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Improved Directivity for Multi-Layer Configured Microstrip Directional Coupler using ANSYS

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Abstract: **Directivity of microstrip directional coupler is measured based on its scattering parameters and coupling factor, directivity and isolation factor. Directivity of the microstrip directional coupler is very low, to overcome these problems many methods were applied like lumped capacitor, lumped inductor, implementing wiggling edges. In this paper we introduce a compensation method to improve directivity, i.e. multilayer configuration. This method valid for tight and closed loop structures. Proposed method is designed by using HFSS software and experimental results will show, multilayer configuration is the best suitable method to improve directivity of directional coupler.**

Index Terms: **Microstrip directional coupler, directivity, ANSYS software.**

I. Introduction

Microstrip directional coupler [1]-[4] has four ports, designing and implementation made on the parameters of insertion loss, isolation loss and coupling loss [5]. In directional coupler to improve directivity, one of the ports has to be terminated and these devices used to detect forward and reverse power. If the input power (P_i) is given in port 1, power received at port 2 is received power (P_r), power received at port 4 i.e coupled port is given by forward coupled power (P_f) and the power received at port 3 is back power (P_b), but in ideal case P_b=0. From these powers in directional coupler, some factors like coupling factor, directivity and isolation factor. To design any type of antenna, these factors have to be considered for practical considerations:

- Coupling factor C=10log($\frac{P_i}{P_f}$)
- Directivity D=10log($\frac{P_f}{P_b}$), in practical case to develop directivity P_b value has to be low.
- Isolation factor I=10log($\frac{P_i}{P_b}$) or 10log($\frac{P_r}{P_f}$)

Microstrip directional couplers are widely used in radar, optical, fiber communications. Directional couplers make good performance while transmitting signals from transmitter to receiver. In RF industry [6], microstrip antennas are made of very cost effective and leakage problem at receiver is null. The manufacturing and designing of microstrip type [7] directional efficiency is very high whereas the directivity is very poor. To improve directivity [8] of microstrip directional coupler, many compensation methods are available, connecting lumped components at the ends of the antenna, dielectric overlay [9] on coupler lines, wigging coupled edges and multilayer configuration [10]. In these methods, multilayer configuration makes important factor. Multilayer configuration can be designed using two-line [11] and three-line layers. Design procedure of multilayer configuration is based on statistical and numerical values. Conventional microstrip couplers are practical sampling devices and can be used to detect either forward or reverse power in practice because one of the coupled ports is usually terminated with lumped element for compensation to improve the directivity. This problem can be overcome using three-line microstrip couplers and have one of the ports of the coupled lines as forward signal detection while terminating the other port of the same-coupled line with a lumped element for compensation of the mismatch for directivity improvement. Then, other coupled line can be used for reverse signal detection and same technique can be applied to improve the directivity. The use of three-line microstrip couplers as reflectometers. However, the design of three-line microstrip directional couplers in the literature again is based on the use of odd and even mode impedance design charts.

To increase the directivity, it has been proposed to design a tightly coupled microstrip directional coupler. In this paper, the directional coupler [12] is operated in the bandwidth limited from 5GHz to 12GHz and has coupling factor of 60dB. Another important way to increase the directivity compared to the previous papers is through matched termination of the ports. In this paper, it has been implemented two-line microstrip directional coupler [13] with closed form. The dual line directional coupler is designed with the parameters like operating frequency, thickness of copper patch and substrate, port impedances. In this paper, it has been analyzed the results and statistical analysis is made on curve fitting method. The analysis of simulation, statistical and graphical methods are present in this paper.

This paper organizes as follows; Section II describes literature survey, Section III gives the information about Method of analysis. Section IV describes simulation results. Section V describes conclusion and future scope.

