DOPPLERISING THE STFC / RAL RADAR CLOUD PROFILER

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ABSTRACT

An approach for re-designing and adding Doppler capability to the STFC RAL 94 GHz Radar Cloud Profiler based on solid state components is described. The current design is shown, and the approach to the re-design is laid out. Following that, the anticipated phases to realisation of the re-design is explained. Results of the first phase will be presented at the symposium.

***Index Terms*—** Millimetre wave radar, radar cloud profiler, RF design, solid state components

1. MOTIVATION

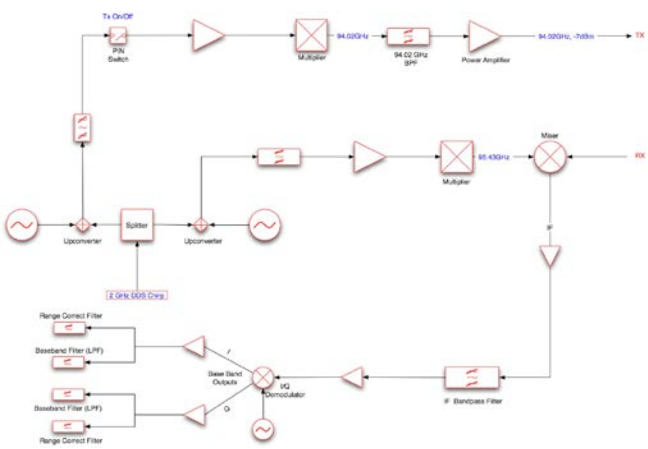

Figure 1: Current design of the RAL Radar Cloud Profiler's RF frontend.

Radars have been used worldwide for many years to provide information on atmospheric conditions, see e.g. [1]. Especially useful are cloud radars, providing information on the signal returned by hydrometeors, e.g. ice crystals and water droplets [2, 3]. For a number of years the UK STFC's Rutherford Appleton Laboratory (RAL) has operated an in-house developed highly sensitive solid state 94 GHz FM-CW Radar Cloud Profiler. This radar is based upon a 78 GHz system that was previously deployed by the UK Met Office [4]. But a different RF approach is used, eliminating the previously applied 78 GHz Gunn diode source and IMPATT amplifier. The instrument has been built in three slightly different versions operated by the UK Met Office [5], Marburg University in Germany [6], and RAL. The system has undergone constant gradual improvements since the first version has been deployed. The current design of the RF frontend of the system operated by RAL is displayed in Figure 1.

Progress in atmospheric research, specifically in the understanding of cloud microphysics processes, and increasing demand from the atmospheric modelling community, make it advisable to upgrade the existing design by including the currently lacking Doppler capability. The contamination of the backscatter signal from clouds by drizzle droplets is explained in [7]. The authors of this paper explicitly recommend Doppler capable Radar to overcome that issue. An example for the benefit of a Doppler capable Cloud Radar is given in [8].

In addition, technical progress in the area of solid state millimetre wave components, including related in-house technology developments, encourage a review and enhancement of the current technical approach. These two goals shall be achieved by the upgrade project introduced below.

2. APPROACH

The general approach adopted in the original design as shown in Figure 1, has been to maximise the RF signal at K_a-band, specifically below 30 GHz, where components are cheaper and performance / efficiency tends to be higher. Frequency translation, via upconversion and multiplication, is then used to obtain the required outputs at W-band (94 GHz).

Although the basic system layout will be retained, it will be extended in the re-design project and the proposed new RF front-end is illustrated in Figure 2. Components marked yellow either originate from in-house development or are based on in-house capabilities (e.g. bonding, packaging).

A significant difference to the original design is the homodyne nature of the system. Only one K_a-band oscillator is used for generating the transmitted signal as well as the

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LO of the frequency downconverter for the received signal. An IF is introduced by offsetting the latter using another upconverter and a low frequency oscillator. This oscillator is also used for providing the LO of the final I/Q demodulator converting the IF signal to baseband. Reducing the number of K_a-band oscillators will have a positive impact on the reliability of the system, as these devices have proved to be a source of unreliability with the three systems produced to date.

