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Design of wideband antenna using interdigital capacitance

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ABSTRACT

A pair of wideband antenna serve as an impedance transformer for the proposed antenna, which consists of a dipole with periodic capacitive loading. Periodic capacitive loading is achieved at each sector by adding interlaced coupling lines. In order to create a broad impedance bandwidth, the periodic interlaced coupling lines split each arm of the dipole into five portions. Currents are dispersed on the various sections at different frequencies. The suggested antenna is an excellent choice for radar applications since it has a high gain and a low amount of cross polarisation. With the aid of innovative design methods including codirectional inclusion of interdigital capacitance, this research study proposes an interdigital capacitance for wideband (WB) applications interdigital capacitor (IDC). The suggested IDC antenna, which works between 4.70 and 11 GHz, has dimensions of 6.36x6.35x1.6 mm3. This page explores in-depth data on gain over frequency, far field patterns, and surface current distribution on antennas. The suggested antenna's feasibility is shown by simulation data that demonstrates excellent equality on return loss.

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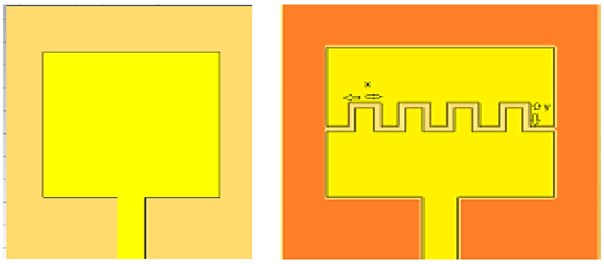
1. INTRODUCTION

Radio frequency (RF) is transformed into alternating current (AC) using an antenna. There are two varieties: transmitting antennas and receiving antennas. The intercepting antenna's function is to receive. RF energy and supplying the electrical gadgets with alternating current [1]–[5]. The transmitting antenna is used to produce an RF field and feed it to electrical equipment. Applications for antennas include sonar, radar, and satellite use. Since the antenna will vibrate due to the interdigital capacitors' lower frequency, the size of the antenna may be reduced [6]–[10]. Typically, as the frequency rises, the capacitor becomes more capacitive because the fringing fields between the fingers are stronger. Metamaterial (MTM) gets its qualities from composite materials like metals and polymers [11]–[15]. They follow recurring patterns. This was created on a 0.035 mm thick FR-4 substrate. The 4.707 to 11 GHz frequency band is where the intended codirectional inter digital capacitance MTM ring operates [16]–[20]. Medical applications, aerospace, sensor detection, infrastructure monitoring, and ultrasonic sensors all utilise metamaterials in their optical filters [21]–[25].

2. ANTENNA DESIGN

In order to create the suggested antenna as shown in Figure 1, the traditional patch antenna was modified by utilising a conventional feed and etching codirectional interdigital capacitance onto the patch (see Figure 1(a)). The suggested structure is made of FR4 with a r=4.4, loss tangent tan=0.02, and dielectric thickness=0.8 mm. Impedance matching is made possible by integrating the interdigital capacitance. The proposed antenna's shape is shown in Figure 1(b) and its characteristics are reported in Table 1.



(a) (b)

Figure 1. Suggested antenna (a) the wide band from antenna A and (b) proposed antenna of the interdigital capacitance

Table 1. Parameters of the proposed antenna

W	L	WG	LG	H	X	Y	FW
6.36	6.35	11.16	11.15	1.6	0.70	1	0.99

The electric field produced by the antenna induces an etched inrectangular patch known as the codirectional interdigital capacitor (IDC). An electromotive force in IDC, which is caused by the electric field produced by the antenna, creates an oscillating voltage between the slots. As a result, inductance is produced by the current flowing through the metal, and mutual capacitance is produced by the electric field in the dielectric gap. As a result, the IDC acts as a parallel L&C circuit resonating structure.

