TM_{110}-MODE RESONATORS: Simple Configurations For Highly Flexible Waveguide Filter Designs

Jens Bornemann
Department of Electrical and Computer Engineering
University of Victoria, Victoria, BC
Canada V8W 3P6

Smain Amari
Department of Electrical and Computer Engineering
Royal Military College, Kingston, ON
Canada K7K 7B4

Uwe Rosenberg
Marconi Communications GmbH
D-71520 Backnang, Germany

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Outline

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- TM_{110}-Mode Resonators
- Design Guidelines
- Design Results
- Non-Resonating Node Model
- Design Variations
- Conclusions

Motivation

Find a waveguide filter configuration

- which allows the number and locations of transmission zeros to be as flexible as possible,
- whose topology is independent of the number and locations of transmission zeros,
- which leads to a relatively compact design,
- which can be manufactured by standard waveguide fabrication techniques,
- which does not require post-assembly tuning.

TM_{110}-Mode Resonators - Advantages

- Resonances are based on TM_{110}-mode cavities allowing lower-order modes to generate cross/by-pass coupling.

- The maximum number of transmission zeros equals the number of TM_{110}-mode cavities.

- The locations of transmission zeros are arbitrary, and simple design guidelines dictate their position with respect to the passband.

- Each transmission zero is independently controlled as each resonance is capable of creating its own transmission zero.

- The filter topology is in-line and, therefore, ideally suited to fit standard waveguide manufacturing technologies.

- Due to the TM_{110}-mode operation, the cavities are short. An N-pole TM_{110}-mode filter usually requires less space than a comparable dual-mode filter based on $TE_{101/011}$ modes.

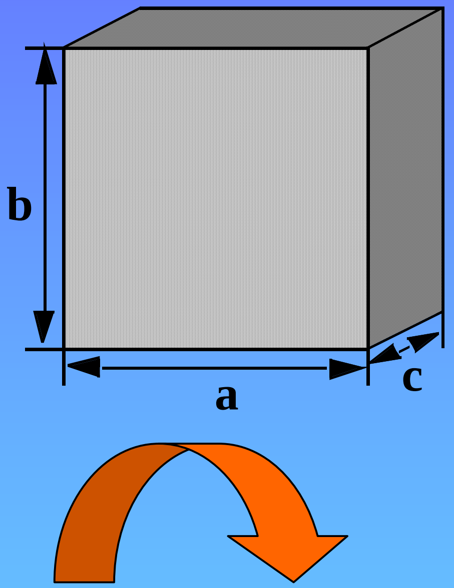
TM_{110}-Mode Resonators - Disadvantage

- Cascaded TM_{110}-mode cavities cannot be designed by standard coupling matrices because the standard inter-resonator coupling matrix formulation fails to capture the physical interactions of fields and modes involved.

- Therefore, a new coupling scheme based on so-called non-resonant nodes is developed and presented.

TM_{110}-Mode Resonators

Cavity



Resonances

$$f_r(TM_{110}) = \frac{v_c}{2}\sqrt{\frac{1}{a^2}+\frac{1}{b^2}}$$

$$f_r(TE_{101}) = \frac{v_c}{2}\sqrt{\frac{1}{a^2}+\frac{1}{c^2}}$$

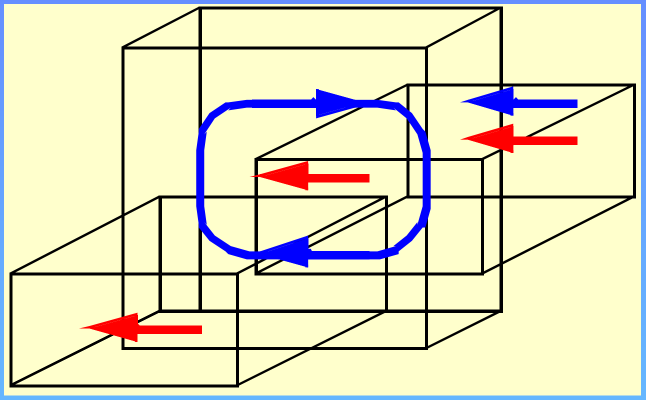
$$f_r(TE_{011}) = \frac{v_c}{2}\sqrt{\frac{1}{b^2}+\frac{1}{c^2}}$$

Cavity dimensions a, b, c selected such that

- **TM_{110} resonates**
- **TE_{10} , TE_{01} do NOT resonate**

TM_{110}-Mode Resonator –The Singlet Coupling Mechanism

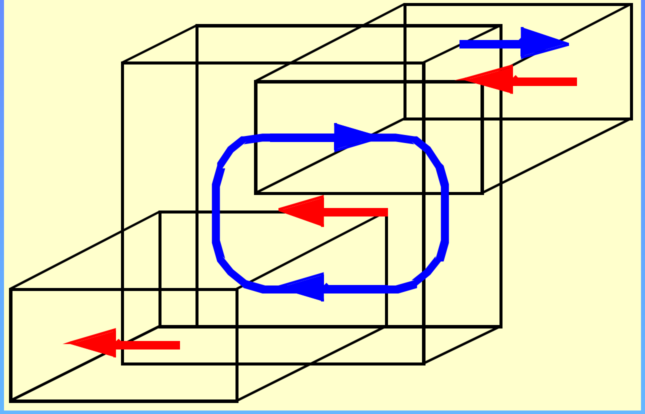
Coupling is predominantly magnetic. An incoming TE_{10} mode excites both TE_{10} and TM_{11} in the cavity.



