RPC-186

RPC 2020

Virtual Research Presentation Conference

Simultaneous X- and Ka-Band Receiver for Astrometry and Navigation

Principal Investigator: Jacob W. Kooi (386H)
Co-Is: Dan Hoppe (333), James Bowen (333), Andy Fung (386), Raju Manthena (333), Zubair Abdulla (333)
Program: Strategic Initiative

Jet Propulsion Laboratory
California Institute of Technology

Assigned Presentation # RCP-186

Tutorial Introduction

Very Long Baseline Array (Owens Valley site)

Abstract

The objective of this Strategic Task is to develop a wideband cryogenic monolithic microwave integrated circuit (MMIC)-based receiver, to cover 8-36 GHz simultaneously, for potential use in developing an X-Ka reference frame for astrometry and navigation.

The receivers are needed to provide reference frames to navigate, including determining positions of quasars for navigation beacons, measuring station locations, and measuring earth orientation to the nano-radian level or better. The measurements of X and Ka band simultaneously allows for calibrations of both the Earth's ionosphere and solar plasma at the exact time and direction of the observations. The acquisition of data in the 8-36 GHz range consolidates several receiver systems (X, Ku, K, and Ka) into one receiver package, which saves space, power, minimize maintenance cost, and allows for additional receivers in VLBA systems.

The instrument are designed and built at JPL. A goal of the proposed work is that our X-Ka band receiver will be tested first in 'stand-alone' in single dish observation mode at the Owens Valley VLBA site (Fig. 1b), with toward the end of the 3rd FY interferometric fringe detection with the VLBA (X / K band) and the DSN at Goldstone (ka band).

Problem Description

a) **Context**: The specific focus of this proposed Task is to design and develop a prototype receiving system that can be used in the Very Long Baseline Array (VLBA). The VLBA has played (and continues to play) a significant role in the development of celestial reference frames, providing many of the measurements for the legacy S-X reference frame. The value of the VLBA is further illustrated by the fact that the U.S. Naval Observatory (USNO) has increased its support for the VLBA, to the point that it now supports 50% of the VLBA observing time, primarily for the purpose of Earth orientation and reference frame observations for terrestrial and near-Earth navigation (A fraction of the USNO-sponsored VLBA time has been used by JPL for its reference frame work.) However, there are increasing concerns about the long-term sustainability of the S-X frame, primarily because of increasing radio frequency interference (RFI) in the S band. In part to begin the transition away from the S-X frame, the NRAO and USNO jointly have considered a new high frequency system for the VLBA, a system that would cover Ka-band.

b) **SOA**: At the present time there is no capability to simultaneously observe X (8-12 GHz) and Ka (26.5 – 36 GHz) frequency bands. This task endeavors to change this paradigm by developing MMIC and Feedhorn technology from 8-36 GHz.

c) **Relevance to NASA and JPL**: This Strategic Initiative is designed to strengthen JPL's leadership in defining the next-generation of celestial reference frames. As part of its vision to be a world leader in deep space telecommunications, the Interplanetary Network Directorate (IND) has invested in higher radio frequency (Ka-band, 36 GHz). In an effort to transition to Ka-band systems, JPL has developed a reference frame based on measurements of quasars at X band (8 GHz) and Ka band (the X/Ka reference frame). We note that the International Astronomical Union, motivated in part by the upcoming Gaia optical catalog release (ca. 2022), may adopt a new International Celestial Reference Frame (ICRF-4) in the next few years which would seamlessly integrate the new Gaia optical frame with the current multi-wavelength radio frames at the S/X, K, and X/Ka radio bands.