II. Literature Survey

This section gives paper description on the previous papers.In [14], authors describe branch guide directional couplers analysis of synthetic technique to extract

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butterworth characterstics by Chebyshev ripple characterstics. Microstrip directional couplers designed using Cohn's slotline in a combination with a microstrip was designed, an octave wide (2-4 GHz) magic tee [15] designed with simulation results. In [16], authors give information about accurate and simple model to transition between probe fed microstrip antenna and microstrip circuit in back to back configuration. In [17], authors designed antenna for wireless communication systems with H-shaped coupling slots on the grounded metal plane. In [18], authors designed microstrip antenna with the quasi-cross-shaped aperture is excited by a U-shaped and an M-shaped microstrip feedline, which leads to two orthogonal polarizations to improve directivity.

III. Method of analysis

In this section, the simulation designing and implementing methods of dual line micro strip directional coupler is given:

The designing procedure of dual line directional coupler is shown in figure 1 and 2. The design procedure requires port impedance, type of material, operating frequencyin MHz, coupling level in dBs and dielectric constant. Table 1 shows the operating specifications of dual line microstrip directional coupler. The physical construction of two strip directional coupler or cross sectional view of coupled microstrip lines is shown in figure 2. The configuration of two line is specified by parameters like W/h shape ratio and s/h spacing ratio. In the design of two line micro strip filters and couplers depend on W/h ratio (corrected shape ratio), s/h ratio (shape ratio), characterstic impedence in even mode impedence (Z_{oe}) , odd mode impedence (Z_{oo}) and length (L) of the substrate plays important role.

TABLE I.
DESIGNING PHYSICAL SPECIFICATION OF DUAL LINE MICROSTRIP DIRECTIONAL COUPLER

Type of material	Operating frequency	Port impedance	Coupling level
FR4	250 MHz	50	-15

Sides	Width	Length	height
48.9mm	100mm	128.8mm	3.048mm

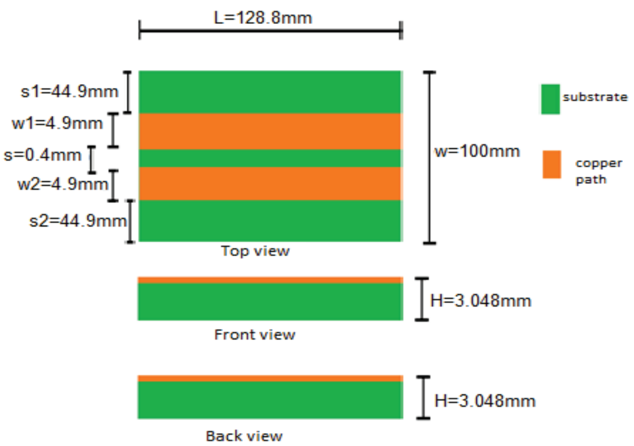

Figure 1. Top, front and back view of dual line directional coupler.

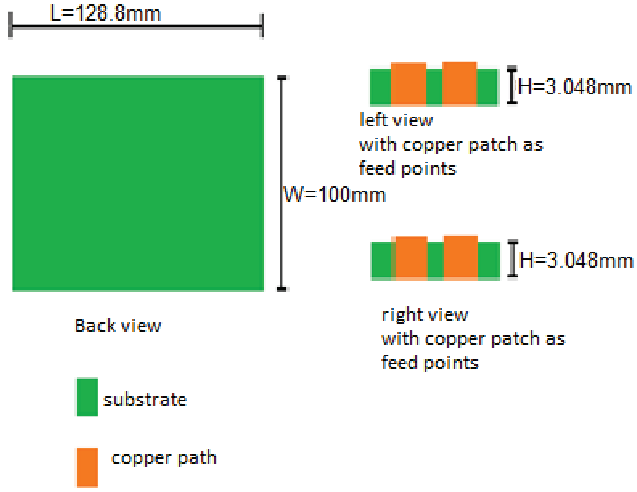

Figure 2. Back, Left and Right view of dual line directional coupler.

