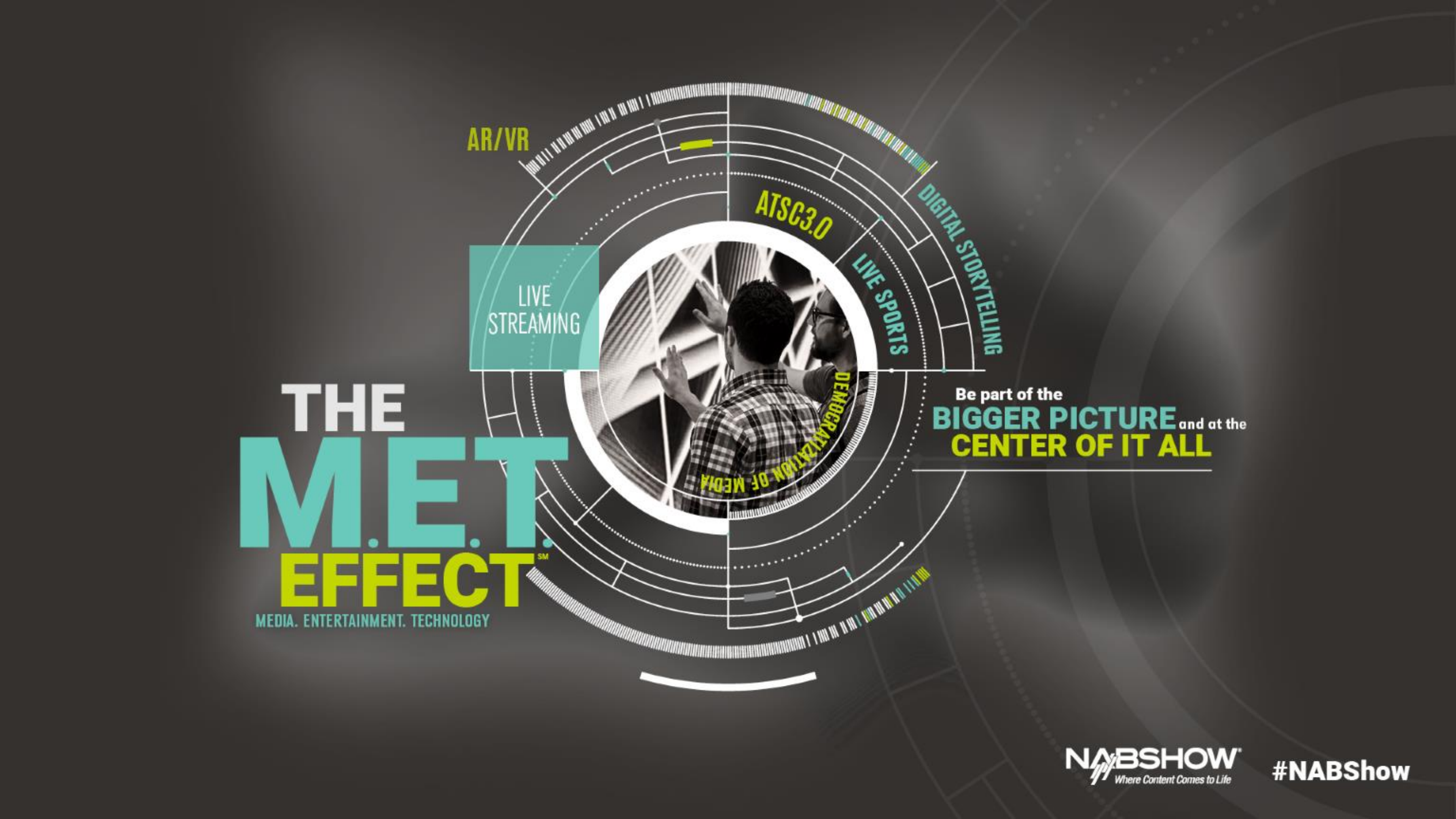
AR/VR
ATSC3.0
DIGITAL STORYTELLING
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Efficient RF Design and Implementation of Translator/Booster Stations

Today's Presentation

Attentive crowd

- FM Transmission Capital Equipment Cost Reduction
  - Simplified Designs
  - Part reduction
  - Manufacturing technique
  - Material choice
- Filter/Combiner Example
- Antenna Example
  - Pattern study, finite element model vs range
- Summary

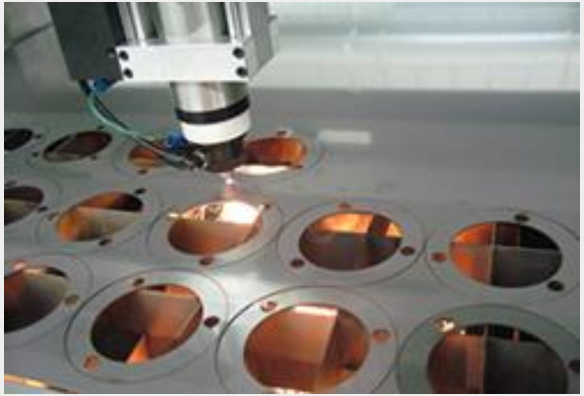
Reducing FM Translator Transmission Costs

Specify product that reduces initial capitol expense and increases operational efficiency

