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Ladder Shaped Patch Antenna for Ku Band Applications

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***Abstract*— In this paper, a ladder shaped patch antenna for Ku band applications is analyzed and theoretically presented. FR4 epoxy, Rogers RT/duroid 5870, Rogers RT/duroid 6006, air substrate whose relative permittivities are 4.4, 2.33, 6.15, 1.0006 respectively are used in different combinations and with change in thickness for each version of the design. Parameters like return loss, bandwidth, gain, and VSWR has been analysed. Three versions are compared with respect to the above mentioned parameters. They are designed at resonant frequencies of 14.4GHz, 14.9GHz, and 16.2GHz. Gain is varied from 3.81dB to 21.84dB. These antennas are designed with help of HFSS (High Frequency Structure Simulator) software. Proposed antenna has a numerous applications in space communication, aircraft and maritime communication, satellite internet, satellite television etc.**

Keywords—Ladder shaped patch; Return loss; VSWR; Gain; Bandwidth

I. INTRODUCTION

Microstrip patch antennas are being widely used in various applications due to its compact structure and ease of usage by directly printing them on printed circuit boards. Also, the rigid structure in fabrication of these patch antennas have made them reliable even in adverse conditions. Patches are of different geometric shapes like rectangular, square, dipole, circular, elliptical, and triangular patches. While these being the regular geometric patches, some unconventional patch designs like E-shape, L-shape, diamond shape etc. are in wide usage due their performance in various parameters according to the purpose of application. These are widely used in wireless communication, satellite communication, space communications, biomedical applications, radars and radar guns etc.

A typical microstrip patch antenna would consist of a substrate, patch which is conducting and a ground plane. Dielectric substrate is placed in between conducting patch and ground plane where patch is printed on top and ground plane is printed at bottom of substrate. Patch and ground plane can simply be understood as positive and negative terminals respectively.

The design proposed in this paper is ladder shaped patch which can be used for the applications in the frequency range of Ku band (12 GHz -18 GHz) such as radar guns, satellite television, satellite communication etc. This was designed with an efficient software tool HFSS (High Frequency Structure Simulator).

II. ANTENNA DESIGN

Initially as shown in Fig. 1, a ladder shape patch is designed. Combination of substrates, thickness and type of substrate are varied to show the difference of gain and bandwidth in each version. For all the three versions patch dimensions are constant. Table I gives the dimension values of the proposed ladder patch.

A. Version 1

In the 1st version, proposed design is placed above two substrates FR4 epoxy which is immediately below the patch and Rogers RT/duroid 5870 below FR4 epoxy. FR4 epoxy has a dielectric constant of 4.4 with a thickness of 1mm and duroid 5870 has a dielectric constant of 2.33 with a thickness of 1mm. So, total thickness of substrate used in the 1st version is 2mm. Fig. 2 shows the design and number of substrates used in 1st version.

Table II shows the details of the substrate for 1st version of proposed design.

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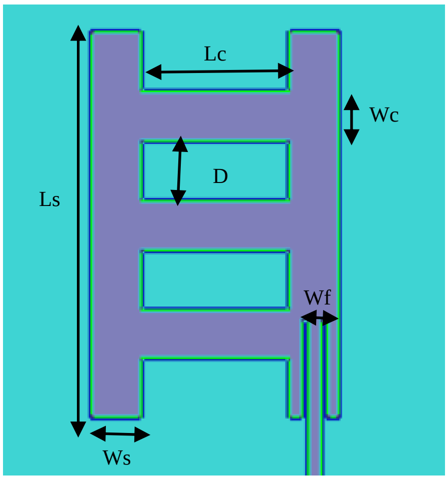

Fig. 1: Ladder Patch

Table I. Dimension values of proposed ladder patch

S. No.	Parameters	Descriptions	Values
1.	L_s	Length of side strips of ladder	7.8 mm
2.	W_s	Width of side strips of ladder	1 mm
3.	L_c	Length of strip between two side strips	3 mm
4.	W_c	Width of strip between two side strips	1 mm
5.	D	Distance between each strip in center	1.2 mm
6.	W_f	Width of feed line	0.25 mm

