A New Approach to the Design of FM Bandpass Filters for IM Product Suppression and FM Channel Combining

MIDWEST REGIONAL BROADCASTERS CLINIC

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ELECTRONICS RESEARCH, INC.
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Filters in FM Broadcast Systems

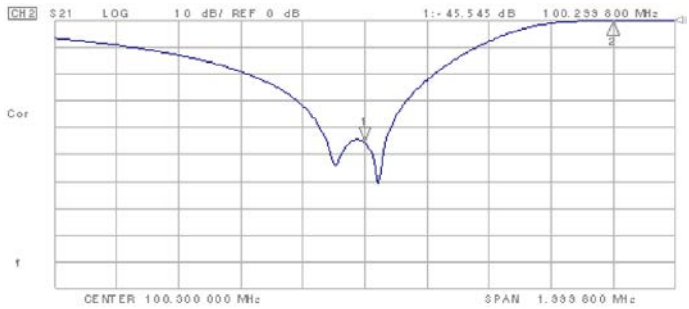
Empire State Building 19 FM Station Auxiliary FM Antenna and Channel Combiner System

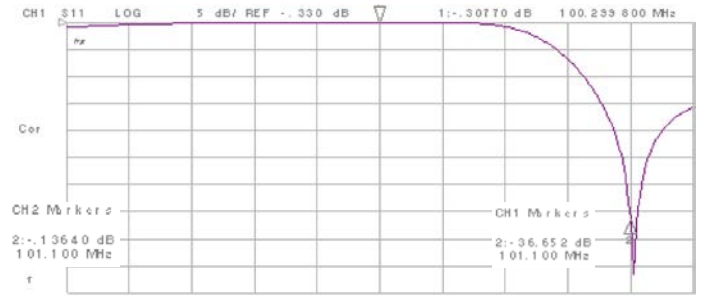
- **Protection for Intermodulation (IM) Products above the emissions mask limits set by FCC 73.317**
  - **The (IM) product results from an interfering FM station signal getting coupled into another FM station's transmitter when two or more stations share a transmitting location.**
    - Spurs created between FM stations can occur not only in the FM band but also in the low band VHF and aviation bands.
    - FCC Rule 73.317(d) specifies that spurs more than 600 kHz removed from the carrier must be attenuated below the carrier frequency by:

      80 dB or $43 + 10\ Log_{10}$ (Power in watts) dB
    - FM Stations operating transmitter output powers of 5 kW or greater must usually meet the 80 dB requirement.

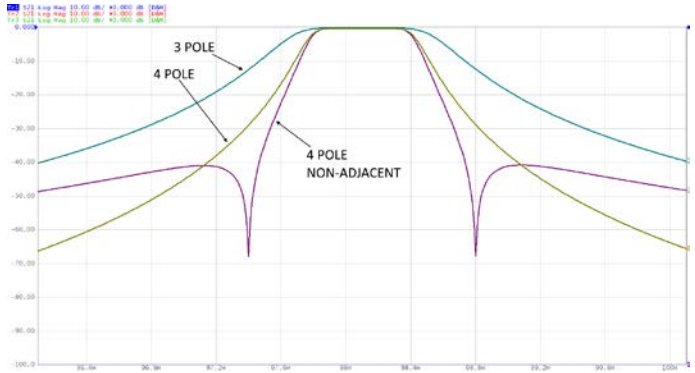
FM Filter Types

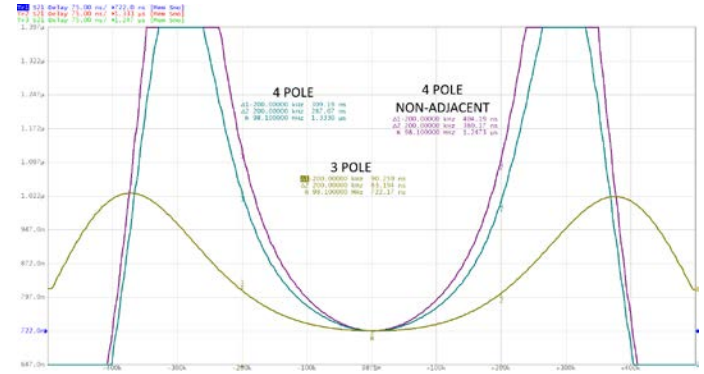
- **Notch Filters: Pass one frequency and reject one frequency**





- **Bandpass Filters: Pass one frequency while rejecting all other frequencies in the FM Band**

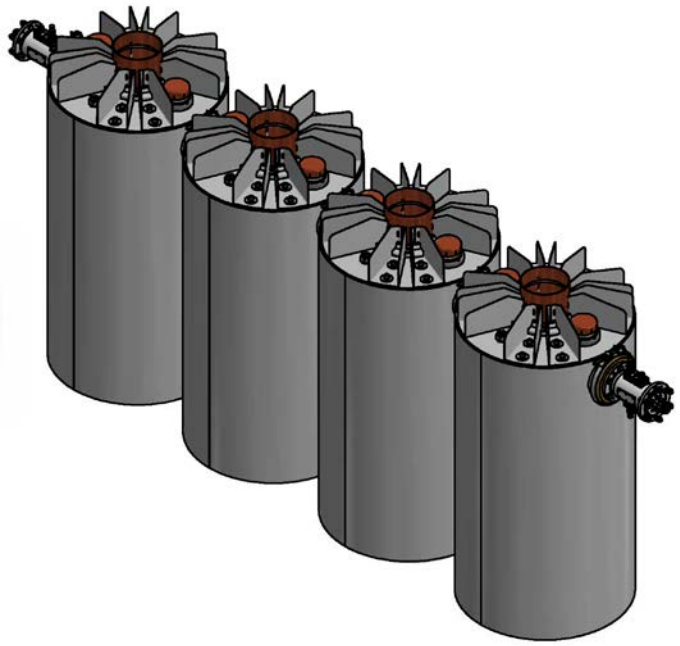




Reflective FM Bandpass Filter Configurations

- **Frequency Spacing**

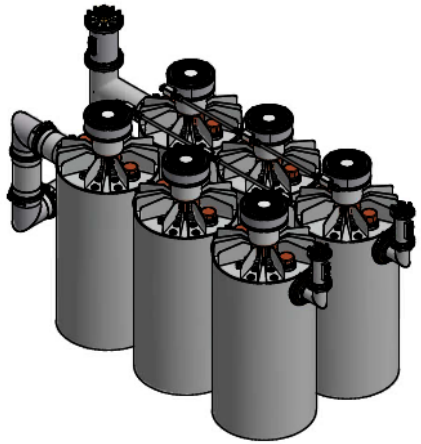
2.0 MHz channel spacing or more use three cavity filters (6 tank Constant Z)



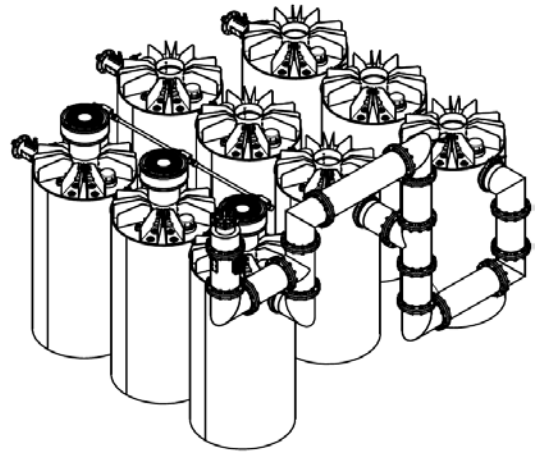
Less than 2.0 MHz spacing use four cavity filters (8 tank Constant Z)

