National Aeronautics and Space Administration

Digitally Tunable Split Ring Resonator Technology for Quantum Rydberg Radar

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Program: FY22 R&TD Innovative Spontaneous Concepts

Objectives:

To advance our understanding and mature the digitally tunable SRR technology for Quantum Rydberg Radar (QRR) from a TRL 2 to 3 through modeling, simulations, experiments and characterization in the laboratory.

Background:

Quantum Rydberg Radar (QRR) builds on the disruptive and proven quantum Rydberg atomic receiver technology, which uses LO (local oscillator)-dressed Rydberg EIT (electromagnetically induced transparency) spectroscopy. QRR integrates state-of-art high sensitivity, low-noise, ultra-broadband, quantum down-conversation – with no antenna/RF front-end/mixers, and a compact detector volume (<1cm3), which makes it a vast improvement over the classical radar. QRR can be tuned to frequency bands from 10kHz-1THz. These characteristics results in multi-science applicability for the future. When configured as a signal-of-opportunity (SoOp) receiver, it has the flexibility to focus on the dynamics and transients of the earth system using existing navigation/communication satellite signals. Recent JPL proposals address use of QRR in the I-to-C bands for soil moisture (SM) applications. In land-surface-hydrology (LSH) applications, the initial focus of QRR is to enable a collocated measurement of the vertical SM distribution from canopy to deep-root-zone, which is not feasible/practical with classical radars due to the need for different antennas and RF front-ends for each band.

