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A Novel Stacked Monopole Microstrip Antenna for Ultra-Wideband Applications

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Abstract

In this study, a novel stacked monopole antenna with microstrip-fed is presented for ultra-wideband (UWB) applications covering 3.1 GHz–10.6 GHz. Three stacked identical radiating elements are utilized to improve the impedance bandwidth. The electrical characteristics of the proposed antenna and also achievable performance are analyzed with the use of an electromagnetic simulation tool based on method of moments (MoM). Both the stacked layer as the parasitic elements and the radiating element of the antenna are fabricated with FR4 substrate material. The permittivity, length, width and thickness of each layer are 4.4, 40 mm, 40 mm and 1.55 mm, respectively. Dimensions of the antenna and parasitic element are optimized with the use of artificial bee colony (ABC) algorithm. The simulation and measurement results exhibit a good performance such as bandwidth, return loss and radiation pattern through UWB range. As a result of this study, a microstrip antenna which is a versatile alternative for wireless communication in UWB applications is obtained.

Keywords: Artificial bee colony, ABC, Monopole, Stacked microstrip antenna, UWB

Ultra Geniş Bant Uygulamaları için Yeni Bir Yığın Monopole Mikroşerit Anten

Öz

Bu çalışmada 3,1 GHz–10,6 GHz aralığını kapsayan çok geniş band (ÇGB, Ultra-wideband-UWB) uygulamaları için mikroşerit beslemeli yeni bir yığın monopol anten sunulmuştur. Empedans bant genişliğini geliştirmek için üç yığınlı özdeş ışıma elemanları kullanılmıştır. Önerilen antenin elektriksel karakteristikleri ve ulaşılabilir performansı, moment metodunu (MoM) temel alan bir elektromanyetik benzetim aracı kullanılarak analiz edilmiştir. Parazitik elemanların yer aldığı yığınlanmış katmanlar ile antenin ışıma elemanının yer aldığı katmanlar, FR4 alttaş malzemesi kullanılarak üretilmiştir. Her katmana ait dielektrik sabiti, uzunluk, genişlik ve kalınlık değerleri sırasıyla 4,4, 40 mm, 40 mm ve 1,55 mm'dir. Antenin ve parazitik elemanın boyutları yapay arı kolonisi (YAK, Artificial Bee Colony-ABC) algoritması kullanılarak optimize edilmiştir. Benzetim ve ölçüm sonuçları, ÇGB boyunca bant genişliği, geri dönüş kaybı ve ışıma diyagramı olarak iyi bir performans sergilemektedir. Bu çalışmanın bir sonucu olarak, ÇGB uygulamaları içinde kablosuz haberleşme için birçok işe uygun bir alternatif mikroşerit anten elde edilmiştir.

Anahtar Kelimeler: Yapay arı kolonisi, YAK, Monopol, Yığın mikroşerit anten, ÇGB

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1. INTRODUCTION

Microstrip antennas (MAs) have been broadly employed in various applications such as wireless local area networks (WLANs), direct broadcast satellite systems (DBSs), mobile satellite communications (MSCs), global positioning systems (GPSs) and other portable devices which demand to small antennas because of having attractive features such as small in size, lightweight, cost-effective, ease in manufacturing, planar structure, and simple in use in handheld devices [1–6]. Conventional geometries such as rectangular, triangular and circular MAs are the most studied ones in the literature because of ease in analysis and design. On the other hand, these conventional MAs are relatively large in terms of size for wireless communication applications such as mobile devices using WLAN and GPS and the other portable devices. Due to the smaller antenna requirements in these frequencies, this conventional structures needed to be modified.

The conventional shaped MAs modified by various methods such as inserting the slots on the regular geometries, using shorting pins and shorting walls, designing the antenna on a substrate with high permittivity and stacking the substrate layers to reduce the antenna size are referred to as compact microstrip antennas (CMAs). CMAs are able to operate in lower frequencies for the same antenna size or operate in the same frequency for the smaller size as compared to the conventional MAs. In analysis, since the CMAs have complex geometries according to the conventional MAs, powerful simulation tools involving rigorous mathematical formulation and extensive numerical procedures such as finite element method (FEM) [5], finite difference time domain (FDTD) method [7] and method of moment (MoM) [8] are utilized for designing and analyzing their performance. In the literature, various CMA designs and the methods for various applications in wireless communication are available in several studies [6,9-20] and these studies may be used with their own limitations and benefits.

