INTERNAL COMPACT PRINTED LOOP ANTENNA WITH MATCHING ELEMENT FOR LAPTOP APPLICATIONS

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***Abstract*— An internal compact printed loop antenna with matching element is presented for laptop applications. Bending to the printed loop structure is employed to reduce the size of antenna. A matching element is used at backside of the substrate to enhance the bandwidth of the antenna. The matching element is of rectangular shape with inverted U shape slot in it. The proposed antenna with wideband characteristics covers GSM900, GSM1900, UMTS, LTE2300, WLAN, WiMAX 3.3/3.5/3.7 bands and is suitable for laptop applications. The antenna structure is simulated using IE3D software.**

Keywords- bended; multiband antenna; printed loop antenna; tablet; wideband antenna.

I. INTRODUCTION

Modern wireless communication system is moving from one generation to another. With the advancement of wireless communication system, wireless networking has become an important function for laptop, notebook and tablet. Nowadays the laptops are available for different wireless applications. Thus, many researchers are getting attracted towards the field of antenna designing for wireless systems. The main point of attraction is size of antenna and its ability to operate at different frequencies.

The basic difference of designing an antenna for laptop and mobile phone applications is that the laptop in earlier development stages is not considered as a wireless communication device. Thus, the space provided for antenna in laptops is small and confined. There are many challenges for antenna design for laptop applications such as its integration into laptops. There is extensive use of conducting materials in the cover of the laptop to minimize radiation from very high speed processors. Thus, it is difficult task to find a place suitable for an antenna in an environment free from the effects of other conductors. Therefore, it has become a necessary to reduce the volume of an antenna and maintaining its multiband operations. The printed loop antenna is a planar structure and can be designed as a low profile antenna. The printed loop antenna structure is a promising candidate for antenna design with reduced volume for multiband operation in the laptops.

The present trend for wireless communication in laptops includes Global System for Mobile Communication (GSM), Digital Cellular Service (DCS), Personal Communication Service (PCS), along with Universal Mobile Telecommunication System (UMTS), Wireless Local Area Network (WLAN) services. In addition to it, World Wide Interoperability For Microwave Access (WiMAX) technology is also used in wireless applications such that it provides wider coverage and higher data transmission speed than WLAN. Long Term Evolution (LTE) is the standard for wireless communication for higher data transmission speed. LTE is marketed as 4G services provided in cellular and data terminals. Nowadays, some internal printed loop antennas have been proposed though only few of them covers all the desired bands required for wireless laptop applications [1]-[10]. Chiu *et al*. (2010) have presented a simple printed loop antenna with a tuning element for hepta-band laptop applications. It has covered GSM850/GSM900, DCS1800, PCS1900, UMTS, WLAN and WiMAX bands [9]. The antenna is printed on a FR4 substrate. Wong *et al*. (2011) have presented a small size loop antenna with a parasitic shorted strip monopole for internal wireless wide area network (WWAN) notebook computer applications [10].

This paper presents a rectangular printed loop antenna structure with wideband operations to cover bands for wireless applications in laptop, notebook and tablets. It uses traditional loop theory for calculating initial dimensions of antenna structure. Then a series of simulation is done to get optimize dimensions of the printed loop structure based on the requirement for desired bands of operations. The rectangular printed loop antenna is further bended; this will further help in reduction of dimensions of the proposed antenna. Thus the bending of the printed loop antenna helps in reduction in volume of antenna structure. The proposed design uses a rectangular matching element with inverted U shape slot in it, at the backside of the substrate as the matching element is used to increase the bandwidth of the antenna [9]. The proposed antenna with wide bandwidth covers eight bands required for laptop's wireless applications. The volume of the proposed antenna is less than the volume of antenna [9],[10]. It has a volume of only $51 \times 12 \times 0.8$ mm^3 is a suitable candidate to be used in laptops for wireless applications. To design and simulate the antenna structure Integrated Environment for 3-D Simulation (IE3D) simulation software is used.

II. DESIGN OF ANTENNA STRUCTURE

A. Traditional Loop Theory

The current distribution of loop antenna structure depends on the dimensions of the loop whether they are small loops or large loops. They may be uniform current distribution or non-uniform current distribution. The uniform current distribution exists in the small loop structures and the uniform current distribution for the loop is valid till the circumference of the loop is less than about 0.2 times of the wavelength (or radius less than 0.03 times of wavelength) [11]. Thus for small loop antenna structure

$$I(\Phi)=I_0 \qquad (1)$$

As the perimeter of the loop structure is increased, there are current variations along its perimeter which must be taken into account. Thus for electrically large loop antenna, the current distribution is non-uniform. Firstly, it is assumed that the variations are co-sinusoidal but this approximation is not being valid near the driving point. Thus a new approximation is given for the electrically large loop antenna which satisfies its non-uniform current distribution [11]. The Fourier series of non uniform current distribution is given in equation

