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4.5G Uygulamaları İçin C Şekilli ve S Şekilli Kıvrımlı Şeritleri ile Kompakt Tek Bantlı Monopole Anten

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Öz

Bu çalışmada, 4.5G uygulamalarında kullanılmak üzere tek kutuplu kompakt mikroşerit bir anten önerilmiştir. Anten, 1,6 mm kalınlığında FR4'ten oluşmaktadır ve S şeklindeki kıvrımlı bir şeridi C şeklindeki şeridin içine basit ve kompakt bir yapı olarak yerleştirilmesi ile düzlemsel beslemeli tek bantlı olarak tasarlanmıştır. Bu yüzden, önerilen anten Ansys HFSS modülünde simüle edilmiştir ve tek frekans aralığında ışıma performansı ve anten kazancı elde edilmiştir. Geri dönüş kaybında -10 dB değeri referans alınarak bant genişliği 54.5 MHz olarak ölçülmüştür ki bu değer 4.5G standardının gereken bant genişliğini kapsamaktadır.

Anahtar Kelimeler: Kompakt mikroşerit anten, 4.5G, c şeklinde anten, s şeklinde anten.

Compact Single-Band Monopole Antenna With C-Shaped And S-Shaped Meander Strips For 4.5G Applications

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Abstract

In this study, we proposed a compact microstrip monopole antenna, capable for 4.5G application. It is consisted of FR4 with thickness of 1.6mm and it was designed as planar-fed single-band by embedding an S-shaped meander strip into a C-shaped strip as a simple and compact structure. Thus, the proposed antenna was simulated in the Ansys HFSS module and various antenna parameters such as radiation performance and antenna gain were obtained in a single frequency range. The return-loss bandwidth was measured as 54.5 MHz centering at 2.59 GHz, covering the required bandwidth of 4.5G standard, as a reference of -10 dB.

Keywords: compact microstrip antenna, 4.5G, c-shaped antenna, s-shaped antenna.

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1. INTRODUCTION

In last decades, wireless communication technologies have efforted a rapidly rapid rise. And designing various antenna models has played an effective and important role on wireless applications. Microstrip antennas can be designed for use in many wireless communication techniques such as Wi-Max, Wi-Fi and WLAN. Microstrip antenna was offered in the beginning 1970's and this development led a breakthrough in the area of antenna design. Owing to easy to manufacture and being cheap, Microstrip Patch Antenna (MPA) is widely used and implemented.

Although MPAs are known by antenna designers as low profile antennas, they perform well on planar and non-planar surfaces. For to be used in popular wireless communication techniques (nowadays especially LTE and LTE-Advanced) above 100 MHz frequencies range, MPAs can be designed [1]. In fact these kinds of antennas are produced on a dielectric substrate. Interoperability into various telecommunication systems is one of the advantages of this structure. However, the most important part here is a reasonable selection range. Decreased performance and reduced structure can lead to a coupling problem. Occasionally, the increase of space leads to indefinite convexity [2-8].

In this paper, we designed an S-shaped embedding meander strip into a C-shaped strip MPA that produces single band resonating at 2.59 GHz with great return loss. The antenna we have designed works at the central frequency of 2.59 GHz, which is 4.5G LTE-Advanced in the literature [9-15].

2. DESIGN OF THE ANTENNA

In general, because of it has only one resonance, microstrip antenna bandwidth is not very wide. Therefore, to design a wideband antenna, minimum two resonant parts are needed as each one operating at its own resonance. So, wideband or multiband performance can be obtained by overlapping of these resonances. To obtain wide bandwidth with a single resonance band so, this design was chosen. Additionally, in this design as in the traditional UWB monopole antenna was deployed a solid ground plane, on the other side as shown in Fig. 1. Achieving wideband together with good impedance matching over the whole operating band, the above design abilities are offered. The C-shaped patch with lengths L_3, L_5 and widths W_1, W_8 is the basis of monopole radiation, which is within the rectangular patch with the S-shaped patch. L_1 and L_2, contain vertical and horizontal stripes, respectively, which constitute the outermost patch. The ground plane of the antenna is a solid rectangular plane as in general microstrip-fed monopole antennas. This simple geometry also facilitates the production of the proposed antenna. Entire size of the antenna has been expressed in mm, and dimensions of ground plane 27 mm and 44 mm, length and width respectively. The width of the microstrip feedline was chosen 1 mm to minimize the return loss by providing 50 Ω characteristic impedance.