3. PARAMETRIC STUDY

Figure 2 parametric analysis is used to determine the best values for key parameters in the suggested antenna. The best value for ground length (LG), ground width (LW), feed width (FG), and feed length (FL) is determined by parametric analysis. Patch substrate, ground, and feed are the main components of the antenna. The bandwidth is in the 4.707 to 10 GHz range.

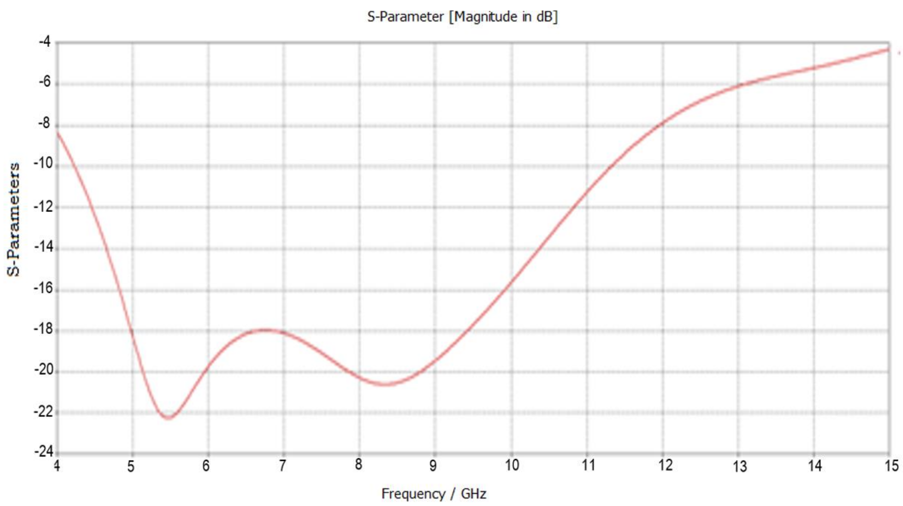


Figure 2. Simulation of S parameter without IDC structure

The necessary feed, patch, ground, and other substrate structures are shown in Figure 3 needed antenna plot with IDC structure. In Figure 4 a comparison of the ranges from the centre to above 0.5 mm, above 1 mm, and above 1.5 mm is shown on the plot. Simulation of an IDC truncated structure with a bandwidth of 5–10 GHz in the centre. The feed is close to the current flow. When comparing the truncated and untruncated structures, the frequency rises and the bandwidth decreases.