The first step for designing procedure is to find even and odd mode impedances, equation 1 and 2 ,

$$Z_{oe} = Z_o \sqrt{\frac{1+10^{C/20}}{1-10^{C/20}}} \qquad (1)$$

$$Z_{oo} = Z_o \sqrt{\frac{1-10^{C/20}}{1+10^{C/20}}} \qquad (2)$$

Where Z_o is port impedance, C is coupling value in dB, after finding even and odd impendences, next step is to find spacing and shape ratios. $({W}/{h})_e$ and $({W}/{h})_o$ are the shape ratios of even and odd mode.

Shape ratio

$$W/_{h} = \frac{8\sqrt{\left[\exp\left(\frac{R}{4.24}\sqrt{\epsilon_r+1}\right)-1\right]\frac{7+4/\epsilon_r}{11}}}{\left[\exp\left(\frac{R}{4.24}\sqrt{\epsilon_r+1}\right)-1\right]} \qquad (3)$$

Where $R = \frac{Z_{oe}}{2}$, $R = \frac{Z_{oo}}{2}$

Spacing ratio

$$\frac{s}{h} = \frac{2}{\pi}\cosh^{-1}\left[\frac{\cosh\left[\frac{\pi}{2}(W/h)\right]-2}{\cosh\left[\frac{\pi}{2}\left(\frac{W}{h}\right)^{1}_{so}\right]}\right] \qquad (4)$$

Where $\left(\frac{W}{h}\right)^{1}_{so}$ is modified term for shape ratio for odd mode geometry.

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Then next step is to find length of the coupler and it is found by,

$$l = \frac{\gamma}{4} \quad (5)$$

where γ is wavelength of the antenna

the effective permitivity constant of dual line couple structure is given by

$$\varepsilon_{eff} = \left[\frac{\sqrt{\varepsilon_{effe}} + \sqrt{\varepsilon_{effo}}}{2}\right]^2 \quad (6)$$

ε_{effe} and ε_{effo} are even and odd mode primitivities. With these parameters, it can be a design dual core microstrip directional coupler.

IV. Simulation Results

In this, it has been presented simulation and analysis results for different cases for two-line micro strip directional coupler. Teflon is considered substrate material [19] and dielectric constant is 2.8. The base design has been considered at -15dB coupling loss and 250MHz operating frequency. Physical dimensions for two strip directional coupler are shown in figure 3. These physical dimensions are analyzed in MATLAB software GUI [20]. Many other parameters like s/h spacing, W/h shape (in eq. W/h), even mode capacitance (Ce) and odd mode capacitance (Co) with dielectric constant, length are considered and analyzed using ANSYS software.

After all physical results are known and obtained by ANSYS software [21]. In this material (teflon), the thickness is 100 millis. With this thickness, spacing between materials is 63.9 millis and width is 95.9 millis. By considering tolerance, these values are considered 65 millis and 100 millis. The layout of two line microstrip had been shown in figure 2.

