Project Report

A Harmonic-Suppression Microwave Bandpass Filter Based on an Inductively Compensated Microstrip Coupler

Submitted by: ANUBHAV ADAK
M.TECH(C.E.D.T)

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Microstrip coupler based bandpass filters are used for many applications.

Several ways to implement bandpass filters are :-

1. Using stub line filters.
   This implementation consumes a large area.

2. Using conventional coupled band pass filters
   a. Asymmetric passband response.
   b. Spurious harmonics at first (2fo) and second (3fo). These are a result of
      inequality in even and odd mode phase velocities in inhomogeneous medium.

To cure the above said problems:-

a. Extra low pass or bandreject filters can be connected after the filter to suppress
   the noise at the cost of increased insertion loss trade off.
   Several techniques were proposed to equalize or compensate the phase velocity
   inequality effect in microstrip couplers.

b. Corrugated or wiggly line couplers were used to remove the phase velocity
   inequality effect. Unfortunately these result from lack of pertinent design
   information.

c. the Unipolar-Compact Photonic bandgap Ground structure can very well
   suppress the spurious transmission of (30-40)dB at harmonic frequencies but it is
   difficult to design and implement

5. The overcoupled resonator was used to extend odd mode phase length but no
   close form solutions are available yet.

d. The capacitive compensating technique was used to improve passband
   symmetry and spurious free response of the microstrip coupler.
   But it needs a lumped capacitor to equalize phase velocities.
   Hence special layout attention is needed.

In this project we are investigating the design of a bandpass filter with spurious 1st and
2nd harmonic noise rejection using
grounded inductors at ground and coupled ports.
Inductive coupling:

In this type of coupling we use short circuited stubs to behave as inductors. \( Z_{in} = jZ \tan \beta l \) (for short circuit stub).

By applying inductive stubs we actually increase the directivity of the coupler at that frequency and attenuate their harmonics.

DESIGN OF INDUCTIVE STUBS

Inductive stubs can be designed using the following equations:

\[
L_s = \frac{1}{2\pi f_0} \text{Im} \left( \frac{Z_0^2 (\cosh \theta - \cosh \theta') + Z_0 Z_B - \Re}{Z_B} \right) \quad (1)
\]

where

\[
\Re = Z_0 \sqrt{(Z_{oe}^2 + Z_{oo}^2) \sinh \theta \sinh \theta' - 2Z_0^2 (\cosh \theta \cosh \theta' - 1)} \quad (2a)
\]

and

\[
Z_B = Z_{oe} \sinh (\theta) - Z_{oo} \sinh (\theta') \quad (2b)
\]

\( Z_0 \) is the characteristic impedance of the coupler
\( Z_{oe} \) is the even-mode characteristic impedance of the coupler
\( Z_{oo} \) is the odd-mode characteristic impedance of the coupler
\( \varepsilon_{eff} \) is the even-mode effective dielectric constant
\( \varepsilon_{eff} \) is the odd-mode effective dielectric constant
\( \theta = \frac{\pi}{2} \) is the even-mode electrical length of the coupler
\( \theta' = \frac{\pi}{2} \sqrt{\varepsilon_{oe}/\varepsilon_{oo}} \) is the odd-mode electrical length of the coupler
INDUCTIVE STUBS INCREASE THE DIRECTIVITY AS SHOWN BELOW

DESIGN OF BAND-PASS FILTER

THE DESIGN SPECS CHOSEN FOR THE DESIGN ARE:-

1. Order of the filter : - 3
2. Frequency response type : - Chebyshev
3. Passband ripple : - 0.1 dB
4. Center frequency : - 2 G Hz.
5. 3-dB cutoff's : - 1.915GHz to 2.115 G Hz
6. Bandwidth : - 200MHz (10% FRACTIONAL BANDWIDTH)

Substrate properties

a. substrate used: RF60-0600
b. Relative permittivity=6.15
c. Substrate thickness=1.5mm
d. Loss tangent=0.002
DESIGN EQUATIONS

