Performance Comparison of Compact Parasitically Coupled with Direct Coupled MSAA

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ABSTRACT

This paper presents an alternate methodology for coupling the signal to microstrip patch antenna array. In this project we proposed parasitically coupling the alternative for direct coupling approach. In case of direct coupling methodology; a four element microstrip antenna is directly fed through a collective feed network using T-junctions and quarter wave transformers while in the proposed parasitically coupled feeding the signal applied to array by gap coupling. Our alternate method simplifies the feeding network and hence compactness is achieved.

The proposed system also includes examining the radiation characteristics of the both coupling techniques. The 2x2 parasitically coupled feed MSAA hardware is fabricated on Arlon Diclad880 substrate. The antenna is designed for center frequency of 5.2 GHz.

The fabricated antenna is tested using Vector Network Analyzer. The return loss (S11) of fabricated parasitically coupled feed MSAA at 5.2 GHz is -14.81 dB which is much better as compared to direct coupled feed microstrip antenna array. The bandwidth of our fabricated antenna is 300MHz. Simulated gain of proposed parasitically coupled fed is 11.84 dB. The parasitically coupled feed MSAA has slightly improved bandwidth and gain.

Keywords: *Parasitic Coupling, Microstrip Antenna, Substrate, Direct Coupling, Microstrip Antenna Array (MSAA).*

I. INTRODUCTION

The growing demand for higher data rate wireless communication systems motivates the usage of microwave wave frequency bands. In contrast to classical radio-link systems for commercial or military use, these new types of systems are dedicated for consumer electronics applications and therefore need to meet tight requirements like small size, light-weight, and low production costs. Moreover, there are also tough constraint challenges for the antenna design, such as high gain and wide bandwidth, while maintaining small size. A microstrip patch antenna would be one solution to meet the requirements mentioned above. Microstrip antenna hardware is fabricated on printed circuit board by etching process [1]. The PCB must be of two sided and generally copper clad. The patch is located on one side of PCB & other side will be work as ground plane. The shape of our designed antenna is rectangular. A single patch standard microstrip antenna has the drawback of small gain and hence whenever there is requirement of more gain the microstrip antenna array is used [2]-[3]. The literature [6] presented the 3x3 parasitically coupled microstrip antenna array in which they attained maximum gain 14.8 dBi. To excite an array with a dominant broadside pattern, feed networks must be used to distribute the power from the transmitter to the antenna elements. Signal can be fed to Microstrip patch antenna by two ways one is contact type and other one is non-contact type. In contact type approach, the RF signal is fed directly to the patch using microstrip feed line. In the non-contact type method, the power is transferred to radiating patch through gap coupling [13]. The most common feeding techniques are coaxial or microstrip feed. The function of feed line is to direct the signal from source to the region under the patch. In the literature [4], [5] parasitic coupled feed antenna array with multi-layer structures is implemented but this approach increases design & fabrication complexity. Furthermore, in multilayer structure the air gap between the layers may affect performance. Some other approach is to use T-junctions and quarter-wave transformers, [7]–[8], [14] but this increases complexity of traditional feeds, especially when the number of elements and the physical width of the microstrip line are large. Hence, these approaches also increase fabrication cost. Recently new configuration of microstrip patch reactively controlled ESPAR with controlled mutual coupling is presented [9]. The bandwidth of Microstrip antenna may be increased by different techniques such as use of a thick substrate, cutting slots or notches like U slot patch antenna and introducing the parasitic elements [12] , [15]. To get the large bandwidth the parasitic coupled antenna are having more potential than that of conventional microstrip antenna is discussed in literature [11]. Our system proposes the use of an alternative method of feeding i.e. parasitically coupled feed for arrays with keeping a single-layer structure. This will reduce the size of microstrip antenna and reduces design complexity and makes a compact antenna also improves the bandwidth.

