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MICROSTRIP RECTANGULAR PATCH ANTENNA USING COPLANAR PARASITIC ROD ELEMENTS WITH SUBSTRATE INTEGRATED FEEDING LINE TECHNIQUE

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Abstract: Microstrip antenna technology is fast growing technology in present days there are broadly used in mobile communication and satellite communication. The microstrip antennas are very low cost and low profile and ease fabrication. However, the bandwidth utilization is the drawback for this system. Now proposed methodology can be reduced that drawback and provide efficient bandwidth utilization factor in proposed method design a microstrip rectangular patch antenna using co-planar parasitic rod elements with substrate intergrading feeding line technique. This proposed method, microstrip rectangular patch antenna is designed for the enhancement of bandwidth, Improvement in front to back ratio, reduction in losses and high-quality factor and power handling capability. The

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proposed method enhances the bandwidth ratio from 4% to 18% it shows that the proposed method gives the best results compared to the existing approach. The simulation and 3D plot results can be obtained from Ansoft HFSS (High-frequency structure simulator) Software.

Keywords: coplanar; parasitic road elements; microstrip; rectangular patch antenna; substrate integrated feeding line.

2010 AMS Subject Classification: 68U20.

1. INTRODUCTION

A microstrip antenna is a wide beam narrowband antenna [1] developed easily by printed circuit technology such as fabricated [2] by etching the antenna element pattern in the metal trace bonded on an insulating dielectric substrate, which procedures a radiating element and another continuous metallic layer on the other side of substrate as ground plane [3]-[23]. Nor only the one shape we use different shapes like square, rectangular, circular, and elliptical shapes also can be used as a radiating patch. As a replacement for of dielectric substrate, we use dielectric spacers [4] for some of the microstrip antennas which give broader bandwidth, but which are more costly. The popularity of microstrip antennas [6] has increased over the past few decades, and it has become a major topic of research for academia and industry. Microstrip antennas offer some advantages such as low profile, low cost, ease of fabrication and wrapping the antenna on a flexible substrate are few among them. Due to its structure and small volume, it finds application in the fields of communication [7], Aeronautics and Medical (Hyperthermia).

The proposed method of this paper is using coplanar parasitic road elements design a microstrip rectangular patch antenna. The effect of parasitic road element [8] on the radiation characteristics of a microstrip patch antenna is investigated that operates in the dominant mode and also effect on the front-to-back ratio of the microstrip patch antenna [9]. For adding coplanar parasitic road elements to designing of microstrip antenna a farther more technique is used that is substrate integrated feeding line technique [10]. This proposed method can enhance the bandwidth utilization.

Our contribution:

- To design of Coplanar rod parasitic elements that Improves the front to back ratio and reduction in losses
- To Decrease in the surface wave antenna
- To enhance the bandwidth.
- To decrease dielectric losses and the conductor losses.
- To avoids the repeated electromagnetic analysis.

Section organization: Section 2 examines literature review in microstrip antennas. Section 3 briefly discussed the methodology part of the study. Section 4 discusses the proposed methodology, i.e., substrate integrated feeding line technique. Section 5 presents the simulation results and 3D Polar plot of Microstrip patch antenna design. Section 6 concludes the paper.

Tse et al. (2018) proposed wideband power divider using substrate integrated waveguide and also provide modified Wilkinson structures. Two stages of a 2-way power divider and their arrangement to form a 4-way power divider for feeding the input perpendicular to the substrate are discussed. The simulated transmission coefficients, reflection coefficients, and isolation for the 2-way power dividers and the 4-way power dividers are also discussed. The designed 4-way power divider with substrate integrated waveguide and modified Wilkinson has−10 dB impedance from 1.6 GH Ma et al. (2017) proposed a short profile aperture-coupled patch antenna array using high front-to-back-ratio.it be implemented at Q-band by using substrate integrated coaxial line method. Measured results indicate that the array can achieve a gain of 17.6 dB at 41.5 GHz and the first side lobe levels are -24.1 dB in the E-plane and -20.4 dB in the H-plane. The holistic FTBR is better than 27 dB in both planes. Z to 3.5 GHz having a fractional bandwidth of 74.5%.