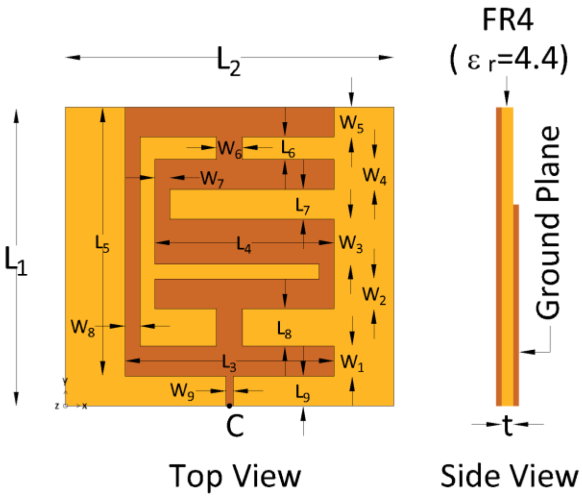

Figure 1. Dimensions of the antenna.

Table I. Antenna Parameters

Parameter	mm	Parameter	mm
L_1	40	L_7	4
L_2	44	L_8	5
L_3	28	L_9	4
L_4	24	W_1	4
L_5	36	W_2	4
L_6	3	W_3	6
W_4	4	W_8	2
W_5	4	W_9	1
W_6	3.5	t	1.6
W_7	2		

To reduce the antenna area, the radiating plane is placed so that the upper surface of the substrate is centered. FR4 substrate with a thickness of 1.6 mm was used to avoid any coupling between the radiating plane and the ground plane. In Table I all dimensions of the recommended broadband antenna are sorted. The antenna could not be produced due to lack of laboratory facilities. This wideband antenna was designed on an FR-4 substrate with 1.6-mm-thick, a loss tangent of 0.024, permittivity of 4.4.

To research and optimize the presented antenna configuration numerically, finite element analysis based on Ansoft HFSS is used. Optimized parameters of designed antenna are seen on Table I. The return loss of proposed antenna seen in Fig. 7. The simulation result clearly shows that the proposed antenna has a resonance at 2.59 GHz and has a 54.5 MHz bandwidth in the same band. Obviously, with reference to -10 dB, the bandwidth covers the entire spectrum from 2.56 to 2.61 GHz. The effects of the C-shape patch, S-shape patch and the addition of an S-shaped patch into the C-shaped patch on the traditional rectangular patch without any changes in the ground plane were examined and analyzed in Fig. 7. In these cases, remember that all non-mentioned dimensions are the same as those listed in Table I. In the case of the C-shaped patch, the resonances are seen at 1.43 and 2.06 GHz, respectively, but the return loss values are quite weak as reference -10 dB. In the case of the S-shaped patch, the resonance frequency of the MPA is quite different from the desired resonance frequency. Nevertheless, in this situation the proposed antenna has resonance at 2.02 GHz. Eventually, it is observed that in the case of embedding an S-shaped meander strip into a C-shaped will remarkable improve return loss value at 2.59 GHz and also proposed design has one resonونce frequency.

2.1. Change in C-Shape Strip Parameters

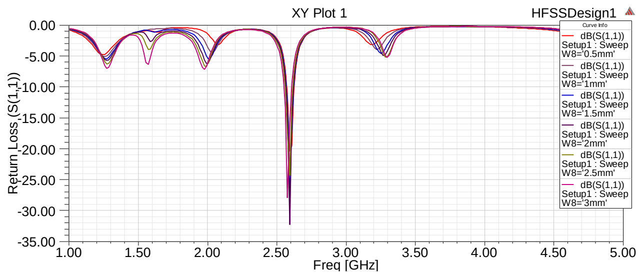

Figure 2. The simulation result of the return loss against the frequency for the various W_8 values in the proposed antenna, other parameters were kept constant.

The W_8 width of the C-shaped strip of the proposed antenna is simulated between 0.5 and 3 mm and the results are given in Fig. 2. In cases where the selected width value is not 2 mm, a small amount of shifts in the desired resonance frequency was observed. Also, there was slight variations in bandwidth. There were great variations in the return loss parameter than the resonance frequency and bandwidth. Considering all parameters, the width of the c-shaped strip, W_8 was decided to be 2 mm.

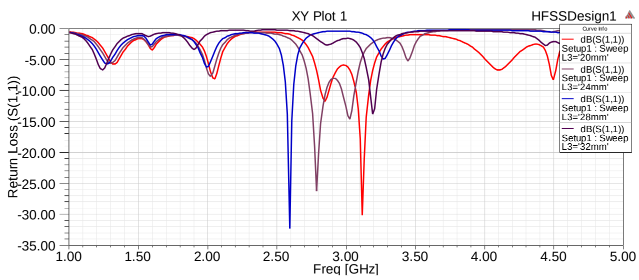

Figure 3. The simulation result of the return loss against the frequency for the various L_3 values in the proposed antenna, other parameters were kept constant.

