COMPUTER INTERFACING OF METEOROLOGICAL SENSORS IN A SEVERE WEATHER AND HIGH RFI ENVIRONMENT

Kenneth Rancourt
Mount Washington Observatory
Gorham, New Hampshire 03581

John Govoni
U.S. Army Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire 03755-1290

Alfred Oxton
Mount Washington Observatory
Gorham, New Hampshire 03581

ABSTRACT

Methods are delineated whereby the outputs of ten different sensors used in a study of wind and ice loading on a cable are protected from Radio Frequency Interference (RFI) and severe weather, and processed for logging on a computer. Twelve separate signals from two types of ice detector, two types of cable load cell (including one tri-axial load cell), a pitot-static anemometer, a wind vane and a thermistor are introduced into a Digital Equipment Corporation MINC-11/23 computer. Four of these signals, which would otherwise be incompatible, are conditioned for acceptance by the the computer. The signals represent high-speed, consecutive samplings of rapidly changing parameters at a sampling frequency controlled by an operator. Sampled data are logged on a printout and are transferred to magnetic tape for off-site analyses. These methods operate successfully on the summit of Mount Washington, a location known for its harsh weather, in an environment with poor electrical ground and relatively high radio and television frequency interference.

INTRODUCTION

While the summit of Mount Washington is an ideal site for icing research, its utilization for that purpose requires an accomodation with high levels of Radio Frequency Interference (RFI) common to other accessible mountaintops. The power density 2 m above ground level on Mount Washington is as high as 10 - 50 $\mu W/cm^2$ in the 10 - 300 MHz frequency range near the principal areas of propagation, and has been measured at up to 10 $\mu W/cm^2$ in the test area. This situation is complicated by the absence of a dependable electrical ground in the boulder-strewn surface of the summit itself. Shielding long conductors carrying signals from sensors to recorders, and grounding the shielding, can be the source of serious problems.

The severity of the weather, which is part of the attraction for certain types of measurements on Mount Washington, can likewise be too much of a good thing. Wind renders human observations, measurements and samplings difficult at best, and combines with the icing process itself to make photographic recording a challenge. "Good" icing events are usually accompanied by winds on the order of 25 m/s, and gusts on the order of 36 m/s are common during icing runs.

Over the past several years there has been growing interest in ice accretion on structures, especially on high-power transmission lines in the Northwest. Ice build-up on power

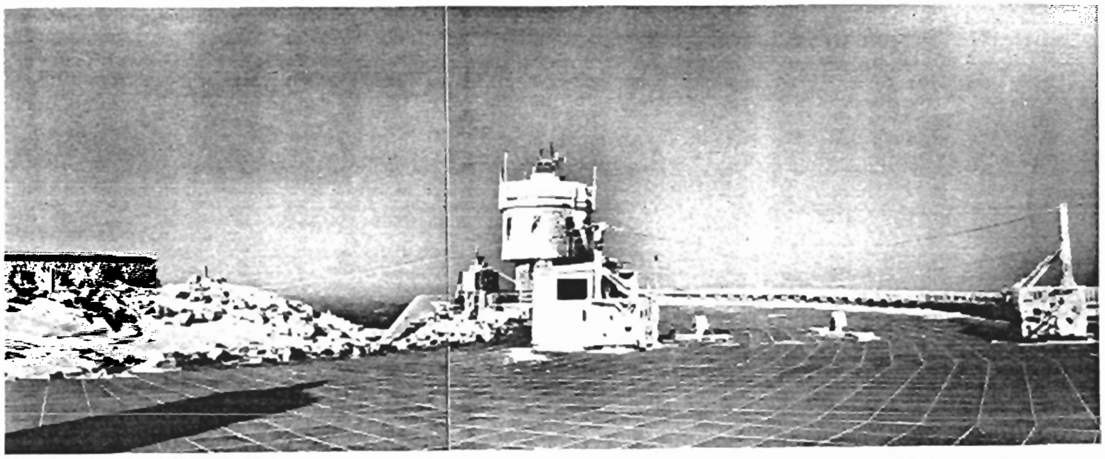

Figure 1. Wire setup with shelter on the roof of the Mt. Washington Observatory.

