DEVELOPMENT OF AN OFF-THE-GRID X-BAND RADAR FOR WEATHER APPLICATIONS

Gianni A. Pablos-Vega[1], José G. Colom-Ustáriz[1], Sandra Cruz-Pol[1], Jorge M. Trabal[2] and V. Chandrasekar[3], Jim George[3], Francesc Junyent[3]
University of Puerto Rico Mayagüez[1], University of Massachusetts Amherst[2], Colorado State University[3]

1. INTRODUCTION

One of the main goals of the NSF Engineering Research Center, Collaborative Adaptive Sensing of the Atmosphere (CASA), is to develop state of the art technology to obtain better weather information of the lower atmosphere [1]. Students from CASA are compromised to establish a precipitation monitoring (PM) and mapping sensing network at western Puerto Rico based on a social, climatological and physical vulnerability assessment. The Student Test Bed (STB) radar network is a systems engineering test bed completely designed and managed by students ranging from undergraduate to PhD levels from a variety of scientific and engineering fields of the CASA partner campuses. The CASA Puerto Rico Student Led Test Bed (STB) will serve to introduce students to system level engineering, develop the foundation for a test bed in Puerto Rico while advancing CASA's strategic planning and goals in developing low infrastructure radar networks.

Meteorological radars have been of great aid in order to gain knowledge of weather events and predict how these could affect people and property, thus proper warnings can be issued to the community. Most weather radars used today to provide forecasting are highly cost systems, thus a low cost radar is considered an attractive alternative to achieve a similar goal. One practical solution is to modify a commercially available marine radar for atmospheric applications. Marine radars are smaller, more compact, and lower in cost than most commercially available weather radars. They also operate in the microwave region, in which water absorption bands reside. In addition, these radars consume less power than most current radars, which gives us the advantage to develop a photovoltaic system so that the radar will no longer need to be connected to the power grid.

Due to the Earth's curvature, complex topography, and the range capability of radars, sampling the atmosphere can be challenging at some particular regions, and easy to move radars are desired for these cases. Deployable sit-and-spin radars have been considered, due to their ease of transport and assembly. Due to the small size of these radars and the frequency band of operation, rainfall attenuation at long ranges is significant [2], and short ranges of less than 15 km were considered for this work. A commercially available marine radar operating at X-band was modified to be used as an Off-the-Grid (OTG) radar for rainfall mapping measurements. OTG radars are capable of operating completely independently of the existing prime-power and communication infrastructure [3]. The use of OTG radars will be helpful at locations where complex topography and lack of infrastructure make the measurements with typical meteorological radars difficult. This radar is low-cost when compared to other meteorological radars, and operate with a photovoltaic system designed for a suitable operation time. Several of these radars can be arranged in a network configuration to cover areas of interests, such as small towns in valleys surrounded by mountains, or for example areas prone to flooding or landslides. Operation of this single radar node with minimum infrastructure requirements and no need for grid power and wired internet network is evidently suitable for remote sites. To complete the validation and testing, the UPRM-OTG radar prototype was deployed at the CSU-CHILL National Weather Radar Facility and data was collected to perform a cross calibration between both radar systems. Preliminary data has satisfactorily shown the capability of the UPRM-OTG sensor for rainfall mapping.

