Featureless Tagging Tracking and Locating (Pillar I: Microresonator Based Waveform Storage)

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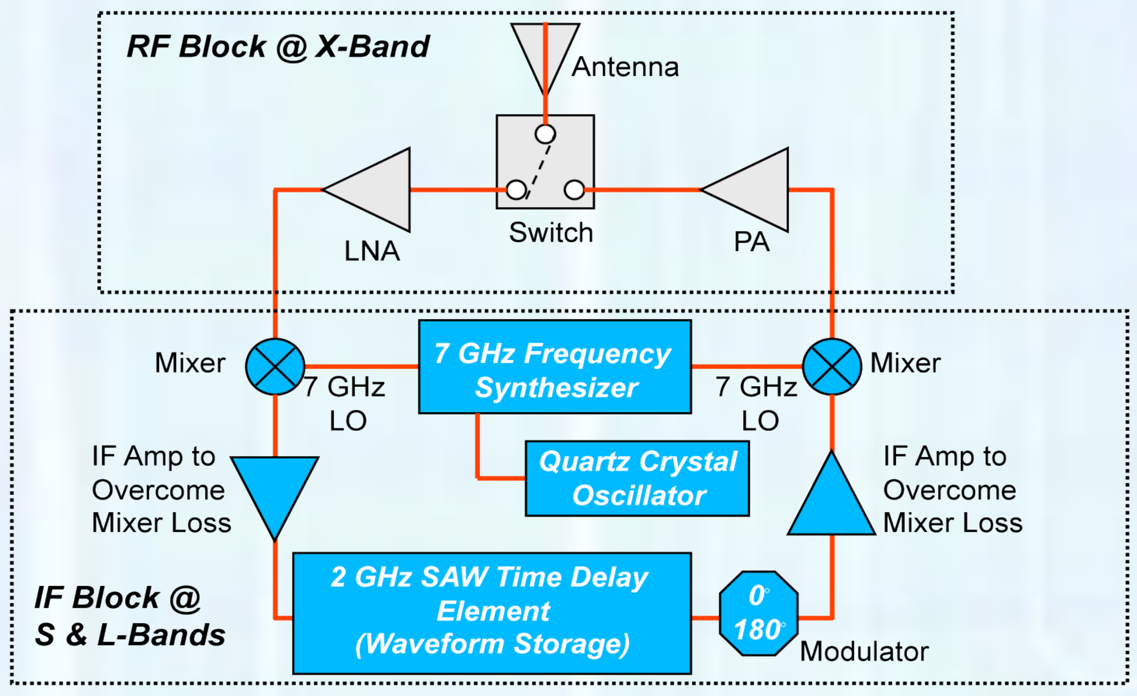
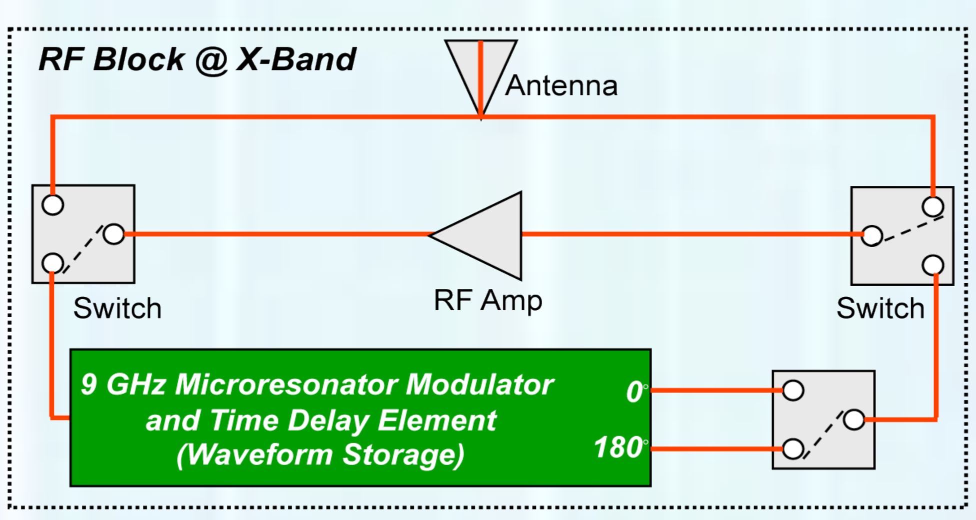
Problem

