FM Tee and Manifold Combiner Designs





Nick Paulin
V.P. RF Engineering

Bandpass filter Agenda

- Why bandpass?
- The basics
- The construction
- The types
- The challenges
- The combiner design
- The system considerations

Why bandpass?

- Bandpass filters provide separation from other frequencies / stations / broadcasters / etc.
- FCC Regulation Compliance – Intermodulation Products
- Used in multiple station combining

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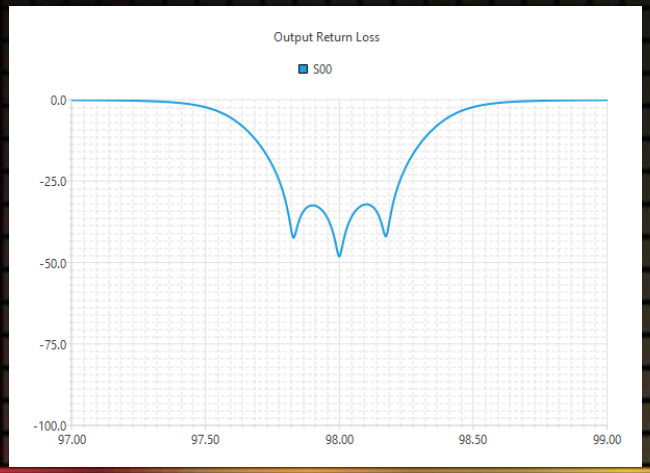
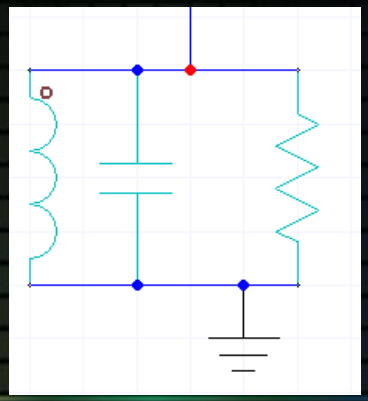
The basics

- Narrowband
- High Q (Quality Factor)
  - Selectivity
  - Insertion loss
  - Bandwidth
- 2, 3 or 4 Pole designs are common for FM applications

The basics

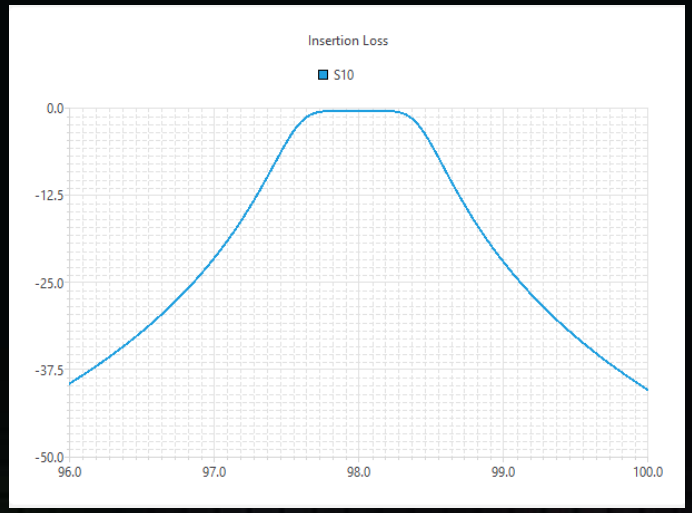
- Composed of ‘tanks’
  - Resonator
  - Loops
- Each ‘tank’ adds 1 pole
- Each pole can be seen in the return loss response