The L_3 length of the C-shaped strip of the proposed antenna is simulated between 20 and 32 mm and the results are given in Fig. 3. In case of the length is 20 and 24 mm, two resonance frequencies are observed but these frequencies are not desired frequencies. Also the return loss values are relatively low. Similarly, if the length is 32 mm, a resonance frequency is observed, but this frequency is not the desired frequency. 28 mm was preferred because of the resonance at the desired frequency and good return loss value.

2.2. Change in S-Shape Strip Parameters

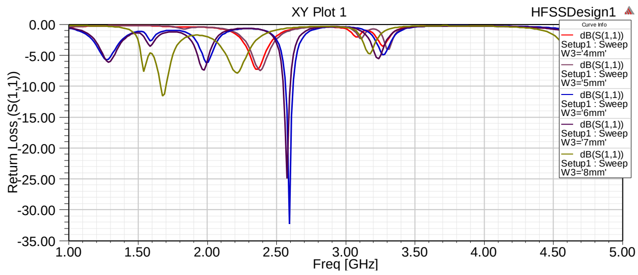

Figure 4. The simulation result of the return loss against the frequency for the various W_3 values in the proposed antenna, other parameters were kept constant.

The W_3 width of the S-shaped strip of the proposed antenna is simulated between 4 and 8 mm and the results are given in Fig. 4. In case of the width is 4, 5 and 8 mm, it is seen that the proposed antenna does not resonate at the desired frequency. In addition, the input impedance matching in these values is quite poor. It is better than the other cases where the width is 7 mm, but the resonance at the desired frequency wasn't achieved. If the simulation result is carefully examined, it will be seen that the best performance will be obtained if the width of S-shape strip is 6 mm.

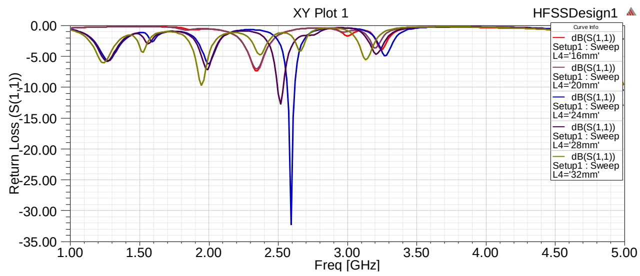

Figure 5. The simulation result of the return loss against the frequency for the various L_4 values in the proposed antenna, other parameters were kept constant.

The L_4 length of the S-shaped strip of the proposed antenna is simulated between 16 and 32 mm and the results are given in Fig 5. In the case where the length of the S-shaped patch is 16, 20 and 32 mm, the value of -10 dB cannot be exceeded, pretty poor impedance matching was observed. In the case of 28 mm, the resonance frequency of the proposed antenna is close to the desired resonance frequency, but the problem of impedance matching has still not been solved. As can be seen from Fig. 5, the length of the S-shaped patch was selected as 24 mm to provide the desired resonance frequency to eliminate the problem of impedance mismatch.

2.3. Change of Size in Ground Plane

The presented antenna is simulated by changing the ground plane length from 20 to 34 mm and Fig. 6 is shown. When the ground plane length is different from 27 mm, it is seen that the bandwidth decreases and the return loss value decreases at the resonance frequency. A decrease in the return loss value means that there is a mismatch in the input impedance of the antenna. In addition, a small amount of shifts in the resonance frequency were observed. Clearly, the optimum ground plane length is 27 mm due to the best possible bandwidth and input impedance matching.

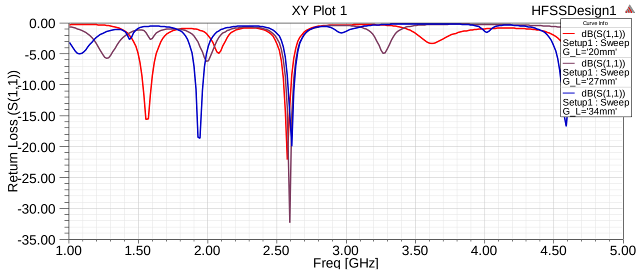

Figure 6. The simulation result of the return loss against the frequency for the various ground plane length in the proposed antenna, other parameters were kept constant.

3. RESULTS AND DISCUSSIONS

The performance of the patch antenna obtained by inserting the S-shaped patch into the C-shaped patch is tested by means of the HFSS software. Various antenna parameters, such as Return loss, VSWR, Gain and Radiation pattern, were analyzed in the frequency range of 1 to 5 GHz. The patch antenna was shown to resonate at a single frequency with reference to -10 dB. Analysis results are shown in the figures.

