SAND2015-8056R

I55US REVALIDATION MANUAL

Prepared for
The Preparatory Commission For The
Comprehensive Nuclear Test Ban Treaty Organization
Provisional Technical Secretariat
International Monitoring System Division
April 2015

Nuclear Treaty Programs
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United States of America
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1 General Station Information

1.1 Station Name and Code, Station Operator, Geographical Coordinates

Station Name/Code: Windless Bight Array, I55US

Administrative and Maintenance Contact

Dr. Curt A. L. Szuberla
Wilson Infrasound Observatories
Geophysical Institute - UAF
903 Koyukuk Drive - Rm 506F
Fairbanks AK 99775-7320
Phone: (907) 474-7347
Fax: (907) 474-7290
Email: cas@gi.alaska.edu

Station Operator Contact Information:

Mr. Jay Helmericks
Wilson Infrasound Observatories
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Fairbanks, AK 99775-7320
United States of America
Phone: (907) 474-6549
Fax: (907) 474-7290
Email: jayh@gi.alaska.edu

Station Coordinates:

Sensor	Latitude (degrees)	Longitude (degrees)	Elevation	Dnorth (km)	Deast (km)
I55H1	-77.71643	167.65042	45.00m	0.000	0.000
I55H2	-77.72960	167.67447	39.14m	-1.471	0.569
I55H3	-77.74163	167.63304	39.05m	-2.812	-0.415
I55H4	-77.73270	167.58291	41.69m	-1.815	-1.604
I55H5	-77.72014	167.57296	42.57m	-0.414	-1.840
I55H6	-77.72641	167.60366	42.91m	-1.113	-1.111
I55H7	-77.72996	167.60324	41.81m	-1.509	-1.121
I55H8	-77.72828	167.58953	42.13m	-1.322	-1.447

1.2 Land Ownership

By means of the Antarctic Treaty, which all announced claimants have signed and ratified, no claims to territorial sovereignty shall be asserted while the Treaty is in force. The Treaty, which has been signed by 44 countries (May 2000), reserves the area south of 60 degrees south a zone for peaceful conduct of research. The Treaty nations coordinate and cooperate to maximize research results and logistics requirements. Scientific observations including the data stream from I55US and all CTBT Antarctic data is required by the Treaty to "be exchanged and made freely available". The complete text of the treaty is included as Attachment 1-A.

In addition to the Treaty, and important to all US activities in Antarctica, is the Presidential Memorandum 6646. The memorandum empowers the US National Science foundation with the authority and responsibility for all US activities in Antarctica.. The memorandum is included as Attachment 1-B. A "Memorandum of Agreement Between the U.S. Department of Defense and the U.S. National Science Foundation, Office of Polar Programs" provides for all "CTBT U.S. IMS station activities conducted in Antarctica. The Memorandum of Agreement is included as Attachment 1-C. An environmental impact study was completed by the National Science Foundation showing that the installation of the Windless Bight array would have no impact on the Antarctic environment. This study is included as Attachment 1-D.

These three documents provide the permissions for the use of all land, ice shelf, facilities and structures used by I55US.

1.3 Equipment Title and Warranty

All equipment at I55US is owned by the United States government and is assigned to University of Alaska for use at I55US. All of the equipment at I55US was installed in either 2012 or 2013 and is no longer under warranty.

Attachment 1-A
The Antarctic Treaty

The Antarctic Treaty

The 12 nations listed in the preamble (below) signed the Antarctic Treaty on 1 December 1959 in Washington, D.C. The treaty entered into force on 23 June 1961; the 12 signatories became the original 12 consultative nations.

As of mid-2000, 15 additional nations (Brazil, Bulgaria, China, Ecuador, Finland, Germany, India, Italy, Netherlands, Peru, Poland, Republic of Korea, Spain, Sweden, and Uruguay) have achieved consultative status by acceding to the treaty, and by conducting substantial scientific research in Antarctica. Russia carries forward the signatory privileges and responsibilities established by the former Soviet Union.

Another 17 nations have acceded to the Antarctic Treaty: Austria, Canada, Colombia, Cuba, Czech Republic, Democratic Peoples Republic of Korea, Denmark, Greece, Guatemala, Hungary, Papua New Guinea, Romania, Slovak Republic, Switzerland, Turkey, Ukraine and Venezuela. These nations agree to abide by the treaty and may attend consultative meetings as observers.

The 44 Antarctic Treaty nations represent about two-thirds of the world's human population.

Consultative meetings have been held approximately every other year since the treaty entered into force, but since 1993 they typically have been held annually. Each meeting has generated recommendations regarding operation of the treaty that, when ratified by the participating governments, become binding on the parties to the treaty.

Additional meetings within the Antarctic Treaty system have produced agreements on conservation of seals, conservation of living resources, and comprehensive environmental protection.

What follows is the complete text of the Antarctic Treaty. The headings for each article were added by the National Science Foundation and are unofficial.

[Preamble]

The Governments of Argentina, Australia, Belgium, Chile, the French Republic, Japan, New Zealand, Norway, the Union of South Africa, The Union of Soviet Socialist Republics, the United Kingdom of Great Britain and Northern Ireland, and the United States of America.

Recognizing that it is in the interest of all mankind that Antarctica shall continue forever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord;

Acknowledging the substantial contributions to scientific knowledge resulting from international cooperation in scientific investigation in Antarctica;

Convinced that the establishment of a firm foundation for the continuation and development of such cooperation on the basis of freedom of scientific investigation in Antarctica as applied during the International Geophysical Year accords with the interests of science and the progress of all mankind;

Convinced also that a treaty ensuring the use of Antarctica for peaceful purposes only and the continuance of international harmony in Antarctica will further the purposes and principles embodied in the Charter of the United Nations;

Have agreed as follows:

Article I
[Antarctica for peaceful purposes only]

1. Antarctica shall be used for peaceful purposes only. There shall be prohibited, inter alia, any measures of a military nature, such as the establishment of military bases and fortifications, the carrying out of military maneuvers, as well as the testing of any type of weapons.
2. The present treaty shall not prevent the use of military personnel or equipment for scientific research or for any other peaceful purposes.

Article II
[freedom of scientific investigation to continue]

Freedom of scientific investigation in Antarctica and cooperation toward that end, as applied during the International Geophysical Year, shall continue, subject to the provisions of the present Treaty.

Article III
[plans and results to be exchanged]

1. In order to promote international cooperation in scientific investigation in Antarctica, as provided for in Article 11 of the present Treaty, the Contracting Parties agree that, to the greatest extent feasible and practicable:
   (a) information regarding plans for scientific programs in Antarctica shall be exchanged to permit maximum economy and efficiency of operations;
   (b) scientific personnel shall be exchanged in Antarctica between expeditions and stations;
   (c) scientific observations and results from Antarctica shall be exchanged and made freely available.
2. In implementing this Article, every encouragement shall be given to the establishment of cooperative working relations with those Specialized Agencies of the United Nations and other international organizations having a scientific or technical interest in Antarctica.

Article IV
[territorial claims]

1. Nothing contained in the present Treaty shall be interpreted as:
   (a) a renunciation by any Contracting Party of previously asserted rights of or claims to territorial sovereignty in Antarctica;
   (b) a renunciation or diminution by any Contracting Party of any basis of claim to territorial sovereignty in Antarctica which it may have whether as a result of its activities or those of its nationals in Antarctica, or otherwise;
2. No acts or activities taking place while the present Treaty is in force shall constitute a basis for asserting, supporting or denying a claim to territorial sovereignty in Antarctica. No new claim, or enlargement of an existing claim, to territorial sovereignty shall be asserted while the present Treaty is in force.

Article V
[nuclear explosions prohibited]

1. Any nuclear explosions in Antarctica and the disposal there of radioactive waste materials shall be prohibited.
2. In the event of the conclusion of international agreements concerning the use of nuclear energy, including nuclear explosions and the disposal of radioactive waste material, to which all of the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX are parties, the rules established under such agreements shall apply in Antarctica.

Article VI
[area covered by Treaty]

The provisions of the present Treaty shall apply to the area south of 60° South latitude, including all ice shelves, but nothing in the present Treaty shall prejudice or in any way affect the rights, or the exercise of the rights, of any State under international law with regard to the high seas within that area.

Article VII
[free access for observation and inspection]

1. In order to promote the objectives and ensure the observation of the provisions of the present Treaty, each Contracting Party whose representatives are entitled to participate in the meetings referred to in Article IX of the Treaty shall have the right to designate observers to carry out any inspection provided for by the present Article. Observers shall be nationals of the Contracting Parties which designate them. The names of the observers shall be communicated to every other Contracting Party having the right to designate observers, and like notice shall be given of the termination of their appointment.
2. Each observer designated in accordance with the provisions of paragraph 1 of this Article shall have complete freedom of access at any time to any or all areas of Antarctica.
3. All areas of Antarctica, including all stations, installations and equipment within those areas, and all ships and aircraft at points of discharging or embarking cargoes or

personnel in Antarctica, shall be open at all times to inspection by any observers designated in accordance with paragraph 1 of this Article.

4. Aerial observation may be carried out at any time over any or all areas of Antarctica by any of the Contracting Parties having the right to designate observers.
5. Each Contracting Party shall, at the time when the present Treaty enters into force for it, inform the other Contracting Parties, and thereafter shall give them notice in advance, of
   (a) all expeditions to and within Antarctica, on the part of its ships of nationals, and all expeditions to Antarctica organized in or proceeding from its territory;
   (b) all stations in Antarctica occupied by its nationals; and
   (c) any military personnel or equipment intended to be introduced by it into Antarctica subject to the conditions prescribed in paragraph 2 of Article I of the present Treaty.

Article VIII
[personnel under jurisdiction of their own states]

1. In order to facilitate the exercise of their functions under the present Treaty, and without prejudice to the respective positions of the Contracting Parties relating to jurisdiction over all other persons in Antarctica, observers designated under paragraph 1 of Article VII and scientific personnel exchanged under subparagraph 1(b) of Article III of the Treaty, and members of the staffs accompanying any such persons, shall be subject only to the jurisdiction of the Contracting Party of which they are nationals in respect to all acts or omissions occurring while they are in Antarctica for the purpose of exercising their functions.
2. Without prejudice to the provisions of paragraph 1 of this Article, and pending the adoption of measures in pursuance of subparagraph 1(e) of Article IX, the Contracting Parties concerned in any case of dispute with regard to the exercise of jurisdiction in Antarctica shall immediately consult together with a view to reaching a mutually acceptable solution.

Article IX
[Treaty states to meet periodically]

1. Representatives of the Contracting Parties named in the preamble to the present Treaty shall meet at the city of Canberra within two months after date of entry into force of the Treaty, and thereafter at suitable intervals and places, for the purpose of exchanging information, consulting together on matters of common interest pertaining to Antarctica,and formulating and considering, and recommending to their Governments, measures in furtherance of the principles and objectives of the Treaty including measures regarding:
   (a) use of Antarctica for peaceful purposes only;
   (b) facilitation of scientific research in Antarctica;
   (c) facilitation of international scientific cooperation in Antarctica;
   (d) facilitation of the exercise of the rights of inspection provided for in article VII of the Treaty;
   (e) questions relating to the exercise of jurisdiction in Antarctica;
   (f) preservation and conservation of living resources in Antarctica.
2. Each Contracting Party which has become a party to the present Treaty by accession under Article XIII shall be entitled to appoint representatives to participate in the meetings referred to in paragraph 1 of the present Article, during such time as the Contracting Party demonstrates its interest in Antarctica by conducting substantial scientific research activity there, such as the establishment of a scientific station or the dispatch of a scientific expedition.
3. Reports from the observers referred to in Article VII of the present Treaty shall be transmitted to the representatives of the Contracting Parties participating in the meetings referred to in paragraph 1 of the present Article.
4. The measures referred to in paragraph 1 of this Article shall become effective when approved by all the Contracting Parties whose representatives were entitled to participate in the meetings held to consider those measures.
5. Any or all of the rights established in the present Treaty may be exercised as from the date of entry into force of the Treaty whether or not any measures facilitating the exercise of such rights have been proposed, considered or approved as provided in this Article.

Article X
[discourages activities contrary to Treaty]

Each of the Contracting Parties undertakes to exert appropriate efforts, consistent with the Charter of the United Nations, to the end that no one engages in any activity in Antarctica contrary to the principles or purposes of the present Treaty.

Article XI
[settlement of disputes]

If any dispute arises between two or more of the Contracting Parties concerning the interpretation or application of the present Treaty, those Contracting Parties shall consult among themselves with a view to having the dispute resolved by negotiation, inquiry, mediation, conciliation, arbitration, judicial settlement or other peaceful means of their own choice.

Any dispute of this character not so resolved shall, with the consent, in each case, of all parties to the dispute, be referred to the International Court of Justice for settlement; but failure to reach agreement on reference to the International Court shall not absolve parties to the dispute from the responsibility of continuing to seek to resolve it by any of the various peaceful means referred to in paragraph 1 of this Article.

Article XII
[review of Treaty possible after 30 years]

1. (a) The present Treaty may be modified or amended at any time by unanimous agreement of the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX. Any such modification or amendment shall enter into force when the depositary Government has received notice from all such Contracting Parties that they have ratified it.
   (b) Such modification or amendment shall thereafter enter into force as to any other Contracting Party when notice of ratification by it has been received by the depositary Government. Any such Contracting Party from which no notice of ratification is received within a period of two years from the date of entry into force of the modification or amendment in accordance with the provision of subparagraph 1(a) of this Article shall be deemed to have withdrawn from the present Treaty on the date of the expiration of such period.
2. (a) If after the expiration of thirty years from the date of entry into force of the present Treaty, any of the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX so requests by a communication addressed to the depositary Government, a Conference of all the Contracting Parties shall be held as soon as practicable to review the operation of the Treaty.
   (b) Any modification or amendment to the present Treaty which is approved at such a Conference by a majority of the Contracting Parties there represented, including a majority of those whose representatives are entitled to participate in the meetings provided for under Article IX, shall be communicated by the depositary Government to all the Contracting Parties immediately after the termination of the Conference and shall enter into force in accordance with the provisions of paragraph 1 of the present Article.
   (c) If any such modification or amendment has not entered into force in accordance with the provisions of subparagraph 1(a) of this Article within a period of two years after the date of its communication to all the Contracting Parties, any Contracting Party may at any time after the expiration of that period give notice to the depositary Government of its withdrawal from the present treaty; and such withdrawal shall take effect two years after the receipt of the notice by the depositary Government.

Article XIII
[ratification and accession]

1. The present Treaty shall be subject to ratification by the signatory States. It shall be open for accession by any State which is a Member of the United Nations, or by any other State which

may be invited to accede to the Treaty with the consent of all the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX of the Treaty.

2. Ratification of or accession to the present Treaty shall be effected by each State in accordance with its constitutional processes.
3. Instruments of ratification and instruments of accession shall be deposited with the Government of the United States of America, hereby designated as the depositary Government.
4. The depositary Government shall inform all signatory and acceding States of the date of each deposit of an instrument of ratification or accession, and the date of entry into force of the Treaty and of any modification or amendment thereto.
5. Upon the deposit of instruments of ratification by all the signatory States, the present Treaty shall enter into force for those States and for States which have deposited instruments of accession. Thereafter the Treaty shall enter into force for any acceding State upon the deposit of its instrument of accession.
6. The present Treaty shall be registered by the depositary Government pursuant to Article 102 of the Charter of the United Nations.

Article XIV
[United States is repository]

The present Treaty, done in the English, French, Russian, and Spanish languages, each version being equally authentic, shall be deposited in the archives of the Government of the United States of America, which shall transit duly certified copies thereof to the Governments of the signatory and acceding States. In witness whereof, the undersigned Plenipo-tentiaries, duly authorized, have signed the present Treaty. Done at Washington the first day of December, one thousand nine hundred and fifty-nine.

For Argentina:
Adolfo Seilingo
F. Bello

For Australia:
Howard Beale

For Belgium:
Obert de Thieusies

For Chile:
Martial Mora M.
L. Gajardo V.
Julio Fscudero

For the French Republic:
Pierre Charpentier

For Japan:
Koichiro Asakai
T. Shimoda

For New Zealand:
G.D.L. White

For Norway:
Paul Koht

For the Union of South Africa:
Wentzel C. du Plessis

For the Union of Soviet Socialist Republics:
V. Kuznetsov

For the United Kingdom of Great Britain and Northern Ireland:
Harold Caccia

For the United States America:
Herman Phleger
Paul C. Daniels

Attachment 1-B
Presidential Memorandum 6646

Memorandum 6646
The White House
Washington

For:
- Secretary of the State
- Secretary of the Treasury
- Secretary of Defense
- Secretary of the Interior
- Secretary of Commerce
- Secretary of Transportation
- Secretary of Energy
- Director, Office of Management and Budget
- Director of Central Intelligence
- Chairman, Joint Chiefs of Staff
- Director, Arms Control and Disarmament Agency
- Director, Office of Science and Technology Policy
- Administrator, Environmental Protection Agency
- Director, National Science Foundation

Presidential Memorandum Regarding Antarctica, February 5, 1982

Subject: United States Antarctic Policy and Programs

I have reviewed the Antarctic Policy Group's study of United States interests in Antarctica and related policy and program considerations, as forwarded by the Department of State on November 13, 1981, and have decided that:

- The United States Antarctic Program shall be maintained at a level providing an active and influential presence in Antarctica designed to support the range of U.S. Antarctic interests.
- This presence shall include the conduct of scientific activities in major disciplines; year-round occupation of the South Pole and two coastal stations; and availability of related necessary logistics support.
- Every effort shall be made to manage the program in a manner that maximizes cost effectiveness and return on investment.
- I have also decided that the National Science Foundation shall continue to:
- budget for and manage the entire United States national program in Antarctica, including logistic support activities so that the program may be managed as a single package;
- fund university research and federal agency programs related to Antarctica;
- draw upon logistic support capabilities of government agencies on a cost reimbursable basis; and
- use commercial support and management facilities where these are determined to be cost effective and will not, in the view of the Group, be detrimental to the national interest.

Other agencies, may, however, fund and undertake directed short-term programs of scientific activity related to Antarctica upon the recommendation of the Antarctic Policy Group and subject to the budgetary review process. Such activities shall be coordinated within the framework of the National Science Foundation logistics support.

The expenditures and commitment of resources necessary to maintain an active and influential presence in Antarctica, including the scientific activities and stations in the Antarctic, shall be reviewed and determined as part of the normal budget process. To ensure that the United States Antarctic Program is not funded at the expense of other National Science Foundation programs, the OMB will provide specific budgetary guidance for the Antarctic program.

To ensure that the United States has the necessary flexibility and operational reach in the area, the Departments of Defense and Transportation shall continue to provide, on a reimbursable basis, the logistic support requested by the National Science Foundation and to develop, in collaboration with the Foundation, logistic arrangements and cost structure required for effective and responsive program support at minimum cost.

With respect to the upcoming negotiations on a regime covering Antarctic mineral resources, the Antarctic Policy Group shall prepare a detailed U.S. position and instructions. These should be forwarded for my consideration by May 15, 1982.

Ronald Reagan

Attachment 1-C
Memorandum Of Agreement

Memorandum of Agreement

Between the

U.S. Department of Defense

And the
National Science Foundation
Office of Polar Programs

Concerning Cooperation on Matters Pertaining to the
Comprehensive Nuclear Test Ban Treaty

Purpose: The purpose of this Agreement is to identify and affirm the roles and responsibilities of the Department of Defense (DoD) and the National Science Foundation (NSF) Office of Polar Programs (OPP) in certain matters related to the Comprehensive Nuclear Test Ban Treaty (CTBT) and to specify a cost-effective means of cooperation to enhance the effectiveness of each Party in carrying out their missions.

Background: The CTBT, signed by the United States on September 24, 1996, specifies various elements of a verification regime including an International Monitoring System (IMS). The CTBT IMS is a network of a Seismic, Radionuclide, Hydroacoustic, and Infrasound Stations. This includes 37 IMS stations and one radionuclide laboratory in specific locations for which the U.S. has responsibility. Six of the 37 U.S. IMS stations are located in areas of Antarctica for which the U.S. has responsibility (three seismic, two infrasound, and one radionuclide).

The DoD, in its national security role of ensuring compliance and monitoring of nuclear arms control treaties and monitoring foreign nuclear activity has a long-term program of support for planning, implementation, and executing provisions of the CTBT. The Secretary of Defense has assigned within the DoD the responsibility for management of the CTBT programs, in accordance with DoD Directive 2060.1 and presidential decisions, to the undersigned.

The NSF, has been tasked in Presidential Memorandum 6646 as the principal agency to manage the United States national program in Antarctica, including logistic support activities. The NSF, through the OPP, budgets and manages three year-round facilities on the continent, operates two ice-capable research vessels, and supports research at temporary field sites. The three year-round facilities managed by the NSF are McMurdo Station, Palmer Station, and the South Pole Station.

The NSF, through a cooperative effort between OPP and the Directorate for Geosciences/Division of Earth Sciences (EAR), has established and maintains seismic stations at Palmer Station and South Pole Station as part of a general use network of seismometers, the Global Seismographic Network (GSN). These stations, which are used by the scientific community, have been designated with the CTBT IMS as "U.S.

Auxiliary Seismic Stations". The Incorporated Research Institutions for Seismology (IRIS), through a Cooperative Agreement administered by NSF/EAR, and the U.S. Geological Survey (USGS) are the lead agencies responsible for the management of these instruments and for quality control and dissemination of the data they produce for research and earthquake monitoring.

Consistent with the Antarctic Treaty and NSF data policies, all data collected from national activities in the Antarctic are made openly available. Under the administration of NSF/EAR and the USGS, all seismic data from the U.S. IMS seismic stations in Antarctica are made available to the research community through IRIS.

The authority for this Agreement is the Economy Act, 31 USC Section 1535 and the National Science Foundation Act of 1950 (42 U.S.C. 1861 et seq.).

General Agreement

Installation and operation of U.S. CTBT IMS Stations in Antarctica

The stations for which the U.S. has responsibility to establish, maintain, and operate in Antarctica, as part of the CTBT, include:

Location	Station	Latitude	Longitude
Primary Seismic			
Vanda, Antarctic	PS-50	77.7	161.9 E
Auxiliary Seismic			
Palmer Station, Antarctica	AS-106	64.8 S	64.0 W
South Pole, Antarctica	AS-114	90.0 S	----------
Radionuclide			
Palmer Station, Antarctica	RN-73	64.7 S	64.1 W
Infrasound Stations			
Palmer Station, Antarctica	IS-54	64.8 S	64.0 W
Windless Bight, Antarctica	IS-55	77.5 S	161.8 E

DOD and NSF/OPP will cooperate on:

- the survey, installation and operation of the six above noted CTBT IMS stations in Antarctica for which the United States has responsibility;
- facilitating open access to data from these instruments;
- the preparation of any environmental assessments that may be required under the Antarctic Conservation Act of 1978 as amended by the Antarctic Science, Tourism, and Conservation Art of 1996; and
- facilitating access to these instruments that may be required by Parties performing inspections in accordance with the terms of the Antarctic Treaty.

Specifically, NSF/OPP will:

- cooperate with the DOD on all stations and coordinate with IRIS and the USGS on the auxiliary seismic stations in the installation of hardware and communications equipment, and any other modifications of the IMS stations that may be required to meet CTBT specifications;
- exercise control of the facilities while operating and maintaining the facilities in accordance with relevant CTBT Operations Manuals;
- notify the designated DoD point of contact of any problems encountered at the facilities relevant to CTBT implementation;
- submit to the DoD, on an annual basis, a budget for support required to maintain and operate the facilities in accordance with IMS specifications and operational reliability; and
- cooperate with the DoD and the, CTBT Organization authorities in the procedures for test and evaluation activities to certify the facilities as part of the IMS.

Specifically, DOD will:

- provide the required specialized CTBT technical equipment and Operations Manuals for the above listed facilities to meet the technical specifications of the Treaty or to perform modifications to the facilities to meet the CTBT IMS operational requirements;

- as necessary, facilitate the training of any NSF/OPP provided operational technicians and provide for the cost of such training;

- provide for the costs of data communications for CTBT purposes and any CTBT required upgrades;

- provide reimbursement to NSF/OPP for the applicable annual operation and maintenance of the IMS facilities and any infrastructure upgrades, as approved in advance by DoD, that are required to bring the facilities to CTBT specifications and operational reliability. Any reimbursement shall be limited to those requirements as agreed to in advance and in writing, and shall be subject to the availability of annual appropriations therefore;

- provide budgetary support for the cost required for management of the facilities for CTBT purposes; and

- notify NSF/OPP of all upgrade requirements and keep NSF/OPP informed on the relevant CTBT Operations Manuals and any changes that we made to these manuals;

- ensure IMS data from the facilities is transmitted to the CTBT International Data Center (IDC). in accordance with IMS station specifications, the IDC Operational Manual, and the CTBT Global Communications Infrastructure specifications; and

- work with the CTBT Organization to specify the appropriate procedures and testing to certify the facilities a, part of the IMS, and then certify the stations through these procedures and testing;

- make available all data collected at the U.S. IMS stations in Antarctica to the NSF, in accordance with the Antarctic Treaty and NSF data policies.

For planning purposes, the DoD and NSF/OPP agree that we will make best efforts to achieve operational certification by the end of FY03 within the context of this agreement.

Implementing Arrangements:

The Director of the National Science Foundation Office of Polar Programs, and the Deputy Assistant to the Secretary of Defense for Nuclear Treaty Programs (CTBT Treaty Manager), for the DoD, are the responsible executives for implementing this Agreement. If a disagreement arises on funding requirements for this Agreernent, the issue will be submitted to the signatories to this Agreement for adjudication.

This Agreement is the over-arching Agreement for all CTBT U.S. IMS station activities conducted in Antarctica. In order to carry out this Agreement it may be necessary to develop additional detailed implementing arrangements between the NSF/OPP and those components acting on behalf of DoD and/or NSF, including the Air Force Technical Applications Center (AFTAC), the University of Mississippi, the U.S. Geological Survey (USGS), and Incorporated Research Institution of Seismology (IRIS). Those separate Arrangement(s) will provide for the statement of work and budget, and will reference this Agreement. All Parties agree that all funding for the provisions of this MOA will be provided by the DoD and that all obligations of funds by the U. S. Government wi11 be made by DoD contract or a successor contract designated by the DoD Executive. Further, both Parties agree that such obligations an subject to the availability of funds and authorization therefor.

All efforts on the part of NSF/OPP will be subject to DoD/NSF mutually agreed upon schedules and cost reimbursement and will be further subject to available resources. Due to the remoteness of the Antarctic and the consequent need for advance planning, any changes, upgrades or new additions must be reviewed and approved at least one year prior to initiation of actual installation/implementation.

Both Parties, in signing this Agreement, acknowledge that each is responsible for the integrity of its own data. This Agreement will enter into force upon the signatures of both parties and will remain in force as long as the United States remains a signatory to the CTBT. This Agreement will be reviewed every three years. Each party has the right to terminate this Agreement, upon written notice from one executive to the other, at least 180 days prior to the termination date. The termination notice will include a statement of the reasons for termination.

For the National Science Foundation

Karl A. Erb
Director
Office of Polar Programs

Date Jan 30, 2001

For the U.S. Department of Defense

Ralph W. Alewine, III
Deputy Assistant to the Secretary of Defense
Nuclear Treaty Programs

Date: 31 January 2001

William A. Bryant
Chief, Contracts Branch
Office of Budget, Finance and Award Management

Date: 1/30/01

Attachment 1-D
Windless Bight Environmental Impact Study

National Science Foundation
Office of Polar Programs
Arlington, Virginia

ENVIRONMENTAL DOCUMENT AND FINDING OF NO SIGNIFICANT AND NOT MORE THAN MINOR OR TRANSITORY ENVIRONMENTAL IMPACT

Installation and Operation of an Infrasonic Array at
Windless Bight near McMurdo Station, Antarctica

I. FINDING

The National Science Foundation (NSF) has prepared an Initial Environmental Evaluation (IEE) and an Environmental Assessment (EA) as a combined environmental document, for the installation and operation of an infrasonic array at Windless Bight, Antarctica. Based on the analyses in the environmental document (IEE/EA), the NSF Office of Polar Programs (OPP) has determined that implementation of Alternative A is not a major federal action which would have a significant effect on the human environment, within the meaning of the National Environmental Policy Act (NEPA) of 1969. The action is not one which would have more than a minor or transitory effect on the antarctic environment, within the meaning of the NSF's implementing regulations for the Protocol on Environmental Protection to the Antarctic Treaty. Therefore, an environmental impact statement and/or a comprehensive environmental evaluation will not be prepared.

The selected alternative, A, provides for data collection as required by the Comprehensive Nuclear Test Ban Treaty and is consistent with the NSF's efforts to promote scientific investigations, and support the United State's treaty obligations, while protecting the antarctic environment. When the array at Windless Bight is no longer needed, or when it reaches the end of its lifetime, the array will be dismantled and removed from Antarctica.

/s/ Erick Chiang	10/27/00
Erick Chiang Head, Polar Research Support Section	Date

II. PURPOSE AND NEED FOR THE PROPOSED ACTION

The NSF proposes to install an Infrasonic Array at Windless Bight, 27 km northeast of McMurdo Station at approximately 77.7454^{o} S, 167.5876^{o} E. Installation of this array at Windless Bight meets United States obligations under the Comprehensive Nuclear-Test-Ban Treaty (CTBT).

The Windless Bight Array is one of the most important infrasound stations in the entire CTBT set of stations due to its low background noise and its role covering the Southern Ocean, an area where suitable locations for arrays are difficult to access. The infrasound structures require minimal ambient atmospheric pressure fluctuations. Unusually low wind levels at Windless Bight, coupled with the desirable location for an array (in Antarctica and close to existing infrastructure), make the Windless Bight location ideal for the re-install of the test array. The eight sensors proposed for installation provide the additional sensitivity requested by the Preparatory Commission of the CTBT Organization (CTBTO). A past experiment at Windless Bight was abandoned in 1985 and there is currently no array installed at Windless Bight. However, operation of an array at this important site for data collection is required by the CTBT under treaty agreements, and new funding has been secured to install the experiment.

Windless Bight is the only location considered in this document for the reinstall of the test array because it has been a proven location in the past, and the CTBTO has designated this specific area as a treaty requirement.

The installation is similar to the array which was attempted in 1985 but with equipment which meets data requirements set by the CTBTO. The new system will allow for digitized data collection, which is preprocessed according to CTBTO specifications, and digital, near real-time telemetry. Further, sensor redundancy as planned in the installation, necessary under the harsh and difficult conditions of Antarctica, is an improvement over the past experiment and will ensure the experiment meets CTBTO requirements for 98% data collection.

Issues which have been identified related to the proposed action include:
- Interference with other projects;
- Releases to the environment;
- Deployment of scientific equipment for the long-term; and
- Long-term and cumulative effects.

III. ALTERNATIVES

<u>Alternative A. Install and Operate an Infrasonic Array at Windless Bight</u>.

The array at Windless Bight will be used to collect time series data on atmospheric pressure fluctuations. The project will require the deployment of eight infrasound sensor-digitizers and radio frequency (RF) telemetry transceivers in enclosures in an arrangement centered around a power system, as outlined in Attachment 1. Enclosures made of wood will contain electronics at each of the eight sites and will be about one meter cubed in size, or 41” x 30” x 20”. The eight sensor RF towers at Windless Bight will be 20 to 25 feet tall. One (ski mounted) hybrid solar/diesel generator power system will also be deployed to Windless Bight to meet power requirements. A 0.8 to 1-km long power cable will be laid across the snow from the power supply to each sensor vault. The power cables will become entombed in the snow/glacial ice of the Ross ice shelf, and new power cables may have to be laid on the snow every 10 to 15 years. The power system has a meteorological subsystem with a telemetry mast and antenna. There is also a separate meteorological system located adjacent to the power system. This meteorological station will also transmit telemetry.

The power supply will be annually raised up onto a new snow surface to avoid burial by accumulated snow. The eight sensor vaults or enclosures will be annually or semi-annually raised above the snow and reinstalled. At each sensor site there will be an acoustical noise reducing pipe array, it will also be raised up at the same time as the enclosure. A telemetry mast and antenna located at each sensor enclosure will be extended and the antennas raised with the enclosure. New guy lines and anchors will be installed as needed. The power supply has a 500 US gallon tank and will consume about 319 gallons of JP8 per year. The power supply also uses a bank of valve regulated lead acid batteries and lubricating oils.

Radio relay equipment, including a telemetry-receiving site which sees Windless Bight, will be added to the area near Crater Hill at the McMurdo TDRS Relay System II (MTRS II) facility, for data. Relay equipment will include two towers approximately 50 feet tall, and one small building (approximately 8’ x 10’); however, if possible the existing structures at the site will be used. A communications hub will be installed at McMurdo station in a secure, locked room of about 160 square feet. Data will be received at the hub from the Crater Hill area via a new copper cable installed between the small CTBT shelter and the MTRS-II site. The distance of covered by the new cable will be less than 1 km.

After installation it is expected that two visits to Windless Bight will be required by a science technician each year for maintenance and calibration. The data will be automatically processed and forwarded to mainland USA. The design lifetime of the equipment is 15 years.

<u>Alternative B. No Action.</u>

In this case there would be no array installed at Windless Bight or receiving towers installed near Crater Hill. Data would not be collected for monitoring nuclear weapons testing and U.S treaty obligations would not be met.

IV. ENVIRONMENTAL EFFECTS AND MITIGATING MEASURES

1. Interference with other projects. To reduce or eliminate the potential of Alternative A to interfere with other projects, frequency selection and frequency hopping protocols will be coordinated with other McMurdo users following existing procedures for such coordination. Space at the MTRS II site and physical space for the communications hub, along with necessary technician support, will be coordinated with RPSC IT personnel and RPSC Science Support personnel. Alternative B would have no effects on other projects.

2. Releases to the environment. Alternative A poses some potential for environmental releases. There is potential for accidental release of power-related fluids including fuel, lubricating oils, and lead acid solution from batteries. Care will be taken during the installation and operation of the power supply to prevent releases from happening. Any spills will be cleaned up. Approximately 319 gallons/year of diesel fuel will be required to power the array, and subsequent air emissions from the diesel-powered generator will be released to the area at Windless Bight. Potential for spills will be minimized by containing the generator, batteries, and any oils or other fluids inside the generator shack. The fuel will be stored in double wall tanks that are placed in a catch pan for tertiary containment. The tanks and pan will be inside the ski mounted power supply shack. The generator will be maintained proactively (for example, seals checked and aged parts replaced before they fail) to reduce the chance of mechanical failure and associated environmental release during remote, unmonitored operation.

The area at Windless Bight is a snow accumulation zone and environmental release can occur when equipment becomes buried in snow and is abandoned. To mitigate this, equipment will be raised above the snow whenever feasible. The power supply will be annually raised up onto the snow surface to avoid burial by accumulated snow and to retain its usefulness. The eight sensor enclosures will be annually raised above the snow and reinstalled. At each sensor site there will be an acoustical noise reducing pipe array; it will also be raised up at the same time as the enclosure.

Equipment that will be released due to accumulated snow includes approximately 6 km of power cables, nine telemetry masts and antennas, and an unknown number of guy lines and anchors. A telemetry mast and antenna located at each enclosure will be extended annually, but will become more and more buried with time. Guy lines and anchors for each of the nine masts will also become buried and will need to be periodically replaced. Eight sections of 0.8 to 1 km long power cables will be run from the generator to each sensor enclosure and will become entombed in the snow/glacial ice of the Ross ice shelf. It is anticipated that the power cables will have to be abandoned every 10-15 years and new cables installed. Alternative B would result in no environmental release.

3. Deployment of scientific equipment for the long-term. The towers and associated equipment will remain at Windless Bight for the duration of the project. In the event that the project runs out of funding, changes in nature, or treaty obligations change, all equipment that can feasibly be will be removed from the area and from Antarctica. Any

equipment upgrades or changes will include complete removal of outdated equipment. Alternative B does not require the deployment of scientific equipment.

4. Long-term and cumulative effects. Long-term and cumulative effects for Alternative A include the persistent release of air emissions from diesel fuel, and the accumulation of science equipment and spills in the area. Long-term effects of environmental releases can be mitigated by reducing the amount of equipment that is left to be buried, and using care when working with fluids on site so that spills are prevented, and cleaned up if they do occur. Alternative B has no long-term or cumulative effects.

V. CONSULTATION WITH OTHERS

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VI. REFERENCES

Osborne, D.L., A Plan for Site Surveys, Installing and Operating Two Infrasonic Arrays in Antarctica, Draft Plan submitted to NSF/OPP, 13 August 1999.

Wilson C.R.et al, Site Survey at I55US Windless Bight, Antarctica. Prepared for Preparatory Commissions CTBTO, August 2000.

2 Site and Infrastructure

2.1 Site Survey Report

A GPS Differential Site Survey was done by a U.S. Antarctic Program (UASAP) contractor. Coordinates from the survey are shown in Figure 2.3.2.

2.2 Local Area Map

Topographic maps and photo maps as are shown in Figures 2.2.1 – 2.2.4 and a Radarsat image of Ross Island looking north in Figure 2.2.5. It is an oblique image composed of radar data and topographic relief data. Although a scale is indicated, it is only for general reference since no single scale is ever correct on an oblique image.

Travel to Antarctica is seasonal and normally available only during the short Antarctic summer. Windless Bight, located about 77.7S and 167.5 E, is immediately South of Ross Island on the Ross Ice Shelf. The Bight area is bounded on the North, East and West by Ross Island. It is a flat and featureless plane of hundreds of square kilometers at the northwest edge of the Ross Ice Shelf. The ice shelf itself is tens of thousands of square kilometers in area and generally also flat and featureless. No commercial transport service exists to Ross Island or its vicinity. The U.S. National Science Foundation's Office of Polar Programs supplies and controls almost all travel to or from Ross Island. The exceptions are New Zealand, and Antarctic tourist/cruise operators who sometimes visit Ross Island. New Zealand has a small research program on Ross Island; however, they also rely on the NSF for transport.

