Machine Learning Implementation for the Inverse Problems Solution

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Motivation:

- machine learning based technique of the microwave device tuning (oscillating system, filter) are discussed
- the introduction of the technique into the educational process is described

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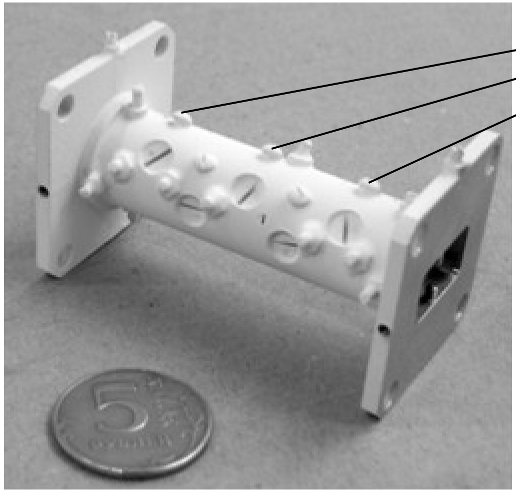
Microwave filters tuning problem is one of the typical inverse problems that affects the manufacturing (mass-production) process mainly, especially when high quality dielectric resonators are implemented



The complexity of this particular inverse problem is determined by:
- too many tuning elements are involved (e.g. screws)
- the experimental tuning process is expensive

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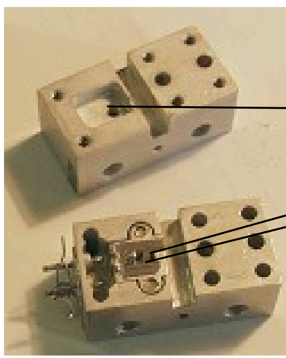
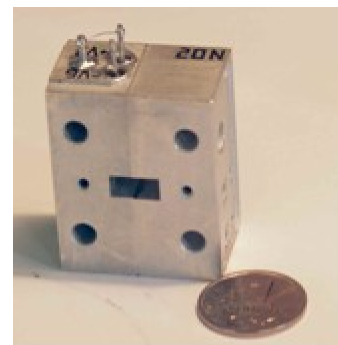
The high-quality resonance sections for oscillating systems determine the phase noise ratio of the microwave generator that is critically important for practice: mapping, navigation, ultra-wide band telecommunications





The complexity of this particular inverse problem is determined by:
- sophisticated dependence of the oscillating system parameters on tuning elements
- the experimental tuning of the generator is extremely expensive

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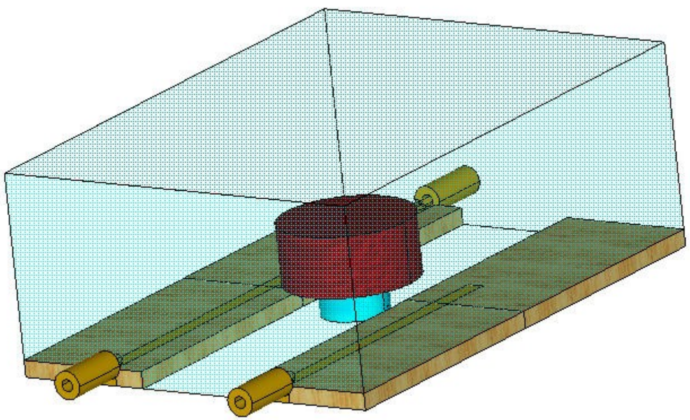
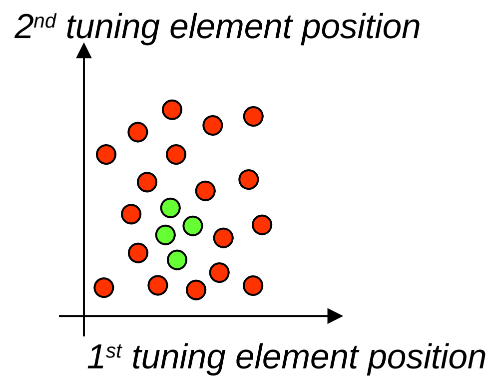
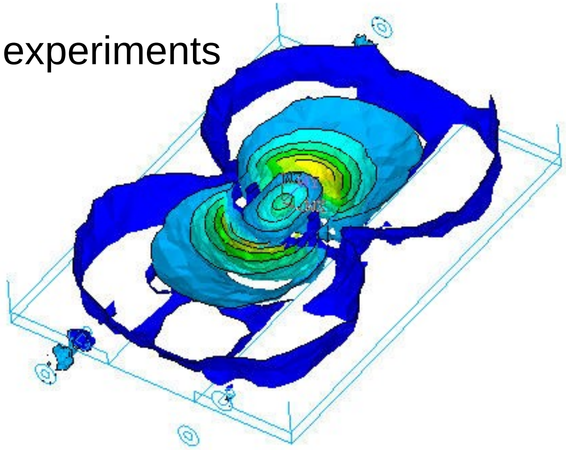
The machine learning is considered as one of the effective solutions for this type of inverse problem:

