SIMULATION STUDY ON H-SHAPED LOG PERIODIC MICROSTRIP ANTENNA ARRAY

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Abstract:

In this paper, the simulation study on a new wideband log-periodically scaled H-shaped microstrip patch antenna array is presented. The simulation has been done using Ansoft High Frequency Structure Simulator (HFSS). The input characteristics of the antenna such as return loss and input impedance have been investigated and the results are compared with a single element rectangular and H-shaped microstrip antennas. The simulated results for radiation pattern and gain of the proposed antenna are also presented.

Key words: Log periodic antenna, Return loss, MSA and radiation pattern.

Introduction

The need for antennas to cover wide bandwidth is of continuing importance, particularly in the field of electronic warfare and wideband radar and measuring systems. Although microstrip patch antennas have many enviable features like simple printed circuit structure, planar profile, light weight and low cost but they generally suffer from limited bandwidth. So the most important disadvantage of microstrip resonator antennas is their narrow bandwidth. To overcome this problem without disturbing their principal advantages, a number of methods and structures have recently been investigated. In this regard mention may be made of multilayer structures [1, 2], broad folded flat dipoles [3], curved line and spiral antennas [4], impedance matched resonator antennas [5,6], resonator antennas with capacitive coupled parasitic patch element [7], log periodic structures [8, 9], modified shaped patch antenna like H-shaped [10] and by using proximity coupling [11]. The H-shaped microstrip patch antenna could replace the rectangular patch at UHF frequencies because of its considerably smaller size. When applied in the frequency range below 2 GHz, the size of conventional rectangular microstrip patches seem to be too large.

In the present paper, for the sake of antenna miniaturisation and bandwidth improvement, H-shaped patch is used instead of rectangular patch, and for further enhancement in bandwidth log periodic technique is applied with five resonating elements. This paper covers three aspects of microstrip antenna design. The first is the analysis and design of single element rectangular microstrip antenna which operates at the central frequency of 3.35 GHz. The second aspect is the design of slot cut H-shaped microstrip antenna, and the third is the design of five element broadband log periodic microstrip antenna. The radiating elements are series fed by a simple coplanar microstrip network. This network consists of an open-circuited feed line with branch lines connected to each radiating element. The feed and antenna elements have been modelled, designed and simulated. Basically, transmission line modelling approach is used to model the antennas.

Design of Rectangular Microstrip Patch Antenna

Consider Figure 1 below, which shows a rectangular microstrip patch antenna of length L, width W resting on a substrate of height h. The co-ordinate axes are selected such that the length is along the x direction, width is along the y direction and the height is along the *z* direction.

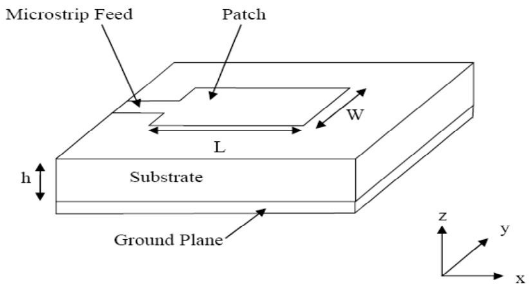

Fig. 1. Microstrip patch antenna

A single element of rectangular patch antenna, as shown in Figure 2, can be designed for the 3.3 GHz resonant frequency using transmission line model [12].

Length L of the patch is given by

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{re}\sqrt{\mu_0\epsilon_0}}} - 2\Delta L \qquad (1)$$

where ΔL is the effective cutback on each side given by

$$\Delta L = 0.412h\frac{\varepsilon_{re}+0.30}{\varepsilon_{re}-0.258}\left(\frac{W/h+0.264}{W/h+o.813}\right)$$

(2)

and ε_{re} is the effective dielectric constant given by

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-0.5} \quad (3)$$

Width of the patch W is given by

$$W = \frac{c}{2f_r}\left(\frac{\varepsilon_r + 1}{2}\right)^{-0.5} \quad (4)$$

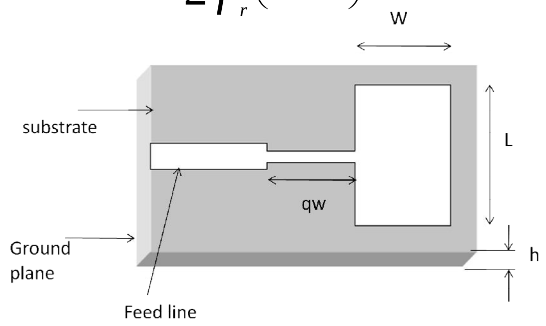

Fig. 2 Typical rectangular patch antenna

Here glass epoxy dielectric material (ε_r =4.5) is selected as the substrate with height of 1.6 mm. Then, a patch antenna that operates at the specified resonant frequency (3.35 GHz) can be designed by using transmission line model equations (1)-(4).