TE_{10}

Direct and bypass coupling in phase

Transmission zero BELOW passband



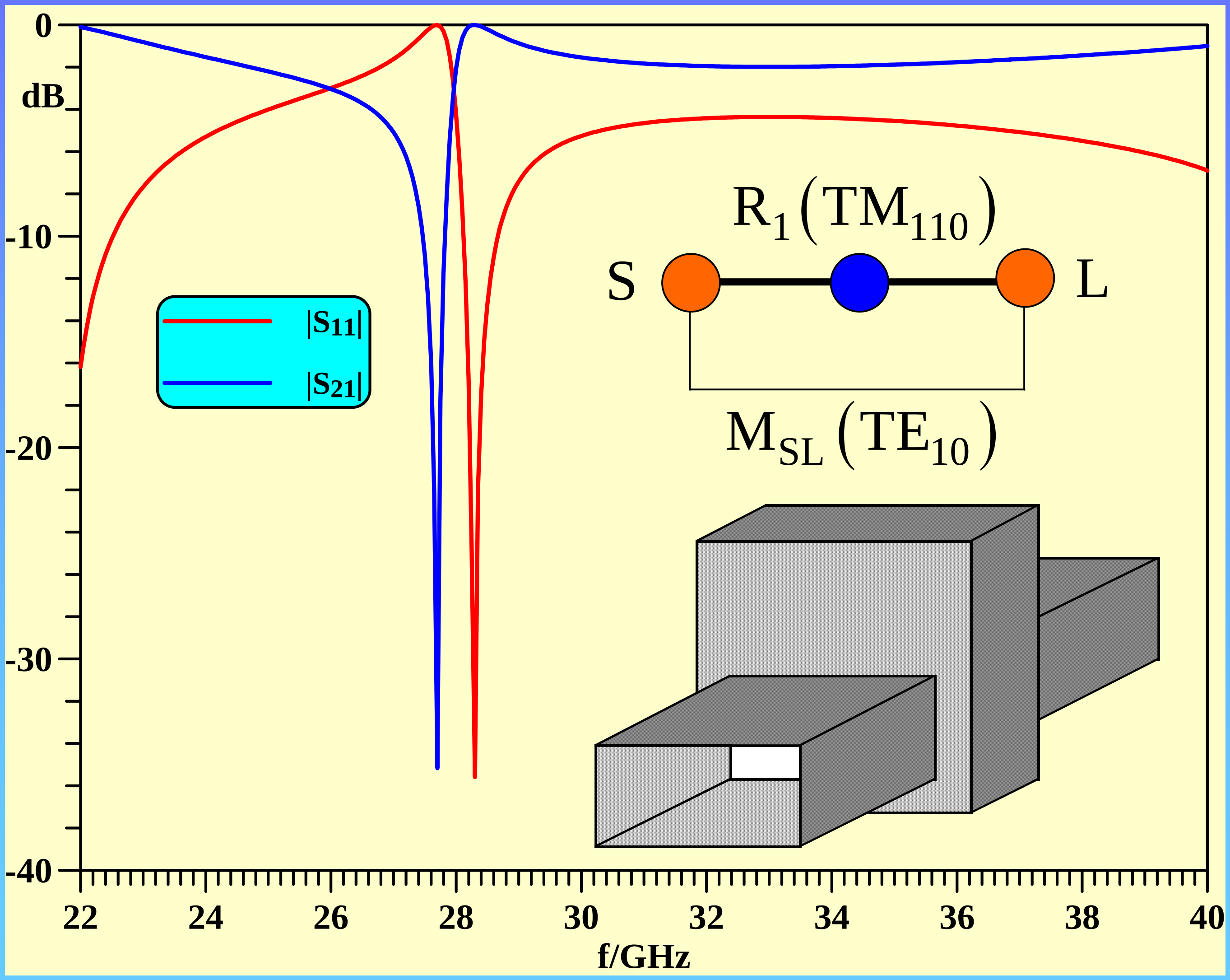
TE_{10}

Direct and bypass coupling out of phase

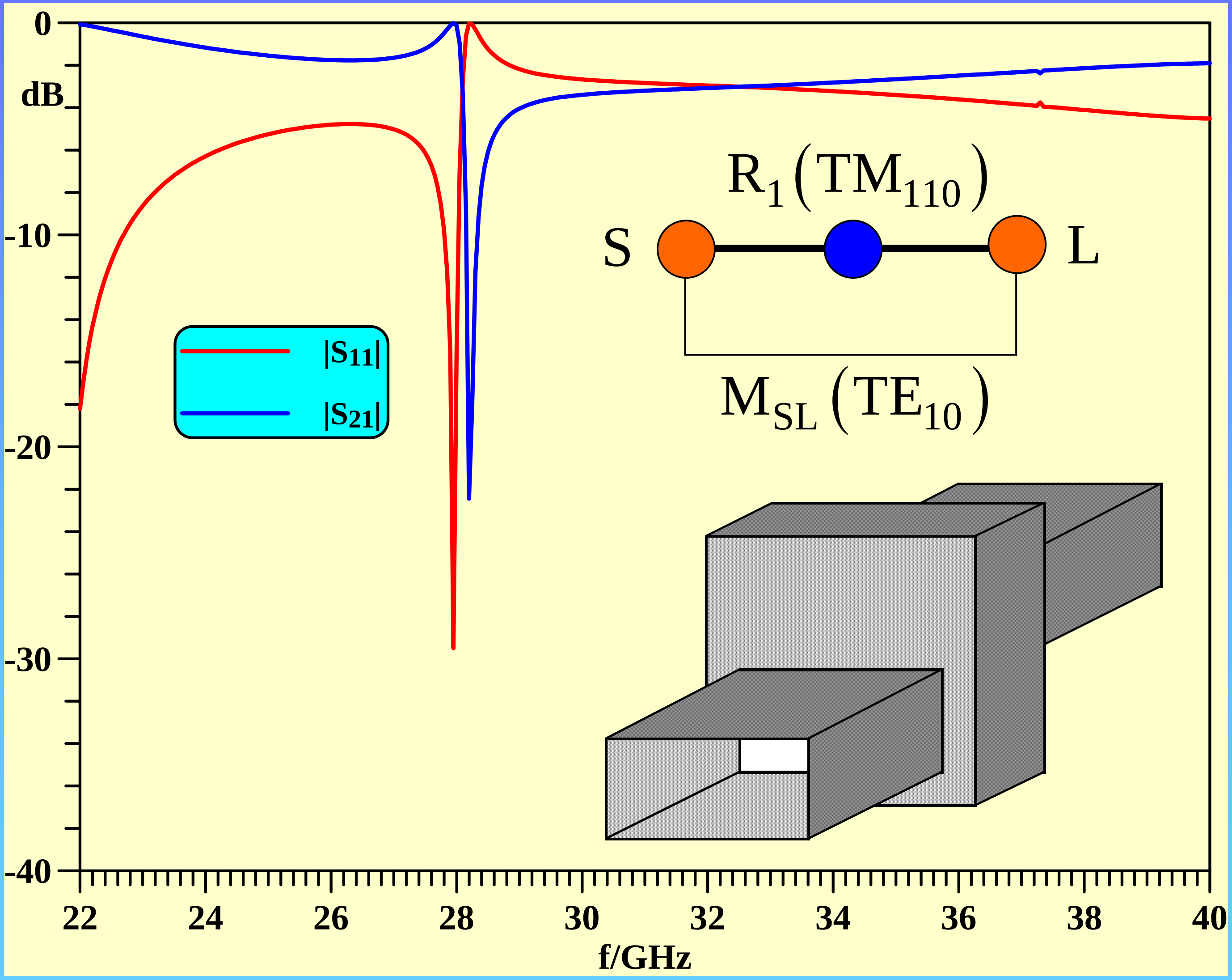
Transmission zero ABOVE passband

Design Guidelines – Single Cavity

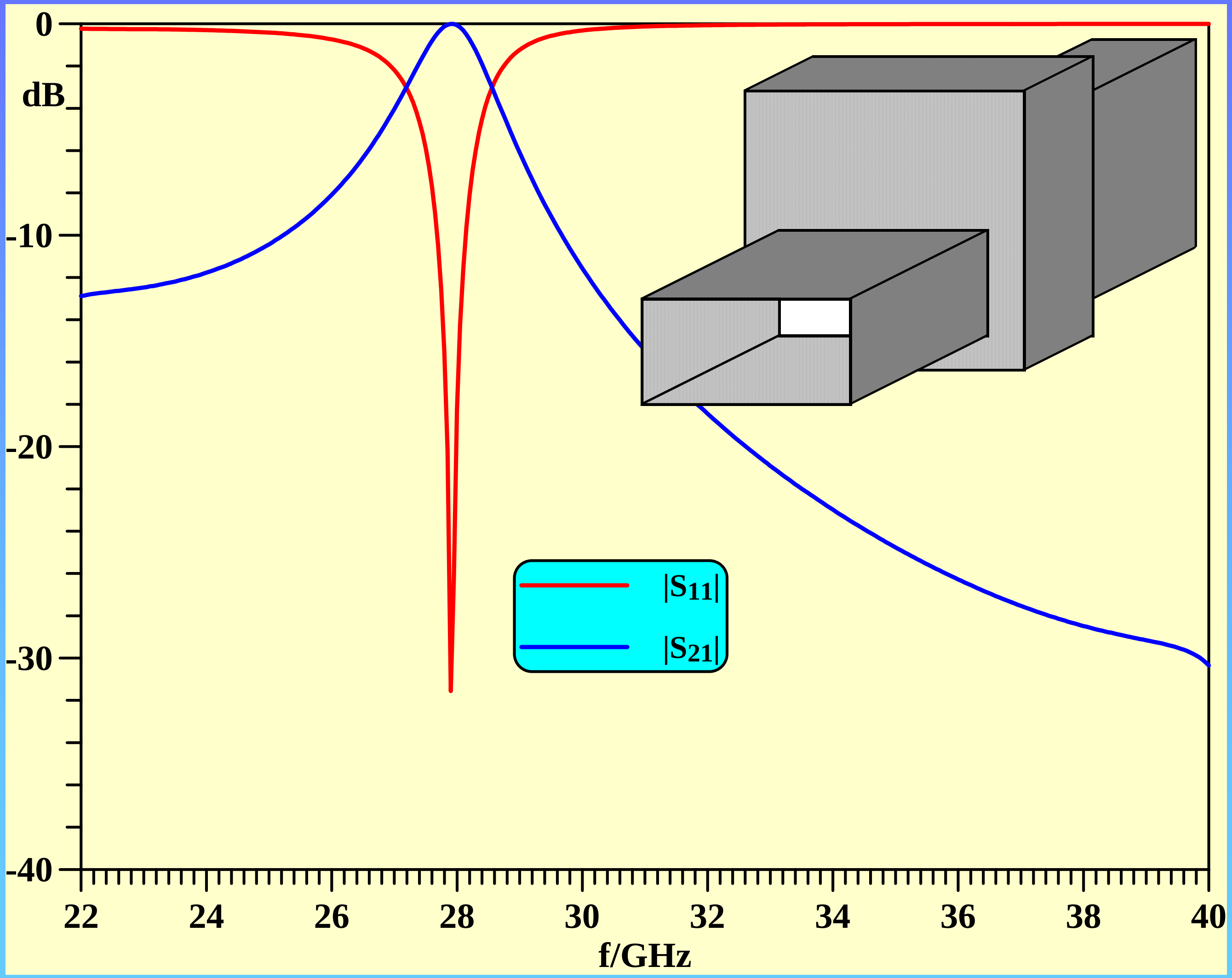
1. Transmission Zero Below Passband