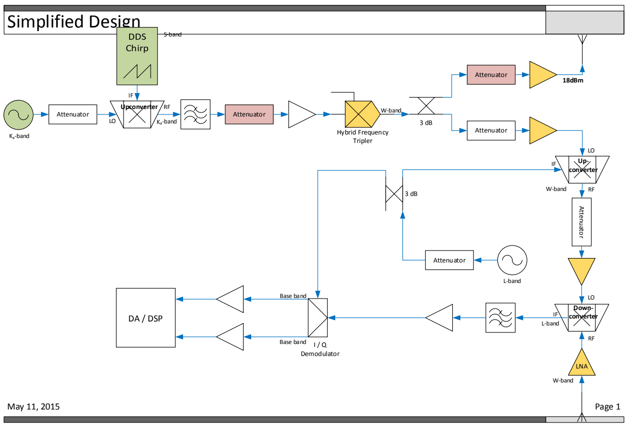

Figure 2: Example for a potential re-design of the RAL Radar Cloud Profiler RF frontend. Components marked yellow are based on in-house development or capabilities.

In-house capabilities (e.g. bonding, packaging, component design) and developments will be utilised for providing driver and power amplifiers at W-band. Furthermore, a hybrid (as opposed to purely active or passive) frequency tripler based on biased Schottky diodes [9] will be applied. Another component developed in-house that potentially could be utilised and allow further extending the fraction of the signal handled at K_a-band would be a 3rd harmonics mixer.

3. REALISATION

The re-design will be realised in three phases. The first phase will be setting up a breadboard demonstrator as displayed in Figure 3. This will omit the step introducing an IF, but will allow assessing the components intended for use in the final design under realistic conditions. It also will allow testing the data acquisition / digital signal processing system and demonstrating the Doppler capability. Results from this phase will be presented.

The second phase will be to set up the system according to Figure 2 on a breadboard taking into account the findings from Phase 1.

The third phase will be the assembly of the final re-design in a weatherproof housing. This will be assessed in routine operation at RAL and deployed for atmospheric research campaigns.

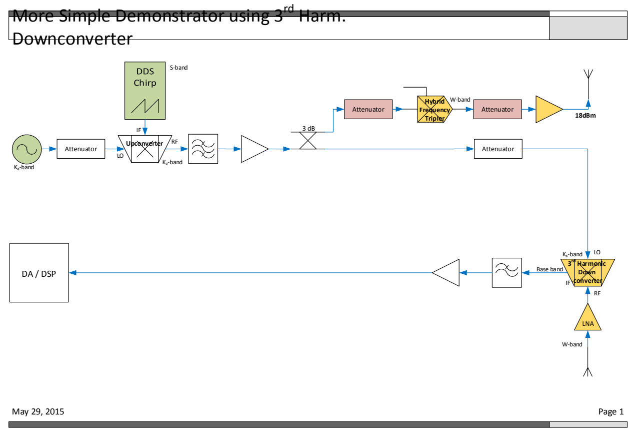

Figure 3: Breadboard demonstrator for the re-design of the RAL Radar Cloud Profiler RF frontend. Components marked yellow are based on in-house development or capabilities.

At this point in time, the assessment of further options is still a possibility. These could involve further system simplification, e.g. using the DDS chirp instead of an additional oscillator for generating the IF as detailed in Figure 2. Options also could arise from further in-house component development.

4. RESULTS

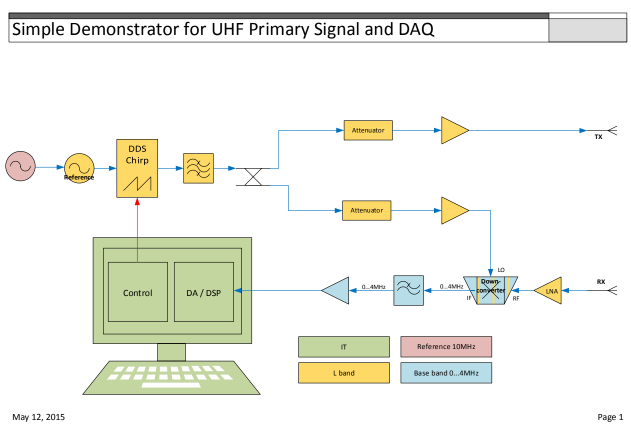

Figure 4: Simple demonstrator for primary signal generation in L band and for testing data acquisition system.