2. SYSTEM AND MODIFICATIONS

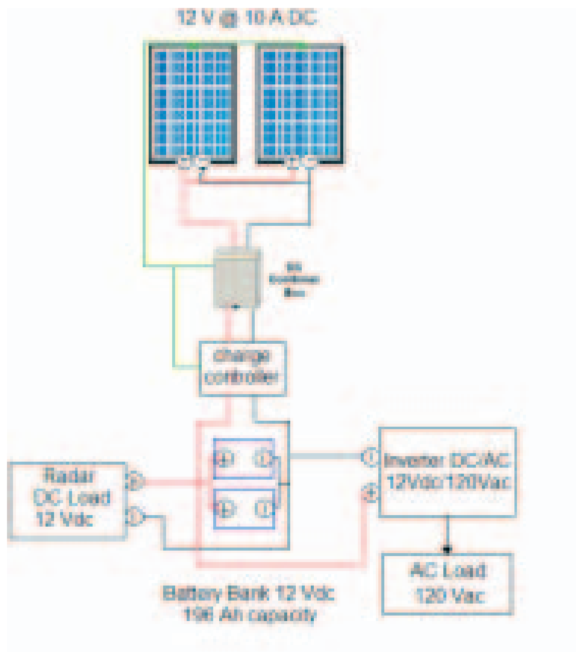

Figure 1. Diagram for the photovoltaic system powering the radar and peripherals

A marine radar made by Furuno (model 1934C-BB) was modified for OTG operation. This radar operates at X-band (9.41 GHz) and has a 4 kW peak power. The supplied antenna is of fan beam type and was changed for a parabolic dish reflector in order to mitigate the clutter problem. This new parabolic dish has a 3.8˚ beam width, a 32.4dB gain and has a tilting mechanism to vary the elevation angle. The antenna rotates at 26 rpm but the data is averaged every ten scans and outputted every three minutes. A digitizer is used in order to acquire the heading pulse, bearing pulse, trigger pulse and video signal, which are then processed and organized in order to obtain the reflectivity measurements in dBZ and create the PPI plot.

The radar was outfitted with the photovoltaic system shown in Figure 1. It was designed for a full charge capacity stand-alone operation of eight hours which is enough to measure most rainfall events. It consists of two 12V gel batteries rated 97.6Ah, 2 solar panels of 12 volts which can deliver up to 85W, all controlled by a charge controller. A sine inverter is also used to feed the computer of the radar, which operates on a windows XP platform. The computer has an INTEL Atom motherboard, which is of low power consumption compared to other motherboards available. The photovoltaic system can be easily re-configured to increase the power requirements of the radar.

3. CALIBRATION

A characterization curve was obtained in order to have a relationship between the digitizer raw data and the power measurements obtained from the data. This led to having 4 coefficients, namely *a*, *b*, *c* & *d*, which yield the relation for the raw counts and the received power. Radars can sense and give information of the atmosphere, but in order to have precise quantitative and qualitative data for better Quantitative Precipitation Estimation (QPE), the radar must be calibrated [4]. There are various ways to calibrate a radar. Some of the ways to calibrate such an instrument would consist in using a corner reflector or a metallic sphere [5] [6] due to their high radar cross section which causes that a transmitted wave reflects itself from the object used almost entirely. These methods were developed mainly because of the natural need to have reliable data as stated in [7], that in order to provide better rainfall estimation, calibration has to be performed.

Various researchers have already shown their performance of their radars after calibration [8] [9]. As shown in [10], a way to have a precise calibration for a radar is to perform a cross calibration where the capabilities of a radar can be compared to another well calibrated radar and perform the adjustments accordingly. This method leads also to have more precise validation of rainfall events measured with the radar since there will be comparison of the events with a well calibrated radar. To perform such type of calibration, a reliable calibrated radar has to be used, such as the CSU-CHILL National Weather Radar, which is calibrated with pin-point accuracy [11]. The CSU-CHILL system was available for this work and a calibration was performed at the CSU-CHILL National Weather Radar Facility (Figure 2). Results from various rainfall events will be presented and compared to CSU CHILL radar data.

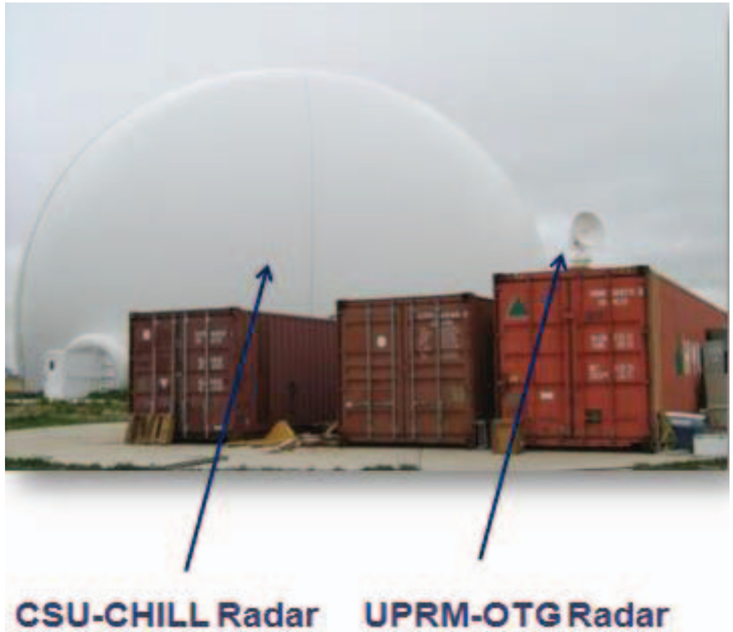

Figure 2. OTG radar evaluation setup at CSU-CHILL

4. BIBLIOGRAPHY

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