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Design and Optimization of Log Periodic Toothed Antenna for UWB Applications

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***Abstract* – The aim of this paper is to design and optimize the performance of log periodic toothed antenna for Ultra Wideband (UWB) Applications. The operating frequency of the antenna is 4-10GHz. The proposed method focuses to optimize the performance of the antenna by achieving the gain of 4.5dB, VSWR<2 and directivity of 5.1dB by using FR4 substrate of relative permittivity 4.4 and dissipation factor 0.013. The substrate dimension is taken as 41.9x41.9x1.6 mm. Further, aperture band rejection technique is used to improve the antenna parameters like radiation pattern, directivity and gain. This antenna is simulated using ANSOFT-HFSS and the results are presented.**

***Keywords* – Log Periodic Toothed Antenna, LPTA, UWB, Aperture Rejection Method.**

I. INTRODUCTION

Over the past few years there has been a strong interest in antennas capable to reject narrow frequency bands within their nominally wideband instantaneous bandwidth. Particular emphasis is placed on a 3.1–10.6 GHz ultra wideband (UWB) systems where the suppression of IEEE802.11a WLAN band of 5.15–5.85 GHz is often desired[2]. Several antenna examples that have their configuration modified for single or multiple band rejections are discussed in [2].Band rejection is commonly achieved by adding (anti)resonant features to the antenna aperture and/or by integrating cavities. An increased VSWR with typical values of 6:1 to 10:1 are considered to be demonstrative of the desired effect. Desired band rejection has also been demonstrated by integrating various types of filters with an antenna. Planar log-periodic antennas shown in fig 1 were originally introduced by DuHamel and Isbell in 1957 [6]. It has been shown that these radiators have electrical properties that repeat logarithmically with frequency and are capable of achieving multiple octave bandwidths. The upper frequency limit is defined by the finite size of the feed region while the lower frequency cut-off is dependent on the length of the outermost teeth. They have been used in various communications and electronic warfare systems, and some researchers have recently considered them for UWB applications [1]. In all these applications the band rejection remains important as the primary method for reducing the receiver saturation and interference from/with nearby antennas and systems. In this paper, we demonstrate aperture band rejection techniques integrated with 4-10 GHz wideband planar log-periodic toothed antennas(LPTA). Other methods include , integrated filter rejection which involves the intedration of band rejection filter in the antenna, and combined aperture and integrated filter rejection. All antennas are fabricated on a 1.6 mm thick FR4 substrate. Aperture rejection method results in simple implementation, reduced size, flexible single or multiple band rejection, and non-periodic nature of the rejection bands[1]. It is done by removing a pair of resonant teeth from the antenna. VSWR greater than 6:1 and increase in the return loss in that frequency band are measured. In this paper, we have implemented aperture band rejection technique to suppress the WLAN band of 5.15-5.85GHz.

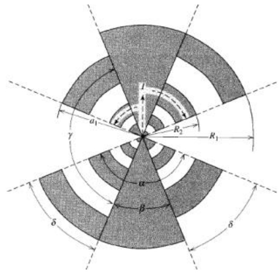

Fig.1. Log Periodic Toothed Antenna

This paper is organized as follows.

- The design of log periodic toothed antenna is introduced and the design is demonstrated using HFSS in Section II.
- Aperture rejection method is discussed in Section III. Measurements and simulations are used to demonstrate important features of this method.
- Fabrication of the proposed antenna design is presented in Section IV.
- Applications and future enhancements discussed in the Section V.

II. DESIGN AND ANALYSIS OF LPTA

A. Design equation of LPTA

The initial design based on the concept of the log-periodic structure was the log periodic toothed antenna (LPTA)which is approximately a frequency independent antenna[7].Following the angle concept, if one tooth has a width W_0 the next smaller one is τW_0 wide, the third is $\tau^2 W_o$, and so on[12].