2. PROPOSED METHODOLOGY

2.1. Parasitic Patch Configuration

In the microstrip patch antenna design with the transmission line model equation, the thickness, desired resonant frequency f_o and the dielectric constant be NIL initially selected. In this antenna design, a substrate material of Rogers RT/duriod 5880(TM) dielectric material is selected with a 1.6 mm height. By using the transmission line model equations, at the resonant frequency of 4.4 GHz a patch antenna is designed.

Parasitic elements are leading to a tuned response that is designed in resonate close to driven radiator element in resonant frequency. An impedance bandwidth of the antenna is effective wider, and it is termed as a double resonance phenomenon technique, and that is the result. A wider effective impedance bandwidth of the antenna is the result, and it also termed as double-resonance phenomenon technique. With this same design. To maximize the substrate thickness; a double substrate layer is used that leads to excitation of surface waves.

The patch width is formulated as

$$W = \frac{c}{2fo\sqrt{\frac{(\varepsilon r+1)}{2}}} \quad (1)$$

Where, f_o = specified central frequency

ε_r =relative permittivity

Patch length,

$$L = \frac{c}{2fo\sqrt{\varepsilon_{rp} \quad \mu_{o\epsilon_o}}} - 2\Delta L \quad (2)$$

where ΔL is the effective extended length because at the rectangular patch edges a parasitic effect is obtained.

$\mu_{o\epsilon_o}$ are the permeability and permittivity in free space, ε_{rp} are the effective permittivity of the patch

$$\varepsilon_{ri} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\frac{1}{\sqrt{1+12h/W_i}} \qquad i = p, r \quad (3)$$

The second step is to determine the width d of the gap. The two reflection poles can be appropriately adjusted by the gap width d, aiming to realize a dual-pole wideband performance.

a. Two layers of Substrate in parasitic patch

A less percentage is enhanced in bandwidth with a one-layer substrate. It improves the BW (bandwidth) with an effective result, and antenna surface is minimized in a double layer of the substrate compared to the single patch. A perfect E boundary is assigned for a plane and the ground. Vacuum is used for the air box, and RT/duriod 5880 (TM) is used for substrate1. We used similar dielectric constant on another patch of a substrate, for decreasing radiations in space which is in both design, a dimension of a patch, ground, and substrate one is same. Substrate 2 Height is 1.72mm. The Design Parameters of the Patch are obtained as follows:

Resonating Frequency F_r = 4.4 GHz

Length of the Patch =16mm

Patch width =18mm

Substrate height =1.6mm

Relative permittivity ε_r = 2.2

2.2. Co-Planar Parasitic Rod elements

A conventional Microstrip Antenna with parasitic rod elements adjacent to the radiating edges of Microstrip antenna is done to improve Front-To-Back Ratio. Length of parasitic elements is kept identical to the length of the radiating side of a patch antenna. A microstrip antenna with a finite ground plane produces more back radiation from the edges of the antenna owing to a surface wave diffraction of the ground plane. To revoke the diffracted energy from edges of a ground plane, parasitic elements length is kept identical to that of the finite ground plane. By designing a conventional microstrip patch antenna, with a full metallic ground plane, the effect of the parasitic rod element on the radiation characteristics of a microstrip patch antenna is investigated that operates in the dominant mode (TM_{10}). By using hollow parasitic rods and varying the radius of the rod, the effect of parasitic rod elements was investigated on the front-to-back (FTBR) ratio of the microstrip patch antenna, In the back-lobe region of the microstrip patch antenna, the magnitude of diffracted surface waves by the E-plane edge is much higher than the magnitude of surface wave diffracted by the H-plane edge. The field reflected by rod elements creates a second field for cancelling the antenna's field at the back side of a patch antenna.

2.3. Substrate Integrated waveguide Design techniques

Thes**e** devices are a form of the dielectric-filled waveguide (DFW), so DFW is a starting point. For TE_{10} mode, the waveguide cut off frequency is not affected as the dimension “b” is not mandatory. It only reduced the dielectric loss to the substrate consists of thickness unknown.

(Thicker=lower loss).

