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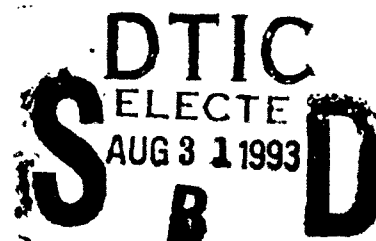
**VHF-UHF NOISE SURVEYS AT
GULKANA, ELMENDORF AFB,
GALENA AFB, KOTZEBUE AND CAPE LISBURNE,
ALASKA AND NRL, POMONKEY, MARYLAND**

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February 1993

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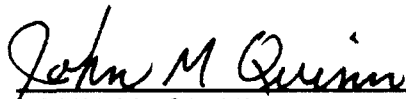


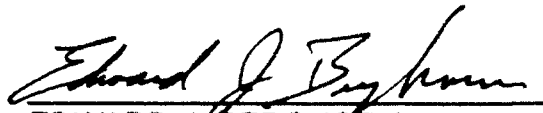
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Preface

MSGT Regina M. Burton of Phillips Lab/GPIA is acknowledged for taking responsibility for the data acquisition and analysis software development. She also participated in the field campaigns and was primarily responsible for the logistics involved.

SSGT Carlton H. Curtis and SRA Micheal A. Beaudet are acknowledged for instrumentation development and participation in the field campaigns.

Introduction.

This report presents results of a series of site and noise surveys performed in Alaska in March and August 1992.

Surveys were performed at the former OTH-B site at Gulkana, in March 1992 (presently the proposed High Frequency Active Auroral Research Program site (HAARP)) with the aim of determining the spectrum occupancy and background noise level at nominally 38 MHz for an imaging riometer to be part of the HAARP research facility. A similar survey at nominal frequencies of 420 MHz and 440 MHz to benefit a future incoherent scatter radar facility was also undertaken. Finally, spectrum occupancy in the frequency range 2 to 22 MHz, (the short wave band) was performed in August 1992 in conjunction with further measurements at 38 MHz. The HF frequency measurements were aimed at a first evaluation of the expected signal levels in the frequency range of the proposed HAARP transmitter.

Three site surveys were performed in March 1992, at Elemendorf AFB near Anchorage. All surveys were aimed at determining the spectrum occupancy and background noise levels at 40 to 50 MHz. This range is of interest for meteor scatter communication links included in the North Warning operational radar system.

Noise surveys were performed at three existing radar sites located at Galena, Kotzebue, and Cape Lisburne, Alaska in August 1992. The surveys covered spectrum occupancy and background noise levels in the 40 to 50 MHz frequency range. The surveys were performed as close as possible to the existing meteor scatter communication installations.

The report contains a presentation of the survey and measurement methodology, including discussions of antenna patterns, absolute noise level calibrations, and noise level predictions. The features of the individual sites are presented with a discussion of the data collected. The data presentation includes time-frequency occupancy charts, time variation at selected frequencies, and mass spectrum plots for identification of unoccupied frequencies.

1. Elements of a Site and Noise Survey.

When performing a noise survey, different considerations must be taken for VHF - UHF frequencies and for HF frequencies. At VHF and UHF frequencies very little ionospheric influence is found. Signals and man made noise are propagated along line of sight paths only, and the galactic noise penetrates the ionosphere essentially unaltered. At HF frequencies, the noise and interference is determined by ionospheric propagation paths from sources found world wide, as well as local sources propagated through line of sight paths. The galactic noise may or may not be a determining factor. Both seasonal and diurnal variations of the man-made noise and interference/spectrum occupancy should be expected at all frequencies. At VHF - UHF the variations can be caused by varying use of communications equipment and machinery or utilities creating noise. At HF, the variation of the ionospheric propagation will cause widely varying levels of noise and interference. A survey lasting a few days cannot determine all possible levels of noise and interference, but will only show the conditions at the time of survey.

VHF - UHF Considerations.

The performance of a communication terminal or a remote sensor is determined by the ratio between the wanted signal and the noise and interference in the radio spectrum used. The determining factor for the signal strength at a given location is the antenna gain in the direction of the incoming wave. The antenna gain is determined by the properties of the antenna itself, and the features of the terrain at the site.

