Feeder Realization for Quasi-lumped Multilayer Resonators With Low Q-factor

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CSECS 2012

WSEAS

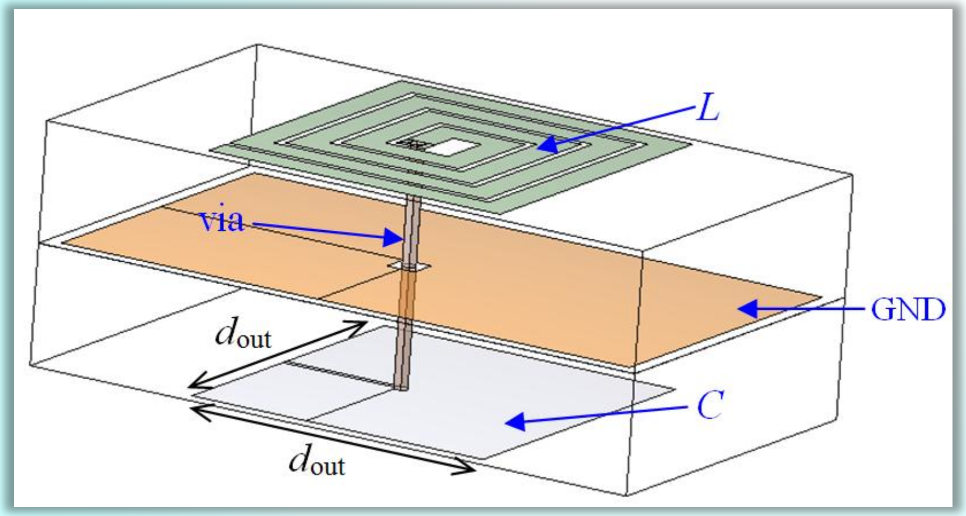
Relevance of quasi-lumped μW resonators

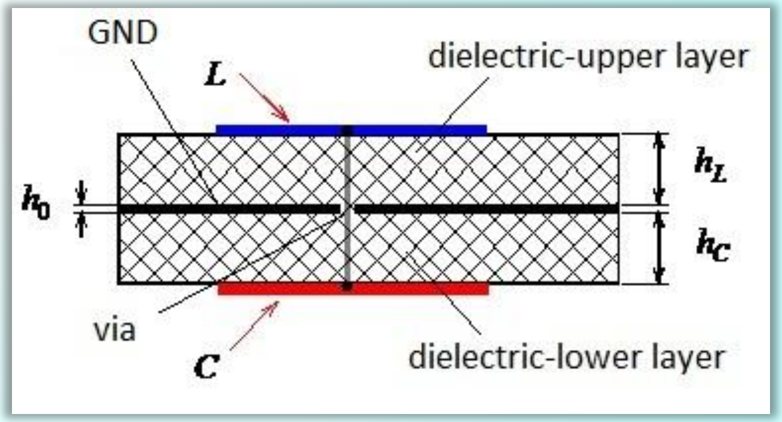
- S.-C. Lin, C.-H. Wang, and C. H. Chen, "Novel Patch-Via-Spiral Resonators for the Development of Miniaturized Bandpass Filters With Transmission Zeros," *IEEE Transactions on Microwave Theory and Techniques*, vol. 55, no. 1, pp. 137–146, Jan. 2007.
- C.-H. Chen, C.-H. Huang, T.-S. Horng, S.-M. Wu, J.-Y. Li, C.-C. Chen, C.-T. Chiu, and C.-P. Hung, "Very Compact Stacked *LC* Resonator-Based Bandpass Filters With a Novel Approach to Tune the Transmission Zeros," *IEEE Microwave and Wireless Components Letters*, vol. 19, no. 5, pp. 293–295, May 2009.
- J.-S. Hong, *Microstrip Filters for RF/Microwave Applications*. Hoboken, NJ: Wiley, 2011.

