# Circuit synthesis in antenna and RF optimization

Jussi Rahola

Optenni Ltd





OPTENNI

# Contents

- Application of circuit synthesis methods in various contexts
  - Single port antenna matching
    - Optimization goals in matching
  - Simultaneous multiport antenna matching
  - Tunable matching circuit design
  - Optimizing carrier aggregation scenarios
- Conclusions and lessons learned

# Optenni Lab - Circuit Synthesis Software for Antenna and RF Optimization

- Worldwide leading solution for circuit synthesis for antenna applications
- Filling a gap between existing electromagnetic and circuit simulators
  - Optimization of both antenna and circuit quantities
  - Design automation for eliminating repetitive design tasks
  - Offering solutions instead of building blocks
- Used by leading wireless companies worldwide
  - 7 out of the 10 largest technology companies in the world are our customers


Optenni Ltd was founded in 2009

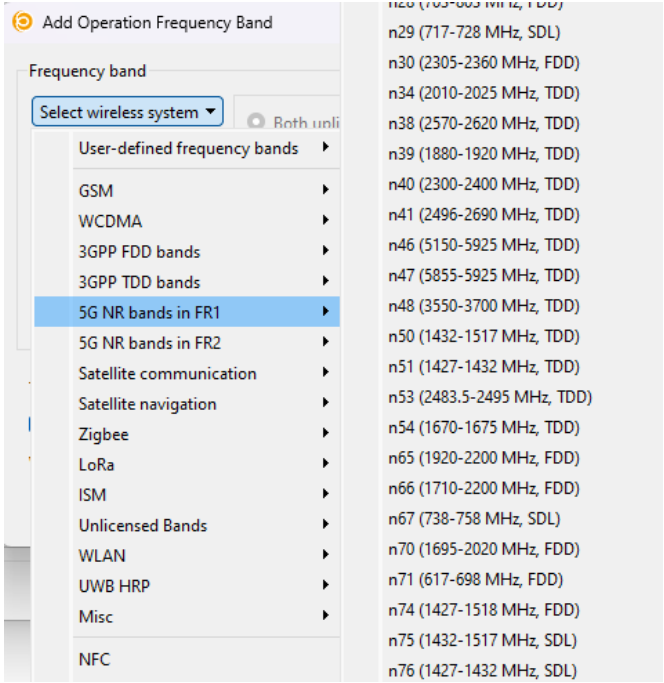




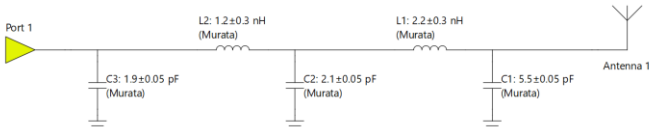
OPTENNI

# Single port antenna matching synthesis

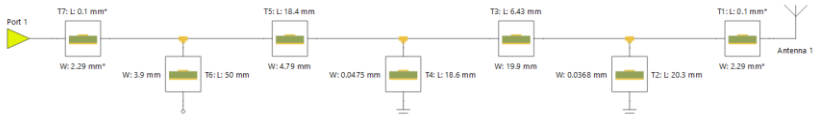
- Typical workflow:
  - Get impedance and efficiency data from electromagnetic simulators or from measurements
  - Select operation band from a list of wireless systems
  - Select number of components
  - Select inductor and capacitor series
  - Press OK
- Within second multiple optimized topologies are generated



