37th AMS Conference on Radar Meteorology, Norman, Oklahoma. 14 – 18 September 2015

Paper ID: 274853

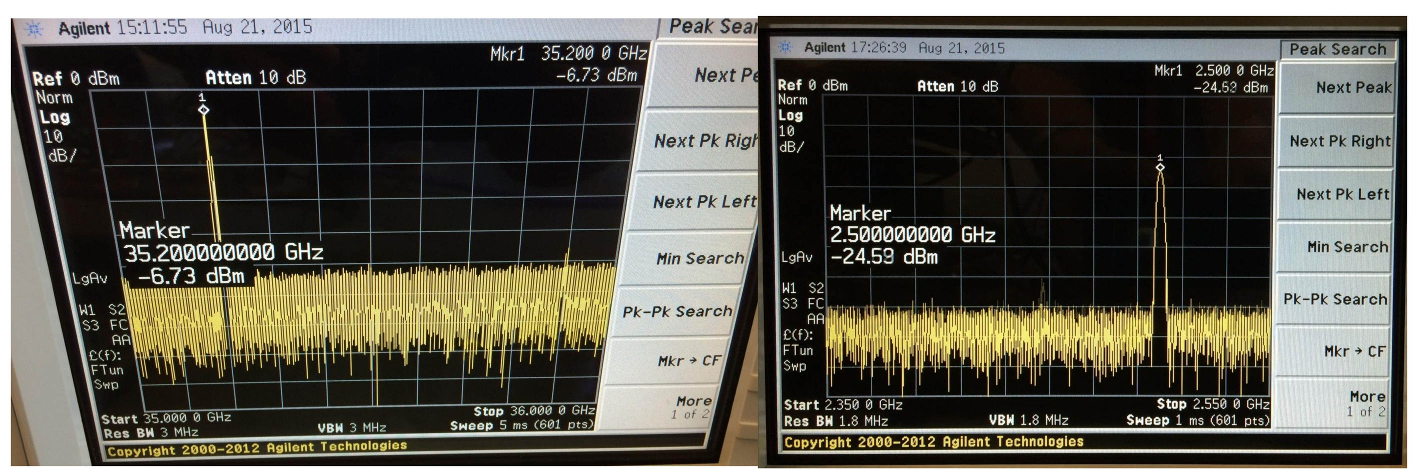
Concept Design and Feasibility Studies for a Ka-band, UAS-based Cloud Sensing Radar

Jingxiao Cai[1], Ridhwan Khalid Mirza[1], Yan (Rockee) Zhang[1], David Delene[2] and Jeffrey Tilley[3]
[1]Intelligent Aerospace Radar Team, Advanced Radar Research Center, University of Oklahoma
[2] Atmospheric Sciences Department, University of North Dakota
[3] Open Science Associates

Introduction

Over the years, as the technology advances, the millimeter wave radars are becoming more prevalent for the detection, analysis and classification of both microphysical cloud particles and larger size hydrometers. The use of unmanned aircraft platforms has enabled larger scale, higher resolution and innovative process for cloud and fog observations (size, shape, dielectric properties etc.).

This research intends to implement the idea of using a novel Ka band radar sensor which can be mounted on a medium sized unmanned aerial vehicle (UAV) platform, and can fly to a much closer range to the cloud systems than existing remote sensors. The FMCW (frequency-modulated continuous wave) waveform and baseband radar scheme is used for the first time for this application, and integrated circuit implementations are being developed to meet the C-SWaP requirements.



(a) (b)

Figure 1: (a) The Transmitting and Receiving Spectrum
(b) The Baseband Signal Spectrum

Radar Sensor Design

The laboratory prototype which is being developed at OU is designed to transmit and receive at 35.2 GHz (Figure 1(a)) with a baseband at 2.5 GHz (Figure 1(b)). As seen in Figure 2 and Figure 3, the system mainly comprises of transmitting and receiving chain. A Phase Locked Loop (PLL) is used to generate a signal which is then up-converted to 35.2 GHz signal and transmitted. This signal is again received by receiving antenna which now has different properties due to scattering, absorption of radar signals. This signal is processed by a FMCW baseband board to extract reflectivity, determine the particle size in cloud observation, analyze visibility and other related factors.