Goals

- Exploit good characteristics of **quasi-lumped multilayer resonator** (small size)
- Find solution for **increasing fractional bandwidth** of the filter (lowering loaded *Q*-factor)
- Investigate **benefits** and **drawbacks** of proposed solution
- Make conclusions regarding improvements

Realization of Multilayer Resonator





Multilayer resonator is implemented on a double-sided microstrip

Substrate: RT/duroid

$\varepsilon_r = 2.2$

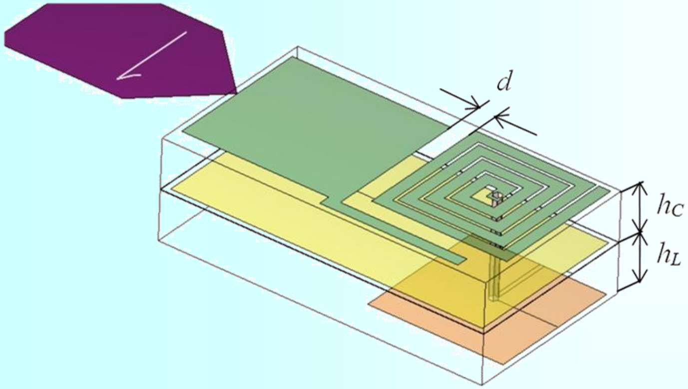
$\tan\delta = 0.001$

$h_C = h_L = 1.575$ mm

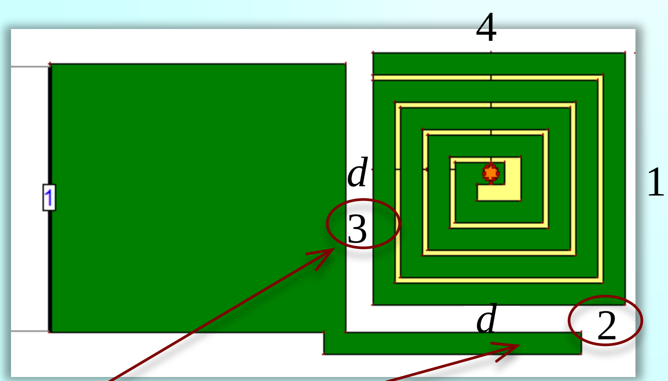
$h_0 = 2t = 36$ μm

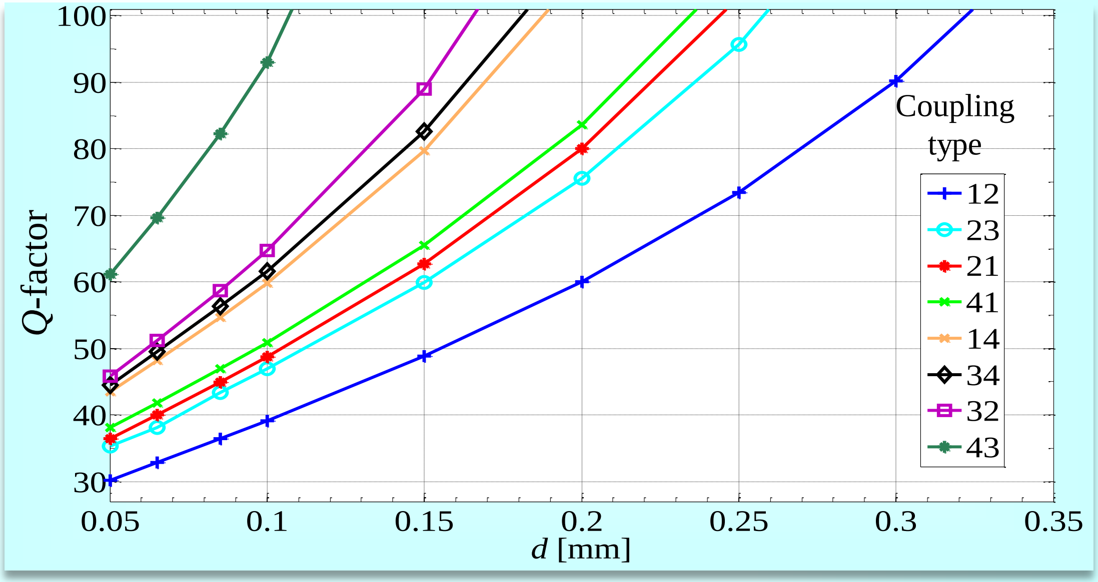
- Minimizes the size of the filter
- Retains wide range of achievable coupling coefficients and Q-factors
- Potential of further improvements

