“Using High Performance Multiplexer Technology to Improve Your HF Station Capability”

by Andrei Fedorishchev
RA6LBS
Agenda

- A bit of history
- What is a multiplexer?
- Can I fry my radios?
- Specifications of multiplexers
- Why do we need additional filters?
- Multiplexer + Filter combo
- Relay switches
- Where is the right place for filters and a switch?
- The devil is in the details ...
- Interconnecting cables
- Some examples and ideas for transmit antennas
- Upside down!
- Can we have any benefits for receive antennas distribution?
- Q & A?
A bit of history:

P33W, WRTC-2010 and Multiplexers

We implemented and used with great success an In-Band style of operation at P33W in 2008: WPX SSB, IARU, and latter WW contests.

After IARU-2008, which we won of course, Harry - RA3AUU asked me if I could suggest something innovative for Russian teams, in order to win WRTC-2010 in Moscow.

Inspired by P33W success with InBand, I was confident that the only place to improve the proposed WRTC setup would be a better utilization of TriBander on 14-28.

And no one could answer my question WHY don’t we have same thing as Duplexers at VHF ...
The very first HF triplexer, circa November 2008
What is a multiplexer?

- Used for decades by VHF–UHF guys!
- Multiplexers enable multi-transceiver stations to share a single multi-band antenna;
- Multiplexers, by themselves, cannot provide the necessary isolation with 100W radios;
- Each transmitter must be connected to a multiplexer through a bandpass filter in order to keep them from interfering with each other;
How does it work?

- It's a filter!

  - Think of a triplexer as a low pass filter, a bandpass filter and a high pass filter with their outputs connected;
  - Triplexer is routing high, mid and low frequencies to three different input ports;
Can I fry my radios?

- YES!

- and NO!
  - Hardware band switching lockout is a must!
  - Power consideration is a must!

- All of this is easy to implement and to control.
Part I

Components of multiplexing technology
Multiplexers vs Antennas

Di- Duo band antennas, simple dipoles feed in parallel with single coax
160/80, or 80/40, or 40/20
or ...... some exotics like 6/4 in Europe

Tri- Tribander gives three bands
usually 20-15-10

Quad- 4band antennas, like
OptiBeam OB12-4 and multiband Verticals!
40-20-15-10

Penta- 5/6 band antennas like Spiderbeam, Hexbeams and multiband Verticals!
20-17-15-12-10-6
Specifications of multiplexers

#1 - Losses
Fractions of Decibel, typical average is $\leq -0.2\text{db}$.

14Mhz: -0.15db.
Specifications of multiplexers

#1 - Losses

Decibel is a ratio of Input to Output Power (dB) = 10 log(Pout/Pin)

<table>
<thead>
<tr>
<th>Multiplexer's Attenuation, db.</th>
<th>Transmitted power at 1500W TX Out</th>
<th>Transmitted power at 100W TX Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0,1</td>
<td>1465</td>
<td>98</td>
</tr>
<tr>
<td>-0,2</td>
<td>1432</td>
<td>95</td>
</tr>
<tr>
<td>-0,3</td>
<td>1399</td>
<td>93</td>
</tr>
<tr>
<td>-0,4</td>
<td>1368</td>
<td>91</td>
</tr>
<tr>
<td>-0,5</td>
<td>1336</td>
<td>89</td>
</tr>
<tr>
<td>-0,6</td>
<td>1306</td>
<td>87</td>
</tr>
<tr>
<td>-0,7</td>
<td>1276</td>
<td>85</td>
</tr>
<tr>
<td>-0,8</td>
<td>1247</td>
<td>83</td>
</tr>
<tr>
<td>-0,9</td>
<td>1219</td>
<td>81</td>
</tr>
<tr>
<td>-1,0</td>
<td>1191</td>
<td>79</td>
</tr>
</tbody>
</table>
Specifications of multiplexers

#1 - Losses

This is not a question of useful power losses, but more of heat dissipation!

Fortunately, this heat is spread among few of the plexer`s components.

<table>
<thead>
<tr>
<th>Multiplexer`s Attenuation, db.</th>
<th>1500W TX Heat generation, Watts</th>
<th>100W TX Heat generation, Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.1</td>
<td>35</td>
<td>2</td>
</tr>
<tr>
<td>-0.2</td>
<td>68</td>
<td>5</td>
</tr>
<tr>
<td>-0.3</td>
<td>101</td>
<td>7</td>
</tr>
<tr>
<td>-0.4</td>
<td>132</td>
<td>9</td>
</tr>
<tr>
<td>-0.5</td>
<td>163</td>
<td>11</td>
</tr>
<tr>
<td>-0.6</td>
<td>194</td>
<td>13</td>
</tr>
<tr>
<td>-0.7</td>
<td>224</td>
<td>15</td>
</tr>
<tr>
<td>-0.8</td>
<td>253</td>
<td>17</td>
</tr>
<tr>
<td>-0.9</td>
<td>281</td>
<td>19</td>
</tr>
<tr>
<td>-1.0</td>
<td>309</td>
<td>21</td>
</tr>
</tbody>
</table>
Specifications of multiplexers

#2 – Isolation, between it`s outputs!

