Parallel Coupled Bandpass Filters
(Stripline and Microstrip)
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Presentation Content
Parallel Coupled Bandpass Filters

1. Technical Articles on Parallel Coupled Bandpass Filters.
2. Description of the Filter.
3. Advantages/Benefits.
4. Disadvantages/Cautions.
5. Parasitic Passband.
8. PCfilter: Computer Software.
11. PCfilter: Frequency Analysis.
13. PCfilter: 3-pole Microstrip Filter.
14. PCfilter: 5-pole Microstrip Filter.
15. PCfilter: 6-pole Microstrip Filter.

Illustration of a Parallel Coupled Bandpass Filter
Technical Articles
Parallel Coupled Bandpass Filters

For Readers who wish to explore a more technical treatment of Parallel Coupled Bandpass Filters and their physical realization in microstrip and in stripline:

Technical articles on Parallel Coupled Bandpass Filters in Microstrip:
6. And dozens & dozens more. . . . . . .

Technical articles on Parallel Coupled Bandpass Filters in Stripline:
Description of the Filter
Parallel Coupled Bandpass Filter

A typical planar parallel coupled bandpass filter consists of a cascade of pairs of parallel-coupled resonator lines that are open-circuited at both ends. The center conductor’s coupled transmission lines are positioned parallel to each other, so that adjacent resonators are coupled along a length equal to the quarter-wavelength: \( \lambda_0/4 \) at the center frequency of the filter: \( f_0 \). There are \( N + 1 \) coupled-line sections in an \( Nth\)-degree parallel coupled bandpass filter.

1. The physical length of each coupled-line center conductor (or resonator) determines the center frequency: \( f_0 \) of the bandpass filter.
2. The line width: \( W \) of each center conductor, and gap spacing: \( S \) between each coupled-line center conductors, predominantly effects the filter’s VSWR and operating bandwidth: \( BW = (f_h - f_L)/f_0 \).
3. For microstrip parallel coupled bandpass filters, the location of the metal top cover above the dielectric substrate effects the RF performance of the filter.
Advantages/Benefits
Parallel Coupled Bandpass Filter

The advantages of Parallel Coupled Bandpass Filters in RF/microwave circuits are:

1. Small physical size, whether constructed in microstrip or stripline.
2. Easy to fabricate RF circuit traces using conventional photo etching techniques.
3. Absence of short circuits (to ground plane) in its transmission line’s center conductors/resonators.
4. Readily packaged with other RF circuit structures in a compact mechanical housing.
5. Produces acceptable passband insertion loss for the application.
6. Produces acceptable out-of-band attenuation for the application.
Disadvantages/Cautions
Parallel Coupled Bandpass Filter

The disadvantages of Parallel Coupled Bandpass Filters are:

1. Parasitic passband at 2 times the filter’s center frequency: $2 \times f_0$.
2. Difficulty to obtain a narrow passband with low insertion loss.
3. Radiation loss from open end-effect at each resonator: Microstrip.
4. As the filter’s bandwidth increases, the gap spacing: $S$ becomes small ($< 0.002”$) in the quarterwave coupled end-sections (Input & output coupled lines), which increases manufacturing difficulties and worsens etching tolerance effects. This narrow-gap problem often becomes unmanageable for bandwidths above 10% to 15%.
5. Material property tolerances in the dielectric constant ($E_r$ or $D_k$) of the actual substrate material has a noticeable adverse effect on the filter’s RF performance: It often shifts the filter’s center frequency: $f_0$, especially in filters with narrow fractional bandwidths: $(f_h - f_L)/f_0$. 
Frequency response of a conventional half-wave parallel coupled line bandpass filter (red solid line) at 100 GHz is compared to its idealized lumped-element band-pass counterpart (green dashed line). The high frequency parallel coupled line filter’s deviation from the ideal lumped element response in the parallel coupled line filter can arise from inadequate control over resonances in the individual filter sections.
Broader Operating Bandwidth
Parallel Coupled Bandpass Filter

As the filter’s operating bandwidth (= passband) increases above 10% to 15%, the gap spacing: S becomes small (< 0.002”) in the quarter-wave coupled end-sections (Input & output coupled lines), which increases manufacturing difficulties and worsens etching tolerance effects.

Three methods are often used to circumvent this difficulty:

1. The impedance of the resonators may be increased, which increases the required spacings.

2. The first resonator may be externally coupled by inductive tapping, instead of using a coupler section. Because the tightest spacings generally occur in the external coupling sections: input & output, this approach significantly extends the useful operating bandwidth.