2. Transmission Zero Above Passband

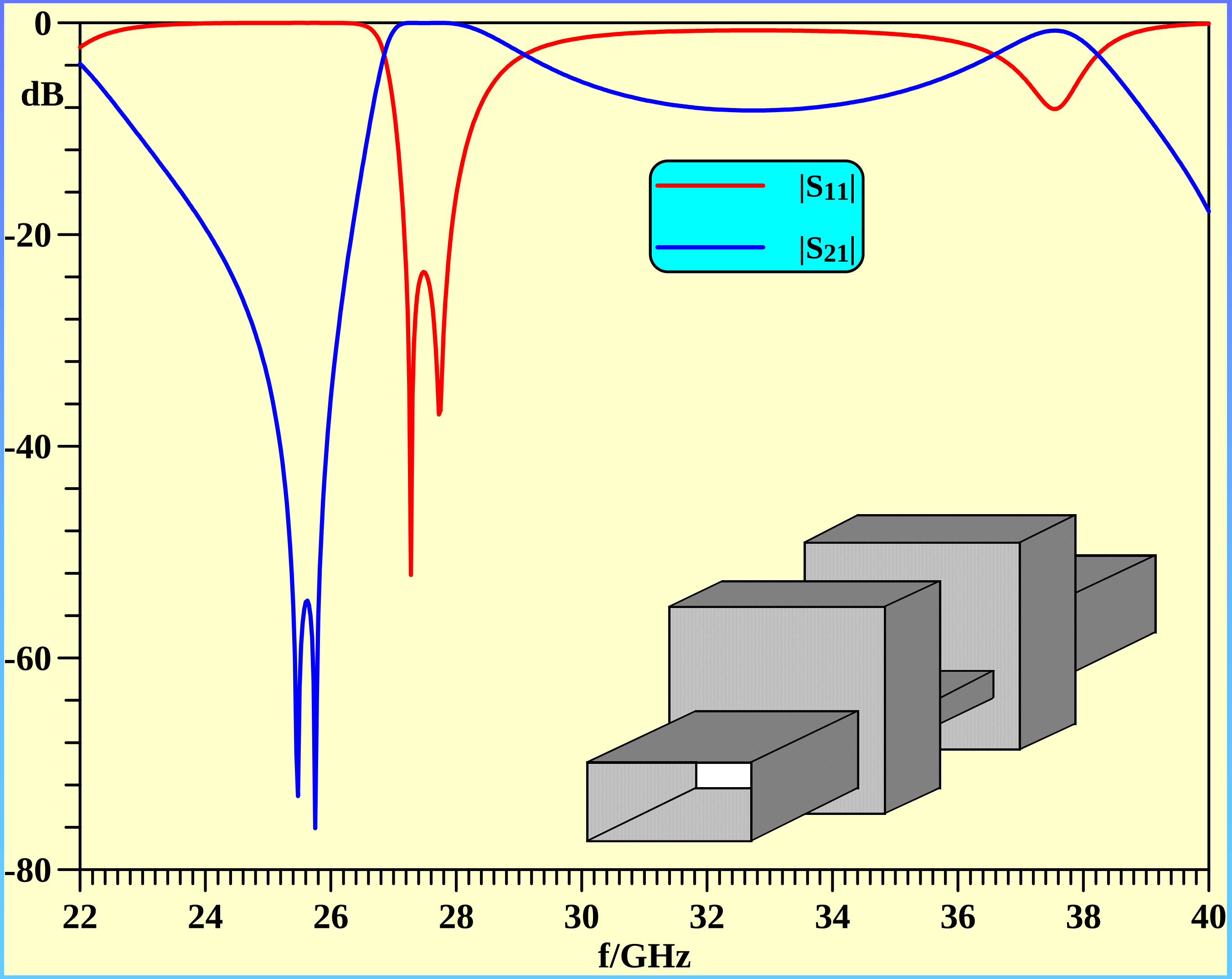


3. No Transmission Zero

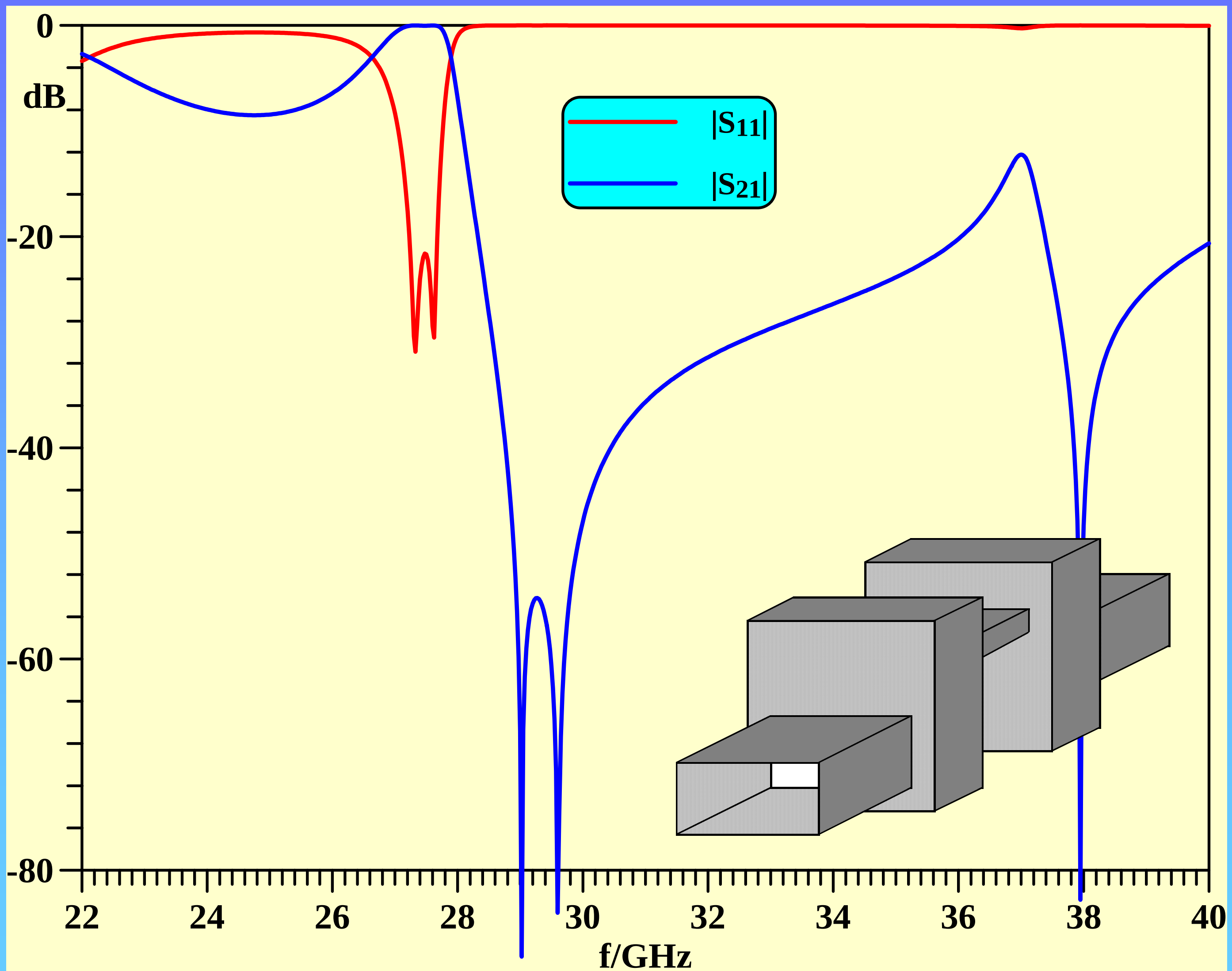


Design Guidelines – Two Cavities

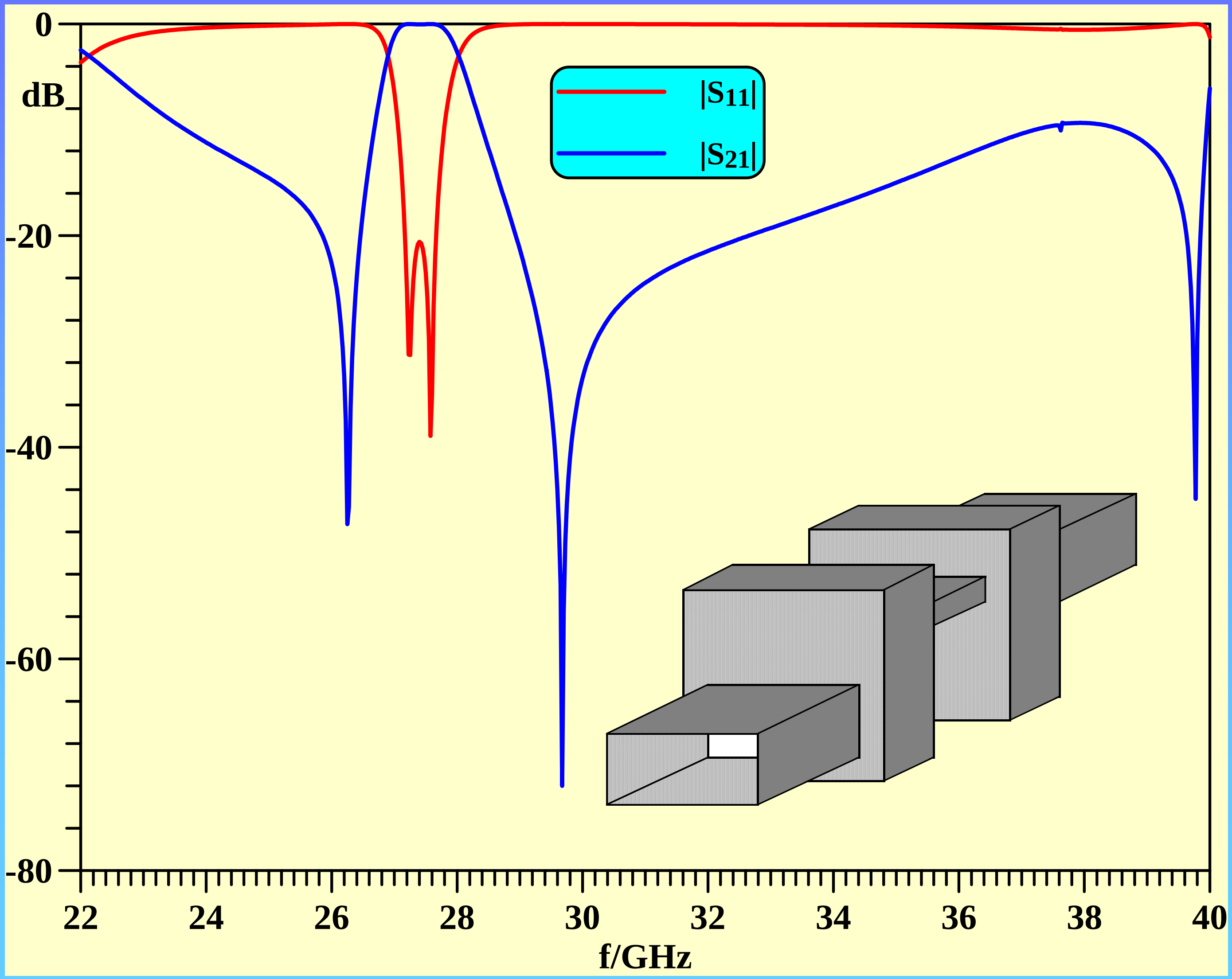
1. Two Transmission Zeros Below Passband



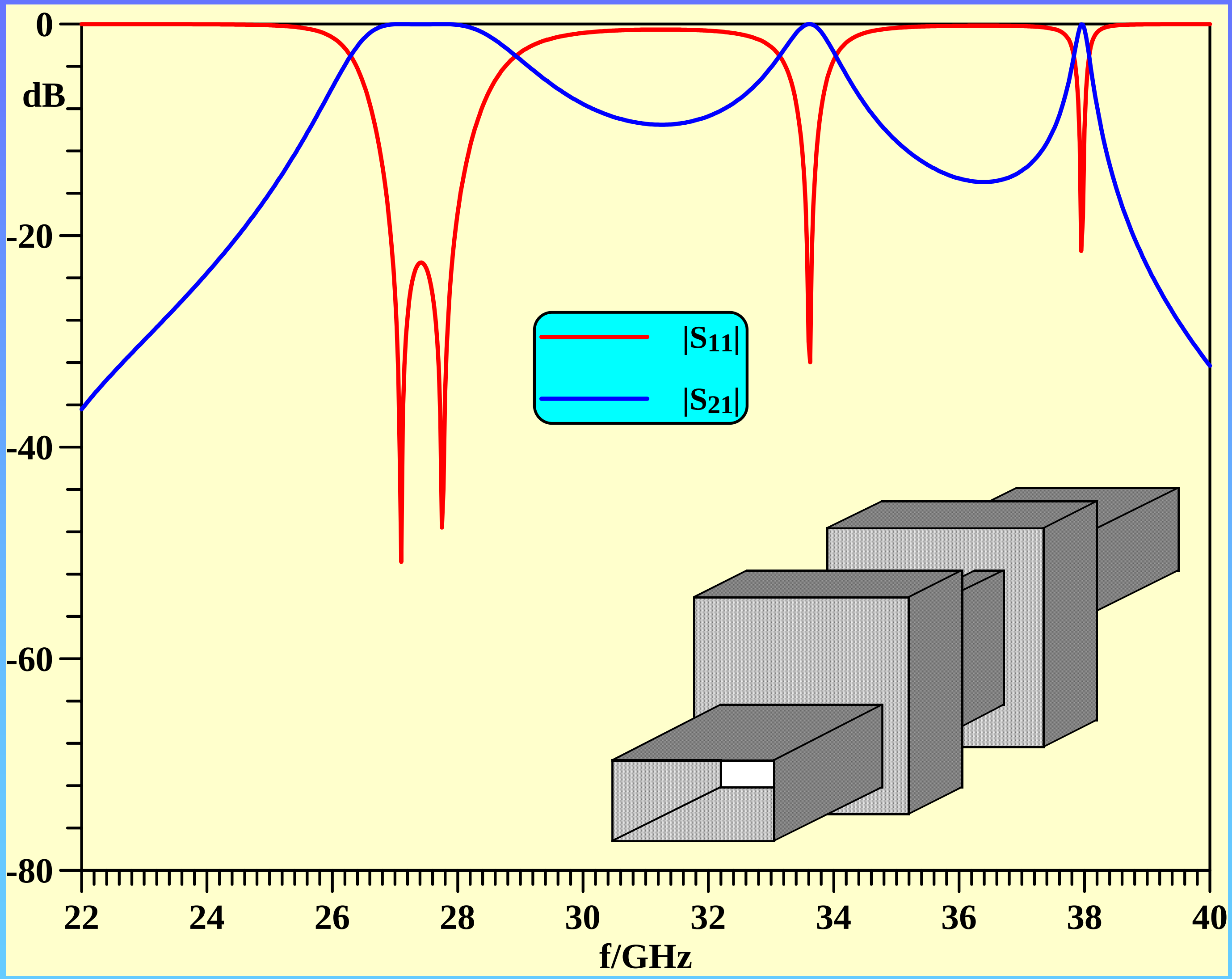
2. Two Transmission Zeros Above Passband