"L" Shaped Feeder Realization



d – distance between feeder and resonator





32

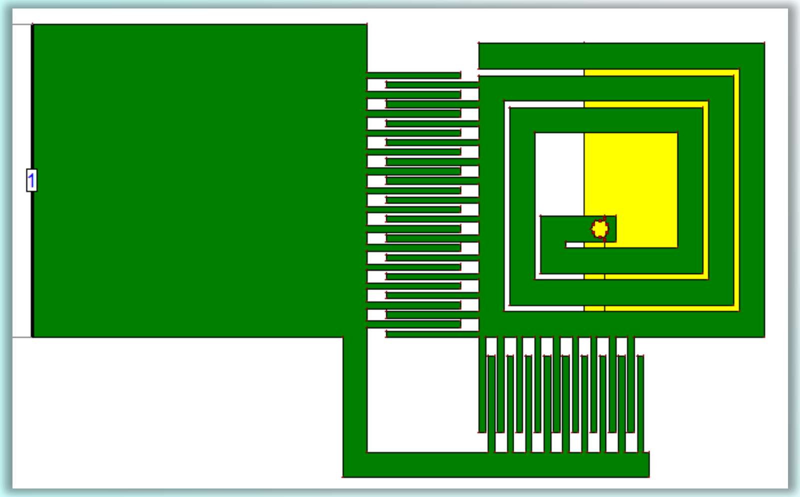
Coupling type "*ij*" refers to the sides of the coil to which feeder is coupled

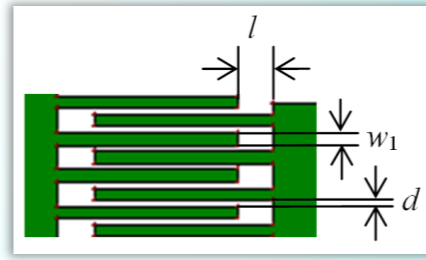
"32" shows coupling to 3rd and 2nd coil segmets

Minimum *Q*-factor obtained is 30

Realized maximum 4% bandwidth for second order filter

Saw-Toothed Feeder for Lower *Q*-factor



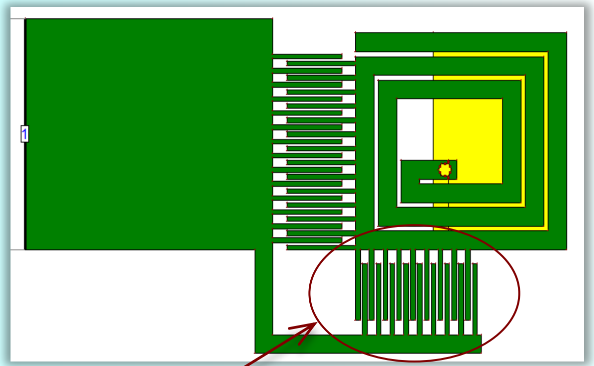


w_1 - width of tooth
d - spacing between teeth
l - overlapping

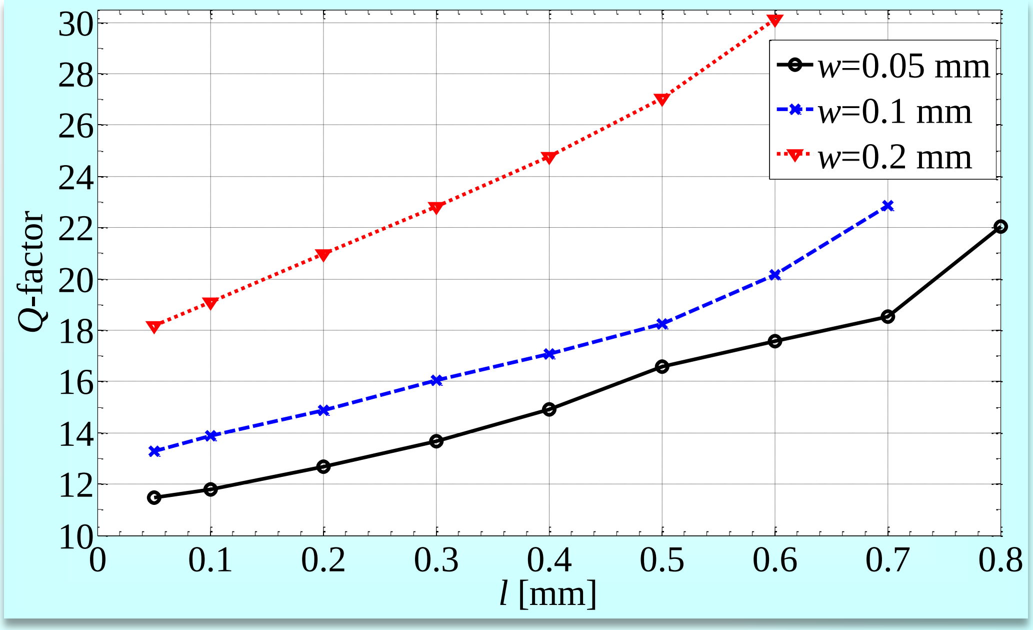
- Dimensions *w* and *d* are kept as constants while *l* is changed
  This way resonator and feeder geometry is unchanged

