

Testing of the impact of dielectric thickness on basic parameters of the microstrip GSM / LTE antenna

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ABSTRACT

The article presents the model of a dual-band LTE antenna operating on the 1800 MHz and 2600 MHz band as well as the results of research on the influence of antenna dielectric thickness on selected parameters. Designed and the built antenna works in the 1.71- 1.93 GHz frequency band for GSM 1800, GSM 1900 and 2.42 - 2.85 GHz frequency for LTE 2500, LTE 2600. Using the transmission line model, the antenna dimensions were obtained and then in the CST Studio Suite environment, the presented parameters were obtained by means of optimization. The parameters obtained before and after the dielectric thickness change were compared with each other. The practically made antenna was tested in the Electromagnetic Compatibility Laboratory of the Military University of Technology.

Keywords: antenna LTE, dielectric thickness, dual band antenna, microstrip antenna, LTE, GSM.

1. INTRODUCTION

Nowadays, one antenna should work in GSM, UMTS and LTE technologies. That is why it is required from telecommunication service providers to develop multi-range antennas. The antenna, which is an inseparable part of portable telecommunications devices, should be characterized by low weight, small size and wide bandwidth. In the practical design of mobile devices, antennas had limited space, especially a small thickness device like laptops, tablets, mobile phones and USB modems. Usually thickness is a range from 5 to 12 millimeters. Antennas, which are characterized by small size, low profile and the ability to work in many frequency bands are the planar antennas. The article presents the model of a dual-band LTE antenna operating on the 1800 MHz and 2600 MHz band and results of the impact of antenna dielectric thickness on selected parameters. LTE technology is revolutionizing the world by providing the fastest data transmission. It is a radical step forward for the wireless industry. The main goal of LTE is to provide a highly efficient, low latency and a safer service. This new system include OFDM (Orthogonal Frequency Division Multiplexing) to avoid interfering signals between symbols that typically limit the performance of high speed systems and MIMO (Multiple-Input Multiple-Output) techniques to increase speed data transmission. The designed and constructed antenna cover the 1.71- 1.93 GHz frequency band for GSM 1800, GSM 1900 and 2.42 - 2.85 GHz for technology LTE 2500, LTE 2600. Using transmission line model, the initial antenna dimensions have been calculated. Flowingly by using optimization in CST Studio Suite environment, the presented parameters were obtained. Article presents parameters before and after changes of dielectric thickness and their comparison. The physical antenna was tested in the Electromagnetic Compatibility Laboratory of the Military University of Technology. The designed antenna model is a microstrip antenna operating in two bands used in Europe in the LTE standard, i.e. 1800 MHz and 2600 MHz^{1,4,5}.

The basic dimensions of the radiator of the microstrip antenna were calculated from the dependence (1) - width and (2) - length^{2,7}.

$$W = \frac{c}{2f_r \sqrt{\frac{\epsilon_r + 1}{2}}} \quad (1)$$

$$L = L_{eff} - 2 * \Delta L \quad (2)$$

Where:

$$L_{eff} = \frac{c}{2f_r \sqrt{\epsilon_{eff}}} \quad (3)$$

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$$\Delta L = 0.412 \frac{(\epsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{eff}-0.264)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2} \left[1 + 12 \frac{h}{W} \right]^{-1/2} \quad (5)$$

The dimensions of the designed antenna were optimized by using the CST Studio Suite environment. Additionally, the main parameters for the selected dielectric thickness were calculated numbers. It should be in a one-column format. References are often noted in the text¹ and cited at the end of the paper.

2. ANTENNAS CONSTRUCTION

If the paper does not have the margins shown in Table 1, it will not upload properly. Fig. 1 shown construction of the dual-band antenna LTE . It is a microstrip antenna, powered by a microstrip line with a SMA female connector with 50 Ohm impedance. It was made on a FR-4 substrate from ROGERS CORPORATION with a size of 192 x 129 mm, dielectric thickness of t=1.5 mm and a relative permittivity $\epsilon_r = 4.6$. The designed antenna was made practically and tested in the Electromagnetic Compatibility Laboratory of the Military University of Technology. Realized the antenna design presented in Figure 1, the assumptions presented in Table 1 were adopted.

