REMOTE OPERATION OF THE YSCAT SCATTEROMETER

Ryan Reed, David G. Long, David V. Arnold

ABSTRACT

A scatterometer is a radar system designed to make precise measurements of the magnitude of the radar echo scattered from surface. If the measurement is made over the ocean's surface, the surface wind speed and direction can be inferred. In order to better understand the relationship between the radar return and the ocean winds we have developed a unique ultra-wide band research scatterometer known as Yscat.

The Yscat radar system is computer controlled, with a separate computer collecting environmental data. During a typical deployment, such as a recently completed 7 month deployment on Lake Ontario, the radar system is required to operate unmanned for weeks at a time, collecting data at a rate of up to 2 GB per week. Controlling such a complex system, and handling such large amounts of data presents a challenging remote operation problem.

We used a novel combination of personal computers, telephone controlled switches, modems, and off the shelf software packages to enable us to perform daily monitoring, trouble shooting, and data transfer via a simple telephone connection. Data was stored on 4 mm DAT tapes for weekly pickup by a technician.

This paper describes the Yscat system and our approach to control, monitoring, and data storage. While our approach is relatively "low tech", it has been very cost effective. This type of approach may be of interest to other designers of unique instrumentation at remote sites.

KEYWORDS

Scatterometer, Remote Operation, Radar

1. INTRODUCTION

A scatterometer is a radar system designed to make precise measurements of the magnitude of the radar echo that is returned to the scatterometer after being scattered from the surface. Using this measurement, the surface can be characterized according to its normalized radar cross section σ°. If the measurement is made over the ocean's surface, the surface wind speed and direction can be inferred. However, correctly interpreting scatterometer measurements requires a detailed understanding of the complex relationship between the wind and σ°.

In order to study this relationship we have developed a highly specialized research radar called the Yscat radar system. This system is designed for long term deployments in the hostile environment of a remote unmanned platform such as the Canadian Centre for Inland Waters research platform located near the south end of Lake Ontario where we recently completed a 7 month deployment. The nature of the deployment site, including the expense and time involved in making service trips, required a rugged, dependable, yet flexible method of controlling, monitoring, diagnosing problems, and enacting fixes from over a thousand miles away, presenting a serious remote operation problem.

2. EXPERIMENT AL SITE

The site for this experiment was a research tower operated by the Canadian Centre for Inland Waters (CCIW). The tower is located at the west end of Lake Ontario, approximately 1.1 km off shore (see Fig. 1). This site is a good location for experiments of this type because it experiences a wide range of environmental conditions during the year. Another advantage is that the response of the lake to the changing environmental conditions is well documented [1].

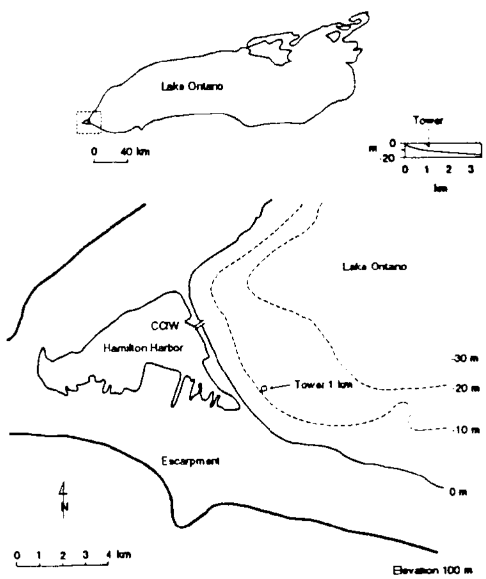

Figure 1: Location of Lake Ontario deployment site

The tower itself is designed to minimize the disruption of the surface airflow (see Fig. 2). It is a two level design with a catwalk located 4 m from the water surface and a large 100m^2 experiment deck located about 6 m from the mean lake surface. At the four corners of the tower are support legs which extend up to 10 m above the lake. In the center of the deck is a small equipment shack and a mast that extends up to 12 m above the surface. The tower is supplied with 120 V power and telephone hook-ups via under water cables which terminate at an on-shore trailer.

