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Multiple Bandwidth Design of Micro strip Antenna for Future Wireless Communication

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Abstract*: We have presented a design of multi-band micro strip antenna which is suitable for operating at a higher frequency and with moderate bandwidth also. Proper selection of dimension, patch, and position of feed is taken into consideration to achieve the target properties of the antenna. Different characteristics of antenna like return loss, VSWR, gain, directivity, and efficiency are verified for different frequencies. The maximum gain of the antenna is found to be more than 3dB at different frequencies and also achieves multiple bandwidths in the direction of max radiation. The proposed structure of the antenna is fabricated, simulated, and tested for obtaining the preferred performance in terms of S11, VSWR, gain and efficiency. The experimental results are verified with simulated results which are in good in accord. Proposed antenna bandwidth is found to be 200MHz to 700 MHz with frequency band from 5.70 GHz to 12.60 GHz.

***Index Terms*: Efficiency, Gain, Multiband and Return loss.**

I. INTRODUCTION

During the last decade, Micro-strip antenna engrossed considerable attention of researchers and industry persons due to the demand of its versatile use of in different engineering fields in wireless communication. Conventional Micro-strip antenna majorly suffers with narrow band, efficiency and gain that restrict its applications in communication sector[1]. Serious efforts are going on among the designers to improve the VSWR, bandwidth and efficiency of the micro strip antenna, due to this reason. Improvement in the bandwidth can be achieved by having different size and shape of slots and notches on the ground or in the patch also. Many other bandwidth improvement methods are also there that are available, but shape and slot changing technique is easy in design and simple in loading and improving bandwidth, exclusive of increasing the array or volume of the antenna structure. Many papers have been reported efficiency for wireless applications using micro-strip patch antenna with bandwidth of 14.3%, 17.4%, 23.5%, 14.6%, and 17.3%, respectively[2], broadband antenna with compact slotted rectangular micro-strip patch reported 26.7% bandwidth[3], W-shaped micro-strip patch antenna reported 36.7% bandwidth enhancement[4], M-slot folded micro-strip patch antenna resulted 21.17% bandwidth[5], E-H shaped antenna enclosed freq range from 1.76GHz - 2.38GHz which is 30% bandwidth[6], and V-slots patch antenna shows around 51% of bandwidth improvement[7].

Few other structures are also reported for the bandwidth enrichment of antenna with frequency range from 4.0 to 8.8GHz is achieved by star-shaped patch antenna[8]; E-shaped, C-shaped, and U-slot patch antennas also obtained band width of 24%, 25% and 0.84%[9], cross shaped and plus shaped patch antenna achieve band width of 6.49% and 53% [10-11]; 27.62 % efficiency is reported in multi-slotted antenna bandwidth[12]. Proposed design is motivated with the references cited and an antenna transmitting characteristics which has been proposed to target the wide and extended bandwidth which is suitable for wireless application[13]. Majority of the literature cited are having gain in terms of 8~10dBi, while proposed design gives the maximum gain to be 15.88dB with 43.12 % efficiency. High frequency simulator structure (HFSS) software is used to optimize the proposed design which is based on FEM "finite element method". For desired performance antenna is fabricated, simulated and tested also. Proposed antenna details in terms of their dimension and other are given as below[14-16].

II. CONFIGURATION OF ANTENNA AND DESIGN

The proposed antenna with dimensions shown in figure is fabricated on "FR4" substrate with the dielectric constant of 4.4 with a size of 60mm x 28mm, thickness of 0.4 mm. Antenna also consists of a rectangular slot patch with the following dimension.

