Electromechanical Modeling of a new class of contour-mode AlN MEMS RF resonators

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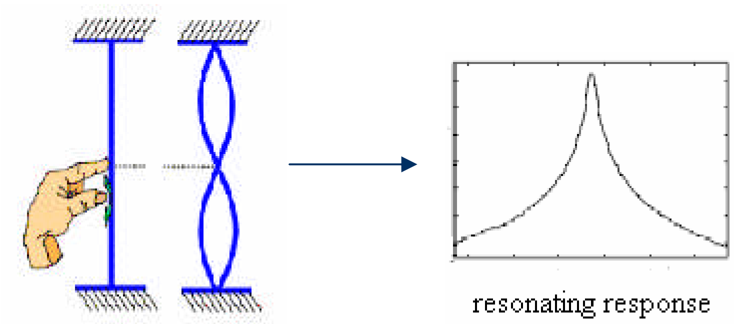
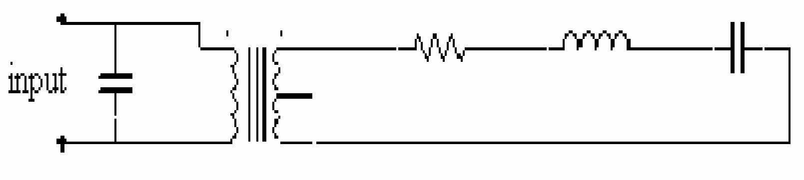
What is a RF MEM resonator?

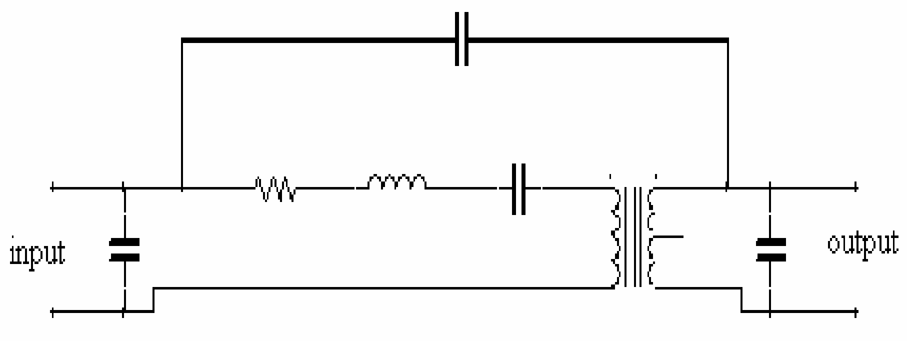
- Radio Frequency Micro-electro Mechanical resonator.
- Device that functions at a certain frequency, based on the geometry of the device.
- Used for filtering and frequency setting in wireless communications.



Contour-mode configuration of the resonator

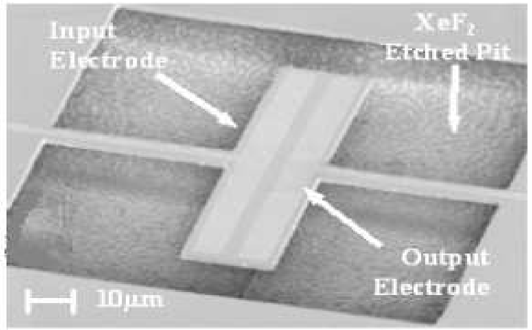
- Contour-mode allows batch fabrication of arrays of piezoelectric resonators with different frequencies on a single chip.
- A contour-mode resonators fundamental frequency is defined by in-plane dimensions.
- One-port configuration has one input.
- Two-port configuration has one input and one output.