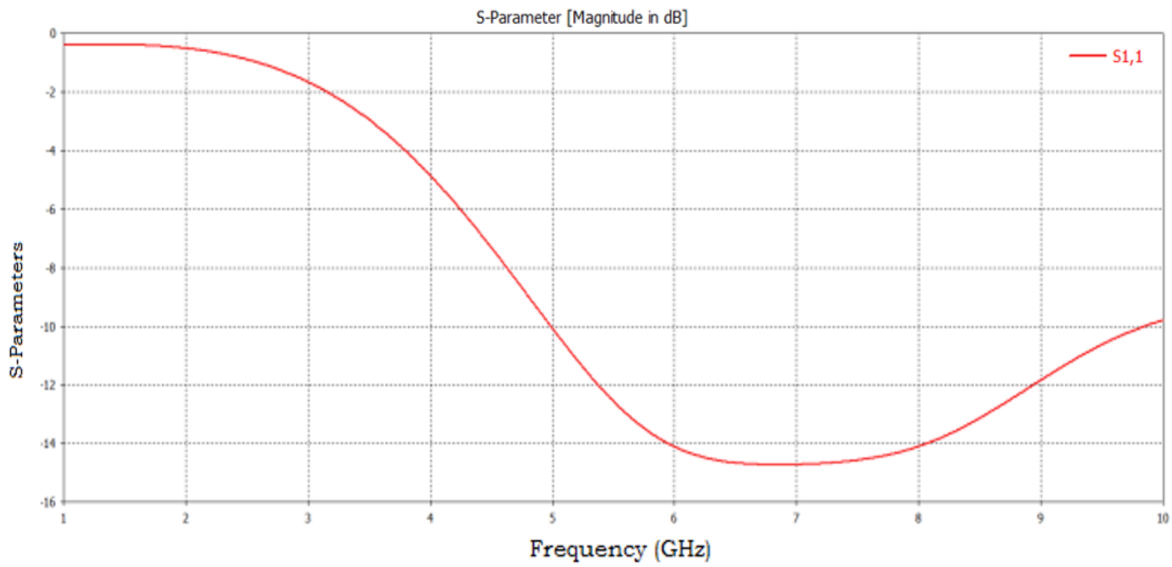


Figure 3. Simulation of S parameter with truncation structure

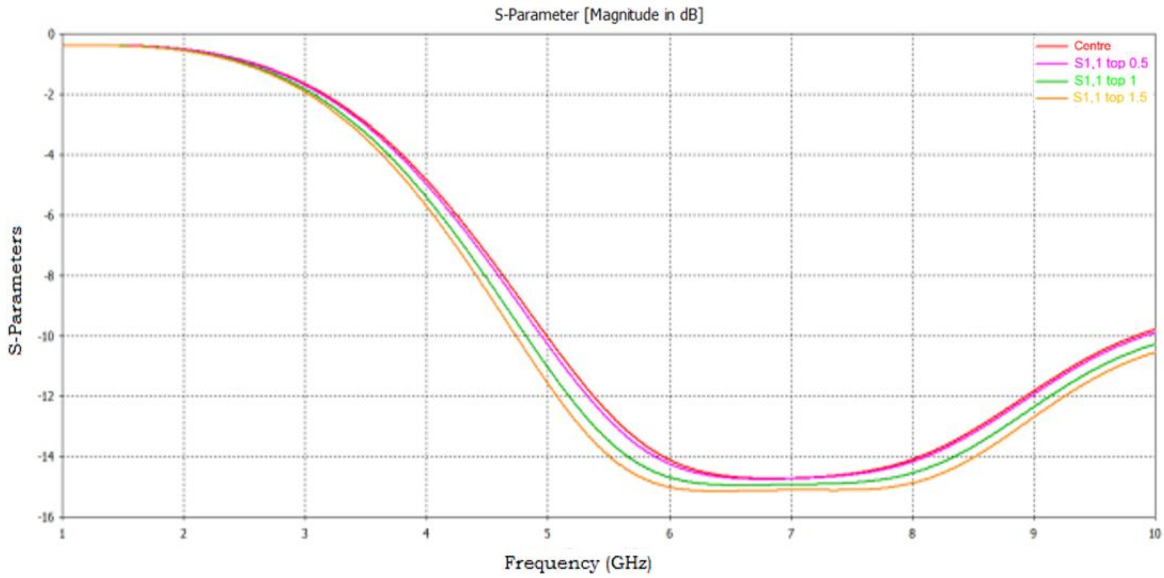


Figure 4. Simulated S parameter for top (0.5 mm, 1 mm, 1.5 mm)

The bandwidth ranges in the below-mentioned figure, Figure 5, are: (5 to 9.7 GHz). Nearer the field, the current flows. In this structure, we compare the ranges from the centre to the bottom of 0.5 mm, 1 mm, and 1.5 mm. Here, the frequency range narrows significantly while the bandwidth widens.