3. Raising the termination resistance presented to the filter by using quarter-wave impedance transformer sections for the input and output sections.
Broader Operating Bandwidth
Parallel Coupled Bandpass Filter

5th-order Microstrip Parallel Coupled Bandpass Filter with tapped RF input section and tapped RF output section.

Microstrip Parallel Coupled Bandpass Filter with single-section impedance transformers at RF input and output sections.
Description of Design Process
Parallel Coupled Bandpass Filters

The design process for a parallel coupled bandpass filter starts with the electrical parameters desired for the filter (which you select), then proceeds to calculate the electrical circuit parameters and physical/dimensional parameters so the filter can be manufactured:

Electrical parameters desired for the filter, based on its intended application in the RF circuit or RF assembly:

1. Center frequency: $f_0$, most often defined in Mega-Hertz: MHz.
2. Operating bandwidth: $BW = f_h - f_L$, also called: Filter’s passband.
3. VSWR desired across filter’s operating bandwidth, often expressed as the amplitude ripple: $L_{ar}$, dB.
4. Attenuation desired at frequencies below the filter’s passband or at frequencies above the filter’s passband; often called: Out-of-band attenuation.
5. A dielectric substrate is selected to fabricate the parallel coupled bandpass filter.
Description of Design Process
Parallel Coupled Bandpass Filters: Select Dielectric Substrate

6. A dielectric substrate is selected based on its compatibility with other RF circuit structures within the assembly, and is based on the filter’s frequency response, both across its passband (for low insertion loss) and at its out-of-band attenuation/rejection:

   a. The dielectric constant: $E_r$ and thickness of the dielectric substrate often determine the frequency when higher-order modes and surface waves could launch, and these higher-order modes/waves could adversely effect the out-of-band attenuation produced by the filter, mostly at frequencies above the filter’s passband.

   b. The thickness of the center conductor can effect the design of the filter, since a thick center conductor allows stronger coupling than a thin center conductor. As such, a thicker center conductor enables larger gap spacings between parallel coupled resonators. Most planar filters fabricated on flexible dielectric substrates (i.e.: not ceramic or quartz) are available with copper center conductors whose metal is 0.0007” thick (1/2-ounce), 0.0014” thick (1-ounce) and 0.0028” thick (2-ounce).
Description of Design Process

Parallel Coupled Bandpass Filters: Number of Sections

With the required/desired electrical parameters defined, and a dielectric substrate & conductor thickness are selected, the electrical synthesis of the parallel coupled bandpass filter can proceed:

1. Determine the number of resonant sections: \( N \), needed in the filter based on its desired passband response: Chebyshev or Butterworth, and its desired out-of-band attenuation: \( A \) at an out-of-band frequency: \( \omega_1 \).

\[
N > \frac{\cosh^{-1}\left(\frac{10^A/10 - 1}{10^{\text{Lar}/10} - 1}\right)}{cosh^{-1}\left(\frac{\omega_1}{\omega_c}\right)}
\]

\[
N > \frac{\log_{10}\left(\frac{10^{A/10} - 1}{10^{\text{Lar}/10} - 1}\right)}{2\log_{10}\left(\frac{\omega_1}{\omega_c}\right)}
\]
Description of Design Process
Parallel Coupled Bandpass Filters: Lowpass Element Values

2. Calculate the lowpass prototype filter element values: \( g_0, g_1, g_2, \ldots, g_{n+1} \) for the N-section bandpass filter that produces the desired passband response: Chebyshev or Butterworth, and the desired out-of-band rejection.

**Butterworth lowpass prototype filter circuit element values**: 
\[
g_0 = g_{n+1} = 1 \quad \text{Series } R_s = R_L = Z_0 \\
g_i = 2 \sin \left[ \frac{(2i-1)\pi}{2n} \right], \; i = 1,2,3,\ldots,n \\
\]

