Band-Tunable TV Mask Filters and FM combiners

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Overview

Tunable UHF filters 100 W to 6 kW (ch 14 to E69)

New 20 kW band tunable mask filter (ch 14-51)

FM Combiners

Filter Tuning
Why Mask Filters?
Powerlite Series of Filters

100-250 Watt

600 Watt

3000 Watt
With water cooling to 7000 W

1500 Watt
Why Band-tunable?

- Accommodate channel change
- Transmitter is band-tunable
- Transmitter / Filter can be moved from one site to another
- Transportable backup transmitter is feasible

- Common parts for wide channel range
  - Volume manufacturing
  - Parts can be stocked
Why higher power tunable filters?

Cylindrical Waveguide Constant Impedance Filter (CIF)
1200 pounds (544 kg)

CHANGING CHANNEL?
New Product

10 kW (air cooled)
20 kW (water cooled)
3 1/8” and 4 1/16” connections
Tunable filter
• Channel 14-51

Weight 105 lbs (48 kg)
Why higher power tunable filters?

- New Solid State Transmitters Approach IOT Efficiency
- Liquid Cooled Transmitters are Becoming More Accepted

- Mask Filters are Generally Average Power Limited (heat)
- Liquid Cooling Available for Filter Using Tx Heat Exchanger
- Additional Heat Load from Filter is about 1 kW

- Solid State Transmitters are OK with Reflective Filter
- IOT Transmitters Need CIF for proper functioning

- Current Solid State Offerings easily band tunable

- Channel 14-51 chosen to accommodate US spectrum auction and channel repack
Why higher power tunable filters?

**Dual Mode Cylindrical Waveguide Filter**
- Advantages
  - Low Loss (~97% efficiency)
  - Free Convection Cooling
- Dis-Advantages
  - Large, Heavy
  - Cavities cut to order

**Coaxial Cavity Band Tunable Filter**
- Advantages
  - Smaller, Lighter
  - Parts can be stocked
- Dis-Advantages
  - Higher Loss (~93% efficiency)
  - Requires water cooling
## New Filter Specs

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Range</td>
<td>14-51</td>
</tr>
<tr>
<td>Number of Poles</td>
<td>6</td>
</tr>
<tr>
<td>Mask</td>
<td>ATSC full</td>
</tr>
<tr>
<td>I/O connectors</td>
<td>3 1/8” or 4 1/16”</td>
</tr>
<tr>
<td>Input Power Rating</td>
<td>20 kW or 25 kW</td>
</tr>
<tr>
<td>Insertion Loss</td>
<td>0.27 dB max fc</td>
</tr>
<tr>
<td></td>
<td>0.38 dB max ±2.69 MHz</td>
</tr>
<tr>
<td>Effective Loss</td>
<td>0.29 dB max</td>
</tr>
<tr>
<td></td>
<td>(93%-95% efficiency)</td>
</tr>
<tr>
<td>Group Delay Var.</td>
<td>150 ns (fc±2.69 MHz)</td>
</tr>
<tr>
<td>Input Return Loss</td>
<td>26 dB min (fc±2.7 MHz)</td>
</tr>
<tr>
<td>Ambient Temp Range</td>
<td>0°C to 40°C (32°F to 104°F)</td>
</tr>
<tr>
<td>Max Water Temp</td>
<td>35°C (95°F)</td>
</tr>
<tr>
<td>Temp Rise at Full Pwr</td>
<td>27-63°C (80-145°F)</td>
</tr>
<tr>
<td>Size</td>
<td>40 in x 25 in x 15 in (102 cm x 64 cm x 38 cm)</td>
</tr>
<tr>
<td>Weight</td>
<td>105 lbs (48 kg)</td>
</tr>
</tbody>
</table>
Power Testing

At Dielectric Factory at 9kW ATSC and 9kW DVB-T (6 MHz)
Power Testing

At WPFO – Litchfield, ME
Special Thanks
WPFO/WGME (Sinclair)
Power Testing - WPFO

