The Analysis of the Radius Impact on the Properties of Cylindrical Antenna with Coaxial Feed

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Abstract— The article presents analysis of conformal multilayer antenna and array antenna with coaxial feed. The antenna has the shape of the cylinder with a radius R. It was examined an effect of change radius R on the basic operating parameters of the antenna.

For the selected frequency range (5031–5090.6 MHz) there was designed planar and cylindrical microstrip antenna and antenna array with coaxial feed. For conformal surface radius length was varied in the range 0.2–160λ. The full-wave analysis of antennas numerical parameters was carried out in CST Studio Suite.

The analysis of the tested antenna has been focused on the determination of the impact of the R-radius of the side surface of the cylinder, on which the conformal antenna have been installed, on the basic operating parameters of the antenna.

1. INTRODUCTION

Themicrostrip antennas constitute one of the most innovative areas of aerial technology for a number of years. An interest in such types of antennas dates back to 1953, when G. A. Deschamps developed a concept of printed antenna [11, 15, 17, 18, 25].

Despite many years, there are still few studies in the literature that describe microstrip antennas on conformal surfaces. Most authors limit themselves only to the analysis of structures made on flat surfaces, which in many cases are not sufficient. Increased interest in this subject matter can be seen in journals and at international conferences only since 1997. During the same period, first review articles about conformal antennas were published and their first practical applications were presented. It was certainly affected by one of the most important research problems in the field of aerial technology which has emerged in the last decade — a problem of conformality of the shape of the surface on which the radiating elements of antennas are installed, as well as the conformality of elements alone.

A conformal antenna is an antenna that conforms to something. In our case, it conforms to a prescribed shape. The shape can be some part of an airplane, high-speed train, or other vehicle. The purpose is to build the antenna so that it becomes integrated with the structure and does not cause extra drag. The purpose can also be that the antenna integration makes the antenna less disturbing, less visible to the human eye, for instance, in an urban environment. A typical additional requirement in modern defense systems is that the antenna not backscatter microwave radiation when illuminated by, for example, an enemy radar transmitter (i.e., it has stealth properties). In microstrip antennas are important parameters of the dielectric, which can be explored to measurein accordance with the methods described in the [1, 2, 9, 12, 16]. Antennas are an essential element of the plurality of measurement [5–8, 10, 19–21].

2. ANALYZED MODELS OF ANTENNAS

To analyze the impact of conformal antennas radius of curvature on their basic parameters and characteristics of radiation there was selected frequency ranges: 5031–5090.6 MHz. This range is used in aviation,in Microwave Landing System (MLS).

For selected frequency was designed planar coaxially fed microstrip antenna and array antenna. Then each antenna was placed sequentially on conformal surfaces: cylinder, sphere, torus, where for each of them full-wave analysis of antennas numerical parameters was carried out in CST Studio Suite.

Figure 1 shows analyzed conformal antenna placed on the side surface of the cylinder. Radiating element has a rectangular shape with dimensions $2L = 14.4$ mm and $2b\Phi = 19.0$ mm (width of radiating element as seen from inside of the cylinder). This element is placed on a dielectric of thickness $h = R - b = 1.52$ mm, dielectric permittivity $\varepsilon = 3.5$ (ROGERS RO3035™). The antenna is fed by a 50 Ω coaxial probe ($\Phi_p = 0$ mm; $Z_p = 4,45$ mm). Around the cylinder of R radius there is vacuum of parameters: ε_0i μ_0. Fig. 2 shows analyzed array antenna.

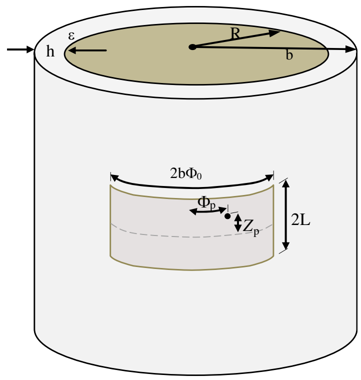

Figure 1: Analyzed conformal antenna on the side surface of the cylinder.

