NASA SBIR 2022 Phase I Solicitation

S11.03 Technologies for Passive Microwave Remote Sensing

Lead Center: GSFC

Participating Center(s): JPL

Scope Title

Components or Methods to Improve the Sensitivity, Calibration, or Resolution of Microwave/Millimeter-Wave Radiometers

Scope Description

NASA requires novel solutions to challenges of developing stable, sensitive, and high-resolution radiometers and spectrometers operating from microwave frequencies to 1 THz. Novel technologies are requested to address challenges in the current state of the art of passive microwave remote sensing. Technologies could improve the sensitivity, calibration, or resolution of remote-sensing systems or reduce the size, weight, and power (SWaP). Companies are invited to provide unique solutions to problems in this area. Possible technologies could include:

- Low-noise receivers at frequencies up to 1 THz.
- Solutions to reduce system 1/f noise over time periods greater than 1 sec.
- Internal calibration systems or methods to improve calibration repeatability over time periods greater than days or weeks.

Expected TRL or TRL Range at completion of the Project

3 to 5

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
Desired Deliverables Description

Research, analysis, software, or hardware prototyping of novel components or methods to improve the performance of passive microwave remote sensing.

- Depending on the complexity of the proposed work, Phase I deliverables may include a prototype system or a study.
- Phase II deliverables should include a prototype component or system with test data verifying functionality.

State of the Art and Critical Gaps

Depending on frequency, current passive microwave remote-sensing instrumentation is limited in sensitivity (as through system noise, 1/f noise, or calibration uncertainty), resolution, or in SWaP. Critical gaps depend on specific frequency and application.

Relevance / Science Traceability

Critical need: Creative solutions to improve the performance of future Earth-observing, planetary, and astrophysics missions. The wide range of frequencies in this scope are used for numerous science measurements such as Earth science temperature profiling, ice cloud remote sensing, and planetary molecular species detection.

References


Scope Title

Advanced Digital Electronic or Photonic Systems Technology for Microwave Remote Sensing

Scope Description

Technology critical to increasing the utility of microwave remote sensing based on photonic (or other novel analog) systems, application-specific integrated circuits (ASICs), and field programmable gate arrays (FPGAs) are showing great promise. This topic solicits proposals for such systems or subsystems to process microwave signals for passive remote-sensing applications for spectrometry or total power radiometry. Example applications include:

- Photonic (or other analog) systems for spectrometers, beam-forming arrays, correlation arrays, oscillators, noise sources, and other active or passive microwave instruments having size, weight, and power (SWaP) or performance advantages over digital technology.
- ASIC-based solutions for digital beam forming creating one or more beams to replace mechanically scanned antennas.
- Digitizers for spectrometry starting at 20 Gsps, 20 GHz bandwidth, 4 or more-bit resolution, and simple interface to a FPGA.
- ASIC implementations of polyphase spectrometer digital signal processing with ~1 W/GHz; 10-GHz-bandwidth polarimetric spectrometer with 1,024 channels; and radiation-hardened and minimized power dissipation.

All systems or subsystems should also focus on low-power, radiation-tolerant broad-band microwave spectrometers for NASA applications. Proposals should compare predicted performance and SWaP to conventional radiofrequency and digital-processing methods.
NOTE: Proposers for specific photonic integrated circuit (PIC) technology should instead see related STTR subtopic T8.07.

**Expected TRL or TRL Range at completion of the Project**

3 to 5

**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**

Demonstration of novel subsystem or system to enable increased capability in passive microwave remote-sensing instruments. Photonic systems specifically are low-TRL emerging technologies, so offerors are encouraged to identify and propose designs where photonic technology would be most beneficial. For electronic solutions, low-power spectrometer (or other application in the Scope Description) for an ASIC or other component that can be incorporated into multiple NASA microwave remote-sensing instruments.

- Depending on the complexity of the proposed work, Phase I deliverables may include a prototype system or a study.
- Phase II deliverables should include a prototype component or system with test data verifying functionality.