**Chebyshev lowpass prototype filter circuit element values**: 
\[
g_0 = 1; \; g_1 = \frac{2a_1}{\gamma}; \; g_k = \frac{4a_{i-1}a_i}{b_{i-1}g_{i-1}} \\
g_{n+1} = \begin{cases} 
1 & \text{for } n \text{ odd} \\
\coth^2 \left( \frac{\beta}{4} \right) & \text{for } n \text{ even} 
\end{cases} \\
\]

where: \( \beta = \ln(\coth \left( \frac{L_{ar}}{17.34} \right)) \); \( \gamma = \sinh\left( \frac{\beta}{2n} \right) \)

\[
a_i = \sin \left[ \frac{(2i-1)\pi}{2N} \right], \; i = 1,2,\ldots,N \\
b_i = \gamma^2 + \sin^2 \left[ \frac{i\pi}{N} \right], \; i = 1,2,\ldots,N \\
N : \text{Order of the filter.} \\
L_{ar} : \text{Maximum passband ripple, dB.} \]
A Note about Passband Amplitude Ripple

Filters synthesized using the Insertion Loss Method produce a passband VSWR that is related to the passband’s amplitude ripple: $L_{ar}$. 1. The passband’s amplitude ripple is directly related to the filter’s input/output VSWR as:

$$\Gamma = \sqrt{1 + 10^{L_{ar}/10}}$$

$$VSWR = \frac{1 + \Gamma}{1 - \Gamma}$$

As such, a higher passband amplitude ripple produces a higher passband VSWR, as shown in the table. Often, higher passband VSWR can adversely affect the performance in communication systems and, therefore, it seems ‘silly’ to publish any filter’s design whose ripple exceeds $L_{ar} > 0.5$dB passband ripple = 9.64dB Return Loss.
Description of Design Process
Parallel Coupled Bandpass Filters: Synthesize Electrical Circuit

Based on calculations from lowpass prototype filter element values: \( g_0, g_1, g_2, \ldots, g_{n+1} \), form the prototype filter electrical circuit as:

\[
\begin{align*}
R_s &= g_0 = 1\Omega \\
L_2 &= g_2 \\
L_4 &= g_4 \\
C_1 &= g_1 \\
C_3 &= g_3 \\
C_5 &= g_5 \\
R_L &= g_{N+1}
\end{align*}
\]

(a) Prototype Lowpass Filter with series inductor input: \( L_1 \).

(b) Prototype Lowpass Filter with shunt capacitor input: \( C_1 \).

where:
- \( N \) = Order of the filter = Number of reactive elements in the filter.
- \( g_0 \) = Generator’s source resistance or generator’s source conductance.
- \( g_i \) = Inductance for series inductors or capacitance for shunt capacitors.
- \( g_{N+1} \) = Load resistance, if \( g_N \) is a shunt capacitor or
  Load conductance, if \( g_N \) is a series inductor.
Description of Design Process
Parallel Coupled Bandpass Filters: Frequency & Impedance Scaling

Frequency scale the prototype element values to the filter’s desired operating frequency using your center frequency: \( f_0 \) and fractional bandwidth: \( (f_h - f_L)/f_0 \). Impedance scale the prototype element values to the filter’s desired impedance level, often: 50 ohms.

1. The series inductor: \( g_k = L_k \) is transformed into a series \( LC \) circuit with element values:

\[
L'_k = \frac{Z_0 g_k}{\Delta \omega_0} \quad C'_k = \frac{\Delta}{\omega_0 Z_0 g_k}
\]

Center frequency:

\[
\omega_0 = \frac{\omega_1 + \omega_2}{2} \quad \text{or} \quad \sqrt{\omega_1 \omega_2}
\]

Fractional bandwidth:

\[
\Delta = \frac{\omega_2 - \omega_1}{\omega_0}
\]

2. The shunt capacitor: \( g_k = C_k \) is transformed into a shunt \( LC \) circuit with element values:

\[
C'_k = \frac{g_k}{\Delta Z_0 \omega_0} \quad L'_k = \frac{\Delta Z_0}{\omega_0 g_k}
\]

Bandpass filter derived from the prototype lowpass filter:
Description of Design Process
Parallel Coupled Bandpass Filter: Realize Physical RF Circuit

Apply distributed RF circuits to scaled bandpass filter using Richard’s Transformations and Kuroda’s Identities. Example: 3-pole bandpass filter.

Equivalent circuit model for parallel coupled lines with open-circuit at both ends.

An array of coupled lines.