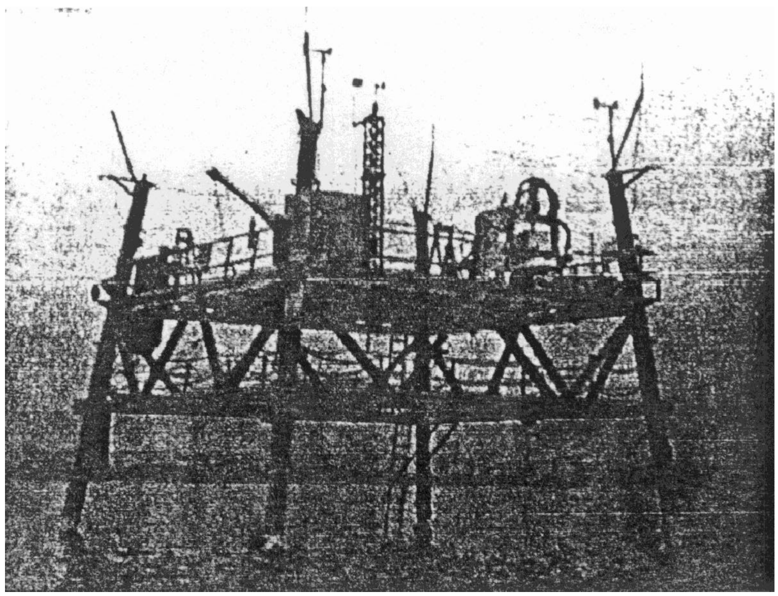

Figure 2: CCIW WAVES research platform. The Yscat scatterometer is the crane-like structure on the front of the platform.

3. EQUIPMENT

The primary instrument used during the experiment was the Yscat radar. Yscat was designed to be a tower mounted radar system which could operate in the hostile environment of a unmanned sea platform. In addition, in order to study the dependence of the radar cross section to various radar and environmental parameters, it was necessary to design the radar so it could continuously vary its operating parameters (frequency, polarization, azimuth, elevation, etc) over a long unmanned deployment. To achieve this goal, it was necessary to develop both a very agile radar system and a novel control system to operate it from over a thousand miles away at minimal cost.

The radar system consists of several subsystems under the control of a main controller. These subsystems include the RF, IF, calibration and pre-processing, and the positioning subsystems. The location of the various sub-systems and equipment is shown in Fig. 3 [2].

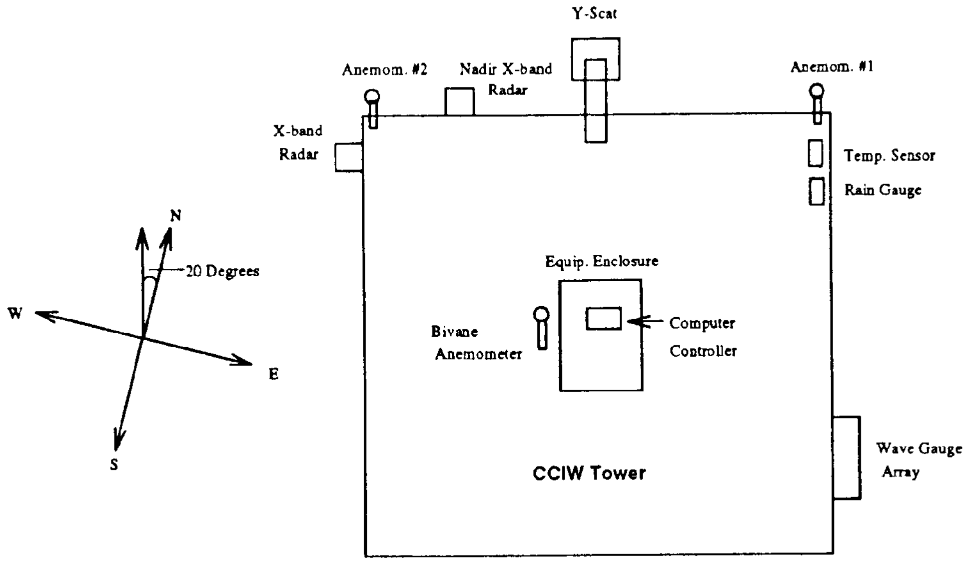

Figure 3: Layout of the various systems on the CCIW tower.

3.1 RF Subsystem

Yscat is an ultra-wide band radar with an operating frequency that can be varied continuously from 2 to 18 GHz. The heart of the RF sub-system is an HP-83590A microwave generator and a variable YIG filter (see Fig. 4). The generator is controlled via an HPIB link to an embedded controller. The generator can be rapidly switched to any frequency from 2-18 GHZ.

From the RF generator, the signal is split between the transmitter and the receiver using a 3 dB power splitter. The transmitter signal is amplified to 23 dBm and either routed through the antenna or through the internal calibration circuit. If the calibration circuit is selected, the signal is attenuated by 60 dB and then split evenly and coupled into the dual channel receiver using 10 dB directional couplers.