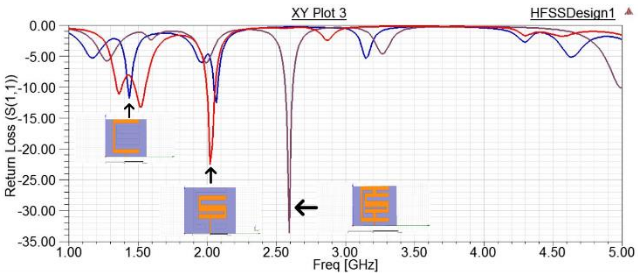

Figure 7. Simulation result of the proposed antenna, the C-shaped strip, the S-shaped strip and the final shape.

Table II. Proposed antenna's return loss and bandwidth.

Resonant Frequency (GHz)	Band covered	Return loss (dB)	Bandwidth (MHz)
2.59	S	-32.33	54.5

The proposed antenna has one resonance frequency in the frequency range 1 to 5 GHz when analyzed according to the return loss parameter. At the desired center frequency of 2.59 GHz, the return loss value is observed to be -32.33 dB. Between two points with return loss values -10 dB around the center frequency, the bandwidth is found 54.5 MHz. The proposed antenna resonates in the frequency range of 2.5 to 2.65 GHz, which corresponds to the LTE-Advance communication. The above-mentioned parameters, such as the resonance frequency and to it corresponding band, return loss and bandwidth, are shown in Table II.

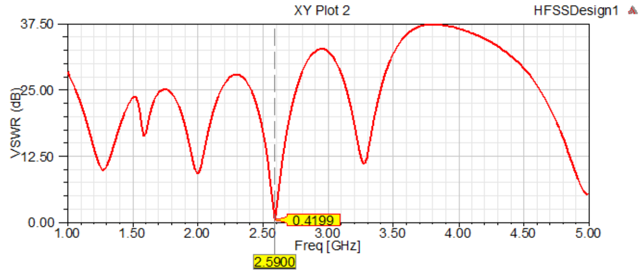

Figure 8. Proposed antenna's voltage standing wave ratio.

Back reflections arising from the empadans difference between the transmission line and the load are called VSWR. VSWR also represents RF power transmission efficiency from power source to load, via a transmission line. The proposed antenna design's VSWR parameter is shown in Fig. 8. Obviously the VSWR value at the desired frequency is about 0.41 dB, which proves to be a excellent matching.

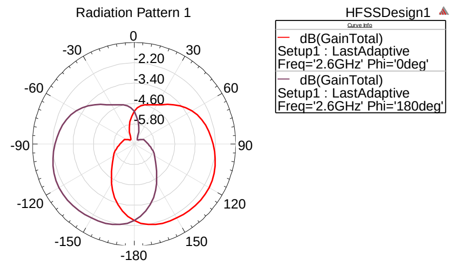

Figure 9. Proposed antenna's directivity at 2.59 GHz in E-plane.

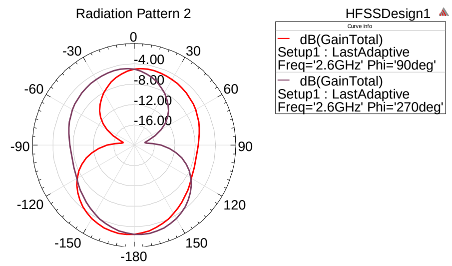

Figure 10. Proposed antenna's directivity at 2.59 GHz in H-plane.

Table III. Proposed antenna's directivity in E and H plane at resonance frequency

Resonant Frequency (GHz)	Directivity in E plane (dB)	Directivity in H plane (dB)
2.59	2.70	2.04

Directivity is a term that expresses how strong the antenna radiation is in certain selected directions. The presented antenna directivity at 2.59 GHz in E and H plane as shown in Fig. 9 and Fig. 10 respectively. The figure shows φ= 0 and φ= 90 degrees states of the radiation pattern. The directivity values at 2.59 GHz for the offered antenna are given in Table III.

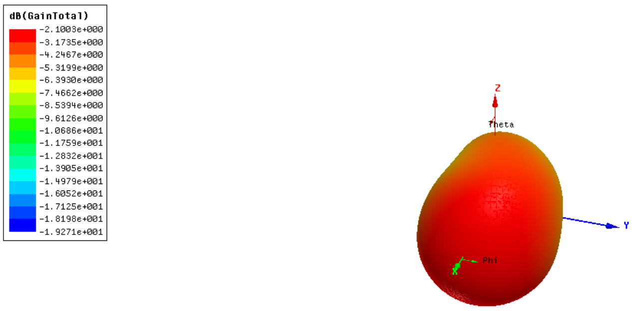

Figure 11. Proposed antenna's gain.

