WE1H-1

# Direct-Coupled TE-TM Waveguide Cavities

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# Outline



- Introduction
- Direct-Coupled TE-TM Waveguide Cavities
- Coupling Control
- Experimental Result
- Conclusions

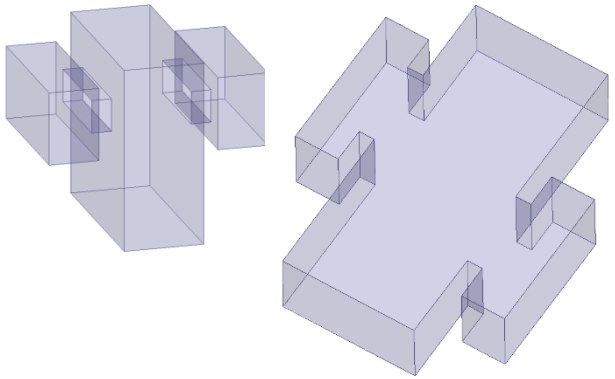
# Introduction



## WAVEGUIDE TECHNOLOGY = LOW LOSS + POWER – SIZE

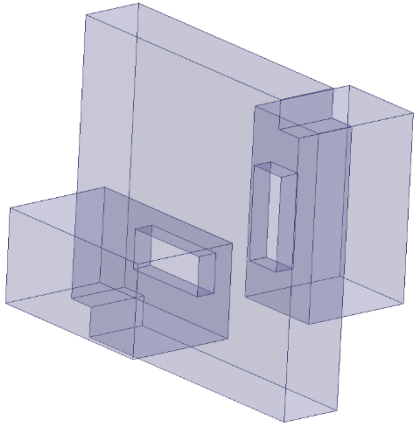
### Cavity structures with enhanced capabilities (multiple poles and/or transmission zeros)

**TM & TE Singlets**



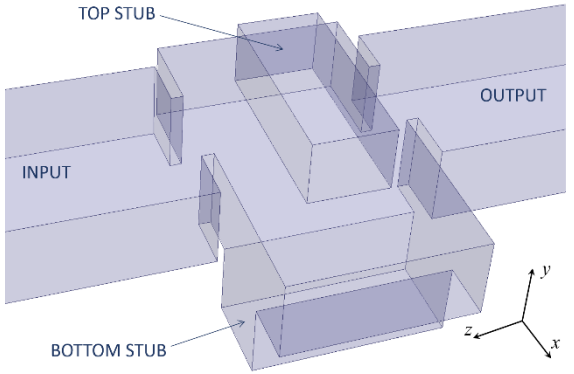
1 Pole + 1 Zero

**TM Dual-Mode (Doublet)**



2 Poles + 2 Zeros

**Stubbed WG Cavity**




3 Poles + 2 Zeros

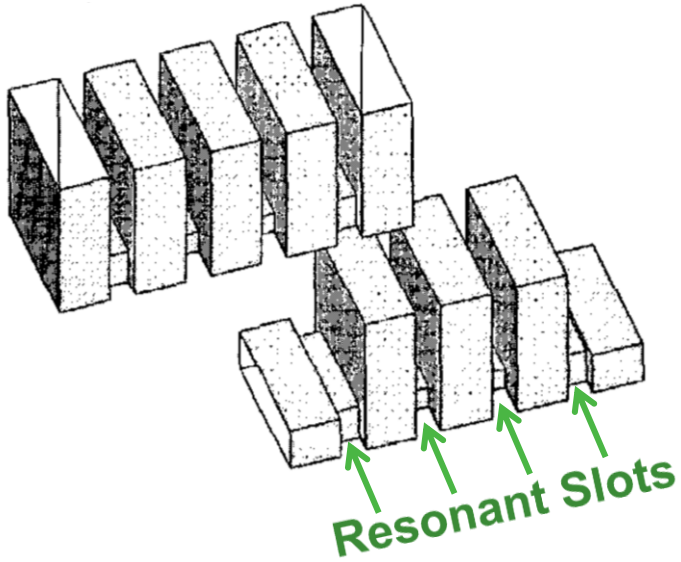
## SUITABLE FOR (AND LIMITED TO) NARROWBAND APPLICATIONS

# Introduction

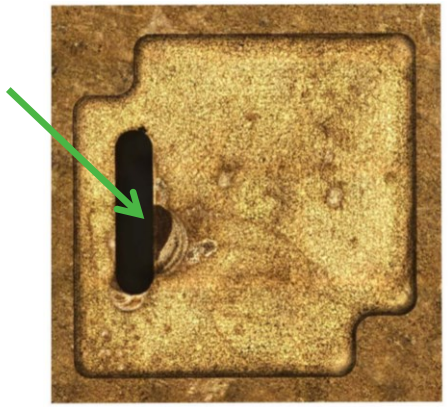


**For TM pseudo-elliptic filters, wide bandwidths can be obtained by mixing resonant cavities and resonant coupling slots/irises**

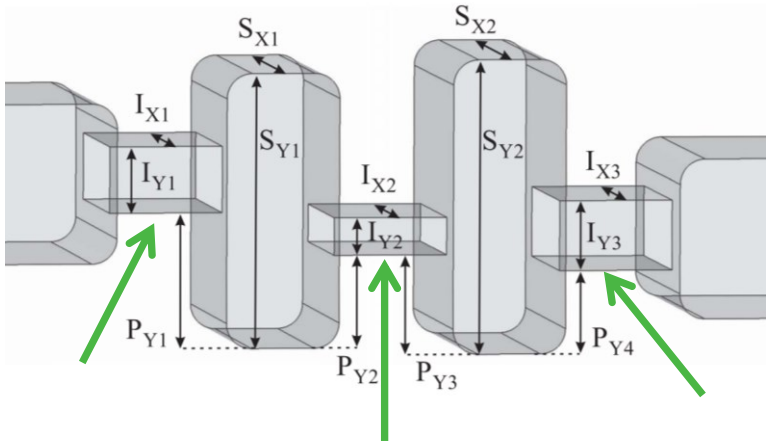
## Psuedo-highpass Filters




## TM Dual-Mode Bandpass



## TM Single-Mode Bandpass




1. U. Rosenberg, *et al.,* "Compact pseudo-highpass filters formed by cavity and iris resonators," *34th European Microwave Conf.*, 2004.
2. C. Bartlett, *et al.*, "Improved TM Dual-Mode Filters With Reduced Fabrication Complexity," in *IEEE Journal of* Microwaves, 2022.
3. C. Bartlett, *et al.*, "Highly Selective Broadband mm-Wave Diplexer Design," in *IEEE Microw. and Wireless Components Letters*, 2022.

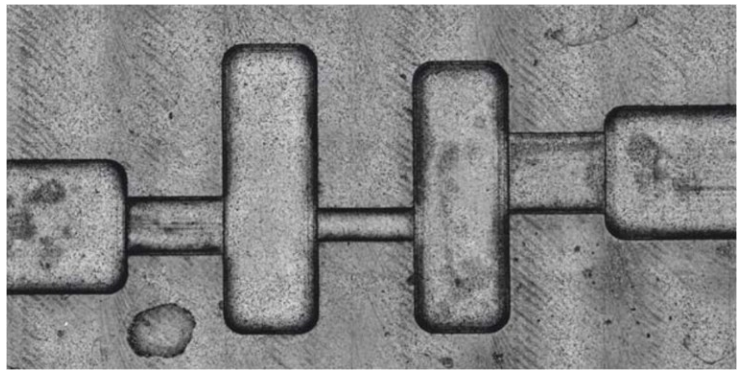
# Introduction

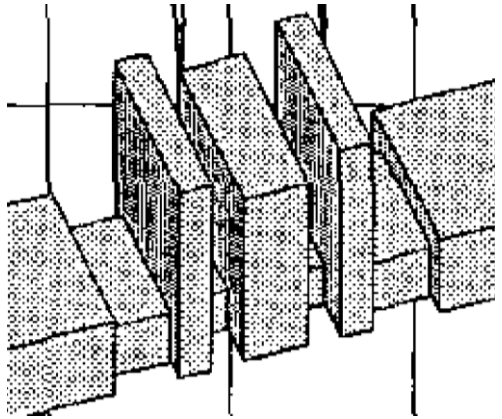


**Those structures provides brilliant solutions for the purposes they are intended for, but some drawback/limitation has to be considered:**

**The heights of the slots (and sometimes the thicknesses) are optimization parameters for certain couplings**

***→reduced heights are commonly required (low Q-factor and low power handling)***





**GENERALLY SUITABLE ONLY FOR <u>WIDEBAND</u> PSEUDO-ELLIPTIC RESPONSES**

# Introduction



## OBJECTIVE OF THIS WORK:

**TO FIND A MORE GENERAL CONFIGURATION THAT IS CAPABLE OF REALIZING BOTH NARROW AND WIDE BAND RESPONSES,**
**THUS PAVING THE WAY FOR THE INTRODUCTION OF A NEW CLASS OF DIRECT-COUPLED WAVEGUIDE FILTERS POSSESSING**

1) **THE STRENGHS OF THE MOST ADVANCED TM PSEUDO-ELLIPTIC FILTERS, AND**
2) **AND THE DESIGN VERSATILITY (BANDWIDTH) OF THE MOST CONVENTIONAL IRIS-COUPLED CAVITY FILTERS**