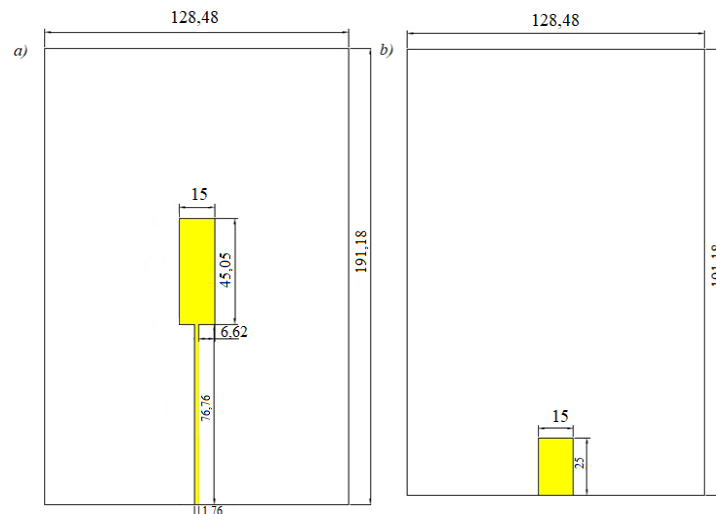


Figure 1. Antenna construction: a) view from the side of the radiator b) view from the side of the screen.

Table 1. Design assumptions.

Design assumptions			
Assumptions		Assumptions	
Frequency	1800, 2600 MHz	Dielectric thickness	1.5 mm
Substrat	FR – 4 (loss free)	Dielectric loss factor $tg\delta$	0.02
Relative permittivity ϵ_r	4.6	Feed	Microstrip Line
VSWR	≤ 2	S_{11}	≤ -10 dB