For line of sight microwave links, a highly directive antenna, mounted as high as possible above the ground is used. The antenna height above ground is determined so the first Fresnel zone does not touch the ground under any occurring value of the atmospheric refractive index.

A zenith looking radar on the other hand can have an antenna mounted at any distance above the ground, provided the ground reflections of side and back lobes of the antenna itself do not create detrimental variations in the overall radiation pattern.

A meteor scatter terminal must have antennas illuminating the common scattering volume sufficiently well to take advantage of the majority of meteor trails occurring within the scattering volume. This requires the antenna gain, not only at boresight, but rather over the full aperture of the antenna, to be tailored to the particular link.

The reflection from the ground beneath the antenna can be used to obtain an additional gain of up to 6 dB in certain directions,

whereas a null in the radiation pattern is obtained in other directions. Long meteor scatter links that have the common scattering volume situated between the terminals around the midpoint of the link profit from antennas mounted approximately 1.5 to 2 wavelengths above ground and pointed to the horizon. This scheme creates a single main lobe at approximately 8 to 10 degrees elevation. Short links on the other hand, can have common scattering volumes covering or even extending beyond the terminals. Such links benefit from antennas mounted approximately 1 wavelength above the ground in order to extend elevation range of illumination. Thus very short links of 200 - 400 miles cannot benefit from too high gain antennas as the angular extent of the scattering volume as seen from the terminals is large.

The above deliberations are valid for flat terrain extending in front of the antenna. If the terrain is hilly, the radiation pattern tailoring described above becomes complicated, and the site is less suited for meteor scatter terminals. Thus, a first criterion for a good meteor scatter site is A FLAT FOREGROUND.

Meteor scatter signals are by nature weak, and noise and interference exceeding the galactic noise background must be avoided. Figure 1-1. shows the duty cycle of a 1200 km meteor scatter link in Greenland as a function of signal to noise ratio. It is seen that an increase of the noise level by a few dB, or a decrease of the signal to noise ratio by a few dB, can decrease the duty cycle of the channel, and thus the average communication capacity by an order of magnitude.

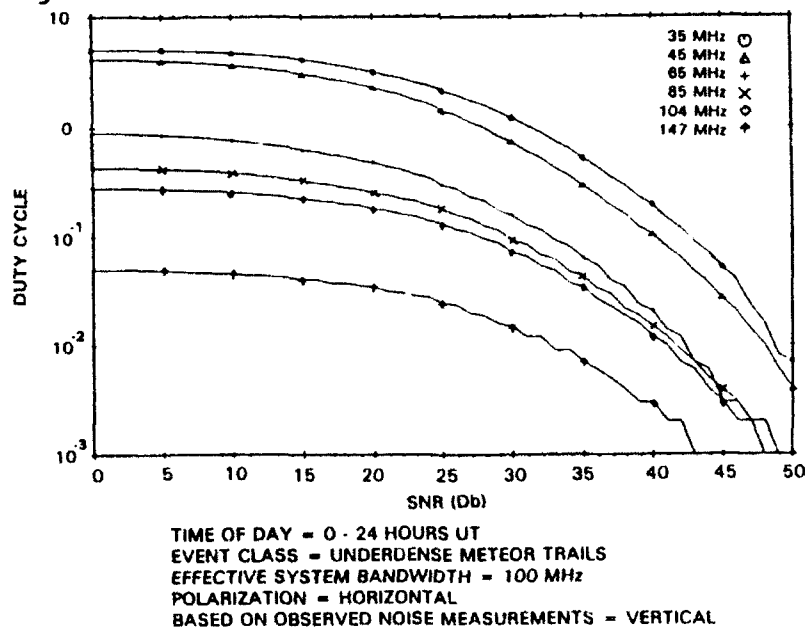


Figure 1-1. Duty Cycle as a function of signal to noise ratio for the PL diagnostic meteor scatter link between Sondrestrom and Thule, Greenland.