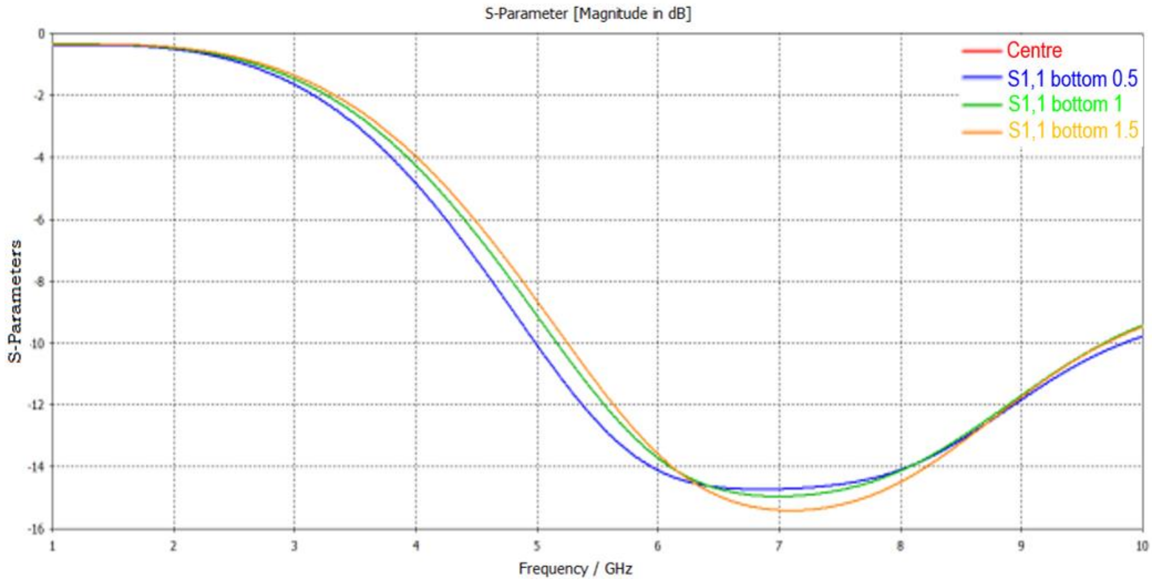


Figure 5. Simulated S parameter for bottom (0.5 mm, 1 mm, 1.5 mm)

4. RESULT AND DISCUSSION

The simulated results are summarised in Table 2, and Figure 6 demonstrates that the suggested antenna presents a single broad band between 24.26 and 30.28 GHz, which covers the assigned UWB short-range radar frequency. Figure 7 compares the proposed antenna and antenna A.

Table 2. Comparison of original and IDC structure

	Original structure (GHz)	IDC structure (GHz)
Resonant frequency	24.26 to 30.28	4.90 to 10.95
S11	4.707 to 11	5 to 10

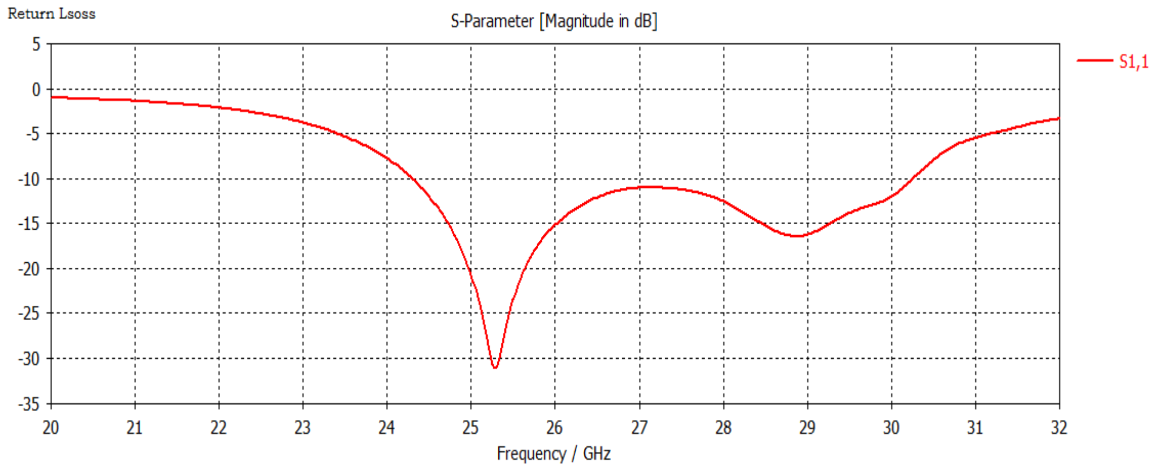


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Figure 6. Simulated returns loss characteristics of proposed antenna