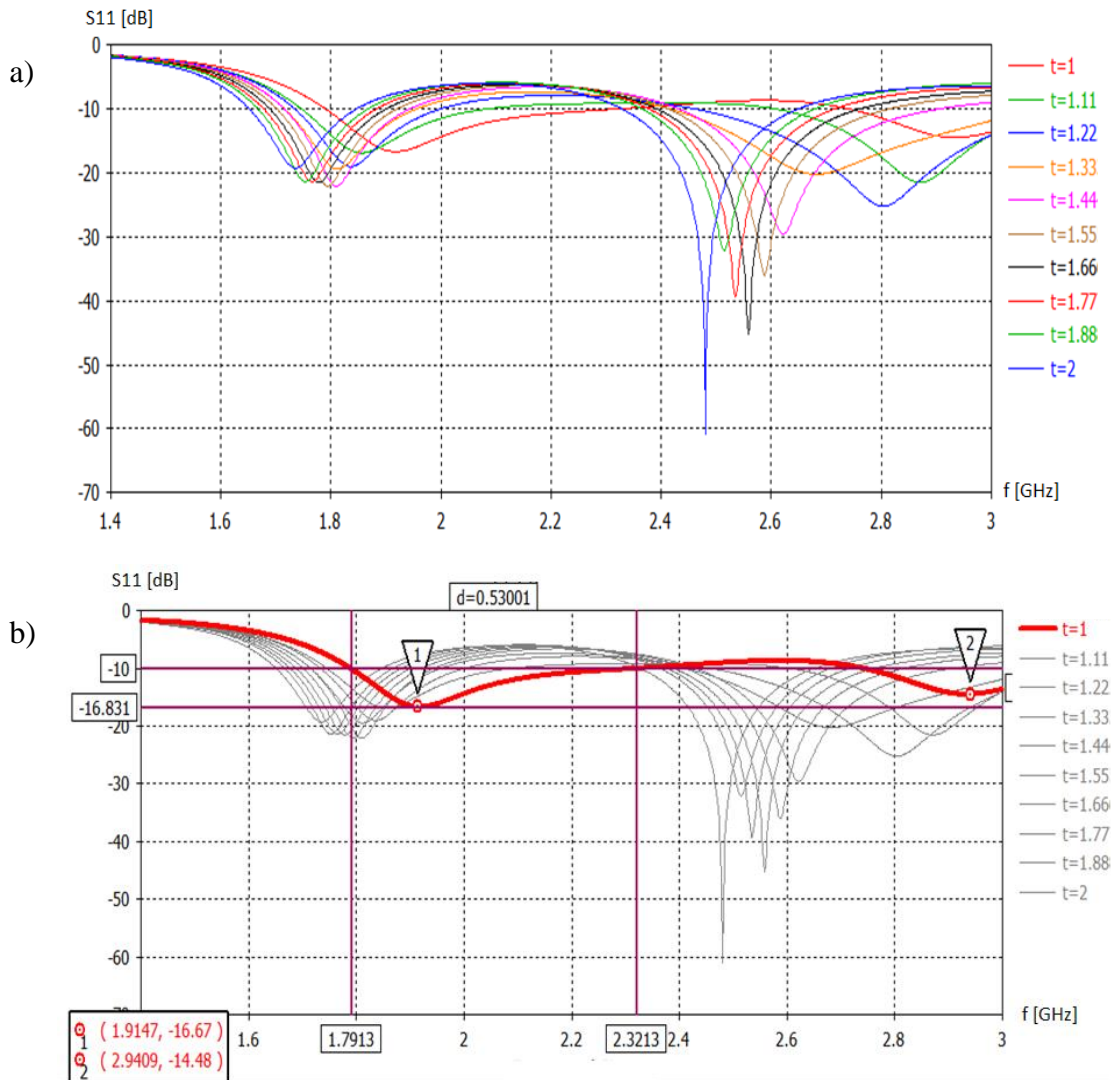
3. SIMULATION RESULTS

During change the thickness of the dielectric in CST Studio Suite environment the following parameters of designed antenna has been analyzed: S11 reflection coefficient, VSWR, input impedance and gain.

3.1 S₁₁ reflection coefficient

Figure 2 presents the results obtained during computer simulation in the CST Studio Suite environment. As you can see, when the thickness of the dielectric increases, the width of the operating band decreases and the center frequencies shift towards the lower frequencies. In the case of reducing the dielectric thickness the situation is reversed – with the decreasing of the dielectric thickness, the operating band becomes wider, and the center frequencies shift towards higher frequencies.

For the smallest thickness of the dielectric, i.e. $t = 1$ mm bandwidth $f_0 = 1.8$ GHz increased from 196 MHz to 530 MHz, and for $f_0 = 2.6$ GHz increased from 433 MHz to 800 MHz. Which means that the bands have almost doubled. While the center frequency shifted to the right sequentially from $f_0 = 1.8$ GHz to $f_0 \approx 1.9$ GHz and from $f_0 = 2.6$ GHz to $f_0 \approx 2.9$ GHz. For the largest thickness of the dielectric, i.e. $t = 2$ mm band was reduced from 223 MHz to 202 MHz, and for $f_0 = 2.6$ GHz decreased from 433 MHz to 330 MHz. By contrast, the center frequencies shifted sequentially left from $f_0 = 1.8$ GHz to $f_0 \approx 1.7$ GHz and from $f_0 = 2.6$ GHz to $f_0 \approx 2.5$ GHz. Of course, the best results remain at the initial thickness of the dielectric, $t = 1.5$ mm.