Galactic noise is always present in a communication system operating above the critical frequency of the ionospheres F2 layer, FoF2. This is generally the case for meteor scatter links operating in the 40 to 50 MHz range. The galactic noise level represents the lowest possible noise level during quiet ionospheric conditions and thus sets the naturally defined lower limit of the noise in the meteor scatter communications channel. The galactic noise level exhibits a diurnal variation caused by the rotation of the earth. Determining this variation to be present at the receiving terminals of a link identifies the communication channel to be galactically noise limited. This is the optimal operation conditions for the link.

Additional noise can occur as wide band noise originating from sources such as faulty electrical equipment, arc welders, vehicles or computers. Such noise can cover a large part of the radio spectrum.

Interference or spectrum occupancy, dependent on the angle of view, is caused by other users of the radio spectrum. Such 'noise' usually occupies a limited part of the spectrum, one or more allocated communication channels for each user. Thus, the second criterion for a good meteor scatter site is that it is GALACTICALLY NOISE LIMITED at the receive frequency. Finally, it must be mentioned that meteor scatter communication system design is a parametric undertaking, where location, terrain, antenna systems, transmitter power, communication protocols, and demands to performance must be traded off. Thus a site must be selected within the context of a particular communication system based on its properties and use.

The components of a site and noise survey at VHF-UHF frequencies then comprise:

- * Evaluation of the terrain at the sites. This includes both the near foreground features, and the horizon blockage determined by distant mountains or other major obstacles. A detailed topographical map should be obtained for analysis of antenna radiation patterns at each site.
- * Search of the radio spectrum of interest. The search should determine which frequencies are in use, and also if the broad band background noise exceeds the galactic noise level.

HF Considerations.

The general discussion of the influence of the signal to noise ratio on communication systems at VHF - UHF is also valid at HF frequencies. However, at HF the signal, noise, and interference levels are mainly determined by ionospheric propagation paths from sources found world wide, as well as local sources propagated through line of sight paths. The galactic noise may or may not be

the determining factor, therefore searching for a galactically noise limited site is not critical, rather a measure of the total signal level at any given frequency is more important.

Ionospheric propagation varies with frequency, solar flux, time of day, and season. The propagation in the lower portion of the band between approximately 2 - 8 MHz is heavily influenced by the presence of the ionosphere's E-layer at 100 km altitude. This layer is present when the ionosphere is sunlit at the layer altitude. The E-layer favors short distance (< 2000 km) paths, and will prevent some long distance signals from reaching the site. The propagation at intermediate frequencies, approximately 6 - 15 MHz, is dominated by the ionosphere's F-layer at 250 - 400 km altitude. The layer supports long distance propagation, and signals originating from any place on Earth can be expected throughout the day and night. At frequencies above approximately 15 MHz propagation is still supported world wide by the ionosphere's F-layer, but a high solar flux is needed to generate enough ionization to support ionospheric reflections.

The HF band is allocated to a variety of uses, such as broadcast, point to point service, maritime and aeronautical mobile service and amateur radio service. Most services have allocations throughout the HF band to enable operation under different ionospheric conditions. The broadcast stations present by far the strongest signals due to the large transmitters used for international broadcasting. Other users in general contribute less signal power, but all parts of the HF band can still be very congested at specific time intervals.

An HF band noise survey in general is therefore a complicated task. Two philosophies can be employed to define the course of the survey. A specific frequency range or direction of propagation can be specified for close examination, or a more exploratory method can be employed to get a first feel for the noise and signal levels present in a part of or the whole HF band. The latter method has been used in the survey presented in this report. For planning purposes, the 2 - 22 MHz spectrum was probed with a simple antenna for a few days. The data can be used for a first exploration of the usage of frequencies to be shared with the HAARP transmitter, and frequencies to be used for diagnostic purposes. More detailed surveys may be needed at a later date when more specific needs for HAARP have been identified.

2. Instrumentation.

The instrumentation used for the noise surveys is composed of various antenna systems with preamplifiers and a Tektronix 2753P programmable spectrum analyzer controlled by a PC computer through an IEEE 488 interface bus. Data acquired by the spectrum analyzer is transferred to the PC and onto an optical disk for permanent storage and retrieval. Finally, the data can be displayed in various ways to illustrate the properties of noise and interference at the site. The analysis and presentation software is discussed in Section 3 of this report. Figure 2-1. shows the spectrum analyzer and computer system as installed at the HAARP site at Gulkana.