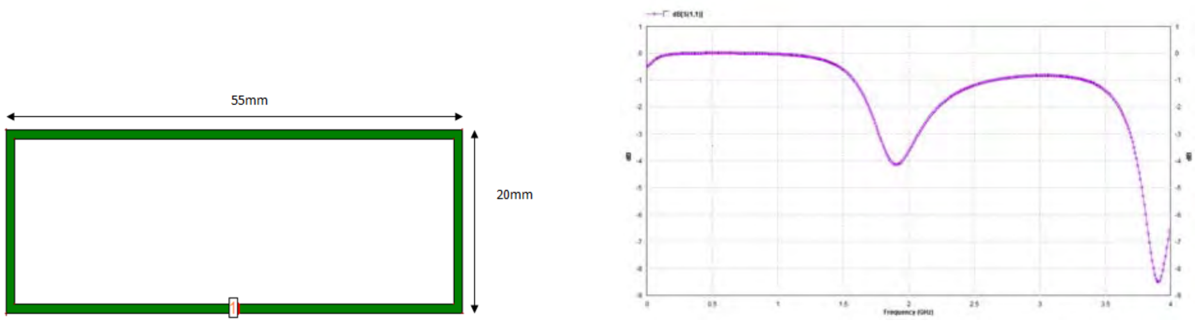
$$I(\Phi')=I_0+2\sum_{n=1}^{M} I_n \cos(n\Phi')$$

where Φ is the measured angle from the feed point of the loop antenna along the circumference.

For the proposed antenna, the electrically large loop is used. The loop is used as a printed element for designing of a compact printed loop antenna for laptop applications. The electrically large loop structure has its perimeter equal to 1-wavelength [11]. Thus by deciding an operating frequency, the perimeter of the rectangular loop is obtained. Traditional loop antenna concepts are used to calculate the perimeter of printed loop antenna and commercial software package IE3D is used for its simulation. RT-Duroid is used as a dielectric material on which structure is printed. It has relative permittivity (ε_r) 2.2 and loss tangent 0.0009.

B. Design of rectangular printed loop antenna

The proposed Printed Loop antenna is designed for laptop applications such as GSM, UMTS, LTE, WLAN, WiMAX 3.3/3.5/3.7. So the frequency range selected for the simulation lies in between 0-4 GHz. However, 2 GHz is selected as operating frequency for deciding the initial dimension of internal compact printed loop. A rectangular printed loop antenna is simulated without any ground plane. The loop antenna structure is electrically large and hence the perimeter of the loop is taken of one wavelength. The structure is simulated without the ground plane is shown in Fig. 1(a). The initial dimension of the loop taken as 55 mm and 20 mm. The feed point is taken at centre of the printed loop antenna. A port is used as feed to the rectangular printed loop antenna. From Fig. 1(b), it is seen that the simple rectangular printed loop has a resonant mode in the rectangular loop nearly at 0.95 GHz which is approximately at half a wavelength [12].



(a) (b)

Figure 1: Rectangular Printed loop without ground plane and simulation results

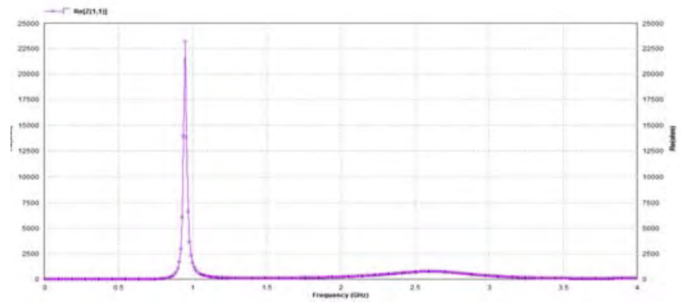


Figure 2: Real part of input impedance for Rectangular Printed loop without ground plane.

In the Fig. 2, it is seen that a very high value of resistance at 0.95GHz, so this mode is referred to as anti-resonance [12]. Thus the rectangular printed loop antenna without ground plane generates traditional loop modes. There is an anti-resonance at half wavelength but due to its larger values of resistance it does not match with 50 Ω of feed and therefore does not generate a resonance [9].

C. Folding of the structure and addition of strip

After the simulation of simple rectangular printed loop structure, the loop is folded and a strip is added to the XZ-plane. The dimension of the strip along X-axis is equal to the length of printed loop antenna and when the length loop is varied the length along X-axis of the strip is also varied. The width of the strip along the Z-axis is fixed to 0.8 mm. The folded printed loop structure is simulated without any ground plane. The dimension of the loop is same as that of simple rectangular loop antenna i.e. A = 55mm, B = 20mm and folding length is taken as 4 mm.The printed loop after the addition of strip shows considerable improvement in return loss. Fig. 3 shows 3D view and the return loss of printed loop antenna with strip. At 2.1557 GHz, the return loss obtained is -18.987 dB.

