



NASA SBIR 2021 Phase I Solicitation

S1.02 Technologies for Active Microwave Remote Sensing

Lead Center: JPL

Participating Center(s): GSFC

Scope Title:

High-Efficiency Solid-State Power Amplifiers

Scope Description:

This subtopic supports technologies to aid NASA in its active microwave sensing missions. Specifically, we are seeking L- and/or S-band solid-state power amplifiers (SSPAs) to achieve a power-added efficiency (PAE) of >50% for 1 kW peak transmit power, through the use of efficient multidevice power combining techniques or other efficiency improvements. There is also a need for high-efficiency ultra-high-frequency (335 to 535 MHz) monolithic microwave integrated circuit (MMIC) power amplifiers, with saturated output power greater than 20 W, high efficiency of >70%, and gain flatness of 1 dB over the band.

Solid-state amplifiers that meet high efficiency (>50% PAE) requirements and have small form factors would be suitable for SmallSats, support single satellite missions (such as RainCube), and enable future swarm techniques. No such devices at these high frequencies, high powers, and efficiencies are currently available. We expect a power amplifier with TRL 2 to 4 at the completion of the project.

Expected TRL or TRL Range at completion of the Project: 2 to 4

Primary Technology Taxonomy:

Level 1: TX 08 Sensors and Instruments

Level 2: TX 08.1 Remote Sensing Instruments/Sensors

Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype
- Hardware

Desired Deliverables Description:

Phase I: Provide research and analysis to advance scope concept as a final report.

Phase II: Design and simulation of 1-kW S-/L-band amplifiers with >50% PAE, with prototype.

State of the Art and Critical Gaps:

Surface Deformation and Change is strongly desired for Earth remote sensing, for land use, natural hazards, and disaster response. NASA-ISRO Synthetic Aperture Radar (NISAR) is a Flagship-class mission, but only able to revisit locations on ~weekly basis, whereas future constellation concepts, using SmallSats would decrease revisit time to less than 1 day, which is game changing for studying earthquake precursors and postrelaxation. For natural hazards and disaster response, faster revisit times are critical. MMIC devices with high saturated output power in the few to several watts range and with high PAE (>50%) are desired.

Relevance / Science Traceability:

Surface Deformation and Change science is a continuing Decadal Survey topic, and follow-ons to the science desired for NISAR mission are already in planning. Cloud, water, and precipitation measurements increase capability of measurements to smaller particles and enable much more compact instruments.

References:

- NISAR follow-on for Surface Deformation: <https://science.nasa.gov/earth-science/decadal-sdc>
- Radar in a CubeSat (RainCube): <https://www.jpl.nasa.gov/cubesat/missions/raincube.php>
- Global Atmospheric Composition Mission: <https://www.nap.edu/read/11952/chapter/9>
- Global Precipitation Measurement Mission: https://www.nasa.gov/mission_pages/GPM/overview/index.html

Scope Title:**Deployable Antenna Technologies****Scope Description:**

Low-frequency deployable antennas for Earth and planetary radar sounders: antennas capable of being hosted by SmallSat/CubeSat platforms are required for missions to icy worlds, large/small body interiors (i.e., comets, asteroids), and for Earth at center frequencies from 5 to 100 MHz, with fractional bandwidths $\geq 10\%$. Dual-frequency solutions or even tri-frequency solutions are desired; for example, an approximately 5- to 6-MHz band, with an approximately 85- to 95-MHz band. Designs need to be temperature tolerant; that is, not changing performance parameters drastically over flight temperature ranges of ~ 100 °C.

High-frequency (V-band) deployable antennas for SmallSats and CubeSats: Small format, deployable antennas are desired (for 65 to 70 GHz) with an aperture size of $\sim 1 \text{ m}^2$ that when stowed, fit into form factors suitable for SmallSats€”with a desire for similar on the more-challenging CubeSat format. Concepts that remove, reduce, or control creases/seams in the resulting surface, on the order of a fraction of a wavelength at 70 GHz are highly desired.

Expected TRL or TRL Range at completion of the Project: 2 to 4

Primary Technology Taxonomy:

Level 1: TX 08 Sensors and Instruments

Level 2: TX 08.1 Remote Sensing Instruments/Sensors

Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype

Desired Deliverables Description:

For both antenna types (low and high frequency) a paper design is desired for Phase I, and a prototype for Phase II. Concepts and prototypes for targeted advances in deployment technologies are welcome and do not need to address every need for mission-ready hardware.

State of the Art and Critical Gaps:

Low-frequency antennas, per physics, are large, and so are deployable, even for large spacecraft. For Small/CubeSats the challenges are to get enough of an antenna aperture with the proper length to achieve relatively high bandwidths. No such 10% fractional antenna exists for the Small/CubeSat form factors.

