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Design and Development of Square Patch Antenna with 90° Hybrid Feed for Communication Applications

V. Saidulu[1]
[1]Department of ECE, Mahatma Gandhi Institute of Technology, Hyderabad, India.
Email: saiduluvadtya@gmail.com

Abstract: Microstrip antennas find wide application in high-speed vehicles, and missiles, tanks, satellite communications etc. The main advantage of these antennas over conventional microwave antenna is lightweight, low volume, low cost, planar structure and compatibility with integrated circuits. The present paper deals with the design and development of 90° hybrid feed square patch stacked antenna for communication applications. The design of square patch and 90° hybrid feed has been carried out at frequency of 3 GHz on epoxy glass substrate, the radiation pattern of the square patch has been experimentally studied. The effect of stacked patches placed above the square patch has been studied experimentally for different cases like 1,2,3 and 4 stacked patches placed one above other above the driven square patch. From the experimental result it has been found that performance of the case of 1 + 2 (one driven element and two parasitic element) is optimum with bandwidth of 16 % and VSWR 1.42 the performance degrades the no of practical elements is increased that is for case 1 + 3 and 1 + 4 etc., The performance of 1 + 2 case of also found to be superior to the performance 1+ 0 and 1+1 cases experimentally studied, also been carried out for cross Polarization and co - polarization.

Keywords: Hybrid feed, Polarization, Square patch antenna, etc.

I. Introduction

The microstrips find potential application in various diversified fields especially in high speed space vehicles, missiles, tanks and other strategic defense equipment's. Since the inception, microstrip antenna attracted attention of large number of researches world over which has given stimulus to the research and development resulting into many diverse applications such as aircrafts missiles, space vehicles, satellite communications, telemetry, radars and other defense equipments [1-6]. The microstrip structures radiating circularly polarized waves play an important role in communication because in such cases problem of alignment is completely removed. Variety of microstrip antenna is one of those, which can provide circular polarization with hybrid feed. In the present endeavor, therefore an attempt has been made to design and develop a square microstrip patch for circular polarization. Cavity model in one of the most widely used methods in analyzing the performance of microstrip antennas. In this model the region between the conducting patch and the ground plane is assumed to be a resonant cavity the main drawback in the cavity theory, i.e, perfect magnetic wall boundary condition, has been overcome in the fringing capacitance mode. In the fringing capacitance mode, the square patch backed by ground plane with a dielectric substrate in between is assumed to be approximating a capacitor. Whenever, the patch is excited the side of the patch is extended due to fringing field. The patch is considered as a capacitor which have to different values of capacitance for excited and unexcited conditions. Whenever the patch is excited the effect of fringing field increases the effective resonator area hence, the increases capacitance. The difference of the patch capacitance under excited and unexcited conditions provides the fringing field capacitance which forms the basis for the source responsible for the entire radiation [5-9]. The design square patch and 90° hybrid feed has been carried out at frequency of 3.0 GHz, an epoxy glass substrate, the radiation pattern of the square patch has been experimentally studied. The effect of stacked patches placed the above the square patch has been studied experimentally for different cases. The structure of 90^{o} hybrid feed is shown in Fig. 1.

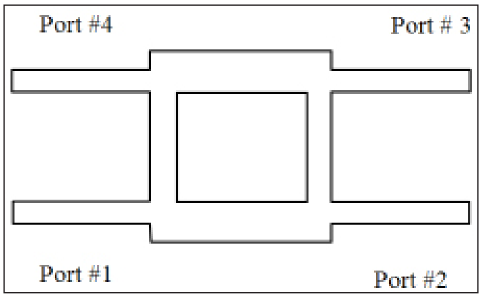

Fig. 1: 90° Hybrid

A. Specifications

The specification of epoxy glass substrate:

Dielectric constant (ϵ_r) = 4.5

Height of the substrate (h) = 0.16 cm

Thickness of the strip (t) = 0.001 cm

Operating frequency (f) = 3.0 GHz

Free space velocity (C) = $3x10^{10}$ cm/sec

Table I: The Width of the Patch as Shown in Table Given Below

Strip impedance (Ω)	Effective dielectric constant (ε_e)	Widths (cm)
50	3.425	0.216
35.35	3.460	0.386

B. Lengths of λ/4 Sections

As the width is different for different impedance arms, so are their dielectric constants, hence the respective wavelengths are also different. The width of the patch and impedance of quarter wavelength which is shown in Table I and II.