D. Addition of large ground plane

A large ground has been added to the structure. The size of ground is defined by using the aspect ratio and diagonal of display screen. The proposed antenna is designed for the display of diagonal size of 10 inch. The aspect ratio of 5/4 is initially taken and height and width of display ground are 200 mm and 160 mm. The return loss of the loop structure with ground plane is shown in Fig.4. It is observed that with the addition of large ground plane, the return loss at resonating frequencies has been improved within the desired range of 0-4 GHz.

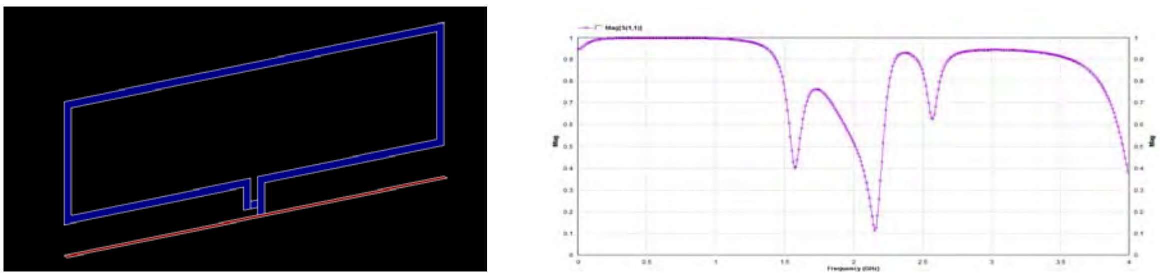


Figure 3: 3D view and Return loss of printed loop antenna with addition of strip.

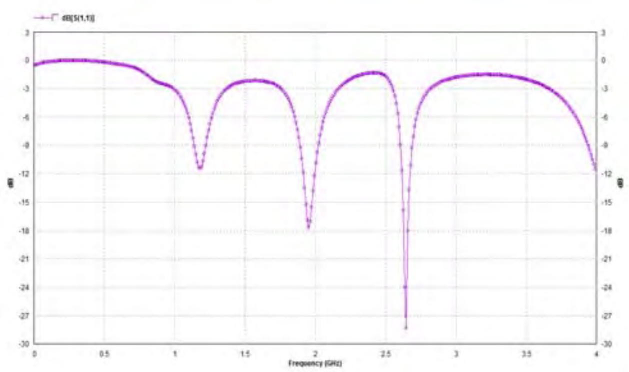


Figure 4: Return loss of printed loop antenna with addition of large ground plane.

E. *Variation of loop dimension*

A series of simulations have been performed so that the dimension (length and width) of the loop is optimised. An analysis has performed on the loop such that certain geometrical parameters of the initial loop are varied to see their effects on antenna parameter. The length and width of the loop have been varied in a combination and its return loss for different combinations are shown in Fig.5. And it is observed that as the length of the printed loop increases and the width of the printed loop decreases the return loss at nearly one-wavelength resonating mode is getting better than the previous combinations. It is also seen that the third and the fourth resonant frequencies are also shifted towards left as the length of loop increases and the width of loop decreases. It is seen that for 65mm × 10mm first and second resonant points have the highest value of return loss. The fourth resonant mode is required for WiMAX coverage but for loop dimension of 65mm × 10mm, the return loss of fourth resonant point only reaches to the value of -4.065 dB. Thus the next better dimension 63mm× 12mm of loop is selected. In this dimension, the return loss of first three resonant points are better than -22 dB and fourth resonant point has value of -7.6 dB.

F. *Variation of thickness of substrate*

After varying the dimensions of printed loop antenna, simulations have been done to see the effect of height of substrate on the antenna parameters such as resonant frequency and return loss. The effect of variation of substrate thickness is shown in Fig. 6, it is seen that with the variation of height of substrate from 0.4 mm to 0.8 mm, the resonant frequency points are slightly shifted towards left. The fourth resonant frequency which is not present in the range from 0 to 4 GHz at 0.4 mm, is also shifted towards lower value in the required range as the height increases. The return loss for second resonant mode is also improved with the increase of height from 0.4mm to 0.8mm.

