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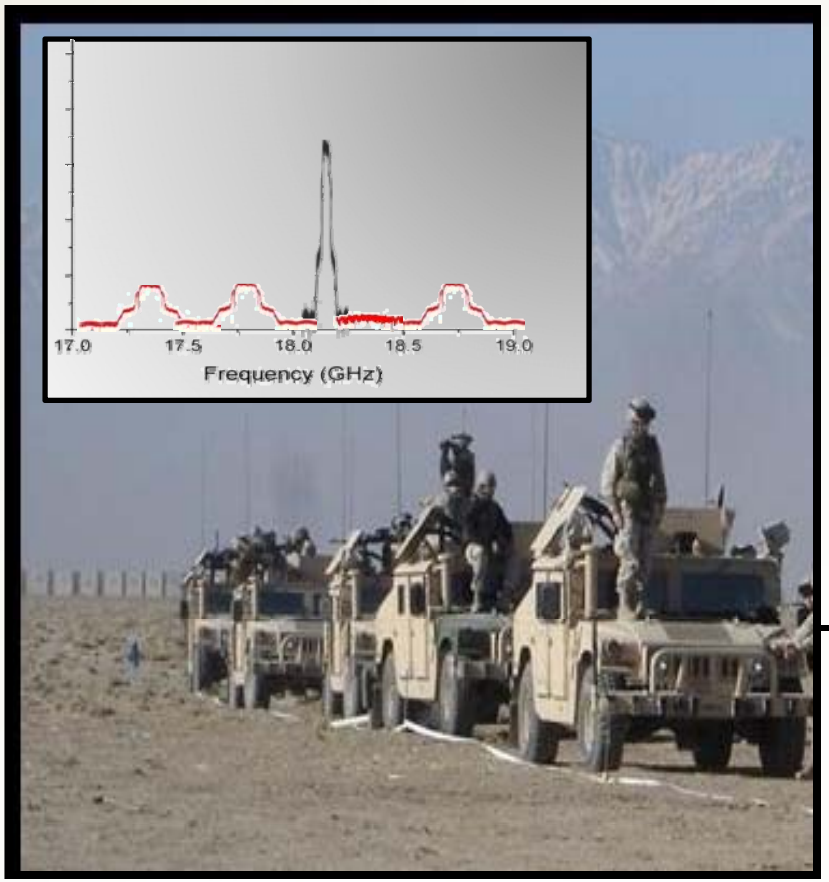
Outline

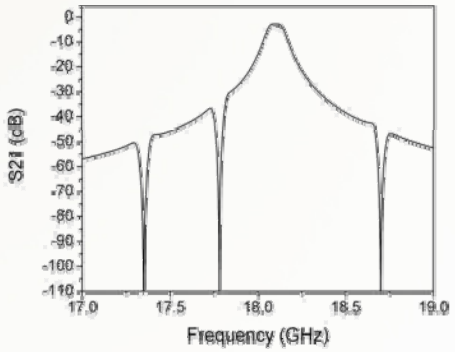
- Problem Statement
- Tunable Microwave Filters
  - Bandpass
  - Bandstop
  - Bandpass / Bandstop Cascade
- Commercialization Efforts
- Conclusion

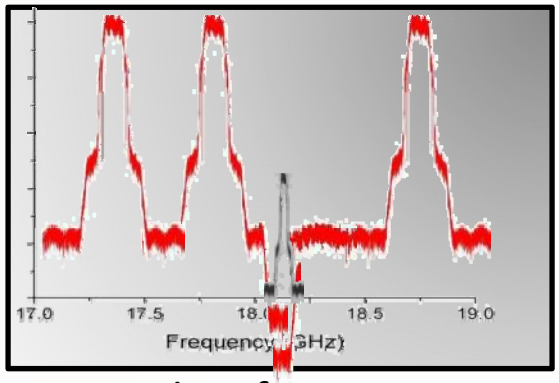
Interference Mitigation

Novel Bandpass/ Bandstop Filter Bank will Allow for Isolation of Desired Frequency Slice

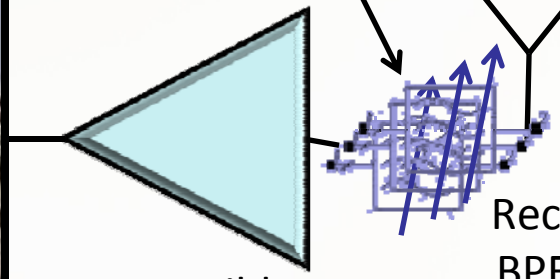
Friendly Signal Isolated in the Midst of Jamming Signals







Window for operation in the midst of jamming signal has been created.

