Wideband Log Periodic-Microstrip Antenna with Elliptic Patches

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Abstract
A broadband microstrip antenna based on log periodic technique was conceived and demonstrated practically. The antenna exhibits a wideband characteristic comparing with other microstrip antennas. Over the operation frequency range, i.e. 2.5-6 GHz, a 50 Ω input impedance has been considered.

Keywords: Microstrip Antenna, Log-Periodic, VSWR, Gain, Pattern

1. Introduction

Currently, there are increasing demands for novel ultrawideband (UWB) antennas with low-profile structures and constant directional radiation patterns for both commercial and military applications [1], Microstrip antenna has gain popularity because of their small size and light weight. However a limitation of microstrip antenna is the narrow bandwidth of the basic element. The bandwidth of the antenna can be increased by reducing the substrate permittivity (εr) or increasing its thickness (h) [2]. Different techniques to enhance the bandwidth of microstrip antenna have been investigated. Most of the effort to enhance the bandwidth has been directed towards improving the impedance bandwidth of the antenna element. The bandwidth can be increased using multilayer structure antenna [3], parasitic element [4], non contact feeding technique [5], different shape slots [6] or log periodic technique [7]. A log-periodic antenna has been successfully operated as a broadband linearly polarized antenna element in free space since 1957 [8,9]. The log-periodic dipole array (LPDA) is an antenna with frequency independency advantage. The input impedance and gain of this antenna remains almost constant over its operating bandwidth, which can be very large. Practical designs of an LPDA could have one octave or more bandwidth [10,11].

In this article, we introduce a new hybrid log periodic-microstrip antenna (LPMA). This antenna is terminated by a novel compensating stub with length of T, instead of a matched load or open-circuit [12]. We show that the proposed LPMA gives better characteristics in comparison with others, especially by increasing the bandwidth. To do this, at first, radiator elements are considered rectangular patches. Next, they are replaced with elliptical patches. Finally, the simulation and measurement results of antenna are analyzed and compared together.

2. Antenna Design

The design principle for log periodic requires scaling of dimensions from period to period so that performance is periodic with the logarithm of frequency. This principle can be applied to an array of patch antennas. The patch length (L), the width (W) and Inset (D) are related to the scale factor τ by:

$$\tau = \frac{\mathrm{Lm}+1}{\mathrm{Lm}} = \frac{\mathrm{Wm}+1}{\mathrm{Wm}} = \frac{\mathrm{Dm,m}+1}{\mathrm{Dm}-1,\mathrm{m}} \quad (1)$$

If we multiply all dimensions of the array by τ it scales into itself with element m becoming element m+l, element m+l becoming element m+2, etc. This self scaling properly implies that the array will have the same radiating properties at all frequencies that are related by a factor of τ. [2] In the equation, Dm,m+1 is distance between patch Pm+1 and Pm, also Wm and Lm are width and length of the patch Pm, respectively. In the elliptical patch design, the great length of the

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ellipse is considered Wm and the small length of the ellipse is Lm

An example of single-layer microstrip log periodic antenna is shown in Fig. 1. This antenna consists of square patches located on a FR4 substrate with dielectric constant equals to 4.4 and 1.6 mm thickness. It is feeding by coaxial cable with 50 ohms. Distance of patch from stripline is 0.2 mm, width of stripline is 3 mm and the distance of end line and the last patch of the strip is 4mm. Logarithmic factor, τ, is considered 1.1.

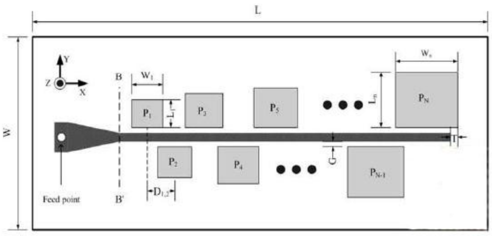


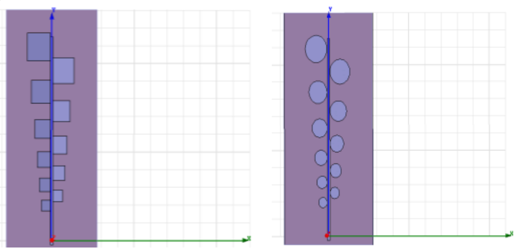
Fig 1- Structural configuration of Log-periodic microstrip antenna [10]

Dimensions, sizes and distances are tabulated in table 1. Antenna length (L) is 270 mm and it's width (W) is 110 mm.