II. SYSTEM DEVELOPMENT

Design Equations:

Step 1: Determination of the Width (W) which is given by,

$$W = \frac{C}{2Fr}\sqrt{\frac{2}{(\epsilon_r+1)}} \text{ ----------------------------- (1)}$$

Step 2: Calculation of effective dielectric constant, ε_{reff}, which is given by,

$$\epsilon_{reff} = \left(\frac{\epsilon_r+1}{2}\right) + \left(\frac{\epsilon_r-1}{2}\right)\left(1+12\,\frac{h}{W}\right)^{-\frac{1}{2}} \text{---- (2)}$$

Step 3: Calculation of the length extension ΔL, which is given by,

$$\Delta L = 0.412\,h\,\frac{(\epsilon_{reff}+0.3)\,(\frac{W}{h}+0.264)}{(\epsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \text{ ------- (3)}$$

Step 4: Now to calculate the length of patch equation is given by,

$$L = L_{eff} - 2\Delta L \text{ ----------------------------- (4)}$$

Where the effective length of the patch Leff,

$$L_{eff} = \frac{C}{2F_r\sqrt{\epsilon_{reff}}} \text{ ------------------------------- (5)}$$

Step 5: Compute Ground Dimensions,

$$W_g = 6h + W \text{ ----------------------------------- (6)}$$

$$L_g = 6h + L \text{ -------------------------------------- (7)}$$

Where h is given by;

$$h = \frac{0.0606\,\lambda}{\sqrt{\epsilon_r}} \text{ -------------------------------------- (8)}$$

Step 6: Compute feed length (fl):

$$fl = \frac{\lambda g}{4} \text{ --- (9)}$$

Compute guide wavelength λg:

$$\lambda g = \left(\frac{\lambda}{\epsilon_{reff}}\right) \text{----------------------------------- (10)}$$

By using above equations we can calculate the required dimensions of proposed antenna for following specifications; Resonant Frequency (Fr) =5.2 GHz, Substrate = Diclad 880, Dielectric constant =2.2, Height of substrate 1.57 mm. DiClad 880 laminate is made from fiberglass/PTFE composite material it has same specifications as that of Rogers 5880 laminate [10].

The Antennas in [2] are need to be optimized and here in our paper we are optimized the design to improve the gain.

The dimensions of the antenna, as indicated in Table 1 and Table 2 are optimized to operate between 5 GHz to 5.5 GHz.

Table 1: Design specifications for 2x2 direct coupled feed MSAA

Sr.No.	Parameter	Value
1	Substrate Width	120 mm
2	Substrate Length	120 mm
3	Substrate Height	1.57 mm
4	Patch Width	29.02 mm
5	Patch Length	17.60 mm
6	Feed line Width (wf)	3.0 mm
7	Feed line Length (lf)	30 mm
8	l1	12.39 mm
9	l2	17.06 mm
10	l3	6.47 mm
11	l4	9.84 mm
12	l5	20.86 mm
13	l6	10 mm
14	w1	5.1 mm
15	w2	4.21 mm