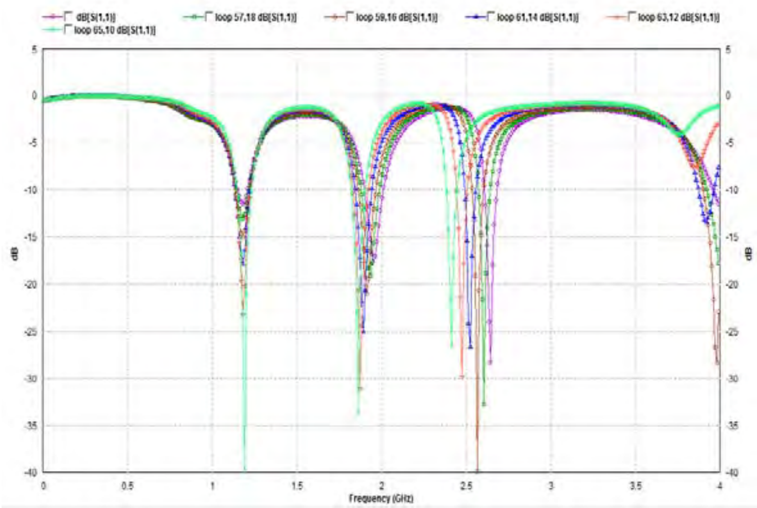


Figure 5: Comparison of return loss of printed loop antenna for different combinations of dimensions of loop structure .

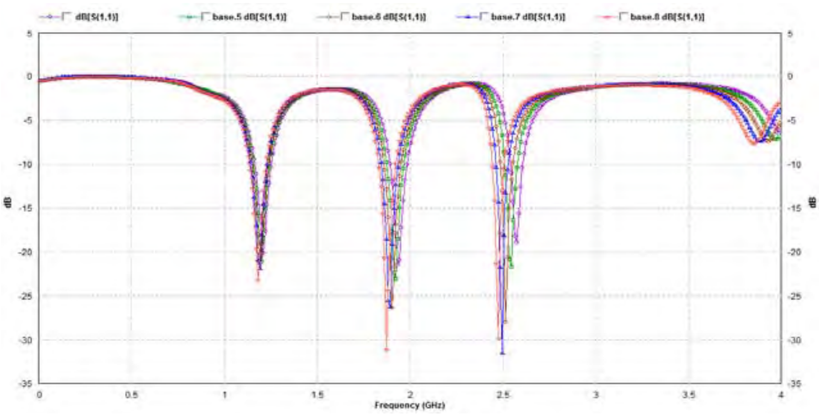


Figure 6: Comparison of return loss of printed loop antenna with different thickness of substrate.

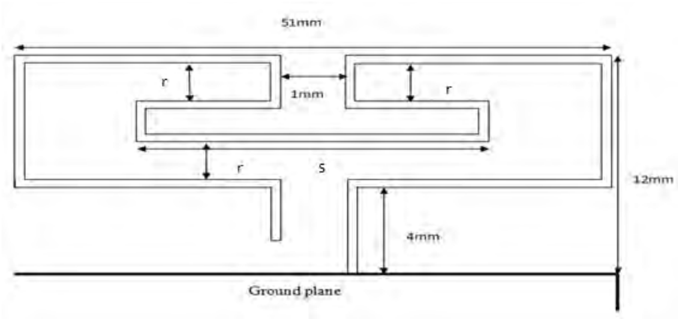
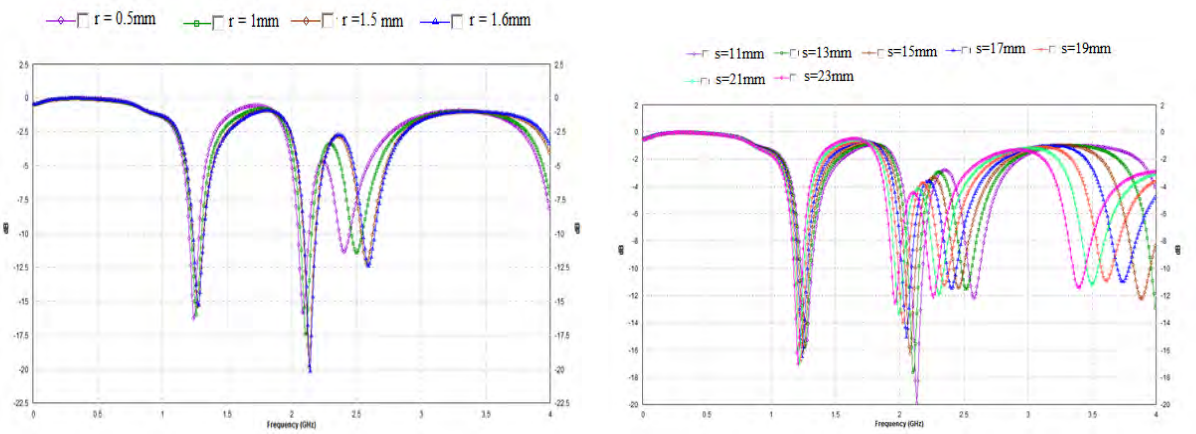


Figure 7: Printed loop antenna structure after bending with parameter ‘r’ and ‘s’.