- Analyzed dimensions
  w = 0.05 mm, 0.1 mm, 0.2 mm while changing *l*

Achieved External *Q*-factor and Constraints

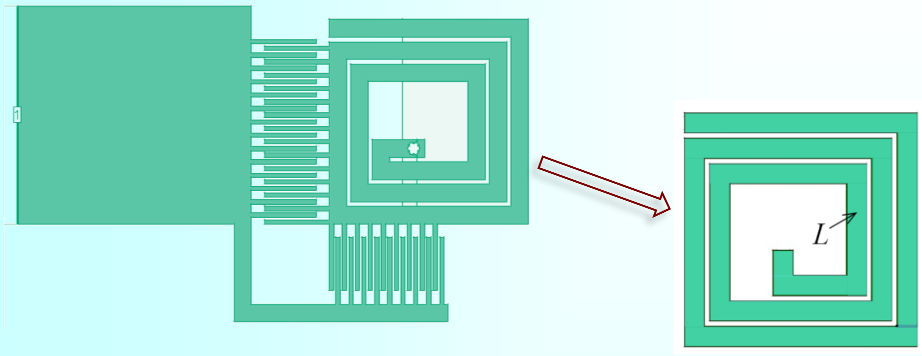


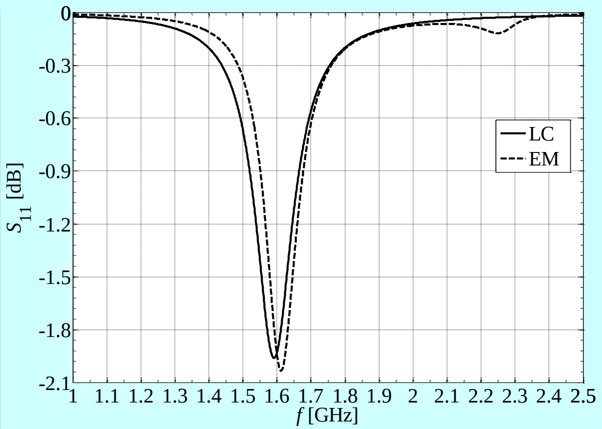
Improvement in lower *Q*-factor
minimum *Q*-factor is 8