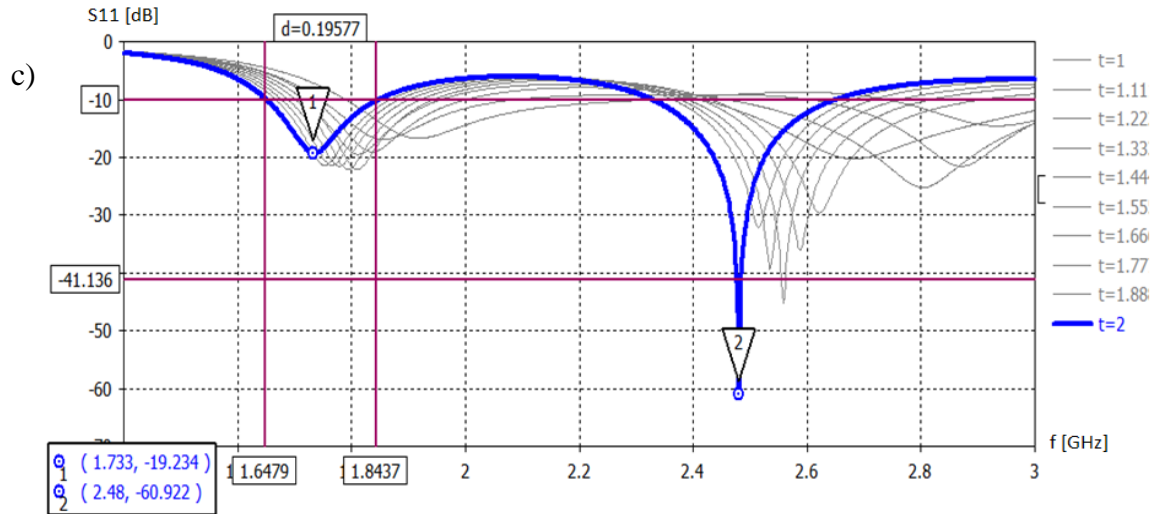


Figure 2. The effect of the dielectric thickness on the reflection coefficient S_{11} for selected thicknesses t [mm]: a) $t=1-2$ [mm], b) $t= 1$ [mm]: c) $t= 2$ [mm].

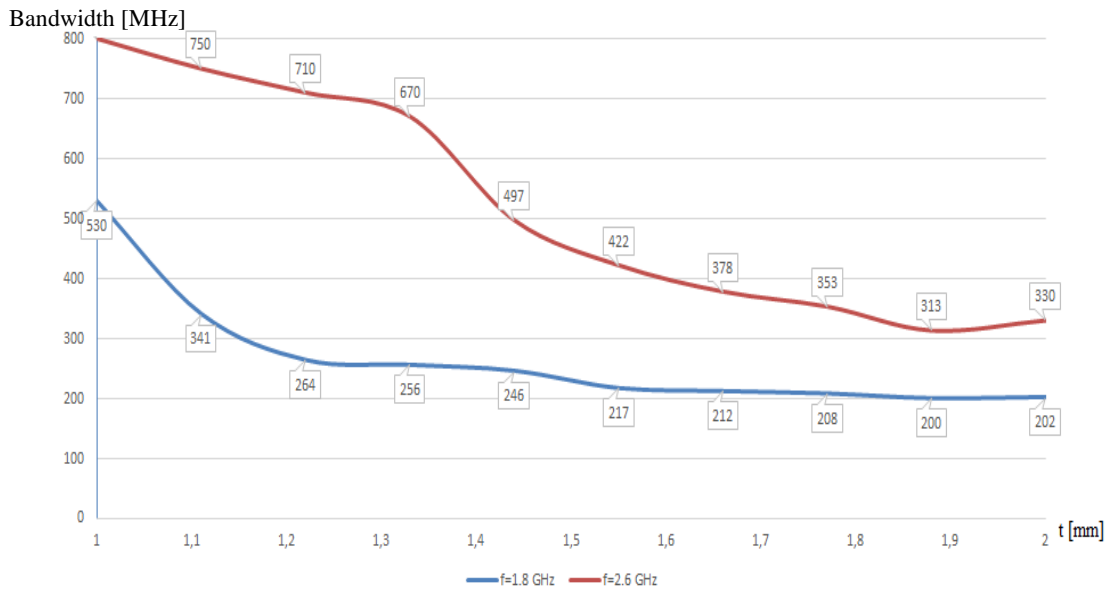


Figure 3. Influence of dielectric thickness on the antenna bandwidth.