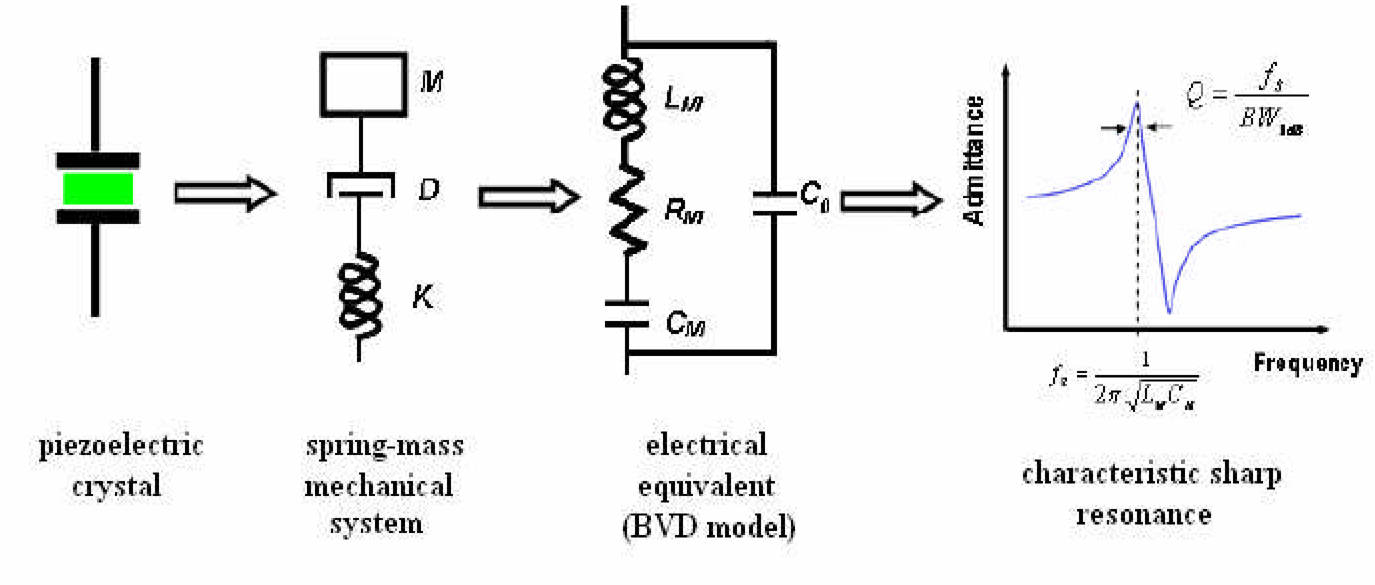


Project Goal Overview

- Fully understand the electrical response of the device:
  - To improve resonator layout
  - To create model libraries
- These devices, developed in the shape of disks, plates or rings, have the unique features, provide a wide range of frequencies and the ability to interface directly with 50 Ω systems.

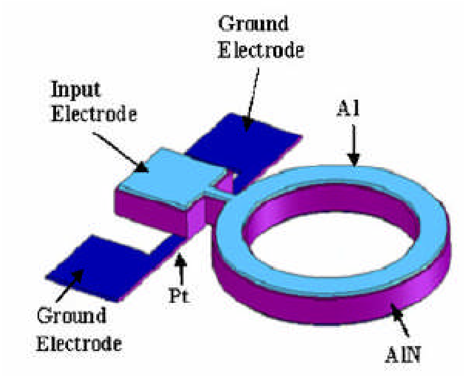


Analogy between mechanical and electrical domain

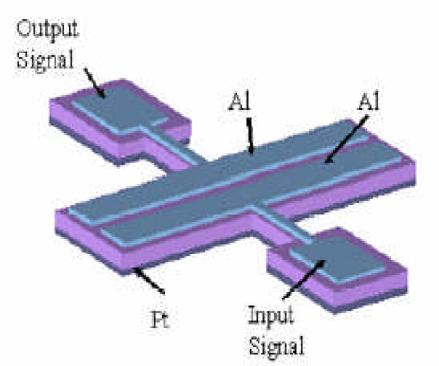


Advantages of resonator configurations

- One-port:
  - Avoids unwanted modes
  - Minimizes motional resistance
  - Maximum energy is coupled



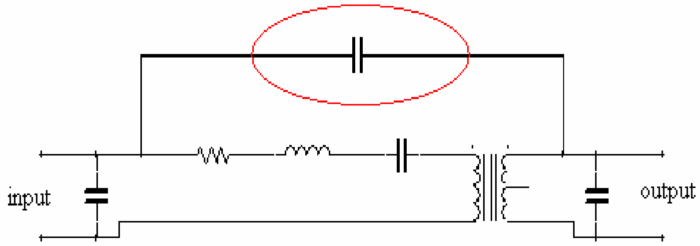
- Two-port:
  - Eliminates all kinds of feedthrough
  - Maintains high electromechanical coupling

