Microstrip broadband LPDA antenna on VHF and UHF bands

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Abstract

Microstrip antenna structures are the subject of many researches by engineers and scientists, and they are constantly evolving. Attempts to modernize designs and individual designs lead to increasingly modern military and commercial solutions. This paper presents the results of work on the development of UHF and VHF broadband antennas. The developed antenna will be the basis for developing an antenna array.

1. Introduction

In today's world, the widespread use of electromagnetic radiation creates the need for new solutions in the field of antenna technology. The use of antennas in radiocommunication systems of the latest technology brings new challenges to designers.
The requirements for modern radio systems in radiolocation, telecommunication, as well as astronomy and medicine, force them to seek new solutions in computer technology. There are several main directions of this work;

• miniaturization of antenna dimensions,
• gaining a wide band of antennas,
• provides scanning capabilities over a wide range of angles.

In addition, a lot of attention is devoted to the issue of energy efficiency of antennas, especially in mobile systems.

2. Broadband LPDA antenna

An antenna that closely relates to the concept of a frequency-independent antenna is a logarithmic-periodic antenna. There are various types of logo-periodic antennas. It turns out, however, that antennas of this type do not have to be just cut pieces of the plane but retain their properties even when we build the antenna according to the pattern by means of a wire.

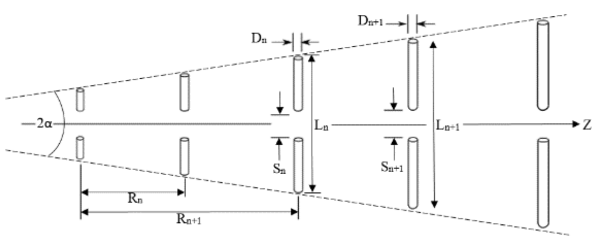

Figure 1. Dipole antenna array with dimensions [1].

This is because the strongest intensity concentration is located near the edge of the conductor and not in the middle of the structure. Thus, by removing the part of the inner surface, thus creating a "contour" antenna, we do not change much of its characteristic. The general concept of the discussed structure is shown in Fig. 1. It consists of a series of parallel dipoles. The dimensions of the dipole length (Ln), the distance between them (Rn), their diameters (Dn) or even the spacing between the dipole arms (Sn) are logarithmically inversely proportional to the scale factor τ as explained below:

$$\frac{1}{\tau}=\frac{L_1}{L_2}=\frac{L_{n+1}}{L_n}=\frac{R_2}{R_1}=\frac{R_{n+1}}{R_n}=\frac{D_2}{D_1}=\frac{D_{n+1}}{D_n}=\frac{S_2}{S_1}=\frac{S_{n+1}}{S_n} \quad (1)$$

An important parameter associated with dipole logarithmic antennas is the distance factor σ between dipoles defined as:

$$\sigma=\frac{R_{n+1}-R_n}{2L_{n+1}} \quad (2).$$

Straight lines passing through the ends of the dipole arms meet at the intersection point to form an angle 2α, which is characteristic for frequency-independent structures. The relationships given in formula (1) allow you to design a perfectly logarithmic structure and therefore infinite. However, as a broadband antenna, the structure of finite dimensions is good. Dimension limitation limits the frequency range to a certain band. The frequency range of such an antenna is determined by the electric length of the shortest and longest dipoles in the system.
The area of constant voltage along the structure is referred to as the transmission area because it resembles a matched transmission line. Each change of distance by λ/4 along the antenna changes phase by 150 °. This means that the phase velocity in the line is vf =0.6v0 where v0 denotes the phase velocity in the free space. Reduced phase velocity is due to loading of line capacity through smaller dipoles. In addition to the input impedance, the most important parameters describing the LPDA antennas are: radiation patterns, directionality, bandwidth, and side lobe level.

3. LPDA antenna in microstrip technology

VHF and UHF antennas are relatively large in size. The solution is their miniaturization, which can be realized by the use of a dielectric substrate. Printed (microstrip) logarithmic antennas are frequency independent antennas whose characteristic impedance Z0 changes logically in frequency.