3.2 Input impedance

Figure 4 presents the results how the dielectric thickness influence on the input impedance obtained during computer simulation in the CST Studio Suite environment. When the thickness of the substrate decreases, the real part of the input impedance decreases. The best result for both ranges is for the initial thickness, i.e. $t = 1.5$ mm. However, for the center frequency $f_0 = 2.6$ GHz beginning from the ground thickness $t = 1.33$ mm, the value of R_{we} oscillates around 50Ω . For the center frequency $f_0 = 1.8$ GHz the best level of R_{we} is for the initial thickness. This means that the antenna could be used for the center frequency $f_0 = 2.6$ GHz with a higher dielectric thickness while for $f_0 = 1.8$ GHz antenna would not work properly because of some noise and interference.

For the imaginary part Z_{we} the situation is reversed. When thickness of the substrate decreases, the imaginary part of the input impedance grows, whereas with the increase of the dielectric thickness the imaginary part of the input impedance

decreases. The best result for both ranges is for the output thickness, i.e. $t = 1.5$ mm. In this case, better level of Z_{we} is for frequency $f_0 = 1.8$ GHz. From the ground thickness $t = 1.5$ mm, the value jX_{we} oscillates within 0Ω . The best result is for the dielectric thickness $t = 1.77$ mm where the $-jX_{we} = 0.95 \Omega$. For the frequency $f_0 = 2.6$ GHz, the best values of jX_{we} oscillates around initial substrate thickness. To improve the antenna work on both frequencies when the dielectric thickness is changed, we can place a tuner to the power line, which will get a better matching.



Figure 4. List of characteristics of dielectric thickness influence on input impedance for $f_0 = 1.8$ GHz and $f_0 = 2.6$ GHz: a) real part b) imaginary part.

3.3 Gain

Figure 5 presents the results how the dielectric thickness influence on gain obtained during computer simulation in the CST Studio Suite environment. With the reduction of the thickness of the substrate, the gain decreases and with the increase of the dielectric thickness the gain grows. The lower frequency $f_0 = 1.8$ GHz let to more noticeable this increase. The value of gain changed from $G = 3.65$ dB to $G = 3.83$ dB. In the case of the higher frequency $f_0 = 2.6$ GHz, this change is smaller, however, there is also an increase from $G = 4.27$ dB to $G = 4.33$ dB. Therefore, with the increase of the dielectric thickness, the efficiency of the antenna grows. It means that most of the power supplied at its input terminals is converted into energy which is radiated into space with including its directional properties.