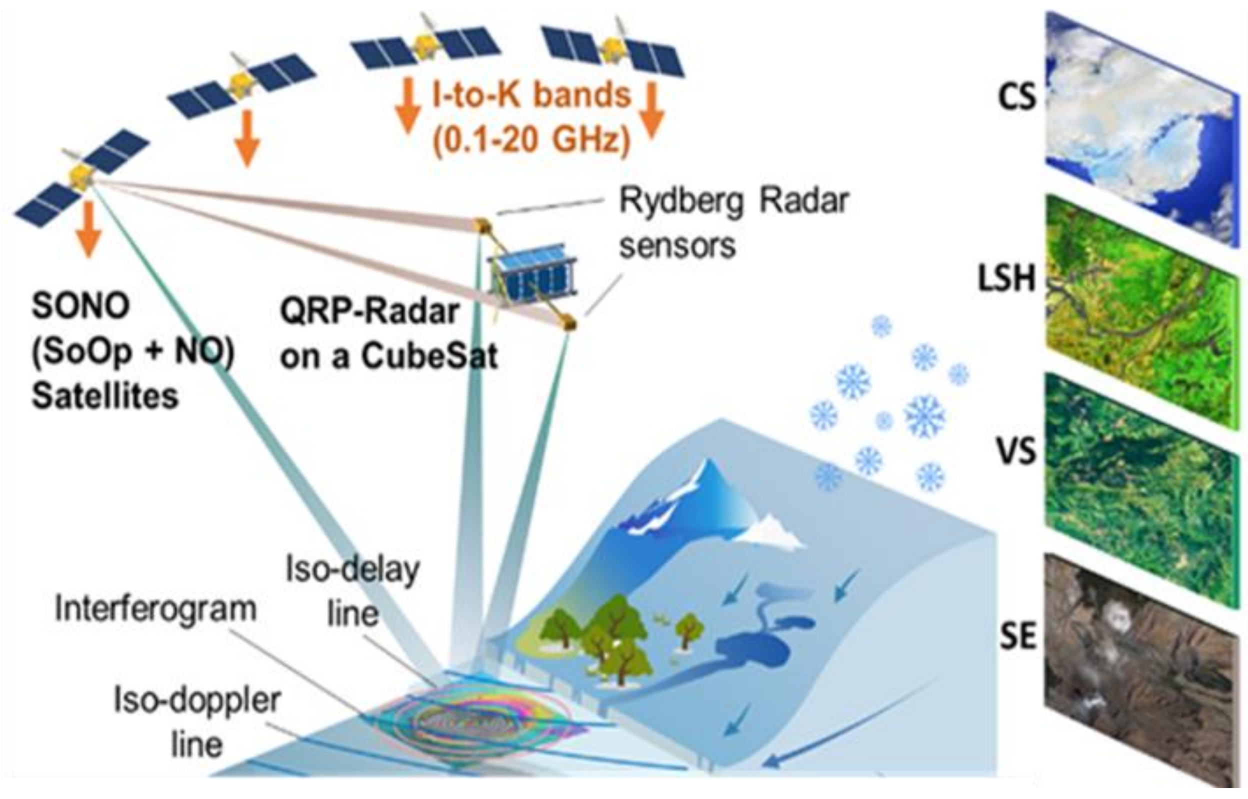

Figure 1. The Quantum Rydberg Radar (QRR) concept for broad-spectrum radar remote sensing for Surface, Topography, and Vegetation (STV) applications.

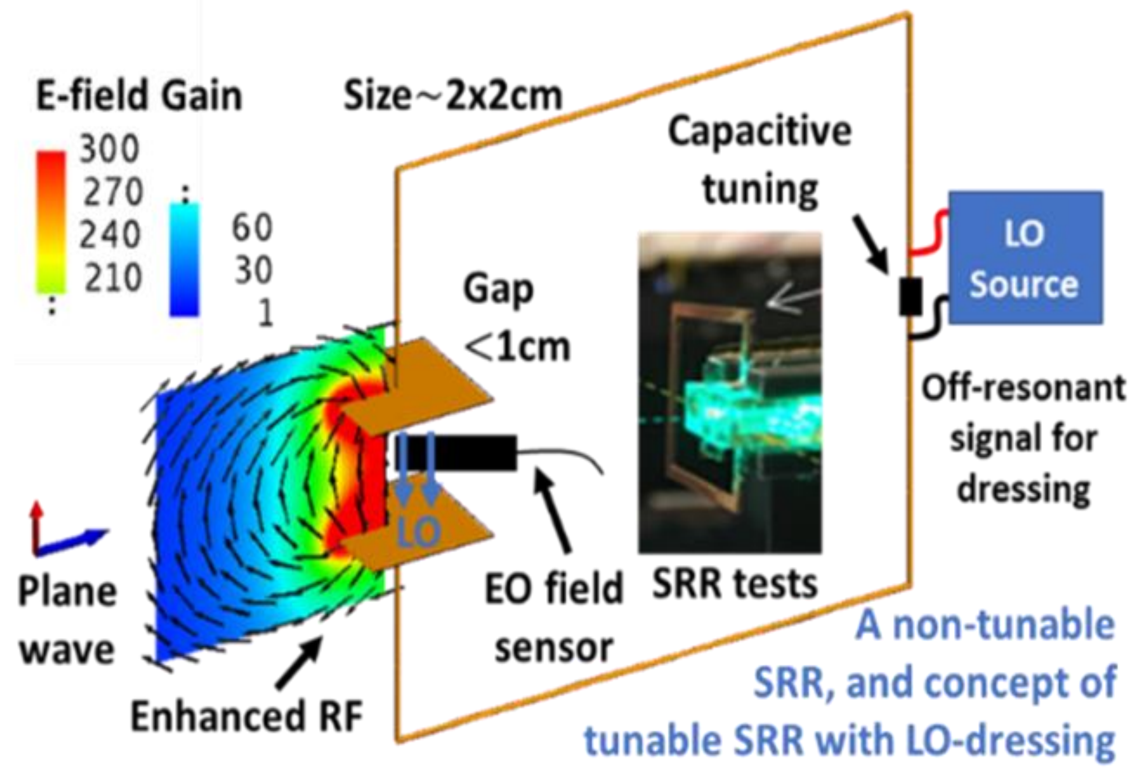

Figure 2. Full-wave electromagnetic simulations of a SRR (split ring resonator) as a field enhancement mechanism for QRR.

Approach and Results:

Currently achievable Rydberg detector sensitivities are ~5μVm^(-1) Hz^(-1/2) in free-space. For SoOp satellite signals identified for LSH-SM, this results in a need for field enhancement (<200x) prior to atomic Rydberg detection. Split ring resonators (SRR) are electrically small structures (<.1λ) which produce an enhanced field (>200x) across the gap portion of the structure in the presence of an E-field at the resonant frequency of the SRR and can satisfy the requirements for QRR in LSH SoOp applications. We mature the SRR concept through design, simulation and measurement in the laboratory for QRR applications in LSH.

