Simple methods for enhancing bandwidth of a rectangular microstrip patch antenna

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DOI:
10.1049/ic.2014.0184

SIMPLE METHODS FOR ENHANCING BANDWIDTH OF A RECTANGULAR MICROSTRIP PATCH ANTENNA

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Key words: Microstrip antenna, bandwidth, filtering patch antenna

Abstract: In this paper we have introduced two methods namely (i) taper matching and (ii) quarter wavelength width extension to increase the bandwidth (BW) of a rectangular microstrip patch antenna (RMPA). Also we have studied the effect of applying both methods on the antenna performance. Simulation and experimental results on a 5GHz patch antenna using these methods have been presented.

1. Introduction

A typical microstrip antenna has a very narrow BW of about 4% [1]-[2]-[3]. In the recent decade, a considerable amount of work has been done to increase the BW of RMPA [4]-[5]-[6]. In Ref. [1] antennas having ultra wide BW have been reported [1]. However, the problem with the available techniques for BW improvement is that either a complex geometrical pattern or a complex patch shape should be used. This may cause difficulties in the antenna fabrication (especially at frequencies above 30GHz) and produces some unwanted variations in the antenna's far field pattern. These issues have been addressed in this paper. Furthermore, usually a band pass filter is required to be incorporated with the transmitting and receiving antennas. In recent years, many attempts have been made to design a microstrip antenna with a built in band pass filter [6]-[7]-[8]-[10]-[11]. Also, in this case the band pass filter (BPF) is constructed either by employing a complex pattern on the patch antenna or by making the BPF separately using microstrip transmission lines and then matching the filter with the antenna. Either method may require complex design or may need more space to accommodate both the antenna and filter together. This problem may be rectified by the proposed methods easily without any necessity to have extra design or complex geometry.

2. Bandwidth Enhancement of Patch Antenna

The following methods have been proposed to improve the band width of a RMPA.

2.1 Taper Matching

A patch antenna operating at 5GHz was designed using the conventional design equations available in the literature [1]. In the 1st design (antenna a) we used a quarter wavelength long rectangular microstrip transmission line (TL) for impedance matching. The antenna substrate was RT/Duroid 5880 with $\varepsilon_r = 2.2$, $h = 3.175$ mm and $t = 0.035$ mm so that we can get large antenna's dimensions (see Fig.1), high gain and high bandwidth. The original calculated length 'L' and width 'W' were 18.1mm and 23.7mm, respectively whereas the optimised values of L, W and the transmission line dimensions 'L_T' and 'W_T' were 17.6mm, 23.7mm, 10.67mm, and 2.84mm, respectively. Also as shown in Fig.1 the substrate length 'L_g' and width 'W_g' were, respectively, 37.15mm and 42.75mm.

In the 2nd (antenna b) design we used a tapered shape quarter wavelength long TL (L_T) on the original design (i.e. L=18.1mm, W=23.7mm) to improve the matching and bandwidth. The optimised taper widths 'W_{fe}' and 'W_f' were 0.3mm and 8.33mm, respectively, which corresponds to the 50Ω standard input impedance.

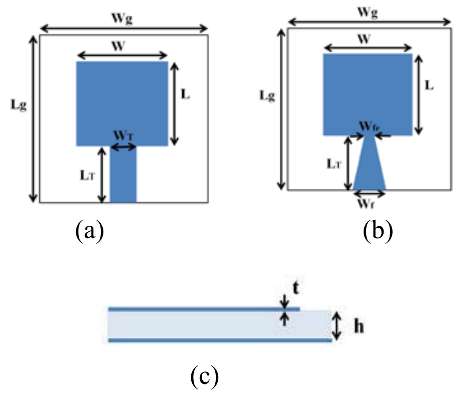

Figure 1: Antenna dimensions (a) rectangular quarter wavelength matching (b) taper matching (c) side view of the antenna

2.2. Quarter Wavelength Width Extension

For this method, firstly, the antennas dimensions are calculated from the conventional formulas as described in section 2.1. When the patch antenna's width 'W' is increased by let say $\Delta W \leq \lambda / 4$ (where λ is the guided wavelength), a second resonance starts appearing at a higher but close to the original resonance frequency. However, as ΔW approaches to $\lambda / 4$ the second resonance starts merging with the first one which ultimately gives a considerable increase in the antenna bandwidth. In our design (antenna b) the new value of the antenna width (i.e. $W + \Delta W$) becomes 34.38mm. Also as the antenna width increases the input impedance of the antenna decreases, so W_T (see Fig.1a) is increased to flatten the ripple in the pass band. Both the antenna length and width can be adjusted to finely control the edges of the S_{11} response. The antenna bandwidth and pass band flatness of

S_{11} can all be controlled by ΔW and W_T which give enough flexibility to create the desired response.

