

# The Influence of Flexible Bending on the Electrodynamic Characteristics of RFID Tags

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**Abstract** — In this paper, we study the effect of the bending effect on the electrodynamic characteristics of the RFID tag. The simulation of RFID tags with a more complex topology was carried out. An antenna based on a circular meander line was taken as the basis of the tag and its reduced model was presented. The results of the study allow us to see the negative changes in the electrodynamic characteristics during flexible deformations. This will allow to take into account during design and production the features of the behavior of RFID tags during operation (transportation, wear, etc.) in order to increase the likelihood of reading tags under adverse operating conditions.

**Keywords** — *RFID, tag, bendibg, flexible, electrodynamic characteristics.*

## I. INTRODUCTION

Currently, the field of Internet of Things is developing very actively. Already now this area has covered many areas of human activity: wearable devices, household electrical appliances, smart home systems, healthcare, public transport, etc.

The actual problem at the present stage of the development of the Internet of things, communications and telecommunications in general is the conversion of physical information into virtual information. To solve it, radio frequency identification technology or RFID (Radio Frequency IDentification) is often used. The conversion of information into physical form is carried out by non-contact reading of data recorded in tags attached to living or non-living objects. RFID systems help you read information that is out of sight. Virtual information is stored in a tag attached to the object, and conversion to physical form occurs by contactless reading of data from this tag. In addition, in various examples of use, the problem of physical deformation of underbody antennas, including RFID, arises. In such cases, it is possible not to identify the label, which may lead to inconsistencies when using this technology in any of the areas of activity. To solve this problem, an integrated approach is needed, namely:

- development of algorithms that allow you to read tags even under the most extreme strains;
- development of antennas in such a way that during physical deformations there remains a high probability of reading this or that tag.

The tag is a microchip with an antenna attached to it. The connection between the tag and the reader can be of two types: capacitive (when using an electric field) and inductive (when using a magnetic field).

Antennas that have at least one of the linear dimensions (length or width) is equal to half the wavelength. Such an antenna behaves like a resonator. There are several types of resonant antennas. In RFID systems, foil half-wave dipoles and microstrip (patch) antennas of various configurations are most prevalent [2]. Microstrip emitters are made as planar antennas, which are printed on a dielectric plate. Usually they consist of three layers: on top - a conductive plate (patch), in the middle - a dielectric layer (substrate), at the base - a conductive metal plate (screen). As a dielectric, widely used materials are used that are used for high-frequency printed circuit boards, for example, fluoroplastic, polycor or others.

The use of helical and meander structures in microstrip antennas for radio frequency identification allows the creation of miniature emitters, the geometric dimensions of which are many less emitted or received wavelengths [1 - 3]. Such conditions are satisfied, for example, by microstrip helical antennas. These antennas are based on a circular or rectangular resonator with a logarithmic, arithmetic or elliptic view of the spiral winding. Antenna structure has axial radiation polarized in a circle or ellipse. However, in the far zone, the polarization of such antennas becomes linear. This leads to a deterioration in cross polarization properties and complicates the possibility of their application for radio frequency identification in the range of 866-915 MHz [4].

## II. RESULTS AND METHODOLOGY

One of the most promising and important technologies for implementing IoT systems is RFID technology. A typical RFID system, shown in Figure 1, can be represented as four main components that interact with each other: reader (RFID reader); readable device (transponder, tag, RFID tag); read antenna and host computer.

The paper uses three-dimensional modeling methods to build a more detailed model of the radio frequency tag. The computer calculates a three-dimensional electrodynamic problem using the finite element method (FEM). Modeling is carried out at certain frequency points, and frequency sweep is used to obtain the full spectrum. Discretization of the computational domain can be performed by both hexagonal

and tetragonal elements of the volumetric partition. In general, the FEM in the frequency domain is universal. That is, it is applicable for solving a wide class of problems.

A typical RFID system, shown in Figure 3, can be represented in the form of four main components that interact with each other: reader (RFID reader); readable device (transponder, tag, RFID-tag); reader antenna; the host computer. An RFID reader is a device for extracting (reading) information from tags in order to further process it. In turn, the label structure is presented in two parts: a microchip responsible for storing and processing information, modulating and demodulating an RF signal; an antenna responsible for receiving and transmitting an RF signal. The reader antenna is necessary for transmitting energy and information to tags, as well as for receiving a response from tags. The host computer is necessary for further processing of information that was extracted from the label (s) using the appropriate software.

The complete task of electromagnetic design and modeling microwave devices and telecommunication devices it is always divided into a set of tasks in separate blocks in which it is possible to solve Maxwell's equations numerically.

Used 3D modeling software CST Studio Suit can analyze almost any electrodynamic structure and is designed to calculate volumetric and planar configurations with waveguide and coaxial connections, as well as other three-dimensional problems.