In this study, a novel stacked monopole antenna with microstrip-fed for ultra-wideband (UWB) applications is designed and fabricated. The antenna contains a radiating element with three electromagnetically coupled elements in a stacked structure. The antenna is fabricated using FR4 substrate in sizes of 40×40 mm^2. The performance and electrical characteristics of the proposed antenna are analyzed with the use of an electromagnetic simulation tool based on method of moments (MoM). The effects of the stacked layers are analyzed and the comparative results are given to illustrate the achievability of the performance. The return loss measurements are performed by Agilent E5071B ENA Series RF Network Analyzer in anechoic chamber to decrease the effects of the external factors such as noise and reflections. The good agreement between simulation and measurement results supports the usability of the presented antenna for UWB applications.

2. ANTENNA DESIGN

In order to design an antenna operating at UWB range, rectangular and triangular shaped slots are formed on rectangular shaped radiating element and the dimensions are optimized with the use of artificial bee colony (ABC) [21-23] algorithm to perform the desired performance. As a result of the optimization, the obtained geometrical configuration is given in Figure 1 whereas the configuration of the parasitic element of the presented monopole antenna is illustrated in Figure 2.

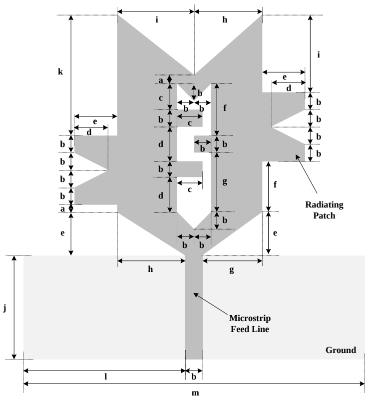


Figure 1. The presented antenna design

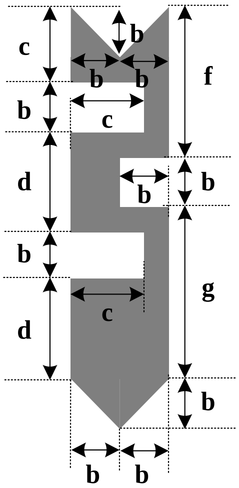


Figure 2. The electromagnetically coupled element used in each layer

The electromagnetically coupled radiating element is shaped in the same manner as the slot of the main radiating patch. Due to ease of production, equivalent substrates are used in each stacked layer. The substrates of 1.55 mm height are used in the antenna and the stacked layers. Other dimensions which are obtained by the ABC algorithm for the radiating elements, microstrip feed and ground element are given in Table 1.

Table 1. Dimensions of the antenna

Parameter	Value (mm)
a	1
b	2
c	3
d	4
e	5
f	6
g	7
h	8
i	9
j	12
k	14
l	19
m	40

3. NUMERICAL RESULTS

The presented antenna is designed to be fed by a microstrip line of 2 mm width and 12 mm length. The radiating element is placed on the top of the FR4 substrate of 4.4 permittivity and 1.55 mm height while rectangular shaped ground element of 40 mm width and 12 mm length is formed on the other side. The positions of left, right and inner strips control the operating frequency while the number of the stacked layers controls the bandwidth and also frequency. Initially, the performance of the designed antenna without any stacked layer is examined and the simulation result is given by the solid curve in Figure 3. According to the simulation result, the antenna is not suitable between 4.7 GHz and 6.1 GHz. To achieve the desired performance, new layers with an electromagnetically coupled parasitic element shown in Figure 2 are inserted on top of the antenna. The dotted and dashed curves in Figure 3 show the simulated return loss results for one and two stacked layers, respectively.

