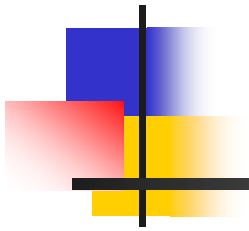

Evolutionary Design of Microwave Circuits

Diploma Thesis

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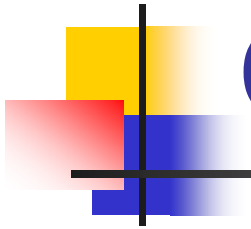
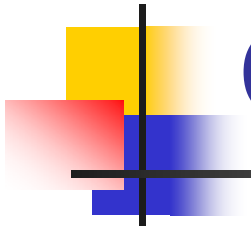


Outline

- Goals
- Evolutionary Approach
- Algorithm Proposal
- Practical Results
- Conclusion

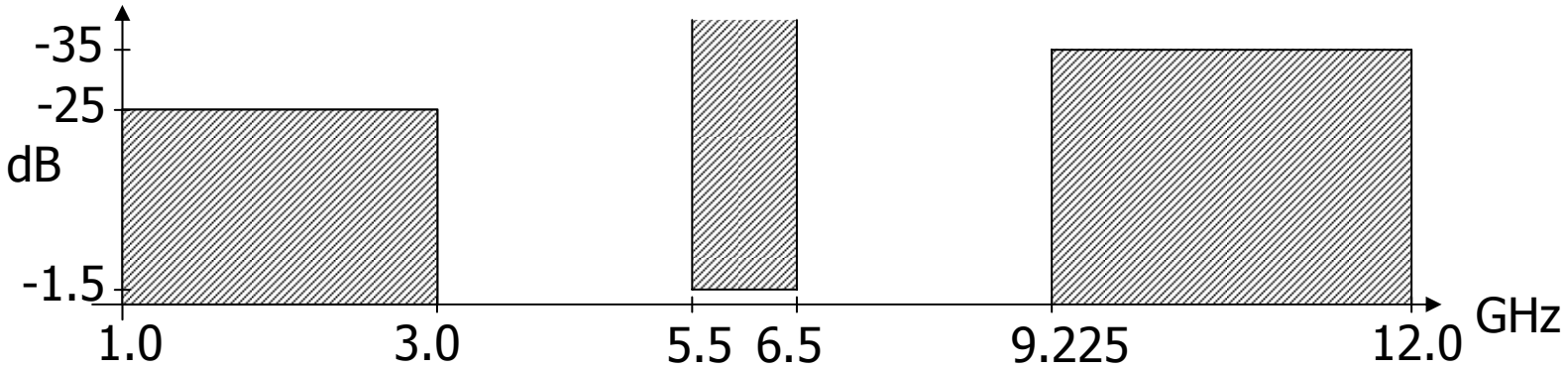


Goals

- Input Requirements
  - Number of ports
  - Available circuit elements
  - Required characteristic *(e.g. transmission)*
- Output circuit
  - Topology with evaluated circuit elements
- Manner
  - Evolution of a circuit
  - External tool for circuit analysis
    - Program MIDE