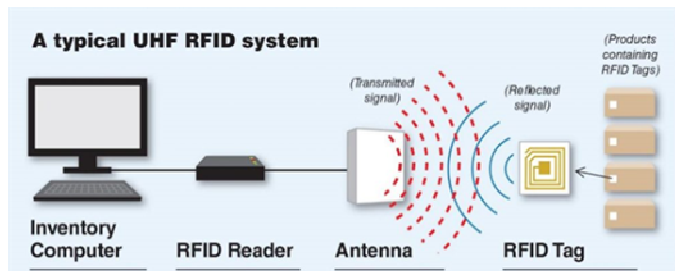


Fig. 1. UHF RFID System Structure.

In earlier works, the effect of bending on the characteristics of the rfid tag [5] was investigated. However, some simplifications were made: the bend was made in orthogonal planes, and also the geometry of the tag was chosen so that these same orthogonal bends could be made. This is due to the limitations of the software, which presents structures in the 2.5 D version.

In the new work, in addition to the free change in the bend gradient due to the use of other software (CST Studio Suite), changes were also made to the structure of the tag itself.

In the presented version, it is possible to change both the radius (gradient) of the bend of the tag and the shape along which the flexible deformation occurs. The article presents an option for bending tags on a cylindrical surface.

The RFID tag was modeled in the CST Studio Suite with the geometrical parameters shown in Figure 2 a):

- Substrate thickness = 1.5 mm;

- Substrate diameter = 35 mm;
- Frequency range: ISM 866-915 MHz.

The chip itself did not take into account in this model, and two ports were connected to connect the chip to the tag antenna. After that, a 3D model was presented, as shown in Figure 2 b).

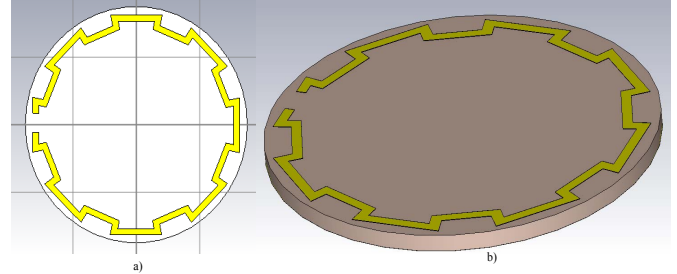


Fig. 2. a) RFID-tag; b) 3D model of RFID-tag in CST Studio Suite.

The following parameters were measured:

- Scattering Coefficients (parameter  $S_{11}$ );
- Voltage Standing Wave Ratio (VSWR);
- Vertical and horizontal radiation patterns and total.

The simulation results are presented in the 3, 4, and 5 figures:

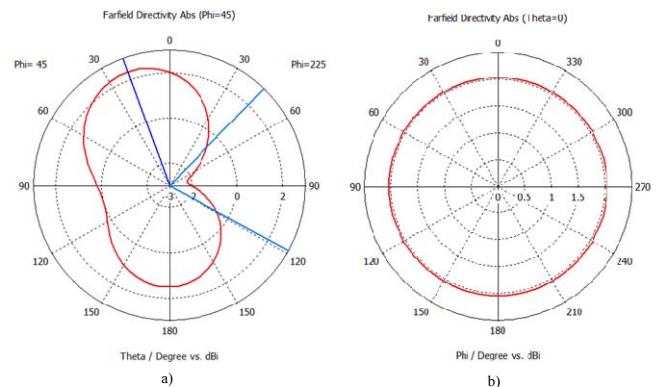


Fig. 3. a) vertical radiation patterns and total before bending; b) horizontal radiation patterns and total before bending.

- a) Frequency = 915 MHz;  
Main lobe magnitude = 2.36 dBi;  
Main lobe direction = 20.0 deg.;
- Angular width (3 dB) = 285.6 deg.
- b) Frequency = 915 MHz;  
Main lobe magnitude = 2.03 dBi.

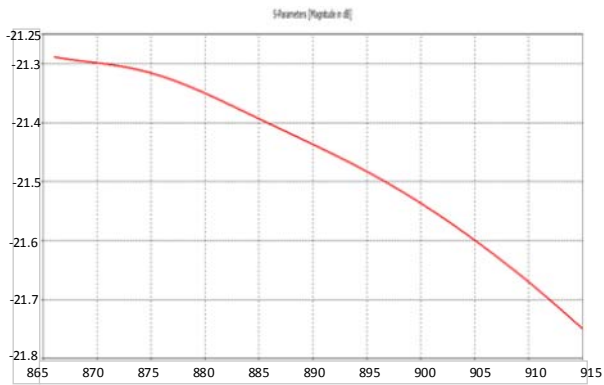


Fig. 4. Parameter S<sub>11</sub> before bending.

