWB antenna with the variation of L, the feedline position from the edge of the substrate is shown in Fig. 2 by maintaining the partial ground width of G=7.6mm and feedline width of W=1.8mm. The ultra wide band operation is only possible for L=3.25mm which is not symmetric, that is, asymmetric feedline results ultra wideband operation. The figure also shows that the return losses for the L=4.325 and L=6.325 are same, because the feedline distance from both the sides of the substrate is same.

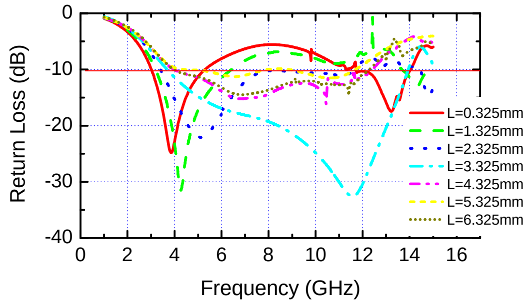

Fig. 2 Simulated return loss in dB showing is that the best performance is obtained for the feedline position L=3.325 from the substrate edge

Fig. 3 shows the proposed antenna return losses for varying the partial ground width "G" from 6.8mm to 8.2 by maintaining L=3.325mm and W=1.8mm. The figure shows that the width of 7.4mm and 7.6mm result wider bandwidth whereas the bandwidth decreases with the wider partial ground. It is also observed that by increasing the partial ground width, the bandwidth decreases as well as some band reject phenomena also observed.

The width of the microstrip feedline was varied from 1.2mm to 2.2 mm and simulated return losses in dB and impedance magnitudes in Ohms are shown in Figs. 4 and 5, respectively by maintaining L=3.325mm for G=7.6mm. Figure 4 shows that the variation of feedline width does not change the bandwidth of the antenna appreciably except for W=2.2mm. It can be seen that the bandwidth is relatively constant between 1.2 and 2 mm, implying that the bandwidth is not very sensitive to the feedline width. However, Fig. 5 shows that the characteristic impedance decreases with the increase of the feedline width. It is also observed that the impedance is very close to 50Ω from the frequency range 6 to 13 GHz for the feedline width of 1.8mm.

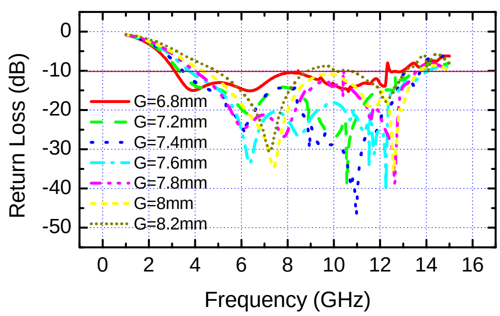

Fig. 3 Simulated return loss in dB showing is that the best performance is obtained for the partial ground width G = 7.4mm and G=7.6 mm.

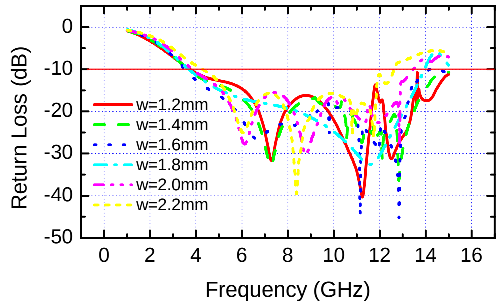

Fig. 4 Simulated return loss in dB for different feedline width with G=7.6mm and L=3.325mm.

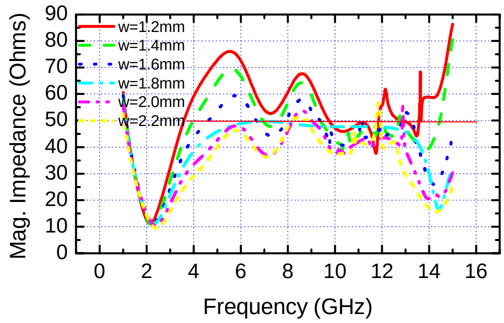

Fig. 5 Simulated return loss in dB for different feedline width with G=7.6mm and L=3.325mm. The best performance is obtained for the feedline width W=1.8mm.