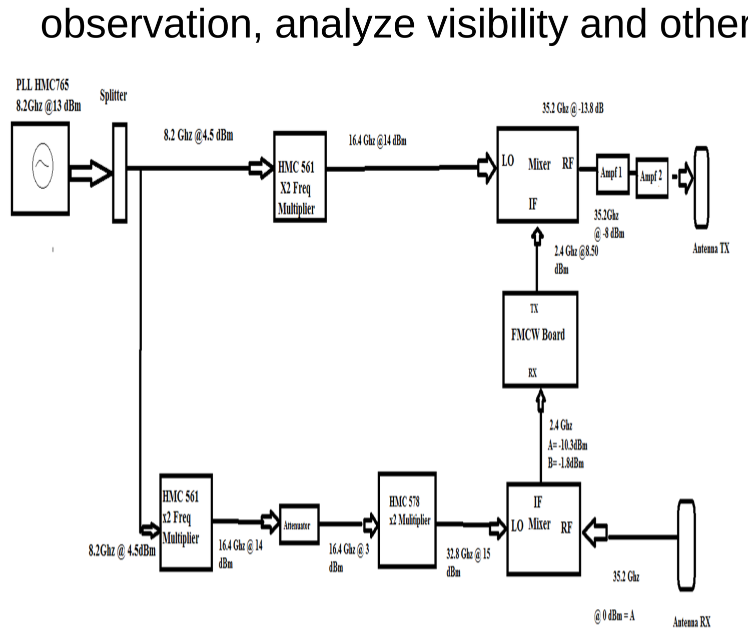


Figure 2: Sensor Block Diagram

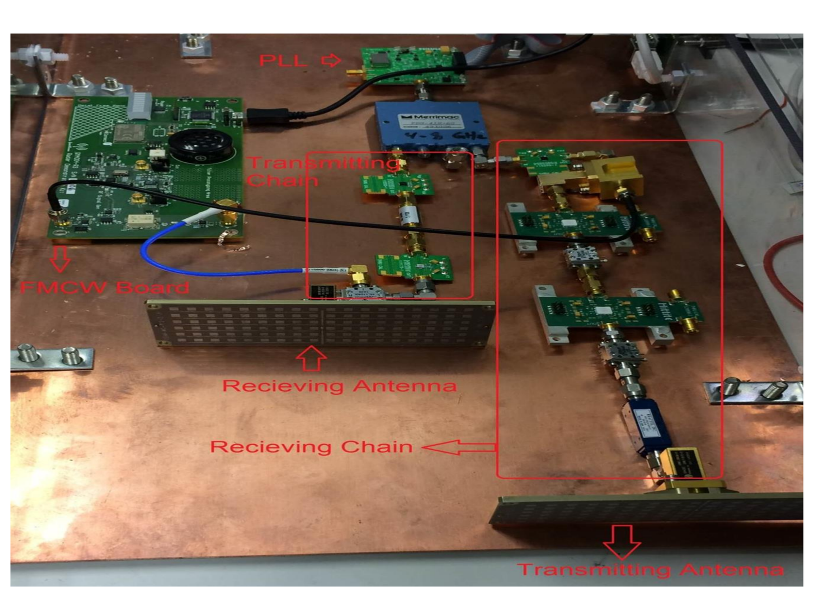


Figure 3: Prototype of Experimental Radar Sensor System

Link budget analysis

Detailed link budget analysis regarding to different types of targets is provided at the initial stage. It could be used as guideline for system design and the baseline of performance expectations. As seen in Figure 4, It was shown that if the airborne radar antenna has a beamwidth of 4.6/15 degrees (Horizontal/Vertical) and a gain at 30 dB, and the FMCW transceiver operates at 35 GHz with 50 MHz ramping bandwidth, 20 MHz LPF cutoff frequency and 1 ms ramping time, 50 m range resolution is achievable at 1km range, with a minimum detectable reflectivity at 0 dBZ and 10 Watt transmitted power. It is sufficient to detect hazard large particles in cloud (i.e. ice) and hydrometeors which are larger than 0.1 mm.

