Filters – Part B

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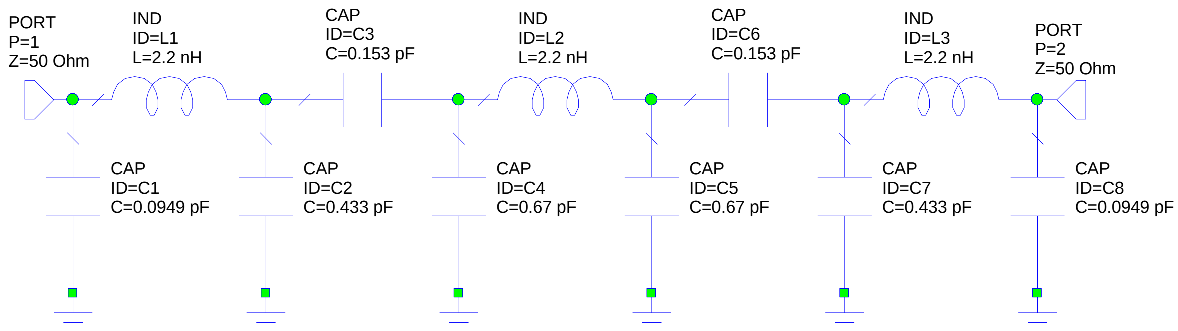
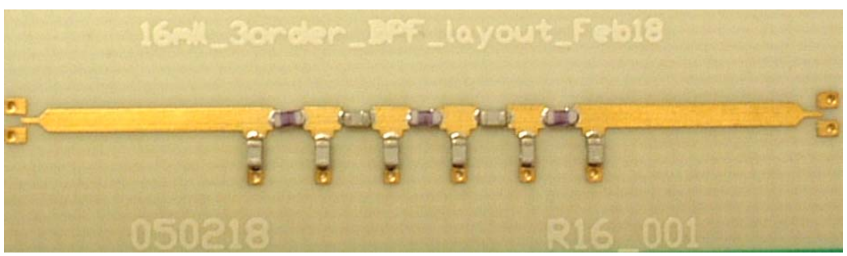
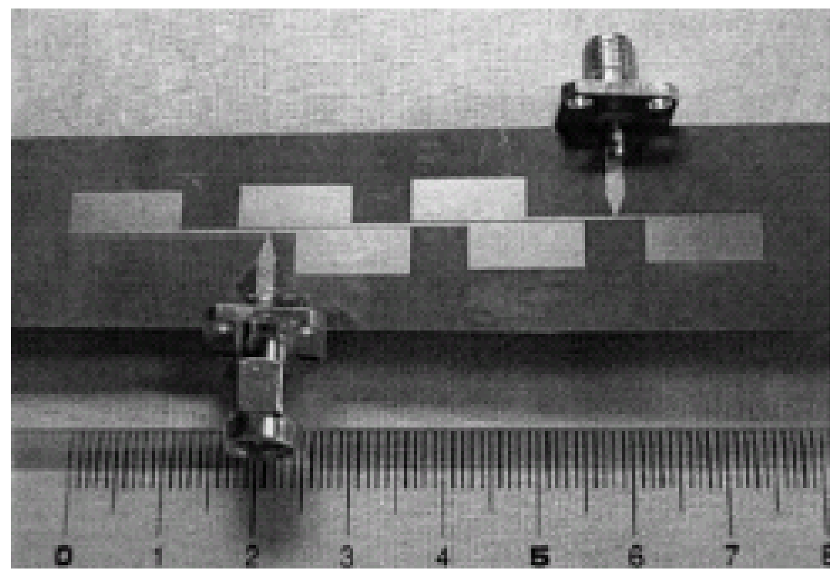
Discrete Element Filter Design

- Two Step Process: Design then Implement
- Common to design assuming ideal capacitors and inductors
- Implementation may require special techniques:
  - Actual filter technology may be different (e.g. planar instead of discrete element)
  - Values of discrete elements from design phase may not be practical