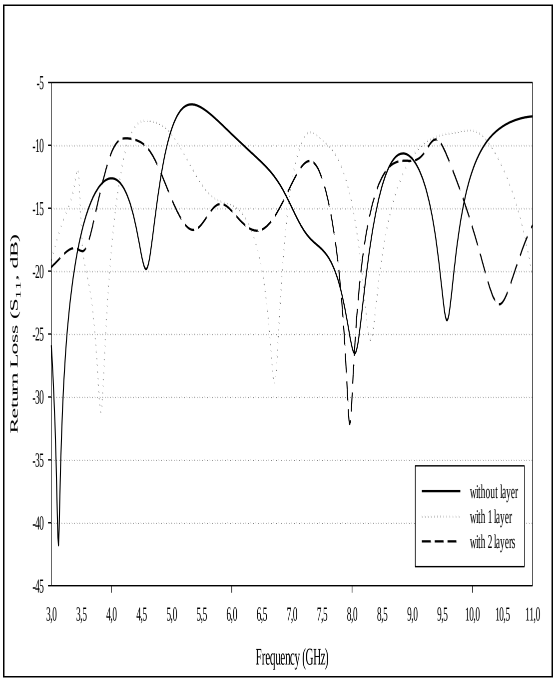


Figure 3. The return loss curves for one and two stacked layers

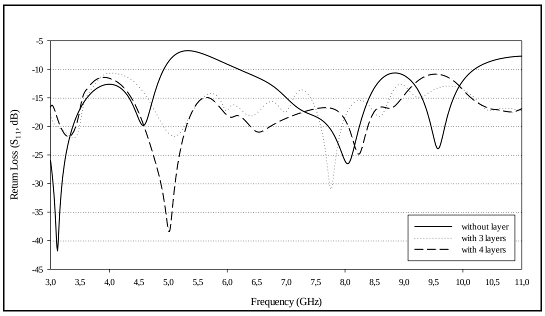


Figure 4. The return loss curves for three and four stacked layers

As can be seen from the Figure 3, although, overall performance of one and two layered structure is acceptable, the performance in some frequency bands is still not suitable for UWB applications. Thus, new layers are added until the aimed performance is reached. The simulated return loss results for the stacked antenna with three and four layers are shown in Figure 4. The performance for four layers are not much better than those of the three layers one. Therefore, the antenna with three layers is selected in order to keep the size of the antenna small and facilitate the design.

Since the Agilent E5071B ENA Series RF Network Analyzer is able to measure for maximum 8.5 GHz, the return loss measurements between 3 GHz and 8.5 GHz are performed in anechoic chamber and given in Figure 5.

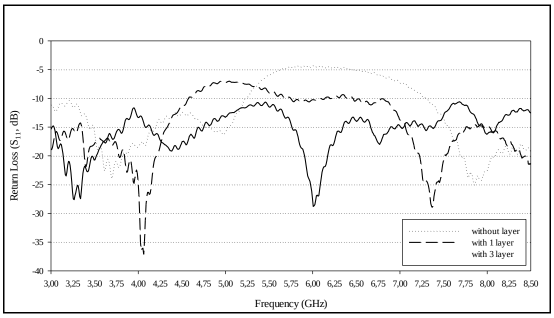
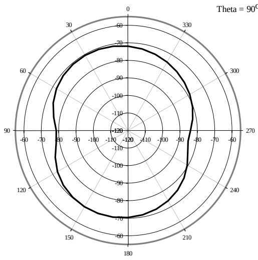
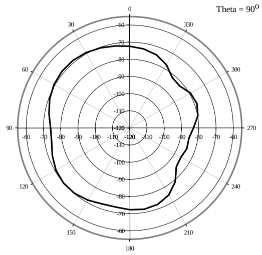


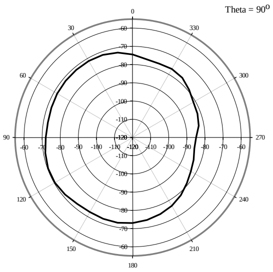
Figure 5. The measured return loss curves

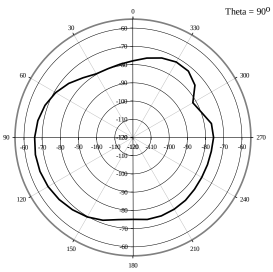
Figures 6 and 7, respectively, show the simulated two-dimensional azimuth and elevation radiation patterns at 3.1 GHz, 4.97 GHz, 6.85 GHz, 8.72 GHz and 10.6 GHz operating frequencies. As can be seen from the Figure 6, the azimuth radiation patterns perform approximately omnidirectional radiation characteristics while the elevation patterns have pretty good performance and the characteristics perform closer as bi-directional except for a small angle range for overall UWB range given in Figure 7.