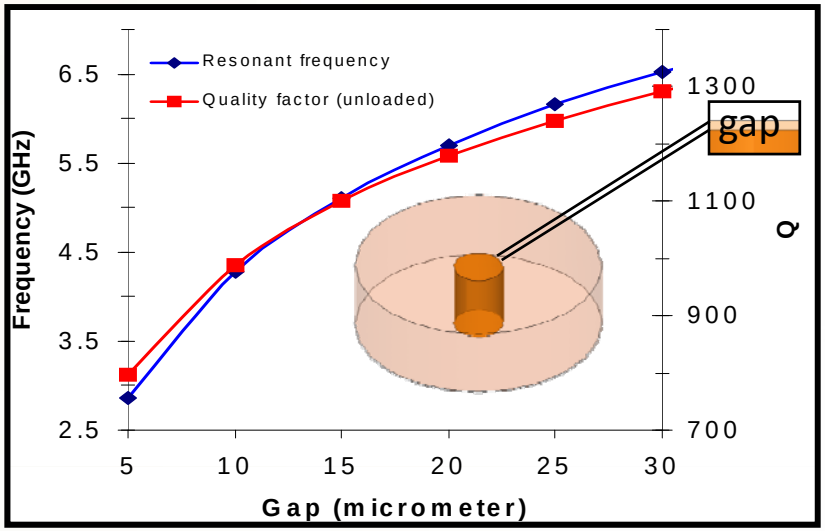


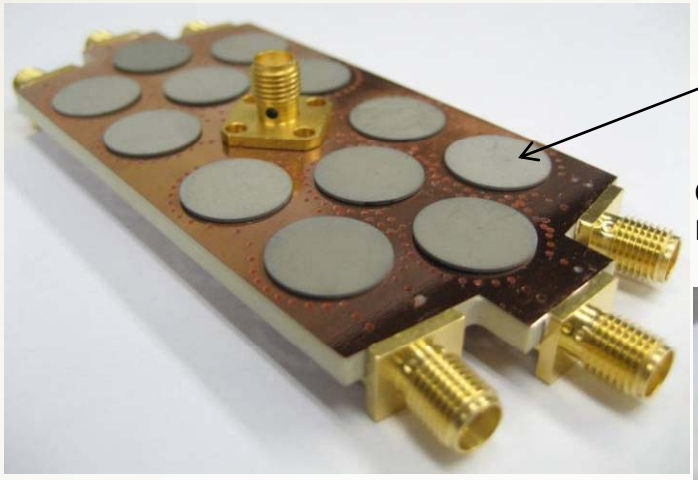
Possibly Saturating LNA

Reconfigurable BPF/ BSF Filter Bank

DARPA ASP Phase I and II

- *Phase 2 filters were constructed using substrate integrated evanescent-mode cavity resonators*
- *Range of Coverage: 0.65 to 6 GHz*

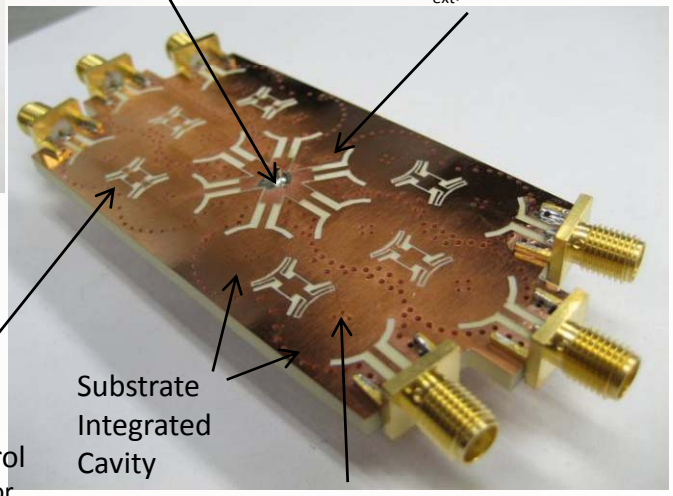




Piezo Actuator

Common Feed

External Q (Varactor Enabled for Variable Q_{ext})



Substrate Integrated Cavity

Bandwidth Control (Varactor Enabled for Variable BW)

Integrated Capacitive Post

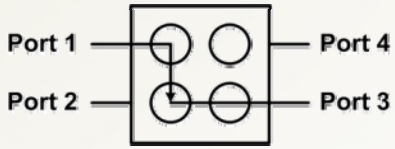
- *Octave coverage per filter bank on a single antenna feed*
- *2.2 dB at 28 MHz at 6 GHz*

<u>Description of Physics</u>

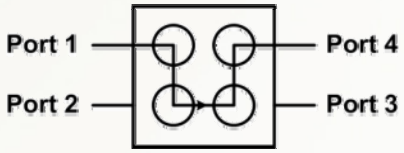
Changing the gap dimension changes the resonant frequency more than an octave, while diaphragm maintains high Q of cavity (>1,000)

