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Design of Four Arm Log Periodic Antenna for MIMO Applications

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ABSTRACT: The log-periodic antennas are very effectively useful to achieve large bandwidth. The planar log-periodic antennas are having advantage of getting large bandwidth with careful design of impedance matching. The chebyshev impedance matching is one of the techniques to provide feed for the antenna followed by impedance matching. In This paper the log-periodic antenna is designed with chebyshev impedance matching technique. The four arm log-periodic antenna is designed for the both linear and circular polarization. The antenna gives circular polarization when the 90^0 phase delay applied between the two dipoles. The antenna is operated at 3GHz gives the band of operation up to k/ka band from 2GHz. The antenna is designed and simulated by using HFSS software, the VSWR, S_{11} and axial ratio plots are generated from 2GHz to 18GHz.

KEYWORDS: Log-Periodic, phase delay, circular polarization, impedance matching.

I. INTRODUCTION

Wideband antennas are mostly designed by using angles rather than lengths, because wavelengths are not depending on angles and these are frequency independent antennas. Frequency independent antennas have consistent far field and impedance properties [1]. Log-periodic antennas are designed for specific purpose to fulfill the large bandwidth requirement. The beginning research of Log-periodic antennas or frequency independent antennas are started in 1957at the university of Illinais by D.U.Hamal and Isbell [2]. With the proper design of these antennas a bandwidth of 10:1 can be obtained.

The multi input multi output antenna systems offers high channel capacities in a multipath propagation [3]. The application of MIMO systems with high data rates is possible by using wide bandwidth antennas. The log-periodic antenna is designed to provide wide bands (2GHz -18GHz) in both linear and circular polarizations.

The antennas described in this paper embody three basic design principles. The first of these is the "angle" concept which is a design approach wherein the geometry of the antenna structure is described, so far as is practical, by angles rather than lengths[4]. The second principle makes use of the fact that the input impedance of an antenna identical to its complement is independent of frequency. The third consists of designing the antenna structure such that its electrical properties repeat periodically with the logarithm of the frequency.

The design of this log periodic antenna is started with some considerations as in the Isbell antenna. That is upper frequency, Lower frequency and the number of elements. According to the considerations the periodic constant (τ) can calculate.

The Log-periodic antenna is a frequency independent antenna s well as self-complimentary antenna. The self-complementary is the physical property is obtained only when the $\alpha+\beta=45^o$. So that the angles α and β are chosen carefully. Actually the antenna propagation is depends on the length of the teeth or β angle. But the antenna does not depend on the boom angle α. So the angle α is depends on the angle β, but never tolerate the condition of self-complementary.

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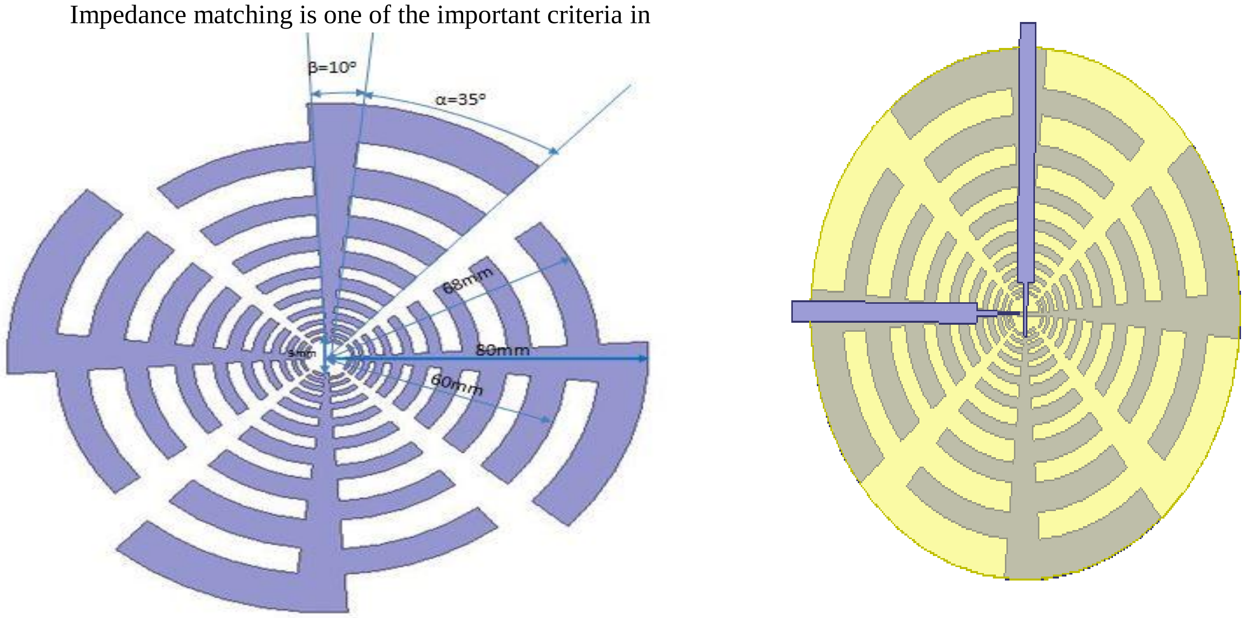
II. LOG-PERIODIC ANTENNA DESIGN