Table II: The Impedance of the Quarter Wavelength

Impedance of the section *(Ω)*	Quarter wavelengths *(cms)*
50	1.3508
35.35	1.3438

The completes the design of the microstrip patch antenna with a branch line 90^0 hybrid as shown in Fig. 2.

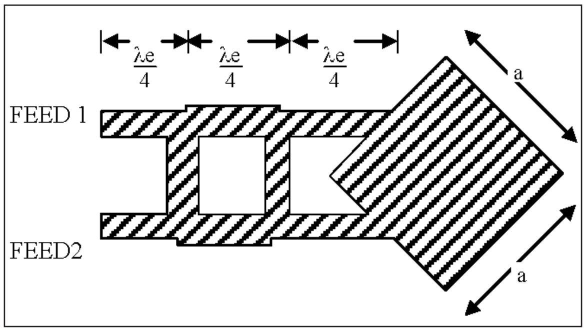

Fig. 2: Square Microstrip Patch with 90° Branch Line Hybrid for CP Operation

C. Design of the Patch

The patch size has been calculated by using iteration method. The approximate patch dimension is determined as

$$a^1 = C/2f_0 \sqrt{\varepsilon_e} = 2.486$$

To account for the fringing field, the change effective dimension is given be 2Δ, where

$$a^1 = 0.00346$$

Thus $a = a^1 - 2\Delta = 2.5$ cm

Hence the patch size is a x a = 2.5 x 2.5 cm^2

II. Development of Antenna

The first step is the tracing of the antenna shape on tracing paper, enlarged artwork is photo reduced using a high precession camera to produce a high resolution negative which later used for exposing the photo resist. The laminate is cleaned to ensure proper adhesion of the photo development process. The photo resist is now applied to both sides of laminate using laminator. After words, the laminate allowed to stand to normalize to soon prior to exposure and development.

The photographic negative is now held in very close contact using corner sheet of the applied photo resist to ensure the fine line resolution required with exposure to proper wavelength light. Polymerization of the exposed photo resist occurred, making it insoluble in the developer solution. The backside of antenna is completely exposed without mask since copper foil is returned to act as a ground plane, the protective corner sheet of the photo resist is removed and antenna is now developed in a developer which removes the soluble photo resist material. Then the antenna is etched visual inspection is used to assure proper etching [10-14].

III. Experimental Investigations

A. Experimental Measurements

The set – up was used for measuring the co-polar and cross-polar pattern of the antenna [2]. During the experiment, the output of the source was fairly constant. The source of the microwave power was quite stable and the frequency variations were negligible small. Isolator was used to avoid the reflection from the antenna. The receiver system was kept in the far zone ($2d^2 / \lambda$). Using the set up the radiation patterns of the antenna was measured. The data of measured radiation pattern using different number of parasitic elements are shown in Tables III and IV. Beam-width (degree) axial ratio and gain was shown in Table VIII and XI. The data VSWR was shown in Table VI. Using the VSWR data, return-loss were we calculated. The data of return loss was shown in Tables V and XII. Calculated the bandwidth from the plot of VSWR, the data of band width was shown in Table XII. The data of axial ratio, maximum radiation is shown in Tables VII, IX, X.

Table III: Data of Co-Polar Radiation Pattern for 90° Hybrid – Feed Square Patch Stacked Antenna

Angle (Degree)	Relative Power (dB)				
	Driven element	Driven element +1 parasitic	Driven element +2 parasitic	Driven element +3 parasitic	Driven element +4 parasitic
-90	-14.49	-12.78	-12.78	-13.7	-15.02
-80	-14.4	-10.36	-9.77	-11.28	-13.7
-70	-13.31	-10.56	-7.14	-12	-13.84
-60	-12	-8	-5.6	-9.38	-13.2
-50	-10.95	-6.1	-3.8	-8.33	-12.13
-40	-10.3	-4.92	-2.75	-6.95	-11.67
-30	-8.98	-3.93	-1.7	-6.03	-10.75
-20	-7.34	-3.28	-1.25	-5.25	-9.2
-10	-6.3	-2.49	-0.48	-4.46	-8.01
0	-5.6	-2	0	-4.07	-6.56
10	-6.49	-2.95	-0.483	-4.52	-7.15
20	-7.48	-3.75	-1.02	-5.64	-8.46
30	-9.31	-4.66	-1.9	-7.28	-10.23
40	-10.8	-6.03	-2.89	-8.4	-11.64
50	-12	-7.34	-4.46	-10.3	-12.66
60	-13.51	-9.25	-5.77	-11.2	-13.7
70	-14.03	-11.87	-8.98	-13.05	-13.7
80	-14.69	-11.93	-10.95	-12.46	-13.75
90	-14.62	-12.78	-12.13	-14.75	14.33