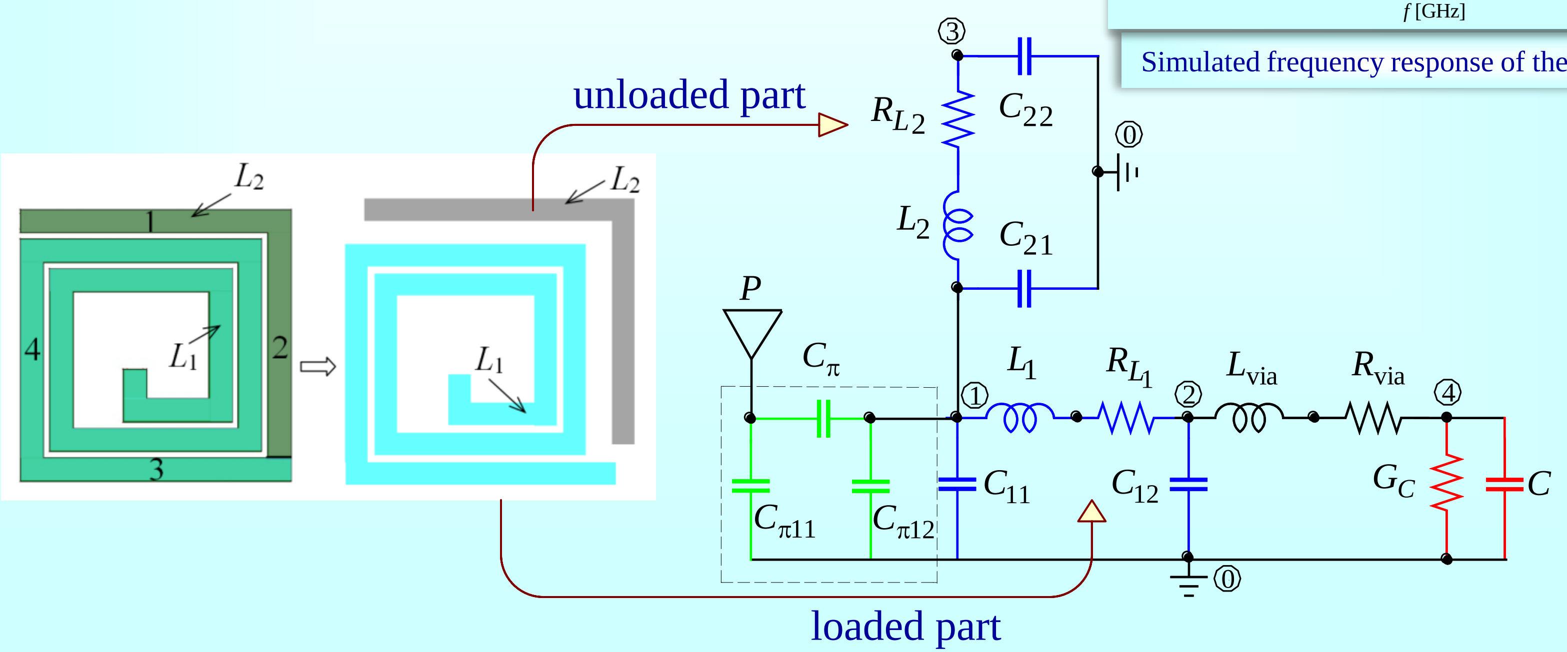
- Denser teeth, larger overlapping → greater adjacent area → greater feeder to resonator coupling → lower *Q*-factor
- Modification of the coil by adding teeth, influences on coil parameters and reduces filter resonant frequency
  Adding teeth to 1st and 2nd segment of the coil destroys coil characteristics and thus is not applicable

Circuit Model of Multilayer Resonator





Simulated frequency response of the resonator



Design Example

SPECIFICATION

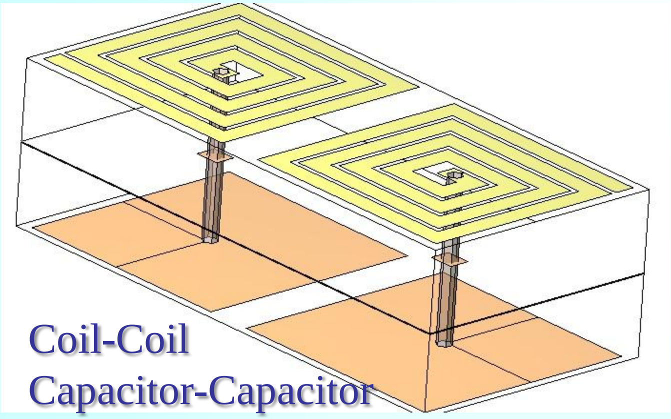
- Second order filter, Chebyshev approximation with 0.1 dB passband ripple
- Fractional bandwidth $B = 0.1$, at a center frequency $f_0 = 1.6$ GHz
- RT/duroid 5880 substrate with $\varepsilon_r = 2.2$, $h = 1.575$ mm, $\tan\delta = 0.001$, $t = 18$ μm
- Multilayer realization with $h_1 = h_2 = 1.575$ mm
- Required coupling coefficient between the two resonators is $K_{12} = 0.0935$ and Q-factors $Q_{ei} = Q_{eo} = 14.9$

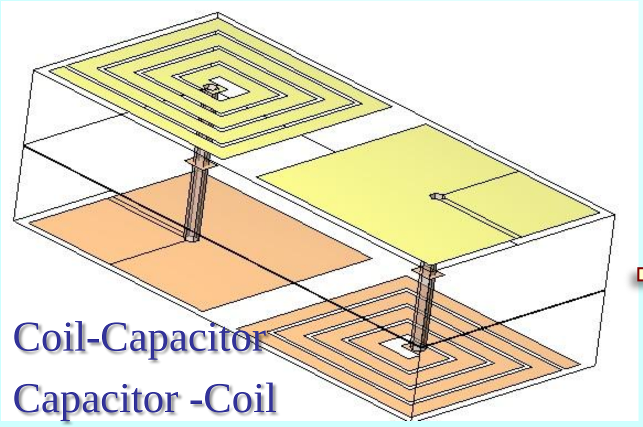
Correction of Filter Center Frequency

- Required coupling coefficient and *Q*-factors were achievable, but implementation had showed great frequency shift downward due to influence of teeth on coil parameters
- It was necessary to reduce coil inductance and/or capacitor capacitance
- Both changes have made simultaneously to diverse influence of changed geometry
- After compensating frequency shift, coupling coefficients were measured

