DEPENDENCE OF ELECTROMAGNETIC ABSORPTION ON GEOMETRICAL PARAMETERS OF MICROWIRES

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The present paper is devoted to the study of electromagnetic absorption properties of microwires. All the measurements have been done in the ELIRI Research Institute by using the vectorial analyzer Agilent 8720 ES. The main goal of the paper is to determine the dependence of electromagnetic absorption properties of microwires on their geometrical parameters. The authors explain the physical meaning of the radiation absorption and its dependence on the microwire parameters. The results of the investigation are useful in making a shield to protect the surroundings from the harmful effects of electromagnetic radiation.

Introduction

Today, in the century of informational technologies and telecommunication systems, the electromagnetic situation of the environment is becoming more and more dangerous and harmful. As we know, both wireless technologies such as WiFi, Bluetooth, WiMAX and mobile communication devices (GSM and CDMA mobile networks) use electromagnetic waves for the transmission of information. The electromagnetic field formed by such devices influences the equipment of the technological process, the computer techniques as well as the users themselves. That is why, the protection of mobile network subscribers and the technological equipment is a very important and necessary task.

All the technologies mentioned above work in the metric and decimetric wavelength bandwidth. In this way, absorbent materials can be used in a known bandwidth in order to manufacture a protection shield. Microwires of different composition, length, thickness and absorption properties are chosen as absorbent materials. Researches have been made according to S_{11} parameter for two types of microwires: Ni-alloy microwire (d=10µm) and Mn microwire (d=30µm).

Similar analyses have been made using as samples microwires of different composition and geometrical parameters: both Mn microwires (d_1=30µm, d_2=50µm) and steel microwires (d_1=10.6µm, d_2=11µm, d_3=11.8µm), as well as thin steel films and strips [2].

The experimental method

The research of electromagnetic properties that depend on geometrical parameters of microwires has been made in ELIRI Research Institute with the help of the Vectorial Analyzer Agilent 8720 ES (fig.1). This device permits to determine very precisely the S parameters in a large bandwidth, of about 50 MHz – 20 GHz. The results from 2 channels were presented on a LCD screen. Three types of calibration for measurements of noncoaxial sectors are used: calibration for open, short and load conditions. This ensures high accuracy in the work with waveguides [1].

Figure 1. The Vectorial Analyzer Agilent 8720 ES.

While investigating we determined the S_{11} parameter for different types of microwires with a different chemical composition and different geometrical parameters. A similar scheme of the measurement installation is shown in figure 2.

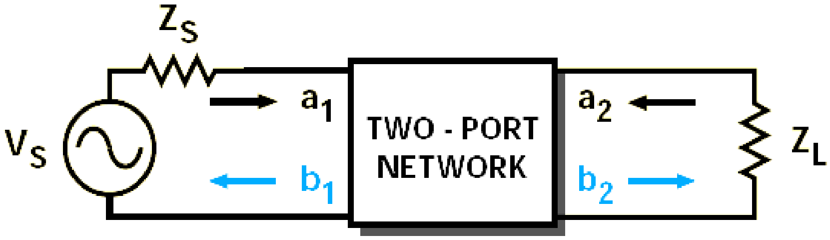


Figure 2. The scheme of research installation.

The notations from figure 2 show:

$|a_1^2|$ - the input incident power, equal to the power available from the voltage source;
$|a_2^2|$ - the output incident power, equal to the power reflected by the load (Z_L);
$|b_1^2|$ - the power reflected by the input port;
$|b_2^2|$ - the power reflected by the output port, equal to the load incident power;
Z_L - load impedance;
Z_S - internal source impedance;
Z_0 - input impedance;
V_S - source voltage.

General information about S parameters is given below:

$S_{11} = \frac{b_1}{a_1}, (a_2 = 0)$ - Input reflection coefficient with the output port terminated by a matched load (Z_L=Z_0 sets a_2=0);

$S_{22} = \frac{b_2}{a_2}, (a_1 = 0)$ - Output reflection coefficient with the input port terminated by a matched load (Z_S=Z_0 sets V_S=0);

$S_{21} = \frac{b_2}{a_1}, (a_2 = 0)$ - Forward transmission (insertion) gain with the output port terminated in a matched load;

$S_{12} = \frac{b_1}{a_2}, (a_1 = 0)$ - Reverse transmission (insertion) gain with the input port terminated in a matched load.

