Log-periodic Antenna For Solar Observations In 100MHz-500MHz

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Abstract – **Solar observations in radio spectrum are highly important for us. They can bring us valuable information about the dynamic between the sun energetic particles and the Earth and our lives more specifically.**

The paper discusses the idea behind choosing a LPDA antenna for solar observations, why that would be really useful and what are the expectations.

We modeled and simulated a LPDA antenna, based and calculated by the theoretical equations for this type of antennas and compare it to a well-known similar antenna with good remarks - CLP-5130-1N.

Keywords – **Log-periodic antenna, solar observations, radio astronomy**

I. INTRODUCTION

One of the most widely spread antennas, among the VHF-channel, is the so called Log-periodic Dipole array (LPDA) antenna, which is the main topic of this paper. We can use the LPDA antenna benefits combining its engineering uses with radio astronomy – the science of studying natural radio emission from celestial sources. [1] LPDA design is one of the frequency-independent antennas, which is very useful for our goals.

A. Construction of a LPDA antenna

The construction and geometry of the LPDA antennas is directly linked to the periodical repeating of the electric properties with the logarithm of the frequency. In LPDA all the dipoles are active elements, the longest dipole works as reflector and successive dipoles act as directors [3]. The directivity of the antenna increases along with the length of the active region, and τ (Tau), while σ (sigma) is constant, because most of the elements are with approximately λ/2 length.[9] With the change in operation frequency, the active region shifts among the elements and hence all the elements will not be active only on a single frequency. This is its special characteristic.[4] Active region: This structural region of the LPDA has element length equal to half wavelength and offers resistive impedance. Here the current through the element is large and in phase with the supplied voltage. [5] The most fundamental facets of the LPDA revolve around three interrelated design variables: α (alpha), τ (tau), and σ (sigma). Any one of the three variables may be defined by reference to the other two. [2]

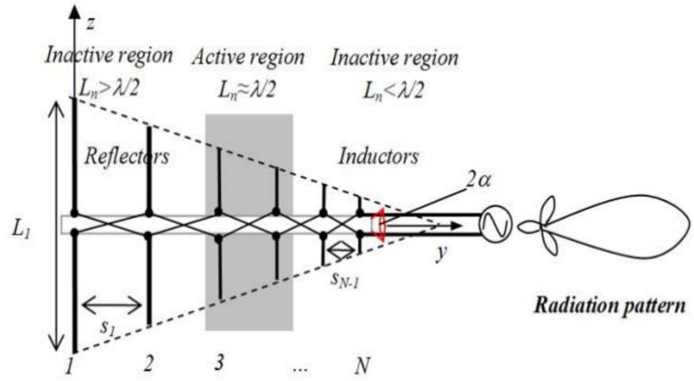

Fig. 1. Scheme of a Log-periodic antenna [3]

B. Equations for the antenna model

Some of the main equations, used for creating the model [9]:

The length of the longest dipole – l_1 is given by the formula:

$$l_1 = \lambda 1/2 = c/(2.f_1) \quad (1)$$

in which $\lambda_1$represents the wavelength of the lowest frequency part of the antenna design and c is the speed of light - 299 792 458 m/s . Then:

$$l_i = \tau \,.\, l_{i-1} \quad (2)$$

For the taper – τ – the ratio of each dipole element to each adjacent:

$$0.8 \le \tau \le 0.98 \quad (3)$$

The value of τ is always less than 1.0, although effective LPDA design requires values as close to 1.0 as may be feasible. σ – spacing in wavelengths between the half wavelength dipole and the shorter adjacent next dipole element. [2]

$$0.03 \le \sigma \le 0.168 \quad (4)$$

We have:

$$B = f_n/f_1 \quad (5)$$

being the relative operating bandwidth and f_1 and f_n representing respectively the lowest and the highest frequency.