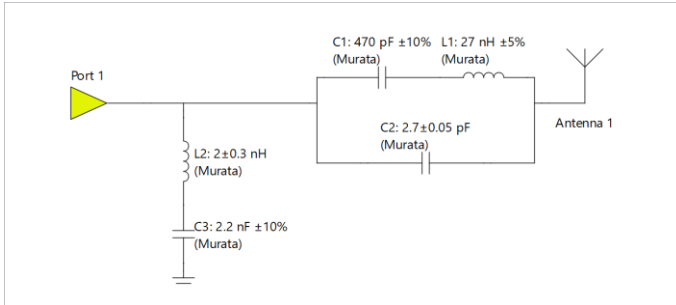
# Examples of generated circuits



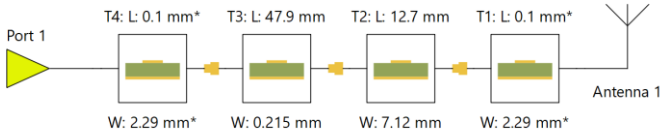

Ladder matching




Microstrip stub matching




Resonator matching



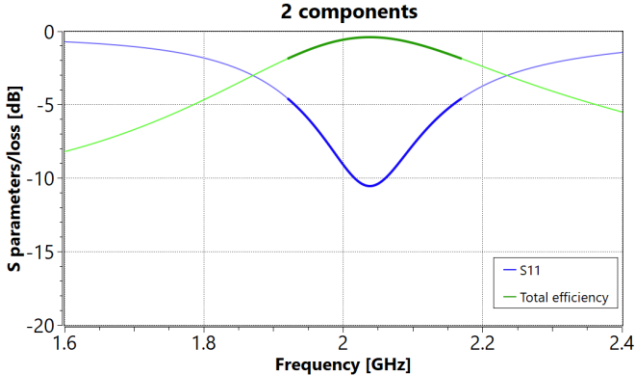

Microstrips: stepped impedance matching

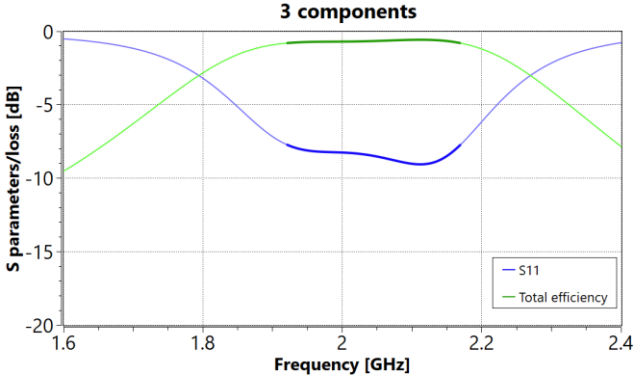


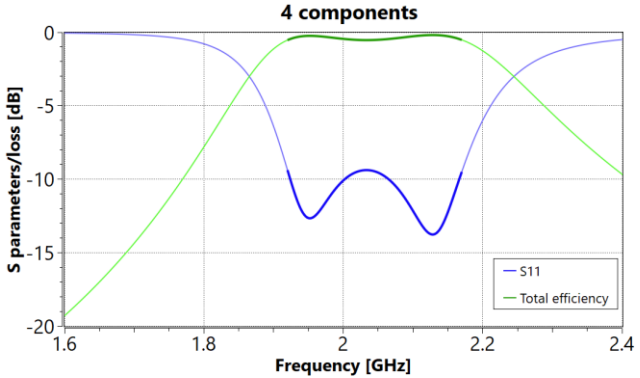


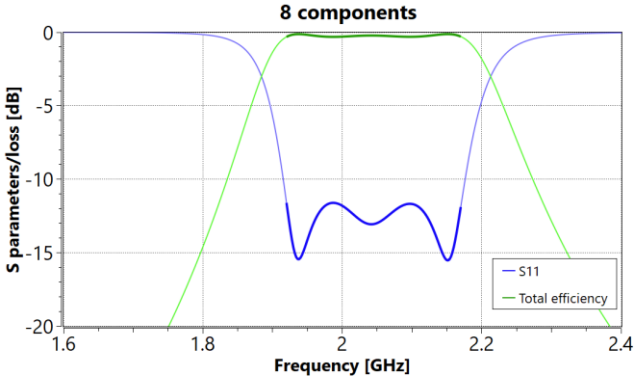
OPTENNI