3. Two Transmission Zeros, One Below, One Above Passband

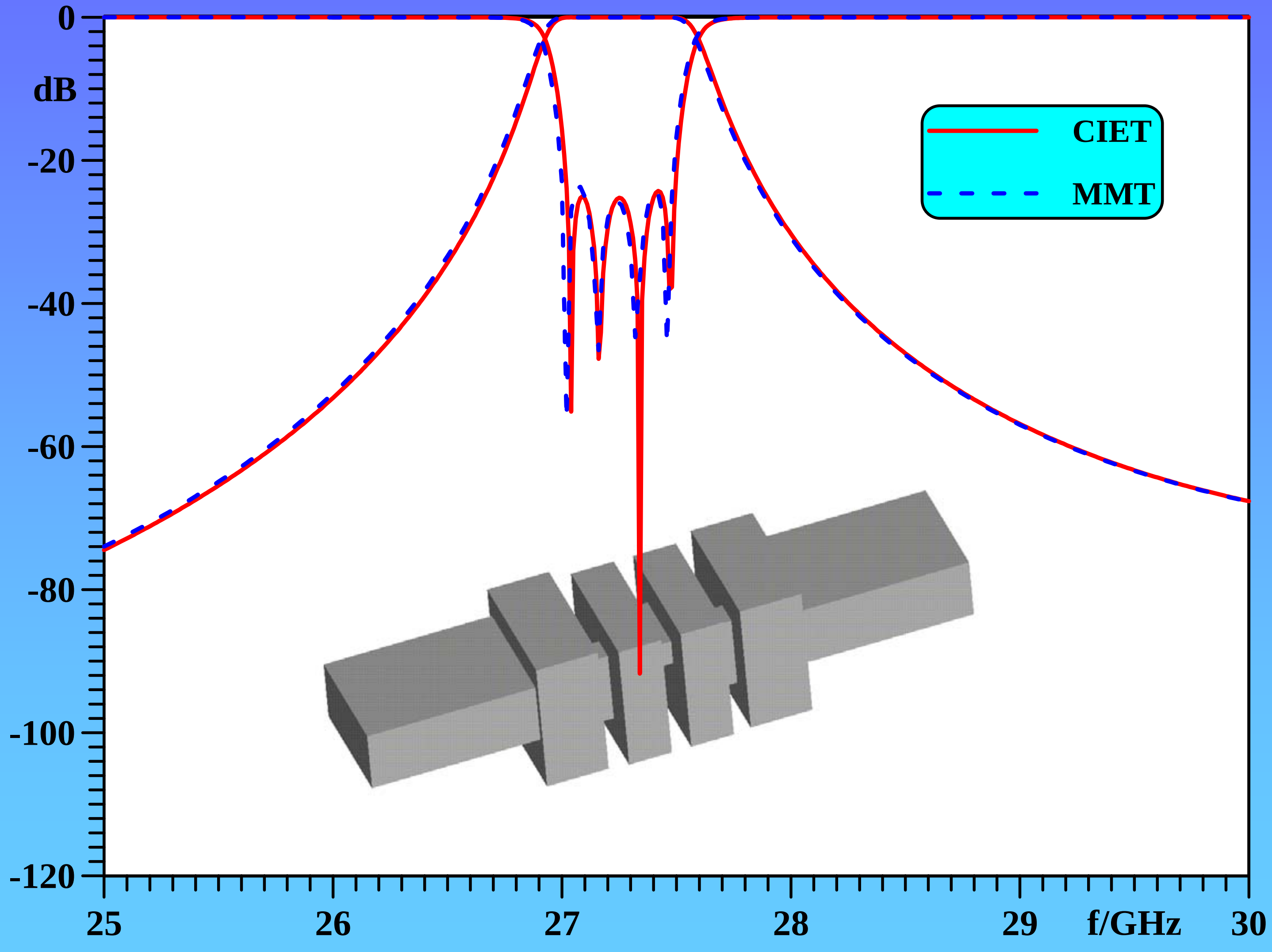


4. No Transmission Zeros

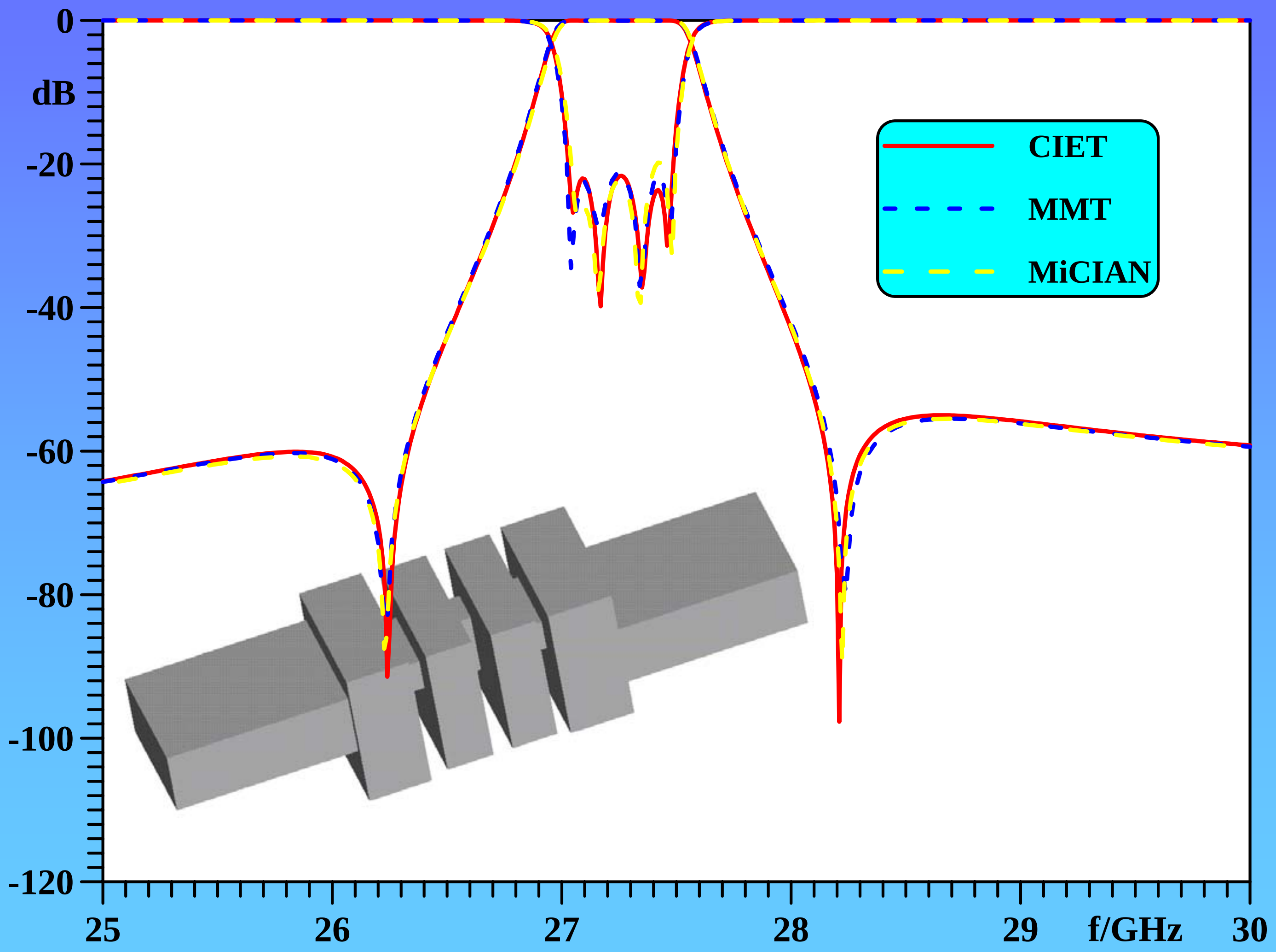


Design Results - Filter Examples

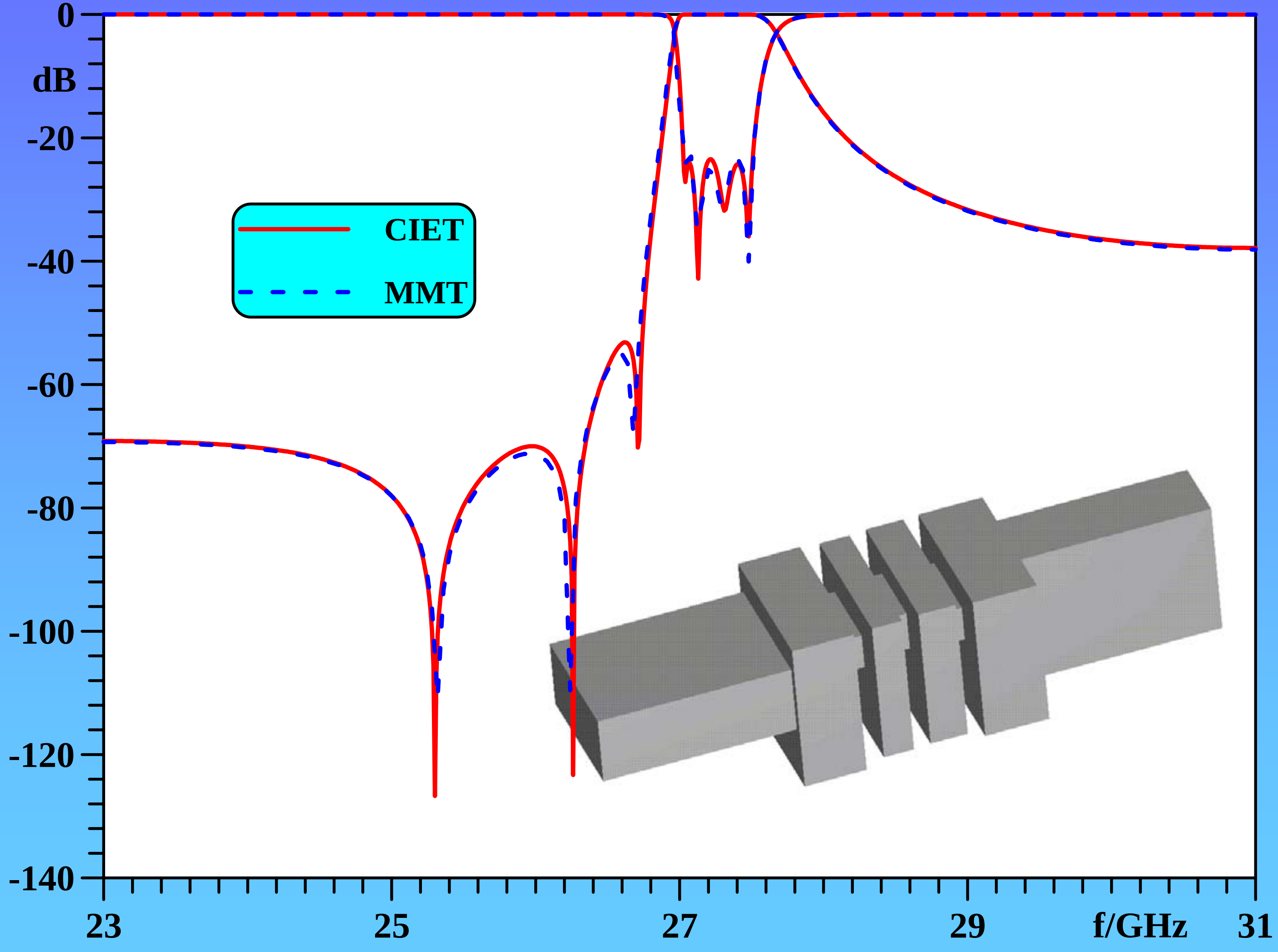
Four-Pole Filter With Chebyshev Response