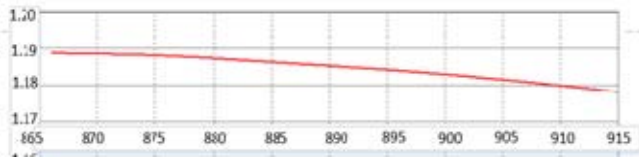


Fig. 5. VSWR before bending.

After that, one half of the mark was bent along a cylindrical surface with a bend angle of 15 degrees. The 3D model of the bent mark is shown in Figure 6. This allowed us to simulate a situation in which the tag bends, for example, during transportation. The data obtained after the calculations are presented in figures 7, 8 and 9:

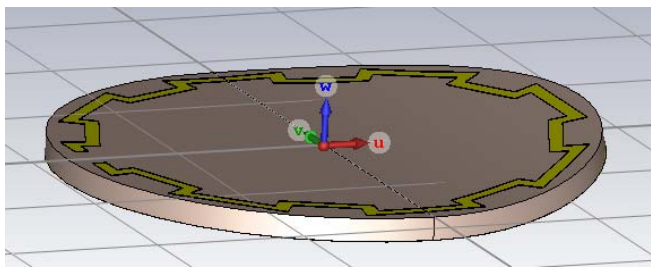


Fig. 6. 3D model of bending RFID-tag in CST Studio Suite after bending by 15 degrees.

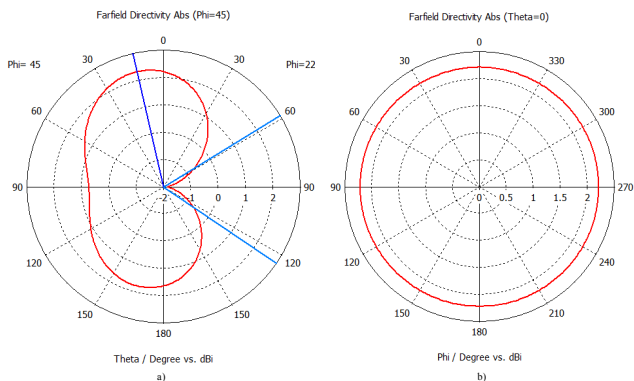


Fig. 7. a) vertical radiation patterns and total after bending by 15 degrees; b) horizontal radiation patterns and total after bending by 15 degrees .

- a) Frequency = 915 MHz;  
Main lobe magnitude = 2.32 dBi;  
Main lobe direction = 13.0 deg.;
- Angular width (3 dB) = 294.3 deg.
- b) Frequency = 915 MHz;  
Main lobe magnitude = 2.21 dBi.

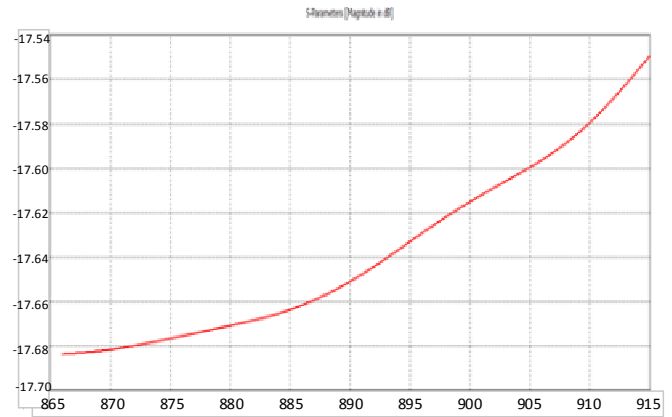


Fig. 8. Parameter S<sub>11</sub> after bending by 15 degrees.

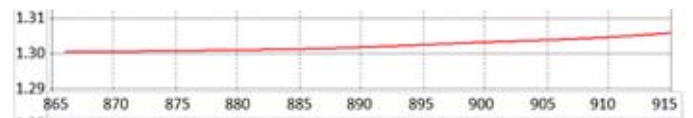


Fig. 9. VSWR after bending by 15 degrees.

After modeling a bend of 15 degrees, a bend of 90 degrees was simulated using the same principle. In Fig. 10, one can observe more serious flexible deformations in comparison with the previous states of the tag. The simulation results are shown in Figures 11, 12 and 13:

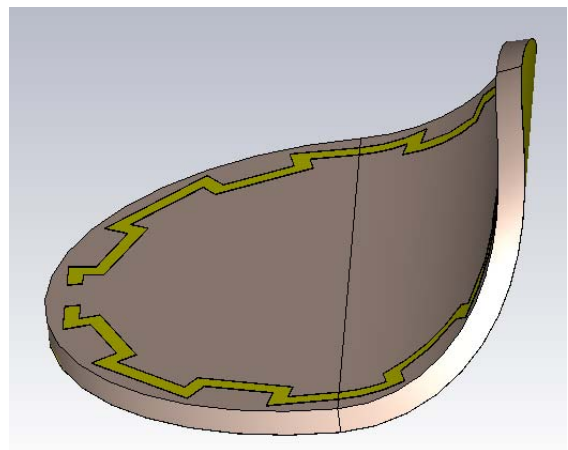


Fig. 10. 3D model of bending RFID-tag in CST Studio Suite after bending by 90 degrees.