As shown in Figure 2, microstrip line feeding mechanism is used. The characteristic impedance of main feed line is 50 Ω. The quarter wave length long line is used between main feed line and patch for impedance matching. The characteristic impedance of branch line is calculated as

$$Z_{\lambda/4} = \sqrt{Z_0 Z_e}$$

where Z_0 is the characteristic impedance of main feed line (=50 Ω)

Z_e – impedance at the patch edge

So the calculated parameters of rectangular microstrip patch antenna are

Resonating frequency f_r = 3.3 GHz
Patch width W = 27.8 mm
Patch length L = 21.42 mm
Branch line length qw = 11 mm
Substrate height h = 1.6 mm
Relative permittivity ε_r = 4.5
Width of main feed line = 3 mm

Design of an H-shaped MSA

The H-shaped microstrip antenna [10] consists of an H-shaped patch supported on a grounded dielectric sheet of thickness 'h' and dielectric constant 'ε_r'. An H-shaped microstrip patch antenna, shown in Figure 3 is obtained by cutting equal rectangular slots along both the non-radiating edges of the rectangular MSA. The H-shaped patch antenna reported here has a size about half that of the rectangular patch.

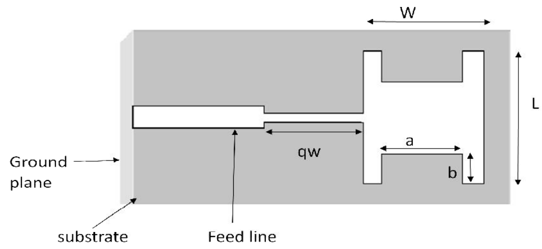

Fig. 3 H-shaped patch antennas

Design parameters of H-shaped patch antenna at resonant frequency of 3.3 GHz are as follows:
L = 14.1mm; W = 18.6mm;
The chosen substrate is glass epoxy having relative permittivity ε_r = 4.5 and height h = 1.6 mm.
Branch line length (qw) = 13mm
Rectangular slot dimensions (a×b) = 9.6 × 4.3 mm^2.

Design of Five Element H-shaped Log Periodic MSA

The five element log periodic MSA is designed for further improvement in the bandwidth of MSA. The series feed has been used MSA. Design parameters of the log periodic MSA for five different resonating frequencies given in Table 1 are calculated using transmission line model and a constant scale factor ($\zeta = \frac{f_i}{f_{i+1}}$) of 0.93. The branch lines are dimensioned as quarter wave transformers between the appropriate antenna element and 50 Ω main feed line. The positions of branch lines are determined in such a way that the distance to the open end equals a whole number of half wavelengths at the appropriate resonant frequency. The positions of branch lines are determined so that the distance to the open end equals a whole number of half wavelength at the respective resonant frequency. This design based on the consideration that the input impedance of particular resonant element transformed into 50 ohm while the input impedance of other elements and the open circuit at the feed end should be transformed into very high impedance and thus would virtually present no load to the main line. Slot dimensions in every rectangular patch and branch line length are optimized. Thus, dimensions of log periodic microstrip antenna whose dimensions of patch length (L), width (W), and spacing distance (d) is related to the factor ζ as follows:

