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SAN DIEGO 2023

We1H-6

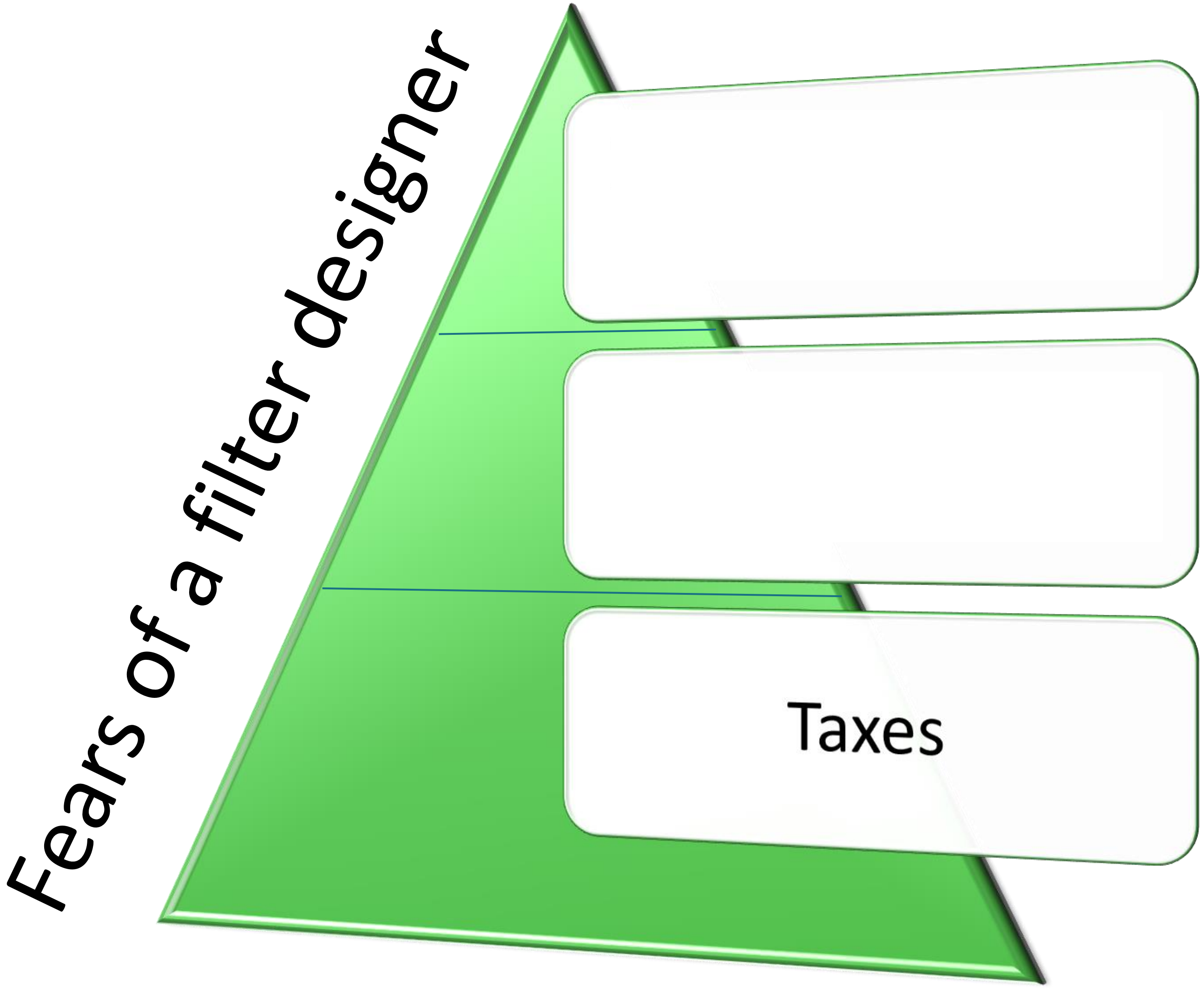
Synthesis of Simplified Cross Coupled Blocks with All Positive Couplings

Stefano Tamiazzo[§], Giuseppe Macchiarella[#], Matteo Oldoni[#]

