EVALUATION OF HF RADIO COMMUNICATIONS IN THE ARCTIC

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ABSTRACT

This project evaluates the feasibility of using HF radio for data communications in arctic conditions. The links evaluated are the Sondrestromfjord-to-GISP 2 link in Greenland and the Fairbanks-to-Barrow link in Alaska.

Two Scientific Radio Systems (SRS) HF SSB transceivers (Model SR-370) are the radios used to meet the communications objective. The radio systems operate in a packet mode whereby data files may be automatically transferred from one machine to the other.

This report addresses the method of evaluation for the SRS radios and the experiments performed. This report also addresses issues of reliability of HF radio communications and explains how to properly operate the SRS radios. Finally are recommendations regarding improving the reliability of these specific SRS radio systems.

ACKNOWLEDGEMENTS

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I. INTRODUCTION

The SRS Model 370 HF radio transceiver is a highly versatile and capable communication system. Problems associated with the versatility include finding the optimum parameters for radio operation in arctic conditions. Hardware problems in the computers had made the radio systems seem inoperable when we first received them. Evaluation procedures were established and followed to return the radios to operating condition. A summary is included on how to operate the radios and change their frequencies. Studies into HF radiowave propagation have shown that the radios cannot be 100% reliable in the arctic but can provide a useful data communications link. A public domain software program, DX, was installed on the computers to predict the frequency performance for a link between any two locations on earth. Sample output of the program for the link between Barrow and Fairbanks is included, which seemed to be verified with our Barrow-to-Fairbanks link experiment. Files were transferred between Barrow and Fairbanks and delivered to PICO to prove reliable data transfer. The system could not operate continuously. Yet, we recommend that the radios be installed in a data communication system and that reliability may be improved over time by further optimizing the frequency of operation or antenna configuration.

II. EVALUATION PROCEDURES

Evaluation consisted of four parts: computers, back-to-back link in lab, data format modes and the Barrow-to-Fairbanks experiment.

A. Computers

The computers were the source of many problems. To start, one of the computers would lose its parameter RAM whenever power was removed. Parameter RAM in the DTK computer, as it turned out, is maintained with a Ni-Cd battery. The solution was to merely leave the computer powered up, allowing the battery to charge. The operating software would not load. According to the technical manual software installation is just a matter of inserting a floppy, turning on the machine, and changing floppies when prompted. It was soon found, however, that the SRS floppies are not bootable disks and the hard drives had been corrupted. Only after hard drive reformatting and uploading MS-DOS 3.0 could the SRS software load. The next problem to turn up was that only one of the computers would control its connected radio/modem group. It was found that the interface cards were not properly configured. Cables had to be routed to their correct connectors and the correct slot had to be found for an interface card. Yet another problem to develop was one of the computers intermittently corrupting its hard drive, necessitating reformatting and reloading of DOS and the SRS software. This intermittent condition persisted until a hard failure of the display driver card showed up. Troubleshooting and inspection turned up an inappropriate mounting bracket on the display driver card. The card would appear to be seated in its slot when in fact it was merely resting on top of the slot without positive contact, being held in place by the secured bracket. To allow positive contact the bracket required bending and cutting to fit.

B. Back-to-Back Link in Lab

Coupling two transceivers back-to-back must meet the criteria of: providing an adjustable attenuation, able to dissipate 100 W, match the RF ports 50 ohm impedance to prevent reflection or high SWR and reduce the transmitters 70.7 volt output to a level on the order of 10 microvolts acceptable to the receiver's front end without damage. Such a network must also be bidirectional to allow for the return of acknowledgements as required by AMTOR and AX.25 Packet data formats.

As soon as both the radio systems were operational it was found that the two could talk to each other while terminated in separate dummy loads with no direct connection between them. All data modes and voice worked without error. The closer the dummy loads were to each other the better the link. If there was to be control of the signal-to-noise ratio in the RF link, distance would have to be put between the two systems. Separating the systems in different rooms and powering them off separate 60 Hz lines removed the unwanted coupling. Energizing both systems from the same 60 Hz line by running an extension cord from room to room allowed the two to hear each other. The level was enough to be heard from the speakers but too low for the modems to notice. RF was running on the power lines. As long as power came from separate breaker panels this would not be a problem in the lab. Two coupling network ideas were built and tried to find RF energy riding on ground. Regardless of the attenuation put between the two systems, they could hear each other loud and clear – as such an adjustable back-to-back RF connection was never achieved. The small coupling between the physically unconnected systems did, however, allow all the data formats to be comparatively tested.