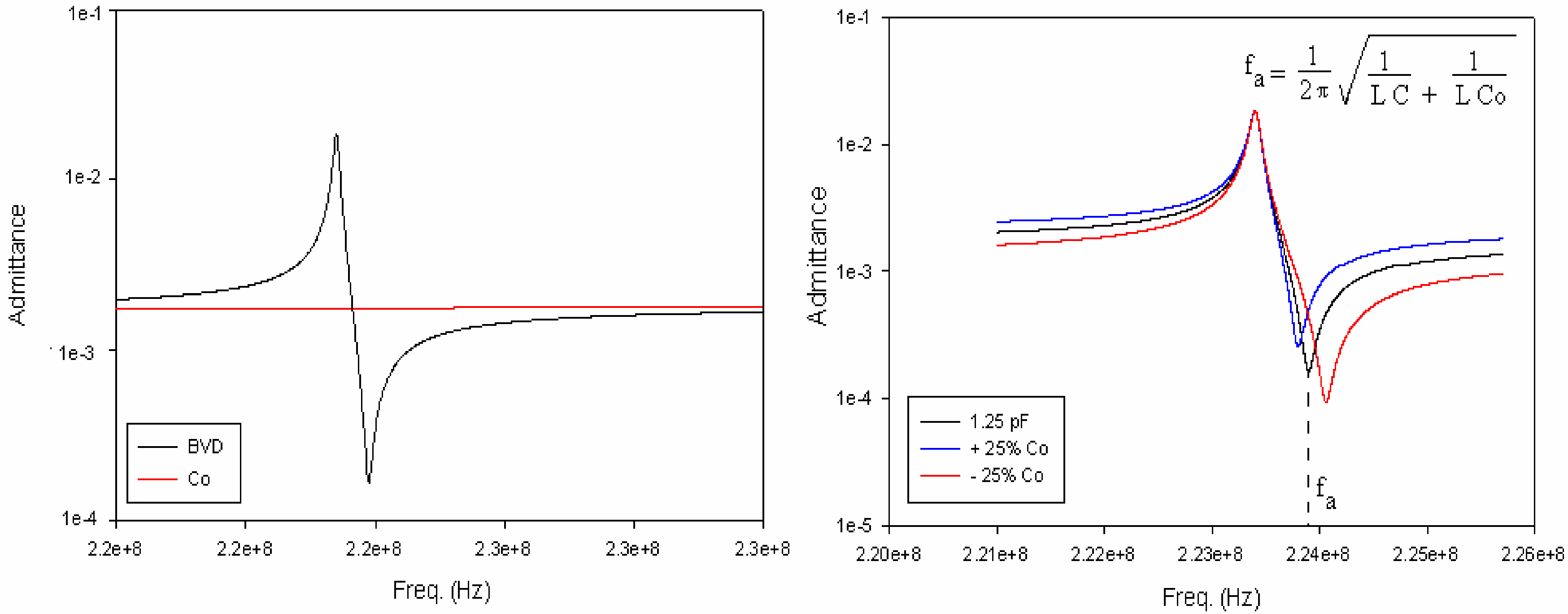


Disadvantages of resonator configurations

- One-port:
  - Suffers parasitic feedthrough at high frequency
- Two-port:
  - Spurious modes are encountered
  - Fabrication process is more complicated