Reconfigurable Bandpass Filters

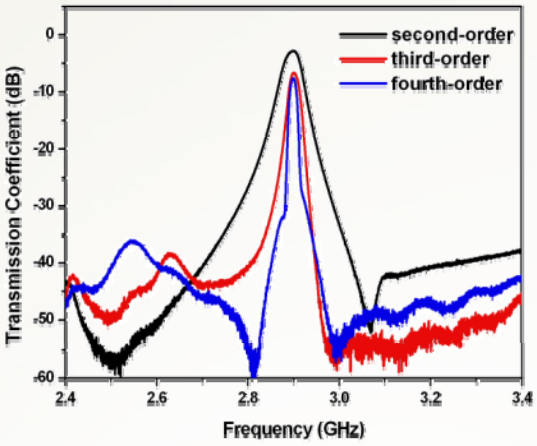
- Field-Programmable Filter Array
  - Measured Results (Higher-Order Filters)

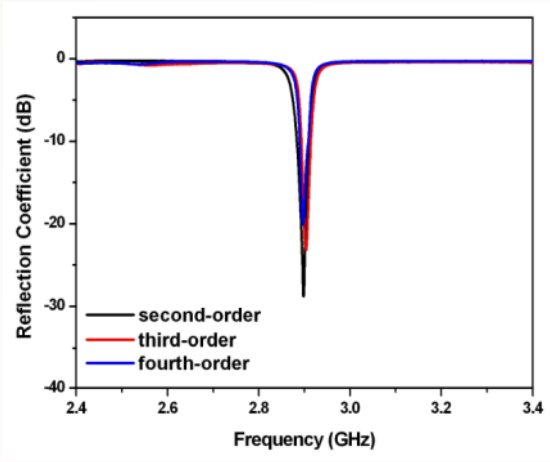


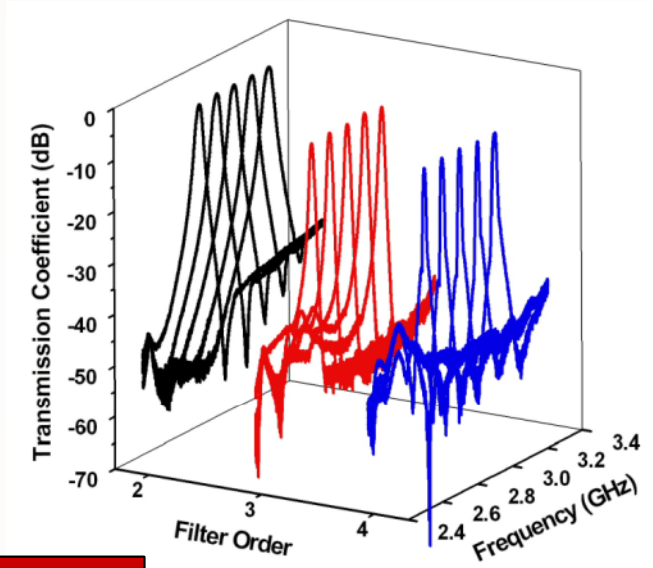
Third-Order Filter



Fourth-Order Filter

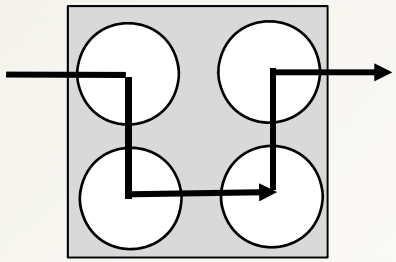




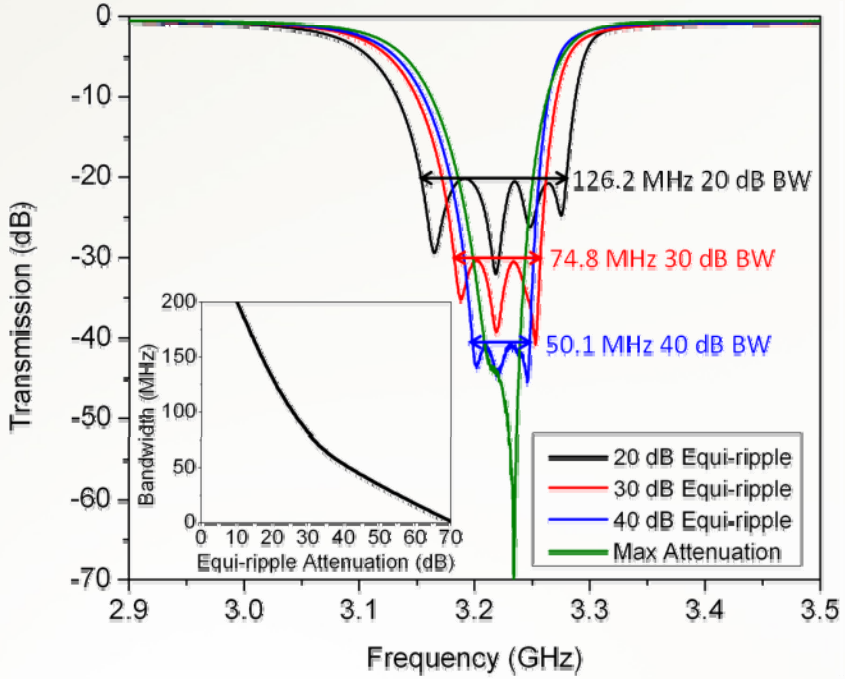