C. Data Format Modes

The SRS SR-812 Data Radio System's capabilities are impressive: endowed with the modes of single side band voice, CW, AX.25 Packet, CCIR 476

AMTOR/SITOR, Baudot radio Teletype (RTTY) and ASCII RTTY. Of the many operating modes only Packet and ARQ are recommended due to their automatic error detection and correction. The other available modes (FEC, RTTY and ASCII) are usable but provide no automated response to errors, thus requiring the operator to look for errors and ask for retransmission. In the lab all modes worked well with just the coupling between the dummy loads. Packet is recommended over ARQ for the advantage of being able to transfer any sort of file – computer program, text, document or spreadsheet – without error. ARQ is a slightly hardier mode than Packet on noisy channels but at the price of being able to send only upper case text. Any lower case characters are converted to upper case. Files such as formatted spreadsheet documents or executable code may not be sent in ARQ.

Packet is the easiest and most versatile of all the modes. Many of the SRS radios could be set up in a network with some forwarding messages to distant stations. Messages are transmitted by typing text or selecting a file, hitting return, and the system does the rest. Data are transmitted in packets composed of the data, an error detecting frame check sequence, routing information and synchronization blocks. The receiving station compares the frame check sequence with the data for any transmission errors. Should there be no errors, the receiving station sends back an acknowledgement (ACK) telling the sender the data arrived error free. If the frame check sequence and data do not agree, a negative acknowledgement (NAK) is returned, meaning "send the data again." This entire process is automatic without need of operator intervention. Should the link be idle for 2 minutes the computers will drop the link for lack of message traffic.

AMTOR stands for Amateur Teleprinting Over Radio whereas SITOR means SImplex Teleprinting Over Radio. The two protocols are identical but for their differing selective call (SELCAL) headers. AMTOR uses a four-letter SELCAL; SITOR uses instead a four- or five-digit SELCAL. For PICO's purposes, a four-letter

AMTOR SELCAL should be used. According to convention, the SELCAL is built up from a station's call sign with the first two and last two letters. For example, given the call sign AL7LO, the SELCAL will be ALLO. Should there be no preassigned call signs, it must be decided on ahead of time what the SELCALs will be before using ARQ. Packet mode uses the entire station call sign.

ARQ error correcting transmissions may be between two stations only. Other stations may monitor but without the benefit of error correction. The initiator is termed the master station and the receiving end is called the slave station. ARQ is a synchronous technique sounding nothing like Packet as heard from the transceivers speaker. The master station automatically maintains timing for its transmissions. Both stations provide "LOCKED" indications to the operators indicating synchronization is achieved. The operator need not keep track of the locked condition once the link is established. A link is established by the master station first sending a continuous stream of SELCAL characters addressing a particular station. Between each block the master automatically pauses, listening for a one character reply. Once replies are heard by the master station equipment, a link is established and message transfer is one way from the master to the slave. The slave automatically responds with an ACK or NAK as appropriate. A NAK response will initiate a re-transmission of the last block. Should the slave fail to reply to a block, the master will buffer the remainder of its message and transmit a stream of phasing characters to resync on. When the slave comes back, message sending automatically resumes where left off.

ARQ operation is a bit like passing a token. The slave may send only after the master manually sends the sequence "+?". The roles then switch; slave becomes master providing the timing for its outgoing traffic. Should the slave see fit, however, the right to send information may be manually usurped or given back at any time. Messages typed in by the operator are buffered until the right to send is acquired. Use the down arrow key to give the token and the up arrow key to take the token. A station need not possess the token to type in a message; just type and hit return. Outgoing traffic will be buffered by the computer until the token is acquired, then sent automatically.

D. Barrow-to-Fairbanks Experiment

The SRS data radio systems were used in an actual test link between Barrow, Alaska, and Fairbanks, Alaska. The Barrow-to-Fairbanks path was chosen for its similarity to the Sondrestromfjord-to-GISP 2 Greenland path; similar distances and latitudes. Many lessons were learned. The diurnal ionospheric variation must be reckoned with by having as many authorized frequencies as possible on hand. Antenna back lobe reception proved to be a significant source of interference at the Barrow site, often making a frequency useless. If a frequency is open, ARQ had only marginally better performance over Packet. It was found that 80-character data packets had the best throughput on good links. A 30-character packet had the best reliability, but made file transfers very slow. Packets longer than 80 characters required many retries, reducing throughput greatly. All conversational message transfers went very well, provided a frequency was open. Problems were experienced with the SRS data radio systems themselves. The computer in Barrow would lock up intermittently in the middle of file transfers, requiring rebooting. The Fairbanks transceiver's synthesizer drifted in the middle of file transfers, making it useless and forcing an end to all further testing. An alignment procedure has subsequently solved the synthesizer drift problem. The computer still experiences occasional lock ups in the middle of long file transfers. We recommend further maintenance on the computer to solve this problem. The floppy drive on this computer, DTK TECH-1230, Serial number E00304634, has eaten several floppy disks and should also be repaired.