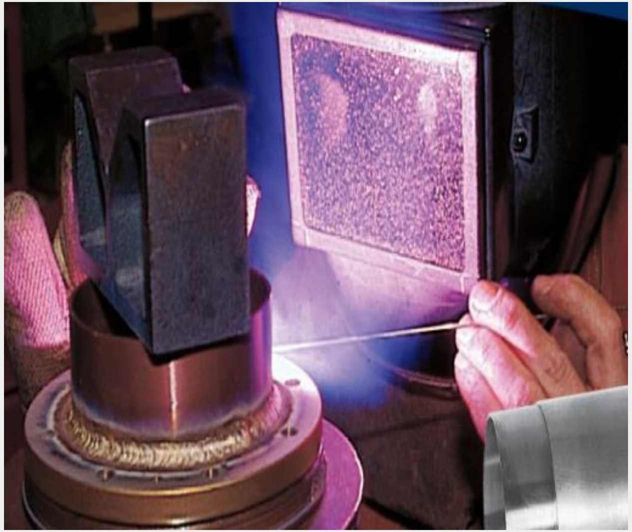
- Starts with Sales
  - Communication and quick answers to problems
- Engineering
  - Simplify design
  - Reduce part count
  - Common parts with UHF products
  - Material choice
  - Minimize solder, braze and welding
  - Volume purchasing
    - Sheet metal
    - Aluminum where possible
- Design to reduce RF tuning and pattern study time

As asked for by Sales

Changes in Machining Technology

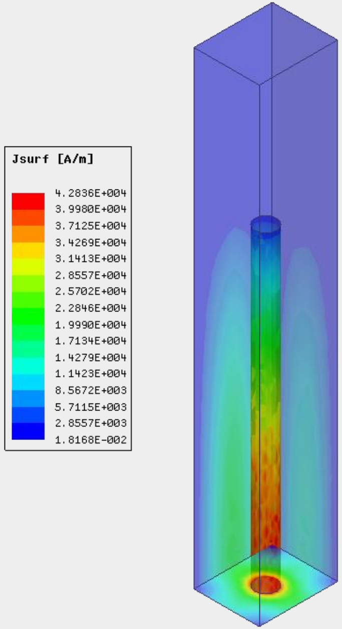


Minimize Welding and Brazing Operations



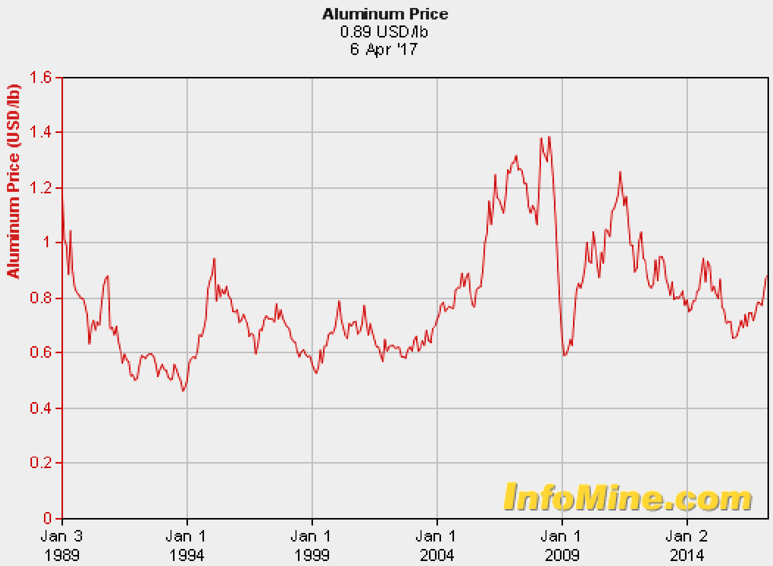
Use Aluminum where Possible

- **Filters**
  - Eigenmode solution for current density
  - Use Aluminum where no loss in performance
- **Components**
  - Aluminum outer conductor where possible (where differential expansion is not an issue)