Figure 2-1. Spectrum Analyzer Used for the Site Survey.

VHF Antenna:

The purpose of the noise survey was to determine man-made noise and interference in the low VHF band (30 - 50 MHz). A broad band discone antenna is suitable for this purpose, as it is sensitive especially to vertically polarized signals at low elevation angles. Such an antenna can also be used to determine the galactic noise background. The gain of the preamplifier is large enough to eliminate losses in the cable between the antenna and the spectrum analyzer, and has a noise figure small enough to enable accurate measurements of the galactic background. The discone antenna is

shown in Figure 2-2. Radiation patterns of the discone antenna, when mounted 2 meters above the ground computed with NEC for the frequencies 30, 35, 40, 45, and 50 MHz, are shown in Figures 2-3. to 2-7. The radiation pattern changes little with frequency throughout the frequency range. The antenna cut off frequency is close to 30 MHz and a slightly lower gain can be seen at this frequency.

Specific operational antenna installations may or may not suppress some of the noise and interference found with the omnidirectional antenna. However, it is often impossible to use operational antennas for site surveys due to the size and complexity of such antennas. The site survey primarily determines if other users of the radio spectrum of interest and broad band noise sources are present. The probability that the operational antenna system will be able to sufficiently suppress unwanted signals must be evaluated after the survey, as well as the feasibility of locating and removing broad band noise sources. In general the only effective way of eliminating noise and interference is to remove the sources or select another frequency of operation.



Figure 2-2. Discone Antenna

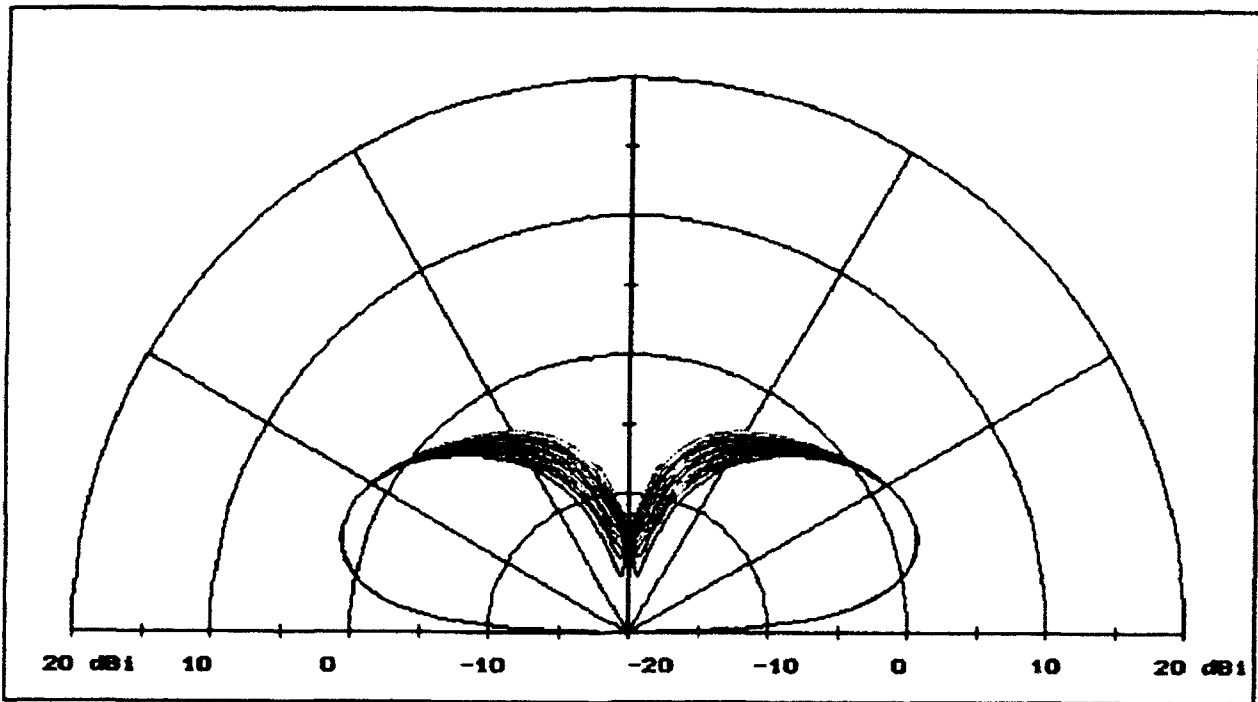


Figure 2-3. Radiation Pattern of Disccone Antenna for 30 MHz.