lines and towers has occasionally caused extensive damage to transmission systems. There is a need, therefore, to quantify icing processes within a program of basic meteorological measurements (Govoni and Ackley, 1983, 1984; Howe, 1982, 1983). The resulting data are necessary for designing and locating power line systems. A recent icing detection and measurement project for the U.S. Army Cold Regions Research & Engineering Laboratory (CRREL) involved an array of test cable spans and the exposure of eight different sensors. These sensors included four ice detectors, three cable load cells (one of which was triaxial), a pitot-static anemometer, a wind vane and a thermistor. The twelve signals generated by these sensors had to be conducted from ~~the~~ test site on the flat roof of the building, across to the tower, a distance of 40 m, and down the tower to the laboratory/computer facility, an additional 30 m. It was also necessary to provide for the continuous operation of a video camera, the output of which was monitored and recorded in the same facility.

All sensor outputs were to be conditioned where necessary for acceptance by a Digital Equipment Corporation MINC-11/23 computer, which would assemble the data and transfer them to magnetic tape for off-site analysis.

The cable setup (Fig. 1) was intended to simulate sections of high-power transmission line. The primary cable, 13 m long, was strung between two steel support cribs at a height of 4.5 m and normal to the prevailing wind. A secondary cable, intended to provide easy access to collected ice for fine measurement and sampling, was strung beneath the primary cable at a height of 3 m. A third cable, 34 m long, was strung from the support crib nearest the summit to a point just below the summit, parallel to the other cables but in the opposite direction.

METHODOLOGY

Videotaping and Videomonitoring

Video cameras are ideal for providing a visual record of icing growth and cable behavior under windy conditions or for remote monitoring. Use of video equipment on a continuous basis, however, requires a camera shelter. A shelter measuring 2 x 2.7 x 2.3 m was prefabricated by CRREL and assembled against one of the two steel support cribs. A dual-pane, insulated window, 1 m^2, in the front of the shelter, looked out toward the other cable support crib along the full length of the primary and secondary cables. The third, longer cable passed over the roof of the shelter and was not visible for videotaping. The video camera, a Panasonic Model No. WV-3400, was fixed firmly to a shelf and was powered by a 12-V power line. Deicing of the window was accomplished manually or by a 150-W infra-red lamp. Adequate illumination for nighttime videotaping was provided by two 250-W mercury vapor lamps anchored in front of the primary cable. The shelter, which was heated primarily to ensure camera stability, served also as a power distribution point for the lamps and other requirements at that location. A Panasonic time-lapse video cassette recorder and a video monitor of the same make were located in the laboratory.

Short, stable, wide-base stands weighted down with concrete pavers, and aluminum and plastic caging, proved adequate to protect the video nightlamps from damage by wind or flying ice. Manual deicing of the video window was adequate if performed frequently enough, but infra-red deicing was much more convenient. Care must be exercised, though, in the use of infra-red lamps. If they are positioned too close to the glass, thermal stresses may cause the glass to break. Our best results were obtained with a shielded lamp outside the shelter about 25 cm from the glass at an angle of approximately 45 degrees. Even so, meltwater droplets had to be cleaned away from the window occasionally. It was our impression that imbedded heaters, such as those in automobile windows, might be effective deicers.

Sensors

The anemometer was a heated pitot-static type designed and constructed by Mount Washington Observatory. It was mounted on a length of pipe fixed to the nearest support crib, and was in the foreground of the video picture for easy monitoring from the laboratory area. Heat tape was laid along the dynamic and static pressure lines and wrapped with fiberglass insulation. Weatherproof cloth tape was then wound around the lines to hold them together and allow for easy passage through the support pipe and into the shelter to a Foxboro differential pressure transducer. Electrical signals from the transducer were carried across the roof, into the tower, and down to a terminal board in the laboratory.

The wind vane, also designed and constructed by the Mount Washington Observatory, is permanently located on the Observatory tower; the electric thermometer is a Yellow Springs Instrument precision thermistor, located in the Observatory instrument shelter. These sensors are used in the regular weather monitoring work of the Observatory. Wind direction and temperature were included in the measurement program as useful additional information, but their inclusion did not justify the expense of sensing closer to the experiment site. Average wind direction, as measured from the tower, is the same as average wind direction at the experiment site, and temperature is typically homogeneous over short distances under icing conditions.