λ₀ = wavelength at ω₀
Description of Design Process
Parallel Coupled Bandpass Filters: Impedance/Admittance Inverters

The Admittance Inverters: \( J_{i,i+1} \) or Impedance Inverters: \( K_{i,i+1} \) in each coupled-line section of the filter are calculated from the lowpass prototype element values: \( g_i \) and the fractional bandwidth: \( \text{FBW} = (f_h - f_L)/f_0 \) as:

For the first coupled-line structure:

\[
Z_0 J_{0,1} = \frac{Z_0}{K_{0,1}} = \sqrt{\frac{\pi \text{ FBW}}{2 g_0 g_1}}
\]

For the intermediate/middle coupled-line structures:

\[
Z_0 J_{i,i+1} = \frac{Z_0}{K_{i,i+1}} = \frac{\pi \text{ FBW}}{2 \sqrt{g_i g_{i+1}}} , \quad i = 1 \text{ to } n - 1
\]

For the last coupled-line structure:

\[
Z_0 J_{n,n+1} = \frac{Z_0}{K_{n,n+1}} = \sqrt{\frac{\pi \text{ FBW}}{2 g_n g_{n+1}}}
\]

From these Admittance or Impedance Inverters, the Even and Odd-Mode Impedances can be calculated.
Description of Design Process

Parallel Coupled Bandpass Filters: Even & Odd-Mode Impedances

Even and Odd-Mode Impedances: $Z_{oe}$ and $Z_{oo}$ for each coupled-line section in the bandpass filter are calculated from the filter’s Admittance Inverters: $J_{i,i+1}$, or Impedance Inverters: $K_{i,i+1}$, and the characteristic impedance of the filter: $Z_0$ as:

$$Z_{0e}|_{i,i+1} = Z_0 \left[1 + Z_0 J_{i,i+1} + (Z_0 J_{i,i+1})^2\right] = Z_0 \left[1 + \frac{Z_0}{K_{i,i+1}} + \left(\frac{Z_0}{K_{i,i+1}}\right)^2\right]$$

$$Z_{0o}|_{i,i+1} = Z_0 \left[1 - Z_0 J_{i,i+1} + (Z_0 J_{i,i+1})^2\right] = Z_0 \left[1 - \frac{Z_0}{K_{i,i+1}} + \left(\frac{Z_0}{K_{i,i+1}}\right)^2\right]$$

From these Even and Odd-Mode impedances, the physical dimensions needed to realize the parallel coupled bandpass filter can be calculated: Strip Width (W) and gap spacing between strips (S), based on the substrate’s dielectric constant, height and strip thickness, and the method to construct: Microstrip or Stripline.
Description of Design Process
Parallel Coupled Bandpass Filter: Physical Dimensions

From the Even and Odd-Mode impedances: $Z_{oe}$ and $Z_{oo}$, the physical dimensions needed to realize the parallel coupled bandpass filter can be calculated: Strip Width: $W_{i,i+1}$ and gap spacing between strips: $S_{i,i+1}$, based on the substrate’s dielectric constant: $E_r$, substrate’s height and strip thickness of the center conductor: $T$, and the method to construct: Microstrip or Stripline.

Top view: General structure of parallel-coupled bandpass filter that use quarter-wavelength line resonators: $N + 1$ sections.
Description of Design Process
Parallel Coupled Bandpass Filter: Stripline Construction

Photograph of a typical 5-pole Parallel Coupled Bandpass Filter constructed in balanced stripline:
1. Metal/copper center conductor is sandwiched between two dielectric materials which have metallization on its bottom surface.
2. Metallization on top surface of dielectric substrate is chemically etched to produce line widths: $W_{i,i+1}$ and gap spacing between strips: $S_{i,i+1}$.

Side view of stripline filter after assembly.
Description of Design Process
Parallel Coupled Bandpass Filter: Microstrip Construction

Photograph of a typical 5-pole Parallel Coupled Bandpass Filter constructed in microstrip:

1. In microstrip construction, metal center conductor is exposed to environment, which makes the small gap spacing between strips susceptible to short circuit by stray pieces of metal: FOD (Foreign Object Debris).
2. Metallization on top surface of single dielectric substrate is chemically etched to produce line widths: $W_{i,i+1}$, and gap spacing between strips: $S_{i,i+1}$.
3. Stand-alone dielectric substrate has metallization on its bottom surface.
4. Caution: Don’t forget effects of metal top cover on RF performance of filter.
PCfilter: Computer Software
Parallel Coupled Bandpass Filter

Atlanta RF (www.AtlantaRF.com) offers RF/microwave CAE software product: *PCfilter* to aid in the design of multi-section Parallel Edge Coupled Bandpass Filters constructed in microstrip or in stripline:

1. *Synthesis* of the filter’s electrical circuit:
   a. Lowpass prototype elements values: Chebyshev or Butterworth.
   b. Even and Odd-Mode Impedances: $Z_{oe}$ and $Z_{oo}$ of each section.
   c. Admittance Inverters: $J_{i,i+1}$ for each section in the filter.

