National Aeronautics and Space Administration

SURFACE PRESSURE SENSING RADAR USING V-BAND (65-70) GHZ

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Project Objective: Develop compact, multi-chip modules working at V-band (65-70 GHz) necessary to demonstrate a differential absorption radar to measure surface pressure.

Surface pressure is important:

- It is the main driver behind atmospheric dynamics
- For studying weather forecasting
- For Prediction of strength and path of storms
- For prediction of dry tropospheric delays, (could help NISAR, SWOT radar range measurements as well as GPS accuracy.

Measurement Principle:

- Radar echo power has a strong gradient with frequencies due to O2 absorption atound 60 GHz.
- This technique makes measurements of two radar channels - one sufficiently far into the O2 band and the other on the wing of the band.
- The ratio of these measurements, or the differential absorption, is a measure of the O2 column abundance, and in turn surface pressure.
- In the presence of hydrometeors, it is possible to get returns along the air column above the surface, enabling estimation of the vertical pressure structure.

L. Millán et al.: DAR surface pressure retrievals

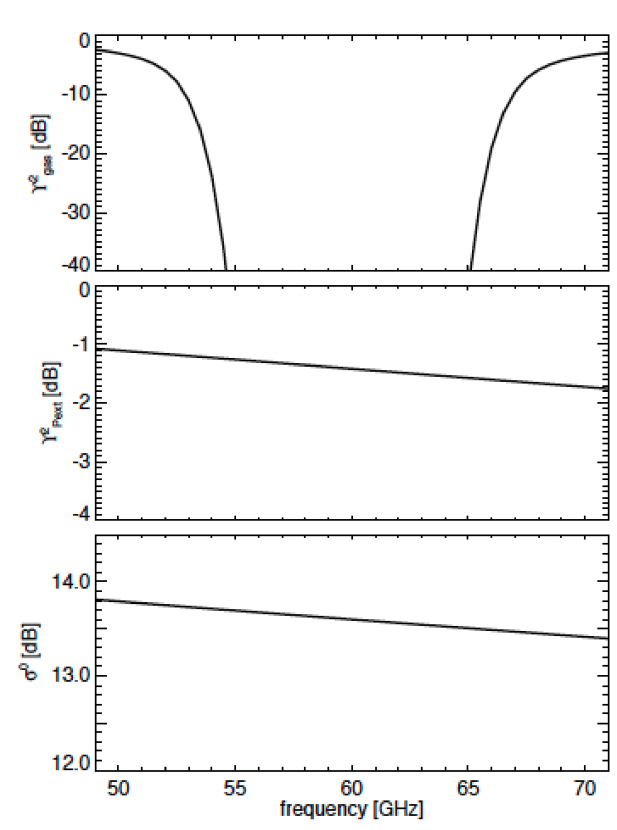

Figure 1. Typical atmospheric transmittance due to gases (top) and hydrometeors (middle) (Eq. 2) for a surface return journey (downward atmospheric pass, surface reflection, upward pass) for a nimbostratus cloud near the 60 GHz O_2 band region. (bottom) Ocean backscatter for a surface wind of 3 $m s^{-1}$ and temperature of 28 °C. Note that only the transmittance due to gases (top) show a significant frequency dependence.

RELEVANCE TO STRATEGIC FOCUS AREA:

- Remote sensing measurement of surface pressure is a priority in the new decadal survey's Planetary Boundary Layer (PBL) component.
- To help answer the decadal survey's "Most Important" questions W-1 as to the PBL processes that control the air-surface fluxes and how they affect weather forecasts, and question W-4 as to why convective storms occur when and where they do.
- NASA strategic objective 2.2 and JPL strategic goal 2 as outlined in NASA Strategic Plan 2014, in a crucial way by contributing to the development of an instrument capable of producing systematic estimates of surface pressure.
- This measurement ability directly addresses one of the seven science goals "Improve the capability to predict weather and extreme weather events (Weather)", called out in Section 4.2 of NASA 2014 Science Plan.

