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

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***Abstract*—This research intends to implement the idea of using a novel Ka band radar sensor which can be mounted on a medium sized 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. Detailed Link Budget Analysis is shown for different types of target**

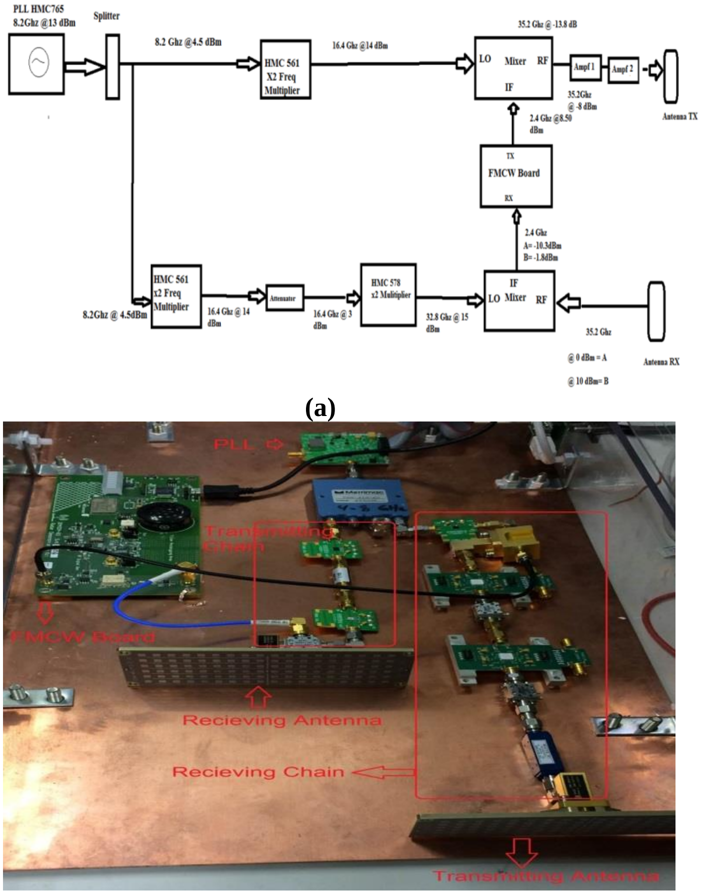
Keywords-FMCW, Ka Band Radar, SWaP, Link Budget Analysis

I. 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 [1]. 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.). The relatively recent development and expanding use of unmanned aircraft platforms has enabled larger scale, higher resolution and innovative process for cloud and hydrometeor observations, which also enables us for potentially the first time to achieve better understanding of the couplings and interactions that must be present from the upper microscale to the mesoscale with regards to determine the cloud microphysical processes (including aerosol interactions) key to cloud development, such as microphysical-dynamical-radiative feedback loops

II. LABORATORY PROTOTYPE

In this paper a small prototype is presented which is operated at 35 GHz. This mounted on a small UAV platform can provide far better resolution and information such as liquid water content in fog layers, hail etc as compared to ground based radars which are almost 10 times the cost of the proposed prototype. In addition to this it clear that millimeter-wave cloud profiling radars operating at 35GHz are more accurate as the attenuation of signals by oxygen and water vapor is minimal near these frequencies [2].



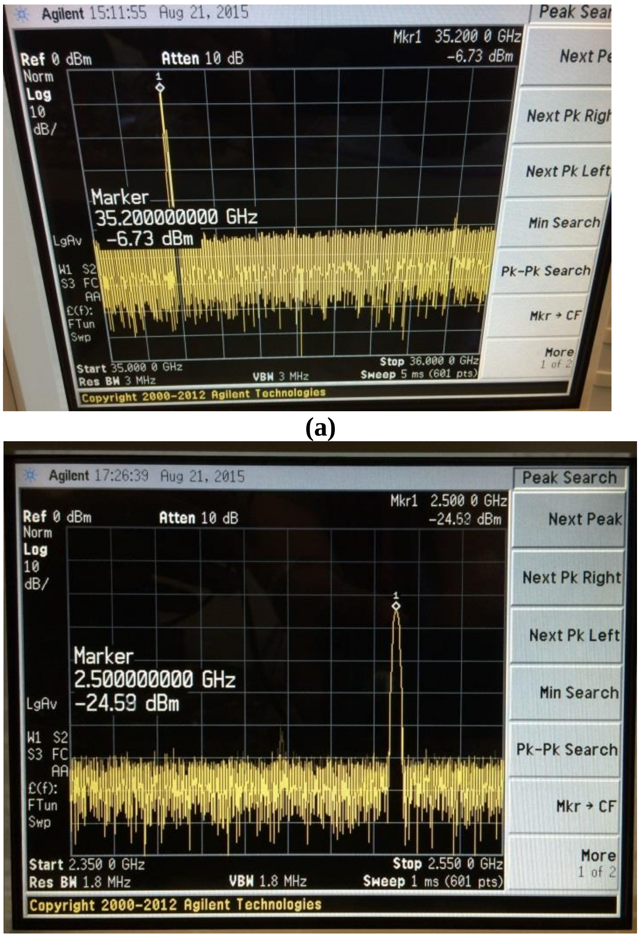
(a)

(b)

Figure 1: (a) Block Diagram of the proposed prototype. (b) Hardware Prototype of the Radar Sensor System.