Note: All the S parameters are non-dimensional magnitudes.

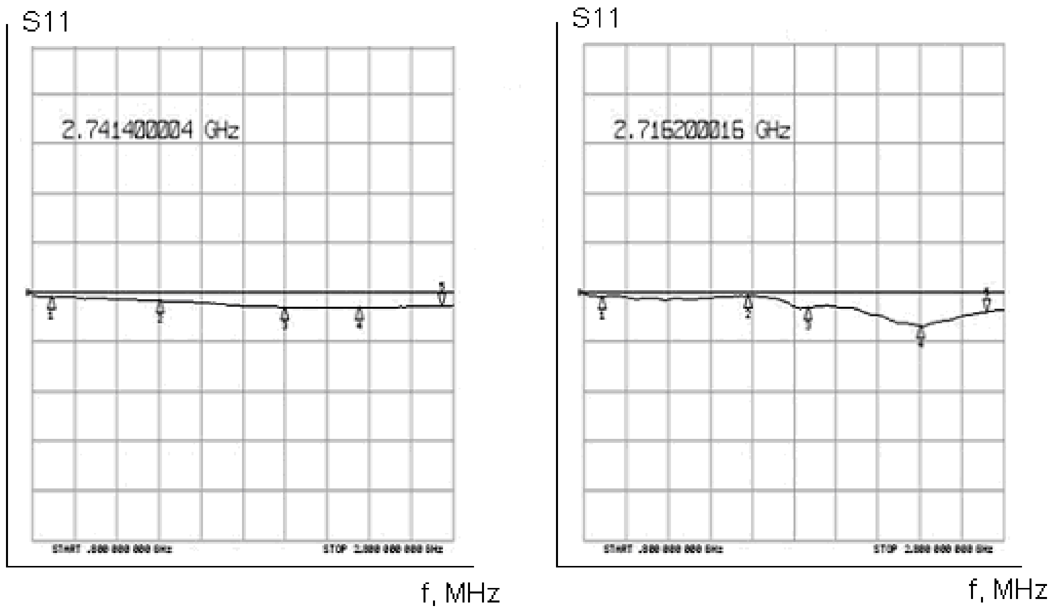
In the future, investigations will be made according to other S-parameters in order to thoroughly study the properties mentioned above.

Experimental results

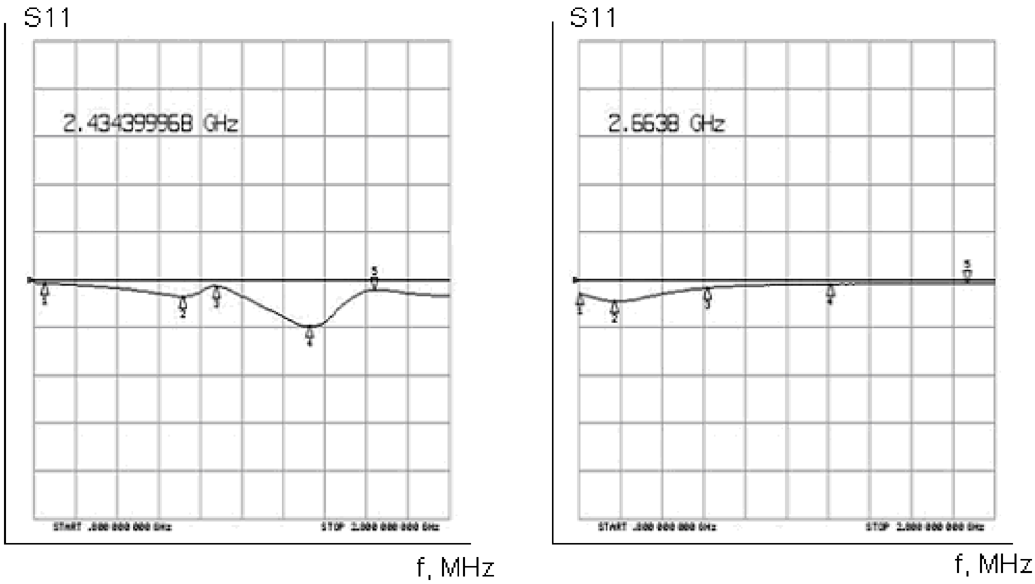
This paper contains spectral graphs of the S_{11} coefficient for two types of microwires:

1. resistive Ni-alloy microwire in glass isolation, d =10µm (sample 1);
2. Mn microwire, ПЭВМТ type, d =30 µm (sample 2).