The value for the cotangent of the apex half-angle α is:

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$$\cot\alpha=(4\sigma/1-\tau) \qquad (6)$$

For calculating the estimated number of the dipole elements we need the relative operating bandwidth of the active region:

$$Bar=1.1+7.7(1-\tau)2\cot\alpha \qquad (7)$$

and the relative operating bandwidth of the structure:

$$B = B.Bar \qquad (8)$$

Using Bar and Bs we can calculate the number of the antenna elements:

$$N = 1+\frac{ln.Bs}{ln.\frac{1}{\tau}} \qquad (9)$$

Based on these and other formulas and with the help of simulation software, we designed a model presented at II. Modeling of the antenna.

C. LPDA antennas and Solar observations

From all the useful applications of the LPDA antenna, we will concentrate on its possibilities of observing the wide solar radio spectrum, more specifically in between 100MHz and 500MHz.

Why solar observations are interesting and important for all of us? – Undoubtedly it is because of the Sun`s role for Earth and the life inhabiting on the latter. It is a common knowledge that flares from the Sun influence the Earth (and respectively us) in one way or another, especially when the Sun is probably one of the strongest radio sources [6]. Although the authors present an application case in their work, they do not provide the direct method of building the antenna. Observing the Sun can help us get more information about these effects and maybe how do they occur, for example the so called Coronal Mass Ejection (CMEs).

Great opportunity for the presented idea is the nearing solar maximum, which for now, is expected around 2025-2026 [7].

We are using the LPDA broadband properties, as the radio spectrum we will observe is from 100MHz to 500MHz. How can these frequencies help for solar observing? – Actually, as we can see in Fig.2, most of the types cover the same ranges of frequencies so there is a chance that we can catch parts of even all of them.

II. Modeling of the Antenna

The modelling and simulation of the presented antenna has been made through ANSYS's HFSS antenna software [10]. The optimal version of the antenna is with 21 elements and the other calculated and simulated parameters are described in Table I.

Type	Characteristics	Duration	Frequency Range	Associated Phenomena
I	Short, narrow-bandwidth bursts. Usually occur in large numbers with underlying continuum.	Single burst: ~1 sec Storm: Hours - days	80 – 200 MHz	Active regions, flares, eruptive prominences.
II	Slow frequency drift bursts. Usually accompanied by a stronger second harmonic. Drift from high to low frequencies.	3 – 30 min	Fundamental: 20 – 150 MHz	Flares, proton emission, shockwaves.
III	Fast frequency drift bursts. Can occur singularly or in groups.	Single burst: 1 - 3 sec Group: 1 - 5 min	10 kHz – 1 GHz	Active regions, flares.
IV	Stationary Type IV: Broadband continuum. Drift from high to low frequencies.	Hours – days	20 MHz – 2 GHz	Flares, proton emissions.
V	Smooth, short-lived continuum. Follows Type III bursts and never occur in isolation.	1 – 3 min	10 – 200 MHz	Active regions, flares.

Fig. 2: Types of solar radio bursts [8]

As presented in the *B. Equations for the antenna model* part, here we show the results of the calculated parameters for the newly designed antenna for the range 100MHz – 500MHz.

Initial data we had was the bandwidth and the width of the radiuses we chose for the elements, alongside with τ and σ parameters and the characteristic impedance input – the frequency range is between 100MHz (as the lowest frequency) and 500MHz (as the highest) with 300MHz being the center frequency or the operational working frequency. The radius of the elements is 1mm as we wanted to be minimum for to be as accurate as possible in the higher frequencies,/it is possible the bottom elements to be corrected and have a wider radius as a final product./ The booms` radius is slightly larger - 4mm, so to be easier to carry the other elements and be wide enough. Also it was easier for the simulation process as the boom elements being with square form – this was in order to lessen the time for simulation and yet have valuable information data afterwards. τ and σ were chosen being in the ranges $0.8 \leq \tau \leq 0.98$ and $0.03 \leq \sigma \leq 0.168$.

As for the dipole elements – we used (1) and (2) equations. The number of the elements was calculated by (9).