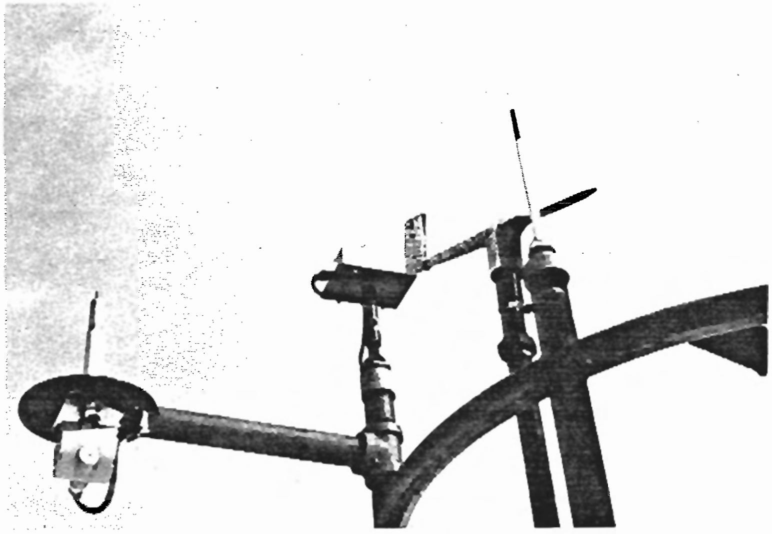

Figure 2. Sensors mounted on the observatory tower. The sensors are, from left to right, Rosemont ice detector Model 872DC, Rosemont ice detector Model 871CB, pitot-static type anemometer, and Dataproducts New England ice detector.

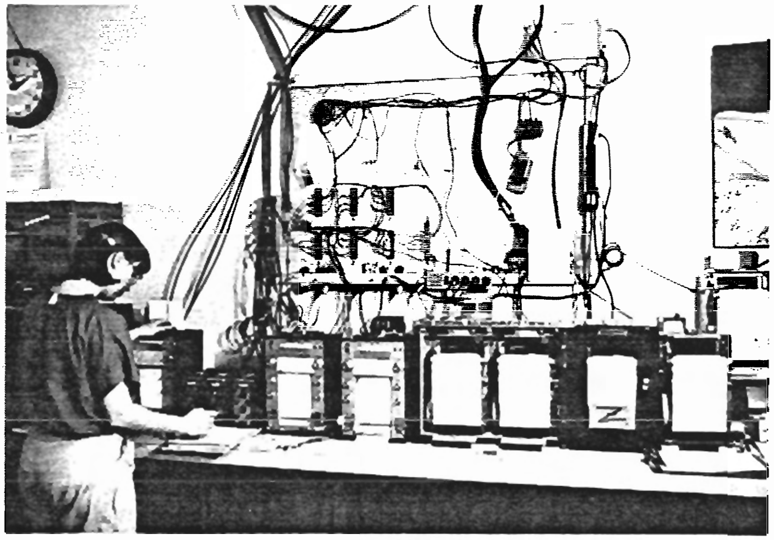

Figure 3. General layout of the chart recording system. The terminal board is in the center, with the recorders at the bottom of the photograph.

A GSE tri-axial load cell was installed between the primary cable and its support, and two Baldwin Lima Hamilton single-axis load cells were installed at the ends of the other two cables. Output wires from these sensors were directed past the shelter to an entryport in the wall of the tower. Wires were held in place on the roof deck by short sections of inverted 3-m angle iron weighted with paving sections.

Of the four ice detectors, one was a Rosemount Model 872DC, one was a Rosemount 871CB, and the other two were prototype models from Dataproducts New England. All of these devices (Fig. 2) were mounted on the Observatory tower with the manufacturers' associated electronic packages located in the coldroom near the top of the tower.