(a) (b)

Figure 8: Return loss of printed loop antenna with (a) variation in ‘r’ and ‘s’ fixed to 11mm, (b) variation in ‘s’ and ‘r’ fixed to 1.5mm.

II. BENDING OF THE PRINTED LOOP

After different simulations for printed folded loop structure, the dimension of loop has been modified for obtaining smaller size of the antenna. This has been done by bending the printed loop structure. The two factors are decided and they are varied to see their effect on the antenna parameters. The length of ‘r’ and ‘s’ are decided as a parameter which are shown in Fig.7 and are varied as ‘r’ from 0.5 mm to 1.6 mm and ‘s’ from 11 mm to 25 mm. The bending of the loop will increase the electrical length of the structure and thus have an option to reduce its dimensions. In Fig. 8(a) & 8(b), the variation of return loss with the variation of ‘r’ and ‘s’ with one parameter fixed at a time are shown. From the Fig.8(a) it is seen that if ‘r’ is varied from 0.5 mm to 1.6 mm there is a slight shift in resonant frequencies to the higher value and the return loss is improved. From the Fig.8(b), it is observed that if ‘s’ is varied from 11 to 23 mm there is a frequency shift to lower values due to the increase in the electrical length of the loop structure with ‘s’. The fourth resonant frequency which is not in the range of 0-4 GHz at s =11mm is shifted from higher values to 3.3975 GHz at s = 23mm. Thus for desired band coverage, the length ‘r’ and ‘s’ are set to 1.5 mm and 23 mm with smaller loop dimensions of 51mm × 12mm.

III. IMPEDANCE MATCHING

Impedance matching is the direct method/technique to influence the impedance behavior of an antenna. The matching element is placed close to the radiating element. The matching element enhances the bandwidth and also improves the radiation efficiency of the antenna[9][14]. To achieve greater bandwidth, a rectangular grounded element with inverted U shape slot is used at the back side of the substrate. The length of the matching element is fixed to 12mm and the width ‘x’ of the matching element is decided through simulations. The distance between the matching element and feed is about 0.5mm. The width ‘x’ is varied from 7mm to 9mm. The return loss for different values of ‘x’ is shown in fig.9. With the addition of matching element two wide bands having return loss better than -6 dB have been obtained. With the increase in ‘x’, the bandwidth of the first band starts increasing while the bandwidth of the second band is reduced. For x = 9mm, the two resonant frequencies of 2.2336 GHz and 3.3483 GHz covering two wide bands of -6 dB bandwidth of 809 MHz and 896 MHz are obtained.

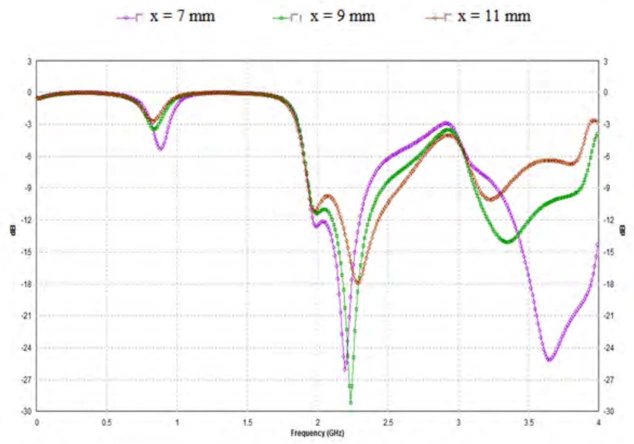
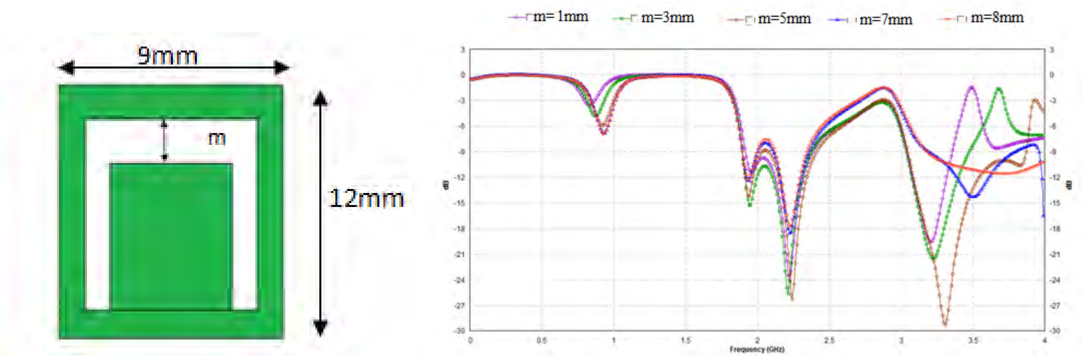


Figure 9: Return loss of printed loop antenna for different values of ‘x’.



(a) (b)

Figure 10: (a) Impedance matching element used at the backside of antenna structure (b) Return loss of printed loop antenna with different values of ‘m’.