Less than 1.2 MHz spacing uses four cavity filters with non-adjacent coupling

FM Combiners with Reflective Bandpass Filters

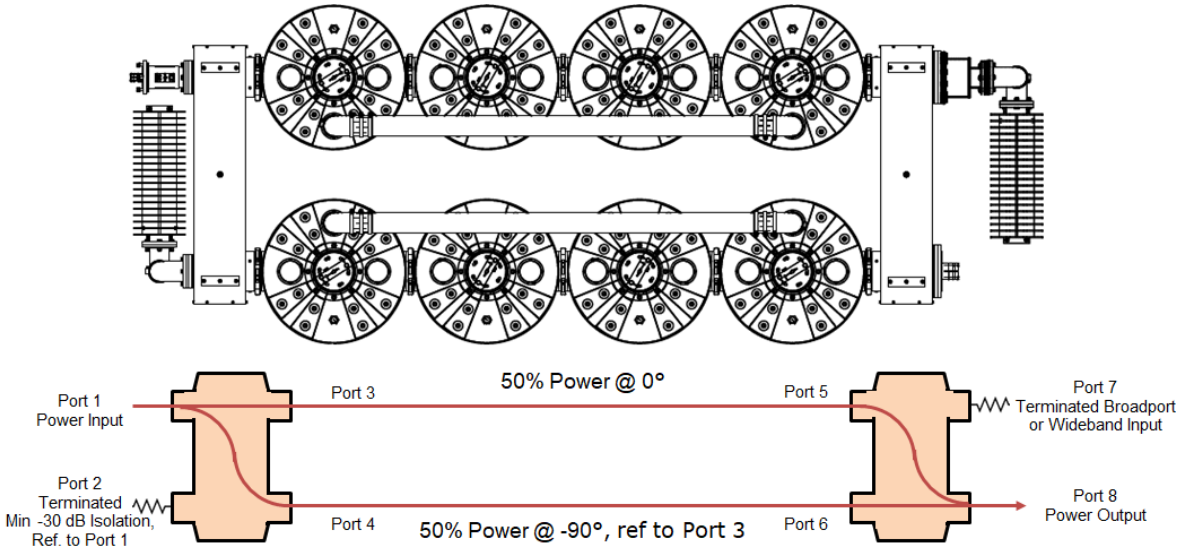


- **Tee or Junction Combiners**
  - **Two (2) 3 or 4-Section Reflective FM Bandpass Filters**
  - **Combined with a Coaxial Tee or Starpoint Junction**
    - **Pros**
      - **Provides good isolation between frequencies**
      - **Consistent insertion loss and group delay for all channels**
      - **Compact Physically and Low Cost**



- **Manifold Combiners**
  - **Three (3) or Four (4) 3 or 4-Section FM Bandpass Filters**
  - **Combined with a series of Coaxial Tees**
- **Cons**
  - **Input return loss performance dependent on the match at the system output**
  - **Reflective filters return out-of-band energy to the source**

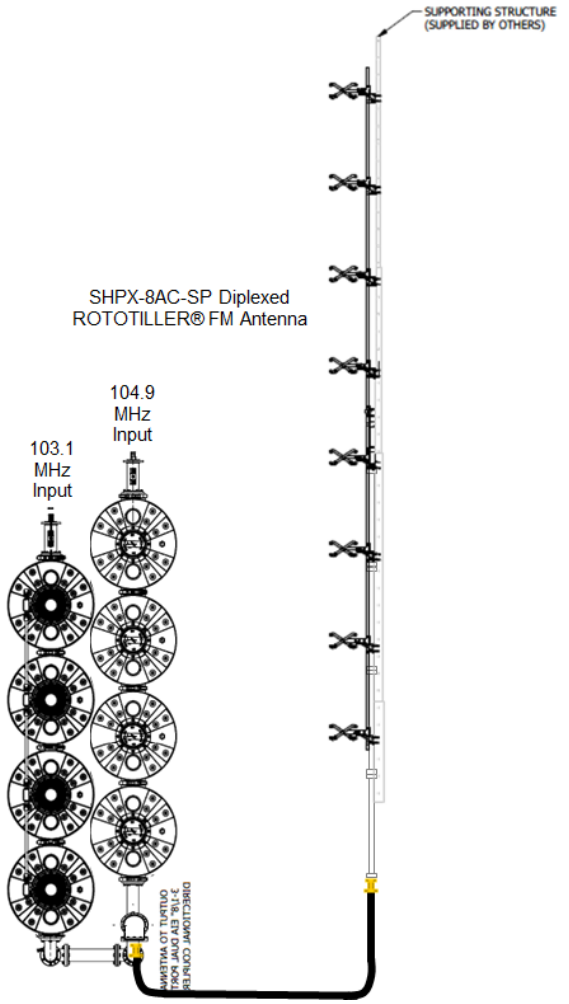
Constant Impedance FM Bandpass Filter



- Reflective Bandpass Filters in a Hybrid Ring
- Hybrids compensate for load variations
- Individual combiner modules are physically large
- More expensive with the additional filter and hybrids
- Benefit of unlimited expansion, new signals added easily

Two FM Station Combined System

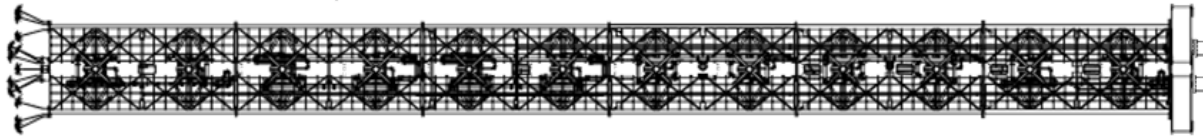
- FM Tee Combiner to combine 103.1 MHz and 104.9 MHz
- Eight-bay diplexed ROTOTILLER® FM Antenna
- 200 feet of rigid line for double slug tuning to optimize system match at both frequencies plus 380 feet of 4-inch semiflexible transmission line



2 or 3 Station Combined Systems with Reflective Filters

- Simple, low-cost systems that deliver excellent performance and long, useful life.
- In most cases, they utilize standard full-wave or half-wave spaced ROTOTILLER® FM antennas.
- Simple, field-proven multi-slug tuning to optimize the match and minimize VSWR.
- Overall system return loss performance relies on the match of the FM antenna and transmission line at the combiner output.

FM Channel Combiner with Constant Impedance Bandpass Filters

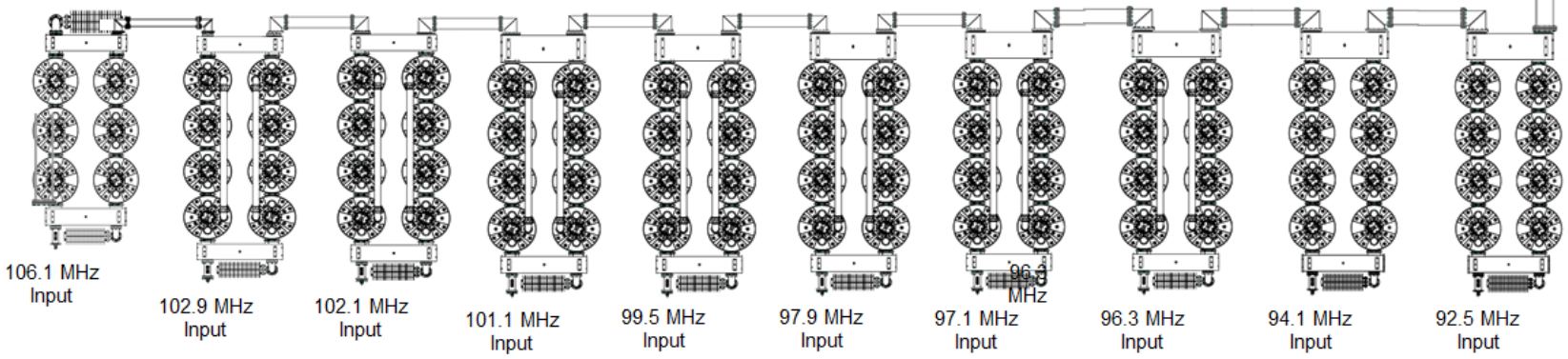


COG3-20P-12CP-240 Master FM Antenna
(Separate inputs for upper six-bays and lower six-bays