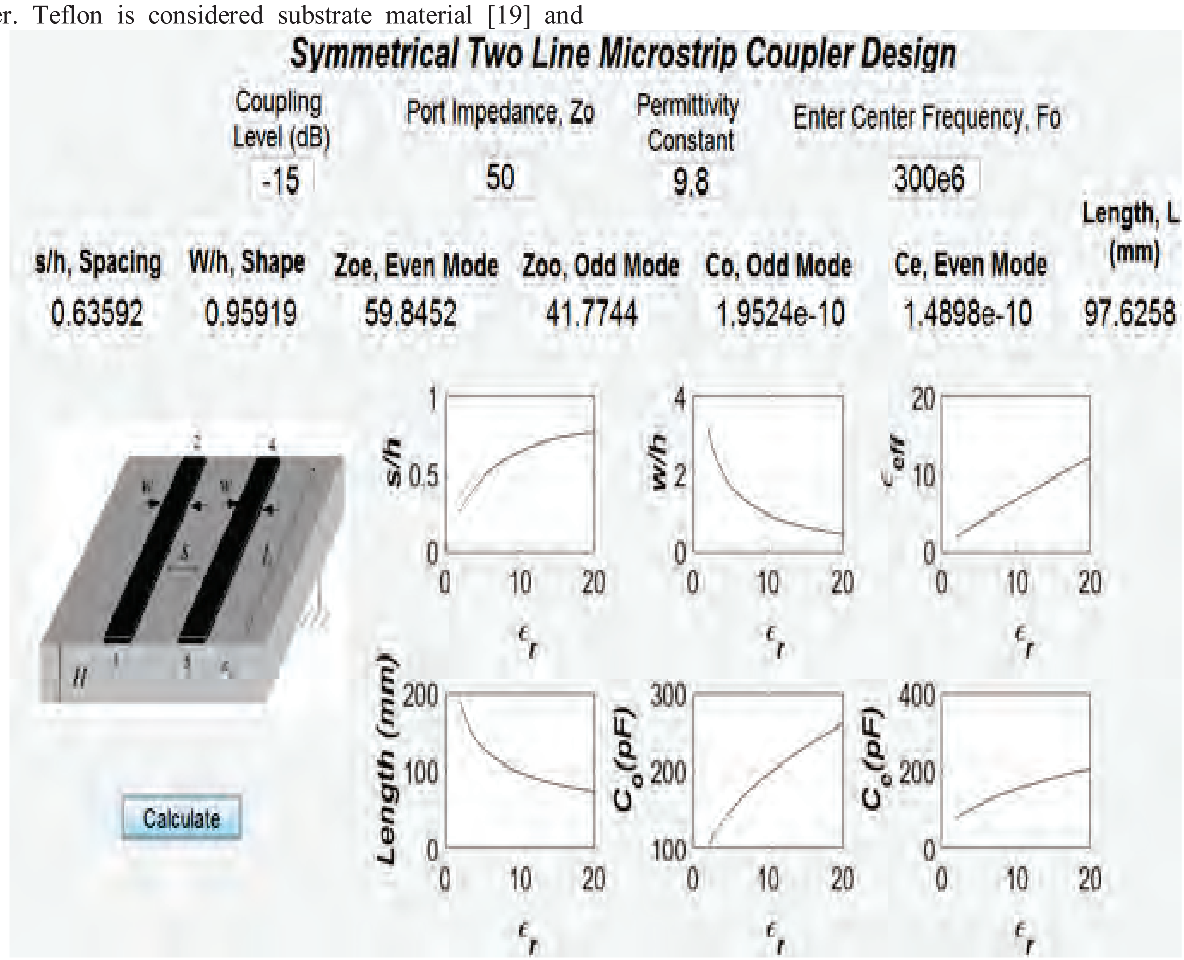

Figure 3. Teflon substrate two strip directional coupler.

In designing of directional coupler for different types of losses has been analyzed. Port losses for all ports scattering parameters has been analyzed here. Directivity, isolation and coupling losses are also considered with different parameters. Figures 4-10 show all the losses of dual line micro strip coupler. For the analysis of results in this paper, it has been considered ANSYS software and parameters are shown in table 1.

From the simulation results port loss for self port i.e S_{11}, S_{22}, S_{33} and S_{44} are given by -28.6dB, -44dB, -27.5dB and -40.4 dB respectively. Coupling loss and isolation loss is -12dB and -24.5dB. where the important parameter for developing the directivity is -34.75dB which is very good parameter in designing the micro strip antennas. The main advantage of multi layer configurations is improving directivity. In this paper, it is shown that directivity of two layer micro strip antenna is improved significantly.