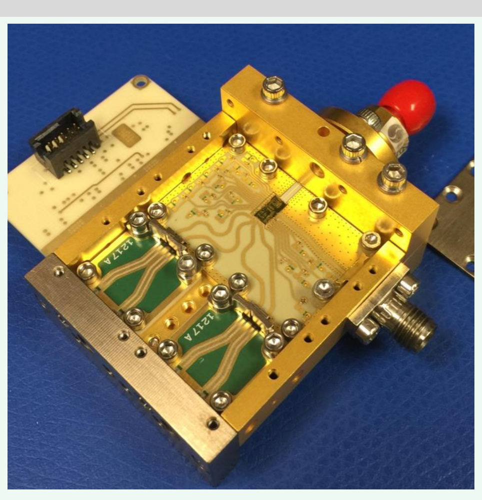

Figure 2. TX Module (RF Side)

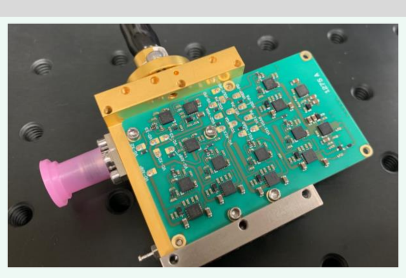

Figure 3. TX Module (Bias Side)

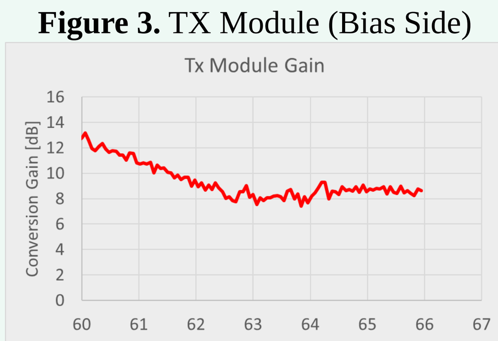

Figure 4. TX Module conversion gain as a function of RF frequency measured at X microwave

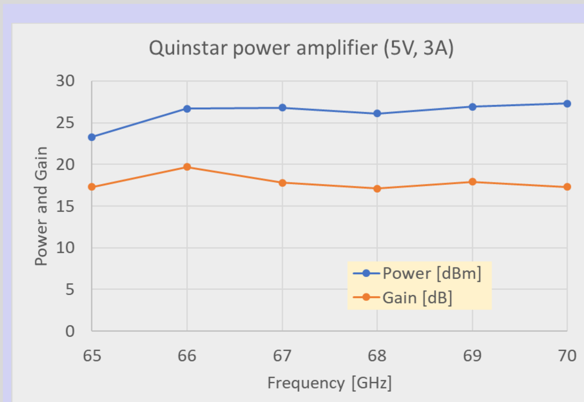

Figure 5. Gain and power as a function of RF frequency

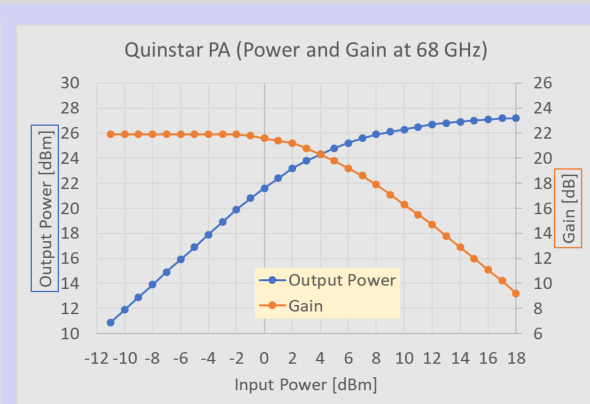

Figure 6. Pout vs Pin curve at 68 GHz

Power Amplifier Option 1: Commercial packaged power amplifier

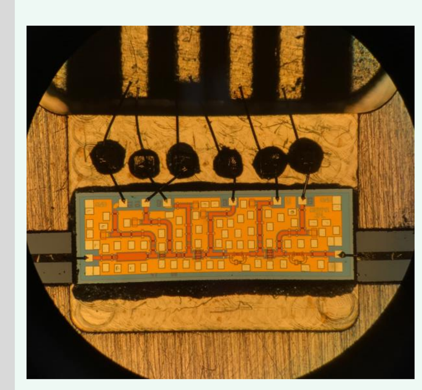

Figure 7. RGVPA fabricated at Ommic foundry.

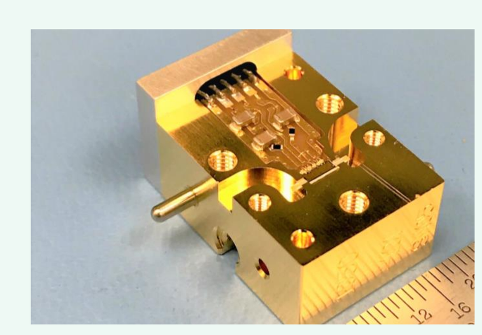

Figure 8. JPL designed GaN power amplifier waveguide Module.

