Combline Filters
for
VHF and UHF

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W1GHZ
Combline V.H.F. Bandpass Filters

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Interior of the 50-MHz. combline filter.
Capacitor input and output Coupling
Tapped input and output coupling
Combineline Filters

• Resonators $< \frac{1}{4} \lambda$ with capacitor loading

• Capacitor input and output
  – Two extra adjustments
  – Swept tuning needed
  – Variable capacitors rare and expensive

• Tapped input and output
  – Simpler tuning
  – Tune for maximum
  – Problem is getting tap point right
First Attempt – 2 meters

- Ansoft Designer SV (Student Version)
  - Filter Design Wizard
  - Design Combline Filter in Stripline
  - Fiddle parameters, make it fit in box

- Large nested aluminum box
  - Stalwart U3789 from Amazon
  - 3 nested boxes with lids

- Variable capacitors from hamfest
Combline – First Attempt 144 MHz
Combline Filter - First Attempt

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Combline Filter for 144 MHz

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Measured

![Graph of Combline Filter](image-url)
First Attempt - Results

- Passband shape unsatisfactory
- VSWR not good enough
- Overcoupled = Tap Point wrong

- Moving tap point toward ground increases coupling
- Reduce overcoupling by moving tap up
Fix First Attempt

• Improve without drilling more holes
• Use Ansoft HFSS for 3D simulation
• Narrower strips, increase spacing, adjust tap
• Now results match simulation
• Flat response, good VSWR, low loss
Fixed 144 MHz Combline Filter
Good Rejection out-of-band
And Low Loss
What Next?

- Confidence in designs
- Calculate other bands, narrower filters
- Record in Notebook
- Move QTH, put up towers and antennas
- FN34uj – Noise peaking on Mt. Mansfield
- Use filter during 2013 10GHz Contest to remove 2-meter noise on Mt. Mansfield
- After 3 years, build some more filters
222 MHz

- FCC moves Analog channel 44 to DTV ch 13
  - 210 to 216 MHz
- Noise increases 16 dB toward Mt. Mansfield
  - Many Transmitters - TV, FM, pager, etc
- Combline filter in stamped aluminum box
- Medium nested box (Stalwart U3789)
222 MHz Combline Filter
Surplus Filter F-197/U
222 MHz Filters

Combline Filter for 222 MHz

Frequency (MHz) dB

-25 -20 -15 -10 -5 0

Comb F-197/U
222 MHz Filters

- Combline Filter – good response, low loss
- Surplus Filter F-197/U
  - Hamfest seller said it had high loss, needed mod
  - Narrower *and* lower loss than combline
  - Better rejection at channel 13
- What about noise?
  - Surplus F-197/U reduces from 16 dB to 2 dB
  - Combline reduces from 16 dB to 3 dB
  - Noise probably not from Channel 13
144 MHz Combline Filter #2

- Desire narrower passband
- Bigger box – Bud chassis
  - Bud AC-406, 9x7x2 inches
- Wider striplines, wider spacing
- Narrow passband, low loss
144 MHz Combline #2
144 MHz Combline #2

Combline Filter for 144 MHz in Bud AC-406 Chassis
432 MHz Combineline Filter

- Build in Diecast Aluminum box – Robust
- Wide striplines, wide spacing proportional to smaller box
- Good flat response, low loss
432 MHz Combline Filter
432 MHz Combline Filter in Diecast box

Combline Stripline Filter for 432 MHz
432 MHz Combiner Filter #2
Small nested box (Stalwart U3789)
Combline Filter for 432 MHz
in small Stalwart box

Loss (dB)

Frequency (MHz)
50 MHz Combline Filter

- Big Chassis: 10 x 8 x 2.5 in (Bud AC-1418)
- Large Capacitors ~140 pf
  - Russian surplus in ebay
- *Wouldn’t tune below 52 MHz*
- Big caps made lines shorter than calculated
- Add 15 pf silver-mica to end capacitors
- Tunes up with low loss ~0.75 dB
- Return Loss > 30 dB
50 MHz Combline Filter
Combline Filter for 50 MHz
Combline Filter Construction

- Aluminum box and striplines
- Air trimmer capacitors
- Compatible metal connections
  - Stainless steel hardware
  - Tinned #4 solder lugs for solder connections
  - No copper to aluminum connections
- Clean aluminum before assembly
- Mostly basic metalworking
  - Drill and tinsnips, no fancy machinery
Tuning Capacitor Construction
Ground and Connector Tap
Combline designs

• Dimensions on Proceedings CD
• Boxes:
  – Bud Chassis
  – Hammond Diecast box
  – Stalwart U-3879 (three nested stamped boxes made in India) from Amazon.com
• Trimmer caps
  – Scrounge from junk boxes and hamfests
  – ebay surplus from Russia
Power handling

- Trimmer caps limit power
- Two meter combline filter used at 25 watts
- Newer LDMOS power amplifiers only need ~5 watts drive
  - LDMOS amplifiers are broadband, so filtering may clean up driver – why waste power on unwanted frequencies (then filter at output to remove them?)
Summary