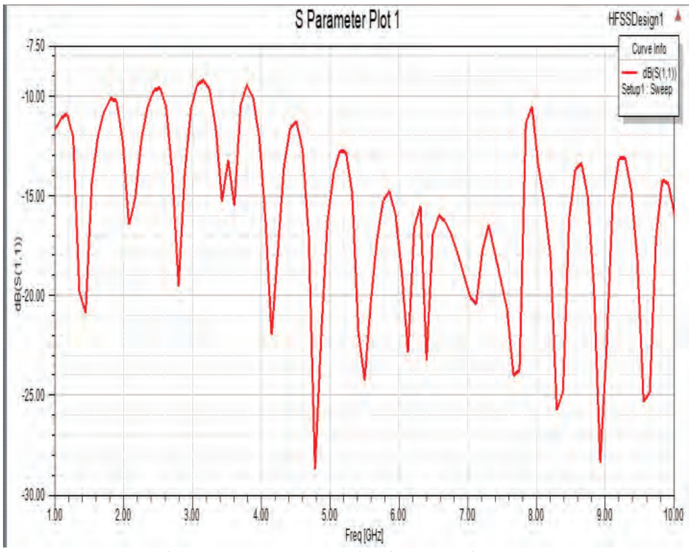

Figure 4. S-parameter plot for port 1 i.e. S_{11}.

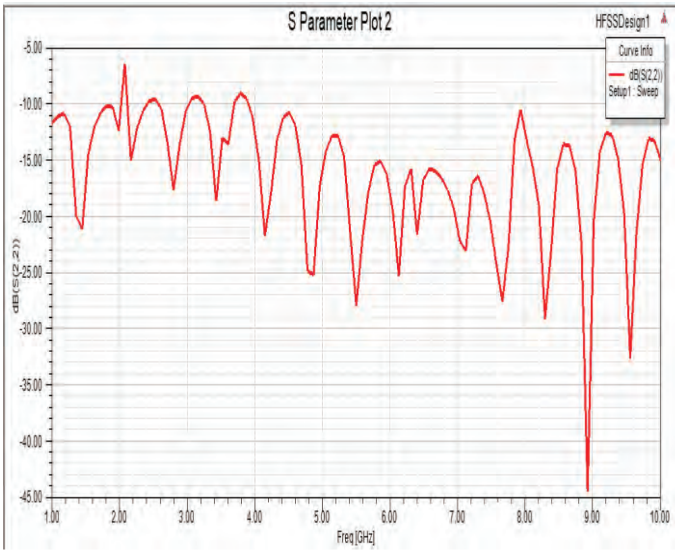

Figure 5. S-parameter plot for port 2 i.e. S_{22}.

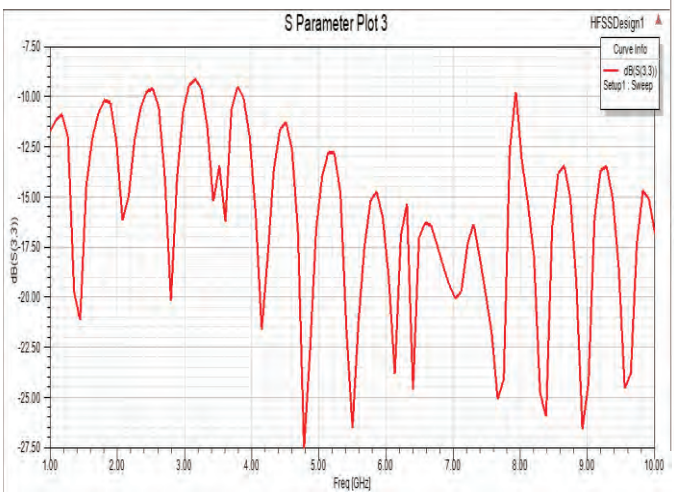

Figure 6. S-parameter plot for port3 i.e. S_{33}.