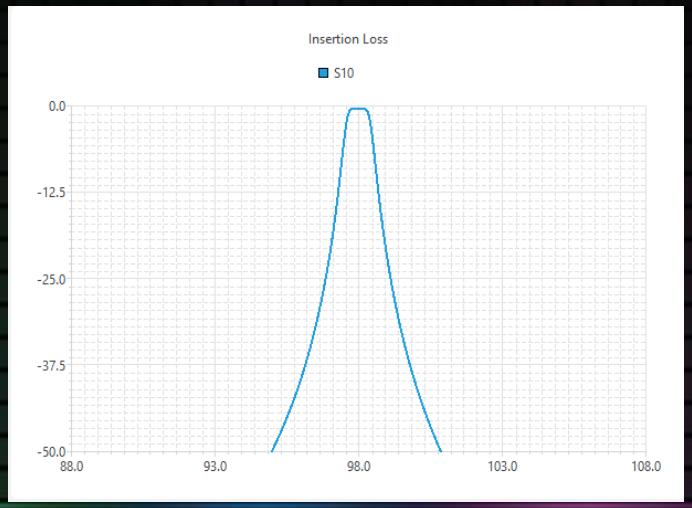




The basics

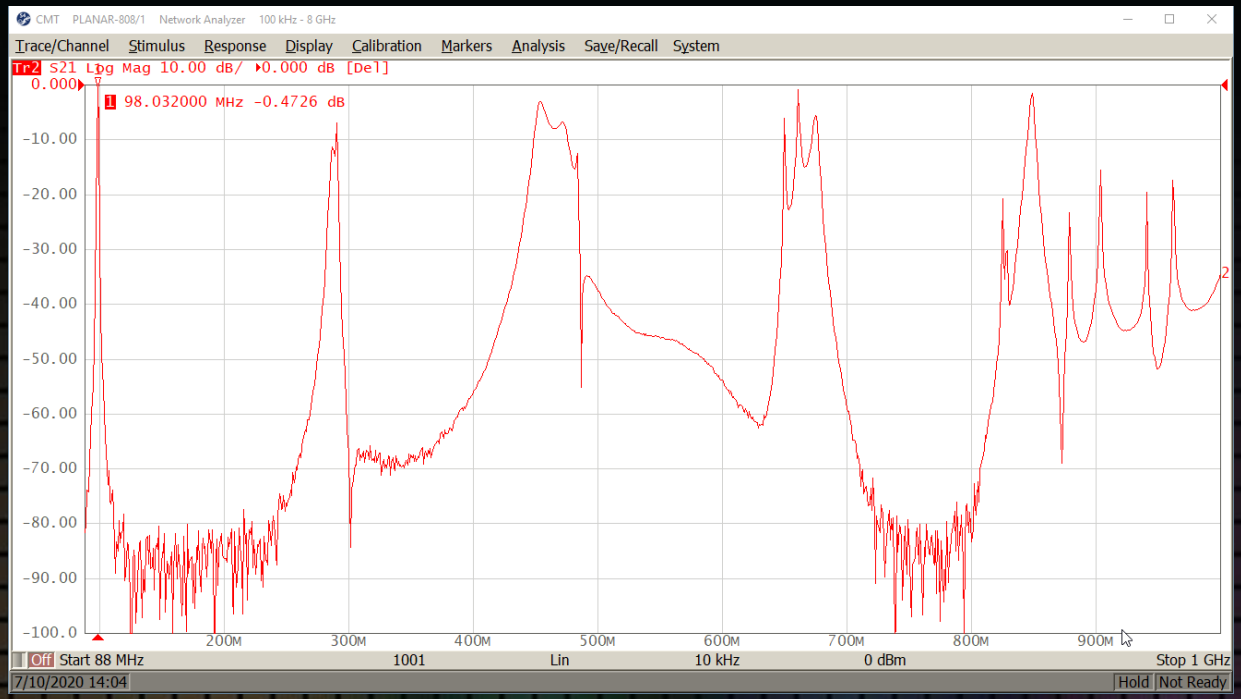
- The top of the chart represents perfect efficiency
- Logarithmic scale
  - Every 10 dB increase the loss 10x
- $\eta = 10^{\frac{dB}{10}} * 100\%$





The basics

- Used for closely spaced applications
- 3x to 10x the operating frequency has no guarantee



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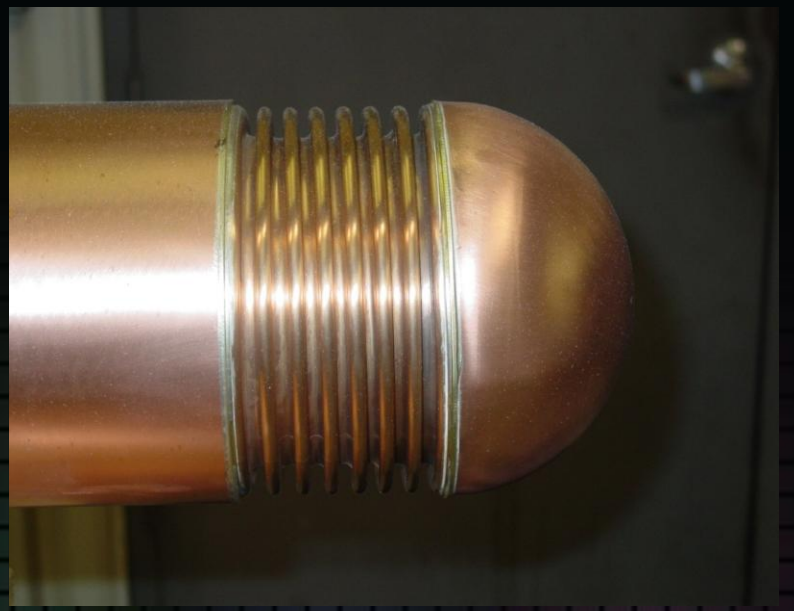
The construction

- ERI filters are loop coupled and the loop is fixed with two bolted connections. No insulating material used in the coupling.
  - Loop coupling works very well for modular cavities
- Other types of coupling you may see…
  - Space coupled
  - Capacitive coupled
  - Direct tap coupled

The construction

- Control rod
  - Invar – Iron/Nickel Alloy
  - Very low CLTE
  - Adds thermal stability
- ERI Filters use bellows to handle expansion and contraction
- Other filters may use a sliding contact using finger stock with Invar



