Design of Unequally Excited Two Elements Antenna Array using Gysel Power Divider

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***Abstract*— In this paper, a Gysel Power Divider has been designed at 1.5 GHz operating frequency. Two rectangular microstrip patch antennas, operating at the same frequency, has been designed and fed to the power divider to form an antenna array. The proposed array offers significant gain, improved reflection co efficient and lower side lobe level compare to that of the conventional antenna array. The relative position of the two output ports have been varied to excite unequal power distribution of the radiating elements to achieve optimum results.**

***Keywords*— Gysel power divider; Antenna array; Gain; Side lobe level**

I. Introduction

In microwave communication, two types of power dividers are generally used: Wilkinson Power Divider (WPD) and Gysel power divider (GPD). Unlike WPD, GPD offers unequal power division ratio and good thermal performance, and thus can be used in beam forming networks. GPD has high isolation and offer good impedance matching at ports. A two port GPD with uniform impedance transmission for random power division ratio has been designed by Lin et al. [1]. Yadav et al. have presented 5 port unbalanced to balanced GPD for arbitrary power distribution [2]. In article [3], Kai Xu Wang et al. proposed GPD and presented its filtering response using coupling structure. A structural analysis of 3 port GPD has been presented in [4] and the results are compared with that of WPD. In article [5-6], GPD has been designed for dual band application. Wang et al. [7] proposed a GPD structure using one resister. A triple band GPD has been designed by Mohsen Hayati et al. in [8].

In this work, a 1:4 GPD is designed to form an array of two rectangular microstrip patch Antennas (RMPA) at 1.5 GHz. We varied the output port distances of the GPD to get optimized results which offers good reflection coefficient, gain and lower the side lobe level compared to that of the conventional array. The proposed array can be used for L Band applications such as Satellite navigation, Digital Audio Broadcasting, Telecommunication and mobile services.

II. Gysel Power Divider

The structure of the proposed Gysel power divider with random power division ratio has been shown in Fig.1. It comprises of two transmission lines ϕ_1 and ϕ_2 , line impedance Z and characteristic impedance Z_0. All the input power is applied at port 1 which is further divided in 1:K ratio between port 2 and 3 where $K^2=P_2/P_3$ and can be calculated from the port voltages as given in Eq. (1) [1]

$$\frac{P_2}{P_3} = \frac{|V_2|^2 / Z_0}{|V_3|^2 / Z_0} \qquad (1)$$

By, simplifying Eq. (1), we get,

$$V_2 = K \times V_3 \qquad (2)$$

By applying ABCD parameter matrix in both upper and lower transmission lines of Fig.1, the results we get, [9]-[12]

$$V_1 = \cos\phi_1 \times V_2 + jZ\sin\phi_1 \times \left(I_2 - \frac{j\cot\phi_2 \times V_2}{Z} \right) \qquad (3)$$

$$V_1 = \cos\phi_1 \times V_3 + jZ\sin\phi_2 \times \left(I_3 - \frac{j\cot\phi_2 \times V_3}{Z} \right) \qquad (4)$$