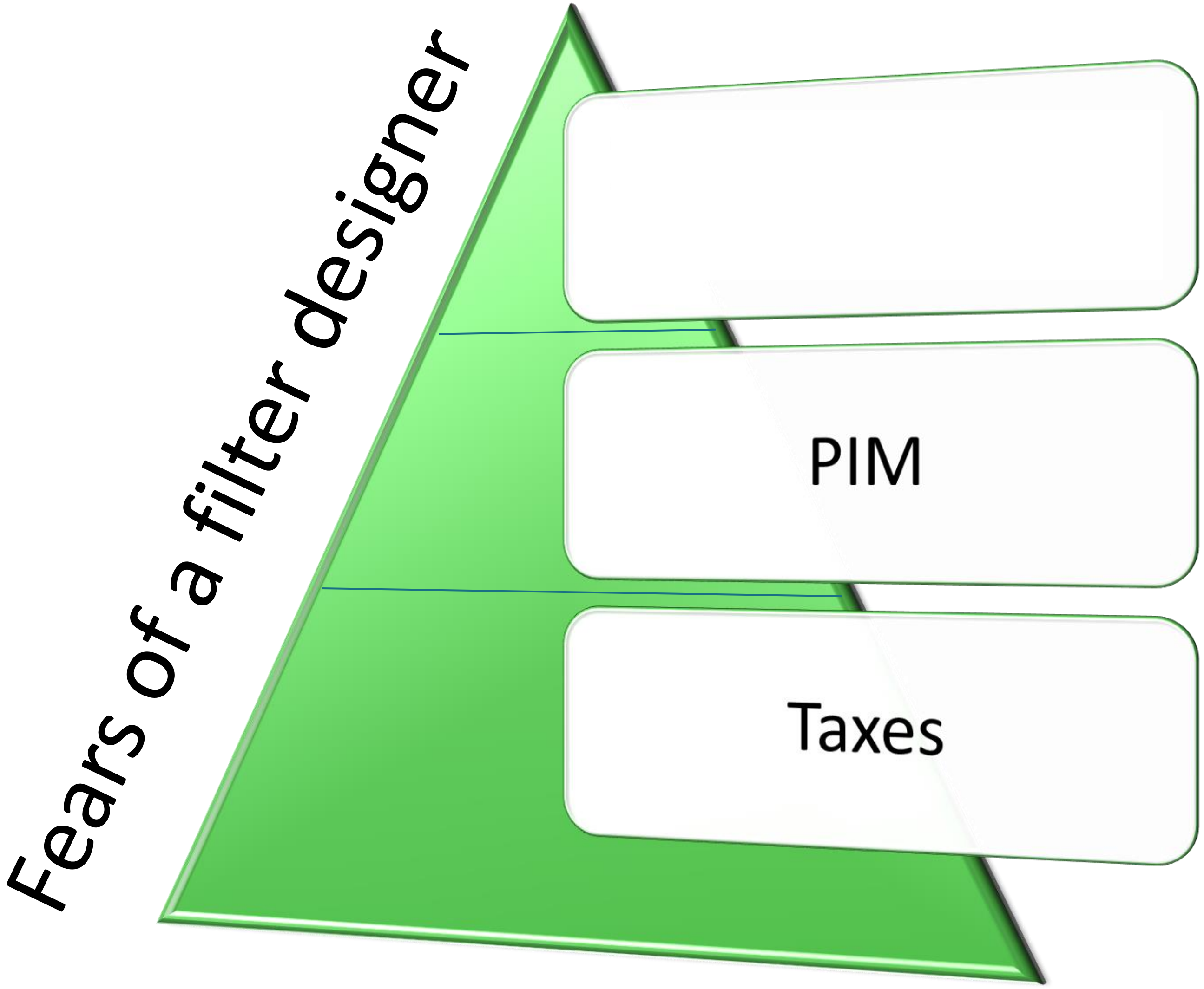
§ COMMSCOPE® now meets next

POLITECNICO MILANO 1863 DEIB DIPARTIMENTO DI ELETTRONICA INFORMAZIONE E BIOINGEGNERIA

Rationale



Rationale



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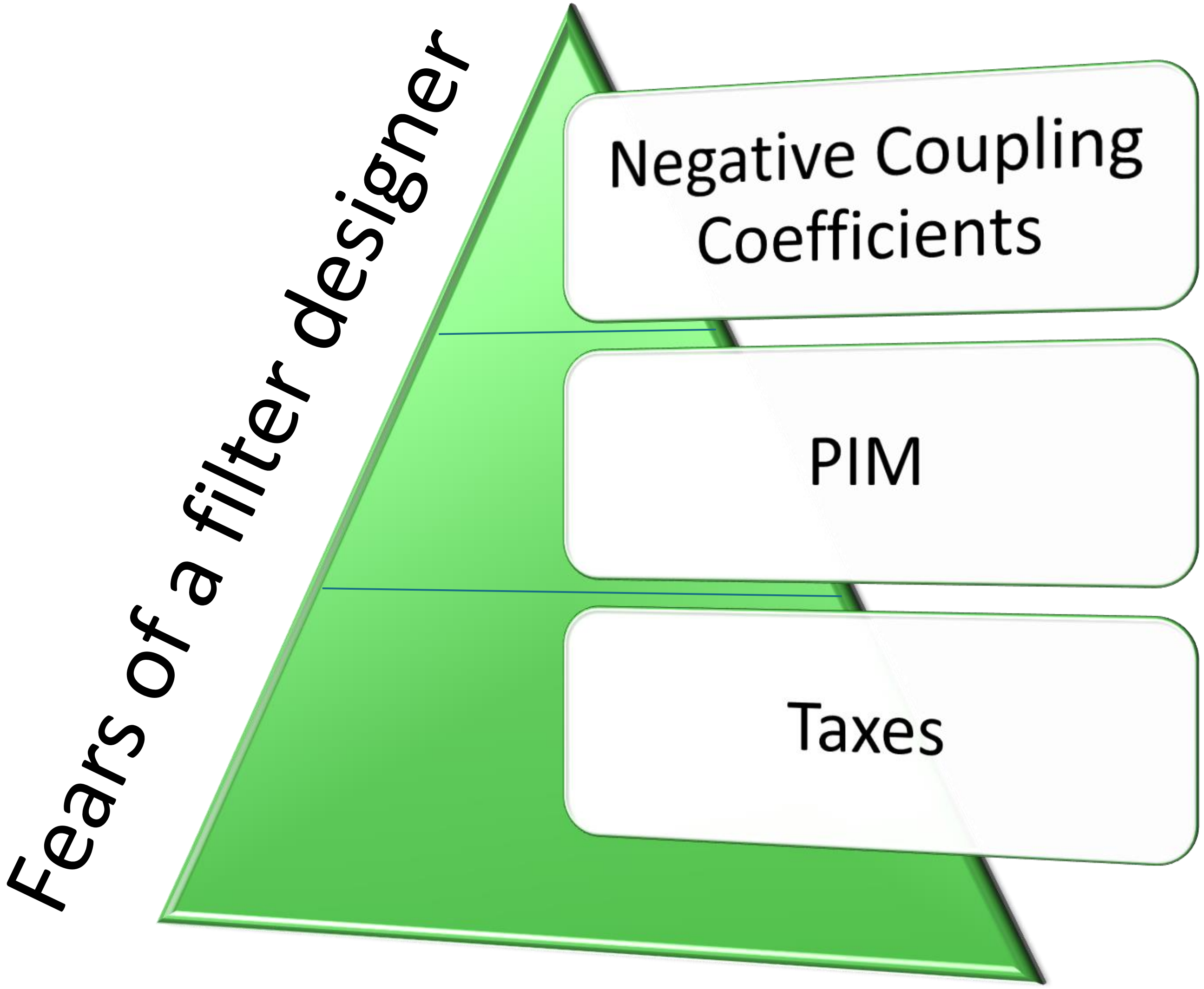

Fears of a filter designer
Negative Coupling Coefficients
PIM
Taxes

Outline

- Problem Statement
- Proposed Solution
- Examples and Conclusions

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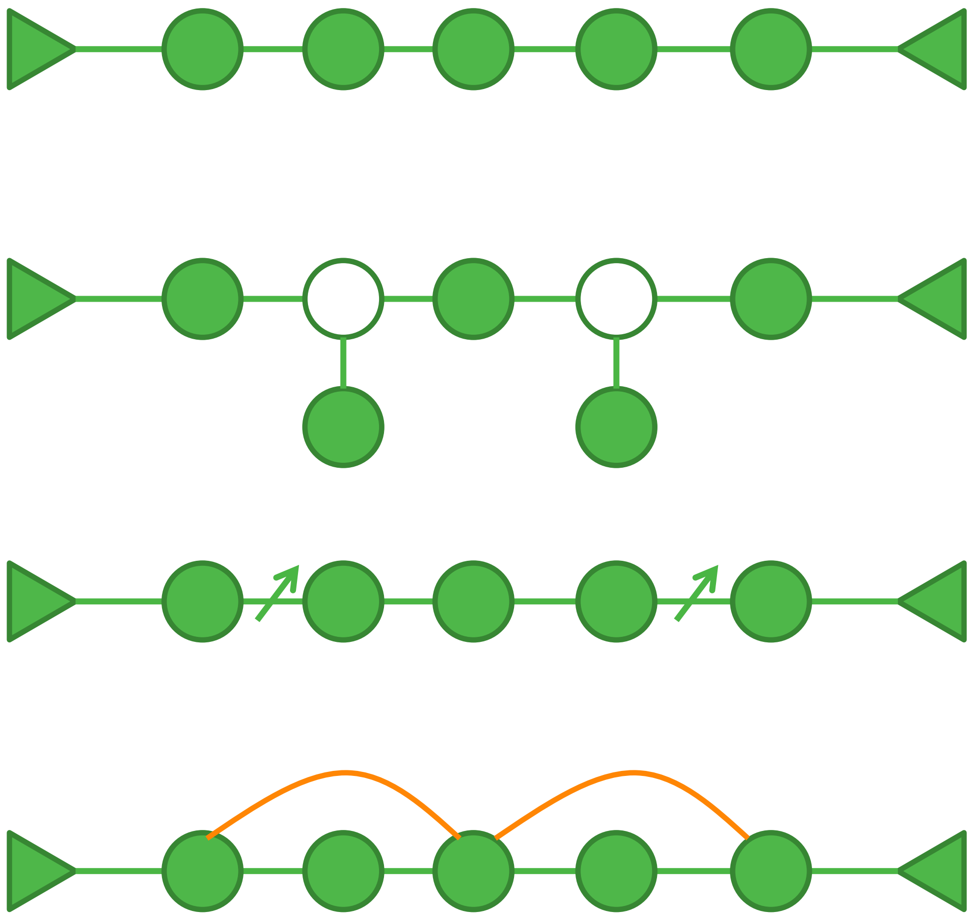
Problem Statement