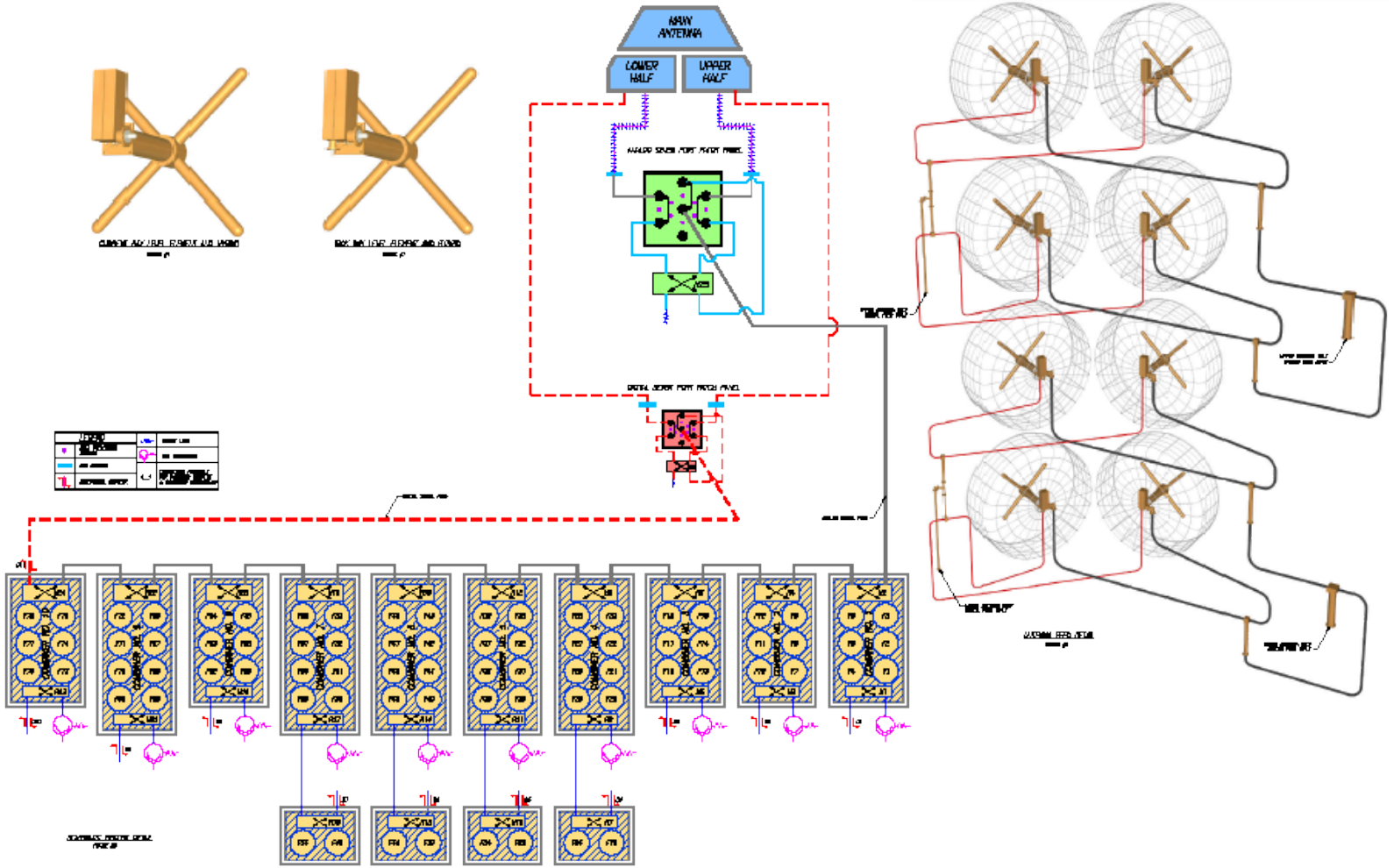
Ten (10) FM Station Power Analysis					
Antenna Model:	COG3-20P-12CP-2				
	Analog			**-10 dBc HD Radio-™**	
Combined power into Each Antenna Input:	79.236 kW	8,901 volts		7.924 kW	2,815 volts
Total Analog and Digital:	**87.160 kW**	**11,716 volts**			
Combined power into Each Transmission Line:	88.566 kW	9,411 volts		8.857 kW	2,976 volts
Total Analog and Digital:	**97.422 kW**	**12,387 volts**			
Combined Power Output into Power Divider:	177.132 kW	13,309 volts		17.713 kW	8,417 volts
Total Analog and Digital:	**194.845 kW**	**21,726 volts**			

Elevated HD Radio Power Levels Require Special Consideration

7-Port Patch Panel and Power Divider

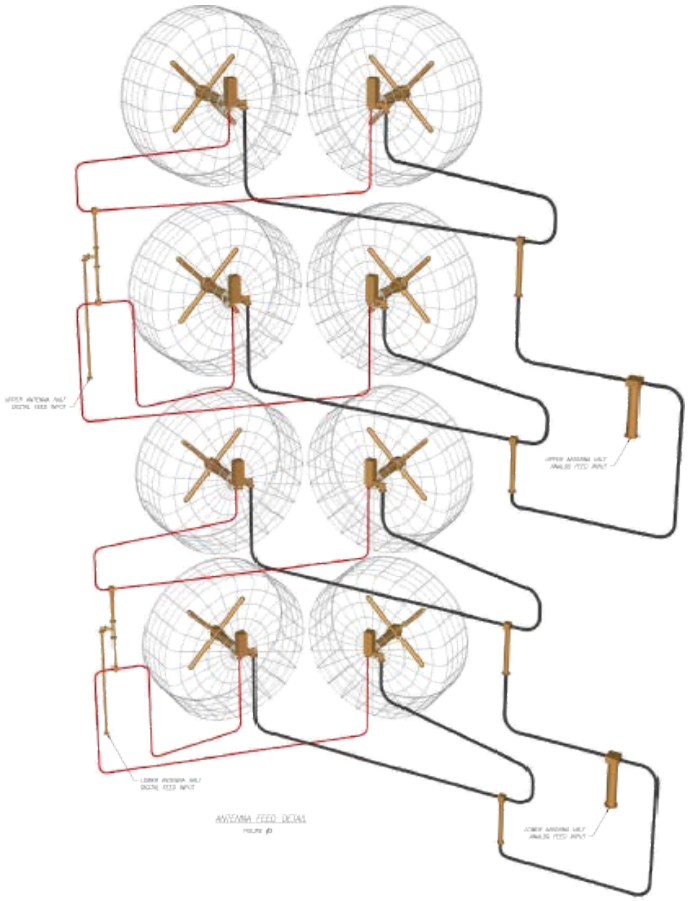


Master FM Antenna Solution Based on Reverse Fed Combiner Systems for HD Radio™

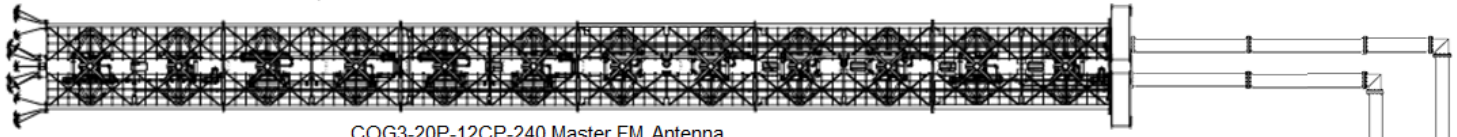


Master FM Antenna Solution High Power HD Radio™

- Empire State Building Master Antenna System fed with two transmission lines
  - Ten (10) stations into right-hand CP input
  - Nine (9) stations into left-hand CP input
- Transmission lines do not require phasing
  - Operation at dissimilar power levels – Not an Issue
- Empire FM Auxiliary is a three-bay custom design with (N-1)/N array design providing optimum downward radiation suppression with 80-inch bay spacing