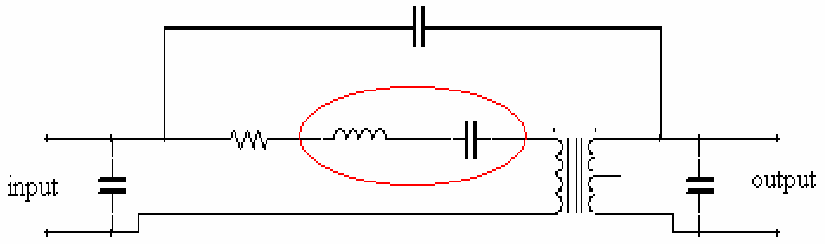
Parameter Analysis

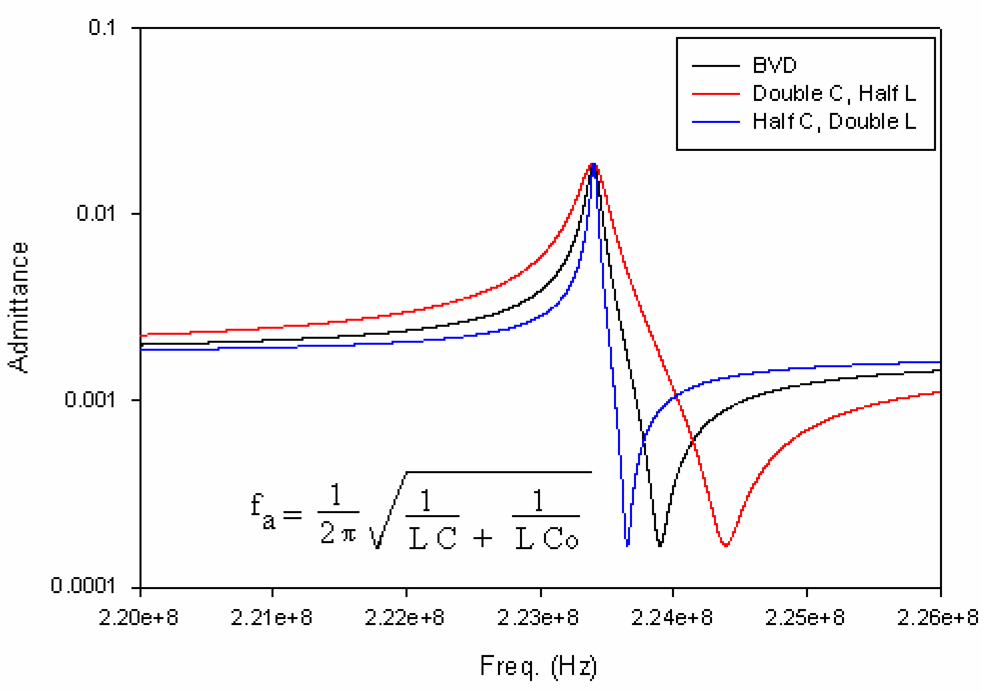




Effect of parallel capacitance on resonator response curve.