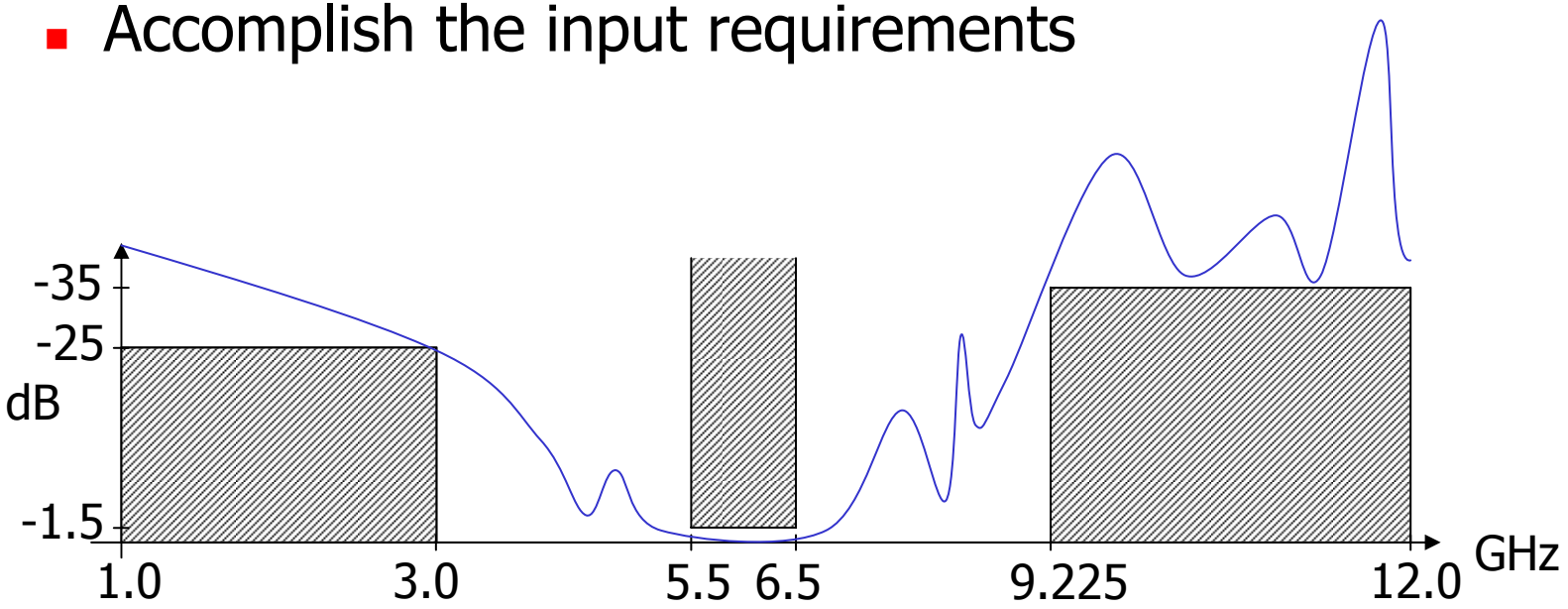
Input Requirements

- Number of ports
  - E.g. 2 for a band pass filter
- Set of available circuit elements
- Required characteristics
  - Between 1 GHz and 3 GHz transmission below -25 dB
  - Passband transmission above -1.5 dB between 5.5 GHz and 6.5 GHz
  - Stopband attenuation between 9.225 GHz and 12 GHz below -35 dB



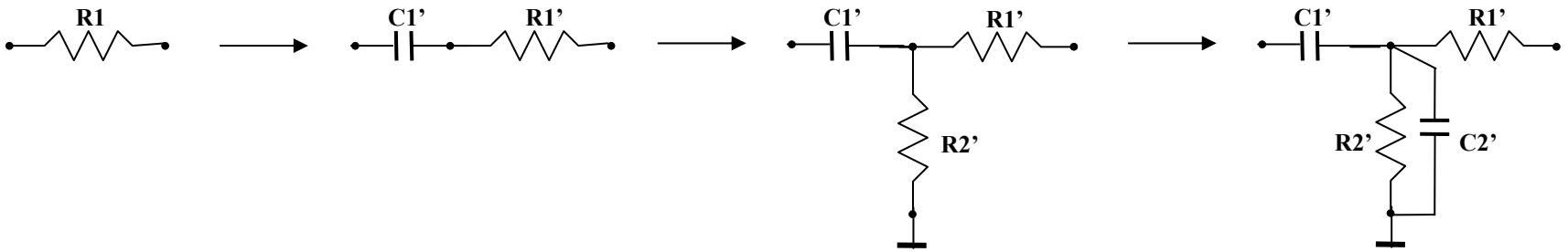
Output Circuit

- Topology with evaluated circuit elements
  - Accomplish the input requirements

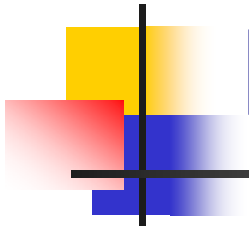


Manner

- Circuit Evolution

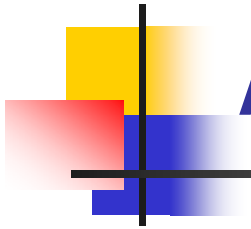


- Circuit Analysis Tool
  - Input: Circuit, Finite set of frequencies
  - Output: S-parameters