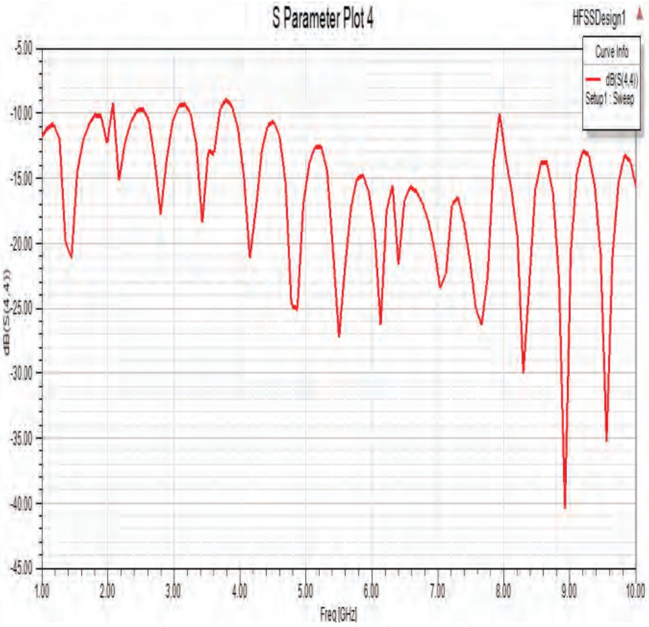

Figure 7. S-parameter plot for port 4 i.e. S_{44}.

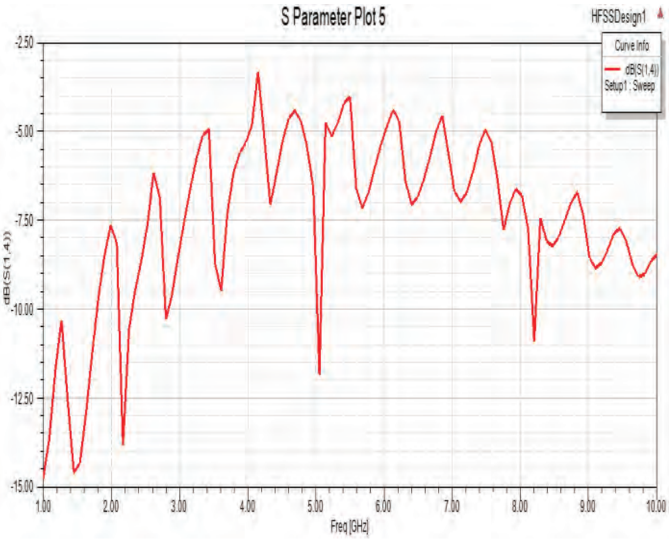

Figure 8. S-parameter plot for coupling loss between port 1 and port 4

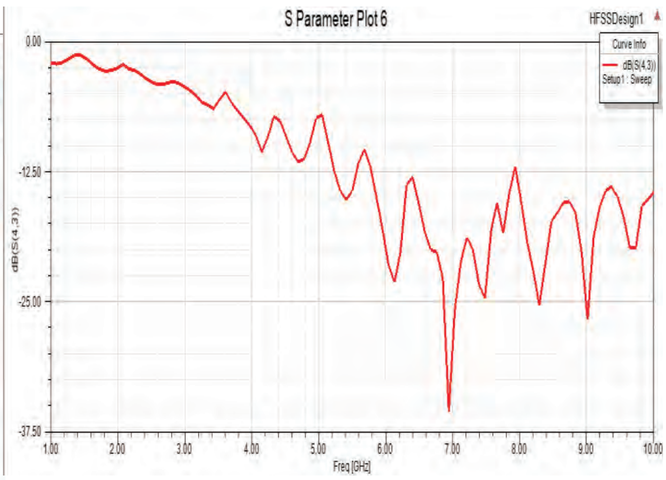

Figure 9. S-parameter plot for directivity between port 4 and port 3.