$$\frac{d_{n+1}}{d_n} = \frac{w_{n+1}}{w_n} = \frac{l_{n+1}}{l_n} = \zeta$$

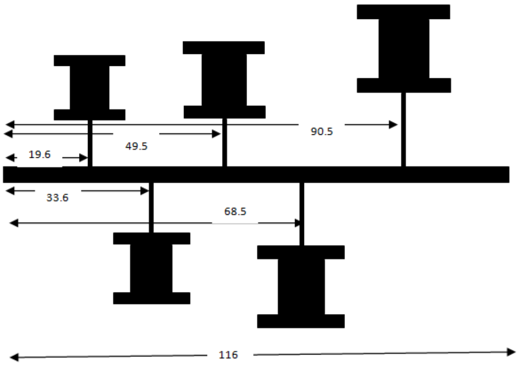

Fig. 4 Layout of five element log periodic MSA

Table 1 Designing parameters for five element log periodic MSA

Patch No.	Resonant freq. (f_r) GHz	Width (W) (mm)	Length (L) (mm)	Slot dimension (mm×mm)	Branch line length (mm)
1.	3.13	21.29	16.23	11.0×4.9	11.33
2.	3.35	19.9	15.14	10.27×4.6	10.58
3.	3.58	18.6	14.1	9.6×4.3	9.89
4.	3.83	17.39	13.11	8.97×4.02	9.24
5.	4.09	16.26	12.2	8.38×3.76	8.64

Results and Discussion

I. Return loss vs. frequency curve

The simulated results for return loss of single element rectangular and H-shaped microstrip antennas, alongwith five element log periodic microstrip antenna using H-shaped patches are presented in Figures 5 -7 respectively.

From Figure 5, it can be seen that the rectangular antenna resonates at 3.35 GHz and has -10 dB bandwidth of 120 MHz (the operating frequency range 3.42 GHz - 3.3 GHz). In percentage, the bandwidth of the antenna is 3.5%.

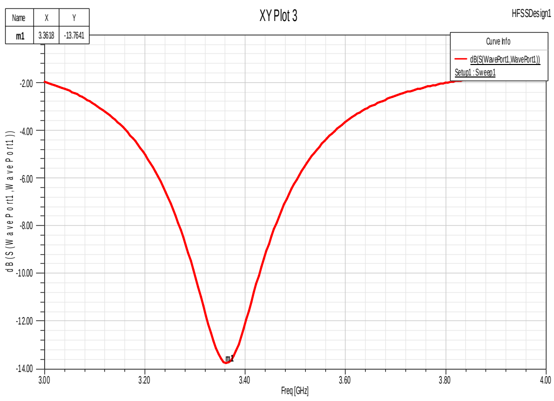

Fig. 5 Return loss of rectangular MSA

From Figure 6, it can be seen that the resonant frequency and -10 dB bandwidth are 3.35 GHz and 320 MHz (the operating frequency range 3.52 GHz - 3.2 GHz) respectively. In percentage, the bandwidth of the antenna is 9.5%. The H-shaped patch antenna has larger bandwidth as compared with the rectangular patch antenna. This is because of the reduction in quality factor (Q) of the patch resonator, which is due to less energy being stored beneath the patch.

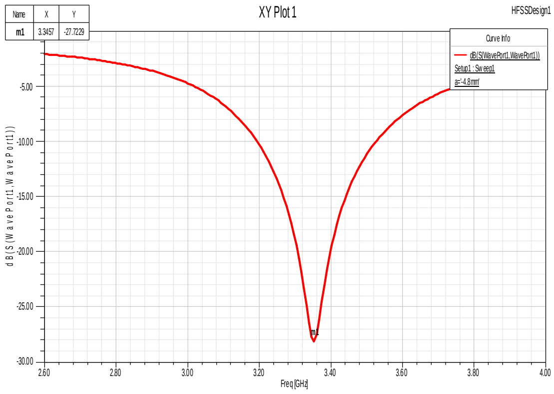

Fig. 6 Return loss of H-shaped MSA

From Figure 7, it can be found that the resonant frequency and -10 dB bandwidth are 3.55 GHz and 1.2 GHz respectively (the operating frequency range 4.32 GHz -3.12 GHz). The percentage bandwidth of the antenna is 33.8%.

The simulation results for VSWR of log periodic MSA for the frequency range from 3 to 4.5 GHz is shown in Figure 8. The VSWR bandwidth, which is the frequency range in which VSWR remains below 2 is found to be 33.8%.