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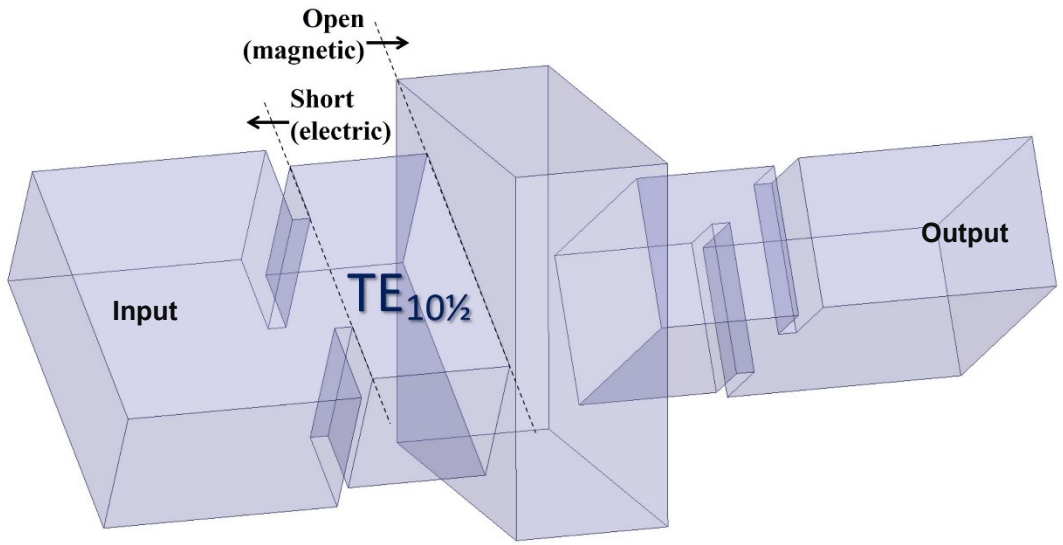
# Direct-Coupled TE-TM Cavities

**BASIC IDEA: TE10 sections and TM11 section are directly coupled without any dedicated coupling discontinuity between them**

**The rectangular TE sections are directly terminated into the much larger square TM section**

**→ *the equivalent of an open-ended (magnetic) condition is seen at one end of the TE sections***

**Basic TE-TM-TE Three-section Configuration**



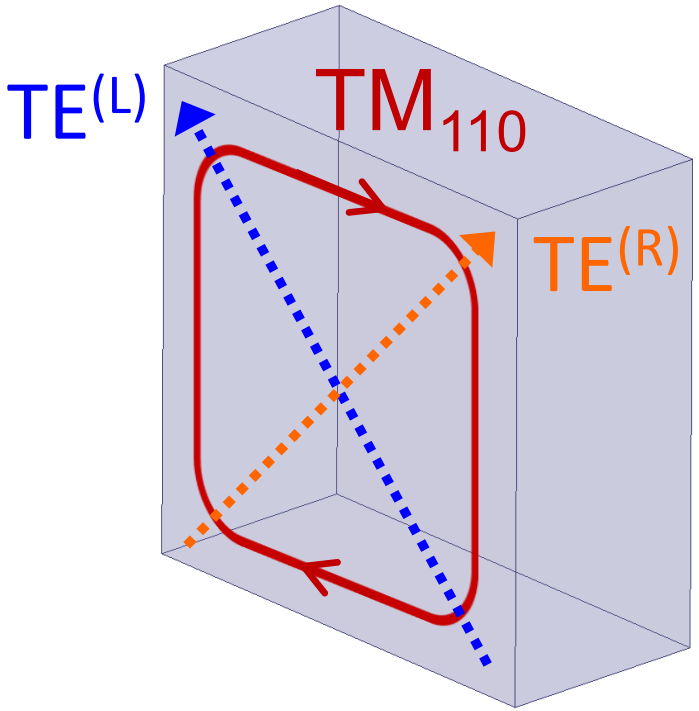

**→TE half-mode resonating with a quarter-wavelength variation along the longitudinal direction becomes feasible within each TE section**

# Direct-Coupled TE-TM Cavities



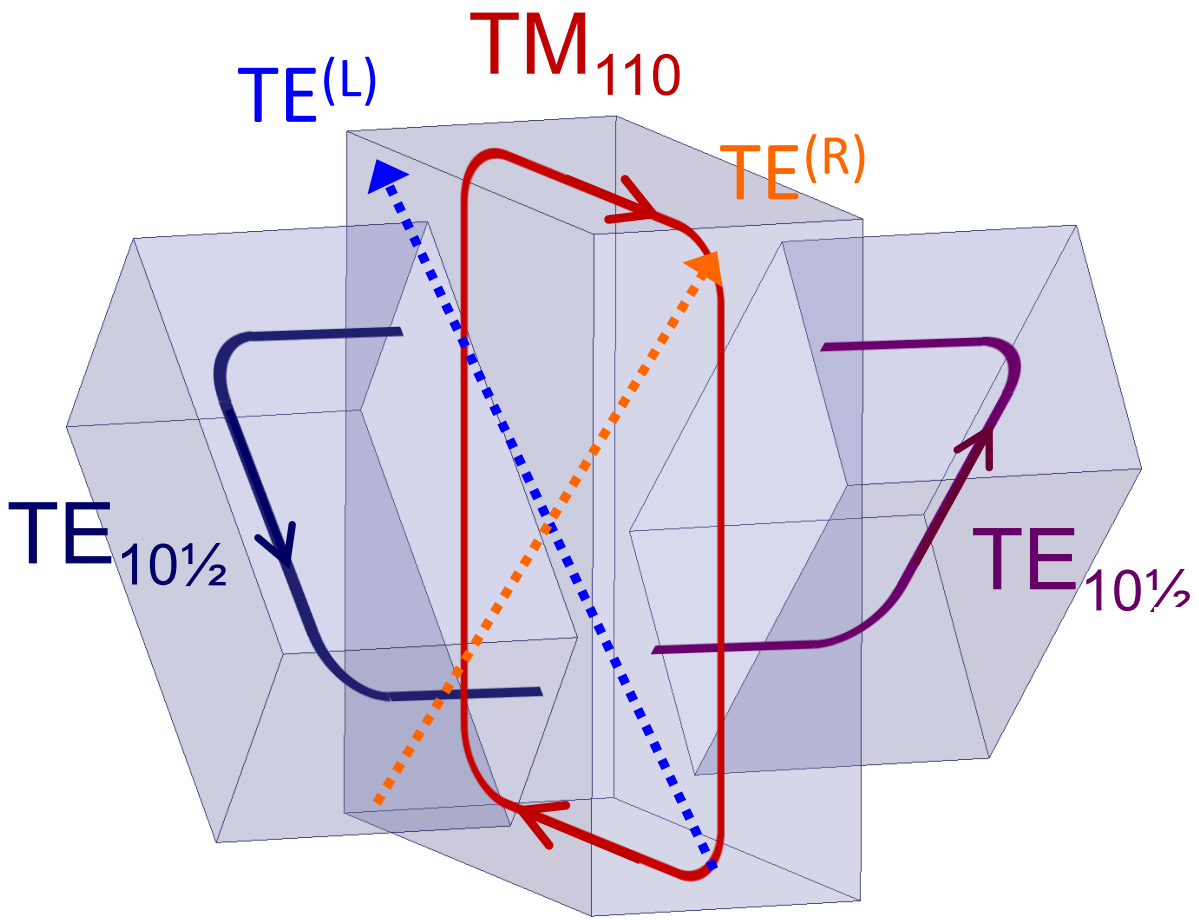
**The square cross-section of the TM section is sized to support a resonant TM110 mode**

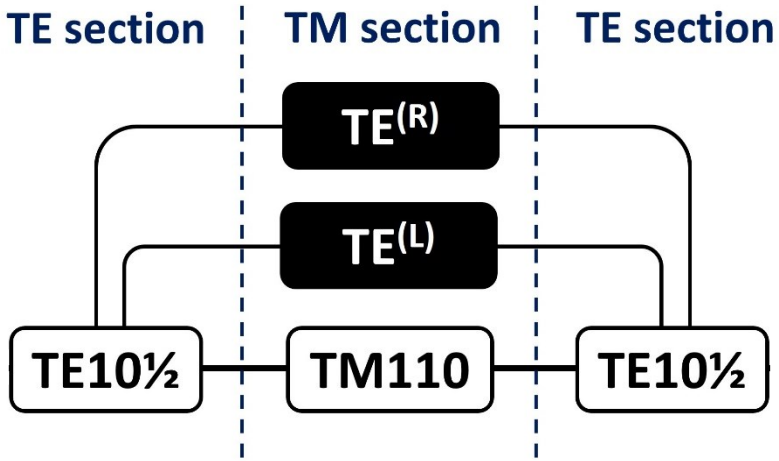
**The square TM section also supports a pair of orthogonal nonresonating TE modes , TE(L) and TE(R), which are polarized along its diagonals**