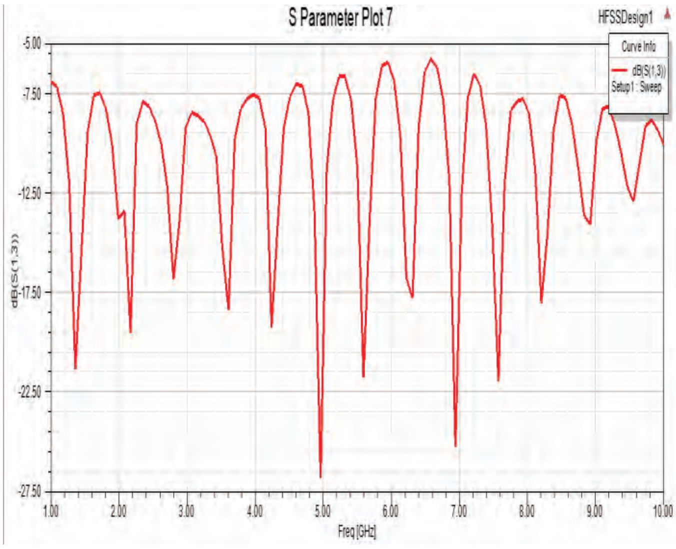

Figure 10. S-parameter plot for isolation loss between port 1 and port 3.

Once all the parameters are given to the model, then simulation starts with ANSYS software. While simulating the thickness of the material is 100mm, length is 128.8 mm and side width of 48.096 were considered. Figure 7 shows the coupling loss between 1 and 4 port, from the graph, it can be analyzed that as the frequency is increasing the coupling loss is reducing. Where as the directivity loss is also becoming low at 7GHz point. From these results, it can be made the statement that it is the best suitable method for improve directivity.

V. Conclusion and Future Scope

In this paper, it has been introduced a compensation method to improve directivity, i.e. multilayer configuration. This method is valid for tight and closed loop structures. The proposed method is designed using ANSYS software and experimental results showed that multilayer configuration is the best suitable method to improve directivity of directional coupler.

In this paper, this work is limited to dual layer configuration, in future this method may get extension to three layer and multi-layer configuration.

References

[1] K. Shibata, K. Hatori, Y. Tokumitsu and H. Komizo, "Microstrip Spiral Directional Coupler," in IEEE Transactions on Microwave Theory and Techniques, vol. 29, no. 7, pp. 680-689, Jul. 1981.

[2] F. C. de Ronde, "A New Class of Microstrip Directional Couplers," G-MTT 1970 International Microwave Symposium, Newport Beach, CA, USA, 1970, pp. 184-189.

[3] M. Dydyk, "Accurate design of microstrip directional couplers with capacitive compensation," IEEE International Digest on Microwave Symposium, Dallas, TX, 1990, pp. 581-584 vol.1.

[4] Jeong-Hoon Cho, Hee-Yong Hwang and Sang-Won Yun, "A design of wideband 3-dB coupler with N-section microstrip tandem structure," in IEEE Microwave and Wireless Components Letters, vol. 15, no. 2, pp. 113-115, Feb. 2005.

[5] Lung-Hwa Hsieh and Kai Chang, "Compact, low insertion-loss, sharp-rejection, and wide-band microstrip bandpass filters," in IEEE Transactions on Microwave Theory and Techniques, vol. 51, no. 4, pp. 1241-1246, April 2003.

[6] K. Sakakibara, Y. Suzuki, Y. Imade and N. Kikuma, "Rotman-lens-feeding double-layer low-profile multibeam millimeter-wave microstrip antenna using bow-tie waveguide microstrip connections," 2016 IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE), Langkawi, 2016, pp. 167-169.

[7] A. A. Deshmukh, A. Parvez, P. Verma, A. Desai, P. Kadam and K. P. Ray, "Space fed ring microstrip antenna array with stacked rectangular microstrip antenna feed," 2016 IEEE Annual India Conference (INDICON), Bangalore, 2016, pp. 1-5.

[8] F. Monà, E. S. Sakomura and D. C. Nascimento, "Microstrip-to-Probe Fed Microstrip Antenna Transition," 2018 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting, Boston, MA, 2018, pp. 1521-1522.M. Young, *The Techincal Writers Handbook.* Mill Valley, CA: University Science, 1989.