Figure 8 depict the far field E plane as shown in Figure 8(a) and H plane as shown in Figure 8(a) at a frequency of 25.29 GHz, and the pattern clearly demonstrates the proposed antenna's successful operation. The radiation pattern of the proposed wide band antenna at the E plane at 25.29 GHz resonant frequency of the circular interdigital capacitance.

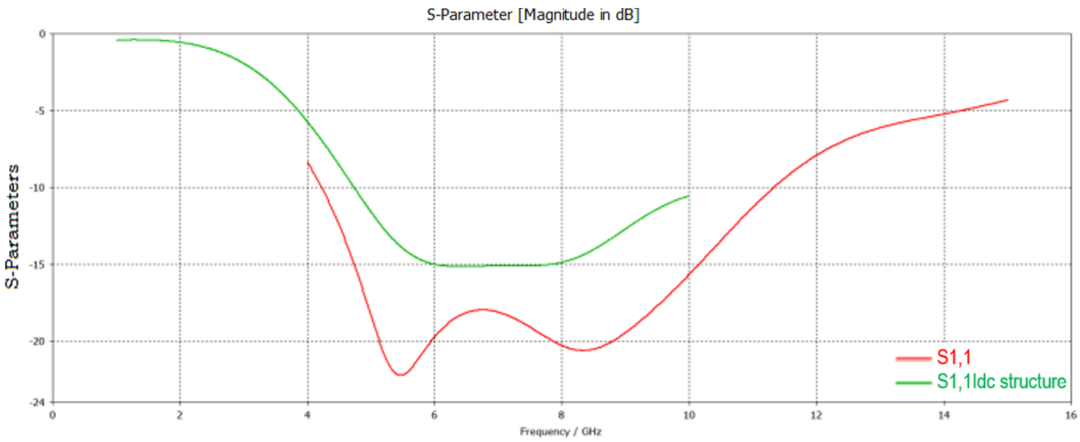

Figure 7. Comparison of antenna A and proposed antenna

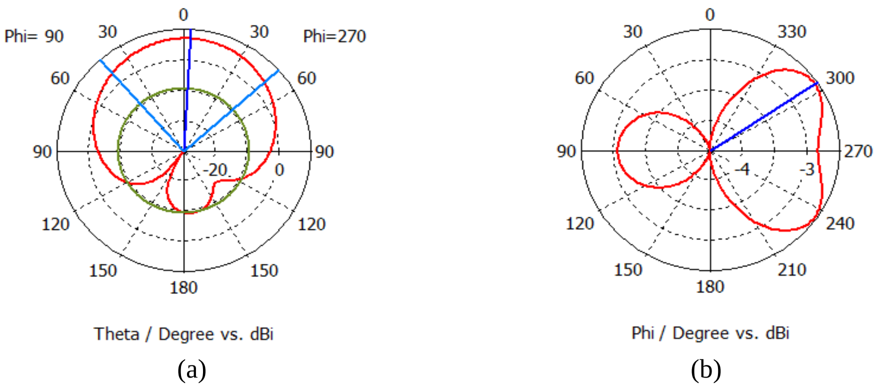

Figure 8. Radiation pattern of (a) E field and (b) H field from proposed antenna at 25.29 GHz resonant frequency

Figure 8 depicts the surface current distribution of the suggested antenna at the resonant frequency, and it is obvious to see that the complementary split ring resonator (CSSR) is what makes the suggested antenna operate in a wider range. Figure 9 depicts the distribution of E plane and H plane surface currents. Figure 10 shows a gain vs frequency plot. It can be seen that the gain is constant across bands and reaches its maximum gain of 3.14 dBi at the resonant frequency of 25.29 GHz.

