# Technologies in Support of Doppler Weather Radar

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## Abstract

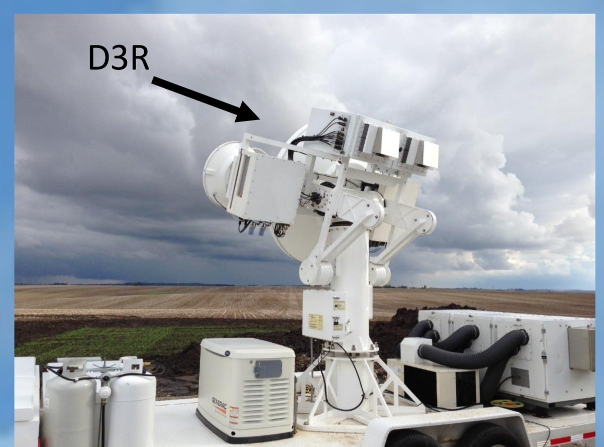
Two technologies, Resistance Temperature Detectors (RTDs) and Software Defined Radio (SDR) are both important upgrades to current Doppler weather radar systems. First, RTDs are used to measure temperatures of specific locations inside ground based radar. Alongside radar hardware, these temperature sensors can provide vital information concerning the temperature of on board electronics. The data collected can ensure the proper functionality of on board computers. Second, SDR is a software replacement for hardware based signal processing in ground based radar. By replacing old computer hardware with newer and more functional replacements, signal processing can be accomplished more quickly and be more operative.

## Background

- The dual-frequency, dual-polarized, Doppler radar (D3R) is a ground-based system developed in support of the ground validation (GV) activities within the Global Precipitation Measurement (GPM) mission. [1]
- The D3R is a Doppler weather radar used for precipitation measurements. This technology can find qualities of precipitation related data such as raindrop size or shape.
- The D3R is a paradigm of ground based systems considering its status as the validation radar of the GPM core satellite.

GPM Core Satellite

https://upload.wikimedia.org/wikipedia/commons/4/4e/Visualization_of_the_GPM_Core_Observatory_and_Partner_Satellites.jpg




## Experiments

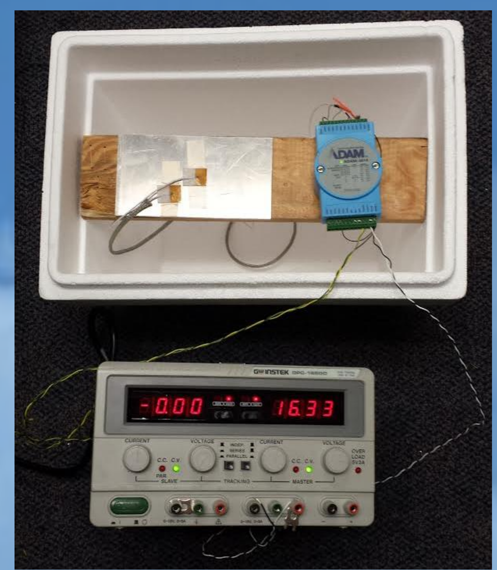
Two technologies that support the functionality and continued operation of Doppler weather radar were analyzed and configured through two experiments:

1) Resistance Temperature Detectors (RTDs) were configured and tested to sample data over moderate period of time.
2) Software Defined Radio (SDR) was utilized to create an FMCW radar to test its functionality and to prepare it for installation in a Doppler weather radar.

These experiments are intended to provide more accurate data from, and more functionality of the use of the radar.

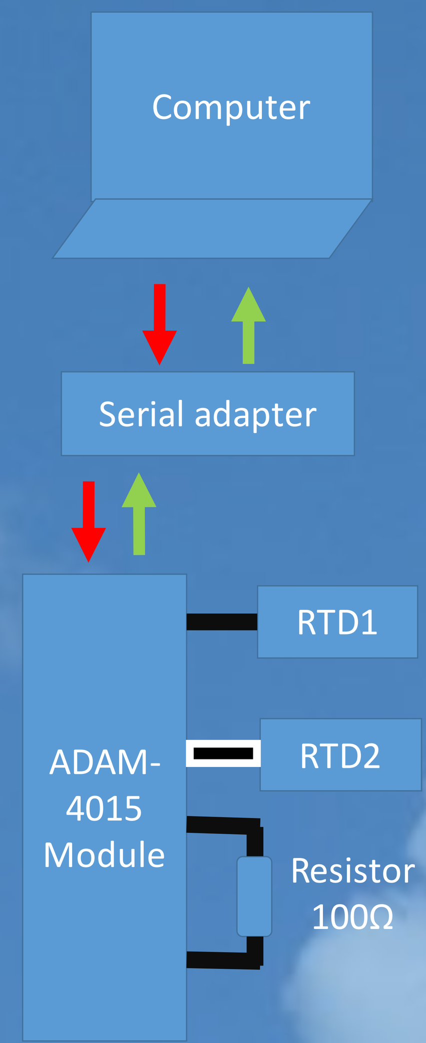
## Resistance Temperature Detectors (RTDs)

- Resistance Temperature Detectors (RTDs) are passive electric components that change their resistance when varying temperatures are applied.
- The RTDs used in this setup were made from platinum due to the material's linear resistance-temperature relationship, large temperature range (-272°C to 961°C) and measurement accuracy.