The Log Mag (logarithmic magnitude) graph as well as the Smith Chart and the Phase Chart ones for microwires as long as 5 cm in comparison with lenghts of 2 cm are shown below. The Log Mag graph is presented in figure 3:



a) b)



c) d)

Figure 3. The Log Mag graphs for sample 1 (a, c) and sample 2 (b, d).
The results are for 5 cm length (a, b) and 2 cm length (c, d).

The figures clearly show that for a length of 5 cm the absorption properties are constant in a larger bandwidth for sample 1 than for sample 2, while for the second sample, absorption is higher for a constant frequency (2.71 GHz). At the same time, for wires 2 cm long, absorption properties are more constant for sample 2, but they are stronger for sample 1.

Because the mentioned technologies work at lower frequencies (for example GSM900 and GSM1800), these samples may be used for manufacturing high-frequency filters. These models of microwires can also be useful for work in a lower bandwidth where their characteristics are more constant and uniform (markers 1 and 2 in diagrams).

Analyzing figure 4 we can prove the statements which have been mentioned above. Firstly, the electromagnetic properties for the first sample are more constant and uniform in comparison with the second one, for microwires 5 cm long. For wires 2 cm long these properties are more uniform for the second sample.

As we can see from figures 4(b) and 4(c) there are a lot of curls, distortions and irregularities, which probably may be caused by parasite (undesirable) capacities and geometrical parameters that appear for short lengths of samples.

A Smith Chart is a graphical representation of the transmission line equations and the mathematical reasons for the circles and arcs. Transmission coefficient, which equals unity plus reflection coefficient, may also be plotted. The Smith Chart contains almost all possible impedances, real or imaginary, within one circle. All imaginary impedances from - infinity to + infinity are represented, but only positive real impedances appear on the "classic" Smith Chart. It is possible to go outside the Smith chart "unity" circle, but only with an active device because this implies negative resistance.

It is worth mentioning that the inferior half of the Smith Chart graph shows the capacitive character of the analyzed model, while the superior half reflects the inductive character of the same sample. The border line between these two halves represents the resonance point, where the reactive components X_L and X_C set off each other and the active resistance component is predominant: $Z = \sqrt{R^2 + (X_L - X_C)^2} = R$ [2].