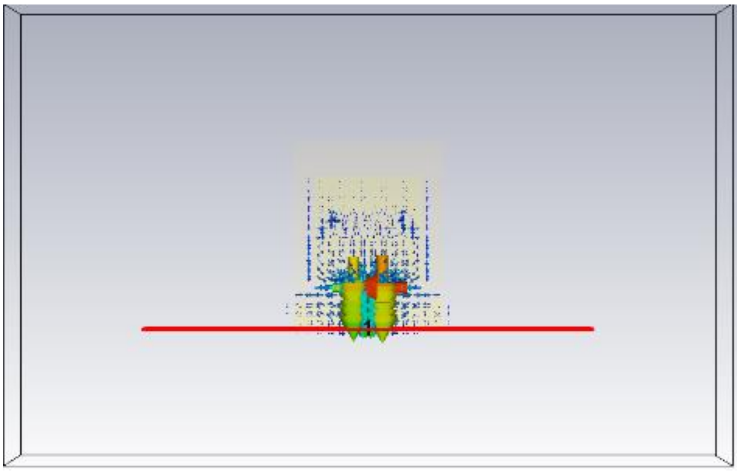

Figure 9. Surface current distribution

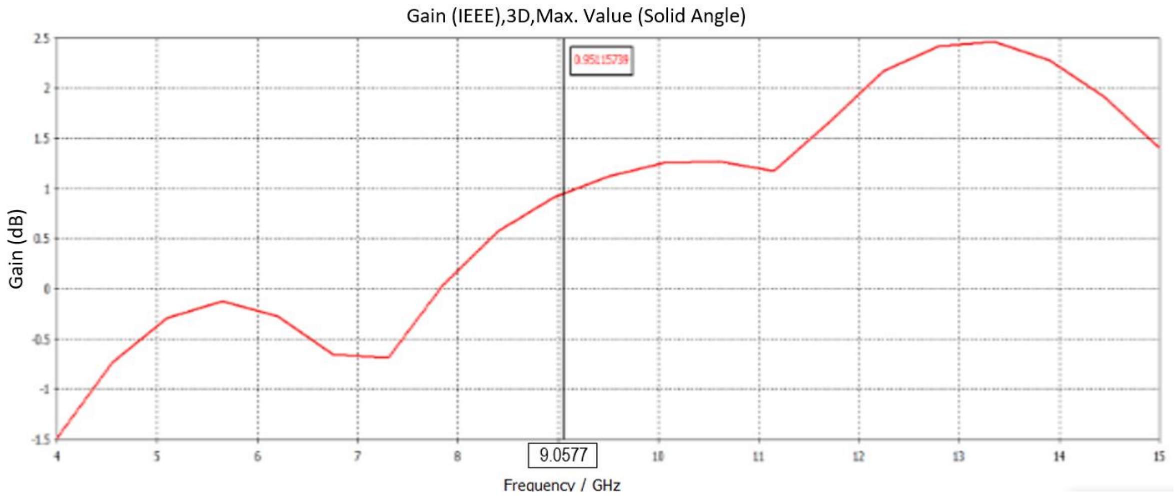

Figure 10. Gainplot of proposed antenna

5. CONCLUSION

When compared to previous studies based on microstrip-fed (double-layer) and coaxially-fed (3D-shaped) slot antennas, the benefits include cost effectiveness, ease of manufacturing, and simplicity of the design (single layer). Because the antenna is operated in series resonant mode, resonant properties may be successfully regulated by adjusting series parameters. Numerous modes that are more similar to the original mode are created by coupling between patches. A left-hand parallel inductor is created by the ground plane's slot. Through the use of this technology, the composite right/left-handed (CRLH) antenna's three operating modes are stimulated, and by appropriately modifying the IDC parameters, closure and mixing of the resonant frequencies are made possible. The patch and slot dimensions are reduced by around 15.5% and 6.2% of their original sizes, compared to the originally planned antenna, respectively. The return loss plot for the simulated structure (antenna A and proposed antenna) is the outcome of the simulation. According to an analysis of the proposed antenna's return loss characteristics, gain, field patterns, and surface current distribution, antenna A's bandwidth should be between 4.707 and 11 GHz. Comparatively, the suggested antenna has a lower bandwidth of 5 to 10 GHz and is suitable for ultra wide band applications.

REFERENCES

[1] G. Kaur, A. Kaur, G. K. Toor, B. S. Dhaliwal, and S. S. Pattnaik, "Antennas for biomedical applications," *Biomedical Engineering Letters*, vol. 5, no. 3, pp. 203–212, Sep. 2015, doi: 10.1007/s13534-015-0193-z.

[2] S. Bhattacharjee, S. Maity, S. K. Metya, and C. T. Bhunia, "Performance enhancement of implantable medical antenna using differential feed technique," *Engineering Science and Technology, an International Journal*, vol. 19, no. 1, pp. 642–650, Mar. 2016, doi: 10.1016/j.jestch.2015.09.001.