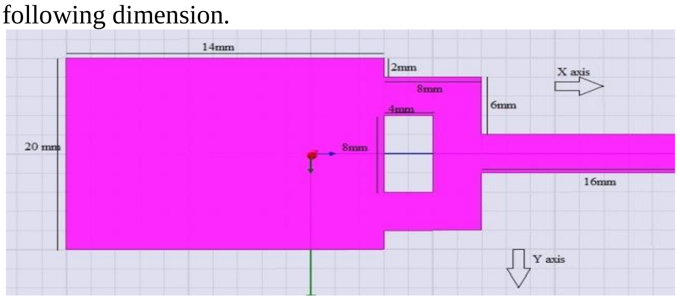

Fig 1: Dimension of patch of proposed antenna

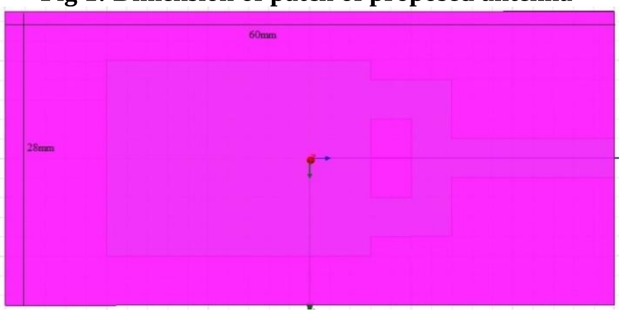

Fig 2: Dimension of ground of proposed antenna

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Proposed design consists of square slot radiating patch and a ground plane fed by a lumped port feed 4mm x 2mm.
Patch of the antenna is excited via lumped port feed. Proposed design of the antenna is as shown in Fig. 1 Antenna is fabricated on double side printed circuit board. Figure 3 and 4 consist of excitation of patch, ground and port are also shown in the following figure.

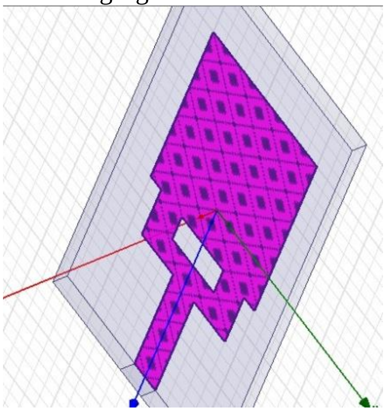

Fig 3: Patch excitation of proposed antenna

Freq (GHz)	8.3	9	9.1	9.2	9.3	11.8	11.9	12	12.1	12.5	12.6	12.7
S11(dB)	-18.29	-20	-22.07	-14.31	-10.51	-11.61	-14.39	-14.34	-11.69	-10.88	-11.33	-10.05

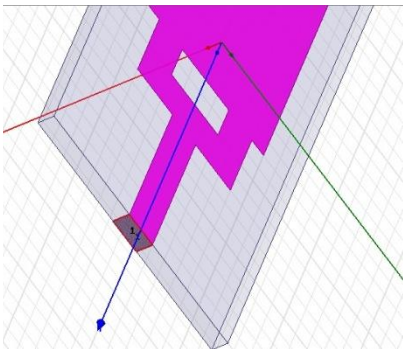

Fig 4: Port excitation of proposed antenna

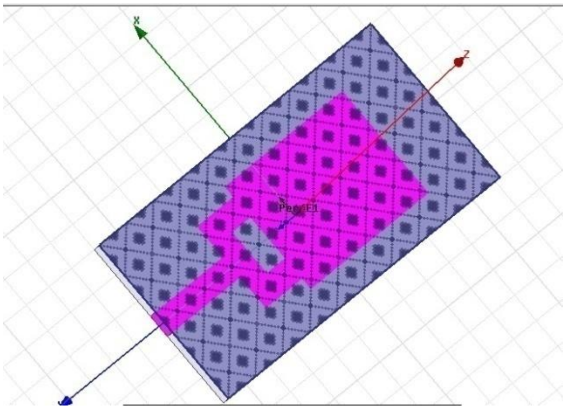

Fig 5: Ground excitation of proposed antenna

III. RESULT AND DISCUSSION

For the desired performance proposed idea of the antenna has been implemented and tested using virtual network analyzer (VNA) and high frequency simulator structure (HFSS) software. Finite element method, FEM based simulator HFSS is used for simulated result. In the following section detail information of the designed antenna characteristic is elaborated.

Reflection coefficient or return loss S_{11} of any antenna is defined as ratio of $Z_{in} - Z_0$ to $Z_{in} + Z_0$ ($\Gamma = \frac{Z_{in} - Z_0}{Z_{in} + Z_0}$) where Z_{in} be input impedance of the antenna and Z_0 is the impedance of transmission lines. S_{11} also define that how much power is reflected back from the antenna. Reflection coefficient is a complex quantity and can be defined as

$$S_{NN} = \begin{Bmatrix} S_{11}, S_{12}, ...S_{1N} \\ S_{21}, S_{22}, ...S_{2N} \\ .... \\ .... \\ S_{N1}, S_{N2}, ...S_{NN} \end{Bmatrix}$$

Table 1: Value of reflection coefficient over frequency range
Typical values of reflection coefficient are in between $0 < \Gamma < 1$. Ideally Z_{in} should be equal to Z_0 such that there is no impedance mismatch and maximum power can be transmitted from the antenna i.e. $Z_0 = Z_{in}$. Magnitude of S_{11} is known as return loss. It can be defined as $R_{Li/p} = 20\log_{10}|S_{11}|dB$. Return loss is used to define whether antenna is single band or multi band. It can also declare that what is the bandwidth of the antenna. Typically we use to calculate the bandwidth below the -10dB.