- ✓ large amount of the marked data is available through computations or experiments







- ✓ the problem definitely has appropriate solution (tuning process converges)
- ✓ the problem is usually separable, it is well conditioned (in contrast with general synthesis problem)

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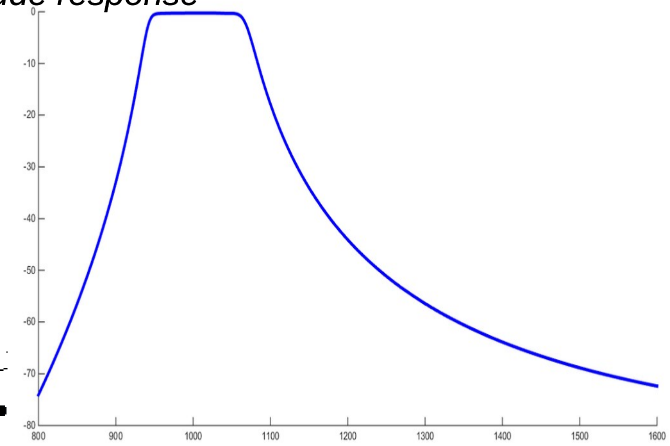
Therefore, tuning problem may be implemented as a relatively simple but important educational problem

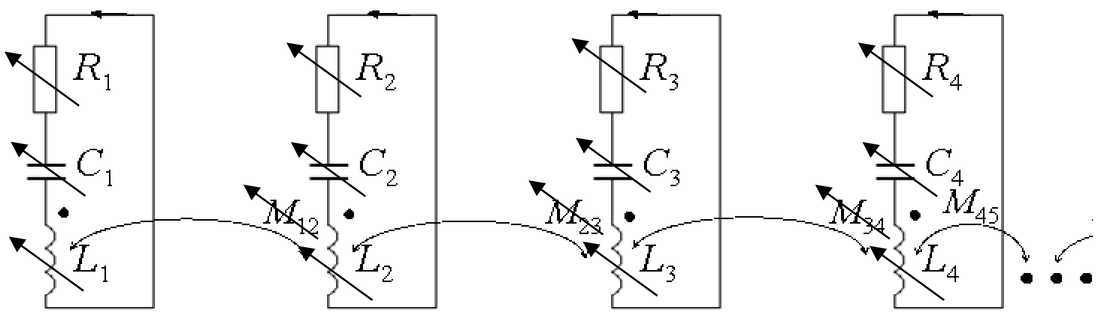
The problem setup:
- the required filter characteristic is given
- the initial setup of the lumped elements model is given
- the cos, sin or exp dependencies of the lumped parameters of the model are determined

The goal is to tune (make a trajectory from the initial to appropriate state) a filter!