The shape of the printed LPDA antennas is based on the use of two radiated surfaces placed on two sides of the laminate. The relationship between the magnitudes τ and σ is given by the formula:

$$\sigma = \frac{1}{4}(1-\tau)cot\alpha \quad (3).$$

Thus the angle α is:

$$\sigma = \frac{4\sigma}{1-\tau} \quad (4).$$

When designing the antenna, a constant directivity curve should be used in order to match such parameters τ and σ so that the resulting antenna dimensions meet the assumptions regarding the radiation characteristics and antenna dimensions. The desired operating range of the antenna is determined on the basis of the dependence:

$$B_s = B \cdot B_{ar} \quad (5).$$

Where *Bs* is the relative width of the working band, B is the band coverage ratio. The bandwidth of the active part of the antenna is:

$$B_{ar} = 1{,}1 + 7{,}7(1-\tau)^2\frac{4\sigma}{1-\tau} \quad (6).$$

However, it should be borne in mind that the radiating elements are placed on a synthetic laminate which is characterized by a certain dielectric permeability εr. The lowest frequency of operation corresponds to a semi-wave dipole whose length is divided by the dielectric permittivity of the substrate, as shown by:

$$L_1 = \frac{1}{2}\cdot\frac{3x10^8}{f_{minimum\cdot\sqrt{\varepsilon_r}}} \quad (7).$$

The lengths of consecutive dipoles are dependent on the coefficient τ:

$$L_{i+1} = \tau \cdot L_i \quad (8).$$

In addition, the distance between dipole feed points depends on the diameter of the dipole and the required input impedance.

$$Z_a = 120\left[ln\left(\frac{L_n}{D_n}\right) - 2{,}25\right] \quad (9).$$

$$S_n = D_n \cos\left(\frac{Z_0}{120}\right) \quad (10).$$

Where Ln/Dn is the ratio of the length to the diameter of the other components. In the case of microstrip LPDA antennas the thickness of the copper patch from which the tracks are made is constant, but the width of the dipole arms can be freely modified.

4. Project of the LPDA antenna

The antenna is made up of 8 half-wave dipoles whose shoulders are alternated on both sides of the laminate along the two-way supply line. The substrate to which copper is applied is made of FR-4 laminate with dielectric permeability εr = 4.6. The thickness of the laminate is 3,048 mm. Based on the directivity curve the coefficient τ = 0.78 is assumed. The coefficient σ is calculated from the formula (3) Fig. 4 shows the characteristic reflection coefficient. In the assumed band, the value of parameter S11 for different frequencies is around -13.25 dB for a frequency in the range of 402-414.1 MHz and reaches a value of -41.05 dB at a frequency of 364.6 MHz and is 0.139. The value of τ is quite low due to miniaturization of antenna dimensions.

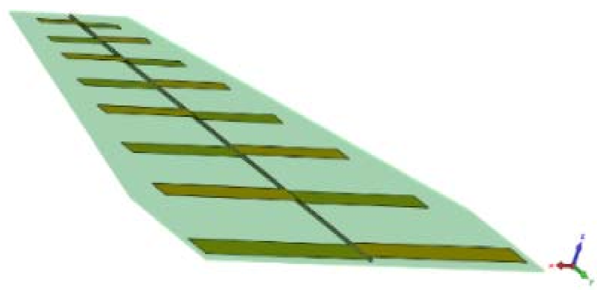

Figure 2. Model of antenna

5. Analysis of the results

The basic geometrical dimensions allowed for the implementation of the model in the CST STUDIO SUITE simulation environment using the FTDT method. In places where there is a high variability of the processes taking place there is a thickening of the cells. In places that do not require such thorough analysis, i.e. in the middle of the structure, the density of cells in the volume unit is reduced. Thanks to such treatment, the simulation may take less time without significant deterioration of its accuracy.
The designed model is built of 705575 cells. The number of cells per wavelength was 20.