Coupling Coefficients

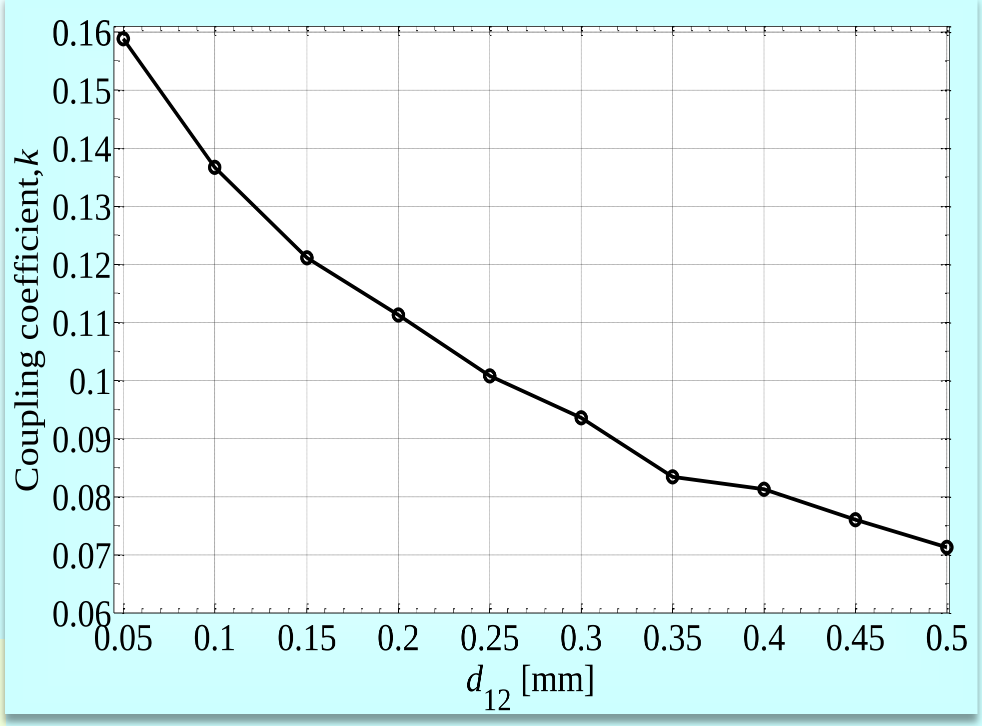
Various possibilities of coupling



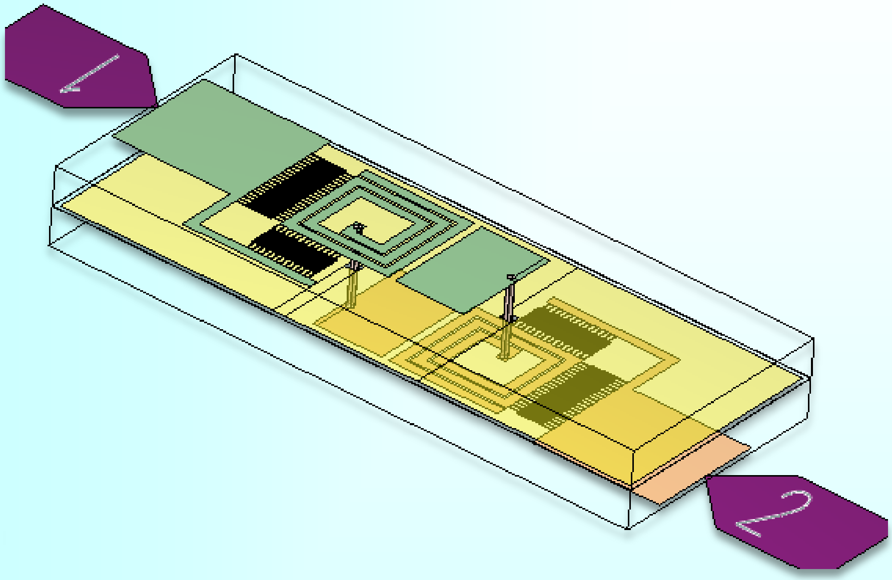


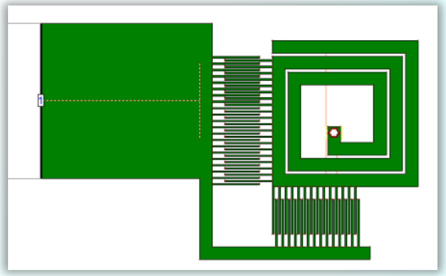
Dimensions for one resonator:
4.6 mm × 4.6 mm (0.036 λ_g x 0.036 λ_g) (specified f_0 = 1.6 GHz)

- Any to any coil segment coupling (16 variants)
- Great range of achievable couplings (max k = 0.265)

