Available online at www.ijsrnsc.org
IJSRNSC
Volume-5, Issue-6, December 2017
Research Paper
www.ijsrnsc.org
Int. J. Sc. Res. in Network Security and Communication
E-ISSN:2321-3256

Study of reflection losses in tuned and EBG power dividers at S, C, X and upper Ku bands

Suresh Angadi[1*], Karteek Viswanadha[2], R.Roopa Sree[3], Sowjanya Madaka[4]

[1*]Department of Electronics and Communication Engineering, VITAM, Visakhapatnam, India
[2]Department of Electronics and Communication Engineering, Delhi Technological University, New Delhi, India
[3]Department of Electronics and Communication Engineering, VITAM, Visakhapatnam, India
[4]Department of Electronics and Communication Engineering, VITAM, Visakhapatnam, India

[*]Corresponding Author: suresh.angadi.101@gmail.com, Tel.: 918919840988

Received: 11/Nov/2017, Revised: 22/Nov/2017, Accepted: 20/Dec /2017, Published: 31/Dec/2017

Abstract—This paper presents the study of reflection losses in a tuned 8 port power divider with circular and square slotted Electromagnetic Bandgap structures (EBG) by varying the dimensions of the slots as well as the transmission lines. Further, the tuning feature makes the proposed power divider not only compact but also to work at S, C, X and the upper Ku bands by introducing periodic structures and thus enhancing the bandwidth with less reflection losses. Various parameters like reflection coefficient, insertion loss of the tuned EBG power divider are studied by varying the number of slots in the ground plane using Agilent Advanced Design System 2009 and 2016 simulators respectively.

Keywords— Power divider , bandwidth, insertion loss, reflective loss, X, Ku-band,ADS.

I. Introduction

Wireless communications are shifting towards the ultra high frequencies and data rates in order to meet the technological advancements. Usually high data rates are achieved using antenna arrays which are highly directional. The gain of an antenna depends on the power it receives from the preceded device which in deed acts as power feeder to antennas. The feeding devices for the antenna arrays should have high isolation, low insertion and reflection losses. Many power dividers like 'T'-junctions, Wilkinson and Geysel are used as power feeding devices for antenna arrays [1]. Wilkinson power divider consists of quarter wavelength transformers on the output lines and a resistor connecting the two output lines which improves the isolation between the output ports [2-3]. Wilkinson power dividers are usually narrow band devices and thereby require cascading of quarter wavelength transformers in order to increase the bandwidth. Conventional power dividers have one input and '2^n' output ports. Power dividers are proposed with 6 output ports in order to achieve good insertion loss and improve reflective losses [4]. But, Wilkinson power dividers are limited to low or medium power applications. Wide bandwidth is achieved in L-band by using the power divider with 6-outputs than compared to that of a conventional 1:2 power divider [4]. Performance parameters of the power dividers can also be improved by changing the properties of the substrate. Slots etched periodically on the ground plane also enhance bandwidth along with reduction in the surface waves and these structures are called as Electromagnetic Band gap Structures (EBG). Bandwidth of power divider can further be enhanced by mounting later on the EBG structures and introducing tuning elements like capacitor and inductor by varying the dimensions of the transmission line. These structures are often used with coupled lines where the power division is achieved by varying the spacing between the lines. Coupled lines facilitate the introduction of tuning elements by varying the spacing between the microstrip lines. These power dividers have wide bandwidth due to the tuning elements present inside them [5]. Apart from the equal power dividers, unequal power dividers are proposed depending on the application. Unequal power dividers often possess wide bandwidths without utilizing the tuning elements [6]. For high power applications, Geysel power dividers are used [7]. These power dividers not only improve the power handling capability but also keeps track on the imbalance at the output ports. Unequal power dividers are designed by cascading the transmission line transformers which improves performance parameters [8]. Wilkinson power divider designed below the dielectric substrate using double-sided parallel strip line increases the bandwidth up to 4GHz [9]. Waveguide power divider is designed using Multi Cavity Modeling Technique (MCMT) and acts as an efficient feed for antenna arrays [10]. Waveguide power dividers also perform filtering functions in order to select the band of interest and suppress the harmonics [11-12]. The improved form of waveguide called Substrate Integrated Waveguide (SIW) is often used to design the power dividers in order to improve the compactness and ease the integration. SIW power dividers proposed can work in K, V, W bands thus improves the isolation [13-14]. Ring type SIW power dividers with 1.5λ length are proposed [15]. Moreover, the impedance of SIW power divider is independent of cut off frequency and isolation resistance [16]. Alternate method for enhancing the bandwidth is realizing power dividers with stepped-impedance transmission lines and stubs [17]. The transmission lines introduce capacitive path in order to suppress the harmonics [17]. Coplanar wave guide (CPW) is another form of planar transmission line which eases the process of integration.

