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DESIGN OF MICROWAVE WIDEBAND MICROSTRIP FILTERS USING DIFFERENT NUMERICAL METHODS

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Проектування широкосмугових мікросмужкових фільтрів НВЧ-діапазону з використанням різних чисельних методів розрахунку

Описано підхід до проектування мікросмужкових НВЧ-фільтрів із застосуванням різних чисельних методів розрахунку і пов’язаних з ними систем автоматизованого проектування. Здійснено розрахунок та моделювання фільтру для системи мобільного зв’язку DCS-1800 із смугою пропускання 1710…1880 МГц. Здійснено порівняння характеристик фільтра, отриманих методами моментів, скінченних елементів та розрахованих за значеннями S-матриць відрізків ліній передачі.

Rapid development of mobile communication systems and growth of the number of corresponding equipment increase the demand for small-size and high-performance microwave filters. At present, theory of filter design is well-studied part of microwave engineering, and there are a large number of filter types and design techniques that can be used for designing and fabrication of filters [1] – [3].

Nowadays, a filter design is usually an iterative procedure involving numerous simulations and optimization of structure of a filter. There a few most used in filter design process numerical techniques: method of moments (MoM), finite-element method (FEM), finite-difference time-domain method (FDTD).

In this paper, the comparison of three numerical methods for a bandpass filter is done. At first, the frequency responses of the filter are calculated using the S-matrix theory, where the topology of a filter is considered as a set of connected segments of transmission line and discontinuities. Each part of the structure is then represented by its S-matrix. The S-matrix for the whole structure is calculated using the rules for S-matrix transformations for cascade and parallel connections of two-port networks. After that, two numerical results were used: MoM and FEM.

Let us design a bandpass microstrip filter for the DCS-1800 band, that is 1710 – 1880 MHz. The parameters of the filter are as follows: passband $BW = 170$ MHz; stopband $SB = 250$ MHz; insertion loss in the stopband $IL \leq -30$ dB; ripple within the passband 0.1 dB. Let the filter be of edge-coupled type.

For the realization of the filter, the RT/Duroid 6010LM laminate was used. The parameters of the material are as follows: dielectric constant $\varepsilon_r = 10.5$; thickness $h = 0.635$ mm; thickness of strip $t = 0.017$ mm; dissipation is defined by $\tan\delta = 0.0023$; height of the top shield $H = 10$ mm.

The Chebyshev response was used. To meet the listed above demands, the 7-order prototype should be used. Using the parameters of low-pass prototype, the parameters of the transmission line segments for the edge-coupled structure can be calculated using the procedure given in [1]. The model of the filter was prepared using the Microwave Office software and is shown in Fig.1.

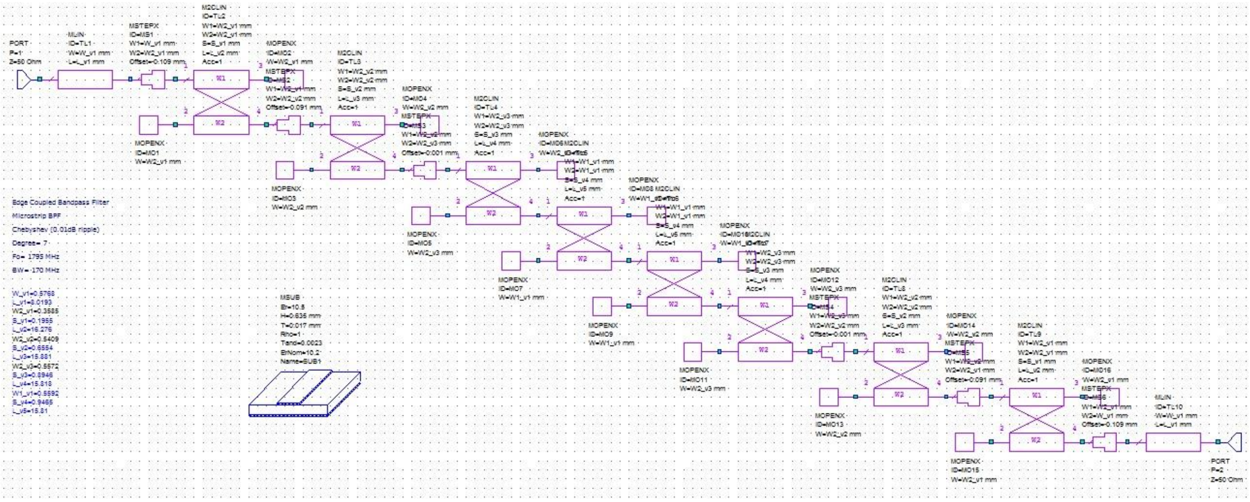


Fig.1. Model of the filter

As it can be seen, the filter topology consists of 8 pairs of coupled microstrip resonators. Using this model, the topology of the filter was generated. It was then used for preparing the 3D model for the filter shown in Fig.2.

The dimensions of the filter are 143.6x10.4 mm^2. The side shielding metal walls should be shifted from the edge strips in order not to influence the electromagnetic fields in it. The resulting dimensions of the filter are 144x16 mm^2.