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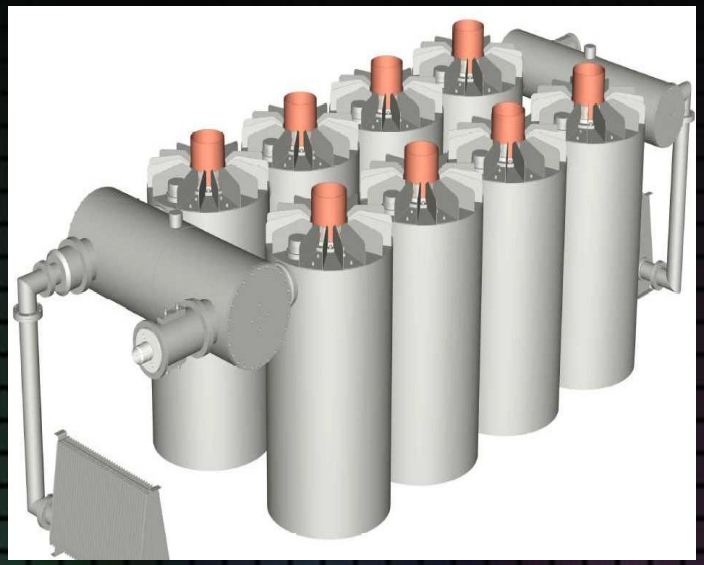
The types

- Channel combining – Reflective filters
  - Tee combiner
  - Branch combiner
  - Star-point combiner
  - Manifold Combiner
  - Advantages: Lower cost
  - Disadvantages: Expansion requires additional engineering
- Constant Impedance Combining
  - Uses 2 reflective filters with 2 hybrids
  - Advantages: Future expansion is very easy using the Wideband port
  - Disadvantages: Cost, physical space

Constant Impedance Combiner

- Two filters in parallel operation
- Split the power 50/50
- Two hybrids to split/combine power



Constant Impedance Combiner

- Directionality
  - The power flows in one direction
  - Not dependent on critical line section lengths
  - Improves port-to-port isolation
- High power handling compared to a single filter
- Resistive loads absorb out of band energy

Vertically Racked Constant Impedance

- Modular design allows for unique and hard to access locations

Floor Racked Constant Impedance

Tee Combiners

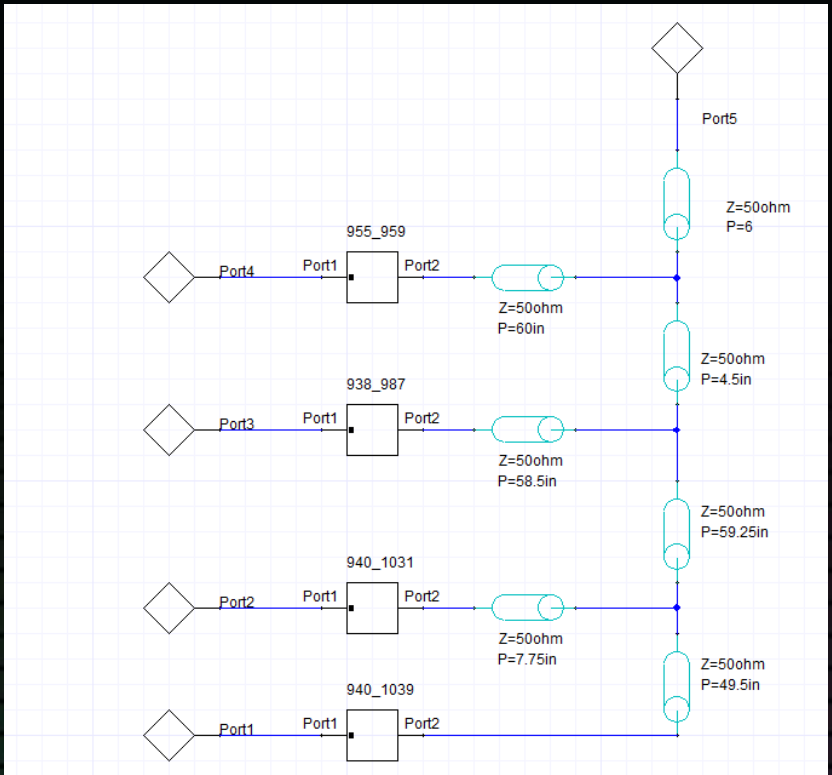
- Two filter share a common point
- Line lengths are critically important
- Simple construction compared to constant impedance