II. Design of the Proposed Power Divider

The proposed power divider is designed on the Rogers RT/duroid 5880 substrate of height 0.254mm and relative dielectric constant of 2.2.The whole design is carried out in ADS 2009 schematic as well as in momentum using method of moments. The characteristic impedance of the input transmission line is fixed at 50 Ω. Quarter wavelength lines of with operational frequency of 10 GHz are designed to have the characteristic impedances of $50\sqrt{2}$ Ω each. Dimensions of main lines (50 Ω lines) especially are tuned stepwise. By doing so, main lines introduce filtering feature to the power divider.

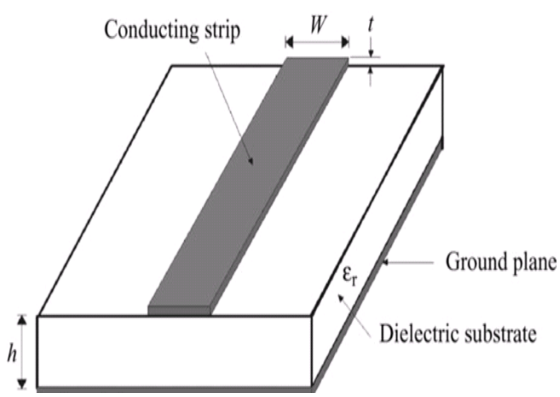

Figure 1. Microstrip Line

From fig.1, the width and length of the input transmission line at 10GHz is calculated by using the following equations:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\frac{1}{\sqrt{1+12h/W}} \quad (1)$$

Where 'ε_r' is the relative dielectric constant and 'h' is the height of the dielectric and 'W' is the width of quarter wavelength impedance transformer line. Characteristic impedance is given by:

$$Z_o = \frac{60}{\sqrt{\varepsilon_{eff}}}\ln\left(\frac{8h}{W}+\frac{W}{4h}\right), \text{ for } W/h \le 1 \quad (2)$$

$$Z_o = \frac{120\pi}{\sqrt{\varepsilon_{eff}}\left[\frac{W}{h}+1.393+0.667+\ln\left(\frac{W}{h}+1.444\right)\right]}, \text{ for } W/h \ge 1 \quad (3)$$

$$\frac{W}{h} = \frac{8e^{A}}{e^{2A}-2}, \text{ for } W/h < 2 \quad (4)$$

$$\frac{W}{h} = \frac{2}{\pi}\left[B-1-\ln(2B-1)+\frac{\varepsilon_r-1}{2\varepsilon_r}\left\{\ln(B-1)+0.39-\frac{0.61}{\varepsilon_r}\right\}\right] \quad (5)$$

Where $A = \frac{Z_o}{60}\sqrt{\frac{\varepsilon_r+1}{2}} + \frac{\varepsilon_r-1}{\varepsilon_r+1}\left\{0.23+\frac{0.11}{\varepsilon_r}\right\}$

$$B = \frac{377\pi}{2Z_o\sqrt{\varepsilon_r}}$$

Using the above design equations, the width (w_o) of the input transmission line is obtained as 0.762 mm and the electrical length (l_o) is tuned to 155^0 or equivalently 9.39mm in order to introduce the shunt L-C elements on the input line. Using the below equation for calculating the length of the quarter wavelength transformer,

Line length= $\frac{c}{4f\sqrt{\varepsilon_{eff}}}$ where 'c' is the velocity of light and 'f' is the frequency of operation. The width of quarter wavelength lines (w_1) is 0.457mm each. Electrical lengths (l_1) of the quarter wavelength lines are tuned to 82° or equivalently 5.08mm in order to introduce the series L-C elements. The transmission line equivalent of the proposed power divider is designed in ADS-2009 schematic as shown in fig.2. The basic idea behind the proposed structure of power divider is to make the divider compact and providing power closest to the ideal value of 8 output power divider.