5.1 VSWR and reflection coefficient (S11) Γ

The VSWR determines the degree of alignment of the power line to the antenna. It's dependents on load impedance ratio to line impedance.
The obtained VSWR does not exceed for any frequency value of 1.6. For a frequency of approximately 364.6 MHz the VSWR is close to unity and is 1.018. The reflection coefficient (often referred to as Γ) is a parameter closely correlated with the VSWR, which determines how much power is fed to the antenna and how much radiation is emitted. Fig. 4 shows the characteristic reflection coefficient. In the assumed band, the value of parameter S11 for different frequencies is around -13.25 dB for a frequency in the range of 402-414.1 MHz and reaches a value of -41.05 dB at a frequency of 364.6MHz.
The obtained characteristic shows that the bandwidth obtained by the antenna is greater than assumed. The antenna receives signals from the 203 MHz frequency range up to approximately 616 MHz. The received bandwidth has a width of 415 MHz.. The obtained VSWR does not exceed for any frequency value of 1.6. For a

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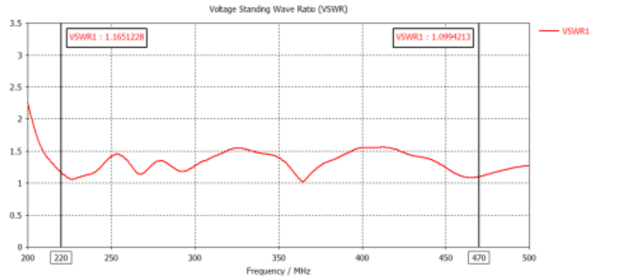

Figure 3. VSWR of microstrip LPDA antenna

Fig. 4 shows the characteristic reflection coefficient. In the assumed band, the value of parameter S11 for different frequencies is around -13.25 dB for a frequency in the range of 402-414.1 MHz and reaches a value of -41.05 dB at a frequency of 364.6MHz.

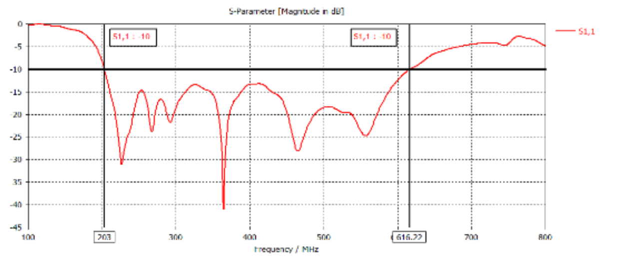

Figure 4. S11 of microstrip LPDA antenna

The obtained characteristic shows that the bandwidth obtained by the antenna is greater than assumed. The antenna receives signals from the 203 MHz frequency range up to approximately 616 MHz. The received bandwidth has a width of 415 MHz.

5.2 Radiations pattern

The radiation pattern is in fact the distribution of radiated energy in space.

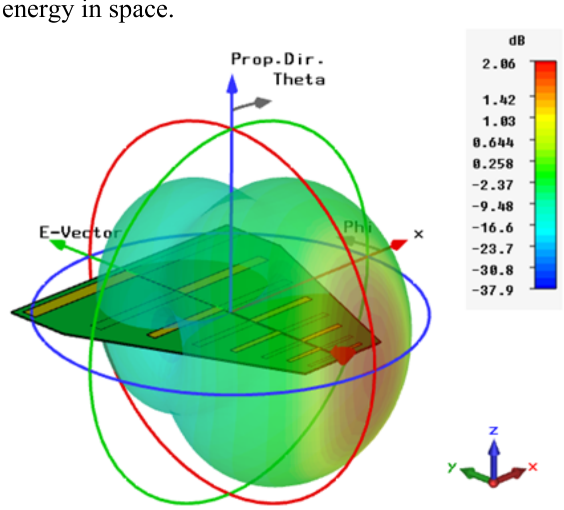

Figure 5. Radiation pattern for 220MHz

It determines the intensity distribution of the electric field on a spherically shaped surface with a sufficiently large radius whose center is the center of the antenna.