As it is seen that with the addition of the matching element the bandwidth of the structure improves though it results in the reduction of the return loss at 0.84 GHz. So in order to improve the return loss, the matching element is modified by making an inverted U shape slot in it [9]. In inverted U shape slot a varying parameter ‘m’ is decided and is shown in Fig.10(a). In Fig. 10(b), the comparison of return loss for different values of ‘m’ is shown. As ‘m’ varies from 1mm to 8mm the return loss of first resonant mode improves considerably. At m = 6 mm it has another resonant frequency that has return loss better than -6 dB. Though with further increase it improves return loss but also result in decreasing of bandwidth for the resonant frequency of near at 2.2 GHz. Thus optimum value selected is 7 mm. For m = 7mm the resonant frequencies are 0.9344 GHz, 2.22541 GHz and 3.5 GHz that cover three bands of -6dB bandwidth which are found as 57MHz, 604 MHz and 949 MHz, respectively is achieved.

The new generations of laptops are provided with the widescreen and of aspect ratio of 16/9, for providing high quality of images. Thus the aspect ratio has been changed from 5/4 to widescreen ratio of 16/9. As the aspect ratio of the screen is changed the size of ground plane is also changed to 220 × 120 mm^2. It is seen from Fig. 11, that changing the aspect ratio of the screen to 16/9 from 5/4 leads to the decrease in return loss at some frequencies but does not affect much, the bands it covers.

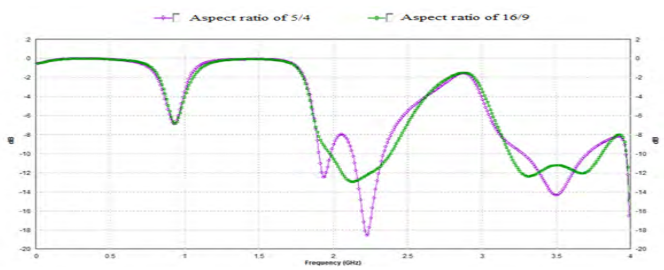


Figure 11: Return loss of printed loop antenna with different aspect ratio of screen

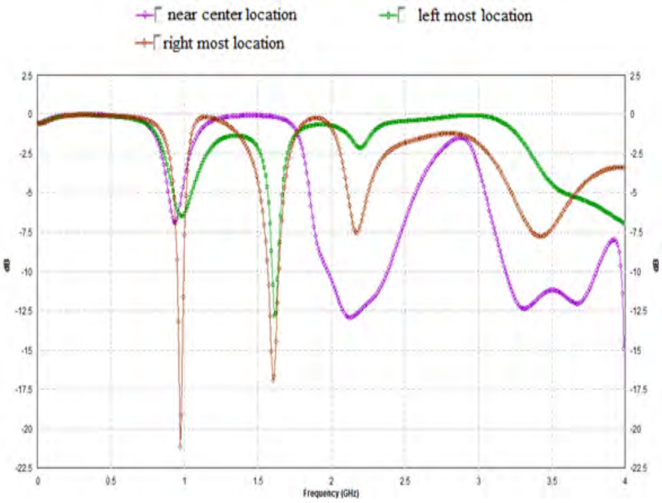
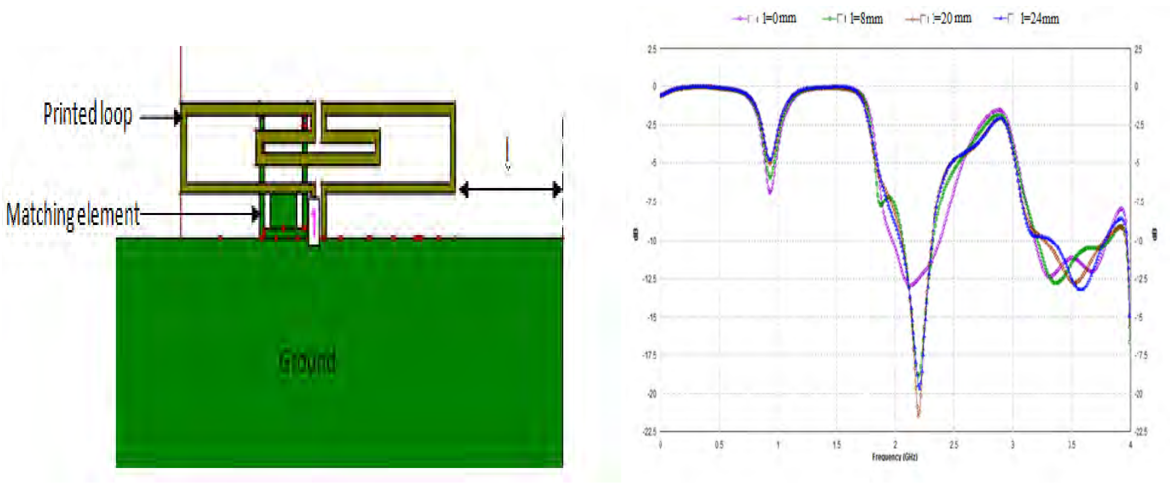


Figure 12: Return loss of printed loop antenna for different locations of matching element.