S-parameter matrix of the tuned power divider is same as that of Wilkinson power divider given by:

$$\frac{-j}{\sqrt{2}}\begin{bmatrix}0 & 1 & 1\\1 & 0 & 0\\1 & 0 & 0\end{bmatrix}$$

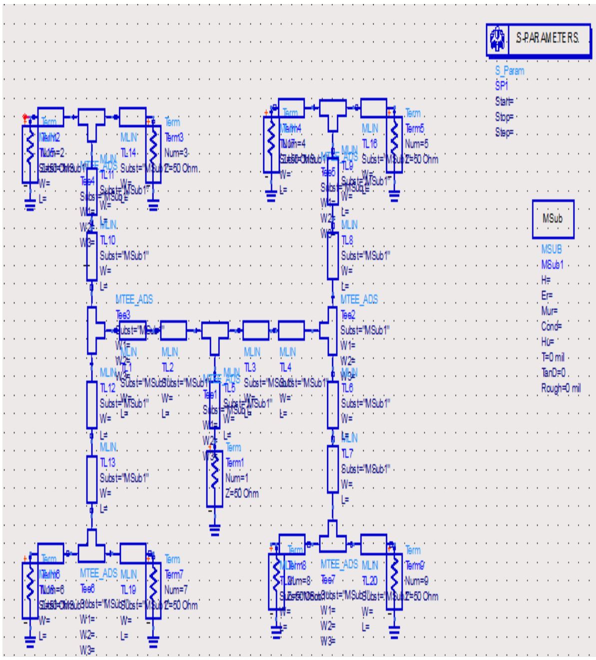

Figure 2. Schematic of the proposed power divider

Fig. 3(a) & 3(b) shows the proposed tuned power divider and its layout in ADS-momentum. As quarter wavelength line is not an impedance matcher and therefore, it introduces tuning elements like inductor and capacitor at each junction of the power divider. These tuning elements form a fourth order band pass filter with wide band pass response and divides power over a large range of frequencies.

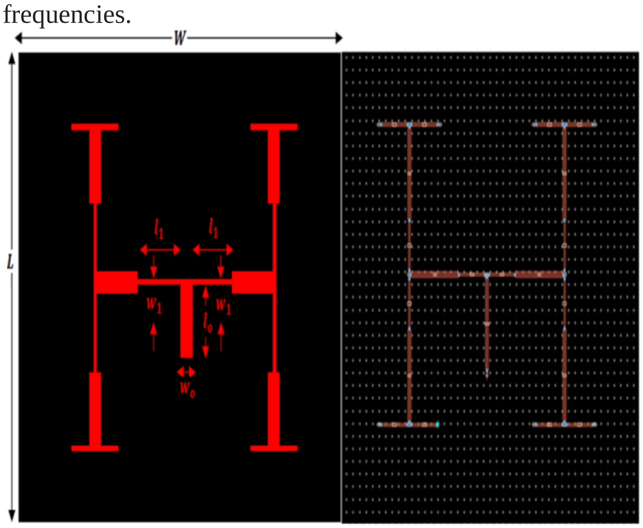

Figure 3(a). Proposed tuned power divider
Figure 3(b). Layout of the proposed tuned power divider

III. DESIGN OF THE PROPOSED POWER DIVIDER WITH SQUARE AND CIRCULAR EBG STRUCTURES

The proposed power divider is implemented using Electronic Band gap Structures (EBG) with width (W) 30.54mm and length (L) of 25.4mm with square and circular etched. Fig. 4(a) & 4(b) shows the proposed 15 slotted EBG tuned power divider and its layout. For the 15 slotted EBG shown in fig. 4(a), the dimensions of square slot (a) are 2.54mm by 2.54mm and the radius (r) of circular slot is 1.25mm. Horizontal (s) and vertical (s_o) spacing is chosen to be 9mm and 3mm respectively..