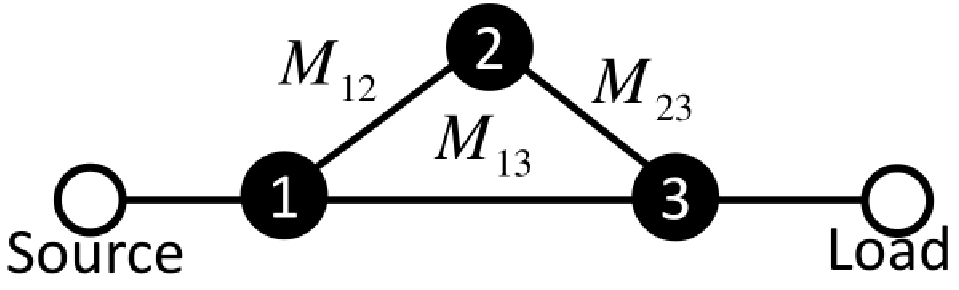
- Generalized Chebychev response
- Inline Structures
- Finite Transmission Zeros
  - Non-resonant nodes
  - Frequency-variant coupling
  - Cross-coupling
    (various cross-coupled sections)
- TZs below the passband
  - Negative cross-coupling!



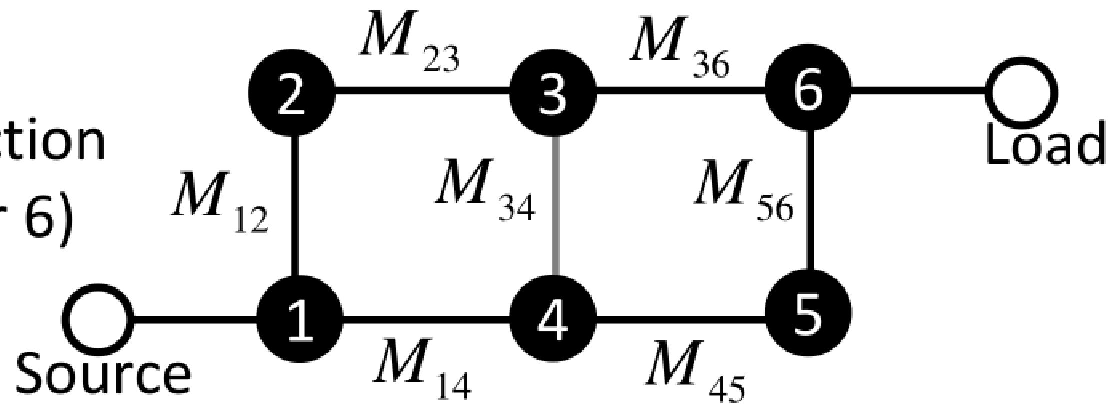
Problem Statement

- Degrees of freedom needed
- Exploit alternative response
- Constrain sign of cross-couplings
- Simplify topology, if possible

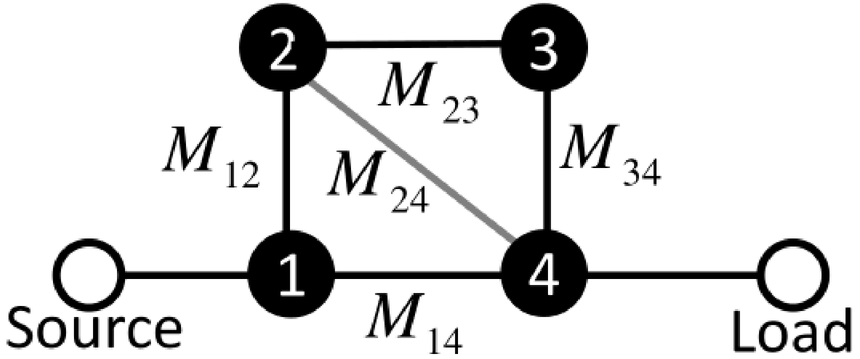
Triplet



Box section
(order 6)



Quadruplet



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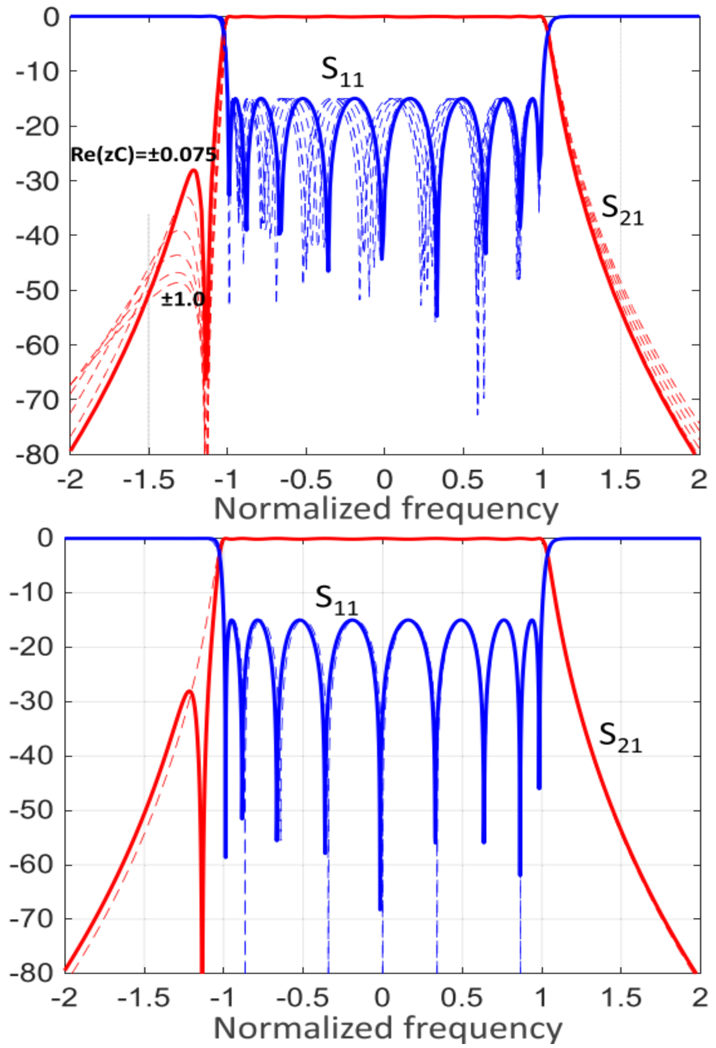
Proposed Solution

- Alternative response:
  Reduced Chebychev of order *N*
  - TZs can be placed
  - *M* complex reflection zeros can be placed
  - Equiripple passband response obtained
  - Other *N-M* RZs and *N* poles are computed
  - Out-of-band atten.: (*N-M*) –order filter

- *2M* real degrees of freedom available!