Discrete Element Filter Design







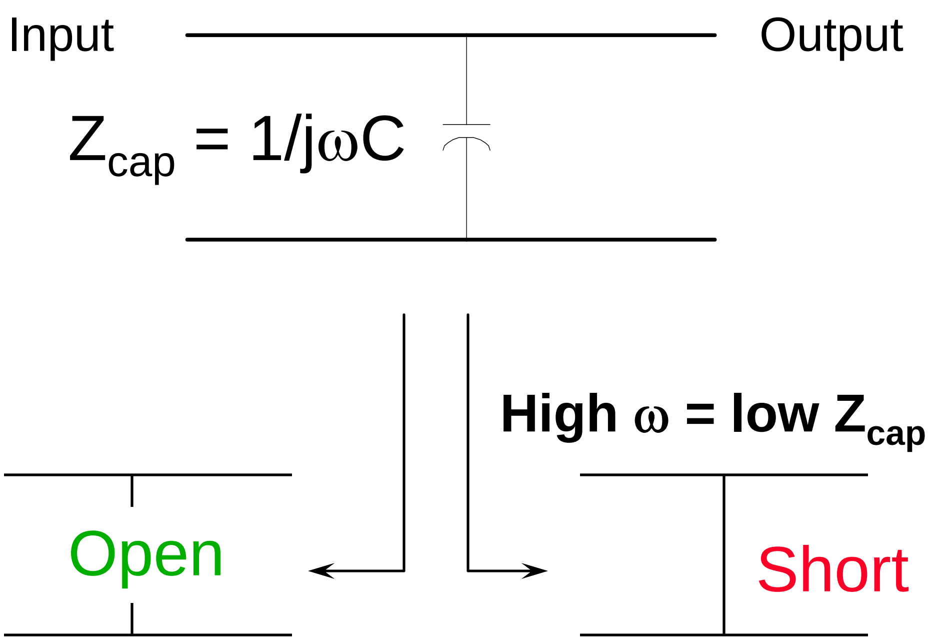
Discrete Element Filter Design

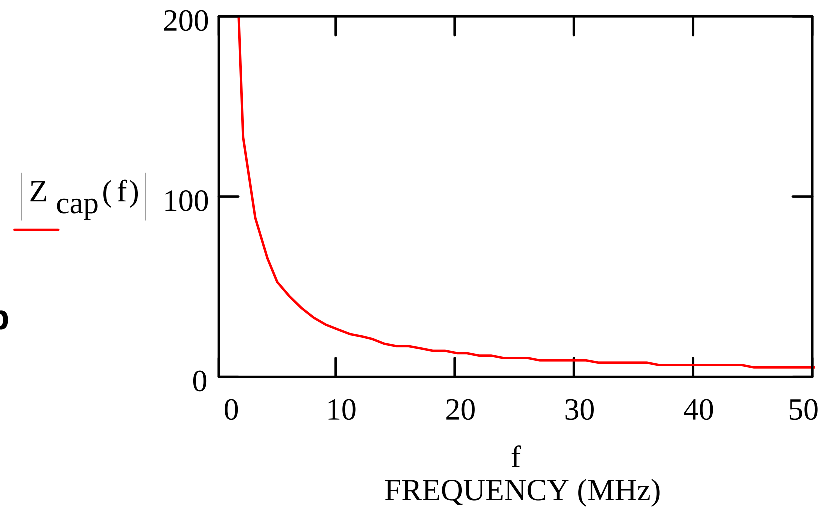
- Simple lowpass filter – need a circuit that allows low frequency signals to pass but blocks high frequency signals
- Frequency selectivity achieved using a device with a frequency-dependent impedance (capacitor or inductor)
- Two options for lowpass response:
  - Series impedance that changes from low to high as frequency increases → series inductor!
  - Shunt impedance that changes from high to low as frequency increases → shunt capacitor!