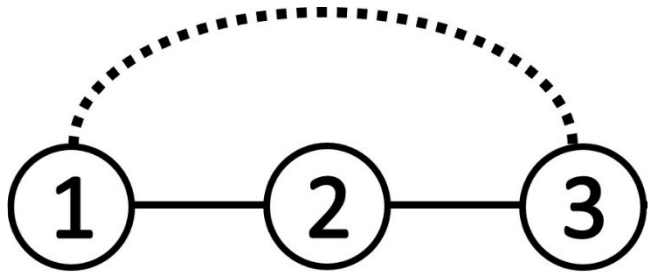


# Equivalent Topology



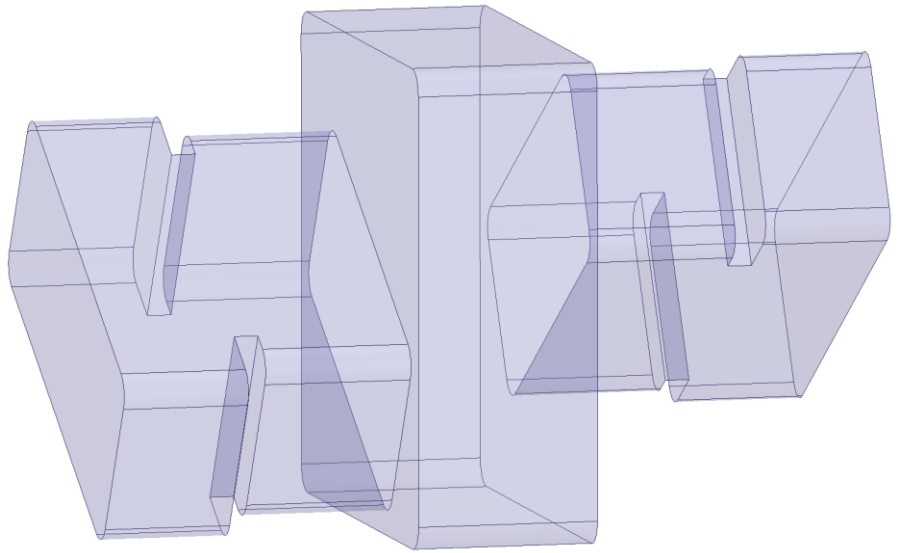


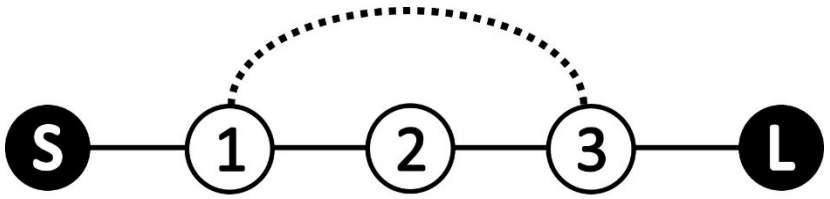



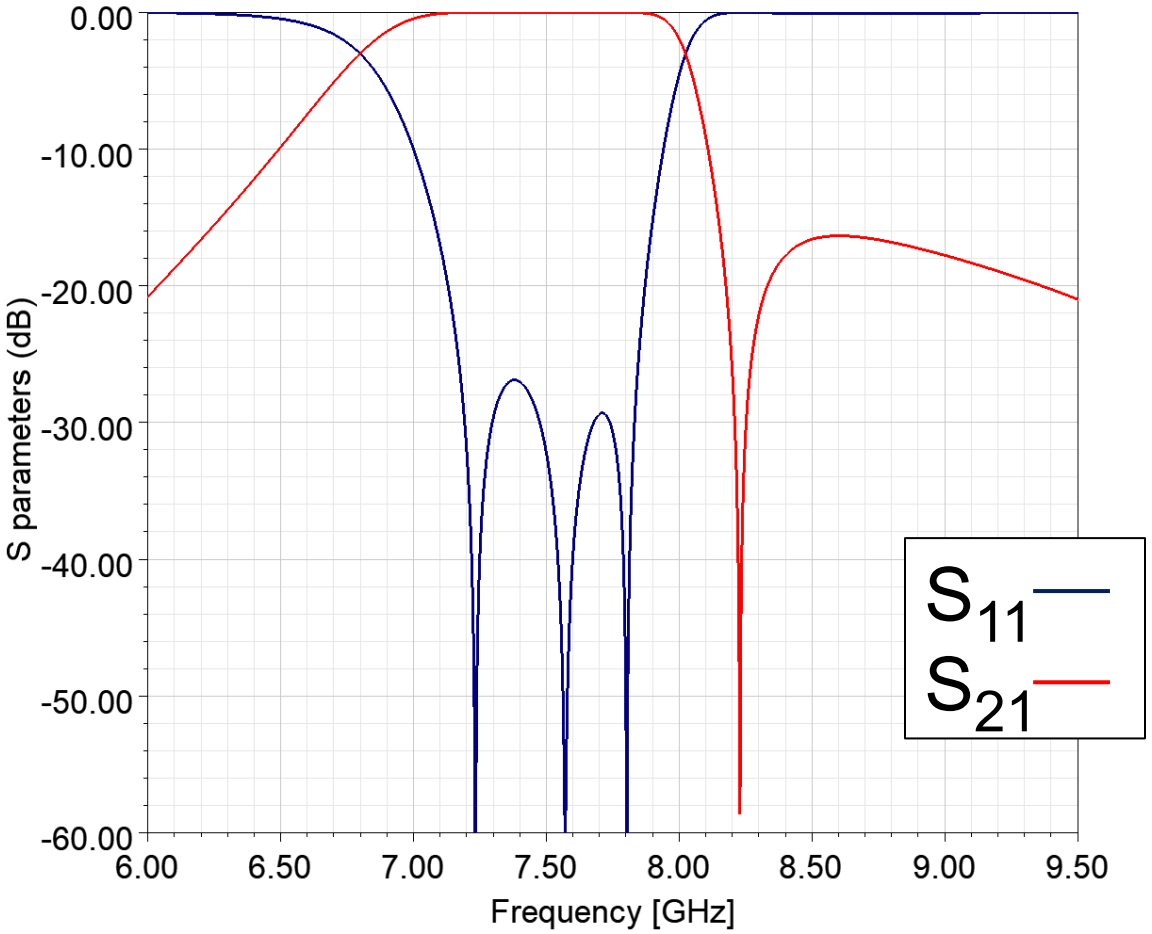



# Typical Response







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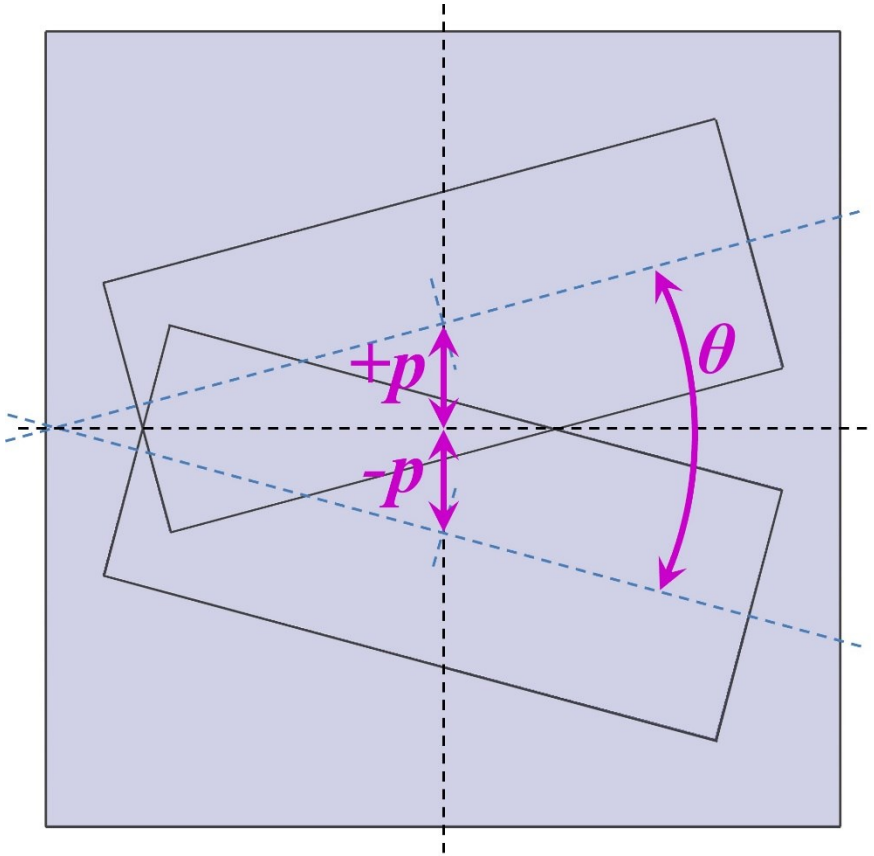
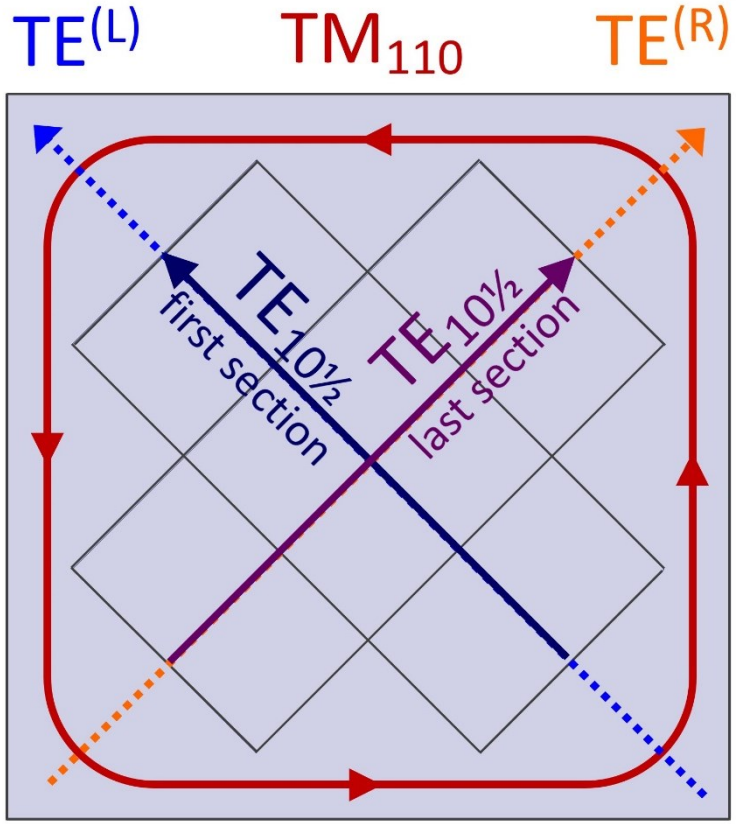
# Coupling Control

All coupling coefficients are FULLY controlled by the POSITION and the ORIENTATION of the TE sections

The size of the TE sections is NOT employed for any coupling purpose
→ it can be set equal to the full size of a standard waveguide
(maximum unloaded Q-factor)