Wall Mounted Tee Combiner

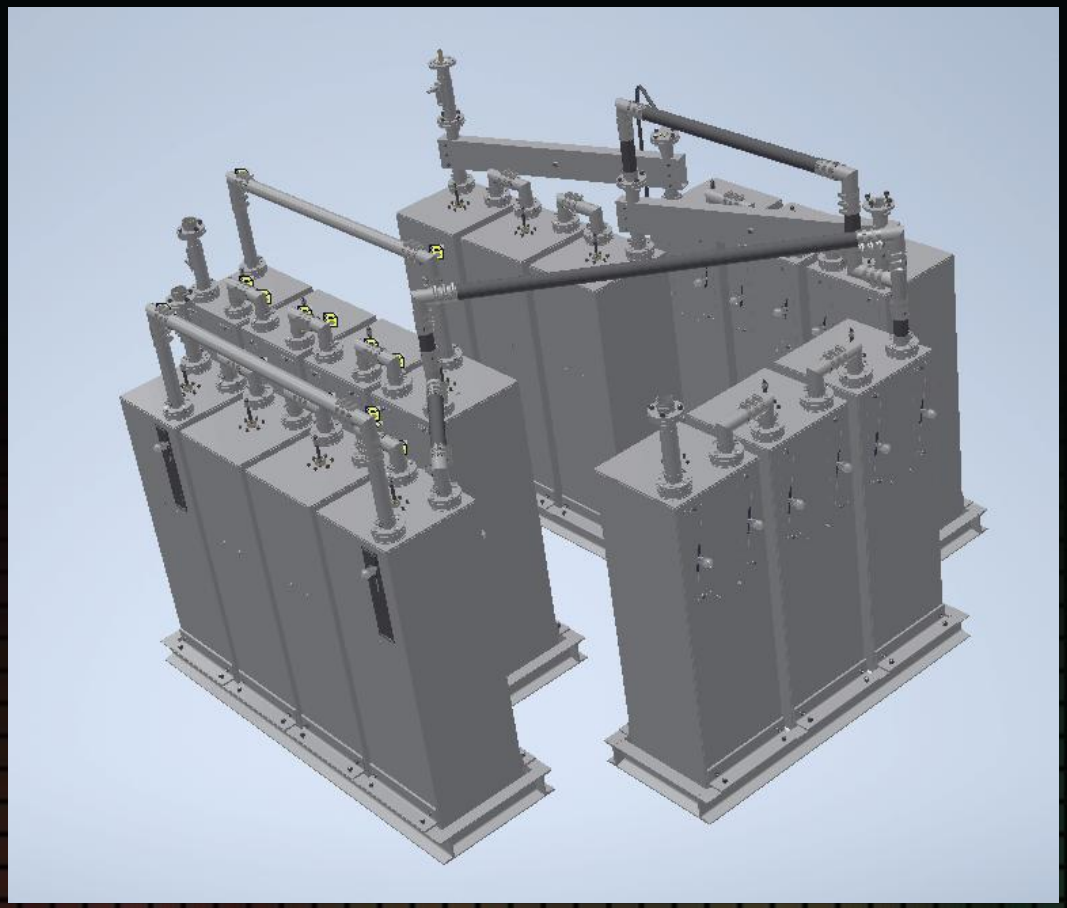
Racked Tee Combiner

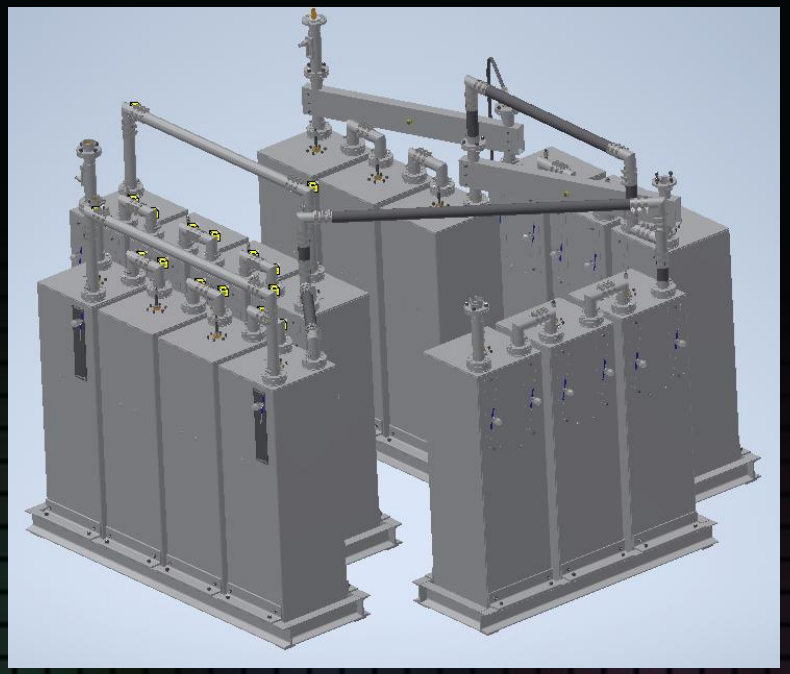
Manifold Combiner

- All the filters plug into a manifold
- All the line sections are critical
- 1 Tee and 1 Filter for each frequency added