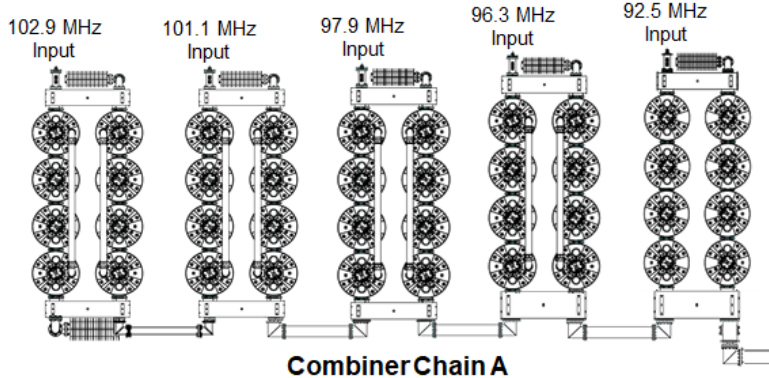


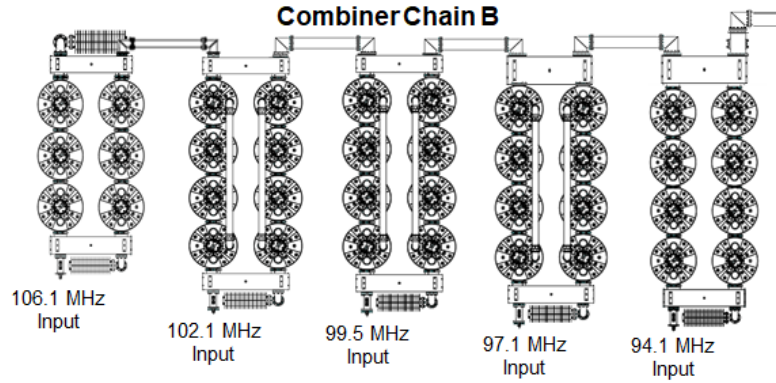
FM Channel Combiner with Constant Impedance Bandpass Filters



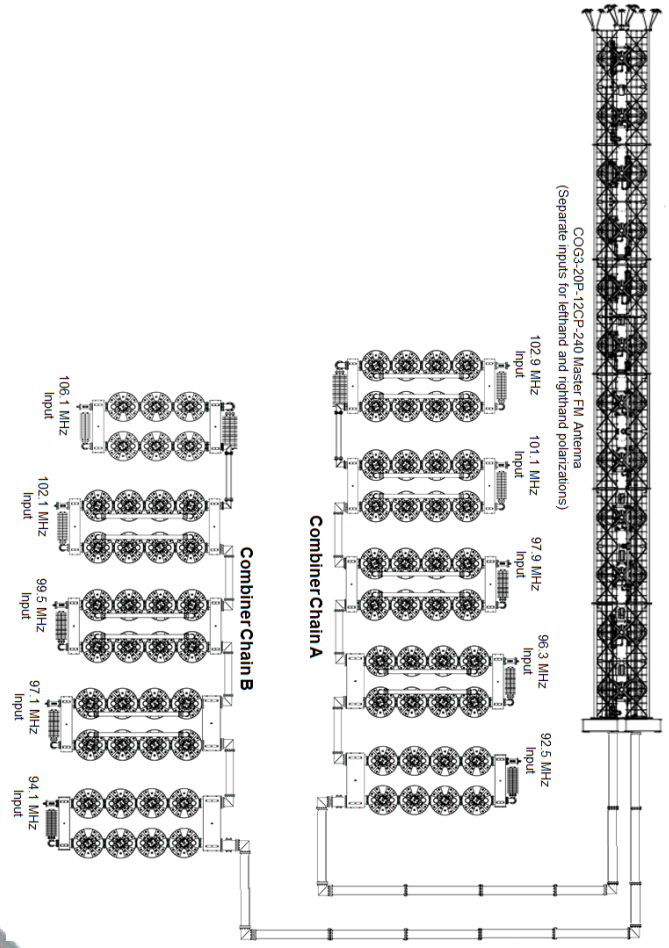
COG3-20P-12CP-240 Master FM Antenna
(Separate inputs for lefthand and righthand polarizations)

Ten (10) FM Station Power Analysis					
Antenna Model:	COG3-20P-12CP-2				
Righthand CP Input (Chain A)	**Analog**			**-10 dBc HD Radio-™**	
Combined power into Antenna:	79.213 kW	6293.086 kW		7.921 kW	3980.097 kW
Total Analog and Digital:	87.135 kW	10,273 volts			
Combined Power Output:	96.275 kW	6,938 volts		9.628 kW	4,388 volts
Total Analog and Digital:	105.903 kW	11,326 volts			
Lefthand CP Input (Chain B)	**Analog**			**-10 dBc HD Radio-™**	
Combined power into Antenna:	79.259 kW	6,295 volts		7.926 kW	3,981 volts
Total Analog and Digital:	87.184 kW	10,276 volts			
Combined Power Output:	96.494 kW	6,946 volts		9.649 kW	4,393 volts
Total Analog and Digital:	106.144 kW	11,339 volts			





Dual Input FM Panel Systems



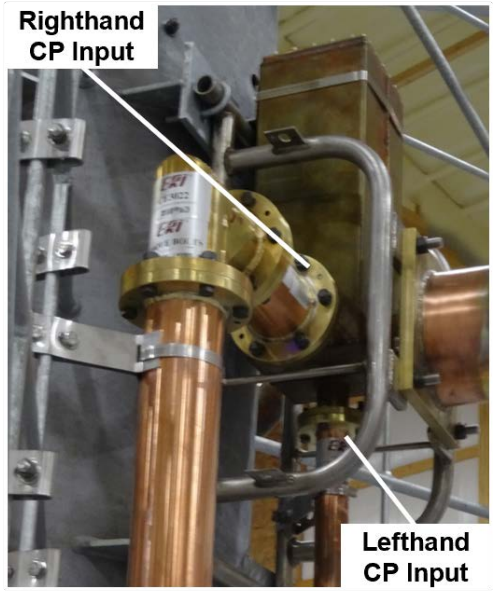
- Significant reduction in the system's combined average power and peak RF voltages.
- Eliminates the expensive patch panel, power divider, 9-3/16-inch components from the system.
- The phased transmission lines used in traditional master FM antenna systems are not required.
- Utilizes the antenna elements and hybrids' full power and voltage handling capability.

Dual Input FM Panel Systems

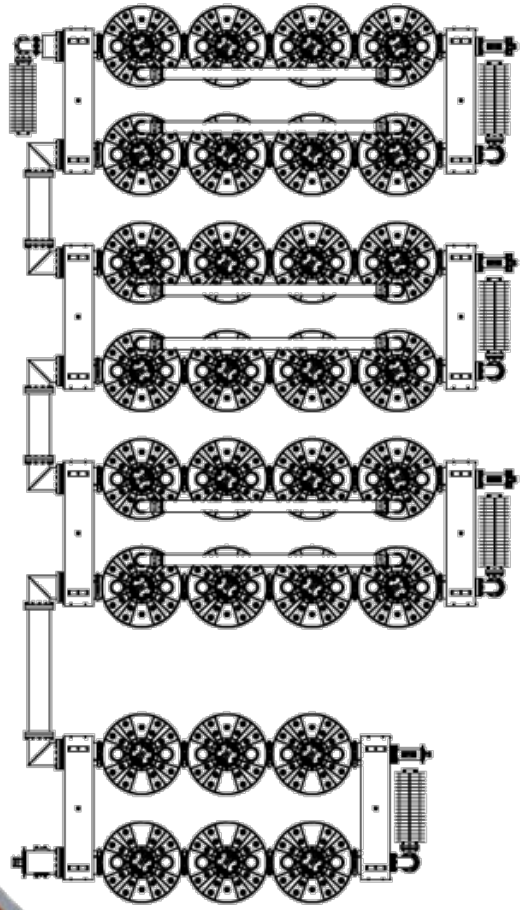
- The element hybrids have a minimum isolation specification of -30 dB across the entire FM band.
- The complete system of elements, hybrids, power dividers, and associated interbay cabling generally performs better than -25 dB of isolation across the band.
- The environment often has a significant impact on isolation and match of the antenna.

