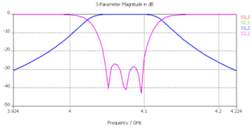
Design and Tuning Coupled-Resonator Filters with group delay approach

- Goal: design of a 3 pole combline filter at 4.074 GHz
- The group delay of the reflection coefficient of sequencally tuned resonator contain all the necessary information to design and tune the frequency $Td(w) = \dfrac{d\phi}{d\,w}$
- And around the resonant frequency it is $Td(w) = -\dfrac{(w^2 + wo^2)}{w^2 \cdot (w2 - w1)} \cdot \dfrac{d\phi}{d\,w1}$
- And the group delay of S11 for the bandpass circuit is given by

$$Td(w) = \frac{2 \cdot (w^2 + wo^2)}{w^2 \cdot (w2 - w1)} \cdot \frac{d\left(\tan^{-1}\left(\frac{Xin(w1)}{Z0}\right)\right)}{d\,w1}$$

Number of resonators	Group delay	Coupling coefficent
N=1	$Td1(w) = \left(\frac{4 \cdot g0 \cdot g1}{w2 - 1}\right)$	$Qe = \frac{g0 \cdot g1 \cdot w0}{deltaw}$
N=2	$Td = \left(\frac{4}{w0 \cdot Qe \cdot k12^2}\right)$	$k12 = \frac{deltaw}{wo(g1 \cdot g2)^{\frac{1}{2}}}$
N=3	$Td3 = Td1 + \left(\frac{4 \cdot Qe \cdot k12^2}{w0 \cdot k23^2}\right)$	$k23 = \frac{delta}{w0 \cdot (g2 \cdot g3)^{\frac{1}{2}}}$

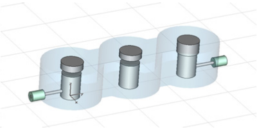


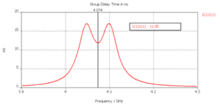
According to the paper by J.B.Ness it is necessary to follow the sequent steps:

1. Short all the resonator except resonator 1

2. Adjust resonator 1 and input coupling to set the specified group dellay

3. Tune the second resonator and the coupling between resonators to get a symmetrical group-delay response about the center frequency and with the specific value. It is also necessary to readjust resonator 1.
4. If the filter as a symmetrical structure with n resonators are only necessary n/2 steps.





It is also possible calculate the group delay in others ways (i.e. touchstone file)

To obtain the requested results a Macro it has been created to center and symmetrised the group delay curve
The Macro calculates the Group delay from the phase of the S11 and finds all the maximum and the minimum value of the group delay curve thanks to a parabolic interpolation.
The goal function is easy done: minimize the distance between the theoretical and the calculated max/min and, when present minimize the difference between the other pick.