All of the elements are built one by one based on the calculated data, the top and booms are connected with excitation ports. It has been determined that the size and distance between the booms heavily impact the transmission line impedance, therefore iterations were made in order to match this impedance with dipole length and position in order to minimize the return loss.

TABLE I
VALUES OF USED PARAMETERS

Radius of elements(dipols)	1 mm
Radius of boom	4 mm
τ	0.9
σ	0.168
L1 (length of first dipole)	1.499 m
L2	1.349 m
L3	1.214 m
L4	1.093 m
L5	0.983 m
L6	0.885 m
L7	0.797 m
L8	0.717 m
L9	0.645 m
L10	0.581 m
L11	0.523 m
L12	0.470 m
L13	0.423 m
L14	0.381 m
L15	0.343 m
L16	0.309 m
L17	0.278 m
L18	0.250 m
L19	0.225 m
L20	0.202 m
L21	0.182 m

On Fig. 3 is shown the result as a model of the antenna:

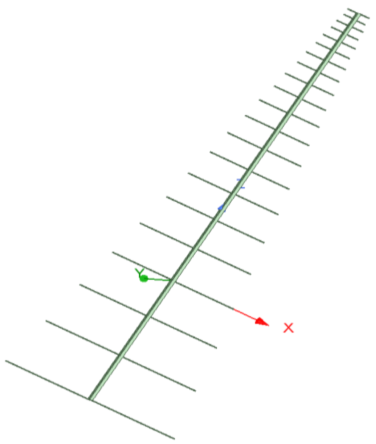


Fig. 3: The simulated model of the antenna

For reference we took the CLP-5130-1N antenna, for the 50MHz – 1300MHz range, which model we simulated and is presented on Fig.4. CLP-5130-1N has the same amount of elements – 21, its boom length is about 2 meters [11].