Simulation has done by varying various sizes of partial ground width G, feedline width W and feedline position from the edge of the substrate L. The best performance is obtained for G=7.6 mm, L=3.325 mm and W=1.8 mm. The return loss, VSWR, characteristic impedance and phase angle of the proposed optimized antenna is shown in Figs. 6 and 7. Fig. 6 shows that the antenna can be operated from 3.69 GHz to 13.92 GHz and within this frequency range the VSWR varies from 1.06 to 1.92. Fig. 7 shows the characteristic impedance variation. The characteristic impedance is 34.6 Ω at 3.69 GHz and 32.7 Ω at 13.92 GHz. However the characteristic impedance varies from 45Ω to 50Ω within the frequency range 4.83 GHz to 13.14 GHz. The phase angle linearly decreases from 19.7^{o} to -5.9^{0} within the frequency range 5 GHz to 12.6 GHz and some nonlinearity are observed at low and high frequencies of UWB range.

Figs. 8 and 9 show the simulated rectangular antenna theta cuts at 0^{o} and 90^{o} radiation patterns at different frequencies starting from 4GHz to 10GHz in 1 GHz steps.

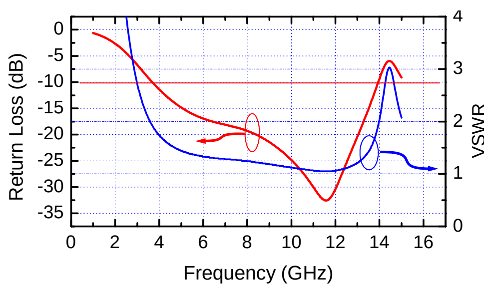

Fig. 6 Simulated return loss and VSWR for the antenna with G=7.6mm, L=3.325mm and W=1.8mm.

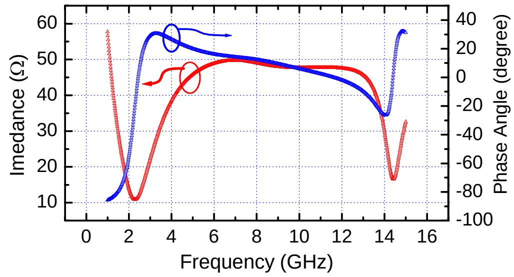

Fig. 7 Simulated characteristic impedance and phase angle for the antenna with G=7.6mm, L=3.325mm and W=1.8mm.

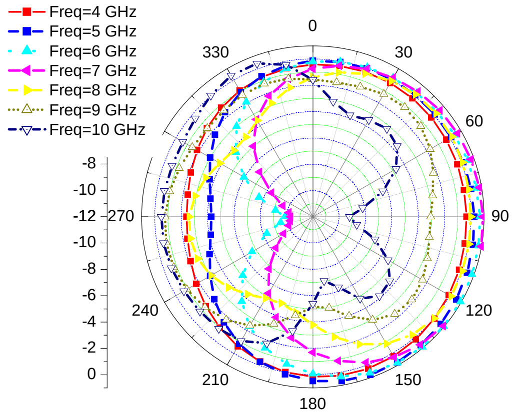

Fig. 8 Radiation patterns of proposed antenna at 4 to 10 GHz in 1GHz step (Theta cuts for 0^o)

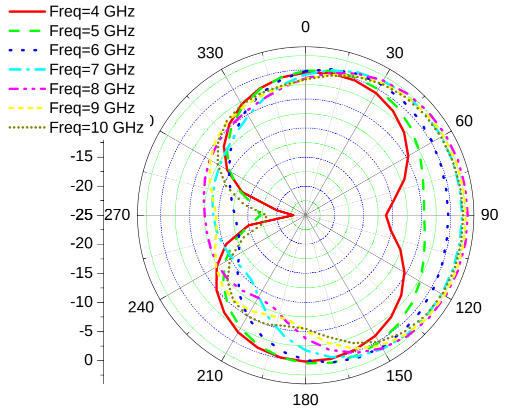

Fig. 9 Radiation patterns of proposed antenna at 4 to 10 GHz in 1GHz step (Theta cuts for 90^o)

The next step is to introduce rectangular cut part in the patch antenna and the behavior of the antenna is studied. The width of the cut part is maintained at 8mm and length of the cut part Lc is varied. The return losses for the antenna without cut (solid), cut length Lc of 6 mm and 14 mm are presented in Fig. 10.The 14mm cut length formed the antenna like a tuning fork structure and thus defined as tuning fork UWB antenna. It is observed from the figure that the UWB range is not varied appreciably by cutting the rectangular patch.