For a rectangular waveguide, cut off frequency of arbitrary mode is found by the following formula

$$F_c = \frac{c}{2\pi}\sqrt{\left(\frac{m\pi}{a}\right)^2} + \sqrt{\left(\frac{n\pi}{b}\right)^2} \quad (4)$$

Where, c = speed of light

m, n = mode numbers

a, b = dimensions of the waveguide

For TE_{10} mode, the more shortened version for this formula

$$f_c = c/2a \quad (5)$$

For dielectric- filled waveguide (DFW) with an equal cut- off frequency a_d is is

$$a_d = \frac{a}{\sqrt{\varepsilon_r}} \quad (6)$$

The determined dimension "a" for the DFW, we can now pass to the proposal equations for substrate integrated waveguide.

$$a_s = a_d + \frac{d2}{0.95\,p} \quad (7)$$

Where, d = diameter

p = pitch (distance between the vias)

The following two situations are mandatory in SIW Design

$$d < \frac{\lambda g}{5}$$

$$p < 2d$$

Where λ_g guided wavelength is

$$\lambda_g = \frac{2\pi}{\sqrt{\frac{\varepsilon_r(2\pi f)2}{c2} - \left(\frac{\pi}{a}\right)2}}$$

3. Results and Discussions

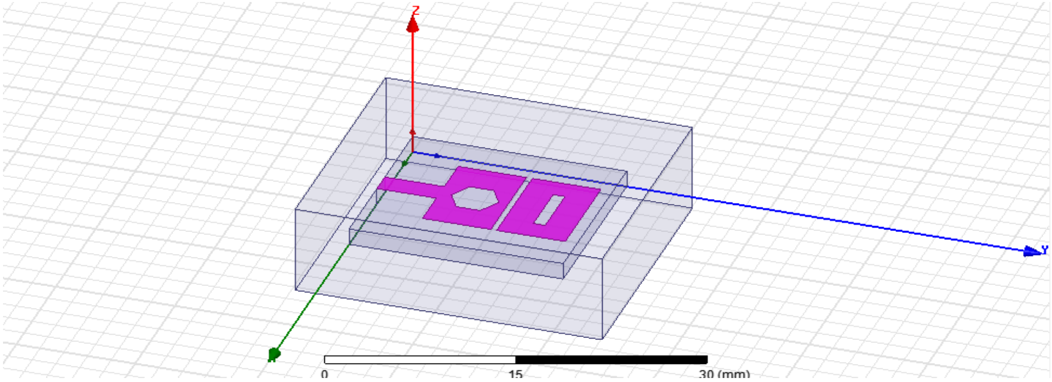

Figure 1: Parasitic Patch Configuration in Microstrip rectangular antenna design

The above figure represents the structure for the bandwidth enhancement in Microstrip patch rectangular antenna.

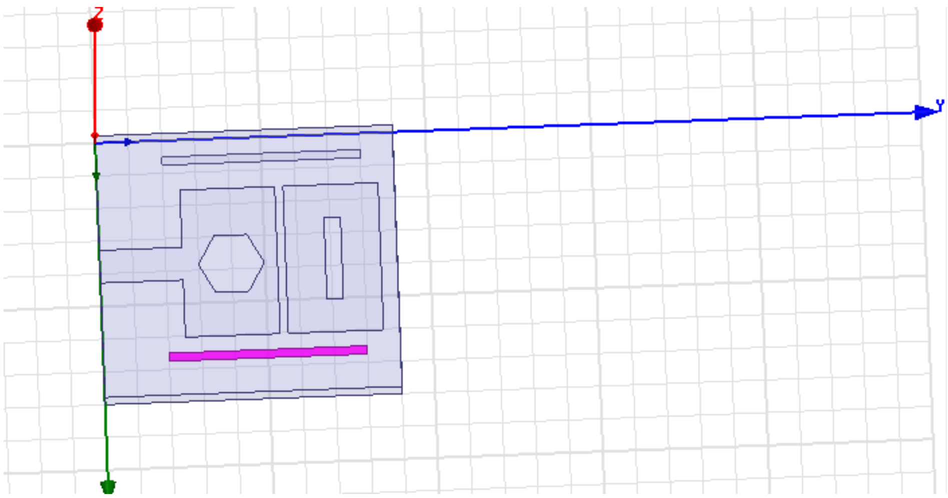

Figure 2: Microstrip patch antenna with Coplanar rods parasitic elements

This figure represents the design of Coplanar rod parasitic elements that Improves the front to back ratio and reduction in losses