First time demo of multiple order and multiple output ports

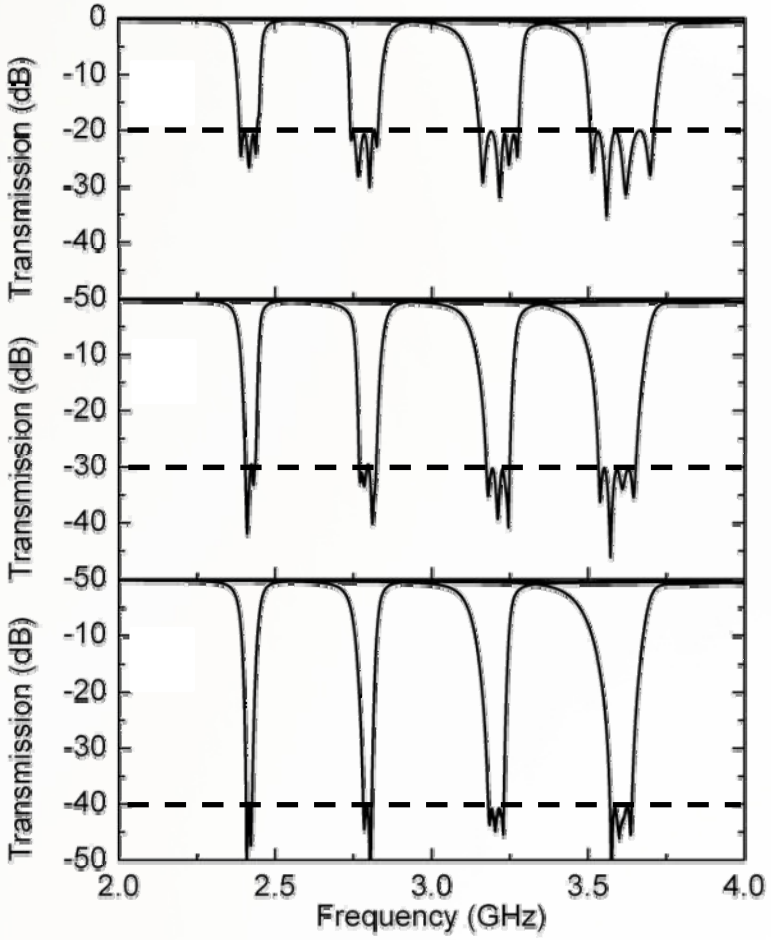
Reconfigurable Bandstop Filters



<0.25 dB in pass band



Wide tuning range with 20, 30, and 40 dB levels of attenuation:

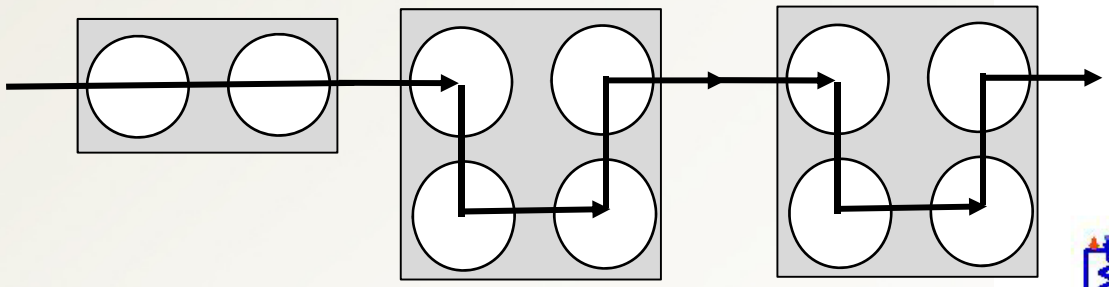


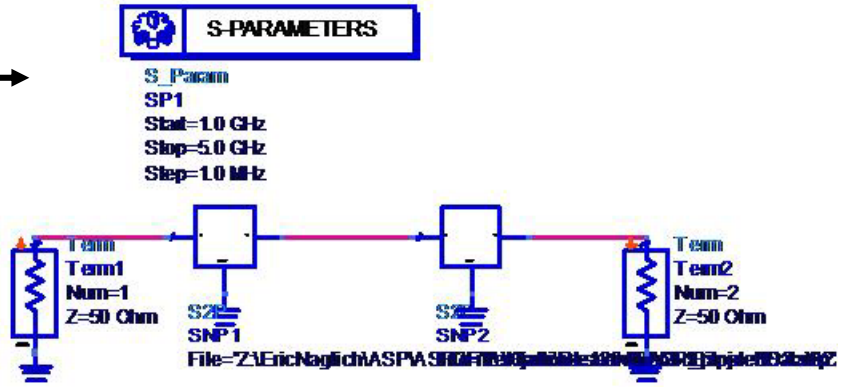
Variable attenuation state across the band

