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Simulation of Paramaters of Frequency Selective Surface in Microwave Band

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***Abstract* — The paper presents the results of numerical simulations of the electrodynamic characteristics of a cell of an infinite 2D frequency-selective surface (FSS) with the topology of the structural element of the Ψ form. The simulation was performed as part of the Finite Element Method (FEM) using the ANSOFT HFSS software product. The results obtained make it possible to predict the possibility of creating highly efficient frequency-selective surfaces using the proposed key element topology.**

Keywords—frequency-selective surface, cell, patch, topology

I. INTRODUCTION

The operation of frequency selection is one of the most important in any microwave radio system. A relatively new way of performing frequency selection is the spatial selection method. It is carried out using the so-called frequency-selective surfaces (FSS), also called spatial filters. Such elements have dispersive transmission and / or reflection characteristics. In the microwave range, FSSs are periodic arrays of the same type of metal elements located on a dielectric substrate. Depending on the assigned technical tasks and methods for their implementation, both 1D and 2D arrangement of elements on the substrate can be used.

FSS have a number of significant advantages in comparison with the well-known classical elements of frequency selection. Among them, one can indicate low profile, the ability to use structures with a limited number in periodic sequences of elements, the ability to work with arbitrary polarization of signals, angular stability, multi-frequency sufficiently high attenuation outside the working bands, and the possibility of using lithography methods, which greatly simplifies and reduces the cost of production.

Becsuse of their advantages, FSSs are quite widely used in practical applications: reflector antennas [1], dichroic sub-reflectors [2], radio identification systems (RFID) [3], lenses antennas [4], systems protection from electromagnetic interference [5].

In this paper, we present the results of modeling the basic electrodynamic characteristics of a cell of an infinite 2D FSS with the topology of the structural element of the Ψ form.

II. STRUCTURE UNDER STUDY

We will consider the electrodynamic structure, which is a cell of an infinitely 2D structure of the Ψ shape. A view of the structural element with the notations is shown in Fig. 1.

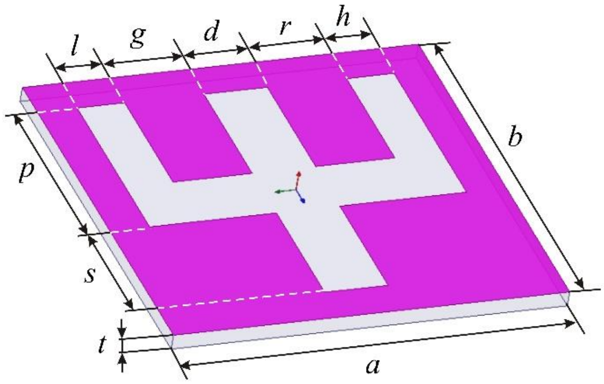

Fig.1. The view of the structure.

Table 1 presents the geometric dimensions of the topological elements of the structure.

TABLE 1. SIZES OF STRUCTURAL ELEMENTS

^{9} **Parameter**	***Value***	**Parameter**	***Value***
a	12.5 mm	g	2.5 mm
b	12.5 mm	d	2 mm
p	6 mm	r	2.5 mm
s	4 mm	h	1.5 mm
l	1.5 mm	t	var

Two structural parameters, namely, the thickness of the substrate t and the relative dielectric constant of the substrate ε_r are variable.

It should be noted that the topology of the basic element of the structure itself is quite complex, and all functional dependencies are multi-parameter. For this reason, the development of a regirous electrodynamic solution that would allow us to analyze the dependences on all parameters is practically impossible. Simulation of parameters was performed numerically using the finite element method (FEM) implemented in the ANSOFT HFSS software.

III. THE RESULYS OF SIMULATIONS

The structure under consideration is complex compositional, and the dependencies describing its properties are complex parametric. One of the most important parameters in this sense is the thickness of the dielectric substrate and the value of relative permittivity.

In Fig. 2 the curves show the dependences of the modulus of the reflection coefficient $|S_{11}|$ via frequency at the fixed value $\varepsilon_r = 2.2$ and variations in the thickness of the substrate from 0.4 mm to 0.7 mm.

