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DETERMINATION OF RESONATOR PARAMETERS USING THE APPROXIMATION METHOD

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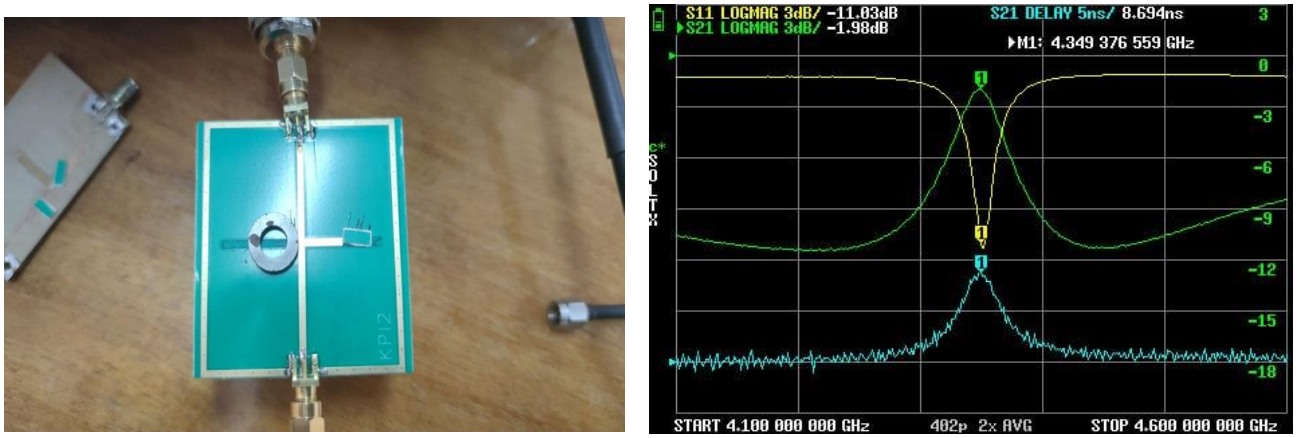
ВИЗНАЧЕННЯ ПАРАМЕТРІВ РЕЗОНАТОРІВ ЗА ДОПОМОГОЮ МЕТОДУ АПРОКСИМАЦІЇ

У доповіді розглянуто використання методу апроксимації задля визначення характеристик резонаторів через S-параметри структур, до яких вони входять.

While researching new methods of data analysis and processing, our team's attention was drawn to a paper Pompeo et al. [1] about available methods for determination of physical parameters of resonators using curve fitting [2].

We decided to investigate curve fitting further and consider its possibilities as a method that can be used to determine the parameters of resonators from the S-parameters of the structures they belong to. This procedure is generally based on approximation, which is a method of replacing an unknown function with a set of simpler functions that approximately reproduce the properties and parameters of the initial function or characteristic [2], [4]. This allows to significantly simplify the final analysis or calculations, depending on the purpose for which the approximation is used.

It is important to note that specialized computer software is used for such calculations, for example, MATLAB provides this capability [6].



a) b)

Figure 1. Two-resonator filter.
a) actual appearance**;** b) experimental measurements of S11, S21, GD.

For example, let's consider a two-resonator band-pass filter in Figure 1(a). The resonators' parameters are unknown to us - quality factor, resonant frequencies, and coupling coefficients. We are given with experimental measurements of S-parameters – Figure 1(b). From [5], we have the formulas for the calculation of S21:

$$S21 = 1 - \frac{C_{P\Sigma}}{1+C_{P\Sigma}} - \frac{C_{S\Sigma}}{1+C_{S\Sigma}},\ C_{P\Sigma} = \frac{K_{P1}}{1+j\cdot X_{P1}},\ X_{P1} = \left(\frac{f}{F_{0P1}} - \frac{F_{0P1}}{f}\right) Q_{0P1} \tag{1}$$

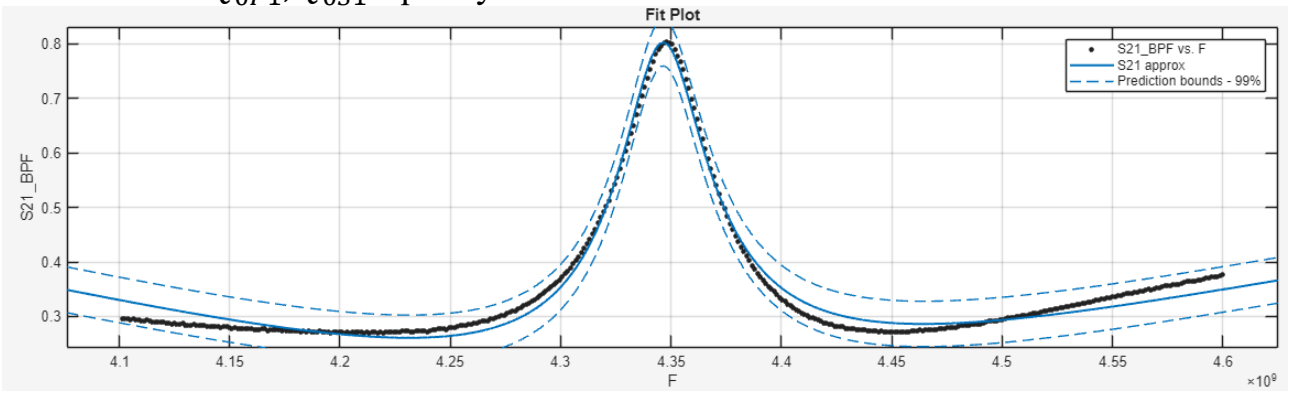
$$C_{S\Sigma} = \frac{K_{S1}}{1+j\cdot X_{S1}},\ X_{S1} = \left(\frac{f}{F_{0S1}} - \frac{F_{0S1}}{f}\right) Q_{0S1}$$

