SQ-DPX

Dual Polarimetric Doppler Radar System

Measure, Analyze & Predict

Operating Manual

Model SQ-100

Revision Information

Revision	Date	Modification
0.1	3/15/2020	KS - Initial version
0.2	4/17/2020	CG – added install and site instructions
0.3	5/7/2020	CG – BACL recommendation
0.4	5/16/2020	CG – BACL RF Emission includes
0.5	5/22/2020	CG – BACL RF Emission updates
0.6	6/2/2020	CG – BACL RF Emission updates controlled only
0.7	6/4/2020	CG – change to preset pulse width and PRF per radar

Table of Contents

General Safety Considerations

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

—Reorient or relocate the receiving antenna.
—Increase the separation between the equipment and receiver.
—Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
—Consult the dealer or an experienced radio/TV technician for help.

The FCC requires the user to be notified that any changes or modifications made to this device that are not expressly approved by StormQuant may void the user’s authority to operate the equipment.

This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment. End users must follow the specific operating instructions for satisfying RF exposure compliance. This transmitter must be at least 1.21 meters from occupational/controlled exposure user and must not be co-located or operating in conjunction with any other antenna or transmitter.

The information in this guide may change without notice. StormQuant assumes no responsibility for any errors that may appear in this guide.

CAUTION	
!	**Do not put liquid-filled containers on the top of the equipment.** Fire or electrical shock can occur if a liquid spills into the equipment.
!	**Establish space in the surroundings of apparatus as much as possible.** It becomes a cause of performance degradation and failure.
⃠	**Do not put any strong impact to LCD because of glass.** Serious injury may cause by broken glass.

SAFETY INSTRUCTIONS

The user and installer must read the appropriate safety instructions before attempting to install or operate the equipment.

DANGER	Indicates a hazardous situation which, if not avoided, will result in death or serious injury.
WARNING	Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
CAUTION	Indicates a potentially hazardous situation which, if not avoided, can result in minor or moderate injury.

Introduction

For over 30 years, the existing US radar network has been successfully deployed as the primary source of data for weather aggregators and meteorologists.

However, there are some drawbacks such as environmental impact, excessive maintenance costs, data latency, and lower altitude limitations. Inaccurate forecasting and the frequency and intensity of catastrophic weather-related events are driving the need for a new, innovative approach to radar.

Our proprietary radar technology improves the speed and accuracy of live weather coverage to help save lives and provide weather information to those who need it.

Data is collected by our StormQuant™ polarimetric Doppler IoT radar sensors that can be deployed as an overlapping nationwide mesh network. The compact, lightweight design only requires standard 110v power and can be installed on existing cellular towers or rooftops.

Outline of System

This system observes the development of rain clouds, outputs the strength of precipitation, the speed of rain clouds (Doppler speed), and observes phenomena of rainfall.