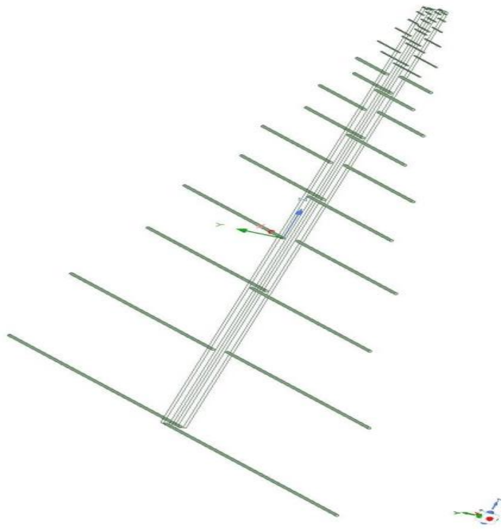


Fig. 4: The mechanical model of CLP-5130-1N

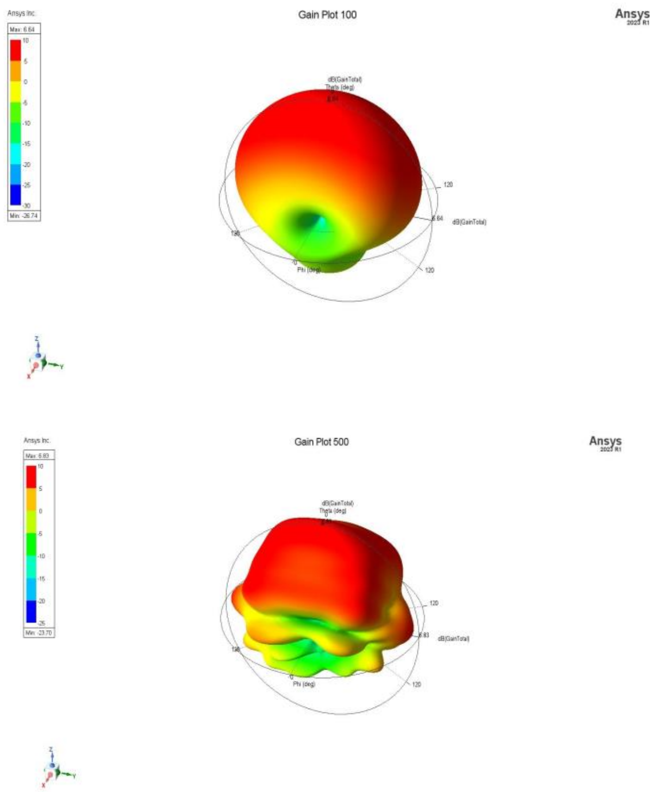
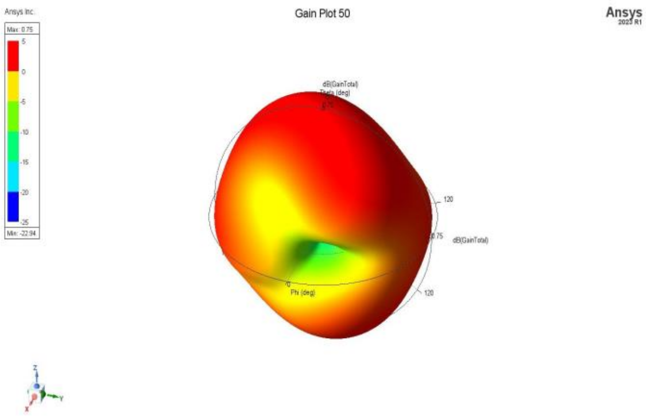
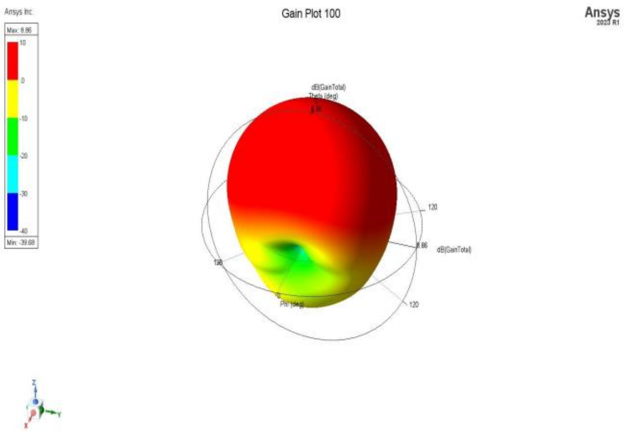
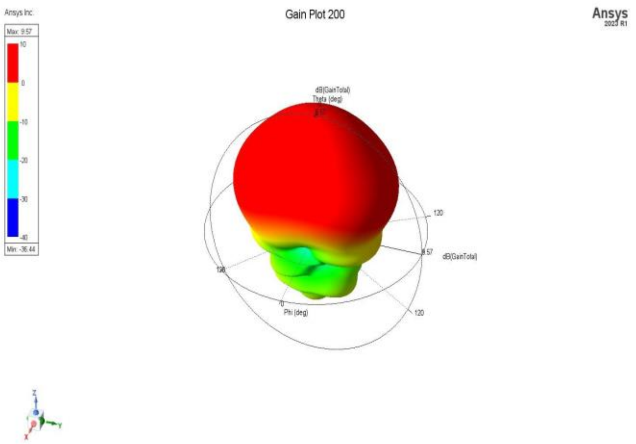
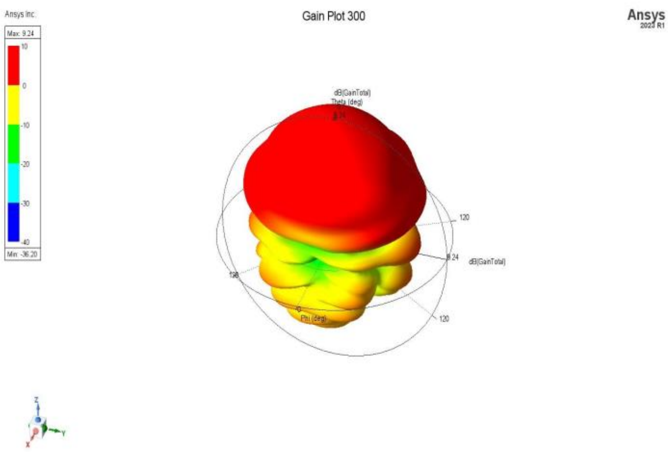