Evolutionary Approach

- Evolution of a single member population
  - Evolution of a circuit
  - Until the required one is found
- Local (Neighbour) Search
  - Hill-Climbing
  - Escape from a local minima
    - Random walk
    - Tabu search
    - Simulated annealing
    - Stochastic hill climbing

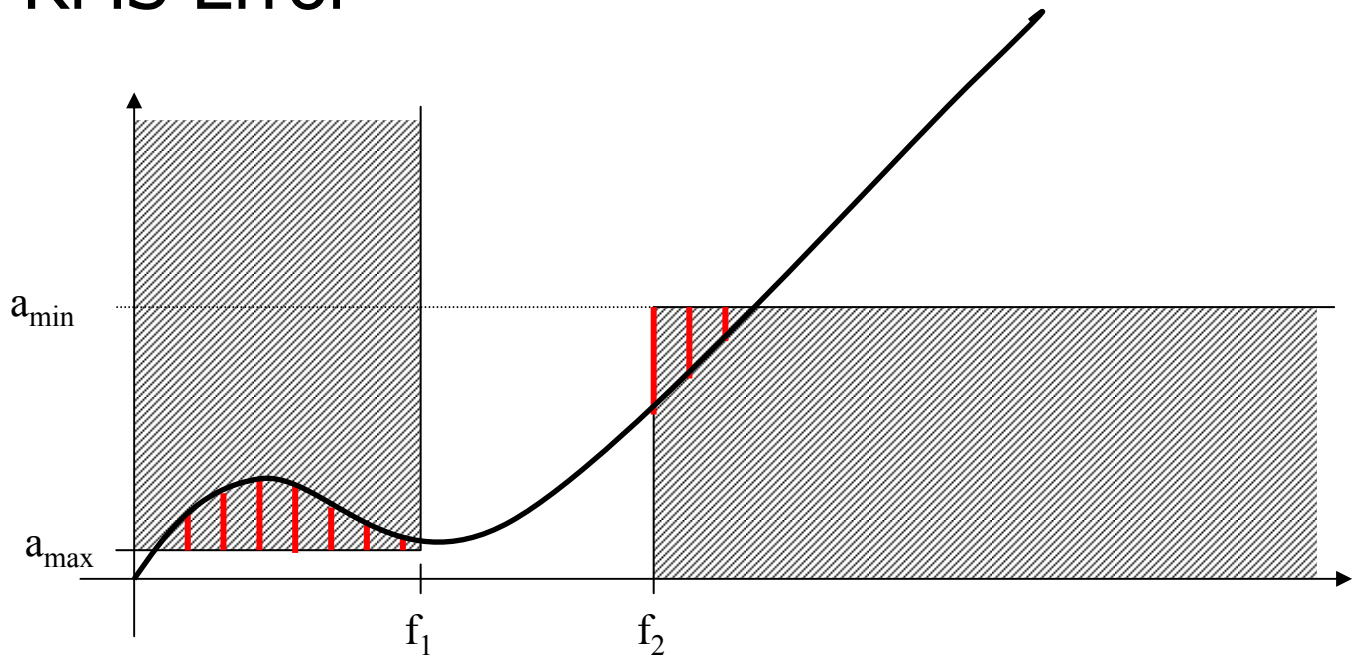


Algorithm

- Objective function
  - For comparison of solutions (circuits)
- Circuit representation
- Evolution
  - Circuit's neighbour
- Single iteration
- Improvements

Algorithm: Objective Function

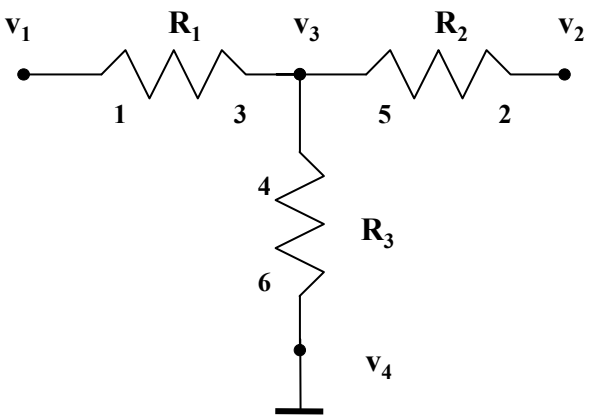
- RMS Error



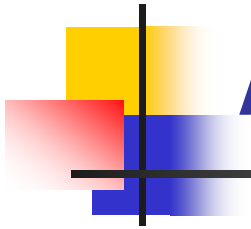
- Required circuit: RMS error is equal to zero

