REALIZATION OF THE NASA DUAL-FREQUENCY DUAL-POLARIZED DOPPLER RADAR (D3R)

Manuel Vega[1,3]*, James Carswell*[2]*, V. Chandrasekar*[1]*, Mathew Schwaller*[3]

[1] Colorado State University
[2] Remote Sensing Solutions
[3] NASA Goddard Space Flight Center

1. INTRODUCTION

The Global Precipitation Measurement (GPM) mission is an international partnership aimed at two things primarily, 1) the advancement in knowledge of the global water cycle and 2) the improvement of weather, climate and hydrological prediction capabilities through more accurate and frequent measurements of global precipitation [1]. Based on its successful predecessor, the Tropical Rain Measuring Mission (TRMM), the GPM core satellite will carry a Ku-band weather radar with the addition of a Ka-band radar in order to improve snow and light rain precipitation measurements. Dual-frequency measurements will also provide the capability of measuring parameters directly related to the microphysics of precipitation such as drop size distribution (DSD). Within GPM, a significant effort is being dedicated to the ground validation (GV) of the dual-frequency precipitation radar (DPR) onboard its core satellite. As part of the GV effort, a ground based Ka/Ku-band fully polarimetric Doppler radar system (D3R), CAD model shown in Figure 3, is under development and scheduled for integration during late summer of 2010. By operating at both Ka- and Ku-band, it is expected that it will provide accurate estimates of rainfall as well as DSD parameters [2]. Furthermore, the full polarimetry capability makes D3R a unique, self-consistent cross validation tool for GPM since it will be capable of retrieving DSDs through both dual-frequency and dual-polarization techniques [3]. This paper will focus on the realization of the novel transceiver technology required for the D3R.

2. TRANSCEIVER DESIGN

Achieving a dual-frequency (Ka/Ku-band), dual-polarized mobile radar system on a single scanning platform places certain size and weight constraints on the hardware used. A lightweight and compact design is required since it will allow the mounting of the RF electronics as close as possible to the antennas, which minimizes front-end losses and makes the system easier to transport between field campaigns. On the other hand, since the main purpose of the D3R is to serve a validation tool for GPM during cold and warm season campaigns (operation in temperatures from -40 to 40C expected), it requires a design approach that not only minimizes size and weight but also maximizes both its reliability and stability over time and temperature.

Given the sensitivity requirement of -10 dBZ at 15 km at both frequencies, suggests the need for a high peak power transmitter. However, recent advances in solid-state technology in the communication industry have made possible the development of rugged, light-weigh, compact 55 W and 220 W power amplifiers at Ka- and Ku-band respectively. Adopting a solid-state power amplifier (SSPA) based transmitter approach requires the use of more advanced waveforms, which in turn, could not only improve the sensitivity but also the sampling capabilities of the D3R. Furthermore, it is well inline with the goal of achieving a lighter and more compact as well as reliable radar system. A detailed sensitivity analysis using the SSPAs mentioned above has been performed and results are shown in Figure 1. Waveforms used in the analysis will be discussed in the following section.