Travel to Windless Bight usually begins by approaching the NSF and requesting permission for travel to Antarctica. Once permission is granted, mandatory medical and fitness exams must be passed, and detailed plans developed for your support in Antarctica. Scheduling is subject to NSF's support of its own programs. Special safety equipment and clothing is issued and must be worn and carried on all flights and kept nearby at other times. NSF supported flights depart Christchurch, New Zealand and fly into either the Annual Sea Ice Runway on McMurdo Sound, or Willy Field or Pegasus Ice Field, snow runways on the Ross Ice shelf. These runways are near the NSF's McMurdo Station, NSF's main support base in Antarctica. All Antarctic travel using NSF supplied sources is controlled by NSF and subject to their extensive safety program. NSF provides all-terrain "shuttle bus" travel from the runways to central McMurdo. All travelers to I55US will be dependent on NSF for their support and travel in Antarctica. Visitors will stay at McMurdo Station's regular housing facilities (unless at the I55US station) and eat in their common dining facilities.

Once settled in McMurdo visitors will partake in NSF mandatory safety training and orientation/living training. You will be instructed in proper safe travel over the ice including an over-night ice/snow campout to practice your survival skills. You will be instructed in safe operating of the over-snow vehicles and road vehicles.

During your stay at McMurdo, you will be able to walk to the CRF location and visit it, as it is located in McMurdo proper. Transport around McMurdo is limited and most short distances are walked. However, transport can also be arranged through the "shuttle bus" service (it follows established routes and times) or the NSF "Taxi", (another shuttle bus that is on an "on call" routing). The CRF room is locked and arrangements must be made for your entry.

Travel to the sensor sites/elements is accomplished by arranging for checkout of a suitable over-the-snow vehicle and survival supplies. During most periods there will not be an established camp in Windless Bight, so you also must arrange for your camp. Your camp will be primitive and have only the bare necessaries. Normally at camp, you will serve your own needs (food, shelter, et cetera) and clean up after yourself. The travel time is such that although you may choose to return to McMurdo each day, most of your day would then be taken up in snow travel. The McMurdo-Scott Base Road is about three miles long and ends at the "Ice Transition", near Scott Base. Flagged trails lead to the various runways (travel on these trails is limited), and the Scott Base Ski Lodge (travel is limited). At the Ice Transition, all travelers are required to check out with NSF's operations control center via their radio and report in every 24 hours thereafter, until safely returned and checked back in. From a location on the Scott Base Ski Lodge Trail about 4 km from the transition, one turns towards I55US (stay on flagged and trail watch for crevasses). This trail to I55US is over about 19 km more snow and is flagged; however, it needs re-flagging at the start of each summer season. Although the trail is almost straight from the Ski Lodge to the central tower of I55US, GPS coordinates and redundant GPS units should be used to locate the central power supply (BOB) and the sensor sites (H1 to H8).

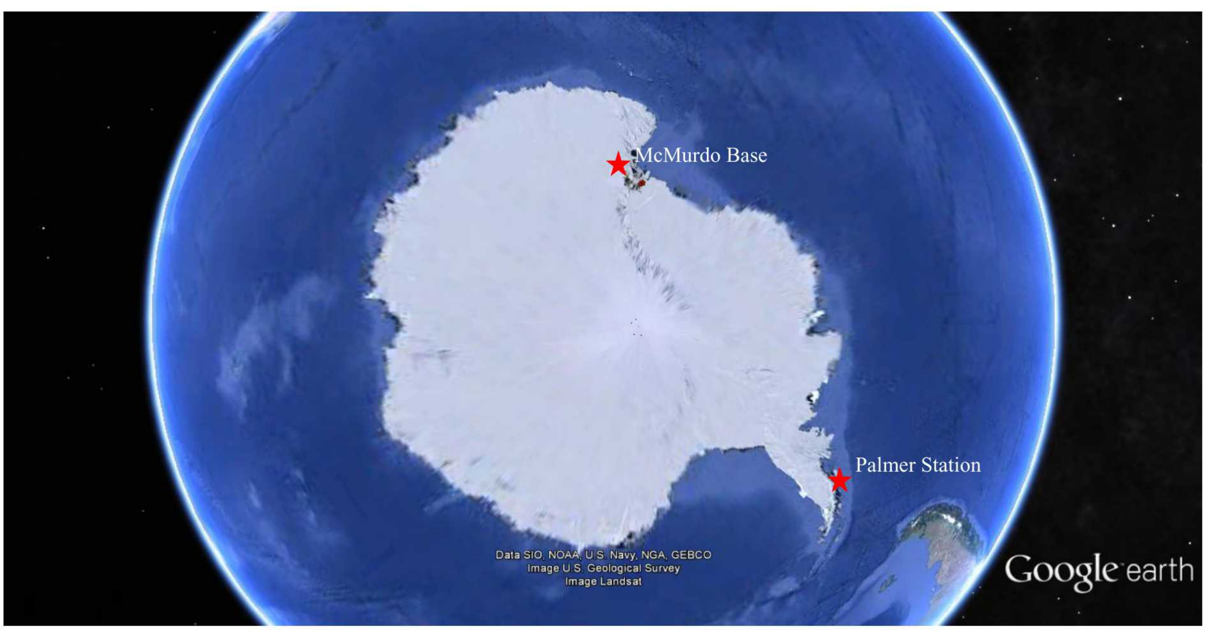


Figure 2.2.1 Google Earth Image of Antarctica

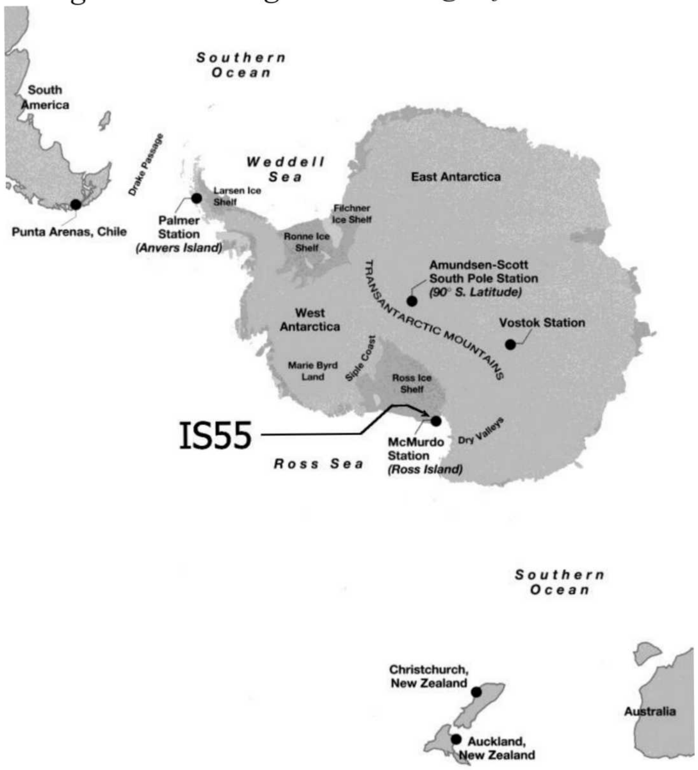


Figure 2.2.2 Map of Antarctica

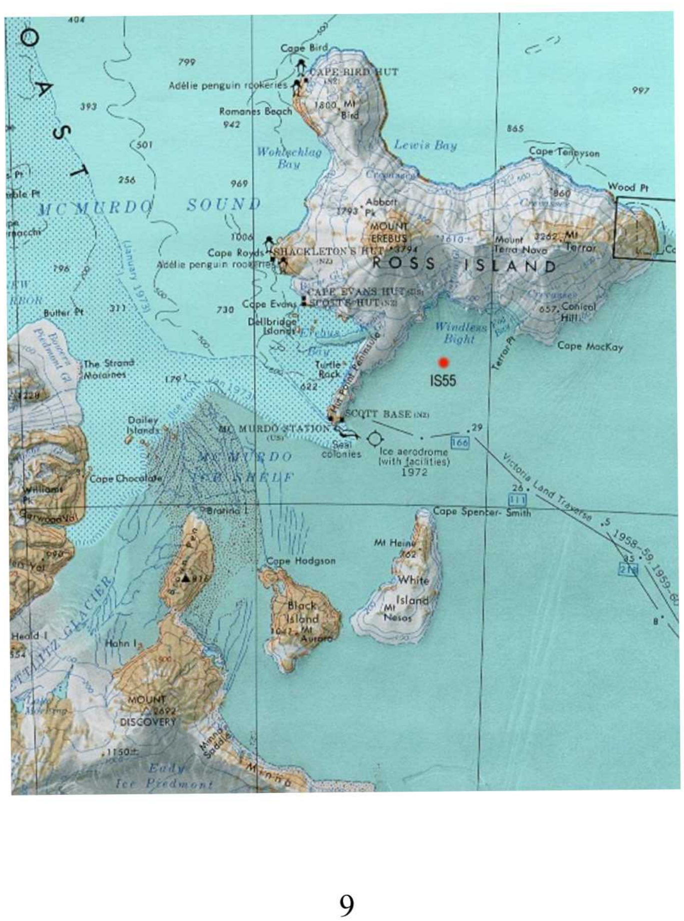


Figure 2.2.3 Topographical Map of I55US

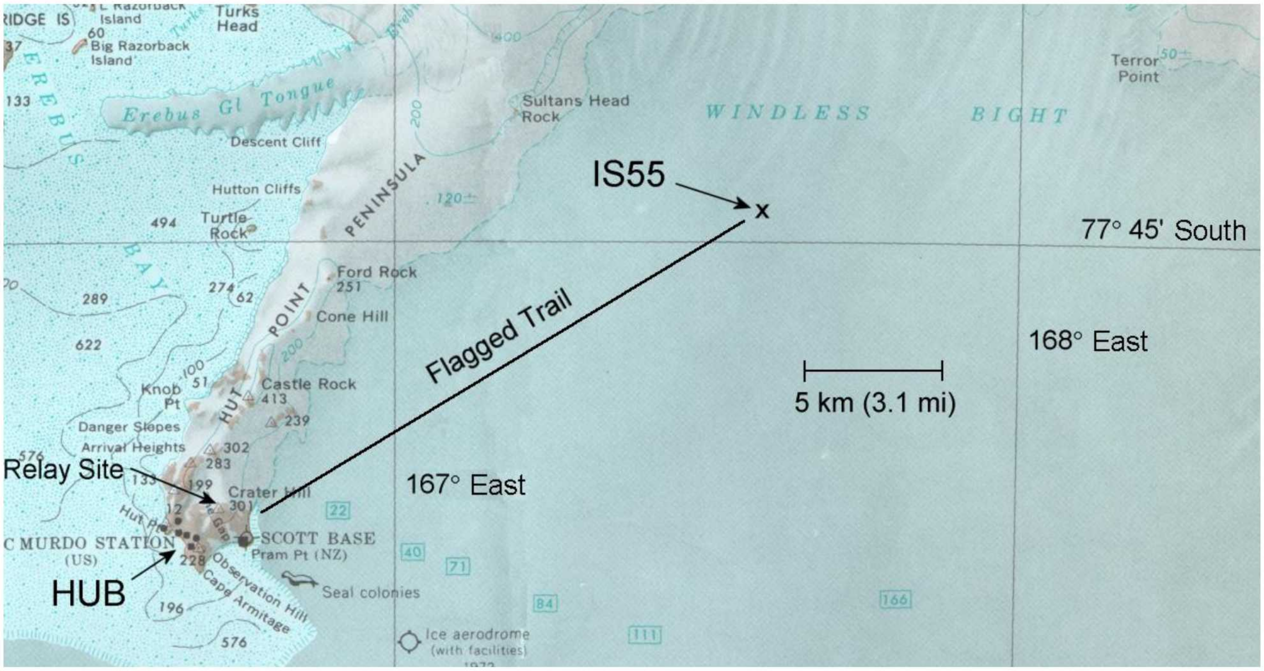


Figure 2.2.4 Map of Ross Island and McMurdo
Scale: 23.5 km (14.6 mi) between the 167 and 168 degree East lines at 77° 45' South.
Scanned from a 1:250,000 scale topographical map

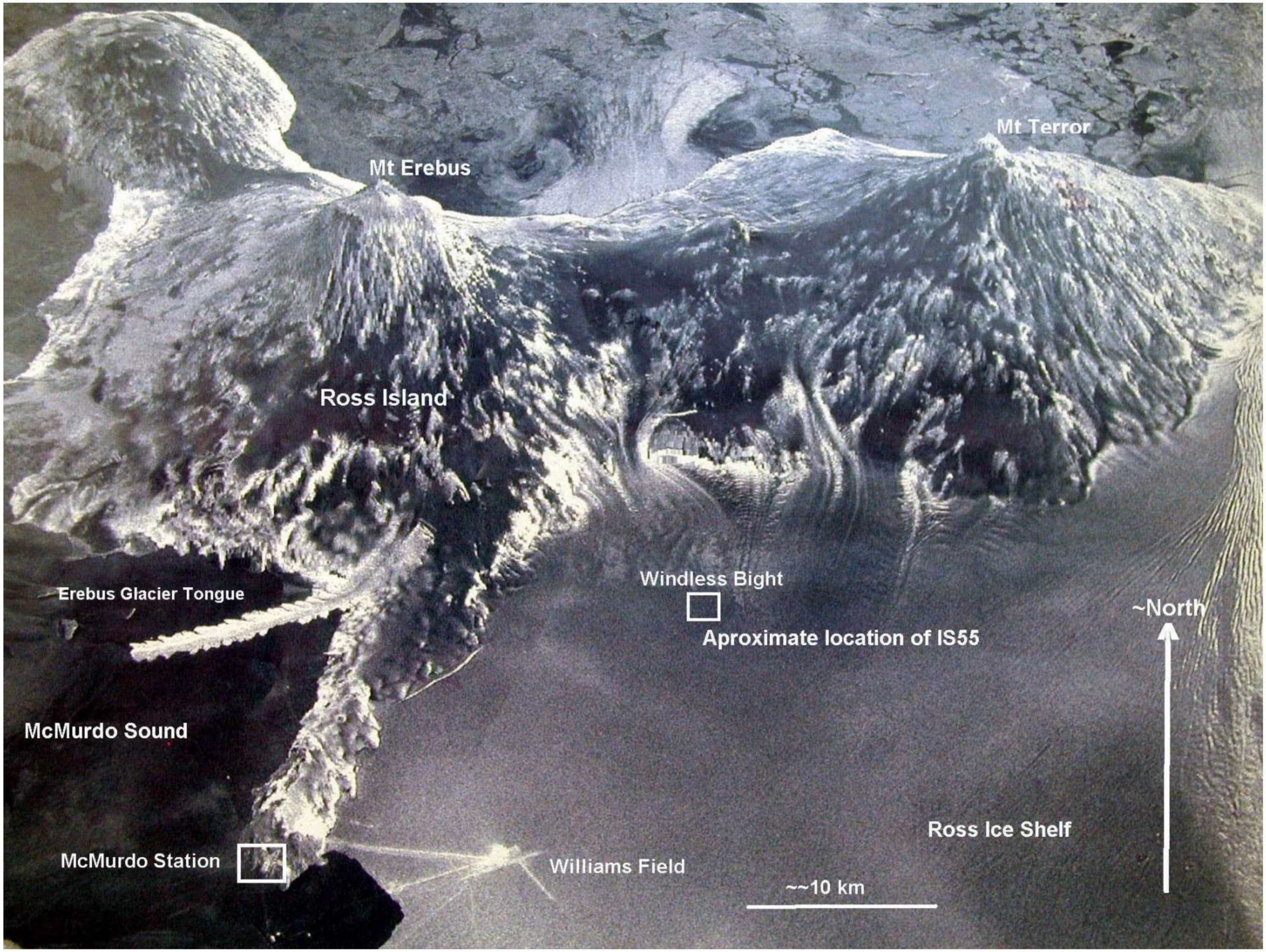


Figure 2.2.5 Oblique image of Ross Island showing McMurdo and Windless Bight

2.3 Station Layout Map

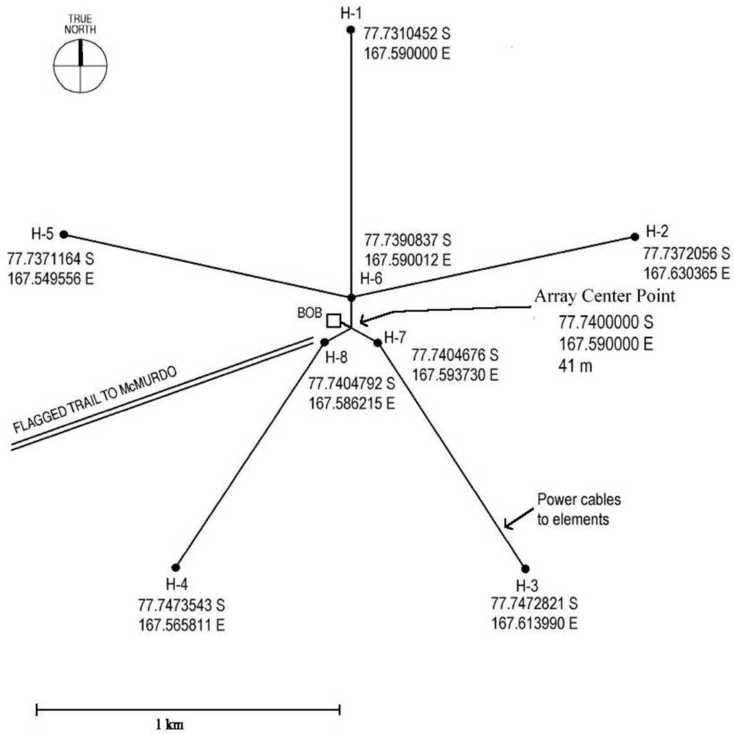


Figure 2.3.1 I55US Station Layout Map and Coordinates 2013

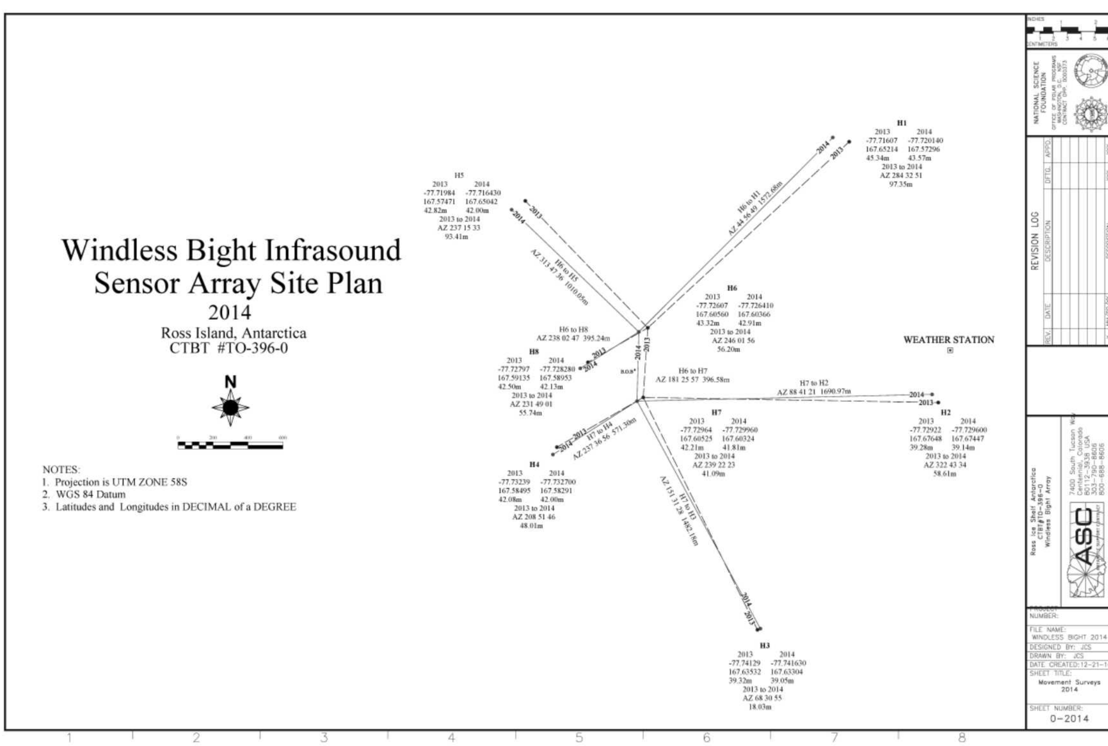


Figure 2.3.2 I55US Station Layout Map and Coordinates 2014

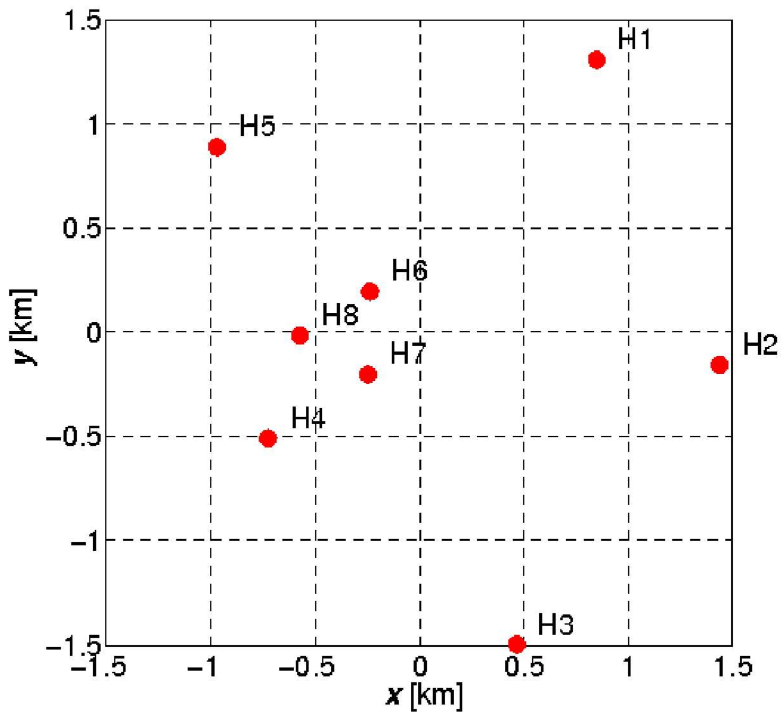


Figure 2.3.3 I55US Array Layout

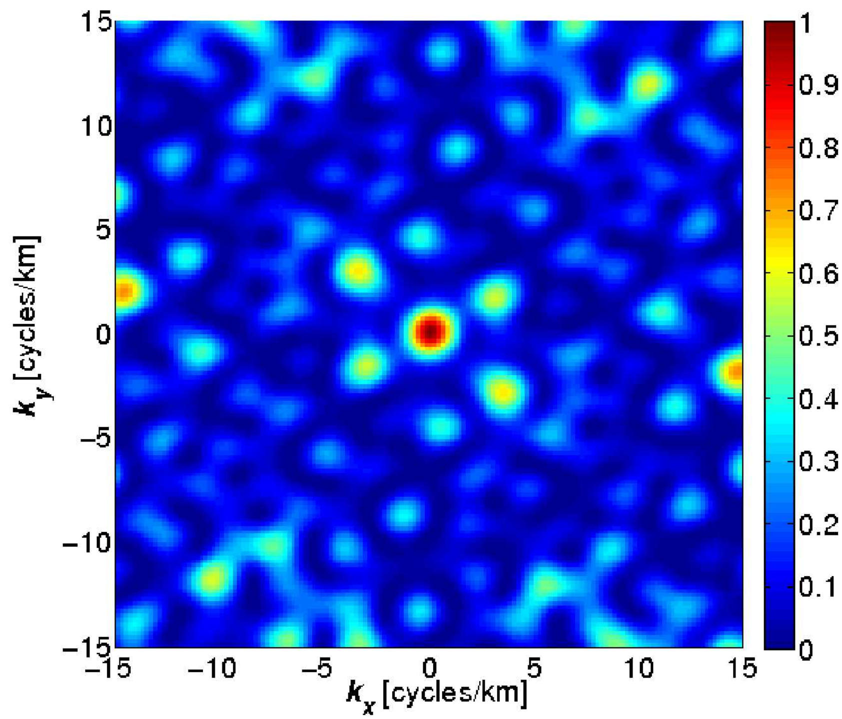


Figure 2.3.4 I55US Array Response

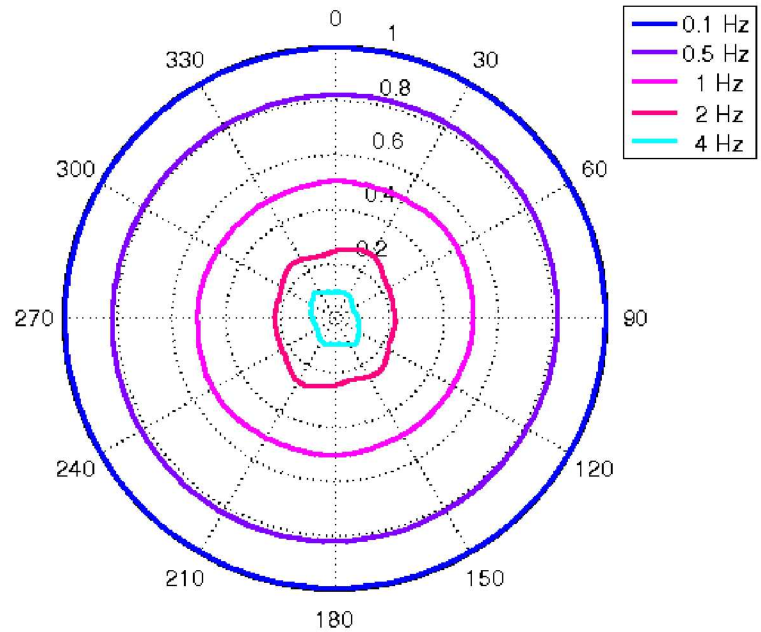


Figure 2.3.5 I55US Average Degree of Correlation Between Array Elements

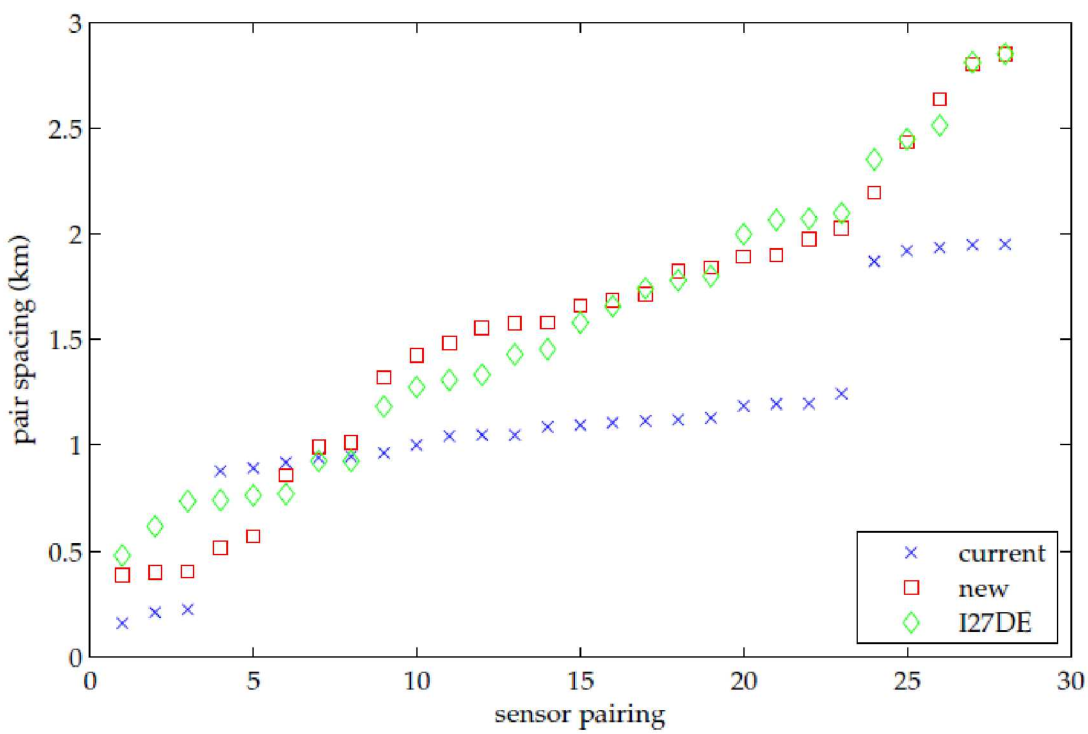


Figure 2.3.6 I55US Sensor Pairing Plot

2.4 Surveyed Coordinates

Actual procedures for performing the survey are included in Attachment 2-B.

Sensor	Latitude (degrees)	Longitude (degrees)	Elevation	Dnorth (km)	Deast (km)
I55H1	-77.71643	167.65042	45.00m	0.000	0.000
I55H2	-77.72960	167.67447	39.14m	-1.471	0.569
I55H3	-77.74163	167.63304	39.05m	-2.812	-0.415
I55H4	-77.73270	167.58291	41.69m	-1.815	-1.604
I55H5	-77.72014	167.57296	42.57m	-0.414	-1.840
I55H6	-77.72641	167.60366	42.91m	-1.113	-1.111
I55H7	-77.72996	167.60324	41.81m	-1.509	-1.121
I55H8	-77.72828	167.58953	42.13m	-1.322	-1.447

2.5 Block Diagram of Array Elements/ Sensor Configurations

In 2013 the I55US eight-element array configuration was modified (Figure 2.3.1). The original design using an outer pentagon and an inner triangle of infrasound sensors was not designed for the full IMS frequency range with only three types of inter-distances between array elements. This design was more tailored to the high frequency part of the spectra and not conducive to IMS monitoring purposes due to the remote location of the station.

The new design is a homogenous distribution array. There are several benefits associated with the new design. The sensor pair spacings are now evenly distributed. This spacing change optimizes the array for lower frequency detections, the expected signal given the array location, and reduces the microbarom detections. Having a homogenous distribution of all the sensors allows the array to be processed as a single array rather than two separate arrays as the IDC has been doing. The design has a roughly non-directional nature, despite the randomization in the individual sensor locations. With the new design the uncertainties are well constrained (less than 1º azimuthal uncertainties at the p = 0.95 level) and less than a 0.3º differential range of azimuthal uncertainties as a function of azimuth. Trace velocity uncertainties are likewise limited to roughly 4 m/s, with less than a 2 m/s differential range of trace velocity uncertainties as a function of azimuth. The new design also significantly improves the Mission Capability, an important feature for a remote array. The array remains Mission Capable during the failure of any one or two sensors in the array.

The I55US array layout and response [Capon, 1969] are shown in Figures 2.3.3 and 2.3.4 after the upgrade. The array response is plotted in wavenumber space with colored contours. A monochromatic signal is represented in wavenumber space by a specific wavenumber located at the intersection of (kx, ky). The maximum values of the wavenumber scale (15 cycles/km) correspond approximately to an infrasonic wave with a frequency of about 5 Hz propagating across the array at the sound velocity (340 m/s).

Figure 2.3.5 represents the average coefficient of correlation through I55US array elements for a wave arriving with a defined azimuth and frequency (0.1 Hz, 0.5 Hz, 1 Hz and 2 Hz). It

shows that the average coefficient of correlation is quite homogeneous in azimuth. A correlation of 0.3 is the threshold generally considered as a minimum for the IDC detection software to be able to build detections. It should be noted that this average coefficient of correlation does not take into account the loss of coherence due to wind turbulence.
Finally Figure 2.3.6 shows the sorted magnitudes of the co-array vectors. They show the relative completeness of the inter-sensor spacing spectra for three infrasound array geometries and how they should function as broadband antennae. The previous I55US geometry is depicted by blue 'x' symbols. Due to the highly symmetric nature of its design, there are two significant gaps in the spacing spectrum, near 0.5 and 1.5 km. The redesigned I55US array geometry is depicted by red squares. It now provides full coverage between 0.4 and 2.85 km with no significant gaps. Also shown is a comparison to a modified I27DE design (based on logarithmic spirals), depicted by green diamonds. This new geometry is in agreement with the recommendations of the Infrasound Expert Group Meeting 2012, Daejon, Korea. The increased detection capability of the station was confirmed after the station upgrade and the results were presented to the Waveform Expert Group Meeting during Working Group B 42.

Each site consists of a concentrically located vault and wind-noise reducing pipe array with an antenna pole next to the vault (as shown in Figure 2.5.1). The wind-noise reducing array is a radial array of pipes with 16 arms. The actual array diameter is 18 meters. Each arm is composed of an eight-meter High Density Polyethylene (HDPE) pipe with an internal diameter of 3.403 cm (1.340 inch) and a wall thickness of 0.383 cm (0.151 inch). Each arm has a reducing Bell to ¾ inch ID pipe that connects to a four to one mini-manifold (Figures 2.5.2 and 2.5.3). Each manifold connects to the vault with an additional half meter of ¾ inch (1.905 cm) hose (Figure 2.5.4) and is further conducted inside the vault by another half meter of hose to the final summing manifold on the sensor (Figure 2.5.8). The outer five meters of each pipe is vented once each meter making a total of 96 ports in the array. The vent is a 1.2 mm diameter hole and was sized to match the acoustic impedance of the pipe.

The vaults are insulated plastic cases. Each vault houses a Chaparral model 50A sensor, Geotech Smart24 digitizer; UAF power regulator board, battery, and a Freewave WiLAN radio (Figure 2.5.8). All the data is authenticated using Spyrus crypto cards which are installed in the Smart24. A pole located beside the vault is used to mount the antenna for the radio modem and the GPS receiver (Figure 2.5.6).

A meteorological system is located at element H7. The system includes a RM Young 05103V-45 wind sensor and a RM Young 41382VC temperature sensor shown in Figure 2.5.8. Data is collected on channels 4-6 of the Smart24 digitizer and transmitted using the same WiLAN radio as the infrasound system. Absolute pressure data is collected using a RM Young 61302V pressure sensor on channel 4 of the Smart24 digitizer at H6.

A complete block diagram of I55US is shown in Figure 2.5.9.