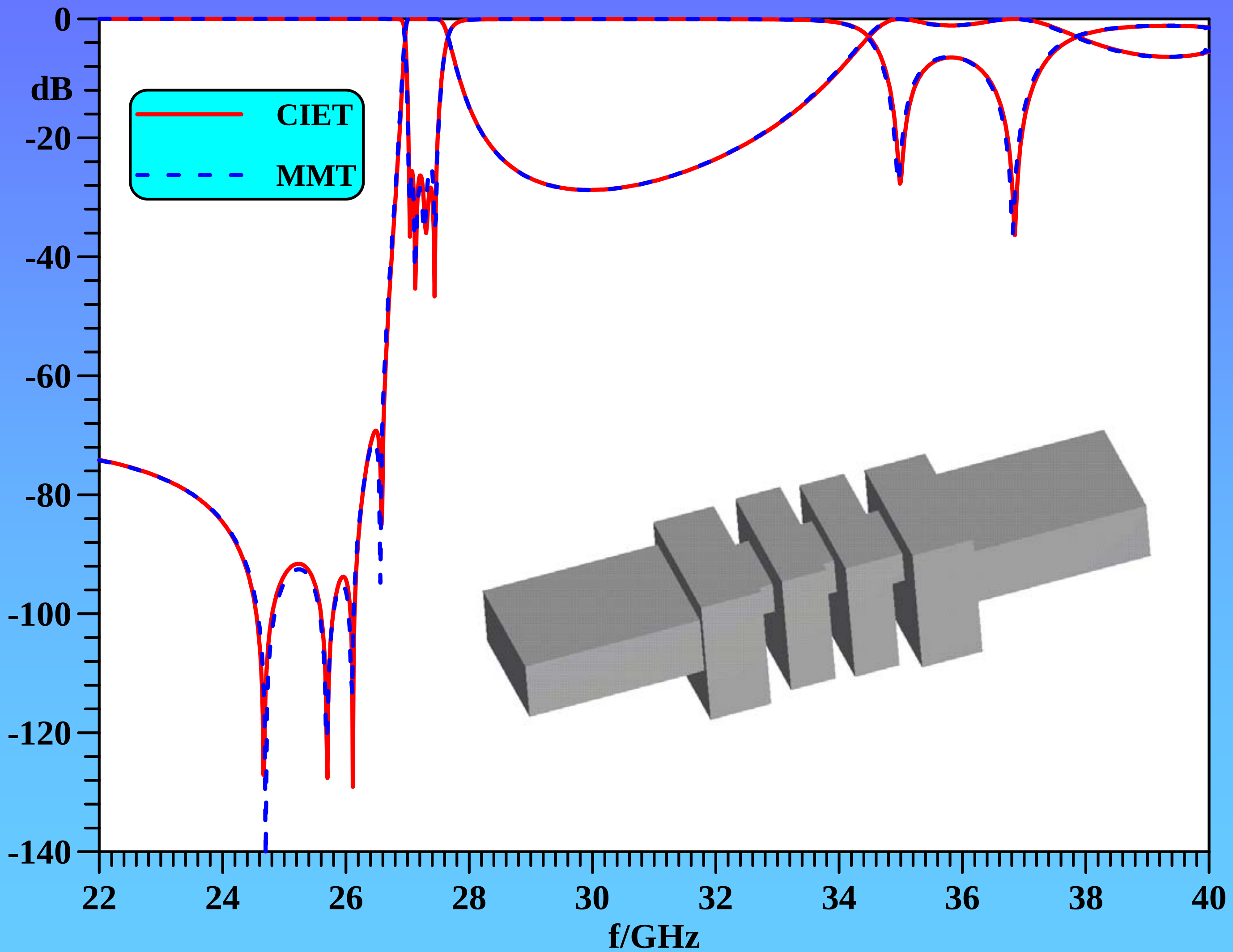
Four-Pole Filter With Elliptic-Function-Type Response



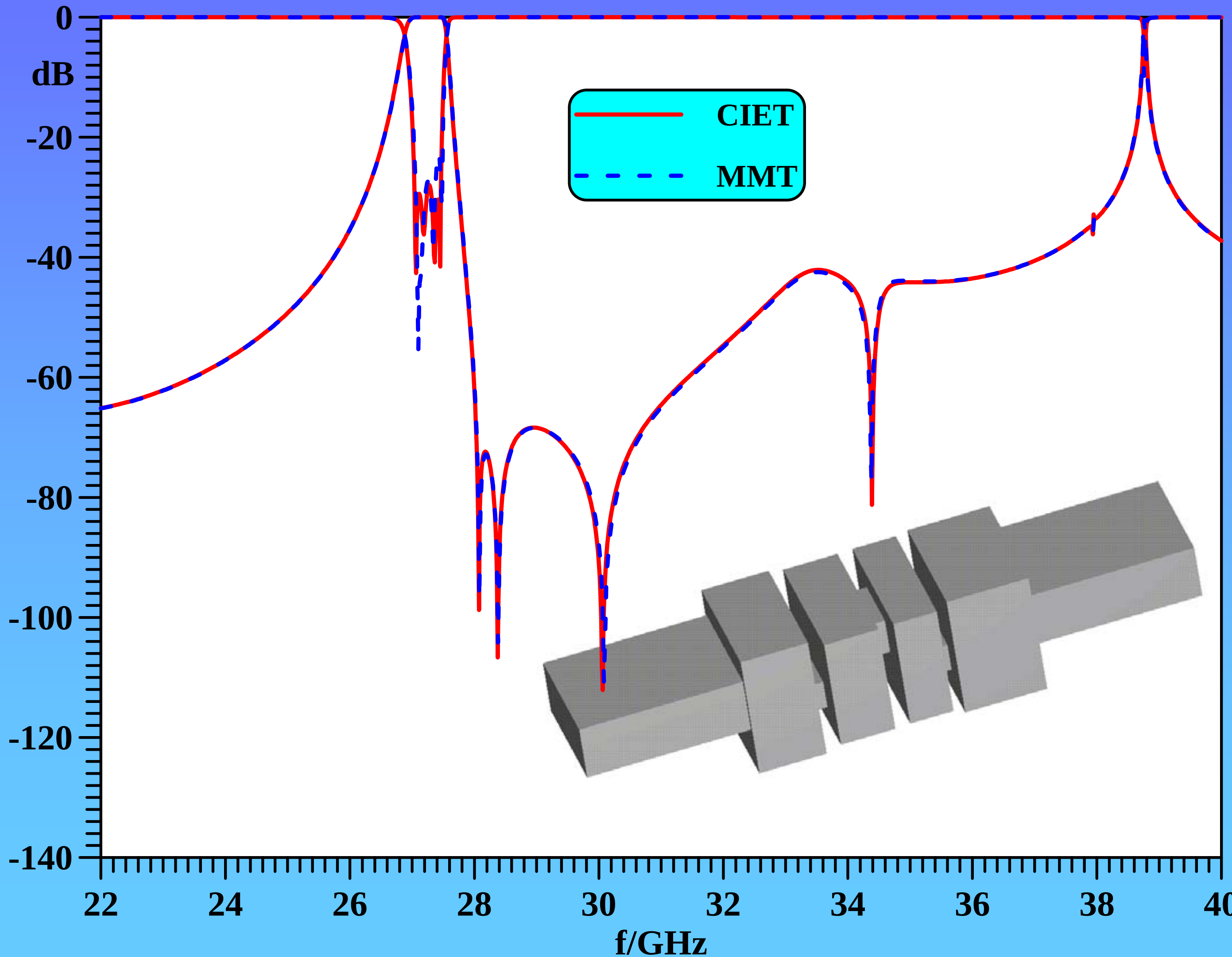
Four-Pole Filter With Three Transmission Zeros Below Passband