# Increase number of components (ideal case)



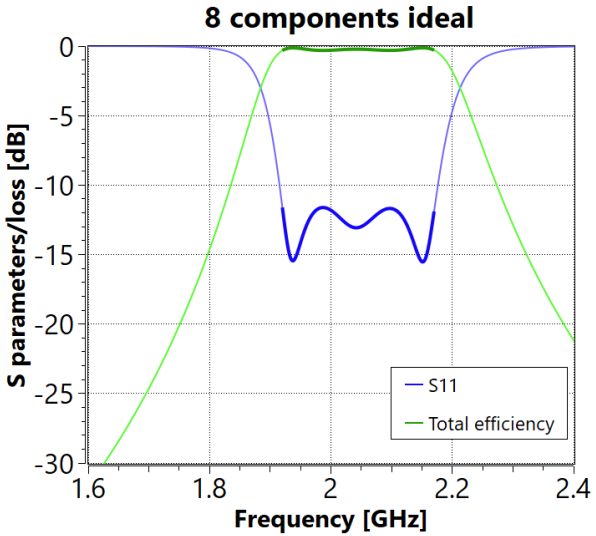



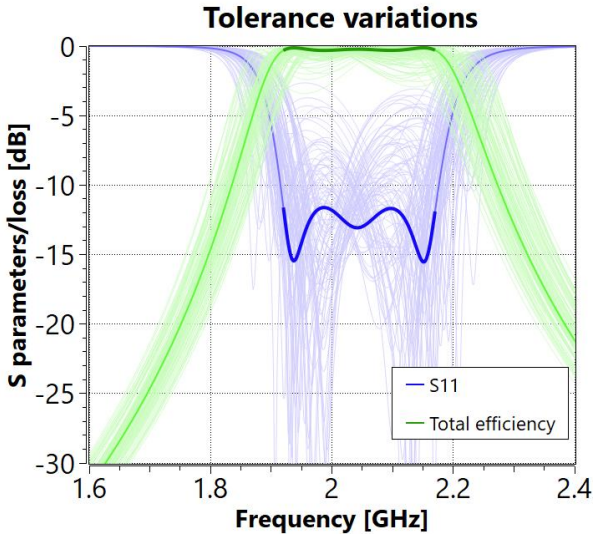




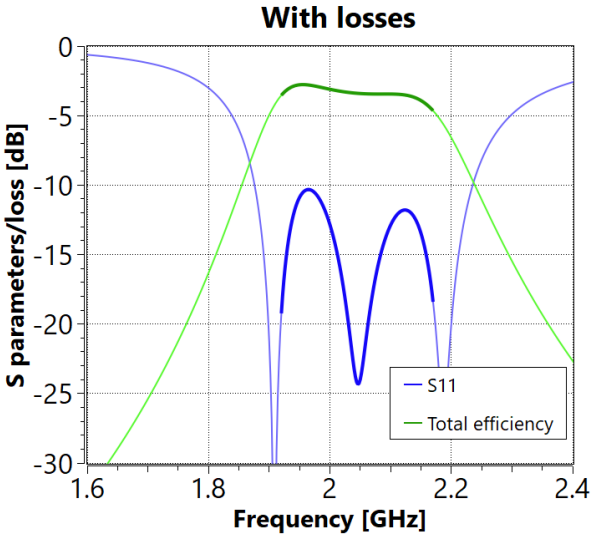

OPTENNI

# Effect of tolerances and losses




3.5 dB degradation




4.3 dB degradation

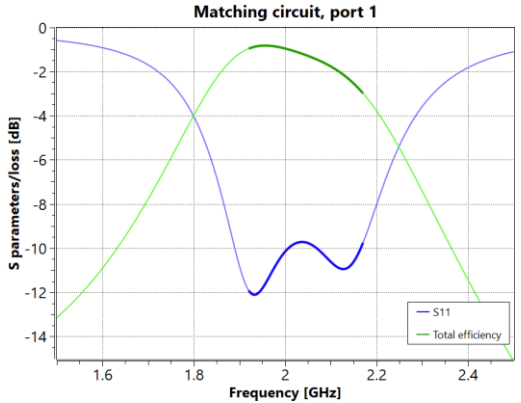


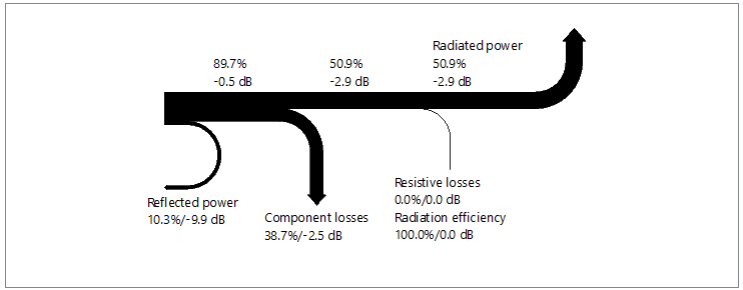


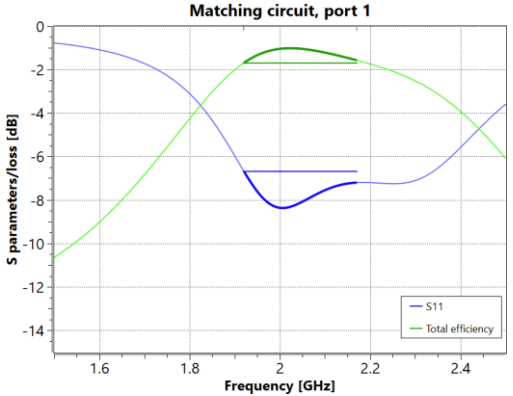
OPTENNI

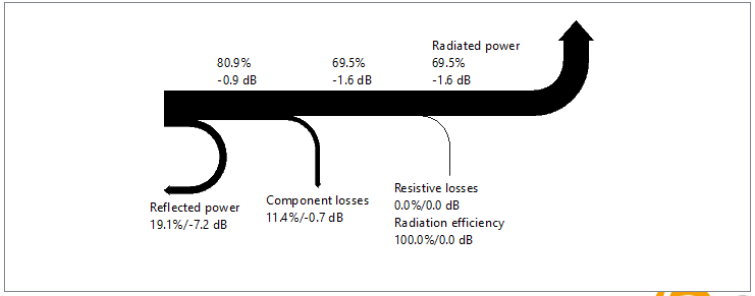