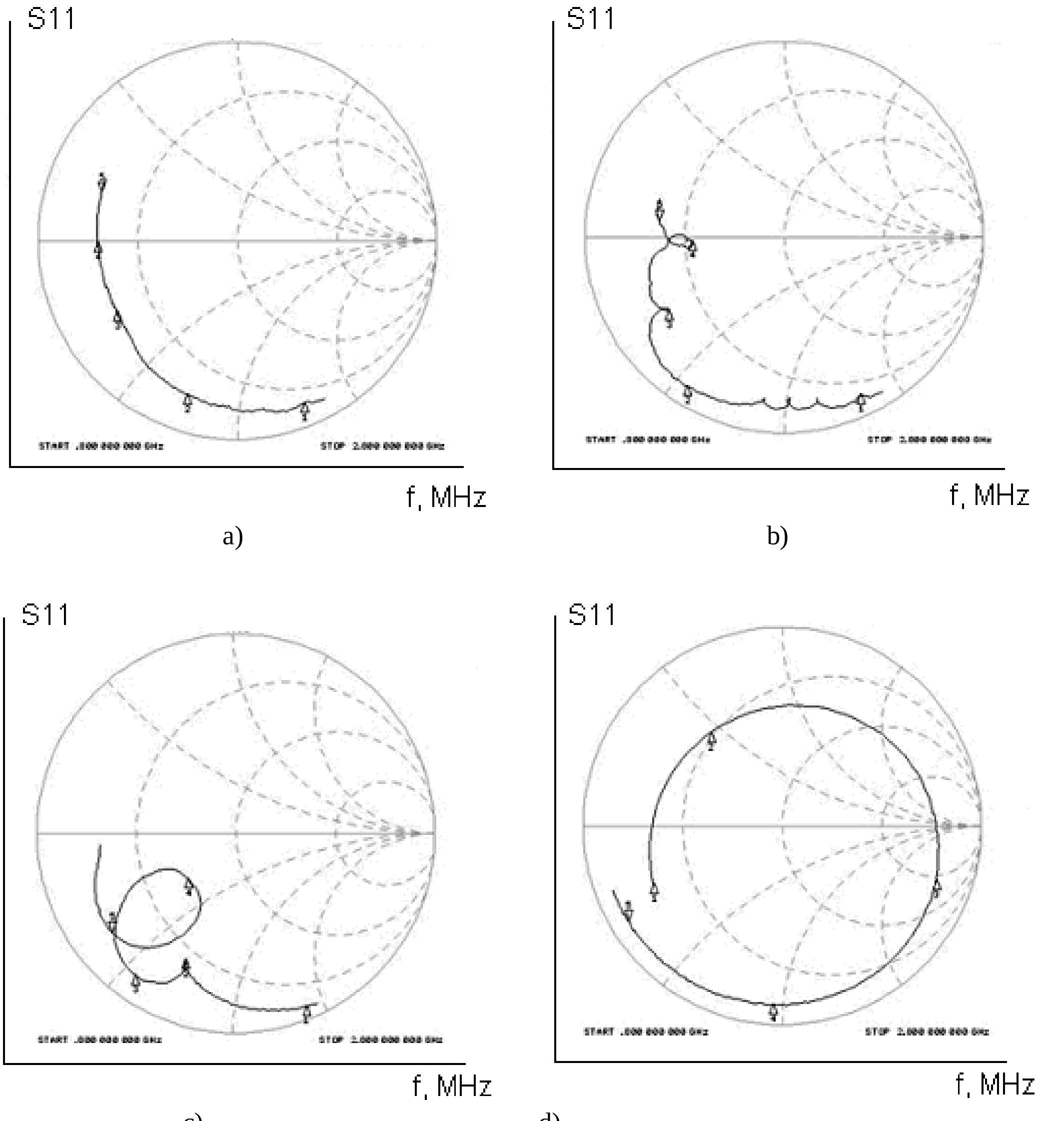
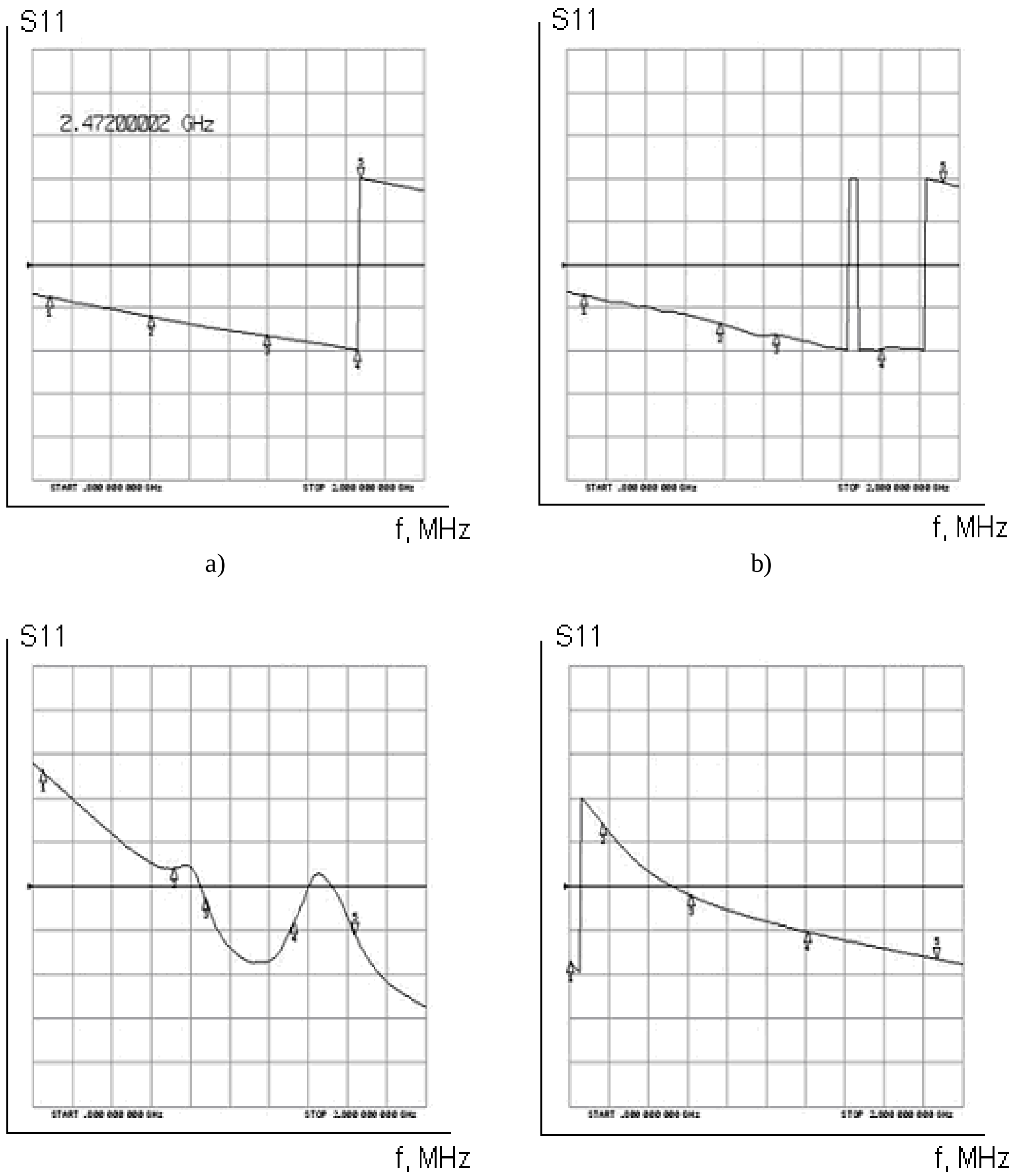