Algorithm: Circuit Representation

- Graph



- Vertices $\mathbf{V} = \{v_1, v_2, v_3, v_4\}$
  - v_1 ... input/output port
  - v_2 ... input/output port
  - v_3 ... 3-port ideal connection
  - v_4 ... short end
- Edges $\mathbf{E} = \{(v_1, v_3), (v_3, v_2), (v_3, v_4)\}$
  - Resistors R_1, R_2, R_3

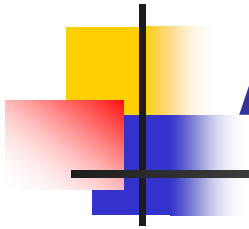


Algorithm: Evolution

- Selection of a circuit's neighbour
  - Application of a single (suitable) operation
    - Change some parameter of a circuit element
    - Change some circuit element
    - Add an edge between two suitable vertices
    - Split a vertex into two vertices, add an edge between them
    - Create a vertex and connect it to a suitable vertex
    - …
    - Inverse operations also included (e.g. remove an edge)

Algorithm: Single Iteration

- Until an acceptable operation is found
  - Select an operation
    - and appropriate operands: suitable vertices, edges, circuit element parameters
- Acceptance criterion
  - Better solution (circuit)
  - Random walk
    - Better solution always accepted, worse solution accepted with fixed probability (e.g. 2%)
  - Simulated annealing
    - Better solution always accepted, worse solution: $p = e^{eval(s)-eval(s')/T}$
  - Stochastic hill climbing
    - Solution accepted with probability: $p = \frac{1}{1+e^{eval(s')-eval(s)/T}}$