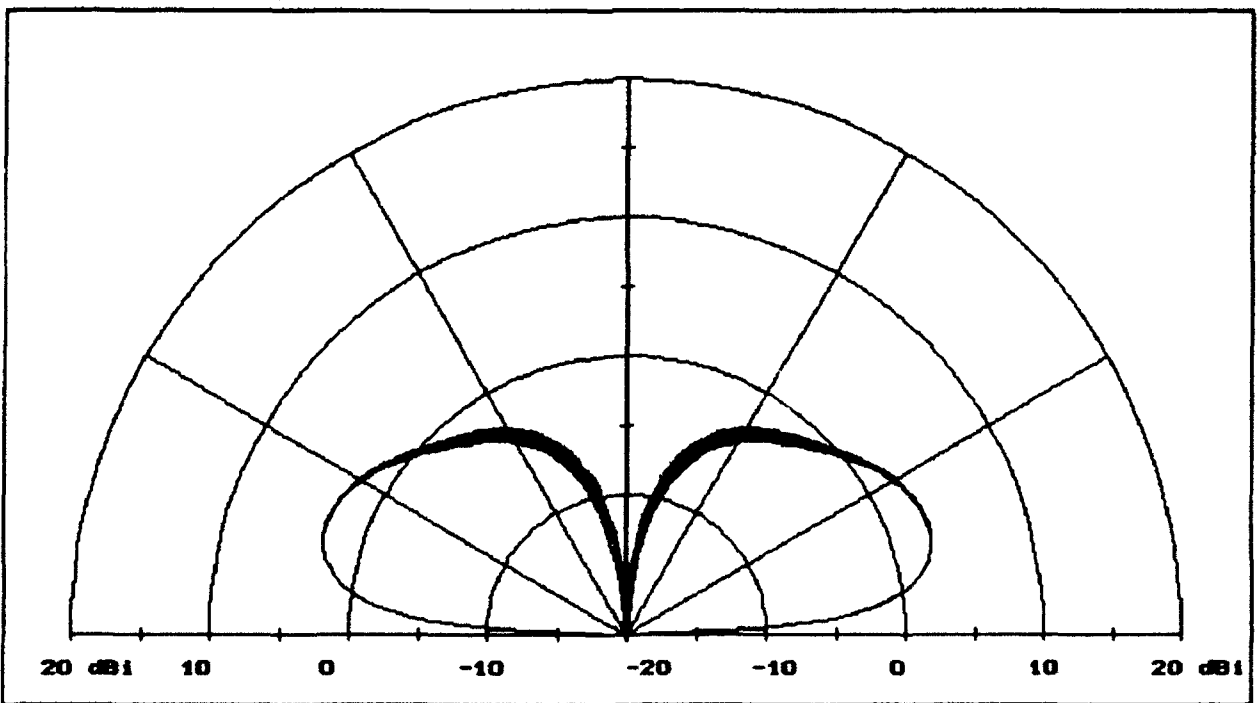


Figure 2-4. Radiation Pattern of Disccone Antenna for 35 MHz.