- Good filters you can build
- Purchased filters are expensive, most not as good
- Can be tuned to other frequencies if needed
- Remove crud from your receiver and clean up your signal
Designing Combline Filters

With Free Software
Combline Filter Design

- Transmission Line Resonators < $\frac{1}{4} \lambda$ long with capacitor loading
- Adjust capacitors for resonance
- Bandwidth
  - Coupling between resonators
  - Input coupling – capacitor or tapped resonators
- Resonator Zo, length, width, spacing interact
- Difficult to calculate even simple cases
- Free software calculates for some types
Capacitor input and output Coupling
Free Software for Filter Design

- Ansoft Designer SV (Student Version)
  - No longer available
  - Many copies distributed at conferences
  - W2PED conference presentation

- INTFIL (from N6JH) – interdigital filters
- WGFIL (WA4LPR) – waveguide filters
- Others?
Ansoft Designer SV
Filter Design Wizard
Choose Filter Properties

Air Stripline is Rectangular bar (thin)
Enter Trial Parameters
Trial Parameters

• Take a guess
• Start with my dimensions
• First trial won’t be right

• Trial is part of TRIAL and ERROR
Dimensions from Trial Parameters

Filter Design Wizard - Medium Properties

Substrate dielectric constant, $E_r$: 1
Substrate height, $h$ [mm]: 50
Conductor thickness, $t$ [mm]: 1
Side spacing, $ss$ [mm]: 20

0 <= $ss$ <= 1000

Units, Ranges...  Calculate with equal linewidths

Variables:
- $p_1$: 153.2 mm
- $w_1$: 42.52 mm
- $s_1$: 22.63 mm
- $C_1$: 41.68 pF
- $C_2$: 33.94 pF
- $p_2$: 14.84 mm
- $p_3$: 138.4 mm
Empirical Design
(Trial and Error)

- Try some parameters
- Look at dimensions that result
- Go back one screen and make changes
- See what happens
- Try again
- Software, we aren’t cutting metal yet

- Take notes so you don’t go in a circle
Change Tline impedance or BW
Dimensions after Changes

Filter Design Wizard - Medium Properties

- Substrate dielectric constant, $E_r$: 1
- Substrate height, $h$ [mm]: 50
- Conductor thickness, $t$ [mm]: 1
- Side spacing, $ss$ [mm]: 20

1 $\leq E_r \leq 128$

Units, Ranges... [Calculate with equal linewidths]

VARIABLES:
- $p_1 = 153.9$ mm
- $w_1 = 30.26$ mm
- $s_1 = 25.81$ mm
- $C_1 = 35.5$ pF
- $C_2 = 27.75$ pF
- $p_2 = 13.44$ mm
- $p_3 = 140.5$ mm

Diagram of the filter design with variables and values.
Keep Fiddling

• Make changes until dimensions fit in box
  – Tline Impedance – Resonator Width
  – BW – Resonator Spacing
  – Electrical Length – Resonator length
  – Side Spacing – at connector ends

• Take notes!

• Save screenshots of final result
Connector Tap Point is Wrong!

- Ansoft Designer gives wrong tap point
- Use INTFIL
- Calculate interdigital filter
- Same Center Frequency, BW, and Tline imp.
- Use this tap point
- Might need small adjustment at tuneup
Other Resonator Shapes

• Rectangular bar
  – change conductor thickness
• Round rods – select “Slabline”
  – Fiddle Tline impedance to change diameter
• Use same Trial and Error approach
Round Resonators – “Slabline”
Slabline Dimensions

Filter Design Wizard - Medium Properties

- Substrate dielectric constant, Er
- Substrate height, h [mm]: 50
- Side spacing, ss [mm]: 20

Units, Ranges... Calculate with equal linewidths

Variables:
- p1: 161.9 mm
- d1: 19.85 mm
- s1: 31.99 mm
- C1: 41.68 pF
- C2: 33.94 pF
- p2: 15.68 mm
- p3: 146.2 mm

Diagram of slabline dimensions and capacitor arrangements.
Combline Filter for 432 MHz in Altoids Tin
Combline Filter for 432 MHz in Altoids Tin
Time to cut metal

- First layout with a Sharpie
- If it looks good:
  - accurate layout with calipers and scriber
- Otherwise:
  - wipe off layout marks with alcohol
  - Go back to software and try again
- Extra holes for tap point adjustment?
Tuneup

- Best – sweeper or network analyzer
- Overcoupled - ripple in passband
  - move tap point up slightly
- Undercoupled – narrow and high loss
  - move tap point down slightly
- OK – tune for maximum at center frequency
- Final tweak – for VSWR at calling frequency
Conclusions

• Good filters:
  – Make clean signals
  – Reduce noise and birdies in receiver

• You can build better filters than you can buy
• Just metalwork with simple tools
• Design your own or use my dimensions