Dual Input FM Panel Systems

- The antenna system isolation over the FM band is limited to -25 dB.
- Coupling between the Righthand and Lefthand polarized signals does occur.
- A constant impedance combiner compensates for changes in match and the loads dissipate any coupled energy without reradiating these signals.



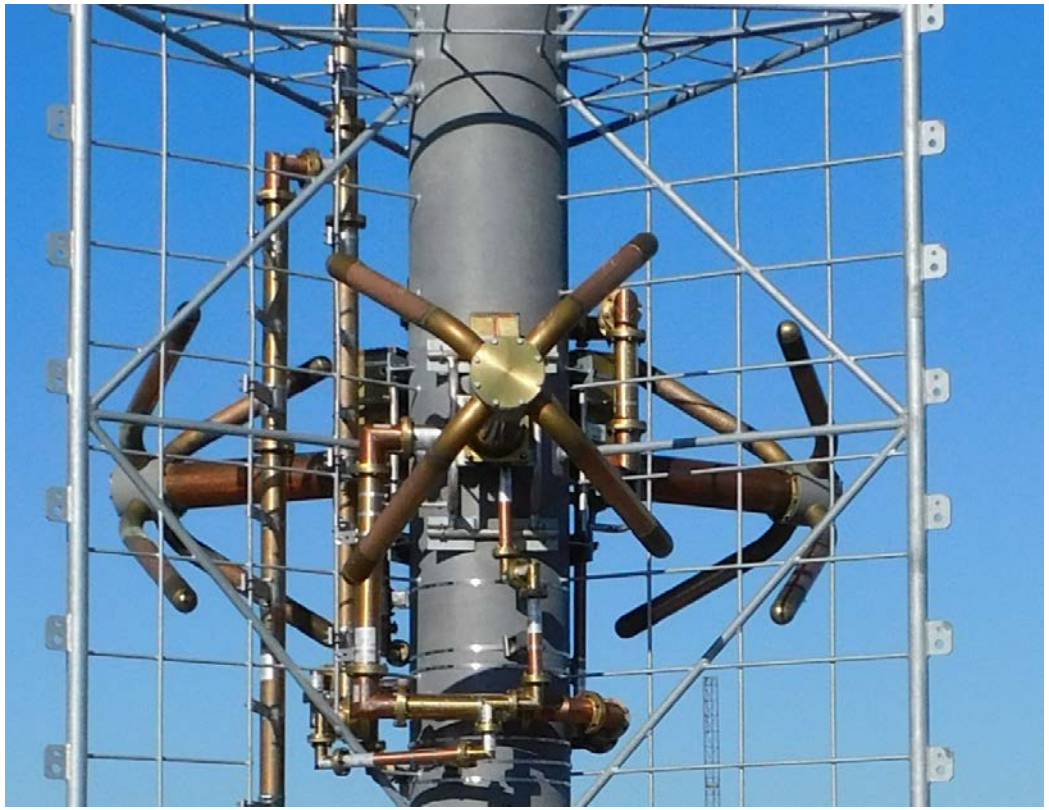
Dual Input FM Panel Systems



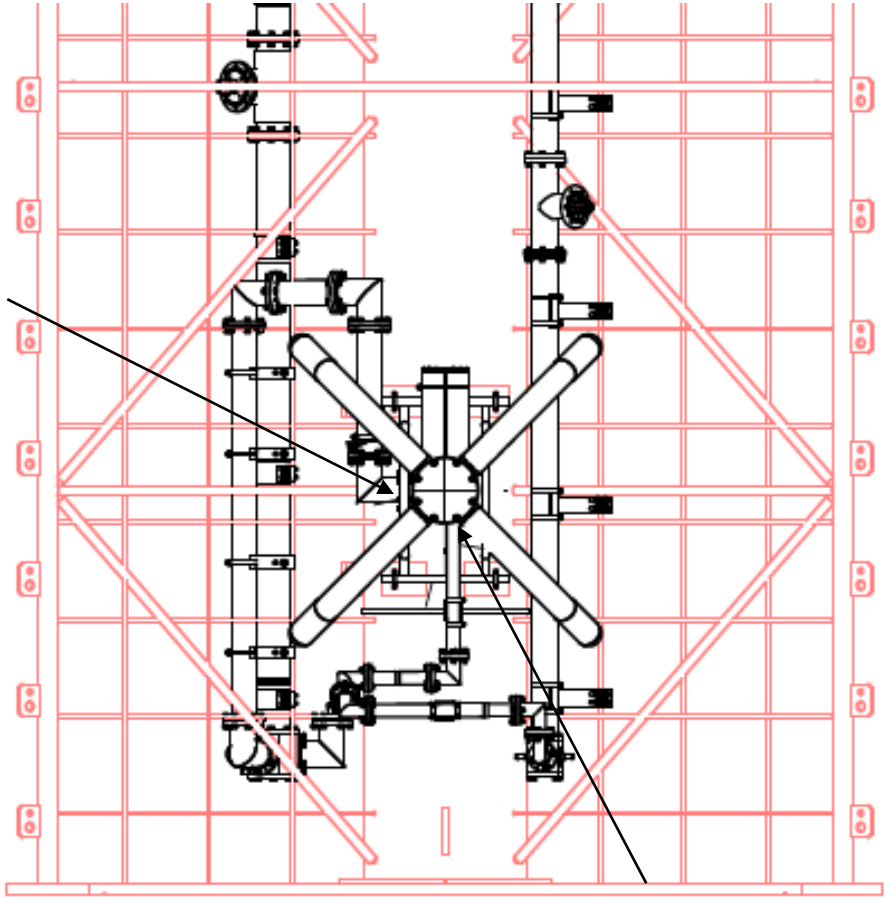
- Changes in weather conditions and ice on the FM antenna elements affect the FM antenna and the transmission line system match and isolation.
- Can cause source-induced multipath that can negatively impact the individual stations using dual input FM antenna systems with combiners using reflective bandpass filters.
- Constant impedance combiners eliminate these items as concerns as the reject loads in the system absorb any reflected energy and compensate for load fluctuations with no impact on system performance.
- The hybrids that are an integral part of the system add transmitter isolation, which is beneficial for channel combiner systems, particularly in systems that include many stations, high FM transmitter power outputs, elevated HD Radio™ power levels, and closely spaced frequencies.
- Constant impedance FM channel combiner systems are a more flexible system design for future system modifications.