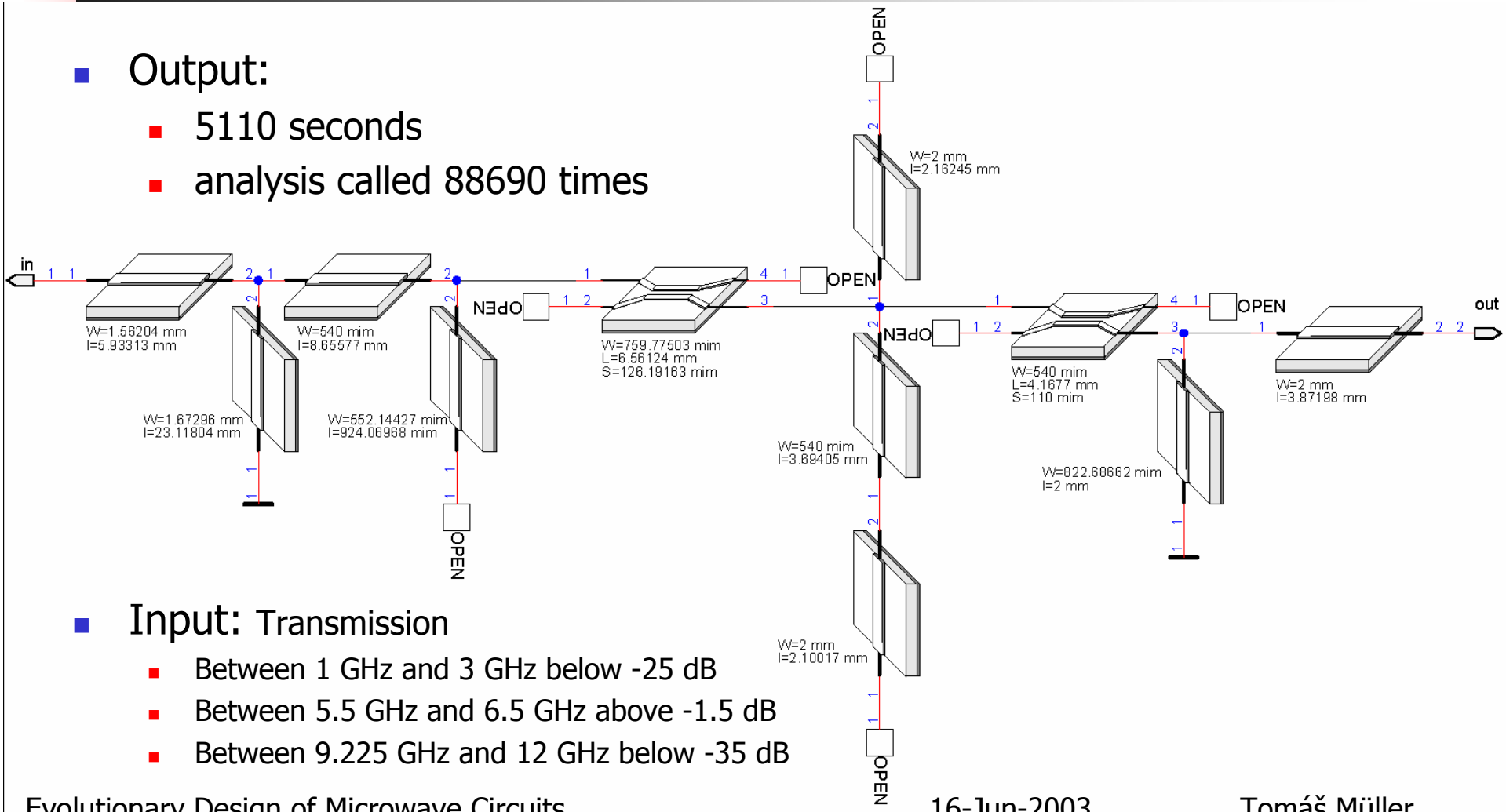


Algorithm: Improvements

- Local (Parameter) Optimization
  - Try to optimize affected circuit parameters
- Choice points
  - After a fixed number of iterations
  - If a good enough solution is not found:
    - return to the previous memorized solution
    - memorize solution and continue
  - Fixed number of returns to a single memorized solution
- RMS Error Estimation
  - Classification of a selected operation
  - Statistics of previous successfulness