Discrete Element Filter Design

$C := 600 \cdot 10^{-12}$

$Z_{cap}(f) := \frac{1}{j \cdot (2 \cdot \pi \cdot f \cdot 10^{6}) \cdot C}$



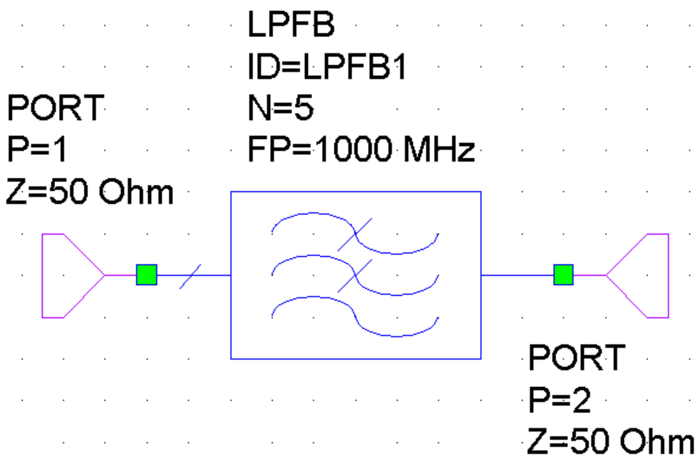


Low ω = large Z_{cap}

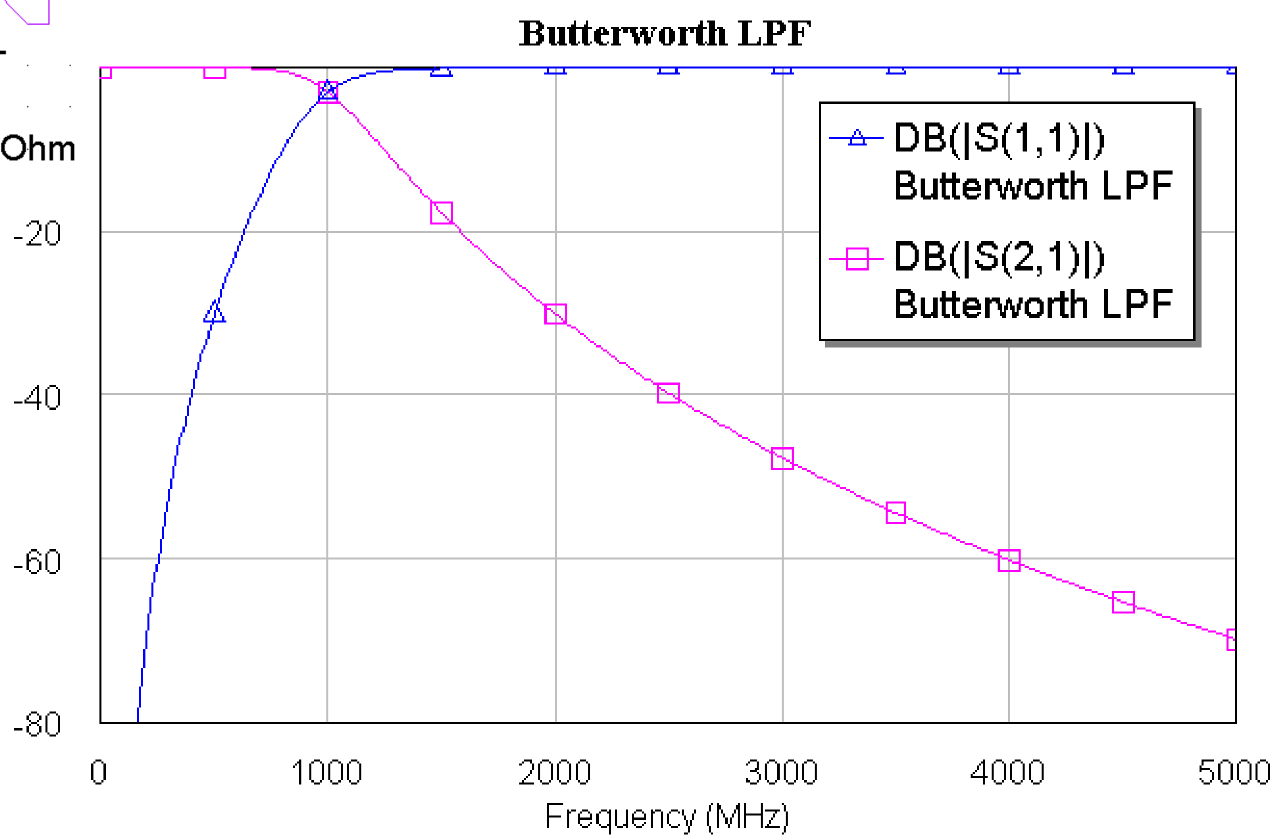
Discrete Element Filter Design

- In order to control bandwidth, attenuation characteristics, etc. the following are needed:
  - Multiple components (inductors and capacitors)
  - A method to determine the value of each component
- A common filter design approach is called the "insertion loss method"
  - A frequency-dependent mathematical function is selected that mimics the desired insertion loss characteristic for the filter
  - An equation for the insertion loss of the selected filter topology is determined; the equation will be a function of the L & C values
  - The equation is forced to equal the desired mathematical function thereby determining the necessary L & C values