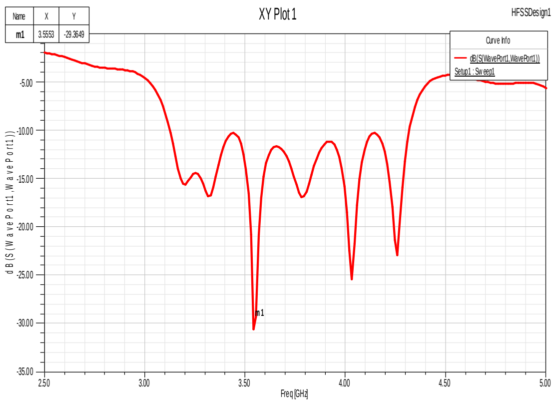

Fig. 7 Return loss of five element log periodic MSA

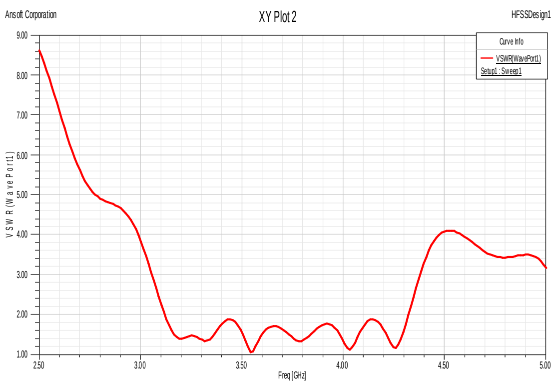

Fig. 8 VSWR of five element log periodic MSA

II. Comparison of Return Loss Values

Figure 9 and Table 2 compare the bandwidths of rectangular, H-shaped and log periodic MSAs.

From Figure 9 and Table 2, it can be inferred that five element log periodic MSA provides higher bandwidth in comparison to single element rectangular and H-shaped microstrip antennas.

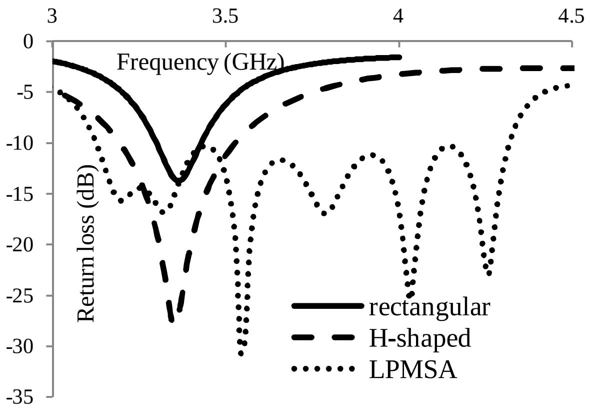

Fig. 9 Return loss comparison

Table 2 Antenna parameter comparison

Antenna Type	Bandwidth (%)	Resonant Frequency (GHz)	Operating Frequency Range (GHz)
Rectangular patch MSA	4.5 %	3.35	3.42-3.3
Slot cut H-shaped MSA	9.5%	3.35	3.52- 3.2
Five element log periodic MSA	33.8 %	3.55	4.32-3.12

III. Input Impedance vs. Frequency Characteristics

The input impedance versus frequency plot of log periodic MSA is shown in Figure 10. At the resonant frequency of 3.55 GHz imaginary part of input impedance is zero and the input resistance is 50 Ω, which means that there is good impedance matching between the feed network and antenna at the resonant frequency.

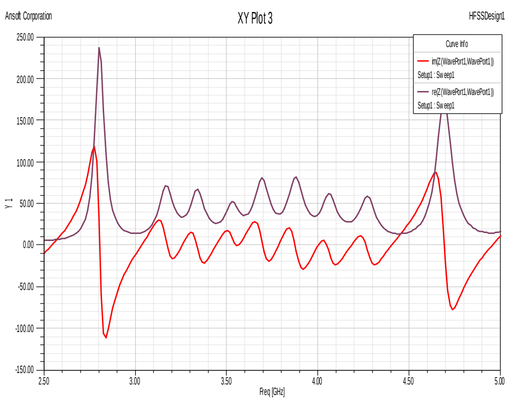

Fig. 10 Input impedance of log periodic MSA

IV. Radiation Pattern

Figure 11 shows the simulated radiation pattern of the five element log periodic MSA at 3.55 GHz. The simulation has been done using Ansoft High Frequency Structure Simulator. The simulated half-power beamwidths (HPBWs) of the antenna in H and E-planes are respectively. The simulated first side lobe levels in these planes are respectively. The simulated gain and directivity values are 3.32 dBi and 5.432 dBi respectively.