where, $I_2=V_2/Z_0$, $I_3=V_3/Z_0$

Combining (3) and (4),

$$\frac{P_2}{P_3} = K^2 = \frac{\sin^2\phi_2}{\sin^2\phi_1} \qquad (5)$$

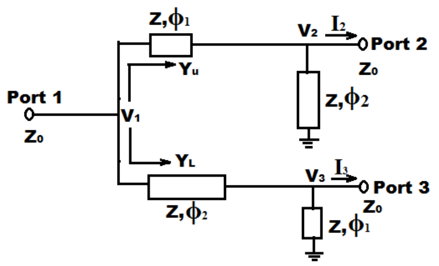


Fig.1 Circuit Analysis of proposed GPD

III. Proposed Structure and Simulated Results

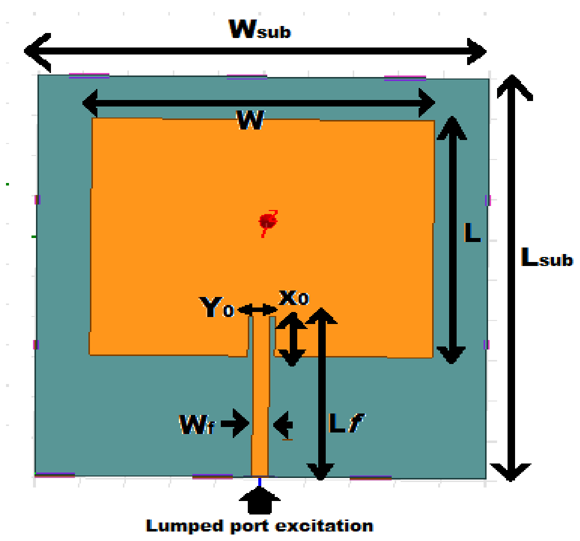


Fig.2 Rectangular Microstrip Patch Antenna

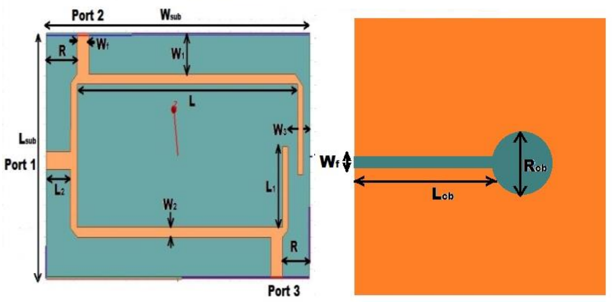
In this paper, one rectangular Microstrip patch antenna (RMPA), a Gysel Power Divider (GPD) and a 1×2 antenna array has been designed at 1.5 GHz resonating frequency. The dielectric substrate has been chosen as Rogers RO 3003 (ε_r =3) with substrate height 1.52 mm.

The top view of single RMPA has shown in Fig.2 and table I represents the dimensions of the proposed structure.

TABLE I. DIMENSION PARAMETERS AND THEIR VALUES OF RMPA

Parameter Name	Parameter Value (mm)	Parameter Name	Parameter Value (mm)	Parameter Name	Parameter Value (mm)
Wsub	50	L	27.69	X_0	12.85
Lsub	49.72	W_f	1.8	Y_0	9.35
W	34.54	L_f	20		

The geometry of proposed GPD has been presented in Fig.3 Table II shows the corresponding dimensions of the GPD parameters. A circle and strip line have been cut at the ground of the structure to achieve high isolation between output ports.



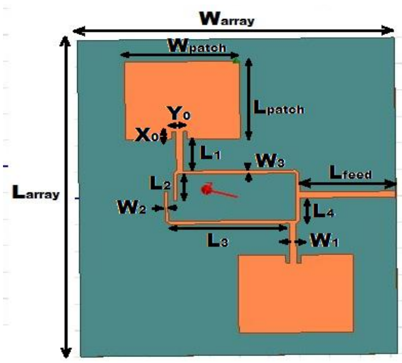
(a) (b)

Fig.3 Gysel Power Divider (a) Top (b) Bottom

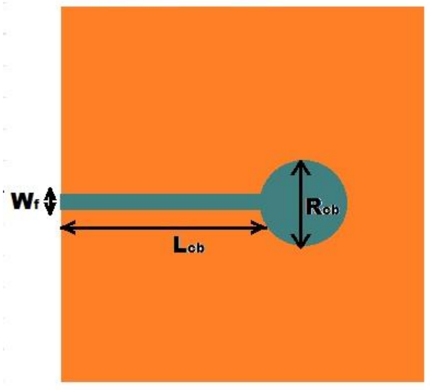
TABLE II. DIMENSION OF PROPOSED GPD

Parameter Name	Parameter Value (mm)	Parameter Name	Parameter Value (mm)
Wsub	50.58	L	42.36
Lsub	30.32	L_{cut}, W_{cut}	32.5,0.3
W_1	5	L_1	11.25
W_f	2.2	L_2	4.7
W_2	1.26	R	6.625
W_3	1	R_{cut}	10

Fig. 4. represents antenna array structure where the dimensions of the circle and strip line at the ground are further modified to accommodate the two radiating elements.



(a)



(b)

Fig.4. Antenna Array (a) Top (b) Bottom

Table III represents the dimensions of antenna array.

TABLE III. DIMENSION OF ANTENNA ARRAY

Parameter Name	Parameter Value (mm)	Parameter Name	Parameter Value (mm)	Parameter Name	Parameter Value (mm)
W_{array}	105	L_{feed}	43.36	R_{cb}	15
L_{array}	120	W_f,W_1	2.2,1.8	L_{cb}	54.5
W_{patch}	34.54	X_0	12.85	L_3	42.36
L_{patch}	27.69	Y_0	9.35	W_2	1
L_1	20	L_2	11.25	W_3	1.26

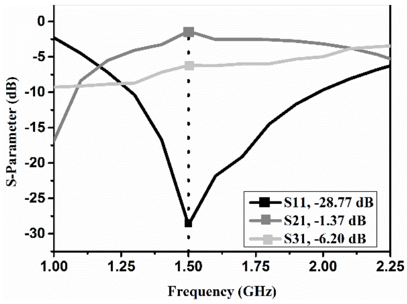


Fig. 5. S-parameter

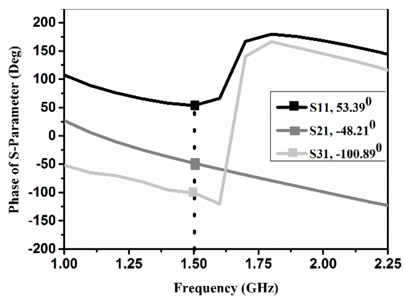


Fig. 6. Phase of S-parameter

As we have applied the input power at port 1, the power is divided between port 2 and port 3 in 1:3 ratio as K is chosen as 3 for the proposed structure. The Reflection co-efficient S11 and Transmission Co-efficient S21 and S31 are obtained at different ports are shown in Fig.5. At 1.5 GHz, the values for S11, S21 and S31 are -28.77 dB, -1.37 dB and -6.20 dB respectively. Fig.6 represents phase of S-parameters of GPD at 1.5 GHz where the values of phases are 53.390, -48.210, -