The ratio of the power density of a directional antenna at one point to the power density at the same point of the non-directional antenna fed by the same power is defined as the gain of the directional antenna at that point. Due to MPAs advantageous properties, are used in a wide variety of applications, but they have two major disadvantages, such as narrow bandwidth and low gain. The proposed antenna gain within the range of 1 to 5 GHz is shown in Fig. 11. Obviously, the gain at central frequency 2.59 GHz is low.

4. CONCLUSION

In this study, a microstrip antenna is designed to operate in a single band in which an electrically small S-shaped patch is inserted into a C-shaped patch. This antenna can be used in modern communication systems, especially in wireless communication. Satisfactory gain was acquired in this antenna on resonant frequency. Also resonance frequency is within the S band frequency range. Additionaly, the gain and directivity are pretty affecting. The size of the proposed MPA is compact and small in order to get the desired resonance frequency. The presented antenna has 1.6 mm thick, although utilizing the FR4 substrate. We suggest that our prototype antenna will work very well in LTE-Advanced communication. Designing an MPA by placing a S-shaped patch into a C-shaped patch is very different from the other LTE-Advanced antennas in the literature.

REFERENCES

[1] C. A. Balanis, "Fundamental Parameters of Antennas," Antenna Theory Anal. Des., pp. 27–114, 2005.
[2] V. Mathur et al., "Design of microstrip antennas fed four-microstrip-port waveguide transition with slot radiators," IEEE Transactions of Antennas Propagation, vol. 55, no. 10, pp. 2769–2773, 2015.
[3] C. C. Yu and X. C. Lin, "A dual-band CPW-fed inductive slot-monopole hybrid antenna," IEEE Transactions of Antennas Propagation., vol. 56, no. 1, pp. 282–285, 2008.
[4] K. Fertas et al., "Design and optimization a CPW-fed tri-band patch antenna using genetic algorithms," Application Computer Electromagn. Soc. J., vol. 30, no. 7, pp. 754–759, 2015.
[5] H.-S. Y. H.-S. Yoon, R. A. Bhatti, "Design of a novel multiband internal antenna for personal communication handsets," TENCON 2007 - 2007 IEEE Reg. 10 Conf., pp. 1991–1994, 2007.
[6] M. T. Islam, M. M. Islam "Dual-band operation of a microstrip patch antenna on a Duroid 5870 substrate for Ku- and K-bands," Sci. World J., vol. 2013.
[7] A. T. Mobashsher, R. Azim, "UWB antenna with notched band at 5.5 GHz," Electron. Lett., vol. 49, no. 15, pp. 922–924, 2013.
[8] K. Sarabandi and N. Behdad, "Dual-band reconfigurable antenna with a very wide tunability range," IEEE Trans. Antennas Propag., vol. 54, no. 2, pp. 409–416, 2006.
[9] S. Parkvall et al., "LTE-Advanced - Evolving LTE towards IMT-Advanced," in IEEE Veh. Technol. Conf., 2008.
[10] F. Boccardi et al., "Multiple-antenna techniques in LTE-advanced," IEEE Commun. Mag., vol. 50, no. 3, pp. 114–121, 2012.
[11] N. Mohankumar, "Performance Evaluation of Multi Antenna Techniques in LTE," Int. J. Mob. Netw. Commun. Telemat., vol. 2, no. 4, pp. 97–105, 2012.
[12] T. Urbanec and M. Pokorný, "LTE tunable antenna design," 2013 7th Eur. Conf. Antennas Propag., pp. 847–850, 2013.
[13] W. Wang, L. Liu, "Design and performance investigation of a 2.6 GHz dual-element MIMO antenna system for LTE terminal," in Proceedings - 2012 6th Asia-Pacific Conference on Environmental Electromagnetics, CEEM 2012, 2012, pp. 226–229.
[14] Y. S. Wang and J. H. Lu, "Internal uniplanar antenna for LTE/GSM/UMTS operation in a tablet computer," IEEE Trans. Antennas Propag., vol. 61, no. 5, pp. 2841–2846, 2013.
[15] Y. Feng, R. Li and F. Ahmed, "Development of a compact planar multiband MIMO antenna for 4G/LTE/WLAN mobile phone standards," in Antennas & Propagation (ISAP), 2013 Proceedings of the International Symposium on, 2013, vol. 1, pp. 539–542.