SAR Tag Size & Power Limitations



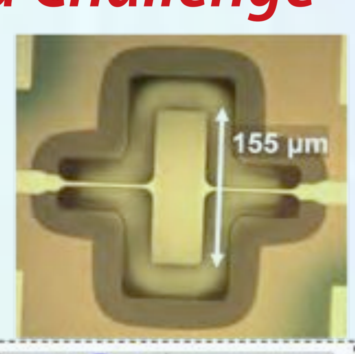
Microresonator Based All-RF Delay Lines for Small, Low-power SAR Tags

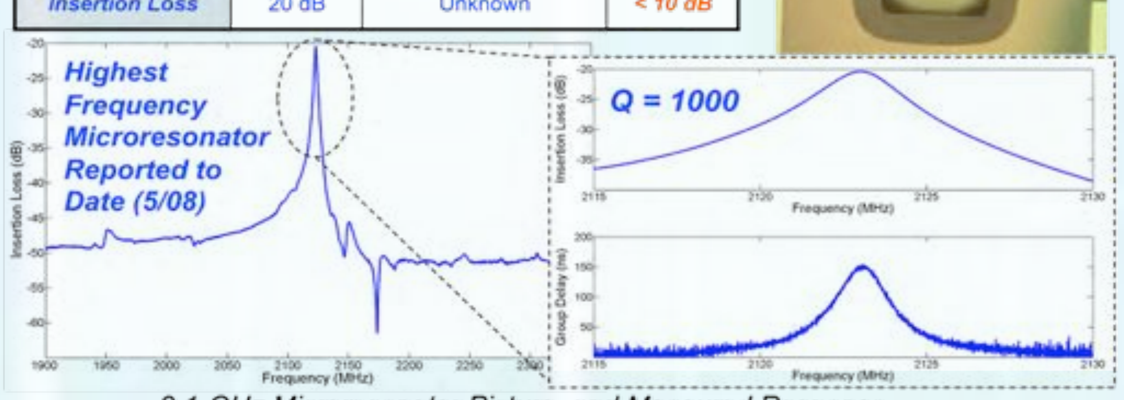


- All-RF tag reduces example part count from > 60 to 6 (>10x Parts)
- All-RF tag reduces example current from 541 mA to only 138 mA (4x Power)

X-Band Acoustic Delay is a Grand Challenge

	Project Start	Scaled to 9 GHz	Desired
f_0	2.1 GHz	9 GHz	9 GHz
Bandwidth	1 MHz	4.3 MHz	50 MHz
Delay	150 ns	35 ns	40 ns
Insertion Loss	20 dB	Unknown	< 10 dB



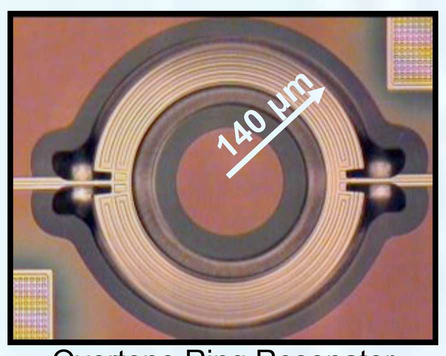


2.1-GHz Microresonator Picture and Measured Response

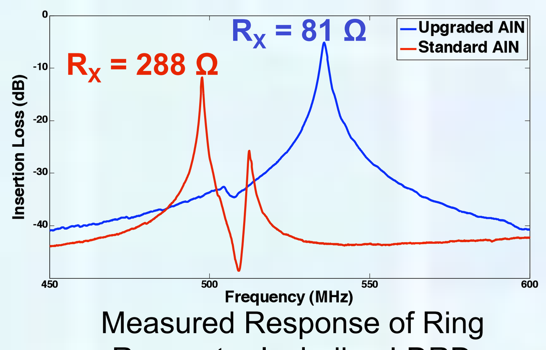
Approach

Keys to 9-GHz Delay Elements

- **Achieving 9-GHz Delay Element**
  - Acoustic delays not available at X-band
  - Microresonator
    - High sound velocity (10 km/s)
    - Low material damping (Q = 2000 @ 10 GHz)
    - Thickness-independent frequency
- **Order-of-Magnitude Higher Bandwidth**
  - High-bandwidth resonant delays do not exist
    - Requires new architecture to overcome fundamental k_t^2*Q barrier
  - Integrated Inductors
    - Resonates out resonator shunt C
    - Reduces insertion loss
    - Removes resonator anti-resonance, increases achievable bandwidth
- **Long, Flat Delay**
  - Flat group delay over wide bandwidth a major challenge
    - Resonators in series to achieve delay
    - Integrated inductors to remove parallel resonances and give flat delay (MEMS)