Figure 4. The Smith Chart graphs for sample 1 (a, c) and sample 2 (b, d).
The results are for 5 cm length (a, b) and 2 cm length (c, d).

Studying the phase graphs of samples, presented below in figure 5, we can see that for both samples, the obtained graphs have common properties. A jump in the graph is found in almost all figures, which corresponds to the resonant frequency. At such frequency, the nature of the reactive component is changed from capacitive (the inferior half of the graphs) to inductive (the superior half of the graphs).



c) d)

Figure 5. The Phase Chart graphs for sample 1 (a, c) and sample 2 (b, d).
The results are for 5 cm length (a, b) and 2 cm length (c, d).

We find it important to point out the physical meaning of electromagnetic absorption: this phenomenon is related to the resonant absorption of electromagnetic energy and its spreading as heat on the active resistance of microwire. The highest absorption is obtained for cases when the wire length value is the multiple of the wavelength of electromagnetic radiation. [3, 4]

Conclusion

In conclusion we would like to state that microwires can be effectively used (compared to thin metallic films and strips [2]), mainly due to their electromagnetic absorption properties. A microwire itself is a very good solution in the manufacture of soft and convenient shields that can protect the environment, as well as the human body from the harmful effects of electromagnetic radiation. Unfortunately, nowadays there are not many solutions for solving this problem. That is why, probably, the utilization of microwire as an absorbent material can be a remarkable success.

Last but not least, the Republic of Moldova produces microwires of different composition and properties which is an important advantage and perspective in their study and useful utilization.

In the nearest future, one of our aims is also to measure the other S-parameters (S_{12}, S_{21} and S_{22}) to better understand the absorption properties of microwires and the best way of their utilization.

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