Virtual Cables at the Nevada Test Site

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Abstract

Shrinking budgets and labor pools have impacted our ability to perform experiments at the Nevada Test Site (NTS) as we did previously. Specifically, we could no longer run heavy cables to remote data acquisition sites, so we replaced the cables with RF links that were transparent to the existing system, as well as being low-cost and easy to deploy. This paper details how we implemented the system using mostly commercial off-the-shelf components.

Key Words

TNC, modem, packet, solar power

Introduction

Changing priorities, shrinking budgets and limited resources have forced us to change the way we conduct experiments at NTS. Once, we ran cable over ground from a centrally located van to remote sensor modules. The cables carried power and RS-422 twisted pair data lines. We no longer have the manpower or money for this. We needed a more flexible, easily-deployed and reusable mechanism of data exchange, so we looked to telemetry.

Since we already had considerable investment in the current hard-wired system, we wanted an RF link that was transparent to the existing hardware, and especially the software, since the programmer was no longer on staff. We wanted a virtual cable.

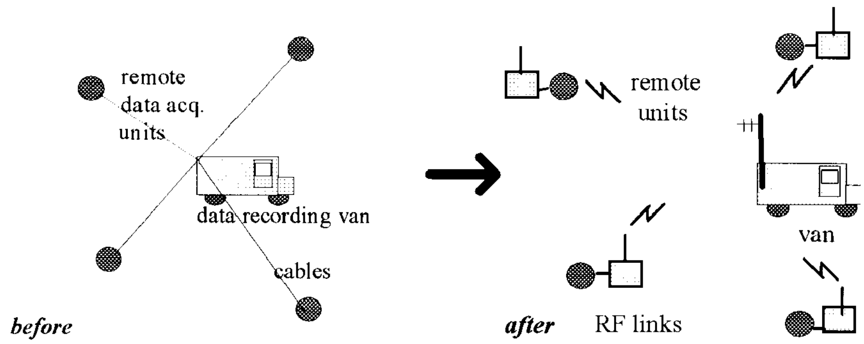

Figure 1

Spectrum Space

We asked the RF frequency coordinator at NTS for spectrum space.The following channels were available:

164.84375	166.65625
165.80625	167.19375
166.41875	171.21875

These are only 10 KHz "splinter" channels, so the data rate was limited to 2400 baud. Our hard-wired system ran at 9600 baud, but it was possible to operate it at lower baud rates.

Adapting 2 Meter Gear

ince the frequencies are close to 2 meters, we were able to use low-cost antennae, antenna tuners, power meters, and other equipment designed for ham radio use, such as the SWR meter shown in figure 2. In some cases, we had to do some adjusting to account for the higher frequencies.

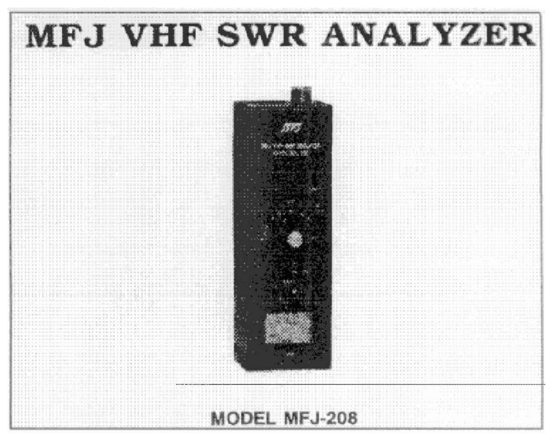

Figure 2

RF MODEM and Transceiver

The RF link consisted of small, 4 watt 160-170 MfIz transceivers interfaced to packet-switching modems. The modems were originally designed for ham radio use, but the firmware had been enhanced by the manufacturer for industrial applications. The technology has long been field proven by amateur radio operators, and the units are inexpensive ($300) and readily available. These devices are called Terminal Node Controllers (TNCs).

The TNCs handle most communication functions autonomously - they perform CRC checking, automatic handshaking and packet resending. They can be programmed to establish connection on power-up, and appear transparent to the RS-232 channel they are inserted into (except for retransmit delays). This was an important feature for us. We did not have the resources to make significant changes the existing hard-wired system to accommodate wireless connections.

The transceivers that we used were Motorola R-NET units (see figure 4). They are small, low-cost ($400), and low-power. Since the system is powered by solar-charged batteries, low power consumption was important to us. For this reason, we chose Paccomm as the TNC supplier. They offered CMOS versions of their TNCs which consumed far less power than their competitors. The TNCs interface to the transceivers through audio signals.