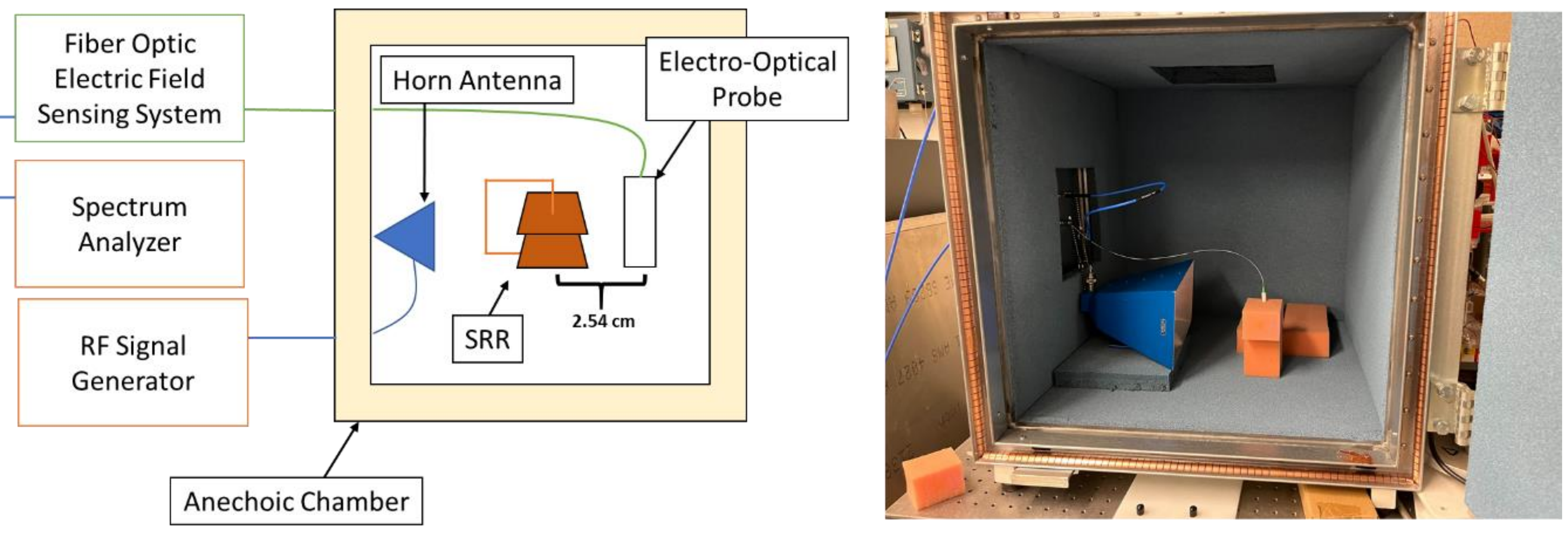

Figure 3. Experiment in an anechoic chamber, with a horn antenna driving the weak external field to the SRR to study field enhancements

Significance/Benefits to JPL and NASA:

Quantum Rydberg Radars (QRR) builds on the disruptive and proven Quantum Rydberg atomic receiver technology. QRR integrates state-of-art high sensitivity, low-noise, ultra-broadband, quantum down-conversion – with no antenna/RF front-end/mixers, and a compact detector, which makes it a vast improvement over classical radars. In this work, we mature a potential key sub-system for QRR – the front-end field enhancement sub-system.