magnitude response



frequency



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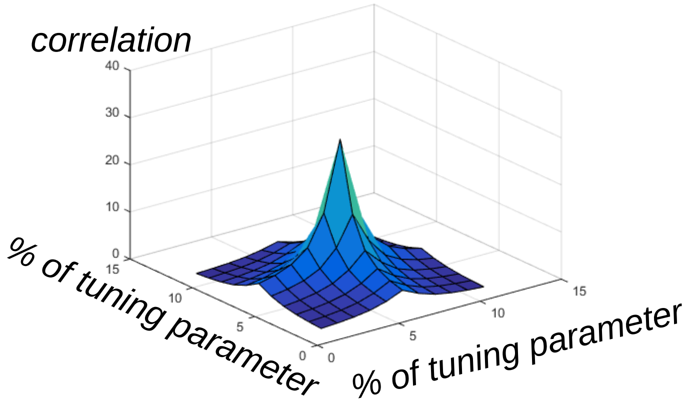
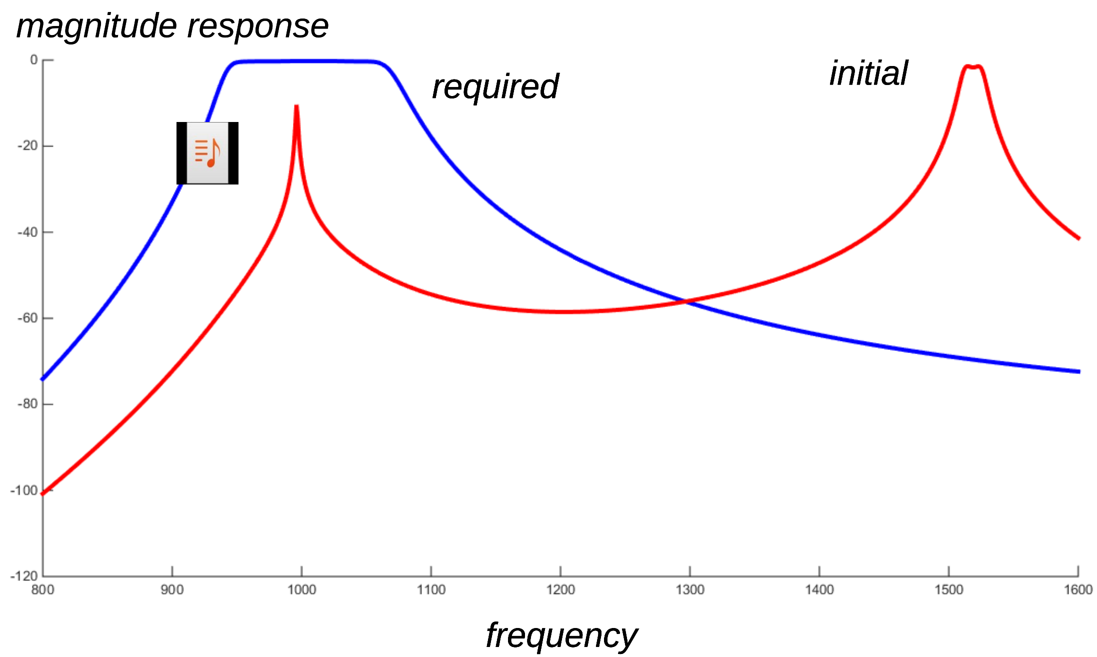
The data markup stage

Students are to prepare computed frequency dependencies of the transfer function on tuning parameters

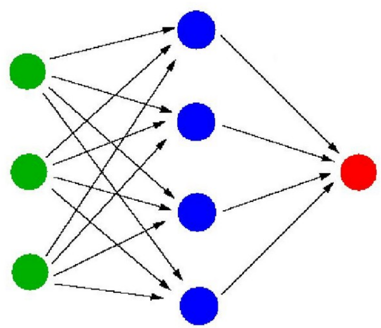




The correlation coefficient is used to determine relation of the current transfer function and the required

Training stage

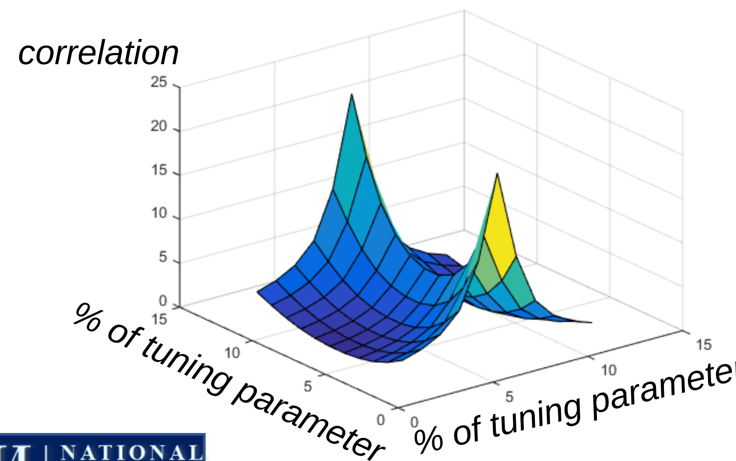
Students are to train relatively simple neural network



