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

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Outline

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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\textsubscript{110}-Mode Resonators - Advantages

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

- The maximum number of transmission zeros equals the number of TM\textsubscript{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\textsubscript{110}-mode operation, the cavities are short. An N-pole TM\textsubscript{110}-mode filter usually requires less space than a comparable dual-mode filter based on TE\textsubscript{101/011} modes.
Cascaded $\text{TM}_{110}$-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

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
Coupling is predominantly magnetic. An incoming $\text{TE}_{10}$ mode excites both $\text{TE}_{10}$ and $\text{TM}_{11}$ in the cavity.
**Design Guidelines – Single Cavity**

1. Transmission Zero Below Passband

![Graph showing transmission characteristics](image)

- $|S_{11}|$ (red line)
- $|S_{21}|$ (blue line)

Frequency range: 22 GHz to 40 GHz

Graph: 0 dB to -40 dB
2. Transmission Zero Above Passband

\[ R_1(TM_{110}) \]

\[ M_{SL}(TE_{10}) \]
3. No Transmission Zero

![Diagram showing |S11| and |S21| over frequency (f/GHz) from 22 to 40 GHz with dB values from -40 to 0 dB.](image-url)
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

![Graph showing |S11| and |S21| with transmission zeros at specific frequencies.](image)
Design Results - Filter Examples
Four-Pole Filter With Chebyshev Response

-120 -100 -80 -60 -40 -20 0 dB

CIET

MMT

f/GHz
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 \( \mu \)Wave Wizard)

measured insertion loss less than 0.4dB over 700 MHz bandwidth
Coupling Scheme for Cascaded Singlets

Non-Resonating Nodes (NRN’s)

Non-Resonating Node Model (NRNRM)
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)

\[
\begin{bmatrix}
0.0000 & 1.0340 & 0.1584 & 0.0000 & 0.0000 \\
1.0340 & 1.4101 & -0.7314 & 0.0000 & 0.0000 \\
0.1584 & -0.7314 & 0.8124 & 1.6932 & 0.2709 \\
0.0000 & 0.0000 & 1.6932 & 2.6058 & 1.7668 \\
0.0000 & 0.0000 & 0.2709 & 1.7668 & 0.0000 \\
\end{bmatrix}
\]
Design Variations: Add a Resonant Iris
Three-pole filter: $2 \text{TM}_{110}$ cavities + resonant iris

(cutter radius included using $\mu$Wave Wizard)
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