Manifold Combiner





Floor Mount Mixed type

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The challenges

- Voltage
  - $V_{pk} = \sqrt{2 * P * Z_o}$

	FM w/ VSWR derating Average Power	Peak Power		Peak Voltage	
7/8"	3.8	41	kW	2,025	V
1 5/8"	13.4	130	kW	3,606	V
3 1/8"	47	441	kW	6,641	V
4 1/16"	77	711	kW	8,432	V
6 1/8"	167	1,538	kW	12,402	V
9"	354	3,300	kW	18,166	V

Example

- 5 Stations: Each at 5 kW each with -10 dBc HD
  - $V_{pk-analog} = \sqrt{5000 * 50 * 2} = 707\ V_{pk}$
  - Digital power: 500 W
  - $V_{pk-digital} = \sqrt{500 * 50 * 2 * 4} = 447\ V_{pk}$
  - Power Total: 5500 W
  - Voltage Total: $1154\ V_{pk}$

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6 1/8"	167	1,538	kW		12,402	V
9"	354	3,300	kW		18,166	V

Example, cont.

- Total output:
  - Power: 27.5 kW
  - Voltage : 5,770 V_{pk}
- Output line size: 3 1/8”
- Filter choices

ERI Filters	Port Size
940	1 5/8"
780	1 5/8"
780	3 1/8"
783	3 1/8"
783	6 1/8"

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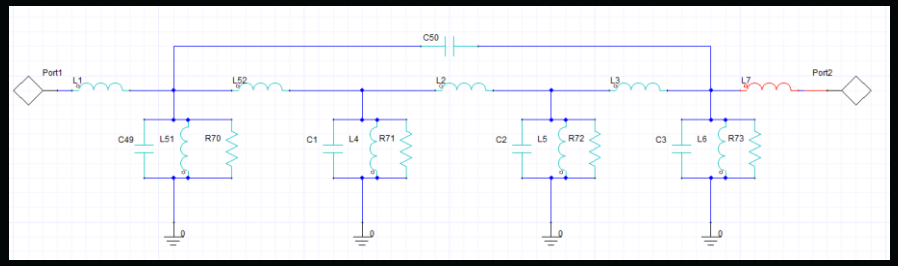
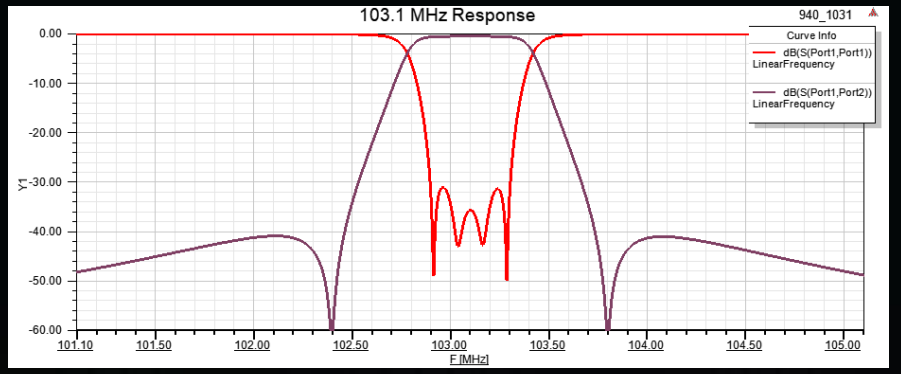
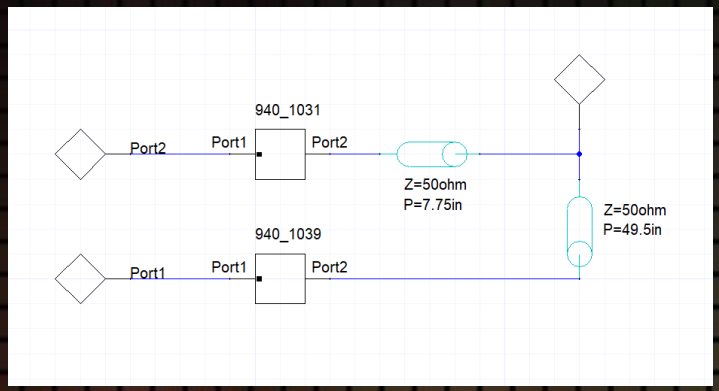
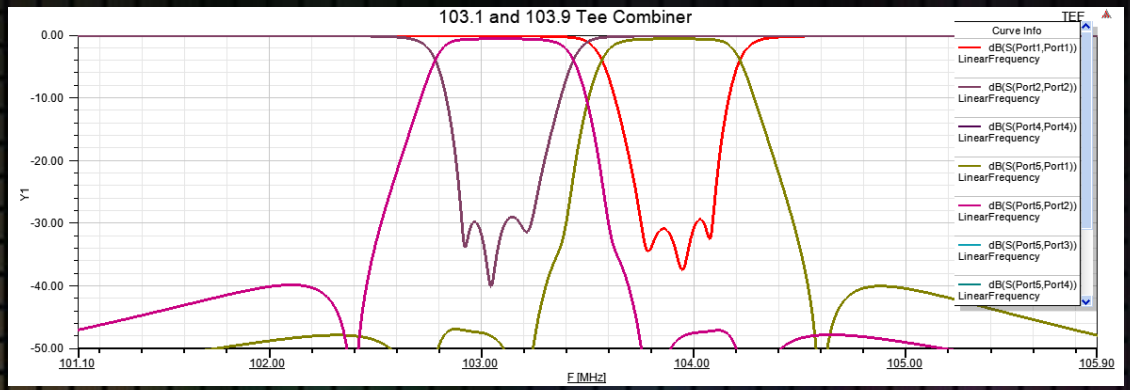
The combiner design
Lumped Element Circuit Model