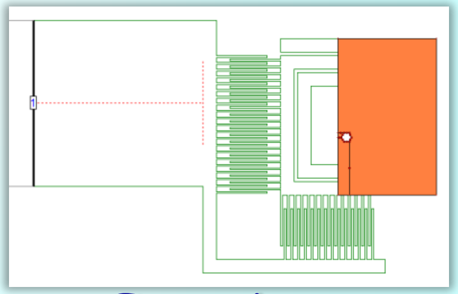


Filter Realization





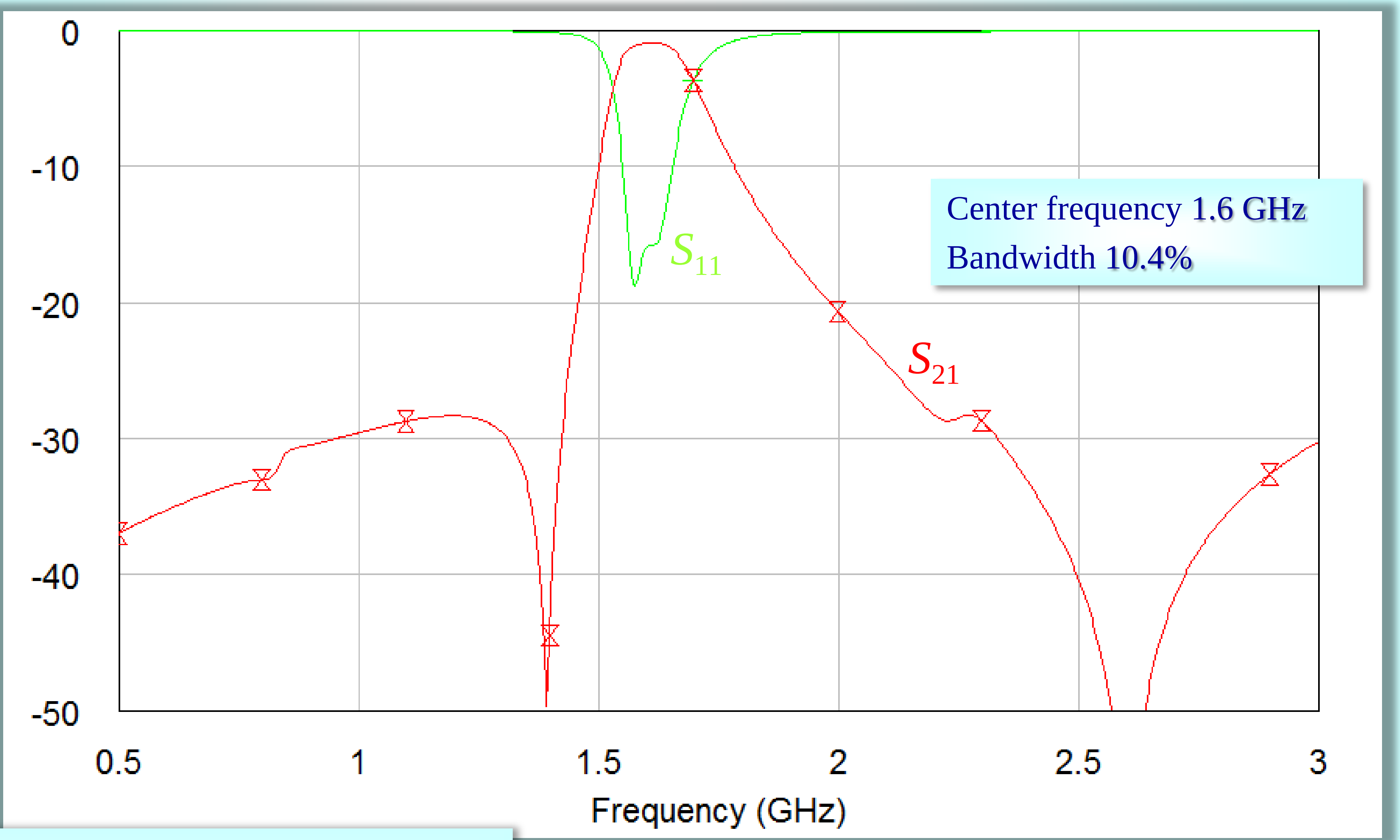
Coil



Capacitor

- Distance between resonators 0.3 mm
- Feeder coupling parameters: d = 0.05 mm, w = 0.05 mm, l = 0.4mm
- Reduced coil length for about 1.375 turns
- Reduced capacitor from 4.6 mm × 4.6 mm to 2.3 mm × 4.6 mm

S-parameters



Center frequency 1.6 GHz

Bandwidth 10.4%

Insertion loss at 1.6 GHz is 0.92 dB

$|S_{11}|_{dB}$ = –15.5 dB, at 1.6 GHz

Conclusion

FILTER

- Multilayer approach
- Size reduction (11.2 × 4.6 mm, 0.087 λ_g x 0.036 λ_g)

SAW-TOOTHED INDUCTIVE FEEDER

- Various adjustments for teeth
- Decreasing the *Q*-factor