Test at >35 kW average power

Exciter
Analog
ATSC
FLO

Two Tube IOT

Two Tube Combiner

Water load

Reflective Test Filter

Analog Mask Filter
Power CCDF

Analog (w/ adjusted aural and APL)

DVB-T
FM Channel Combiners

- Allow multiple FM stations to broadcast from the same antenna

2-10 channels; 3 kW to 60 kW per station
Intermodulation products in FM transmitters

\[ f_b \quad f_a \quad 2 \times f_a - f_b \]

IM product falls in FM broadcast or air navigation band
Can interfere with neighboring broadcasters or airports
Filter Rejection Controls IM level

\[ f_a + f_b + 2f_a - f_b \]

Turn around loss

transmitter
Filter Rejection

4 pole filter response

3 pole filter response
Filter Rejection and combiner channel spacing

**FM Filter Rejection**

<table>
<thead>
<tr>
<th># of poles</th>
<th>dB Rejection at spacing from (f_o)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.8 MHz</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>45</td>
</tr>
</tbody>
</table>

**IM rejection calculation**

\[
\text{CIF} = 2 \times \text{Rejection} + 30 \text{ dB}
\]

\[
\text{manifold} = 2 \times \text{rejection}
\]

Minimum channel spacing to get -80 dB min IM rejection:

<table>
<thead>
<tr>
<th># of poles</th>
<th>spacing in MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CIF manifold</td>
</tr>
<tr>
<td>2</td>
<td>4.4 10.2</td>
</tr>
<tr>
<td>3</td>
<td>1.6 2.4</td>
</tr>
<tr>
<td>4</td>
<td>0.8 1.2</td>
</tr>
<tr>
<td>5</td>
<td>any 0.8</td>
</tr>
</tbody>
</table>
Combiner upgrade to add new channel

Original combiner
For 4.8 MHz channel spacing

Upgraded combiner
For 1.6 MHz channel spacing
Common cavities make field upgrade viable

Add filter cavity and change iris plates, retune
Filter Tuning

Patience Required!
Tuning Options

- Buy or rent vector network analyzer (VNA) and try it yourself
- Hire qualified field engineer
- Work with station group to use central engineer / VNA and exchange filters
- Return filter to factory for re-tuning
Tuning Procedures

- Available at www.dielectric.com
Equipment Needed

Vector Network Analyzer (VNA) purchase
- Keysight Technologies (formerly Agilent)
- Rohde & Swarz
- Anritsu
- Advantest
- Copper Mountain

VNA Rental
- Electro-rent
- Test Equity
- Advanced Test Equipment Rentals
- Metric Test
- TRS-RenTelco

- Calibration Kit and Cables
- Adaptors type N to 7-16
  Or type N to 1 5/8” or 3 1/8”
- Allen keys and standard wrenches
Time Domain Tuning

- Time domain tuning
- Agilent (key sight) app note AN1287-8
- Requires VNA with time domain transform (TDR) option
- Response in time domain corresponds to each physical adjustment
Time Domain Tuning

• Important Step 1: Before making any adjustments on tuned filter save:
  • input return loss (S11)
  • transmission response (S21)
  • output return loss (S22) to VNA memory

These memory traces will serve as template for tuning the filter at the new channel
Time domain – S11 response

input coupling

resonator 1

resonator 2

1-2 coupling

2-3 coupling

resonator 3
Conclusions

- Powerlite filter series (100 W to 7 kW)
  - UHF Band tunable (470-860 MHz)

- New Higher Power tunable filter
  - 10 kW convection, 20 kW water cooled
  - Ch 14-51

- FM Combiners
  - Impact filter has on IM generation
  - Combiner upgrade to add channels

- Filter Tuning
  - Field Engineer or station group RF expert
  - Having spare filter for station group makes sense
Questions