2. *Synthesis* of distributed circuit in microstrip or balanced stripline:
   a. Synthesis of line widths: $W_{i,i+1}$ and gap spacing between strips: $S_{i,i+1}$.
   b. Synthesis of physical length of each resonator section

3. *Frequency Analysis* response profile of parallel coupled bandpass filter based on physical dimensions:
   a. VSWR/Return Loss, thru-path Insertion Loss and phase
   b. Frequency when higher-order modes may launch.

Software product: *PCfilter* provides the User with full design capability, from Synthesis to Frequency Analysis of Parallel Edge-Coupled Bandpass Filters and their Distributed form: Microstrip or Stripline.
PCfilter: Synthesis of Electrical Circuit
Parallel Coupled Bandpass Filter

Example: Data entry for synthesis of electrical circuit for User’s Parallel Coupled Bandpass Filter:

User enters filter’s center frequency and operating bandwidth.

User enters passband ripple and selects number of sections: N.

Please enter the following Design Data:
- Filter’s Center Frequency, MHz = 1200.
- Filter’s Passband Bandwidth, MHz = 120.
- Desired Bandwidth for Filter = 10.00 %
- Select RESPONSE profile for your Filter:
  *1: Tchebyscheff (Equi-ripple) Passband Response (Default).
  2: Butterworth (Maximally Flat) Passband Response.
  RESPONSE profile selected = 1

- Enter Passband RIPPLE Level in dB:
  - Enter 0.01 for VSWR = 1.10; R.L. = 26.4 dB.
  - Enter 0.05 for VSWR = 1.24; R.L. = 19.5 dB (Default).
  - Enter 0.10 for VSWR = 1.35; R.L. = 16.5 dB.
  - Enter 0.20 for VSWR = 1.54; R.L. = 13.5 dB.
  - Enter 0.50 for VSWR = 2.00; R.L. = 9.6 dB.
  - Or a value of your choice.
  Enter Passband RIPPLE in dB = 0.00986

- Select METHOD for entering Number of Filter Sections:
  *1: User enters Number of Filter Sections: N (Default).
  METHOD selected = 1

- Number of Resonate Poles: N < 12 = 6
- Impedance of the System: Zo, Ohms = 50.
Example: Synthesis data of electrical circuit for User’s Parallel Coupled Bandpass Filter:

Summary: Baseline electrical design parameters for User’s bandpass filter.

Electrical circuit synthesized from filter’s baseline electrical parameters.
PCfilter: Synthesis of Physical Circuit
Parallel Coupled Bandpass Filter

Example: Synthesis data of distributed circuit for User’s Parallel Coupled Bandpass Filter constructed in stripline.

Summary: Electrical and physical design data on User’s parallel coupled filter.

Synthesis of distributed RF circuit for User’s Parallel Coupled Bandpass Filter in stripline.

```
Summary: Electrical and physical design data on User’s parallel coupled filter.
```

PCfilter (v. 1.3)  Date: 6/24/2017 at 20: 2: 4 Hours
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RF/Microwave Computer-Aided Engineering Design Data For
Multi-Section Parallel Coupled Line Bandpass Filters.

SYNTHESIS of Physical Dimensions for your Parallel Coupled Line Bandpass Filter results in the following design data:

Flow = 1140.000 MHz     Response = Tchebyscheff
Fo  = 1200.000 MHz     # of Poles = 6
Fhigh= 1260.000 MHz     Ripple (Am) = 0.010 dB
BW = 120.000 MHz       Zo of System= 50.00 Ohms
Er = 2.550             Construction= Stripline
B = 0.500 inches       Strip Thick = 0.0017 inches

<table>
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<tr>
<th>Section</th>
<th>Line Width:W</th>
<th>Section Gap Spacing:S</th>
<th>Resonator Length</th>
<th>Open-End Capacitance</th>
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<tr>
<td></td>
<td>(K) Inches</td>
<td>(K,K+1) Inches MM</td>
<td>Inches</td>
<td>pico-farads</td>
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<tr>
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<tr>
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<td>0.0244</td>
<td>1.5397</td>
<td>0.1468</td>
</tr>
</tbody>
</table>

Total Length of your Bandpass Filter = 10.7782 inches.