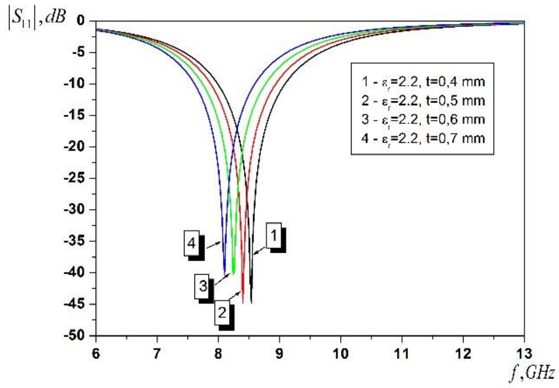

Fig. 2. The dependenceis of $|S_{11}|$ via frequency with variation of t .

A change in thickness in this interval leads to a shift in the resonance absorption frequency towards lower frequencies by $\Delta F \approx 500\,MHz$. All curves are smooth with a fairly high level of steepness. If one concentrates on the magnitude of the return loss of -10 dB (at the level of VSWR ≈ 2), the matching bandwidth is 900 MHz. For all the dependencies, the steepness level is approximately the same and reaches a value of 0.038 dB / MHz.

The dependences $|S_{11}|$ for a fixed value $t = 0.5$ mm and for a variation in the values of relative permittivity ε_r as a function of frequency are quite predictable (Fig. 3). With increasing ε_r values, the peaks of the resonance curves shift to a lower frequency region. The magnitude of the maximum displacement is $\Delta F \approx 1.93 GHz$. In this case, the curves remain smooth, the steepness of the fronts does not fundamentally change. However, with increasing ε_r values, the level of return losses decreases.

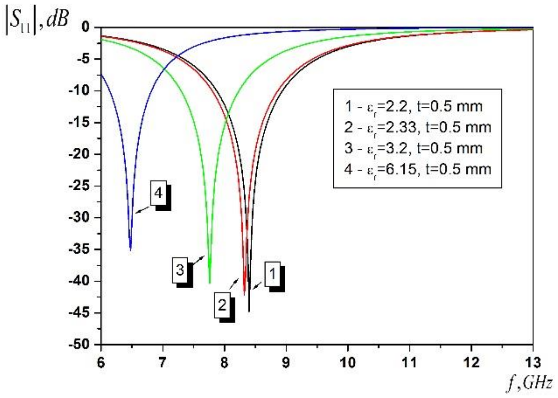

Fig. 3. The dependenceis of $|S_{11}|$ via frequency with variation ε_r .

Another important characteristic of any frequency-selective surface is the degree of its transparency (or transmission coefficient $|S_{21}|$). In Fig. 4 one can find the cell dependences of $|S_{21}|$ at the fixed value $\varepsilon_r = 2.2$ and variation of the substrate thickness t in the frequency range under consideration.

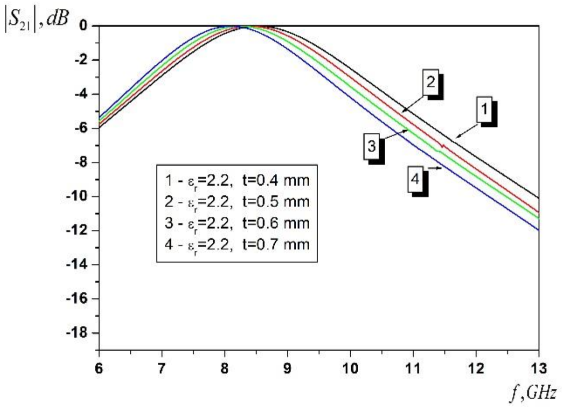

Fig. 4.The dependenceis of $|S_{21}|$ via frequency with variation t .

When comparing the dependences for the reflection coefficients $|S_{11}|$ in Fig. 2,3 and transmission coefficients $|S_{21}|$ in Fig. 4, it is necessary to note the following features. The dependences for $|S_{11}|$ are of a pronounced resonance character with rather high values of the return losses at the resonance frequencies. Dependencies $|S_{21}|$ have a completely “blurry” look. So, the bandwidth within which the surface transparency does not fall below the value - 3 dB is more than 2.89 GHz. With increasing frequency, the transparency of the surface decreases significantly. Near the end of the frequency range, it does not exceed -12 dB.

With a symmetrical patch placement with the same topology on the back (free) side of the substrate, significant changes occur during the interaction of the incident wave and the element of the frequency-selective surface. In Fig. 5 the dependences of $|S_{11}|$ via the frequency for a fixed thickness of the substrate t and the variation of ε_r values are shown.