Leakage from transmit port - 20, to receive ports - 15 and 10!
Isolation, measured, 14Mhz to 21Mhz, typical

Q: Where do you want to put notches?

A:
1) At the middle of the band;
2) At the center frequency of harmonics;

14Mhz: -(33 ÷ 43)db.
21Mhz: -(30 ÷ 46)db.
Isolation, measured, 14Mhz to 28Mhz, typical

14: -\( \frac{39}{44} \)dB.
28: -\( \frac{33}{39} \)dB.
Specifications of multiplexers

#2 - Isolation between its outputs!

<table>
<thead>
<tr>
<th>Isolation</th>
<th>1500W TX, Leakage power</th>
<th>100W TX, Leakage power</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10 db.</td>
<td>150W</td>
<td>10W</td>
</tr>
<tr>
<td>-20 db.</td>
<td>15W</td>
<td>1W</td>
</tr>
<tr>
<td>-30 db.</td>
<td>1,5W</td>
<td>0,1W</td>
</tr>
<tr>
<td>-40 db.</td>
<td>0,15W</td>
<td>0,01W</td>
</tr>
<tr>
<td>-50 db.</td>
<td>0,015W</td>
<td>0,001W</td>
</tr>
</tbody>
</table>
Why do we need ISOLATION?

2 issues:

- **Safety:**
  Unknown, and different level of damage to different radios

- **Interference:**
  Starting figures at around +10dbm may be, but again differs by radios and some other factors
How many decibels of isolation do we need?

- Think of DX pedition utilizing 2 or 3 or 4 station at the same time? When sum of QRM from this multiple radios is going into play?

- And what is the criteria of “QRM free” operation?
  - Harmonics level? – NO
  - No any other signs of station transmission? - YES
  - Different band combination - different isolation requirements?
    - Think of 10 meters noise level vs 80 meters ...

We have now, 8 YEARS OF EXPERIENCE with 100 – 4500W power levels, different Rigs and Ops;

Observation: –(80÷100) db. should be fine for almost any condition.
Target figure is -90 db. of isolation for the complete system

Neither the Triplexer alone, nor the band pass filters available in 2008 on the market, was close to this figure.

Best of the market, W3NQN design filters, has been modified with extra rejection sections, to satisfy tougher requirements.
Triplexer + W3NQN BPF
14/21 isolation

14: -57db.
21: -62db.
Triplexer + modified W3NQN filter, 14/21 isolation:

14: -96db.
21: -103db.

40 db. improvement!
Triplexer + PerfoBox filters, 1500W series, 14/21 isolation:

14: -94db.
21: -88db.
Quadplexer + PerfoBox filters, 1500W series, 7/21 isolation:

7: -95db.
21: -101db.
Interconnecting Cables

- **Shielding Effectiveness:**
  - Messi & Paoloni >105db.
  - Andrew LMR-240 >90db.
  That’s good enough.

- **Connectors!**
  - Should always be clean and tighten well!
  - Soldered cables braid to the body of connector!
  - Bad connectors easily destroys low loss path;
Relay switches:

- KK1L – entry level switch
  - $(85\div64)\text{db. isolation, best case,}$
  - \textit{not enough for this task}

- RK-226 – good choice
  - $(90\div80)\text{db. isolation, typical,}$
  - \textit{(due to extra relay)}

- Matrix switches – best of the best
  - $(125\div95)\text{db. Isolation, typical}$
  - \textit{And any power levels!}
Matrix switch, best of the best
Isolation in Matrix Switch system, measured, 2008:

14/21: 
- 111db. / - 101db.

7/21: 
- 119db. / - 101db.
Multiplexer + Filter + Relay switch Combos
Classic, 2x6 switch combo:

Great if it would be like this:
Classic, 2x6 switch combo:
Classic, 2x6 switch combo:

- Leakage is determined by the switch!
- Not enough isolation in the switch can destroy performance of the best filters and Triplexer!
Classic, 2x6 switch combo:

Actually:

leakage is here!
with KK1L relay switch

14: -62db.
28: -56db.
with RK-226 relay switch

14: -84db.
28: -81db.
with Matrix switch

14: -111db.
28: -101db.
Where is the **BEST** place for the filters and a switch?
Best layout:

Antenna

TriPlexer

6x2 Relay Switch

6xBPF

6xBPF
Isolation, THE BEST, MatrixSwitch and BPF ahead

14: -116db.
28: -128db.
# Summary of isolation

<table>
<thead>
<tr>
<th>Components:</th>
<th>14 to 28 isolation, as example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TriPlexer and Filters combos:</strong></td>
<td></td>
</tr>
<tr>
<td>Triplexer 200W, minimum, db.</td>
<td>-40 / -34</td>
</tr>
<tr>
<td>Triplexer + Set of PerfoBox 200W filters</td>
<td>-96 /-103</td>
</tr>
<tr>
<td>Triplexer + Set of PerfoBox 1500W filters</td>
<td>-94 /-88</td>
</tr>
<tr>
<td><strong>Relay Switches:</strong></td>
<td></td>
</tr>
<tr>
<td>2x6 Switch KK1L, best</td>
<td>-85 / -64</td>
</tr>
<tr>
<td>2x6 Switch RK226, worst</td>
<td>-83 / -77</td>
</tr>
<tr>
<td>Matrix Switch</td>
<td>-111 / -98</td>
</tr>
<tr>
<td><strong>Complete SYSTEMS:</strong></td>
<td></td>
</tr>
<tr>
<td>Triplexer + (3 x Filters) + KK1L</td>
<td>-62 / -64</td>
</tr>
<tr>
<td>Triplexer + (3 x Filters) + RK226</td>
<td>-73 / -79</td>
</tr>
<tr>
<td>Triplexer + (3 x Filters) + Matrix switch</td>
<td>-111 / -101</td>
</tr>
<tr>
<td>Triplexer + Matrix switch + Six pack of Filters ahead</td>
<td>-116 / -128</td>
</tr>
</tbody>
</table>
Part II

MULTI BAND antennas
Some examples for multiband antennas
Some examples for multiband antennas
Some examples for multiband antennas

6x2 Relay Switch

TriPlexer
20 15 10

BPF
20
15
10

Radio 1

Radio 2
Some examples for multiband antennas
Some examples for multiband antennas

When on 10, you can be on 6 m. also!
Part III.

Upside Down ?
YES!
Benefits:

- For in-band remote sites
- Hardline and installation time saving solutions
Upside down “bricks”
Upside down "bricks"
Upside down summary:
Part IV

- RECEIVE ONLY APPLICATIONS
Can we have any benefits with Multiplexer technology for receive only applications?

Yes!
Lets compare with the classic of the distribution:

Wide band splitters:

SPLITTER/COMBINER, know also as a “Magic T” or “-3db.”
Wideband splitters:

The weak point is internal losses:

- -3.1db. in a 2 way splitters;
- -6.3db. in a 4 way splitters;
- -9.5db. in a 6-8 way splitters;

Plus losses in a feedline.
For 1000 feet of RG6 size cable it is -3÷4db.

Total losses may be over -12db. in a 6 way splitting!
And 6 way splitting is a must for Winning size Multi stations!
CLASSIC LAYOUT:
Receive signal distribution for 3 station only, (small M/S), with wideband splitters:

Number of receive antennas is always limited due to the lack of space ... 
But now we have limitation on screen ...

8 x 1 Relay Switch #1
8 x 1 Relay Switch #2

8 x 1 Relay Switch #3 is not shown for simplicity

Losses is determined by nature of wideband splitters
Can we overcome this loss-related problem in a larger size stations with the MultiPlexer technology?
Advanced receive signal distribution for M/M, big M/S:

Unlimited number of directions,
Up to 4 bands, 3 station on each band!

Total losses is:
-4.1db. station #1 of each band
-7.3db. stations #2,3 of each band
Advanced receive signal distribution for M/M, big M/S:

Unlimited number of directions,
Up to 4 bands, 3 station on each band!
For DX pedition:

Coax and installation time saving solutions!
DX petition advanced layout:

You can first combine *(into single feedline)*,
and then split *(at the radios)*
different band signals!
DX expedition advanced layout:

Direction #1
- RX Quad Plexer #1
- 1x4 Antenna Switch
- 20, 15, 10, 160
- losses: -1db

Direction #2
- RX Quad Plexer #1
- 1x4 Antenna Switch
- 20, 15, 10, 80
- losses: -1db

Direction #3
- RX Quad Plexer #1
- 1x4 Antenna Switch
- 20, 15, 10, 40
- losses: -1db

Direction #4
- RX Quad Plexer #1
- 1x4 Antenna Switch
- 20, 15, 10, 20
- losses: -1db

SINGLE coax feedline to the tent with 4 stations, running on 4 different bands!

ANY direction on ANY band!

Losses: -3 db. only!

SINGLE Ethernet cable, to control 4 direction on 3 antenna switches with LBS receive antenna systems components!
Q & A?

- LowBandSystems, of Russia
- DX Engineering - USA distribution