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2.3. Width Extension and Taper Matching

This method is basically a combination of the two methods as described in sections 2.1 and 2.2. The patch antenna used in section 2.2 with $W = 34.38\,\text{mm}$ is redesigned to operate at 5GHz using tapered matching.

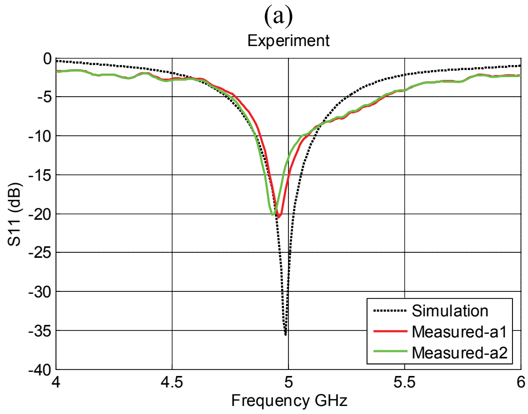
The values of input (W_f) and output (W_{fe}) taper widths were optimised to increase the antenna bandwidth. These optimised values are $W_f = 6\text{mm}$ and $W_{fe} = 7\text{mm}$ which gives the widest and deepest response around 5GHz.

3. Results and Discussions:

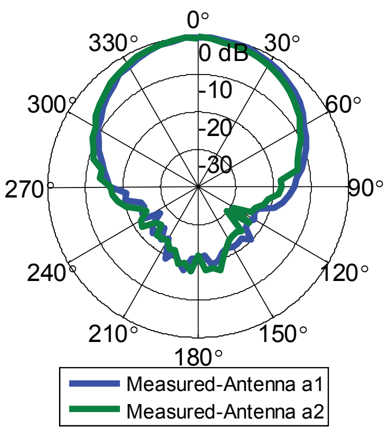
Taper Matching: Two samples of rectangular and tapered matching for each designed patch antenna have been fabricated and tested (see Figs 2a and 3a). The measured and simulation results for the two matching methods are shown in Figs 2 and 3.

(antenna a_1) (antenna a_2)

(a)



(b)

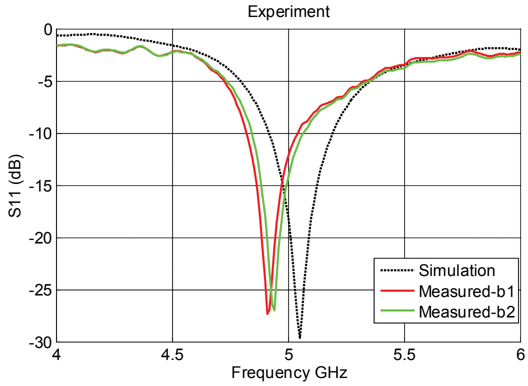


(c)

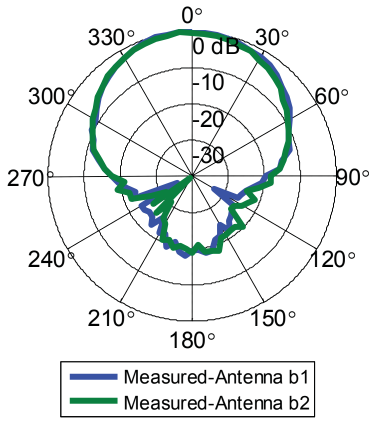
Figure 2. Test results for Antenna a (a) fabricated antennas (b) results (c) measured far-field pattern

(antenna b_1) (antenna b_2)

(a)



(b)

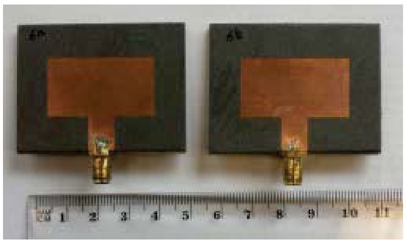


(c)

Figure 3. Test results for design b (a) fabricated antennas (b) results (c) measured far-field pattern