100.890 for S11, S21 and S31 respectively. Fig.5 and Fig.6 ensure that there is unequal power distribution from port 1 to port 2 and port 3 due to different transmission co efficient magnitude and phase.

Fig.7 and Fig.8 presents reflection co efficient and gain of the proposed array respectively. At 1.5 GHz, S11 for array has been found as -18.67 dB. It has been found that due to power leakage from the radiating edges of both of the patches in array, S11 reduces. The gain of the proposed array is 12.5 dB at 1.5 GHz which is significantly higher than the conventional array as shown in Fig.8.

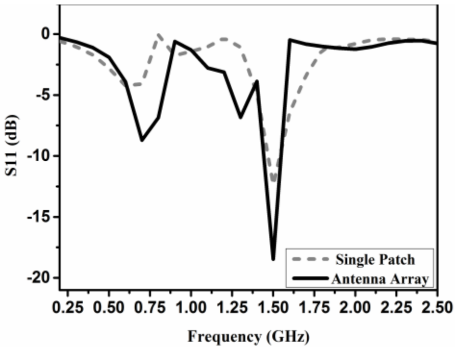


Fig. 7. S11 for Single RMPA and Antenna Array

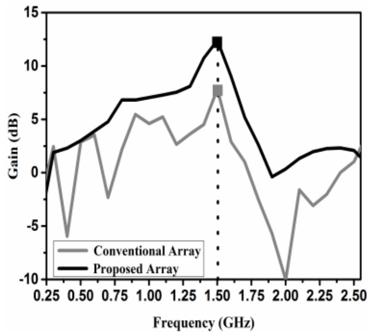


Fig. 8. Gain of Single RMPA and Antenna Array

The distance R between port 2 and port 3 as shown in Fig. 5 has been varied and the corresponding parametric study of S11 has been reported. Fig. 9 represents the parametric analysis of port distance R for different s11. Side lobe level difference has been shown in Fig.10. For conventional array, the minimum SLL has been found as -12.05 dB whereas for proposed array using GPD, minimum SLL is -22.024 dB.

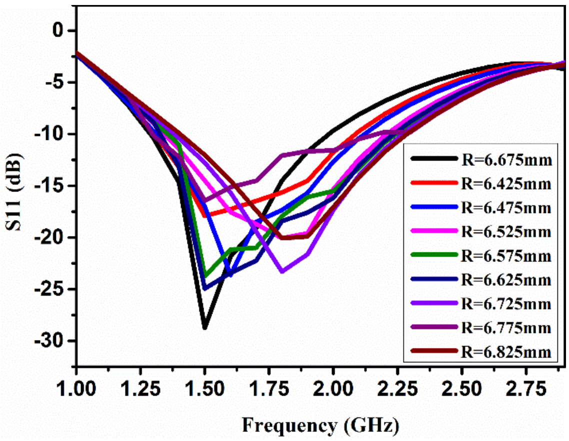


Fig.9 Parametric study of S11 for varying R

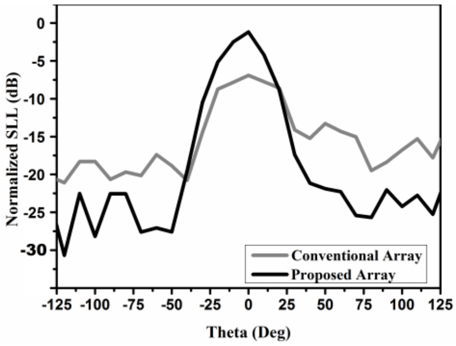


Fig. 10. Side Lobe Level (SLL) comparison of conventional array and proposed antenna array

CONCLUSION

In this paper, a 3 port GPD has been designed at 1.5 GHz frequency which is capable of providing arbitrary power distribution at output ports. A single patch RMPA has been proposed at 1.5 GHz which has fitted at 2 output ports of the GPD and a 2 element antenna array has been achieved. The array has offered excellent impedance matching and 12.5 dB gain. The distance between two output ports from the arm of the corner of the two arms of GPD has varied and a parametric analysis of S11 for different port distances also has been shown here. The design has also reduced the SLL value by an amount 5dB compared to that of the conventional array of two elements.

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