10 Channel LPFM Combiner

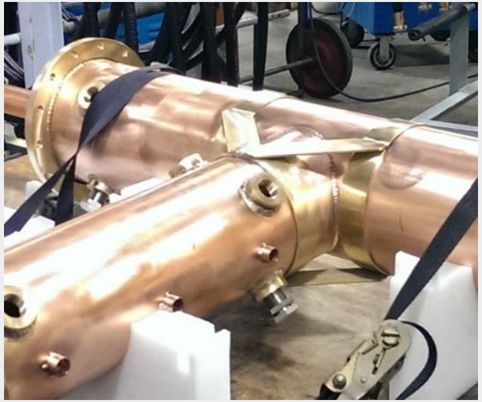
Material Cost



Copper: $2.66/lb

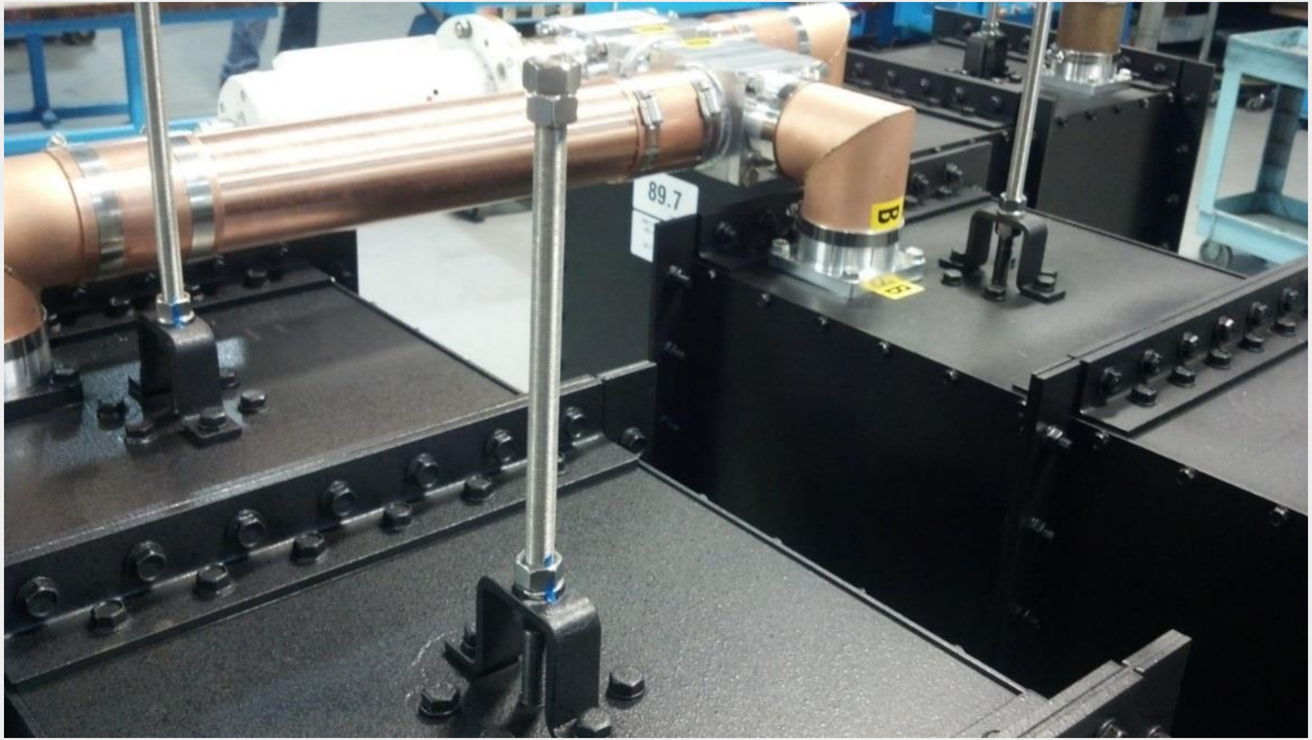
Aluminum: $0.89/lb

Coax Tee



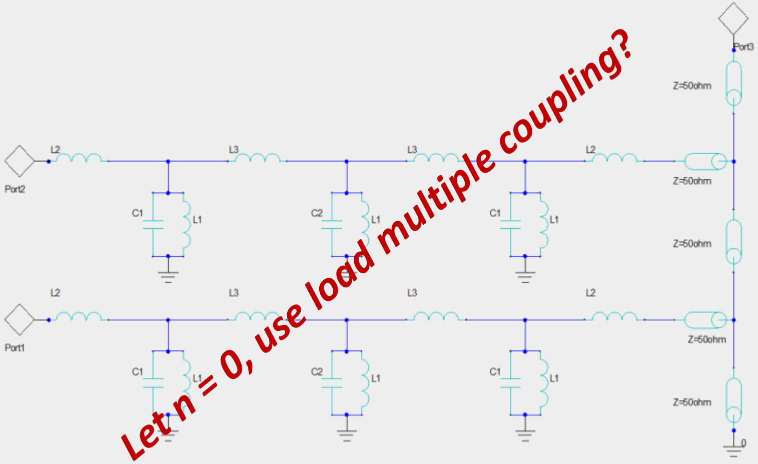
- **Less $**
  - Material cost
  - Manufacturing time
  - Labor
- **Performance**
  - Small, more compact
  - No efficiency hit

Three Channel Branch Combiner



- **Tee example**
  - Three CH combiner
- **Performance**
  - Allows for smaller footprint

2 Channel Combiner, Closer Look



2-Channel Manifold

- Filters placed ≈ n λ/2 from junctions
- Tees spaced ≈ n λ/2
- Short ≈ n λ/4 from Tee
- Short can be replaced w filter to eliminate a Tee

Two Channel Branch Combiner

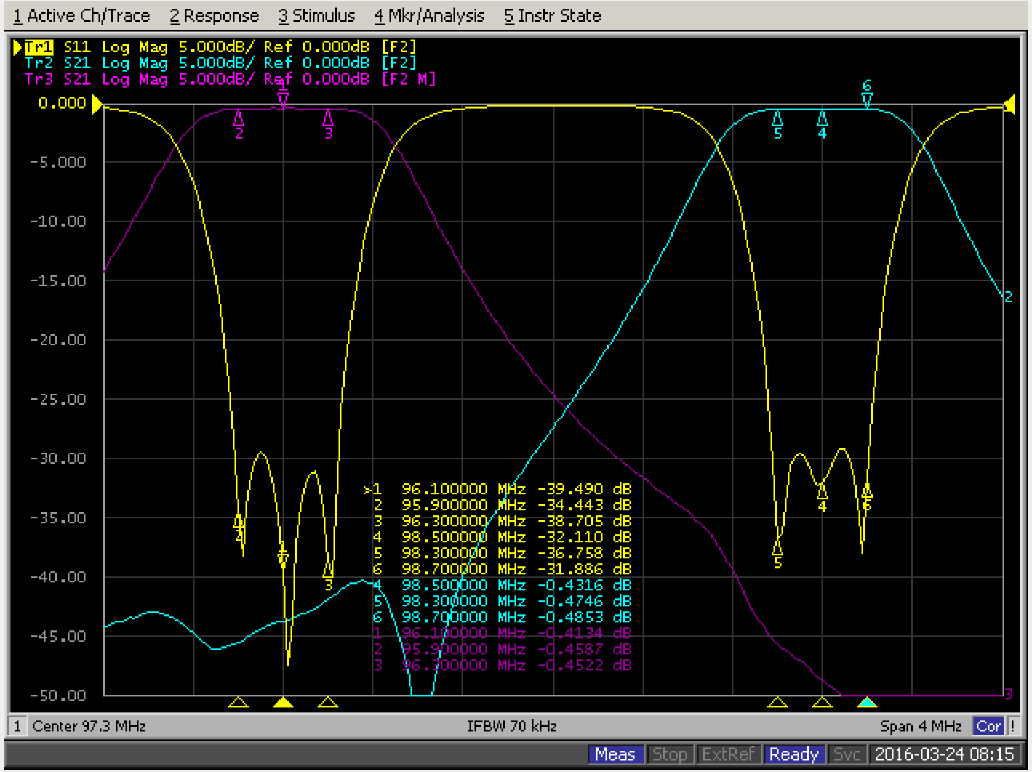
- **Simplified design**
  - Elimination of Tees and delay lines
  - One filter “box”
- **Band tunable**
  - Tee/delay line design not easily tuned
  - Spacing set by rejection levels
- **Lower cost**
  - Reduced part count
  - Same design for all channels
  - Less labor: manufacture, assemble, test
- **Easy Install**
  - Smaller size
  - Space limited sites