Proposed Solution

- Given: N, passband RL,TZs
- Place 1 complex reflection zero
- Compute the Reduced Chebychev response
- Synthesize the filter
- Verify sign of cross-coupling

- Sweep the position of the free complex reflection zero (CRZ)
- Map cross-coupling vs CRZ

Proposed Solution

- Given: N, passband RL,TZs
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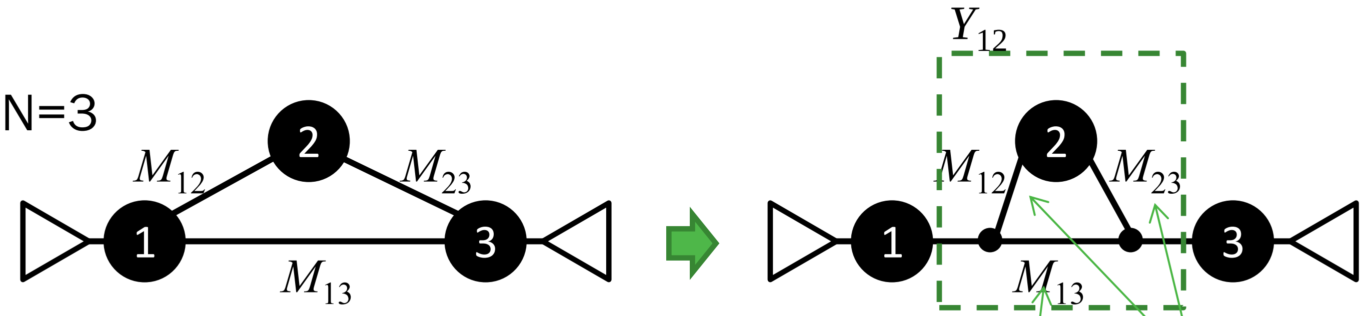
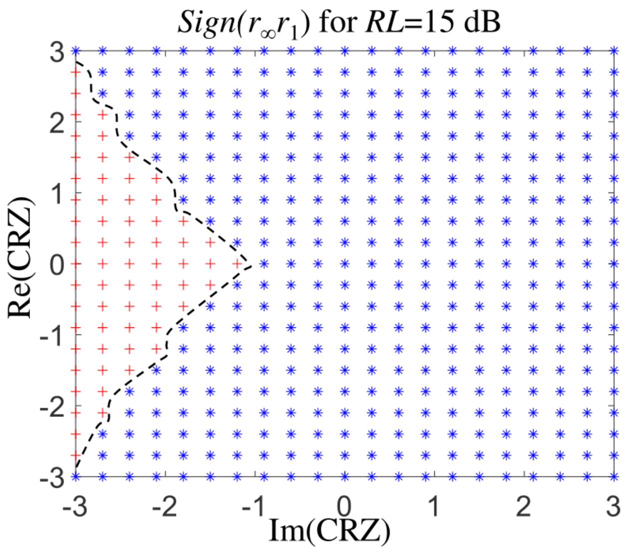
For N=3



- Extract the outer resonators
- The remainder has trans-admitt.: $Y_{12}(s) = jr_\infty + \dfrac{r_1}{s - j\lambda_1}$
- All positive or all negative if
  $r_\infty\, r_1 > 0$ (If all negative, can be reversed)

→ Im(CRZ) below passband!



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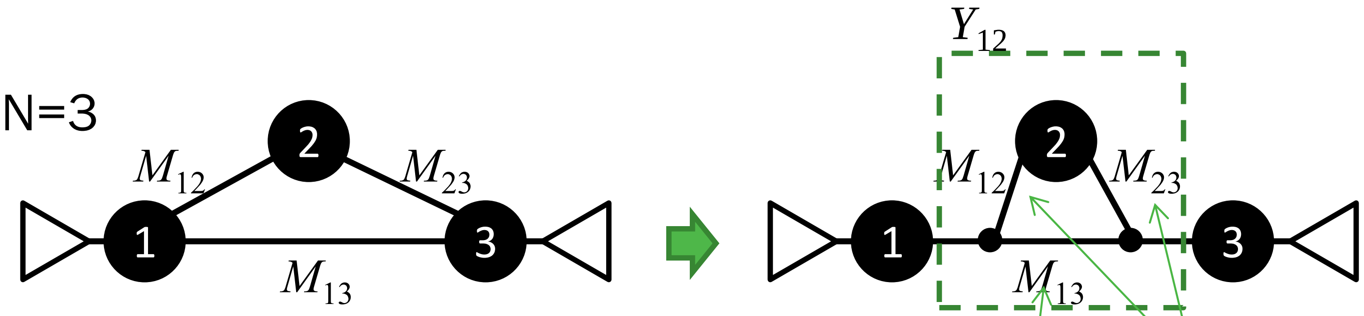
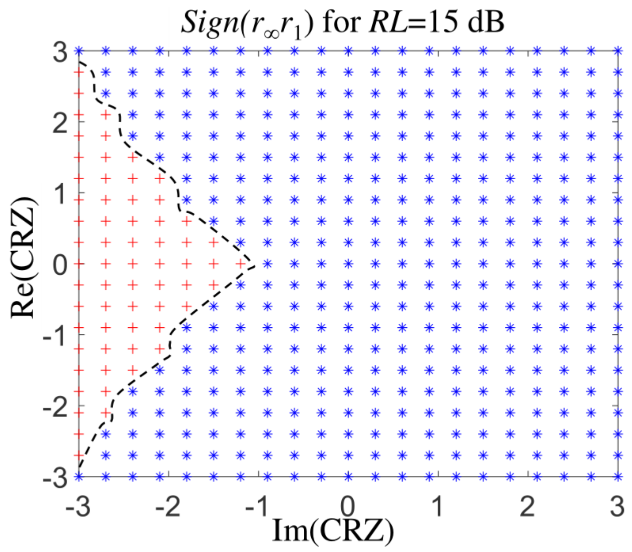
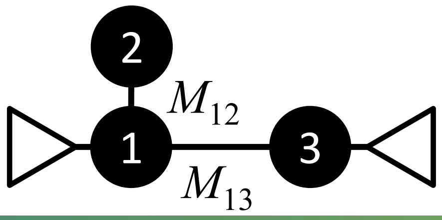
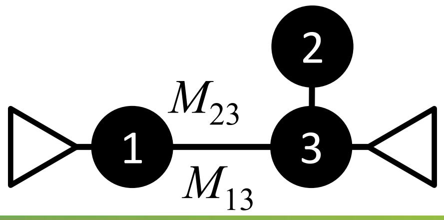


- Extract the outer resonators
- The remainder has trans-admitt.: $Y_{12}(s) = jr_\infty + \frac{r_1}{s - j\lambda_1}$
- All positive or all negative if
  $r_\infty\, r_1 > 0$ (If all negative, can be reversed)
  → Im(CRZ) below passband!
- On the boundary:
  $r_\infty\, r_1 = 0$
  Either M_{12} or M_{13}=0!
  →Degenerate triplet



3 resonators
1 finite TZs
2 imaginary RZs
1 complex RZ



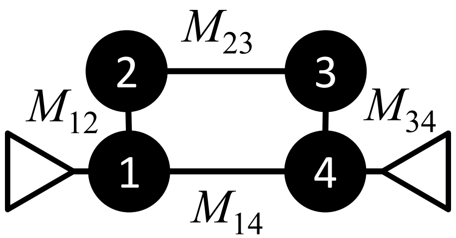


Proposed Solution

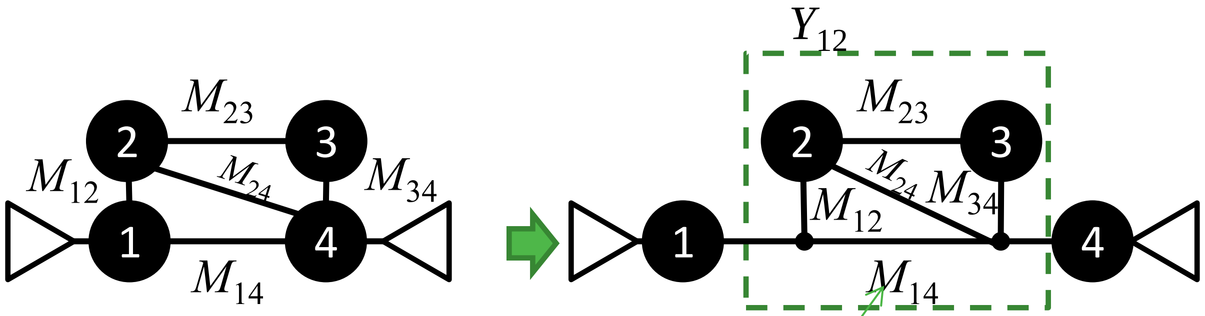
- Given: N, passband RL,TZs
- Place 1 complex reflection zero
- Compute the Reduced Chebychev response
- Synthesize the filter
- Verify sign of cross-coupling