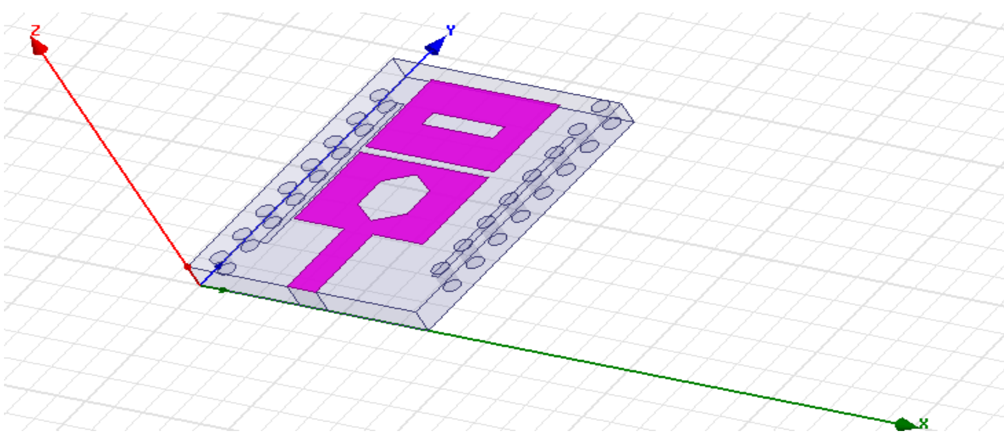

Figure 3: Two-layer Substrate coupled with Integrated Substrate waveguide of coplanar parasitic Rods

This figure represents for power handling capacity and increases in a quality factor that is design by two-layer Substrate coupled with Integrated Substrate waveguide of coplanar parasitic Rods.

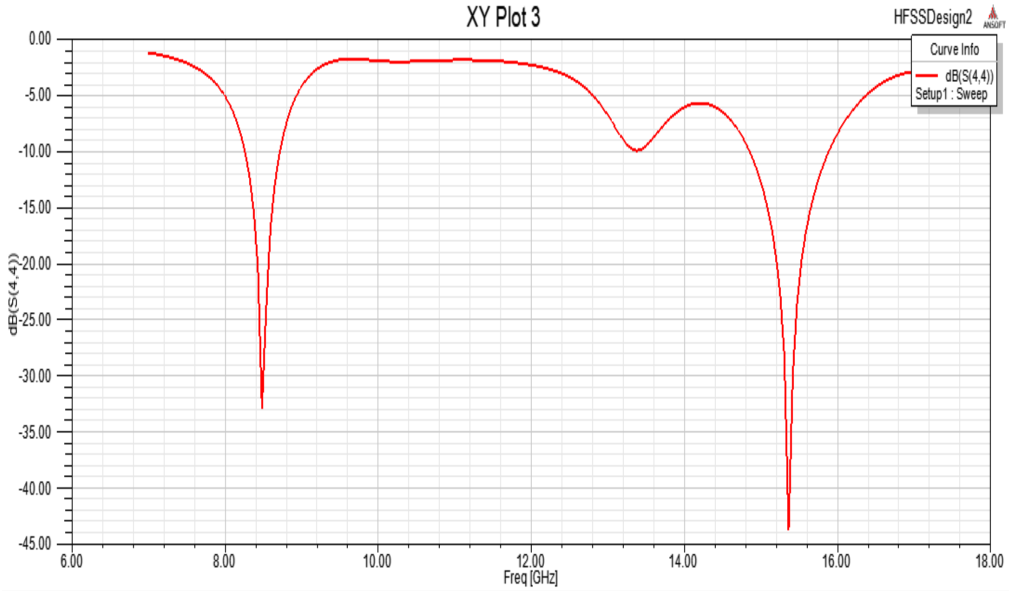

Figure 4: Bandwidth Enhancement of Microstrip patch antenna

The above figure represents using a parasitic patch for the bandwidth enhancement. Decrease in the surface wave antenna and improvement in the bandwidth with 18GHz in the double layer of a substrate when compared to the one patch. The perfect E boundary is assigned ground plane and patch. Vacuum, used for air box and RT/duriod 5880 (TM) is for a substrate. Dielectric constant = 2.2 and height = 1.57mm