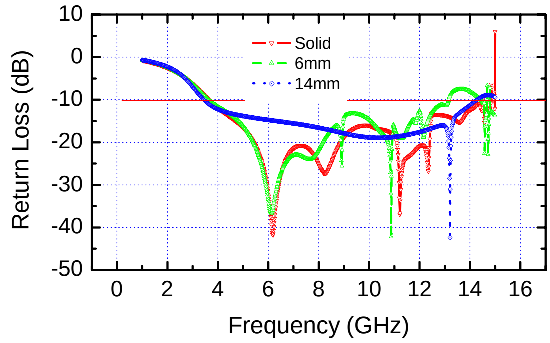

Fig. 10 Simulated return loss in dB for rectangular patch (solid), cult length of 6mm and 14mm (tuning fork structure)

The characteristics impedance of the tuning fork UWB antenna is presented in Fig. 11. The figure shows that the impedance decreases at lower band; increases at middle band and remain constant at high band of UWB range. However, the characteristic impedance is within the range of 35 to 68 Ω.

The simulated current distribution at 4GHz for the rectangular, cut lengths of 6mm and 14mm are presented in Fig. 12. The current is mainly distributed on the edge of the patch close to feedline.

The radiation pattern of the rectangular, 6mm and 14mm cuts are presented in Fig. 13 at 4GHz, 6 GHz and 8GHz for $\varphi=0^o$ and $\varphi=90^o$. The radiation pattern for three different types antenna shows similar patterns, however, the tuning fork structure results more uniform radiation pattern compared to other two structures.

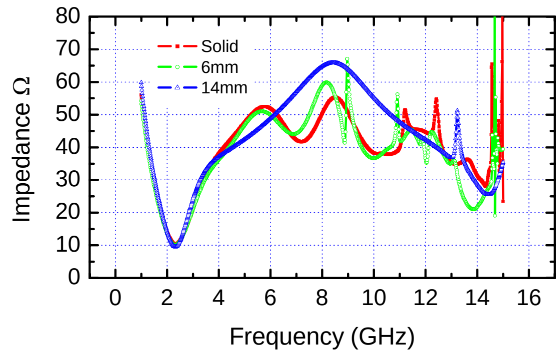

Fig. 11 Simulated characteristic impedance for rectangular patch (solid), cult length of 6mm and 14mm (tuning fork structure)

IV. Conclusion

In this simulation paper, a simple tuning fork structure for a planar UWB antenna has been proposed and investigated in details to find its bandwidth properties. The behavior of antenna is influence by the feed width, position of feedline and the partial ground size. The analysis results show that a simple tuning fork type UWB antenna can be obtained by optimizing the parameters.

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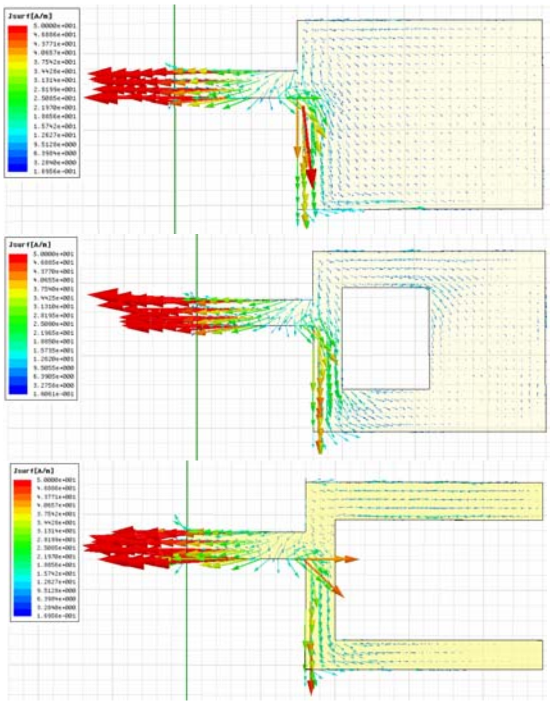