Sales took the picture in the chamber

Two Channel Branch Combiner

Load, Multiple Coupled Combiner

- 3-pole design
- 96.1 MHz and 98.5 MHz
- Loss < .45 dB
- VSWR < 1.08:1
- Isolation > 40dB

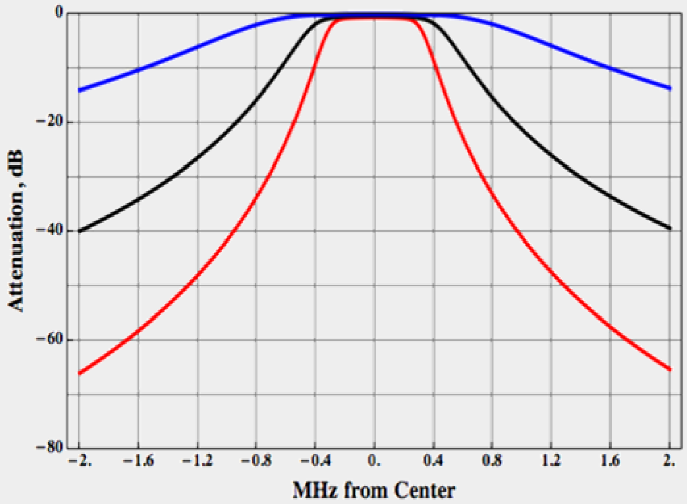


More Savings with Multiple Source Coupling

Typical FM Filter Topology

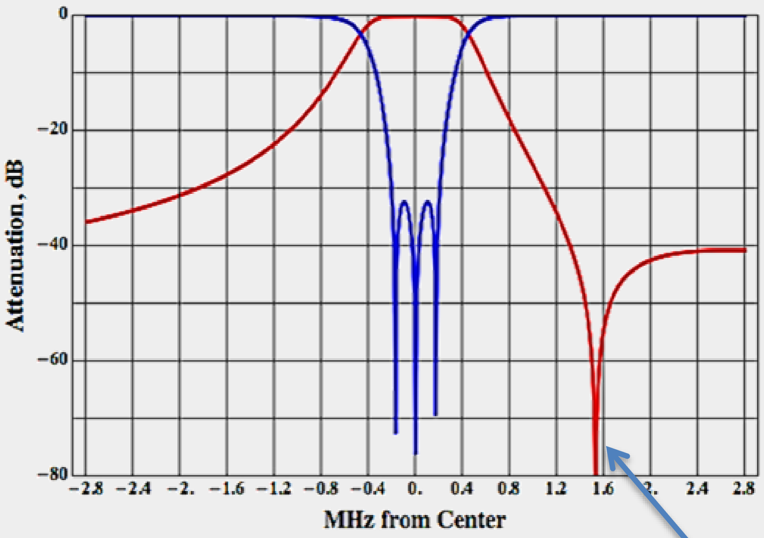
- Sequentially coupled from input to output
- Chebshev g number from lowpass prototype
- Determined normalized coupling coefficients, $M_{i,j}$
- Coupling bandwidth, $\Delta F_{1,2} = BW_r * M_{1,2}$

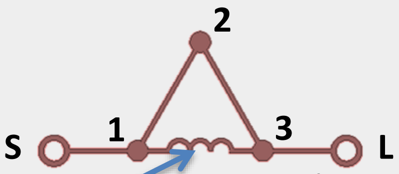
Coupling routing diagram



Number of Poles Chebyshev	Min. CH Spacing, MHz	
	CIF	Junction
2	8.4	9.0
3	1.6	2.4
4	.8	1.2

More Savings with Multiple Source Coupling





Places zero above passband

Crossed Coupled Technology

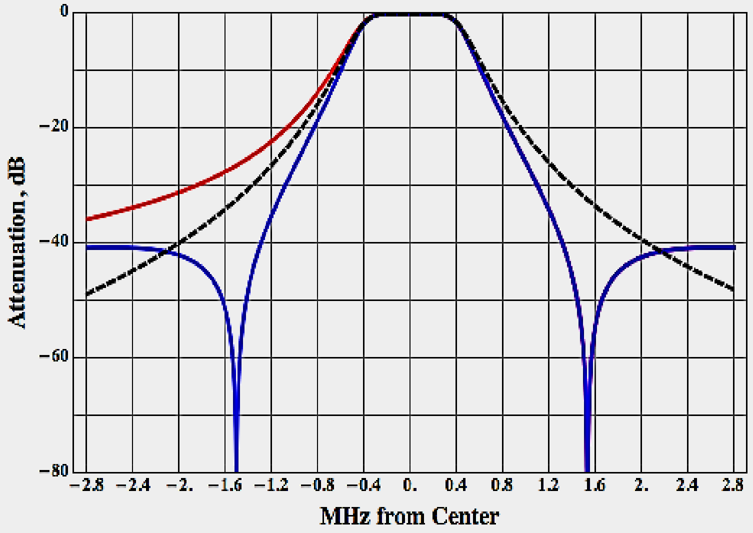
- More recently, X-coupled filters have been used to provide greater rejection
- Filters designed using insertion loss theory