The illustrations 5,6 and 7 show the radiation characteristics for the three frequencies that would be most beneficial to use for receiving VHF radio signals from the UHF band. The result is that the antenna is quite large in directionality. The usable beam of radiation at -3db ranges from about 100 ° to 150 °.

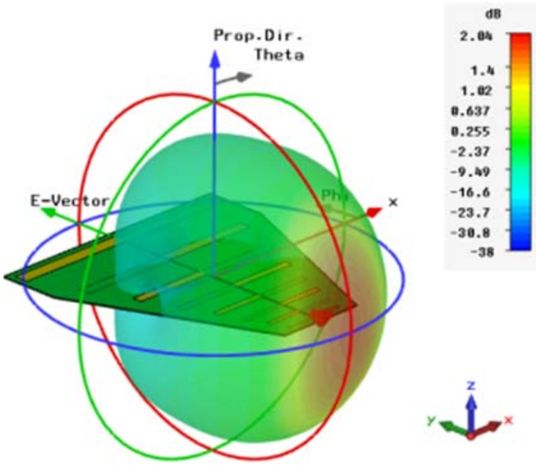

Figure 6. Radiation pattern for 364MHz

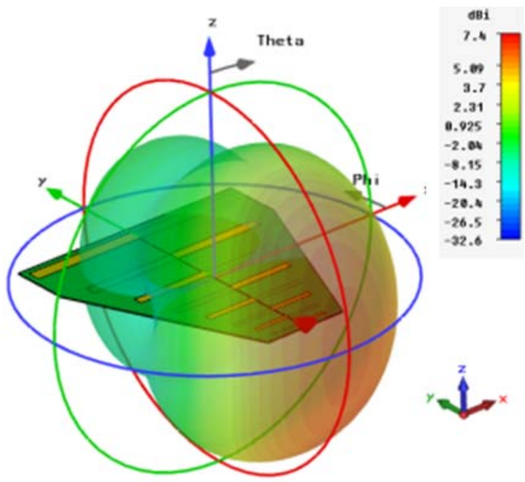

Figure 7. Radiation pattern for 470MHz

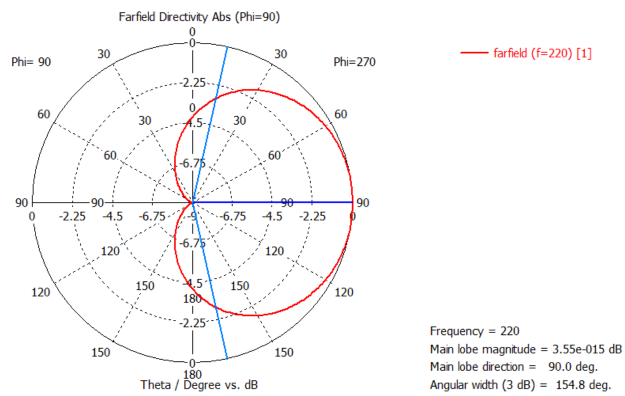

Figure 8. The amplitude-normalized radiation pattern in vector plane H for 220 MHz

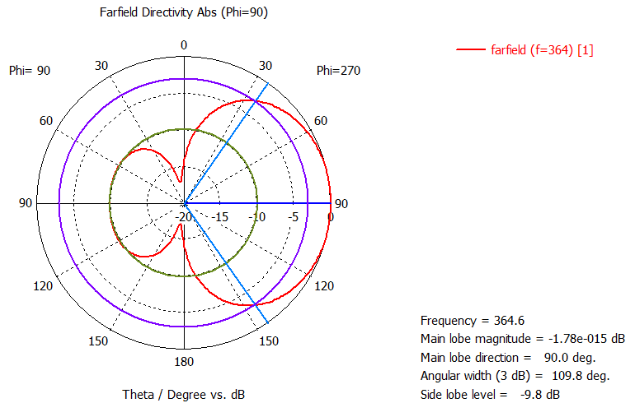

Figure 9. The amplitude-normalized radiation pattern in vector plane H for 364 MHz