The location of matching element is varied to see its effect on the resonant frequencies and bandwidth it covers. The simulation is conducted on three locations. The location 1 is the position when the matching element is placed at the right most corner of the of the printed loop antenna. The location 2 is the position when the matching element is placed at near centre position that is near to the feed whereas the third location of the matching element is the one for which the matching element is placed at the left most corner of the printed loop. All the locations for matching element is at backside of substrate. In Fig. 12, there is comparison for different locations of matching element based on return loss. It is clearly seen that best location of the matching element is near center location as it covers the desired frequency wide bands. This is because at near center location the matching element is nearer to the feed and the impedance matching is improved [11].

The best location for antenna in laptop is at top edge of the ground plane [13]. Thus position of printed loop antenna is placed at the top edge of display screen ground. The position of the antenna is varied at the top edge of display ground. The effect of variation of the location of an antenna on the top of the display screen is seen through series of simulations.

The effect of variation of the location of an antenna on the top of the display screen is seen through series of simulations. (‘l’ is the distance between the top right most edge of antenna and right most edge of the ground as shown in Fig. 13(a)). It is seen from Fig. 13(b) that as ‘l’ is varied from 0mm to higher values, it affects the impedance matching of the antenna.



(a) (b)

Figure 13: (a) Printed loop antenna structure showing parameter ‘l’ (b) Return loss of printed loop antenna with different values of ‘l’.

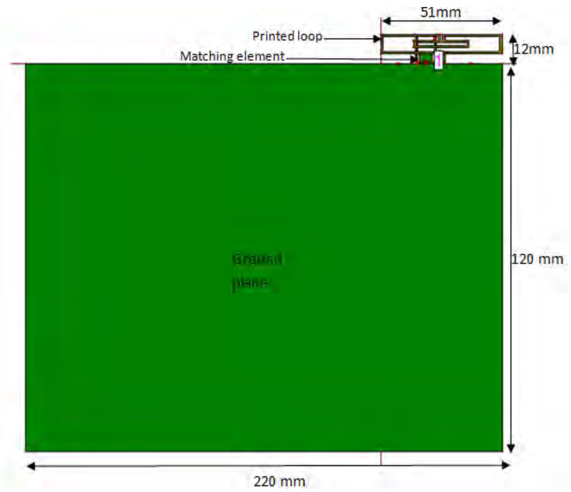
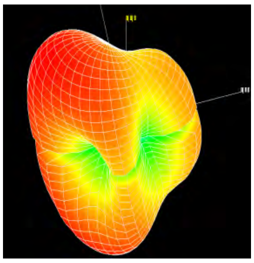
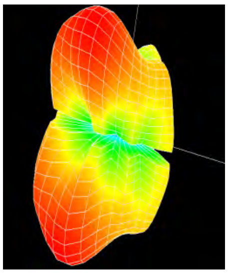


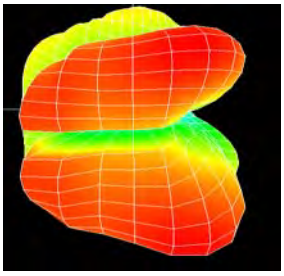
Figure 14: Final proposed printed loop antenna for laptop applications.



(a)



(b)



(c)

Figure 15: 3D radiation pattern of the proposed antenna (a) at 0.9523 GHz b) at 2.005 GHz c) at 3.3584GHz.

IV. RESULT AND DISCUSSION

After series of modification to the initial printed loop structure, a final proposed antenna is obtained with desired bands and gain. The final proposed printed loop antenna is shown in Fig. 14 The dimension of final structure for the proposed antenna is 51mm × 12mm and has substrate thickness of only 0.8 mm. The volume of final antenna is $51\times12\times0.8$ mm^3.

Table 1: Antenna parameters of final printed loop antenna with matching element.