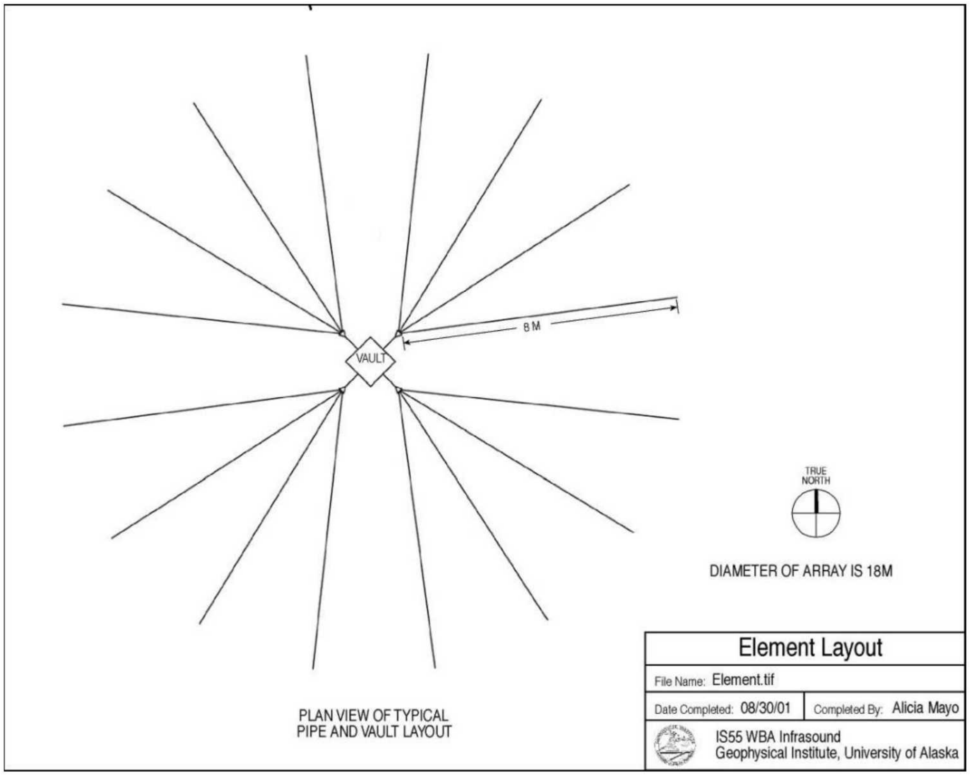


Figure 2.5.1 I55US Wind Filter Layout

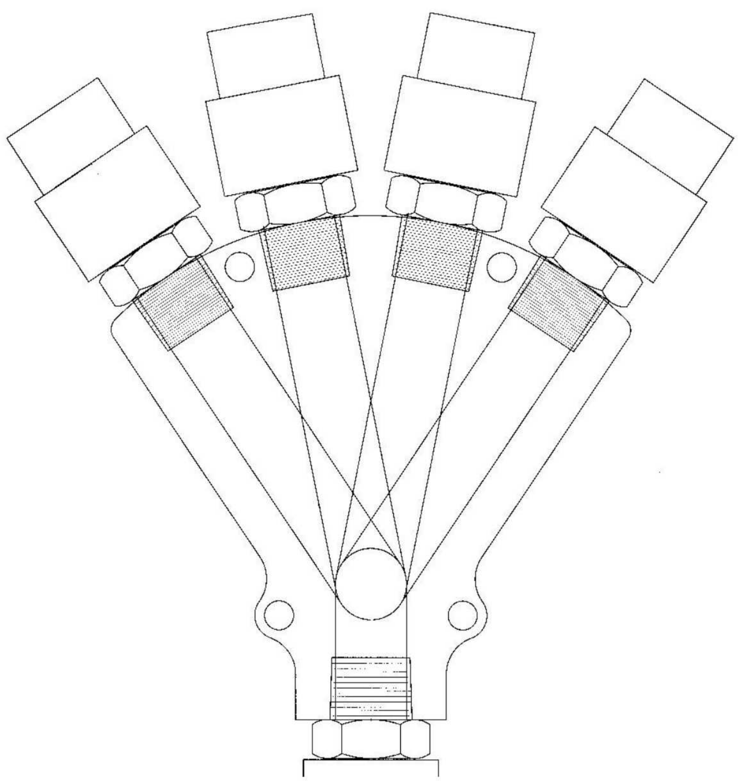


Figure 2.5.2 I55US Wind Filter Manifold Drawing

Figure 2.5.3 I55US Wind Filter Manifold

Figure 2.5.4 I55US Wind Filter entry into vault

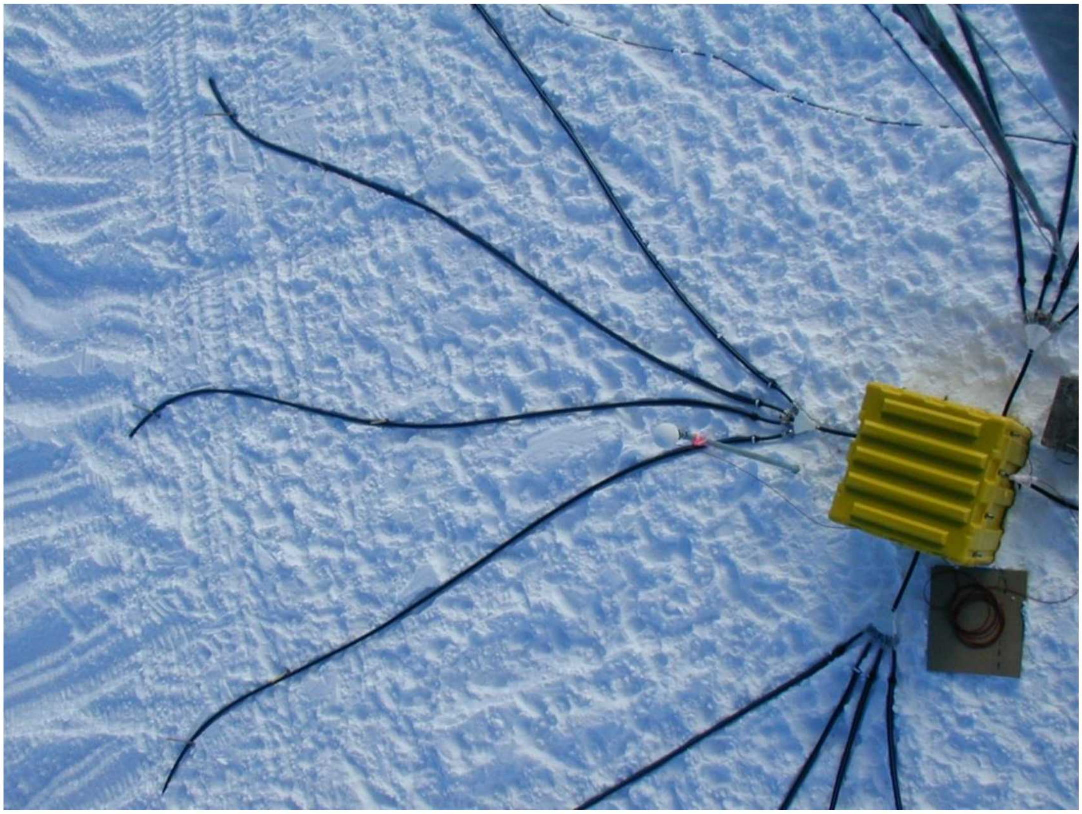


Figure 2.5.5 I55US Wind Filter Layout Top View

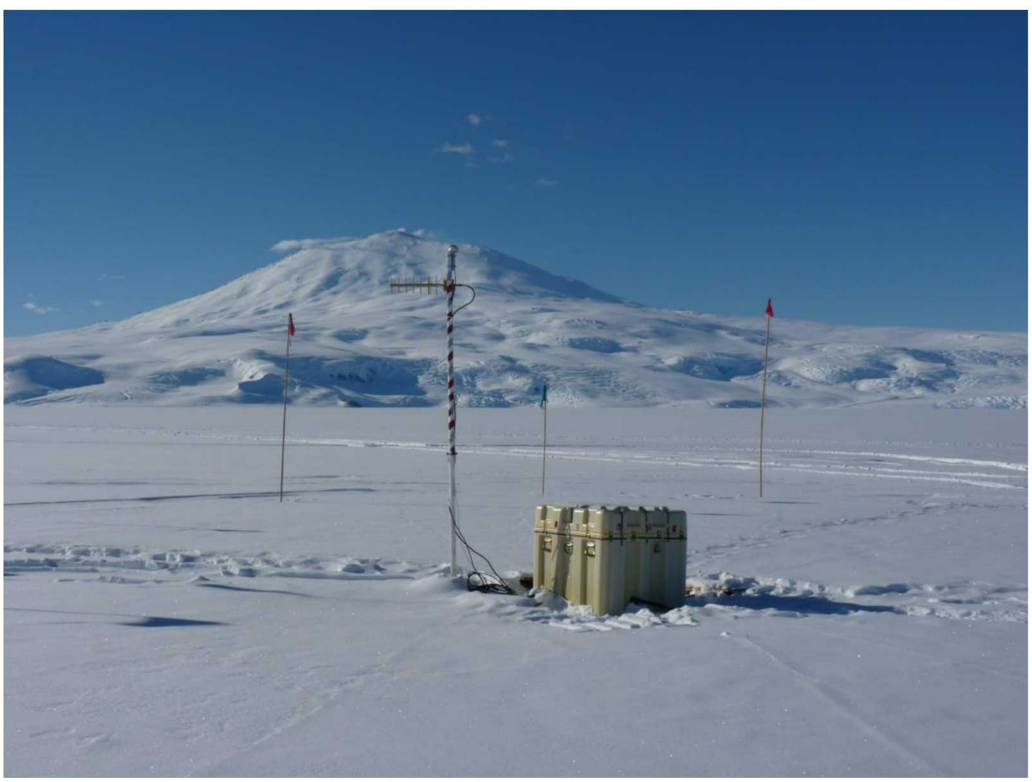


Figure 2.5.6 I55US Element

Figure 2.5.7 I55US MET Station at H7

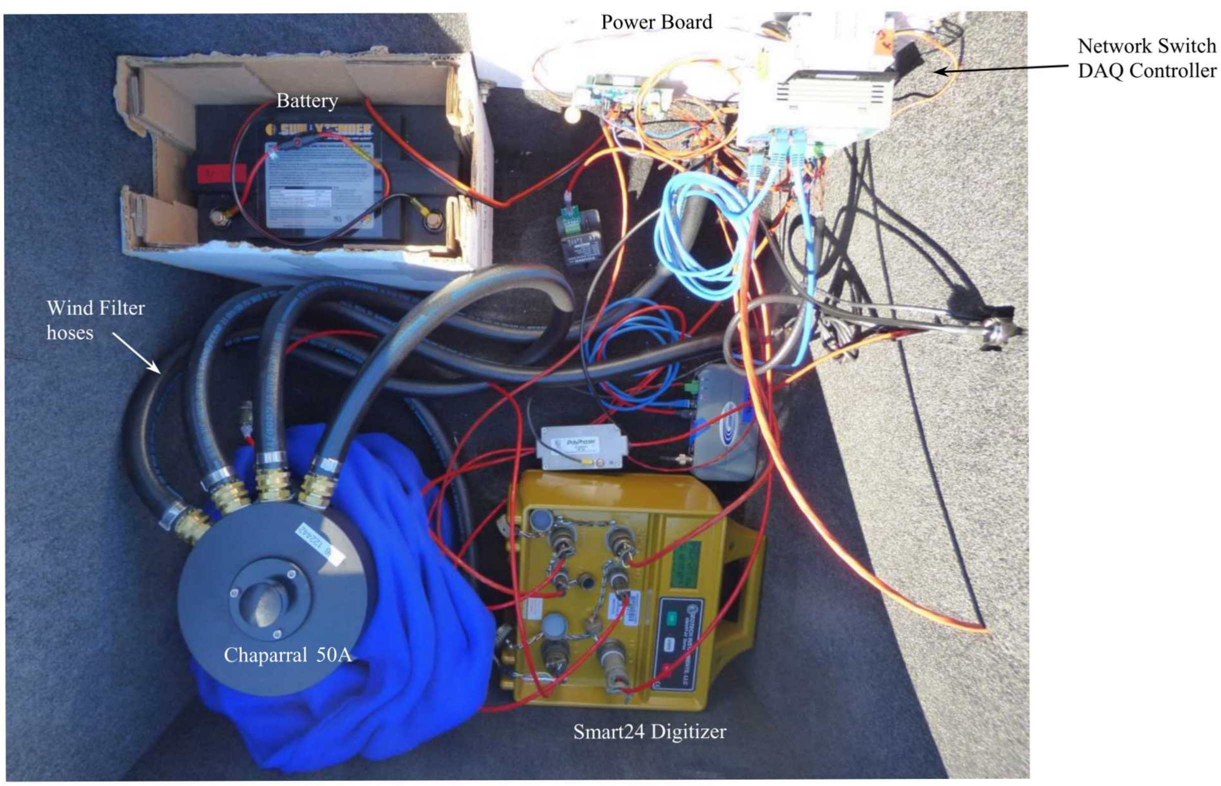


Figure 2.5.8 I55US Vault Interior

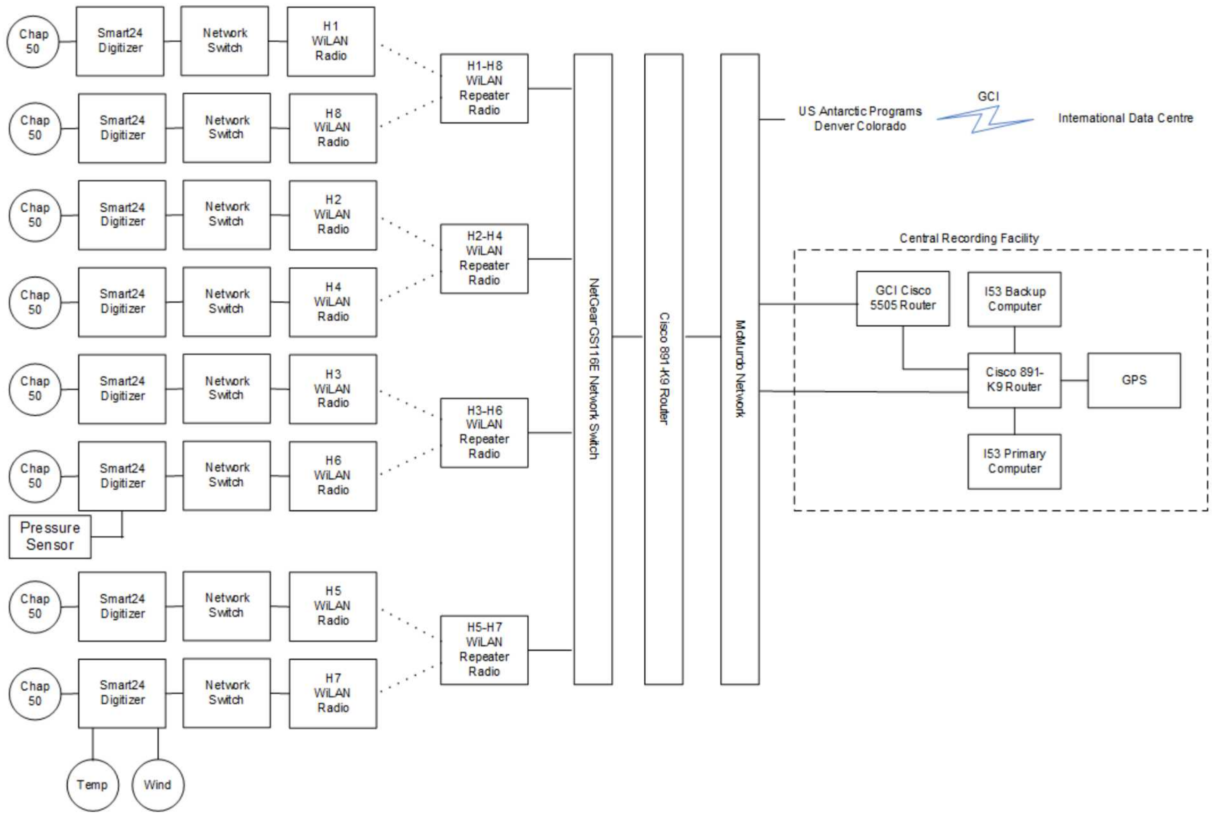


Figure 2.5.9 Block Diagram of I55US

2.6 Block Diagram of Central Facility

The CRF (Central Recording Facility) is located in the "town" of McMurdo, Antarctica (Figure 2.6.1). McMurdo is the US National Science Foundation's central logistics and supply base for the US Antarctic Program in western Antarctica and South Pole. It is a coastal station on the barren ash and lava volcanic hills at the southern tip of Ross Island, about 3,864 km south of Christchurch, New Zealand, and 1360 km north of the South Pole. The original station was constructed in 1955-1956. The station is the primary logistics facility for airborne re-supply of inland stations and for field science projects. The station is also the waste management center for much of the U.S. western Antarctic Program. Year-round and summer science projects take place at McMurdo. The mean annual temperature is –18 C. Temperature may reach +8 C in the summer and –50 C in the winter. The average wind is 12 knots, but winds have exceeded 100 knots. Wind speeds are much lower at Windless Bight (see Infrasound Site Survey in Attachment 2-A). The austral winter population ranges from 150 to 200, and the summer population may exceed 1,100. The station is normally isolated from late February until early October, except for a brief period in August when several closely spaced flights deliver personnel, supplies, and early science parties.

The Central Recording Facility (CRF) is located in room 227 of Building 159 at McMurdo Station (Figure 2.6.2). With the exception of room 227, building 159 houses the McMurdo electronics lab. The room is 10 by 15 feet (Figure 2.6.3) and houses both the I55US and PS50 VNDA Central Recording Facilities (CRF).

Data comes into the CRF on the McMurdo network which connects to the I55US Cisco 891 router. The router connects all of the CRF equipment on the LAN side as well as connecting to the McMurdo network and the internet on the WAN side. The router also serves as a firewall. On the LAN side two Dell desktop computers running the CTBTO Standard Station Interface (SSI) software receive the data from the elements and package them into a CD1.1 frame and sign the frame before transmission to the IDC. The CD1.1 frames are transmitted through the Cisco 891 to the GCI Cisco 5505 router through a second WAN port. The GCI router is located in the I55US network chassis. Only one SSI computer is powered on at a time. Other equipment on the CRF LAN are the UAF housekeeping computer which is running the Geotech GeoHub software for command and control of the digitizers and receiving a second data stream with a more extensive set of state-of-health data for station monitoring. Also connected are an NTP100 timeserver for the SSI and housekeeping computers, the UPSs for both the housekeeping computer and the CRF equipment, and a DAQ X300 which is used to monitor room temp. A photo of the CRF is shown in Figure 2.6.3.

With this configuration UAF Personnel can establish remote connections allowing them to troubleshoot or change the configuration of either the equipment at the CRF or equipment at the vaults.

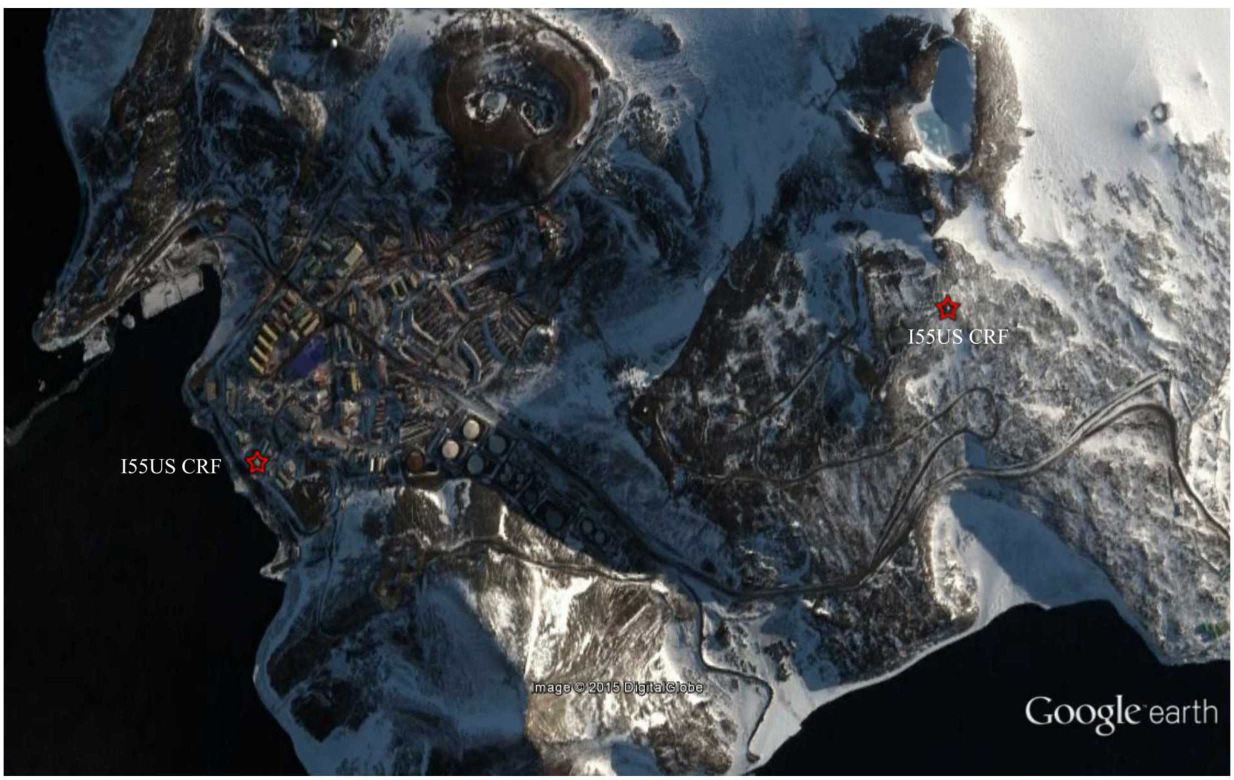


Figure 2.6.1 McMurdo Base

Figure 2.6.2 Building 159 McMurdo Station, Antarctica

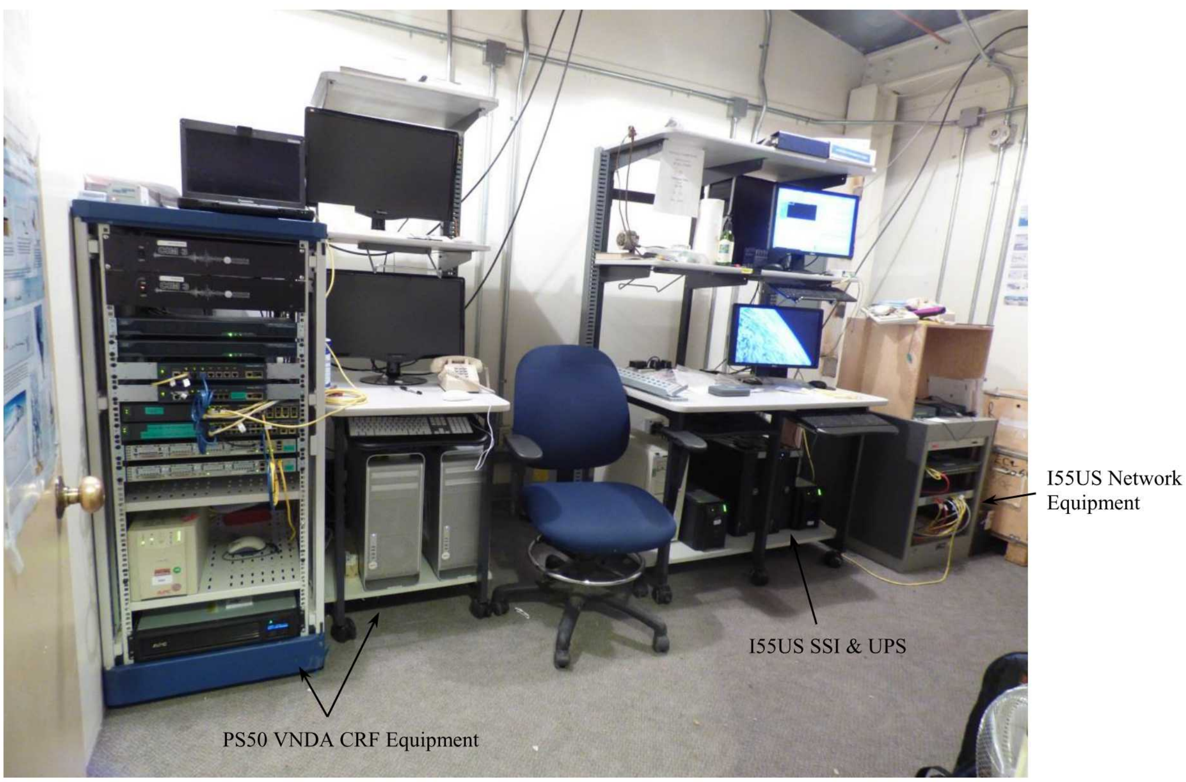


Figure 2.6.3 Central Recording Facility

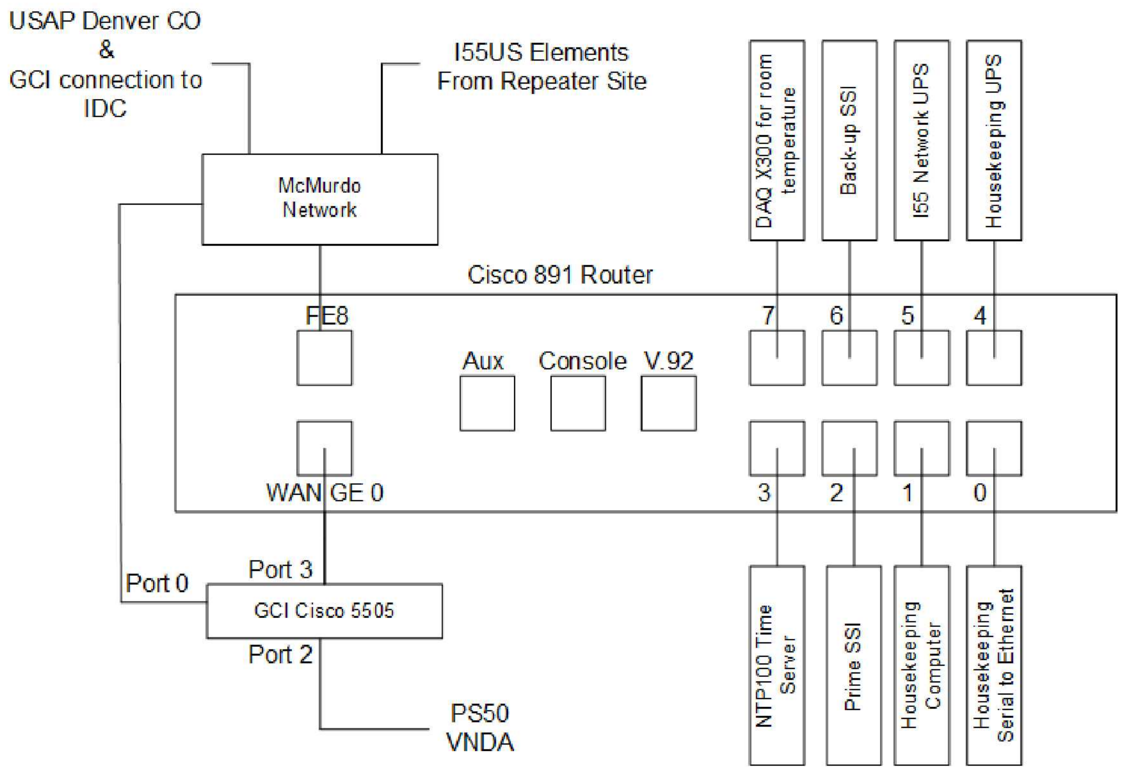


Figure 2.6.2 CRF Network Connections

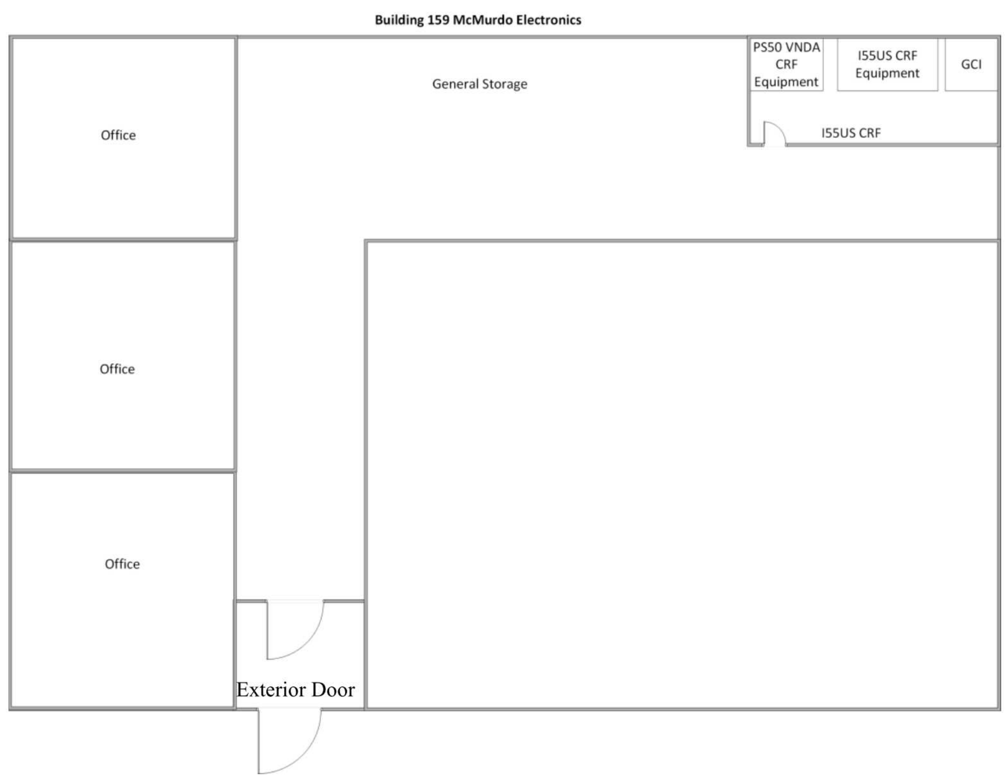


Figure 2.6.3 Building 159 McMurdo Station

2.7 Intra-Site Communications Overview

Intra-site communications for I55US are shown in Figure 2.5.9. The communication link from the CRF to each of the array elements is Ethernet based using a combination of radios and the McMurdo network. Between the relay site located on the hill above McMurdo Base and each array element, data is transmitted using Freewave FGR2-PE 900 MHz network radios. Each element has an individual radio while at the relay site there are four radios. Each radio at the relay site connects to two elements as shown in Figure 2.5.9. At the relay site the radios connect to a network switch and Cisco router. There is also a pair of Freewave DGR-115R/H serial radios for communications with the BOB power system. To connect the serial Freewave radio to the Netgear switch and Cisco router a Blackbox LES301A serial to Ethernet converter is used. The Cisco router connects to the McMurdo network and generates a VPN tunnel to the CRF router that all the traffic passes through.

2.8 External Communications Overview

Data is sent from the Central Recording Facility in Building 159 via Ethernet to a McMurdo Station router located in Building 165. The data is then transmitted from McMurdo to Brewster, Washington through a satellite link and then to the U.S. Antarctica Program (USAP) in Englewood, Colorado by means over the internet. At the RSPC facility in Colorado the data is routed through a Nokia 440 Firewall to the CTBT GCI equipment located at the RPSC facility. (Figure 7.2.1).

2.9 Power Supply Overview

The sensors in the array are powered from a remote central Hybrid Power System (BOB) made by Northern Power Systems (Figures 2.9.1, 2.9.2, 2.9.3, and 2.9.8). The Hybrid system uses solar power whenever possible to charge the batteries. The power system is controlled by a PLC, called the SC1000 controller. This small computer system controls the various aspects of the power system. Its first goal is to maintain flawless power to the CTBT load. If the SC1000 cannot maintain power to the load its second job is to preserve itself, so that no damage occurs to the power supply system. Battery charging is controlled by the SC1000 computer to maximize available solar power and battery lifetime. When there are insufficient solar resources and the main battery bank drops below 24.0 volts, the SC1000 uses the diesel generators to supply power and charge the batteries. If the battery voltage drops below 22.4 volts the SC1000 will automatically shed the load to preserve the power system. This would only occur with several major charging system failures. The internal environment of the power shelter is also controlled by the SC1000 to maintain the best internal temperatures and air supply to operate or preserve the power supply. BOB has internal backup via its redundant systems and is designed to be very robust, minimizing the likelihood of failure. BOB’s redundancy extends to: dual diesel electric generator sets, dual rectifier banks, triple strings of PV cells, dual battery banks, and dual low voltage to high voltage converters to power the sensor vaults. Hybrid Power System runtime calculations are shown in Figure 2.9.9. If all charging systems in BOB fail, BOB has 8 days of reserve power from the batteries.

The batteries from the Hybrid Power System provide power to each site. The power is carried to each array element with armored cable laid in the snow. The power cable connects to a fuse located inside the vault then to a UAF power supply board (Figure 2.9.7). The UAF power supply board is a conformal coated board with a 48VDC input and a 13.5 VDC output. It uses Vicor's VI-J00 (VI-JN2-IW) for 48 VDC->13.5 VDC. A Linear Technology LTC4365 is used for Over/Under/Reverse voltage protection for the load. The under voltage is also used as a low voltage shutdown to protect the batteries. There is housekeeping circuitry to monitor temperature, humidity, battery voltage, charge current, and input voltage that is separate from the power path. The connects to both the load and a Concorde SunExtenter PVX-1040T battery which can run the vault electronics for at least 120 hours (5 days) at the minimum temperature extreme expected. Diagrams of the power are shown in Figures 2.9.4, 2.9.5, and 2.9.6.

The I55US CRF is powered off of the McMurdo mains through an APC 1500 Smart UPS unit as shown in Figure 2.9.9. The APC units provide power conditioning as well as providing 1 hour of backup power. The computers at the CRF are configured for auto-shutdown based on UPS runtime; however, a power failure at McMurdo Base jeopardizes life support functions and is therefore fixed on a very high priority basis.

Power at the relay site is a combination of McMurdo mains and DC as seen in Figure 2.9.10. Two Elpac FWC100024A-11B power converters are connected to McMurdo mains at the relay site with their output connected to a Morningstar Sunsaver solar charge controller. The controller has load and charging outputs. The charging output connects to two SunExtender PVX-1040T batteries through a RigRunner 4005 DC power distribution unit. The batteries serve as back-up power in the event of power loss. The output from the load side of the controller connects to a RigRunner 4012 DC power distribution unit. The power distribution unit supplies power to the radios and to a TDK-Lambda DPX40-24WS12 power supply. The TDK-Lambda supplies power to the Cisco router and Netgear network switch.

Figure 2.9.1 I55US Hybrid Power System (BOB)

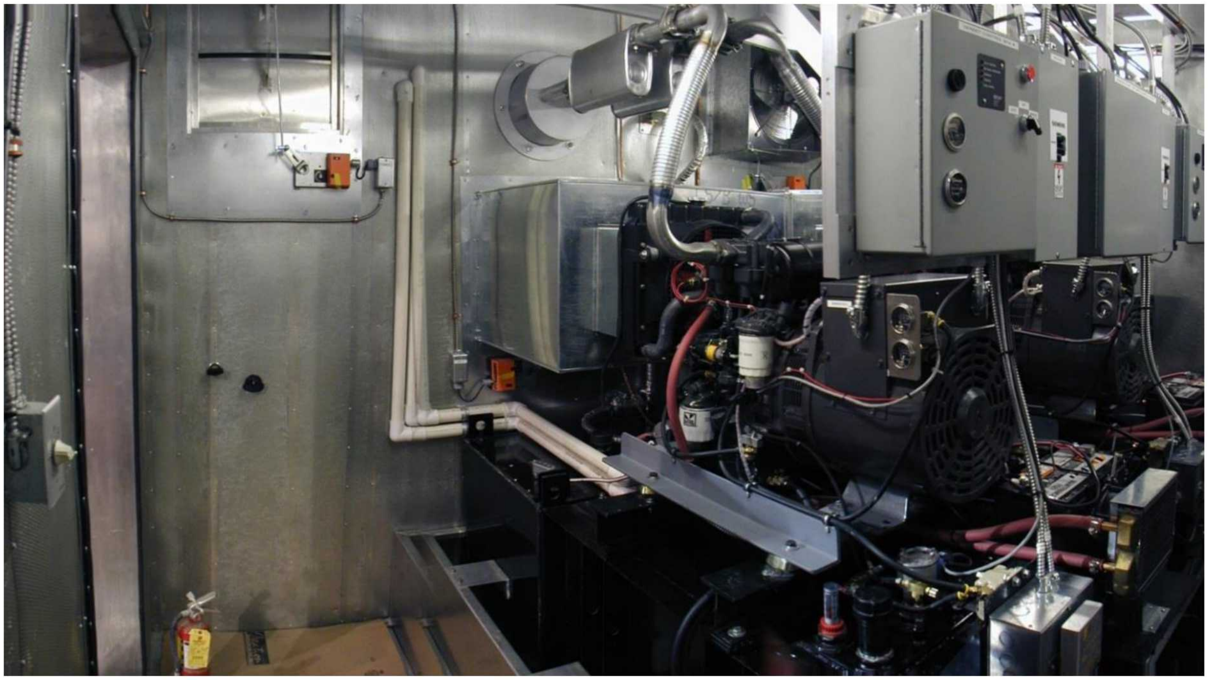


Figure 2.9.2 Hybrid power supply's engine room
From the door of the equipment room, showing left to right, outside entrance door, air intake louvers, engine A (and behind engine B) sitting on the 500 US gallon fuel tank. Above the engines are their engine control units, and against the far wall are the engine and radiator exhaust equipment