III. SRS RADIO OPERATION SUMMARY

A. Power Up The System In The Sequence

1. Power Supply.
2. Transceiver.
3. Modem.
4. Monitor.
5. Computer.
6. The computer will automatically boot itself into the SRS operating program. Type F1 for Communicate when the computer offers such selection. Packet mode will appear in about half a minute. Should nothing be selected the system will in time default to Packet.

The following operation summaries are applicable to operating software version 3.20, and may vary somewhat on future software releases.

B. To Send a Packet Mode Message

1. Power up the system. See A above.
2. Type F1.
3. Select destination station. The computer will present a list of pre-loaded destination stations to choose from. Use the arrow keys to highlight a choice and press ENTER. ESC will exit back to the communicate screen.
4. Wait. The transceiver will now scan from a list of frequencies assigned to the selected destination; transmitting a call on each and listening for a reply. This may take a while (five minutes, more or less). Once the system hears the distant station the computer will ring like a phone indicating that you have a link. Messages may now be sent and received in a

conversation-like manner provided there is an operator at the distant station to converse with. Just type the message and hit ENTER.

C. **To Send a File From Hard Disk in Packet Mode**

1. Should a link already be established, skip to 2 below, otherwise Power up the system as in A above and/or establish a link as in B above.
2. Press F4. The computer will present a list of file functions.
3. Select type of file to send. Press F1 to "Send HardDisk Text File" or F2 to "Send HardDisk NON Text File" as applicable. If unsure, press F2. Other choices are included in the file functions menu and may be selected without harm.
4. Select the file to be transferred. The computer should have presented a list of the files stored in the hard disk's DATA directory. Use the arrow keys to highlight a choice and press ENTER. ESC will cancel the file transfer and return the computer to the communicate screen.
5. If a link is already up, the file transfer will proceed. An operator need not be in attendance at the distant station. If a link is not up, the computer will present a list of pre-loaded destination stations to choose from. Use the arrow keys to highlight a choice and press ENTER. ESC will cancel the file transfer and return the computer to the communicate screen. The transceiver will now scan from a list of frequencies assigned to the selected destination, transmitting a call on each and listening for a reply. This may take a while; five minutes more or less. Once the system hears the distant station, the computer will ring like a phone indicating that you have a link. The file transfer process will now proceed.
6. In an established link the computer will now check with the distant station to see if a file by the same name already exists. If there is such a

file, the transfer will be canceled and the computer will say so; otherwise, the transfer will continue and the number of characters in the file will be indicated . As a rule of thumb expect on the order of 10 minutes for the transfer of 5000 characters using 80 character packets under good link conditions.

7. To drop the link, press F3 while in the communicate screen.

D. **Packet Mode Manually Changing Frequency**

1. Place the system in non adaptive mode: press F6 and F2 in order. The computer should display the short message: "Non Adaptive Mode Selected"
2. Press F1 for a list of destination stations. Use the arrow keys to highlight a selection and press ENTER. Esc will return the computer to the communicate screen.
3. A list of assigned frequencies will be shown. Highlight and press ENTER. Frequency selection is now complete.

E. **To Send a Message in ARQ Mode**

1. If already in Packet mode, skip to step 2; otherwise, power up into Packet mode as in A above.
2. Place the system in ARQ mode by pressing: F6, F1, F4.
3. Manually select operating frequency on the transceiver's front panel. Ensure the transceiver is returned to REMT mode after tuning.
4. The system is now ready to receive ARQ messages. To initiate transmission, press F8. A SELCAL selection screen will pop up.

5. Select the applicable AMTOR or SITOR format and enter the distant station's SELCAL. Press ENTER. The transceiver will initiate continuous synchronous transmissions.
6. When LOCKED is shown at the bottom of the screen, a link is established. Messages may now be sent in conversation-like manner. Use the up and down arrow keys to pass the token.
7. To capture incoming text and files to hard disk, press F5. To disable file capture, press F5 again
8. To drop the link, press F3.

F. Manually Changing Frequencies in ARQ Mode

The SRS operating program makes no provision for automated frequency changes while in ARQ mode. Changing frequencies must be done manually at the transceiver's front panel.