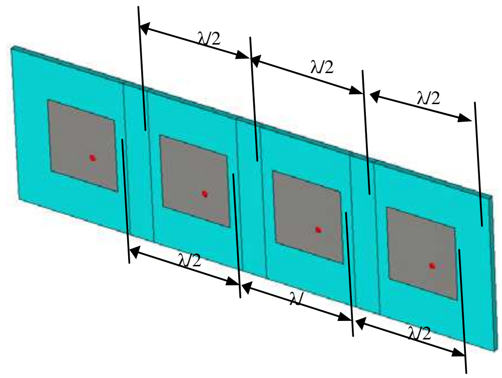

Figure 2: Analyzed array antenna (4 × 1).

3. CYLINDRICAL MICROSTRIP ANTENNA

The chapter presents analysis of conformal coaxially fed antenna (shown on Fig. 1) working in the frequency range between 5031–5090.6 MHz and placed on the side surface of the cylinder with radius R, which value was changed within the range 0.507–168.95λ_0 (30–10000 mm). The aim of this analysis is to examine impact of curvature of the side surface of the cylinder on antenna's basic parameters.

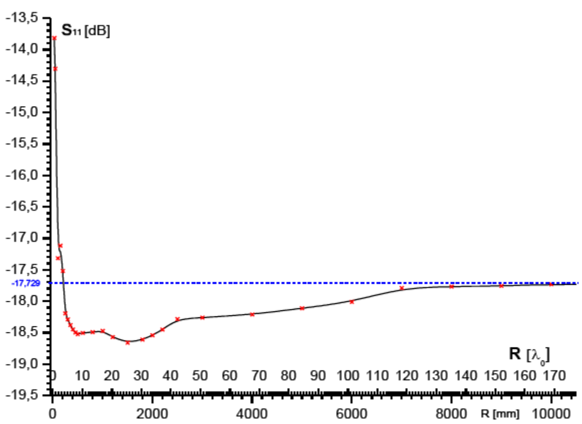

Figure 3: Reflection coefficient S11 of cylindrical conformal antenna depending on length of cylinder radius R.

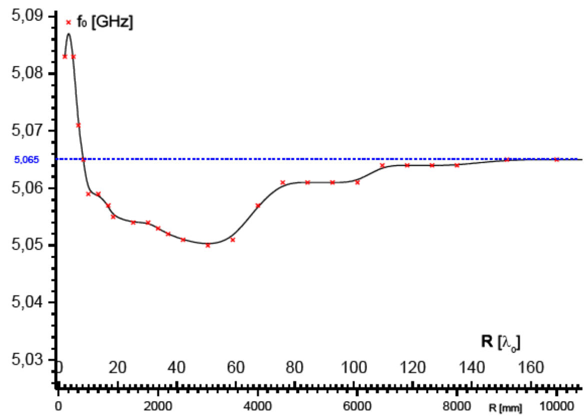

Figure 4: Resonance frequencies of conformal antenna depending on length of sphere radius R.

The graph in Fig. 3 shows dependence of reflection coefficient S_{11} for conformal antenna resonance frequency placed on cylinder side surface depending on cylinder radius R.

Next Fig. 4 shows dependence of antenna resonance frequency f_0 on cylinder radius R. Almost for all changes of radius length the value of antenna resonance frequency is maintained at the level of planar antenna resonance frequency $f_0 = 5.065$ MHz (dashed line). Only in the range of low values of radius $R < \lambda_0$ we can observe increase in resonance frequency.

Figure 5 and Fig. 6 presents bandwidth of cylindrical conformal antenna Δf depending on cylinder radius R.

Figure 7 and Fig. 8 shows normalized E-plane and H-plane patterns for different radii R.

4. CYLINDRICAL MICROSTRIP ARRAY ANTENNA

Antenna array shown in Fig. 2 was next placed on the and placed on the side surface of the cylinder R surface with radius R. Analysis results for array antenna working in the frequency range 5031–5090.6 MHz placed on the surface of the sphere are shown in Figs. 10–12. Radiations pattern of the antenna can also be determined from measurements of the near field [13, 14].