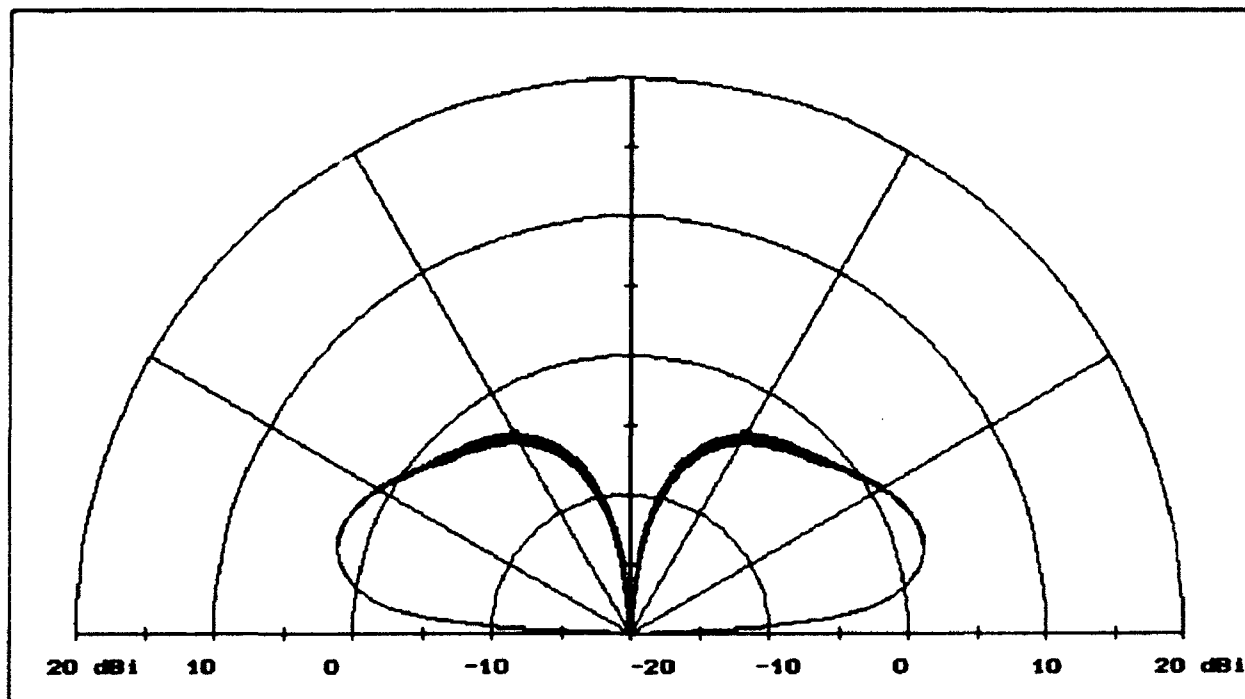


Figure 2-5. Radiation Pattern of Disccone Antenna for 40 MHz.