Overtone Ring Resonator

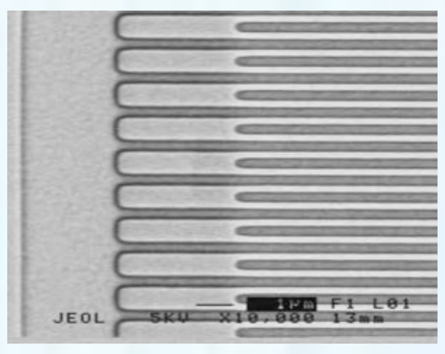


Measured Response of Ring Resonator Including LDRD-developed Improved AlN Material

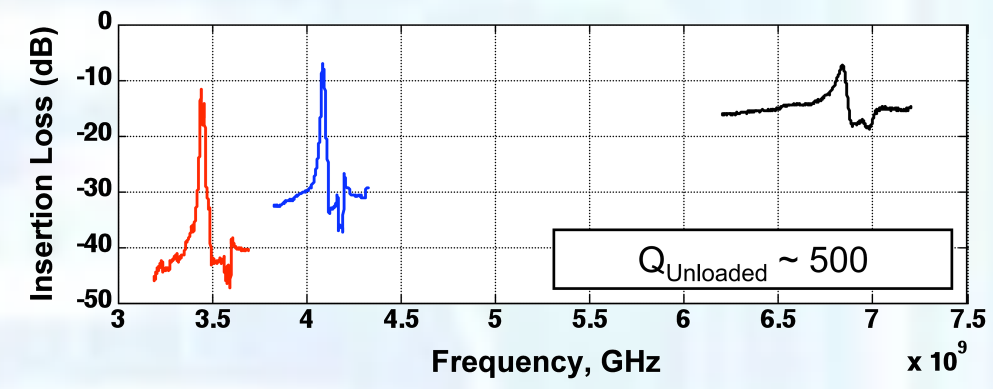
Results

Microresonator: Pushing Towards 9 GHz

- Optical Lithography Demonstrated Down to 250 nm (10-GHz Resonator)
- New Width Extensional Resonator for Reduced Insertion Loss and Spurious Modes
- Performance is 12 dB lower insertion loss than work from UPenn (e-beam) reported 1/09



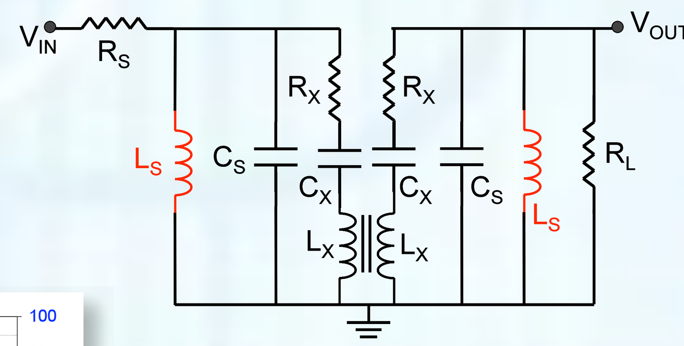
0.5-µm Pitch Al Traces On Top of a Micro-Resonator

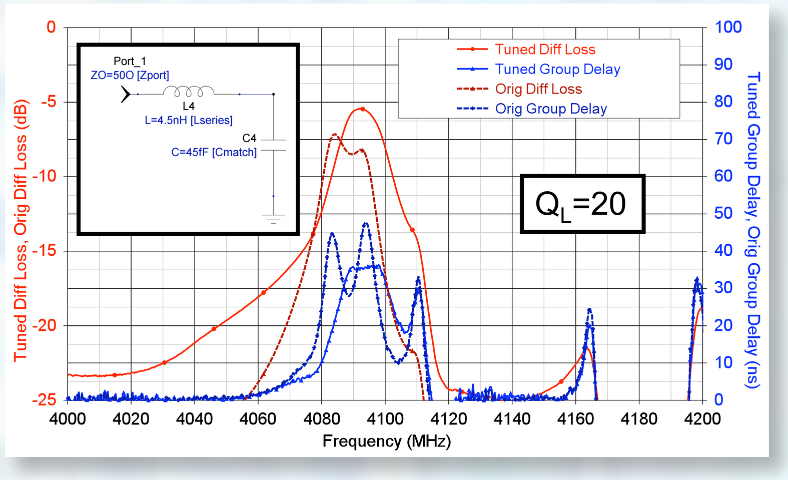


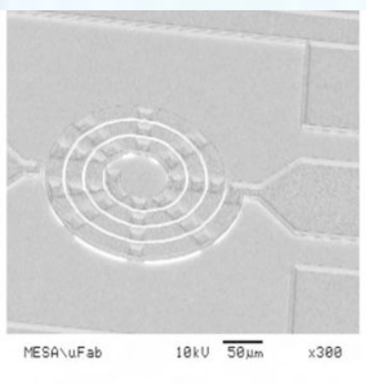
Super High Frequency Microresonators Measured Performance