# Optimization goals in antenna matching

- Instead of minimizing S11, maximize antenna efficiency



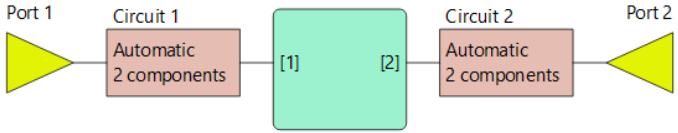



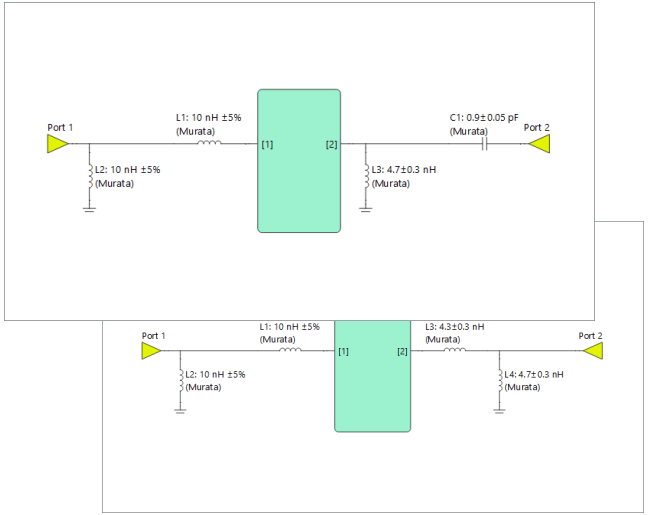



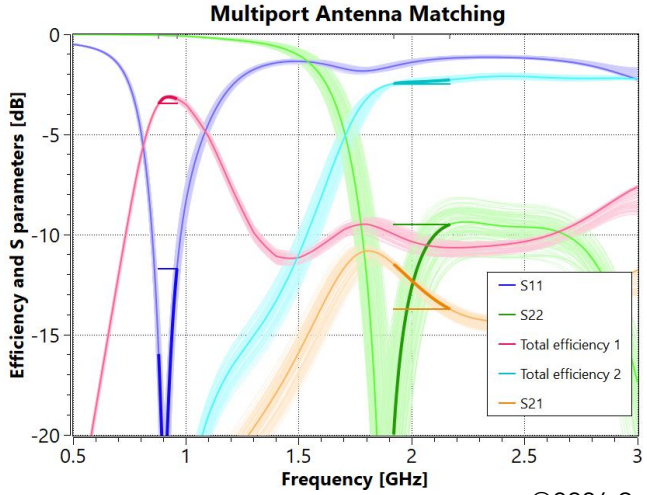



# Simultaneous multiport antenna matching

- Enter efficiency targets for each port
- Select component type
- Press OK
- Multiple optimized topologies presented



