# Size Reduction of Log Periodic Microstrip Patch Antenna using Artificial Magnetic Conductor-A Review

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*Abstract*—This paper describes the technique of size reduction of log periodic microstrip antenna with the help of AMC (Artificial Magnetic Conductor).Log periodic antenna presented in this paper operating over ISM band, but it suffers from large antenna size. To reduce the size of this antenna AMC technique is used as ground plane.

**Keywords**: Log periodic antenna, microstrip antenna, Artificial Magnetic Conductor

## I. INTRODUCTION

The invention of microstrip patch technology has helped greatly to reduce the size of an antenna, which in turn allows the reduction of the size of wireless communication devices. Due to the low-cost in manufacturing process and compact in physical size, recently a microstrip patch antenna is one of antenna types commonly used for communication devices. Although it has many advantages such as low cost, low weight, low profile and ease for fabrication, in general microstrip patch antenna is almost accompanied with several limitations, such as having narrow bandwidth and low gain [1]-[2]. Because of its widely used for wireless communication systems, researches and developments related to the microstrip patch antenna and its applications have been conducted all across the world, not only to overcome these limitations but also to further increase its strength, namely to lower the manufacturing cost and to further reduce the size [3]-[5].

There have been many studies conducted about techniques to minimize the size of an antenna patch needed for a given resonant frequency, or often called patch miniaturization. One proposed method is to use metamaterials as ground plane [4]-[5]. In [5], the use of metamaterials can reduce the patch size and its total antenna dimension up to 65% compared to the conventional microstrip patch antenna.

## II. AN OVERVIEW OF AMC

The artificial magnetic conductor (AMC) also knows as high impedance surface (HIS) is a structure that has a distinct property regarding its reflection phase. Hence, reflection phase is the phase of reflected electric field on a surface relative to the incident phase. As is well-known, a perfect electric conductor (PEC) is a material that can exhibit 180 degree reflection phase. The theoretical opposite of PEC called as a perfect magnetic conductor (PMC) defined as a material that is naturally unavailable and can exhibit zero degree reflection phases relative to the incident wave. The AMC which is known as a material that can exhibit zero degree reflection properties within a certain narrow frequency band is a physical approximation of PMC [6]-[7].

Implementation of an AMC structure can be realized by using a periodic structure. Further, it can also be implemented by printing over a grounded substrate a doubly periodic array of printed metallic patch elements. Recently, the advent of the structure has opened up new possible applications such as antennas, reflectors, and radar absorbers. In this paper, the AMC structure will be deployed by use of a textured HIS in form of a doubly periodic array of square patches placed symmetrically on the upper side of a grounded substrate. The patches are separated each other by specifying outer gaps width and separated with the edge of substrate by specifying inner gaps width.

In most situations, Conventional ground planes adversely affect the performance of electromagnetic devices particularly for radio communication. Though they can be used as reflectors but they suffer from problems like (1) Phase reversal of reflected waves (2) Propagating surface waves. Both of which deteriorate the antenna performance. Thus, artificial magnetic conductors (also called high impedance ground planes) gained a sufficient attention in recent years and have emerged as an intelligent option. Dan F. Sievenpiper in 1999 introduced the concept of AMC by texturing the conductive surface with a special geometry, thus varying its electromagnetic properties [8]. Thus, an AMC can be typified as an electromagnetic band gap material or artificially engineered material with a magnetic conductor surface for working in a specified frequency band. Thus, AMC structures can be fabricated based on periodic dielectric substrates and various metallization patterns [8] [9] [10]. Several types of AMC ground planes have been extensively studied.

### A. *Geometry*

Figure 1, shows a high impedance surface which consists of array of metal protrusions on a flat metal sheet.

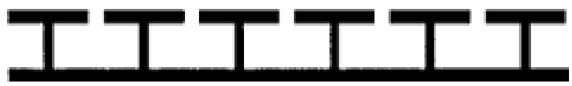

Fig. 1: side view of artificial magnetic conductor surface

The surface can be realized using printed circuit board technology, in which the vertical connections are formed by metal plated vias (vertical interconnect access) which connect the metal plates on the top surface of the structure to a solid conducting ground plane on the bottom surface.