1. Press the 2ND key and the FUNC key in order. Transceiver display will change from "REMT" to "FREQ".
2. Press the FREQ key and enter the wanted operating frequency. Use a leading zero for frequencies below 10 MHz. Press the ENT key to complete the entry.
3. Press the 2ND key and the FUNC key in order. The transceiver will display "Function Select".
4. Press the transceiver's up arrow key once. The display will show "Rem Control".
5. Press the ENT key. The display should now say "REMT". Frequency selection is now complete. NOTE the mode and frequency information in the computer screen's lower right corner may not be correct and is to be expected.

G. Avoiding Problems

The system should be powered up by turning on the power supply, transceiver and modem before turning on the computer; otherwise, error messages will be displayed on the monitor until the computer is satisfied with the transceiver and modem initialization. When powering the system down, turn the computer off first; should the modem or transceiver be turned off first, the computer will lock up. If it is desired to use the computer to run a program other than the SRS operating program, the modem and transceiver must be on until the SRS operating program has been exited.

After a session of ARQ operation, insure the link is down by pressing F3; otherwise, the transceiver will continue radiating needless power as long as the system is an ARQ master station.

IV. HF PROPAGATION

High Frequency (HF) radiowave propagation is a phenomenon that is dependent upon many physical parameters of the atmosphere and is thus time variant and somewhat mysterious. We will attempt to outline the major aspects of HF radiowave propagation.

A. Theory

HF radiowaves are generally defined as those between 3 and 30 MHz. The corresponding wavelengths are from 100 to 10 meters. Items much smaller than 1/10 of a wavelength are generally not "seen" by the radiowaves, and hence do not disturb their direct line propagation.

The typical long distance HF communication link uses the so-called sky wave means of propagation where the radiowave travels up to some height in the ionosphere and is then reflected down as if the ionosphere were a metallic conductor. Not only does the conductivity of the ionosphere change with time, but so does the height of the reflecting layers.

The source of energy which ionizes particles in the earth's ionosphere is the sun. The flux of ionizing radiation and particles from the sun is highly variable and peaks with sunspot activity. The 10.7 cm (2800 MHz) solar flux number is directly related to the sunspot number and hence the influx of ionizing radiation from the sun. The 10.7 cm solar flux number is reported on WWV (5, 10, 15, 20 MHz) at 18 minutes after each hour and on WWVH (5, 10, 15 MHz) at 45 minutes after the hour. The higher the number, the higher the level of ionization in the ionosphere and better the HF propagation, provided there are no solar storms occurring. Solar storms can cause a complete blackout of HF communications by generating large amounts of noise. Sunspots seem to peak on an 11-year cycle and we are currently just past the maximum.

The ionosphere is generally regarded as ionizing in layers as depicted in Figure 1. A more exact description of the phenomenon is shown in Figure 2. The E layer is the lowest useful region of the ionosphere for HF propagation and is at an average height of about 70 miles. The atmosphere is still dense enough so that ions and electrons set free by solar radiation do not have to travel far before they meet and recombine to form neutral particles. Ionization of the E layer is thus greatest around local noon and practically disappears after sundown.

The region of ionization mainly responsible for long distance communication is the F layer. At its altitude, about 175 miles at night, the air is so thin that recombination takes place very slowly. In the daytime, the F layer splits into two parts, F1 and F2, having heights of about 140 and 200 miles, respectively. They merge again at sunset.

The Lowest Usable Frequency (LUF) is the lowest frequency that will propagate under specific conditions. It is generally an output of a predictor program, such as the ones explained in the following section.

The Maximum Usable Frequency (MUF) is the highest frequency that will propagate under the specific conditions. The MUF is proportional to the amount of ionization in the ionosphere, moving to higher frequencies when the ionization level increases. The MUF is generally given by the following expression:

$$MUF = 8.9788 \cdot 10^6 \cdot \sqrt{N},$$

where N is the number of electrons per cubic meter.

The optimum frequency is obviously between the LUF and the MUF, and is generally chosen as ~75-80% of the MUF.

A problem specific to high latitude regions is that of polar absorption events. Periods of high solar activity and variations in the earth's magnetic field are generally discerned by auroral activity. This highly time-variable ionosphere can

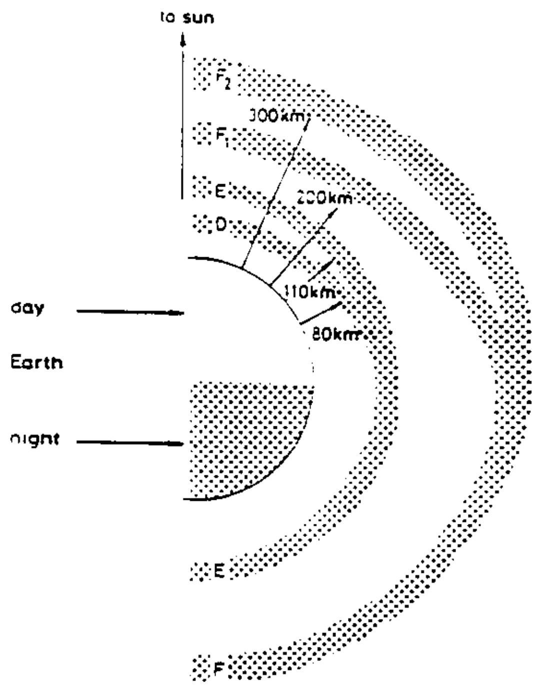

Figure 1. Ionospheric regions as a function of height above the earth's surface.