Single Master FM Antenna Solution for Directional and Nondirectional Stations

- Dual Input 1180 Elements on a COGWHEEL® Support Spine
- Separate Inputs with Clockwise and Counterclockwise circular polarization
  - Clockwise Input is Nondirectional
  - Counterclockwise Input is Directional

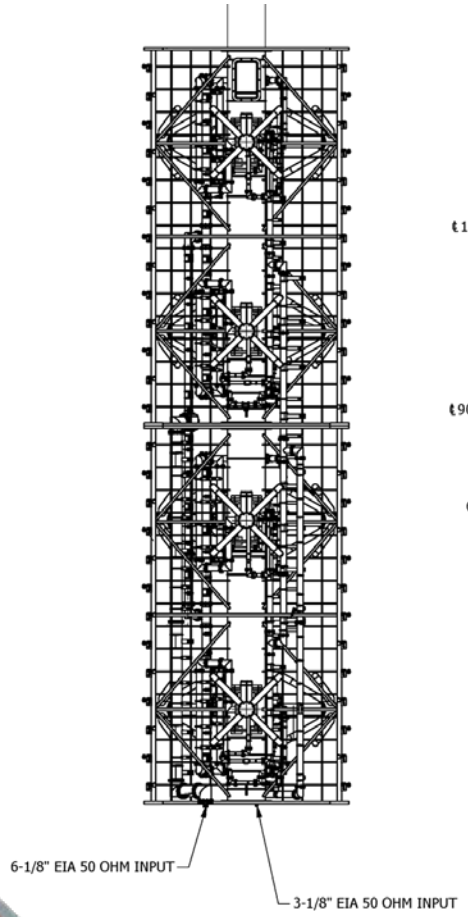


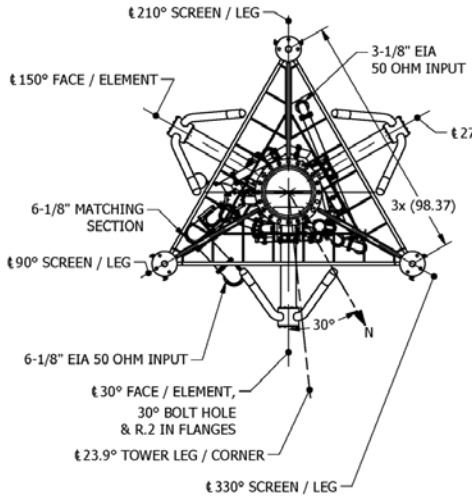
Master FM Antenna Solution

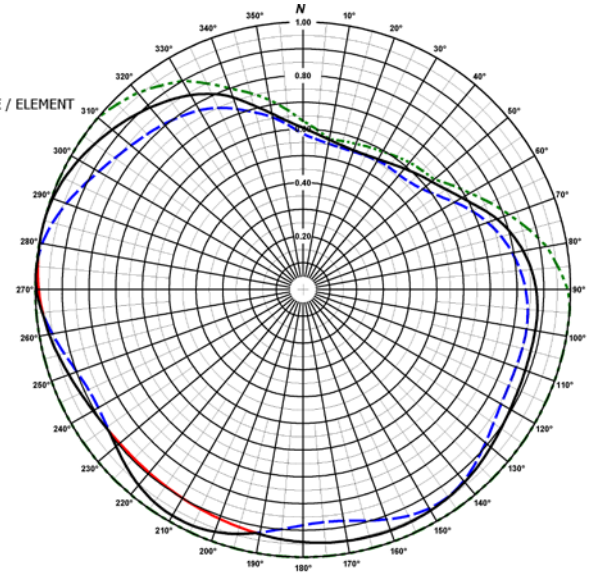


- **Righthand polarization inputs are fed with equal power levels in every element of each bay**
- **The Lefthand polarization feed harness has asymmetrical power division and is phased to provide the desired WTOP-FM directional azimuth pattern**

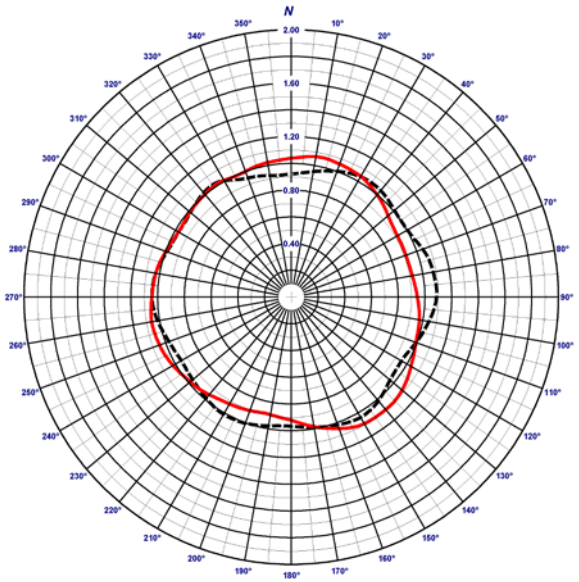
COGWHEEL® Master FM Antenna







WTOP-FM Directional Pattern
Lefthand CP Input

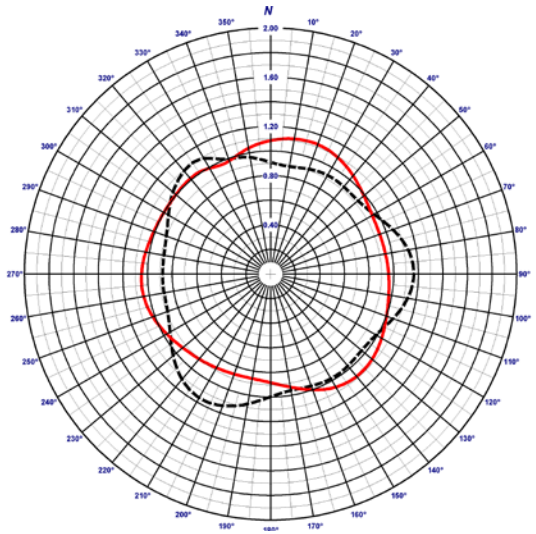


WTOP-FM Nondirectional Pattern
Righthand CP Input

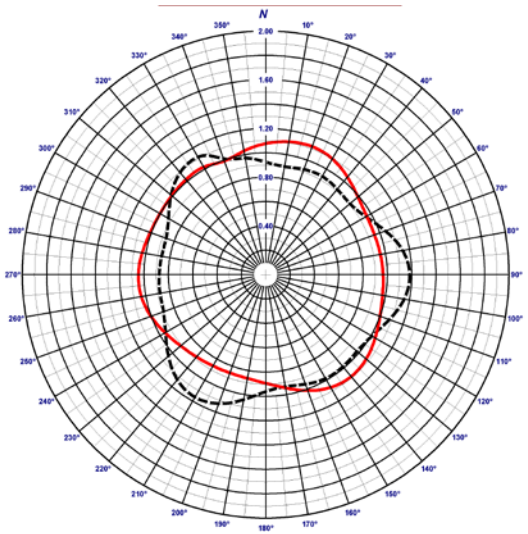
HORIZONTAL VERTICAL COMPOSITE FCC ENVELOPE