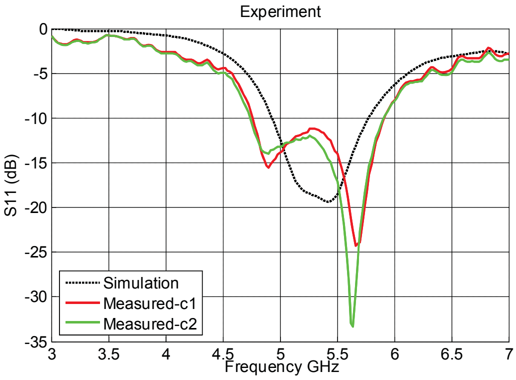
The measured bandwidths of the antennas shown in Figs.2 and 3 are, respectively, 202MHz (4.05% at $f_0 = 4.982\,\text{GHz}$) and 220MHz (4.46% at $f_0 = 4.93\,\text{GHz}$), where f_0 is the centre frequency. The results clearly show that the taper matching gives 18 MHz wider bandwidth and also the S_{11} parameter is 5dB lower as compared with the conventional quarter wavelength matching.

Quarter Wavelength Width Extension: Various patch antennas with fixed $W = 33\text{mm}$ and different W_T were fabricated. Figure 4 shows the simulation and measured results for the optimised one (see Fig.4a) which has $W_T = 8\text{mm}$ (Fig.4a). The results show that the S_{11} response (Fig.4b) is quite flat in the pass band and gives a bandwidth of 1.18GHz (i.e. 22.18% at $f_0 = 5.32\,\text{GHz}$). The far- field pattern of the antenna at this frequency is shown in Fig.4c.

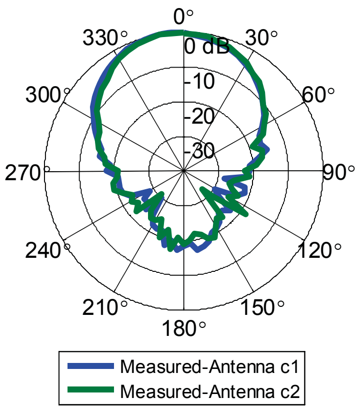


(antenna c_1) (antenna c_2)

(a)



(b)



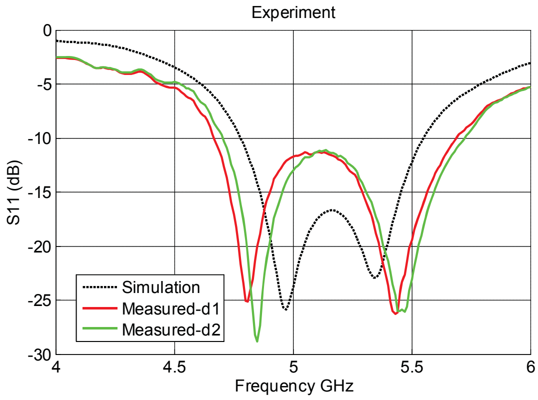
(c)

Figure 4. (a) The fabricated antenna, (b) simulation and measured results and (b) measured far-field pattern

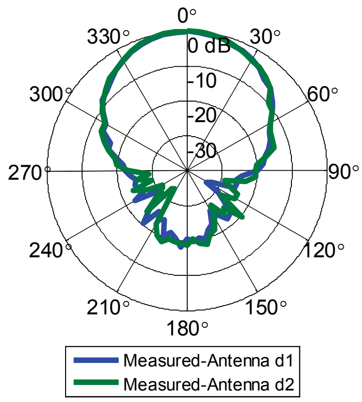
Width Extension and Taper Matching: Two fabricated samples of the antenna that are fabricated by this method are shown in Fig.5a. Figures 5b shows both the simulation and measured S_{11} responses which are in good agreement and Fig.5c shows the designed antenna far-field pattern. The measure bandwidth is 1.018GHz (i.e. 19.52% at $f_0 = 5.21\text{GHz}$) which is about 5 times larger than a typical patch antenna.

(antenna d_1) (antenna d_2)

(a)



(b)



(c)

Figure 5. (a) Fabricated antennas (b) S_{11} response (c) Far-field pattern

4. Conclusion

Two methods namely (i) taper matching and (ii) quarter wavelength width extension have been proposed to increase the bandwidth of a rectangular microstrip patch antenna. The taper matching is a simple method to improve the patch antenna bandwidth and impedance matching. With quarter wavelength width extension a large increment in bandwidth (i.e. 22.18%) is measured. With the combination of these two methods, again, a considerable bandwidth improvement (i.e.19.52%) is achieved. All tested antennas have given a typical patch antenna radiation pattern and their measured directivities range from about 10dBi to 11.43dBi.

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