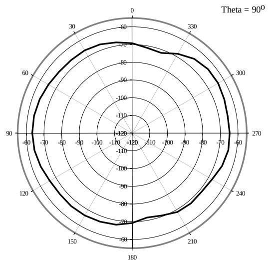


(a) (b)





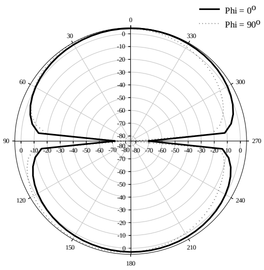
(c) (d)



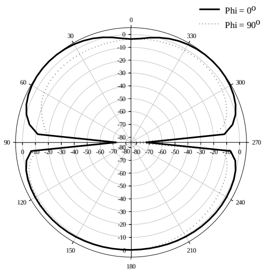
(e)

Figure 6. The simulated radiation patterns of the presented antenna for $\theta = 90^\circ$ operating at (a) 3.1 GHz, (b) 4.97 GHz, (c)

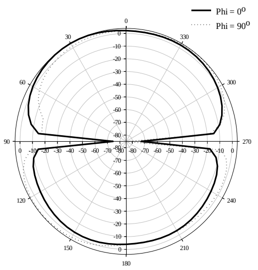
6.85 GHz, (d) 8.72 GHz and (e) 10.6 GHz



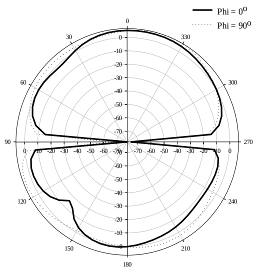
(a)



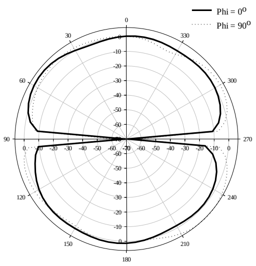
(b)



(c)



(d)



(e)

Figure 7. The simulated radiation patterns of the presented antenna for $\varphi = 0^\circ$ (solid) and $\varphi=90^\circ$ (dashed) operating at (a) 3.1 GHz, (b) 4.97 GHz, (c) 6.85 GHz, (d) 8.72 GHz and (e) 10.6 GHz

4. CONCLUSION

A novel and microstrip-fed compact stacked monopole antenna for UWB applications is designed and presented. The designed antenna performs satisfactory results by covering the entire frequency band from 3.1 GHz to 10.6 GHz. The presented antenna is simple in design and fabrication and compact in size with 40×40 mm^2 outer dimensions. Design of the antenna is carried out with the use of an electromagnetic simulation tool based on method of moments (MoM). Dimensions of the designed antenna are determined by optimizing the main radiating element and parasitic element with the aid of artificial bee colony algorithm (ABC). The resultant antenna is fabricated on the FR4 substrate with permittivity of 4.44 and height of 1.55 mm. The simulation and measurement results have a good agreement with UWB frequency band requirements.

5. REFERENCES

1. Balanis, C.A., 2005. Antenna Theory: Analysis and Design, Wiley Interscience.
2. James, J.R., Hall, P.S., 1989. Handbook of Microstrip Antennas, Peter Peregrinus Ltd., London.
3. Garg, R., Bhartia, P., Bahl, I., Ittipiboon, A., 2001. Microstrip Antenna Design Handbook, Artech House, London.
4. Kumar, G., Ray, K.P., 2003. Broadband Microstrip Antennas, Artech House, London.
5. Pozar, D.M., Schaubert, D.H., 1995. Microstrip Antennas: The Analysis and Design of Microstrip Antennas and Arrays, Wiley-IEEE Press.
6. Bicer, M.B., Akdagli, A., 2012. A Novel Microstrip-Fed Monopole Antenna for WLAN/WiMAX Applications, Journal of Electromagnetic Waves and Applications, vol. 26 (7), pp. 904–913.
7. Taflove, A., 2005. Computational Electrodynamics: The Finite-Difference Time Domain Method, Artech House, London.
8. Harrington, R.F., 1993. Field Computation by Moment Methods, Wiley-IEEE Press, NJ.
9. Gautam, A.K., Yadav, S., Kanaujia, B.K., 2013. A CPW-Fed Compact UWB Microstrip Antenna, IEEE Antennas and Wireless Propagation Letters, vol. 12, pp. 151–154.
10. Oraizi, H., Hedayati, S., 2011. Miniaturized UWB Monopole Microstrip Antenna Design by the Combination of Giusepe Peano and

Sierpinski Carpet Fractals, IEEE Antennas and Wireless Propagation Letters, vol.10, pp. 67-70.