The actual bandwidth depends on how large and smaller the features of the antennas dimensions. The 160mm diameter antenna is designed on FR4 substrate with ε_r of 4.4 with a thickness of 1.6mm in a circular fashion. The geometry of four arm log-periodic antenna was shown in Fig.1.The antenna is designed with 19 radiators and also called as teethes of the antenna which radiates when the length is equal to quarter wavelength. The apex angle is of 35^0 and boom angle is of 10^0. This antenna is designed and simulated in HFSS 14.0 software.

Fig.1. Log-Periodic antenna designed in HFSS software, (a) Top View and (b) Bottom view.

III. IMPEDANCE MATCHING



(a) (b)

Impedance matching is one of the important criteria in frequency independent antennas. The nominal impedance of a single arm of antenna is 90Ω, such that for the two arm log periodic antenna it can be 180Ω. The two arm antenna size is very high when compared to two arms of a four arm log periodic antenna and the expected impedance is in the order of 133Ω [1] the input impedance line is of 50Ω, so it requires a matching network to match the antenna impedance to input impedance. Here the three section chebyshev impedance transformer is designed between near center feed to input feed line. The impedance transformer is designed by using three micro strip lines having different lengths and widths.

Here it requires two matching networks to feed the four arms simultaneously with the 'T' shape and is called as T shaped matched network. This can be designed by using HFSS software with common source gives the sufficient measurements of VSWR and Far-Field parameters.

In order to simplify the external beam former and make the antenna bidirectional, a microstrip line matching network is integrated to the aperture. The matching network not only transforms the nominal impedance of the LP to 50Ω but also functions as a balun, thereby simplifying the external beam former to a single 90^o hybrid for dual-CP use.

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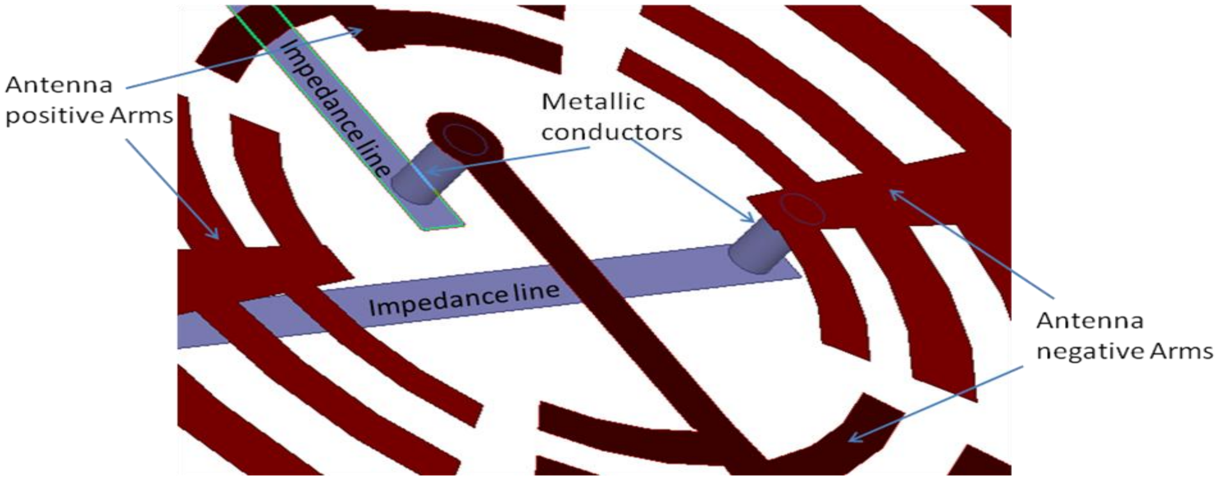

Fig.2. Feed the antenna with impedance transformer

Each pair of arms is fed with impedance transforming microstrip line where the boom of one arm acts as the ground plane and the signal line is attached to the opposite arm near the centre with a metal via (this can be seen in the close up of the feed region). Thus, the 4-arm LP aperture now has two inputs which are excited with appropriate phases for dual-CP shown in Fig.2.