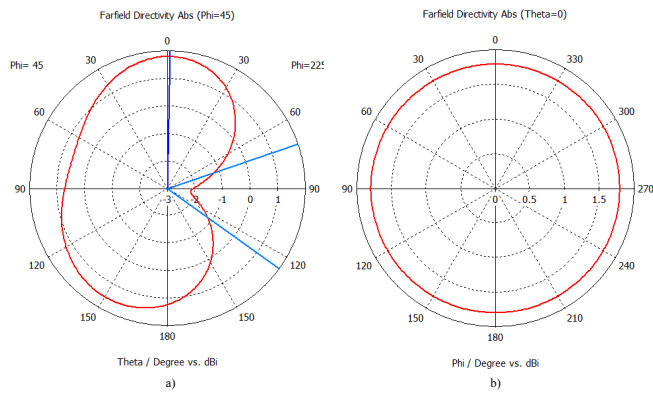


Fig. 11. a) vertical radiation patterns and total after bending by 90 degrees; b) horizontal radiation patterns and total after bending by 90 degrees.

- a) Frequency = 915 MHz;  
 Main lobe magnitude = 1.79 dBi;  
 Main lobe direction = 1.0 deg.;  
 Angular width (3 dB) = 305.5 deg.
- b) Frequency = 915 MHz;  
 Main lobe magnitude = 1.79 dBi.

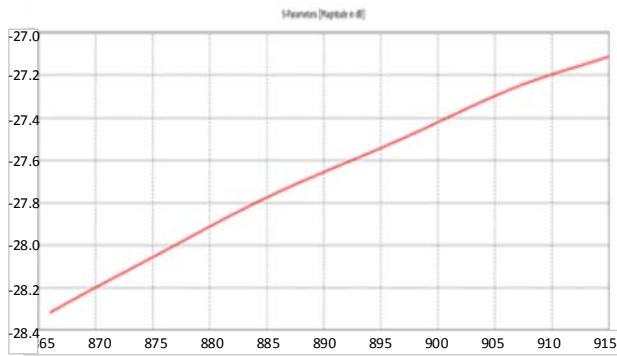


Fig. 12. Parameter  $S_{11}$  after bending by 90 degrees.

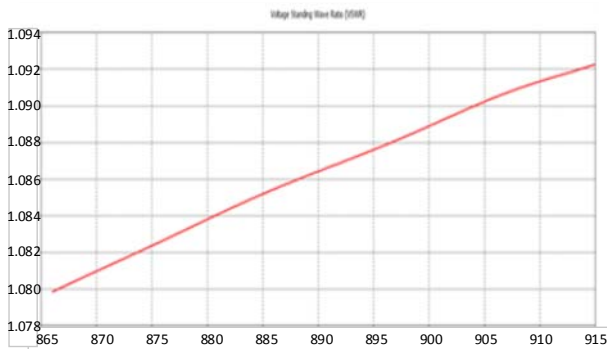


Fig. 13. VSWR after bending by 90 degrees.

### III. CONCLUSION

Thus, changes were made to the topology of the tag under study - an antenna was selected based on the circular meander of the line. Unlike the earlier version of the tag, where two meander lines were presented that converge with each other through the frame and the ports in the center of this frame itself. In addition, other software, CST Studio Suite, was taken as the basis for the calculations. This package uses the same calculation methods as in the previously used software, however, due to the absence of restrictions on the bending gradient, it became possible to study the electrodynamic characteristics of more topologically complex tags on different surfaces. Measurements were taken in the normal state of the tag, also bending at 15 and 90 degrees. Results are obtained in which a higher resistance to flexible deformations is observed in comparison with the previously studied tag. Negative changes are available only at certain angles, but even in this case (with deterioration), the characteristics do not go beyond the normal range in the presented label. VSWR is still less than 3, radiation patterns also did not undergo severe deterioration. The tag shows bending resistance along a cylindrical surface.

### ACKNOWLEDGEMENT

The article was prepared within the framework of the Academic Fund Program at the National Research University Higher School of Economics (HSE) in 2019 — 2020 (grant № 19-04-005) and by the Russian Academic Excellence Project «5-100».

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