backpropagation and gradient-based optimization are presumed

input is a transfer function at the current step

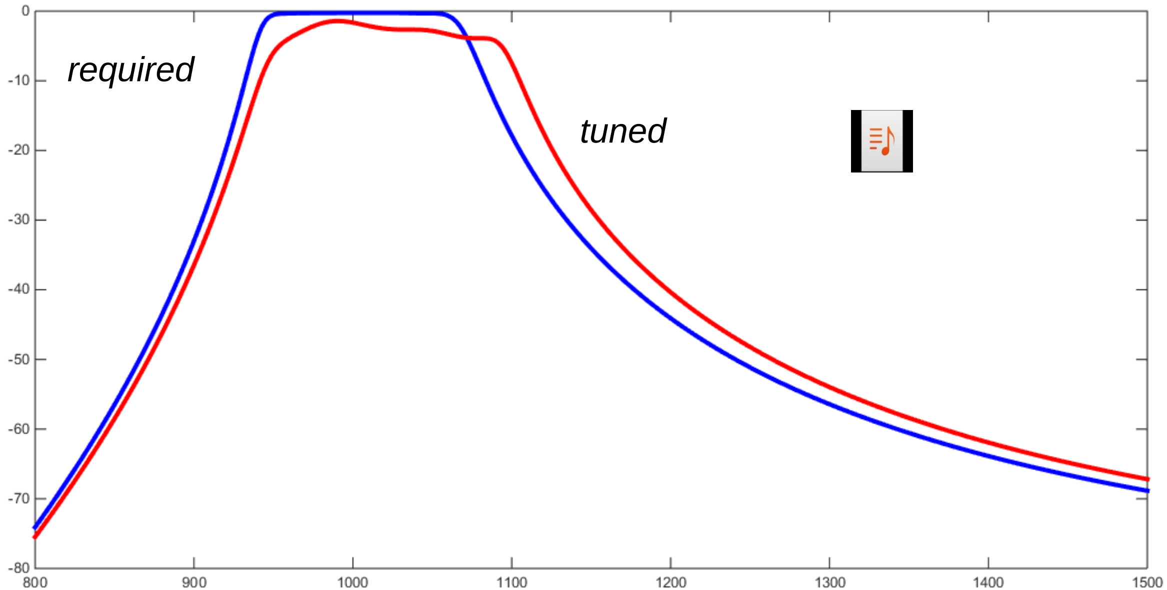
outputs are the increase/decrease decisions for each tuning parameter



Testing stage

Students are to test the trained network

magnitude response



frequency

the overall resulting transfer function is to be determined

the number of tuning steps is to be evaluated

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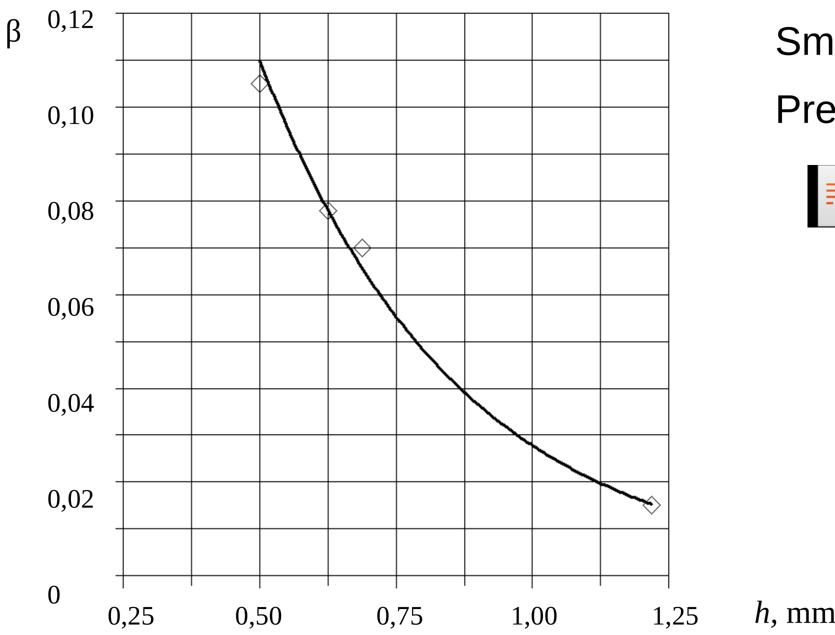
Simplified problem – oscillating system