Resonant frequency (GHz)	Gain (dBi)	Antenna Efficiency (%)	Radiation Efficiency (%)	Frequency Range (GHz)	Bandwidth (MHz)
0.9385	2.30	67.86	90.03	0.91009- 0.967246	57.1554
2.1349	4.79	85.18	92.84	1.86678- 2.53418	667.339
3.3152	6.29	84.40	90.89	3.07408- 4.0	925.92

From the Table 1, it is seen that the gain reaches up to 6.29 dBi at resonant frequency 3.3152 GHz. It is seen that the final antenna has three bands centre at 0.9385 GHz, 2.1349 GHz, 3.3152 GHz of -6 dB bandwidth which are found to be 57 MHz, 667 MHz and 925 MHz. The bands covered are GSM 900, GSM1900, UMTS, WLAN at 2.4 GHz, WiMAX 3.3/WiMAX 3.5 and WiMAX 3.7. The antenna efficiency at 0.9385GHz, 2.1349 GHz and 3.3152 GHz are 67.86%, 85.18% and 84.40%, respectively. The radiation efficiency is better than 88% for all bands. The 3D radiation pattern for the designed antenna is shown in Fig. 15. The radiation pattern is though not purely omnidirectional but provides a wide coverage and is thus suitable for operations in laptop applications.

V. CONCLUSION

The proposed internal compact printed loop antenna with matching element for laptop applications has been successfully designed and simulated using procedure of traditional loop antenna along with IE3D software. The proposed antenna is a compact printed loop antenna which is required for modern small and slim laptops. Bending to the printed loop structure is employed to reduce the size of antenna. In addition to it, a matching element is used at backside of substrate to enhance the bandwidth of the antenna. The matching element is of rectangular shape with inverted U shape slot in it. The proposed antenna occupies a volume of $51\times12\times0.8\ mm^3$. RT Duroid has been used as dielectric material. The proposed antenna which has a simple structure making its fabrication easy, covers GSM900, GSM1900, UMTS, LTE2300, WLAN, WiMAX 3.3/3.5/3.7 bands.

REFERENCES

[1] K. L. Wong, L. C. Chou, and C. M. Su, "Dual-band flat-plate antenna with a shorted parasitic element for laptop applications," *IEEE Trans. Antennas Propag.*, vol. 53, pp. 539–544, Jan. 2005.

[2] D. Liu and B. Gaucher, "A quadband antenna for laptop applications,"in *Proc. IEEE Antennas and Propagation Society Int. Symp.*, Hawaii, Jun. 2007, pp. 128–131.

[3] C. H. Kuo, K. L. Wong, and F. S. Chang, "Internal GSM/DCS dualband open-loop antenna for laptop application," *Microw. Opt. Technol. Lett.*, vol. 49, pp. 680–684, Mar. 2007.

[4] C. Zhang, S. Yang, S. Lee, S. E. Ghazaly, A. E. Fathy, H. K. Pan, and V.K. Nair, "A lowprofile twin-PIFAlaptop reconfigurable multi-band antenna for switchable and fixed services wireless applications," in *Proc. IEEE Antennas and Propagation Society Int. Symp.*, Hawaii, Jun. 2007, pp. 1209–1212.

[5] C. W. Chiu, Y. J. Chi, and S. M. Deng, "An internal multiband antenna for WLAN andWWAN applications," *Microw. Opt. Technol. Lett.*, vol. 51, pp. 1803–1807, Aug. 2009.

[6] K. L. Wong and L. C. Lee, "Multiband printed monopole slot antenna for WWAN operation in the laptop computer," *IEEE Trans. Antennas Propag.*, vol. 57, pp. 324–330, Feb. 2009.

[7] K. L. Wong and F. H. Chu, "Internal planar WWAN laptop computer antenna using monopole slot elements," *Microw. Opt. Technol. Lett.*, vol. 51, pp. 1274–1279, May 2009.

[8] K. L. Wong and S. J. Liao, "Uniplanar coupled-fed printed PIFA for WWAN operation in the laptop computer," *Microw. Opt. Technol. Lett.*, vol. 51, pp. 549–554, Feb. 2009.

[9] Chen-Wen Chiu and Yu-Jen Chi, "Printed Loop Antenna with a U-Shaped Tuning Element For Hepta-Band Laptop Applications." *IEEE Trans. Antennas Propag.*, vol. 58, pp. 3464-3470, Nov. 2010

[10] Kin-Lu Wong, Wei-Ji Chen, and Ting-Wei Kang, 2011. Small-Size Loop Antenna with a Parasitic Shorted Strip Monopole For Internal WWAN Notebook Computer Antenna. *IEEE Trans. Antennas Propag.*, vol. 59, pp. 1733-1738, 2011.

[11] Balanis C. A.1997.Antenna Theory and Design, Second Edition. John Wiley & Sons. Inc.

[12] K. D. Katsibas, C. A. Balanis, P. A. Tirkas, and C. R. Birtcher, "Folded loop antenna for mobile hand-held units," *IEEE Trans. Antennas Propag.*, vol. 46, pp. 260–266, Feb. 1998.

[13] Z. N. Chen, *Antennas for Portable Devices*. West Sussex, U.K.:Wiley, 2007, pp. 122–124.

[14] Garg, R., Bhartia, P., Bahl, I. and Ittipiboon, A. 2001. Microstrip Antenna design Handbook.

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