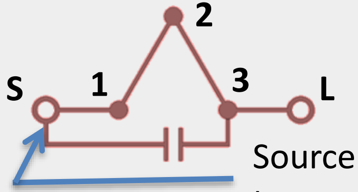
$$\frac{V_{out}}{V_{in}} = \frac{a_m S^m + a_{m-1} S^{m-1} + \cdots + a_1 S^1 + a_0}{b_n S^n + b_{n-1} S^{n-1} + \cdots + b_1 S^1 + b_0}$$

- Tri-Section, normalized coupling coefficients extracted from polynomials

	1	2	3
1	0	$M_{1,2}$	$M_{1,3}$
2	$M_{1,2}$	0	$M_{2,3}$
3	$M_{1,3}$	$M_{2,3}$	0

More Savings with Multiple Source Coupling





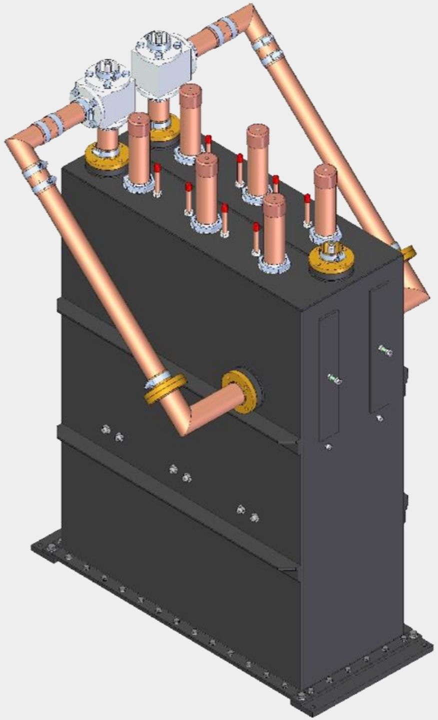
Source multi-resonator coupling, 2 transmission zeros

Multiple Source Coupling

- Tighter channel spacing for given filter order
- ***Efficiency gain***
- Size reduction
- Easy implementation

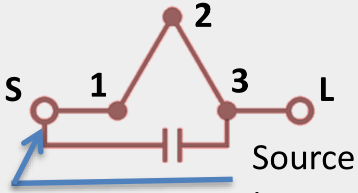
	S	1	2	3	L
S	0	1.36	0	-.052	0
1	1.36	0	1.47	0	0
2	0	1.47	0	1.41	0
3	-.052	0	1.41	0	1.39
L	0	0	0	1.39	0

More Savings with Multiple Source Coupling



Multiple Source Coupling and Efficiency

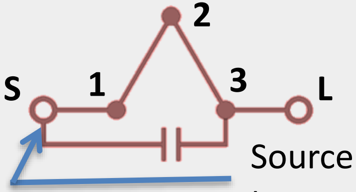
- Tighter channel spacing for given filter order



Source multi-resonator coupling, 2 transmission zeros

More Savings with Multiple Source Coupling

Plot of loss vs # of poles for LPFM

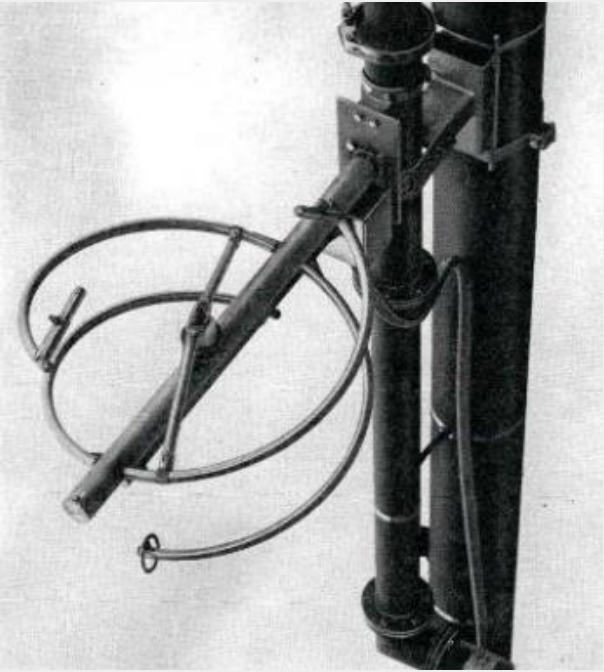


Source multi-resonator coupling, 2 transmission zeros

Multiple Source Coupling and Efficiency

- Allows for greater passband width
- Reduces loss
- Increases rejection to eliminate need for higher order filter