Output wires from the three load cells ran to a large terminal board and continued to individual Vishay signal amplifiers, one for each of the five signals. Amplifier outputs were connected to individual channels of three Brush Model 222 dual-channel recorders (Fig. 3). The remaining channel was dedicated to the anemometer output. Because the Brush recorders were intended only for short-term, high-speed recordings of cable behavior, the amplified signals from the three axes of the primary load cell, and the signal from the anemometer were conducted also to four Esterline Angus 424A recorders devoted to continuous monitoring.

The outside signals from the four ice detectors were likewise conducted to the terminal board. The signal from the Model 872DC Rosemount was directed to another Esterline Angus 424A recorder, where its cycling behavior could be observed in detail, especially during periods when cloud liquid-water content and cloud median droplet diameter were manually measured by the multicylinder method. Signals from the remaining ice detectors were directed to a Rustrak multi-channel event recorder.

Computer and Signal Conditioning

The Digital Equipment Corporation MINC-11/23 computer permits data entry from up to 64 single-ended instrument channels and is particularly suited to accomodating multiple sensor outputs. Nine preamplifier channels were used to scale the input voltages so that the full dynamic range of the A to D converters could be utilized. The data acquisition and display program allowed the operator to select sampling durations between 1 and 60 minutes. Sampling frequency, which was approximately 2000 samples per channel per minute, was not selectable except through program changes. Printout format provided the operator with a complete picture of the sensor outputs. The operator was able to inform the computer of