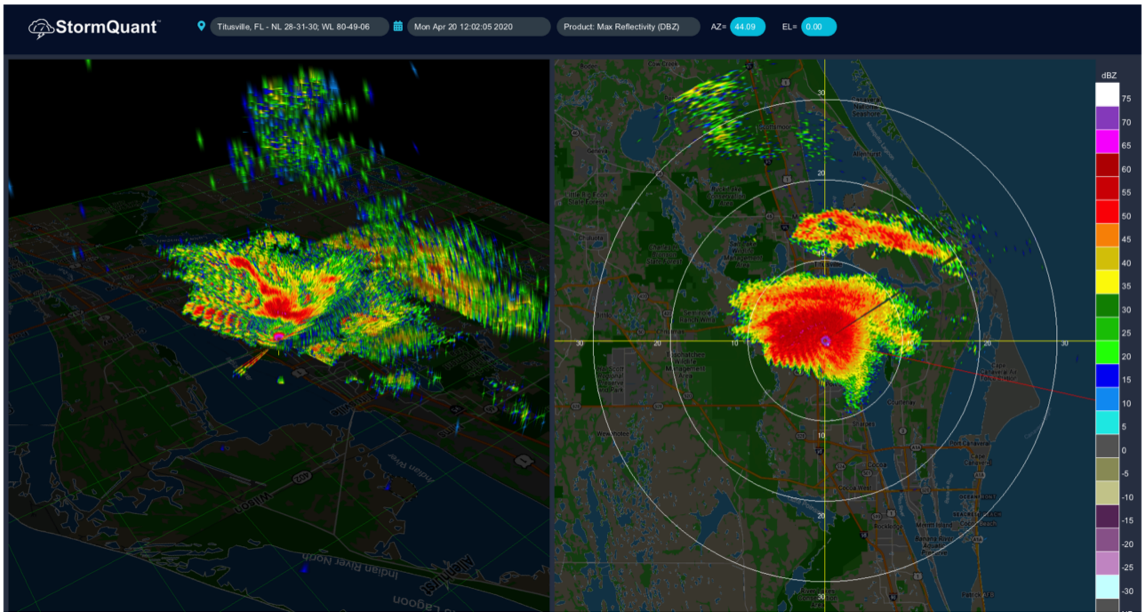

Figure 1 StormQuant Reflectivity Dashboard

Figure 2 StormQuant Radar

StormQuant Radar Design

The StormQuant radar system is a pulse radar that works in the X-Band frequency between 9300 and 9500 MHz with a transmitter output of 100 watts. The antenna is an inverted periscope design with 32 dBi gain and is capable of elevation and azimuth movement. The system is dual polarimetric and is intended to map meteorological phenomenon within 35 Km. It is connected via ethernet and Internet to a server that is used for meteorological product generation. The major components are as follows (figure 3 and 4):

Radome
Antenna
Transmitter
Receiver
Data Acquisition System
Computer
Power Supplies