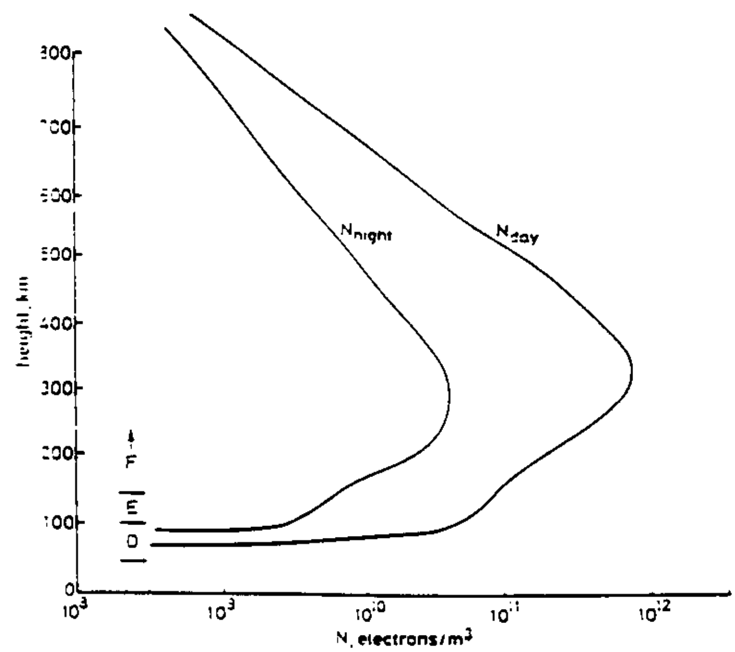

Figure 2. Number of electrons/m^3 versus height above the earth during an average day and night.

seriously impair or even completely block HF communications by creating very high absorption of propagating signals. Furthermore, the time-varying properties of the ionosphere impart a multipath distortion to the radio signal, which garbles the modulation of information on that radio signal. These polar absorption events are concentrated in the auroral zone, which includes both Alaska and Greenland.

B. DX and IONCAP Software Predictors

An HF propagation path prediction program has been acquired and loaded to the computer hard drives. Called DX, in the public domain, the program generates plots of signal to noise levels expected between the Maximum Usable Frequency (MUF) and the Lowest Usable Frequency (LUF) for a specified path. DX will also give a diurnal plot of LUF and MUF which is nothing more than the signal to noise plot without the S/N numbers. DX produces the LUF/MUF plot according to date, receiver/transmitter site map coordinates and the 10.7 cm solar flux number. For the signal to noise plot DX requires the additional equipment parameters of: transmit power, transmit/receive antenna gains and receiver site ambient noise. Plots for the Sondrestromfjord to GISP 2 path are attached in Appendix B. The 10.7 cm solar flux number is broadcast on WWVH at 45 past the hour and WWV at 18 past. Solar flux is an indirect indicator of the sun's Extreme UltraViolet (EUV) radiation falling on the F-layer and ionizing it.

SRS has provided a three-year, summer months, IONCAP propagation prediction on floppy disk for the Greenland link. IONCAP predictions are based on the same parameters used by DX except for solar flux. Sun spot numbers from an average solar cycle are used instead, allowing long-term predictions. DX predictions, on the other hand, must be from day to day. Use the IONCAP predictions for a long-term outlook. Fine tune with the DX program in the short term.

C. Other Users

Perhaps the primary source of interference is that of other users. The HF frequency bands are used extensively throughout the world for private and broadcast communications. Amateur or HAM bands are defined globally, but other frequency band designations are often defined differently by different countries. We recommend that the frequency band designations for Greenland be obtained from the Danish government so that appropriate frequency choices can be made.

V. ANTENNAS

The antennas tested were the ones that came with the SRS radios, namely folded dipole long wire antennas.