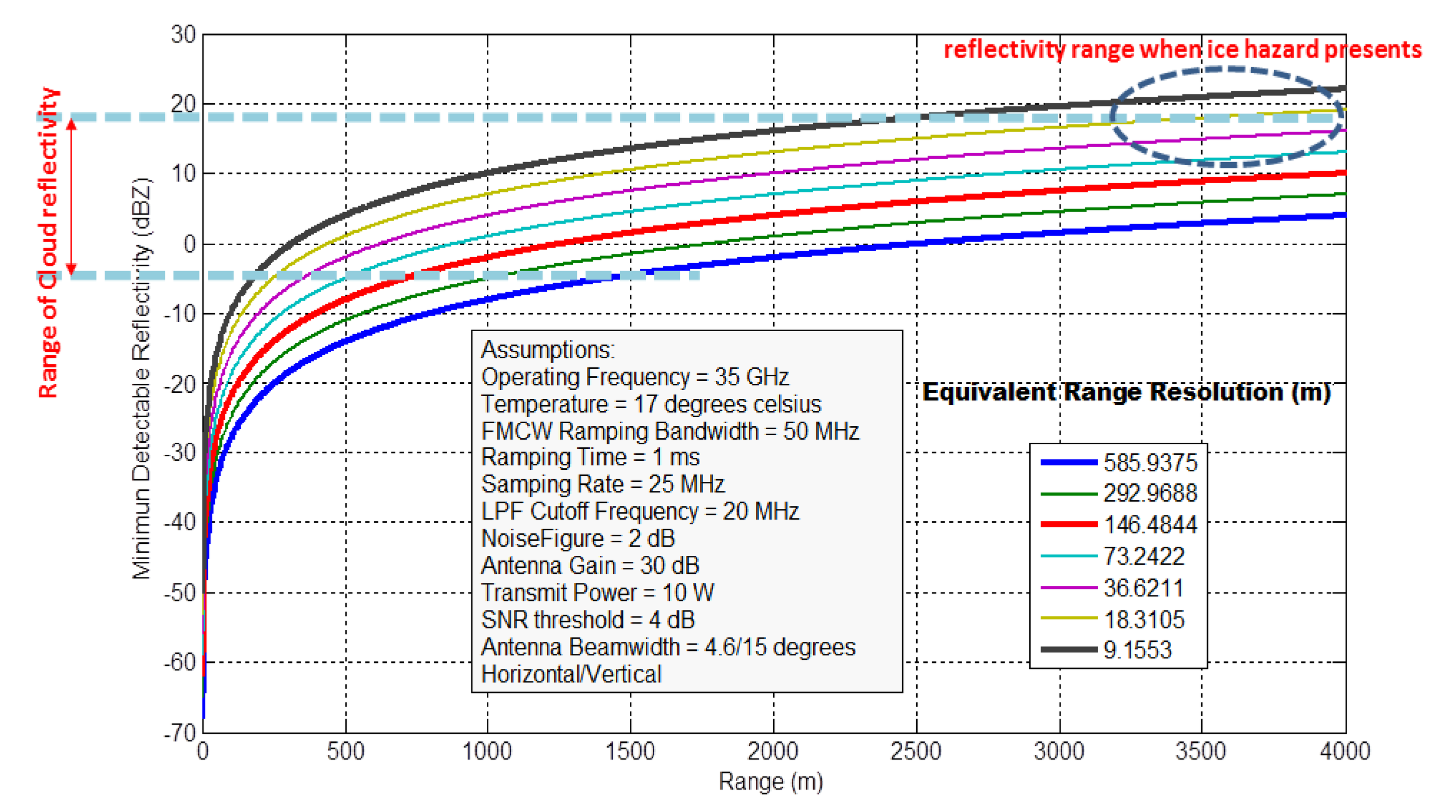


Figure 4: Link Budget Analysis

Laboratory Experiment

The initial field test of this prototype radar was taken place indoor with a rectangular aluminum board or an aluminum sphere target in a relatively short range (since transmit power is only -6 dBm (Figure 1(a))). The size of rectangular board is 20 inches by 15 inches and the diameter of the sphere is 39 inches. The setup of this initial in-door test is shown in Figure 5 and the background reflection is shown in Figure 6.