- The RTDs in our experimental setup (shown left) are connected to a sheet of aluminum suspended inside an insulated environment to equalize and stabilize temperature.

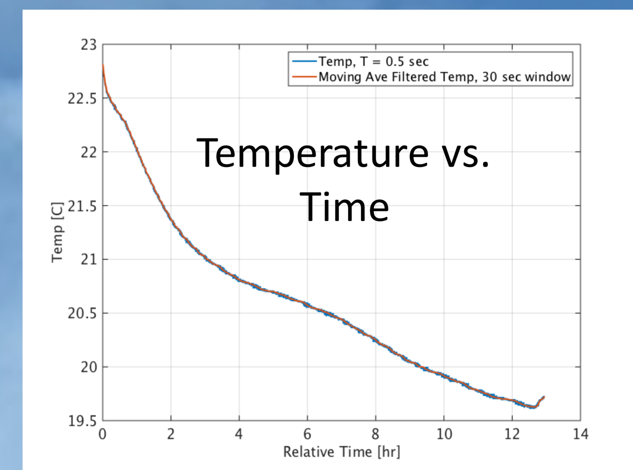
## Experimental Setup

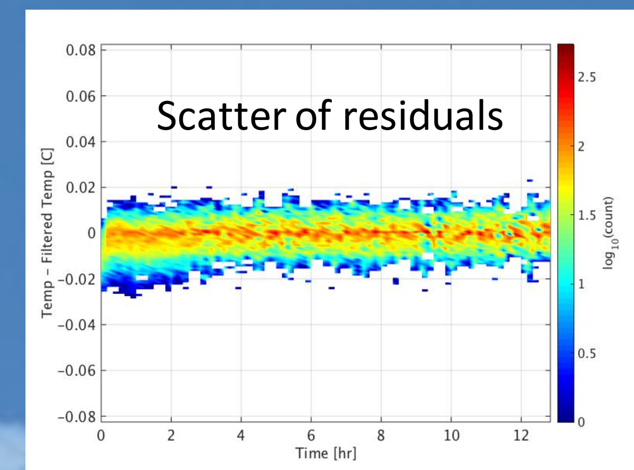



1) First, the computer sends a signal to the serial adapter requesting the temperature using an ASCII and hexadecimal message.
2) The serial adapter converts the message into an analog signal.
3) The ADAM Module reads the temperature of two RTD (one has insulating braiding to reduce noise) and resistor to measure noise and sends the data back as an analog signal.
4) The adapter converts signal to a string of ASCII characters.
5) A program on the computer accepts, parses and writes the data to a file.

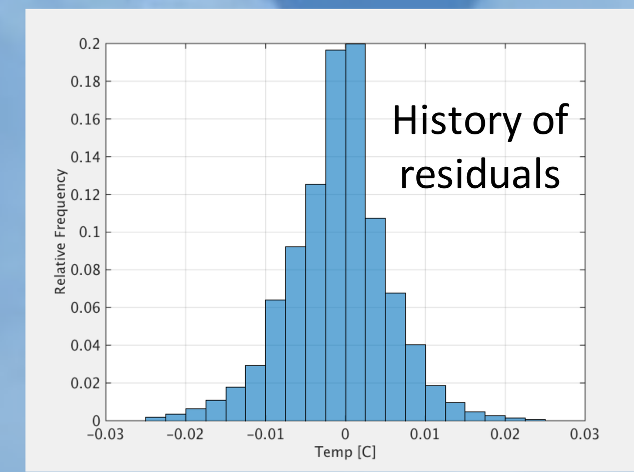
## Data Collected

- A python script, transcribed all the data to a file. The data was then imported to MATLAB and several graphs were created.




- By looking at the scatter of residual temperatures, we were able to conclude that high end RTDs alongside ADAM modules sample temperatures at up to 0.1 degree C° precision.
- The history of residuals confirms that the frequency of temperatures that fall 0.1 degree away from the average are quite low.