TABLE I- Sizes and dimensions designed for log-periodic microstrip antenna with logarithmic factor of 1.1

m	f (GHz)	L_m (mm)	W_m (mm)	$D_{m,m+1}$ (mm)
1	2.3	10.62713	12.2212	10.62717
2	2.53	11.68985	13.44332	11.68989
3	2.783	12.85883	14.78765	12.85888
4	3.0613	14.14471	16.26642	14.14477
5	3.36743	15.55918	17.89306	15.55925
6	3.704173	17.1151	19.68237	17.11517
7	4.07459	18.82661	21.6506	18.82669
8	4.482049	20.70927	23.81566	20.70936
9	4.930254	22.7802	26.19723	22.78029
10	5.42328	25.05822	28.81695	25.05832
11	5.965608	27.56404	31.69865	27.56415

In the next stage, for comparison and verifying the results, elliptical patches are used instead of rectangular patches. We hypothesize that the elliptical patches can improve the results. Fig. 2 shows the geometrical structure of two kinds of antennas.

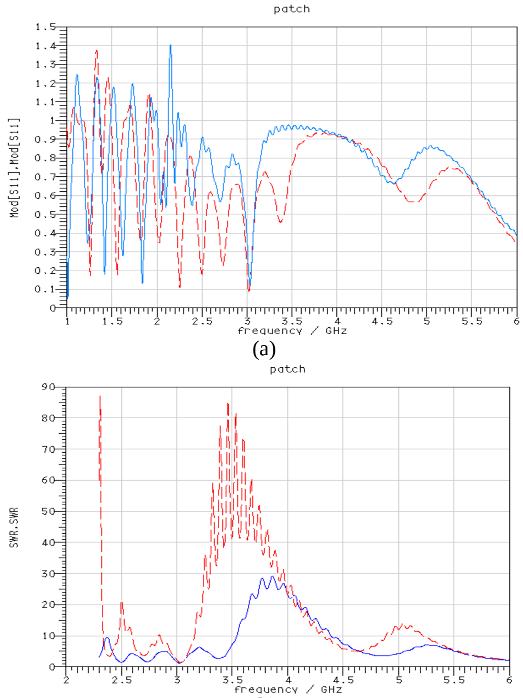


(a) (b)

Fig 2- (a) Simulated image of log-periodic microstrip antenna with rectangular patches (b) Simulated image of log-periodic microstrip antenna with elliptical patches

3. Simulation Results

In this section, to verify the design results, we simulated our design in software environment. We show simulated results of the proposed LPMA. All simulations have been done by CST. These results are shown in Fig. 3 to Fig. 9. Diagrams related to the antenna using rectangular patch is shown with discrete lines and antenna using elliptical patch with continuous line in all graphs.



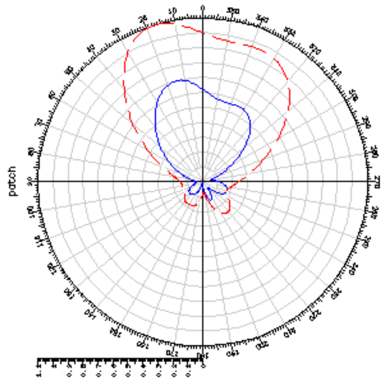
(a)

(b)

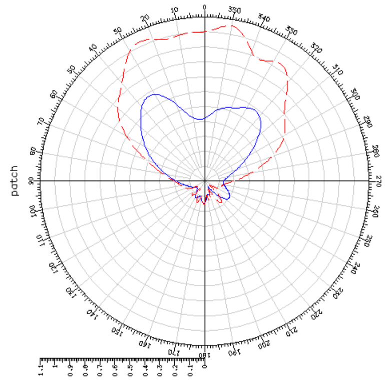
Fig 3- Comparison simulated S parameters between Using rectangular patches & elliptical patches (a) S11 (b) VSWR

As be seen in Fig.3, after replacing the elliptical patch, VSWR decreases to <2 from f=2.3 GHz to f=3.4 GHz

Figures 4 and 5, show the replacement of the elliptical patches with the rectangular patches causes in reducing the side lobes and increasing the directivity Rotation angles in some of directs which can be seen, is caused by differences in polarization in the elliptical shapes to the rectangular shapes. Photos the antenna structure using elliptical patches and rectangular patches also shows figure 6.