**State of the Art and Critical Gaps**

- Photonic systems for microwave remote sensing are an emerging technology not used in current NASA microwave missions, but they may enable significant increases in bandwidth or reduction in SWaP. Again, state-of-the-art digital electronic solutions typically consume many watts of power.
- Digital beamforming: most digital beamforming applications have focused on either specific narrowband approach for commercial communications or military radars. NASA needs solutions that consume low power and operate over wide bandwidths.
- Digitizers: High-speed digitizers exist but have poorly designed output interfaces. Specifically designed ASICs could reduce this power by a factor of 10 but pose challenges in design and radiation tolerance. A low-power solution could be used in a wide range of NASA remote-sensing applications.
- Spectrometers: The state of the art is currently the use of conventional microwave electronics for frequency conversion and filtering for spectrometers. Wideband spectrometers still generally require over 10 W. Current FPGA-based spectrometers require ~10 W/GHz and are not flight qualifiable.

**Relevance / Science Traceability**

Photonic systems may enable significantly increased bandwidth of Earth-viewing, astrophysics, and planetary
science missions. This may allow for increased bandwidth or resolution receivers, with applications such as
hyperspectral radiometry.

Broadband spectrometers are required for Earth-observing, planetary, and astrophysics missions. The rapid
increase in speed and reduction in power per gigahertz in the digital realm of digital spectrometer capability is
directly applicable to planetary science and enables radio-frequency interference (RFI) mitigation for Earth science.

References

- Ulaby, Fawwaz; and long, David: *Microwave radar and radiometric remote sensing*, Artech House, 2015.
- Chovan, Jozef; and Uherek, Frantisek: "Photonic Integrated Circuits for Communication
- S. Pulipati et al.: "Xilinx RF-SoC-based Digital Multi-Beam Array Processors for 28/60 GHz Wireless
- Johnson, Joel T. et al.: "Real-Time Detection and Filtering of Radio Frequency Interference Onboard a
  Spaceborne Microwave Radiometer: The CubeRRT Mission," *IEEE Journal of Selected Topics in Applied
  Instrumentation* 8.01, 2019, [https://ntrs.nasa.gov/citations/20170003103](https://ntrs.nasa.gov/citations/20170003103)

Scope Title

Deployable Antenna Apertures at Frequencies up to Millimeter Wave

Scope Description

Deployable antenna apertures are required for a wide range of NASA passive remote-sensing applications from
SmallSat platforms. Current deployable antenna technology is extremely limited above Ka-band. NASA requires
low-loss deployable antenna apertures at frequencies up to 200 GHz or beyond. Deployed aperture diameters of
0.5 m or larger are desired, but proposers are invited to propose concepts for smaller apertures at higher
frequencies.

NASA also requires low-loss broad-band deployable or compact antenna feeds with bandwidths of two octaves.
Frequencies of interest start at 500 MHz. Loss should be as low as possible (less than 1%). The possibility of
thermal control is desired to improve system calibration stability.

Expected TRL or TRL Range at completion of the Project

3 to 5

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

- Analysis
- Prototype
- Hardware
Desired Deliverables Description

Phase I deliverables should consist of analysis and potential prototyping of key enabling technologies.

Phase II deliverables should include a deployable antenna prototype.

State of the Art and Critical Gaps

Current low-loss deployable antennas are limited to Ka-band. Deployable apertures at higher frequencies are required for a wide range of applications, as aperture size is currently an instrument size, weight, and power (SWaP) driver for many applications up to 200 GHz.

Relevance / Science Traceability

Antennas at these frequencies are used for a wide range of passive and active microwave remote sensing, including measurements of water vapor and temperature.

References

- Passive remote sensing such as performed by the Global Precipitation Mission (GPM) Microwave Imager (GMI): [https://gpm.nasa.gov/missions/GPM/GMI](https://gpm.nasa.gov/missions/GPM/GMI)