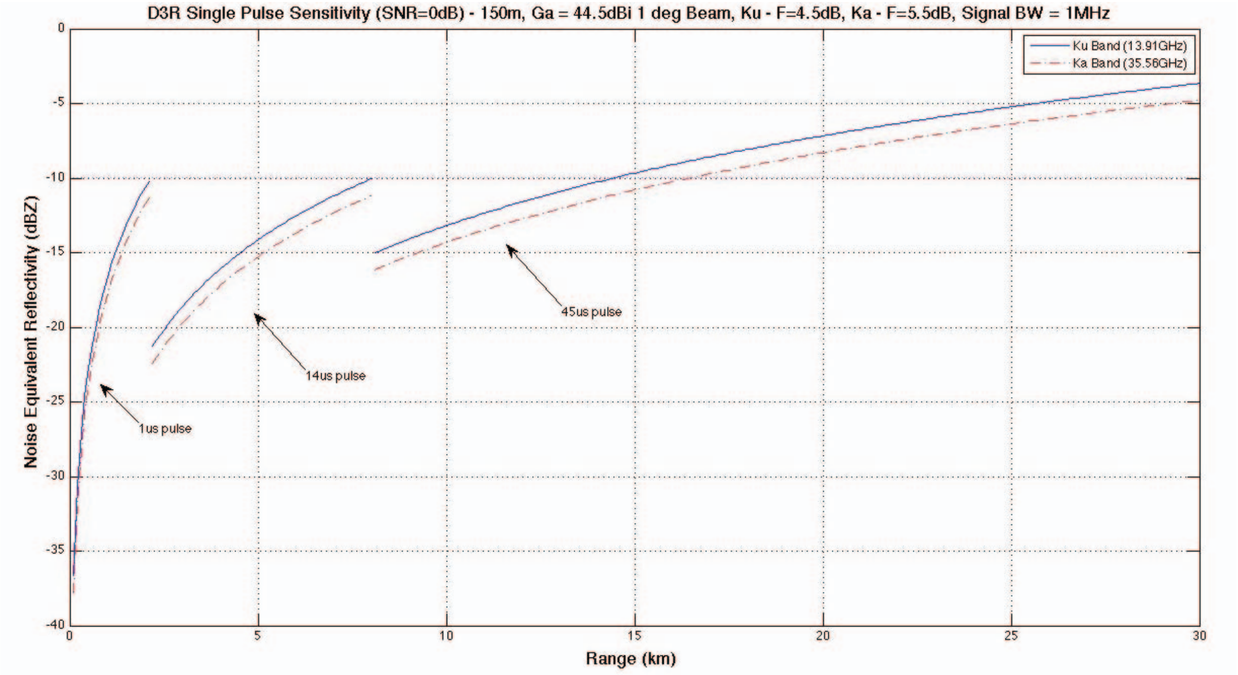

Figure 2 D3R single channel expected sensitivity.

Conventional approaches such as the use of a high peak power tube-based transmitter (e.g. extended interaction klystrons (EIK) and traveling wave tubes (TWT)) could also provide the D3R with the required sensitivity. However, these typically require the use of high voltage power supplies, which end up requiring more space and may not be as reliable when compared to SSPAs. Another point to mention is the overall stability of the system. Working at relatively low power levels allows for a much better calibration loop design. The current design achieves a cal to leakage ratio greater than 38 dB for both the Ka- and Ku-band transceivers. This will allow us to keep track of transceiver gain transfer function fluctuations with 0.1 dB precision or better. For these and other reasons not mentioned above, the D3R will use solid-state technology versus a tube-based approach. A more detailed discussion on the transceiver design will be presented in this paper as well as test results obtained prior to integration. Test results will be used to reassess the expected system performance.

3. WAVEFORM DESIGN

As mentioned in the previous section, adopting a solid-state transmitter approach brings with it some challenges with regards to waveform design. However, with recent developments in digital signal synthesis and processing technologies, more advanced waveforms have become feasible. Achieving the required sensitivity of -10 dBZ at 15 km with the proposed SSPAs, as shown in Figure 1, will require the use of pulse compression. Consequently, with the use of long pulse compressed waveforms come large blind ranges as well as range side lobe contamination. To overcome these a novel waveform composed of three consecutive, non-linear FM, frequency-separated pulses, shown in figure 2, is being studied. In this scheme, blind ranges are mitigated by optimizing the time-bandwidth product of pulses 1 and 2 to achieve the sensitivity of the middle and farthest ranges while pulse 3 (no FM) is used to sample ranges closest to the radar. On the other hand, since very large reflectivity gradients (30-40 dB/km) [4] aren't uncommon in precipitation measurements, range side lobes need to be minimized. To achieve this, a non-linear FM technique similar to the one shown in [5] will be used. Range side lobe levels greater than 40 dB are expected. More details into how these waveforms will be digitally synthesized and processed will be shown in the paper.