Fig. 12 Simulated surface current density at 4 GHz for rectangular patch (solid), cult length of 6mm and 14mm (tuning fork structure)

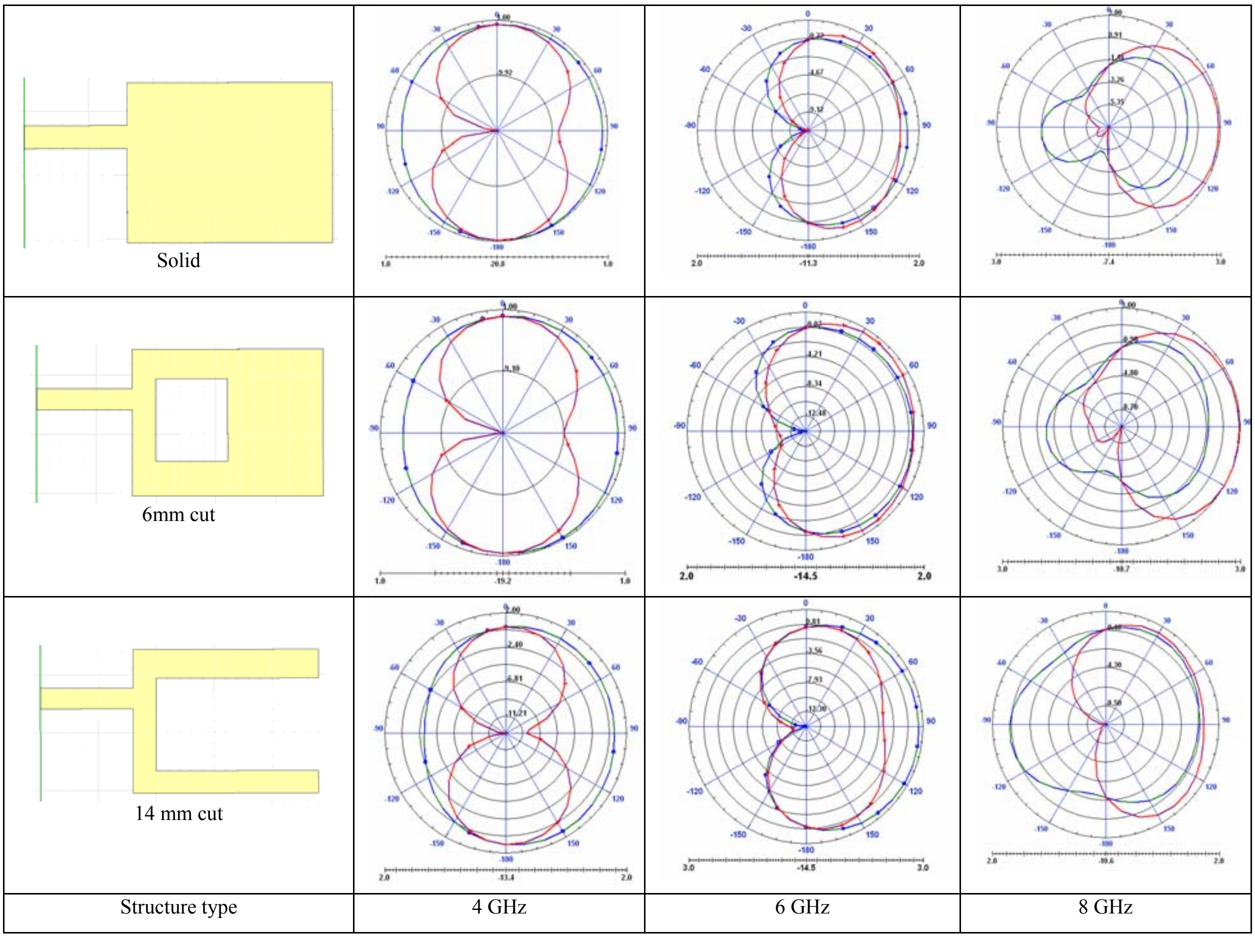

Fig. 13 Simulated radiation patterns at 4GHz, 6GHz and 8 GHz for rectangular patch (solid), cult length of 6mm and 14mm (tuning fork structure)