- Sweep the position of the free complex reflection zero (CRZ)
- Map cross-coupling vs CRZ

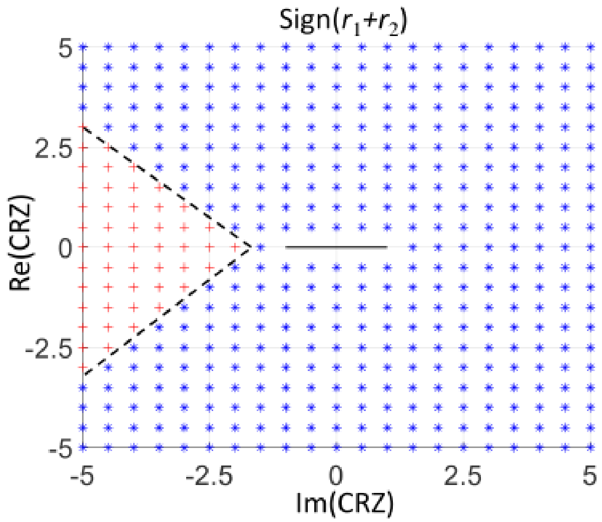
5 resonators
2 finite TZs
3 imaginary RZs
1 complex RZ

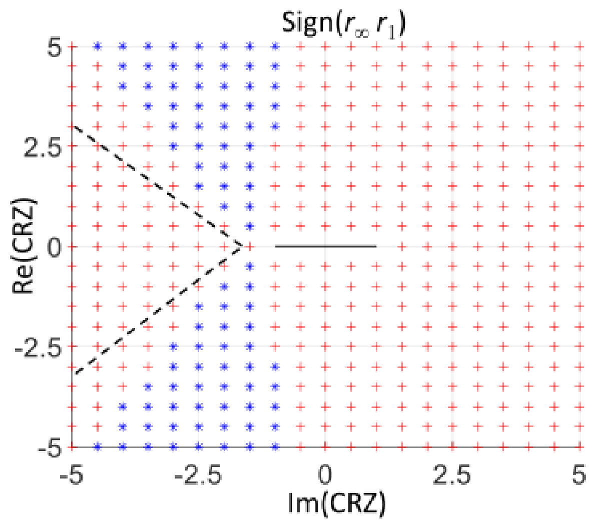


For N=4



- Extract the outer resonators
- The remainder has trans-admitt.: $Y_{12}(s) = jr_\infty + \dfrac{r_1}{s - j\lambda_1} + \dfrac{r_2}{s - j\lambda_2}$
- Uniform signs: $r_\infty\ r_1>0$
- Degenerate topology (M_{24}=0): $r_1 = -r_2$



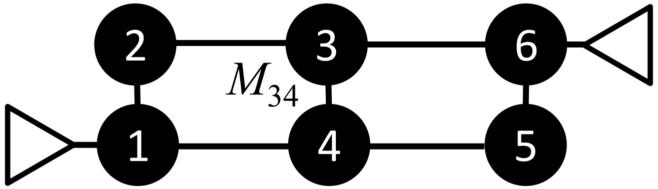


Proposed Solution

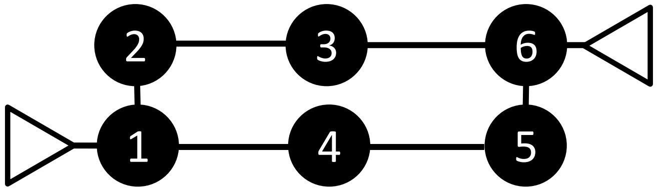
- Given: N, passband RL,TZs
- Place 1 complex reflection zero
- Compute the Reduced Chebychev response
- Synthesize the filter
- Verify sign of cross-coupling

- Sweep the position of the free complex reflection zero (CRZ)
- Map cross-coupling vs CRZ

For N=6



- Extract the outer resonators (1, 6)
- The remainder has: $Y_{12}(s) = \frac{r_1}{s-j\lambda_1} + \frac{r_2}{s-j\lambda_2} + \frac{r_3}{s-j\lambda_3} + \frac{r_4}{s-j\lambda_4}$
- Conditions:
  - Uniform signs: $r_1\, r_3 > 0$ or $r_1\, r_2 > 0$
  - Degenerate topology ($M_{34}=0$): $r_1 = -r_2$ or $r_1 = -r_3$ or $r_1 = -r_4$
  - Depend on position of the two zeros



6 resonators
2 finite TZs
5 imaginary RZs
1 complex RZ

Outline

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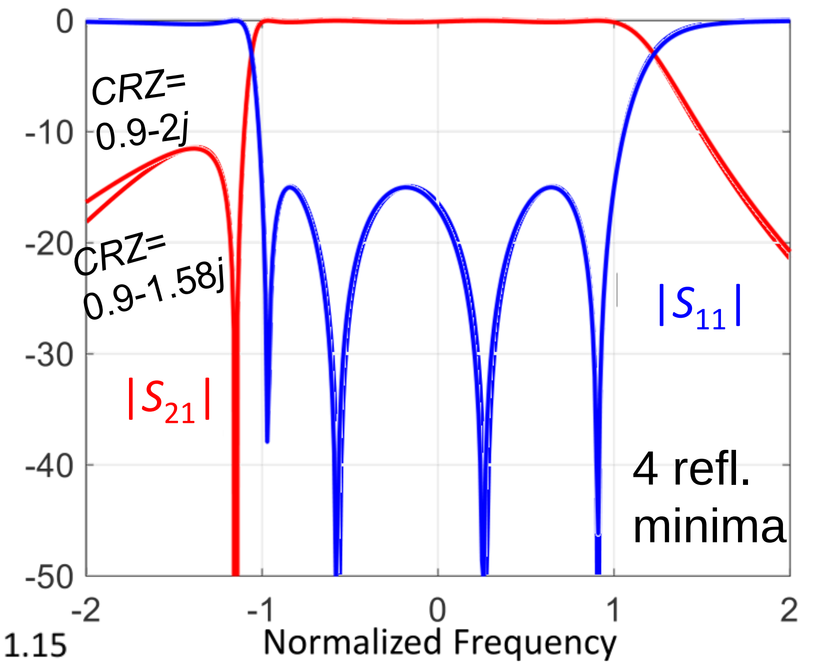
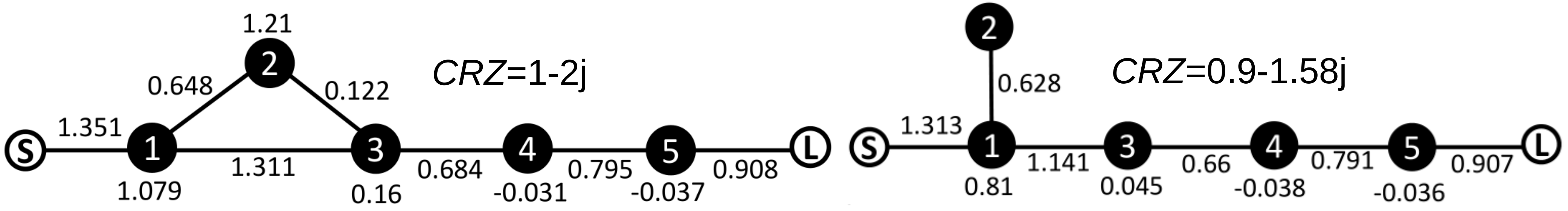
Examples: Triplet