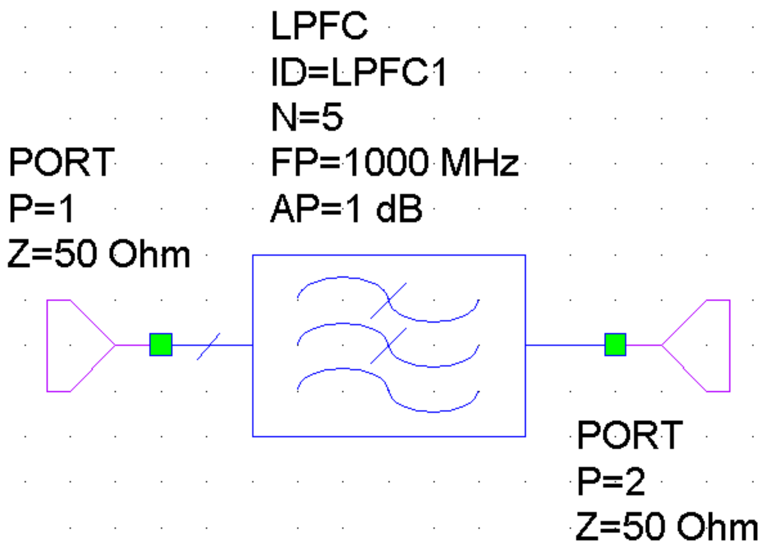
Discrete Element Filter Design



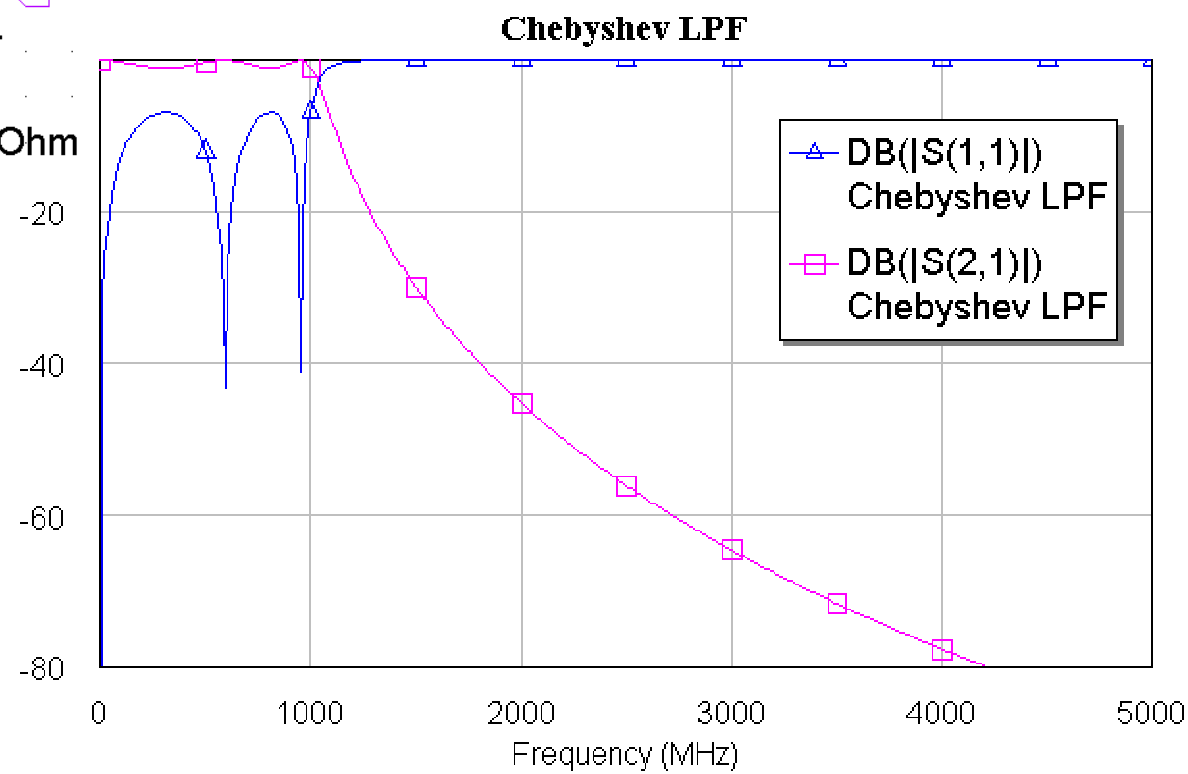
BUTTERWORTH



Discrete Element Filter Design



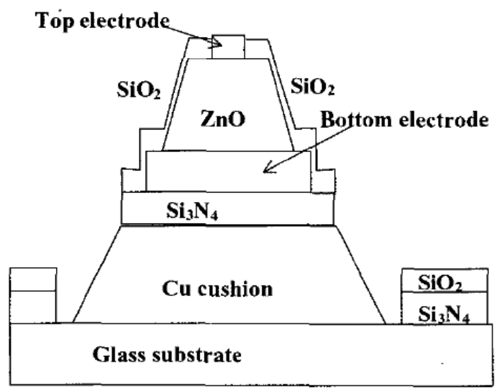
CHEBYSHEV



Discrete Element Filter Design

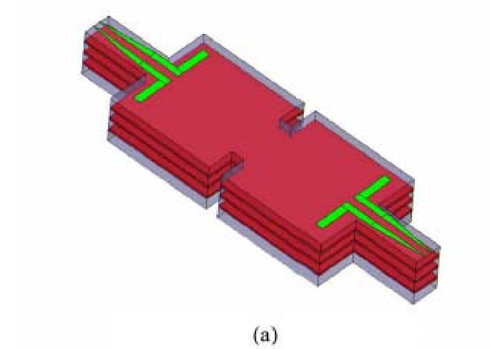
- Finishing the design → once the component values are determined the design is implemented
  - If a lumped element filter is being built the implementation is relatively straightforward
  - If a different type of filter is being built, the structures in the filter are made to emulate the L & C electrical response…the subject of more advanced filter design courses!
- For high-pass, band-pass and band-stop filters: the topologies determined from the insertion loss method can transformed to alternate topologies in a fairly straightforward way…also the subject of more advanced filter design courses!