Let the width of the widest tooth be W_1, which is approximately one quarter wavelength corresponding to the lower frequency limit. Then, the width of n^{th} tooth, W_n, is:

$$W_n = W_1 \tau^n \quad (1)$$

where τ is a constant, representing the ratio of width of $(n+1)^{th}$ tooth to width of n^{th} tooth.

Taking the logarithm of both sides,

$$\log W_n = \log W_1 + n \log\tau \quad (2)$$

For a given antenna, log W_1 and log τ are constant. Consequently, the logarithm of W_n increases in equal steps with n. That is, log W_n increases periodically-hence the name "log periodic"[4]. It is also implied that whatever electrical properties the antenna may have at a frequency f_0, will be repeated at all frequencies given by $\tau^n f_0$.

B. Design of LPTA in HFSS

The 4 to 10GHz planar log-periodic aperture is designed with the geometrical parameters R_n = 23.86mm, R_o = 6.84 mm, τ = 0.7, α = 135˚, and β = 45˚is shown in fig 2. The dimensions are found from the [5,9].The wide β angle is chosen so that the feeding recta-coax line can fit in the center region of the antenna. The antenna is constructed to be self-complementary [8], with α and β adding up to 180˚. This is done to have stable beam patterns and reduced impedance ripple across the entire frequency band. The antenna designed using HFSS is shown in the fig 2.

C. Results

The simulation results of designed log periodic toothed antenna is given in the table 1.The return loss of designed LPTA is shown in the fig 4. It is evident that the dips observed in the graph indicates the impedance matching of the designed antenna. However, the best matching occurs at 6GHz which is the resonant frequency of the designed LPTA. The gain of designed LPTA is obtained as 4.38dB.The directivity of the designed LPTA is observed as 3.5dB.The VSWR remains less than 2:1 for the operating frequencies and is shown in fig 6.

III. APERTURE REJECTION

A. Band rejection

Log periodic toothed antennas have multiple teeth which length directly determine corresponding ,log periodically distributed resonances[9].Use of band-rejection techniques is important for broadband radiators because they allow the elimination of known undesirable frequencies from entering the receiver[1]. The methods in band rejection include aperture rejection, Integrated filter rejection and combined aperture and integrated filter rejection. In this paper, the aperture method of band rejection is presented in detail.

B. Aperture Band rejection

Aperture rejection [1] is a method of band selectivity that results in the modification of the antenna aperture. In this method, a pair of resonant teeth is removed from the structure resulting in increased mismatch at the resonant frequency. Removing a pair of resonant teeth also alters the far-field pattern of the antenna. Due to this, the antenna pattern is deformed and the rejection is centered at the location the pair of teeth would be normally resonant. Aperture rejection generally produces about 25dB realized gain reduction. The log periodic antenna with 2^{nd} pair of teeth removed is shown in fig 3.

C. Simulation

The center frequency of the rejection band is directly related to the log-periodic growth rate, τ. If the largest (R_n) and smallest dimensions(a_0) of the antenna are held constant, the growth rate can be used to set the number of resonant teeth used in the antenna aperture[1]. (3) shows how to compute when the number of desired teeth, , is odd and specified as:

$$\tau = \left(\frac{a_0}{R_n}\right)^{2/x} \qquad (3)$$

The aperture band rejection is shown in fig 3. Here, second pair of teeth is removed to reject 5.15-5.85GHz ISM band. The simulations from [1] have shown that rejection bandwidth obtained by removing different pairs of teeth from a radiator with a constant growth rate is essentially constant. As the growth rate increases, the number of teeth in the aperture for a given size increases and the percentage bandwidth related to each pair of resonant teeth is decreased. For sharp and narrowband rejection, a high growth rate is desirable. As the growth rate decreases, the sharpness of the rejection decreases.