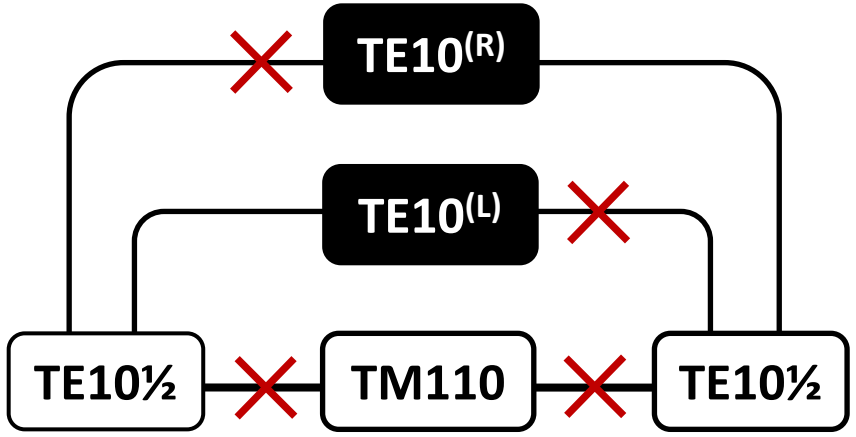


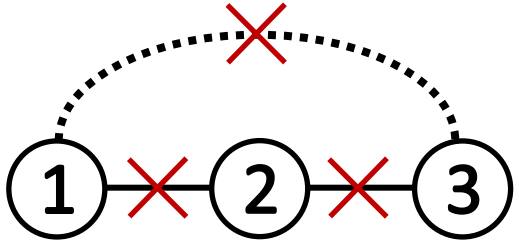
# Total Isolation Condition




1) TE sections are centered (p=0)
2) TE sections parallel with diagonals (θ=90°)

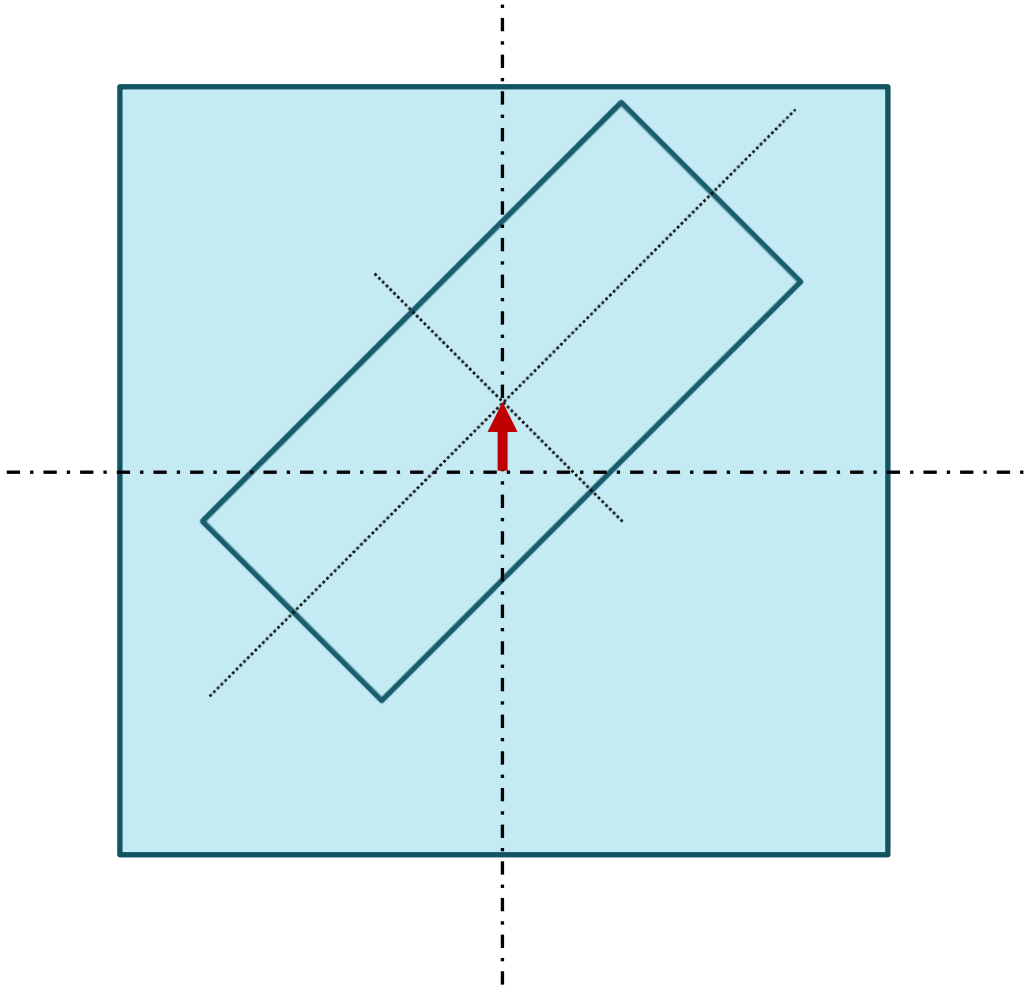
ALL MODES ARE UNCOUPLED/ISOLATED
→ TM110 mode cannot be excited and no by-pass coupling between TE modes can occur



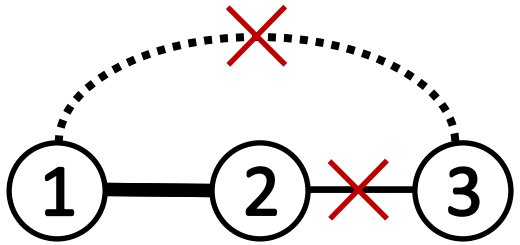



# Coupling Control



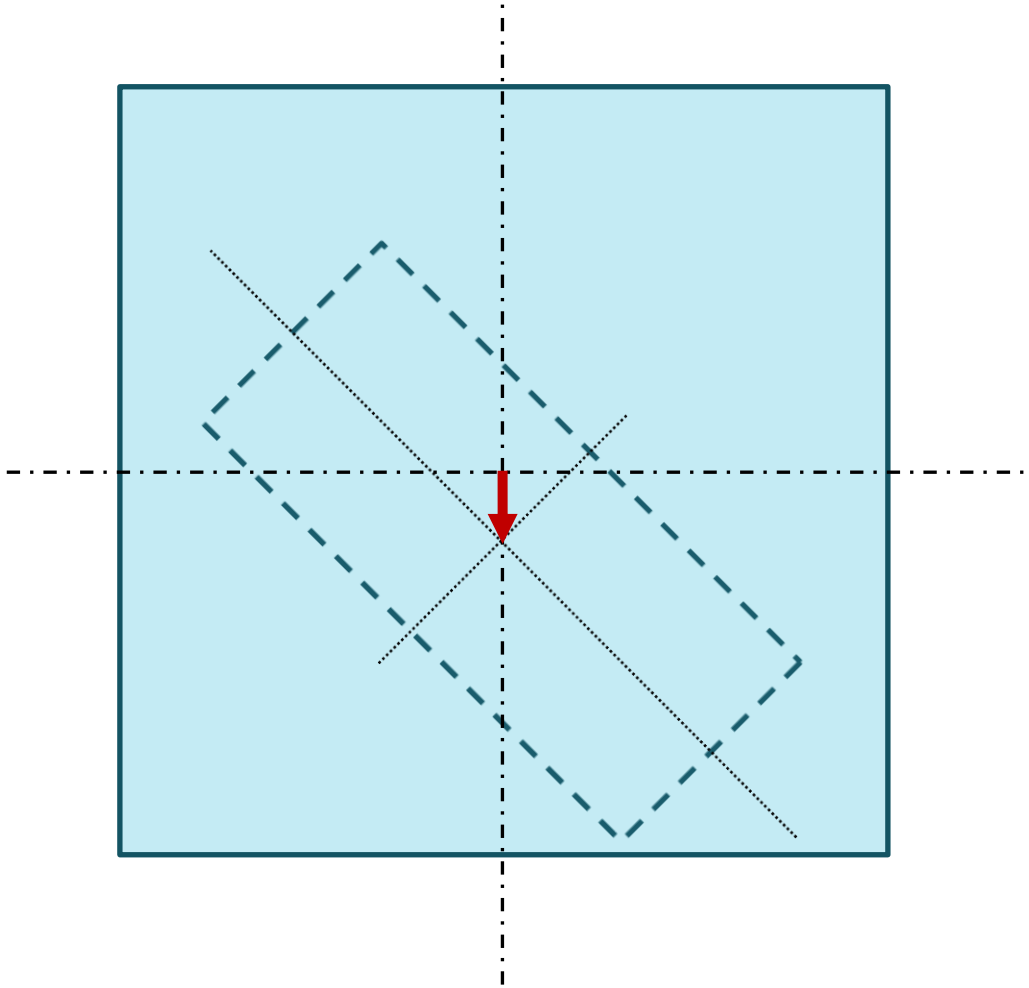


**Starting from the isolation condition: the offset of the first TE section controls the coupling between its TE10½ and the TM110**
**→ Coupling M12**