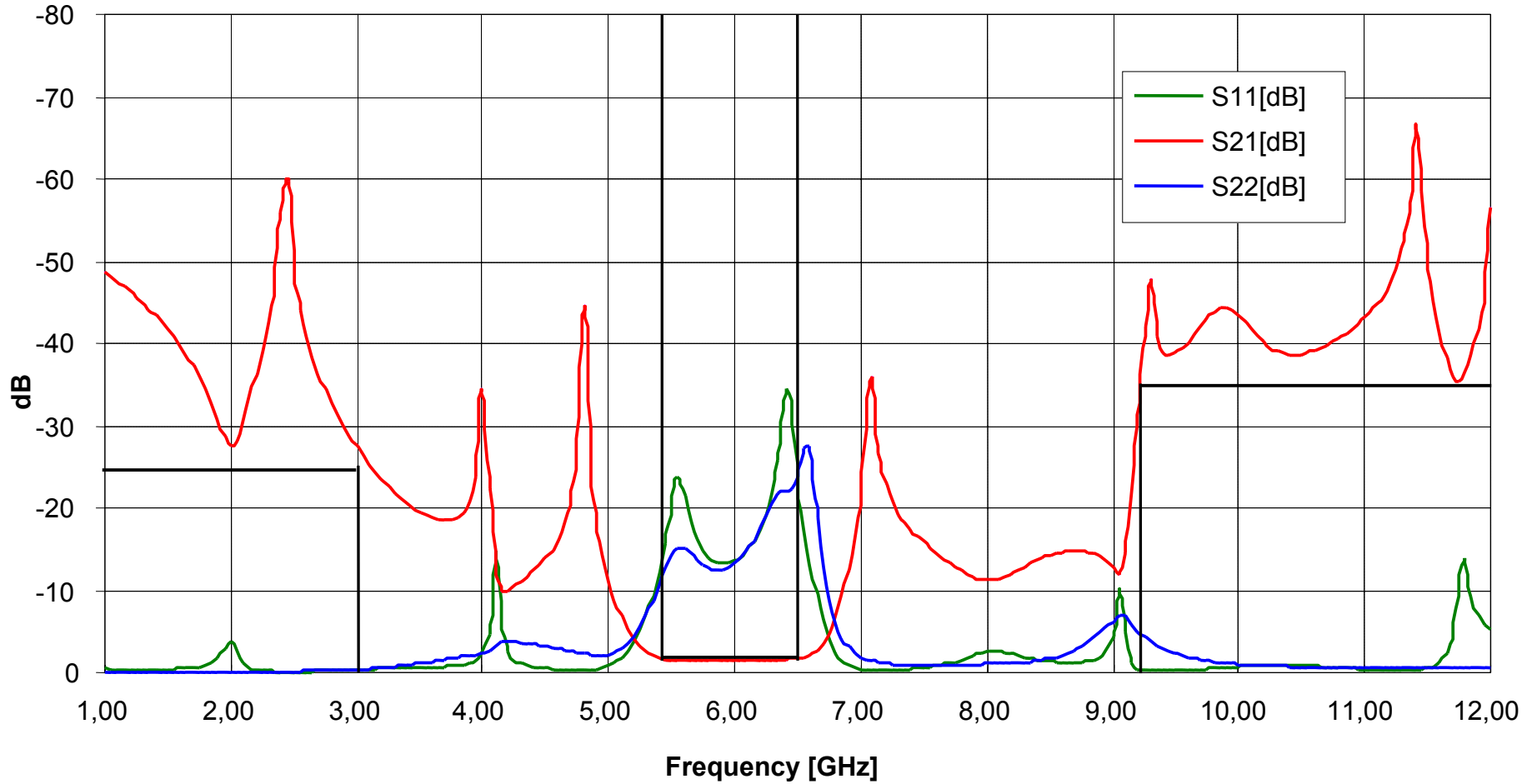
Practical Results: Band Pass Filter

- Output:
  - 5110 seconds
  - analysis called 88690 times



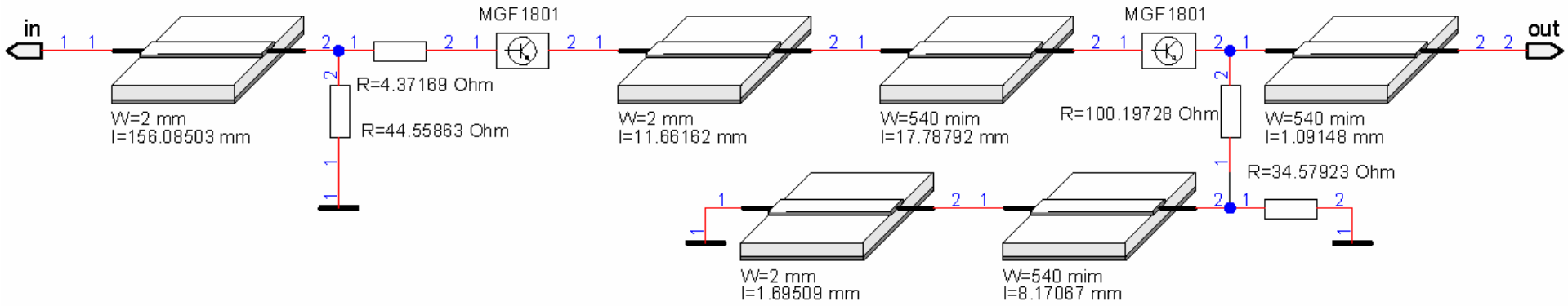
- Input: Transmission
  - Between 1 GHz and 3 GHz below -25 dB
  - Between 5.5 GHz and 6.5 GHz above -1.5 dB
  - Between 9.225 GHz and 12 GHz below -35 dB