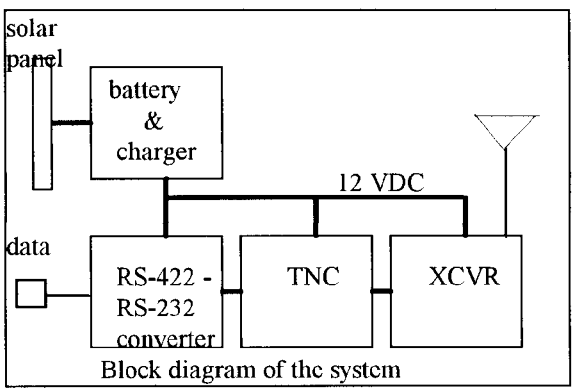

Figure 4

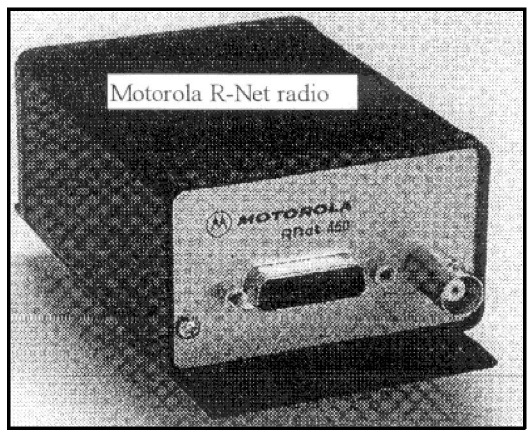

Figure 3

Packaging

The transceiver, TNC, battery, and solar charger are mounted in a NEMA box. The box is mounted on a small ‘A’ frame structure made of anodized aluminum (figure 5). It resembles a small step ladder and it can be folded up for easy transport and compact storage. An 18 watt solar panel is mounted on the other side of the frame. A whip antenna is installed on the top. The antenna is removable and the battery is held by a hasp that is easily unlatched so that the battery can be removed quickly. These items are removed when the unit is moved or stored.