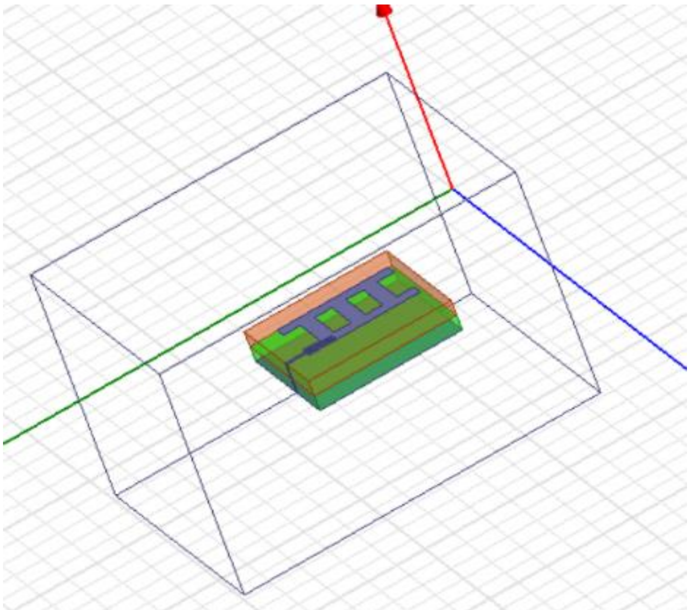
Fig. 2: 1st version of proposed ladder patch

Table II. Substrate details for 1st version

S.No	Substrate	Dielectric Constant	Thickness (mm)
1.	FR4 epoxy	4.4	1
2.	Rogers RT/duroid 5870	2.33	1

B. *Version 2*

In the 2nd version, proposed design is placed above two substrates Rogers RT/duroid 6006 which is immediately below the patch and Rogers RT/duroid 5870 below Rogers RT/duroid 6006. Rogers RT/duroid 6006 has a dielectric constant of 6.15 with a thickness of 1.5mm and Rogers RT/duroid 5870 has a dielectric constant of 2.33 with a thickness of 1.5mm. So, total thickness of substrate used in the2nd version is 3mm. Fig. 3 shows the design and number of substrates used in 2nd version.

Table III shows the details of the substrate for 2nd version of proposed design.

C. *Version 3*

In the 3rd version, proposed design is placed above three substrates FR4 epoxy which is immediately below the patch, air gap below FR4 epoxy and Rogers RT/duroid 5870 below air gap. FR4 epoxy has a dielectric constant of 4.4 with a thickness of 0.75mm, air has a dielectric constant of 1.0006 with a thickness of 0.5mm and Rogers RT/duroid 5870 has a dielectric constant of 2.33 with a thickness of 0.75mm. So, total thickness of substrate used in the 3rd version is 3mm. Figure 4 shows the design and number of substrates used in 3rd version.

Table IV shows the details of the substrate for 2nd version of proposed design.

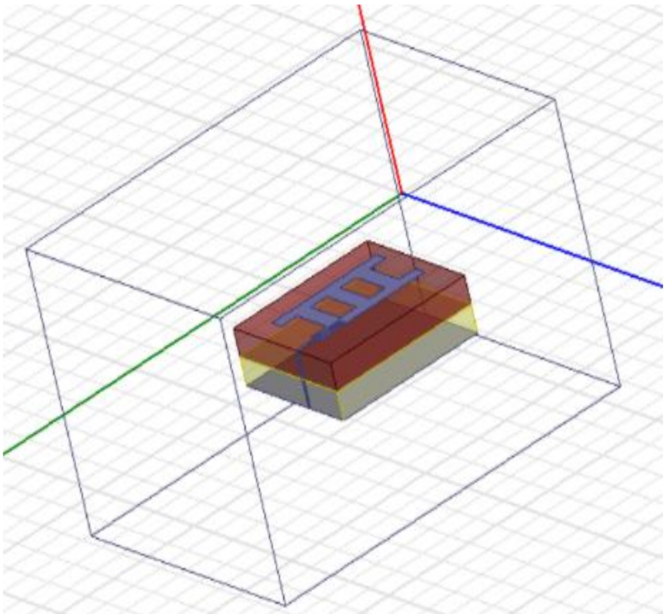
Fig. 3: 2nd version of proposed ladder patch