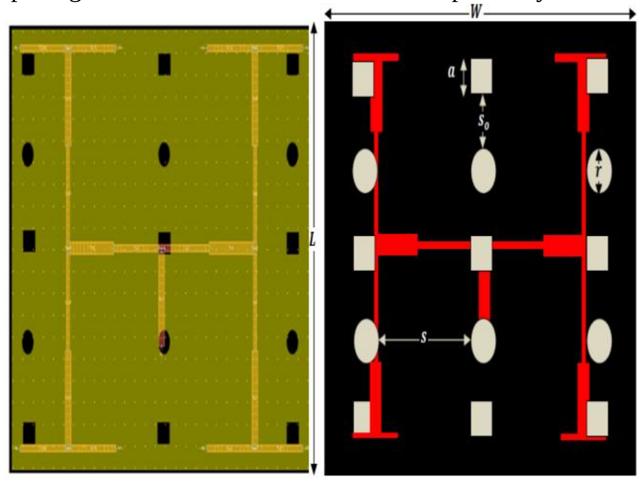

Figure 4(a). Proposed tuned power divider with 15 slotted EBG structure
Figure 4(b). Layout of the tuned power divider with 15 slotted EBG structure

Fig. 5(a) & 5(b) shows the proposed 42 slotted EBG tuned power divider and its layout. For the 42 slotted EBG structure shown in fig. 5, the dimensions of square slot (a') are taken as 1mm by 1mm and the radius (r_o) of circular slot is 0.5mm. Horizontal spacing (s') between the slots is chosen to be 3.2 mm and vertical spacing (s_o') is chosen to be 4.1mm.

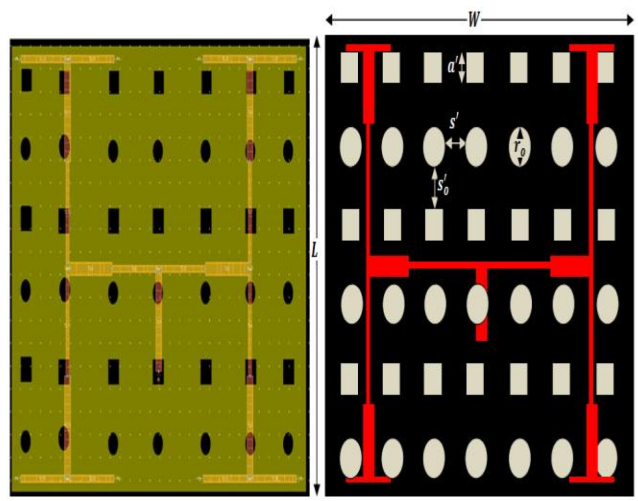

Figure 5(a). Layout of the proposed power divider with 42 slotted EBG
Figure 5(b). Proposed power divider with 42 slotted EBG

IV. Results and Discussions

All the simulated results are observed at 3.152 GHz, 5 GHz, 11.32 GHz, 12 GHz and 12.11 GHz respectively using ADS-2009 simulator using method of moments. The schematic of the proposed power divider is simulated using

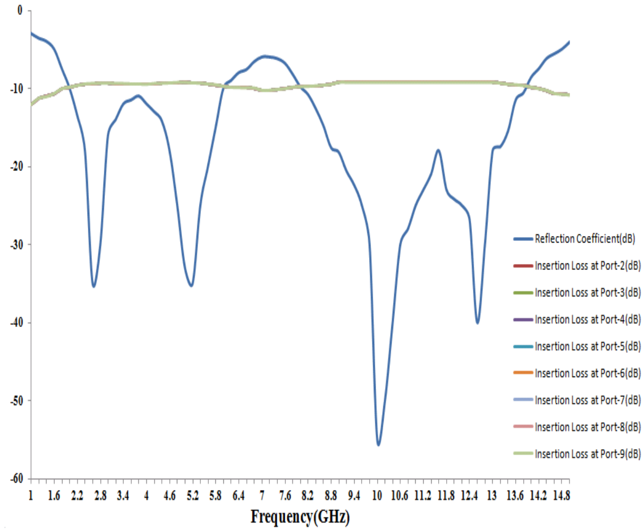

Figure 6. Consolidated plot of reflection coefficient and insertion loss of the tuned power divider