Fig. 5: Simulation of the radiation pattern of CLP-5130-1N for 100MHz (top) and 500MHz (bottom).









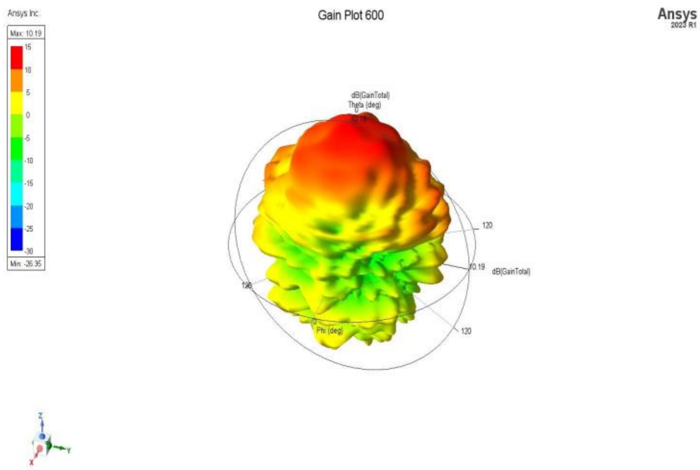


Fig. 6: Simulation of the radiation pattern of the new log-periodic antenna for 50MHz, 100MHz, 200MHz, 300MHz and 500MHz.from the top to bottom

At figure 7 is presented graph with both S11 parameters for the both CLP-5130-1N (blue line) antenna and the new simulated model (red line).

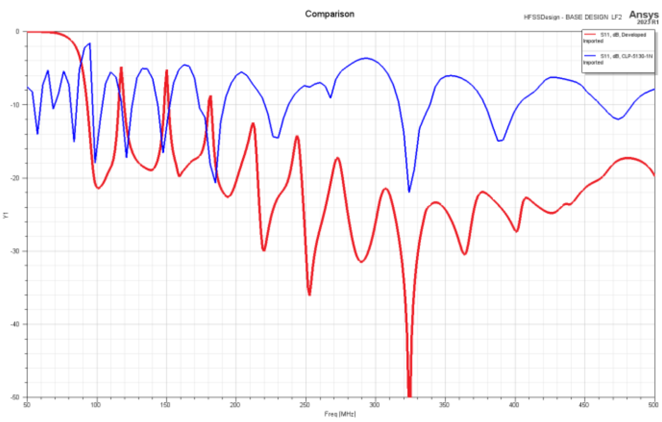


Fig. 7: S11 parameter plot for CLP-5130-1N(blue line) and the developed antenna (red line)

We could see that the red plot is fairly good and working for the antenna range, but yet it could be optimized. Here the S11 parameter is the best at around 330MHz with return loss of somewhere at -50dB.

For comparison, we could see that the blue line, representing the S11 plot for the CLP-5130-1N antenna, is also the best at 330MHz, but with somewhere near -20dB return loss.

In general the return loss of the newly designed antenna is about 10dB lower than the reference on the whole frequency band of interest, which results in higher gain and low noise temperature.

III. CONCLUSION

Using the formulas given in the Introduction and simulation software, we created about a 4 meters long log-periodic antenna with total of 21 dipole elements. We created a simulation of the CLP-5130-1N antenna to compare with the results. In conclusion we can say that the new design has excels the referenced antenna in the observed radio range with better radiation patterns and higher gain, so it will be capable of observing and monitoring the Sun and its various radio emission.

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