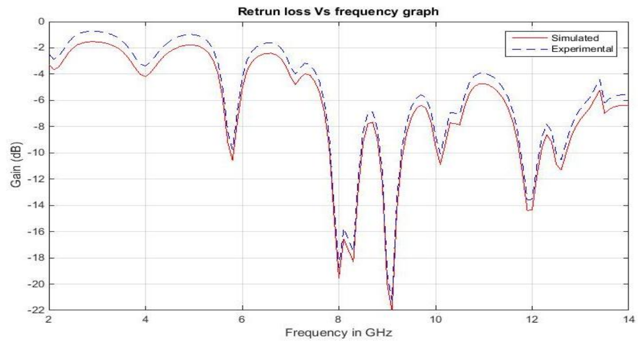

Fig 6: Plot of simulated and experimental return loss Vs frequency

Figure 6 shows the reflection coefficient (S11) versus frequency of antenna. Simulation result of antenna gives following resonant frequency which together gives broader bandwidth also. Bandwidths are in the range of 200MHz to 700MHz at following frequency band below -10 dB.

5.70GHz to 5.90GHz (200MHz bandwidth)
7.80GHz to 8.50GHz (700MHz bandwidth)
8.80GHz to 9.20GHz (400MHz bandwidth)
10.00GHz to 10.20GHz (200MHz bandwidth)
11.80GHz to 12.20GHz (400MHz bandwidth)
12.40GHz to 12.60GHz (200MHz bandwidth)

Experimental results are found to be in good accord and acceptable agreement with the simulated result. Discrepancy generated between the simulated and experimental result comes due to fabrication losses, while simulated results are taken in due ideal conditions.

Following table shows the frequencies on which the return loss is less than -10dB.

Standing wave ratio (SWR) of voltage standing wave ratio (VSWR) is also a function of reflection coefficient (S_{11}) and it is defined as $VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$. During the transmission of signal from antenna standing wave is created because of forward and reverse transmission of the signal/current in the transmission lines. VSWR can be calculated with the help of maximum voltage of standing wave measured along the transmission line and minimum voltage of standing wave measured along the transmission line. i..e $VSWR = \frac{V_{\max}}{V_{\min}}$.

For better efficiency and transmission of the signal typical value of the standing wave ratio should be $1 < VSWR < \alpha$.

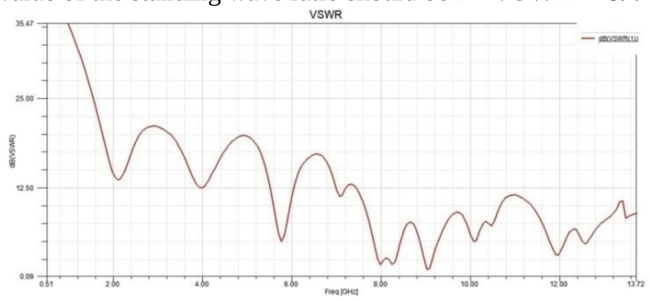

Fig 7: Plot of voltage standing wave ratio (VSWR) Vs frequency of proposed antenna

Table 2: Range of frequencies on which the VSWR is around 1

Freq (GHz)	8.3	9	9.1
VSWR	2.13	1.9	1.37

Gain of the antenna which comes from the simulated result and measured gain at different frequency especially when the return loss is minimum is also shown. It is clear from Figure _ that gain varies from -16.66 dB to 15.88 dB over the frequency range from 8.3 GHz to 13.67 GHz. Maximum and minimum simulated gain are found at 15.88 dB at 13.42 GHz and -16.66 dB at 9.3 GHz.

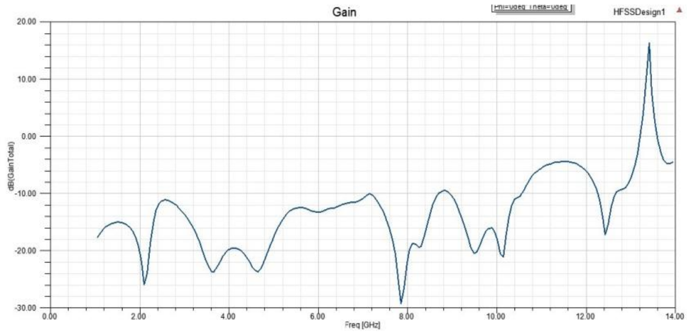

Fig 8: Plot of gain of the proposed antenna versus frequency

Sufficient gain of the antenna at different frequencies are as shown in the below table.