Fig. 6 shows the consolidated plot of reflection coefficient and insertion loss of the schematic layout of proposed tuned power divider shown in fig.2.

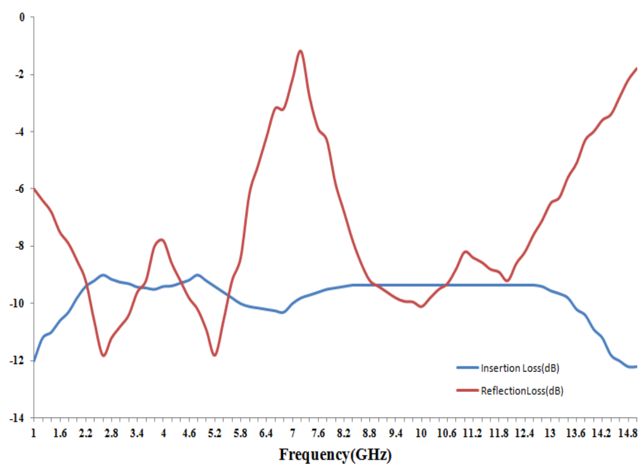

Figure 7. Consolidated plot of reflection co-efficient and insertion loss of the proposed power divider in momentum

A flat band with low ripples is observed between 8.2 GHz to 13.4 GHz. Theoretical insertion loss is given by:

$$S_{21(\text{Theoritical})} = 10\log\left[\frac{\text{Power}_{\text{received}}}{\text{Power}_{\text{inputted}}}\right]$$

Theoretically the insertion loss for an 8:1 power divider has to be -9.03dB. Consolidated plot of insertion loss and reflection coefficient for the layout in momentum are shown in fig. 7.

$$S_{21(\text{Practical})} = 10\log\left[\frac{\text{Power}_{\text{received}} - \text{Power}_{\text{losses}}}{\text{Power}_{\text{inputted}}}\right]$$

Losses considered are conductor, dielectric and insertion type.

Fig. 8(a) shows the plot of reflection coefficient (blue graph) and insertion loss (red graph) of a 15 slotted EBG power divider as shown in fig. 4(a) and fig. 8(b) shows the plot of reflection co-efficient for the 42 slotted EBG power shown in fig. 5(a).

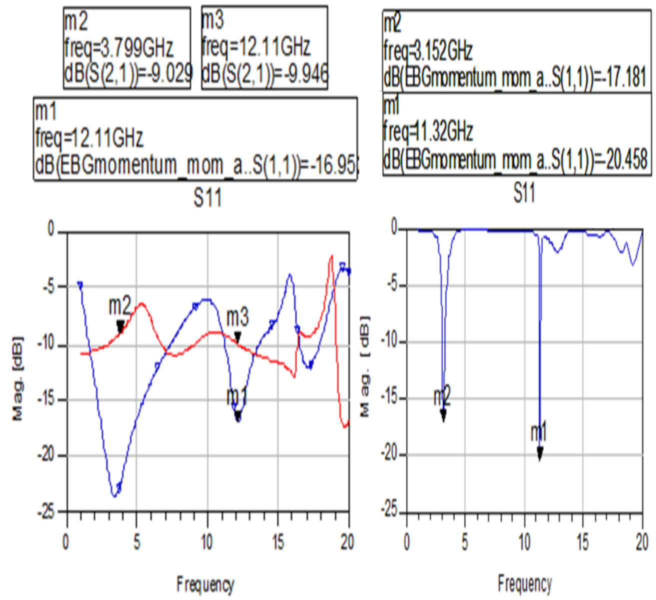

Figure 8(a).Reflection coefficient and insertion loss plot of 15 slotted EBG power divider.