For Zo = 50.00 Ohms, Line Width = 0.3636 inches in Er = 2.550.
For Fo = 1200.00 MHz, Quarter Wavelength = 1.5397 inches.
Maximum usable operating frequency = 4.890 GHz before possible launch of higher-order modes.

Atlanta RF
Services, Software & Designs
PCfilter: Frequency Analysis
Parallel Coupled Bandpass Filter

Frequency Analysis of your Parallel Coupled Line Bandpass Filter results in the following response profile:

Flow = 1140.000 MHz  Response = Tchebyscheff
Fo = 1200.000 MHz  # of Poles = 6
Fhigh = 1260.000 MHz  Ripple (Am) = 0.00986 dB
BW = 120.000 MHz  Zo of System = 50.00 Ohms
SR = 5.000 u"  Resistivity = 1.700 u-Ohm-cm
Loss Tangent = 0.00100

<table>
<thead>
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<th>Frequency (MHz)</th>
<th>Input Port: S11</th>
<th>Input Impedance</th>
<th>Thru Loss: S21</th>
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<td>Phase Real</td>
<td>Imag dB</td>
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<td>1075.00</td>
<td>99.990</td>
<td>-0.17</td>
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</tbody>
</table>

Source Impedance: Zs = 50.000 Ohms.
Load Impedance: ZL = 50.000 Ohms.

Example: Frequency analysis data of distributed circuit for User’s Parallel Coupled Bandpass Filter: Stripline.

Summary: Electrical design parameters for User’s parallel coupled stripline filter.
Example: 6-pole Stripline Bandpass Filter

Parallel Coupled Bandpass Filter: Synthesis of Dimensional Data

Parallel-Coupled Transmission-Line Resonator Filters, S.B. Cohn, IRE, MTT-6, April 1958.

PCfilter (v. 1.3) Date: 5/28/2017 at 18:33: 3Hours
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RF/Microwave Computer-Aided Engineering Design Data For
Multi-Section Parallel Coupled Line Bandpass Filters.

SYNTHESIS of Physical Dimensions for your Parallel Coupled
Line Bandpass Filter results in the following design data:

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Fo = 1200.000 MHz # of Poles = 6
Fhigh = 1260.000 MHz Ripple (Am) = 0.010 dB
BW = 120.000 MHz Zo of System = 50.00 Ohms
Er = 2.550 Construction = Stripline
B = 0.500 inches Strip Thick = 0.0017 inches

<table>
<thead>
<tr>
<th>Section (K)</th>
<th>Width: W</th>
<th>Section Spacing: S</th>
<th>Resonator Length: K, Length: K+1</th>
<th>Cohn's Width: W</th>
<th>Cohn's Gap: S</th>
<th>Cohn's Length: L</th>
<th>Error: Cohn - PCfilter, inches</th>
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<tbody>
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<td>0.110</td>
<td>1.456</td>
<td>0.0052 -0.0027 -0.0837</td>
</tr>
<tr>
<td>3</td>
<td>0.3532</td>
<td>0.1636</td>
<td>1.5397</td>
<td>0.360</td>
<td>0.158</td>
<td>1.455</td>
<td>0.0068 -0.0056 -0.0847</td>
</tr>
<tr>
<td>4</td>
<td>0.3544</td>
<td>0.1722</td>
<td>1.5397</td>
<td>0.361</td>
<td>0.163</td>
<td>1.455</td>
<td>0.0066 -0.0092 -0.0847</td>
</tr>
<tr>
<td>5</td>
<td>0.3532</td>
<td>0.1636</td>
<td>1.5397</td>
<td>0.360</td>
<td>0.158</td>
<td>1.456</td>
<td>0.0068 -0.0056 -0.0837</td>
</tr>
<tr>
<td>6</td>
<td>0.3408</td>
<td>0.1127</td>
<td>1.5397</td>
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<td>1.467</td>
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<td>7</td>
<td>0.2323</td>
<td>0.0244</td>
<td>1.5397</td>
<td>0.236</td>
<td>0.021</td>
<td></td>
<td>0.0037 -0.0034</td>
</tr>
</tbody>
</table>

Total Length of your Bandpass Filter = 10.7782 inches.

Note: Foreshorten resonator length by: \( d = 0.165B = 0.165 \times 0.5" = 0.0825" \)
Example: 6-pole Stripline Bandpass Filter
Parallel Coupled Bandpass Filter: Frequency Analysis Results

Parallel-Coupled Transmission-Line Resonator Filters, S.B. Cohn, IRE, MTT-6, April 1958.