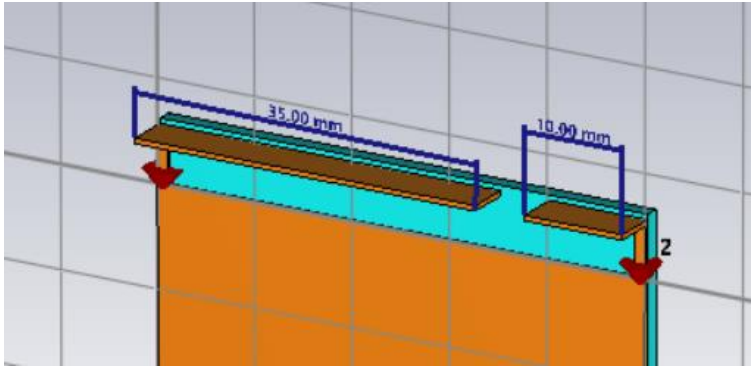


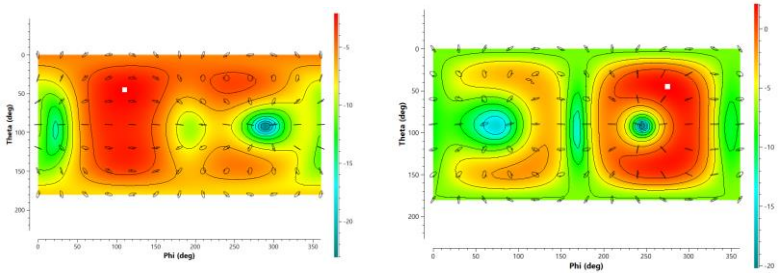



OPTENNI

# Efficiency in multiport antenna systems

- In a multiport antenna system, the radiation efficiency is a function of the termination and excitation of all ports
- The termination and excitation affects the near fields and the far fields
- If the complex radiation patterns of each port are known (one port excited at a time), the radiation efficiency for each termination and excitation condition can be found by a linear combination of the element patterns