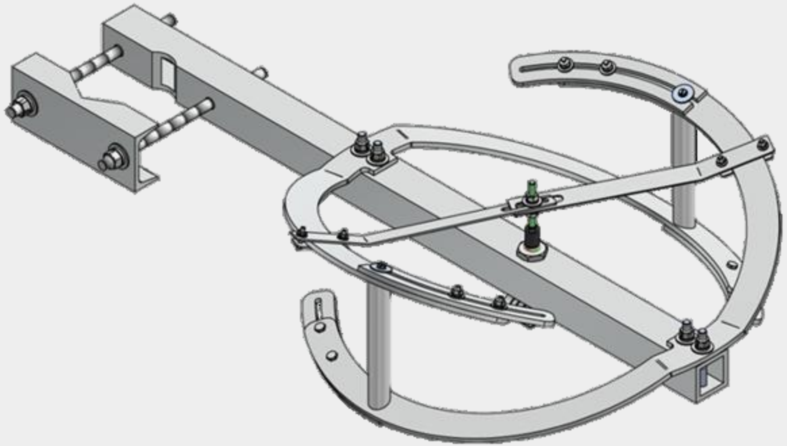
Ring Style Evolution: 1967 - Today



RCA's BFC
Introduced: NAB 1967 by Matti Siukola

Dielectric's DCRM
Example of Present Day FM Ring Style

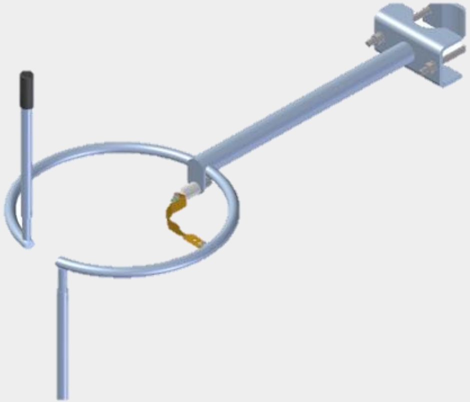
Low Power Translator Antenna



Dielectric's DCRT

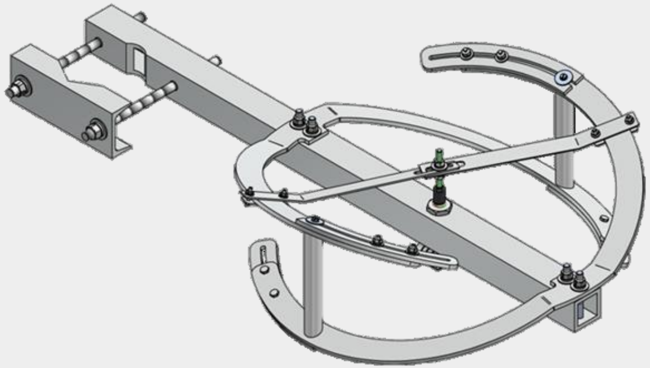
- Ring style antenna converted to the low power world
- H/V ratio controlled by helical pitch – stable across the FM band
- Assembled and tuned on site for desired frequency according to settings charts
- Impedance controlled by arm length and feed strap position

Low Power Translator Antennas



Stub Loop

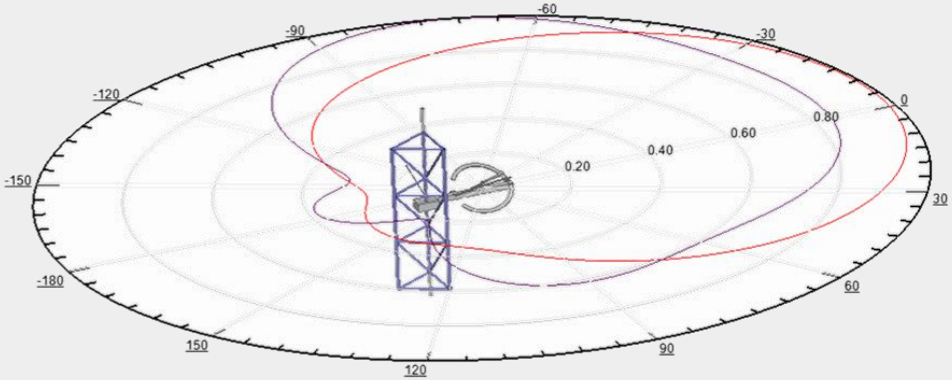
- H/V ratio and impedance controlled by feed and stub length



Dielectric's DCRT

- H/V ratio and impedance controlled independently

Translator Pattern Studies

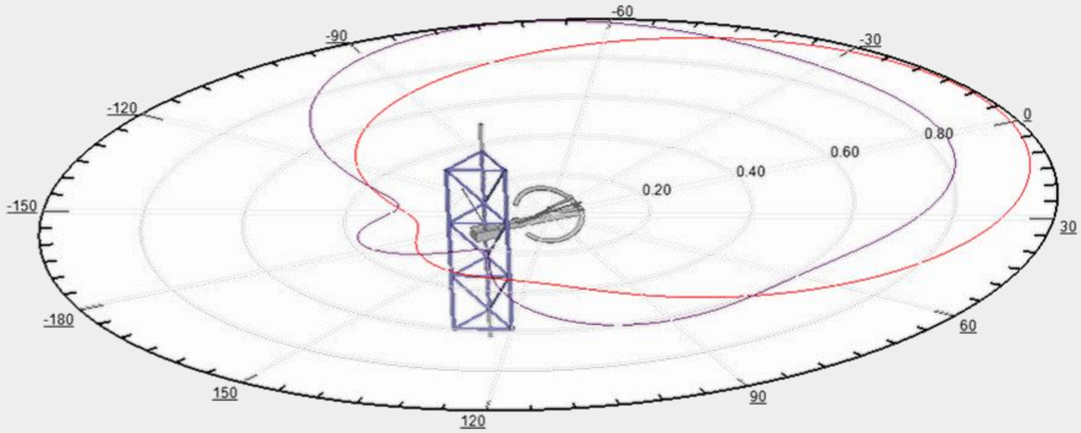


- **Traditional method** : Scaled or full size model
    - Can take longer with more antennas in the queue
    - More expensive for labor intensive patterns
    - *Not required for translator antennas*

- **Alternative method** : 3-D model evaluated using software (such as HFSS)
    - Same options as a physical model (parasitics, bay tuning, etc.)
    - Fewer resources required, faster results*
    - Cost effective in most cases