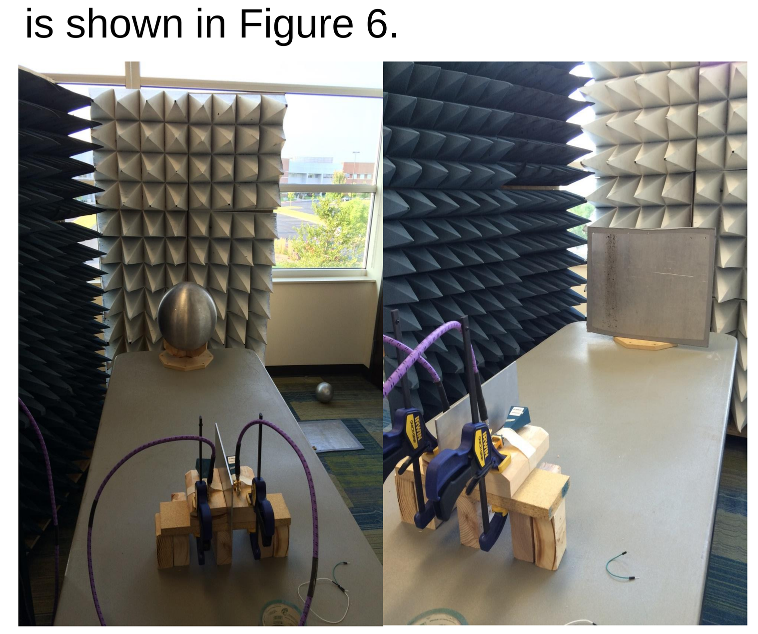


Figure 5: In-door Test Environment

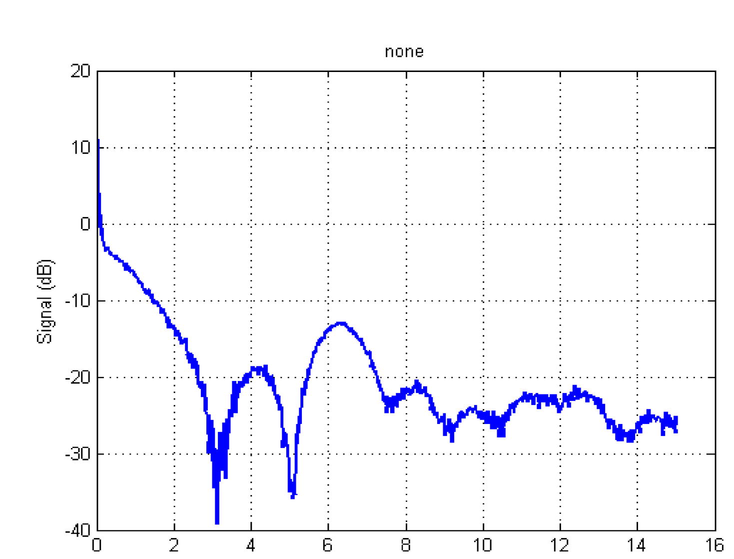


Figure 6: Background Reflection

Initial Results

The initial result is shown in Figure 7. Due to the delay in the circuit, the measured location of target is about 1.8 meters further than where it actually was. An another issue is the accuracy which could be affected by numerous factors including linearity of frequency modulating wave and components used, the frequency accuracy of IF, etc. In Figure 7. there is an offset for the appeared range of the sphere, which is probably due to propagation effect in the lab environment and antenna configuration. Further improvements on the sensitivity and calibration are expected.

