Effect of Different Substrates on Slotted Log Periodic Fractal Koch Antenna

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***Abstract*—This paper discussed about the effect of different substrates on slotted Log Periodic Fractal Koch Antenna (LPFKA). This log periodic antenna is comprised of ten radiating elements with titled slot angles and placed on both sides of the substrate in crisscross arrangement. This LPFKA was designed at frequency between 0.47 GHz and 0.79 GHz which focus on UHF TVWS bands. A comprehensive study between the performances of the proposed antenna on different substrates is carried out. With the gains from 7.07 dBi to 7.95 dBi and reflection coefficient below than -10 dB over desired frequencies, this antenna is suitable and has a big potential for UHF TVWS applications.**

Keywords— LPFKA; UHF TVWS; substrate; electrical permittivity

I. INTRODUCTION

Recently, UHF TVWS applications have received huge attention for various commercial applications due to its advantages of high data transfer rate. TVWS bands are used for 'Super Wi-Fi' because the signal can travel further and penetrate wall better [1-2]. Conventional microstrip patch antenna usually operates over a limited frequency range which unable to satisfy the bandwidth requirements for UHF TVWS applications. Numerous methods have been offered to extend the bandwidth such as parasitic element [3], partial ground [4] and air-gap technique [5]. Another method is log periodic [6-7], which offers many benefits such as high bandwidth and low cross-polarization ratio over a wide frequency range.

Nonetheless, the size of microstrip patch antenna at UHF is very large as its length is inversely proportional to the frequency. Several miniaturization techniques are applied such as metamaterial [8], co-planar waveguide [9] and fractal Koch technique [10]. Another simple method is to use high dielectric material substrate [11] since height and dielectric constant of the substrate influence the antenna properties. In addition, this technique succeeded to enhance the resonant frequency and bandwidth of the antenna.

The main objective of this paper is to study the effect of different substrate materials on the resonant characteristics of slotted LPFKA. The proposed antenna has a dimension of 300 mm x 280 mm planned on FR-4 board with dielectric constant of ε_r=4.7 and loss tangent of tan δ = 0.019.It has proven that the proposed antenna exhibits high gain ranging from 7.07 dBi to 7.95 dBi over UHF TVWS frequencies.

II. ANTENNA STRUCTURE

Fig. 1 shows the proposed LPFKA designed for UHF TVWS frequencies. This LPFKA consists of 10 radiating elements that exist on both side of the substrate in crisscross arrangement.

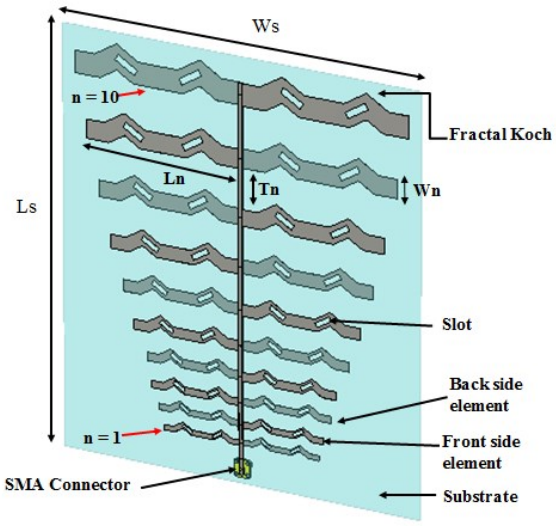


Fig. 1: Proposed LPFKA with Ls = 300 mm and Ws = 280 mm.

TABLE I. DIMENSION OF SLOTTED LPFKA

n	Ln (mm)	Wn (mm)	Tn (mm)
1	65/8	3.68	11.3
2	70/8	4.32	13.2
3	75/8	5.04	15.6
4	80/8	6.00	18.3
5	90/8	7.04	21.6
6	100/8	8.24	25.4
7	110/8	9.76	30.0
8	120/8	11.52	35.0
9	130/8	13.50	41.0
10	140/8	15.84	45.0

In this paper, fractal Koch structure with 30° flare angle has been integrated as the radiating elements of log periodic antenna to enable its size miniaturization. In order to improve the reflection coefficient of first iteration antenna, two rectangular slots are inserted at each radiating elements with 30° flare angle. Detailed dimensions of the antenna are listed in Table I.

Fig. 2 shows the parametric studies on different substrates. In order to study the effect of substrate variation on the reflection coefficient, antennas were designed at the same frequency. Same dimension of slotted LPFKA and substrate thickness was used in order to have a valid comparison. It can be concluded that FR-4 exhibit better performance of the reflection coefficient while matching better than -10dB throughout the required UHF TVWS bands. By referring to Fig. 2, the slotted LPFKA with Roger and Taconic substrate are unable to cover all the required UHF TVWS bands. The results of simulations are tabulated in Table II. It is detected that the resonant frequency slightly decreases to the lower frequencies with increase in electrical permittivity of the substrates used.