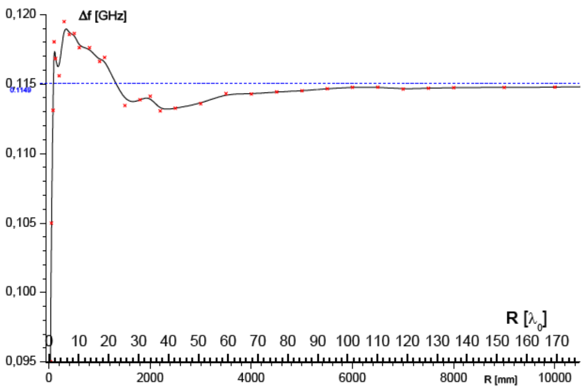

Figure 5: Bandwidth depending on length of cylinder radius R.

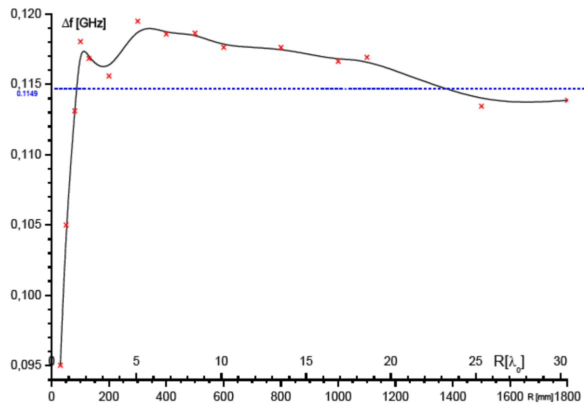

Figure 6: Bandwidth depending on length of cylinder radius $R < 25\lambda_0$.

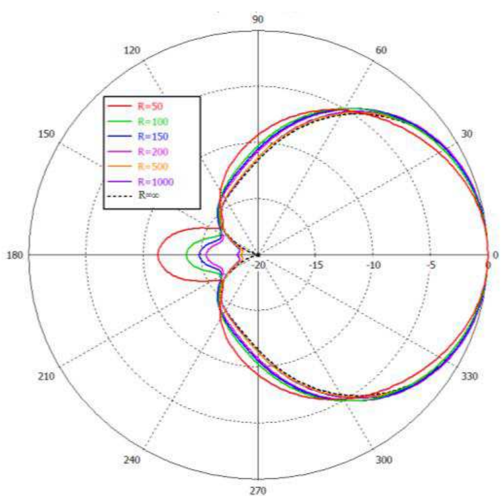

Figure 7: Normalized E-plane patterns for different radii R.

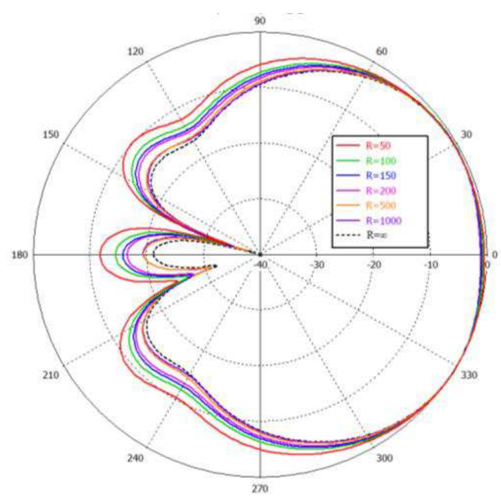

Figure 8: Normalized H-plane patterns for different radii R.