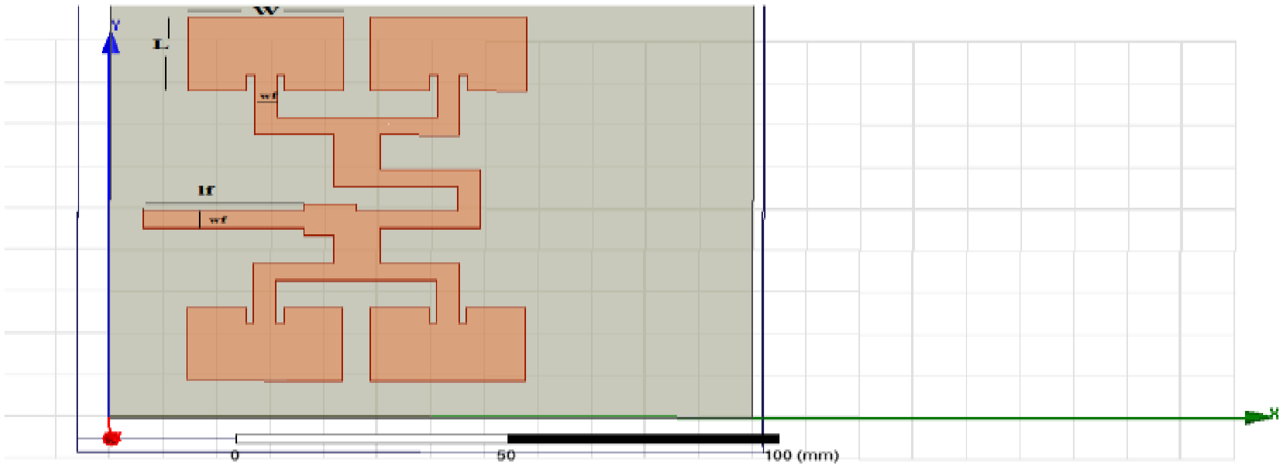

Figure 1: 2x 2 direct coupled feed MSAA

Table 2: Design specifications for proposed 2x2 parasitically coupled feed MSAA

Sr.No.	Parameter	Value
1	Substrate Width	90 mm
2	Substrate Length	80 mm
3	Substrate Height	1.57 mm
4	Patch Width	25.24 mm
5	Patch Length	17.99 mm
6	Feed line Width (fx)	4.28 mm
7	Feed line Length (fy)	15.94 mm

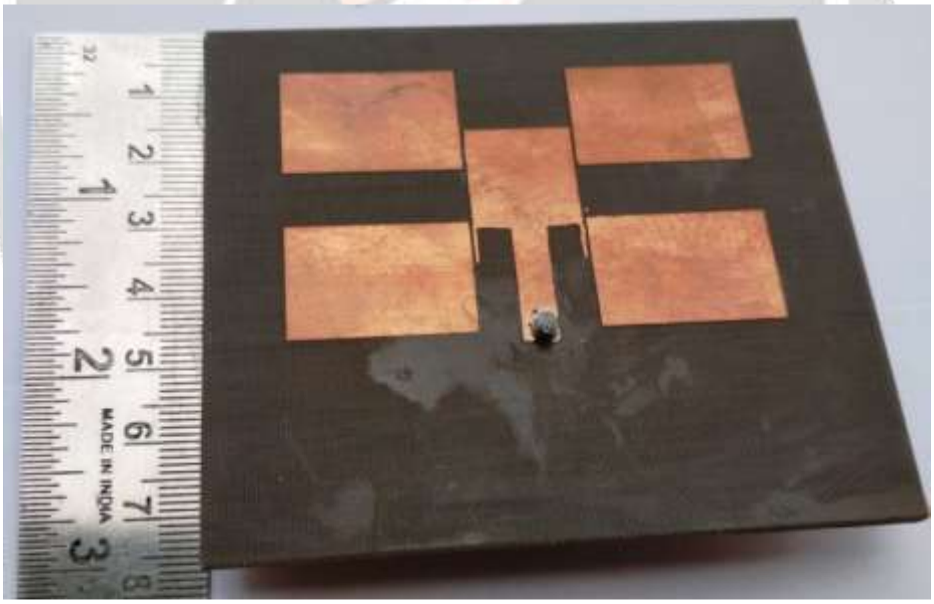

Figure 2: Fabricated hardware of proposed 2x2 parasitically coupled feed MSAA

III. RESULT & DISCUSSION

In this section, we are comparing the performance of proposed parasitically coupled fed MSAA with that of direct coupled fed microstrip array. In the analysis antenna is characterized by return loss (S11), Gain, Bandwidth.

Simulated results:

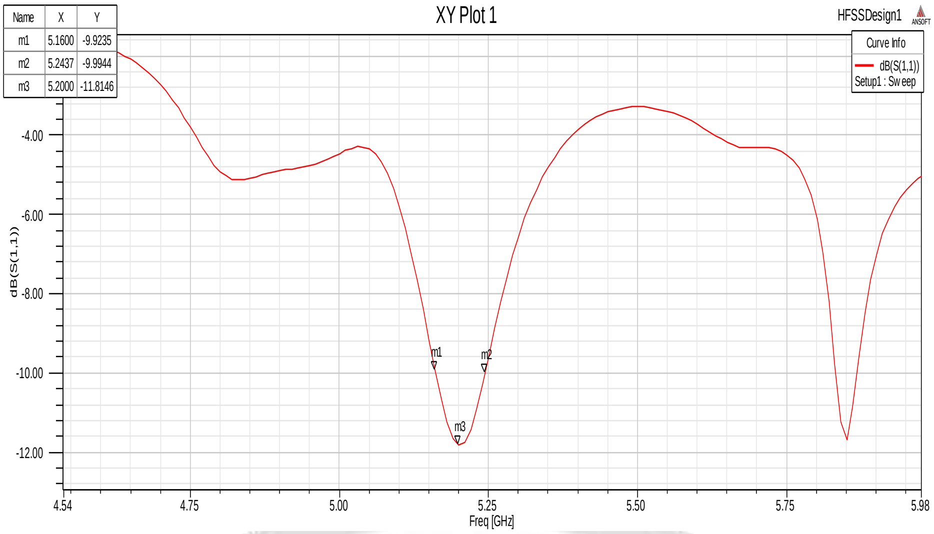

Figure 3: Return loss & Bandwidth of direct coupled fed MSAA

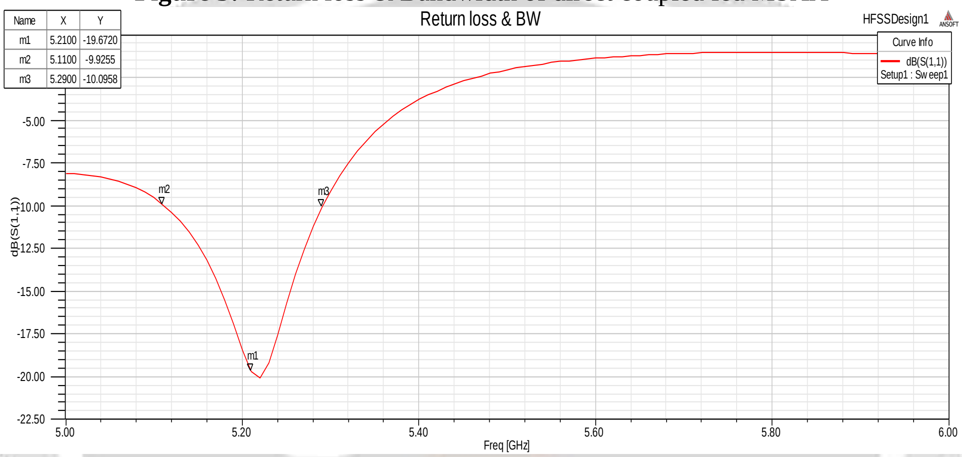

Figure 4: Return loss & Bandwidth of proposed parasitically coupled fed MSAA

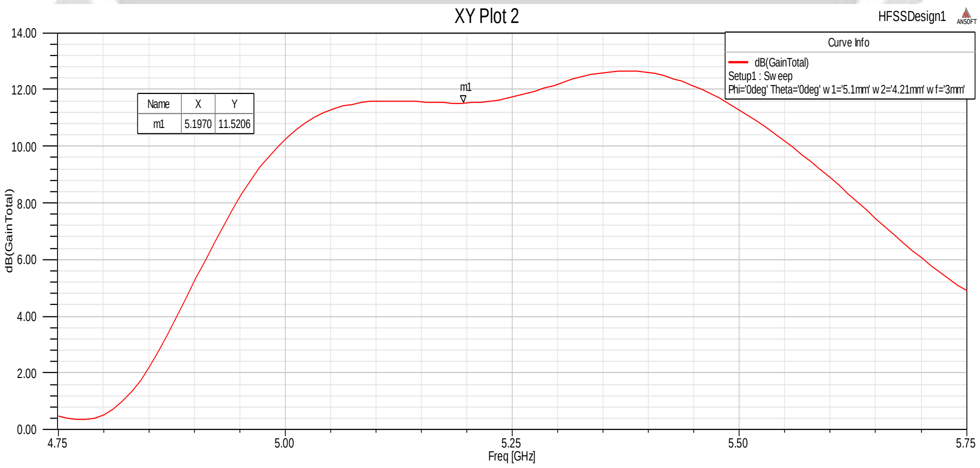

Figure 5: Gain of direct coupled fed MSAA

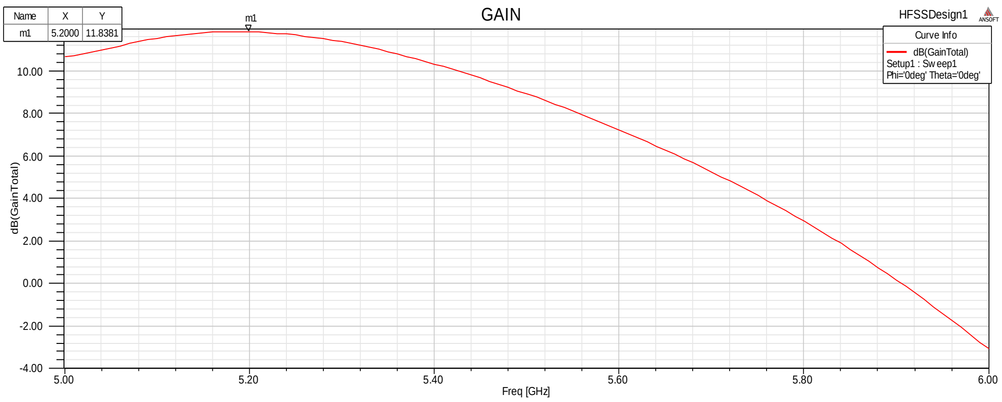

Figure 6: Gain of proposed parasitically coupled fed MSAA

Table 3: Comparison of simulated results

Parameters / Antenna Type	Return Loss	Gain	Bandwidth
Direct Coupled Feed MSAA	-11.81dB	11.52 dB at 5.19 GHz	83MHz
Parasitically Coupled Feed MSAA	-19.67 dB	11.84 dB at 5.20 GHz	180MHz

Measured Results:

Proposed parasitically coupled MSAA is fabricated on Diclad 880 substrate, with (εr) = 2.2, (h) = 1.57 mm, and tested. The measurement was conducted with an Agilent N9923A network analyzer with highest measurable frequency at 6.00 GHz. We have observed Return loss, VSWR, Bandwidth and Smith Chart for resonant frequency 5.2GHz.

The difference between the measured and simulated results is due to Dielectric material losses, Soldering losses & Manufacturing Errors [16].