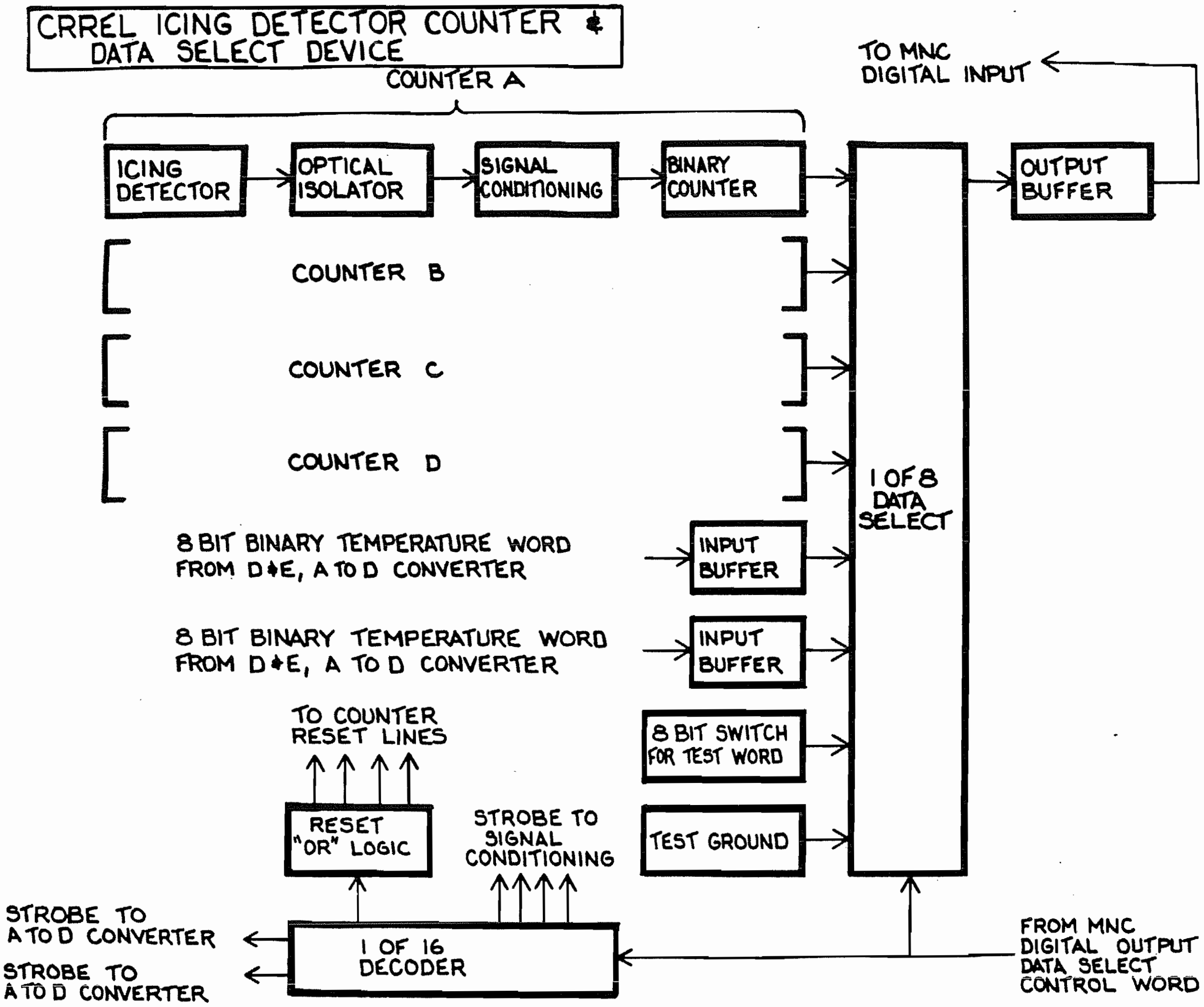

Figure 4. Multiplexer/counter device constructed for the CRREL ice detectors.

changes in gain settings and other variable factors that affected internal calculations. After a run was terminated, a subroutine automatically transferred the computer record to a Techtran tape recorder in a format compatible with an offsite computer system used for analysis.

To simplify computer programming, the outputs of all the ice detectors were processed through a specially constructed multiplexer/counter. Normally the ice detector output is a mechanical relay closure intended to either turn on an alarm or turn on a heater, or both; however, mechanical relay contacts "bounce" repeatedly while opening and closing. Bounce does not signficantly affect the control functions of an ice detector, but the binary event counter used to count individual contact closures for computer entry had to be modified to discriminate between true closures and bounces. This was accomplished with a multiplexer/counter (Fig. 4), designed and built in-house, which consists of circuitry to "debounce" the relay closure signal, four 2^8 binary event counters (one for each ice detector), two eight-bit binary parallel inputs, two test words, and a one-of-eight data select linked to an eight-bit computer input port. Data collection and reset is controlled by a four-bit control word generated by the computer.

DISCUSSION

As expected, problems with RFI surfaced over the first three to four months of the project, during which time they were reduced or eliminated. These problems affected all of the electronic circuitry to some degree, but were principally evident in the high-impedance, high-gain Vishay amplifiers for the load cell signals. Here RFI appeared as a non-uniform dc offset in the zero signal baseline, and also as noise riding along with and masking the signal. This noise could be an order of magnitude greater than the signal. Variation in the amplitude of the noise and in the degree of shift in the zero signal baseline can be attributed to variation in the RFI environment, specifically the activation or deactivation of broadcast equipment, interaction between broadcast signals, and fluctuations in the standing wave ratios of the various transmitter antennae. The interference was exacerbated by the poor local ground and the multiplicity of existing ground paths giving rise to so-called "ground loop circuits" and resulting 60-Hz hum. RFI affected all of the recorders associated with the Vishay amplifiers and the computer. RFI also affected the video signal and caused episodes where the picture was either distorted or completely obliterated.

The methods employed to reduce RFI were straightforward, simple and, wherever possible, aimed at reducing the length of conductors, providing adequate shielding for conductors, ensuring a ground common to all connected elements, eliminating extraneous grounds, providing filters, and, in the case of the video camera, positioning in a spot that was relatively "cold" with respect to RFI as indicated by observation of the monitor. Conductors running parallel to each other were separated as much as practicable from each other, and unavoidable conductor intersections were made at right angles to reduce electrical coupling.

A particularly effective and cheap means of reducing RFI flowing on the outside of a shielded conductor is to use a ferrite core from the deflection yoke of a defunct television set as an RF choke (Woodward, 1982; Atkins, 1984). Looping the conductors three or four times through a ferrite core at each end of the run creates a crude but effective choke coil. This technique was employed very successfully in the video wiring and at the inputs of the Vishay amplifiers.

In addition to the ferrite RF chokes, removable capacitors of several values in the 100 - 300 μF range served as low-pass filters attenuating the high-frequency component of interference remaining across the Brush recorder inputs.