Capacitance Cancellation Utilizing On-Chip Inductors

- Shunt or series inductor cancels the parasitic capacitance at the input and output
- Increases kt² and max. bandwidth
- Flattens group delay
- Modeled matching circuit relatively insensitive to inductor Q and inductance



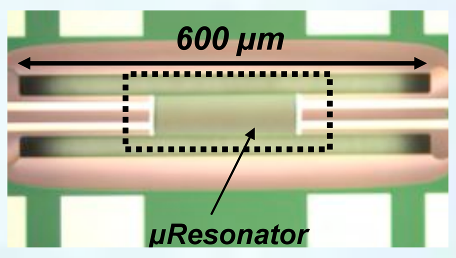




Microresonator Accomplishments

	Project Start	Current Status	Current Status	Current Status	Desired
f_0	2.1 GHz	3.95 GHz	6.8 GHz	9.3 GHz	9 GHz
Bandwidth	2 MHz	16 MHz	34 MHz	50 MHz	50 MHz
Delay	150 ns	35 ns	15 ns	10 ns	40 ns
Insertion Loss	20 dB	4 dB	7 dB	17 dB	< 10 dB

- Optical Lithography Demonstrated Down to 250 nm (10 GHz Resonator)
- Width Extensional (WE) Resonator Design has Much Lower Insertion Loss
- Resonators Demonstrated up to 9.3 GHz
- Insertion Losses (IL) Reduced to as Low as 4 dB
- Integrated Inductors Demonstrated for Future Reductions in Insertion Loss and Group Delay plus Wider Bandwidth
- Upgraded AlN Deposition Capability Will Reduce Existing Resonator IL from 7 to 3 dB



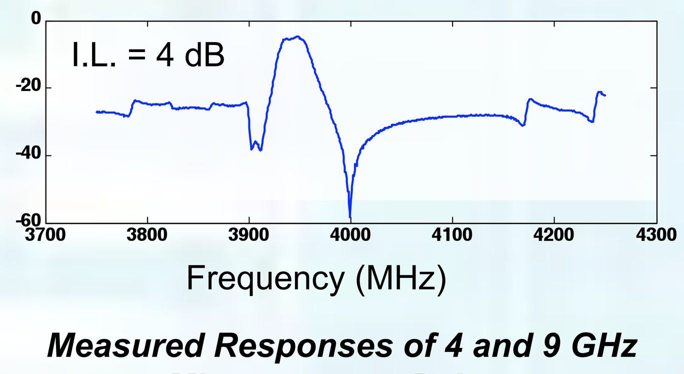
Width Extensional Resonator

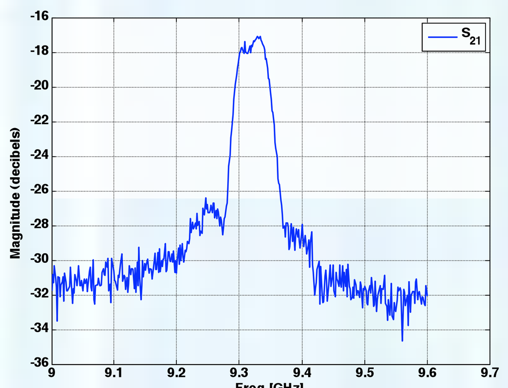
Significance

Microresonator Impact

Impact of Microresonator Technology

- Blue Force Tracking and Locating
  - Size, Power, and Cost Reductions
  - Accurate Geo-location: Low-loss, Wide-bandwidth Waveform Storage
- National Security and Defense
  - Real-time Spectrum Analysis and Cognitive Radio (20 MHz–10 GHz in 1 Chip)
  - Miniature X-Band Filters with High Frequency Selectivity (Jam Resistant, Low Power)
  - Small, Low-power Clocks and Sensors (Passive Vibration Spectrum Analyzer)





Measured Responses of 4 and 9 GHz Microresonant Delays

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