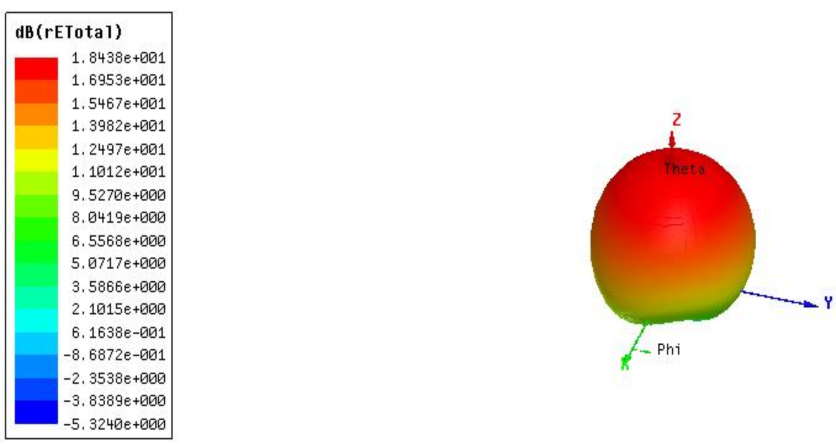

Figure 5: 3D Polar plot of Microstrip patch antenna design

As in the case of the microstrip line feeding, by spurious radiation of the feeding part, the radiation design of the antenna is unchanged. The simulation results proved that the antenna array covers the 18GHz ISM band and radiates with a low side lobe level and a good front-to-back ratio

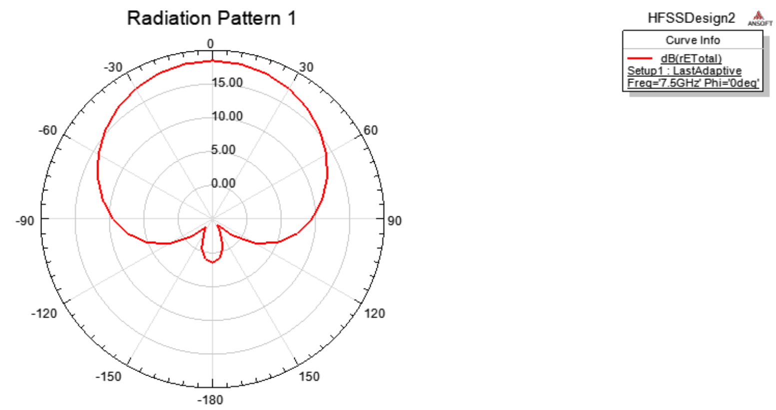

Figure 6: Radiation Pattern of Microstrip rectangular patch antenna

The radiated field components are evaluated using the field equivalence principle and can be expressed in normalized form as

$$E_\theta = \sin\varphi \left(\frac{\sin u}{u} s \right) \left(\frac{\sin v}{v} \right) * \cos \left(\frac{kL\sin\theta\cos\varphi}{2} \right)$$

$$E_\varphi = \cos\theta\cos\varphi \left(\frac{\sin u}{u} \right) \left(\frac{\sin v}{v} \right) * \cos \left(\frac{kL\sin\theta\cos\varphi}{2} \right)$$

From this figure, we observe that the radiation pattern is broader in E plane and good impedance matching