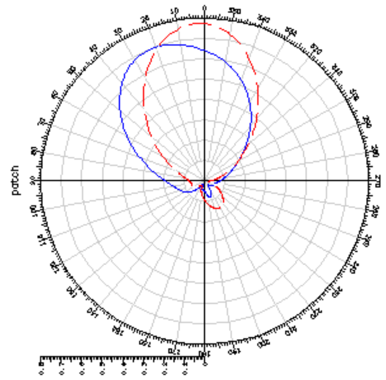


(a)

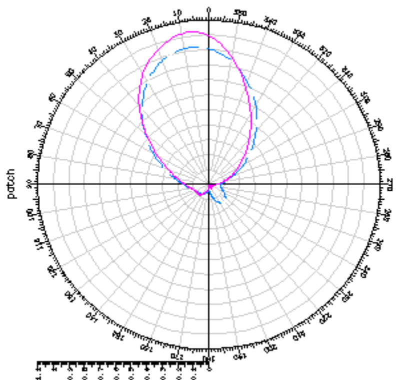


(b)

Fig 4- Comparison simulated pattern between Using rectangular patches & elliptical patches in f=2.3GHz (a) E plane (b) H plane.

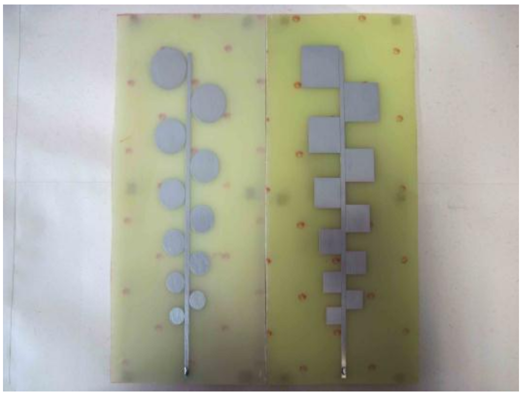


(a)



(b)

Fig 5- Comparison simulated pattern between Using rectangular patches & elliptical patches in f=3.4GHz (a) E plane (b) H plane

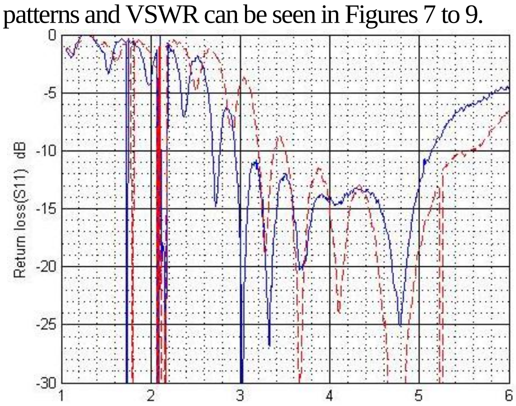


(a) (b)

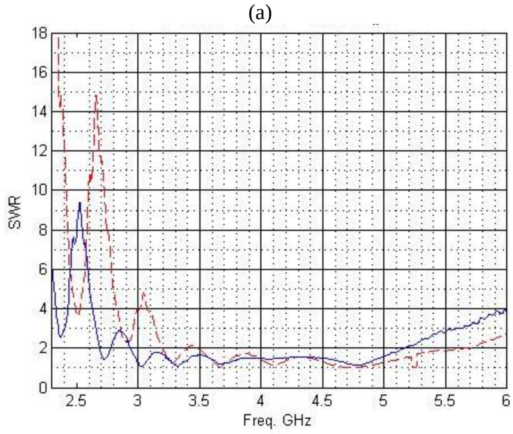
Fig 6- photos the antenna structure (a) Using elliptical patches (b) Using rectangular patches

4. Experimental Results

After the simulation phase and to obtain desired results, sample antenna with τ=1.1 was made (OR implemented) based on the dimensions and sizes in Table I. Substrate has chosen FR4 with dielectric constant 4.4. For comparison of results, conditions in implementation and simulation have been assumed similar. To improving the results, such as simulation, it is considered a 3 mm distance between substrate and the ground. Results from the implementation such as patterns and VSWR can be seen in Figures 7 to 9.