Bandpass/Bandstop Cascade

- *A 2-pole bandpass filter was cascaded with two 4-pole bandstop filters:*

ADS Cascade of individual BP and BS measurements shows over 120 dB of attenuation over a 21 MHz bandwidth!

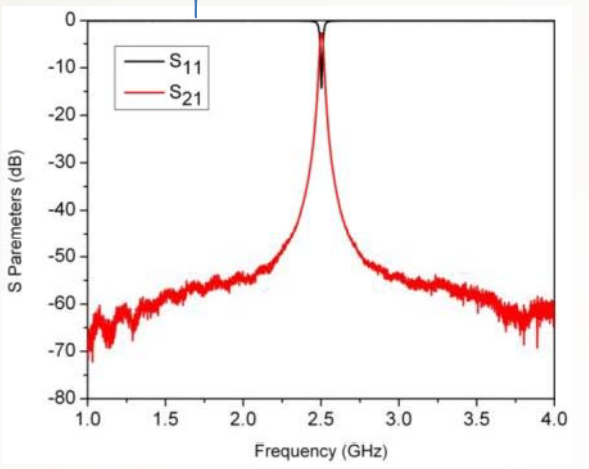


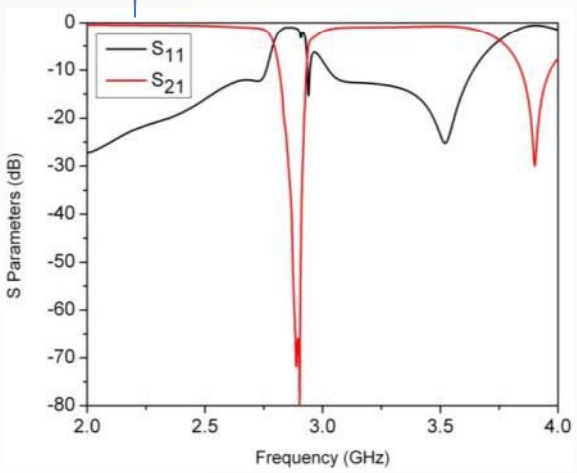


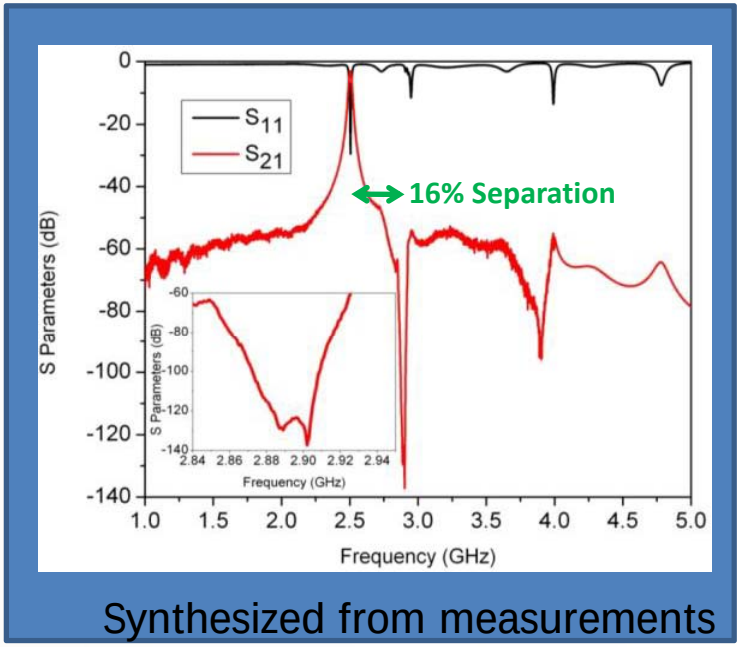
2nd order bandpass

4th order bandstop

4th order bandstop

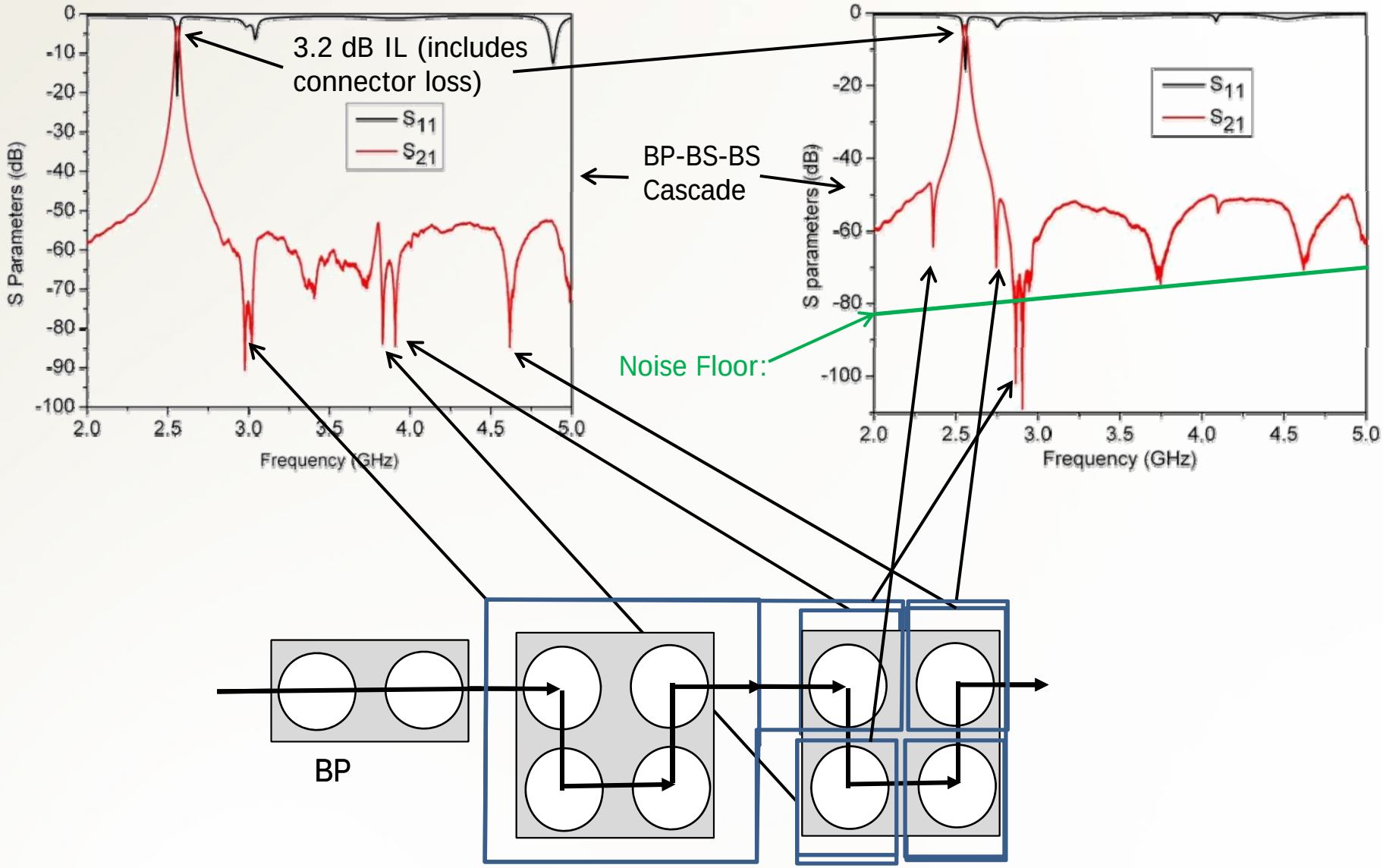




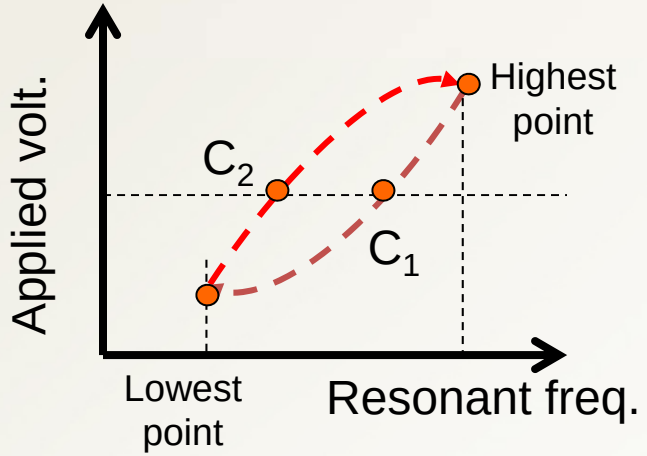