* With good starting point

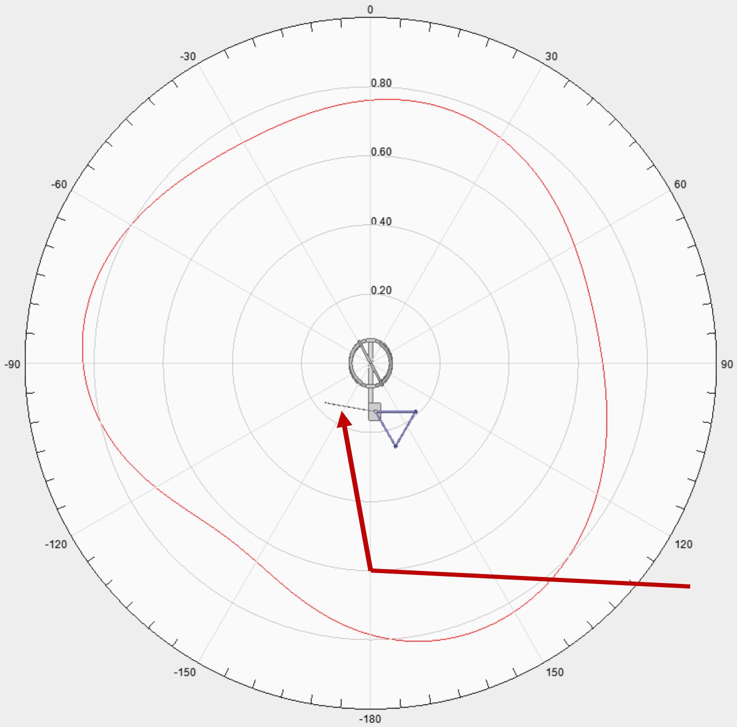
Pattern Study Example, HFSS



DCRT

- Translator application
- Single bay
- Directional
- Tower, 18.5” face, 1.5” leg, Z braced

Pattern Study Example, HFSS



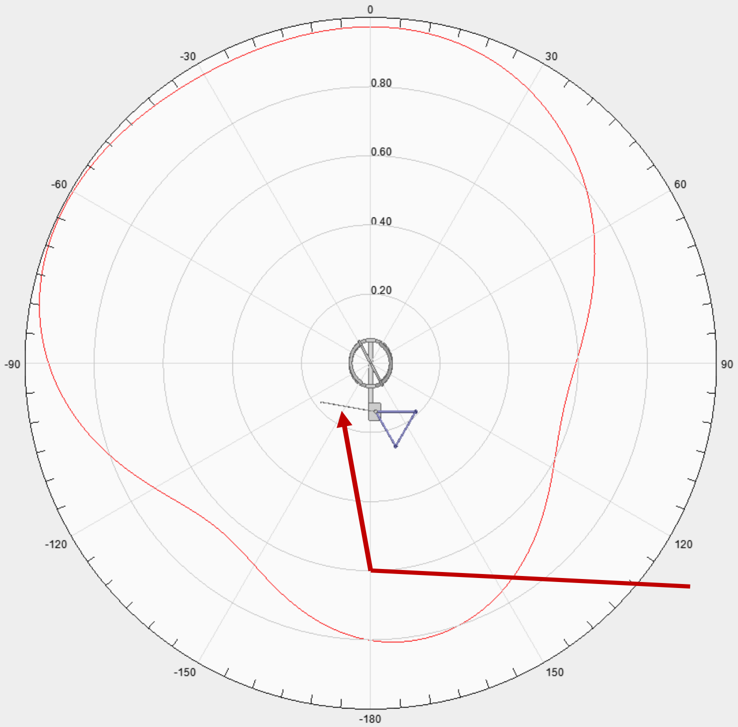
DCRT

- Import or draw tower
- Pull bay from models
- Use pattern history for starting point
  - Horizontal parasitic
  - Vertical parasitic
  - Orientation on tower