All the metal elements arranged in a two dimensional lattice structure can be viewed as mushrooms or thumbtacks protruding from the flat metal surface. Top view is shown in Figure 2.

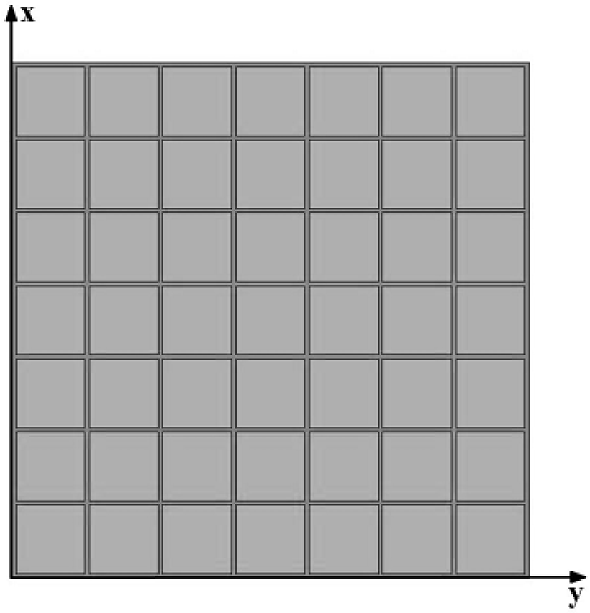


Fig. 2: Top view of the high-impedance surface

### B. The Effective Medium Model

The properties of high impedance surface can be described with the help of effective medium model. The surface impedance of the structure is made equal to that of a parallel resonant LC circuit. As the construction of textured surfaces is done in such a way that geometrical features are much smaller in comparison to wavelength or in other words, wavelength is longer than the size of individual features, thus the electromagnetic structure can be described using lumped parameters. When the voltage is applied parallel to the surface; building up of charges takes place at the ends of the top metal plates.

This is nothing but capacitance. In response to the varying radio – frequency field, the charges move back and forth. The charges flow around a long path though the vias and the bottom metal surface. Thus, a magnetic field is associated with these currents and with that is associated an

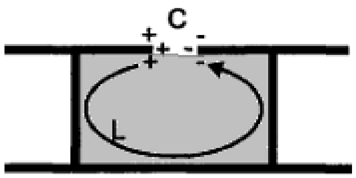


Fig. 3: Origin of the capacitance and inductance in the effective medium model

inductance. From the figure, it can be concluded that the structure acts as a kind of two dimensional electric filters to prevent the propagation of currents along the surface. Near the LC resonance frequency, the structure exhibits high surface impedance. The tangential electric field at the surface is finite, while the tangential magnetic field is zero. Also the electromagnetic waves are reflected without any phase reversal that otherwise occurs on a flat metal sheet. Hence, in this frequency range, the structure is often called a ―magnetic conductor‖. Thus reflection phase can be calculated with the help of effective medium model. Usually at low frequencies, the reflection phase is Π, as it is on a flat metal surface. Then, near the resonance frequency where the surface impedance is high; the reflection phase crosses through zero. However at higher frequencies the phase approaches – Π.

## III. DESIGN SPECIFICATIONS

Design of the modern microwave communication systems and off board equipment for air craft and ship EW/ECM needs for proper technical solutions of small-size broadband antennas. Microwave front often contain in small cylindrical volumes, so the main goals in antenna design are low profile, small weight and high reliability of parameter in desired frequency band.

LOG-periodic dipole array (LPDA) antennas used in broadband applications can achieve high directivity and low cross-polarization ratio over a very large frequency range. Such wideband antennas have typically been constructed using radiating element. In application space and weight is restricted, antennas need to be light-weight and to have small physical size and increase frequency.

