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Log Periodic Implementation of Circular Patch Antenna for K-band Applications

Amiya Kumar Gupta
Assistant Professor
Deptt. of Electronics & Comm. Engineering,
Gandhi Institute of Engineering & Technology,
Gunupur, Rayagada, India

B Dev Kumar*
B. Tech.
Deptt. of Electronics & Comm. Engineering,
Gandhi Institute of Engineering & Technology,
Gunupur, Rayagada, India

Biswajita Swain
B. Tech.
Deptt. of Electronics & Comm. Engineering
Gandhi Institute of Engineering & Technology
Gunupur, Rayagada, India

Abstract

Paper demonstrates the study of circular micro-strip patch antenna. The center frequency 21.5GHz is chosen as the resonating frequency with variety of wireless applications under K-band whose frequency range is defined by the IEEE as 18GHz to 26GHz. HFSS12 is being used as the software to design and study of the performance of the antenna. The antenna is designed on a FR4 epoxy substrate having a relative permittivity of 4.4. To operate all over the frequency range of K-band the log periodic implementation of the antenna is done by the frequency scaling method using a scaling factor 'τ'. The return loss, VSWR, directivity and gain of the proposed antenna are analyzed from the simulation results.

***Keywords**: HFSS, Frequency Scaling, Log-Periodic, Circular, K-band, FR4 epoxy.*

****Author for correspondence*** bdevkumar123@gmail.com

1. Introduction

In this anon of the modern world, communication has become the requisite part of our life. As human beings have ears and eyes, antenna has also taken the place of ears and eyes in the area of technology. Circular patch micro-strip antennas are becoming a popular for portable wireless system because they are light weight, low cost, low volume, easily manufacturable and also other characteristic such as low profile and conformable due this reason antenna can use airborne and spacecraft application. Micro-strip antenna has increasingly taken un-replaceable place in finding the applications in microwave systems from RADAR, Telemetry navigation, Bio-Medical system, GPS, Mobile, Satellite communication and Missile system because they are having property of light weight, low volume, low cost, ease of fabrication and ability to be printed directly on the circuit board.

Micro-strip Patch Antenna is a low profile antenna that is robust, small in size, offers relatively high gain and it can be fabricated using photolithographic technique. Modern day communication systems such as mobile phones and satellites make use of micro-strip patch antenna extensively for small size and better operating characteristics. The use of micro-strip antenna is not limited to communication systems and nowadays it finds wide application in the field of aeronautics and missile applications. A micro-strip patch antenna is generally designed to operate at a particular frequency based upon its specifications. This leads to a space limiting problem with the advent of modern communication systems where the use of multiple antennas for different resonant frequencies is no longer dispensable as it increases the system size and complexity. To get over this problem, multiband antennas are designed where the same antenna can resonate at different frequencies and this reduces the system size and the overall cost of manufacturing. Moreover, micro-strip patch antenna can be easily fabricated using printed technologies on a large scale and this reduces the cost of manufacturing. This paper specially focuses on the frequency range 15GHz to 28GHz which is used in 5G application. Work has been demonstrated on the circular patch and stimulated using the HFSS12 software. HFSS stands for High Frequency Structure Simulator and is an industry-standard simulation tool for 3D-Full wave electromagnetic field simulation. It is essential for the design of High-Frequency and High-speed component design. Combination of multiple patches as a log periodic array will give a wide band radiation from a low profile antenna structure [5].

2. Mathematical Formulation of Patch Geometry

Micro-strip antennas have got many methods of analysis. The most popular models are the transmission-line, cavity and full wave. Transmission model is the easiest of all. It is very easy to analyze using the transmission-line. Since the dimension of the circular patch is treated a circular loop, the actual radius of the patch is given by [1].

$$a = \frac{\mathrm{F}}{[1+\frac{2\mathrm{h}}{\pi \varepsilon \mathrm{r} \mathrm{F}}[\ln\left(\frac{\pi \mathrm{F}}{2h}\right)+1.7726]]1/2} \qquad \text{Where,} \qquad F = \frac{8.791X10^{9}}{\mathrm{fr}\sqrt{\varepsilon \mathrm{r}}}$$

3. Log-Periodic Implementation of Circular Patch

Another type of an antenna configuration, which closely parallels the frequency independent concept, is the Log-Periodic structure introduced by DuHamel and Isbell. University of Illinois at Urbana-Champaign had patented the Isbell and Mayes-Carrel antennas and licensed the design as a package exclusively to JFD electronics in New York. Lawsuits regarding the antenna patent which the UI Foundation lost evolved into the Blonder-Tongue Doctrine. A log periodic antenna is a directional, broadband, narrow-beam antenna, multi-element that has impedance and radiation characteristics which are regularly repetitive as a log function of the excitation frequency.