Table IV: Data for Cross - Polar Radiation Pattern 90° Hybrid - Feed Square Patch Stacked Antenna

Angle (Degree)	Relative Power (dB)				
	Driven element	Driven element +1 parasitic	Driven element +2 parasitic	Driven element +3 parasitic	Driven element +4 parasitic
-90	-17.4	-16.53	-16.45	-15.73	-17.69
-80	-16.36	-12.17	-11.26	-15.03	-17.76
-70	-16.71	-11.62	-11.05	-12.8	-16.15
-60	-14.06	-9.37	-7.69	-11.47	-15.1
-50	-12.37	-7.21	-5.45	-10.56	13 85
-40	-11.06	-6.05	-4.06	-8.88	-12.59
-30	-10.07	-5.2	-2.66	-8.04	-11.33
-20	-9.3	-4	-1.89	-6.85	-10.14
-10	-8.11	-3.13	-0.98	-5.52	-9.52

Angle (Degree)	Relative Power (dB)				
	Driven element	Driven element +1 parasitic	Driven element +2 parasitic	Driven element +3 parasitic	Driven element +4 parasitic
0	-7.06	-2.62	-0.45	-4.69	-7.9
10	-8.32	-3.36	-1.1	-5.73	-9.43
20	-9.86	-4.6	-2.13	-7.51	-10.84
30	-10.8	-6.36	-3.36	-9.23	-12.1
40	-13.08	-8.18	-4.8	-10.9	-14.2
50	-14.64	-11.38	-6.71	-13.32	-15.15
60	-15.58	-12.87	-10.4	-14.71	-16.02
70	-16.85	-11.96	-9.93	-15.38	-16.76
80	-16.64	-13.94	-12.87	-16.63	-17.48
90	-18.57	-16.38	-16.7	-17.22	-17.55

Table V: Data of Return – Loss for 90° Hybrid - Feed Square Patch Stacked Antenna

Frequency (GHz)	Driven element	Driven element +1 parasitic	Driven element +2 parasitic	Driven element +3 parasitic	Driven element +4 parasitic
2	-1.434	-1.51	-1.52	-1.38	-1.28
2.1	-1.7	-1.76	-1.86	-1.62	-1.55
2.2	-1.99	-2.12	-2.29	-1.85	-1.79
2.3	-2.49	-2.65	-2.87	-2.21	-2.12
2.4	-3.18	-3.49	-3.74	-2.92	-2.65
2.5	-3.76	-4.12	-4.37	-3.78	-3.38
2.6	-4.37	-5	-5.07	-4.59	-4.18
2.7	-5.33	-6.46	-7.35	-5.61	-5.04
2.8	-6.72	-8.84	-10.35	-7.85	-6.36
2.9	-8.8	-11.28	-12.73	-10.16	-7.7
3	-11.5	-13.84	-15.2	-12.62	-10.58
3.1	-8.8	-10.88	-12.51	-9.84	-7.63
3.2	-6.15	-8	-9.31	-7	-5.26
3.3	-4.87	-5.95	-6.81	-5.43	-4.21
3.4	-3.67	-4.43	-5	-4.1	-3.25
3.5	-2.92	-3.39	-3.67	-3.13	-2.68
3.6	-2.49	-2.78	-2.92	-2.65	-2.29
3.7	-2.11	-2.43	-2.53	-2.27	-1.93
3.8	-1.82	-1.99	-2.12	-1.89	-1.72
3.9	-1.66	-1.76	-1.82	-1.7	-1.62
4.0	-1.41	-1.53	-1.59	-1.5	-1.34