First activities in the project have focused on setting up a demonstrator for generating the primary signal. The concept for this is shown in Figure 4. The demonstrator also serves the purpose of testing the data acquisition (DA) system.

This demonstrator already utilises the Direct Digitisation Source (DDS) that is planned to be used in the RF design for the complete system. This is supplied with a fixed-frequency reference signal by a phase-locked coaxial resonator oscillator (PCRO), which in return is provided with a 10 MHz reference signal by an oven-controlled crystal oscillator (OCO).

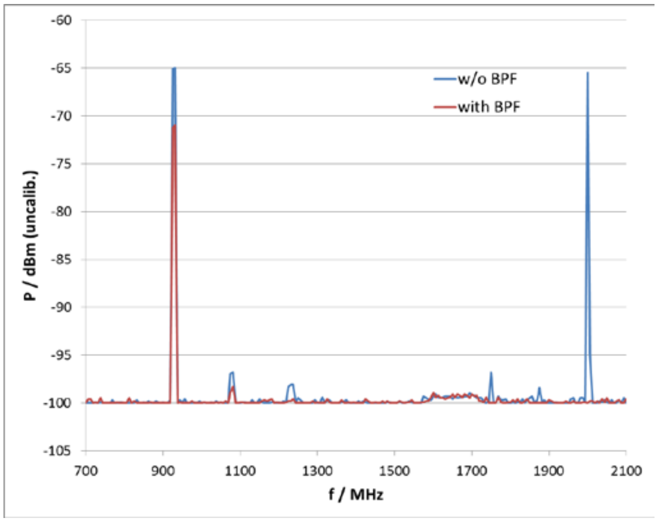

Figure 5: Output of the DDS for a 5 MHz chirp on top of a carrier frequency of 921.5 MHz. The blue line indicates the signal as generated from the DDS. The red line shows the signal after applying a band pass filter with a pass band of 145…1000 MHz.

The DA system applied in the demonstrator will most likely be upgraded for the future complete system. However, the basic signal processing and retrieval algorithms will remain the same. It also should be noted that signals arriving at the DA part of the future complete system will be in the same frequency range – base band 0…4 MHz.
The first step in setting up the demonstrator was to assess the DDS used for generating the primary signal at L band. An example for a 5 MHz chirp on top of a carrier frequency of 921.5 MHz can be found in Figure 5. The blue line in this figure indicates the signal as generated by the DDS. This shows a strong undesired signal at the reference frequency of the DDS (2000 MHz), and some other spurious signals. Applying a band pass filter with a pass band of 145…1000 MHz eliminated the signal at the reference frequency and got rid of most of the other spurious signals. This is indicated by the red line in Figure 5.

5. OUTLOOK

Following the finalisation of the demonstrator for generating the primary signal at L-band as shown in Figure **4**, the DA system will be set up and tested. This combination will be thoroughly assessed in the laboratory. There might also be the opportunity to test it with real atmospheric observations during rainfall.
These subsystems will be used further for setting up the simple demonstrator at W-band according to Figure 3. This demonstrator again will be thoroughly tested in the laboratory. Furthermore, the opportunity for testing it with real atmospheric observations during rainfall and fog periods might arise.
Eventually the re-designed W-band Doppler radar cloud profiler as shown in Figure 2 will be built. After thorough tests in the laboratory, this system shall be deployed for atmospheric observations at the Earth and Atmospheric Observations Group at RAL. It is anticipated that the system also will be employed for field campaigns and demonstrations in collaborations with universities, research institutes and national weather services.

6. REFERENCES

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