IV. CIRCULAR POLARIZATION

There are several ways for creating circular polarization for both radiating and receiving. The antenna type is an important factor when applying the circular polarization. Basically log-periodic antenna is a dipole kind of antenna. So the circular polarization can be achieved by using the crossed dipole method.

Crossed Dipole methods:

In this method circular polarization is achieved from the linear polarized antenna. In this method the dipoles are arranged in a cross with the antenna having the same center point but their axes at right angles to each others. The connection between these crossed dipoles is the major role while achieving the circular polarization. The feed points are from only one transmission line but the phase delay between them is 90^o. Initially the two dipoles are radiated with linear polarization. The linear polarized waves with 90^o phase delay combination gives circular polarization. This is the principal method to produce circular polarization. Initially it generates bidirectional and can be converted into unidirectional by placing some reflectors at the bottom side of the antenna. This arrangement is known as turnstile antenna.

Another way to produce circular polarization is by providing individual feeds and maintaining 90^o phase delay between them. In circular polarization there are two kinds: left hand circular polarization (LHCP) and right hand circular polarization (RHCP). They are generated by simply lag or lead of phase delay between two dipoles.

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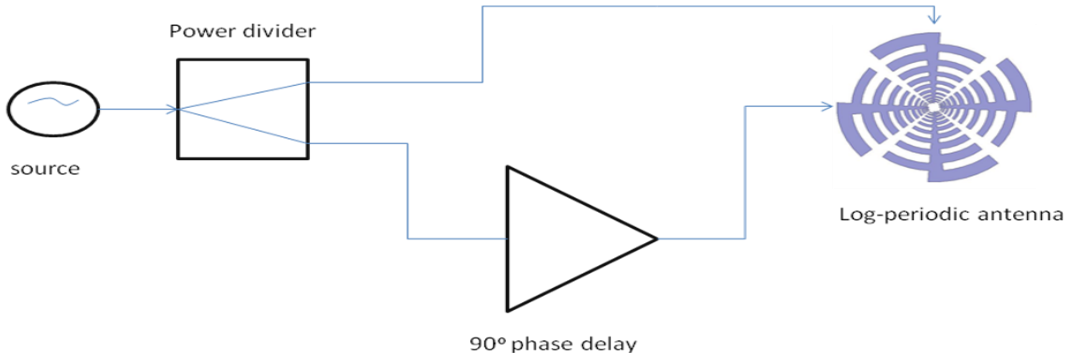

Fig.3. Network for the antenna to provide Circular Polarization

V. SIMULATION RESULTS

The near field results are measured within the radiation box. The near field results are characterized by using Return Loss (S_{11}) and VSWR plots with reference to the frequency scale and as shown in the Fig.4 and Fig.5 respectively. These results are showing that the antenna is operating in the band of 2-18GHz and can be extended up to K/Ka band at the operating frequency of 3GHz

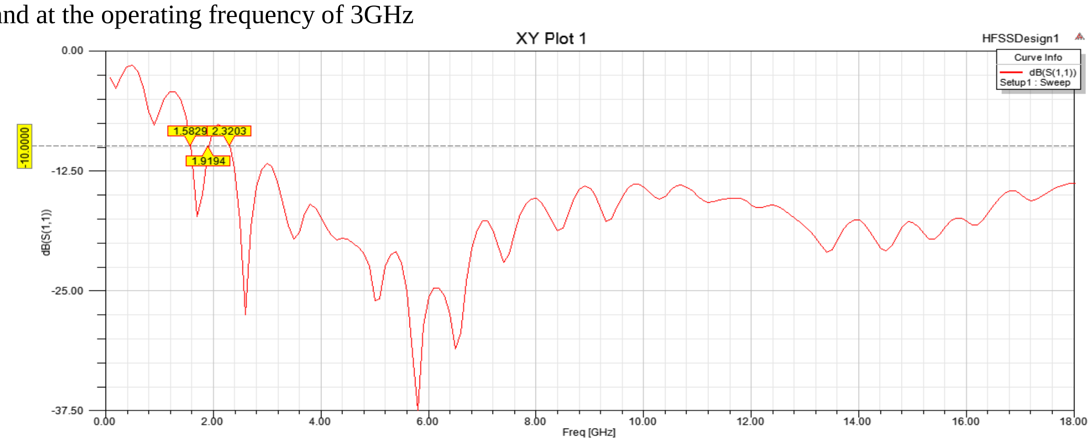

Fig.4 Variation of Return loss for S_{11} with Frequency (GHz) at 3GHz operating Frequency