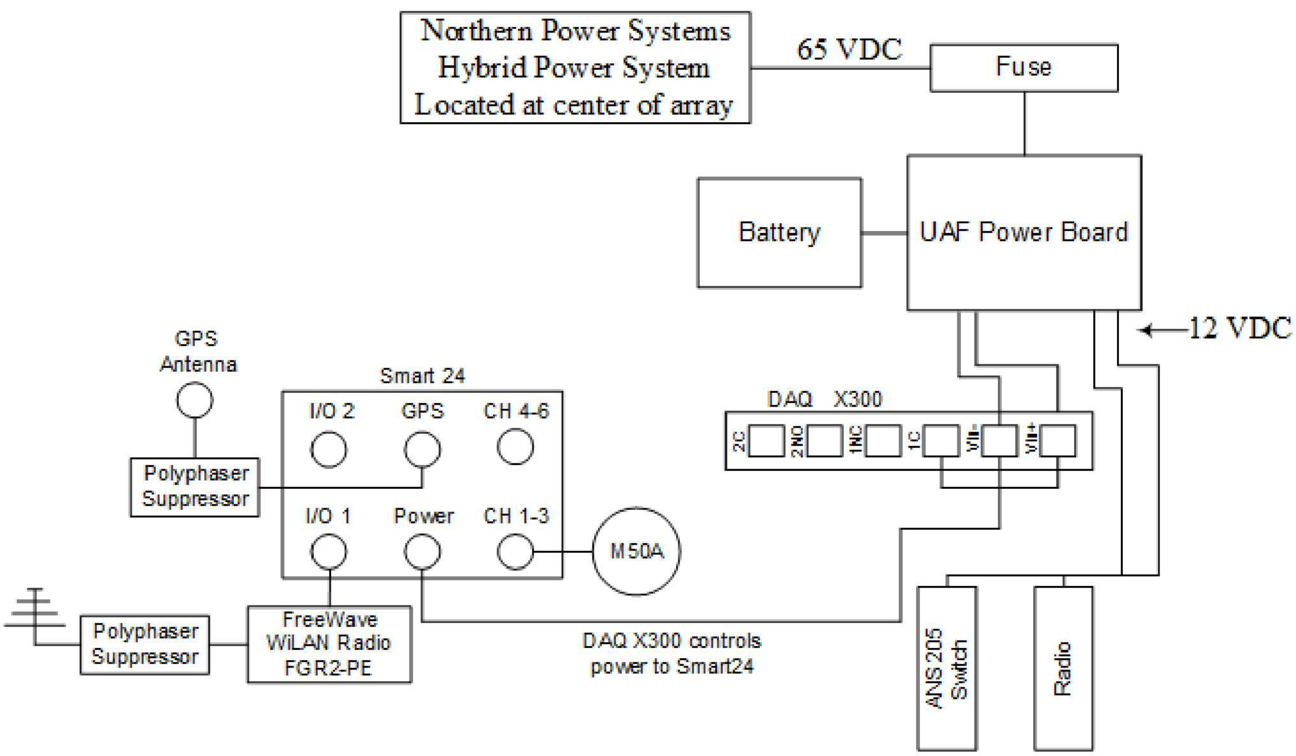


Figure 2.9.3 I55US Vault Power H1-H5 and H8

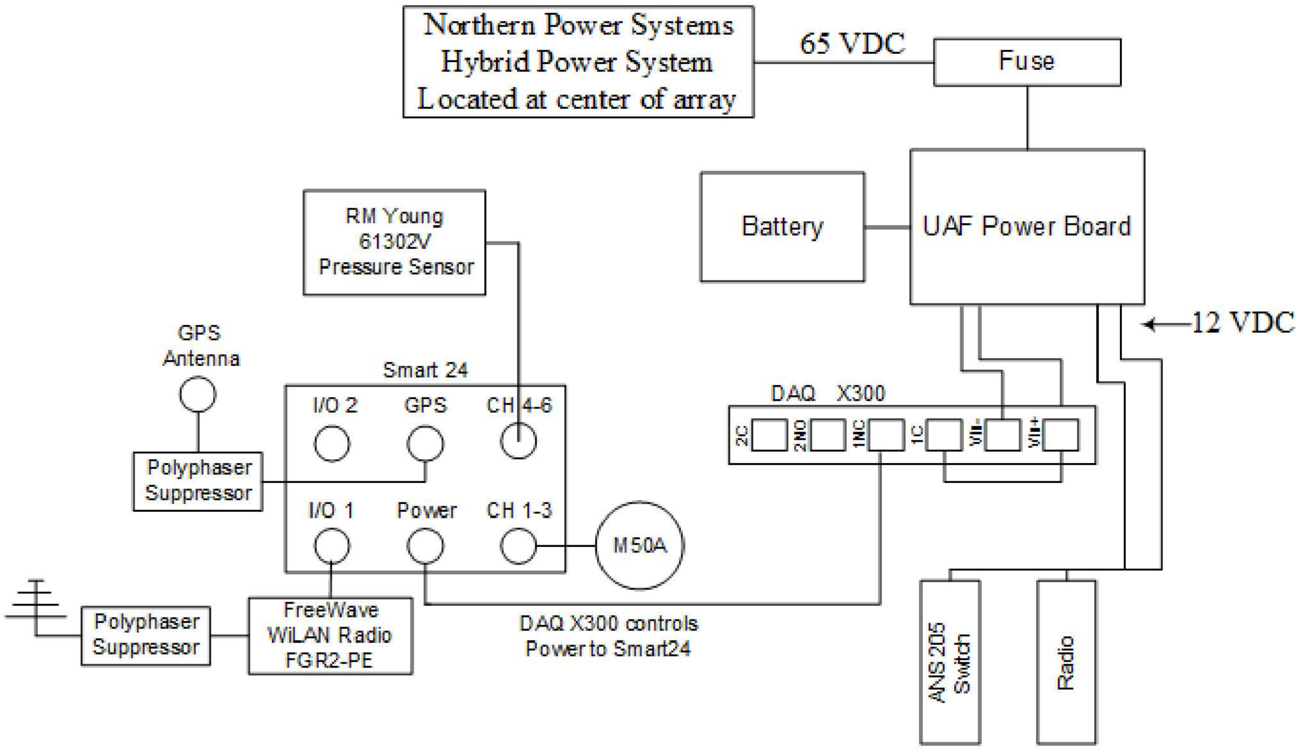


Figure 2.9.4 I55US Vault Power H6

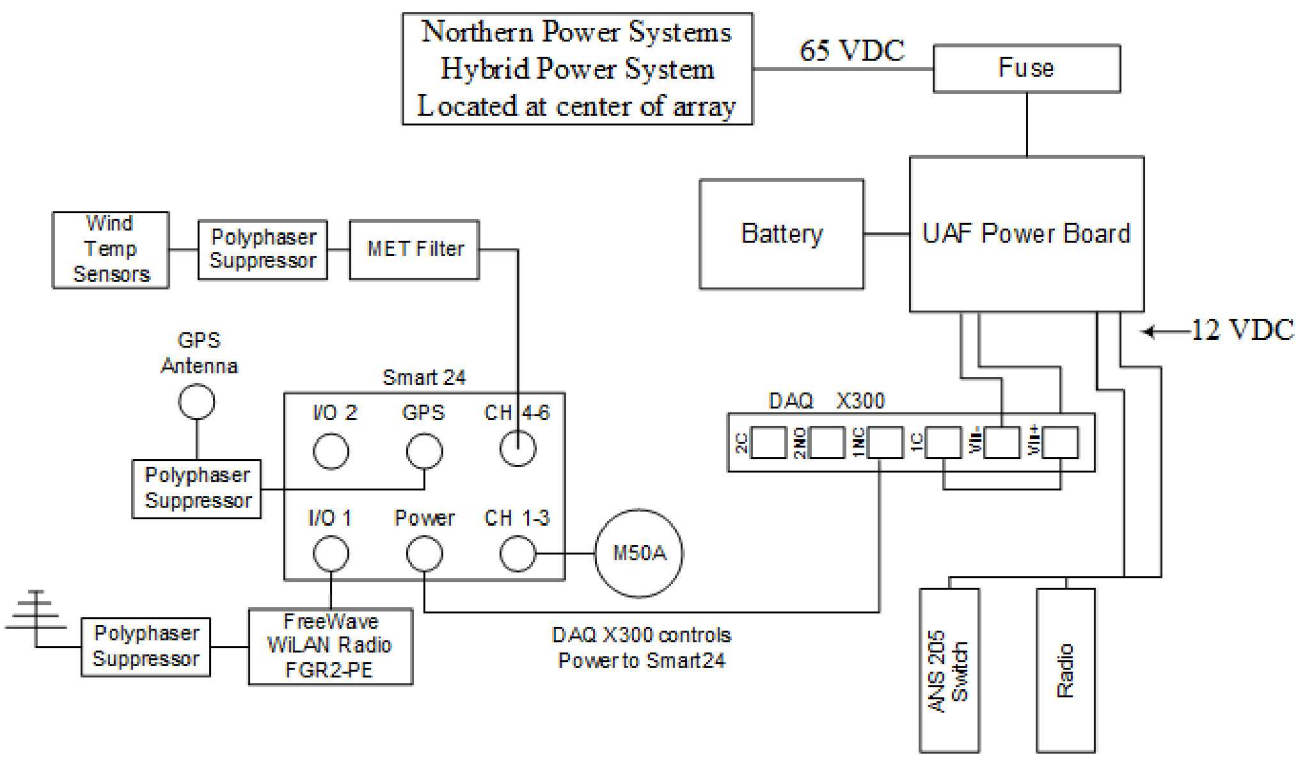


Figure 2.9.5 I55US Vault Power H7

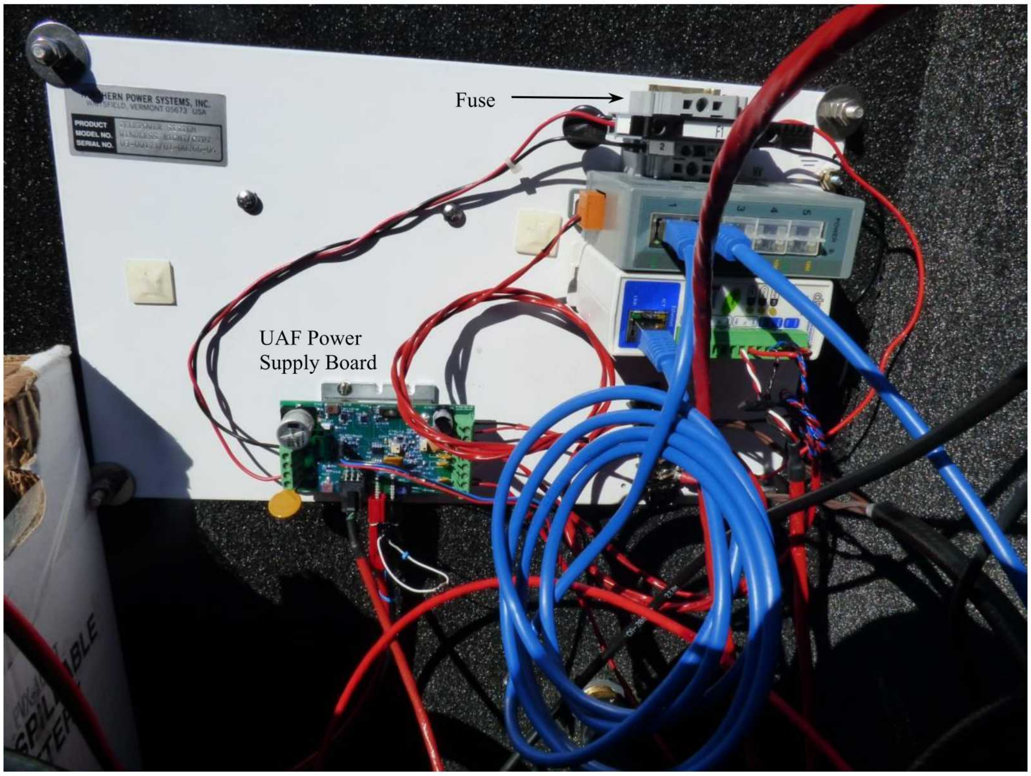


Figure 2.9.6 UAF Power Board

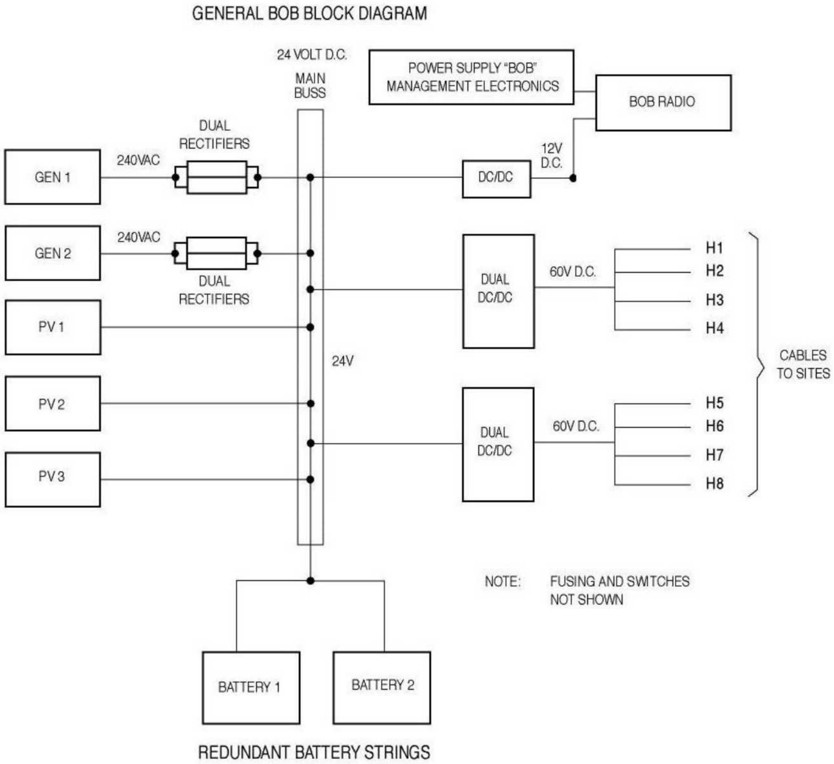


Figure 2.9.7 I55US Hybrid Power System (BOB) Schematic

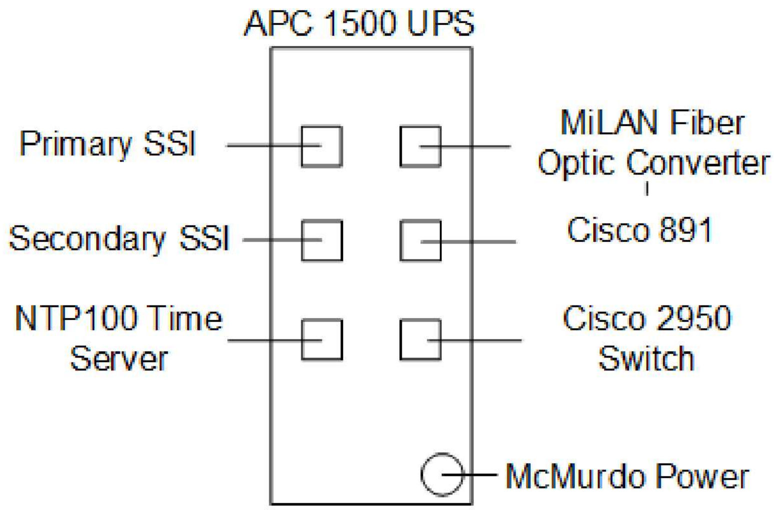


Figure 2.9.8 I55US CRF Power

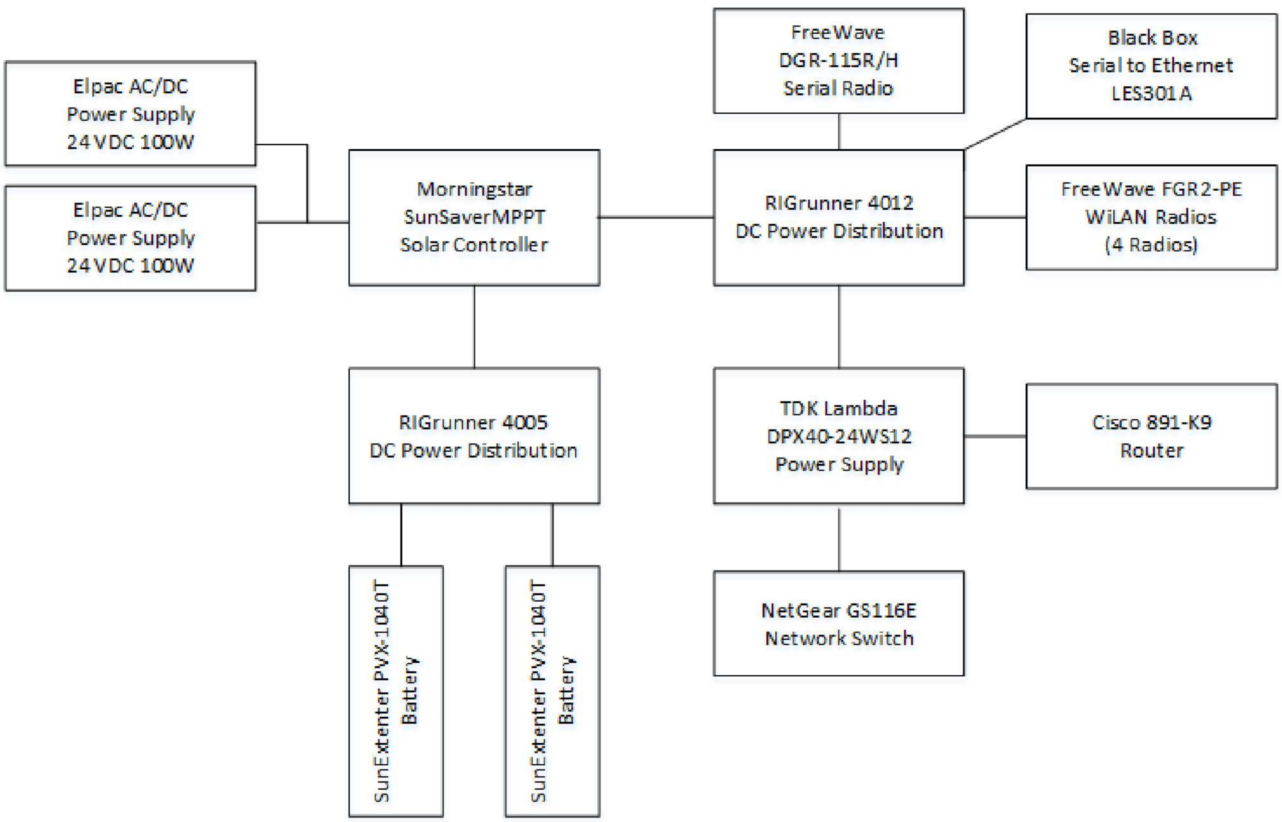


Figure 2.9.9 I55US Relay Power

University of Alaska, Geophysical Institute

Infrasonic Instrumentation Site at Windlass Bight, Antarctica

Resource / Site Data

Solar Data:	McMurdo Station
Site Elevation:	Sea Level

System Data

24	System Voltage in VDC
12 VDC	Available thru DC-DC Converter
120 VAC	Available thru DC-AC Inverter
266	Amp-Hrs/Day @ Average Continuous Load
266	Average Continuous Load in Watts
97,098	Total Annual Load in Amp-Hours
108,200	Estimated Annual Power Production in Amp-Hours

System Derates

0%	Genset derate for Altitude and Temperature
7%	PV Array Losses for Cell Mismatch, Interconnect Line Losses and Cell Fouling
92%	Genset Rectifier Charging Efficiency
92%	Battery Cycle Efficiency
88%	DC-AC Inverter Efficiency
100%	Battery Capacity @ 77° F (Standard Test Condition)
89%	Battery Low Temp Capacity @ 50° F

VRLA Battery Bank

Type:	GNB Absolyte IIP
Model:	3-100A19
4	# Modules/String
2	# Parallel Strings
2304	Amp Hour Capacity @ C100 Discharge Rate
6.1	Number of Days of System Autonomy from 100% Battery State of Charge down to 20% SOC at Interior Shelter Temperature of 50° F

Fossil Fuel Genset

Mfg:	Lister Petter
6.0	Genset size in kW
100.0	Rectifier Output in DC Amps
JP8	Fuel Type
LPW2	Genset Model Number
0.6	Estimated Fuel Consumption in Gallon/Hour
319	Estimated Annual Fuel Consumption at above rate.
200	Recommended Size of Fuel Tank in Gallons

Photovoltaic Solar Array

Module:	Siemens Solar SM 55
1980	PV Array Size in Peak Watts
55	Size in Watts of Individual PV Module Selected
2	# of PV Modules per String
36	Total # of PV Modules per Array
3.35	PV Output per module in DC Amps @ 50° C Cell Temp
Vertical	POA: Tilt Angle towards the Sun of Solar Array

PV Array is optimized for Maximum Year Round Solar Capture

Projected Daily Load Profile in DC Amp-Hours

	"Customer" DC AHrs	"Enviro" DC AHrs	"Controller" DC AHrs	Total Daily DC Load	Excess Renewable Energy Avail for Dump Loads
January	204	50	12	266	91
February	204	50	12	266	-70
March	204	50	12	266	-176
April	204	50	12	266	-249
May	204	50	12	266	-266
June	204	50	12	266	-266
July	204	50	12	266	-266
August	204	50	12	266	-261
September	204	50	12	266	-204
October	204	50	12	266	-92
November	204	50	12	266	76
December	204	50	12	266	142

Solar Resource

Avg Sun-Hr per Day	PV Amp-Hrs per Day
6.4	357
3.5	196
1.6	90
0.3	17
0.0	0
0.0	0
0.0	0
0.1	5
1.1	62
3.1	174
6.1	342
7.4	408

Average Annual Sun-Hours:	2.47
Total Annual "Solar" Amp-Hours:	50,167
% of System Energy by PV	**48%**

Genset Contribution

Est. Monthly Runtime	Average Run Time Duration	Est. # of Days Between Runs	Genset AHrs per Day
2	1.0	15.5	6
19	3.8	5.6	67
55	6.9	3.9	178
77	8.5	3.3	255
84	8.4	3.1	272
82	8.2	3.0	273
84	8.4	3.1	272
83	8.3	3.1	267
62	7.8	3.8	208
28	5.6	6.2	90
2	1.0	15.0	7
2	1.0	15.5	6

Typical Genset Runtime Duration in Hrs:	5.7
Average Monthly Genset Runtime:	48.4
Total Annual "Genset" Amp-Hrs:	58,033
% of Sys Energy by Genset	**52%**

Projected Power System Outputs versus Overall System Load

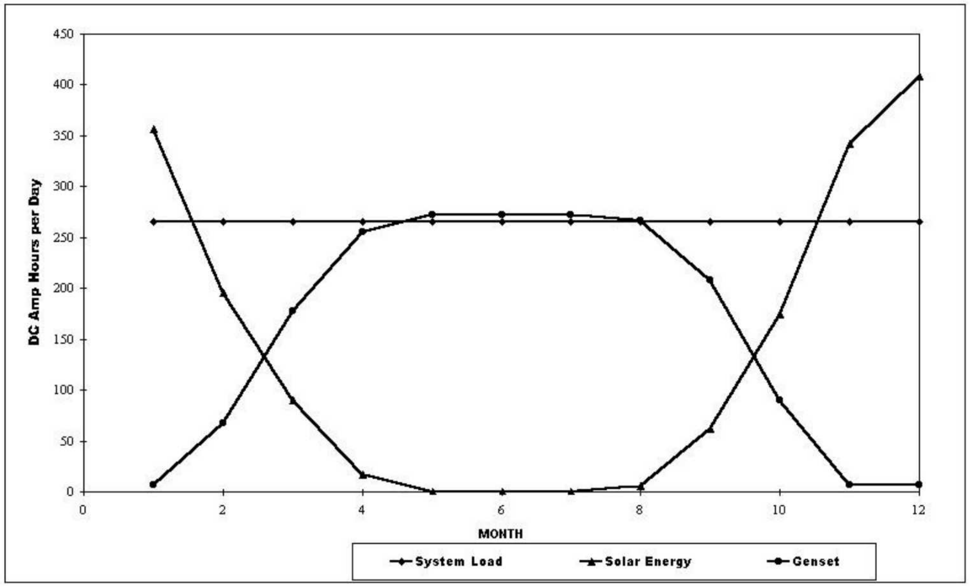


Figure 2.9.10 I55US Hybrid Power System Power Curve

Power Consumption

Array Elements:	
Smart-24:	1.9 Watts
Chaparral 50A:	.5 Watts
Switch	2.0 Watts
Device Controller	.5 Watts
Freewave Radio (Average)	2.8 Watts
Total =	7.7 Watts

Batteries
Model: PVX-1040T
Manufacturer: Concorde SunExtender
Voltage: 12 Volts
Capacity: 104 Amp Hour(s)
Chemistry: Lead
Dimensions: 305 mm L x 168 mm W x 227 mm H
Weight: 28.6 kg

CRF UPS Manufacturer: APC UPS
Model: Smart-UPS 3000VA with an additional

Power Consumption
H1-H5, H8:
The SMART-24 digitizer with GPS receiver, switch, device controller, and sensor together uses approximately 7.7 watts of power or less than .64A of current. For a 10.5 volt cutoff, the 104 Amp hour battery should be able to sustain the system for over 6.5 days at warmer temperatures or 4 days at -40C.
H6:
The pressure sensor introduces an additional drain of of 0.04 watts (0.004A) to the system, minimally impacting the runtime.
H7:
The MET sensors introduce an additional drain of 0.5 watts (0.04A) to the system. For a 10.5-volt cut-off with the same battery we should be able to sustain the system for approximately 6 days.

CRF:
The computer, media converters, Cisco switch and router and Netgear switches are connected to the APC UPS. The UPS can sustain this load for approximately 1 hour.

2.10 Security

The vaults at the I55US sensor sites have two randomly placed pushbutton switches to indicate if the lid is opened. The pushbutton switches are electronically latched so that only one has to go high momentarily for it to be positively detected. The status of the switch is sent back to the CRF once a second. No physical access security is provided to prevent access to the array other than the extreme remote location. The vaults are made of plastic and will show any tampering that was done to get into the vault through the side. The lid of the vault is padlocked shut.

The Remote CRF in Fairbanks has software running that monitors the major alarm functions of the vaults and data system. Upon detection of an alarm, a list of designated operators in Fairbanks is notified via email. See section 10 for a complete description of this function and other information. The remote CRF is located in room 506B in the C.T. Elvey building at the Geophysical Institute on the University of Alaska campus in Fairbanks, Alaska. This is the same location in which I53US's CRF is located. The room is locked with a carefully controlled set of keys.

Building 69, where the relay equipment is located, is not a locked facility. It contains high value NASA and NSF communication equipment that must be accessed by NSF and NASA. Frequently in the Arctic and Antarctic where buildings are remote like B69 from the main base, buildings are not locked for safety reasons and because of their remoteness limits possible vandalism. However, data is signed at the sites and therefore cannot be tampered with at the relay site.

The CRF is located in Building 159 at McMurdo station, which is a locked room.

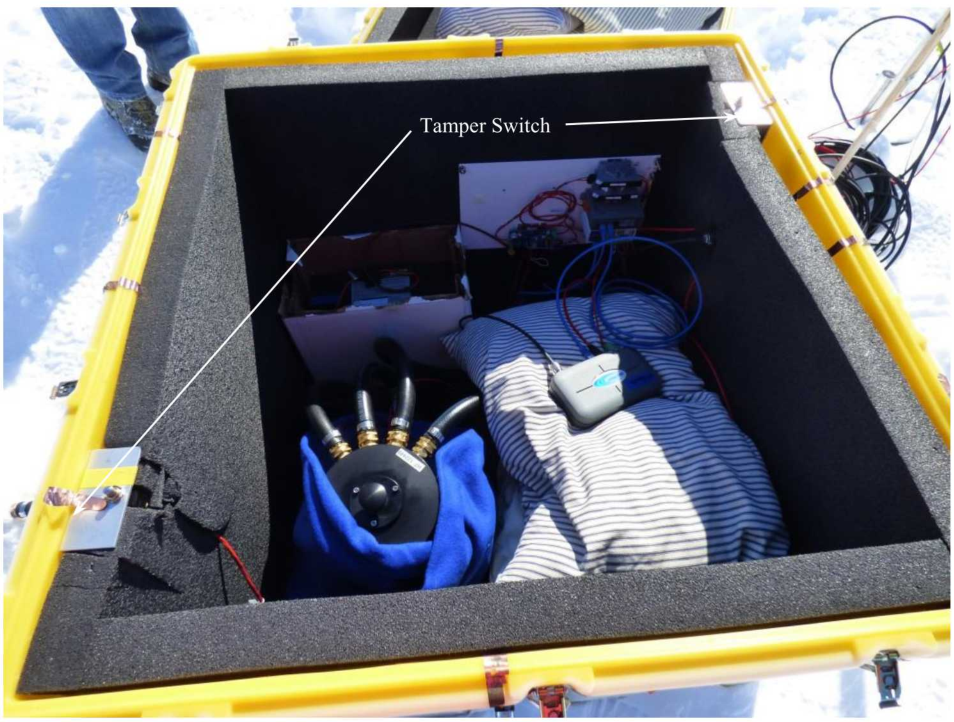


Figure 2.10.1 Tamper Switches

2.11 Grounding and Lightning Protection

Although lightning in Antarctica is rare, at each of the elements a PolyPhaser IX-3L surge suppressors are installed between the radio and the antenna. In addition, there is a PolyPhaser IX-3L surge suppressor installed at H7 for the MET station (Figure 2.11.1). The surge suppressors are connected to the site ground which is connected to the radio antenna/GPS antenna mast (Figure 2.11.2).

At the Relay Site and at the CRF, I55US grounding is connected to the building grounds.

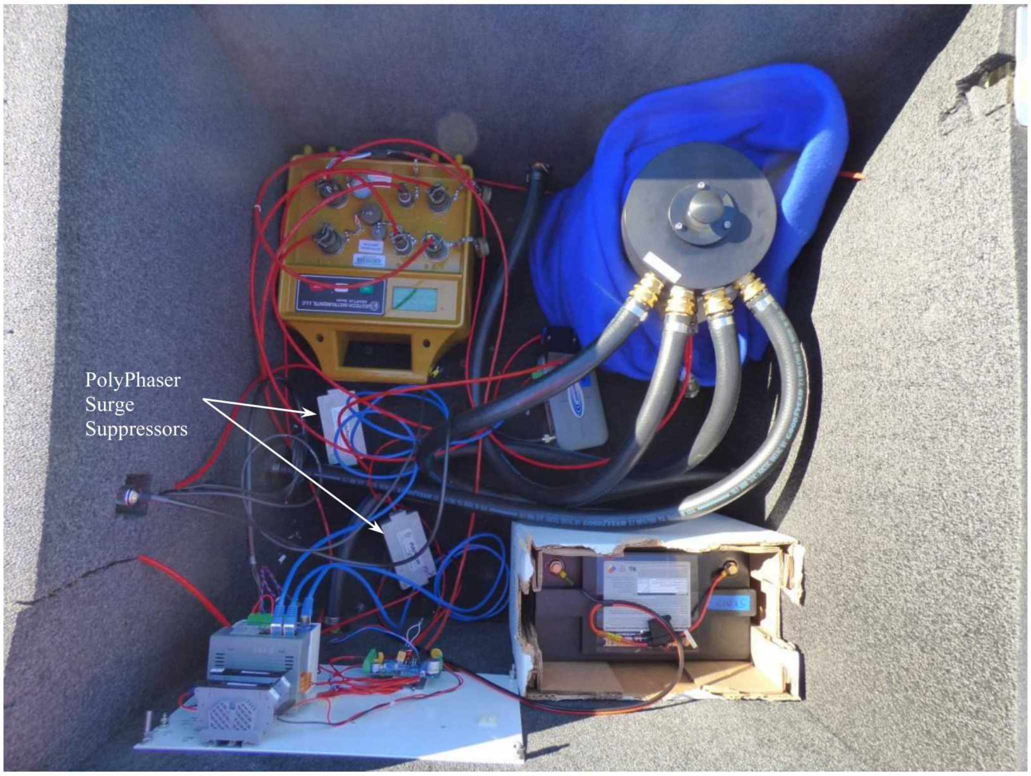


Figure 2.11.1 I55US Site Surge Suppressors

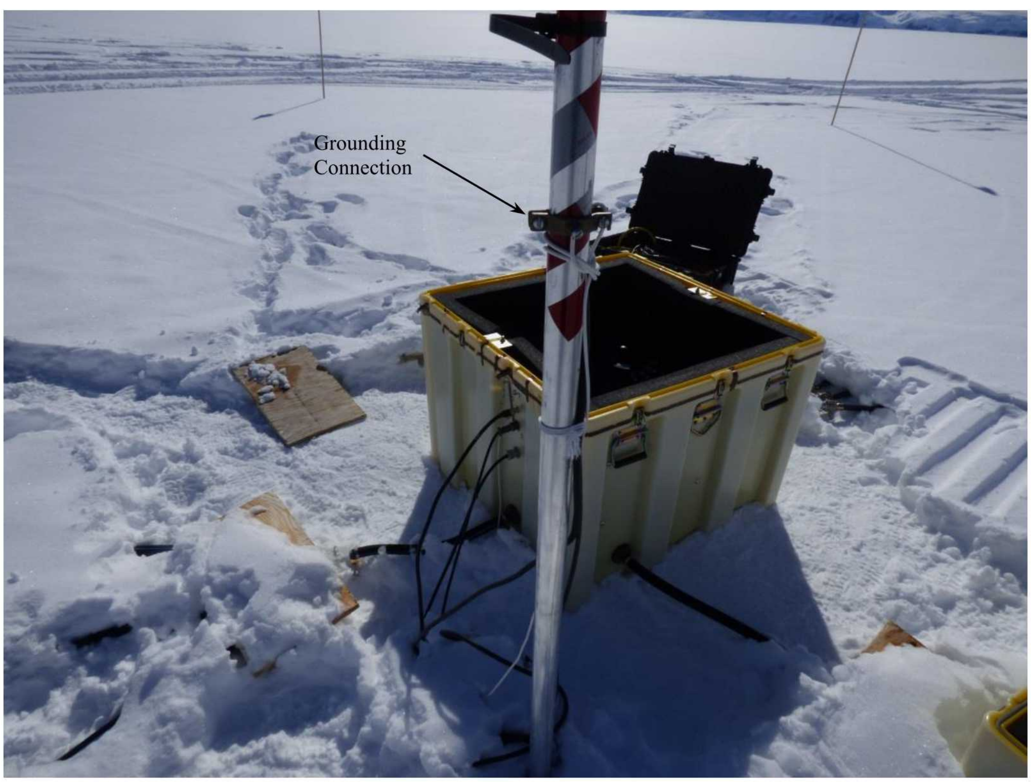


Figure 2.11.2 I55US Site Grounding

3 Data Acquisition

3.1 Infrasonic Data Acquisition Equipment

Generic Block Diagrams showing all of the equipment at the array elements, including data acquisition and communications equipment are shown in Figure 3.1.1.

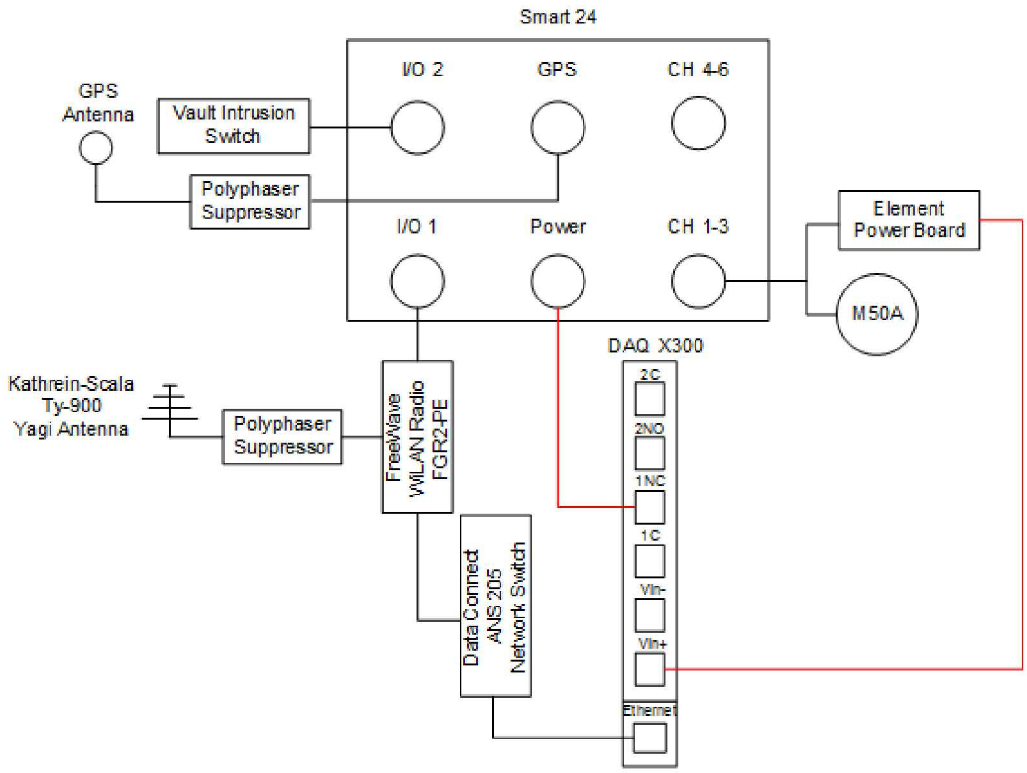


Figure 3.1.1 I55US Data Acquisition Block Diagram H1-H5, H8

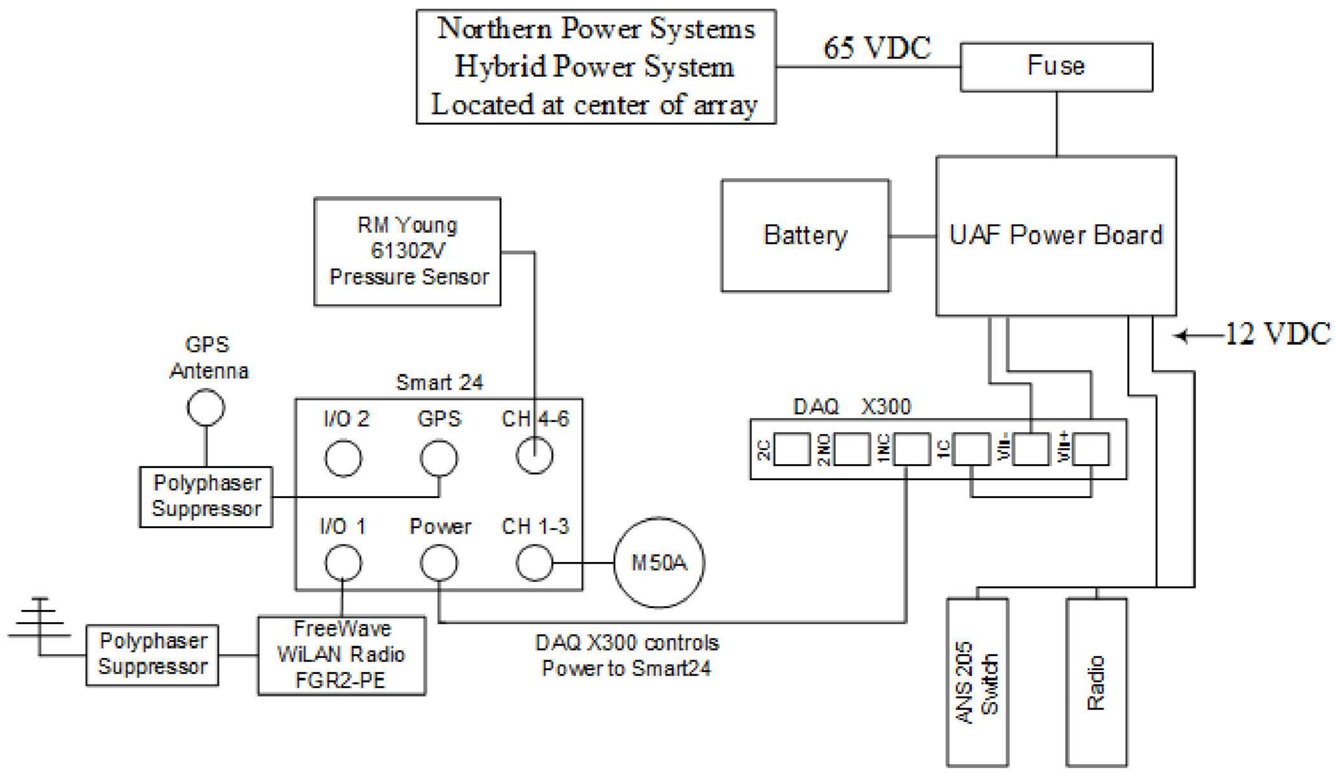


Figure 3.1.2 I55US Data Acquisition Block Diagram H6

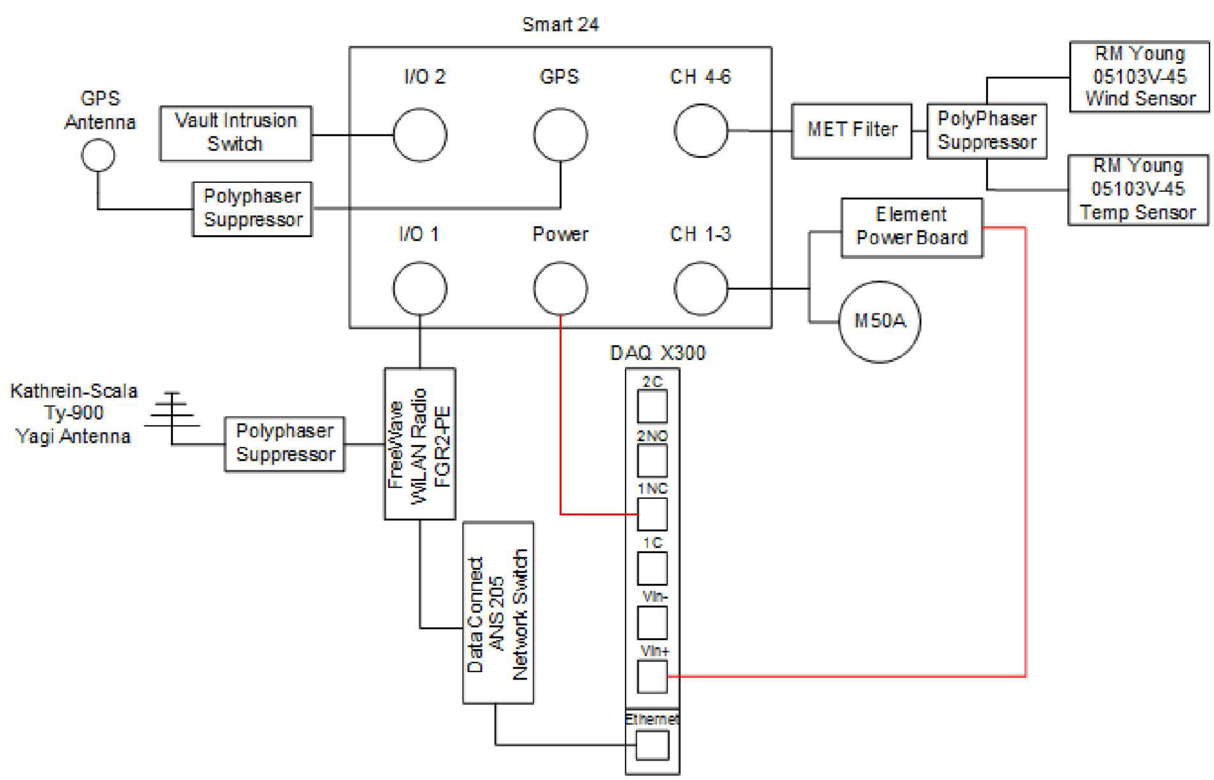


Figure 3.1.3 I55US Data Acquisition Block Diagram H7

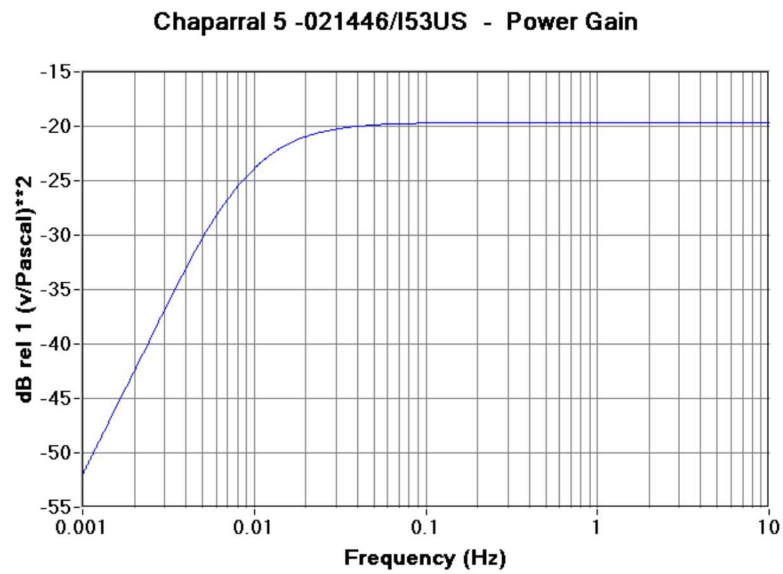
Equipment	Manufacturer	Model	Sites
Security token	SafeNet	SES3100-F	CRF
Security token	Spyrus	Fortezza	Elements
WILAN Radios	FreeWave	FGR2-PE	All
WILAN Radio	FreeWave	DGR-115R/E	BoB,Relay
Serial-Ethernet Converter	Blackbox	LES301A	BoB, Relay
12 dBi Yagi Antenna	Scala	Ty-900	H1,H2,H3,H5,H6,H7
Antenna Coax Lighting Protector	Polyphaser	IS-B5OLN-C2	All
Digitizer	Geotech Instruments	Smart24	Elements
GPS Receiver	Trimble	Accutime 2000	Elements
GPS Time Server	Masterclock	NTP100-GPS	CRF
Humidity Temperature Sensor	RM Young	41382VC	H7
Wind Speed-Wind Direction Sensor	RM Young	05103V-45	H7
Barometric Pressure Sensor	RM Young	61302V	H6
Infrasound Sensor	Chaparral	50A	Elements
Batteries	Concorde	PVX-1040T	Elements
Web Monitor	Control by Web	X300	Elements
Voltage Level Shifter (Temp)	Geotech Instruments	(Wind & Temp)	H7
Network Switch	Data Connect	ANS205	Elements
Network Power Switch	Baytech	MRP100A.23.254-03	CRF
Ethernet Switch	NETGEAR	GS116E	CRF
Router	Cisco	891-K9	CRF, Relay
Computer	Dell	T3600	CRF
UPS	APC	SUA1500	CRF
Power Supply	TDK-Lambda	DPX40-24WS12	Relay
Power Supply	Elpac Power Systems	FWC100024A-11B	Relay