End sections: 0, 1 and n, n+1
For $k=0$ and $k=n$

$$\frac{J_{k+1}}{Y_A} = \frac{1}{\sqrt{g_k g_{k+1} \omega_i}}$$

$$h = \frac{1}{\tan \theta_{1}} + \left( \frac{J_{01}}{Y_A} \right)^2$$

$$(Y_{\infty})_{k+1} = Y_A \left( \frac{J_{k,k+1}}{Y_A} \sqrt{h} + 1 \right)$$

$$(Y_{\infty})_{k+1} = 2Y_A - (Y_{\infty})_{k+1}$$

Insertion sections: 1, 2, ..., n-1
For $k=1$ to $k=n-1$

$$\frac{J_{k,k+1}}{Y_A} = \frac{1}{\omega_i \sqrt{g_k g_{k+1}}}$$

$$N_{k,k+1} = \sqrt{\left( \frac{J_{k,k+1}}{Y_A} \right)^2 + \frac{\tan^2 \theta_{1}}{4}}$$

$$(Y_{\infty})_{k,k+1} = hY_A \left( N_{k,k+1} + \frac{J_{k,k+1}}{Y_A} \right)$$

$$(Y_{\infty})_{k,k+1} = hY_A \left( N_{k,k+1} - \frac{J_{k,k+1}}{Y_A} \right)$$
BANDPASS FILTER

A third order bandpass filter at fo= 2 GHz passband frequency with Chebyshev frequency response, fractional bandwidth of 10% and passband ripple of 0.1dB
The values of couplers and stubs are listed below.

<table>
<thead>
<tr>
<th>COUPLER</th>
<th>COUPLER'S DIMENSION, length(l),width(w),spacing(s) (in mm)</th>
<th>ELECTRICAL LENGTH $\psi$ (in deg)</th>
<th>Zoe($\Omega$)</th>
<th>Zoo($\Omega$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,4</td>
<td>15.375 1.45 0.30</td>
<td>68.73</td>
<td>67.94</td>
<td>39.55</td>
</tr>
<tr>
<td>2,3</td>
<td>12.9    1.55 1.5</td>
<td>58.78</td>
<td>57.7</td>
<td>50.06</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>STUB</th>
<th>INDUCTOR VALUES(nH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,4,5,8</td>
<td>0.51</td>
</tr>
<tr>
<td>2,3,6,7</td>
<td>1.4</td>
</tr>
</tbody>
</table>
EXPERIMENTAL RESULTS

THE SIMULATION RESULTS ARE COMPARED BELOW.

------------------------------------------
s11comparison--------------------------------------------

<table>
<thead>
<tr>
<th>freq (GHz)</th>
<th>CONVENTIONAL(S21)</th>
<th>PROPOSED(S11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00E+00</td>
<td>2.00E+09</td>
<td>-1.60E+01</td>
</tr>
<tr>
<td>2.00E+09</td>
<td>4.00E+09</td>
<td>-1.40E+01</td>
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<tr>
<td>4.00E+09</td>
<td>6.00E+09</td>
<td>-1.20E+01</td>
</tr>
<tr>
<td>6.00E+09</td>
<td>8.00E+09</td>
<td>-1.00E+01</td>
</tr>
<tr>
<td>8.00E+09</td>
<td>0.00E+00</td>
<td>-8.00E+00</td>
</tr>
</tbody>
</table>

freq (GHz)

S11
CONVENTIONAL(S21)

MEASURED S11

S11

FREQ(GHz)

-34dB

CONVENTIONAL(S21)

simulated_conventional

freq(GHz)
RESULTS

Thus our filter meets all the design specifications and additional we get harmonic noise rejection of approximately 40 dB at 1\textsuperscript{st} harmonic (4 GHz) and 24 dB at 2\textsuperscript{nd} harmonic (6 GHz).
REFERENCES