The transmit antenna is a custom designed 36" ellipsoidal figure reflector that provides a nearly constant 5 degree beam width over most of the operating bandwidth (from 2 - 18 GHz) of the radar system. The feed is a dual polarization, sinuous feed in order to minimize WSWR changes over the large frequency range. This special antenna design is crucial to making broad spectrum measurements of the same size surface patch.

The receive antenna is a conventional quad-ridge, dual-polarization rectangular horn with an aperture of 10 x 10 cm. This provides a broader pattern than the transmit antenna to help minimize the effects of pointing alignment errors.

The receiver is a dual pol system designed to maximize the system SNR. After each polarization is received and amplified using low noise amplifiers, both channels are mixed down to the IF in a single side band mixing operation (see Fig. 4).

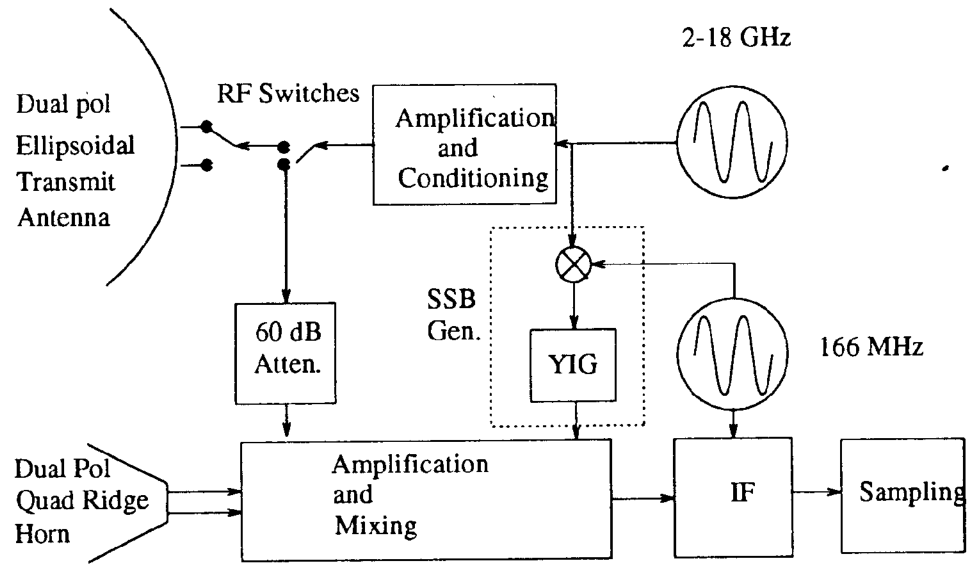

Figure 4: Y-scat block diagram.

The SSB LO is generated by mixing the RF carrier with the desired IF signal in a normal double sideband mix, and then filtering off one of the sidebands using a voltage controlled YIG filter. The YIG filter has a 30 MHZ 3 dB bandwidth that can be varied continuously from 2 to 18 GHz. This provides about 60 dB of carrier and sideband suppression over the entire operating range.

3.2 IF Subsystem

The IF sub-system is designed to operate at a constant frequency regardless of the operating mode of the RF sub-system. The IF signal source is an HP-86568B signal generator which can be remotely set. Under normal operation the IF is 166 MHZ (see Fig 5).

The horizontal and vertical signals are received from the RF system, split into I and Q signals, and mixed down to baseband. The baseband signal is high pass filtered at 1 Hz to eliminate antenna feed through and any returns from stationary targets, and then amplified from 0-60 dB using a programmable filter-amplifier. The signal is then digitized by the computer/controller. The entire SSB IF circuit is phase balanced and a sample and hold circuit is utilized to provide an image rejection of more than 40 dB across the baseband bandwidth of ±500 hz.