There are 6 unknown characteristics in (1):

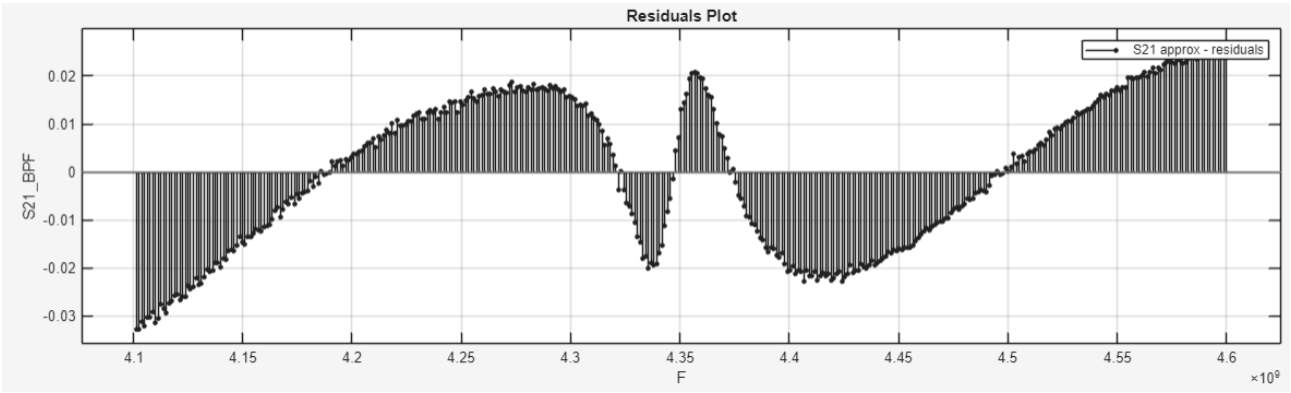
K_{P1}, K_{S1}- coupling coefficients of the resonators

F_{0P1}, F_{0S1}- resonant frequencies of the resonators

Q_{0P1}, Q_{0S1}- quality factors of the resonators



a)



b)

	Value
F_p1	4.3333e+09
F_s1	4.3461e+09
K_p1	9.6732
K_s1	8.5984
Q_0p1	25.8479
Q_0s1	1.0801e+03

c)

Goodness of Fit

	Value
SSE	0.1011
R-square	0.9834
DFE	395.0000
Adj R-sq	0.9831
RMSE	0.0160

d)

Figure 2. S21 approximation results.
a) graphical representation; b) approximation residuals;
c) derived K, F and Q; d) approximation quality.

Given the formulas (1) and the measurement data in Figure 1(b), it is possible to determine the unknown parameters of the band-pass filter resonators using approximation. We use MATLAB to do it [6].

As illustrated in Figure 2(a) - the approximation accurately reproduces the S21 characteristic, as proved by qualitative characteristics in Figure 2(d),. The main result of the approximation, are the coupling coefficients and Q-factors of the resonators, shown in Figure 2(c).

The main benefit of this method lies in the possibility of determining microwave characteristics (coupling coefficients, Q-factors) from experimental data, which was impossible before. As any approximation, this method requires a special approach, like choosing of the starting point and/or approximation step, as well as broader verification, which are the tasks for future study.

Acknowledgement.

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References

1. Pompeo, Nicola & Torokhtii, Kostiantyn & Alimenti, Andrea & Silva, Enrico. (2025). A method based on a dual frequency resonator to estimate physical parameters of superconductors from surface impedance measurements in a magnetic field. 10.48550/arXiv.2501.11966.
2. Sandra Lach Arlinghaus, PHB Practical Handbook of Curve Fitting. CRC Press, 1994.
3. Cecil Hastings Jr., Jeanne T. Wayward, James P. Wong Jr., Approximations for Digital Computers. Princeton University Press, 1955.
4. N. I. Achieser, Theory of Approximation. Dover Pubns, 1992.
5. Рішення про реєстрацію договору, який стосується права автора на твір №7325 від 14.11.2024р Комп’ютерна програма «Filter Response Visualization Tool» Авдєєнко Г. Л. , Стоянов І.О., Живков О. П., Тичинський-Мартинюк В. Ю.
6. Imran, Omar. (2019). MatLab for Engineers.