Cohn's 1958 Stripline Parallel Coupled Bandpass Filter: N = 3 Chebyschev; Passband Ripple: Lar = 0.01dB; Fo = 1200MHz; BW = 120MHz (10%); Er = 2.55; B = 0.50"; T = 0.0017"; Tan δ = 0.0025.
Example: 3-pole Microstrip Bandpass Filter
Parallel Coupled Bandpass Filter: Synthesis of Dimensional Data


**Flow** = 11500.000 MHz  
**Response** = Tchebyscheff  
**Fo** = 11950.000 MHz  
**Fhigh** = 12400.000 MHz  
**BW** = 900.000 MHz  
**Er** = 3.800  
**H** = 0.015 inches

# of Poles = 3  
Ripple (Am) = 0.200 dB  
Zo of System = 50.00 Ohms  
Construction = Microstrip

**SYNTHESIS of Physical Dimensions for your Parallel Coupled Line Bandpass Filter** results in the following design data:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0242</td>
<td>0.0040</td>
<td>0.1442</td>
<td>0.0255 0.0033 0.1385 0.0013</td>
<td>-0.0007 -0.0057</td>
</tr>
<tr>
<td>2</td>
<td>0.0298</td>
<td>0.0196</td>
<td>0.1429</td>
<td>0.0315 0.0180 0.1365 0.0017</td>
<td>-0.0016 -0.0064</td>
</tr>
<tr>
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<td>0.0298</td>
<td>0.0196</td>
<td>0.1429</td>
<td>0.0315 0.0180 0.1365 0.0017</td>
<td>-0.0016 -0.0064</td>
</tr>
<tr>
<td>4</td>
<td>0.0242</td>
<td>0.0040</td>
<td>0.1442</td>
<td>0.0255 0.0033 0.1385 0.0013</td>
<td>-0.0007 -0.0057</td>
</tr>
</tbody>
</table>

Total Length of your Bandpass Filter = 0.5741 inches.
Example: 3-pole Microstrip Bandpass Filter
Parallel Coupled Bandpass Filter: Frequency Analysis Results


Childs 1976 Microstrip Parallel Coupled Bandpass Filter: \( F_0 = 11,950 \text{MHz}; 900 \text{MHz Bandwidth}; N = 3 \) Chebyshev; 0.2dB Passband Ripple; \( E_r = 3.8; H = 0.015''; T = 0.0007'' \); Copper; \( \tan \delta = 0.0001 \)

Frequency analysis predicted by PCfilter.
Example: 5-pole Microstrip Bandpass Filter
Parallel Coupled Bandpass Filter: Synthesis of Dimensional Data


Flow = 9250.0 MHz
Response = Tchebyscheff
Fo = 10000.0 MHz
Fhigh = 10750.0 MHz
BW = 1500.0 MHz
Zo of System = 50.0 Ohms
Er = 10.200
Construction = Microstrip
H = 0.025 inches
Strip Thick = 0.0002 inches

<table>
<thead>
<tr>
<th>Section (K)</th>
<th>Width: W (Inches)</th>
<th>Spacing: S (Inches)</th>
<th>Length: L (Inches)</th>
<th>Hong2001 Dimensions, Inches</th>
<th>Error = Hong - PCfilter, Inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0136</td>
<td>0.0059</td>
<td>0.1124</td>
<td>0.0152 0.0063 0.1123 0.0016 0.0004 -0.0001</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.0206</td>
<td>0.0194</td>
<td>0.1109</td>
<td>0.0226 0.0213 0.1091 0.002 0.0019 -0.0018</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.0214</td>
<td>0.0257</td>
<td>0.1107</td>
<td>0.0234 0.0287 0.1085 0.002 0.003 -0.0022</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.0214</td>
<td>0.0257</td>
<td>0.1107</td>
<td>0.0234 0.0287 0.1085 0.002 0.003 -0.0022</td>
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<td>0.0226 0.0213 0.1091 0.002 0.0019 -0.0018</td>
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</tr>
<tr>
<td>6</td>
<td>0.0136</td>
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<td>0.1124</td>
<td>0.0152 0.0063 0.1123 0.0016 0.0004 -0.0001</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The dimensional data presented is an example of how to synthesize physical dimensions for a Parallel Coupled Line Bandpass Filter, based on specific design parameters. The table shows the calculated dimensions compared to those from *Microstrip Filters for RF/Microwave Applications* by J. Hong and M.J. Lancaster (2001).
Example: 5-pole Microstrip Bandpass Filter
Parallel Coupled Bandpass Filter: Frequency Analysis Results