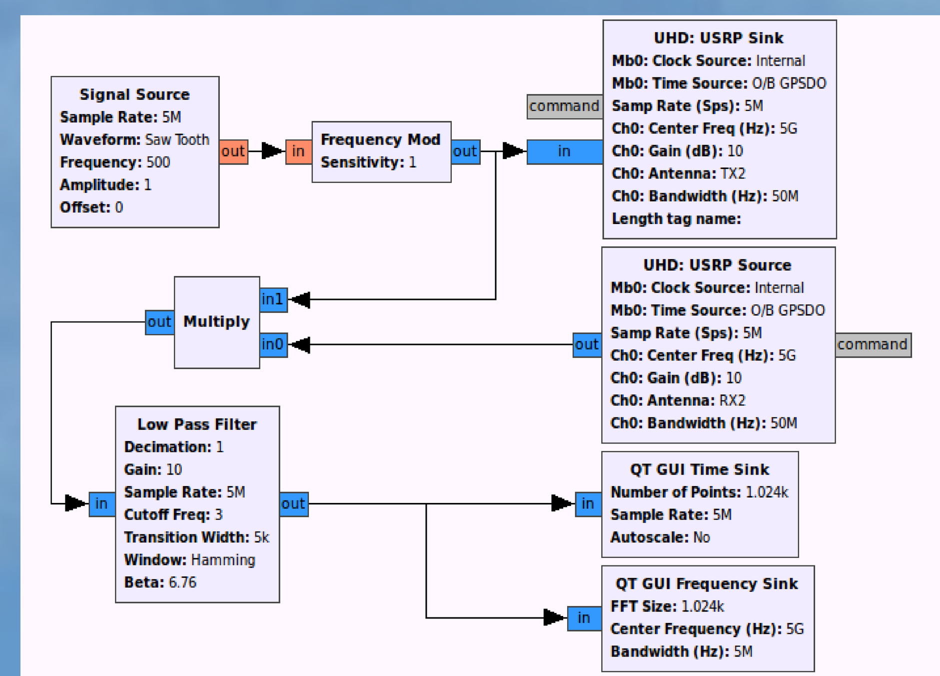



## Software Defined Radio (SDR)

- In radar systems, signals are processed directly with hardware that can mix, filter, modulate, etc. a provided input.
- In order to provide flexibility in signal processing, Software Defined Radio (SDR) can be used as a replacement for some of these hardware components. SDR is a system that allows hardware in radio communication systems to be replaced with software-based substitutes.
- The Ettus E310 was the software defined radio used in this experiment. It has a frequency coverage of 70 MHz to 6 GHz and a 56 MHz bandwidth.
- The E310 features a built in Xilinx Zynq 7020 Processor removing the necessity for an on board computer system.

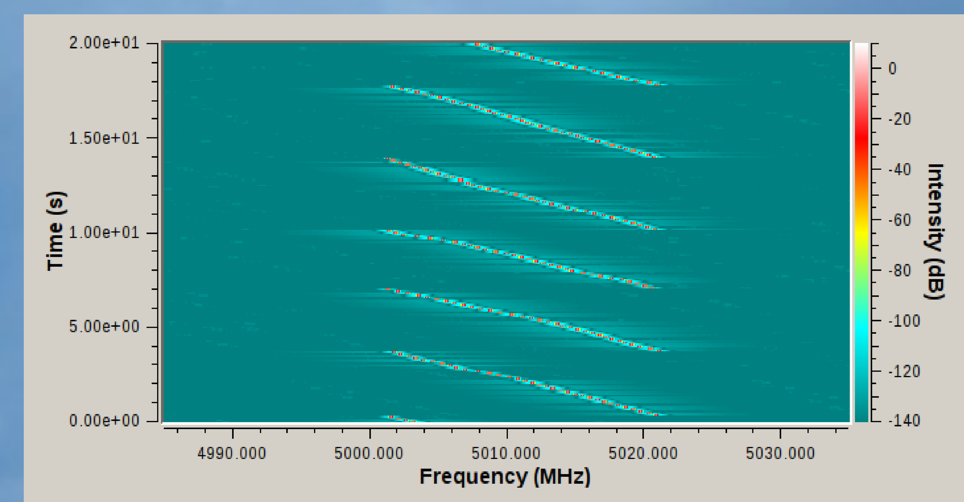
## Signal Block Diagram

- A software flowchart produced with GNU Radio allows any configuration of signal processing blocks to be arranged in order to encode, filter, mix, etc. a signal.




## Data Collected

- To demo the functionality of GNU Radio and the E310, a proof of concept FMCW radar was created.
- In conjunction with the flow graph to the left, the E310 emits a chirp signal, such as the one below.




- After the signal leaves the E310, reflects off any surface, and returns through a horn, the signal can be processed.

## Conclusion

Both the Resistance Temperature Detectors and the Software Defined Radio both prove to be viable additions to Doppler weather radar. These technologies will hopefully enable future lower-cost radar designs to further our understanding of Earth's weather systems, a collective goal shared by each member NASA's Earth Science Division.

## Acknowledgments

I would like to thank my mentor, Manuel Vega, for all of his guidance on this project, and for providing me with all the necessary tools and resources to accomplish my goals. Thank you also to Manohar Deshpande and Jeff Piepmeier for improving my understanding of signal processing.

[1] Manuel A. Vega et. al., "Salient features of the dual-frequency, dual-polarized, Doppler radar for remote sensing of precipitation," in Radio Science, vol. 49, iss. 11, November 2014, pp. 1087-1105.