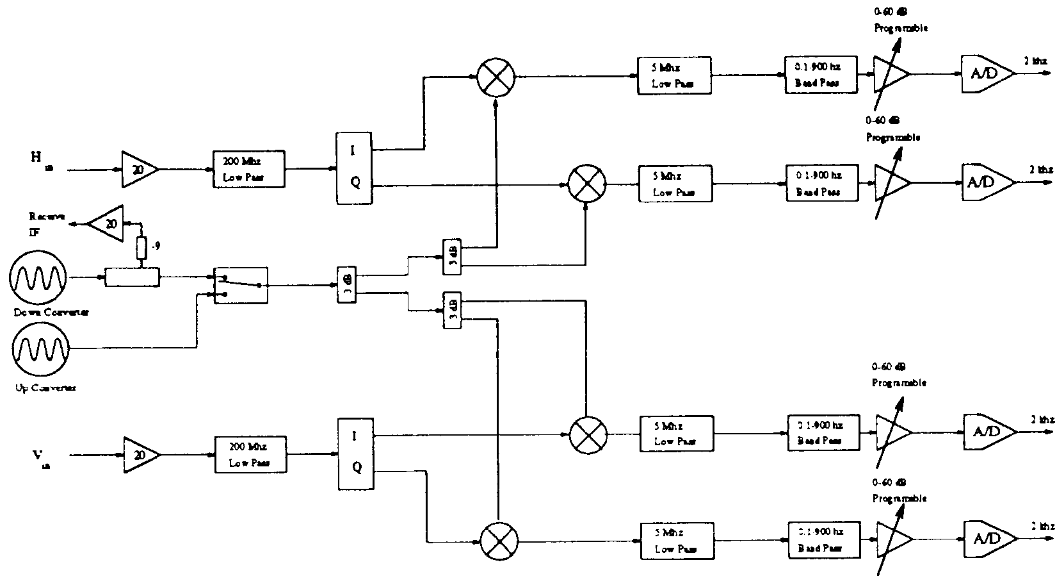

Figure 5: IF circuit block diagram.

3.3 Environmental System

Yscat is designed to support data intensive studies of ocean scattering and the air/sea interface in general. It includes a full complement of environmental sensors. The most crucial measurement for interpreting the radar data is the surface wind speed. This is assured by the use of two anemometers located at the two most northern corners of the tower. The system also measures air temperature, humidity, and water temperature. Thirty second averages of all these measurements are computed and transmitted to the main computer. In addition to these instruments, Yscat also monitors a bivane wind stress sensor and an eight wire wave gauge array. Data from these sensors was collected at 10 Hz and stored on separate data tapes.

3.4 Control

The remote control problem was challenging because the deployment site made it impractical to manually operate the radar and auxiliary systems, yet the experiment goal required the radar parameters (position, frequency, polarization, operating mode, etc.) to be constantly varied. The solution was to design the system around a 486 personal computer that performs preliminary data processing and coordinates the control signals sent to the RF, IF and sampling, positioning, and environmental sub-systems of the radar.

In order to minimize the duties of the main controller, the RF and positioning subsystems are controlled by their own computer controllers which handles the details of operation and reception of commands from the central controller. The main controller reads commands from pre-written batch files which contain commands to operate the radar system for several days at a time.

The RF sub-system embedded controller is a Kila V80 (IBM compatible) computer-on-a-board. The Kila controls the RF subsystem via a GPIB card and an A/D card. The GPIB card communicates commands to the HP signal generator. The A/D card allow the Kila to monitor system temperature and supply voltages, generates digital signals that control switches in the RF system, and synthesize analog signals for generating FM pulses and sweeping the center frequency on a YIG filter. The Kila receives commands from and transmits control information to the central controller via 9600 baud RS-232 connection to the main controller.

The positioning sub-system is controlled by two stepper motor controllers for the elevation and azimuth axes, respectively. These two controllers are pre-programmed by the central controller with anticipated control parameters and motions. The motor controllers then receive commands from the central controller via a 9600 baud RS-232 connection, which are executed according to the pre-programmed instructions. The movements of the radar are monitored by the central cont roller via two absolute encoders with a custom interface card. If the movements commanded by the motor controllers do not meet the tolerances set by the central controller, the motor controllers are commanded to correct the position.