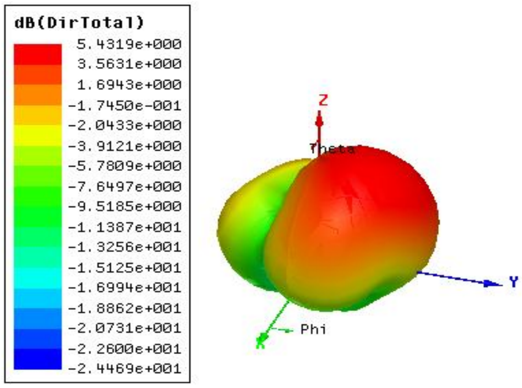

Fig.11 3D Far Field Pattern of five element log periodic MSA

Conclusion

In this paper, rectangular and H-shaped microstrip antennas alongwith five element log periodic microstrip antenna have been studied through simulation using Ansoft High Frequency Structure Simulator (HFSS) and their return loss compared with each other. It has been observed from the study that five element H-shaped patch log periodic microstrip antenna provides wider bandwidth (ten times) in comparison to rectangular microstrip antenna. The simulation results have shown that H-shaped microstrip antenna produced reduction in size and higher bandwidth (9.5%) in comparison to rectangular microstrip antenna (3.5%) for the same resonating frequency. The log periodic antenna provides nearly omni-directional pattern with reasonable gain which can be suitable for application in wireless communication.

REFERENCES

[1]. Hall, P. S. Wood, C and Garrett, C, “Wide bandwidth microstrip antennas for circuit integration”, Electron. Lett. , 15, pp. 458-460, 1979.

[2]. A. Henderson, J. R. James and C. M. Hall, “Bandwidth extension techniques in printed conformal antennas,” Military Microwaves, Vol. MM 86, pp.329-334, 1986.

[3]. Dubost, G., Nicolas, M. and Havot, H. “Theory an applications of broadband microstrip antennas”, Proceedings of the 6th European Microwave Conference, Rome, pp. 21S—219, 1976.

[4]. Wood, C, “Curved microstrip lines as compact wideband circularly polarised antennas”, IEE J. Microwaves, Opt. & Acoust, 3, pp. 5-13, 1979.

[5]. Van De Capelle, A., De Bruyne J., Verstraete, M., Pues, H. and Vandensande J. “Microstrip spiral antennas”, Proceedings of the International IEEE Symposium on Antennas and Propagation, Seattle, pp. 383-386, 1979.

[6]. H. F. Pues and A. R. Van de Capelle, “An impedance matching technique for increasing the bandwidth of microstrip antennas,” IEEE Trans. Antenna Propagat., Vol. AP-37, No.11, pp.1345-1354, November 1989.
[7]. Pues H. F. and Van De Capelle A. R. “Impedance-matching of microstrip resonator antennas” Proceedings of the North American Radio Science Meeting, Quebec, p. 189, 1980.
[8]. H. Pues, Ir., J. Bogaers, Ir., R. Pieck, Ir. and A. Van de Capelle, Dr. Ir. “Wideband quasi-log-periodic microstrip antenna”, IEE PROC, Vol. 128, Pt. H, No. 3, , pp. 159-163, June 1981.
[9]. V. B. Romodin, V. I. Oznobikhin and V. V. Kopylov, “Log Periodic Microstrip Array”, IEEE - Russia Conference, Mia-Mep 9, 1999.
[10]. Ravi Kant and D.C.Dhubkarya, “Design & Analysis of H-Shape Microstrip Patch Antenna”, publication in the “Global Journal of Research in Engineering”, Vol. 10 Issue 6 (Ver 1.0), pp. 26-29, Nov. 2010.
[11]. D. M. Pozar and B. Kauffman, “Increasing the bandwidth of a microstrip antenna by proximity coupling,” Electronic Letters, Vol. 23, pp. 368-369,April 1987.
[12]. Dearnley, R.W., “A broad-band transmission line model for a rectangular microstrip antenna”, Antennas and Propagation, IEEE Transactions volume 37, pp 6-15, jan 1989.