Table III. Substrate details of 2nd version

S.No	Substrate	Dielectric Constant	Thickness (mm)
1.	Rogers RT/duroid 6006	6.15	1.5
2.	Rogers RT/duroid 5870	2.33	1.5

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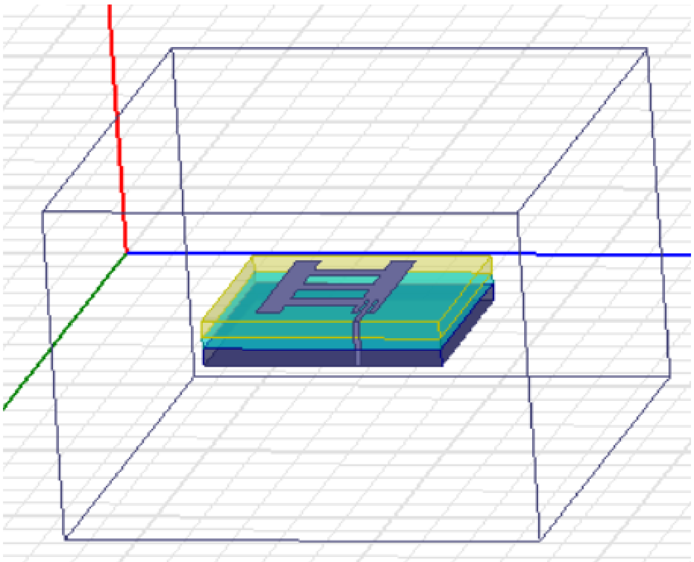

Fig. 4: 3rd version of proposed ladder patch

Table IV. Substrate details of 3rd version of proposed design

S.No	Substrate	Dielectric Constant	Thickness (mm)
1.	FR4 epoxy	4.4	0.75
2.	Air Gap	1.0006	0.5
3.	Rogers RT/duroid 5870	2.33	0.75

III. RESULTS

In this section, results i.e. return loss, VSWR, and gain and of the proposed three versions are evaluated.

A. Return Loss

Return loss is defined as a factor which would describe the difference between incident and reflected power. It is measured in decibels. Fig. 5 shows return loss with respect to frequency plot for 1st, 2nd, 3rd versions of the proposed design.

For the 1st version at 14.4GHz frequency, a return loss of -18.19dB (m1) and bandwidth is m5-m4 = 14.6331-14.2700 = 363MHz.

For the 2nd version at 14.9GHz frequency, a return loss of -26.30dB (m2) and bandwidth is m7-m6 = 15.1539-14.5426 = 611.3MHz.

For the 3rd version at 16.2GHz frequency, a return loss of -22.27dB (m3) and bandwidth is m9-m8 = 16.3515-16.0206 = 330.9MHz.

B. VSWR

VSWR is abbreviation for Voltage Standing Wave Ratio. This can be given as the ratio of maximum voltage to the minimum voltage. It is also a measure of impedance mismatch between antenna and port. More is the mismatch, more is the value of VSWR. Hence, it is preferred that mismatch is low i.e. VSWR should be low and nearer to unity. Minimum value of VSWR is 1 and maximum value is 2 for good match between impedance of port and antenna. Fig. 6 shows the VSWR with respect to frequency plot for 1st, 2nd, and 3rd versions of the proposed design.

For 1st version at 14.4GHz frequency, VSWR is 1.28 (m1).For 2nd version at 14.9GHz frequency, VSWR is 1.10 (m2). For 3rd version at 16.2GHz frequency, VSWR is 1.33 (m3). In all three versions VSWR is less than 2 and is almost near to unity and hence there is only a minimum impedance mismatch.

C. Gain

Gain is a factor that gives directional efficiency of an antenna. Gain for any antenna is preferred to be more than 3dB. Fig. 7 depicts gain of 1st, 2nd, and 3rd versions of proposed design. For 1st version at 14.4GHz frequency, gain is 3.81dB (m1). For 2nd version at 14.9GHz frequency, gain is 21.84dB (m2). For 3rd version at 16.2GHz frequency, gain is 15.73dB (m3).

Table V shows the summary of the obtained result parameters for 1st, 2nd, and 3rd versions of the proposed ladder shape patch antenna.