11. Lui, W.J., Cheng, C.H., Cheng, Y., Zhu, H., 2005. Frequency Notched Ultra-Wideband Microstrip Slot Antenna with Fractal Tuning Stub, Electronics Letters, vol. 41(6), pp. 294- 296.

12. Sadat, S., Fardis, M., Geran, F., Dadashzadeh, G., Hojjat, N., Roshandel, M., 2006. A Compact Microstrip Square-Ring Slot Antenna for UWB Applications, IEEE Antennas and Propagation Society International Symposium, Albuquerque, NM, pp. 4629–4632.

13. Liang, J., Chiau, C.C., Chen, X., Parini, C.G., 2005. Study of a Printed Circular Disc Monopole Antenna for UWB Systems, IEEE Transactions on Antennas and Propagation, vol. 53 (11), pp. 3500–3504.

14. Chung, K., Kim, J., Choi, J., 2005. Wideband Microstrip-Fed Monopole Antenna having Frequency Band-Notch Function, IEEE Microwave and Wireless Components Letters, vol. 15 (11), pp. 766–768.

15. He, X., Shen, D., Zhou, Q., Zhang, X., Zeng, J., Lv, Y., 2015. A Novel CPW-Fed Compact UWB Microstrip Antenna, IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting, Vancouver, BC, pp. 1972–1973.

16. Yin, X.C., Ruan, C.L., Ding, C.Y., Chu, J.H., 2008. A Compact Ultra-Wideband Microstrip Antenna with Multiple Notches, Progress in Electromagnetics Research, vol. 84, 321-332.

17. Prombutr, N., Kirawanich, P., Akkaraekthalin, P., 2009. Bandwidth Enhancement of UWB Microstrip Antenna with a Modified Ground Plane, International Journal of Microwave Science & Technology;2009, Vol. 2009, Special section p.1.

18. Khandelwal, M.K., Kanaujia, B.K., Dwari, S., Kumar, S., Gautam, A.K., 2015. Analysis and Design of Dual Band Compact Stacked Microstrip Patch Antenna with Defected Ground Structure for WLAN/WiMax Applications, AEU - International Journal of Electronics and Communications, vol. 69 (1), pp. 39–47.

19. Rawat, S., Sharma, K.K., 2014. Annular Ring Microstrip Patch Antenna with Finite Ground Plane for Ultra-Wideband Applications, International Journal of Microwave and Wireless Technologies, vol. 7 (2), pp. 179-184.

20. Abbak, M., Özgür, S., Akduman, I., 2015. Shorted Stacked Antenna with Folded Feed for Microwave Detection of Brain Stroke, Telecommunications Forum Telfor (TELFOR), 2015 23rd, Belgrade, pp. 603-606.

21. Akdagli, A., Bicer, M.B., Ermis, S., 2011. A Novel Expression for Resonant Length obtained by using Artificial Bee Colony Algorithm in Calculating Resonant Frequency of C-Shaped Compact Microstrip Antennas, Turkish Journal of Electrical Engineering & Computer Sciences, vol. 19(4), pp. 597-606.

22. Toktas, A., Bicer, M.B., Akdagli, A., Kayabasi, A., 2011. Simple Formulas for Calculating Resonant Frequencies of C and H Shaped Compact Microstrip Antennas Obtained by Using Artificial Bee Colony Algorithm, vol. 25 (11–12), pp. 1718–1729.

23. Akdagli, A., Toktas, A., 2010. A Novel Expression in Calculating Resonant Frequency of H–Shaped Compact Microstrip Antennas Obtained by using Artificial Bee Colony Algorithm, vol. 24 (14–15), pp. 2049–2061.