[3] K. Ito, W. Xia, M. Takahashi, and K. Saito, "An implanted cavity slot antenna for medical communication systems," in *2009 3rd European Conference on Antennas and Propagation*, 2009, pp. 718–721.

[4] C. Liu, Y.-X. Guo, X. Liu, and S. Xiao, "An integrated on-chip implantableantenna in 0.18-μm CMOS technology for biomedicalapplications," *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 3, pp. 1167–1172, Mar. 2016, doi: 10.1109/TAP.2016.2518201.

[5] A. Kiourti and K. S. Nikita, "A review of implantable patch antennasfor biomedical telemetry: challenges and solutions [wireless corner]," *IEEE Antennas and Propagation Magazine*, vol. 54, no. 3, pp. 210–228, Jun. 2012, doi: 10.1109/MAP.2012.6293992.

[6] C. Liu, Y.-X. Guo, and S. Xiao, "Capacitively loaded circularly polarized implantable patch antenna for ISM band biomedical applications," *IEEE Transactions on Antennas and Propagation*, vol. 62, no. 5, pp. 2407–2417, May 2014, doi: 10.1109/TAP.2014.2307341.

[7] A. K. Skrivervik, J.-F. Zurcher, O. Staub, and J. R. Mosig, "PCS antenna design: the challenge of miniaturization," *IEEE Antennas and Propagation Magazine*, vol. 43, no. 4, pp. 12–27, 2001, doi: 10.1109/74.951556.

[8] C.-L. Yang, C.-L. Tsai, and S.-H. Chen, "Implantable high-gain dental antennas for minimally invasive biomedical devices," *IEEE Transactions on Antennas and Propagation*, vol. 61, no. 5, pp. 2380–2387, May 2013, doi: 10.1109/TAP.2013.2238494.

[9] A. Kiourti, J. R. Costa, C. A. Fernandes, A. G. Santiago, and K. S. Nikita, "Miniature implantable antennas for biomedical telemetry: from simulation to realization," *IEEE Transactions on Biomedical Engineering*, vol. 59, no. 11, pp. 3140–3147, Nov. 2012, doi: 10.1109/TBME.2012.2202659.

[10] M. L. Scarpello *et al.*, "Design of an implantableslot dipole conformal flexible antenna for biomedical applications," *IEEE Transactions on Antennas and Propagation*, vol. 59, no. 10, pp. 3556–3564, Oct. 2011, doi: 10.1109/TAP.2011.2163761.