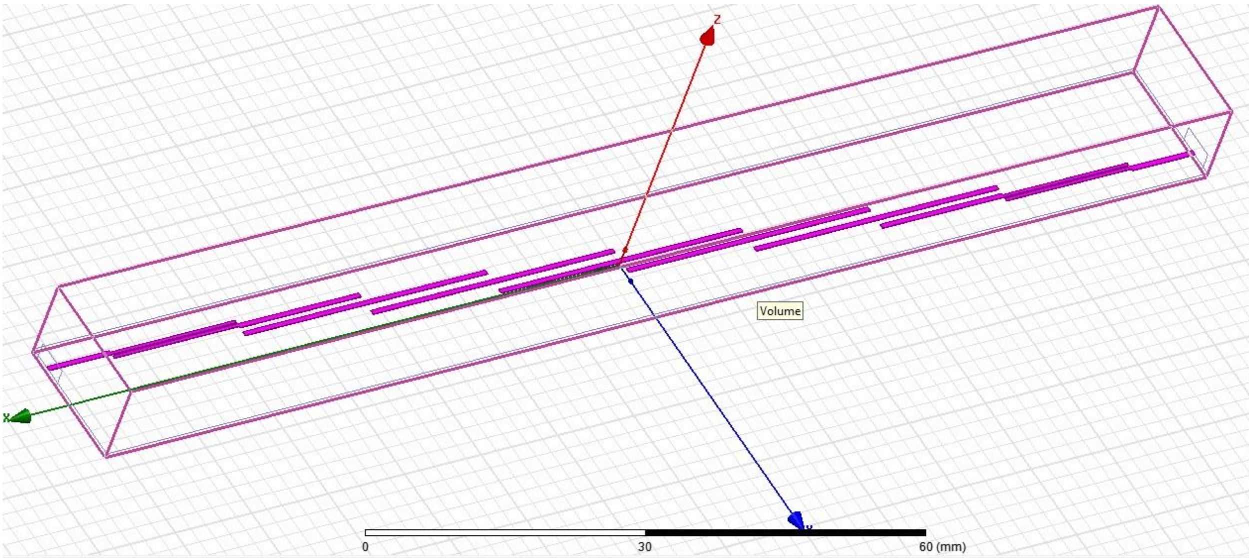
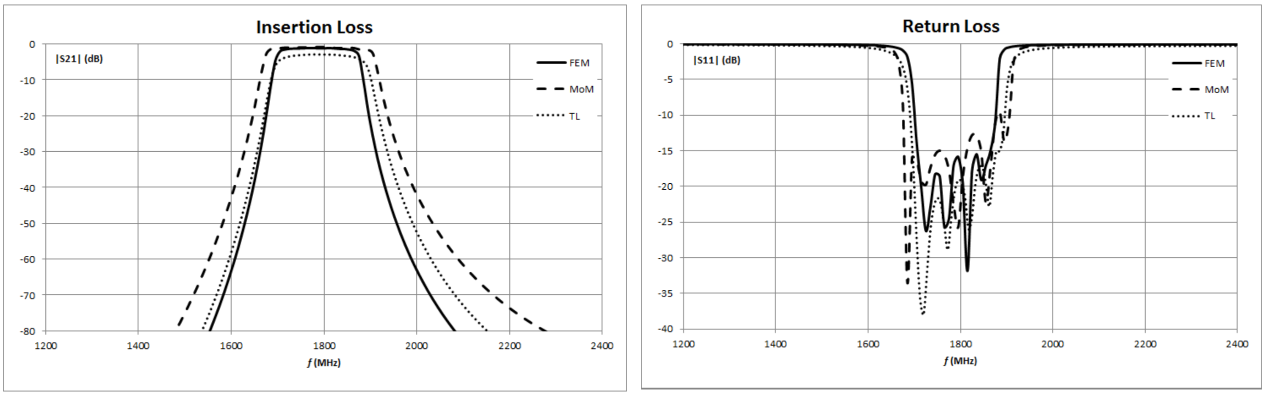


Fig.2. Model of the filter.

To perform the analysis using MoM method, the grid of 0.05x0.05 mm^2 was used. The dimensions of all elements were approximated in order to correspond to the grid cells. This rounding impacts the end characteristics of the filter, worsening them.

The topology was then extracted from the model and used to prepare the 3D model for analysis using FEM method. The HFSS software was used for this purpose. The model is shown in Fig.2.

In Fig.3, the simulated results for the frequency responses of the filter are shown. It can be seen that there is a considerable difference in frequency responses for the three methods exists.



(a) (b)

Fig.3. Frequency responses of the filter calculated by different numerical techniques.
(a) Insertion loss. (b) Return loss.

The method based on the S-matrix theory (marked as TL in Fig.3) is based on lumped-element network representation of microwave sturctures and is then the least precise amongst the three compared methods. The MoM is 2.5D technique, which can be implemented only for planar structures, i.e. the structures consisting of a few layers. FEM is 3D model, where the accuracy of the results can be increased by increasing the number of the cells (of tetrahedral shape). FEM method is the most precise among the three considered techniques.

Microstrip structures are planar and the 2.5 techniques are implemented to analyse them most frequently, as it is expected that the time consumed for performing the simulation will be less than the one for 3D methods. However, in our example FEM method has demonstrated higher speed relative to MoM with higher accuracy.

Thus, general calculations and rough estimation of the filter's characteristics can be done using S-matrix calculations and MoM simulation, but the final analysis and optimization of a filter are worth being performed using 3D numerical techniques.

References

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