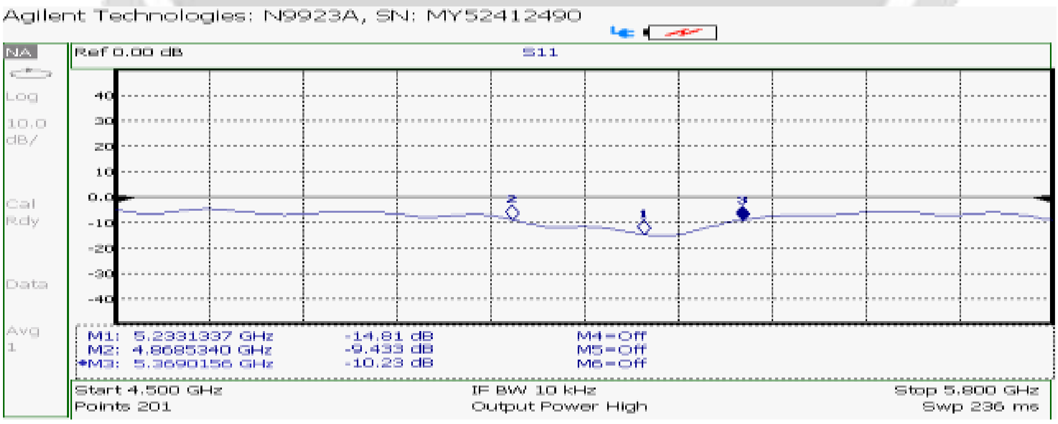

Figure 7: Return loss & Bandwidth of proposed parasitically coupled fed MSAA

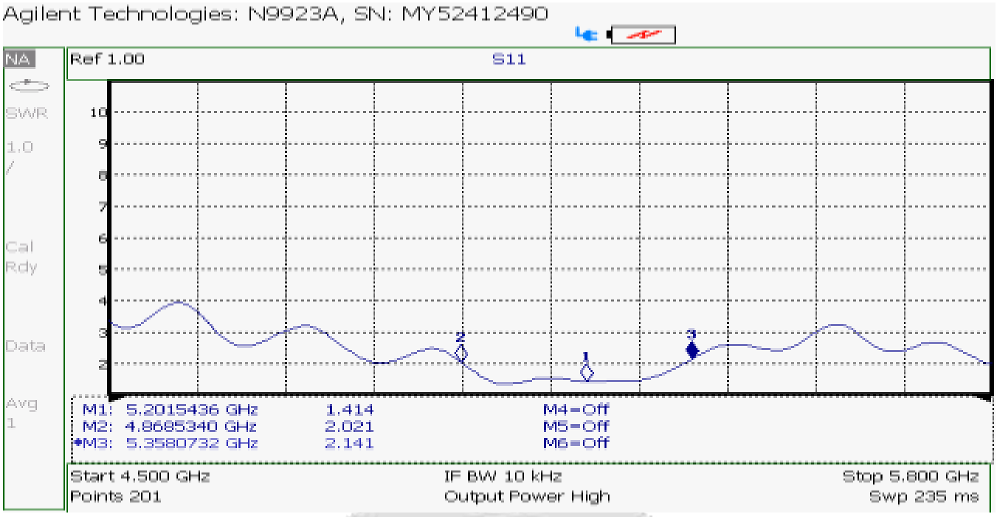

Figure 8: VSWR of proposed parasitically coupled fed MSAA

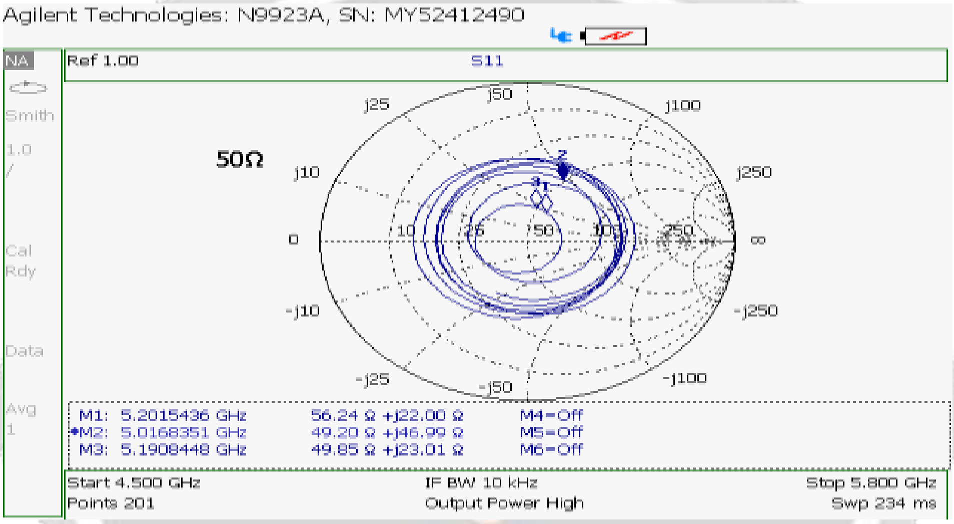

Figure 9: Smith Chart of proposed parasitically coupled fed MSAA

Table 4: Measured results taken using VNA

Parameters / **Antenna Type**	**Return Loss**	**VSWR**	**% Bandwidth**
Parasitically Coupled Feed MSAA	-14.81dB at 5.23GHz	1.41	9.78 %

IV. CONCLUSION

The work of this dissertation part is concentrated on comparison of two possible feeding approaches of a four element microstrip patch array on single layer structure. The first approach is a direct coupled feed MSAA that uses T-junctions and quarter-wave length transformers and the second is the parasitically coupled feed MSAA that uses capacitive gap coupling. The antennas are designed to operate between 5 to 5.5 GHz frequency band with resonant frequency 5.2 GHz. The proposed antenna by parasitically coupled feeding is fabricated on Diclad 880 substrate. The dimensions of direct coupled MSAA are 120 mm x 120 mm are much larger than those of proposed antenna, which measures 90 mm 80 mm. That means due to simplified feeding network in the proposed antenna we have got compactness and improved results than direct coupled antenna array. From the result it is seen that bandwidth of parasitically coupled feed MSAA is greater than bandwidth of direct coupled feed MSAA. Applications of our designed antenna are WLAN or Wi-Fi.

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