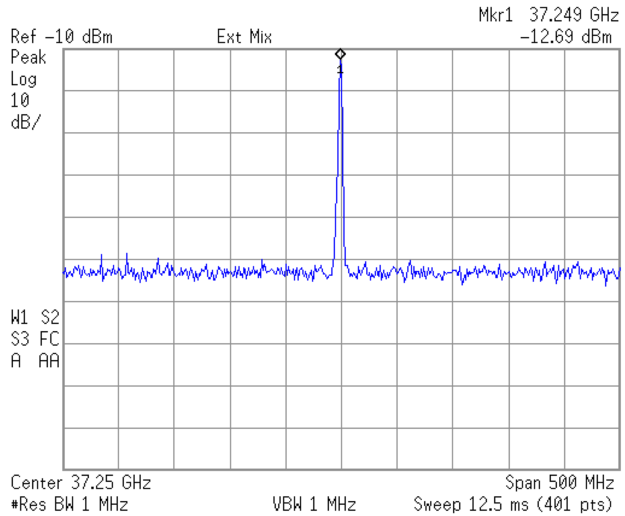
Students are to markup the data, train and test the network



Coupling coefficient β vs depth of the tuning screw h

Smaller number of tuning parameters is required

Preliminary data set is given



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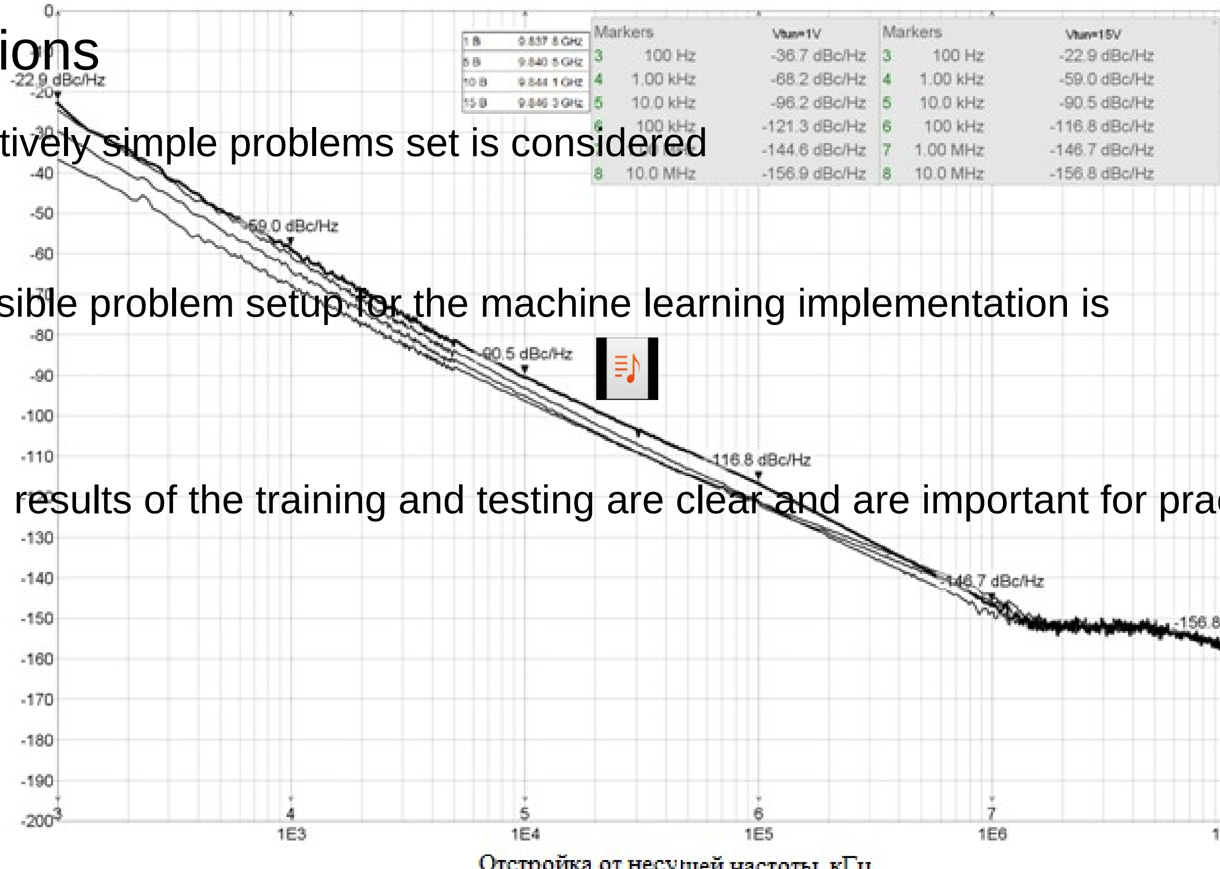
Conclusions

- ✓ relatively simple problems set is considered
- ✓ comprehensible problem setup for the machine learning implementation is developed
- ✓ results of the training and testing are clear and are important for practice



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Thank you for attention!

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