The design principle for log-periodic antenna requires scaling of dimensions for period to period so that performance is periodic with the logarithm of frequency. This principle can be applied to an array of patch antennas [1]. The patch length (L), the width (W) is related to the scale factor (τ).

$$\tau = \frac{L_{n+1}}{L_n} = \frac{W_{n+1}}{W_n}$$

If we multiply all the dimensions of the array by τ it scales into itself with element n becoming element n+1, element n+1 becomes n+2 and so on. The self-scaling property implies that the array will have the same radiating properties at all frequencies that are related by a factor of τ.

$$f_1, f_2 = \tau f_1, f_3 = \tau^2 f_1, etc$$

The various relations for square patch antenna is,

$$f_r = \frac{c}{2(L + 2\Delta L)\sqrt{\epsilon_{eff}}}$$

Where, c is the velocity of light.

$$\Delta L = 0.412h \frac{(\epsilon_{eff} + 0.3)[\frac{W}{h} + 0.264]}{(\epsilon_{eff} - 0.3)[\frac{W}{h} + 0.8]}$$

$$\epsilon_{eff} = \frac{(\epsilon_r + 1)}{2} + \frac{(\epsilon_r - 1)}{2}[1 + 12\frac{h}{W}]^{-\frac{1}{2}}$$

For efficient radiation, the width W is

$$W = \frac{c}{2f_r\sqrt{\frac{(\epsilon_r + 1)}{2}}}$$

For a given resonance frequency, the effective length is

$$L_{eff} = \frac{c}{2f_r\sqrt{\epsilon_{eff}}}$$

$$L = L_{eff} - 2\Delta L$$

 

Where,

$\varepsilon_{reff}$ = Effective dielectric constant
$\varepsilon_r$ = Dielectric constant of substrate
h = Height of dielectric substrate
W = Width of the patch

## IV. CALCULATED PARAMETERS

Calculation of design parameter for square patch microstrip log-periodic antenna is shown in table 1. The substrate used with dielectric constant of 2.1 and height of 4.03mm. The scaling factor τ = 1.24 the loss tangent of material is .0001. The feeding of an antenna is microstrip line feeding of 6 mm width. The design consideration of proposed geometry (in Fig.1) is shown in table-1.

| Patch | Width W=L (in mm) |
|---|---|
| 1 | 7.56 |
| 2 | 9.37 |
| 3 | 11.62 |
| 4 | 14.41 |
| 5 | 17.87 |
| 6 | 22.16 |
| 7 | 27.48 |
| 8 | 34.07 |
| 9 | 42.25 |

Table. 1: Calculated parameters of LPMA

Calculations of reduced size log periodic microstrip antenna using AMC is shown in table 2. The substrate used with dielectric constant of 2.1 and height of 1.515mm the ground plane with AMC with height 1.515mm and the AMC unit cells of 7mm. The scaling factor τ = 1.24 the loss tangent of material is .0001. The feeding of an antenna is microstrip line feeding of 6 mm width. The design consideration of proposed geometry (in Fig.2) is shown in table-2

| Patch | Width W=L (in mm) |
|---|---|
| 1 | 4.89 |
| 2 | 6.06 |
| 3 | 7.51 |
| 4 | 9.31 |
| 5 | 11.54 |
| 6 | 14.31 |
| 7 | 17.74 |
| 8 | 22 |
| 9 | 27.28 |