TABLE VI: DATA OF VSWR FOR 90° HYBRID - FEED SQUARE PATCH STACKED ANTENNA

Frequency (GHz)	Driven element	Driven element +1 parasitic	Driven element +2 parasitic	Driven element +3 parasitic	Driven element +4 parasitic
2	12.14	11.48	11.4	12.6	13.5
2.1	10.2	9.88	9.35	10.7	11.2
2.2	8.76	8.2	7.6	9.4	9.69
2.3	7	6.6	6.1	7.9	8.2
2.4	5.51	5.04	4.71	6	6.6
2.5	4.69	4.29	4.05	4.66	5.2
2.6	4.05	3.52	3.23	3.87	4.23
2.7	3.36	2.81	2.5	3.2	3.54
2.8	2.71	2.13	1.91	2.36	2.85
2.9	2.12	1.75	1.6	1.9	2.4
3	1.72	1.51	1.42	1.61	1.84
3.1	2.12	1.8	1.62	1.95	2.42
3.2	2.94	2.3	2.04	2.6	3.4
3.3	3.66	3.03	2.68	3.3	4.2
3.4	4.8	4	3.54	4.3	5.4
3.5	6	5.18	4.8	5.6	6.53
3.6	7	6.3	6	6.6	7.6
3.7	8.25	7.17	6.9	7.68	9
3.8	9.55	8.76	8.2	9.2	10.12
3.9	10.48	9.88	9.55	10.2	10.7
4.0	12.28	11.34	10.94	11.6	12.92

TABLE VII: DATA OF AXIAL RATIO FOR 90° HYBRID - FEED SQUARE PATCH STACKED ANTENNA

Angle (Degree)	Driven element	Driven element +1 parasitic	Driven element +2 parasitic	Driven element +3 parasitic	Driven element +4 parasitic
-90	-2.91	-3.75	-3.67	-2.03	-2.67
-80	-1.96	-1.81	-1.49	-3.75	-4.06
-70	-3.4	-1.06	-3.9	-0.8	-2.31
-60	-2.06	-1.37	-2.09	-2.09	-1.9
-50	-1.42	-1.11	-1.65	-2.23	-1.72
-40	-0.76	-1.13	-1.31	-1.93	-0.92
-60	-1.09	-1.27	-0.96	-2.01	-0.58
-20	-1.96	-0.72	-0.64	-1.6	-0.94
-10	-1.81	-0.64	-0.5	-1.06	-1.51
0	-1.46	-0.62	-0.45	-0.62	-1.34
10	-1.83	-0.41	-0.617	-1.21	-2.28
20	-2.38	-0.85	-1.11	-1.87	-2.38
30	-1.49	-1.7	-1.46	-1.95	-1.87
40	-2.28	-2.15	-1.91	-2.5	-2.56
50	-2.64	-4.06	-2.25	-3.02	-2.49
60	-2.07	-3.62	-4.63	-3.51	-2.32
70	-2.82	-0.09	-0.95	-2.33	-3.06
80	-1.95	-2.01	-1.92	-4.17	-3.73
90	-3.95	-3.6	-3.93	-2.47	-3.22

TABLE VIII: DATA FOR BEAM-WIDTH (DEGREE)

No. of Elements in 90^0 Hybrid - Feed Square Patch Stacked Antenna	Beam-width (Degree)	
	Co-Polar Plane	Cross-Polar Plane
1+0	59	56
1+1	79	64
1+2	98	65
1+3	69	60
1+4	50	53

TABLE IX: DATA FOR MAX. RADIATED POWER (dB)

No. of Elements in 90° Hybrid - Feed Square Patch Stacked Antenna	Maximum radiated power (dB)	
	Co-Polar Plane	Cross-Polar Plane
1+0	-5.6	-7.06
1+1	-2	-2.62
1+2	0	-0.45
1+3	-4.07	-4.69
1+4	-6.56	-7.9

TABLE X: DATA FOR AXIAL RATIO (dB)

No. of Elements in 90° Hybrid - Feed Square Patch Stacked Antenna	Axial ratio (dB)
1+0	-1.46
1+1	-0.62
1+2	-0.45
1+3	-0.62
1+4	-1.34

TABLE XI: DATA FOR GAIN (dB)

No. of Elements in 90° Hybrid - Feed Square Patch Stacked Antenna	Gain (dB)
1+0	8.95
1+1	7.11
1+2	6.10
1+3	7.97
1+4	9.91

TABLE XII: DATA FOR RETURN – LOSS (dB)

No. of Elements in 90° Hybrid - Feed Square Patch Stacked Antenna	Return-loss (dB)
1+0	-11.5
1+1	-13.84
1+2	-15.2
1+3	-12.62
1+4	-10.58

TABLE XIII: DATA FOR VSWR

No. of Elements in 90° Hybrid - Feed Square Patch Stacked Antenna	VSWR
1+0	1.72
1+1	1.51
1+2	1.42
1+3	1.61
1+4	1.84

TABLE XIV: DATA FOR BAND – WIDTH

No. of Elements in 90° Hybrid - Feed Square Patch Stacked Antenna	Band – Width (%)
1+0	5.33
1+1	10.66
1+2	16
1+3	8
1+4	2.66