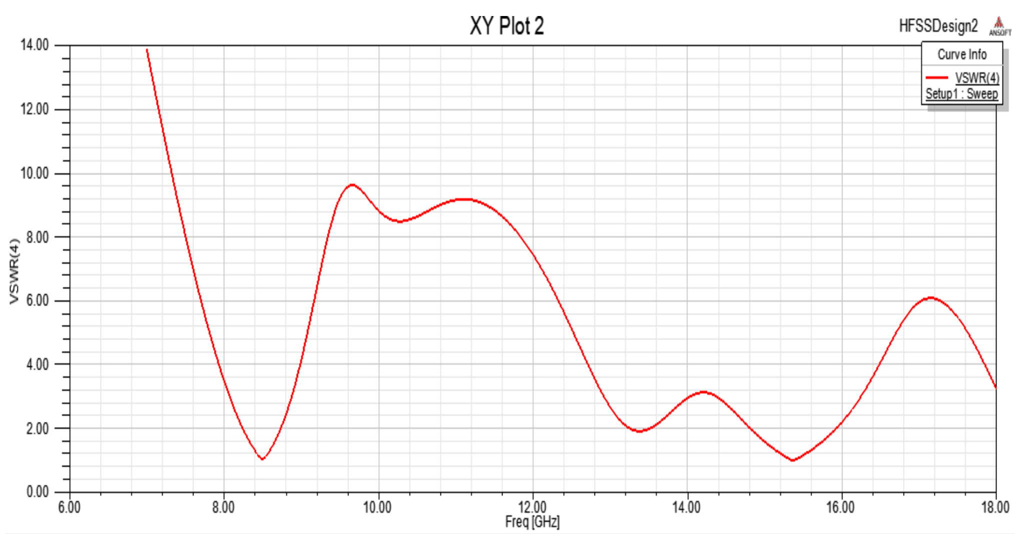

Figure 7: Microstrip to Substrate Integrated Waveguide in S Parameter

The VSWR plot for Microstrip antenna with parasitic rod radius = 1.5mm. By decreasing the S parameter value, the dielectric losses and the conductor losses are minimized. The frequency in wideband avoids the repeated electromagnetic analysis.

4. CONCLUSION

The design of microstrip rectangular patch antenna using coplanar rod parasitic elements that Improves the front to back ratio and reduction in losses. The design by two layers Substrate coupled with Integrated Substrate waveguide of coplanar parasitic Rods increases the power handling capacity and increase in quality factor. The simulation outcomes proved the antenna array covers the 18GHz ISM band and radiates with a low side lobe level and a good front-to-back ratio. By decreasing the S parameter value, the dielectric losses and the conductor losses are minimized. The frequency in wideband avoids the repeated electromagnetic analysis.

CONFLICT OF INTERESTS

The author(s) declare that there is no conflict of interests.

REFERENCES

[1] V.S. Bhaskar, E.L. Tan, K.H.H. Li, M.S. Tse, 1 to 4 Way wideband power divider using substrate integrated waveguide and modified Wilkinson structures, in: 2018 IEEE International Symposium on Electromagnetic Compatibility and 2018 IEEE Asia-Pacific Symposium on Electromagnetic Compatibility (EMC/APEMC), IEEE, Singapore, 2018: pp. 554–557.

[2] K. Xing, B. Liu, Z. Guo, X. Wei, R. Zhao, Y. Ma, Backlobe and Sidelobe Suppression of a Q-Band Patch Antenna Array by Using Substrate Integrated Coaxial Line Feeding Technique, Antennas Wirel. Propag. Lett. 16 (2017) 3043–3046.

[3] M. Dashti, J.D. Carey, Graphene Microstrip Patch Ultrawide Band Antennas for THz Communications, Adv. Funct. Mater. 28 (2018), 1705925.

[4] R. Kushwaha, V.K. Singh, N.K. Singh, A. Saxena, D. Sharma, A Compact Pentagonal Textile Microstrip Antenna for Wide Band Application, in: A. Kalam, S. Das, K. Sharma (Eds.), Advances in Electronics,

Communication and Computing, Springer Singapore, Singapore, 2018: pp. 793–799.

[5] M. Patel, P. Kuchhal, K. Lal, V. Singh, H. Patel, Design and Performance Analysis of High Gain Narrow Band Patch Antenna Array at X-Band, in: R. Singh, S. Choudhury, A. Gehlot (Eds.), Intelligent Communication, Control and Devices, Springer Singapore, Singapore, 2018: pp. 907–912.

[6] W. An, Y. Li, H. Fu, J. Ma, W. Chen, B. Feng, Low-Profile and Wideband Microstrip Antenna With Stable Gain for 5G Wireless Applications, Antennas Wirel. Propag. Lett. 17 (2018), 621–624.