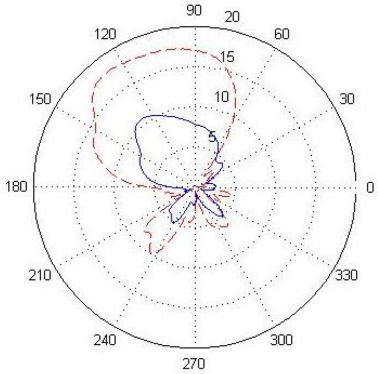


(a)

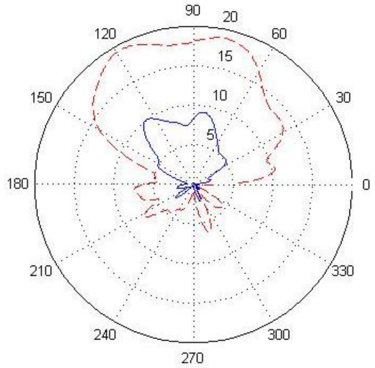


(b)

Fig 7- Comparison simulated S parameters between Using rectangular patches & elliptical patches (a) S11 (b) VSWR

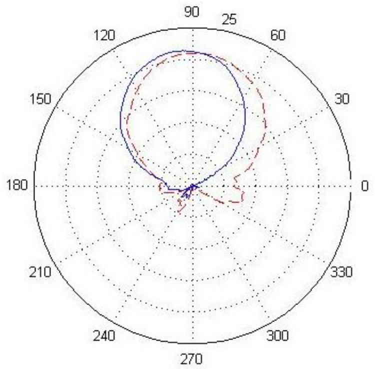


(a)

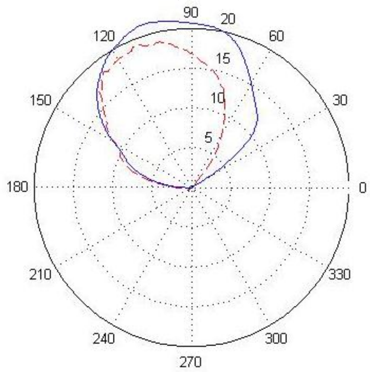


(b)

Fig 8- Comparison Measurement pattern between Using rectangular patches and elliptical patches in f=2.3 GHz (a) E plane (b) H plane



(a)



(b)

Fig 9- Comparison Measurement pattern between Using rectangular patches and elliptical patches in f=3.4 GHz (a) E plane (b) H plane

Diagrams obtained from measurements are shown in Fig 7. As was predicted in simulations, Elliptical patches significantly to reduce the VSWR plots below the value 2. The patterns of electrical and magnetic field obtained from measurements sample made using of rectangular and elliptical patches are compared In Fig 8 and 9. Small differences can be seen in simulated and measured results to be due to the lack of ideal conditions as the building.

5. Conclusion

Simulation and manufacture results and compare them show that the use of elliptical patch in the design has increased bandwidth. Although it may not necessarily increase the bandwidth in the entire design, the results have shown that the replacing of elliptical patch with rectangular patch, have considerably improved VSWR due to the curvature of the corners. As we can see that the VSWR parameter is less than 2 from the initial frequency we designed (2.3 GHz) to the final frequency (6 GHz), which in this matter, can be considered ideal. Also In frequency with the proper directivity and high gain, the replacement of elliptical patch improves patterns and reduces annoying side lobes and patterns are becoming sharper. Finally we can say if the design using appropriate materials and frequency proportional to its, elliptical patch can be improve the expected results in most parameters in the designed frequency.

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