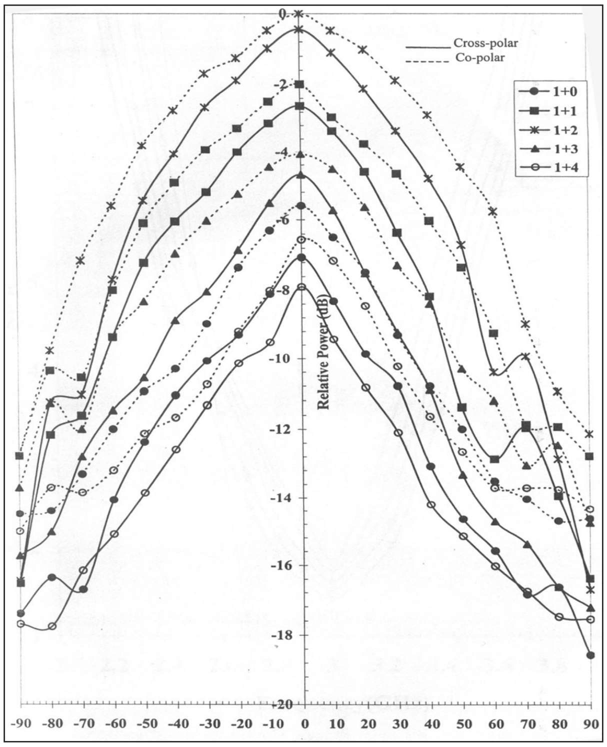

Fig. 4: Radiation Pattern of 90° Hybrid-Feed Square Patch Stacked Antenna for Co-Polar and Cross-Polar Plane

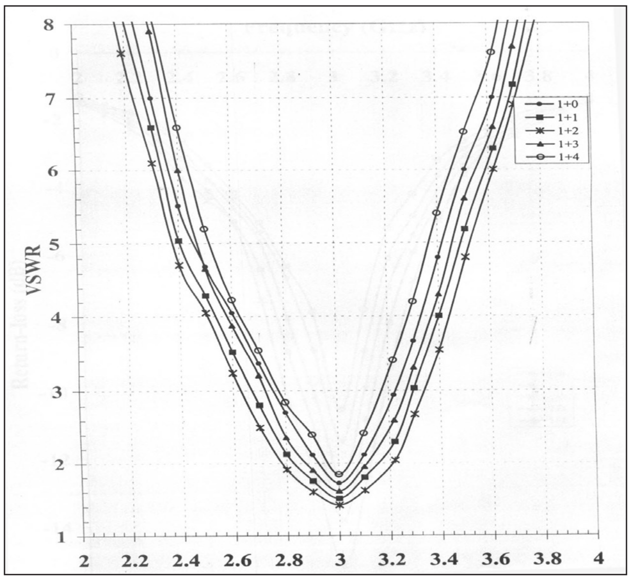

Fig. 5: Variation of VSWR with Frequency for 90° Hybrid-Feed Square Patch Stacked Antenna

IV. RESULTS AND DISCUSSION

Measurements were made for various parameters such as co - polar and cross - polar radiation pattern, VSWR, Return-loss and Max. Radiated power and Axial-ratio which is shown in Tables from III to XIV. It is found that the Radiated power is maximum for the antenna with 2 parasitic elements. Initially the radiated power increase with parasitic elements and becomes maximum for 2 parasitic elements and decreases if number of parasitic element is increased. This is also observed from the VSWR data and return loss. VSWR is obtained at 3 GHz for the cases of optimum 2 parasitic element and return loss of found to be less than -15 dB. The variation of the Radiated power for co-polar and cross - polar cases is shown in Fig. 4 and VSWR is shown in Fig. 5. It is observed that radiation increases with parasitic element and becomes maximum for 2 parasitic elements loaded patch. The radiated power decreases with increasing value of parasitic elements. The Axial ratio is found to be maximum for 3 parasitic elements antenna and value falls with increasing and decreasing no. of parasitic elements. However the axial ratio with the limits and radiation remains in circular - polarization.

V. Conclusion

A 90^0 hybrid - feed square patch stacked antenna has been designed on epoxy glass substrate. The patches are square patch, for feeding, a suitable point on patch is marked where input impedance is 50 ohm. The antenna is developed by using photolithographic process.

From the experimental results it has been found that the performance of the square patch stacked with 2 parasitic elements is found to be optimum.

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