Four-Pole Filter With Four Transmission Zeros Below Passband

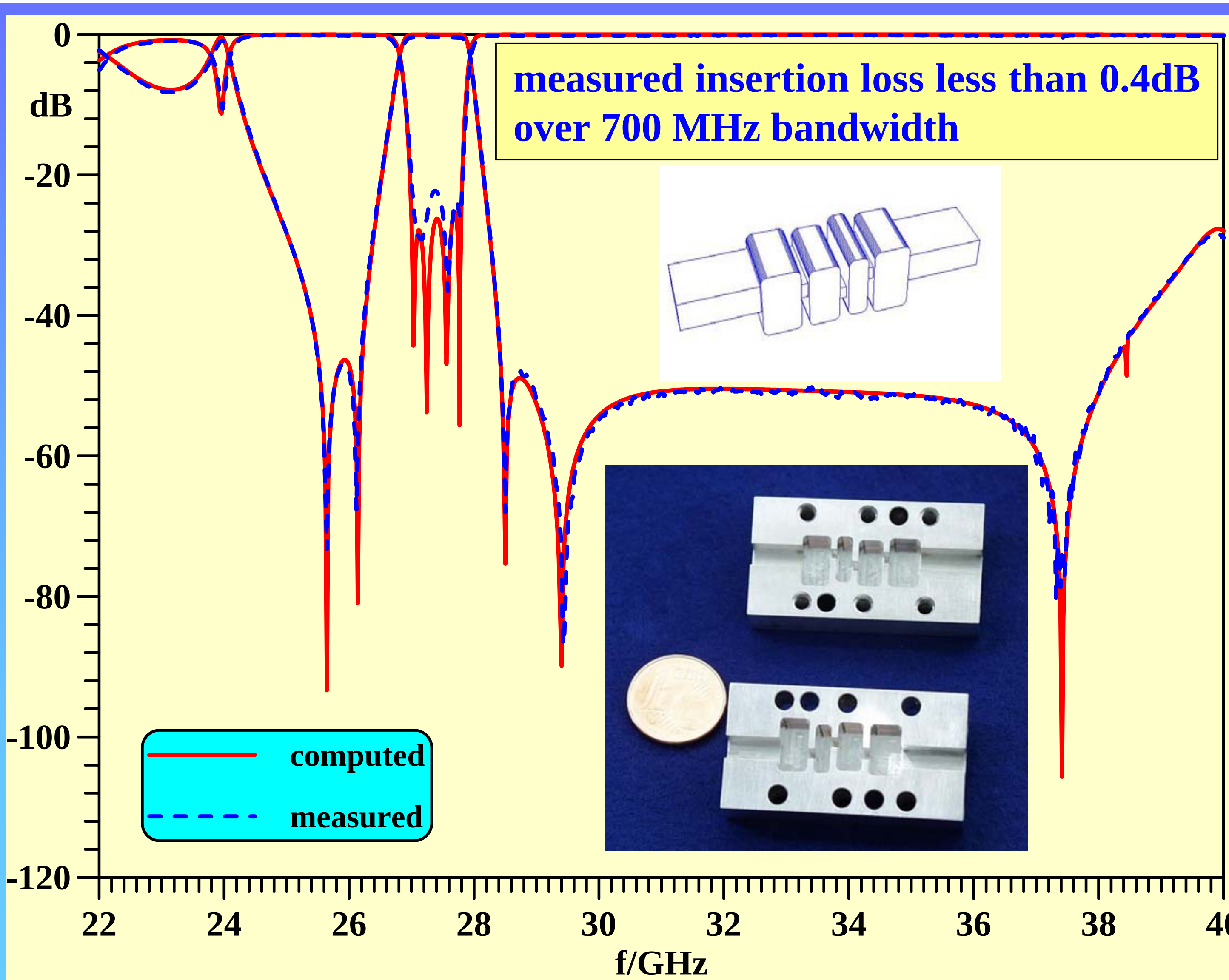


Four-Pole Filter With Four Transmission Zeros Above Passband

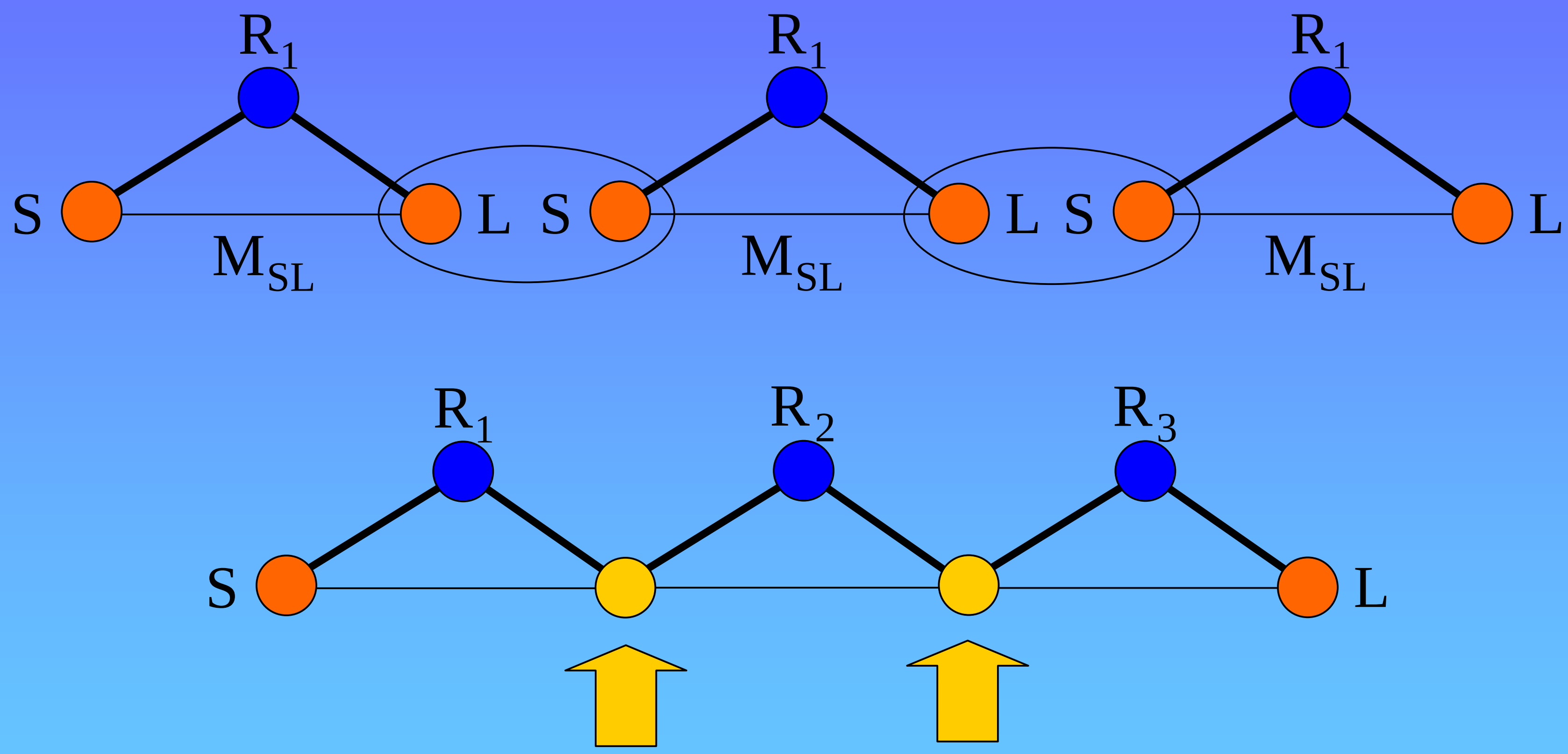


Measurement

(cutter radius included using µWave Wizard)



Coupling Scheme for Cascaded Singlets

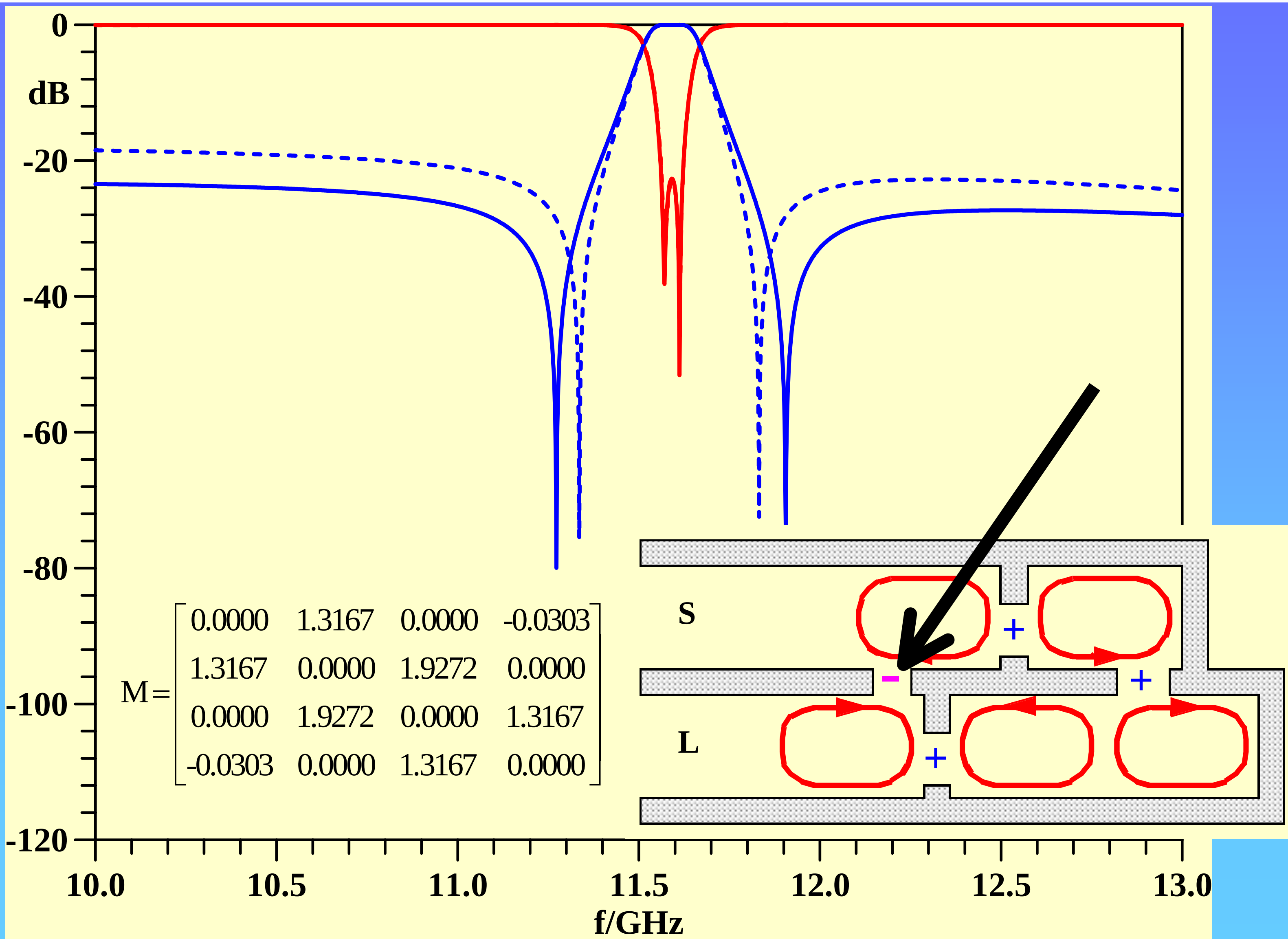


Non-Resonating Nodes (NRN's)

➔Non-Resonating Node Model (NRNM)