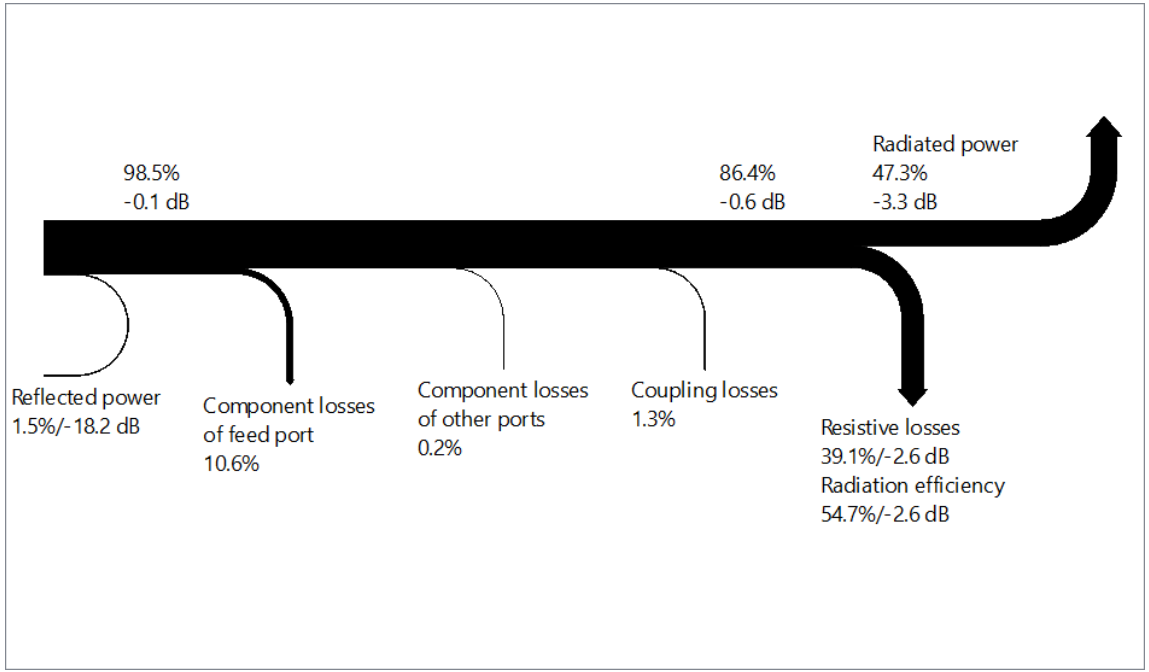








OPTENNI

# Loss terms in multiport antenna matching




Goal: maximize minimum efficiency over all ports and all target frequencies

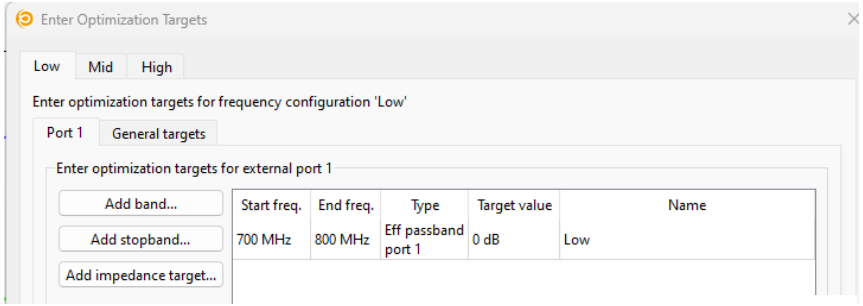


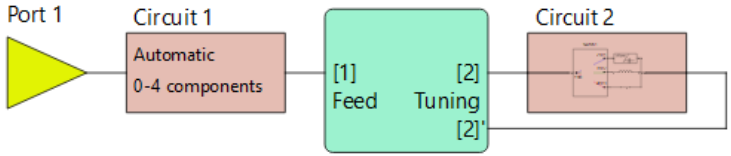


OPTENNI

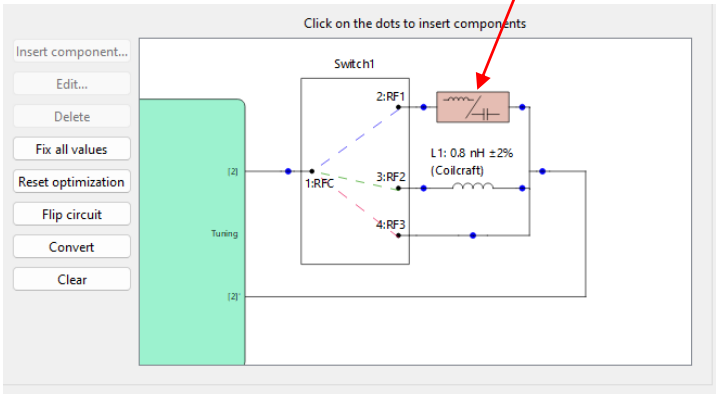
# Tunable matching circuit design

- Define operation targets for multiple frequency configurations
- Insert a switch to the aperture port and set the switch state for each frequency configuration
- Set component types and synthesis settings




Generic reactance component

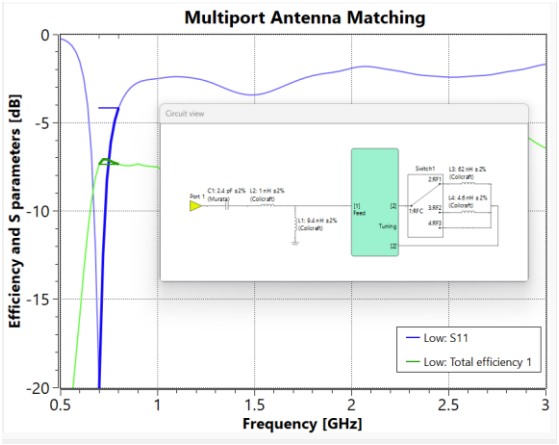


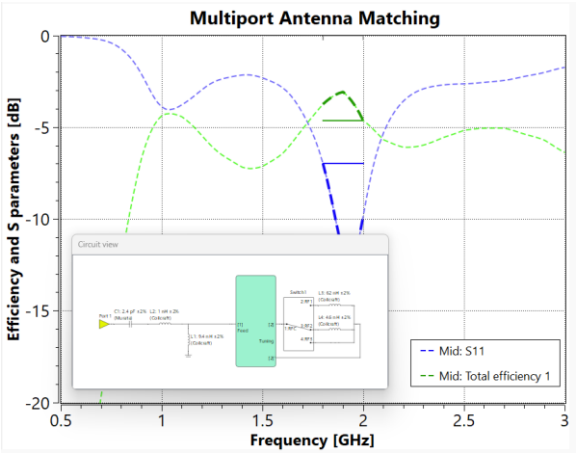


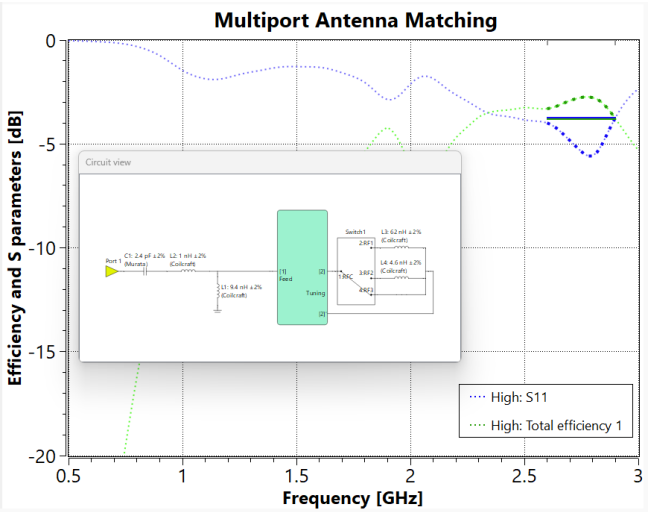



OPTENNI

# Tunable results




Goal: maximize minimum efficiency over all frequency configurations (with different switch states)