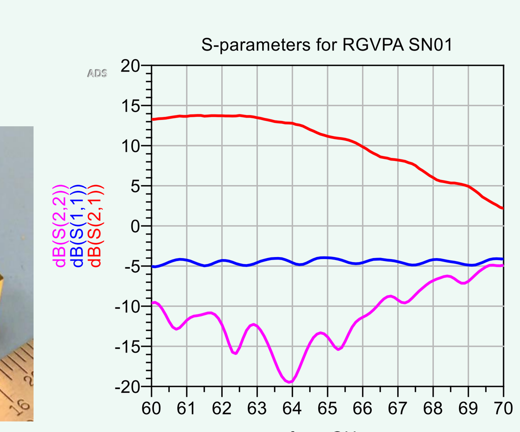

Figure 9. RGVPA SN01 S-parameters

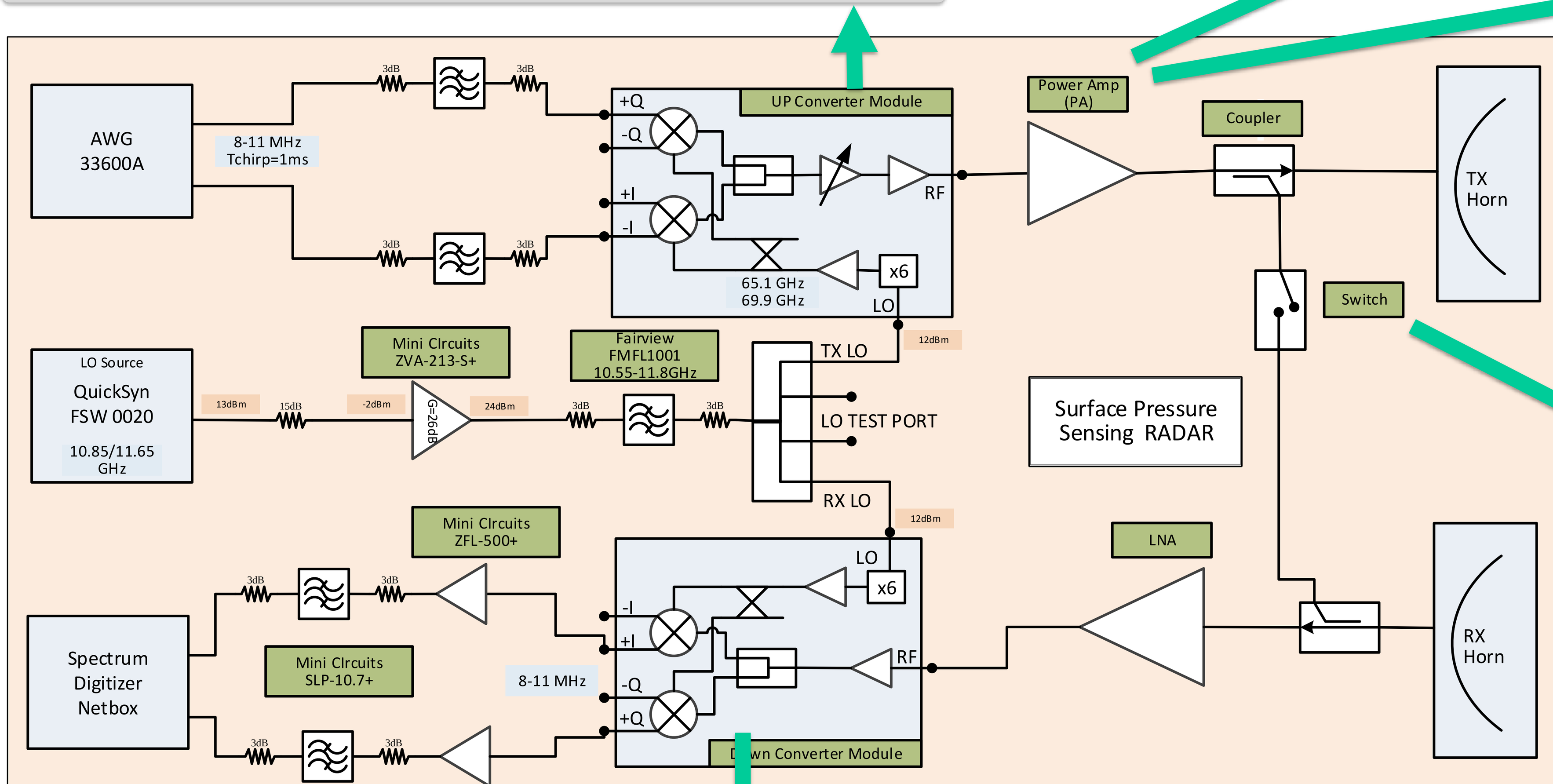

Figure 1. Instrument Block Diagram:

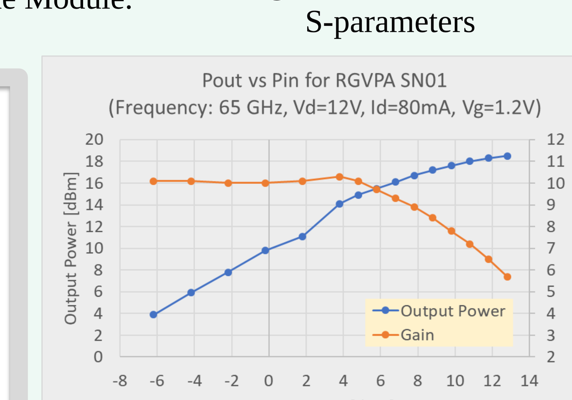

Figure 10. RGVPA SN01 Pout vs Pin curve

Power Amplifier Option 2: JPL designed V-band GaN power amplifier

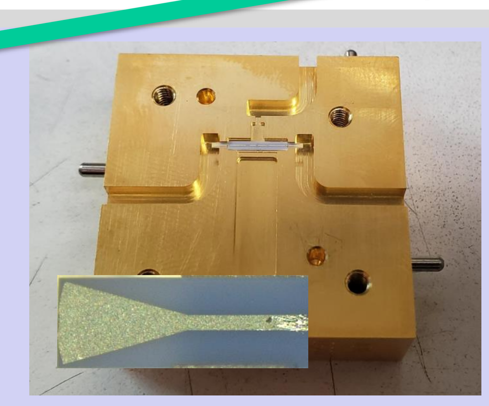

Figure 11. V-band radial probe mounted back-to-back with a thruline in a waveguide block

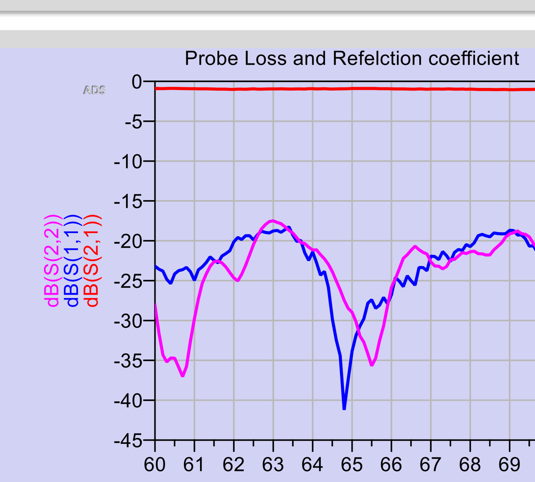

Figure 12. V-band radial probe s-parameters.

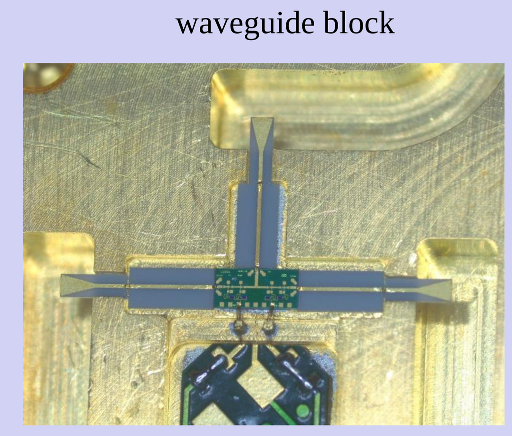

Figure 13. V-band MMIC switch packaged in a waveguide block

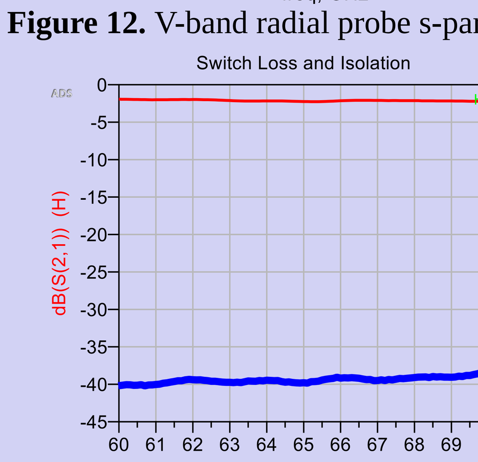

Figure 14. V-band insertion loss and isolation.