[9] M. M. Fahmi, J. A. Ruiz-Cruz, K. A. Zaki and A. J. Piloto, "Multilayer Multi-Section Broadband LTCC Stripline Directional Couplers," 2007 IEEE/MTT-S International Microwave Symposium, Honolulu, HI, 2007, pp. 173-176.

[10] P. Mondal and S. K. Parui, "Multi-mode resonator based asymmetric broadband 10dB directional coupler," 2018 3rd International Conference on Microwave and Photonics (ICMAP), Dhanbad, 2018, pp. 1-2.

[11] X. Xingyu and M. A. Abou-Khousa, "Miniaturized 3D directional coupler for compact monostatic microwave imaging systems," 2016 16th Mediterranean Microwave Symposium (MMS), Abu Dhabi, 2016, pp. 1-4.

[12] A. K. Tiwari, S. Awasthi and R. K. Singh, "A Leaky-Wave Antenna With Improved Directivity and Scanning Range," 2018 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), Gorakhpur, 2018, pp. 1-5.

[13] S. Jun-Yu et al., "High-directivity single- and dual-band directional couplers based on substrate integrated coaxial line technology," 2013 IEEE MTT-S International Microwave Symposium Digest (MTT), Seattle, WA, 2013, pp. 1-4.

[14] A. Giménez, J. Verdú and P. De Paco Sánchez, "General Synthesis Methodology for the Design of Acoustic Wave Ladder Filters and Duplexers," in IEEE Access, vol. 6, pp. 47969-47979, 2018, doi: 10.1109/ACCESS.2018.2865808.

[15] F. C. de Ronde, "A New Class of Microstrip Directional Couplers," G-MTT 1970 International Microwave Symposium, Newport Beach, CA, USA, 1970, pp. 184-189, doi: 10.1109/GMTT.1970.1122803.

[16] D. F. Monà, E. S. Sakomura and D. C. Nascimento, "Microstrip-to-Probe Fed Microstrip Antenna Transition," 2018 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting, Boston, MA, 2018, pp. 1521-1522, doi: 10.1109/APUSNCURSINRSM.2018.8609140.

[17] Z. Chen, X. Dai and G. Luo, "A new H-slot coupled microstrip filter-antenna for modern wireless communication systems," 2018 International Workshop on Antenna Technology (iWAT), Nanjing, 2018, pp. 1-3, doi: 10.1109/IWAT.2018.8379131.

[18] H. Li, L. Kang, F. Wei, Y. Cai and Y. Yin, "A Low-Profile Dual-Polarized Microstrip Antenna Array for Dual-Mode OAM Applications," in IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 3022-3025, 2017, doi: 10.1109/LAWP.2017.2758520.

[19] Aastha, A. Kaur, A. S. Dhillon and E. Sidhu, "Performance analysis of microstrip patch antenna employing Acrylic, Teflon and Polycarbonate as low dielectric constant substrate

E-ISSN 2581 - 7957
P-ISSN 2277 - 3916

DOI: 10.32377/cvrjst 1907

materials," 2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), Chennai, 2016, pp. 2090-2093.

[20] T. Seki, N. Honma, K. Nishikawa and K. Tsunekawa, "Millimeter-wave high-efficiency multilayer parasitic microstrip antenna array on teflon substrate," in IEEE Transactions on Microwave Theory and Techniques, vol. 53, no. 6, pp. 2101-2106, June 2005.

A. R. Alavizadeh, A. Zargari and W. R. Grise, "The application of ANSYS software in analyzing and predicting thermal behavior," Proceedings: Electrical Insulation Conference and Electrical Manufacturing and Coil Winding Conference (Cat. No.99CH37035), Cincinnati, OH, USA, 1999, pp. 583-588, doi: 10.1109/EEIC.1999.826274.