Figure 8(b). Reflection coefficient plot of a 42 slotted EBG power divider

A 0.01mm change in the side of a square slot shifts the dips to K and K_a bands and the insertion loss of less than -15.12dB is obtained. A 0.01mm change in the radius of the circular slot shifts the frequencies to lower gigahertz range with high insertion loss. Therefore, a trade-off has been chosen to obtain proper return and insertion loss values. Table.1. shows the tabular data of reflection losses of normal power divider, 15 slotted and 42 slotted EBG power dividers in the S and Ku bands. Reflective losses are highly reduced at S, C, X and Ku bands. 15 slotted EBG power divider works at multiple bands than that of a 42 slotted EBG power divider.

TABLE I Comparison between EBG power dividers and tuned power divider.

Frequency (GHz)	**S_{11} of tuned power divider(dB) [Fig.7]**	**S_{11} of 15 slotted EBG power divider(dB) [Fig.8(a)]**	**S_{11} of 42 slotted EBG power divider(dB) [Fig.8(b)]**

3.152	-10	-23.8	-17.181
5	-11.6	-17	-0.1
11.32	-8.1	-14	-20.458
12	-9	-16	-0.8
12.11	-9.1	-16.95	-1

V. CONCLUSIONS

Reflective losses of EBG and tuned power dividers are studied and compared. The designer can choose these power dividers depending on the type of application. High degree of compactness is achieved by using the proposed power dividers. Subsequently, the antenna array size gets reduced with increased gain and directivity when fed with the proposed power divider. EBG power dividers have low reflective losses with square, circular slots but frequency range of operation is limited. Further, EBG power dividers have insertion loss closest to the ideal value. These power dividers can be used in the TDRS (Tracking Data Relay Satellites) in order to feed the phased array antennas in the satellites.

VI. REFERENCES

[1] A.Nassiri, "*Power dividers and couplers*", Massachusetts Institute of Technology, U.S.Particle Accelerator School, pp.1-66, 2010.

[2] Mohsen Hayati, Ashkan Abdipour, Arash Abdipour, "*A Wilkinson Power Divider with Harmonic Suppression and Size Reduction using High-low Impedance Resonator Cells*", Radio Engineering, Vol.24, Issue.1, 2015.

[3] Sandeep kumar, Mithilesh kumar, "*Modified Wilkinson Compact Wide Band (2-12GHz) Equal Power Divider*", American Journal of Engineering Research (AJER), Vol.03,Issue.10, pp. 90–98, 2014.

[4] S. S Chorage, Shilpa. V. Joshi, Harshada. S. Ahiwale, Archana. M. Gaikwad, ,"*Design And Performance Analysis Of 1:6 Power Divider For L Band Frequency*", International Journal of Wireless Networks and Communications., Vol.8, Issue.1, pp. 15–21,2016.

[5] Gurrachman, T., Object, Arisesa, H., Putu Hernida. I.D, Permana, D. "*Design and implementation of coupled-line Wilkinson power Dividers using alumina substrate*", International Journal of Engineering Trends and Technology, Vol.9,Issue.7, pp. 363–365, 2014.

[6] T. R. Subramanian , "*Dual Band Wilkinson Power divider without Reactive Components*", Department of Electronics System Engineering,Indian Institute of Science, pp.1-6,2012.

[7] S. Banu, A. Vishwapriya, R. Yogamathi, A. V. Meenakshi, S. P. K Babu, "*Comparison of Wilkinson Power Divider And Gysel Power Divider Using Ads For The Frequency Range of 3 Ghz*", Fourth International Workshop on Computer Networks & Communications,pp.1-8, 2012.

[8] Qaroot, A.M., Dib, N.I.,Gheethan, A.A., "*Design methodology of multi-frequency unequal spilt Wilkinson power dividers using transmission line transformers*", Progress In Electromagnetics Research B, Vol.22, pp. 1–21, 2010.