Lesson learned: switch off-state capacitance as important as on-state resistance

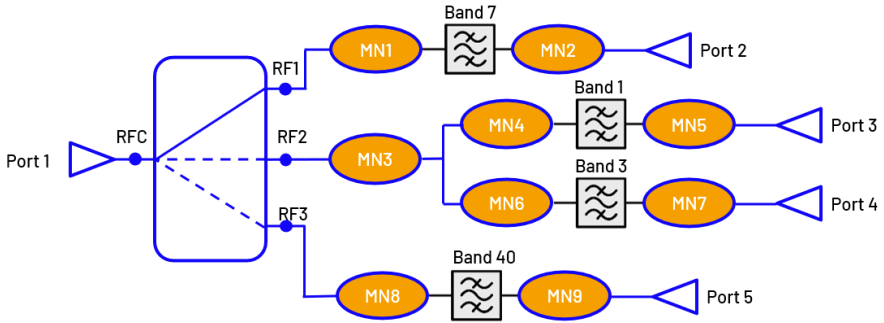


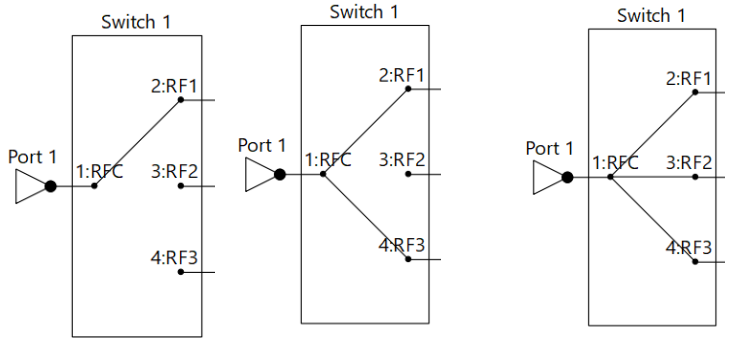


OPTENNI

# Carrier aggregation optimization

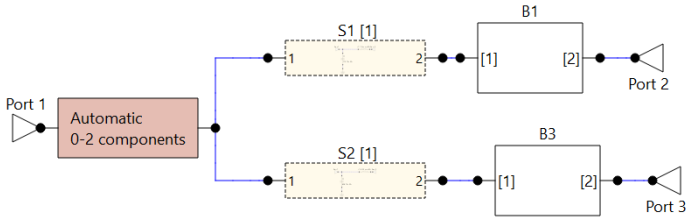
- Challenge: multiple RF branches need to be active at the same time
- The different branches are loading each other
- Design example:
  - Receive branches for band 7, bands 1+3 and band 40
  - Any combinations for the three cases are allowed
  - A multithrow SP3T switch is used