3.2 Sensor Information

Sensor:	Chaparral 50A Infrasound Sensor
Output type	Differential
Maximum	36 volts peak-to-peak (signal+ to signal-)
	±9 volt max signal to ground
Nominal Sensitivity:	400 mV/Pa (CTBT setting)
Passband:	Flat to within +0, -3 dB from 0.01 Hz to 50 Hz
	Flat to within +0, - 0.5 dB from 0.06 Hz to 10 Hz
Self-noise	Less then 0.10nPa2/Hz @ 1 Hz, (-80dB Pa2/Hz, rel to 1 Pa)
	Less than 1mPa RMS, 0.02 to 50 Hz 60
	Less than 0.2 mPa RMS, 0.5 to 2 Hz,
Dynamic range	99dB high gain, 113dB in low gain @ 0.5 Hz to 2 Hz
Output Impedance	150Ω non-reactive, (recommend load >10kΩ)
	(Recommended less than 10,000pf loading)
Physical:	Sensor will function in any position or attitude. Sealed to IP-67 with acoustic inlets sealed and mating electrical connector or cap installed
Operating Temperature	-40º C to +65º C
Humidity	95% (non-condensing)
Dimensions	16.5" (42 cm) maximum height
	9.9" (25 cm) maximum diameter
Weight	17.6 lbs (8 Kg), for 4-port version
Power Supply Voltage:	12V (Input range 9-18 volts)
Current Drain:	40 mA

Sample Pole-Zero Response (Actual PAZ included in Attachment 4A):
Zeroes: 2 at s-plane origin, 1 at -0.0360
Poles: -0.05797, -0.0671, -0.0083

Overall Sensor Response (Acoustic + electronics):



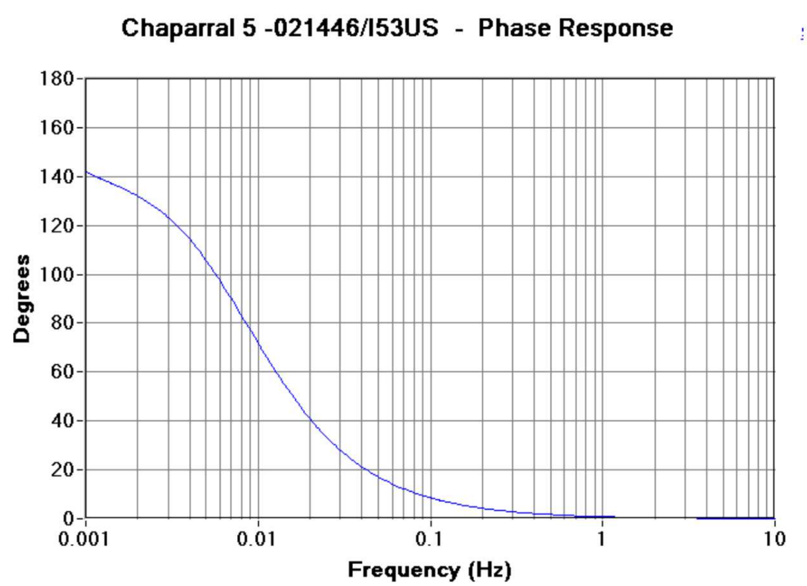


Figure 3.2.1 Chaparral 50A Sensor Response

3.3 Sensor Self-Noise

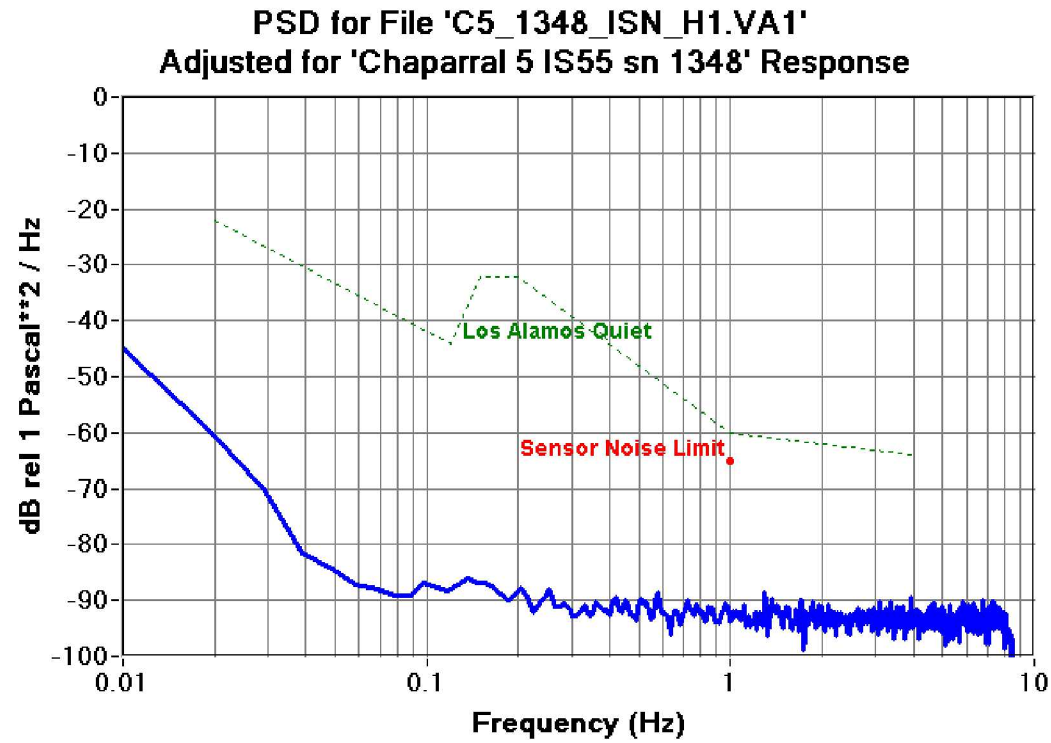


Figure 3.3.1 I55US Chaparral Self Noise

Dynamic Range:

Dynamic Range uses the ratio of the RMS value of the maximum sensor output (0.707 * 73.80 Pa = 52.18 Pa) to the RMS value of the sensor self-noise in a two-octave passband centered at 1 Hz (.5 – 2 HZ).

RMS of Noise (.5 – 2 HZ): <u>0.0622</u> (mPa)
Dynamic Range: <u>120.8</u> dB

3.4 Digitizer System

Measuring Counts/Volt and the Full-Scale (Clip) of the Crystal SemiconductorCS5321 Delta-Sigma Modulator/ CS5322 Digital Filter used in the SHI AIM24S Digitizers

The Crystal Semiconductor CS5376A Digital Filter when used in conjunction with the CS5371A Delta-Sigma Modulator and the CS3301A Preamp provides output data in a 24-bit format. This combination 'does not output a full-scale digital code of +/- 8,388,607 (+/- 23-bits) but is scaled to a lower value, 6,134,970 (+/- 22.55-bits) to allow some overrange capability.' This translates to 73.1 % of the implied 24-bit range.

The capability of the digitizer is specified to this 62.5% value. For the SMART24, the factory data sheet indicates a full-scale of +/- 10 volts with a bit-weight (LSB) of 1.6356µV. This factory specified clip level is at the 73.1% of the 24-bit level.

To measure the counts/volt of the SMART24 digitizers, a DC Voltage equal to +/- 1 Volt or +/- 0.1 Volt is applied to the digitizer input (Table 1). Average the counts for + and - to correct for offset. Multiply by 10 when necessary.

Digitizer	Counts/ Volt Test Voltage	Nominal Counts/Volt	Measured Counts/Volt	Nominal µVolts/ Count	Measured µVolts/ Count
SMART24	1 Volt	611416	610653	1.63555	1.63759

Table 1 – Counts per Volt Measurement

3.5 Digitizer Noise and Dynamic Range

Figure 3.5.1 shows the results of an input terminated noise test performed by Sandia National Laboratories on a Smart24 digitizer System noise and Dynamic Range are shown in Table 3.5.1

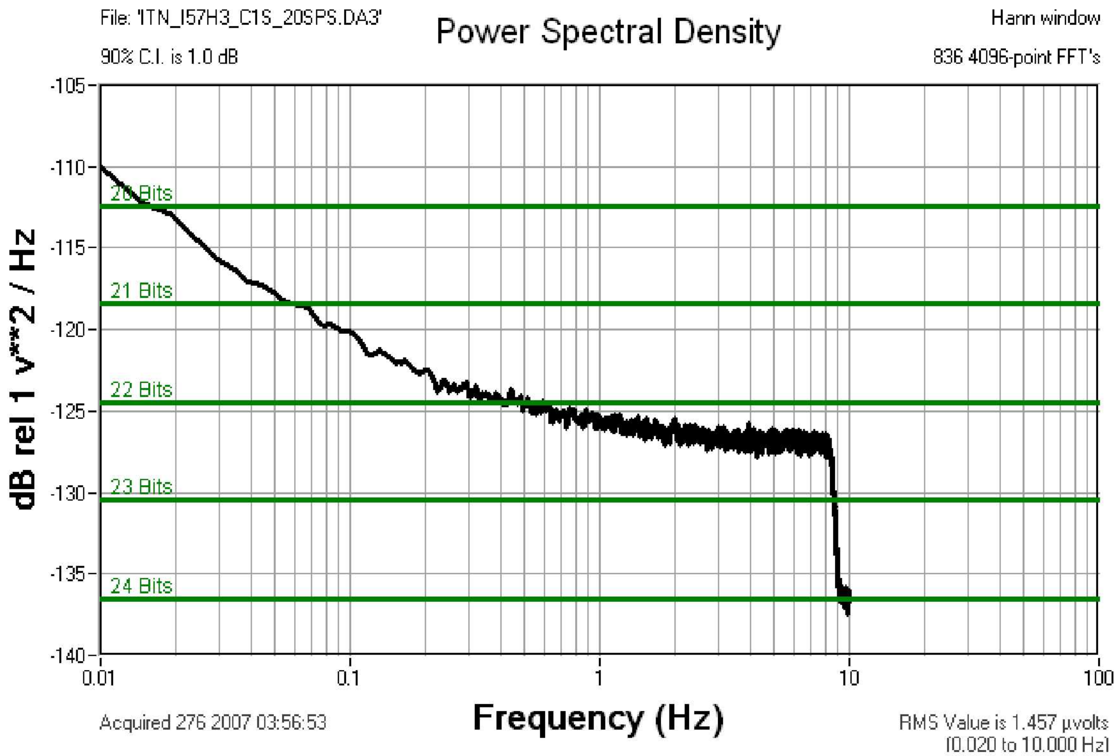


Figure 3.5.1 Power Spectrum Smart24

SMART24 Serial Number	Full Scale RMS volts	Band RMS µvolts	Bandwidth Limited Dynamic Range (dB)
1223	7.07	1.437	133.8

Table 3.5.1 System Noise and Dynamic Range

Note: If "q" is the quantizing step (i.e., bit weight in volts/count) for the digitizer, the bandwidth-limited dynamic range is taken to be the ratio in dB of the RMS of a full-scale sine wave to the RMS of the input-terminated noise over the appropriate frequency band. The value of "q" is 1.635548 µvolt/count for the infrasound system.

$$Dynamic\ Range = 20\log_{10}\left(\frac{q \cdot 2^{23} \cdot 0.625 \cdot 0.7071}{RMS\ Noise}\right)$$

Data Time Stamp

The Time Tagging Test performed by Sandia National Laboratories**,** uses a Programmable GPS Timing Reference to input a 2-second wide step pulse into the SMART24 digitizer once per minute to check the accuracy of the time tag the digitizer adds to the data packet. Figure 3.5.2 is the result of a data time stamp test completed on a Smart24 at Sandia National Laboratories.

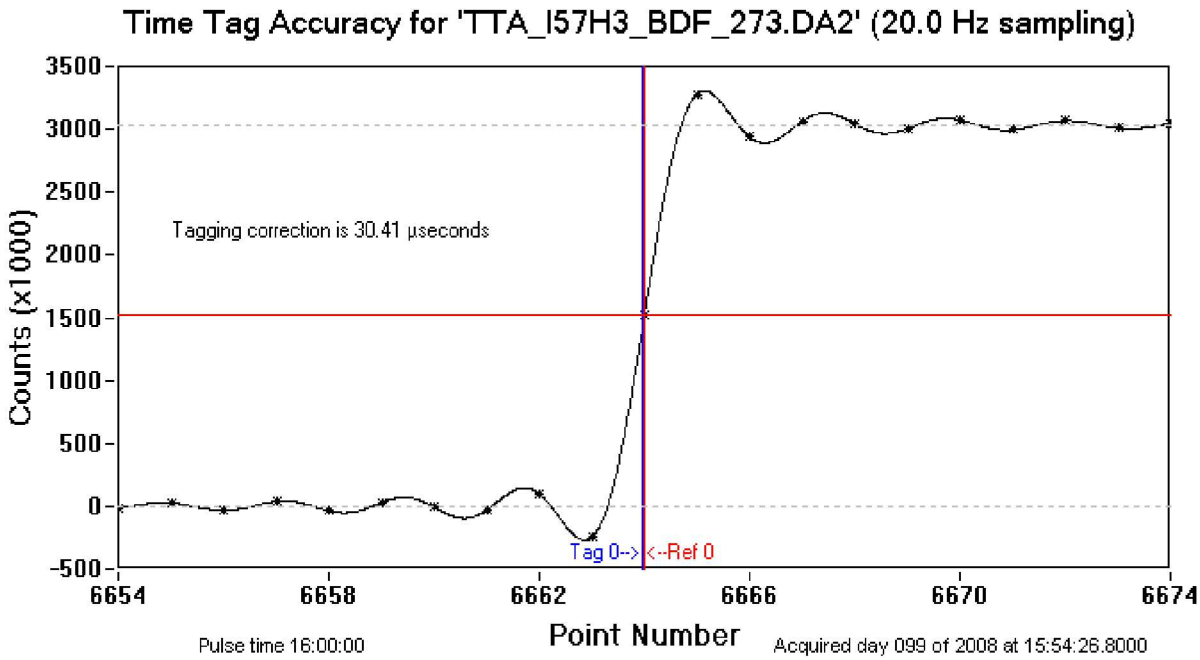


Figure 3.5.2 Time Tag Accuracy Plot

3.6 Digitizer Command Set

Command	Function	Note	Section
ABT	Abort setup	I	3.6.4.1.1
AGK	Generate New DSA Key Pair	I	3.6.4.8.1
ANO	Anonymous FTP Access Enable/Disable	I	3.6.1.3.12
ARK	Return DSA Public Key	I	3.6.4.8.2
ASK	Start/Abort A Pending DSA Key Pair	I	3.6.4.8.3
ASR	Accept new setup parameters & reboot	I	3.6.4.1.2
AUG	Set User DSA G Values	I	3.6.4.8.4
AUP	Set User DSA PValues	I	3.6.4.8.5
AUQ	Set User DSA QValues	I	3.6.4.8.6
AZC	Set Scheduled Autozero Channels	A	3.6.4.7.6
AZE	Set Scheduled Autozero Enable/Disable	A	3.6.4.7.2
AZG	Save & Start Using New Scheduled Autozero Parameters	A	3.6.4.7.7
AZI	Set Scheduled Autozero Interval	A	3.6.4.7.4
AZN	Immediate Autozero Command	I	3.6.4.7.1
AZR	Set Scheduled Autozero Repetitions	A	3.6.4.7.5
AZS	Set Scheduled Autozero Start Time	A	3.6.4.7.3
BTL	Reboot into the boot loader mode	I	3.6.4.1.3
CAA	Set calibration amplitude	C	3.6.2.1.2
CAC	Set calibration digital control on/off	C	3.6.2.1.7
CAD	Set calibration duration	C	3.6.2.1.5
CAF	Set calibration frequency	C	3.6.2.1.3
CAG	Calibration go command	I	3.6.4.4.1
CAH	Calibration halt command	I	3.6.4.4.2
CAI	Set calibration interval	C	3.6.2.1.8
CAM	Set CD 1.1 authentication mode	R	3.6.1.4.7
CAO	Set calibration output signal	C	3.6.2.1.1
CAR	Set calibration repetitions	C	3.6.2.1.9
CAS	Set calibration output relay state	C	3.6.2.1.6
CAT	Set calibration start time	C	3.6.2.1.10
CAW	Set calibration pulse or bit width	C	3.6.2.1.4
CBF	Set CD 1.1 Backfill Mode	I	3.6.1.4.23
CCD	Set CD 1.1 data channel output disables	R	3.6.1.3.9
CCE	Set CD 1.1 data channel output enables	R	3.6.1.3.8

CCL	Set CD 1.1 calib/calper mode & values	I	3.6.1.4.8
CCM	Set CD 1.1 compression mode	I	3.6.1.4.6
CCN	Set CD 1.1 channel name	R	3.6.1.4.3
CCP	Set CD 1.1 connection request remote port	I	3.6.1.4.12
CDA	Set CD 1.1 destination IP address	I	3.6.1.4.11
CDE	Enable/disable CD 1.1 profile	R	3.6.1.4.15
CDF	Set CD 1.1 data frame size	R	3.6.1.4.9
CDS	Set CD 1.1 data frame save size	I	3.6.1.4.21
CDT	Set CD 1.1 data type	I	3.6.1.4.4
CIP	Set CD 1.1 command input port	I	3.6.1.4.17
CLN	Set CD 1.1 location name	R	3.6.1.4.2
CNC	Set CD 1.1 Creator Name	I	3.6.1.4.19
CNS	Set CD 1.1 Station Name	I	3.6.1.4.20
CRR	Set CD 1.1 connection request retry	I	3.6.1.4.18
CRT	Set CD 1.1 connection request timeout	I	3.6.1.4.16
CSF	Set CD 1.1 SOH alert frame output frequency	R	3.6.1.4.10
CSN	Set CD 1.1 site name	R	3.6.1.4.1
CSS	Set CD 1.1 SOH frame save size	I	3.6.1.4.22
CST	Set CD 1.1 sensor type	I	3.6.1.4.5
DDC	Set LCD Data Display Control	I	3.6.4.1.10
FZS	Get Fortezza Card Status	I	3.6.4.5.9
GCD	Global ADC channel disables	R	3.6.1.1.4
GCE	Global ADC channel enables	R	3.6.1.1.3
GCS	Get Data Channel Statistics	I	3.6.4.5.6
GCT	Set GPS cycle time	I	3.6.4.2.1
GET	Get all setup parameters	I	3.6.4.1.4
GPC	Set GPS Configuration	I	3.6.3.2.2
GPS	Get GPS status	I	3.6.4.5.3
GPT	Get GPS Satellite Tracking Status	I	3.6.4.5.7
HLP	Get Command Help	I	3.6.4.1.7
HWS	Get hardware status	I	3.6.4.5.5
ICA	Set IP port PPP client IP address	R	3.6.1.3.11
IDM	Set IP mode	R	3.6.1.3.7
IPA	Set IP address	R	3.6.1.3.1
IPD	Set IP domain name	R	3.6.1.3.5
IPE	Set IP port enable/disable	R	3.6.1.3.8
IPG	Set IP gateway address	R	3.6.1.3.3
IPH	Set IP host name	R	3.6.1.3.4
IPM	Set IP address mask	R	3.6.1.3.2
IPN	Set IP DNS server address	R	3.6.1.3.6
IPS	Get TCP/IP status	I	3.6.4.5.4
ISA	Set IP port PPP server IP address	R	3.6.1.3.9
ISM	Set IP port PPP server IP mask	R	3.6.1.3.10
JST	Set jamset threshold	I	3.6.3.1.2

LGD	Disable LOG messages	I	3.6.4.6.2
LGE	Enable LOG messages	I	3.6.4.6.1
LGL	Set Log Level on/off	I	3.6.4.6.4
LGO	Logout this Connection	I	3.6.4.1.8
LGT	Enable/Disable long time in LOG messages	I	3.6.4.6.3
OFF	Power off	I	3.6.4.1.5
OSC	Perform an ADC offset calibration	I	3.6.4.3.1
PCS	Get PCMCIA PC Card Status	I	3.6.4.5.8
PSW	Enter password	I	3.6.4.2.1
RBT	Reboot	I	3.6.4.1.6
RCL	Set ADC input relay state	I	3.6.4.3.2
SCG	Set channel gain	I	3.6.1.1.5
SCP	Set client password	I	3.6.4.2.5
SCU	Set client username	I	3.6.4.2.6
SET	Set current time.	I	3.6.3.3.1
SFD	Set Factory Defaults	I	3.6.4.1.9
SFG	Set Front End Gain	I	3.6.1.1.6
SFT	Set ADC FIR Filter Type	R	3.6.1.1.8
SOH	Get state of health parameters	I	3.6.4.5.2
SPB	Set serial port baud rate	R	3.6.1.2.1
SPC	Set serial port character mode	R	3.6.1.2.4
SPM	Set serial port communications mode	R	3.6.1.2.2
SPP	Set serial port communication protocol	R	3.6.1.2.3
SPW	Set password	I	3.6.4.2.2
SRP	Set primary sample rate	R	3.6.1.1.1
SRS	Set secondary sample rate	R	3.6.1.1.2
SSD	Enable/Disable ADC Time Sync Delay Correction	R	3.6.1.1.9
SSS	Set Sensor Sensitivity	I	3.6.1.1.7
SUN	Set system username	I	3.6.4.2.4
TSM	Set time synchronization mode	I	3.6.3.1.1
TYP	Get Smart Series type	I	3.6.4.5.1
URT	Set USGS RTD Format	R	3.6.1.2.5
USR	Enter system username	I	3.6.4.2.3

Notes: I) Immediate Commands
R) Setup commands that require an ASR command to save new configuration parameters and reboot the system.
C) Calibration commands that require a CAG command to set.
A) Autozero commands that require a AZG command to set.

Figure 3.6.1 Smart24 Commands

3.7 Meteorological Sensors

<u>RM Young model 05103V-45 Wind Sensor</u>

Wind Speed Specification Summary

Range	0 to 100 m/s (224 mph)
Sensor	14 cm diameter 4-blade helicoid polypropylene propeller, 29.4 cm air passage per revolution
Distance Constant	2.7 m (8.9 ft.) for 63% recovery
Threshold Sensitivity	1.0 m/s (2.2 mph)
Transducer	Centrally mounted stationary coil, 2K Ohm nominal DC resistance
Output Signal	50 mV per M/S

Wind Direction (Azimuth) Specification Summary

Range	360° mechanical, 355° electrical (5° open)
Sensor	Balanced vane, 38 cm (15 in) turning radius.
Damping Ratio	0.3
Delay Distance	1.3 m (4.3 ft) for 50% recovery
Threshold Sensitivity	1.1 m/s (2.4 mph) at 10° displacement
Damped Natural Wavelength	7.4 m (24.3 ft)
Undamped Natural Wavelength	7.2 m (23.6 ft)
Transducer	Precision conductive plastic potentiometer, 10K ohm resistance (±20%), 0.25% linearity, life expectancy 50 million revolutions, rated 1 watt at 40°C, 0 watts at 125°C
Output Signal	13.9 mV per degree

General

Power Requirement: 8 - 24 VDC (5mA @ 12 VDC)
Operating Temperature: -50 to 50°C (-58 to 122°F)

<u>RM Young Model 41372VC Temperature Sensor</u>

Temperature

Measuring Range:	-50 to +50°C
Accuracy at 23°C:	±0.3°C
Response Time:	10 seconds (Without Filter)
Sensor type:	Platinum RTDW
Output signal:	0-1 or 0-5 VDC (jumper option)
Power Required:	8-30 VDC at 7 mA
Recommended Cable:	5 conductor shielded, Young 18446

3.8 Manufacturer's Manuals

All manuals are on line

4 Configuration, Response, and resolution of Data Channels

4.1 Instrument/Digitizer Response

PAZ (POLES AND ZEROES) FOR Chaparral 50A

```
# Chaparral 50A Infrasound sensor response based on information
# provided by Chaparral.
# Response in poles and zeros for the output from the Chaparral 50A sensor.
#
#   Sensor sensitivity = 0.4 V/Pa at 1.0 Hz
#
# source=theoretical sequence=1 description=infrasound
# type=paz information=Chaparral
#
# Listed fields:
#
# The value of A0 listed before the poles
# normalizes the response to unity. Response
# should be multiplied by 0.4 to give Chaparral 50A response in Volts/Pa.
#
# The number of poles, their Real part, Imaginary part and errors
# are listed.
#
# The number of zeros, their Real part, Imaginary part and errors
# are listed under the poles.

theoretical    1  infrasound paz       Chaparral

#A0 - 3.141E+02

# Number of poles – 4

# Real               Imaginary          Real Error         Imaginary Error
 0.00000000E+00      0.00000000E+00     0.00000000E+00     0.00000000E+00
-3.14000000E+02      0.00000000E+00     0.00000000E+00     0.00000000E+00
-0.18800000E+00      0.00000000E+00     0.00000000E+00     0.00000000E+00
-0.04400000E+00      0.00000000E+00     0.00000000E+00     0.00000000E+00

# Number of zeros – 3

# Real               Imaginary          Real Error         Imaginary Error
 0.00000000E+00      0.00000000E+00     0.00000000E+00     0.00000000E+00
 0.00000000E+00      0.00000000E+00     0.00000000E+00     0.00000000E+00
-0.17000000E+00      0.00000000E+00     0.00000000E+00     0.00000000E+00
```

FAP (Frequency and Phase) for the SMART-24

```
# Instrument response: channel I58H1_BDF
#
#
# Chaparral 50A Infrasound Sensor
#
#
#
# Geotech Smart24 Digitizer
#
# Geotech Smart24 digitizer based on information provided by Geotech.
# Response in FAPs for the output from the Geotech Smart24
#
#   Digitizer sensitivity = 3.0581e+05 counts/volt
#                        3.27 microvolts/count
#
#   Ncalib = 0.0000081750 Pa/count  Ncalper = 1.0 sec
#
# Theoretical response: frequency-amplitude-phase table (73 points)
#
# These FAPs are theoretical and were computed by John Merchant
# of SNL from the FIR stages provided by Geotech.
# The amplitudes were scaled to be 1 count/Volt at 1.0 Hz.
# The amplitudes would need to be multiplied by 6.11621e+05 to get
# the response in counts/Volt.
# The phase comes from Geotech's claimed -67 microseconds of delay
# in the preamplifier multiplied by 2 * pi * f and converted to degrees.
#
#    source     sequence description  type     source of
#             number                       information
#  Measured response 20 Hz sampling rate
#  Number of fap
#
# source=theoretical sequence=2 description=digitizer
# type=fap information=SNL
#
# Number of fap=73
#
# Listed fields:
# Frequency  Amplitude Phase(deg)  AmEr             PhEr#
#
```

theoretical 2 digitizer fap SNL

Number of FAPs

73

# Freq	Amplitude	Phase	Amp Error	Phase Error
0.00100000	1.00033415	-0.00002412	0.00000000	0.00000000
0.00150000	1.00033414	-0.00003618	0.00000000	0.00000000
0.00200000	1.00033412	-0.00004824	0.00000000	0.00000000
0.00250000	1.00033410	-0.00006030	0.00000000	0.00000000
0.00300000	1.00033408	-0.00007236	0.00000000	0.00000000
0.00350000	1.00033404	-0.00008442	0.00000000	0.00000000
0.00400000	1.00033401	-0.00009648	0.00000000	0.00000000
0.00450000	1.00033396	-0.00010854	0.00000000	0.00000000
0.00500000	1.00033392	-0.00012060	0.00000000	0.00000000
0.00550000	1.00033386	-0.00013266	0.00000000	0.00000000
0.00600000	1.00033381	-0.00014472	0.00000000	0.00000000
0.00650000	1.00033375	-0.00015678	0.00000000	0.00000000
0.00700000	1.00033368	-0.00016884	0.00000000	0.00000000
0.00750000	1.00033361	-0.00018090	0.00000000	0.00000000
0.00800000	1.00033353	-0.00019296	0.00000000	0.00000000
0.00850000	1.00033345	-0.00020502	0.00000000	0.00000000
0.00900000	1.00033336	-0.00021708	0.00000000	0.00000000
0.00950000	1.00033327	-0.00022914	0.00000000	0.00000000
0.01000000	1.00033317	-0.00024120	0.00000000	0.00000000
0.01500000	1.00033194	-0.00036180	0.00000000	0.00000000
0.02000000	1.00033021	-0.00048240	0.00000000	0.00000000
0.02500000	1.00032799	-0.00060300	0.00000000	0.00000000
0.03000000	1.00032528	-0.00072360	0.00000000	0.00000000
0.03500000	1.00032209	-0.00084420	0.00000000	0.00000000
0.04000000	1.00031842	-0.00096480	0.00000000	0.00000000
0.04500000	1.00031428	-0.00108540	0.00000000	0.00000000
0.05000000	1.00030968	-0.00120600	0.00000000	0.00000000
0.05500000	1.00030461	-0.00132660	0.00000000	0.00000000
0.06000000	1.00029910	-0.00144720	0.00000000	0.00000000
0.06500000	1.00029314	-0.00156780	0.00000000	0.00000000
0.07000000	1.00028674	-0.00168840	0.00000000	0.00000000
0.07500000	1.00027992	-0.00180900	0.00000000	0.00000000
0.08000000	1.00027268	-0.00192960	0.00000000	0.00000000
0.08500000	1.00026504	-0.00205020	0.00000000	0.00000000
0.09000000	1.00025701	-0.00217080	0.00000000	0.00000000
0.09500000	1.00024860	-0.00229140	0.00000000	0.00000000
0.10000000	1.00023982	-0.00241200	0.00000000	0.00000000
0.15000000	1.00013488	-0.00361800	0.00000000	0.00000000
0.20000000	1.00001046	-0.00482400	0.00000000	0.00000000
0.25000000	0.99988530	-0.00603000	0.00000000	0.00000000
0.30000000	0.99977856	-0.00723600	0.00000000	0.00000000
0.35000000	0.99970708	-0.00844200	0.00000000	0.00000000

0.40000000	0.99968269	-0.00964800	0.00000000	0.00000000
0.45000000	0.99971030	-0.01085400	0.00000000	0.00000000
0.50000000	0.99978684	-0.01206000	0.00000000	0.00000000
0.55000000	0.99990140	-0.01326600	0.00000000	0.00000000
0.60000000	1.00003671	-0.01447200	0.00000000	0.00000000
0.65000000	1.00017166	-0.01567800	0.00000000	0.00000000
0.70000000	1.00028461	-0.01688400	0.00000000	0.00000000
0.75000000	1.00035702	-0.01809000	0.00000000	0.00000000
0.80000000	1.00037673	-0.01929600	0.00000000	0.00000000
0.85000000	1.00034035	-0.02050200	0.00000000	0.00000000
0.90000000	1.00025416	-0.02170800	0.00000000	0.00000000
0.95000000	1.00013343	-0.02291400	0.00000000	0.00000000
1.00000000	1.00000000	-0.02412000	0.00000000	0.00000000
1.50000000	1.00046681	-0.03618000	0.00000000	0.00000000
2.00000000	1.00008150	-0.04824000	0.00000000	0.00000000
2.50000000	0.99997599	-0.06030000	0.00000000	0.00000000
3.00000000	1.00047661	-0.07236000	0.00000000	0.00000000
3.50000000	1.00050550	-0.08442000	0.00000000	0.00000000
4.00000000	0.99996827	-0.09648000	0.00000000	0.00000000
4.50000000	0.99989234	-0.10854000	0.00000000	0.00000000
5.00000000	1.00029867	-0.12060000	0.00000000	0.00000000
5.50000000	1.00025831	-0.13266000	0.00000000	0.00000000
6.00000000	0.99983056	-0.14472000	0.00000000	0.00000000
6.50000000	0.99991233	-0.15678000	0.00000000	0.00000000
7.00000000	1.00043875	-0.16884000	0.00000000	0.00000000
7.50000000	1.00063885	-0.18090000	0.00000000	0.00000000
8.00000000	0.99974018	-0.19296000	0.00000000	0.00000000
8.50000000	0.79200447	-0.20502000	0.00000000	0.00000000
9.00000000	0.20804073	-0.21708000	0.00000000	0.00000000
9.50000000	0.00698548	-0.22914000	0.00000000	0.00000000
10.00000000	0.00000013	-0.24120000	0.00000000	0.00000000