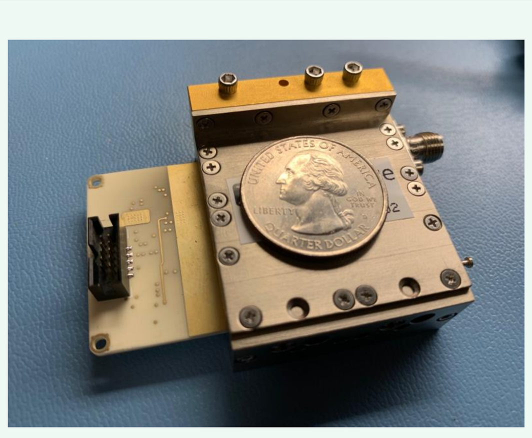

Figure 15. RX Module (RF Side)

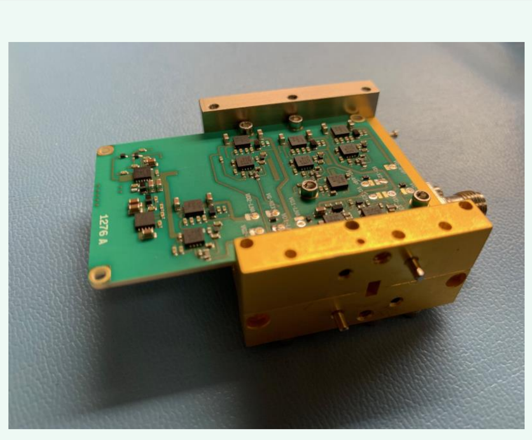

Figure 16. RX Module (Bias Side)

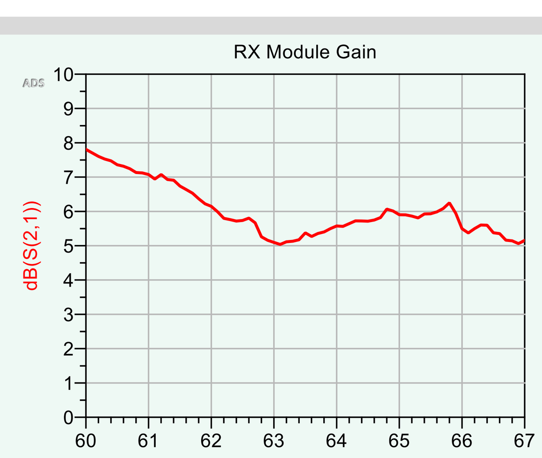

Figure 17. RX module gain as a function of RF frequency measured at X microwave

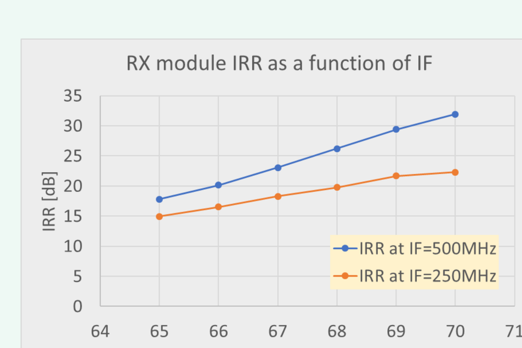

Figure 18. RX Module image rejection ratio as a function of IF

Approach

The main challenge in this research is development and integration of state-of-the-art components in V-band, which is a relatively unexplored band for radar applications.

Figure 1 shows the instrument block diagram. This RTD focuses on maturing the technology to allow development of all the necessary blocks: 1) up converter module, 2) power amplifier, 3) coupler, 4) switch, 5) Low Noise Amplifier, 6) down converter module and 7) LO distribution.

Benefits to NASA and JPL (or significance of results):

All existing and planned precipitation and cloud radars operate at Ku, Ka, W or a combination of these bands (e.g. TRMM, GPM, CloudSat). V-band (65-70 GHz) is mostly unexplored band for radar applications and hence there is a severe need for development of microwave components such as up down converters, power amplifiers, switches and LNAs at these frequencies. Figure 1 shows the system level block diagram for differential absorption radar, which could be built as part of the next Instrument Incubator Program or a future Earth Venture call. All the blocks have been matured as part of this RTD to put together a demonstration instrument. This technology development can be leveraged to write a proposal for building the complete instrument for remote sensing measurement of pressure. This work positions JPL as the leader in the advanced technology for a new and innovative measurement concept that will complement existing and planned cloud and precipitation missions (specifically the Cloud Convection Precipitation "targeted observables"). The inherent low mass and volume architecture of the proposed instrumentation provides many possible avenues to space including future Instrument Incubator programs and Earth Ventures calls.

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