As seen in the figure 1, system is designed to transmit and receive at 35.2 GHz with a baseband at 2.5 GHz (seen in Figure 2(b)). As seen in Figure 1(a) and (b), 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 (seen figure 2(a)) with the help of frequency multipliers, amplifiers and sub harmonically pumped mixers 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 down converted and processed by a FMCW baseband board to extract reflectivity, determine the particle size in cloud observation, analyze visibility and other related factors.

There are two antenna’s used in the system, one is used for transmitting and the other one is used for receiving. Both the antennas are to be aligned straight and in the same position to as to reduce the errors.



(a)

(b)

Figure 2: (a) ***The Transmitting and Receiving Spectrum*****. (b) The Baseband Signal Spectrum**

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III. 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.

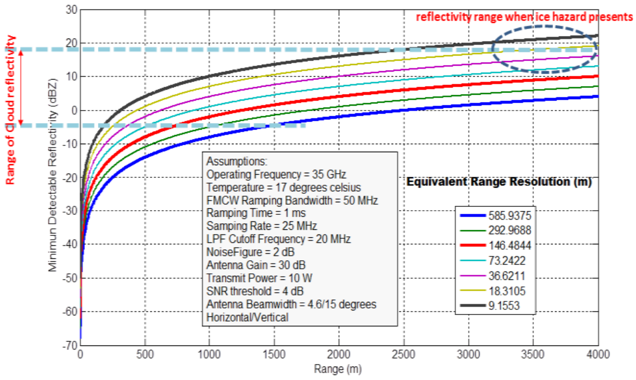


Figure 4: Link Budget Analysis

IV. LABORATORY EXPERIMENT

The initial field test of this prototype radar was taken place indoor with a rectangular aluminum board and aluminum sphere targets in a relatively short range (since transmit power is only 0 dBm). 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.

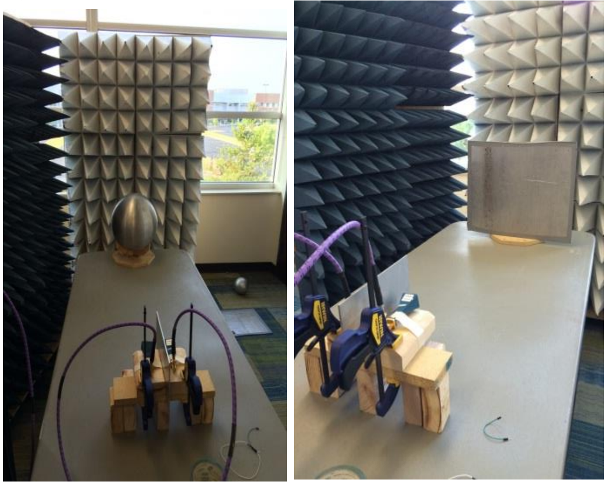


Figure 5: In-door Test Environment with sphere target and rectangular target

It should be noted that there are two antenna’s used in the system, one is used for transmitting and the other one is used for receiving. Both the antennas are to be aligned straight and in the same position to as to reduce the errors.

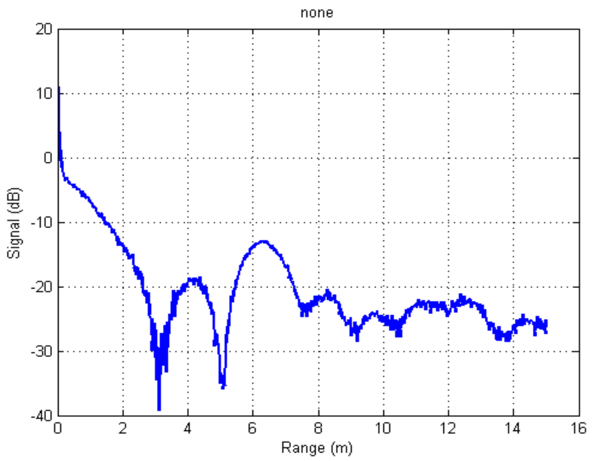
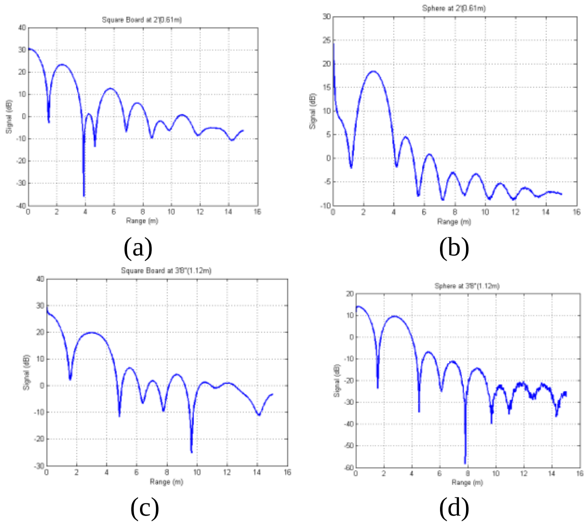


Figure 6 : Background Reflection

V. 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 meter 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 improvement on the sensitivity and calibration is expected.



(a) (b)

(c) (d)

Figure 7 : (a) Square Target at 0.61m (b) Sphere Target at 0.61m (c) Square Board at 1.12m (d) Sphere at 1.12m.

VI. FUTURE WORK AND 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. More realistic test will be hold. Better device and more advanced algorithm can be used to achieve higher accuracy. Doppler measurements can be added for velocity information

ACKNOWLEDGMENT

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.

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