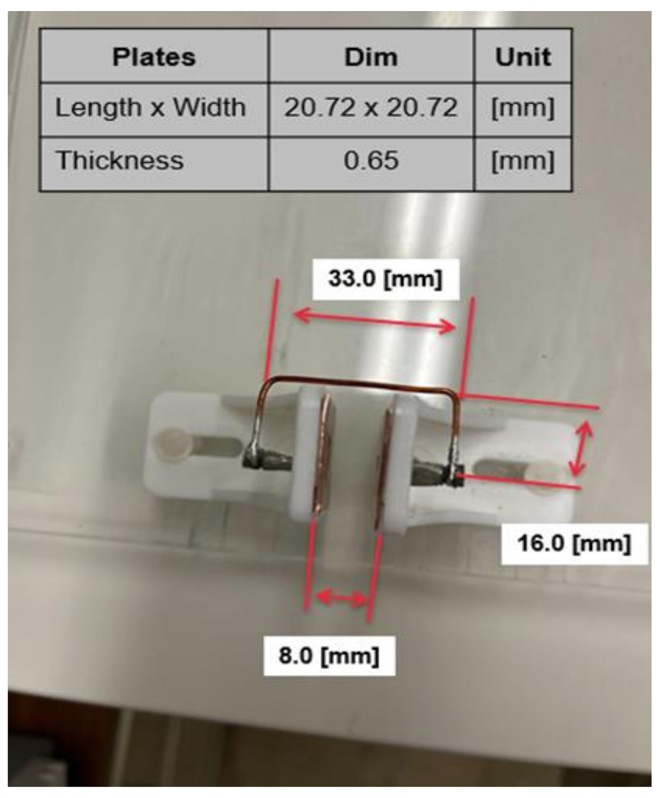

Figure 4. Fabricated design for SRR

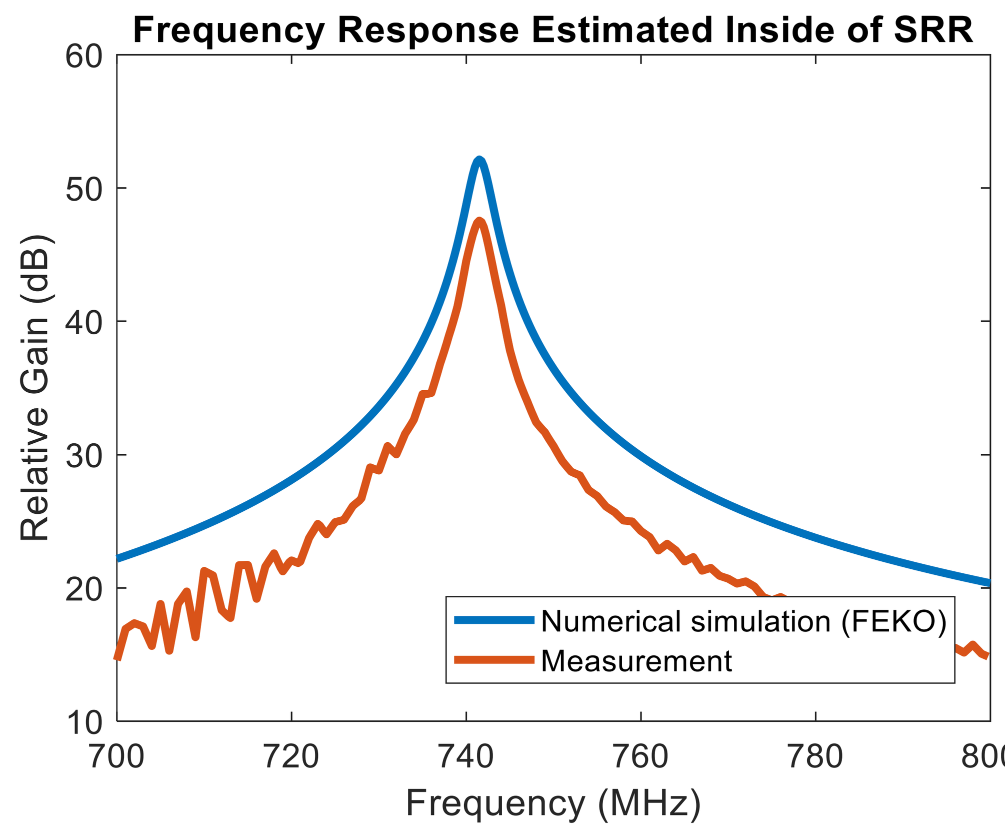

Figure 5. Results for field enhancements

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Clearance Number: CL#22-5549
Poster Number: R22225

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