High-frequency antennas can often be hosted without deployment, but a $\sim 1\text{-m}^2$ -diameter antenna on a Small/CubeSat is required to be deployable. Specific challenge for high-frequency deployable antennas is to deploy the aperture with enough accuracy such that the imperfections (i.e., residual folds, support ribs, etc.) are flat enough for antenna performance.

Relevance / Science Traceability:

Low-frequency-band antennas are of great interest to subsurface studies, such as those completed by MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding) and SHARAD (Shallow Radar) for Mars, and planned for Europa by the REASON (Radar for Europa Assessment and Sounding: Ocean to Near-surface) on the Europa Clipper. Studies of the subsurfaces of other icy worlds is of great interest to planetary science, as is tomography of small bodies such as comets and asteroids. Because of the impact of the ionosphere, low-frequency sounding of Earth is very challenging from space, but there is great interest in solutions to make this a reality. Lastly, such low-frequency bands are also of interest to radio-astronomy, such as that being done for OLFAR, <https://research.utwente.nl/files/5412596/OLFAR.pdf>

V-band deployable antennas are mission enabling for pressure sounding from space.

References:

For low-frequency deployables, see similar missions (on much larger platforms):

- REASON: <https://www.jpl.nasa.gov/missions/europa-clipper/>
- MARSIS: https://mars.nasa.gov/express/mission/sc_science_marsis01.html

For high-frequency deployable, see similar, but lower frequency mission:

- RainCube: <https://www.jpl.nasa.gov/cubesat/missions/raincube.php>

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Scope Title:

Steerable Aperture Technologies

Scope Description:

Technologies enabling low-mass steerable technologies, especially for L or S bands including, but not limited to antenna or radio-frequency (RF) electronics, enabling steering: cross track $\pm 7^\circ$ and along track $\pm 15^\circ$. This would enable a complete antenna system with a mass density of 10 kg/m² (or less) with a minimum aperture of 12 m².

Examples of different electronics solutions include completely integrated TR (transmit/receive) modules, with all control features for steering included; or alternatively, an ultra-compact TR module controller, which can control N modules, thus allowing reduction in size and complexity of the TR modules themselves.

Expected TRL or TRL Range at completion of the Project: 2 to 4

Primary Technology Taxonomy:

Level 1: TX 08 Sensors and Instruments

Level 2: TX 08.1 Remote Sensing Instruments/Sensors

Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype

Desired Deliverables Description:

Phase I: A paper study with analysis.

Phase II: Prototype of subcomponent.

State of the Art and Critical Gaps:

No technology currently exists for such low mass density for steerable arrays.

Relevance / Science Traceability:

Surface Deformation and Change science is a key Earth Science Decadal Survey topic.

References:

NISAR follow-on and Surface Deformation:

- <https://nisar.jpl.nasa.gov/>
- <https://science.nasa.gov/earth-science/decadal-sdc>

Scope Title:

Low-Power W-Band Transceiver

Scope Description:

Require a low-power compact W-band (monolithic integrated circuit or application-specific integrated circuit (ASIC) preferred) transceiver with up/down converters with excellent cancellers to use the same antenna for transmit and receive. Application is in space landing radar altimetry and velocimetry. Wide-temperature-tolerant technologies are encouraged to reduce thermal control mass, either through designs insensitive to temperature changes or active compensation through feedback. Electronics must be tolerant to a high-radiation environment through design (rather than excessive shielding). In the early phases of this work, radiation tolerance must be considered in the semiconductor/materials choices, but it is not necessary to demonstrate radiation tolerance until later. For ocean worlds around Jupiter, bounding (worse case) radiation rates are expected to be at less than 50 rad(Si)/sec with minimal shielding during the period of performance (landing or altimeter flyby), but overall total dose is expected to be in the hundreds of krad total ionizing dose (TID). Most cases will be less extreme in radiation.

Expected TRL or TRL Range at completion of the Project: 2 to 4

Primary Technology Taxonomy:

Level 1: TX 08 Sensors and Instruments

Level 2: TX 08.X Other Sensors and Instruments

Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype

Desired Deliverables Description:

Phase I: Paper study/design.

Phase II: Prototype.

State of the Art and Critical Gaps:

Low-power-consumption transceivers for W-band are critical for studies of atmospheric science, pressure sounding, and atmospheric composition for both Earth and planetary science. Such transceivers currently do not exist.

Relevance / Science Traceability:

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- <https://solarsystem.nasa.gov/missions/ace/in-depth/>
 - <https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19710011019.pdf>

References:

Missions for atmospheric science and altimetry applications:

- <https://solarsystem.nasa.gov/missions/ace/in-depth/>
- https://descanso.jpl.nasa.gov/monograph/series13/DeepCommo_Chapter8--14102_9.pdf

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