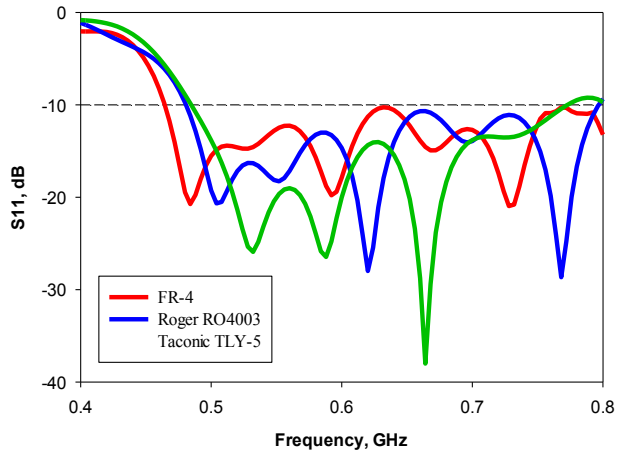


Fig. 2: Reflection coefficient changes over different substrates

TABLE II. COMPARISON OF DIFFERENT SUBSTRATES

Material	Electrical Permittivity (Ɛr)	Loss Tangent	Return Loss (S11)	
			0.47 GHz	0.79 GHz
FR-4	4.7	0.019	-12.887	-10.403
Roger RO4003	3.55	0.0	-7.1707	-11.884
Taconic TLY-5	2.2	0.0009	-6.7879	-9.2354

III. RESULTS AND DISCUSSION

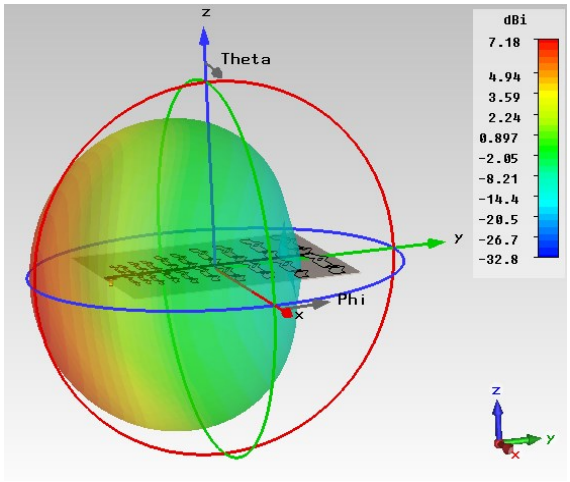
This slotted LPFKA is designed with operating frequencies of 0.47-0.79 GHz. Based on the parametric study, FR-4 is the best substrate material as it gave best results regarding utilization of bandwidth, resonating frequency and reflection coefficient. FR-4 has good fabrication process, good electrical insulator and can be implemented for fabrication since it exhibit better performance of the reflection coefficient while matching better than -10dB over UHF TVWS bands.

A. Return Loss

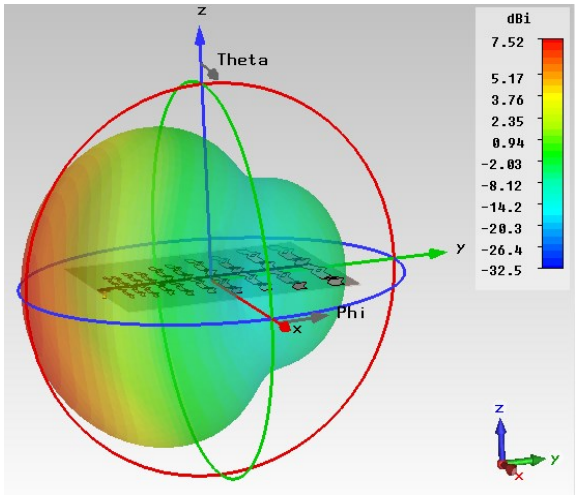
The reflection coefficient of slotted LPFKA with FR-4 substrate has been plotted as depicted by Fig. 2. The graph shows that the reflection coefficient has -10dB impedance bandwidth from 0.47-0.79 GHz which covering the whole UHF TVWS bands.

B. Radiation Pattern

The antenna radiation pattern determined in the far-field region and it is presented as a function of the directional coordinates. The proposed antenna obtained high gain between 7.07 and 7.95 dBi over the operated frequencies as depicted in Fig. 3. Fig. 4 shows the polar radiation pattern for slotted LPFKA using FR-4 substrate at 0.47 GHz and 0.79 GHz. The proposed antenna recorded directional radiation for 0.47 GHz and 0.79 GHz at Y-Z plane (elevation angle).