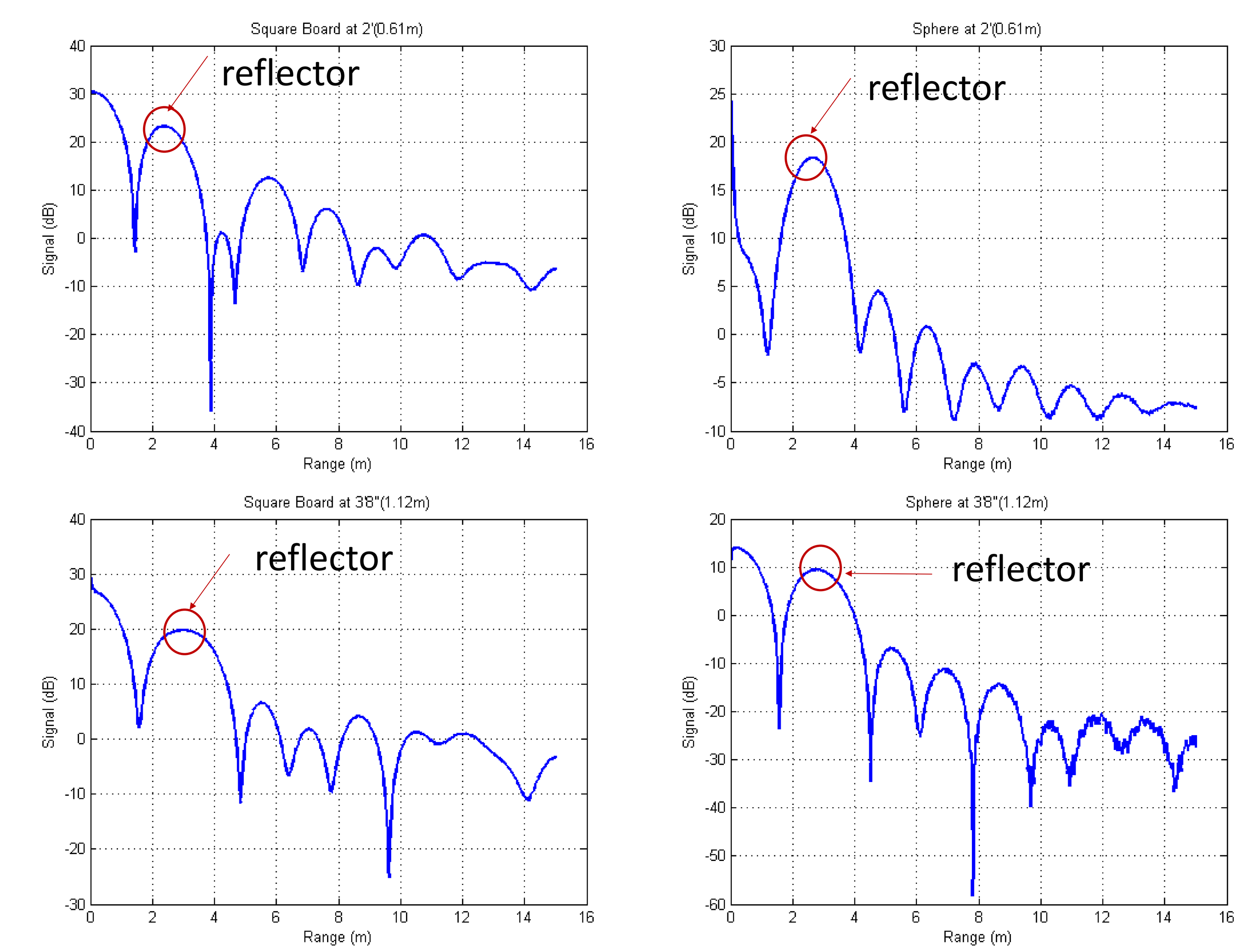


Figure 7: Field Test Results

Conclusion

The initial low-cost Ka-band FMCW radar design and link budget analysis show promises to be applied to airborne cloud sensing applications. The C-SWaP of the current system can meet the requirements of Group 3 (or even smaller) UAV payloads. Further system integration, validation and experiments are needed to enhance the technology readiness level.

Future Work

More realistic tests will be hold. Better device and more advanced algorithm will be used to achieve higher accuracy. Doppler measurements will be added for velocity information.

CONTACT: rockee@ou.edu Tel: (405)325-6036

This material is based upon work supported by the National Aeronautics and Space Administration (NASA) under Grant NNX11AM10A. Any opinions, findings, and conclusions or recommendations expressed in this article are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration.

School of
Electrical & Computer Engineering