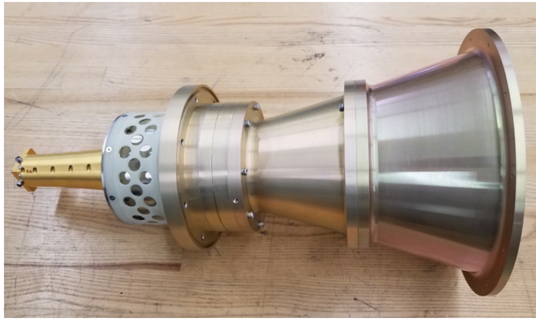
Methodology

a) Formulation, theory or experiment description

This work leverages the design and development conducted under a prior strategic initiative, ‘Technology for the North American Array’. To successfully construct a 8-36 GHz receiver, a number of key technologies (as outlined below) need to be advanced. A prior LNA designed in NGC’s 35 nm InP process by then-graduate student Ahmed Akgiray, has achieved between 13-20 K from 8-40 GHz [PhD dissertation, Caltech 2013], in a chip designed for 8-50 GHz. Similar results were obtained at JPL in a design using OMMIC, again intended for the wider 8-50 GHz frequency range. Both of these chips, with their wider bandwidth, have compromised noise performance in order to obtain the gain up to 50 GHz.

b) Innovation, advancement

i. 8-36 GHz Quad Ridged Feedhorn design, assembly, and performance verification.
ii. Design of 8-36 GHz Optimized (OMMIC) MMICs.
iii. Wafer probing of set forth MMIC design (Caltech, CRAL).
iv. Redesign of the LNA Housing input/output transition to Coax - CPW.
v. Development of a 8- 36 GHz IF processor / downconverter.
vi. Development of a 8- 40 GHz Quadrature Hybrid (Yebes Observatory, Spain).



Assembled 8-36 GHz Quad Ridged Feedhorn

Results

a) Accomplishments versus goals

Despite FY20 challenges, the set forth goals were largely met in that:

i. Assembled Quad-ridged Feedhorn Beam patterns were measured at 8, 20, 36 GHz, fitting the computer simulated performance well.

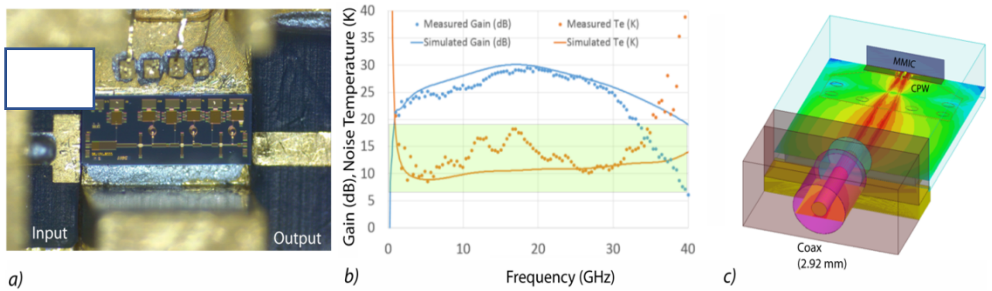
ii. Successful OMMIC waver run 2019.

iii. OMMIC MMIC chips (25) have been cryogenic wafer probed at the Caltech Radio Astronomy laboratory (CRAL). Reduced data shows good gain, and noise performance with the best devices in que for assembly into mixer blocks.

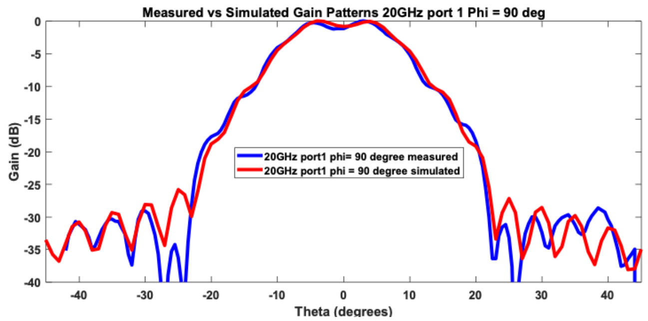
iv. LNA Housing Coax - CPW LNA input/output transition have been received from the supplier (ATP) and are awaiting assembly into new mixer blocks with above mentioned OMMIC chips and existing NGC MMIC chips.

v. All the IF processor / downconverter hardware has been received and is presently being assembled.

vi. An Yebes observatory (SPAIN) collaboration has produced an excellent performing cryogenic 8-40 GHz Quadrature Hybrid prototype. It is anticipated (budgeted) that qty=5-6 will be procure in FY 2021.



a) Capacitive compensation. b) Example of the NGC's InP 35 nm MMIC process (35LN1A1) LNA performance.
c) Coax-Coplanar Wave (CPW) transition (both measured and modeled) to help increase the high frequency performance.