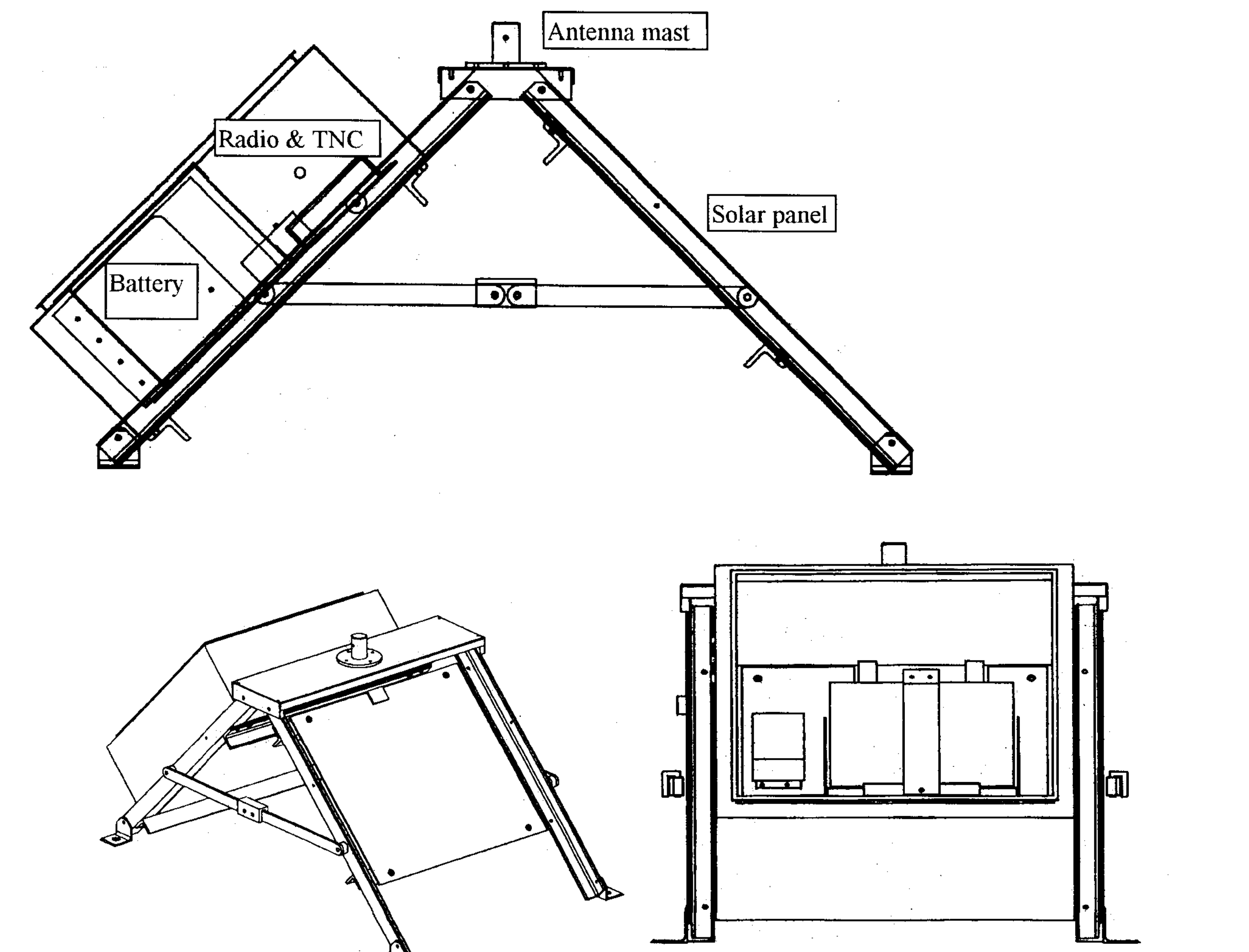

Figure 5

Solar Power

The solar charging circuit is basically a linear regulator that is controlled by a simple state machine, which puts the battery in bulk charge mode, then finishing mode, the float charge mode. The solar charger was the one item that we did not purchase off-the-shelf. We combined the RS-422/RS-232 converter circuitry, the solar charger, and a step-down switching regulator that powered the remote data acquisition unit and put all the circuitry on one pc board. The charger also has a low-voltage disconnect to keep the battery from being over-discharged by disconnecting the load if the battery voltage drops below a preset voltage.

There are plety of sunny days in the Nevada desert, but the first time we fielded the system, it was unusually cloudy for several days. The batteries ran out at the end of the third day. It seems that battery power is always less than the calculated amount. We are currently working on a more efficient switching regulator design for the battery charger.

Where there is lots of sun, there is lots of heat. We had to paint the NEMA boxes with reflective paint to reduce the heat in the box. Battery life is shortened by heat. The batter charger must respond to changes in temperature and reduce the charge termination voltage or the batteries will be “cooked”. Also, solar output voltage drops as temperature increases.

Battery Storage and Maintenance

The battery holder was mechanically designed so that the battery could be removed easily. After the experiment was over, we collected the batteries and stored them in a shelter with a “smart” battery charger to keep them at a float charge. Although the batteries are sealed, they are lead-acid, and regulations dictate that we keep all lead-acid batteries in an open shelter so that hydrogen buildup can not occur. So we were kicked out of our air-conditioned warehouse and had to settle for a three-sided shelter. Now we will need to get a charger that can sense temperature, and adjust the float voltage accordingly. Our temporary solution is to lower the float voltage so that high temperatures will not cause the batteries to dry out.

Testing the System

We were able to test our configuration of the TNCs before we had our RF transceivers and licenses by coupling the audio input of one TNC to the audio output of the other, and turning up the modulation adjustment so that we had plenty of audio signal. Then we tied them to two laptop computers and simulated the data exchange between a remote data acquisition unit and the central logging computer.

When the transceivers were connected to the system, we used an old Cushman communication monitor to set the TNC modulation levels. This instrument was very helpful in observing the activity of the communication link between remote units and the base station. Our ears learned to recognize the demodulated audio signatures of an attempted startup of a link, a retry, etc.

Fielding the System

Several problems arose when we fielded the system. First, the solar chargers would burn out when there was full sunlight and the local transmitters were being tuned up. They did not burn up if there was low light, or if the transmissions were short bursts. We suspected that RF energy was being absorbed by the solar panels and somehow causing the maximum voltage level of the battery charger chip to be exceeded. We installed RF filtering on the solar input lines to the charger circuit, and the problem has not recurred.

Secondly, we had problems with the software configuration of the TNCs. These devices have dozens of parameters that can be modified, and programming errors can cause puzzling results. In our case, the devices were dropping out of transparent mode. The result was that certain control characters, such as line feeds, were being filtered out of the data stream. This caused problems for our existing system software. This sounds like a simple problem, but it led us in circles for a long time, since we suspected dropped characters, buffer overruns, modulation level problems, etc.

Thirdly, we had adjacent channel interference. Although we always sent commands to the remote units sequentially so that the remote units would reply sequentially and avoid colliding with each other, the TNCs perform automatic retry on error, and the retry from one unit might occur when another unit is transmitting. The problem results from lack of spacing between the antennae at the van. We investigated the solution that repeater stations employ: resonators. At the frequencies we are using, the resonators are huge tanks that would scarcely fit into our van, much less stay in tune while traversing the rough roads of the desert. We alleviated the problem by intelligent deployment - the remote units that were closest in frequency were placed farthest apart, so that the corresponding antennae at the van were pointing 180 degrees apart. The three-element beams used at the van have a 17 dB gain differential, front to back. Ultimately, we will have to work out a scheme for moving the antennae to different masts, but we have yet to come up with one that does not impact ease of deployment.

Lessons Learned from the Desert

Unlike the heavy, metal-jacketed cables that we use in the hard-wired systems, the light weight wires from the solar panel to the NEMA box on the remote unit can not be run near the ground. Rodents will gnaw through them.

Crows and solar panels do not go together. The crows like to sit on the top of the A frame of the remote units and soil the solar panels. We alleviated the problems by drilling small holes along the upper solar panel support bar, and putting tie-wraps through the holes. The long tails of the tie-wraps were not trimmed, but were allowed to protrude out at a 45 degree angle along the top of the A frame. A crow would attempt to land on one of these, which would bend under its weight, and it would fly away (sometimes).

Conclusion

It is possible to build a low cost RF link that is retrofitted transparently to an existing hard-wired data acquisition system, provided the system can handle the reduced baud rate and transmission delays. But using solar panels and batteries to power the remote units adds another level complexity to the project, as environmental factors need to be addressed.