4.2 Data Channel Parameters

```
BEGIN STATION
STA=I55US
NAME=Windless Bight, Antarctica
LOCALITY=-
STAT_PROV=-
COUNTRY=United States of America
NET=INFRA
stream_list=I55US
site_list=I55H1,I55H2,I55H3,I55H4,I55H5,I55H6,I55H7,I55H8

BEGIN SITE
        STA=I55H1
        ONDATE=2001336
        OFFDATE=-1
        LAT=-77.71643
        LON=167.65042
        ELEV=0.04500
        STANAME=Windless Bight, Anta
        STATYPE=ss
        REFSTA=I55H1
        DNORTH=0.000000
        DEAST=0.000000
        DELEV=0.000000

    channel_list=BDF
        BEGIN CHANNEL
                CHAN=BDF
                ONDATE=2014350
                OFFDATE=-1
                CTYPE=n
                EDEPTH=0.000000
                HANG=-1.0000000
                VANG=-1.000000
                DESCRIP=Infrasonic Micropressure data
                INSNAME=Chaparral 50A differential pressure microphone
                INSTYPE=M50A
                BAND=b
                DIGITAL=d
                SAMPRATE=20
                NCALIB=0.000008575
                NCALPER=1.000000
                DFILE=I55US_bb_rsp_2013315
                RSPTYPE=fap
                TIME=1418796878
                ENDTIME=9999999999.999
```

```
                JDATE=2014350
                CALRATIO=1
                CALPER=1.00
                TSHIFT=0
                INSTANT=y
                CAPABILITY=1
        END CHANNEL

END SITE

BEGIN SITE
        STA=I55H2
        ONDATE=2001336
        OFFDATE=-1
        LAT=-77.72960
        LON=167.67447
        ELEV=0.03914
        STANAME=Windless Bight, Anta
        STATYPE=ss
        REFSTA=I55H1
        DNORTH=-1.471
        DEAST=0.569
        DELEV=-.00586
   channel_list=BDF
        BEGIN CHANNEL
                CHAN=BDF
                ONDATE=2014350
                OFFDATE=-1
                CTYPE=n
                EDEPTH=0.000000
                HANG=-1.0000000
                VANG=-1.000000
                DESCRIP=Infrasonic Micropressure data
                INSNAME=Chaparral 50A differential pressure microphone
                INSTYPE=M50A
                BAND=b
                DIGITAL=d
                SAMPRATE=20
                NCALIB=0.000008683
                NCALPER=1.000000
                DFILE=I55US_bb_rsp_2013315
                RSPTYPE=fap
                TIME=1418796878
                ENDTIME=9999999999.999
                JDATE=2014350
                CALRATIO=1
```

```
                CALPER=1.00
                TSHIFT=0
                INSTANT=y
                CAPABILITY=1
        END CHANNEL

END SITE

BEGIN SITE
        STA=I55H3
        ONDATE=2001336
        OFFDATE=-1
        LAT=-77.74163
        LON=167.63304
        ELEV=0.03905
        STANAME=Windless Bight, Anta
        STATYPE=ss
        REFSTA=I55H1
        DNORTH=-2.812
        DEAST=-0.415
        DELEV=-0.00595
    channel_list=BDF
        BEGIN CHANNEL
                CHAN=BDF
                ONDATE=2014350
                OFFDATE=-1
                CTYPE=n
                EDEPTH=0.000000
                HANG=-1.0000000
                VANG=-1.000000
                DESCRIP=Infrasonic Micropressure data
                INSNAME=Chaparral 50A differential pressure microphone
                INSTYPE=M50A
                BAND=b
                DIGITAL=d
                SAMPRATE=20
                NCALIB=0.000008036
                NCALPER=1.000000
                DFILE=I55US_bb_rsp_2013315
                RSPTYPE=fap
                TIME=1418796878
                ENDTIME=9999999999.999
                JDATE=2014350
                CALRATIO=1
                CALPER=1.00
                TSHIFT=0
```

```
                INSTANT=y
                CAPABILITY=1
        END CHANNEL

END SITE

BEGIN SITE
        STA=I55H4
        ONDATE=2001336
        OFFDATE=-1
        LAT=-77.73270
        LON=167.58291
        ELEV=0.04169
        STANAME=Windless Bight, Anta
        STATYPE=ss
        REFSTA=I55H1
        DNORTH=-1.815
        DEAST=-1.604
        DELEV=-0.00331
    channel_list=BDF
        BEGIN CHANNEL
                CHAN=BDF
                ONDATE=2014350
                OFFDATE=-1
                CTYPE=n
                EDEPTH=0.000000
                HANG=-1.0000000
                VANG=-1.000000
                DESCRIP=Infrasonic Micropressure data
                INSNAME=Chaparral 50A differential pressure microphone
                INSTYPE=M50A
                BAND=b
                DIGITAL=d
                SAMPRATE=20
                NCALIB=0.000008494
                NCALPER=1.000000
                DFILE=I55US_bb_rsp_2013315
                RSPTYPE=fap
                TIME=1418796878
                ENDTIME=9999999999.999
                JDATE=2014350
                CALRATIO=1
                CALPER=1.00
                TSHIFT=0
                INSTANT=y
                CAPABILITY=1
```

END CHANNEL

END SITE

BEGIN SITE
STA=I55H5
ONDATE=2001336
OFFDATE=-1
LAT=-77.72014
LON=167.57296
ELEV=0.04257
STANAME=Windless Bight, Anta
STATYPE=ss
REFSTA=I55H1
DNORTH=-0.414
DEAST=-1.840
DELEV=-0.00243
channel_list=BDF
BEGIN CHANNEL
CHAN=BDF
ONDATE=2014350
OFFDATE=-1
CTYPE=n
EDEPTH=0.000000
HANG=-1.0000000
VANG=-1.000000
DESCRIP=Infrasonic Micropressure data
INSNAME=Chaparral 50A differential pressure microphone
INSTYPE=M50A
BAND=b
DIGITAL=d
SAMPRATE=20
NCALIB=0.000008845
NCALPER=1.000000
DFILE=I55US_bb_rsp_2013315
RSPTYPE=fap
TIME=1418796878
ENDTIME=9999999999.999
JDATE=2014350
CALRATIO=1
CALPER=1.00
TSHIFT=0
INSTANT=y
CAPABILITY=1
END CHANNEL

END SITE

BEGIN SITE
STA=I55H6
ONDATE=2001336
OFFDATE=-1
LAT=-77.72641
LON=167.60366
ELEV=0.04291
STANAME=Windless Bight, Anta
STATYPE=ss
REFSTA=I55H1
DNORTH=-1.113
DEAST=-1.111
DELEV=-0.00209
channel_list=BDF,LDA
BEGIN CHANNEL
CHAN=BDF
ONDATE=2014350
OFFDATE=-1
CTYPE=n
EDEPTH=0.000000
HANG=-1.0000000
VANG=-1.000000
DESCRIP=Infrasonic Micropressure data
INSNAME=Chaparral 50A differential pressure microphone
INSTYPE=M50A
BAND=b
DIGITAL=d
SAMPRATE=20
NCALIB=0.000008183
NCALPER=1.000000
DFILE=I55US_bb_rsp_2013315
RSPTYPE=fap
TIME=1418796878
ENDTIME=9999999999.999
JDATE=2014350
CALRATIO=1
CALPER=1.00
TSHIFT=0
INSTANT=y
CAPABILITY=1
END CHANNEL

BEGIN CHANNEL
CHAN=LDA

```
            ONDATE=2014350
            OFFDATE=-1
            CTYPE=n
            EDEPTH=0.000000
            HANG=-1.0000000
            VANG=-1.000000
            DESCRIP=Infrasonic pressure data
            INSNAME=R.M.Young absolute pressure microphone
            INSTYPE=R.M. Young 61302V
            BAND=l
            DIGITAL=d
            SAMPRATE=1
            NCALIB=0.068220416
            NCALPER=1.000000
            DFILE=
            RSPTYPE=
            TIME=1384200000
            ENDTIME=9999999999.999
            JDATE=2013315
            CALRATIO=1
            CALPER=1.00
            TSHIFT=0
            INSTANT=y
            CAPABILITY=8
        END CHANNEL

END SITE

BEGIN SITE
        STA=I55H7
        ONDATE=2001336
        OFFDATE=-1
        LAT=-77.72996
        LON=167.60324
        ELEV=0.04181
        STANAME=Windless Bight, Anta
        STATYPE=ss
        REFSTA=I55H1
        DNORTH=-1.509
        DEAST=-1.121
        DELEV=-0.00319
    channel_list=BDF,LKO,LWD,LWS
        BEGIN CHANNEL
            CHAN=BDF
            ONDATE=2014350
            OFFDATE=-1
```

CTYPE=n
EDEPTH=0.000000
HANG=-1.0000000
VANG=-1.000000
DESCRIP=Infrasonic Micropressure data
INSNAME=Chaparral 5 differential pressure microphone
INSTYPE=M50A
BAND=b
DIGITAL=d
SAMPRATE=20
NCALIB=0.000007975
NCALPER=1.000000
DFILE=I55US_bb_rsp_2013315
RSPTYPE=fap
TIME=1418796878
ENDTIME=9999999999.999
JDATE=2014350
CALRATIO=1
CALPER=1.00
TSHIFT=0
INSTANT=y
CAPABILITY=1
END CHANNEL

BEGIN CHANNEL
CHAN=LKO
ONDATE=2014350
OFFDATE=-1
CTYPE=n
EDEPTH=0.000000
HANG=-1.0000000
VANG=-1.000000
DESCRIP=Temperature
INSNAME=RM Young temperature/humidity sensor
INSTYPE=41382VC
BAND=l
DIGITAL=d
SAMPRATE=1
NCALIB=0.000065490
NCALPER=1.000000
DFILE=-
RSPTYPE=-
TIME=1384200000
ENDTIME=9999999999.999
JDATE=2013315
CALRATIO=1

```
        CALPER=1.00
        TSHIFT=0
        INSTANT=y
        CAPABILITY=7
END CHANNEL


BEGIN CHANNEL
        CHAN=LWD
        ONDATE=2014350
        OFFDATE=-1
        CTYPE=n
        EDEPTH=0.000000
        HANG=-1.0000000
        VANG=-1.000000
        DESCRIP=Wind Sensor Direction
        INSNAME=RM Young 05103V-45 wind sensor
        INSTYPE=05103V-45
        BAND=l
        DIGITAL=d
        SAMPRATE=1
        NCALIB=0.000235767
        NCALPER=1.000000
        DFILE=-
        RSPTYPE=-
        TIME=1384200000
        ENDTIME=9999999999.999
        JDATE=2013315
        CALRATIO=1
        CALPER=1.00
        TSHIFT=0
        INSTANT=y
        CAPABILITY=7
END CHANNEL

BEGIN CHANNEL
        CHAN=LWS
        ONDATE=2014350
        OFFDATE=-1
        CTYPE=n
        EDEPTH=0.000000
        HANG=-1.0000000
        VANG=-1.000000
        DESCRIP=Wind Sensor Speed
        INSNAME=RM Young 05103V-45 wind sensor
        INSTYPE=05103V-45
```

```
            BAND=l
            DIGITAL=d
            SAMPRATE=1
            NCALIB=0.000065462
            NCALPER=1.000000
            DFILE=-
            RSPTYPE=-
            TIME=1384200000
            ENDTIME=9999999999.999
            JDATE=2013315
            CALRATIO=1
            CALPER=1.00
            TSHIFT=0
            INSTANT=y
            CAPABILITY=7
        END CHANNEL

END SITE

BEGIN SITE
        STA=I55H8
        ONDATE=2001336
        OFFDATE=-1
        LAT=-77.72828
        LON=167.58953
        ELEV=0.04213
        STANAME=Windless Bight, Anta
        STATYPE=ss
        REFSTA=I55H1
        DNORTH=-1.322
        DEAST=-1.447
        DELEV=-0.00287
    channel_list=BDF
        BEGIN CHANNEL
            CHAN=BDF
            ONDATE=2014350
            OFFDATE=-1
            CTYPE=n
            EDEPTH=0.000000
            HANG=-1.0000000
            VANG=-1.000000
            DESCRIP=Infrasonic Micropressure data
            INSNAME=Chaparral 5 differential pressure microphone
            INSTYPE=C5
            BAND=b
            DIGITAL=d
```

```
            SAMPRATE=20
            NCALIB=0.000009402
            NCALPER=1.000000
            DFILE=I55US_bb_rsp_2013315
            RSPTYPE=fap
            TIME=1418796878
            ENDTIME=9999999999.999
            JDATE=2014350
            CALRATIO=1
            CALPER=1.00
            TSHIFT=0
            INSTANT=y
            CAPABILITY=1
        END CHANNEL

    END SITE
```

4.3 Overall Response

4.3.1 Sensor Response

Chaparral 50A Infrasound sensor response based on information
provided by Chaparral.
Response in poles and zeros for the output from the Chaparral 50A sensor.
#
Sensor sensitivity = 0.4 V/Pa at 1.0 Hz
#
source=theoretical sequence=1 description=infrasound
type=paz information=Chaparral
#
Listed fields:
#
The value of A0 listed before the poles
normalizes the response to unity. Response
should be multiplied by 0.4 to give Chaparral 50A response in Volts/Pa.
#
The number of poles, their Real part, Imaginary part and errors
are listed.
#
The number of zeros, their Real part, Imaginary part and errors
are listed under the poles.

theoretical 1 infrasound paz Chaparral

#A0 - 3.141E+02

Number of poles – 4

# Real	Imaginary	Real Error	Imaginary Error
0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
-3.14000000E+02	0.00000000E+00	0.00000000E+00	0.00000000E+00
-0.18800000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
-0.04400000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00

Number of zeros – 3

# Real	Imaginary	Real Error	Imaginary Error
0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
-0.17000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00

4.3.2 FIR/IR

Geotech Smart24 Response

The Smart24 is based on the Cirrus Logic® multichannel seismic chip set. The chipset consists of the CS3301 preamp, CS5371A ΔΣ modulator and the CS5376A digital filter. The basic block diagram is shown in Figure 4.3.1

The majority of the following text and images are courtesy of Cirrus Logic.

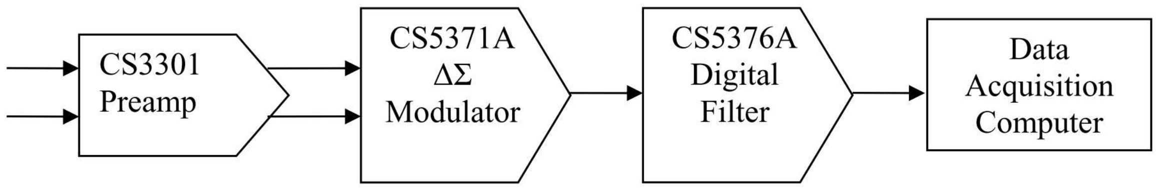


Figure:4.3.1 Digitizer Single Channel Block Diagram

The digitizer transfer function involves an analog preamp filter, a ΔΣ modulator and a digital filter.

Pre-amp

The CS3301A is a low-noise differential input, differential output amplifier with programmable gain, optimized for amplifying signals from low-impedance sensors such as geophones. The gain settings are binary weighted (x1, x2, x4, x8, x16, x32, x64) and are selected using software selectable settings. The pre-amp is a broadband (comparable to the digitizing bandwidth) amplifier with a measured delay time of 0.000067 seconds. The linear phase shift (in radians) is -2*pi * t_0 *f, t_0 = 0.000067 sec.

ΔΣ modulator

The CS5371A is a single channel high-dynamic-range ΔΣ modulator. It converts differential signals from the CD3301A to an oversampled serial bit stream at 512 kbits per second. The serial bit stream is input to the CS5376A.

Digital Filter

The CS5376A is a multi-function digital filter, which is comprised of SINC and FIR filters, used to filter and decimate the output of the CS5371A for an appropriate output sample rate. A block diagram of the digital filter is shown in Figure 4.3.2. The sample rate is selectable from 4000 samples per second (sps) to 1 sps as shown in Table 4.3.1. The SINC Filters block is comprised of three SINC filters with multiple filter stages in each SINC filter. Figure 4.3.3 shows the individual SINC filters and stages used for the 20 sample per second implementation. Table 4.3.2 shows the filter details of the 20 SPS implementation. The SINC Filter coefficients are shown in Table 4.3.4, Table 4.3.5 and Table 4.3.5.

The two FIR filters compensate for the SINC droop and create a low-pass corner to block aliased components on the input signal. The linear phase coefficients are shown for convenience in Table 4.3.6 and Table 4.3.7 for FIR1 and FIR2 respectively.

The -3 dB corner frequency for the combined SINC and FIR digital filters at 20 sps is 8.578 Hz.

Figure 4.3.2 Overall Digital Filter Block Diagram

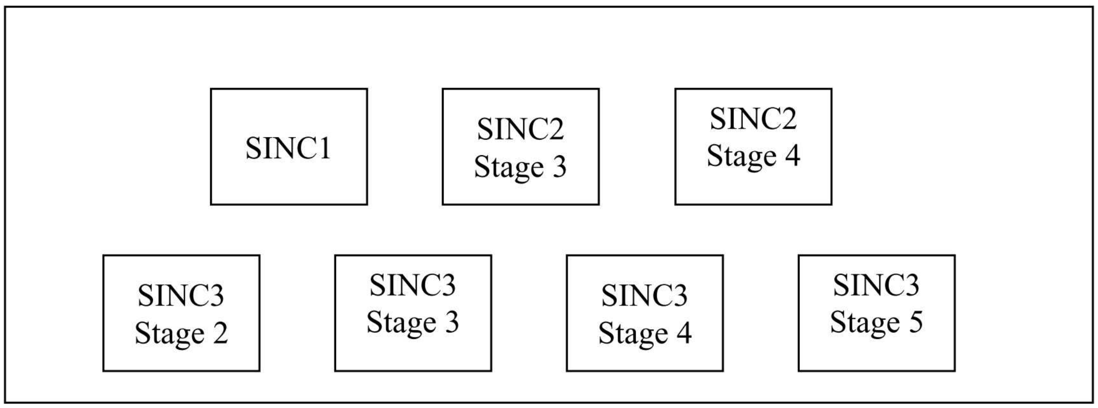


Figure 4.3.3 SINC Filters/Stage for 20 sps implementation

Table 4.3.1: Output Sample Rates with Decimations

FIR2 Output Word Rate	SINC Decimation	FIR1 Decimation	FIR2 Decimation	Total Decimation
4000	16	4	2	128
2000	32	4	2	256
1000	64	4	2	512
500	128	4	2	1024
333	192	4	2	1536
250	256	4	2	2048
200	320	4	2	2560
125	512	4	2	4096
100	640	4	2	5120
50	280	4	2	10240
40	1600	4	2	12800
25	2560	4	2	20480
20	3200	4	2	25600
10	6400	4	2	51200
5	12800	4	2	102400
1	64000	4	2	512000

Table 4.3.2 : 20 SPS SINC Filter Implementation

SINC1 – Single stage, fixed decimate by 8

5th order decimate by 8, 36 coefficients

SINC2 – Multi-stage, variable decimation

Stage 3: 5th order decimate by 2, 6 coefficients

Stage 4: 6th order decimate by 2, 7 coefficients

SINC3 – Multi-stage, variable decimation

Stage 2: 4th order decimate by 5, 17 coefficients

Stage 3: 4th order decimate by 5, 17 coefficients

Stage 4: 5th order decimate by 2, 6 coefficients

Stage 5: 6th order decimate by 2, 7 coefficients

Stage 6: 6th order decimate by 3, 13 coefficients

Table 4.3.3: SINC1 Filter Coefficients

Filter Type	Filter Coefficients	
SINC1	$h_0 = 1$	$h_{18} = 2460$
5th order decimate by 8	$h_1 = 5$	$h_{19} = 2380$
36 coefficients	$h_2 = 15$	$h_{20} = 2226$
	$h_3 = 35$	$h_{21} = 2010$
	$h_4 = 70$	$h_{22} = 1750$
	$h_5 = 126$	$h_{23} = 1470$
	$h_6 = 210$	$h_{24} = 1190$
	$h_7 = 330$	$h_{25} = 926$
	$h_8 = 490$	$h_{26} = 690$
	$h_9 = 690$	$h_{27} = 490$
	$h_{10} = 926$	$h_{28} = 330$
	$h_{11} = 1190$	$h_{29} = 210$
	$h_{12} = 1470$	$h_{30} = 126$
	$h_{13} = 1750$	$h_{31} = 70$
	$h_{14} = 2010$	$h_{32} = 35$
	$h_{15} = 2226$	$h_{33} = 15$
	$h_{16} = 2380$	$h_{34} = 5$
	$h_{17} = 2460$	$h_{35} = 1$

Table 4.3.4 : SINC2 Filter Coefficients

Filter Type	Filter Coefficients
SINC2 (Stage 1)	$h_0 = 1$
SINC2 (Stage 2)	$h_1 = 4$
4th order decimate by 8	$h_2 = 6$
5 coefficients	$h_3 = 4$
	$h_4 = 1$
SINC2 (Stage 3)	$h_0 = 1$
5th order decimate by 2	$h_1 = 5$
6 coefficients	$h_2 = 10$
	$h_3 = 10$
	$h_4 = 5$
	$H_5 = 1$
SINC2 (Stage 5)	$h_0 = 1$
6th order decimate by 2	$h_1 = 6$
7 coefficients	$h_2 = 15$
	$h_3 = 20$
	$h_4 = 15$
	$H_5 = 6$
	$H_6 = 1$

Table 4.3.5: SINC3 Filter Coefficients

Filter Type	Filter Coefficients	
SINC3 (Stage 1)	$h_0 = 1$	$h_9 = 80$
SINC3 (Stage 2)	$h_1 = 4$	$h_{10} = 68$
SINC3 (Stage 3)	$h_2 = 10$	$h_{11} = 52$
4th order decimate by 5	$h_3 = 20$	$h_{12} = 35$
17 coefficients	$h_4 = 35$	$h_{13} = 20$
	$h_5 = 52$	$h_{14} = 10$
	$h_6 = 68$	$h_{15} = 4$
	$h_7 = 80$	$h_{16} = 1$
	$h_8 = 85$	
SINC3 (Stage 4)	$h_0 = 1$	$h_3 = 10$
5th order decimate by 2	$h_1 = 5$	$h_4 = 5$
6 coefficients	$h_2 = 10$	$h_5 = 1$
SINC3 (Stage 5)	$h_0 = 1$	$h_4 = 15$
6th order decimate by 2	$h_1 = 6$	$h_5 = 6$
7 coefficients	$h_2 = 15$	$h_6 = 1$
	$h_3 = 20$	
SINC3 (Stage 6)	$h_0 = 1$	$h_7 = 126$
6th order decimate by 3	$h_1 = 6$	$h_8 = 90$
13 coefficients	$h_2 = 21$	$h_9 = 50$
	$h_3 = 50$	$h_{10} = 21$
	$h_4 = 90$	$h_{11} = 6$
	$h_5 = 126$	$h_{12} = 1$
	$h_6 = 141$	

Table 4.3.6: FIR1 Coefficients for Linear Phase response

Filter Type	Filter Coefficients (normalized 24-bit)	
FIR1 (Coefficient set 0)	$h_0 = 558$	$h_{24} = 8388607$
Low pass, SINC compensation	$h_1 = 1905$	$h_{25} = 7042723$
Linear phase decimate by 4	$h_2 = 3834$	$h_{26} = 4768946$
48 coefficients	$h_3 = 5118$	$h_{27} = 2266428$
	$h_4 = 365$	$h_{28} = 189436$
	$h_5 = -14518$	$h_{29} = -1053303$
	$h_6 = -39787$	$h_{30} = -1392827$
	$h_7 = -67365$	$h_{31} = -1084130$
	$h_8 = -69909$	$h_{32} = -496361$
	$h_9 = -19450$	$h_{33} = 39864$
	$h_{10} = 97434$	$h_{34} = 332367$
	$h_{11} = 258881$	$h_{35} = 375562$
	$h_{12} = 375562$	$h_{36} = 258881$
	$h_{13} = 332367$	$h_{37} = 97434$
	$h_{14} = 39864$	$h_{38} = -19450$
	$h_{15} = -496361$	$h_{39} = -69909$
	$h_{16} = -1084130$	$h_{40} = -67365$
	$h_{17} = -1392827$	$h_{41} = -39787$
	$h_{18} = -1053303$	$h_{42} = -14518$
	$h_{19} = 189436$	$h_{43} = 365$
	$h_{20} = 2266428$	$h_{44} = 5118$
	$h_{21} = 4768946$	$h_{45} = 3834$
	$h_{22} = 7042723$	$h_{46} = 1905$
	$h_{23} = 8388607$	$h_{47} = 558$

Table 4.3.7: FIR2 Coefficients for Linear Phase response

Filter Type	Filter Coefficients (normalized 24-bit)	
FIR2 (Coefficient set 0) Low pass, passband to 40% fs Linear phase decimate by 2 126 coefficients	h0 = -71	h63 = 8388607
	h1 = -371	h64 = 3875315
	h2 = -870	h65 = -766230
	h3 = -986	h66 = -1854336
	h4 = 34	h67 = -137179
	h5 = 1786	h68 = 1113788
	h6 = 2291	h69 = 454990
	h7 = 291	h70 = -642475
	h8 = -2036	h71 = -553873
	h9 = -943	h72 = 298975
	h10 = 2985	h73 = 533334
	h11 = 3784	h74 = -49958
	h12 = -1458	h75 = -443272
	h13 = -5808	h76 = -116005
	h14 = -1007	h77 = 318763
	h15 = 7756	h78 = 208018
	h16 = 5935	h79 = -187141
	h17 = -7135	h80 = -238025
	h18 = -11691	h81 = 68863
	h19 = 3531	h82 = 221211
	h20 = 17500	h83 = 22850
	h21 = 4388	h84 = -174452
	h22 = -20661	h85 = -81993
	h23 = -15960	h86 = 114154
	h24 = 18930	h87 = 109009
	h25 = 29808	h88 = -54172
	h26 = -9795	h89 = -109189
	h27 = -42573	h90 = 4436
	h28 = -7745	h91 = 90744
	h29 = 49994	h92 = 29702
	h30 = 33021	h93 = -62651
	h31 = -47092	h94 = -47092
	h32 = -62651	h95 = 33021
	h33 = 29702	h96 = 49994
	h34 = 90744	h97 = -7745
	h35 = 4436	h98 = -42573
	h36 = -109189	h99 = -9795
	h37 = -54172	h100 = 29808
	h38 = 109009	h101 = 18930
	h39 = 114154	h102 = -15960
	h40 = -81993	h103 = -20661
	h41 = -174452	h104 = 4388
	h42 = 22850	h105 = 17500

h43 = 221211	h106 = 3531
h44 = 68863	h107 = -11691
h45 = -238025	h108 = -7135
h46 = -187141	h109 = 5935
h47 = 208018	h110 = 7756
h48 = 318763	h111 = -1007
h49 = -116005	h112 = -5808
h50 = -443272	h113 = -1458
h51 = -49958	h114 = 3784
h52 = 533334	h115 = 2985
h53 = 298975	h116 = -943
h54 = -553873	h117 = -2036
h55 = -642475	h118 = 291
h56 = 454990	h119 = 2291
h57 = 1113788	h120 = 1786
h58 = -137179	h121 = 34
h59 = -1854336	h122 = -986
h60 = -766230	h123 = -870
h61 = 3875315	h124 = -371
h62 = 8388607	h125 = -71

References:

1. CIRRUS LOGIC, INC., “CS3301A Low-power, Programmable Gain, Differential Amplifier”, March 2007.
2. CIRRUS LOGIC, INC., “CS5371A/CS5372A Low-power, High-performance ΔΣ Modulators”, September 2009.
3. CIRRUS LOGIC, INC., “CS5376A Low-power, Multi-channel Decimation Filter”, September 2008.
4. Geotech Instruments, LLC, Personal Communications on Smart24 implemenation, 2009, 2010

4.3.3 System Response

FAP (Frequency and Phase) for SMART-24/50A System

The following is a Frequency, Amplitude, and Phase (FAP) file for the 50A and SMART-24 digitizer.

```
# Instrument response: channel I58H1_BDF
# Chaparral 50A Infrasound Sensor
# Chaparral 50A Infrasound sensor response based on information
# provided by Chaparral.
# Response in poles and zeros for the output from the Chaparral 50A sensor.
# Sensor sensitivity = 0.4 V/Pa at 1.0 Hz
# source=theoretical sequence=1 description=infrasound
# type=paz information=Chaparral
#
# Listed fields:
# The value of A0 listed before the poles
# normalizes the response to unity. Response
# should be multiplied by 0.4 to give Chaparral 50A response in Volts/Pa.
#
# The number of poles, their Real part, Imaginary part and errors
# are listed.
# The number of zeros, their Real part, Imaginary part and errors
# are listed under the poles.
#
#
# Geotech Smart24 Digitizer
# Geotech Smart24 digitizer based on information provided by Geotech.
# Response in FAPs for the output from the Geotech Smart24
#   Digitizer sensitivity = 3.0581e+05 counts/volt
#                           3.27 microvolts/count
#
#   Ncalib = 0.0000081750 Pa/count  Ncalper = 1.0 sec
#
# Theoretical response: frequency-amplitude-phase table (73 points)
#
# These FAPs are theoretical and were computed by John Merchant
# of SNL from the FIR stages provided by Geotech.
# The amplitudes were scaled to be 1 count/Volt at 1.0 Hz.
# The amplitudes would need to be multiplied by 3.0581e+05 to get
# the response in counts/Volt.
# The phase comes from Geotech's claimed -67 microseconds of delay
# in the preamplifier multiplied by 2 * pi * f and converted to degrees.
#
#    source     sequence description  type     source of
#               number                          information
```

Measured response 20 Hz sampling rate
Number of fap
#
source=theoretical sequence=2 description=digitizer
type=fap information=SNL
#
Number of fap=73
#
Listed fields:
Frequency Amplitude Phase(deg) AmEr PhEr#
#

theoretical 1 infrasound paz Chaparral
#A0
3.141E+02
Number of poles 4

# Real	Imaginary	Real Error	Imaginary Error
0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
-3.14000000E+02	0.00000000E+00	0.00000000E+00	0.00000000E+00
-0.18800000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
-0.04400000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00

Number of zeros 3

# Real	Imaginary	Real Error	Imaginary Error
0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
-0.17000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00

theoretical 2 digitizer fap SNL
Number of FAPs
73

# Freq	Amplitude	Phase	Amp Error	Phase Error
0.00100000	1.00033415	-0.00002412	0.00000000	0.00000000
0.00150000	1.00033414	-0.00003618	0.00000000	0.00000000
0.00200000	1.00033412	-0.00004824	0.00000000	0.00000000
0.00250000	1.00033410	-0.00006030	0.00000000	0.00000000
0.00300000	1.00033408	-0.00007236	0.00000000	0.00000000
0.00350000	1.00033404	-0.00008442	0.00000000	0.00000000
0.00400000	1.00033401	-0.00009648	0.00000000	0.00000000
0.00450000	1.00033396	-0.00010854	0.00000000	0.00000000
0.00500000	1.00033392	-0.00012060	0.00000000	0.00000000
0.00550000	1.00033386	-0.00013266	0.00000000	0.00000000
0.00600000	1.00033381	-0.00014472	0.00000000	0.00000000
0.00650000	1.00033375	-0.00015678	0.00000000	0.00000000
0.00700000	1.00033368	-0.00016884	0.00000000	0.00000000

0.00750000	1.00033361	-0.00018090	0.00000000	0.00000000
0.00800000	1.00033353	-0.00019296	0.00000000	0.00000000
0.00850000	1.00033345	-0.00020502	0.00000000	0.00000000
0.00900000	1.00033336	-0.00021708	0.00000000	0.00000000
0.00950000	1.00033327	-0.00022914	0.00000000	0.00000000
0.01000000	1.00033317	-0.00024120	0.00000000	0.00000000
0.01500000	1.00033194	-0.00036180	0.00000000	0.00000000
0.02000000	1.00033021	-0.00048240	0.00000000	0.00000000
0.02500000	1.00032799	-0.00060300	0.00000000	0.00000000
0.03000000	1.00032528	-0.00072360	0.00000000	0.00000000
0.03500000	1.00032209	-0.00084420	0.00000000	0.00000000
0.04000000	1.00031842	-0.00096480	0.00000000	0.00000000
0.04500000	1.00031428	-0.00108540	0.00000000	0.00000000
0.05000000	1.00030968	-0.00120600	0.00000000	0.00000000
0.05500000	1.00030461	-0.00132660	0.00000000	0.00000000
0.06000000	1.00029910	-0.00144720	0.00000000	0.00000000
0.06500000	1.00029314	-0.00156780	0.00000000	0.00000000
0.07000000	1.00028674	-0.00168840	0.00000000	0.00000000
0.07500000	1.00027992	-0.00180900	0.00000000	0.00000000
0.08000000	1.00027268	-0.00192960	0.00000000	0.00000000
0.08500000	1.00026504	-0.00205020	0.00000000	0.00000000
0.09000000	1.00025701	-0.00217080	0.00000000	0.00000000
0.09500000	1.00024860	-0.00229140	0.00000000	0.00000000
0.10000000	1.00023982	-0.00241200	0.00000000	0.00000000
0.15000000	1.00013488	-0.00361800	0.00000000	0.00000000
0.20000000	1.00001046	-0.00482400	0.00000000	0.00000000
0.25000000	0.99988530	-0.00603000	0.00000000	0.00000000
0.30000000	0.99977856	-0.00723600	0.00000000	0.00000000
0.35000000	0.99970708	-0.00844200	0.00000000	0.00000000
0.40000000	0.99968269	-0.00964800	0.00000000	0.00000000
0.45000000	0.99971030	-0.01085400	0.00000000	0.00000000
0.50000000	0.99978684	-0.01206000	0.00000000	0.00000000
0.55000000	0.99990140	-0.01326600	0.00000000	0.00000000
0.60000000	1.00003671	-0.01447200	0.00000000	0.00000000
0.65000000	1.00017166	-0.01567800	0.00000000	0.00000000
0.70000000	1.00028461	-0.01688400	0.00000000	0.00000000
0.75000000	1.00035702	-0.01809000	0.00000000	0.00000000
0.80000000	1.00037673	-0.01929600	0.00000000	0.00000000
0.85000000	1.00034035	-0.02050200	0.00000000	0.00000000
0.90000000	1.00025416	-0.02170800	0.00000000	0.00000000
0.95000000	1.00013343	-0.02291400	0.00000000	0.00000000
1.00000000	1.00000000	-0.02412000	0.00000000	0.00000000
1.50000000	1.00046681	-0.03618000	0.00000000	0.00000000
2.00000000	1.00008150	-0.04824000	0.00000000	0.00000000
2.50000000	0.99997599	-0.06030000	0.00000000	0.00000000
3.00000000	1.00047661	-0.07236000	0.00000000	0.00000000

3.50000000	1.00050550	-0.08442000	0.00000000	0.00000000
4.00000000	0.99996827	-0.09648000	0.00000000	0.00000000
4.50000000	0.99989234	-0.10854000	0.00000000	0.00000000
5.00000000	1.00029867	-0.12060000	0.00000000	0.00000000
5.50000000	1.00025831	-0.13266000	0.00000000	0.00000000
6.00000000	0.99983056	-0.14472000	0.00000000	0.00000000
6.50000000	0.99991233	-0.15678000	0.00000000	0.00000000
7.00000000	1.00043875	-0.16884000	0.00000000	0.00000000
7.50000000	1.00063885	-0.18090000	0.00000000	0.00000000
8.00000000	0.99974018	-0.19296000	0.00000000	0.00000000
8.50000000	0.79200447	-0.20502000	0.00000000	0.00000000
9.00000000	0.20804073	-0.21708000	0.00000000	0.00000000
9.50000000	0.00698548	-0.22914000	0.00000000	0.00000000
10.00000000	0.00000013	-0.24120000	0.00000000	0.00000000

4.4 CD Parameters

BEGIN STREAM
STA=I55US
IPADDRESS= 157.132.83.100 (Primary)
IPADDRESS= 157.132.83.100 (Back-up)
PROTOCOL=CD1.1
DATAFRAME_MASK=I55H1/BDF,I55H2/BDF,I55H3/BDF,I55H4/BDF,I55H5/BDF,I55H6/BDF,I55H6/LDA,I55H7/BDF,I55H7/LKO,I55H7/LWD,I55H7/LWS,I55H8/BDF
END STREAM
END STATION

5 Central Processing Facility

5.1 Central Processing Facility Overview

Data from the elements comes into the CRF through the repeater site on the McMurdo network which connects to the I55US Cisco 891 router. The router connects all of the CRF equipment on the private LAN side as well as connecting to the McMurdo network and the internet on the WAN side. The router also serves as a firewall. On the LAN side two Dell desktop computers running the CTBTO Standard Station Interface (SSI) software receive the data from the elements and package them into a CD1.1 frame and sign the frame before transmission to the IDC. The CD1.1 frames are transmitted through the Cisco 891 to the GCI Cisco 5505 router through a second WAN port. The GCI router is located in the I55US network chassis. Only one SSI computer is powered on at a time. Other equipment on the CRF LAN are the UAF housekeeping computer which is running the Geotech GeoHub software for command and control of the digitizers and for receiving a second data stream from the digitizers with a more extensive set of state-of-health data for station monitoring. This data stream is forwarded on to UAF for station monitoring. Also connected are an NTP100 timeserver for the SSI and housekeeping computers, the UPS for the housekeeping computer and the UPS for the CRF equipment, and a DAQ X300 which is used with a temperature to monitor room temp. A photo of the CRF is shown in Figure 5.1.1 and the CRF connections in Figure 5.1.2.

With this configuration UAF personnel can establish remote connections allowing them to troubleshoot or change the configuration of either the equipment at the CRF or equipment at the vaults.

