Today’s Presentation

- 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 capital 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)
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 $\approx n \lambda/2$ from junctions
- Tees spaced $\approx n \lambda/2$
- Short $\approx n \lambda/4$ from Tee
- Short can be replaced with 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
- Chebyshev g number from lowpass prototype
- Determined normalized coupling coefficients, $M_{i,j}$
- Coupling bandwidth, $\Delta F_{1,2} = BW_r \times M_{1,2}$

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<th>Number of Poles</th>
<th>Chebyshev</th>
<th>Min. CH Spacing, MHz</th>
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Coupling routing diagram
More Savings with Multiple Source Coupling

Crossed Coupled Technology

- More recently, X-coupled filters have been used to provide greater rejection
- Filters designed using insertion loss theory
  \[
  \frac{V_{out}}{V_{in}} = \frac{a_m S^m + a_{m-1} S^{m-1} + \cdots + a_1 S + a_0}{b_n S^n + b_{n-1} S^{n-1} + \cdots + b_1 S + b_0}
  \]
- Tri-Section, normalized coupling coefficients extracted from polynomials

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<tr>
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<td>M_{1,3}</td>
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Places zero above passband
More Savings with Multiple Source Coupling

Multiple Source Coupling

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

Source multi-resonator coupling, 2 transmission zeros

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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

Multiple Source Coupling and Efficiency

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

Source multi-resonator coupling, 2 transmission zeros
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

DCRT tunes easily with consistent H/V ratio
• **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

- 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
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 tunes easily

- 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