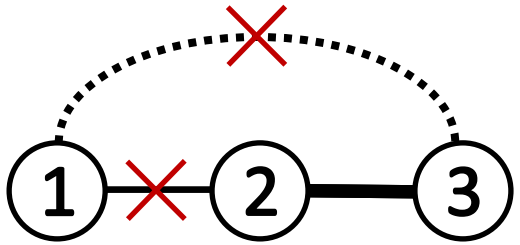


# Coupling Control



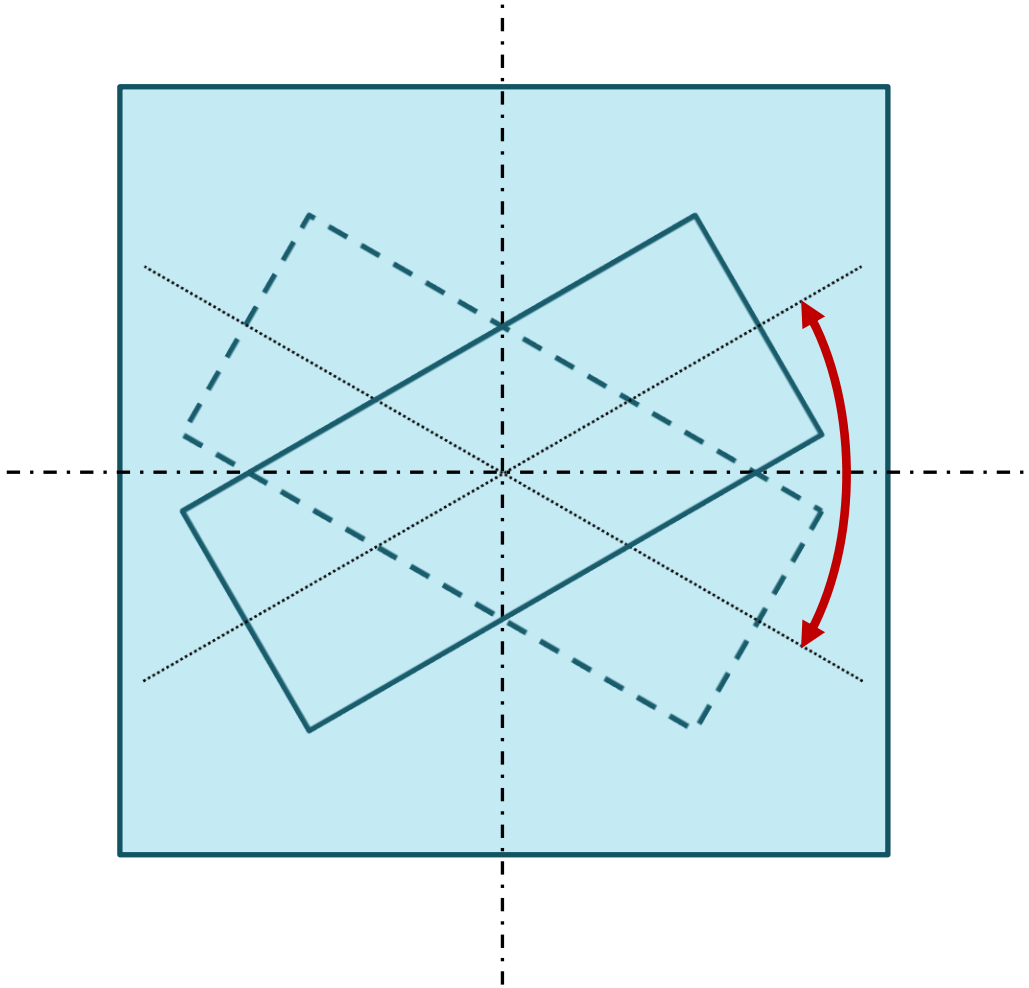


**Starting from the isolation condition: the offset of the third TE section controls the coupling between its TE10½ and the TM110**
**→ Coupling M23**



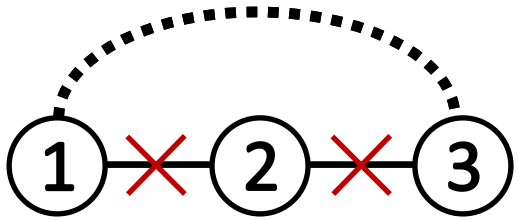
# Coupling Control





**Starting from the isolation condition: the angle between the TE sections controls the by-pass coupling between the two TE10½ modes**