D. Results

The simulated[10] return loss of LPTA with aperture rejection is shown in the fig 5.It is observed from the graph that the return loss is more between the frequency band 5.15-5.85GHz.This is due to the removal of second pair of teeth which was resonant at that particular frequency. The gain is obtained as 4.5dB and the directivity is 5.1dB.The VSWR increases above 6:1 for the rejection band and remains less than 2:1 for other operating frequencies and is shown in fig 7.

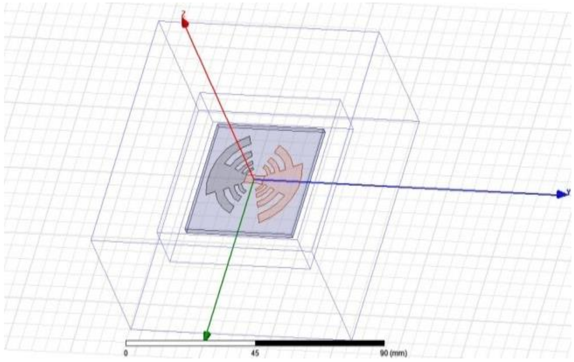

Fig.2. Design of LPTA

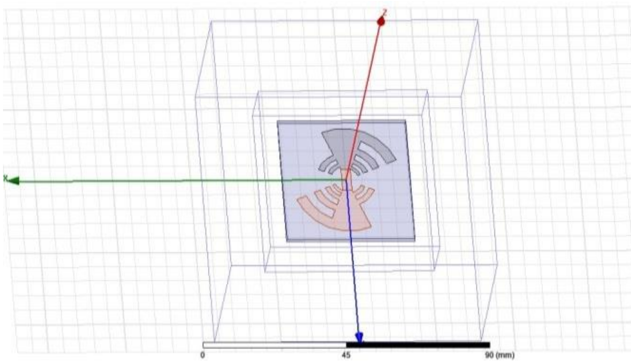

Fig.3. Aperture Rejection Method

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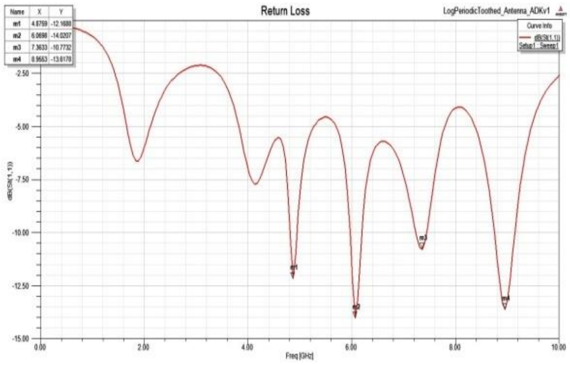