COGWHEEL® Master FM Antenna

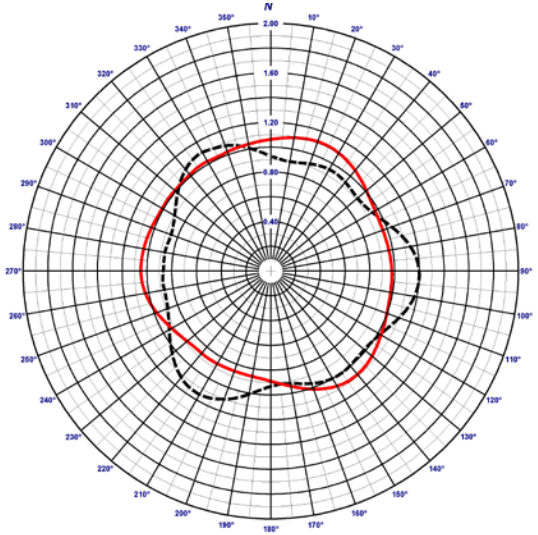
Righthand CP Input



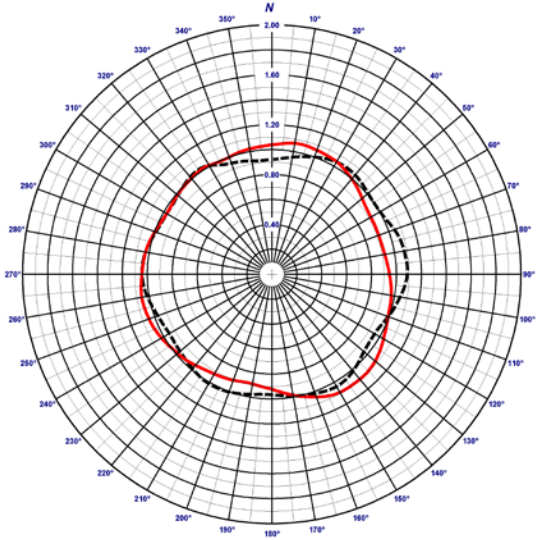
WAMU 88.5 MHz



WPFW 89.3 MHz



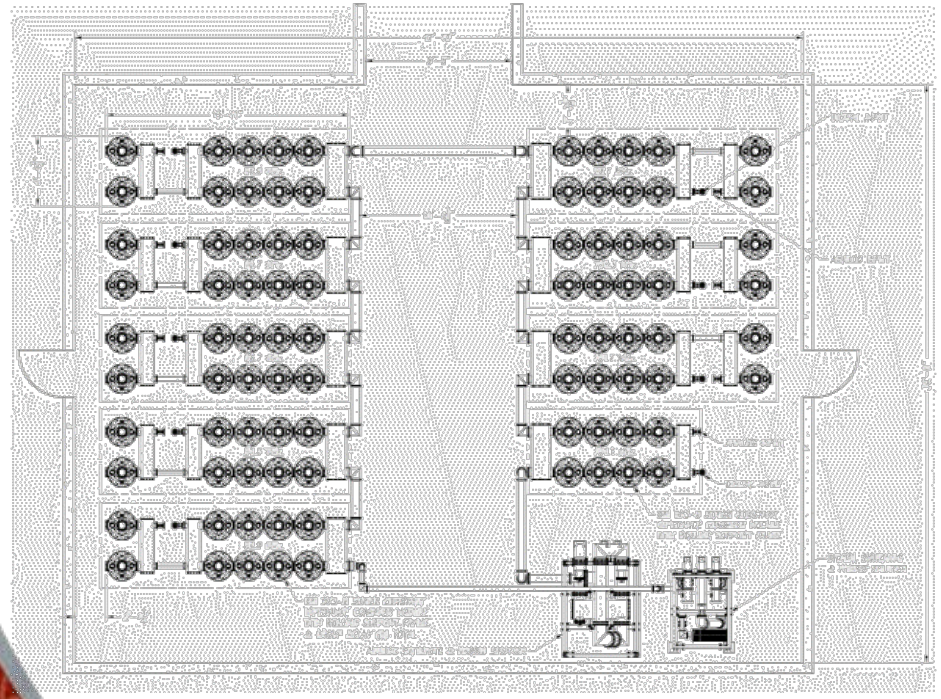
WETA 90.9 MHz



WTOP-FM 103.5 MHz

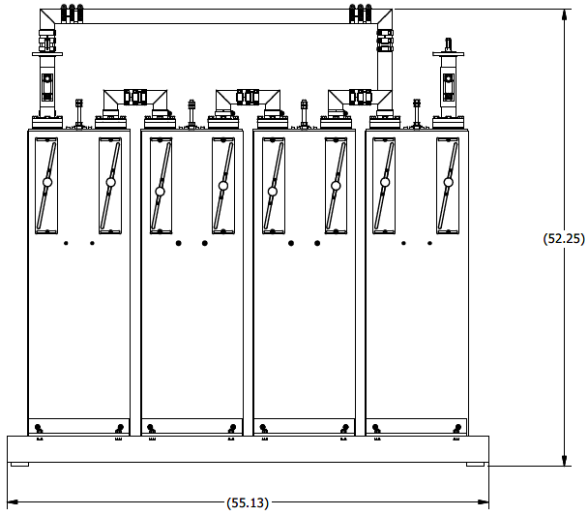
VERTICAL HORIZONTAL

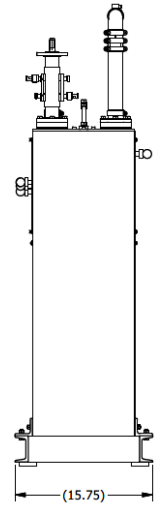
The Space You Would Like for Your Nine (9) FM Station Combiner System

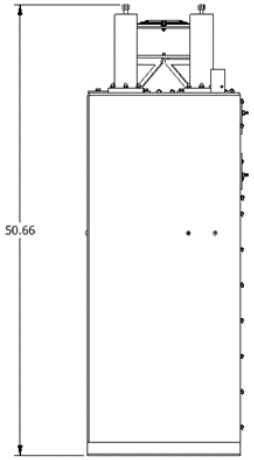


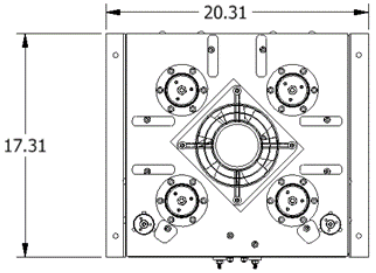
The Space You Have for Your Nine (9) Station FM Combiner System

FI940 Versus 955 Four-Pole FM Bandpass Filter





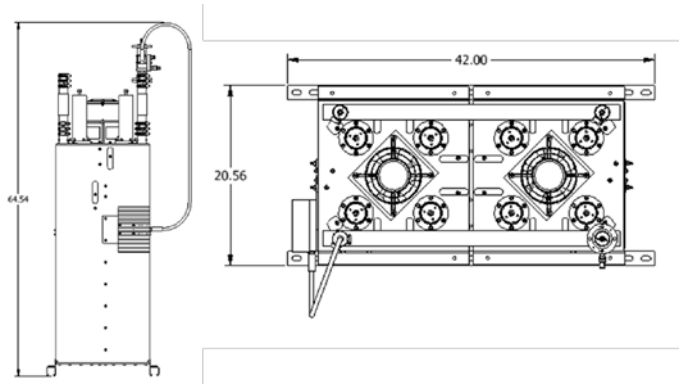


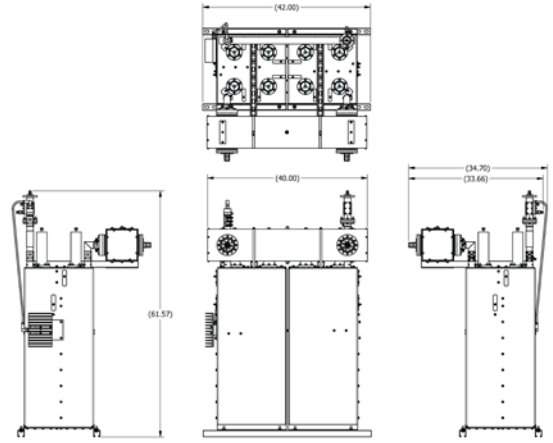


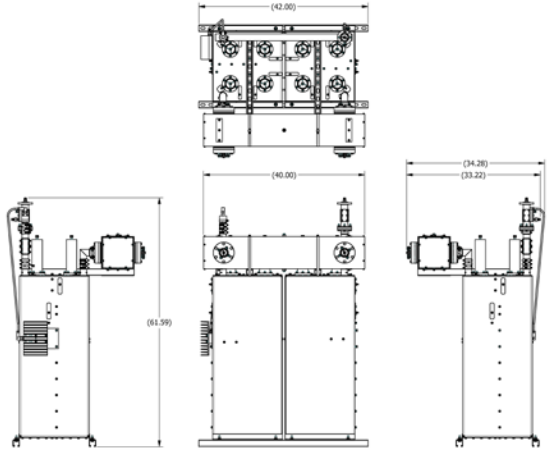
FI940 Reflective FM Bandpass Filter

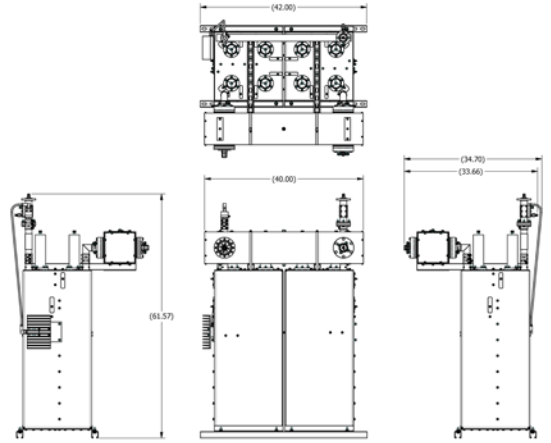
- Includes cross-coupling for higher rejection for use in applications with closely spaced frequencies
- Folded design for minimum footprint
- ERI's Bellows Temperature-Compensation Technology, temperature stable using Invar
- Rugged 3/16-inch thick aluminum construction eliminates the oil-can effect from heating
- 1-5/8-inch EIA Flanged or Unflanged Input and Output connections
- The filter can be tuned to different bandwidths based on the need
- Factory tuned to customer's specified channel yet can be easily field converted to any FM channel