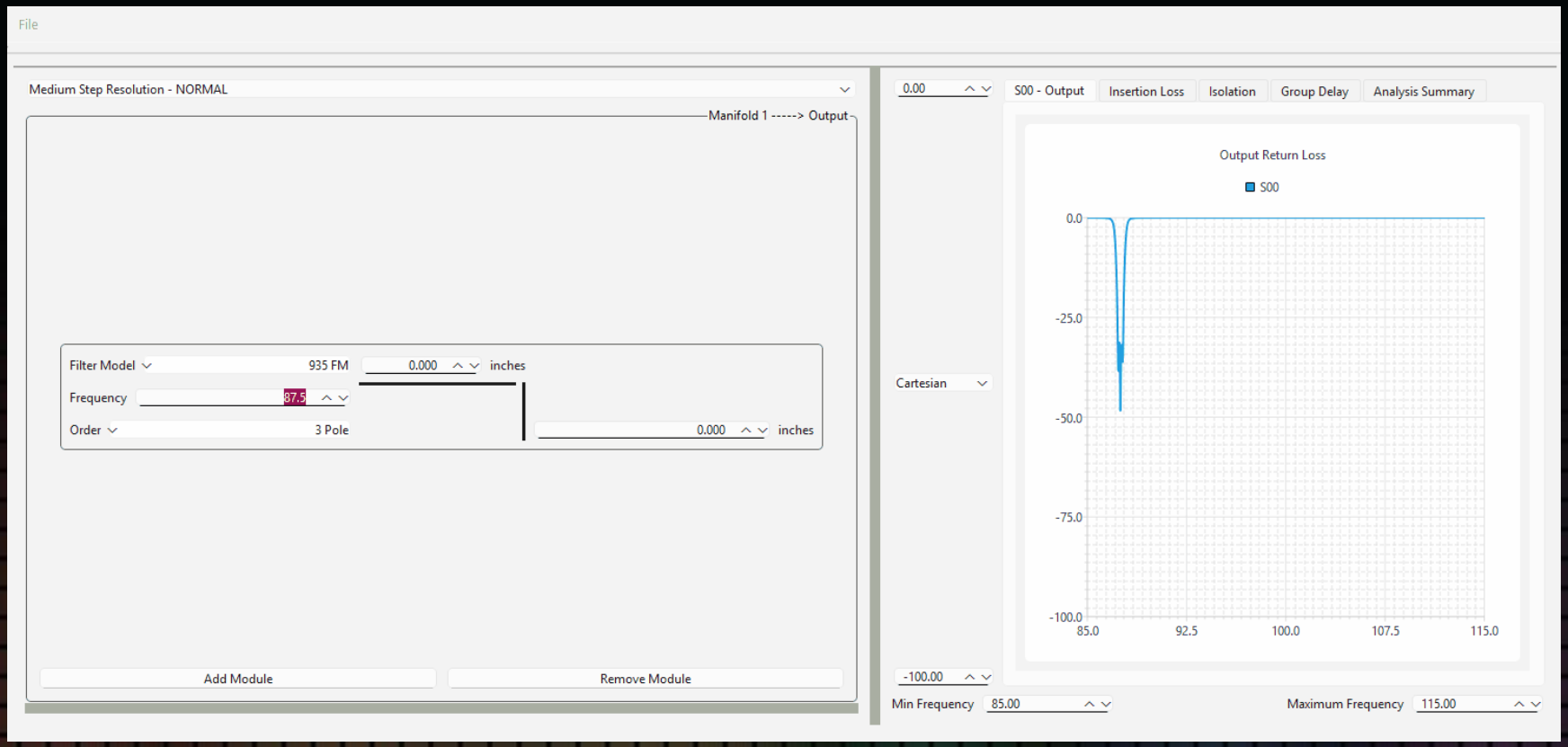




Limitations of the Circuit analysis

- Pros
  - Evaluate for practicality
  - Reasonable performance data for return loss, port to port isolation, and group delay variation
  - Creates a good starting point for a final design
- Cons
  - Lumped elements are ideal
  - Real world have additional physical length that needs to be accounted for