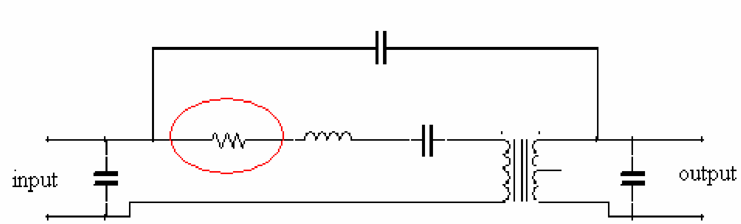
Parameter Analysis

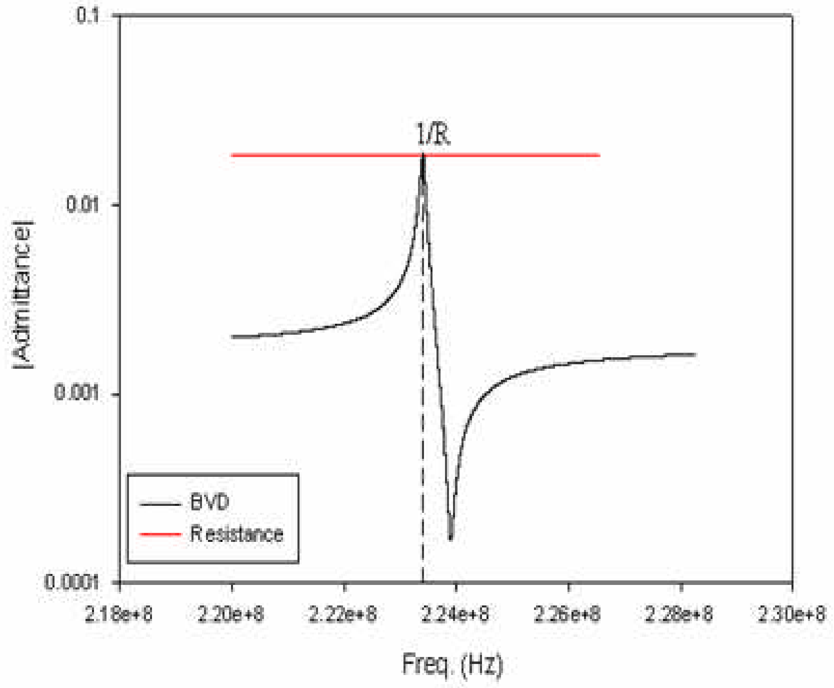


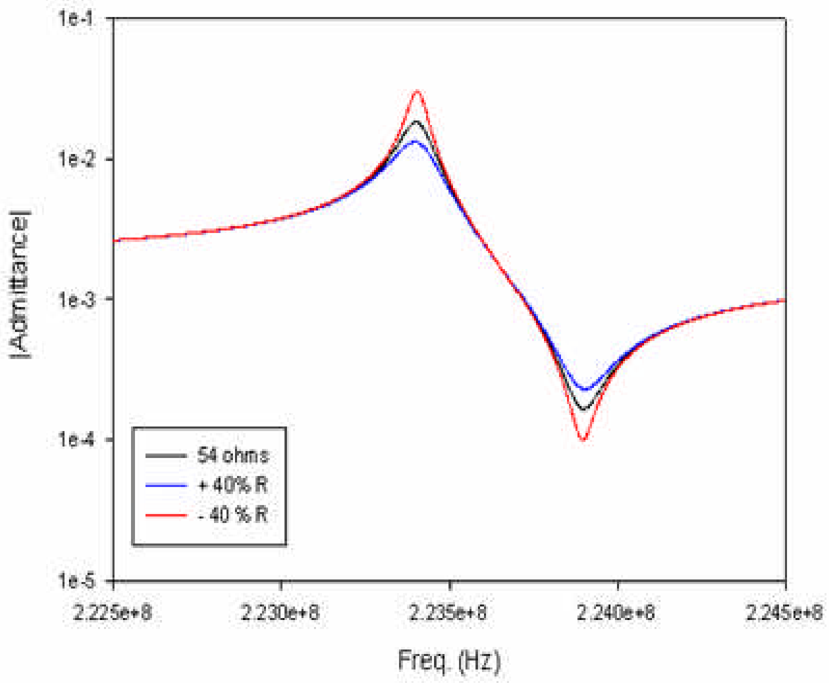


Effect of the capacitance and inductor on the resonator response curve.

Parameter Analysis



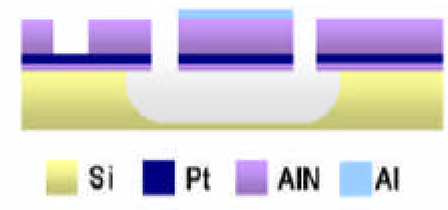


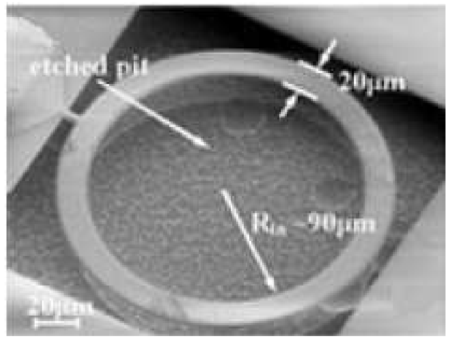


Resistance effect on the curve of the resonator response curve.

Preparation of the samples

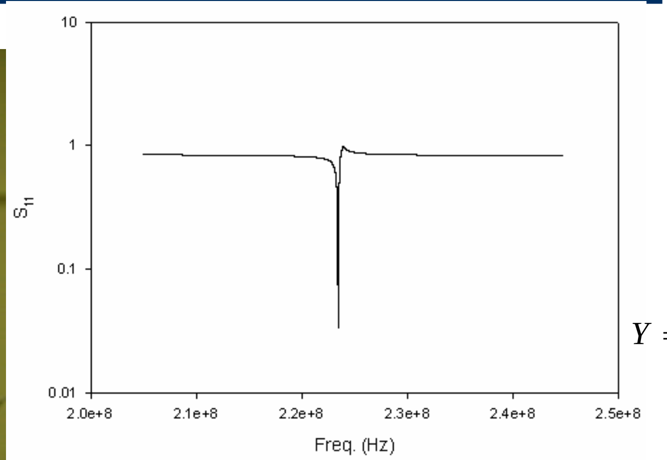
- Devices analyzed were previously manufactured, just needed to be cleaned and released.
- Cleaning: Plasma etching with O_2 to remove the photo resist layer.
- Releasing: Plasma etching with SF_6 to release vibrating element from substrate.