Practical Results: Band Pass Filter

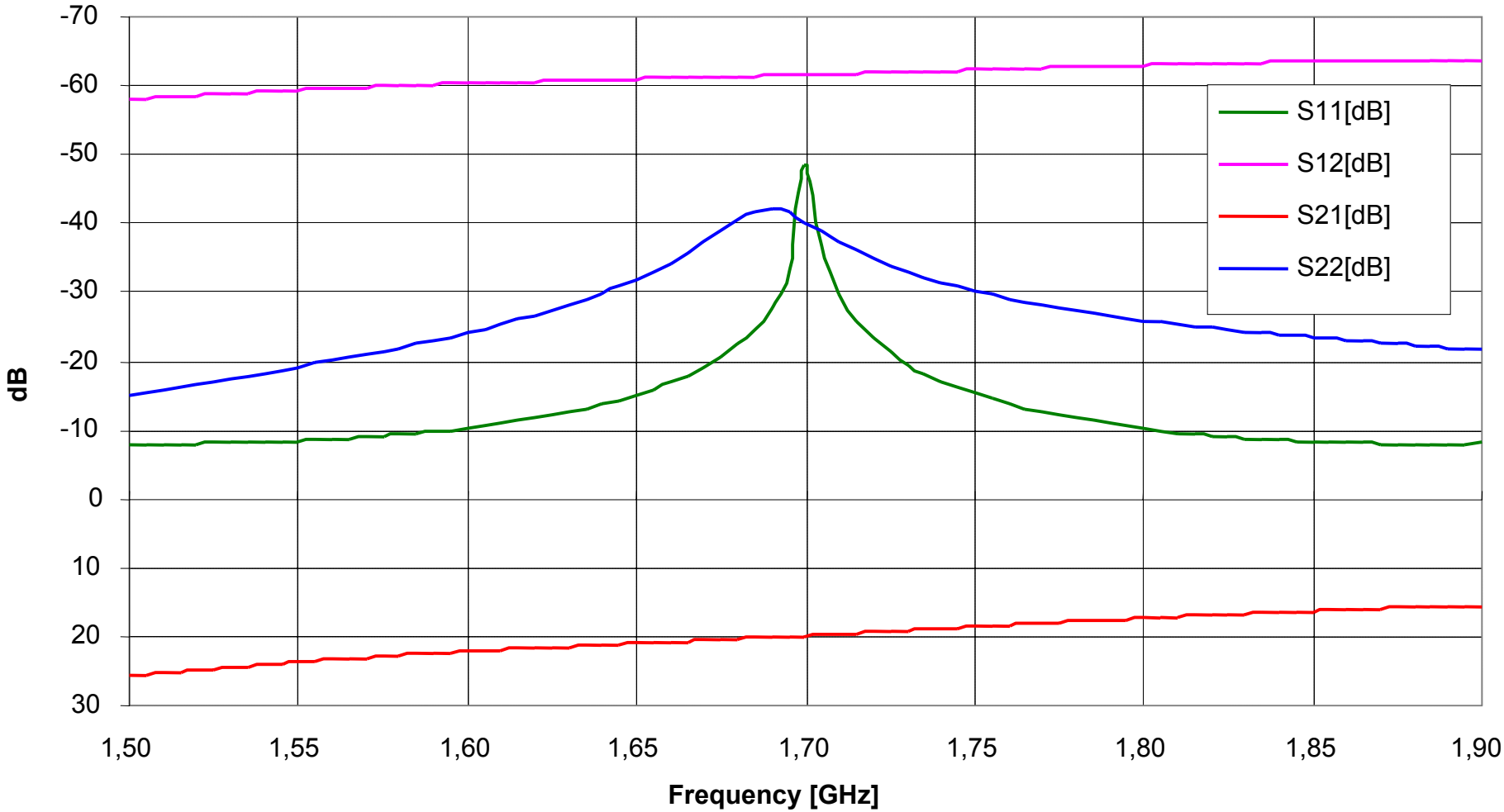


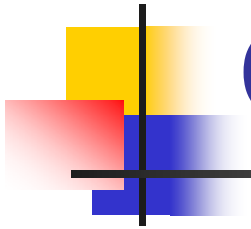
Practical Results: Amplifier

- Input:
  - Transmission at 1.7 GHz is above 17 dB
  - Reflection both on input and output gate is less then -40 dB at frequency 1.7 GHz
  - Use of a MGF1801 transistor
- Output:
  - 150 seconds, analysis called 5306 times, MGF1801 used two times



Practical Results: Amplifier





Conclusion

- Very promising evolutionary algorithm for microwave circuit design
- Ability to solve many interesting even rather complicated assignments
- No knowledge of traditional design strategies and algorithms
- Completely novel approach