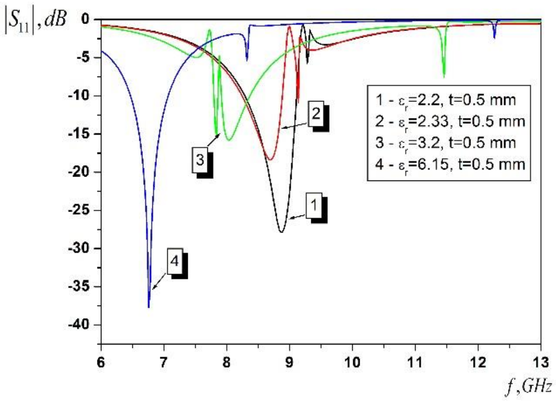

Fig.5. The dependenceis of $|S_{11}|$ via frequency with variation ε_r .

It is evident that frequency dependencies with variations of relative dielectric constants are more complex and ambiguous.

For small values of the relative permittivity $\varepsilon_r = 2.2$, there is no additional parasitic resonances in the structure (or they are very insignificant). As the values increase to 2.33 ... 3.2, the resonance phenomena increase significantly. At the value $\varepsilon_r = 3.2$, significant resonance phenomena appear immediately in two frequency ranges. Moreover, in the frequency range from 7.45 to 8.73 GHz, they turn out to be significant. In this case, the return loss is significantly reduced. At the same time, the level of matching remains at an acceptable level (with the exception of single frequencies). With a further increase in the value of ε_r, noticeable changes in the characteristic occur. Firstly, the maximum is significantly shifted to the low-frequency region (more than 2 GHz). Secondly, the level of return losses increases significantly (from -15 ...- 20 to -37 dB). And finally, the observed level of parasitic resonances does not exceed - 3 dB.

Bilateral placement of structural elements leads to significant changes in the dependences $|S_{21}|$ via frequency when the values ε_r vary. The corresponding dependences are shown in Fig. 6.

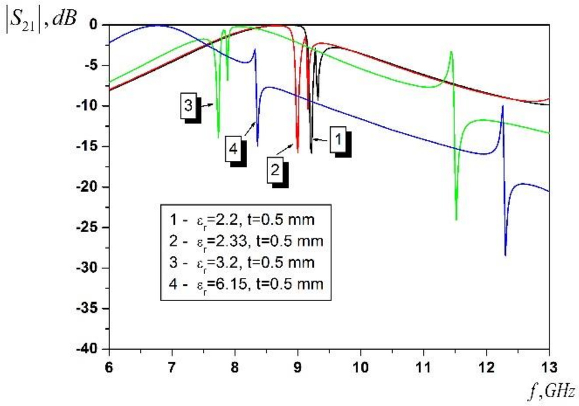

Fig.6. The dependenceis of $|S_{21}|$ via frequency with variation ε_r .

Comparison of dependencies in Fig. 4 and Fig. 6 indicates the appearance of additional resonances in the structure due to both resonances between the topological elements and the presence of two-sided shielding. This is evidenced by abrupt changes in the amplitude $|S_{21}|$ near certain frequencies. At the same frequencies, an abrupt change in the phases of oscillations occurs. With small changes in the values of ε_r, a relatively small shift of the minima of the transmission coefficients to the low-frequency region occurs. The offset does not exceed the value $\Delta F \approx 210\,МГц$. With increasing values of ε_r in the characteristics, resonances associated with two-sided shielding prevail. One group is in the low-frequency region, and the second group is in the high-frequency region. At the same time, with increasing frequency, a significant decrease in the transparency of the structure is observed (the coefficient $|S_{21}|$ reaches values of -23.86 ... -28.36 dB). The transparency bands of the structure turn out to be substantially offset from each other, and they turn out to be substantially narrower. At the same time, in the characteristics (with values of $\varepsilon_r = 3.2$ and $\varepsilon_r = 6.15$), quite wide frequency ranges are observed, within which the value $|S_{21}|$ varies quite smoothly (in the band from 8.56 GHz to 11.98 GHz, the coefficient varies in the range from -7.4 dB to -16 dB).

IV. CONCLUSIONS

Thus, the presented results of numerical simulation of the electrodynamic characteristics of a cell of an infinite 2D FSS with the Ψ topology of the structural element of the species showed the possibility of spatial frequency selection. It has been established that two types of resonances can occur in the structure, associated both with the ratio of the geometric dimensions of the structural element and with the presence of two-sided shielding. The influence of the thickness of the dielectric substrate and the dielectric constant on the reflection and transmission coefficients is studied. The totality of the results allows us to predict the creation of sufficiently technologically advanced and highly efficient frequency-selective surfaces in the microwave range.

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