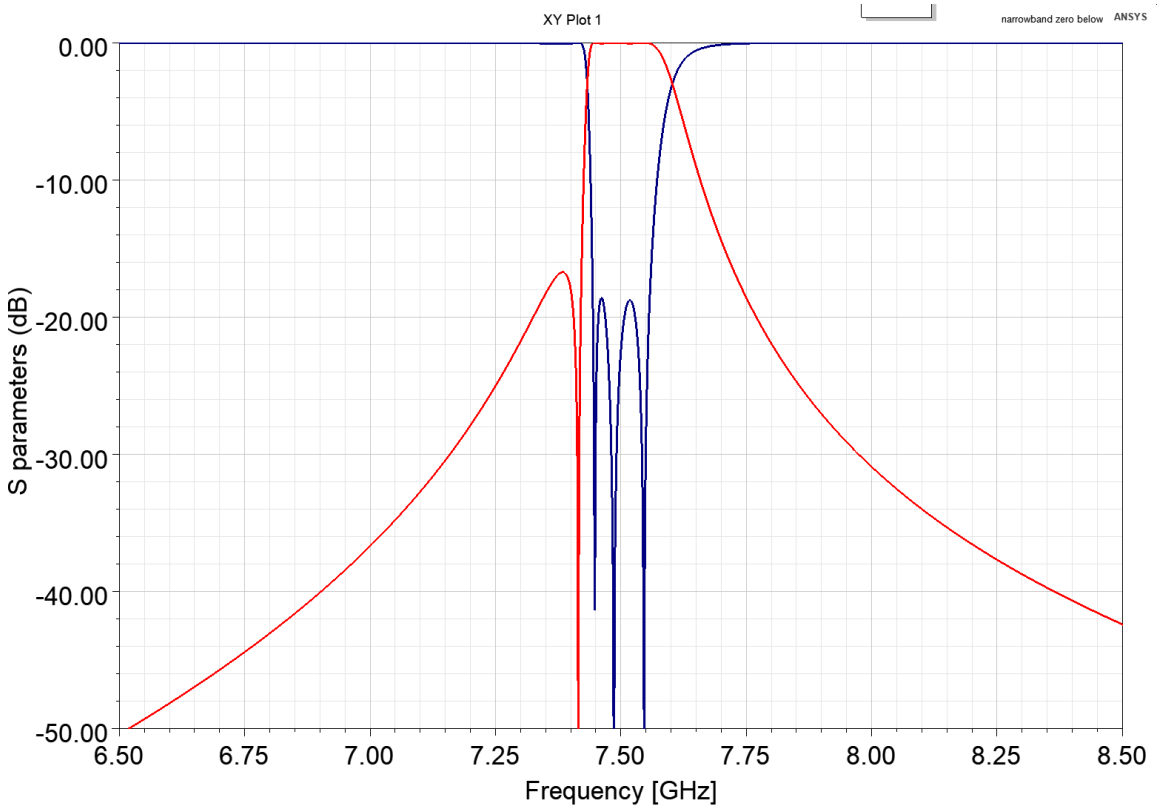
**→ Coupling M13**



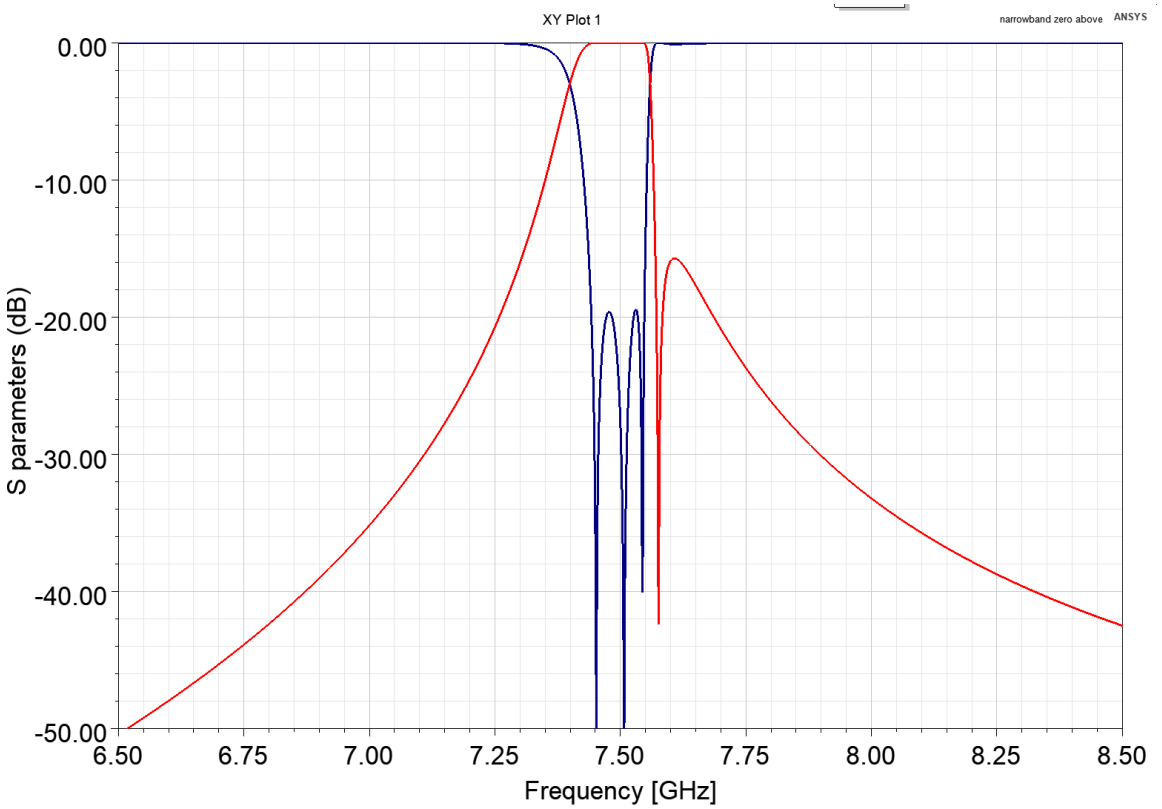
# Transmission Zero Location



## TE sections offset SAME directions



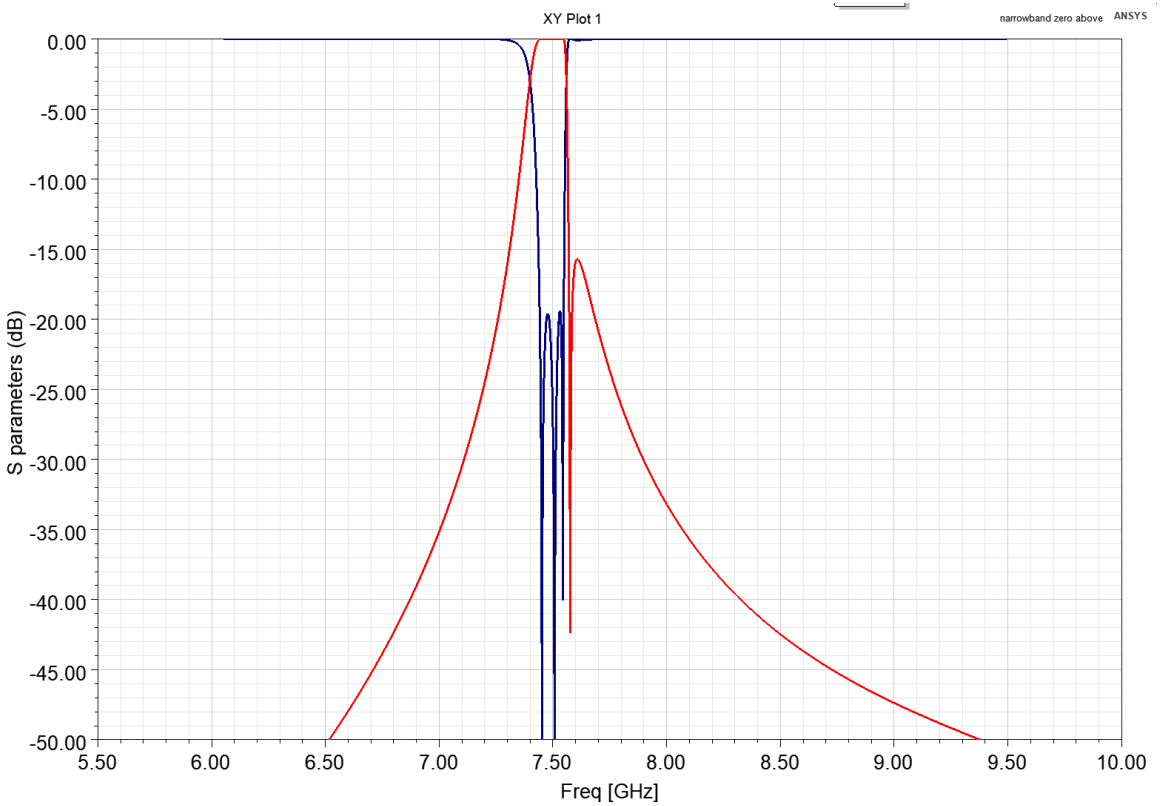

## TE sections offset OPPOSITE sides



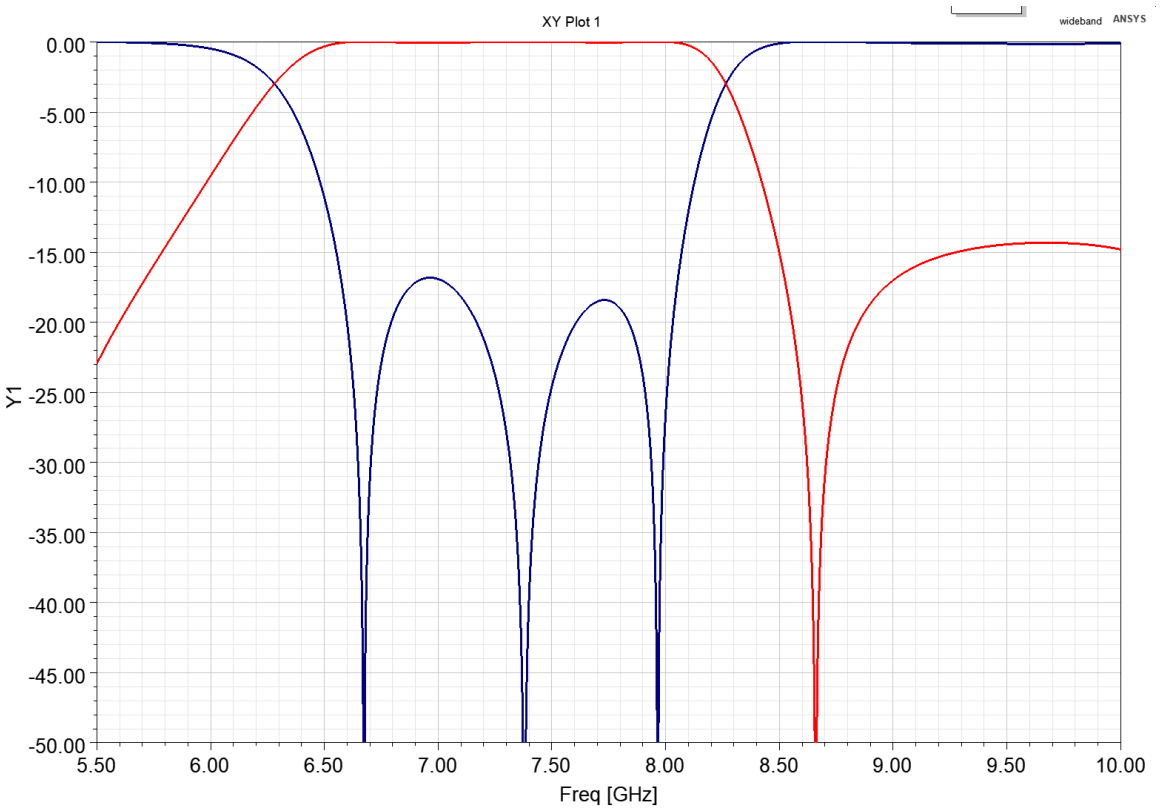
# Design Versatility



## Small Offsets + Almost Right Angle




## Large Offsets + More Acute Angle



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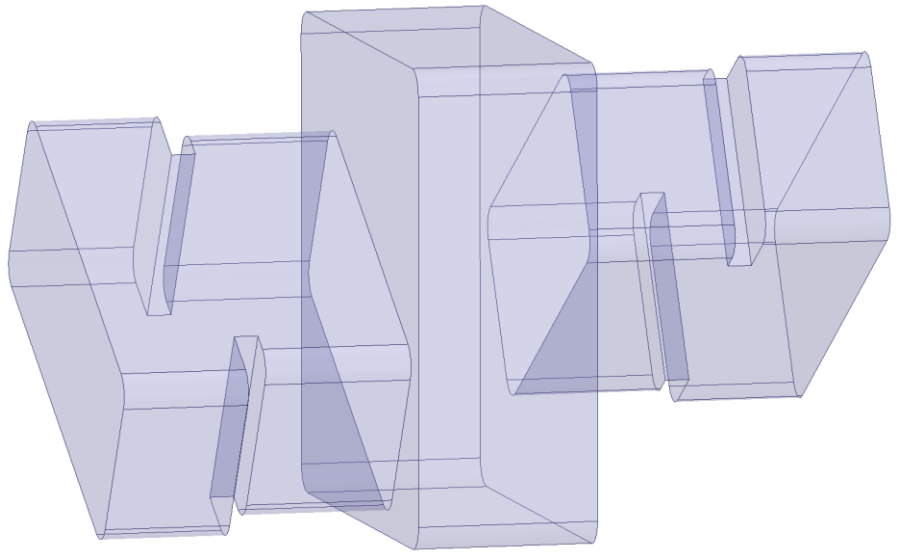
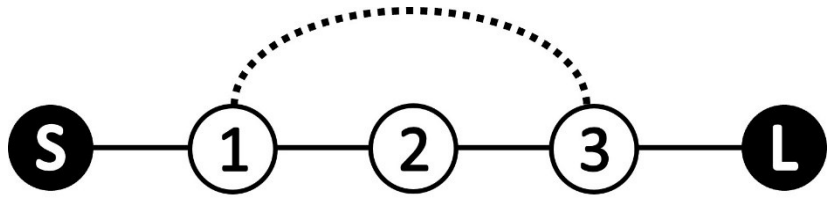
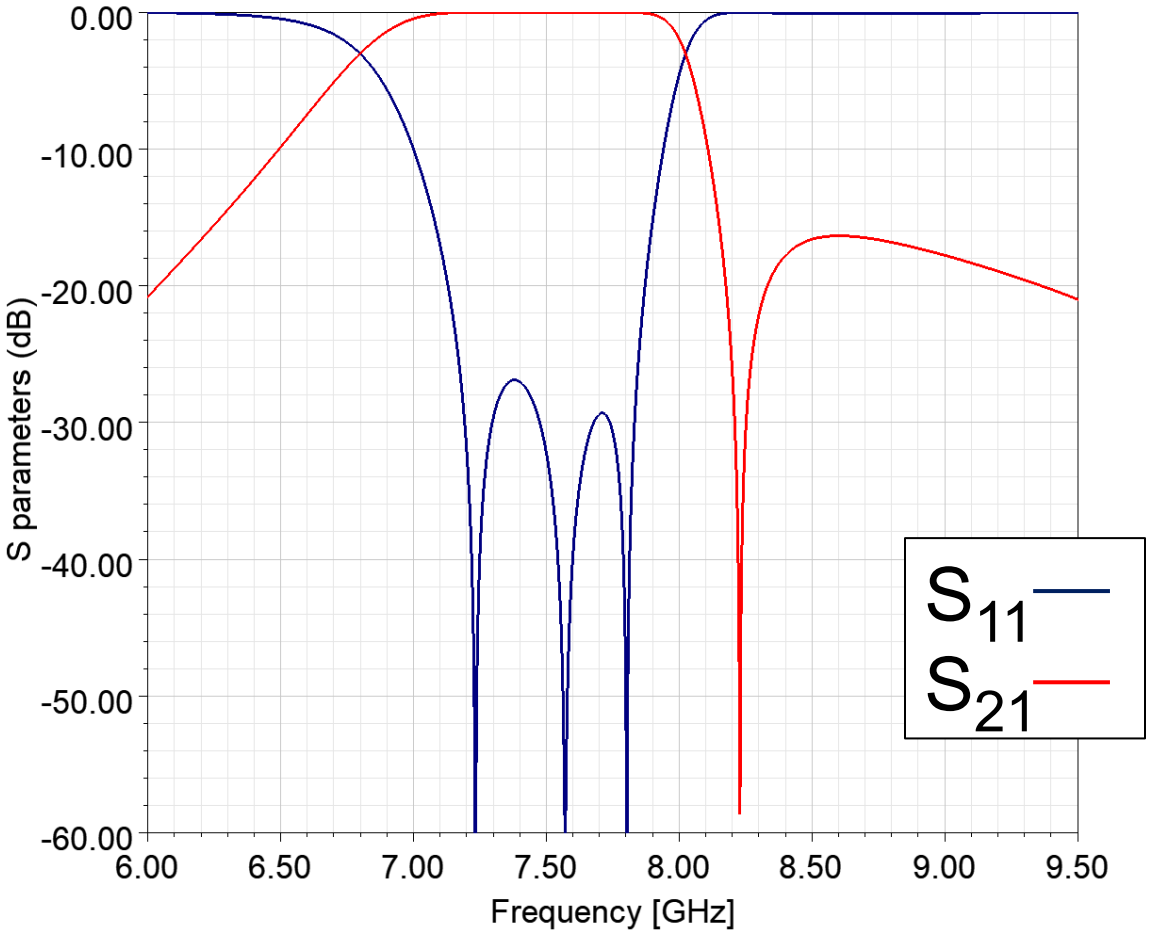
# Basic TE-TM-TE Configuration