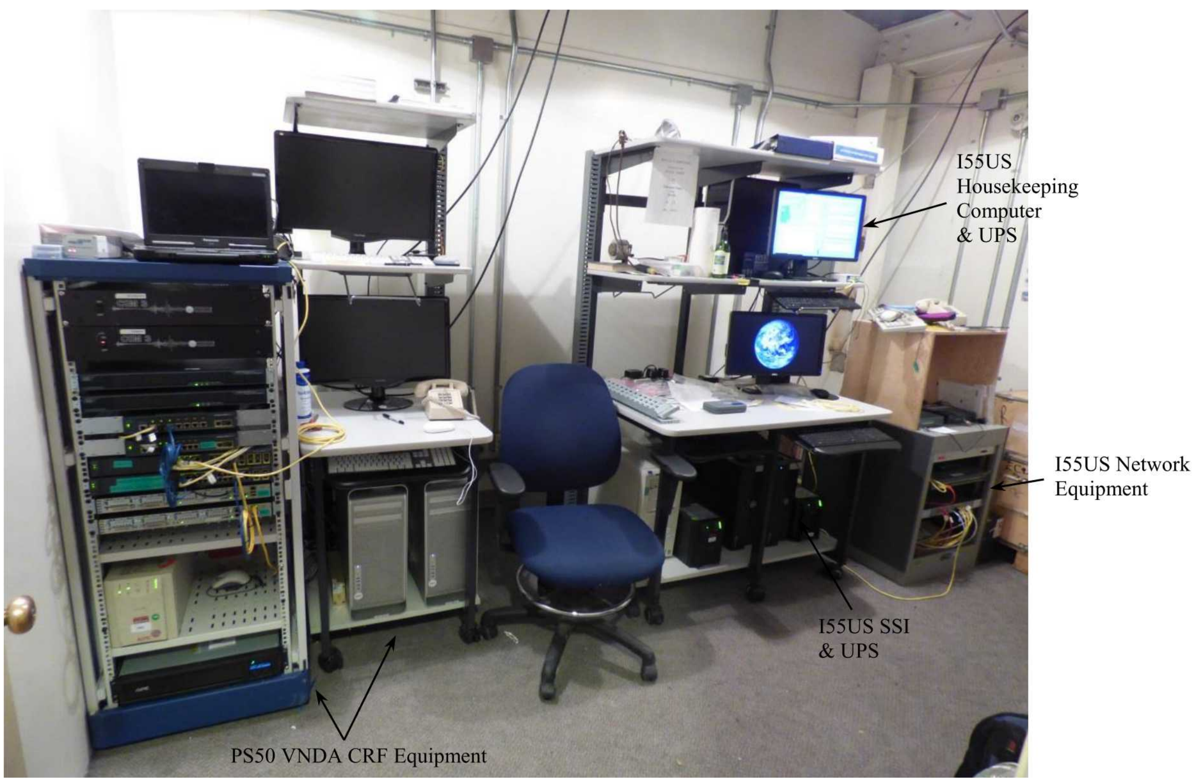


Figure 5.1.1 I55US Central Recording Facility

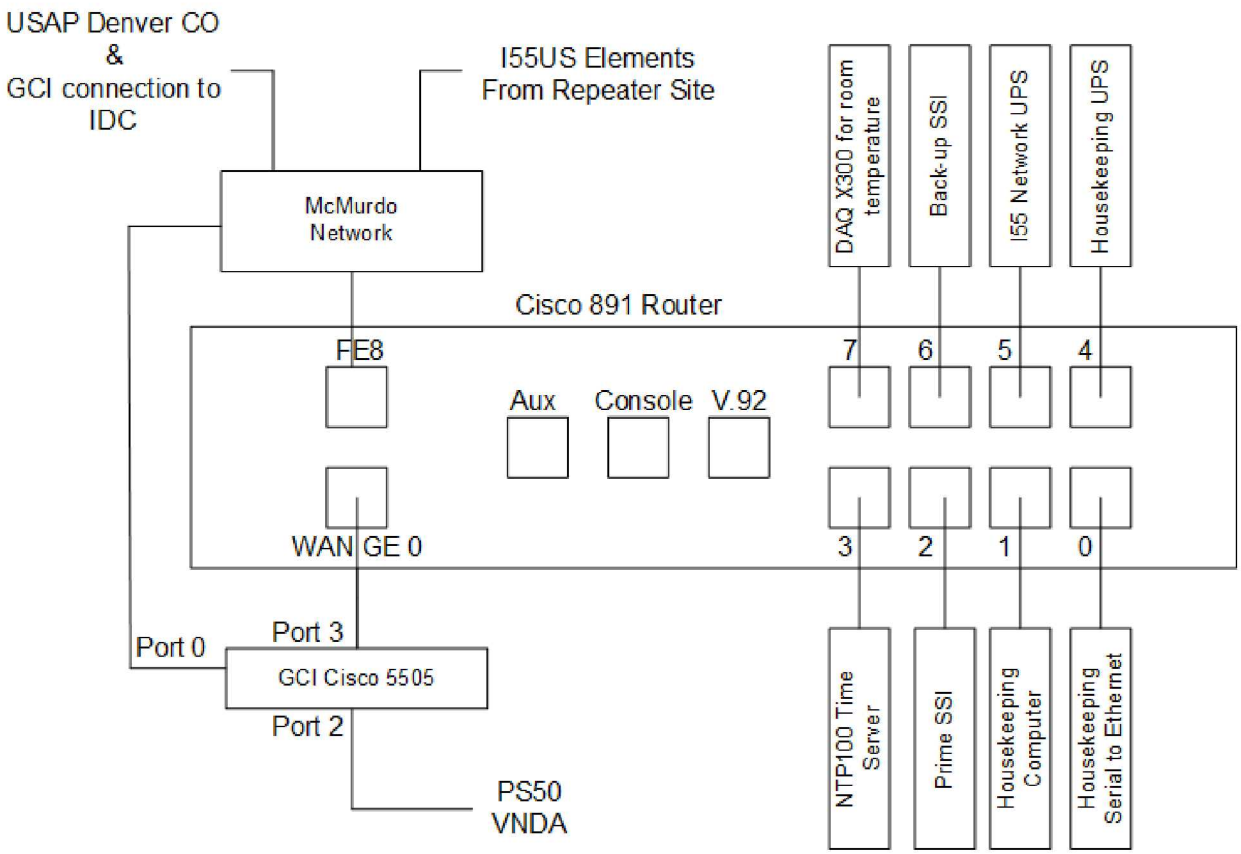


Figure 5.1.2 CRF Block Diagram

5.2 Data Acquisition System Specifications

- Dell Precision T3600
- Centos Operating environment
- Intel Xeon
- 4 GB RAM.
- 300 GB Internal Hard Drive

5.3 Data Formats

Sub-channel data from the elements to the CRF is in pseudo CD 1.1 format (no Ack/Knacks). Data from the CRF to the IDC is in CD 1.1 format and uses CD 1.1 protocol.

5.4 Data Acquisition Commands

Command	Function	Note	Section
ABT	Abort setup	I	3.6.4.1.1
AGK	Generate New DSA Key Pair	I	3.6.4.8.1
ANO	Anonymous FTP Access Enable/Disable	I	3.6.1.3.12
ARK	Return DSA Public Key	I	3.6.4.8.2
ASK	Start/Abort A Pending DSA Key Pair	I	3.6.4.8.3
ASR	Accept new setup parameters & reboot	I	3.6.4.1.2
AUG	Set User DSA G Values	I	3.6.4.8.4
AUP	Set User DSA PValues	I	3.6.4.8.5
AUQ	Set User DSA QValues	I	3.6.4.8.6
AZC	Set Scheduled Autozero Channels	A	3.6.4.7.6
AZE	Set Scheduled Autozero Enable/Disable	A	3.6.4.7.2
AZG	Save & Start Using New Scheduled Autozero Parameters	A	3.6.4.7.7
AZI	Set Scheduled Autozero Interval	A	3.6.4.7.4
AZN	Immediate Autozero Command	I	3.6.4.7.1
AZR	Set Scheduled Autozero Repetitions	A	3.6.4.7.5
AZS	Set Scheduled Autozero Start Time	A	3.6.4.7.3
BTL	Reboot into the boot loader mode	I	3.6.4.1.3
CAA	Set calibration amplitude	C	3.6.2.1.2
CAC	Set calibration digital control on/off	C	3.6.2.1.7
CAD	Set calibration duration	C	3.6.2.1.5
CAF	Set calibration frequency	C	3.6.2.1.3
CAG	Calibration go command	I	3.6.4.4.1
CAH	Calibration halt command	I	3.6.4.4.2
CAI	Set calibration interval	C	3.6.2.1.8
CAM	Set CD 1.1 authentication mode	R	3.6.1.4.7
CAO	Set calibration output signal	C	3.6.2.1.1
CAR	Set calibration repetitions	C	3.6.2.1.9
CAS	Set calibration output relay state	C	3.6.2.1.6
CAT	Set calibration start time	C	3.6.2.1.10
CAW	Set calibration pulse or bit width	C	3.6.2.1.4
CBF	Set CD 1.1 Backfill Mode	I	3.6.1.4.23
CCD	Set CD 1.1 data channel output disables	R	3.6.1.3.9
CCE	Set CD 1.1 data channel output enables	R	3.6.1.3.8

CCL	Set CD 1.1 calib/calper mode & values	I	3.6.1.4.8
CCM	Set CD 1.1 compression mode	I	3.6.1.4.6
CCN	Set CD 1.1 channel name	R	3.6.1.4.3
CCP	Set CD 1.1 connection request remote port	I	3.6.1.4.12
CDA	Set CD 1.1 destination IP address	I	3.6.1.4.11
CDE	Enable/disable CD 1.1 profile	R	3.6.1.4.15
CDF	Set CD 1.1 data frame size	R	3.6.1.4.9
CDS	Set CD 1.1 data frame save size	I	3.6.1.4.21
CDT	Set CD 1.1 data type	I	3.6.1.4.4
CIP	Set CD 1.1 command input port	I	3.6.1.4.17
CLN	Set CD 1.1 location name	R	3.6.1.4.2
CNC	Set CD 1.1 Creator Name	I	3.6.1.4.19
CNS	Set CD 1.1 Station Name	I	3.6.1.4.20
CRR	Set CD 1.1 connection request retry	I	3.6.1.4.18
CRT	Set CD 1.1 connection request timeout	I	3.6.1.4.16
CSF	Set CD 1.1 SOH alert frame output frequency	R	3.6.1.4.10
CSN	Set CD 1.1 site name	R	3.6.1.4.1
CSS	Set CD 1.1 SOH frame save size	I	3.6.1.4.22
CST	Set CD 1.1 sensor type	I	3.6.1.4.5
DDC	Set LCD Data Display Control	I	3.6.4.1.10
FZS	Get Fortezza Card Status	I	3.6.4.5.9
GCD	Global ADC channel disables	R	3.6.1.1.4
GCE	Global ADC channel enables	R	3.6.1.1.3
GCS	Get Data Channel Statistics	I	3.6.4.5.6
GCT	Set GPS cycle time	I	3.6.4.2.1
GET	Get all setup parameters	I	3.6.4.1.4
GPC	Set GPS Configuration	I	3.6.3.2.2
GPS	Get GPS status	I	3.6.4.5.3
GPT	Get GPS Satellite Tracking Status	I	3.6.4.5.7
HLP	Get Command Help	I	3.6.4.1.7
HWS	Get hardware status	I	3.6.4.5.5
ICA	Set IP port PPP client IP address	R	3.6.1.3.11
IDM	Set IP mode	R	3.6.1.3.7
IPA	Set IP address	R	3.6.1.3.1
IPD	Set IP domain name	R	3.6.1.3.5
IPE	Set IP port enable/disable	R	3.6.1.3.8
IPG	Set IP gateway address	R	3.6.1.3.3
IPH	Set IP host name	R	3.6.1.3.4
IPM	Set IP address mask	R	3.6.1.3.2
IPN	Set IP DNS server address	R	3.6.1.3.6
IPS	Get TCP/IP status	I	3.6.4.5.4
ISA	Set IP port PPP server IP address	R	3.6.1.3.9
ISM	Set IP port PPP server IP mask	R	3.6.1.3.10
JST	Set jamset threshold	I	3.6.3.1.2

LGD	Disable LOG messages	I	3.6.4.6.2
LGE	Enable LOG messages	I	3.6.4.6.1
LGL	Set Log Level on/off	I	3.6.4.6.4
LGO	Logout this Connection	I	3.6.4.1.8
LGT	Enable/Disable long time in LOG messages	I	3.6.4.6.3
OFF	Power off	I	3.6.4.1.5
OSC	Perform an ADC offset calibration	I	3.6.4.3.1
PCS	Get PCMCIA PC Card Status	I	3.6.4.5.8
PSW	Enter password	I	3.6.4.2.1
RBT	Reboot	I	3.6.4.1.6
RCL	Set ADC input relay state	I	3.6.4.3.2
SCG	Set channel gain	I	3.6.1.1.5
SCP	Set client password	I	3.6.4.2.5
SCU	Set client username	I	3.6.4.2.6
SET	Set current time.	I	3.6.3.3.1
SFD	Set Factory Defaults	I	3.6.4.1.9
SFG	Set Front End Gain	I	3.6.1.1.6
SFT	Set ADC FIR Filter Type	R	3.6.1.1.8
SOH	Get state of health parameters	I	3.6.4.5.2
SPB	Set serial port baud rate	R	3.6.1.2.1
SPC	Set serial port character mode	R	3.6.1.2.4
SPM	Set serial port communications mode	R	3.6.1.2.2
SPP	Set serial port communication protocol	R	3.6.1.2.3
SPW	Set password	I	3.6.4.2.2
SRP	Set primary sample rate	R	3.6.1.1.1
SRS	Set secondary sample rate	R	3.6.1.1.2
SSD	Enable/Disable ADC Time Sync Delay Correction	R	3.6.1.1.9
SSS	Set Sensor Sensitivity	I	3.6.1.1.7
SUN	Set system username	I	3.6.4.2.4
TSM	Set time synchronization mode	I	3.6.3.1.1
TYP	Get Smart Series type	I	3.6.4.5.1
URT	Set USGS RTD Format	R	3.6.1.2.5
USR	Enter system username	I	3.6.4.2.3

Notes: I) Immediate Commands
R) Setup commands that require an ASR command to save new configuration parameters and reboot the system.
C) Calibration commands that require a CAG command to set.
A) Autozero commands that require a AZG command to set.

5.5 Remote Commands

All commands listed can be run remotely using a VPN connection.

5.6 Software Programs

Need this for SSI

SMARTServer

This application is the data server that accepts real-time data from the SMART-24 stations and stores it in the relational database, making it available to other clients. It also can forward data in real-time using Earthworm or CD1.1 protocol. This document describes in detail the SMARTServer features and operation.

SMARTDBConfig

This application is used to create the structure used by the SMARTGeoHub® Central Station database, consisting of station (or network), sites, and channels (or components), with their associated parameters. This application's features and operation are described in the SMARTDBConfig User's Manual (available separately).

SMART24Config

This application allows the user to configure the SMART-24 instruments. Via a TCP/IP or serial connection (PPP) to the SMART-24, this software lets the user setup and control all aspects of the operation of the SMART-24. This application's features and operation are described in the SMART24Config User's Manual (available separately).

SMARTGeoViewer®

This is a powerful, user-friendly software application for display of real-time seismic or infrasound data, designed to operate as either a local or remote client for the SMARTGeoHub® database server. It is a data viewer with extended zooming capabilities. This application's features and operation are described in the SMARTGeoViewer® User's Manual (available separately).

SMARTGeoSOH Monitor

This application checks the state of health (SOH) of remote SMART-24 instruments and their comunication link status, displays on a graphical interface and logs the SOH alarm conditions. SMARTGeoSOHMonitor operates as either a local or remote client for SMARTGeoHub®'s DataBase Server. This application's features and operation are described in the SMARTGeoSOH User's Manual (available separately).

FileGen (or SMARTGen)

This application outputs the real-time data received from the remote stations as data files of fixed, user-selectable time duration. Either a simple data format can be used, or the SUDS format primarily for the use of the automated earthquake data processor, SMARTQuake®. In turn, SMARTQuake® can keep ring buffers in SUDS, miniSEED, SEG-Y, and CSS3.0 formats. This program operates as either a local or remote client for SMARTGeoHub®'s DataBase Server.

5.7 Network Security

A firewall has been implemented at the CRF and at the relay site using the Cisco 891 routers. The only inbound access to the CRF computers is through an authenticated VPN connection.

6 Intra-Site Communications

6.1 Communication System Description

Intra-site communications for I55US are shown in Figure 6.1.1. The communication link from the CRF to each of the array elements is Ethernet based using a combination of radios and the McMurdo network. Between the relay site located on the hill above McMurdo Base and each array element, data is transmitted using Freewave FGR2-PE 900 MHz network radios. Each element has an individual radio and 12 dB Yaggi antenna. At the relay site there are four Freewave FGR2-PE 900 MHz network radios and 12 dB Yaggi antennas. Each radio at the relay site connects to two elements as shown in Figure 6.1.1. There are an additional 4 Freewave radios located in the rack as cold spares. There are 10 antennas mounted to the relay site so all radios, including cold spares, have their own antenna. The cold spares would need power to be connected to be activated. At the relay site the radios connect to a network switch and Cisco router. There is also a pair of Freewave DGR-115R/H serial radios for communications with the BOB power system. To connect the serial Freewave radio to the Netgear switch and Cisco router a Blackbox LES301A serial to Ethernet converter is used. The Cisco router connects to the McMurdo network and generates a VPN connection to the CRF router for the data to pass through.

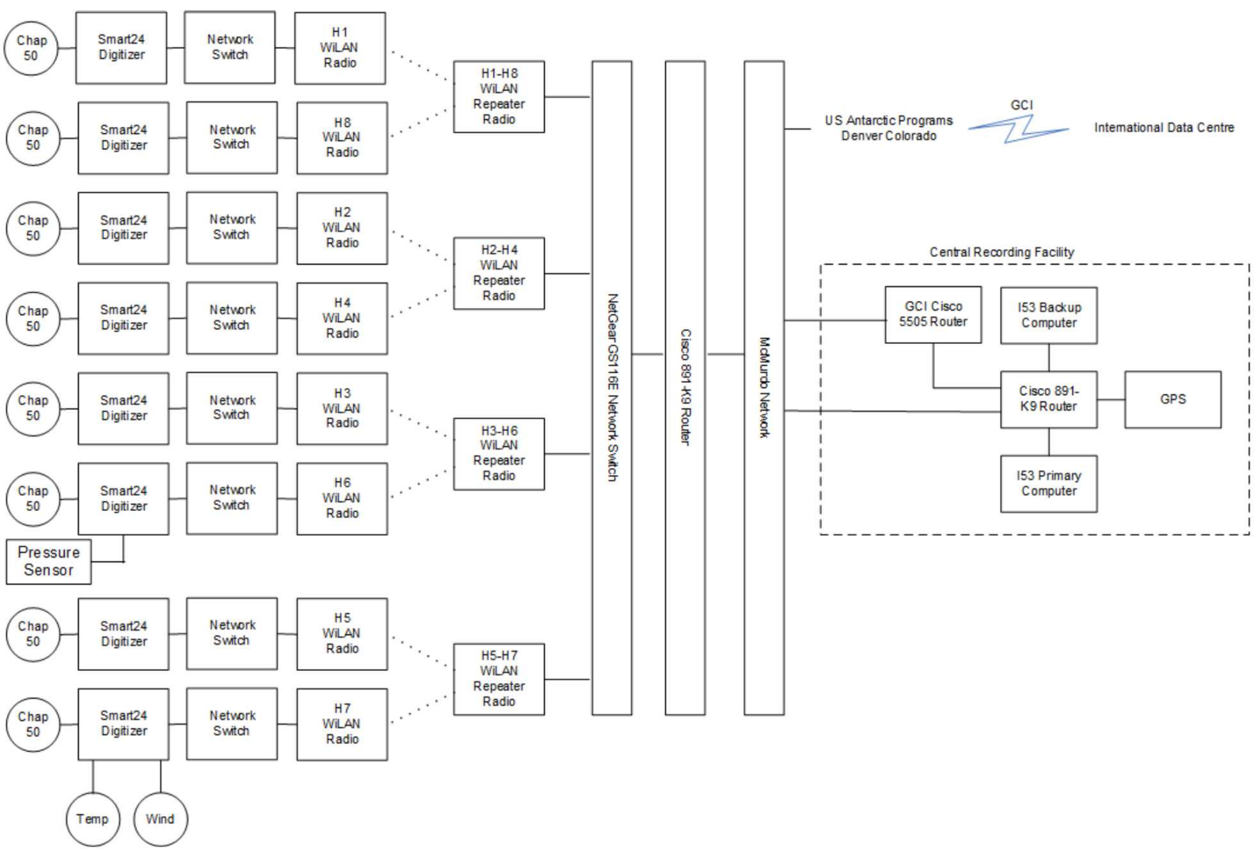


Figure 6.1.1 I55US Communications

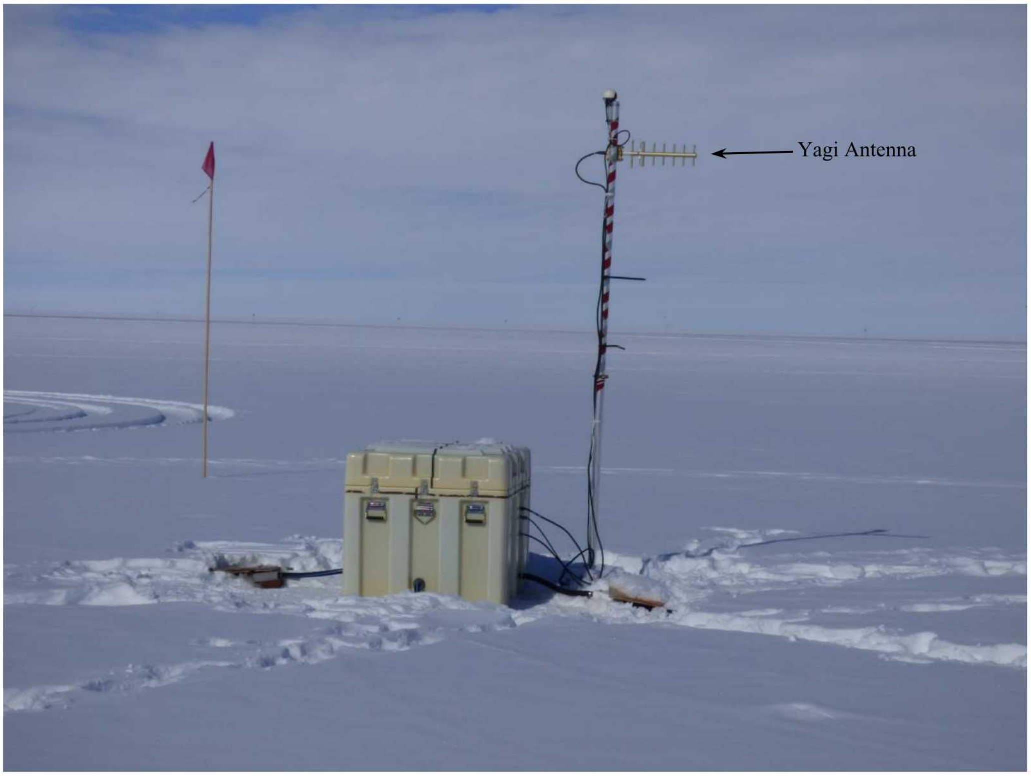


Figure 6.1.2 I55US Element Antenna and Mast

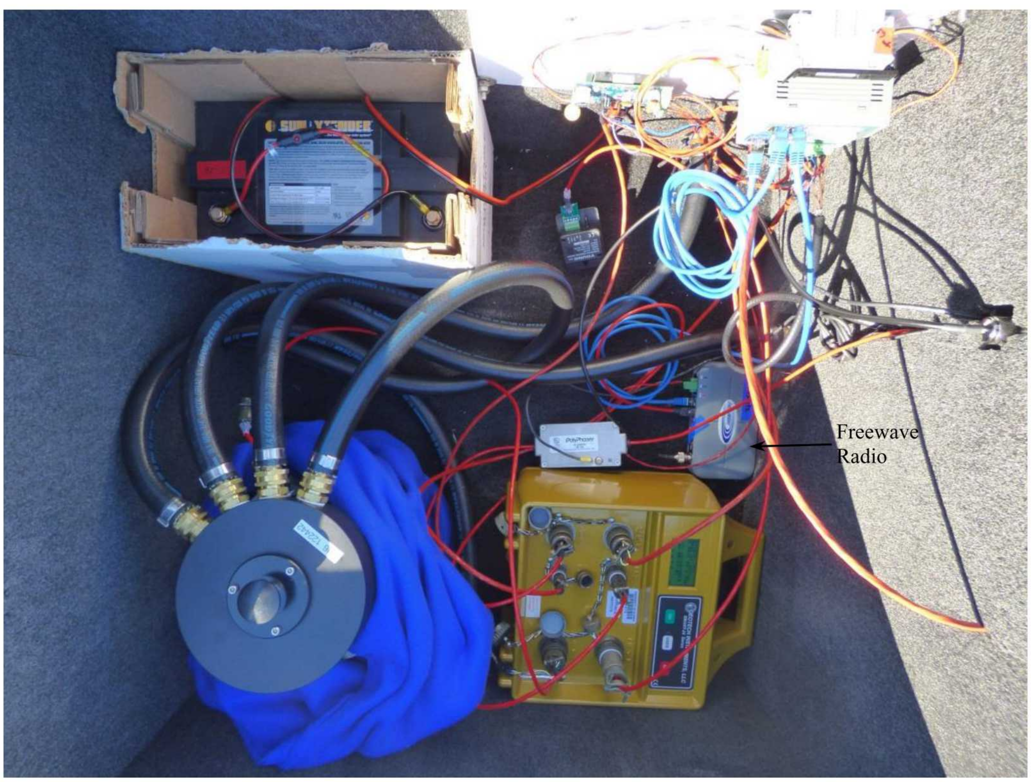


Figure 6.1.3 I55US Radio Location

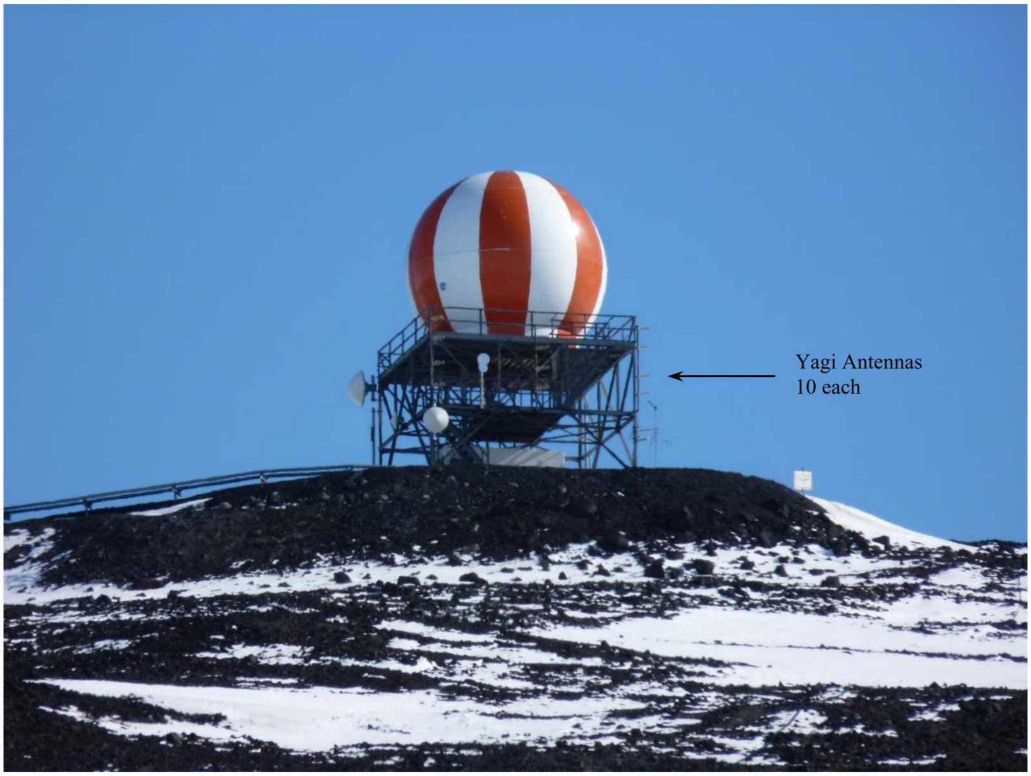


Figure 6.1.4 I55US Relay Site, Building 69

Figure 6.1.5 I55US Relay Radios

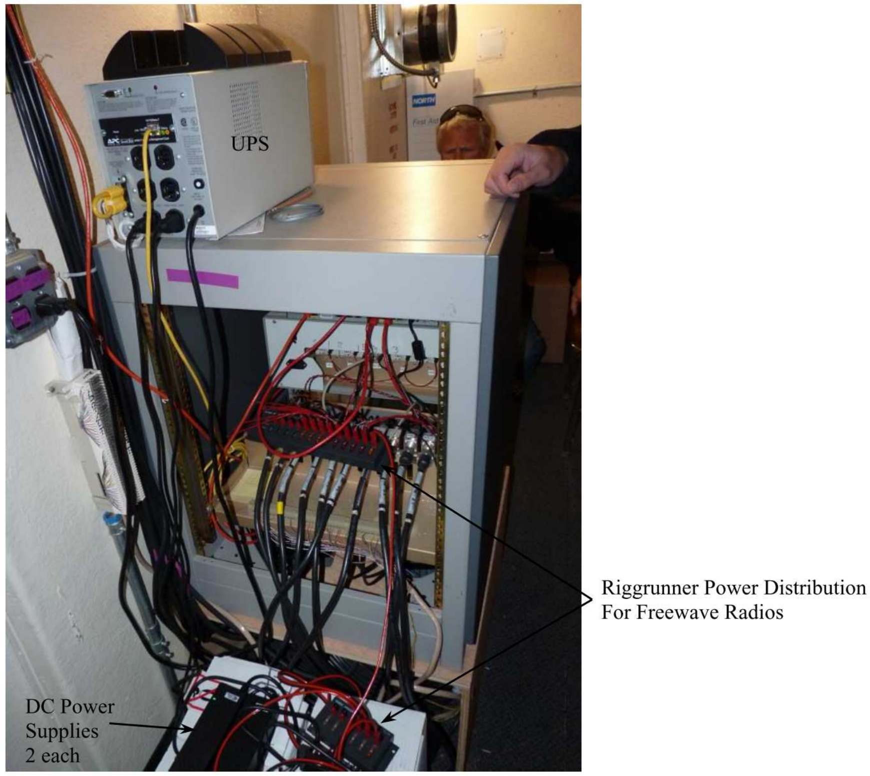


Figure 6.1.6 I55US Relay Rack Power Distribution

6.2 Manufacturer's Specification Sheets

Manuals for I55US communications equipment can be found online.

Freewave Spread Spectrum Radio Modem:

<u>Freewave Technologies Model No. DG115H</u>

Frequency		902 to 928 MHz
Transmitter:		
	Output Power	1 W (+30dBm) at 9.5 to 14.0 V
		400 mW (+26 dBm) at 7.5 to 9.5 V
	Range	20 miles
	Modulation	GFSK, 120 kBs – 170 kBs
	Occupied bandwidth	230 kHz
Receiver:		
	Sensitivity	-108 dBm at 10-6 raw BER
	Selectivity	40 dB at fc ± 230 kHz
		60 dB at fc ± 460 kHz

Data Transmission:

Error Detection	32 bit CRC, resend on error
Data Encryption	Substitution, dynamic key
Link Throughput	115 Kbaud
Interface	RS-232 1200 Baud to 115.2 Kbaud, async, full duplex

Power Requirements:

Transmit current	650 mA at 12V for 1W
	600 mA at 8.5V for 400mW
Receive current	100 mA at 12 V
Idle current	65 mA at 12V

Operating Modes:	Point-to Point
	Point-to Multipoint
	Peer-to-Peer
	Store and Forward Repeater

Operating Environment -40°C to +75°C

Freewave Technologies Model No. FGR2-PE

Cisco 891 Router

- High performance for secure broadband and Metro Ethernet access with concurrent services for enterprise small branch offices
- Business continuity and WAN diversity with redundant WAN links: Fast Ethernet (FE), V.92, ISDN Basic Rate Interface (BRI), Gigabit Ethernet (GE), ADSL2+/VDSL (Annex A/B/M), Multimode G.SHDSL, and Small Form-Factor Pluggable (SFP)
- Integrated secure 802.11a/g/n access point (optional) based on the draft 802.11n standard; dual-band radios for mobility and support for autonomous or Cisco Unified WLAN architectures
- Enhanced security including:
  - Firewall with advance application and control for email, instant messaging (IM), and HTTP traffic
  - Site-to-site remote-access and dynamic VPN services: IP Security (IPsec) VPNs (Triple Data Encryption Standard [3DES] or Advanced Encryption Standard [AES], Dynamic Multipoint VPN [DMVPN], Group Encrypted Transport VPN with onboard acceleration, and Secure Sockets Layer [SSL] VPN)
  - Intrusion prevention system (IPS): An inline, deep-packet-inspection feature that mitigates a wide range of network attacks
- Web Security with Cisco ScanSafe deployment: An 8-port 10/100 Fast Ethernet managed switch with VLAN support and 4-port support for Power over Ethernet (PoE) (optional for certain models) to power IP phones or external access points; the Cisco 892FSP, 896VA, 897VA, and 898EA have an 8-port 10/100/1000 Gigabit Ethernet managed switch with VLAN support; no PoE support is available for the Cisco 892FSP

- Metro Ethernet features including:
    - One 1000BASE-T Gigabit Ethernet WAN port
    - One 10/100BASE-T Fast Ethernet WAN port on the Cisco 891 and 892 or 1-port Gigabit Ethernet WAN porton the Cisco 892FSP, 896VA, 897VA, and 898EA
    - One 1-port Gigabit Ethernet SFP socket for WAN connectivity on the Cisco 892F, 892FSP, 896VA, 897VA, and 898EA

      (**Note:** Only the 1000BASE-T Gigabit Ethernet WAN or the SFP is operational at a given time.)
    - Intelligent hierarchical quality of service (HQoS): Support for hierarchical queuing and shaping
    - Connectivity Fault Management (CFM), based on 802.1ag
    - 802.3ah standards-based link operations, administration, and maintenance (OA&M)
    - Ethernet Local Management Interface (E-LMI) for the customer edge
    - CFM Interworking and backward compatibility
    - Performance management based on IP service-level agreement (SLA) for Ethernet
- Dedicated console and auxiliary ports for configuration and management
- Two USB 2.0 ports for security eToken credentials, booting, and loading configuration from USB available on the Cisco 891, 892, and 892F

Netgear GS116E Switch

Antennas

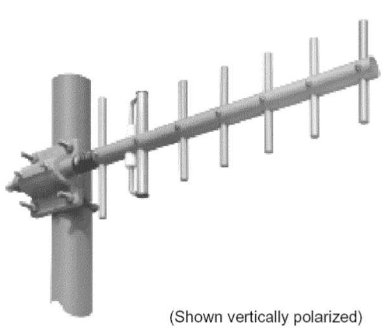
Scala TY900

The Kathrein Scala Division TY-900 is a rugged broadband yagi antenna specifically designed for professional fixed-station applications in the 890–960 MHz band.

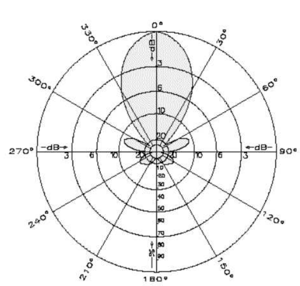
The TY-900 is fabricated of 6061/T6 aluminum rod and seamless drawn pipe, anodized for maximum reliability and corrosion resistance. The hardware and fastenings are stainless steel. The internal balun, coax feed and connector are sealed in a foam potting system to prevent moisture penetration and assure long service life in severe environmental conditions. The heavy aluminum mounting casting allows installation for V or H polarization.

Specifications:

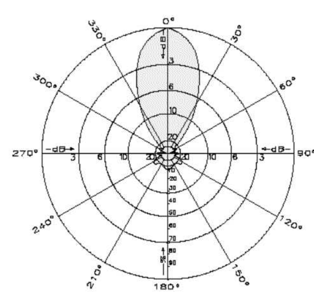
Frequency range	890–960 MHz (broadband)
Gain	12 dBd
Impedance	50 ohms
VSWR	< 1.5:1 maximum (1.35:1 typical)
Polarization	Horizontal or vertical
Front-to-back ratio	>20 dB
Maximum input power	100 watts (at 50°C)
H-plane beamwidth	48 degrees (half-power)
E-plane beamwidth	40 degrees (half-power)
Connector	N female
Weight	3 lb (1.4 kg)
Dimensions	23 x 7 inches (584 x 178 mm)
Equivalent flat plate area	0.24 ft 2 (0.022 m 2)
Wind survival rating*	150 mph (240 kph)
Shipping dimensions	28 x 10 x 4.5 inches (710 x 254 x 114 mm)
Shipping weight	5.0 lb (2.3 kg)
Mounting	For masts of 1.25 to 2.375 inch (32 to 60 mm) OD.



(Shown vertically polarized)



H-plane
Horizontal pattern – V-polarization
Vertical pattern – H-polarization



E-plane
Horizontal pattern – H-polarization
Vertical pattern – V-polarization

6.3 Radio Telemetry

Freewave spread spectrum radios in the frequency band 902 to 928 MHz are used with an output power of 750 mW, eliminating the need for frequency licensing. Specifications for the radios and antennas are listed in 6.2.

6.4 Cable Telemetry

Data from the I55US relay station is transmitted to the CRF over the McMurdo Base network.

7 External Communications

7.1 Description of GCI Topology

The I55US Cisco 5505 router connects to the McMurdo at the Central Recording Facility in Building 159. The data is then transmitted from McMurdo to Brewster, Washington through a satellite link and then to the U.S. Antarctic Program (USAP) facility in Englewood, Colorado. At the RSPC facility in Colorado the data is routed through a Cisco 5505 router/firewall to the CTBT GCI equipment located at the USAP facility.

7.2 External Communications Block Diagram

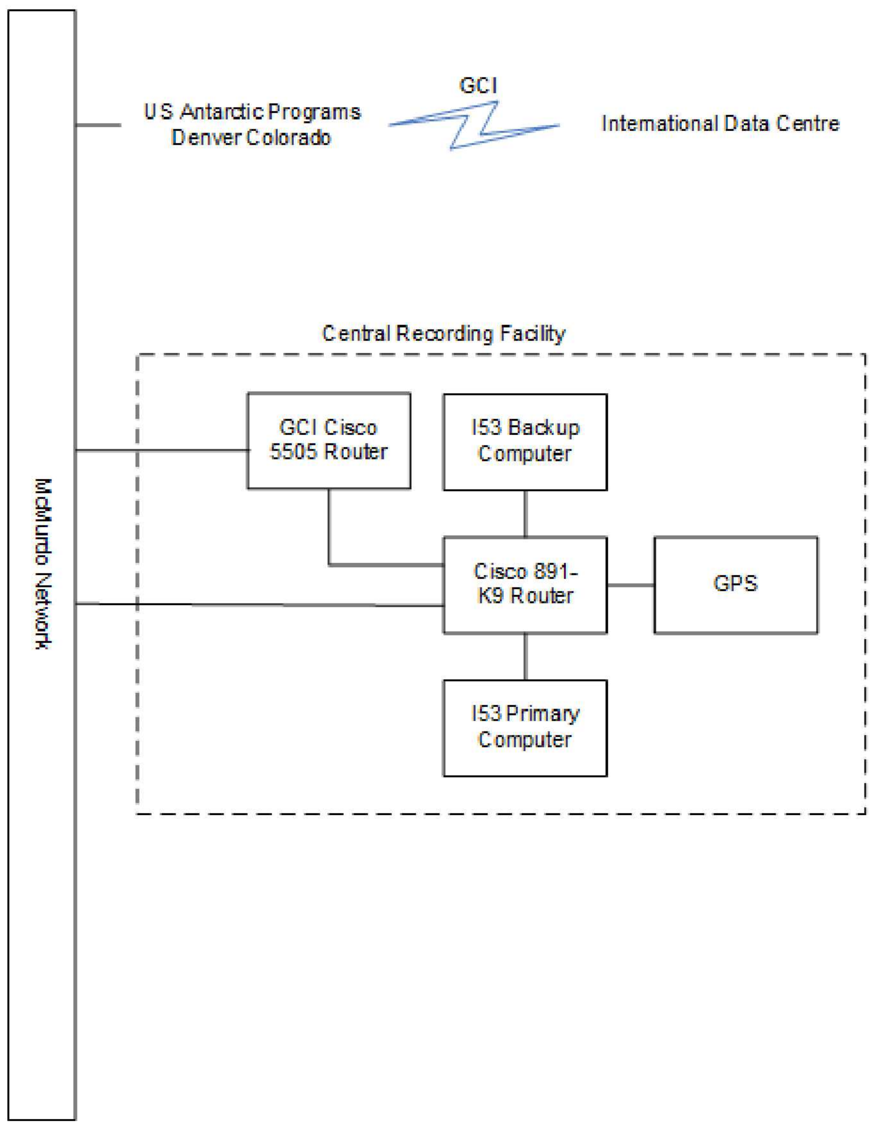


Figure 7.2.1 IS55 External Communications

Cisco 5505

WAN Support

• PPP RFC1661, 1662
• Frame Relay FRF.1, RFC1490
• HDLC Cisco
•ATM
• ISDN BRI
• T1 (optional)

LAN Support

• 10/100 Mbps Ethernet

8 Authentication

8.1 Data and Command Authentication Overview

This station uses the Geotech Instruments SMART-24 digitizer data acquisition system. Data authentication on the channel sub-frame is performed by the SMART-24. The SMART-24 uses an internal Crypto PC Card for all critical authentication operations, including key generation, storage and protection of the private key, data hashing, and digital signature calculation. The SMART-24 builds a CD-1.1 Channel Sub-Frame structure and signs it. It sends the sensor data and authentication signatures to the SSI computer at the CRF. The SSI computer assembles the data and signatures into complete CD1.1 frames, generates a signature for the complete CD1.1 frame using a Spyrus Lynks SES3100-F USB card, inserts this signature into the frame, and sends the frames to the final data recipients.