[11] Z. Duan, Y.-X. Guo, R.-F. Xue, M. Je, and D.-L. Kwong, "Differentially fed dual-band implantable antenna for biomedical applications," *IEEE Transactions on Antennas and Propagation*, vol. 60, no. 12, pp. 5587–5595, Dec. 2012, doi: 10.1109/TAP.2012.2209197.

[12] K. Carver and J. Mink, "Microstrip antenna technology," *IEEE Transactions on Antennas and Propagation*, vol. 29, no. 1, pp. 2–24, Jan. 1981, doi: 10.1109/TAP.1981.1142523.
[13] J. Hong and M. J. Lancaster, *Microstrip filters for RF / microwave*, vol. 7, Wiley-Interscience Publication, 2001.
[14] N. Dib, J. Ababneh, and A. Omar, "CAD modeling of coplanar waveguide interdigital capacitor," *International Journal of RF and Microwave Computer-Aided Engineering*, vol. 15, no. 6, pp. 551–559, Nov. 2005, doi: 10.1002/mmce.20099.
[15] G. D. Alley, "Interdigital capacitors and their application to lumped-element microwave-integrated circuits," *IEEE Transactions on Microwave Theory and Techniques*, vol. 18, no. 12, pp. 1028–1033, Dec. 1970, doi: 10.1109/TMTT.1970.1127407.
[16] N. Kinayman and M. I. Aksun, *Modern microwave circuits*. Boston: Artech House, 2005.
[17] R. Garg, P. Bhartia, I. Bahl, and A. Ittipiboon, *Microstrip antenna design handbook*. Boston: Artech House, 2001.
[18] D. M. Pozar, "Microwave Engineering," May 1998.
[19] Q. Zhao, S.-X. Gong, W. Jiang, B. Yang, and J. Xie, "Compact wide-slot tri-band antenna for WLAN/WiMAX applications," *Progress In Electromagnetics Research Letters*, vol. 18, pp. 9–18, 2010, doi: 10.2528/PIERL10081601.
[20] S. Chatterjee, U. Chakraborty, I. Sarkar, P. P. Sarkar, and S. K. Chowdhury, "A compact microstrip antenna for mobile communication," in *2010 Annual IEEE India Conference (INDICON)*, Dec. 2010, pp. 1–3, doi: 10.1109/INDCON.2010.5712711.
[21] J. H. Yoon, "Fabrication and measurement of rectangular ring with open-ended CPW-fed monopole antenna for 2.4/5.2-GHz WLAN operation," *Microwave and Optical Technology Letters*, vol. 48, no. 8, pp. 1480–1483, Aug. 2006, doi: 10.1002/mop.21736.
[22] S. Radiom, M. Baghaei-Nejad, H. Aliakbarian, L.-R. Zheng, G. A. E. Vandenbosch, and G. Gielen, "Miniaturization of UWB antennas and its influence on antenna-transceiver performance in impulse-UWB communication," *Wireless Personal Communications*, vol. 71, no. 4, pp. 2913–2935, Aug. 2013, doi: 10.1007/s11277-012-0979-6.
[23] X.-B. Ma and H.-X. Zheng, "A compact tri-band bandpass filter with adjustable third passband using square open loop resonator embedded by open stubs," *Microwave and Optical Technology Letters*, vol. 54, no. 8, pp. 1817–1819, Aug. 2012, doi: 10.1002/mop.26957.
[24] I. J. BahI and P. Bharta, *Microstrip antennas*. Boston: Artech House, 1980.
[25] M. J. Ammann and Zhi Ning Chen, "Wideband monopole antennas for multi-band wireless systems," *IEEE Antennas and Propagation Magazine*, vol. 45, no. 2, pp. 146–150, Apr. 2003, doi: 10.1109/MAP.2003.1203133.

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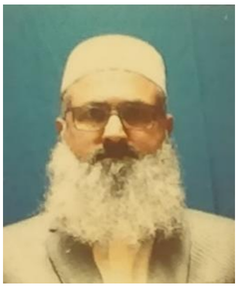

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