It is well known and very much attractive due to its frequency independent nature. The log-periodic antenna is attractive for use in wide-band arrays due to it’s an end-fire structure; its physical aperture (normal to the main-beam direction) is smaller than the other designs. However, it is undoubtedly obvious that the standard form of the antenna will lead to severe dispersion of the frequency components in a pulsed waveform. This is due to the antenna excitation at the “nose” (the front end nearest to the shortest dipole element) and low-frequency components of the signal have to travel down the antenna structure until they reach a dipole that is near resonance. They have to travel back the same distance as radiated fields before they can combine with the high-frequency components radiated from short dipole elements near the feed. In log periodic antennas the electrical property varies periodically with logarithm of frequency [1] and the frequency scaling property leads to the determination of the dimensions. This results in a time delay which is approximately proportional to the wavelength of the component. One of the prominent advantages of these antennas is the straight forward design procedure which facilitates their engineering application.

Another advantage of LPA is that for the same frequency band it will be possible to obtain different gains through the adjustment of its elements. Antenna measurements over extensive frequency bands can be related to time-domain responses to pulses, eliminating through computer processing multipath effects and other interferences. A LPA antenna has an educational application, being an interesting acquisition for antenna teaching laboratories in developing countries. A LPA antenna project or experiment could be easily implemented requiring only the reconfiguration of the antenna and not being necessary to build a newer one. The mode supported by the circular patch antenna can be found by treating the patch, ground plane and the material between the two as a circular cavity. The radius of the patch is the only degree of freedom to control the modes of the antenna (Balanis, 1982) [9]. The antenna can be conveniently analyzed using the cavity model (Richards, 1988; Gonca, 2005). The cavity is composed of two electric conductors at the top and the bottom to represent the patch and the ground plane and by a cylindrical perfect magnetic conductor around the circular periphery of the cavity. The dielectric material of the substrate is assumed to be truncated beyond the extent of the patch (Richards, 1988). The field configuration within the cavity can be found using the vector potential. The magnetic vector potential as must satisfy, the homogeneous wave equation (Balanis, 1982). Because the entire shape of it cannot be solely specified by angles, it is not truly frequency independent. Traditionally log-periodic micro-strip antenna occupies a large size on a single substrate. The inset-feed is easy to fabricate as it is implemented on the same substrate surface that accommodates the radiating patch. The width of the line is small as compared to that of the patch. The overall widths also vary and needs to be designed for different thickness and permittivity values of the substrate. The design and construction of a LPA antenna for ultra-wide band applications is extremely difficult. The antenna would have low portability and its installation would be expensive and complicated. A reconfigurable log-periodic antenna, built using inexpensive and reusable materials can be used in UWB applications with minimum size and cost. It would be possible to operate in many distinct frequency bands like S band, C band, X band. The possibility of reconfiguring so many physical parameters in the same log-periodic antenna is difficult. The maximum distance between two arcs of the circular patch was taken as $\lambda/2$ [2].

We calculated the frequencies, length, width, dist and radius for designing the Log periodic Implementation by using the below formula [3]

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

Where "L" indicates the length of the patch and "W" indicates the width and 'n' indicates the no of element [10].

$$\tau = f_{n+1}/f_n = R_n/R_{n+1} = \lambda_n/\lambda_{n+1}$$

Where "f" indicates the frequency of the patch, "R" indicates radius of the patch and "λ" indicates the wavelength of the corresponding frequency [6]. If the value of τ nearly equal to1 then the antenna frequency will reach continuous variation [7]. A log periodic antenna is a broadband, directional, multi-element, narrow-beam antenna that has radiation and impedance characteristics which are regularly repetitive as a logarithmic function of the excitation frequency. It is well known and very much attractive due to its frequency independent nature. The log-periodic antenna is attractive for use in wide-band arrays due to it's an end-fire structure; its physical aperture (normal to the main-beam direction) is smaller than the other designs. However, it is undoubtedly obvious that the standard form of the antenna will lead to severe dispersion of the frequency components in a pulsed waveform. This is due to the antenna excitation at the "nose" (the front end nearest to the shortest dipole element) and low-frequency components of the signal have to travel down the antenna structure until they reach a dipole that is near resonance [9].