Using a Quick Designer

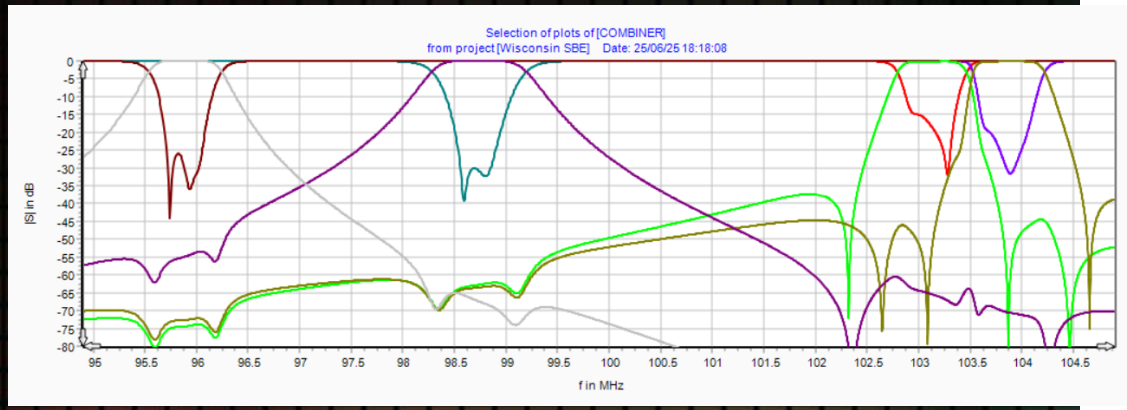


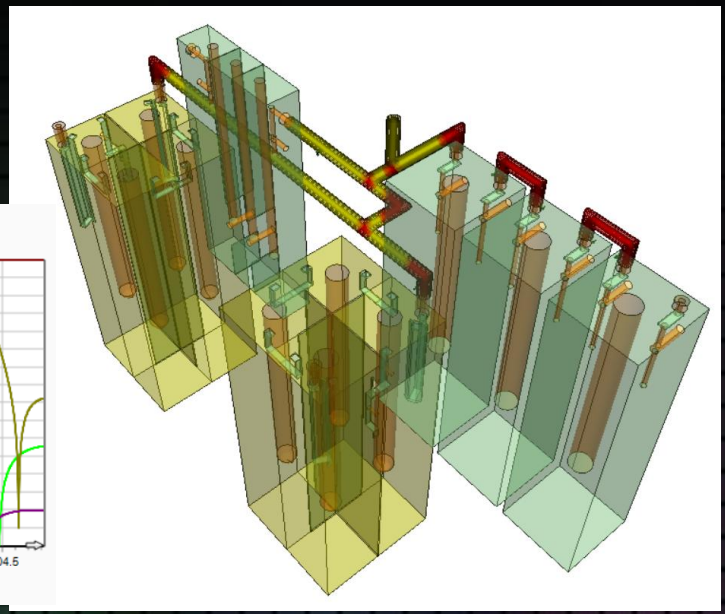
Tee / Manifold Combiners

- Use physical transmission line to combine two filters
- Input loop designs (short circuit at filter input) are different across filter styles and manufacturers
- The ideal circuit needs to be conditioned differently for each style filter to simulate accurately

Verify the manifold network

- Can use a 3D FEM analysis tool
  - Visualize the layout
  - Provides more insight into actual performance





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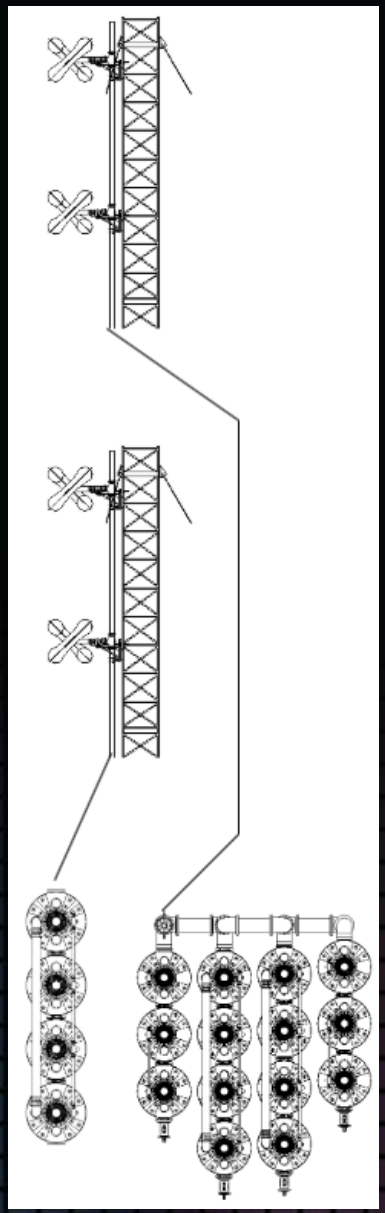
The system considerations

- When to choose manifold over constant impedance?
  - When space is a premium
  - Transmitters use tubes? Count on a phasing loop.
  - The output line size and filter size align appropriately