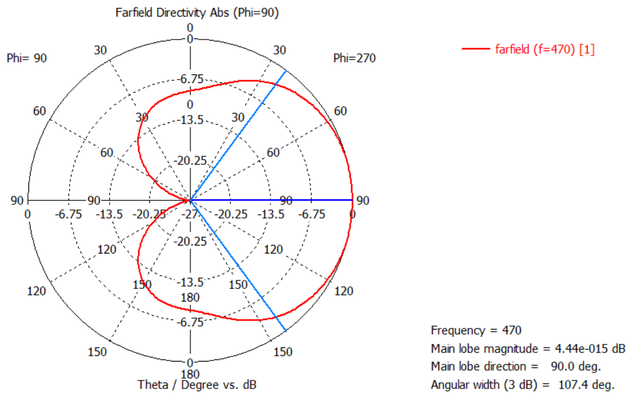

Figure 10. The amplitude-normalized radiation pattern in vector plane H for 470 MHz

5.2 Impedance

The antenna input impedance can be defined as the ratio of the voltage to the current at the antenna input to which the receiver's transmission line is connected.

If the antenna is tuned to the operating frequency, the input impedance is a pure resistance. If there is no resonance tuning, the reactance also appears. The waveform shown in the figure shows the dependence of the real part of the input impedance on the frequency.

The above visualization of current distribution in the structure of the antenna confirms that in the LPDA antennas the individual dipoles are responsible for the reception of different frequencies.

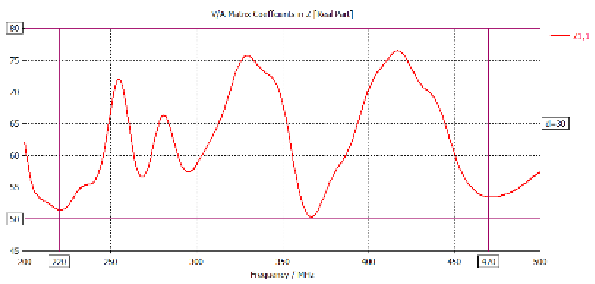

Figure 11. Real part of impedance

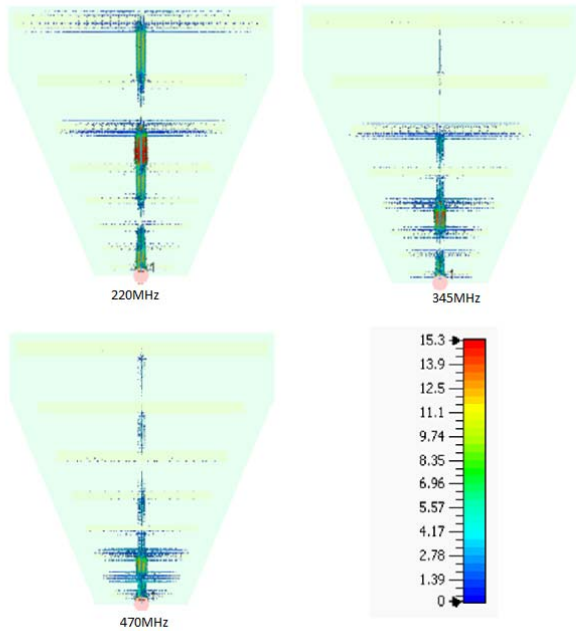

Figure 12. Current distribution in the vector plane of the electric field

7. Summary

The aim of the study was to design and simulations LPDA antenna based on dielectric working in the frequency range 220 - 470MHz. During the design of the model, the methods of designing LPDA and microstrip antennas were combined, resulting in a positive effect. It is worth noting that the desired working range was obtained using a modified method of determining the length of dipoles, starting from the shortest, not theoretical assumption, from the longest. The antenna in the 203-616 MHz band and even wider has a reflection coefficient below -10dB. It is possible to duplicate the designed antenna to create an antenna array that would have a higher energy gain and the ability to create a narrower beam in the main radiation direction

8. References

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