- Limited number of combinations compared to “L” shaped inductive feeder but greater filter bandwidth

Further research

FURTHER RESEARCH COULD INCLUDE:

- Analysis of higher-order bandpass filters for increased selectivity
- Analysis of conductive coupling for further decreasing of *Q*-factor

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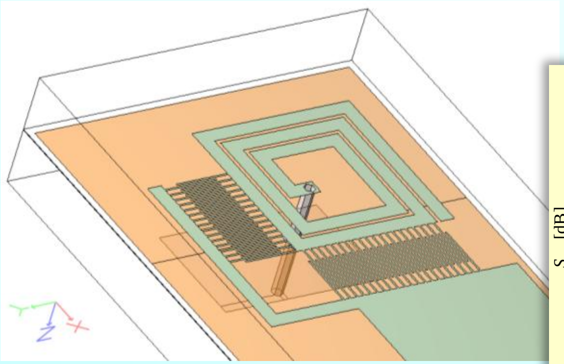
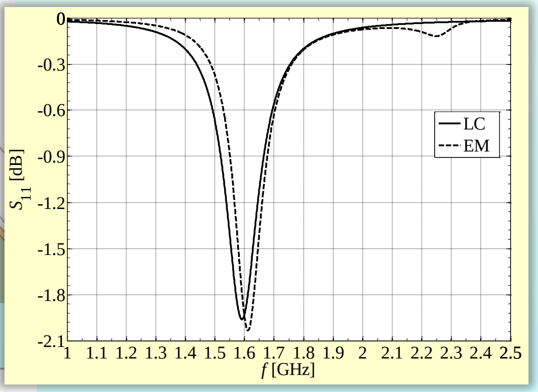
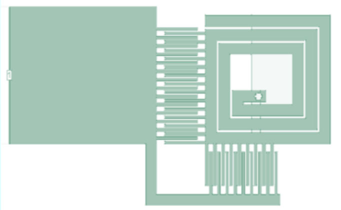
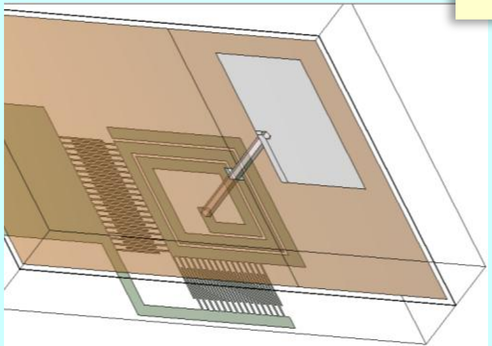
Your questions and observations are welcome and appreciated!









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