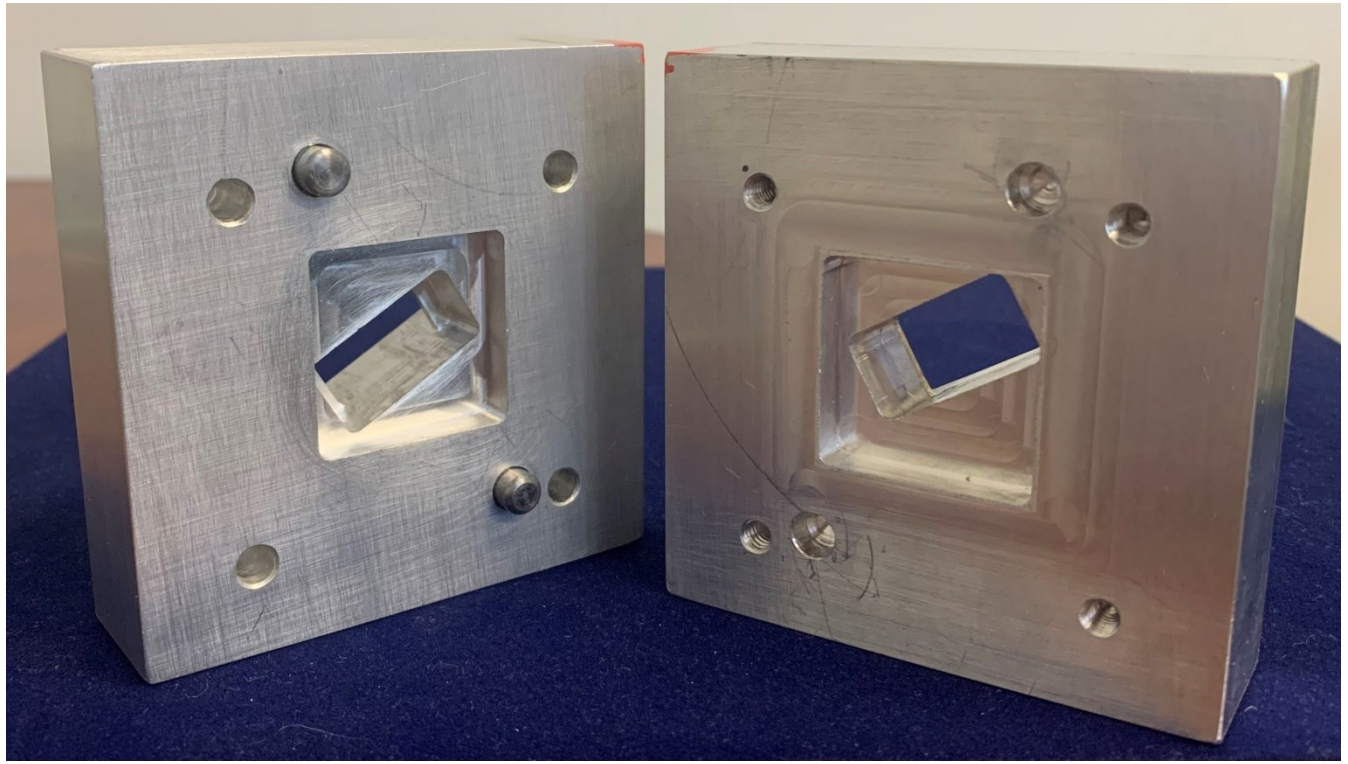




# Manufactured Prototype



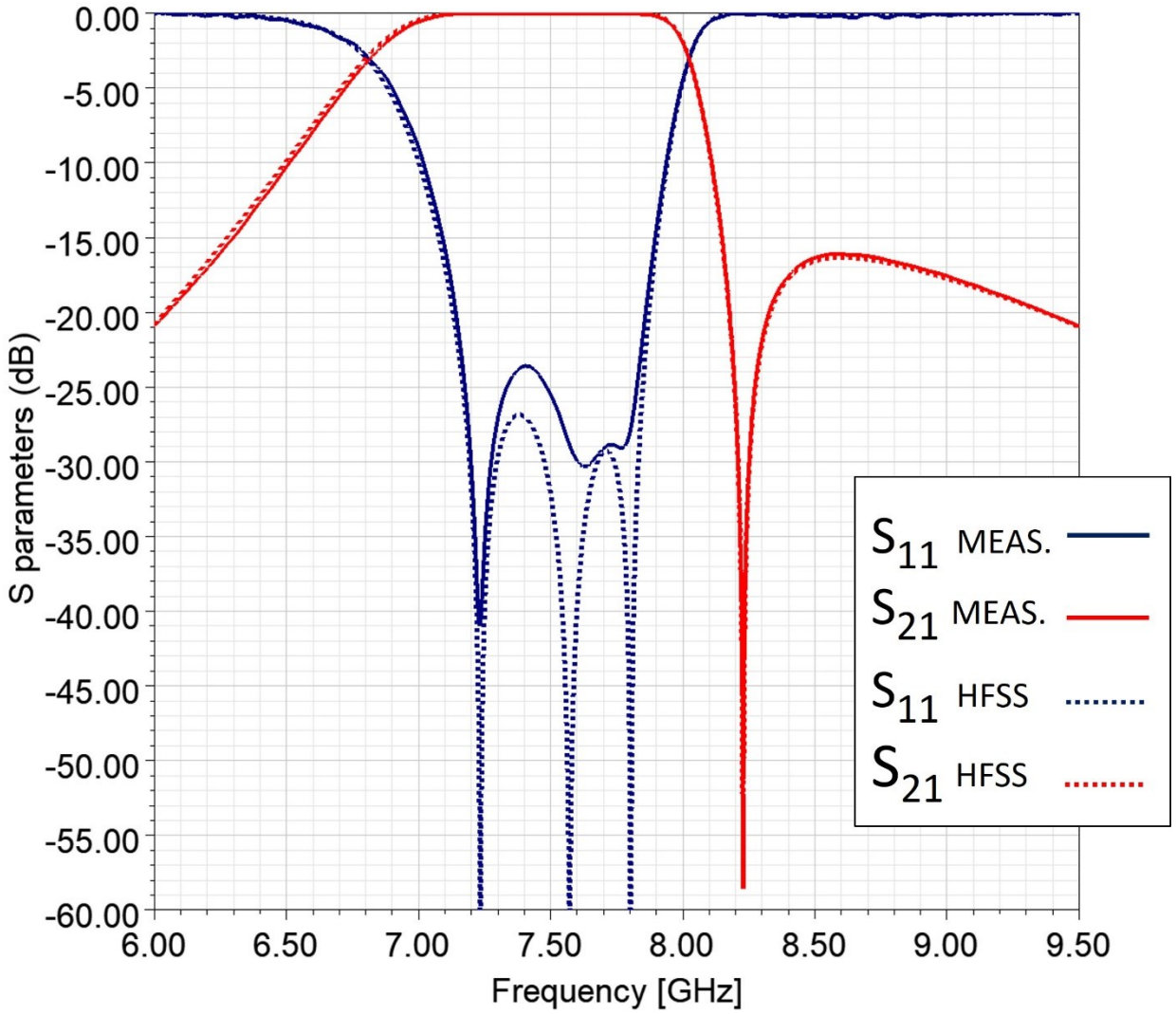


**Aluminum prototype (no silver plating)**

**→ WR112 flanges are manufactured on the other side of each block**

# Measurements



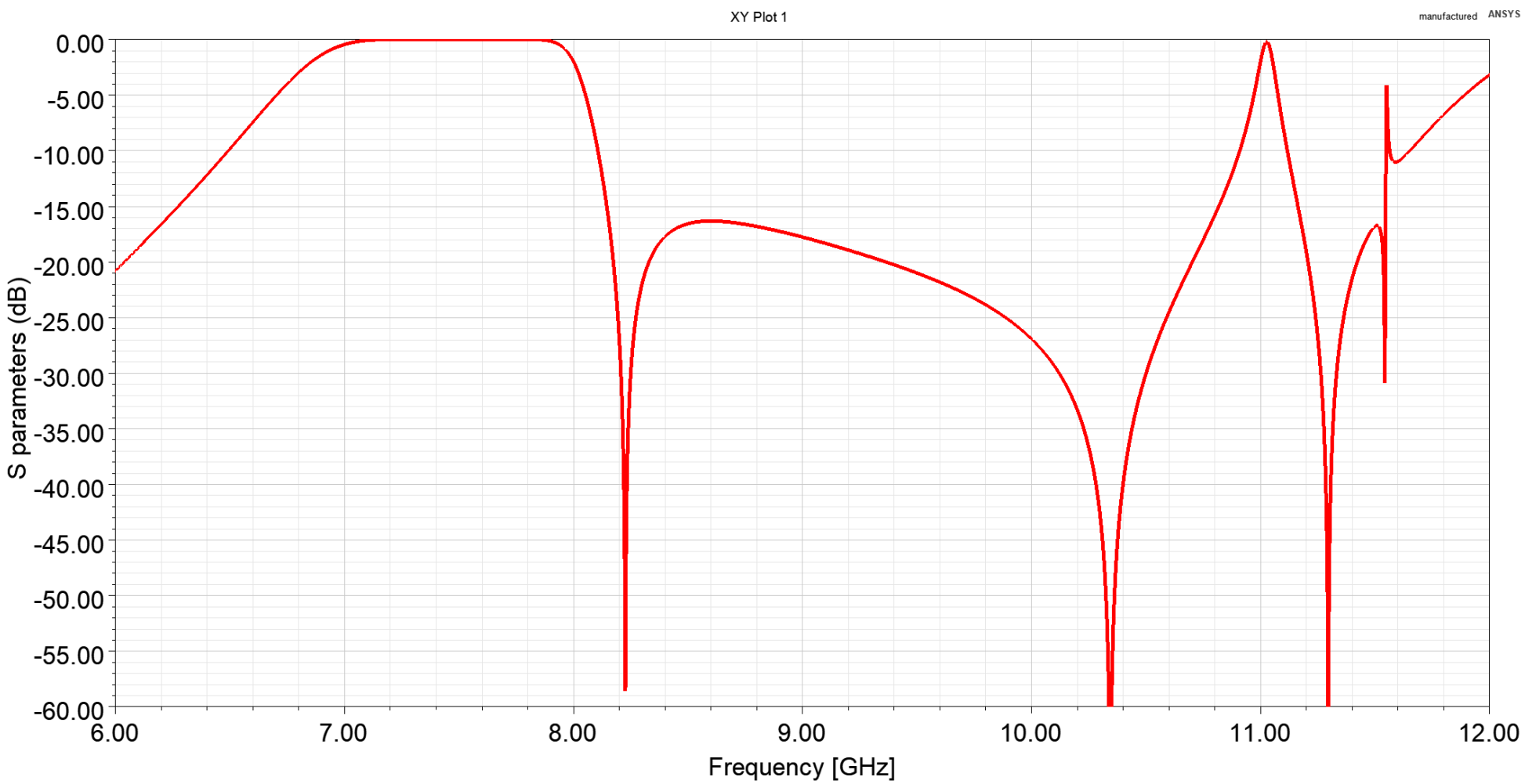



**Insertion loss < 0.05 dB**
**Average Experimental Q≈5600**

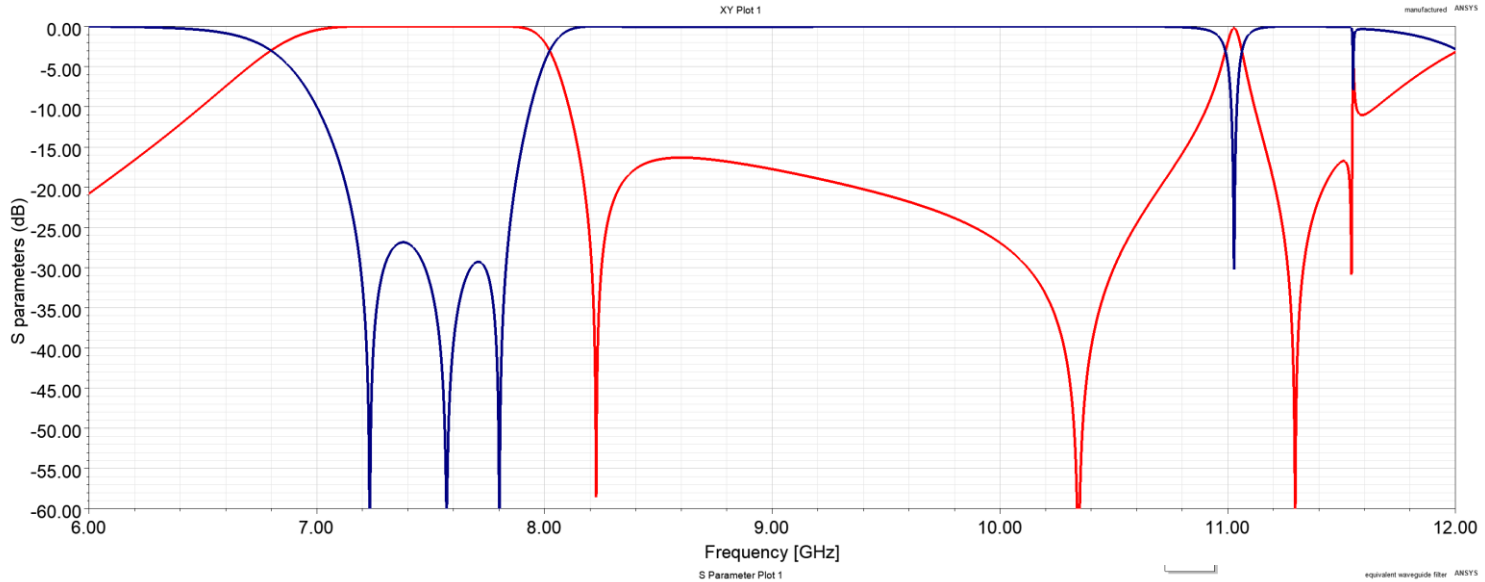
**→ the simulated unloaded Q for ideal silver surfaces are 8000 for the TE10½ and 9300 for the TM110**

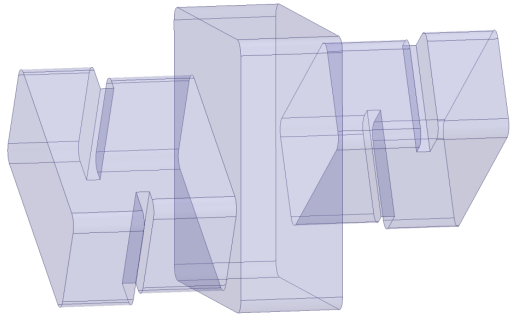
# Spurious Free Stopband

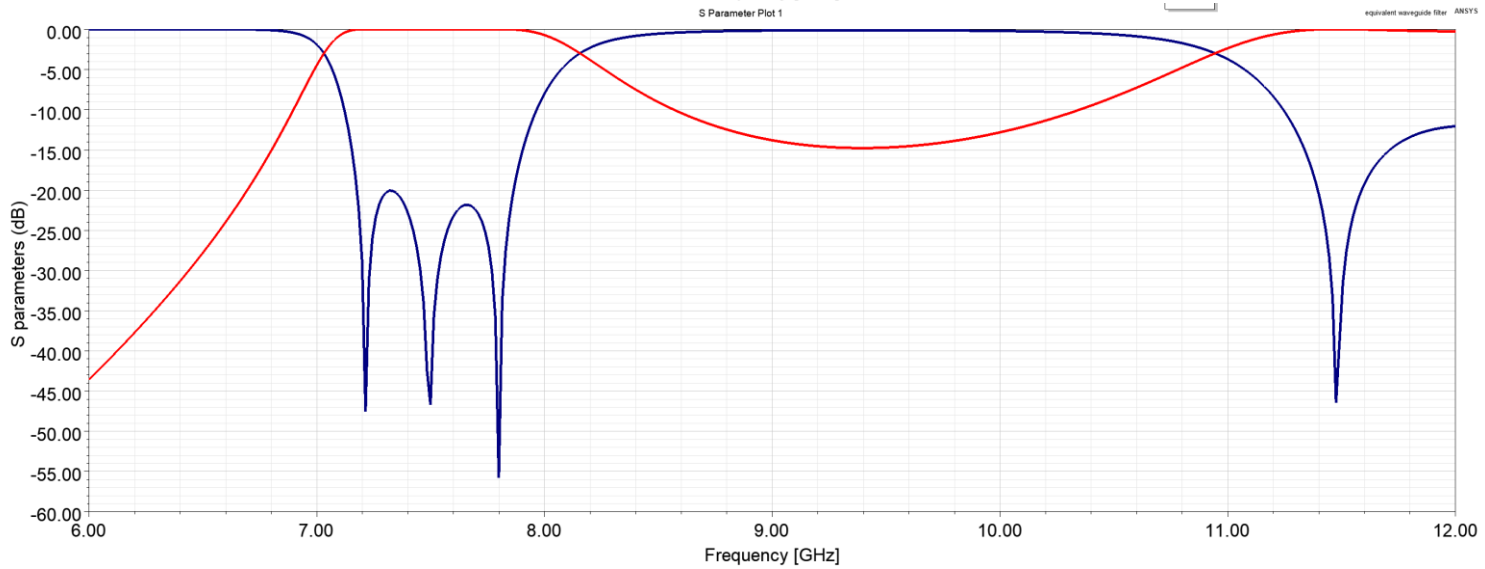