Fig.4. Return loss of LPTA

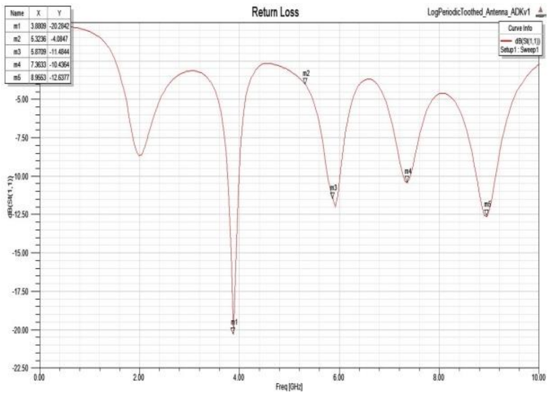

Fig.5. Return loss after Aperture rejection

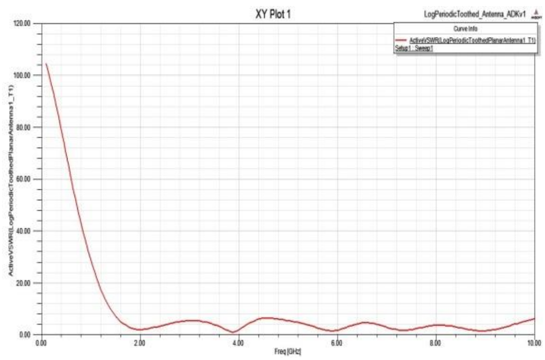

Fig.6. VSWR of LPTA

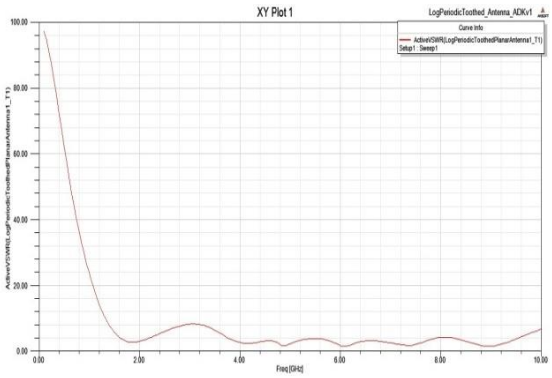

Fig.7. VSWR after aperture rejection

Table 1: Comparison of the performance

Quantity	LPTA Before Aperture Rejection	LPTA After Aperture Rejection
Total Gain	4.38dB	4.5dB
Total Directivity	3.5dB	5.1dB
Realized Gain	1.25dB	1.3dB
Radiation Efficiency	80%	87%


[a] Front view [b] Rear view
Fig.8. Log Perioic Toothed Antenna (LPTA)


[a] Front view [b] Rear view
Fig.9. LPTA after Aperture Rejection method

IV. Fabrication

The proposed antenna has an operating bandwidth between 4 to 10 GHZ and substrate dimensions along x-axis and y-axis are 41.9mm respectively. Thickness of the substrate material is 1.6mm and port gap width is 7mm. The antenna is considered to be self complementary [8], hence the tau(τ) and sigma(σ) are 0.65mm and 0.81mm,the delta and beta angles are 45 degrees[8] and outer radius of toothed arm is 23.3mm.The subsrate material used is FR-4 which has dielectric constant of 4.4 and loss tangent 0.013.FR-4 is a composite material composed of woven fiber glass cloth with an epoxy resin binder that is flame resistant (*self-extinguishing*). With near zero water absorption, FR-4 is most commonly used as an electrical insulator possessing considerable mechanical strength [11].The fabricated antenna is shown in fig 8 and fig 9.

V. Applications and Future Enhancements

A. Applications

An immediate application of the concepts being developed here are for the global positioning system (GPS)[3]. The antennas being considered here can potentially be used in airborne systems where jamming signal generated on the ground are incident on the antenna. Due to their advantage of linear polarized radiation, the log periodic toothed antenna and can be easily flush mounted which makes it an ideal candidate for use in radar and military applications. It can also be used in base station by conforming multiple LPTA to a cylindrical mast yielding an omni directional pattern.

B. Future Enhancements

Multi-polarized antennas, including the four-arm log-periodic antenna, spiral, and sinuous antenna should be explored for their potential applications using surface micromachining technology. In addition to aperture rejection, integrated filter rejection and combination of aperture and integrated filter rejection can be employed for better results.

VI. Conclusion

In this paper the log-periodic toothed planar antenna for UWB applications was designed by using FR-4 substrate. From the simulation results, we can see that this antenna is well matched and return loss dips in frequency ranges from 4 to 10 GHz which makes it suitable for UWB applications. The radiated field at the front end of the antenna is vertically polarized. The comparison between existing and proposed design is been tabulated in table1. Gain of 4.38dB and directivity of 3.5dB is obtained from the existing design. The antenna is optimized by aperture band rejection technique. The simulated gain is 4.5dB and directivity is 5.1dB.The radiation efficiency of the antenna has been increased to 87%.Hence, we conclude by presenting the design of LPTA antenna for UWB applications and aperture band rejection technique for optimizing it.

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