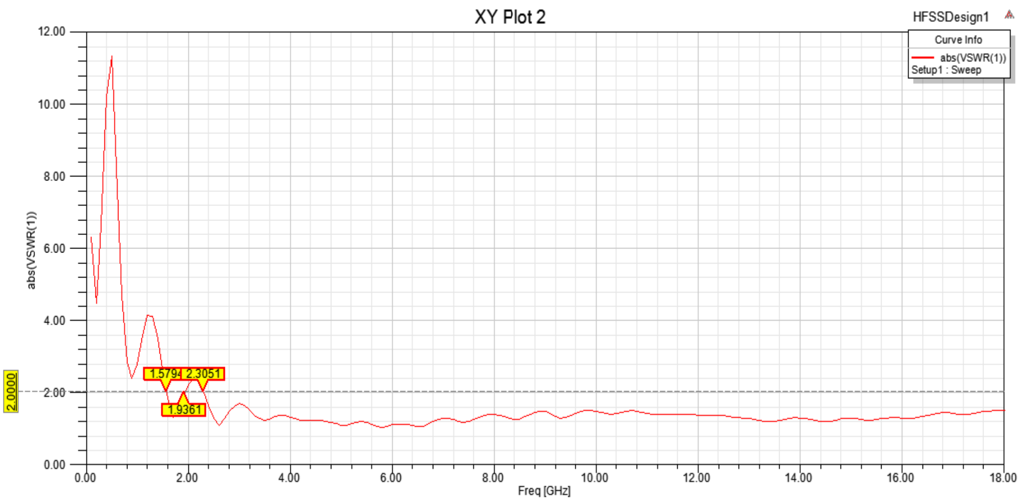

Fig.5 Variation of VSWR for VSWR with Frequency (GHz) at 3GHz operating Frequency

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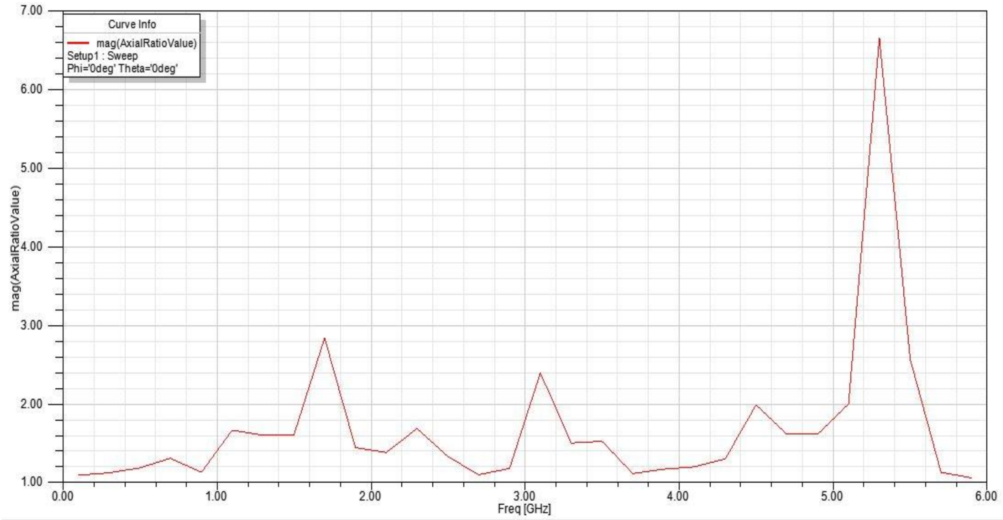

Fig.6. Axial ratio of log-periodic antenna at 3GHz

From the Fig.4 and Fig.5, it is clearly observed that the antenna is operated effectively at the 3GHz operating frequency. And it provides large Bandwidth about 10:1. Fig.4 shows the amount of power is reflecting back to the antenna with respect to the amount of power radiating. As per the standards the S_{11} values must be less than the -10dB and VSWR values are between 1 and 2, then the antenna is said to be working properly. Here the above plots are truly satisfied that the standards. From Fig.6 the antenna is said to be either linearly polarized or circularly polarized by observing the plots. The value of the axial ratio is in between 1 to 5 then the antenna is in circular polarization.

VI. CONCLUSION

The parameters of log-periodic antenna are analyzed by using the concept of Isbell antenna. The Antenna analysis is done to operate the antenna at the operation frequency of 3GHz, and the band of operation is between 2GHz to 18GHZ (up to K-Band). The two arm log-periodic and four arm log-periodic antennas are designed and simulated by using High Frequency Structured Simulator (HFSS) software. The circular polarization is achieved for the log-periodic antenna by using Cross Dipole Concept. The Near and Far Field characteristics (S_{11}, VSWR and Radiation Patterns) are simulated, which Shows the antenna is operating between 2GHz to 18GHz. The impedance matching is provided by 3-section chebyshev impedance matching transformer. This antenna provides very higher bandwidths, which is useful for the higher data rates and provides effective channel capacity. So these antennas are applicable for the MIMO applications like defense, aero space technology, mobile communication devises and satellite communication devices.

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