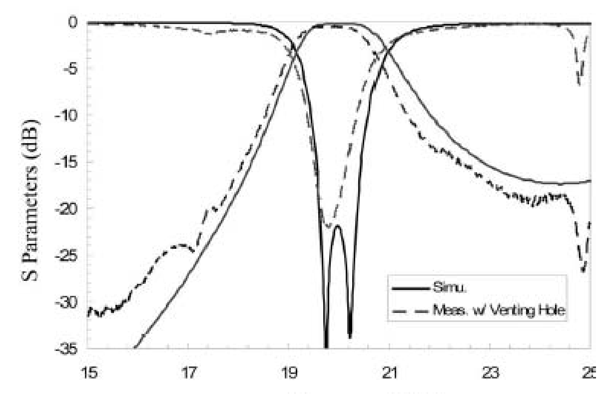
Some Advanced Filters – BAW, MEMS and Micromachined



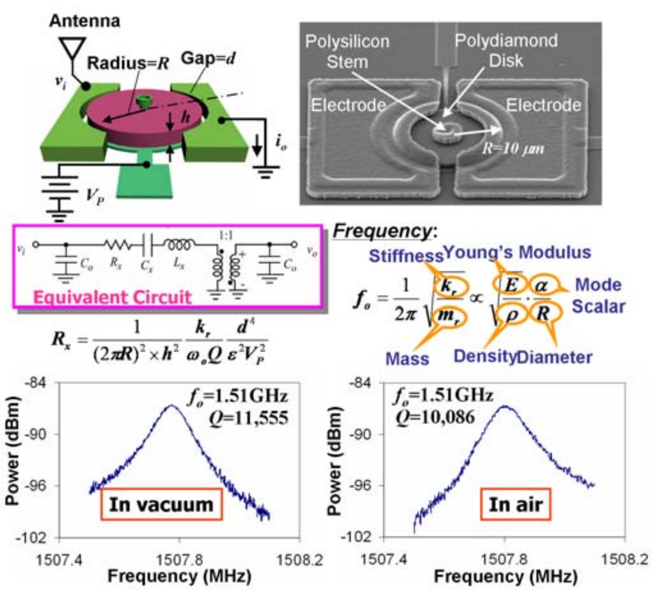
Bulk Acoustic Wave

Micromachined Filter





MEMS Vibrating Filter



Filters – Conclusions

- Filters are important to radio performance
  - Selecting the desired frequency band from the broad spectrum of incident EM energy
  - Rejecting signals at specific frequencies that may come from sources outside or inside the radio
- Implementation, as compared to 'design' is often the most challenging task
- High performance usually runs counter to low cost and small size
- Operating frequency generally dictates the technologies that can be used
- Major impact on system performance usually associated with size, although performance can affect rest of radio design

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