QRFH measured (blue) and Simulated (red)

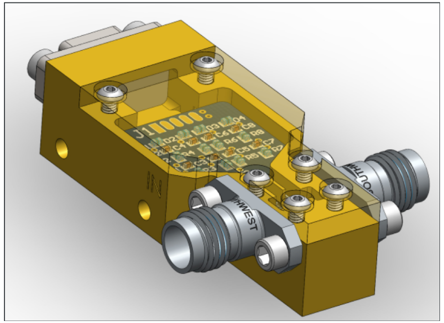
Results

b) Significance

The above mentioned accomplishments have led to a collaborative ‘memo of understanding’ with NRAO to use one of the VLBA antenna’s as a testbed for the prototype 8-36 GHz X-Ka band receiver. This has since been agreed upon by NRAO. The instrument is well on its way to demonstrate for the first time simultaneous X-Ka band Celestial Reference frame observations.

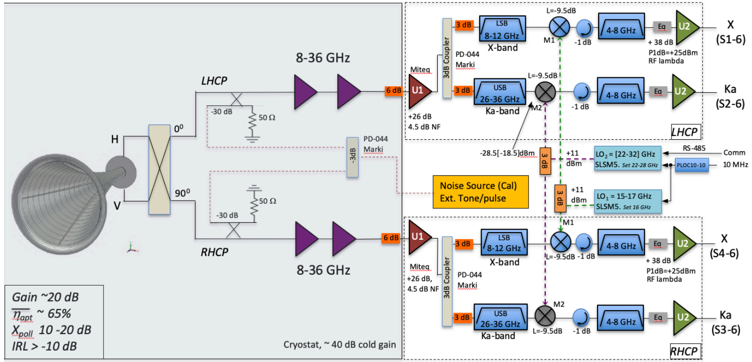
c) Next steps

The X-Ka band receiver will be taken to the roof of Building 238 (DSN) to do ‘on the sky’ observations and provide debugging opportunities in Oct-Dec 2020. Following successful completion arrangements have been made with NRAO for ‘on-site’ single dish- and an interferometric observations of a small sample of known quasars



Standard 8-40 GHz LNA Housing

Yebes Observatory 8-40 GHz Cryogenic Quadrature Hybrid.



IF Processor / Downconverter. All the hardware has been procured. Output is LHCP and RHCP (VLBA interface).

Publications

A. Fung, L. Samoska, J. Bowen, S. Montanez, J. Kooi, M. Soriano, C. Jacobs, R. Manthena, D. Hoppe, A. Akgiray, R. Lai, X. Mei, M. Barsky, "X- to Ka- Band Cryogenic LNA Module for Very Long Baseline Interferometry", Proc. IEEE-MTT Int. Microwave Symp., 2020.

References

J. E. Velazco, L. Ledezma, J. Bowen and L. Samoska and [illegible] Soriano and A. Akgiray and S. Weinreb and J. Lazio, "Ultra-Wideband Low Noise Amplifiers For The Next Generation Very Large Array," *2019 IEEE Aerospace Conference*, Big Sky, MT, USA, 2019, pp. 1-6, doi: 10.1109/AERO.2019.8742126.

"New Technologies Driving Decade-Bandwidth Radio Astronomy: Quad-Ridged Flared Horn & Compound-Semiconductor LNA", Ahmed Halid Akgiray, PhD Thesis, California Institute of Technology Pasadena, California April 19, 2013.

[Samoska 2016]: L. Samoska *et al*., "Cryogenic low noise MMIC amplifiers for U-Band (40–60 GHz)," *2016 11th European Microwave Integrated Circuits Conference (EuMIC)*, London, 2016, pp. 81-84, doi: 10.1109/EuMIC.2016.7777495

[Varonen 2017]: Varonen, M., Samoska, L., Kangaslahti, P., Fung, A., Gawande, R., Soria, M., Peralta, A., Lin, R., Lai, R., Mei, X., & Sarkozy, S. (2017). Cryogenic MMIC Low-Noise Amplifiers for V-band. In *2017 IEEE MTT-S International Microwave Symposium, IMS 2017* (pp. 172-175). [8058970] IEEE Institute of Electrical and Electronic Engineers. https://doi.org/10.1109/MWSYM.2017.8058970