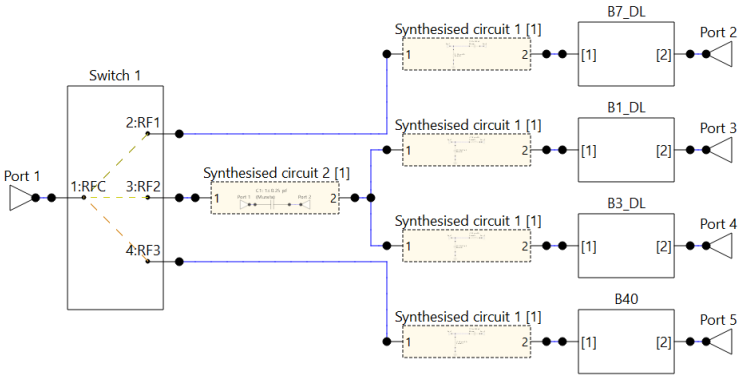


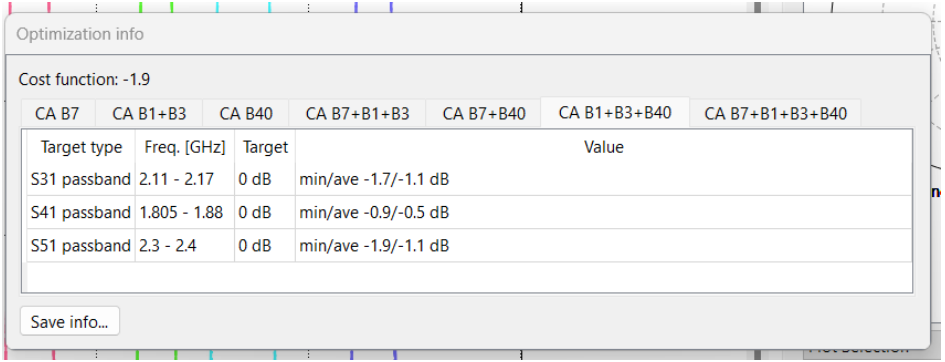



# Carrier aggregation setup

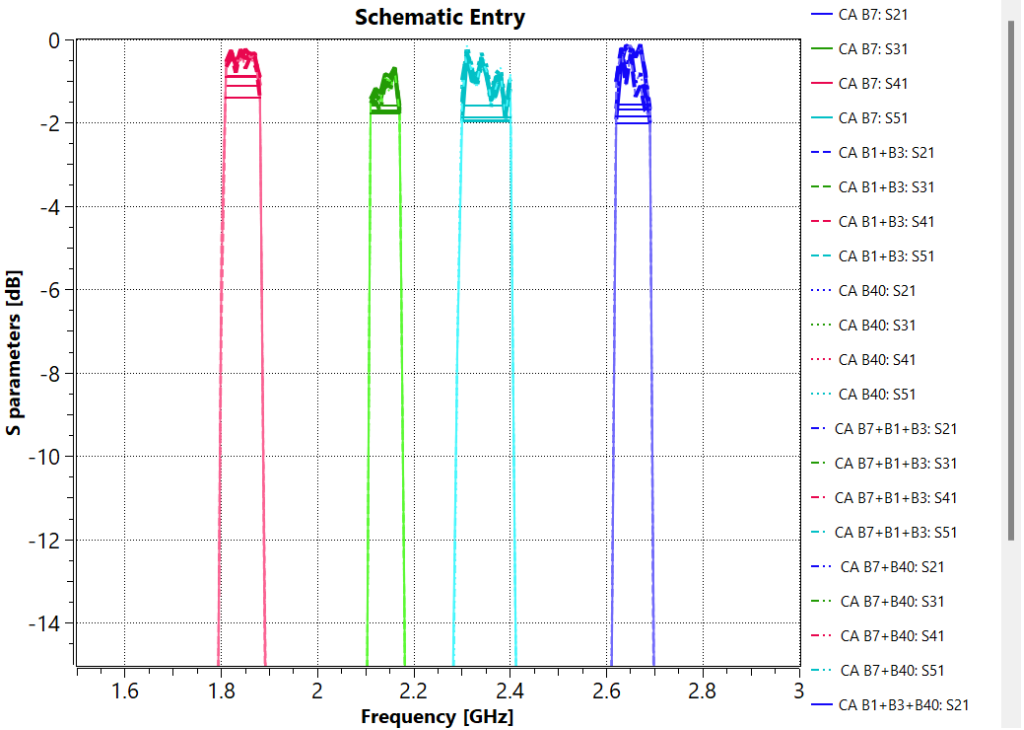
- Instead of optimizing all at once, it is more efficient to prematch the different branches first
- Final setup: define the pass and stop band targets for the 7 configurations

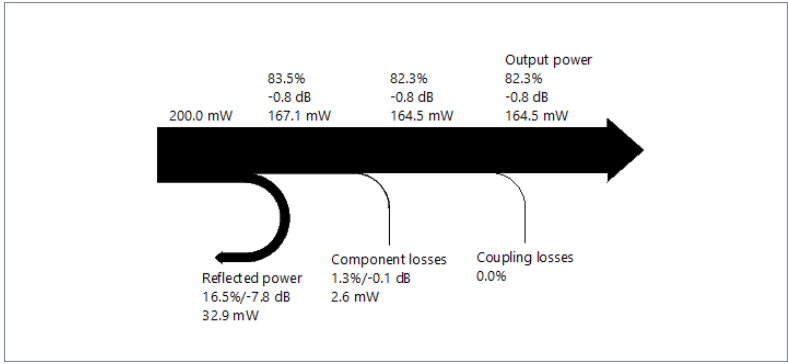


# Carrier aggregation results








OPTENNI

# Conclusions and lessons learned

- Matching circuit synthesis can produce multiple broadband matching circuits which operate between two complex frequency dependent impedances
- Instead of minimizing reflected power, maximize power transfer
- When number of matching components is increased, matching circuit losses and tolerance problems may increase
- Simultaneous multiport antenna matching can produce a huge number of topology combinations. Optimize for best efficiency
- In tunable matching, pay attention to switch losses and off-state capacitance
- In carrier aggregation setups, it is useful to prematch parts of the RF chain and then fine-tune the total problem


15 years of innovation in antenna and RF design automation