[9] Nor, M.Z.B.M., Rahim, S.K.A., Sabran, M.I. bin, Rani, M.S.B.A., "*Wideband planar Wilkinson power divider using double-sided parallel-strip line technique*" Progress In Electromagnetics Research C, Vol.36, pp. 181–193,2013.

[10]. Debendra Kumar Panda, Ajay Chakraborty, "*Analysis of a 1:2 Rectangular Waveguide Power Divider for Phased Array Application Using Multiple Cavity Modeling Technique*", IEEE Progress In Electromagnetics Research Symposium, Cambridge, USA,pp.361-368, 2006.

[11] Ali Musa Mohammed, Yi Wang, "*Four-way Waveguide Power Dividers with Integrated Filtering Function*", IEEE- European Microwave Conference (EuMC), Europe, pp.486-489, 2015.

[12] Song, K., Fan, Y. ,Zhang, B., "*Ku-band multiway rectangular waveguide power divider*", Microwave and Optical Technology Letters, Vol.52, Issue.11, pp. 2560–2563, 2015.

[13] Rahali, B., "*Design of K-band substrate integrated Waveguide coupler, Circulator and power divider*", International Journal of Information and Electronics Engineering, Vol.4, Issue.1, pp.47-53, 2015.

[14] Bouchra Rahali, Mohammed Feham, Junwu Tao, "*Design of K-band substrate integrated waveguide coupler,circulator and power divider*", International Journal of Information and Electronics, Vol.4,Issue.1, pp.1-6, 2014.

[15] Djerafi, T., Hammou, D., Wu, K. , Tatu, S.O. , "*Ring-shaped substrate integrated Waveguide Wilkinson power Dividers/Combiners*", IEEE Transactions on Components, Packaging and Manufacturing Technology, Vol.4,Issue.9, pp. 1461–1469, 2014.

[16] Deslandes, D., Boone, F., Wu, K., "*Composite corporate traveling-wave power dividers for slot array waveguide antennas*", International Journal of RF and Microwave Computer-Aided Engineering, Vol.19, Issue.2, pp. 177–186,2009.

[17] Deng, P.-H., Guo, J.-H. ,Kuo, W.-C., "*New Wilkinson power dividers based on compact stepped-impedance transmission lines and shunt open stubs*", Progress In Electromagnetics Research, Vol.123, pp. 407–426,2012.

[18] Arpit Nagar, Khem Singh Solanki, "*Design and analysis of microstrip patch antenna*", International Journal of Scientific Research in Network Security and Communications, Vol.1, Issue.1, pp.1-5, 2013.

Authors Profile

Mr. Suresh Angadi pursued his B.Tech in electronics and communication engineering from G.V.P College of Engineering (Autonomous), Visakhapatnam in 2007 and M.Tech in digital communication from Maulana Azad National Institute of Technology (NIT-Bhopal) in 2009. He is presently working as assistant professor in the department of electronics and communication engineering at VITAM College of engineering, Visakhapatnam. He has published twenty six journals of repute.

Mr. Karteek Viswanadha pursued his B.Tech in electronics and communication from G.V.P College of Engineering (Autonomous), Visakhapatnam in 2007 and M.Tech in communication systems from Birla Institute of Technology and Sciences, Pilani (B.I.T.S, Pilani) in 2009. He is presently pursuing Ph.D in the area of millimeter wave devices and antennas from Delhi Technological University (Formerly Delhi College of Engineering), New Delhi.

Ms. Rokkam Roopa Sree pursued her B.Tech degree in electronics and communication engineering from Aditya College of Engineering, Tekkali in 2014 and M.Tech from Gayatri College of Engineering for Women, Visakhapatnam in 2017. She is presently working as assistant professor in department of electronics and communication engineering at VITAM College of Engineering, Visakhapatnam.

Ms. Sowjanya Madaka pursued her B.Tech in electronics and communication engineering from Nightingale College of Engineering, Visakhapatnam in 2013 and M.Tech from Gayatri College of Engineering for Women in 2015. She is presently working as assistant professor in the department of electronics and communication engineering at VITAM College of engineering, Visakhapatnam.