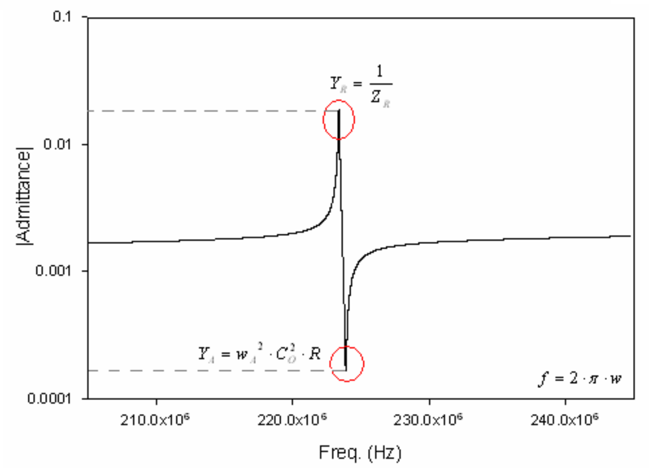


Measurement procedure

Work station



$$Y = \frac{1 - S_{11}}{50 \cdot (1 + S_{11})}$$



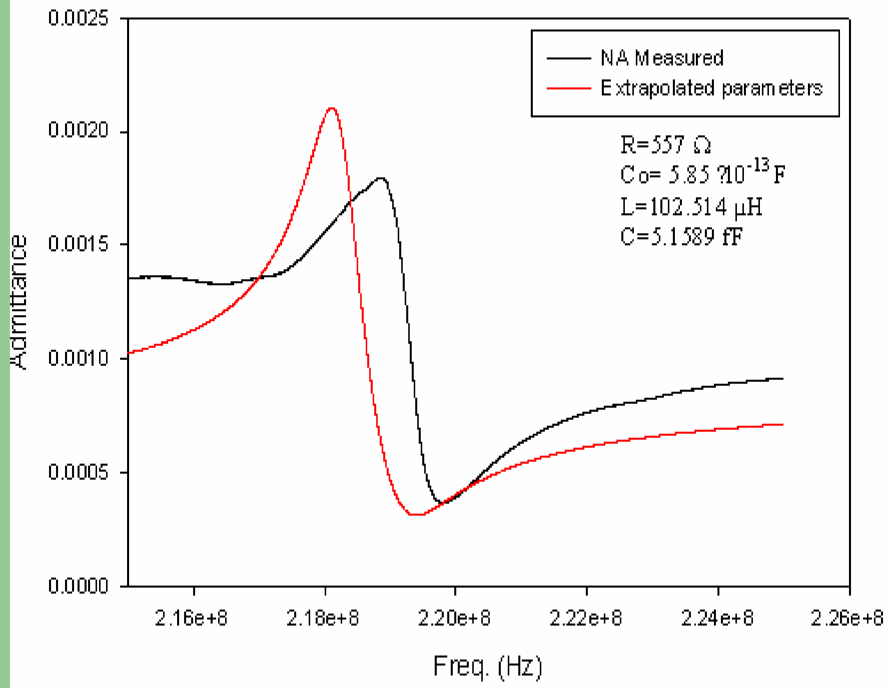
$$Z_R = R$$

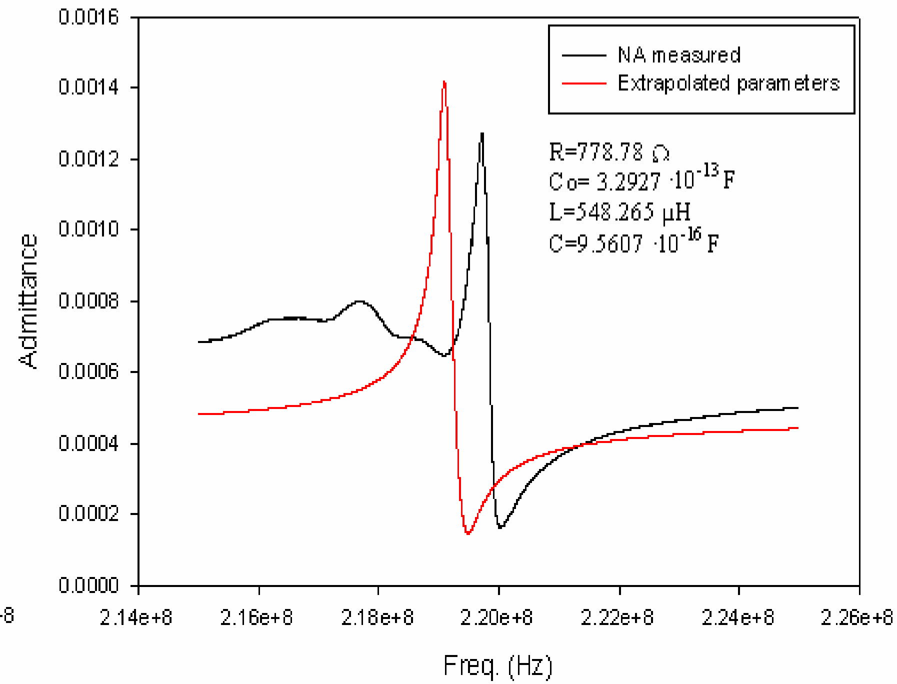
$$Z_A = \frac{1}{w_A^2 \cdot C_O^2 \cdot R}$$

$$w_A{}^2 - w_R{}^2 = \frac{1}{L \cdot C_O}$$

$$w_R = \frac{1}{\sqrt{L \cdot C}}$$

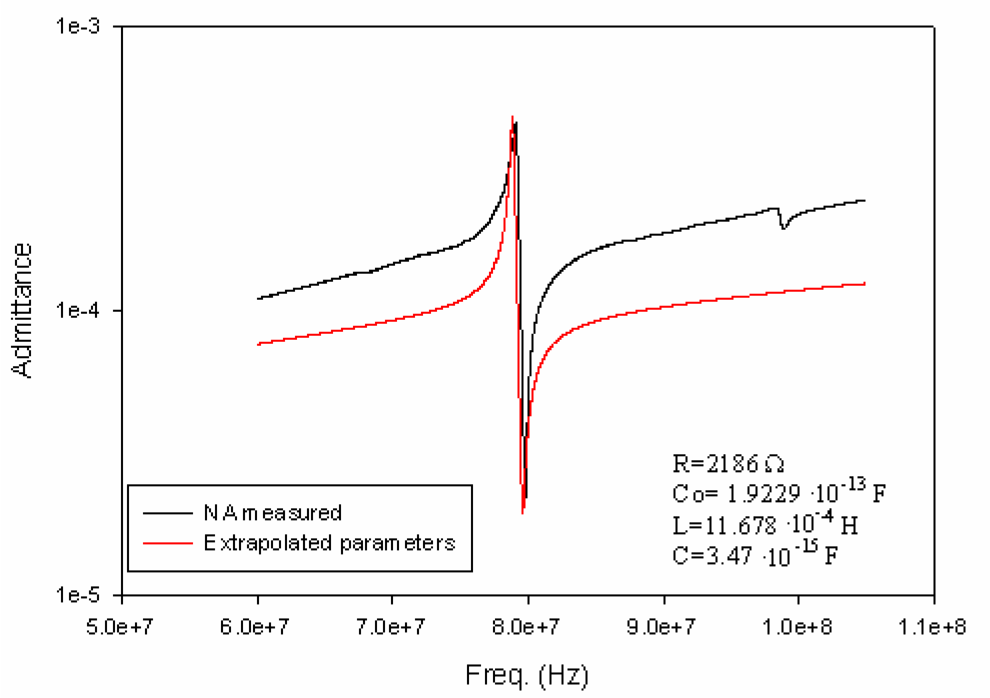
Electrical parameters of one-port device





Admittance measured from Network Analyzer and admittance obtained from electrical parameters extrapolated.

Electrical parameters of 2-port device



Extrapolated parameters obtained from 2-port device compared to NA measured admittance.

Conclusion and Future plans

- The extrapolation technique is a good first approximation for the admittance curve; improvement could be achieved by using more critical points and adding elements to the model.
- Bad measurements due to:
  - Contact issues (probes)
  - Probably oxidized devices (not manufactured recently)
- Use of features available at the probe station
  - Vacuum pump (down to 5 mTorr)
  - Reduction of temperature (300 K – 4.5 K)

Acknowledgements

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Questions?