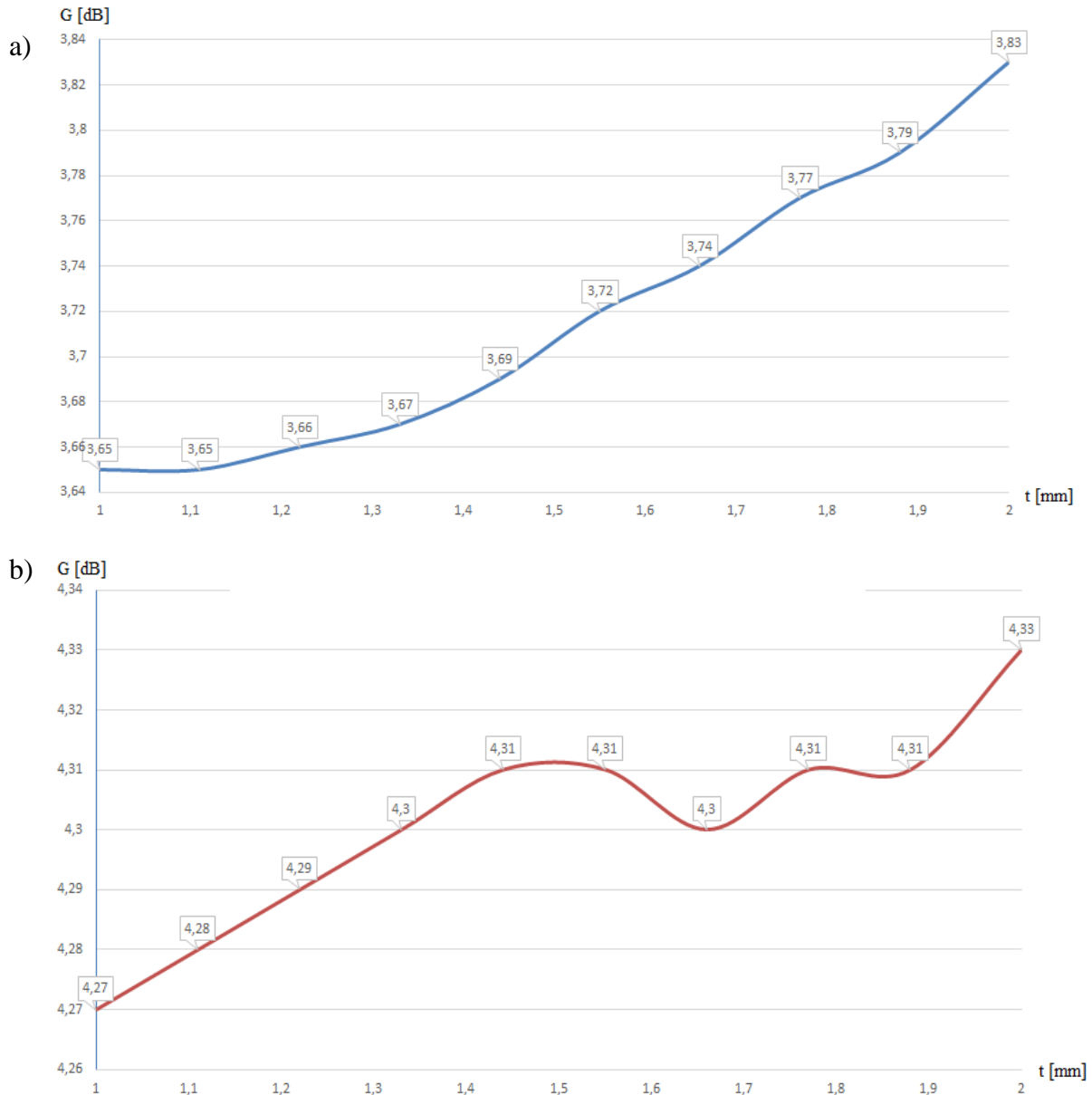


Figure 5. List of characteristics of dielectric thickness influence on on gain for $f_0 = 1.8$ GHz and $f_0 = 2.6$ GHz:
a) real part b) imaginary part.

4. ANALYSIS OF PRACTICALLY OBTAINED RESULTS

The antenna designed and described in this article was physically made and research at the Faculty of Electronics of the Military University of Technology in the Laboratory of Electromagnetic Compatibility.

The band obtained during computer simulations for $VSWR < 2$ marginally differ from the results obtained during laboratory tests. Respectively for the range:

- 1.8 GHz, the band during the simulation was 1.70 GHz - 1.94 GHz and for the physical antenna: 1.78 GHz to 2.11 GHz. However, the values at 1.82 GHz to 1.99 GHz oscillate almost at $VFS = 2$,
- 2.6 GHz, the band during the simulation was 2.41 GHz - 2.88 GHz while after testing in the laboratory 2.24 GHz to 2.81 GHz. The band has expanded by 10 MHz.