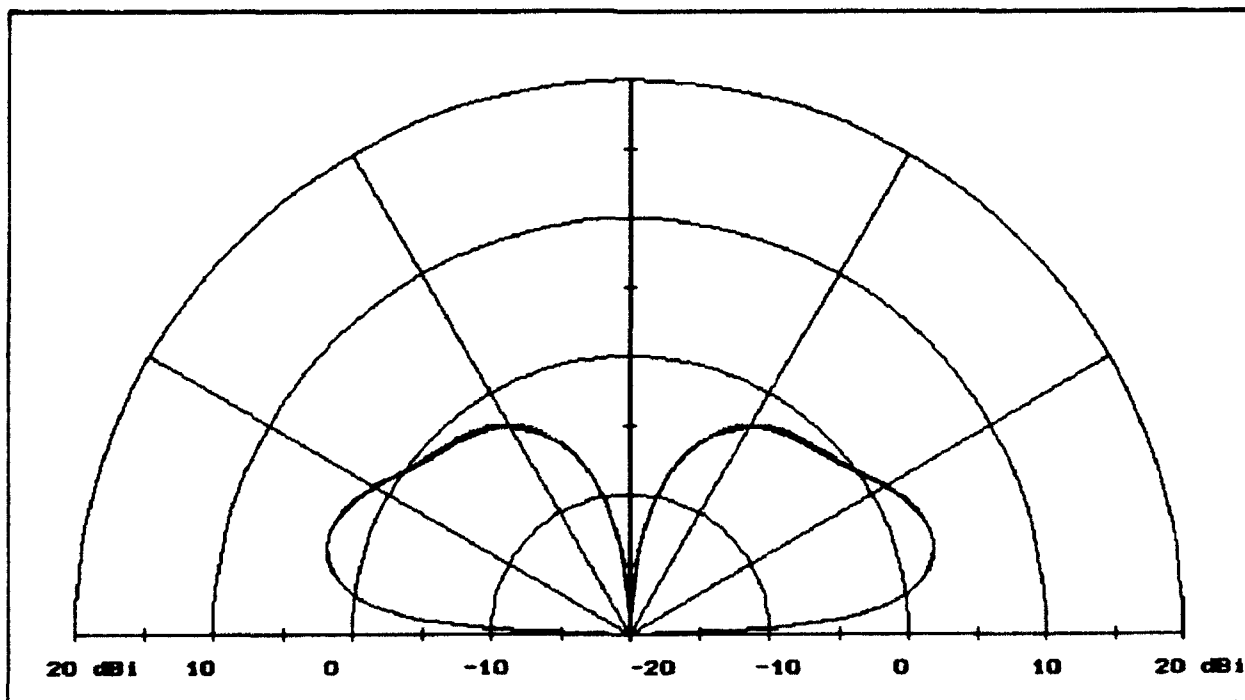


Figure 2-6. Radiation Pattern of Disccone Antenna for 45 MHz.

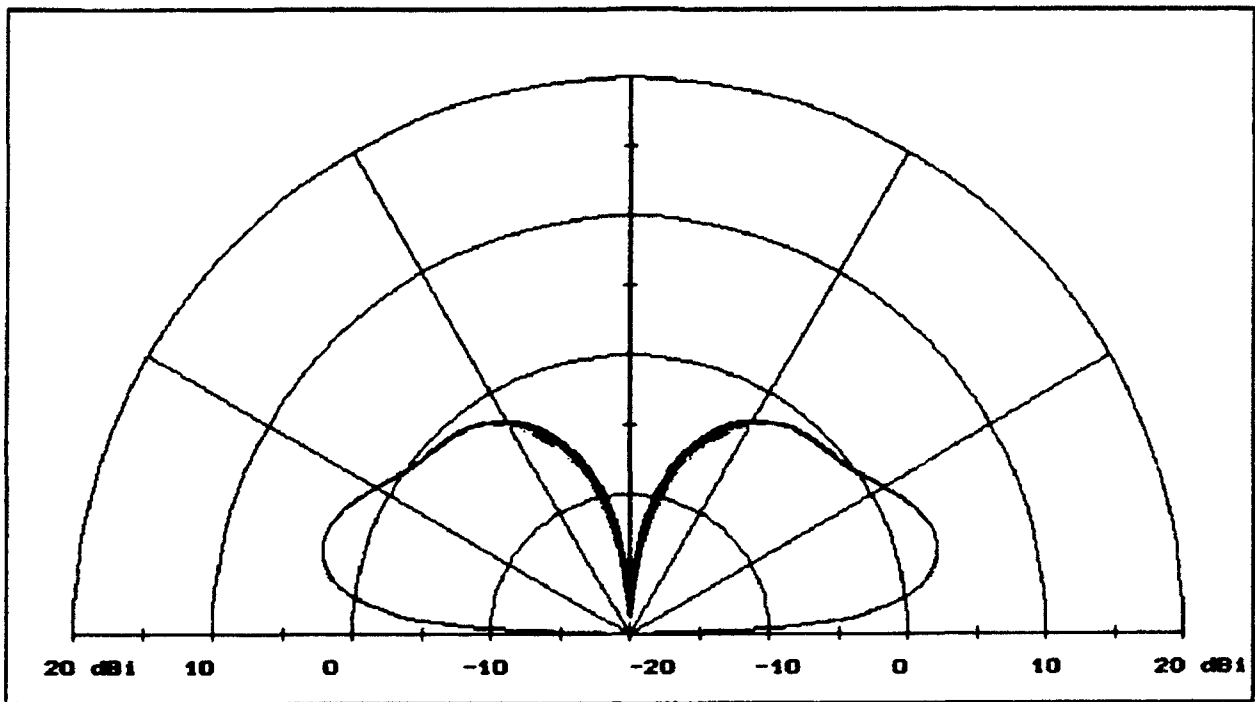


Figure 2-7. Radiation Pattern of Disccone Antenna for 50 MHz.

UHF Antenna.