Example: 6-pole Microstrip Bandpass Filter
Parallel Coupled Bandpass Filter: Synthesis of Dimensional Data


SYNTHESIS of Physical Dimensions for your Parallel Coupled Line Bandpass Filter results in the following design data:

- **Flow** = 3800.000 MHz
- **Response** = Tchebyscheff
- **Fo** = 4000.000 MHz
- **# of Poles** = 6
- **Fhigh** = 4200.000 MHz
- **Ripple (Am)** = 0.200 dB
- **BW** = 400.000 MHz
- **Zo of System** = 50.00 Ohms
- **Er** = 3.800
- **Construction** = Microstrip
- **H** = 0.020 inches
- **Strip Thick** = 0.0002 inches

<table>
<thead>
<tr>
<th>Section</th>
<th>Width: W</th>
<th>Spacing: S</th>
<th>Length: L</th>
<th>Bahl6 Dimensions, Inches</th>
<th>Error = Bahl6 - PCfilter, Inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>(K)</td>
<td>Inches</td>
<td>(K,K+1)</td>
<td>Inches</td>
<td>Width: W</td>
<td>Gap: S</td>
</tr>
<tr>
<td>---------</td>
<td>----------</td>
<td>------------</td>
<td>-----------</td>
<td>-----------</td>
<td>--------</td>
</tr>
<tr>
<td>1</td>
<td>0.0316</td>
<td>0 1</td>
<td>0.0042</td>
<td>0.4335</td>
<td>0.0317</td>
</tr>
<tr>
<td>2</td>
<td>0.0401</td>
<td>1 2</td>
<td>0.0216</td>
<td>0.4294</td>
<td>0.0403</td>
</tr>
<tr>
<td>3</td>
<td>0.0406</td>
<td>2 3</td>
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<td>0.4291</td>
<td>0.0407</td>
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<tr>
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<td>0.0408</td>
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<tr>
<td>5</td>
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<td>4 5</td>
<td>0.0280</td>
<td>0.4291</td>
<td>0.0407</td>
</tr>
<tr>
<td>6</td>
<td>0.0401</td>
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</tr>
<tr>
<td>7</td>
<td>0.0316</td>
<td>6 7</td>
<td>0.0042</td>
<td>0.4335</td>
<td>0.0317</td>
</tr>
</tbody>
</table>
Example: 6-pole Microstrip Bandpass Filter
Parallel Coupled Bandpass Filter: Frequency Analysis Results

Bahl 1989 Microstrip Parallel Coupled Bandpass Filter: Fo = 4GHz; 400MHz Bandwidth; N = 6 Chebyshev; 0.2dB Passband Ripple; Er = 3.8; H = 0.02"; T = 0.0002"; Tan δ = 0.0001

Frequency analysis predicted by PCfilter.

Atlanta RF
Services, Software & Designs
Summary
Parallel Coupled Bandpass Filters

Parallel Coupled Bandpass Filters are effective means to allow desired RF signals to pass-thru a communications circuit, while attenuating RF signals operating at out-of-passband frequencies.

A design process has been presented for the electrical and dimensional design of Parallel Coupled Bandpass Filters constructed in microstrip or in stripline transmission lines.

Atlanta RF’s software product: PCfilter is presented, which offers the User with a valuable and viable design aid for the electrical synthesis, dimensional synthesis and frequency analysis of Parallel Coupled Bandpass Filters constructed in microstrip or in stripline. As with all computer-generated RF circuit designs, the User is encouraged to confirm the physical design generated by PCfilter in an electromagnetic simulator, then adjust physical dimensions (if needed), prior to manufacturing the filter.
Atlanta RF LLC was founded to provide engineering solutions, design software solutions, and product development solutions to the high-frequency RF/microwave industry in the areas of: Telecommunications (ground segment), Satellite (space segment) and military/defense (RF front-ends).

Through teamwork, Atlanta RF applies our diverse technical experience to your project's challenges with creative and innovative solutions while holding ourselves accountable for the results. With professionalism and commitment to our clients, Atlanta RF will be there for you, both today and tomorrow.

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- Atlanta RF Software: Sales@AtlantaRF.com
- Atlanta RF Designs: Designs@AtlantaRF.com

Or, contact Atlanta RF by phone at: 678-445-5544, to reach our Atlanta-area office in Georgia, USA, and discuss our support to your current or future projects & products.
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