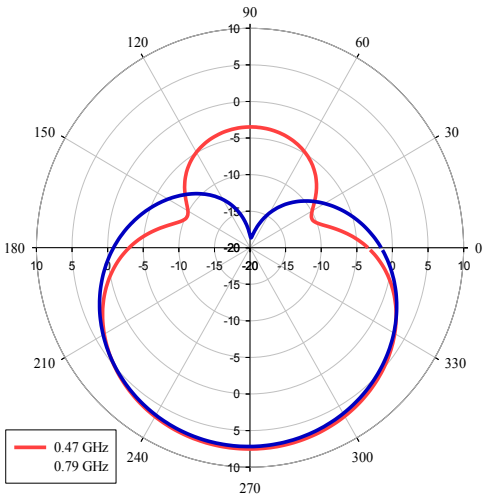


(a)

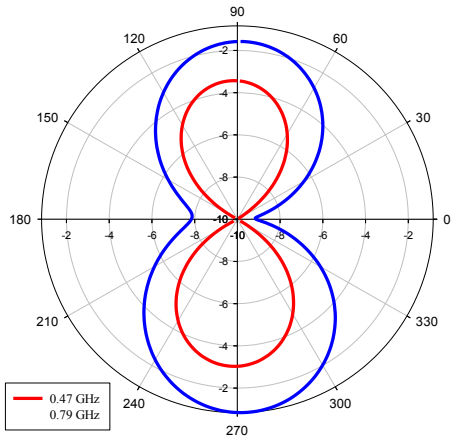


(b)

Fig. 3: 3D simulated radiation pattern for slotted LPFKA at (a) 0.47 GHz (b) 0.79 GHz



(a)



(b)

Fig. 4: Polar radiation pattern (a) E-Co and (b) H-Co

IV. CONCLUSION

This slotted LPFKA is proposed with operating frequencies from 0.47-0.79 GHz. Effect of different substrates on slotted LPFKA have been thoroughly studied. It is found that by selecting a suitable substrate, specific antenna requirements can be met because many limitations such as high return loss, low gain and low efficiency can be overcome. It can be concluded that FR-4 is the best substrate material as it gave best result amongst the other dielectrics used and has satisfactory value of gain and directivity for use in UHF TVWS applications.

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REFERENCES

[1] Yohannes D. Alemseged, Gabriel Porto Villardi, Chen Sun, Ha-Nguyen Tran, Hiroshi Harada, "Distributed decision making to improve link quality in coexisting TVWS secondary networks," *WCNC 2012 Workshop on Future Green Communications*, 2012.

[2] M. Y. Abou Shahine, M. Al-Husseini, Y. Nasser, K. Y. Kabalan and A. El-Hajj, "A reconfigurable miniaturized spiral monopole antenna for TV white spaces," *Progress in Electromagnetics Research Symposium Proceedings*, Stockholm, Sweden, August 12-15, 2013.

[3] Hsu, H. T., Huang, T. J., "A Koch-shaped log periodic dipole array (LPDA) antenna for universal ultra-high frequency (UHF) radio frequency identification (RFID) handheld reader," *IEEE Transactions on Antennas Propagation*, vol. 61, no. 9, 2013.

[4] Kumar, J. and Shirgan, S.S., "Compact partial ground plane 1x2 patch antennas," *Sixth International Conference on Computational Intelligence and Communication Networks*, pp. 33-37, 2014.

[5] RSA Raja Abdullah, D. Yoharaaj, and Alyani Ismail, "Bandwidth Enhancement technique in microstrip antenna for wireless applications," *Progress in Electromagnetic Reseach (PIER)*, Vol. 2, No. 6, 2006.

[6] A. Moallemizadeh, H.R. Hassani, and S. Mohammad Ali Nezhad, "Wide bandwidth and small size LPDA antenna," *6th European Conference on Antennas and Propagation (EUCAP),* pp. 1-3, 2012.

[7] M. N. A. Karim, M. K. A. Rahim, H. A. Majid, O. B. Ayop, M. Abu, and F. Zubir, "Log periodic fractal Koch antenna for UHF band applications," *Progress in Electromagnetic Research (PIER),* Vol. 100, pp. 201-218, 2010.

[8] M.S. Alam, M.T. Islam and N. Misran, "A novel compact split ring slotted electromagnetic band-gap structure for microstrip patch antenna performance enhancement," *Progress in Electromagnetics Research*, 2012, vol. 130, pp. 389-409.

[9] A. Moallemizadeh, H.R. Hassani, and S. Mohammad Ali Nezhad, "Wide bandwidth and small size LPDA antenna," *6th European Conference on Antennas and Propagation (EUCAP),* pp. 1-3, 2012.

[10] M.N.A. Karim, M.K.A. Rahim, H.A. Majid, O.B. Ayop, M. Abu, and F. Zubir, "Log periodic fractal Koch antenna for UHF band applications," *Progress in Electromagnetic Research (PIER),* vol. 100, pp. 201-218, 2010.

[11] M. H. Ullah anf M. Islam, "A compact square loop patch antenna on high dielectric ceramic-PTFE composite material," *Applied Physics A,* pp. 1-9, 2013.

[12] A. Ismahayati, P.J. Soh, R. Hadibah, G.A.E. Vandenbocs, "Design and analysis of a multiband Koch fractal monopole antenna," *IEEE International RF and Microwave Conference*, 2011.