[7] B. Bag, P.P. Sarkar, Dual Band Parasitic Element Patch Antenna for LTE/WLAN Applications. J. Electric. Electron. Eng. 10 (2017), 21-26.

[8] S. Seok, Advanced Packaging and Manufacturing Technology Based on Adhesion Engineering, Springer International Publishing, Cham, 2018.

[9] K. Gong, X.H. Hu, P. Hu, B.J. Deng, Y.C. Tu, A Series-Fed Linear Substrate-Integrated Dielectric Resonator Antenna Array for Millimeter-Wave Applications, Int. J. Antennas Propagation. 2018 (2018), 9672790.

[10] Z.-C. Hao, Q. Yuan, B.-W. Li, G.Q. Luo, Wideband W-Band Substrate-Integrated Waveguide Magnetoelectric (ME) Dipole Array Antenna, IEEE Trans. Antennas Propagat. 66 (2018), 3195–3200.

[11] J. Zhang, X. Zhang, A.A. Kishk, Broadband 60 GHz Antennas Fed by Substrate Integrated Gap Waveguides, IEEE Trans. Antennas Propagat. 66 (2018), 3261–3270.

[12] K.F. Lee, K.M. Luk, H.W. Lai, Microstrip patch antennas. World Scientific, Singapore, (2017).

[13] M.H. Seko, F.S. Correra, S.A. Long, D.R. Jackson, Microstrip feeding for the excitation of a higher-order resonant mode in cylindrical dielectric resonator antennas, in: 2017 SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference (IMOC), IEEE, Aguas de Lindoia, 2017: pp. 1–5.

[14] M. Srinivasan, S. Annadurai, A bandwidth analysis using broadband dual-polarization and stable-beam width slot antenna fed by U-shape micro strip line, in: 2017 IEEE International Conference on Electrical, Instrumentation and Communication Engineering (ICEICE), IEEE, Karur, 2017: pp. 1–4.

[15] B.C. Pan, T.J. Cui, Broadband Decoupling Network for Dual-Band Microstrip Patch Antennas, IEEE Trans. Antennas Propagat. 65 (2017), 5595–5598.

[16] M.M. Fakharian, P. Rezaei, A.A. Orouji, A novel slot antenna with reconfigurable meander-slot DGS for cognitive radio applications, Appl. Comput. Electromagn. Soc. J. 30 (2015), 748–753.

[17] S.-J. Park, D.-H. Shin, S.-O. Park, Low Side-Lobe Substrate-Integrated-Waveguide Antenna Array Using Broadband Unequal Feeding Network for Millimeter-Wave Handset Device, IEEE Trans. Antennas Propagat. 64 (2016), 923–932.

[18] Y. Li, K.-M. Luk, 60-GHz Substrate Integrated Waveguide Fed Cavity-Backed Aperture-Coupled Microstrip Patch Antenna Arrays, IEEE Trans. Antennas Propagat. 63 (2015), 1075–1085.

[19] M.M. Kartha, M. Jayakumar, Performance analysis of dielectric resonator antenna on substrate integrated waveguide cavity with dumbbell slot for wideband applications, Int. J. Control Theory Appl. 9 (2016), 7471-7478.

[20] M. Blech, U.S. Patent No. 9,099,787. Patent and Trademark Office, Washington, DC, (2015).

[21] S.D. Choudhary, A. Srivastava, M. Kumar, Design of single‐fed dual‐polarized dual‐band slotted patch antenna for GPS and SDARS applications, Microw. Opt. Technol. Lett. 63 (2021), 353–360.

[22] D. Singh, S.D. Choudhary, B. Mohapatra, Design of microstrip patch antenna for Ka-band (26.5–40 GHz) applications, Mater. Today: Proc. 45 (2021), 2828–2832.

[23] P.S. Gautam, D. Singh, S.D. Choudhary, B. Mohapatra, Design and Comparison of Multislot Microstrip Patch Antenna for WiMAX and WLAN Application, in: 2018 International Conference on Advances in Computing, Communication Control and Networking (ICACCCN), IEEE, Greater Noida (UP), India, 2018: pp. 717–720.