- The CRZ region for uniform signs depends on the position of the triplet
- Synthesis:
  - Decide the topology (sequence of extractions)
  - Place the CRZ and compute Reduced Chebychev response
  - Extract everything else but the triplet
  - Check the condition on the residuals of trans-admittance
  - Sweep the CRZ and build the map
- Empirically: largest region when triplet on source or load
- Non-degenerate and degenerate topologies



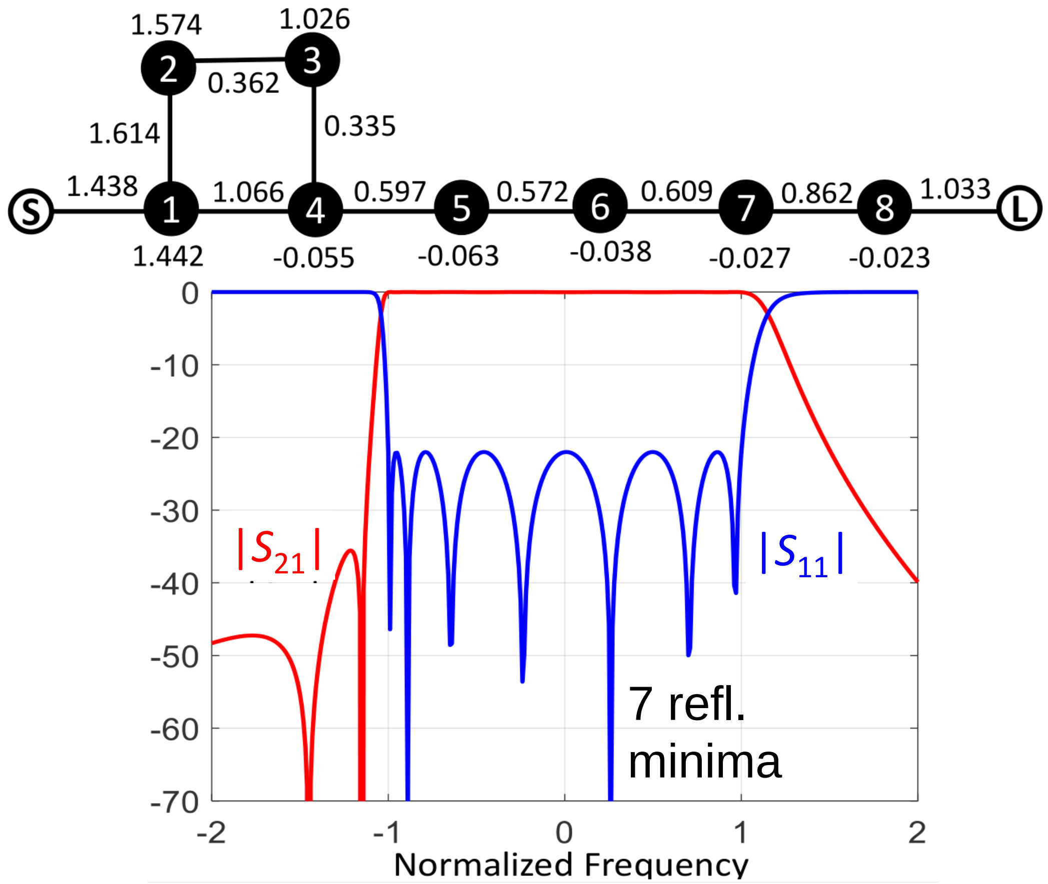
N=5
RL=15dB
TZ=-1.1



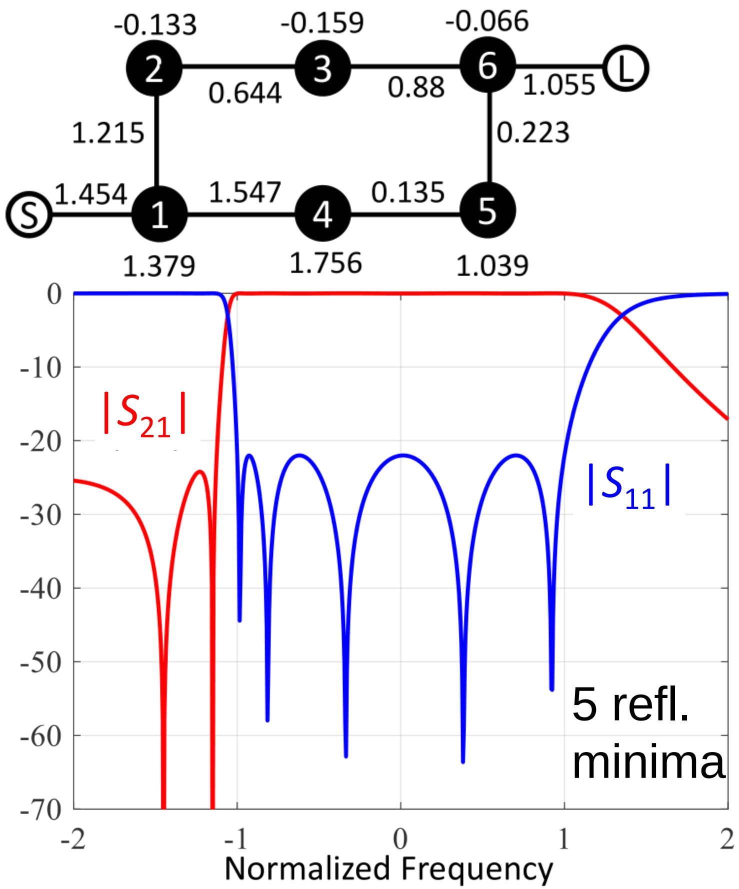
Examples: Quadruplet and 6-Box

- The CRZ region for uniform signs depends on the position of the quadruplet/box