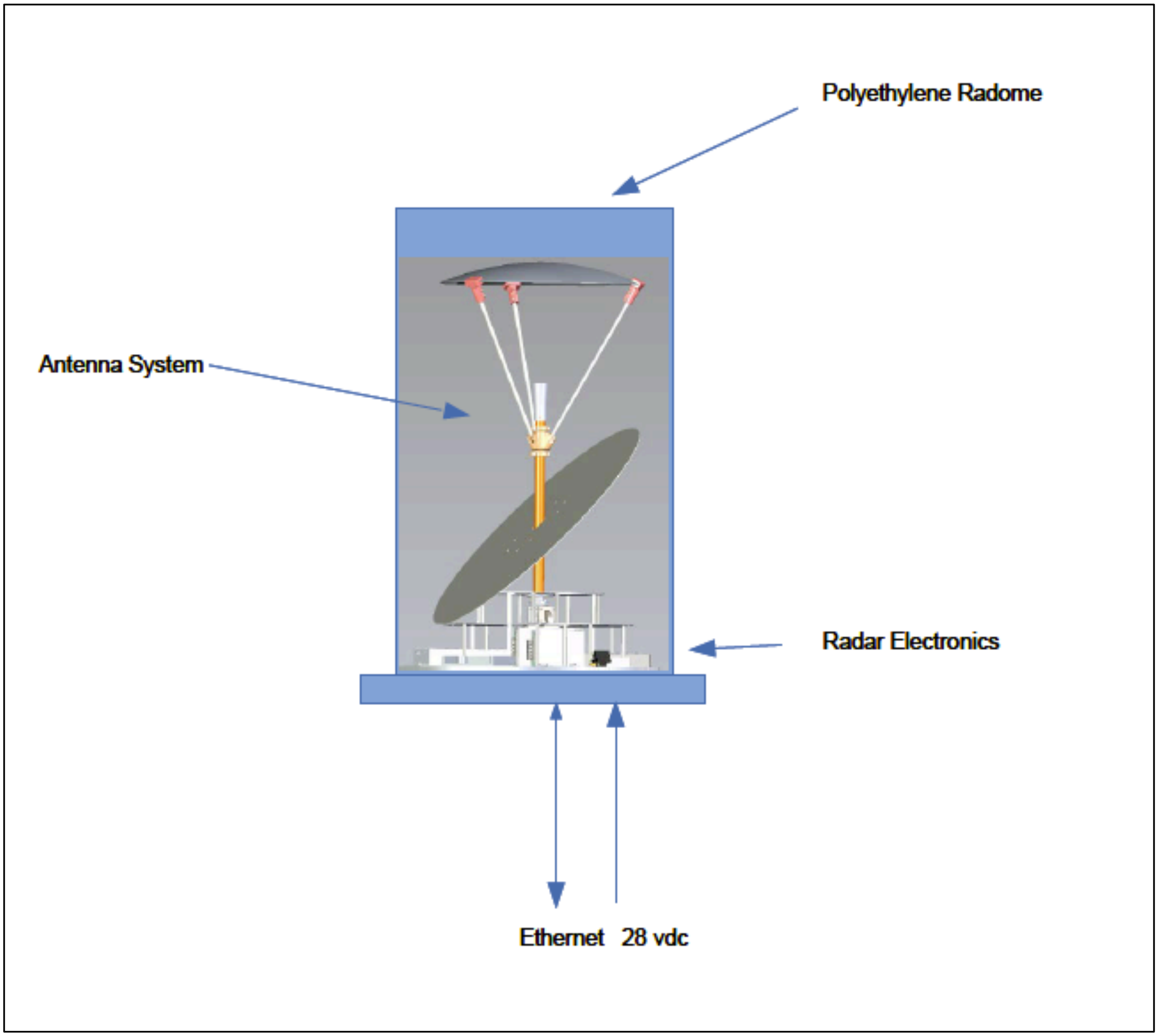

Figure 3 StormQuant Radar Major Components and Connections

Radome:
The covering over the radar, or radome, is composed of a uv resistant, tough plastic polymer that will protect the radar for many years.

The purpose is to allow radar waves to exit and return to the antenna as well as protect all of the internal electronics from the weather.

Antenna:

The antenna is within the radome and consists of a 50 cm dish suspended above a splash plate. The splash plate moves to place the antenna beam anywhere in 360 degrees of azimuth and 0 to 45 degrees of elevation. This configuration allows for much quicker beam positioning as well as much higher reliability as compared to conventional altitude/azimuth mounts. In addition, the efficiency of this type of configuration is higher than conventional systems, leading to better sensitivity of weather phenomena.

The antenna is designed for dual polarization operation which allows for particle identification. The antenna is also designed for low sidelobes and very high front-to-back ratios which reduce interference.

Transmitter:

The transmitter is a two staged device that is bias controlled during operation. The output is 100 watts and is split evenly between two output channels connected to the antenna. The duty cycle is less than 3%.

The transmitter is designed with high efficiency, state of the art components and produces 100 watts of peak power. The average power depends on the pulse width and pulse repetition frequency which is preset to around 0.4% or 0.4 Watts.

The design minimizes out of band spurious outputs and complies with all FCC requirements. This system has been tested and certified by an FCC approved laboratory.

Receiver:

There are two receivers that sample the outputs of two circulators. The receiver outputs are fed to 16-bit ADCs and then to computers fordata transfer.

The receiver is a single conversion, high gain, low noise design which optimizes the detection of return signals and sends them to the data acquisition system which performs several math functions before outputting the data for display.

The receiver is actually two identical receivers, one for each channel that is eventually characterized as vertical and horizontal polarizations. These channels are matched and calibrated before they send their data to the data acquisition system.

Data Acquisition:

Two 16-bit ADC run at 25 MSPS and feed a FPGA in two streams. These streams represent two orthogonal polarizations that are used to generate all of the downstream products. Initial computations are accomplished in the gate array and processor and then packaged for transmission to the host computer. Calibration, data reduction, initial product generation and encryption is accomplished in each radar.

In addition, the data acquisition system samples local weather (temperature, humidity and ambient air pressure) as well as GPS data for use in timing and positional information. All these data are sent to the host computer.

The FPGA accomplishes polarization discrimination and initial reflectivity measurements in addition to initial Doppler calculation.

Computer:

A multi-core NVIDIA GPU is used for data transfer, encryption and manipulation of the two polarimetric streams. Data is sent from this computer via Ethernet and Internet to a host server. Products are generated within this server and made available to users via a client application.

Power Supplies

There are two commercial grade power supplies contained within the radar enclosure. Both are rated at operations from -30C to +50C temperature range. Each has self-test features and significant voltage and amperage protections to guarantee long life and dependability. Input filters on all outside power as well as Ethernet are included in the radar enclosure. System voltages are continuously monitored.