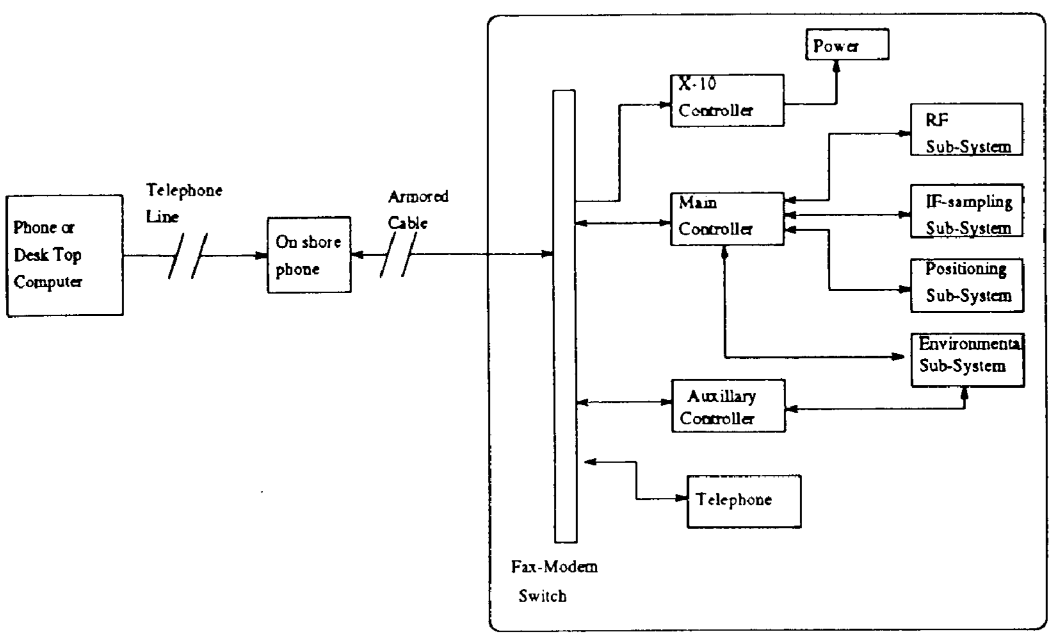

Figure 6: Signal flow diagram of Yscat radar control system.

In addition to commanding the RF and positioning sub-systems, the central controller is also tasked with controlling the IF and sampling sub-system. The IF sub-system consists of 2 HP signal generators, 2 programmable filters which handle 2 channels each, and a custom IF circuit which performs the single side-band mix down operation from the IF frequency (50 - 500 MHZ) to baseband. The control of these systems is primarily via GPIB interface and digital I/O from an A/D card. Since the parameters of these systems are not changed often, the load on the central controller is minimal.

Control of the environment monitoring sub-system is divided between two sub-controllers. A meteorological station consisting of two anemometers, an air temperature gauge, a humidity sensor, and a rain gauge are controlled with a Kila V80 computer-on-a-board. Data from each of the sensors is averaged for 30 seconds, coded with a time stamp, and transmitted to the main controller where it is stored in an 8 Kbyte buffer until the main controller is free to read the data and store it with the rest of the radar data.

The second portion of the environmental sub-system operates independently of the main controller and consists of a bivane wind stress sensor, an eight wire wave gauge array, a water temperature sensor, and two auxiliary radars. The data is recorded at approximately 30 Mbytes/day after compression and is stored on separate 4 mm dat tapes, which are changed weekly by technicians.

Since the radar system is so complex, periodic monitoring, reprogramming, and trouble shooting is required. Towards this end, the main controller is connected an on shore telephone line with an armored underwater cable. The total cable run is approximately 1.1 km. The main controller has a 9600 baud modem which serves as a line driver for the long tower to shore cable run. In addition to the main controller, the auxiliary radar controller and an X-10 phone operated switching module controller are connected to the phone line using an off-the-shelf 4 channel fax-modem-phone switch. This switch answers the phone and can be commanded to ring one of four lines using telephone touch tone signals. If the X-10 controller is selected, then the power to any of the main systems can be manually turned off and on over the phone line using a touch tone phone. This is useful for the inevitable reboots needed with the computer controllers. If either the main controller or the auxiliary controller are selected, then the designated modem answers the phone and activates a commercial software package which momentarily interrupts whatever is running on the controller and attempts to turn over control of the computer to the caller. If the call is from a computer running the correct software, control is handed over to the calling computer and the interrupted program continues running. All this occurs with minimal interruption of the radar control program. Once control has been handed over trouble shooting, monitoring, reprogramming, and data transfers can be effected over the phone, if possible, or the system can be shutdown to wait for a service trip. This simple communication scheme proved very useful since control could be established from any phone jack using a laptop computer equipped with a modem. This allowed complete testing of the control system before leaving the deployment area and also allowed for daily monitoring of system performance.

This combination of custom and off the shelf equipment proved to be an inexpensive, robust and flexible means of controlling a very complicated radar system from our lab over a thousand miles away. The Lake Ontario deployment lasted from the beginning of May to the end of November and required only four on site trips because of hardware failures (not including weekly data pick-up, which was performed by the CCIW staff) including setup, maintenance. and take down. Although admittedly "low-tech", this system provided the necessary control and monitoring functions at low cost and complexity. Without a remote operation system like the one described here, deployments of more than a few weeks would be very impractical for a system like ours if not impossible.

4. CONCLUSION

The nature of field experiments conducted in support of radar remote sensing research generally limits the length of the experiment because of the harsh environment and control requirements. The Yscat radar system avoids these limitations by utilizing rugged, off the shelf equipment to implement a rather simple and inexpensive system for remote control. While some aspects of the radar system are unique to this particular experiment, the control system should be of interest to anyone considering experiments involving unique instrumentation in remote locations.

References

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