Table 3: Value of gain of antenna over the range of frequency

Freq in [GHz]	Gain in dB
13.27	2.88
13.32	7.05
13.37	11.81
13.42	15.88
13.47	9.22
13.52	4.63
13.57	1.34

Efficiency of the proposed antenna is also found to be in good accord with measured and simulated one. 92.81% and 91.12% are the simulated and measured efficiency of the proposed design respectively. Due to the design tolerance of the proposed design small discrepancy if found between the measured and simulated results.

Figure 9 show the plot of the radiation pattern of proposed antenna which also shows that antenna is directional in a particular angle.

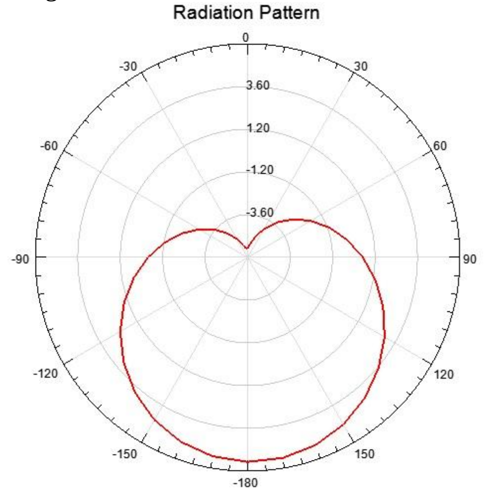

Fig 9: Plot of simulated radiated power versus angle of proposed antenna

Requirements of the wireless communication devices are somehow satisfied with the proposed design in terms of return loss, VSWR and gain of the antenna.

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It is also evident that antenna delivers maximum power in broadside side/direction within the operating band and the 3 dB beam width. From the design it is also evident that at 12.2 GHz to 12.7 GHz antenna can radiate maximum power at these specified beam widths.

Table 4. Some of the performance parameter of the proposed antenna

Freq [GHz]	S11 (dB)	VSWR	Gain dB	Directivity	Efficiency %
8.3	-18.29	2.13	-14.79	4.23	50.54
9	-20.00	1.90	-9.74	3.54	47.34
9.1	-22.07	1.37	-12.24	3.26	53.19
9.2	-14.31	3.46	-14.24	3.07	57.25
9.3	-10.51	5.35	-16.66	3.03	58.36
9.4	-8.53	6.85	-19.19	3.01	58.9
11.7	-9.21	6.29	-4.73	6.14	55.95
11.8	-11.61	4.70	-4.73	6.53	55.89
11.9	-14.39	3.36	-4.73	6.99	55.48
12	-14.34	3.39	-4.73	8.32	53.35
12.1	-11.69	4.64	-7.31	10.19	53.66
12.2	-9.61	5.99	-6.42	9.11	64.28
12.3	-8.62	6.77	-2.44	5.38	92.81
12.4	-9.15	6.34	-0.23	4.73	86.605
12.5	-10.88	5.10	-1.86	4.4	78.91
12.6	-11.33	4.84	-2.43	4.68	72.57
12.7	-10.05	5.65	-4.59	5.43	67.54
12.8	-8.84	6.58	-9.00	6.57	60.07
13.17	-6.98	8.37	-2.33	9.16	47.57
13.22	-6.55	8.88	-0.09	9.32	46.32
13.27	-6.55	8.88	2.88	9.36	45.25
13.32	-5.86	9.78	7.05	9.29	44.36
13.37	-5.86	9.78	11.81	9.11	43.65
13.42	-5.22	10.69	15.88	8.84	43.12
13.47	-5.22	10.69	9.22	8.84	43.12
13.52	-6.99	8.36	4.63	8.47	42.76
13.57	-6.99	8.36	1.34	8.02	40.6
13.62	-6.67	8.73	-1.03	7.51	42.64
13.67	-6.49	8.95	-2.67	6.97	42.9

IV. CONCLUSION

Micro-strip patch antenna is successfully designed and presented with accord return loss and VSWR. Proposed design is having bandwidth of 400 to 700 MHz and radiates in broadside direction. Minimum return loss is -22.07dB at 9.1 GHz frequency. The designed antenna also has a maximum gain of 15.88 dB and 86% efficiency. In the frequency range of 12.5 to 12.7 GHz efficiency is about 70% with around 70% power is radiated.

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