A. Long Wire Antennas

The folded long wire antennas are about 100 feet in length and come complete with an RF balun to match the impedance over the full range of operation from 3.5 to 30 MHz. Antenna performance will diminish below 3.5 MHz. The balun is contained in a small (8-inch) length of PVC pipe in the center of the folded long wire antennas. The HF radiowaves propagate outward perpendicularly from the long axis of the long wire antenna. That is, to send a radio beam to the north, the antenna would be strung up in an east-west configuration. Unfortunately, the radio beam will also propagate to the south, and one-half of the energy will be going the wrong direction. This is called the back lobe of the antenna radiation pattern. Furthermore, the antennas receive radio energy in the same pattern in which they transmit. Therefore, unwanted RF energy will enter the radio from the undesired backlobe of the antenna.

There are several cautions which must be mentioned for proper installation of the antennas.

1. Be careful not to contact or come near any overhead power transmission lines.
2. The antennas must be strung horizontally, and well off of the ground, preferably at least 20 to 30 feet.
3. The antennas should be well away from any metallic building or any metallic structure that will cause reflections of the electromagnetic energy, thus interfering with the proper transmission of HF radiowaves.

B. Installation Procedure

This is a recommended procedure for installing the folded long wire antennas on the masts fabricated by the PICO machine shop. The goal is to erect the antenna masts in a self supporting manner. The masts should be separated by at least the length of the antenna (100 ft), but not more than 200 ft and optimally about 150 ft. After the masts are erected, pull the antenna taut between the poles. The sag in the middle should be on the order of a few feet at most. The coaxial cable will hang down vertically from the balun in the center of the antenna.

Procedure:

1. Four people make erection of the masts easy and safe.
2. Assemble the masts by screwing together four sections. Two chain wrenches or strap wrenches are required. The metal fittings are 4 inches in diameter. Attach base plate and top fitting to masts – match numbers on the fittings and pipe.
3. Attach three guy ropes to screw eyes on the top fitting of each mast. Rope should be sufficiently strong to safely support mast in expected weather conditions. Guy ropes should be at least 50 ft long.
4. Choose location for masts. Primary concern is the antenna beam direction, which is perpendicular to the antenna longitudinal axis, i.e., perpendicular to the line between the two masts. Other concerns are that the masts are separated by a proper distance, are not located near metal structures or where the antenna will be below tree level.
5. Before erecting the masts, carefully unroll the antenna, being careful not to kink or twist the wire, and lay on the ground to insure adequate mast separation.
6. Thread antenna halyard (rope to hoist antenna into place) through the hole in the top fitting of each mast. The antenna halyard should be at

least 80 feet long, and the middle of the rope should be at the top of the mast.

7. Grunt time. Erect the mast to a self supporting, guyed stance. We suggest 1 person at the mast base, holding it down, 2 people on guy lines to pull the antenna upward, and 1 person lifting the mast up at an angle, starting at the top fitting and walking toward the base, until the 2 people pulling on the guys can take over. The lifting person should also have the third guy in hand so that he can back off into guyed position once he no longer is required to hold the mast. Stake the guys at approximately 120 degree rotational separation. Stake the base plate down, either through the holes in the plate or around all edges of the plate so that it cannot slide.
8. Erect the second mast in similar fashion.
9. Connect the coaxial cable to the antenna balun in the middle of the antenna. Wrap the connector tightly with electrical tape to weather proof the connection.
10. Tie the antenna halyards to the ends of the antenna and hoist the antenna to its horizontal operating position about 30 feet above the ground. Be careful to keep the coaxial cable from kinking. Stake the antenna halyards behind the mast away from the base and in line with the antenna.
11. Congratulations. Now feed the other end of the coax to the radio, again being careful not to twist or kink the cable.

C. Beam Antennas

Another type of antenna is a multi-element beam antenna. This antenna has several advantages over the long wire antenna. These are listed below.

1. The beam antenna has more gain. That is, it directs the HF radiowave in a more focused pattern, thus sending the same energy farther. For a given link distance, the beam antenna would make the link operate better and more reliably than a long wire antenna.
2. The beam antenna is more compact than a long wire antenna and requires only one mast, making erection easier and less expensive. Because the beam antenna takes up less physical space, it can be mounted in locations unsuitable for long wire antennas.
3. The beam antenna has very little gain in the back lobe direction. Thus, less interference can couple into the radio from the back side. This is especially important in the arctic, where many HF radio signals come from countries over the pole.

A slight disadvantage of beam antennas is that they need to be aimed upward so that the radio energy will reflect and bounce back down to earth at the correct distance away. The angle for an 800 km link is about 20° above the horizon. Long wire antennas do not have this problem because they radiate energy at all elevation angles.