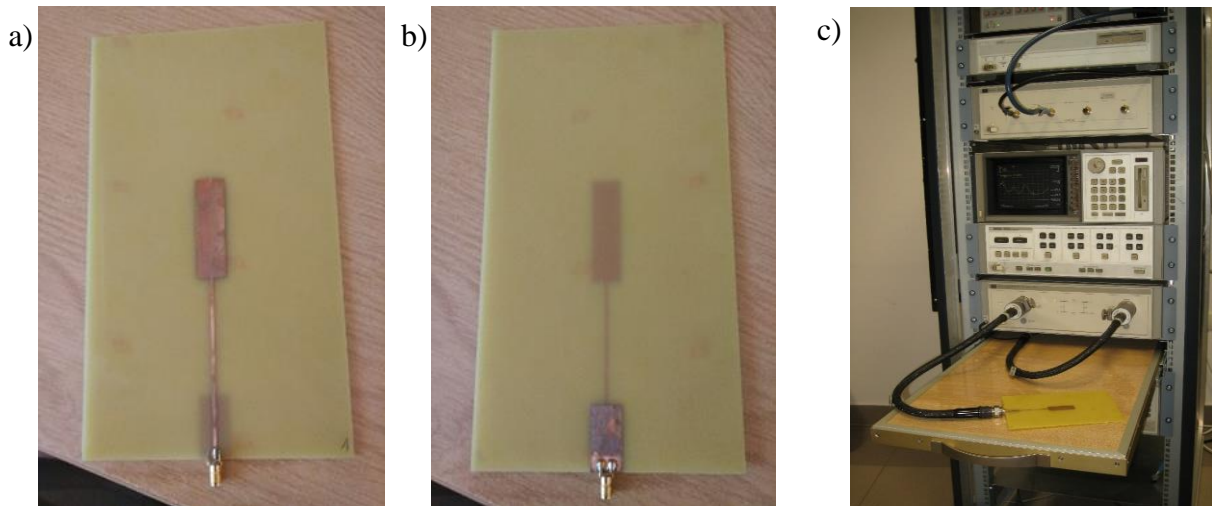
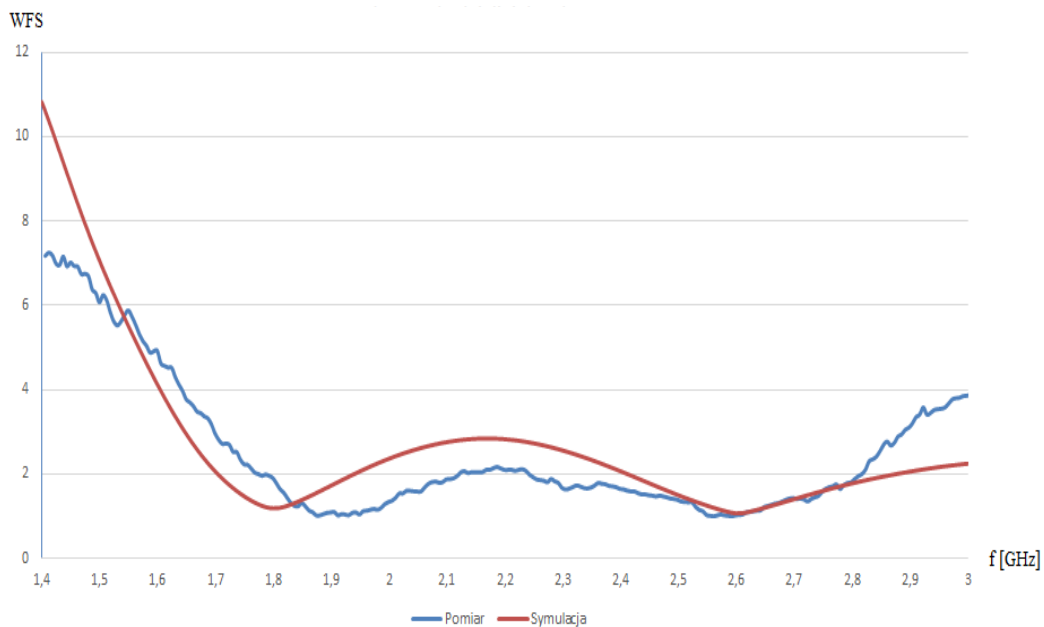


Figure 6. The model of the physically constructed antenna: a) the view from the side of the radiator, b) the view from the side of the screen, c) the physical model of the tested antenna on the measurement stand in the WAT Laboratory of Electromagnetic Compatibility.