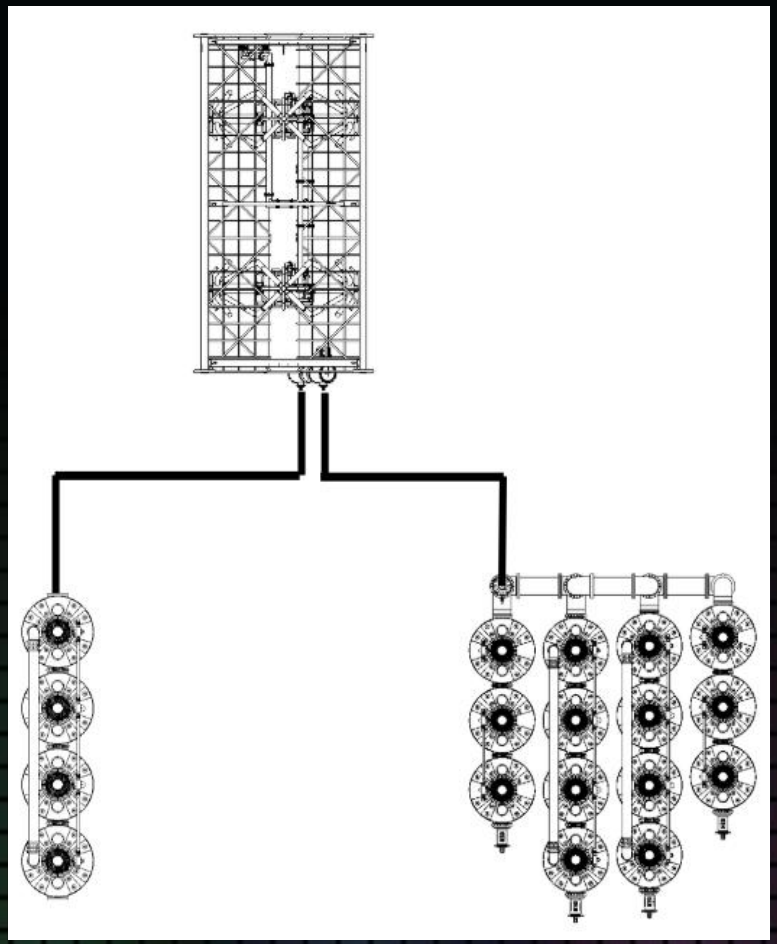
Co-located Arrays

- System A and System B are two unique operations
- Arrays typically have 10 ft or more physical separation
- Changes in System A have no affect on System B



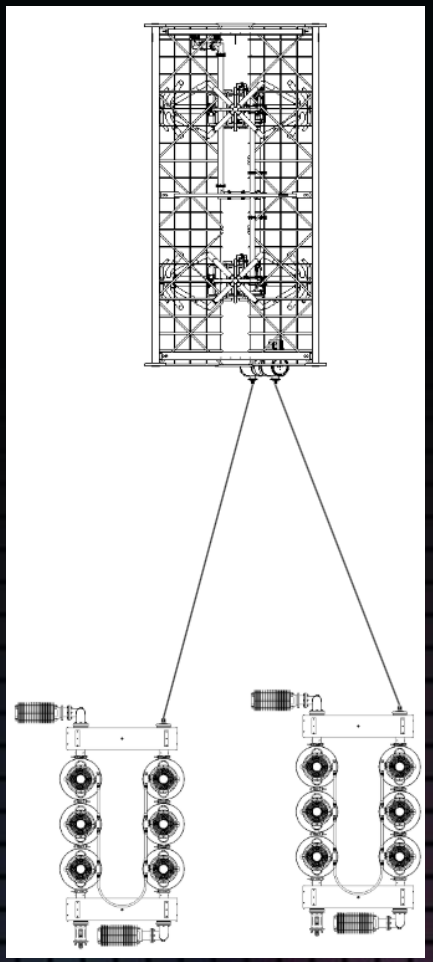
Dual Input Panels with a Manifold

- Direct coupling path from Combiner A to Combiner B
- Changes within the panel affect both combiners A and B
- More susceptible to isolation changes due to weather events
- Unwanted energy will reradiate in the opposite polarization
- YMMV



Dual Input Panels with Constant Impedance

- Unwanted energy will be absorbed in a reject load
- Consistent performance across weather conditions
- Antenna isolation becomes less of a factor for intermodulation products or self induced interference



Summary

Type	Pros	Cons
Tee / Manifold	Lower cost	All placed in one location
	Smaller foot print	Not easy to rearrange after designed
		Not as easy to expand later
		Harder to rack
		Short circuits reflect unwanted energy in dual input systems
Constant Impedance	Absorbs unwanted RF into loads	Higher cost
	Can be place in different rooms	More floor space
	Easy to rack	
	Better synergy with dual input systems	

System	Combiner Type
Single Input	Manifold or Constant Impedance
Dual Input	Constant Impedance
Co-Located	Manifold or Constant Impedance

Questions