Synthesized from measurements

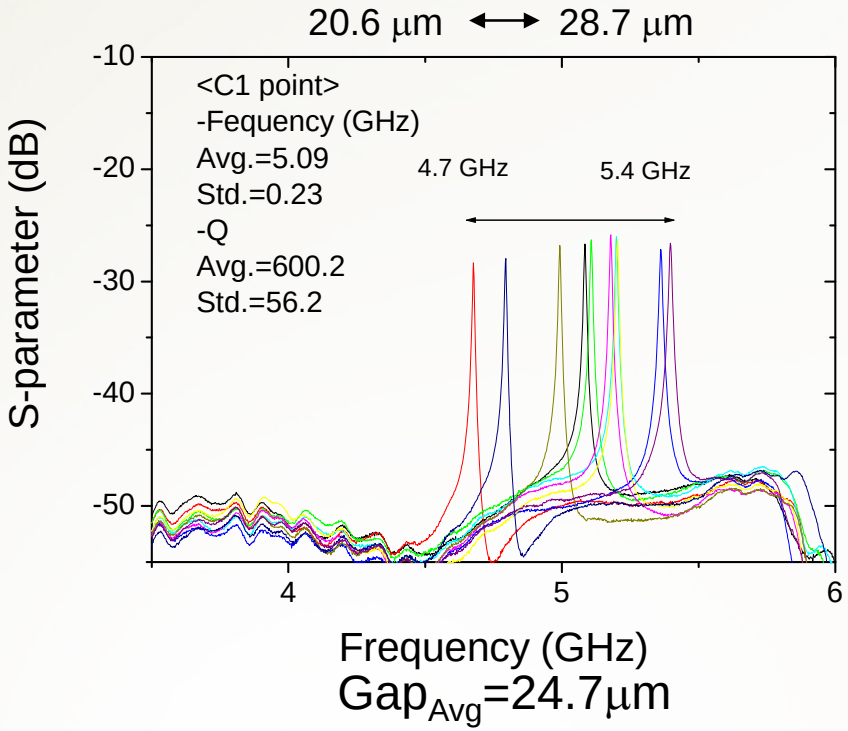
Bandpass/Bandstop Filter Cascade

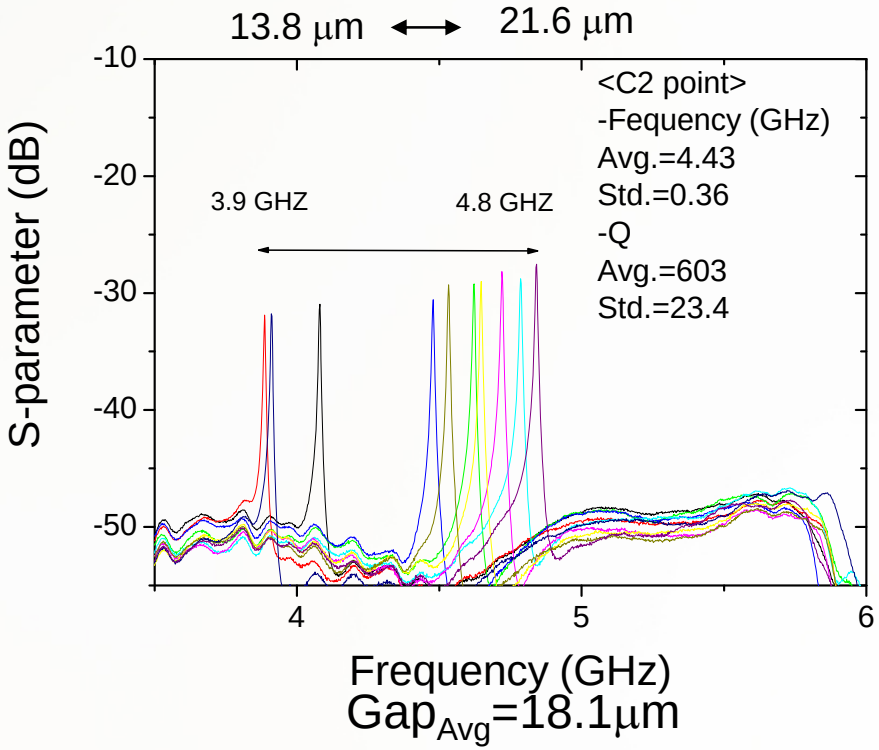


Eliminating Process Variation



Sample Yield 100%



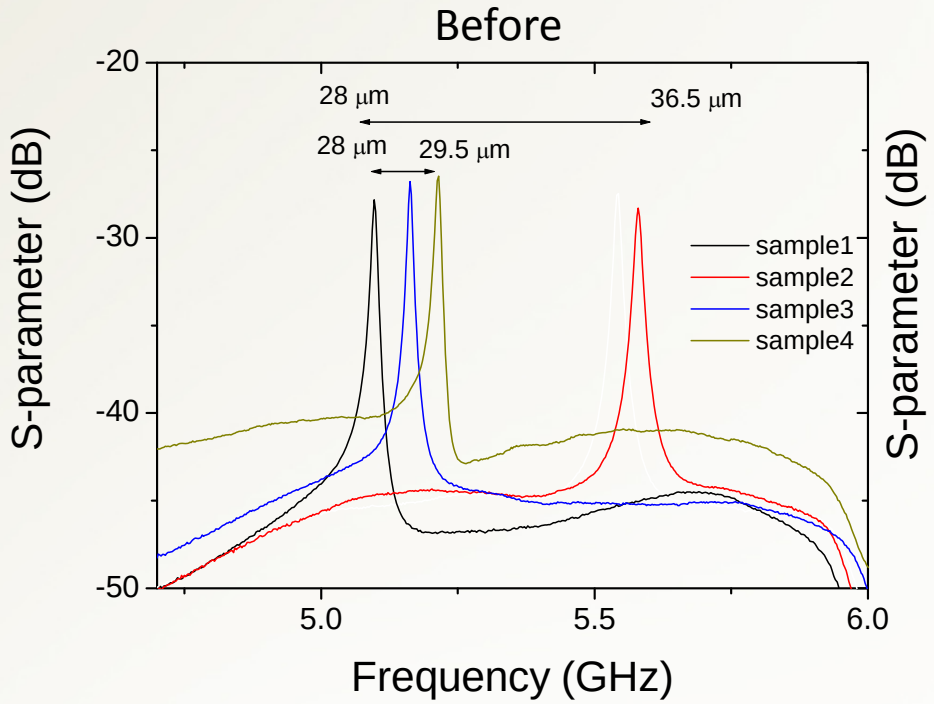


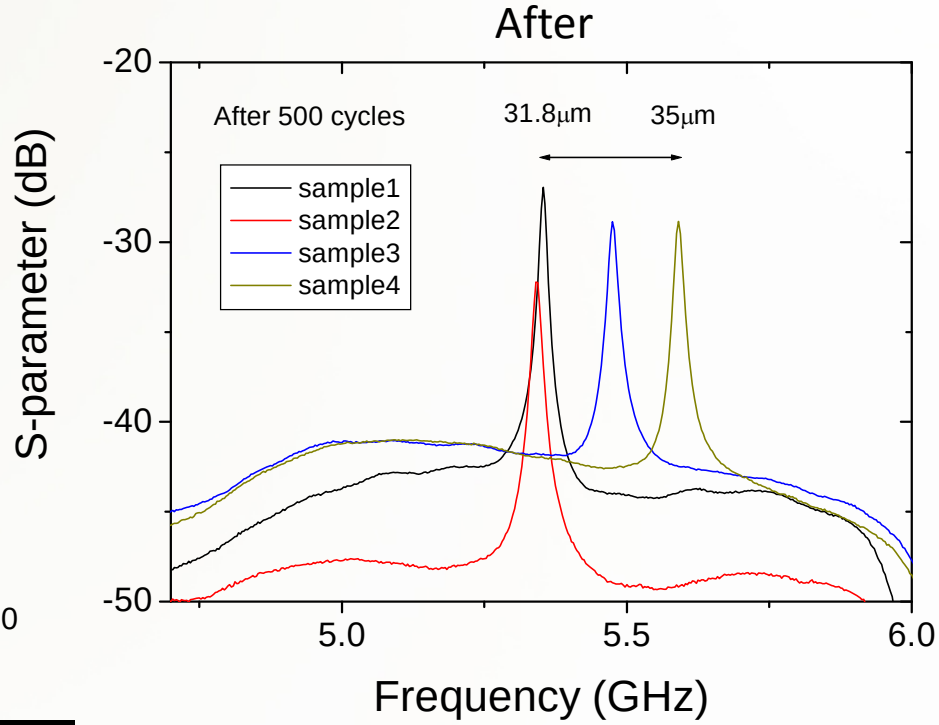
Expected Filter Performance

- The total tuning range can be taken from the highest measured frequency at the lowest control-voltage bias point (3.1 GHz) to the lowest frequency of the highest control-voltage bias point (5.9 GHz), over piece part population.
  - This yields a tuning range of 1.9:1 for all resonators
  - Initial gap height was estimated to be 28um +/- 4.5 um.
  - Q at midband remained sufficient (~600 at 5 GHz)

Thermal Cycle Testing (500 Cycles)

Center Frequency at Unbiased Diaphragm "Rest" Position





	Gap (before)	Gap (after)	Difference
Sample1	27.5	31.8	4.3
Sample2	36.5	31.8	4.7
Sample3	28.8	34.2	5.4
Sample4	29.2	35	5.8

- Temperature range: -45 °C ~ +85 °C
- Dwell time: 15 Min
- Temperature change rate: above 13 °C /sec
- **Avg. difference=5.1 μm**

At this sample size and temperature range, testing proves that attachment technique survives thermal cycling

Conclusions

- Novel tunable microwave filters have shown great promise for low cost, compact co-site interference mitigation.
- Manufacturing yield and initial environmental analysis has been enabled through the RF Alliance.
  - Will allow for additional environmental analysis and system integration.

Thank You!