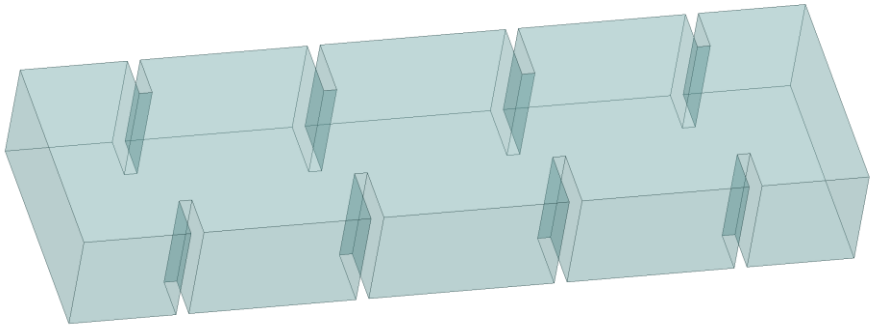


# Comparison vs Standard WG





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# Conclusions



- Innovative structure based on direct-coupled TE-TM sections (with no dedicated coupling element)
- Basic building block for the definition of a new class of direct-coupled waveguide filter combining the strengths of the most advanced TM filters and the versatility of the more standard iris-coupled waveguide filters
- Future development: higher order filters

# ...Thank You...

RS MICROWAVE COMPANY, INC

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