Table. 2: Calculated parameters of LPMA with AMC

## V. DESIGN IN HFSS

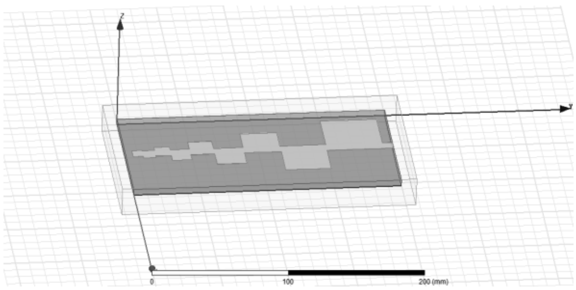

Fig. 3: Log periodic microstrip antenna

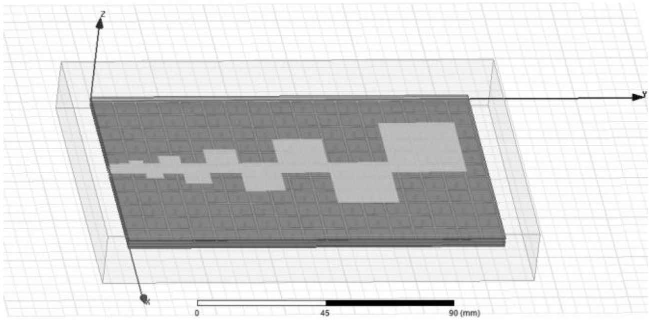

Fig. 4: Log periodic microstrip antenna with AMC

## VI. RESULTS

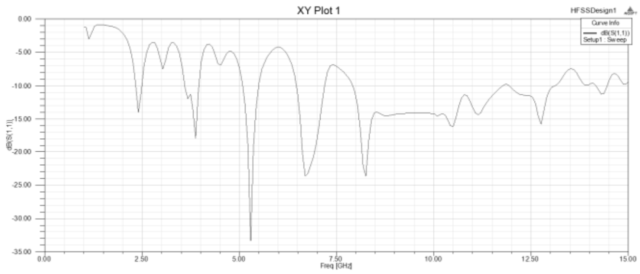


Fig. 5: Return loss of LPMA

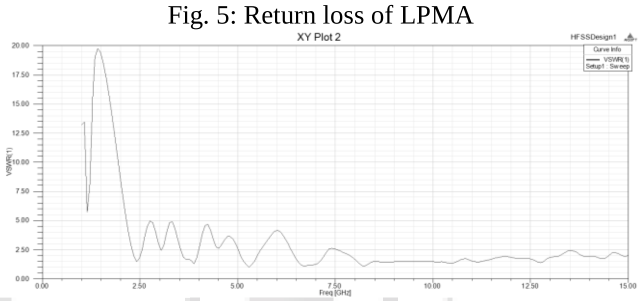


Fig. 6: VSWR of LPMA

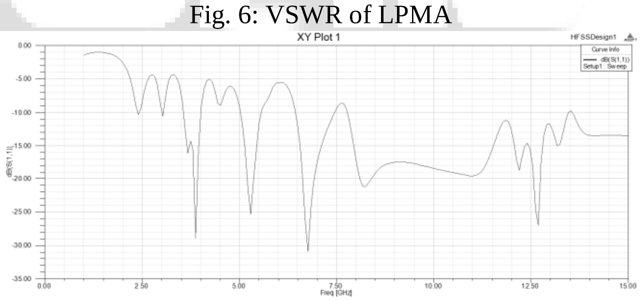


Fig. 7: Return loss of LPMA with AMC

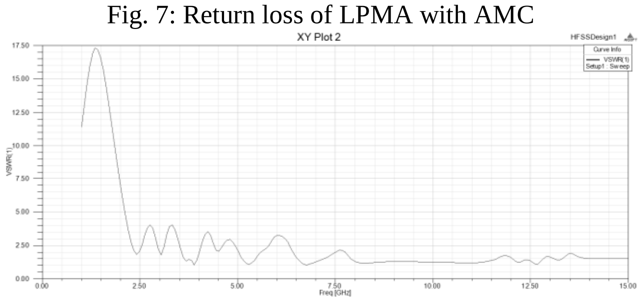


Fig. 8: VSWR of LPMA with AMC.

Here figure 5 and 6 showes the Returnloss and VSWR of log periodic microstrip patch antenna without Artificial magnetic conductor. While figure 7 and 8 showes the results of Returnloss and VSWR of log periodic microstrip patch antenna with Artificial magnetic conductor as ground plane. Design 1 covers the frequency range from 2.45 GHz to 13.69 GHz. Design 2 also covers this range but with AMC and with size reduction.

## VII. CONCLUSION

The performance of log periodic antenna is better than single patch antenna. The antenna shown in this paper covers the frequency range from 2.45 GHz to 13.69 GHz.

Also Artificial magnetic conductor technique used as a ground plane in this design helps to reduce the size of proposed antenna the patch size can be reduced up to 31% of actual antenna size.

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