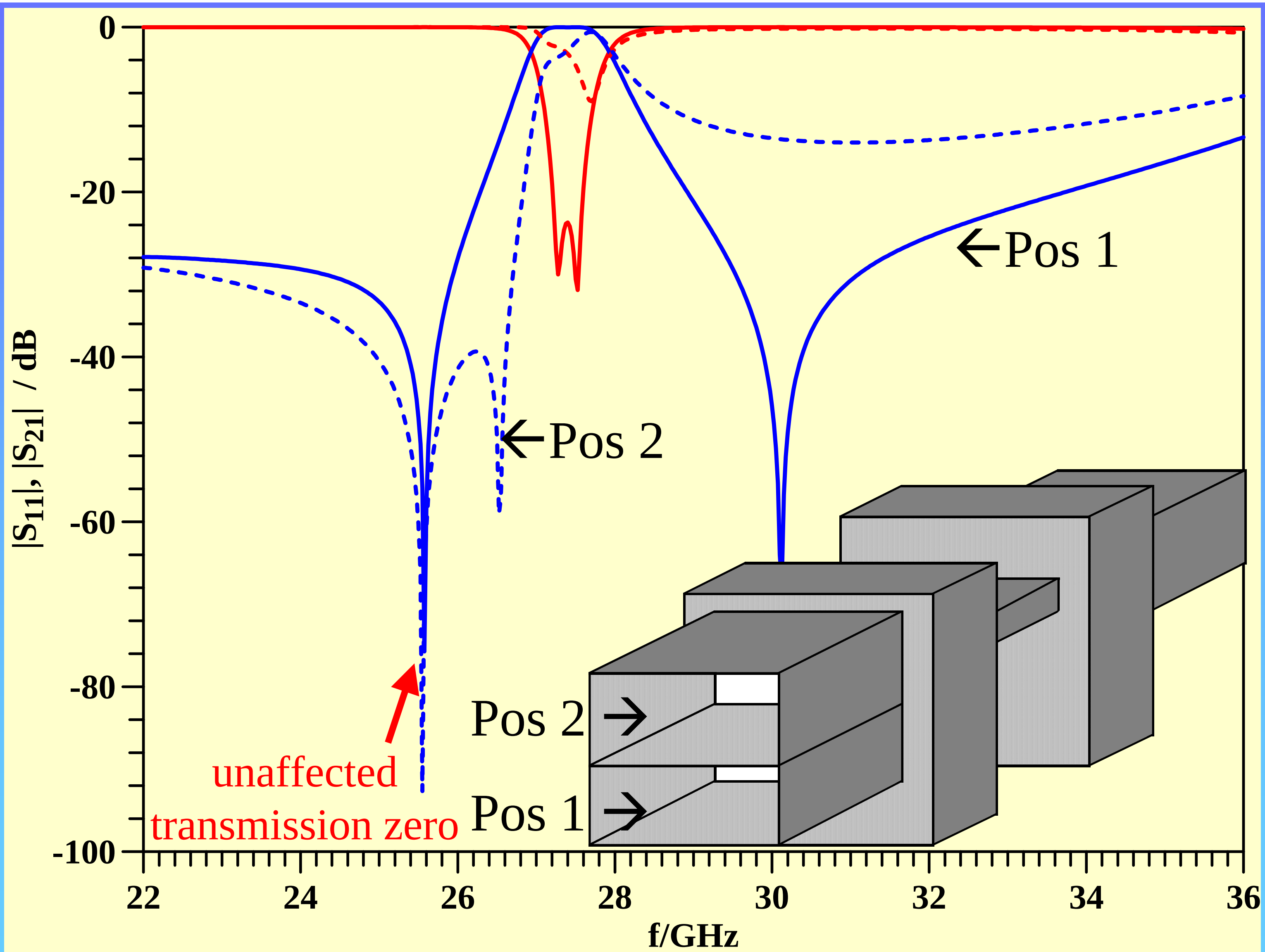
Conventional Design

[changing a single cross-coupling moves all transmission zeros]

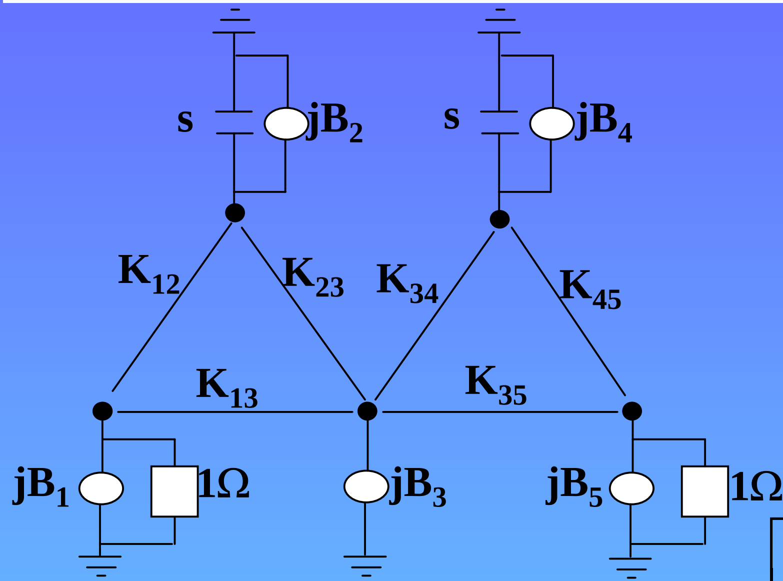


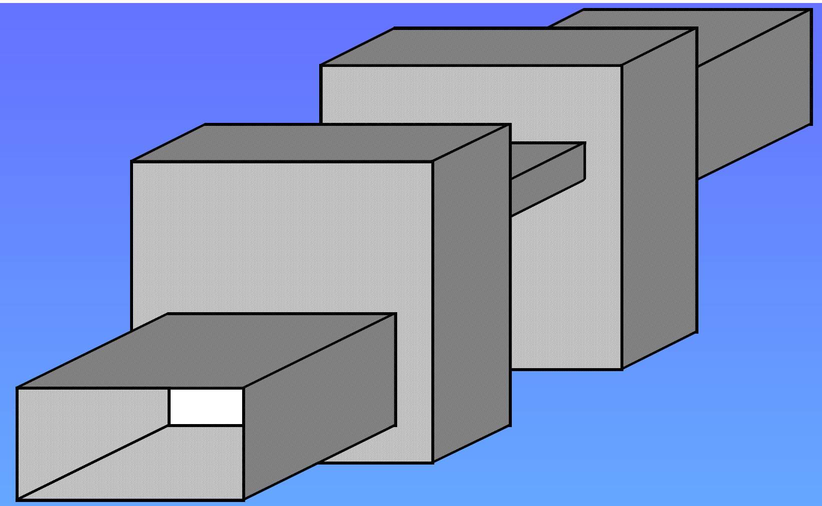
Design with Singlets

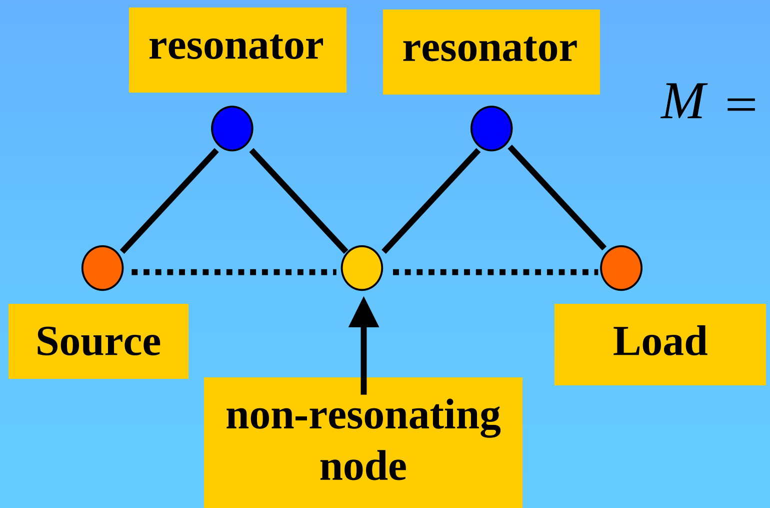
[changing a single bypass-coupling moves only one transmission zero]



Non-Resonating Node Model (NRNM)