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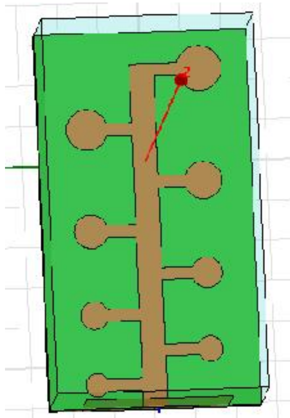

Fig. 1: Log periodic circular patch antenna

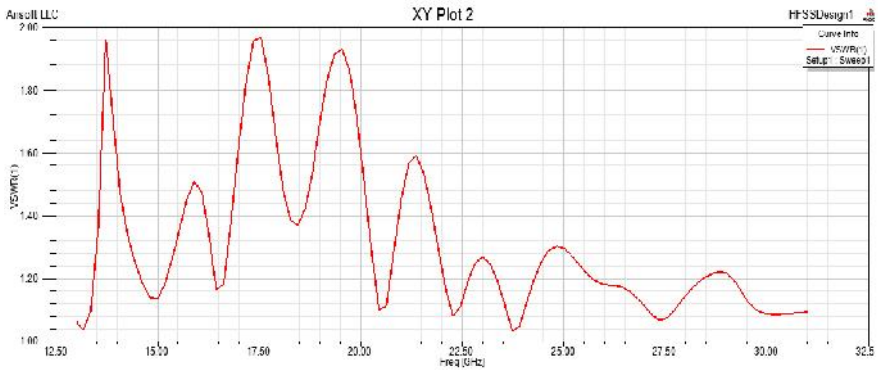

Fig. 2: S-Graph of log periodic circular patch antenna

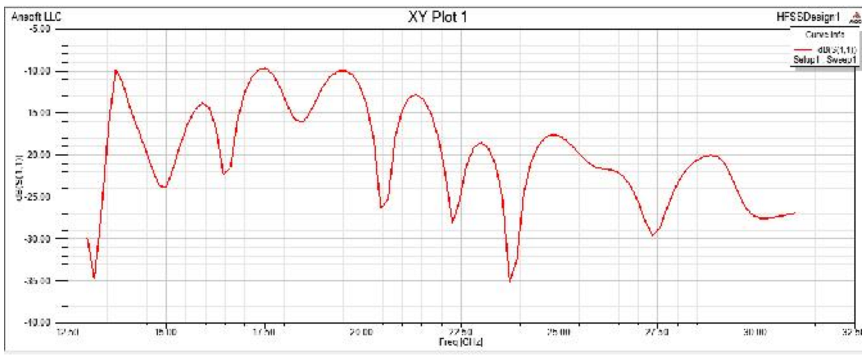

Fig. 3: VSWR Graph of log periodic circular patch antenna

Parameters	Log Periodic Circular Patch Antenna
Resonant Frequency	20.45 GHz
S11	-35.03 dB
VSWR	0.84

4. Applications

- I/Q Modulator Ranges 18 to 21.5 GHz.
- K-under band, 12–18GHz, mainly used for satellite communications, terrestrial microwave communications, and radar, especially police traffic-speed detectors.
- The test 5G network used a 15GHz frequency band.
- This frequency band is very useful for wireless mobile technologies like 5G.
- These circular patch antennas are used for the designing of airborne, missile and spaces craft.
- It is used in the fields of RFID.

5. Conclusion

This project was aimed to study the Log-Periodic implementation of circular patch antenna. Along with this, various parameters like length, width, radius, effective area, resonant frequency, scaling factor, distance were determined.

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