FI940 Constant Impedance Models

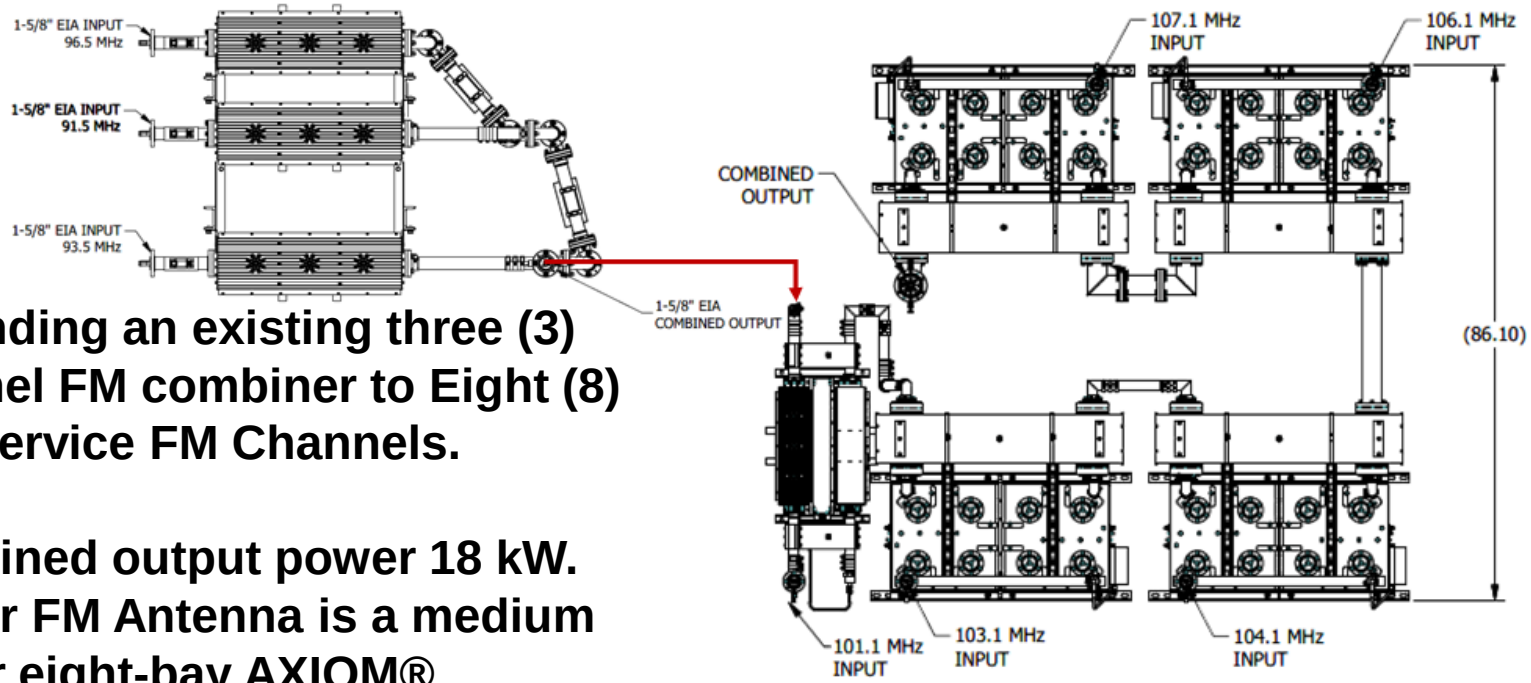








DMS Broadcasting, Cayman Islands



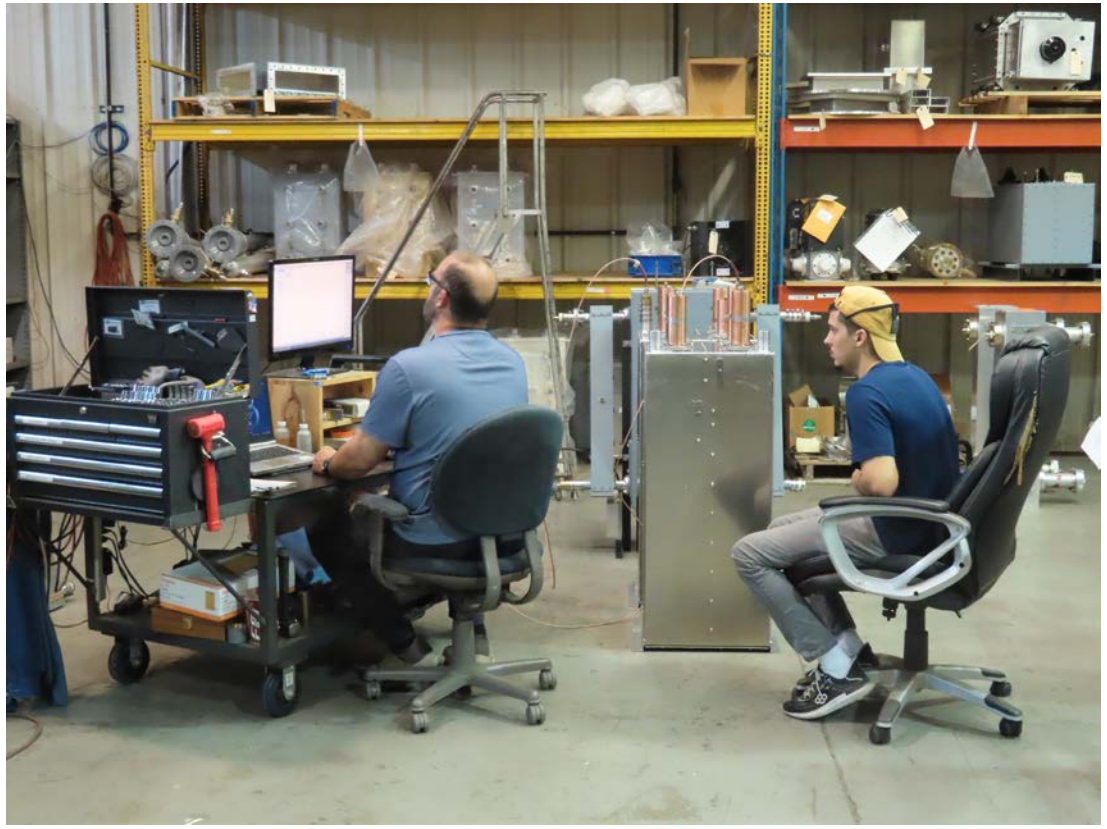
Expanding an existing three (3) channel FM combiner to Eight (8) Full-Service FM Channels.

Combined output power 18 kW. Master FM Antenna is a medium power eight-bay AXIOM®

DMS Broadcasting, Cayman Islands

DMS Broadcasting, Cayman Islands

DMS Broadcasting, Cayman Islands



Questions?

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