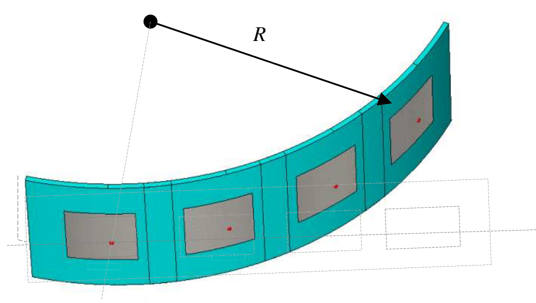

Figure 9: Analyzed cylindrical microstrip array antenna (4×1).

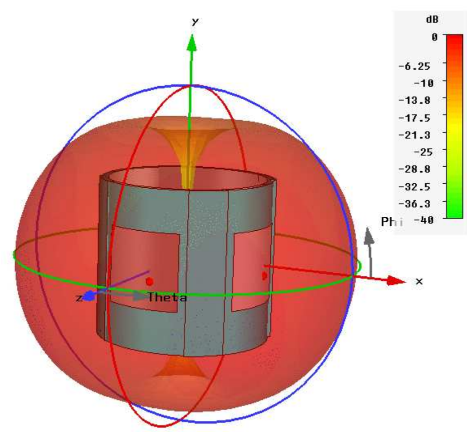

Figure 10: Characteristics of the radiation in the full angular range conformal array antenna.

Calculated characteristics of the radiation in the full angular range have been presented in Fig. 10.

Figure 7 and Fig. 8 shows normalized E-plane and H-plane patterns for different radii R.

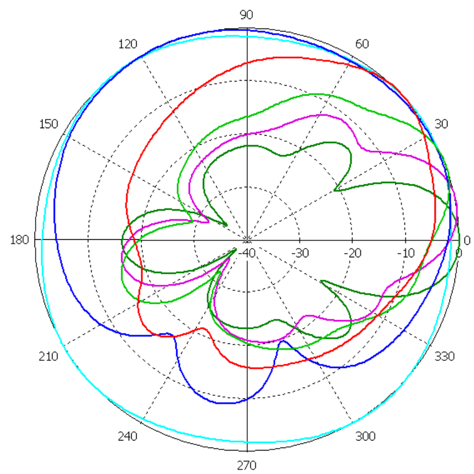

Figure 11: Normalized E-plane patterns for different radii.

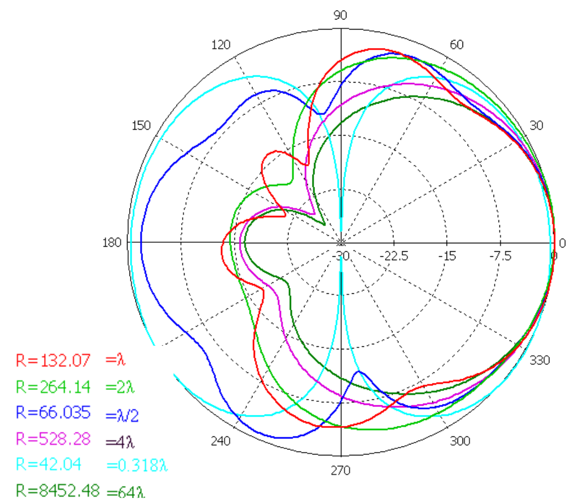

Figure 12: Normalized H-plane patterns for different radii.

5. CONCLUSIONS

The analysis of structures of conformal antennas is a complex and complicated process. Presented analysis shows how many factors affect the final result. In order to obtain the conformal multilayered structure which would be optimal at desired angle, one shall be prepared for a series of calculations and simulations. Nevertheless, the necessity of concentrating and focusing propagated radio waves increases the demand for integrated antennas systems of cylindrical, spherical or conical shape, thanks to which both the desired properties of spatial radio channels, as well as significant reduction in the number of aerial system components can be obtained. Due to the aforementioned reasons, a considerable widespread of conformal antennas is expected in the future.

Characteristics of radiation, as well as of the working bandwidth, are closely related to the value of R-radius measured on the side surface of the cylinder on which the analyzed antenna is installed. Along with the increase in curvature of the antenna radiator (reduction in the R-radius), the radiation beam is widened, and the working bandwidth of the antenna narrows.

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