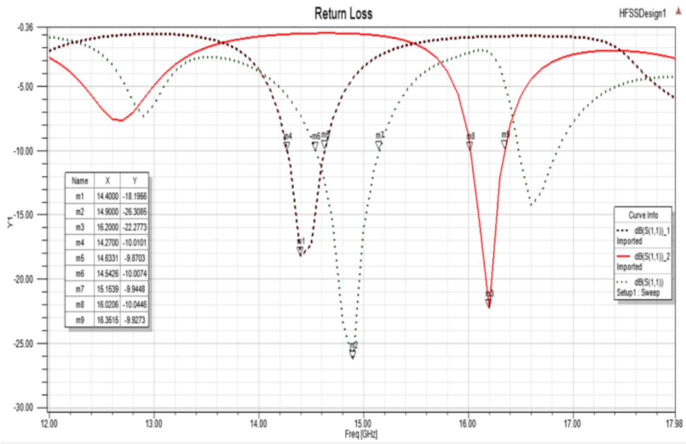

Fig. 5: Return Loss vs. Frequency for 1st, 2nd, 3rd versions of proposed patch

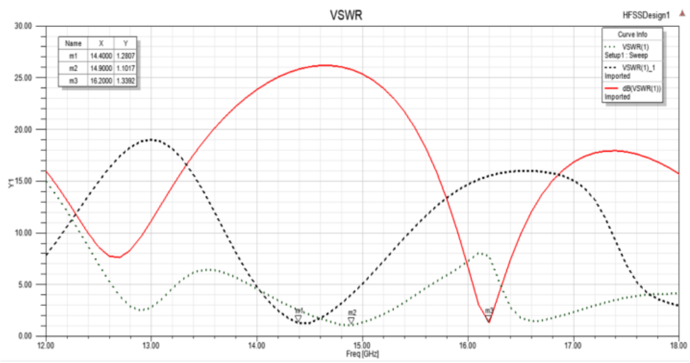

Fig. 6: VSWR vs. Frequency for 1st, 2nd, 3rd versions of proposed patch

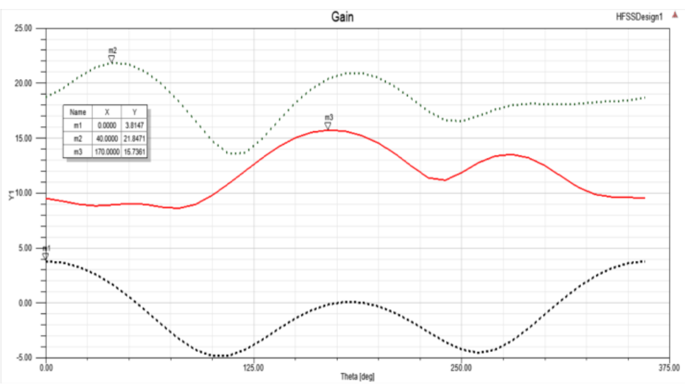

Fig. 7: Gain plot for 1st, 2nd, 3rd versions of proposed design

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Table V. Summary of results of 1st, 2nd, 3rd versions of ladder patch

S.No	Parameters	Version 1	Version 2	Version 3
1.	Resonant Frequency (GHz)	14.4	14.9	16.2
2.	Return Loss (dB)	-18.19	-26.30	-22.27
3.	Bandwidth (MHz)	363	611.3	330.9
4.	VSWR	1.28	1.10	1.33
5.	Gain (dB)	3.81	21.84	15.73

IV. CONCLUSIONS

A ladder shaped antenna have been designed for Ku band applications using different combinations and thickness of four substrates FR4 epoxy, Air gap, Rogers RT/duroid 5870, Rogers RT/duroid 6006 and a lumped port feed line is used to excite the antenna. By observing results in all three versions, return loss is way less than -10dB which depict that losses are minimal during transmission. VSWR is nearer to unity in all three versions. Gain is more than 3dB in all three versions. Return loss, gain, VSWR, and bandwidth are pretty much good when substrates used are only meta-materials which are less lossy in nature. Designed antenna can be used for satellite communication applications, space communications, radar guns for law enforcement, maritime telecommunication etc.

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