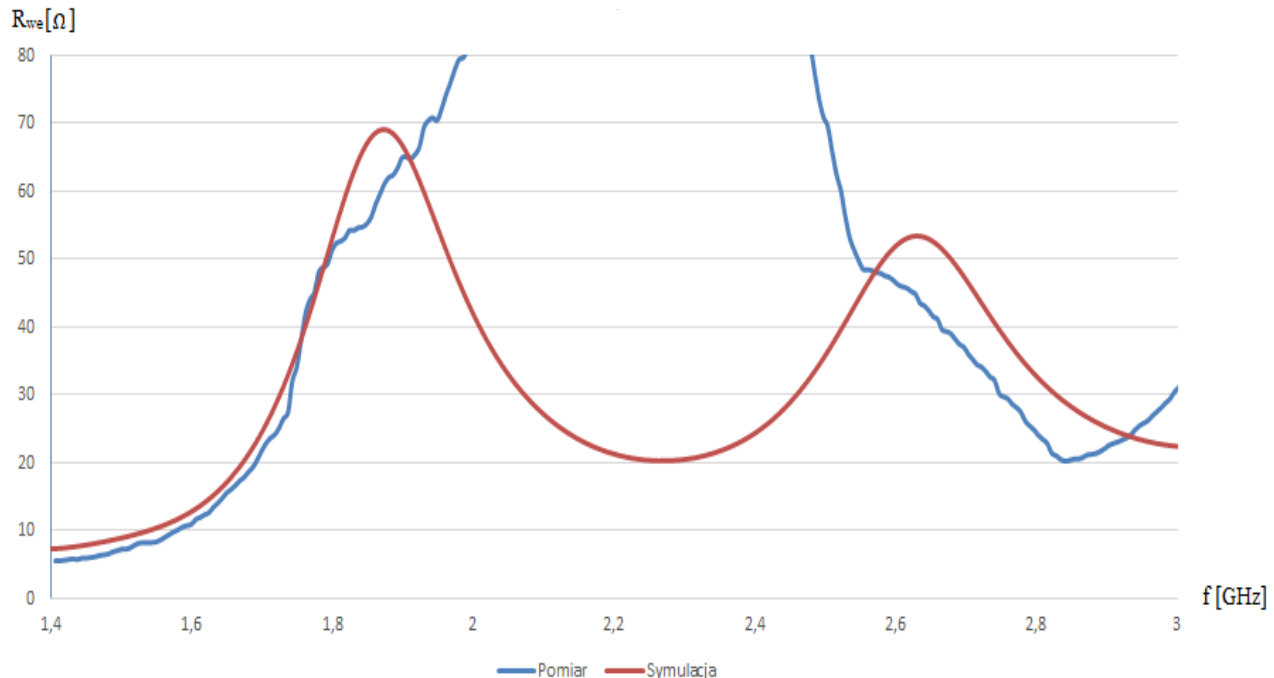


Figure 7. List of characteristics a) WFS b) reactance c) resistance of the antenna physically made and simulated in the CST program.

5. SUMMARY RESULTS

Received results physical antenna model research in the Electromagnetic Compatibility Laboratory slightly differ from those obtained during computer simulation in the CST Studio Suite environment. The laminate that was used to create the antenna was a substrate of the low quality. Choose of the substrate is very important on the stage of antenna design. For example we can find at ROGERS catalog materials, that the dielectric thickness tolerance for the majority of produced laminates is up to $\pm 7\%$, and for the FR-4 laminate family up to $\pm 15\%$.^{4,8}

The antenna was designed in the CST Studio environment on the substrate FR - 4 with a dielectric constant $\epsilon_r = 4.6$. The dielectric constant ϵ_r of most FR-4 laminate family can vary $\pm 10\%$ or more.⁸

The research the impact of antenna dielectric thickness on selected parameters showed that a change in thickness even of 0.1 mm causes a change in bandwidth, gain or impedance. The change in dielectric constant ϵ_r has a similar effect.

The bands obtained in the laboratory almost completely overlap with the bands supported by LTE and GSM technology. Moreover the dielectric thickness significantly influence on selected antenna parameters.

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