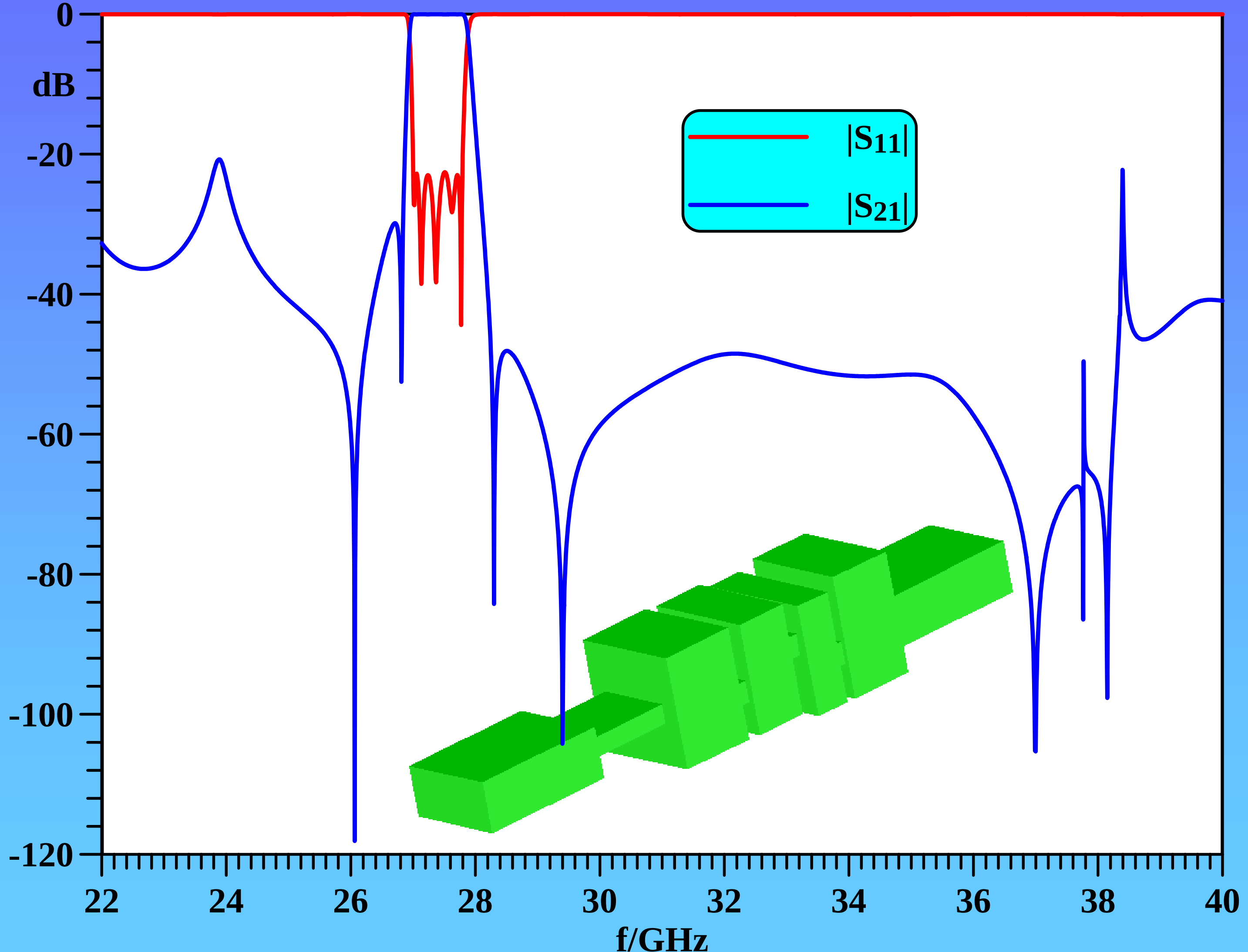




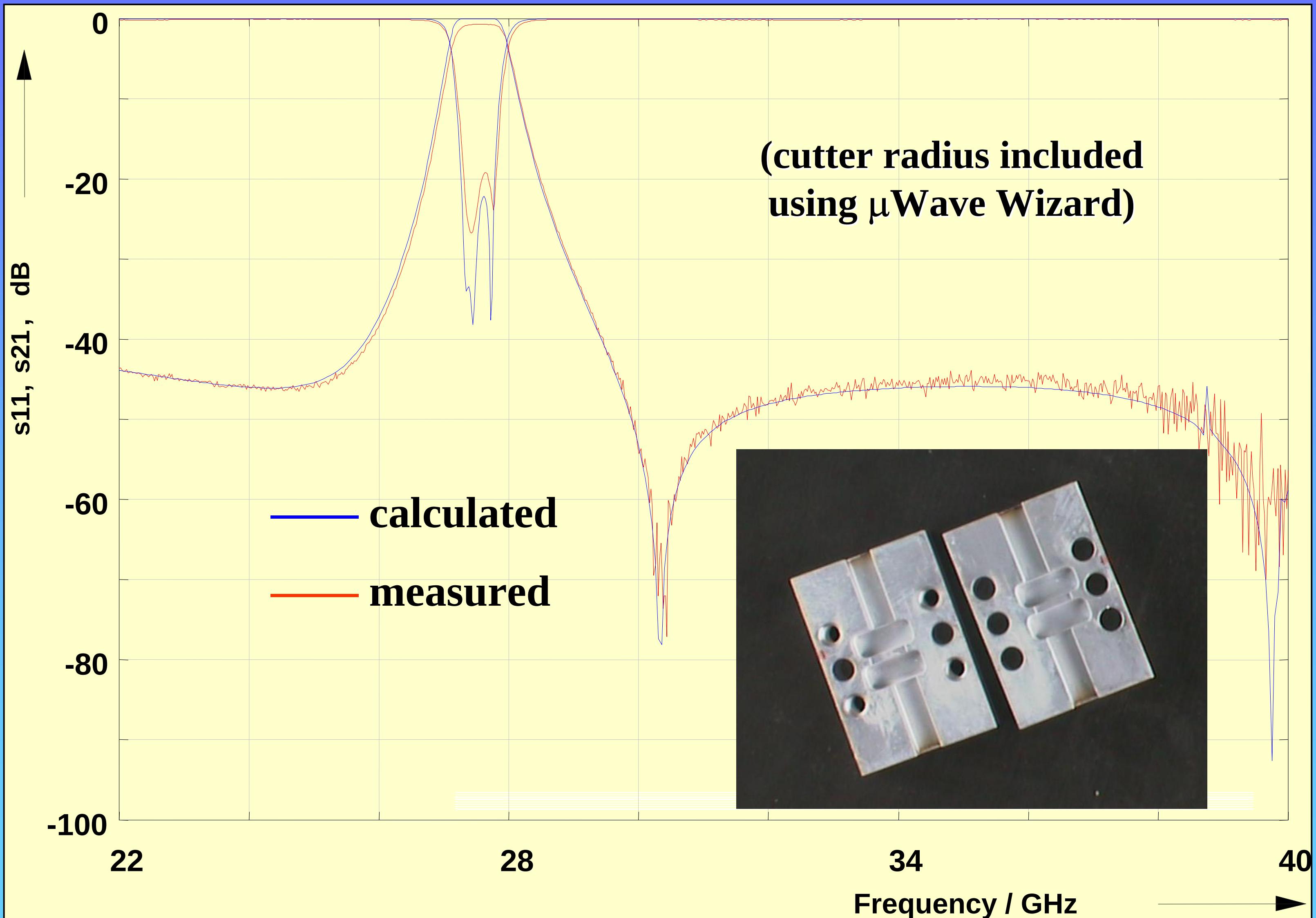


$$M = \begin{bmatrix} 0.0000 & 1.0340 & 0.1584 & 0.0000 & 0.0000 \\ 1.0340 & 1.4101 & -0.7314 & 0.0000 & 0.0000 \\ 0.1584 & -0.7314 & 0.8124 & 1.6932 & 0.2709 \\ 0.0000 & 0.0000 & 1.6932 & 2.6058 & 1.7668 \\ 0.0000 & 0.0000 & 0.2709 & 1.7668 & 0.0000 \end{bmatrix}$$

Design Variations: Add a Resonant Iris

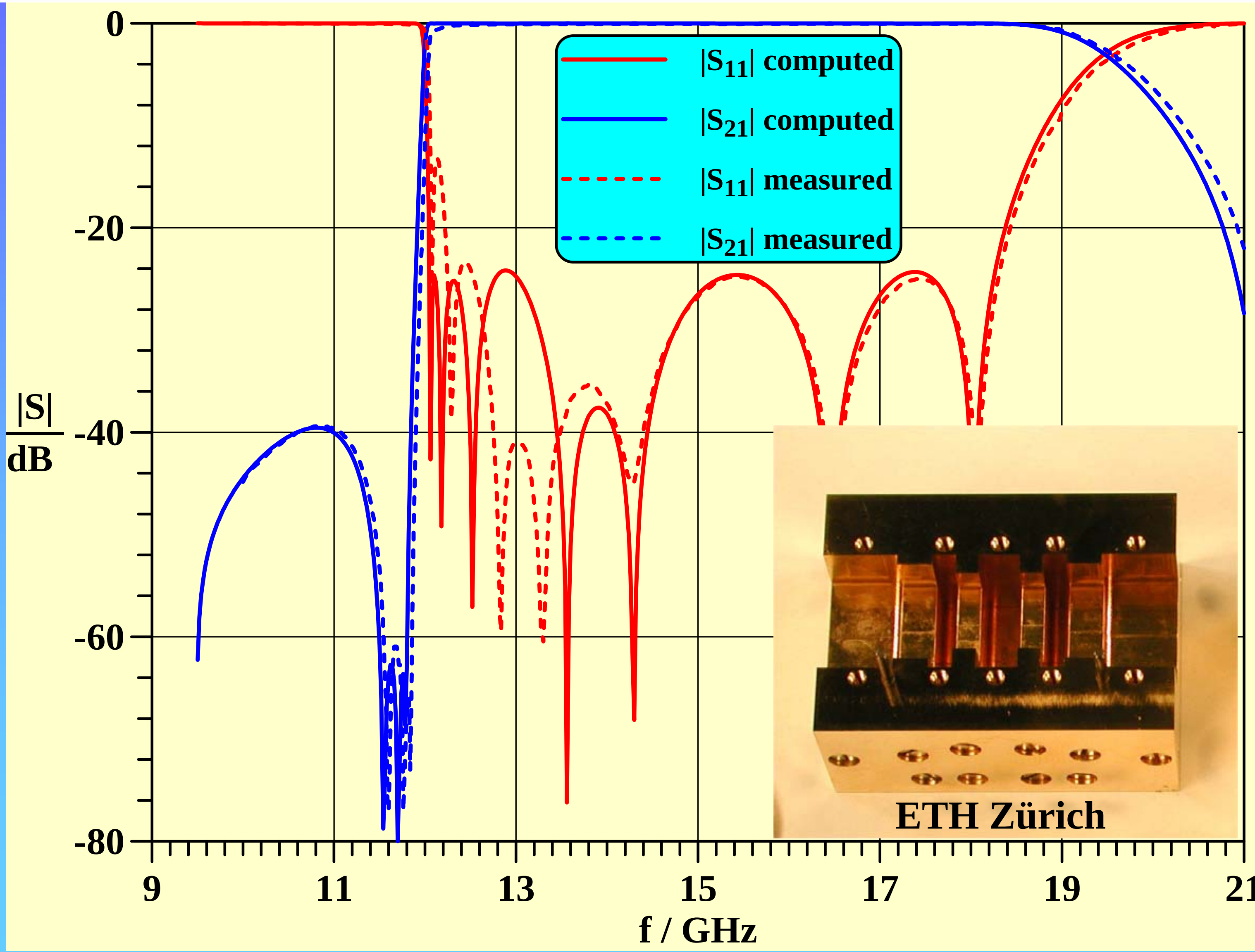


Three-pole filter: 2 TM_{110} cavities + resonant iris



Seven-pole Quasi-Highpass Filter:

3 TM_{110} cavities + four resonant irises



Conclusions

- Cascaded TM_{110}-mode resonators offer an attractive solution for in-line waveguide bandpass filters with arbitrarily located transmission zeros.
- These filters have simple geometries, which lend themselves to design by accurate and fast CAD tools, but retain a high flexibility as to the number and locations of transmission zeros.
- A new coupling matrix approach based on the Non-Resonant Node Model aids in the design of the filters.
- Excellent agreement with measured data is demonstrated.
- TM_{110}-mode resonators are shorter than comparable cavities based on half-wavelength resonances.

Further Reading

- **U. Rosenberg, S. Amari and J. Bornemann, "Inline TM_{110}-mode filters with high design flexibility by utilizing bypass couplings of non-resonating $TE_{10/01}$ modes", *IEEE Trans. Microwave Theory Tech.*, Vol. 51, pp. 1735-1742, June 2003.**
- **U. Rosenberg, S. Amari and J. Bornemann, "Mixed-resonance compact in-line pseudo-elliptic filters", in *2003 IEEE MTT-S Int. Microwave Symp. Dig.*, pp. 479-482, Philadelphia, USA, June 2003.**
- **S. Amari, U. Rosenberg and J. Bornemann, "Singlets, cascaded singlets and the non-resonating node model for advanced modular design of elliptic filters", *IEEE Microwave Wireless Component Lett.*, Vol. 14, pp. 237-239, May 2004.**
- **S. Amari, U. Rosenberg and J. Bornemann, "A novel approach to dual and triple-mode pseudo-elliptic filter design", in *34th European Microwave Conf.*, Amsterdam, The Netherlands, Oct. 2004.**
- **U. Rosenberg, S. Amari, J. Bornemann and R. Vahldieck, "Compact pseudo-highpass filters formed cavity and iris resonators", in *34th European Microwave Conf.*, Amsterdam, The Netherlands, Oct. 2004.**