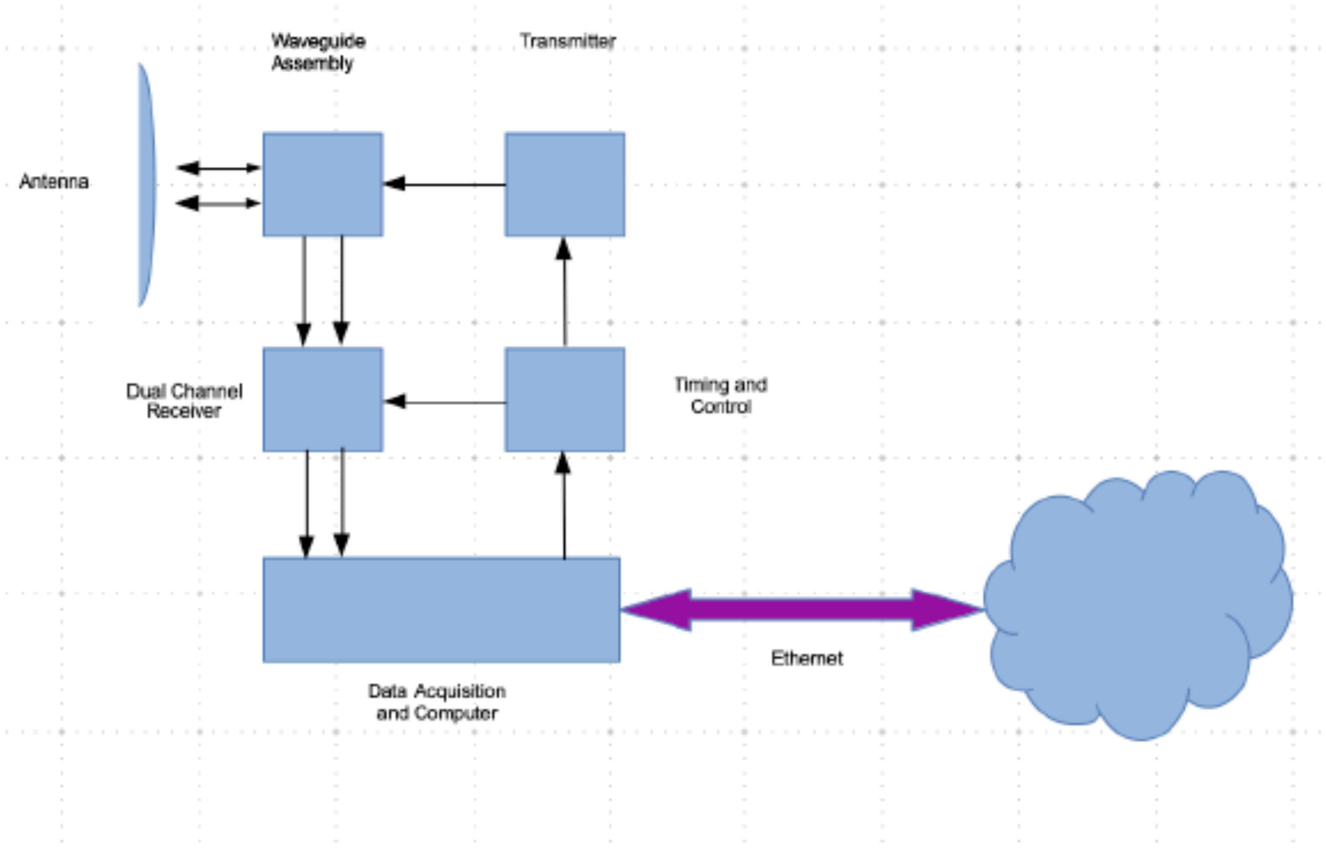

Figure 4 Major Electrical Components

Installation

STORMQUANT SITE SURVEY CHECKLIST

The following items are considered by StormQuant representative during the conduct of a site survey.

1. Locate the radar. Best radar location if multiple candidate sites are available
   Latitude ___ Longitude ___
   Point of Reference if Lat/Long not available ___________________
   a. Choose highest site possible.
      Altitude _____
   b. Stay clear of man-made structures (buildings and power lines) and local terrain (mountains, hills, trees) that may screen the radar signals.

Obstruction	Distance	Azimuth

   c. Frequency Interference Sources

Source	Type of Emission	Distance/Azimuth

   d. Place on tall building.
      - Make sure you are in clear area.
      - Place close to middle of roof if possible (the edges act as a shield against Interference, etc.).
      - Do not place radar near other antennas.
      - Suitable platform or tower for placement.
        Platform/Tower Height: ____
      - Existing lightning arrestment system (LARS) for lightning suppression.

- Any special equipment required for installation (crane, lifts, etc.): ____
- Required Building permits/codes:
  ____
  ____

e. Place on tall tower.
   - Determine tower height to clear obstruction _____.
   - Place far away from trees, building and other obstructions.
   - Determine if ground foundation is suitable
   - Place guy wires for stability if required.
   - Any special equipment required for installation (crane, lifts, etc.): ____
   - Existing lightning arrestment system (LARS) for lightning suppression.
   - Required Building permits/codes:
     ____
     ____

f. Special environment concerns (extreme temperatures, high wind and lightning area):
   ____

g. Site Access limitations (location, security, etc.)
   ____
   ____
   ____

h. Coordinate location with existing StormQuant radar coverage.