8.2 Hardware Specifications

The SMART-24 digitizer uses a Spyrus Fortezza Card. The Spyrus is a National Security Agency (NSA) designed FORTEZZA Crypto Card that delivers high-performance encryption and digital services in an industry standard.

Spyrus Lynks SES3100-F USB cards are connected to the SSIs.

Spyrus SES3100 Technical Specifications

Cryptographic Algorithms	• ECDSA 256, 384, 521 key generation, sign and verify operations • ECMQV 256,384,521 key establishment methods • EC Diffie-Hellman 256,384,521 key establishment methods • RSA 1024/2048/4096 X9.31 key generation; 512/1024/2048 sign and decrypt • SHA-1 and SHA-224/256/394/512 hash algorithms • AES-128/192/256 ECB, CBC, Counter mode, and AES key wrap • DES, two & three-key triple-DES with ECB, CBC • DSA 1024 • KEA key exchange: 1024-bit exchanges with 80-bit SKIPJACK keys • SKIPJACK 80-bit key
Interfaces	• USB 1.1 Compliant & USB 2.0 compatible
Security Certifications	• Overall FIPS 140-2 Level 2 validation • Physical Security FIPS 140-2 Level 3
Electrical	• Operating voltage: Vcc = 5VDC ± 5% • Power consumption: <1 W average • Lithium battery
Environmental	• Operating temperature: 0°C to 55°C • Storage temperature: -20°C to 65°C • Humidity: 90%, non-condensing
Standards Compliance	• Microsoft WHQL certified drivers • Microsoft CryptoAPI, PKCS #11 Interoperability • FIPS PUB 186 Digital Signature Standard, FIPS PUB 185 SKIPJACK, FIPS PUB 180-2 Secure Hash Algorithm, FIPS PUB 46 DES Standard, FIPS PUB 197 AES standard • FCC part 15, subpart J, class B certified

8.3 Hardware Location, Physical Packaging, and Anti-Tamper Protection

The vaults at the I55US sensor sites have two randomly placed pushbutton switches to indicate if the lid is opened. The pushbutton switches are electronically latched so that only one has to go high momentarily for it to be positively detected. The status of the switch is sent back to the CRF once a second. No physical access security is provided to prevent access to the array other than the extreme remote location. The vaults are made of plastic and will show any tampering that was done to get into the vault through the side. The lid of the vault is padlocked shut.

Building 69, where the relay equipment is located, is not a locked facility. It contains high value NASA and NSF communication equipment that must be accessed by NSF and NASA. Frequently in the Arctic and Antarctic where buildings are remote like B69 from the main base, buildings are not locked for safety reasons and because of their remoteness limits possible vandalism. However, data is signed at the sites and therefore cannot be tampered with at the relay site.

The CRF is located in a locked room in Bldg. 159 at McMurdo station.

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9 Operations and Maintenance

9.1 Staff

The I55US station operator, University of Alaska Fairbanks (UAF), has five staff members involved in operation and maintenance of the facility. These positions include program manager, 2 field engineers, and 2 technicians technician. All personnel are located at the UAF facility. In addition USAP personnel are on-site for maintenance and some repairs.

9.2 Preventative Maintenance

At UAF, the station is routinely monitored for data quality and uptime. Additionally, a site visit is conducted on an annual basis during the Austral summer. During this visit because of the 1-2 meter of snowfall received every year; the equipment vaults, power cable, and GPS/antenna poles are dug out and placed back on top of the snow. A contract is in place for preventative maintenance to be performed on the I55US power plant known as BOB during the UAF visit. In addition, the following preventative maintenance procedures are undertaken at the station:

- Battery testing;
- Battery terminal cleaning;
- Cable and cable connector integrity checks;
- UPS status and condition checks;
- General site integrity;
- Site security;
- Off-line spare parts test/evaluation;
- Maintenance of wind-noise-reducing filters;
- Maintenance of telemetry equipment.
- Maintenance of instrument vaults and the CRF
- Corrosion control of grounding system and metal parts;
- Additional measures on an as needed basis.

9.3 Operational Irregularity Procedures

Any time operational irregularities are noted by UAF personnel, or any other users of I55US data, troubleshooting procedures and possible maintenance actions are undertaken. All procedures and actions are logged into UAF records. These records will be used for completing reports required by the PTS such as monthly reports and equipment failure reports. If problems are identified that would affect data quality, all users would be notified.

9.4 Urgent Repair Procedures

Traces and uptime statistics are displayed real time on the workstation in the CRF and on a computer at UAF. Waveforms from the 8 pressure sensors and the 4 meteorological sensors, uptime statistics, security, PV voltages, battery voltages and charge rate, and SOH are examined on normal weekdays. If a problem arises initial troubleshooting will take place from UAF. If the problem cannot be corrected remotely, the on-site USAP technician will be contacted.

Estimates of various repair/replace times are shown below.

- Microbarometer: 1 day (replaced with on-site spare).
- Digitizer: 1 day (replaced with on-site spare).
- GPS antenna: 1 day (replaced with on-site spare).
- Radios: 1 day (replaced with on-site spare).
- Media Converters 1 day (replaced with on-site spare)
- CRF workstation: 1 day (replaced with on-site spare)

9.5 Equipment Troubleshooting

Equipment troubleshooting for the I55US array equipment involves the identification of a faulty module. Problem identification for most equipment involves interfacingwith the device remotely from UAF and checking system diagnostics. State of health parameters are available on the majority of the equipment used at I55US (ie. Sensors, digitizers, GPS receivers, radios, UPS, etc.). Once identified as faulty, the unit is replaced by on-site spares. Faulty units are returned to the UAF depot where they are either repaired or returned to the manufacturer. After repair the unit is reinstalled or placed in on-site spares pool as appropriate.

On-site checking: All IP based equipment can be accessed from the CRF, Relay site, or equipment vault by plugging into the appropriate network switch or using the CRF computers.

Remote checking: All equipment at I55US can be queried by logging into the station computer via a VPN connection. Once logged on to the station computer, any of the digitizers can be accessed.

9.6 Calibration Procedures

It is planned to calibrate the station on a schedule of once per year during the preventative maintenance visit.

10 Data Quality and State-of-Health Monitoring

10.1 Available State-of-Health Parameters

- GPS lock status
- GPS on/off status
- Enclosure intrusion status
- Battery Voltage
- Input Voltage
- Vault Temperature
- Vault Current

The Remote Hybrid Power Supply (BOB) in Windless Bight sends back SOH information to the McMurdo caretaker and the Fairbanks operator. BOB reports a comprehensive set of information on its current operating condition and health. The data includes:

- Battery voltage
- Charge/discharge currents
- Internal temperatures
- Fuel level
- Current equipment status
- Met data (wind speed, direction, outside temperature, pressure, and solar radiation)

10.2 Transmitted State-of-Health Parameters

The following is a list of state of health information sent to Vienna in the headers of the CD1.1 data flow. Referring to Table 20 of the CD1.1 Formats & Protocols document, the following bytes/bits are set by the digitizers at the elements:

<u>Byte 2</u>

<u>Bit</u>	
2	Zeroed data
3	data clipped

<u>Byte 3</u>

<u>Bit</u>	
2	digitizer open
3	vault open

<u>Byte 4</u>

<u>Bit</u>	
1	Clock differential too large
2	GPS off
3	GPS unlocked

10.3 State-of-Health monitoring

The following procedure is used to monitor the state-of-health (SOH) channels and detect potential data errors or instrument failures

Pressure and state-of-health data are automatically loaded into the data processing and analysis program Icicle. This program runs continuously on the computer in the CRF. Any irregularities in the pressure or meteorological data can be investigated further by examining the data in Matlab. SOH errors trigger an immediate email notification to the station operator. The response is determined by the urgency of the fault.

The station operator, or one of the other principal members of the UAF infrasound team, will check at least once every normal working day the state-of-health information transmitted for each channel in the array. The state-of-health information that will be examined includes the status of each clock at the array, calibration status and telemetry status. Any anomalies will be reported to the IDC in a problem report. Continuous records of data quality are collected by the Icicle software operating on our data receiver at UAF. All recorded information is saved to an archive which is backed up periodically and accessible by all members of the UAF infrasound team. Any anomalies in these channels will be investigated and a problem report will be filed if corrective action is required. Problems of particular interest include data gaps or spikes.

10.4 Data Quality Monitoring

Pressure waveform data quality monitoring currently consists primarily of accounting for any data outages, spikes, and clipping that may be present in the waveforms. Unlike monitoring of the majority of state-of-health parameters, pressure waveform data quality cannot be easily and efficiently automated because values of zero, as outages would be represented, have real significance. Thus, when monitoring quality of pressure data, the following procedure has been adopted:

1. The waveform data are loaded continuously into the interpretation software.
2. Any clipping that is present in the data will be represented as “spiky,” “bursty”, or unusually noisy data, and can be easily recognized.
3. Any data spikes can be recognized by their high amplitude, lack of correlation if present on only one channel, and lack of move out if present on multiple channels. If present on all channels, the operator must take special care to ensure that the “spike” is not indeed a signal.

Based on the results of items 2, and 3 a data quality report can be generated with descriptions of major data quality problems as well as estimates as to the amount of data actually interpretable.

A newer method of QC for the station has been developed at UAF. Figure 10.4.1 is the graphical result of a prototype algorithm designed to analyze data quality. In this case, the algorithm was applied to data recorded by I53US on May 6, 2011 as labeled in the top left corner of the figure. In the top right corner is a brief summary of common data quality problems: gaps in time, data drops, noisy sensors, and time lock problems. Gaps in time are defined as any interval between consecutive values of time greater than 1.5*dt (where dt is the expected time difference between consecutive samples, i.e. the multiplicative inverse of the sample rate). If no gaps in time are present (as is the case in this example) a green check mark is drawn to the left, otherwise a red ‘X’ is drawn. Data drops are defined as any set of NaN (Not-a-Number) values in the time series or a consecutive set of five or more pressure measurements with constant value. Since two consecutive pressure measurements commonly have the same value even in ‘good’ data, we have temporarily chosen a threshold of five consecutive values, but this value is subject to change and might need to be made to increase with higher sample rates. If no data drops are present, a green check mark is drawn, otherwise a red 'X' is drawn, and the number of sensors with data drops is stated to the right. Currently, the summaries of noisy sensors and time lock problems are off-line. However, the intent is to also display green check marks and red 'X's so that anyone (even those not familiar with signal processing) can easily gauge the quality of the data.

Top Panel

The top panel is intended to illustrate at which times data quality problems occur within the time series. Each time series is represented by a line plot extending from hours 0 to 24 along the x-axis and positioned at a value along the y-axis equal to the corresponding sensor's number. Data without quality problems are depicted with a green line. Gaps in time (though not seen in this figure) would appear as breaks in the green line (or colorless lines) extending over the time ranges of the time gaps and present across all plots. Data drops are identified by a black line slightly thicker in width than the green line to aid in the visibility of short duration data drops. Noisy data (though not seen in this figure) would result in a red line with the same thickness as the black line. It should be noted that the three data types mentioned thus far are mutually exclusive, meaning that every data point will be flagged as either 'good,' dropped, or noisy, but not a combination of two or three types. However, a time lock problem is not mutually exclusive with the other three data types. For example, a time lock problem can occur while the data are noisy. Therefore, the current plan is to illustrate time lock problems with either a blue ellipse or a blue rectangle which will overlay the line plots.

Middle Panel

The middle panel contains a plot showing the standard deviation of each time series (y-axis) as a function of time (x-axis) over the whole day. The standard deviation of each time series is illustrated by a different color as described in the legend at the top of the plot. The standard deviation was calculated for each consecutive 10 minute window (no overlap) for data without drops. Those resulting values were plotted at the times corresponding the center of the windows and then connected by a line plot.
The intention of this plot is to provide more information to an analyst about how the noise level in one time series compares to the noise levels of the other time series as a function of time. However, in order to be more effective, maybe the time series should first be band-pass filtered over different frequency ranges before calculating standard deviations. This will probably result in the middle panel being replaced with multiple panels.

Bottom Panel

The bottom panel displays the power spectral density (PSD) plots as a function of frequency for the time series that have no data drops (time series 1 and 4 in this figure). A $\log_{10}$ scale is used to map frequency in units of Hertz along the x-axis, and a linear scale is used to display sound pressure level in units of decibels along the y-axis. The PSD plots are calculated using the 'pwelch' command in MATLAB with its default settings. The color scheme used in this panel is the same as that used for the middle panel, but a legend is still added to the bottom left corner of the PSD plot for the sake of clarity. Even though the times series that contain data drops are currently being excluded from the bottom panel, this might not occur with future versions of this algorithm. Ideas being considered to incorporate time series with data drops include 1) replacing the data drops with manufactured values and 2) focusing on segments of data spanning less than 24 hours which contain no data drops.

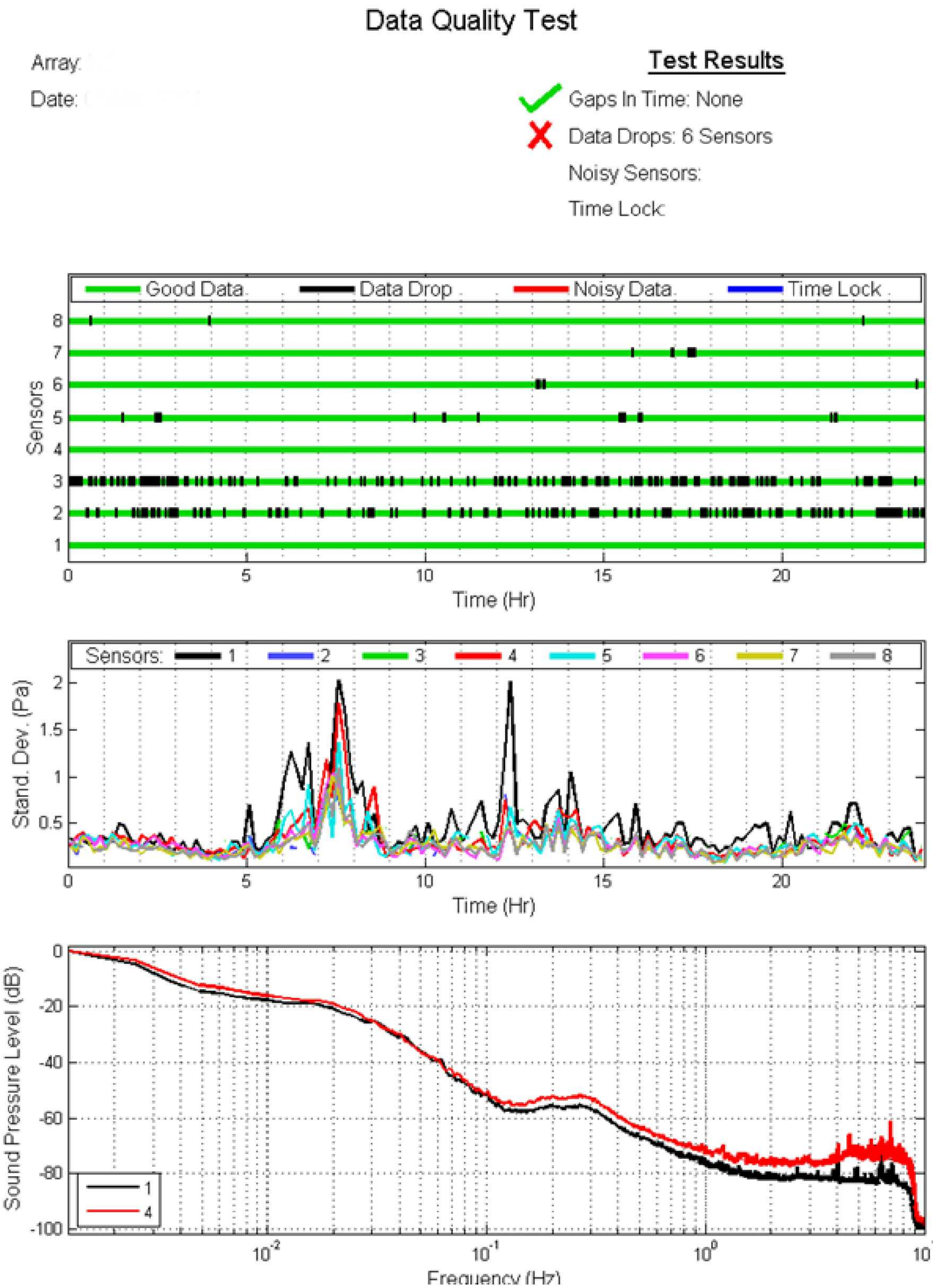


Figure 10.4.1 I58US Prototype QC Monitoring

10.5 Background Noise Monitoring

Noise levels will be monitored on a weekly basis and any sustained increase in noise levels will be noted in a problem report.

On a continuous basis pressure and meteorological waveforms are converted from the native framestore format into CSS3.0 via the CDTools software. MATLAB software is used to calculate and stack spectral estimates. Plotting software is used to provide an easily interpreted display of spectral energy levels as a function of element and wind speed

11 Records and Reporting

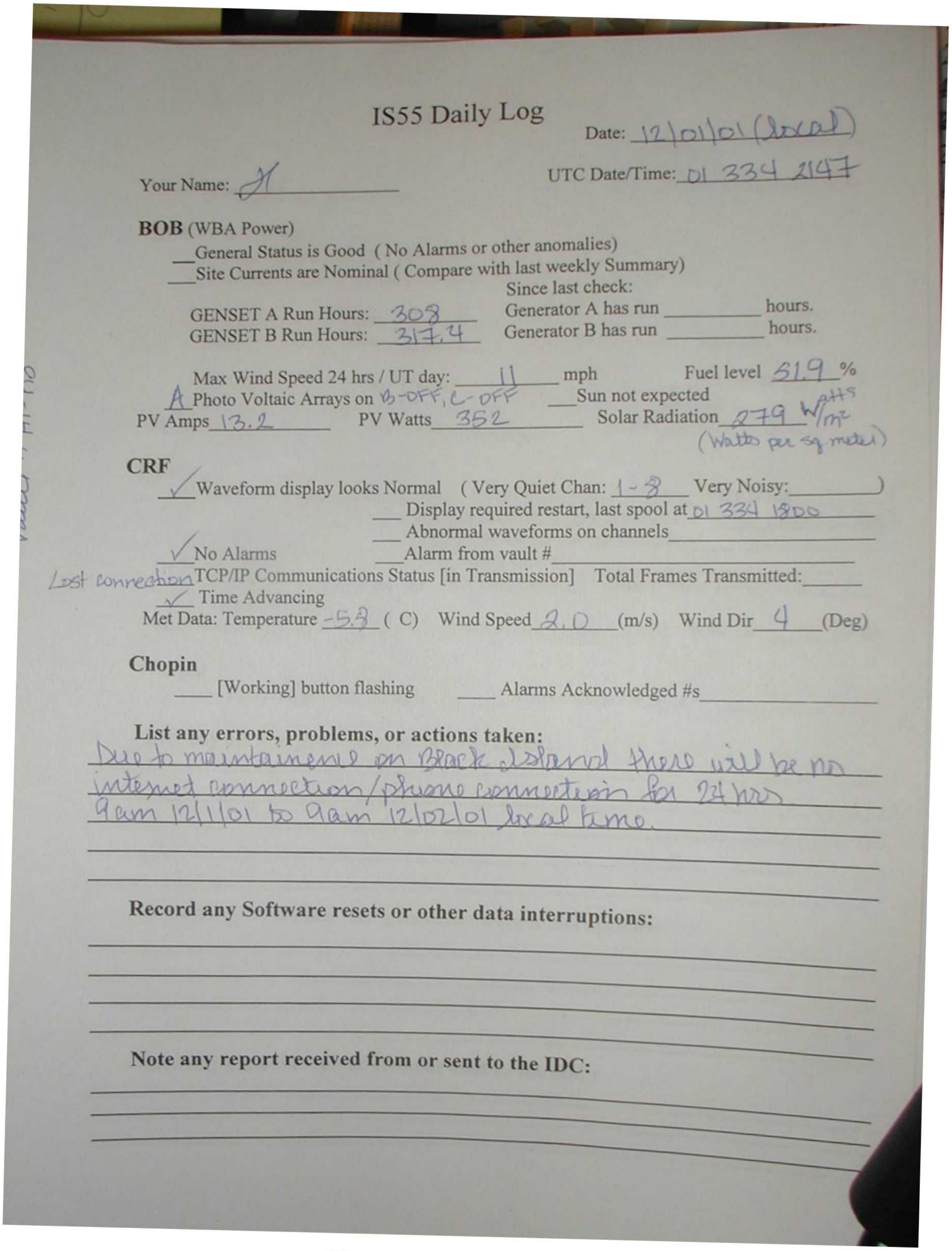
11.1 Record Keeping Procedures

The procedures used follow the requirements given in the T&E and O&M manuals. A Daily log will be maintained as a hardcopy. The log book provides an unchangeable reference of station operations. An electronic copy may be generated for plotting trends and for sending to the CTBTO if necessary. The Daily log will consist of a check list of items to examine each day to verify the health of the station and logging room to note errors, problems, actions taken, data interruptions, and any emails to or from the CTBTO.

The Weekly log will be maintained in the same form as the Daily log. The Weekly log will be a summary of the previous week's events and a weekly trend log of some of the state of health information.

An equipment log will be maintained that lists all equipment in use at the site with serial numbers. Any equipment changes or failures will be noted in this log. The log will facilitate patterns in equipment failures and finding places for improvement.

11.2 Routine Records



IS55 Daily Log

Date: 12/01/01 (local)

Your Name: [illegible]

UTC Date/Time: 01 334 2147

BOB (WBA Power)

__ General Status is Good (No Alarms or other anomalies)

__ Site Currents are Nominal (Compare with last weekly Summary)

Since last check:

GENSET A Run Hours: 308 Generator A has run ________ hours.

GENSET B Run Hours: 317.4 Generator B has run ________ hours.

Max Wind Speed 24 hrs / UT day: 11 mph Fuel level 51.9 %

A Photo Voltaic Arrays on B-OFF, C-OFF __ Sun not expected

PV Amps 13.2 PV Watts 352 Solar Radiation 279 Watts/m² (Watts per sq. meter)

CRF

✓ Waveform display looks Normal (Very Quiet Chan: 1-8 Very Noisy: ________)

__ Display required restart, last spool at 01 334 1800

__ Abnormal waveforms on channels ________

✓ No Alarms __ Alarm from vault # ________

Lost connection TCP/IP Communications Status [in Transmission] Total Frames Transmitted: ______

✓ Time Advancing

Met Data: Temperature -5.3 (C) Wind Speed 2.0 (m/s) Wind Dir 4 (Deg)

Chopin

__ [Working] button flashing __ Alarms Acknowledged #s ________

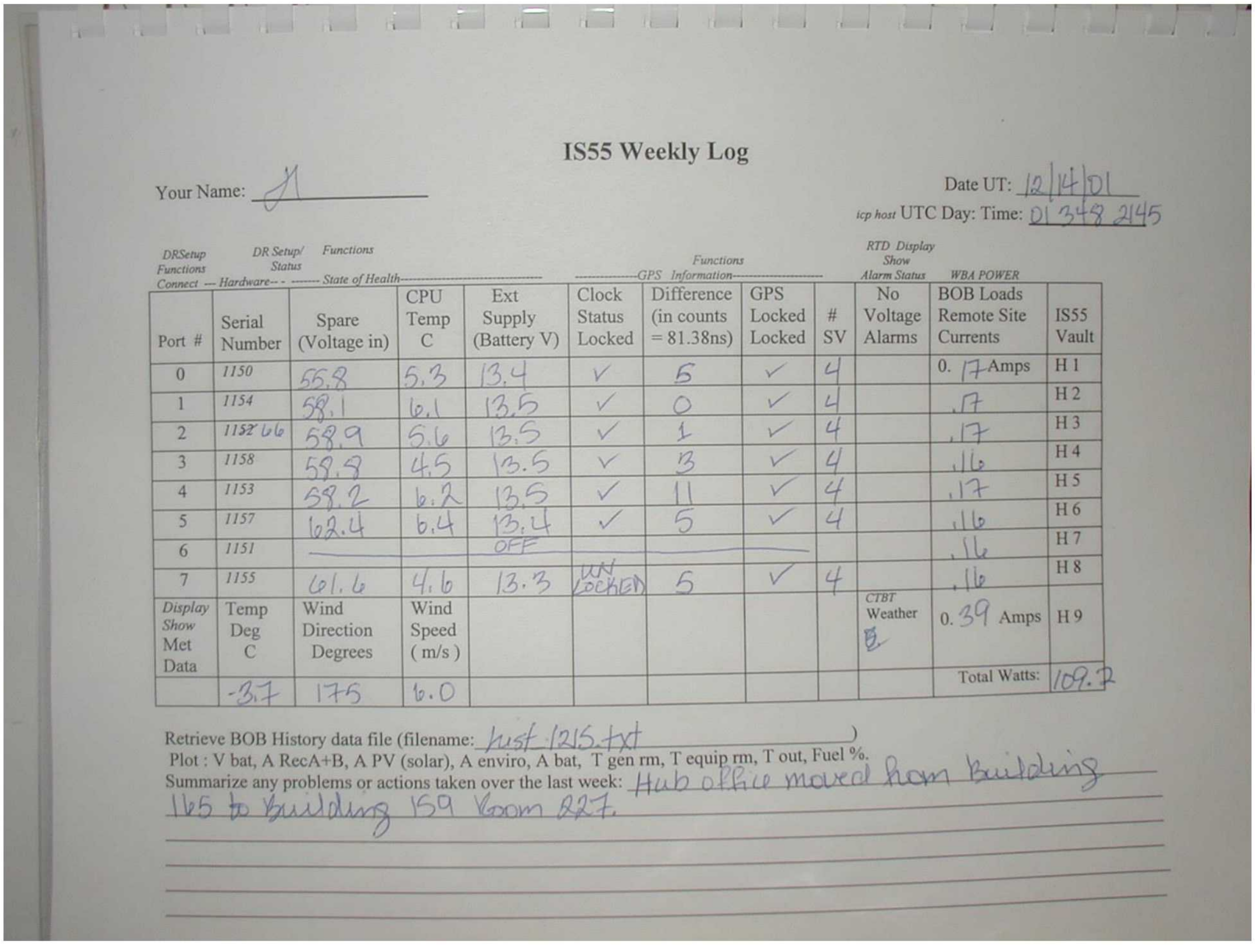
List any errors, problems, or actions taken:

Due to maintainence on Black Island there will be no internet connection/phone connection for 24 hrs 9am 12/1/01 to 9am 12/02/01 local time.

Record any Software resets or other data interruptions:

Note any report received from or sent to the IDC:

Figure 11.2.1 I55US Daily Report



IS55 Weekly Log

Your Name: _[signature]_

Date UT: 12/14/01

icp host UTC Day: Time: 01 348 2145

DRSetup Functions Connect — DR Setup/Status Functions Hardware — State of Health — Functions GPS Information — RTD Display Show Alarm Status — WBA POWER

Port #	Serial Number	Spare (Voltage in)	CPU Temp C	Ext Supply (Battery V)	Clock Status Locked	Difference (in counts = 81.38ns)	GPS Locked Locked	# SV	No Voltage Alarms	BOB Loads Remote Site Currents	IS55 Vault
0	1150	55.8	5.3	13.4	✓	5	✓	4		0. 17 Amps	H 1
1	1154	58.1	6.1	13.5	✓	0	✓	4		.17	H 2
2	~~1152~~ 66	58.9	5.6	13.5	✓	1	✓	4		.17	H 3
3	1158	58.8	4.5	13.5	✓	3	✓	4		.16	H 4
4	1153	58.2	6.2	13.5	✓	11	✓	4		.17	H 5
5	1157	62.4	6.4	13.4	✓	5	✓	4		.16	H 6
6	1151			OFF						.16	H 7
7	1155	61.6	4.6	13.3	UN LOCKED	5	✓	4		.16	H 8
Display Show Met Data	Temp Deg C	Wind Direction Degrees	Wind Speed (m/s)						CTBT Weather ☑	0. 39 Amps	H 9
	-3.7	175	6.0							Total Watts:	109.7

Retrieve BOB History data file (filename: hist 1215.txt)

Plot : V bat, A RecA+B, A PV (solar), A enviro, A bat, T gen rm, T equip rm, T out, Fuel %.

Summarize any problems or actions taken over the last week: Hub office moved from Building 165 to Building 159 Room 227.

Figure 11.2.2 I55US Weekly Report

11.3 Configuration Change Notification

A report will sent to the Technical Secretariat describing any proposed configuration changes. Changes will not become effective at the station until approved by all parties.

11.4 Notification of Outages

The CTBTO will be notified by email of any planned down time before the action occurs, but the station operator will not wait for a response from CTBTO before starting work. After the work has been completed the CTBTO will receive an email report with the actual down time, and full details of what work was done.

11.5 Equipment Status Notification

Any change in equipment status will be reported to the Technical Secretariat via Problem Reports. These reports will be completed whenever the Station Operator or Technical Secretariat identifies a condition at the station that might affect station operations. Content of the report will include diagnosis of the problem, the type of maintenance required to solve it.

12 Testing and Evaluation

12.1 Equipment Installation Report

No Equipment Installation Reports were completed.

12.2 Major station Outages

12.3 Equipment Failure History

12.4 Data Availability Statistics

Data Availabilty statiscs for this station can be found on the PTS PRTool.

12.5 Independent Sub-Network Statistics

There are no sub-networks associated with this station.

13 Station Inventory

13.1 Sensors

As of December 5, 2001

Manufacturer	Model	Serial Number	Location	Actual Sensitivity (mV/Pa)
Chaparral	50A	122413	H1	391
Chaparral	50A	122414	H2	396
Chaparral	50A	122453	H3	407
Chaparral	50A	122417	H4	395
Chaparral	50A	122439	H5	399
Chaparral	50A	122442	H6	402
Chaparral	50A	122449	H7	400
Chaparral	50A	122451	H8	405
Chaparral	50A	122415	Spare	401
Chaparral	50A	122450	Spare	405

Device	Model	LOCATION	SERIAL NUMBER
Barometer	RM Young 61302V	H4	BPA6586
		Spare	BPA7093

13.1 Digitizers

TYPE	SERIAL NUMBER	LOCATION	Sensitivity (counts/V)
Geotech Smart-24 D	2031	H1	299773
	2032	H2	299924
	2033	H3	299869
	2042	H4	299556
	2041	H5	299894
	2036	H6	299525
	2039	H7	299279
	2038	H8	300462
	2035	Spare	305453
	2034	Spare	

13.2 Intra-Site Communications

TYPE	Location	Serial Number
Data Connect ANS205 10/100 Switch	H1	ANS205CR00AYIBD00343
	H2	ANS205CR00AYIBD00354
	H3	ANS205CR00AYIBD00376
	H4	ANS205CR00AYIBD00335
	H5	ANS205CR00AYIBD00377
	H6	ANS205CR00AYIBD00375
	H7	ANS205CR00AYIBD00366
	H8	ANS205CR00AYIBD00342
	Spare	ANS205CR00AYIBD00356
	Spare	ANS205CR00AYIBD00364

TYPE	Location	Serial Number
ControlbyWeb X300 Web Power Relay Switch	H1	000CC8028500
	H2	000CC80284FE
	H3	000CC80284FD
	H4	000CC80284FB
	H5	000CC80284F9
	H6	000CC80284F6
	H7	000CC80284FA
	H8	000CC80284F7
	Spare	000CC80284FF
	Spare	000CC80284FC

13.3 External Communications

TYPE	Location	SERIAL NUMBER
Netgear JGS524 Network Switch	Relay Site	2HL5283B5003A
Netgear JGS524 Network Switch	Spare	2HL5283A50039

Cisco 891-K9 Router	CRF	FTX1614865F
Cisco 891-K9 Router	Relay Site	FTX16318416
Cisco 891-K9 Router	Spare	FTX16318415

13.4 All Other Critical Components

GPS Receivers

MODEL NUMBER	LOCATION	SERIAL NUMBER
Trimble Acutime Gold	H1	01732321
	H2	01732270
	H3	01732293
	H4	01733446
	H5	01732731
	H6	01732796
	H7	01732406
	H8	01732578
	Spare	01732297
	Spare	71426125

Central Recording Facility GPS

MODEL NUMBER	Location	SERIAL NUMBER
Masterclock NTP Time Server NTP100-GPS	CRF	12208048
	Spare	12208056

Crypto Cards

MODEL NUMBER	LOCATION	SERIAL NUMBER
Spyrus Fortezza	H1	3002-F8000231
Spyrus Fortezza	H2	3002-F8000235
Spyrus Fortezza	H3	3002-F8000237
Spyrus Fortezza	H4	3002-F8000238
Spyrus Fortezza	H5	3002-F8000239

Spyrus Fortezza	H6	3002-F8000232
Spyrus Fortezza	H7	3002-F800023A
Spyrus Fortezza	H8	3002-F8000234
Spyrus Fortezza	Spare	3002-F8000233
Spyrus Fortezza	Spare	3002-F8000236
Spyrus SES3100-F	CRF	3003-F0001928
Spyrus SES3100-F	CRF	3003-F00018E0

Workstation

Manufacturer	Location	Model	SERIAL NUMBER
Dell Computer	ws01-i55us	T3600	J6SDXV1
	ws02-i55us		J6SCXV1
Dell Monitor	ws01-i55us	U2212HM	CN-0PF48H-64180-28E-0DRL
	ws02-i55us		CN-0PF48H-64180-28E-04UL

UPS

Manufacturer	Model	Location	Serial Number
APC	SUA1500RM2U	CRF	AS0447131941

MET Station

Device	Manufacturer	Location	Model Number	Serial Number
Wind Sensor	RM Young	H7	05103V-45	118960
Wind Sensor	RM Young	Spare	05103V-45	118959
Temp Sensor	R.M. Young	H7	41382VC	22265
Temp Sensor	R.M. Young	Spare	41382VC	21534

Power Units

Device	MODEL NUMBER	LOCATION	SERIAL NUMBER

Morningstar Solar Charge Controller	SunSaver MPPT	Relay Site	000CC8028500
		Spare	

Device	Model	Location	Serial Number
Concord Sun Xtender Battery	PV-1040T	H1	SX002
		H2	SX007
		H3	SX013
		H4	SX005
		H5	SX004
		H6	SX008
		H7	SX012
		H8	SX009
		Relay	SX001
		Relay	SX006

Communications

DEVICE	MANUFACTURER	MODEL NUMBER	Location	SERIAL NUMBER
Radio Antenna	Kathrein-Scala	TY-900	BOB	LG037-18727-050
			H1	LG037-18727-127
			H2	LG037-18726-149
			H3	LG037-18727-128
			H4	LG037-18726-148
			H5	LG037-18727-105
			H6	LG037-18727-106
			H7	LG037-18727-123
			H8	LG037-18727-108
			Relay	LG037-18727-126
			Relay	LG037-18726-063
			Relay	LG037-18726-059
			Relay	LG037-18727-129
			Relay	LG037-18726-078
			Relay	LG037-18726-143

			Spare	LG037-18726-150
			Spare	LG037-18726-080
			Spare	LG037-18727-142
			Spare	LG037-18727-109

DEVICE	MANUFACTURER	MODEL NUMBER	Location	SERIAL NUMBER
Network Radio	FreeWave	FGR2-PE	H1	8661473
			H2	8688817
			H3	8688813
			H4	868-8795
			H5	8688831
			H6	8663711
			H7	8688833
			H8	8659949
			Relay	8688818
			Relay	8664631
			Relay	8688842
			Relay	8656294
			Relay	8660660
			Relay	8689946
			Relay	8689740
			Relay	8688812
			Repair	8689812
			Spare	868-8814
			Spare	868-7801
			Spare	868-8847
Serial Radio	FreeWave	DGR-115R/H	BOB	904-2304
			Relay	904-2607
			Spare	904-0320

			Spare	

Device	Manufacturer	Model	Location	Serial Number
Serial2Ethernet	Black Box	LES301A	CRF	B129020000-0104
Serial2Ethernet	Black Box	LES301A	Relay	B129020000-0108
Serial2Ethernet	Black Box	LES301A	Spare	B129020000-0096
Serial2Ethernet	Black Box	LES1101A	Spare	40010667061035
Serial2Ethernet	Black Box	LES1101A	Spare	40010705061076
Serial2Ethernet	B&B Electronics	VESP211	Spare	000EBE0027BA
Serial2Ethernet	B&B Electronics	VESP211	Spare	000EBE0027B6
Serial2Ethernet	B&B Electronics	VESP211	Spare	000EBE002F18
SM Fiber Converter	Black Box	SM1310 /Plus-SC	Spare	0200904006
SM Fiber Converter	Black Box	SM1310 /Plus-SC	Spare	0200904009
SM Fiber Converter	Black Box	SM1310 /Plus-SC	Spare	0200904011
SM Fiber Converter	Black Box	SM1310 /Plus-SC	Spare	0200904013

Miscellaneous

GPS/MET Surge Protection
PolyPhaser IX-3L
H1-H8 (2 each at H7 & H6)

MET Translation Box v2
University of Alaska Fairbanks
H7

Magnetic Proximity Switch
C&K MPS20WGW
H1-H8

UAF Power Supply Board
UAF/Vicor DC Pwr v1
H1-H8