Start with one horizontal parasitic

- Distance and angle from bay optimized
- Optimize length

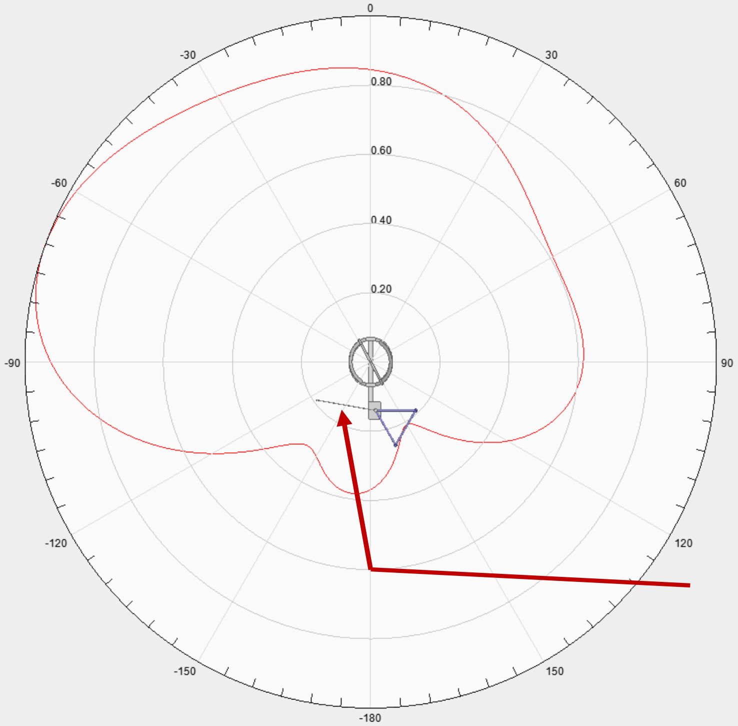
Pattern Study Example, HFSS



Start with one horizontal parasitic

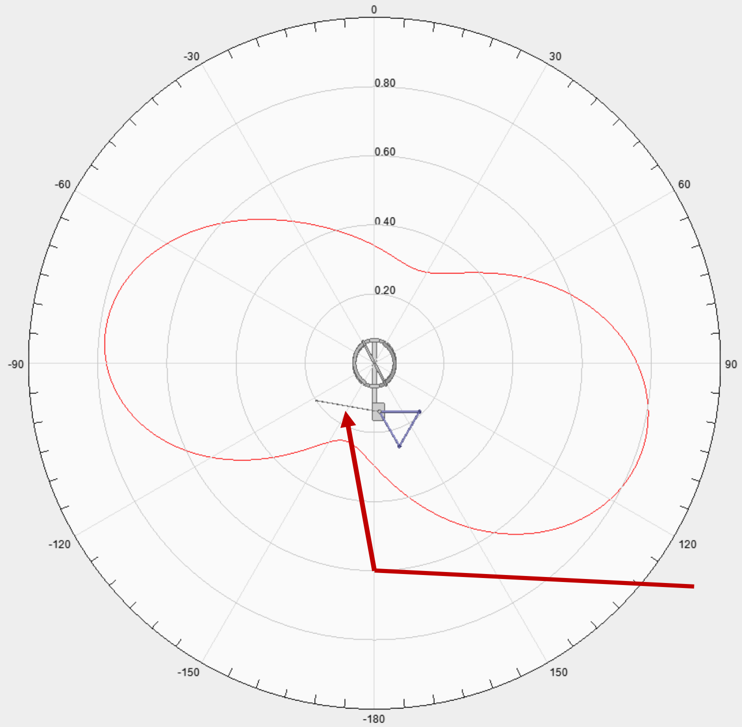
- Optimized length

Pattern Study Example, HFSS



Start with one horizontal parasitic
- Optimized length

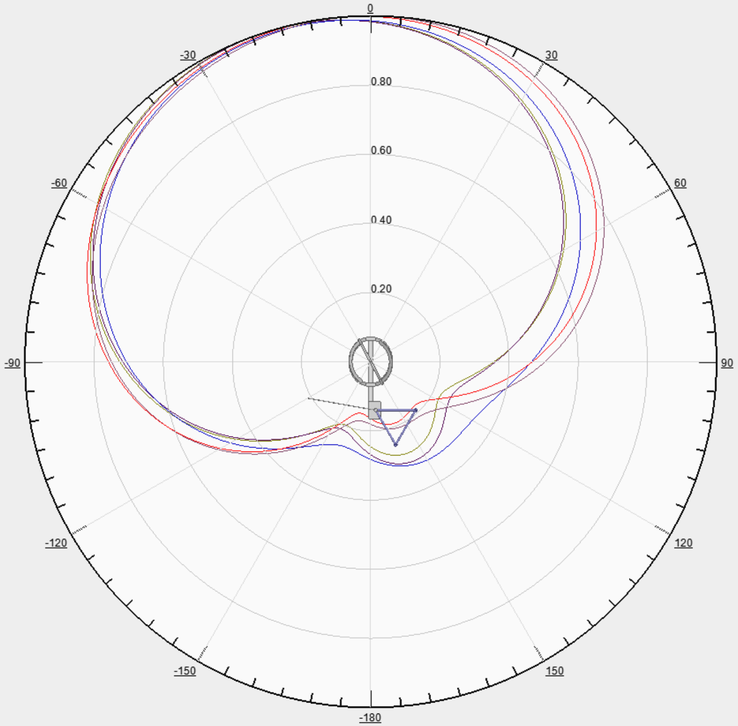
Pattern Study Example, HFSS



Start with one horizontal parasitic

- Optimized length

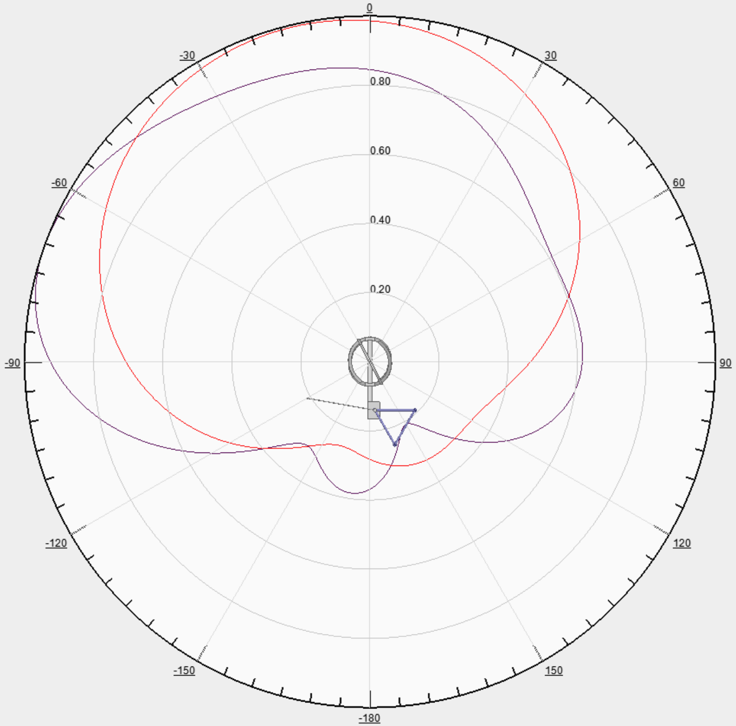
Pattern Study Example, HFSS



DCRT

- Vertical variation with horizontal parasitic

Pattern Study Example, HFSS



DCRT

- H pol
- V pol

Summary/Conclusions

- Starts with Sales
    - Communication and quick answers to problems
      (Don't let them take pictures)
- Engineering
    - Simplify design
    - Reduce part count
    - Common parts with UHF products
    - Minimize solder, braze and welding
    - Volume purchasing
        - Sheet metal
        - Aluminum where possible
- Design to reduce RF tuning and pattern study

NEED GOOD PICTURE