N=8; RL=22dB; TZ=-1.45, -1.15; CRZ=1-2.83*j*

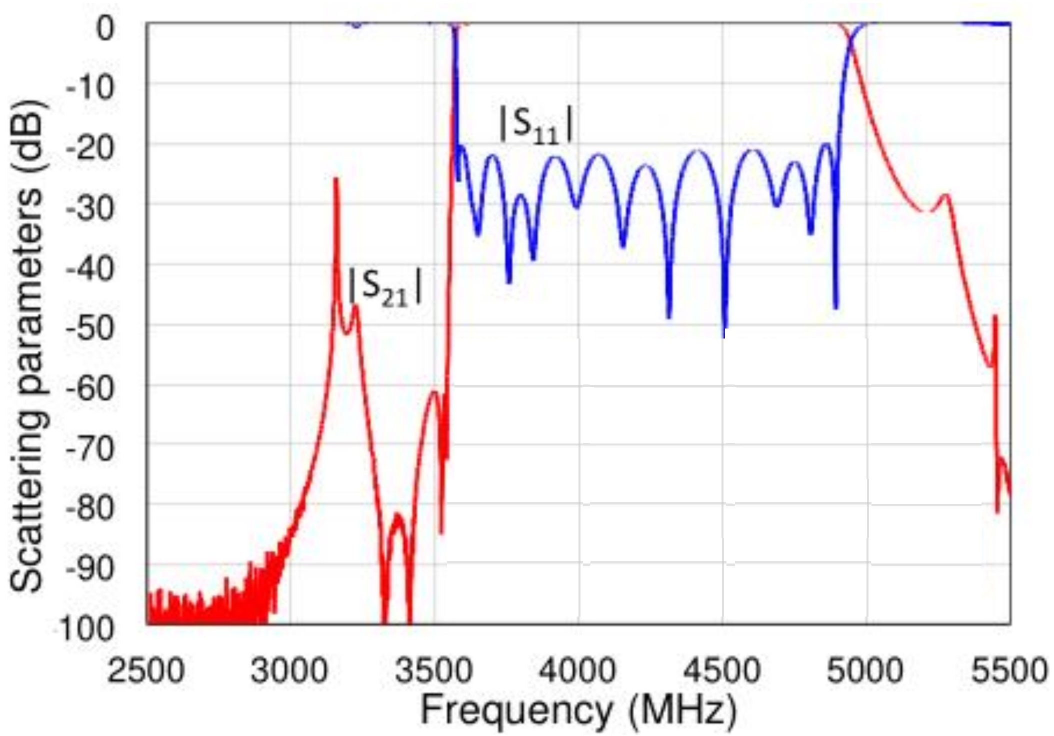


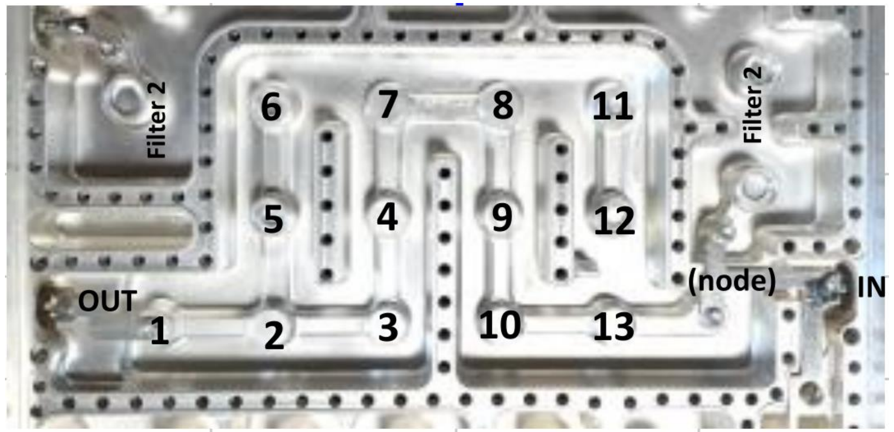
N=6; RL=22dB; TZ=-1.45, -1.15; CRZ=1-2.99*j*

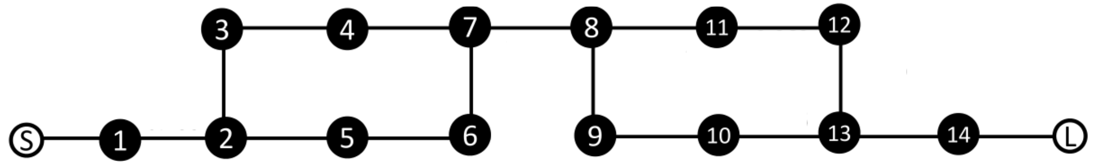


Examples: 14-order Filter

- Filter manufactured and shown in a previous paper
- Was optimized to obtain 2 degenerate 6-box sections





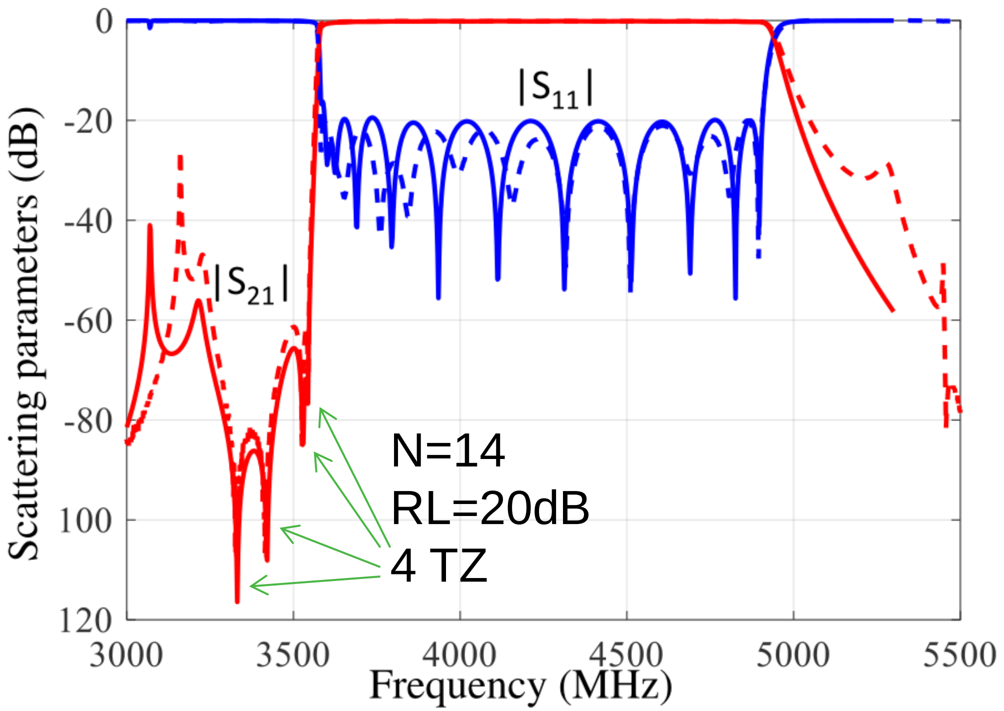


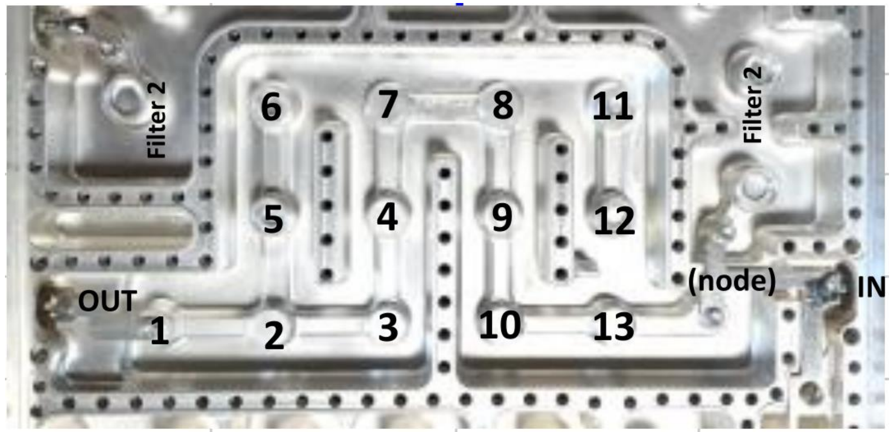
Fit the response with a N=14 Reduced Chebychev response with 2 CRZ (initially corresponding with the spurious S21 peaks at 3200MHz)

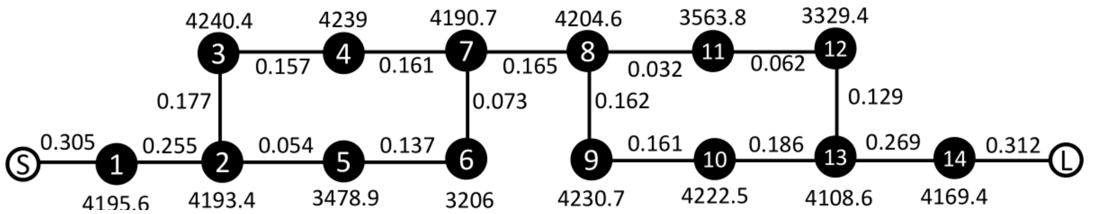
- Can it be obtained by the new technique?