2. Power availability – 110 VAC required
   a. Power Source: __________________
   b. Peak Output Capacity (KVA): ____________
   c. Uninterruptable Power Supply: ______________
   d. Emergency Generator (must match site requirements):
   ____

3. Network availability (for retrieving radar data and remote administration access).
   a. Ethernet: Wired ___ Wi-Fi ___
   b. Designated IP Address: __________________
   c. Expected data rate upload : ____ Mb/s
   d. Network provider: ___________________

e. Security requirement for radar accessibility through host network: ____

4. Determine radiation hazard zone in accordance with FCC OET Bulletin 65.

   a. The total number of emitters
   b. The specific RF Exposure Limits for the Radar (check Equipment authorization file for copy of RF exposure calculation.

Installation Quick Start

After radar is placed on a suitable tower do the following:

1) Connect AC power
2) Connect Ethernet
3) Turn on power switch. Wait a few minutes for computers to boot and initiate communications.
4) Connect to the radar
   a) If connected directly via monitor/keyboard to the radar expect to login directly
      login: sq
      password: *******
   b) If connecting to the radar remotely (across an ethernet connection using a laptop) in a terminal.
      $ ssh sq@<sq-radar-ip-address>
5) Reloading XDMA driver
   a) Unload the driver
      $ sudo rmmod xdma
   b) Load the driver
      $ sudo modprobe xdma
6) Change directories to the pdrs build directory
   $ cd ~/sq/stormquant-beta/cmake-build/pdrs/
7) Reset the radar to ensure the radar is clear and initialized
   $ sudo ./pdrs -r
8) Starting the radar
   The software comes with a script to turn the radar on. This *radaron* script contains the preset pdrs parameters (4 uSec pulse width and 1000 Hz PRF)).

   $ sudo ./radaron

9) Radar is currently operating

10) Shutting down the radar
   a) Stop the running pdrs program (if it's running)
      Note: ctrl-c is the control and c keys pressed simultaneously.
      $ ctrl-c
   b) Turn off radar
      // Turn off the transmitter by reinitializing/resetting the FPGA configuration:

$ sudo ./radaroff

c) Sync the file system

   $ sync

d) Shutdown the operating system

   $ shutdown now

Software and File Structure

Software and Firmware are written in advanced languages and include error detection and mitigation. In general, there are 3 general modules of software:

Motion Control
Data Acquisition
Operational Control

<u>Motion Control</u>

This module allows for the operation of the antenna position and scanning capabilities. There are several primary scan patterns which can be controlled by this module

PPI – Plan Position Indicator

This scan type produces volumetric data and typically runs from 0 to 45 degrees in elevation and 0 to 359 degrees in azimuth. Normally azimuth is set to 60 second rotation while elevation is incremented by 2 degrees. Speed, max elevation and elevation increment are all programmable.

Scan – Preset elevation

This can allow the operator to set a particular elevation angle and scan in azimuth only. This is useful when solar calibrations are conducted.

RHI – Radar Height Indicator

This is a rectangular equivalent to a PPI scan which is polar. RHI scans can be set to range or cloud height for optimal presentation of weather targets

CAPPI- Constant altitude PPI

This scan pattern is actually a re-ordering of data from a standard volumetric PPI scan. This is very useful when analysis of cloud heights and altitude profiles are required

Data Acquisition

The data acquisition system controls not only the reception of radar data from the receiver but also the generation of pulses to the transmitter.

Transmitter control is preset to the following:

Pulse width – 4 uSec
Pulse repetition frequency – 1000 Hz

There is a preset number of conversions accomplished by the ADC system within this module. Each of two channels pulls in 16-bit conversions and passes them to the FPGA for processing.

Significant filtering is accomplished within this module to reduce the noise level of the radar system to a minimum. This allow for a significant increase in sensitivity.

Data from this module is sent to the host computer for further processing and product generation

These products include:

Reflectivity
Storm intensity is displayed in a standard dBz color palette for PPI, Scan and RHI displays

Velocity
Storm velocities are displayed in a standard m/s display. The presence of tornadic activity as well as high levels of turbulence can be detected here.

Particle Identification

This product includes a color-coded display showing ice, snow, rain, hail, sleet, graupel and several other particle types. The display colors are labeled accordingly.