VI. RECOMMENDATIONS

We recommend that the SRS radio transceivers be set up for data communication in Greenland using the Packet data format. The link will not be 100% reliable, but can handle the bulk of data communications that are not of extremely critical time dependence. The frequencies that worked best between Fairbanks and Barrow were between 6.8 and 8.0 MHz. We recommend that the radios be installed and frequencies in this range, and in the neighboring ranges, be tried on a temporary basis. Once it has been determined which frequencies will work in Greenland, then we recommend that a license be obtained for those frequencies from the responsible authorities. Further recommendations to improve radio communications operation and reliability are given below.

A. Frequency Selection

Frequency selection for the Sondrestromfjord-to-GISP2 link may be drawn from the IONCAP predictions. It is recommended that 15 frequencies be made available to cover the band from 3.8 MHz to 9.0 MHz. This coverage is expected to be adequate through the summer of 1994.

B. Beam Antenna

A beam antenna is recommended to alleviate the hindrance of back lobe interference. Such an antenna installation must be capable of:

1. Coverage in the band of 3.8 MHz to 9.0 MHz.
2. Matching the 50 ohm Transceiver RF port impedance.
3. Radiating 100 watts nominal power.
4. Possess a high Front-to-Back ratio.

C. Lightning Protection

The need for lightning protection must be considered. Do the weather conditions in Greenland require lightning protection? Just one strike can reduce a $14,000 rig to ashes. For further information see the ARRL Handbook mentioned in the references.

D. Network Installation

For best results it is recommended these particular settings be used in the SRS operating program's SR-812 Network Installation Routine:

In the Main Menu:

B) Toggle Monitor / Conversation Default – Conversation.

F) Toggle Adaptive HF / Manual Freq Default – Adaptive HF.

I) Change Default packet length – 080 characters .

N) Select Packet Mode Carrier Detect – Phase Locked Loop.

O) Select Packet Mode Connect Level – Reduced Power.

P) Collision Avoidance On / Off – Off.

In Menu #2:

E) Change # of Re-connect Attempts – 10.

H) HF Transceiver – Present.

VII. REFERENCES

Scientific Radio Systems, Inc. OPERATOR-MAINTENANCE INSTRUCTION MANUAL/ TM-0812-2 JUNE 1991 SR-812 DATA RADIO SYSTEM. Rochester, NY.

Scientific Radio Systems, Inc. OPERATOR-MAINTENANCE INSTRUCTION MANUAL/TM-0370, May 1990. HF SSB TRANSCEIVER. Rochester, NY

Teters, L. R. *et al.* Estimating the Performance of Telecommunication Systems Using the Ionospheric Transmission Channel - Ionospheric Communications Analysis and Prediction Program User's Manual. U. S. Department of Commerce. Washington D.C. 1983. NTIS PB84-111210.

These are the instructions on how to read the IONCAP predictions.

American Radio Relay League. *The ARRL Handbook for Radio Amateurs.* 69th ed. The League. Newington CT. 1991. (This is an excellent all around source for anybody using radios. Highly recommended.)

APPENDIX A

HOW TO READ IONCAP PREDICTIONS

IONCAP produces a very thorough output file. An explanation of the many variables is included on the following page. Optimum frequency is tabulated on the IONCAP output file.

HOW TO READ THE IONCAP PREDICTIONS

```
                        METHOD 23    IONCAP PC.26    PAGE    8

        JUN    1992            SSN = 121.
FAIRBARR                                     AZIMUTHS           N. MI.      KM
64.83 N  147.80 W - 71.27 N  156.80 W    336.54  148.18       435.2     805.9
ITSA 1 Antenna Package         MINIMUM ANGLE    2.0 DEGREES
XMTR    2.0   TO   30.0   HORZ. DIPOLE H    10.50 L    -.50 A    .0  OFF AZ      .0
RCVR    2.0   TO   30.0   HORZ. DIPOLE H    10.50 L    -.50 A    .0  OFF AZ      .0
POWER =     .100 KW   3 MHZ NOISE = -144.7 DBW    REQ. REL = .90  REQ. SNR = 44.8
MULTIPATH POWER TOLERANCE = 10.0 DB   MULTIPATH DELAY TOLERANCE =   .300 MS
```

REQUIRED RELIABILITY (→ REQ. REL = .90)

REQUIRED SIGNAL-TO-NOISE RATIO IN DECIBELS (→ REQ. SNR = 44.8)

UNIVERSAL TIME (→ UT)

MAXIMUM USABLE FREQUENCY (MHz) (→ MUF)

OPTIMUM FREQUENCY (MHz) (→ 5.6)

RELIABILITY = THE PROBABILITY THAT THE SNR EXCEEDS THE REQ. SNR (→ REL)