Examples: 14-order Filter

- Filter manufactured and shown in a previous paper
- Was optimized to obtain 2 degenerate 6-box sections





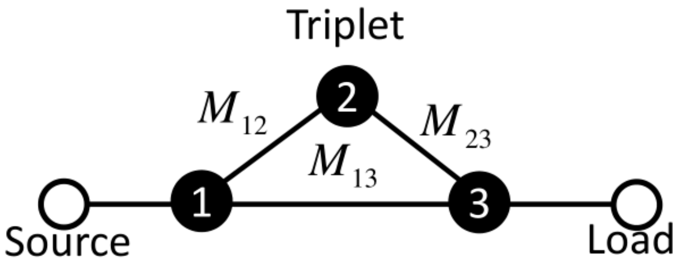


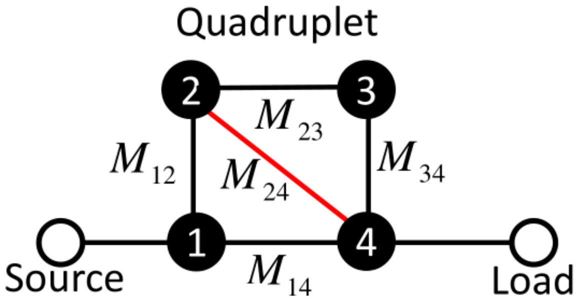
Fit the response with a N=14 Reduced Chebychev response with 2 CRZ: -1.987*j*, -0.025-1.687*j*
Synthesize → Indeed gives 2 degenerate 6-box!
Simulate → Very good agreement!

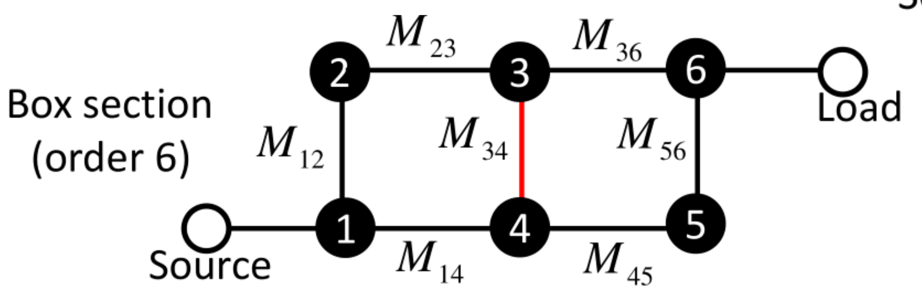
- Can it be obtained by the new technique?
- Yes, and it could be improved too (CRZs further below 2700MHz)!

Conclusions

- Complex Reflection Zeros allow degrees of freedom:
  - All positive coupling coefficients
  - Degenerate structures







- Maps to place CRZ
- Guidelines for simplified design
- Confirmed by several examples

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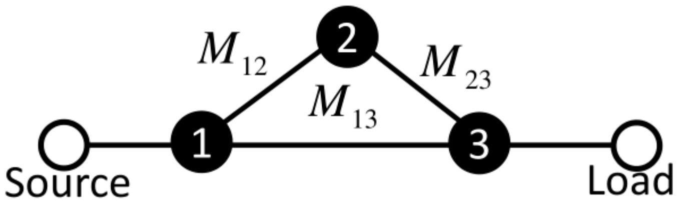
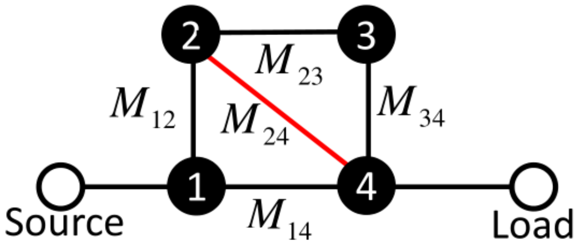
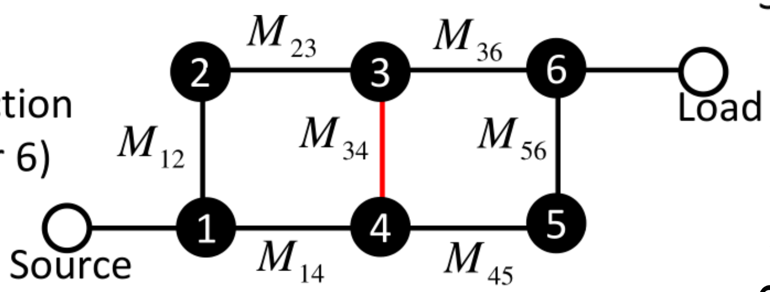
Triplet

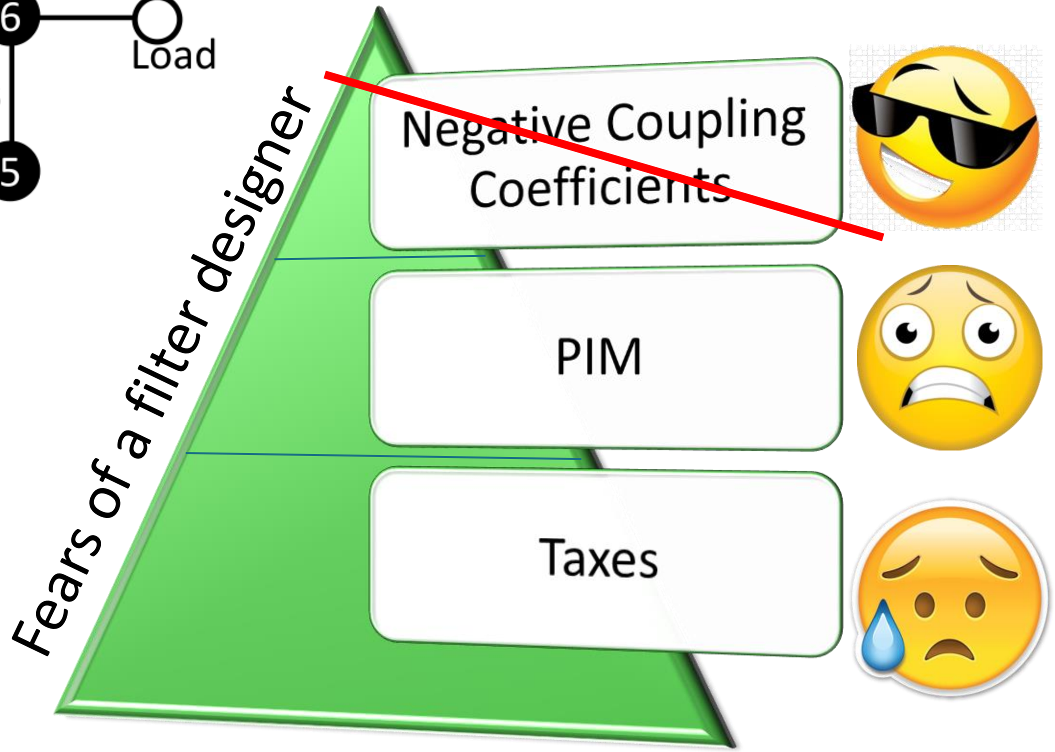


Quadruplet



Box section (order 6)





- Maps to place CRZ
- Guidelines for simplified design
- Confirmed by several examples

- We still have the other fears…

Thank you!

Questions?

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