Lightning or the buildup of static charges around the test site can cause serious damage to sensors or the electronic devices they are connected to. While there is no certain protection against lightning damage to equipment in the field, we have employed may strategies to minimize it. For example, setting an AM radio receiver with an outside antenna on a usually clear VHF frequency, such as the 121.5-MHz aircraft emergency channel, provides a good indication of the presence of the static buildup that precedes lightning activity. Static on this frequency provides a warning that allows vulnerable equipment to be disconnected before a lightning storm. Separating conductors from each other and from unintended conductors generally helps to prevent spot discharge, as does avoiding sharp bends and corners in the conductors themselves (Becker, 1978; Jalbert, 1981). Wherever a good ground exists, however, the emphasis should be on providing an easy path to the ground and impeding the path between the ground and the signal receptors. Tests will be conducted in the future to determine if the metal frame of the Observatory building constitutes an adequate ground. If so, conductors will be dressed as described above to the wall of the building, and grounded there.

The creation of "lightning loops" or the kinking of conductors over the remainder of the run retards and deamplifies surges but may make conductors more vulnerable to RFI by increasing their length, and thereby their effectiveness as antennae, or by allowing inductive coupling. The relative importance of potential lightning damage versus magnification of the RFI problem must be weighed for each site. On Mount Washington, we found that any additional RFI, resulting from our attempts to protect against lightning, could be managed with the strategies described above. If used, lightning loops should comprise four to six turns, about a meter in diameter (Becker, 1978). Custom surge suppressors may also be employed if they do not diminish or alter the signal from the sensor. The computer was protected from surges by an SVRS 88102CU suppressor, manufactured by the Superior Electric Company of Bristol, CT. Descriptions of the use of this and similar devices can be found in Jalbert (1981).

CONCLUSIONS

RFI and severe weather hinderances to computer tabulation of sensor inputs can be adequately minimized, though some expense may be involved. Proper shielding and grounding procedures should be scrupulously followed wherever possible, including using double-shielded conductors and avoiding consumer quality devices (video cameras, for example) that are housed in plastic, rather than metal, cases. In future work of this nature, we will be attempting to locate preamplifiers outside, close to the load cells instead of at the end of a long cable run. This will increase the signal-to-noise ratio on the line and will result in fewer problems at the recorder and computer inputs. We also intend to begin using fiber optics where appropriate. Lightning loops on remaining metallic conductors may be replaced or supplemented with surge suppressors.

The usefulness of video cameras for recording and monitorig remote events cannot be overemphasized. Though video resolution is inadequate for precision measurement of observed elements without expensive accessories, the ability to monitor the test site continuously, at the time of the test or later, is of great value. In this case the video recording showed instances of interaction between cables that might not otherwise have been noted and allowed detailed study of the ice accretion process.

Conditioning signals for acceptance by a computer and creating software to sample sensor output are technical problems where solutions are guided by the requirements of the project. Because project requirements may evolve during the course of the work, software versatility, especially in the area of selectivity with respect to sampling frequency and duration, is important.

REFERENCES

Atkins, P., 1984: Telephone RFI cures, QST Jour. Amer. Radio Relay League, LXVIII:3, pp. 44.

Becker, J., 1978: Lightning protection, Ham Radio Mag., Dec. 78, pp. 18-27.

Govoni, J.W. and S.F. Ackley, 1983: Field measurements of combined icing and wind loads on wires, Proc. of 1st Int'l Workshop, Atmospheric Icing of Structures, CRREL Special Report 83-17, pp. 205-215.

Govoni, J.W. and S.F. Ackley, 1984: Combined icing and wind loads on a simulated power line test span. Proc. of 2nd Int'l Workshop, Atmospheric Icing of Structures, Trondheim, Norway.

Howe, J.B., 1982, 1983: Measurements and analysis of icing and wind loads on wires. Unpublished report to USACRREL.

Jalbert, J.S., 1981: Protecting remote terminals and computer ports from lightning. Denison University Report Sept. 1981, Denison University, Granville, OH 43023.

Woodward, G., Ed., 1982: Amateur Radio Handbook, Amer. Radio Relay League, Newington, CT 06111. 2:29-30.