UT	MUF												
9.0	7.5	5.6	2.0	3.0	5.0	8.0	11.0	14.0	17.0	21.0	25.0	30.0	FREQ
	.66	.63	.00	.15	.57	.63	.26	.21	.05	.00	.00	.00	REL
	.00	.00	.00	.04	.26	.00	.18	.00	.00	.00	.00	.00	MPROB
	.31	.30	.07	.15	.28	.30	.15	.12	.05	.00	.01	.01	S PRB

THE PROBABILITY THAT THE REQUIRED RELIABILITY WILL BE MET (→ .31)

THE PROBABILITY OF AN ADDITIONAL MODE WITHIN THE MULTIPATH TOLERANCE (→ MPROB)

APPENDIX B

DX DOCUMENTATION AND PREDICTIONS

The following outputs from the DX program show the LUF and MUF referenced to universal time for the specific location of Fairbanks and Barrow, Alaska, on the day of 3 June 1992. The solar flux was entered as 118 solar flux units. It is apparent that LUF and MUF follow a diurnal variation and the frequencies used over the course of the day must cover the range of 3.8 to 9 MHz, as outlined in the recommendations.

```
==========================================================================
Ver 4.2                 DX -- SIGNAL TO NOISE (dB/10)              (c) 1990
==========================================================================
Date: 3 JUN 1992   JULIAN day: 155       Flux: 118      SSN: 69
FAIRBANKS Location                       BARROW Location
Latitude: 64.8333  Longitude: 147.8333   Latitude: 71.2667   Longitude:
 156.8333
Beam heading: 337 degrees                Beam heading: 148 degrees
(Megahertz)   LOCAL   FREQUENCY          Distance: 805 Km
LUF     MUF   TIME        5    10   15   20   25   30   35   40   45   50
===========   ====   |====|====|====|====|====|====|====|====|====|====|
 2.4    6.8    0     | ------
 2.1    6.3    1     | ---0-
 1.9    5.5    2     | ----
 2.0    5.8    3     | -----
 2.4    6.5    4     | -----
 2.8    7.0    5     |  -----
 3.3    7.4    6     |  -----
 3.9    7.7    7     |   -----
 4.4    8.1    8     |   -----
 4.9    8.4    9     |    ----
 5.2    8.6    10    |    -----
 5.5    8.9    11    |     ----
 5.8    9.0    12    |     ----
 5.9    9.2    13    |     ----
 6.0    9.2    14    |     ----
 5.9    9.2    15    |     ----
 5.8    9.1    16    |     ----
 5.6    8.9    17    |     ----
 5.3    8.7    18    |    -----
 4.9    8.5    19    |    ----
 4.5    8.2    20    |   -----
 4.0    7.9    21    |   -----
 3.4    7.6    22    |  ------
 2.9    7.3    23    |  -----
                     |====|====|====|====|====|====|====|====|====|====|
                          5    10   15   20   25   30   35   40   45   50
```

```
========================================================================
Ver 4.2                DX -- DIURNAL MINIMUF/QLOF                (c) 1990
========================================================================
Date: 3 JUN 1992    JULIAN day: 155       Flux: 118      SSN: 69
FAIRBANKS Location                        BARROW AK Location
Latitude: 64.8333   Longitude: 147.8333   Latitude: 71.2667   Longitude:
 156.8333
Beam heading: 337 degrees                 Beam heading: 148 degrees
(Megahertz)    LOCAL   FREQUENCY          Distance: 805 Km
LUF     MUF    TIME        5    10   15   20   25   30   35   40   45   50
==========     ====   |====|====|====|====|====|====|====|====|====|====|
 2.4    6.8     0     | -     |
 2.1    6.3     1     | -    |
 1.9    5.5     2     | -   |
 2.0    5.8     3     | -    |
 2.4    6.5     4     | -    |
 2.8    7.0     5     |  -    |
 3.3    7.4     6     |  -    |
 3.9    7.7     7     |   -    |
 4.4    8.1     8     |   -    |
 4.9    8.4     9     |    -   |
 5.2    8.6     10    |    -    |
 5.5    8.9     11    |     -   |
 5.8    9.0     12    |     -   |
 5.9    9.2     13    |     -   |
 6.0    9.2     14    |     -   |
 5.9    9.2     15    |     -   |
 5.8    9.1     16    |     -   |
 5.6    8.9     17    |     -   |
 5.3    8.7     18    |    -    |
 4.9    8.5     19    |    -   |
 4.5    8.2     20    |   -    |
 4.0    7.9     21    |   -    |
 3.4    7.6     22    |  -     |
 2.9    7.3     23    |  -    |
                      |====|====|====|====|====|====|====|====|====|====|
                           5    10   15   20   25   30   35   40   45   50
```