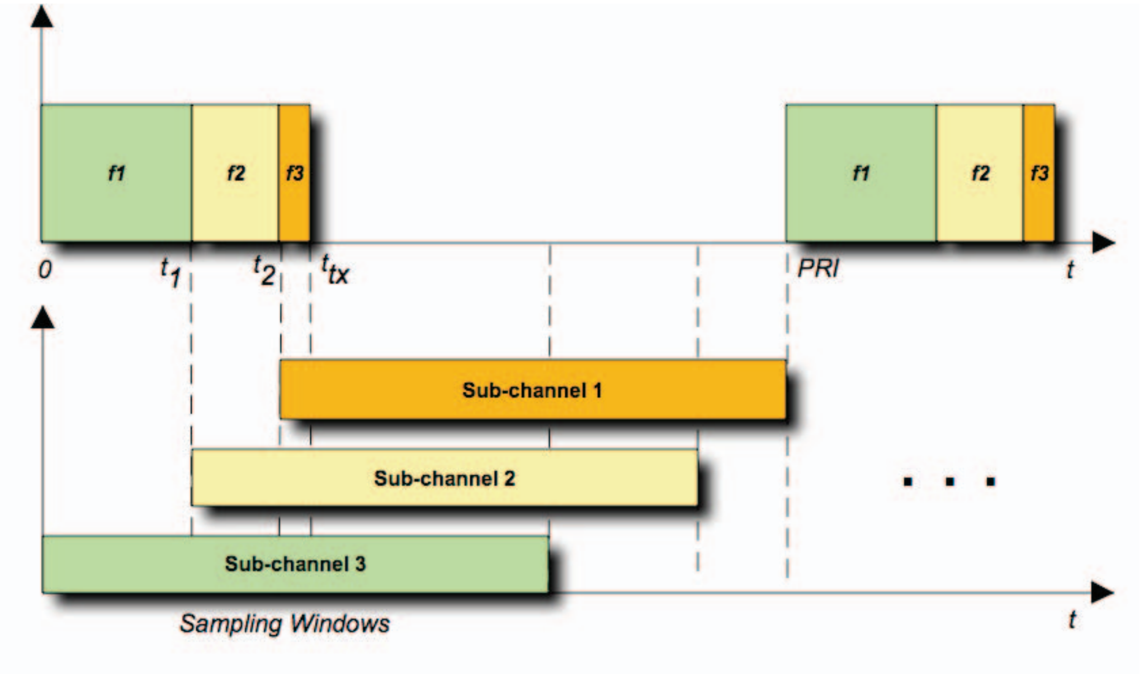

Figure 2 D3R frequency diversity pulse compression waveform and receiver timing diagram.

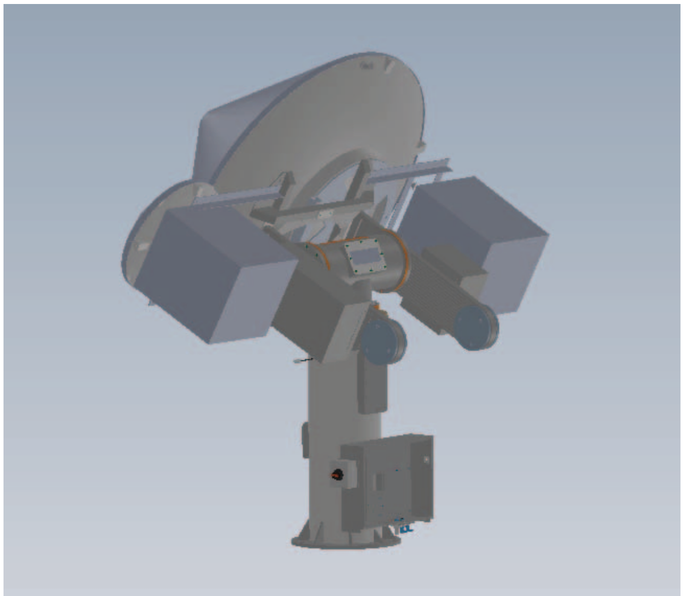

Figure 3 D3R CAD model including Ka- (far left) and Ku-band (far right) transceiver boxes.

4. REFERENCES

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