The aim of the noise survey at 410 MHz to 450 MHz was to identify sources strong enough to influence the sensitivity of an incoherent scatter radar. Such a radar operates with its antenna at high elevations when probing the heated part of the ionosphere above the HAARP transmitter. Consequently a Yagi antenna pointed at zenith was chosen for the survey. The 14 element Yagi is shown in Figure 2-8. Radiation patterns computed with NEC at 420, 425, 430, 435, 440, 445, and 450 MHz, for the antenna mounted 2 meters above ground are shown in Figures 2-9 to 2-15. A large variation of the radiation pattern with frequency is seen. The antenna was designed for the 432 - 435 MHz band. The radiation patterns in the frequency range 420 to 435 MHz show a main lobe directed at zenith as expected. Low elevation side lobe gain increases with frequency until they become the dominant lobes above 435 MHz. This is a common phenomenon with gain optimized Yagi antennas, where the main lobe gain drops off rapidly as frequency is increased above the design frequency. Since the antenna has low losses, side lobe gain must increase when the main lobe gain decreases. The Yagi antenna fed a low noise preamplifier and another amplifier was placed at the spectrum analyzer input in an effort to overcome the quite high noise figure of this instrument.



Figure 2-8. Yagi Antenna (center) Used for the 410 - 450 MHz Measurements.

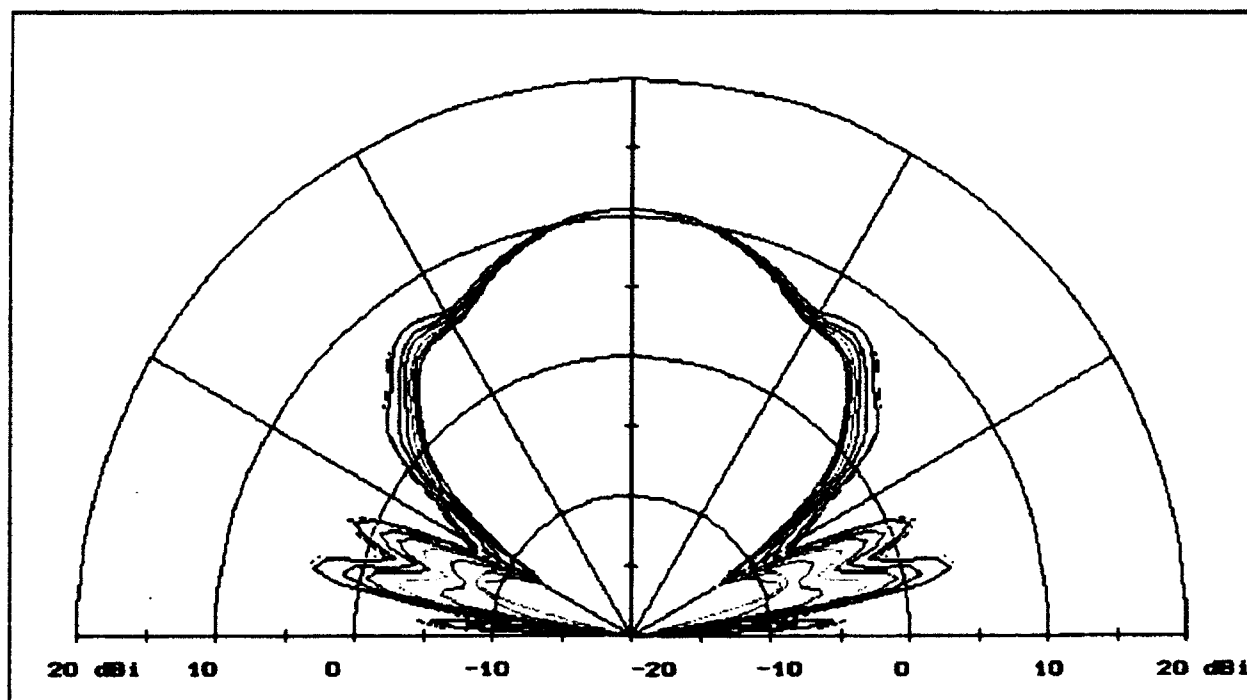


Figure 2-9. Radiation Pattern of 14 Element Yagi for 420 MHz.

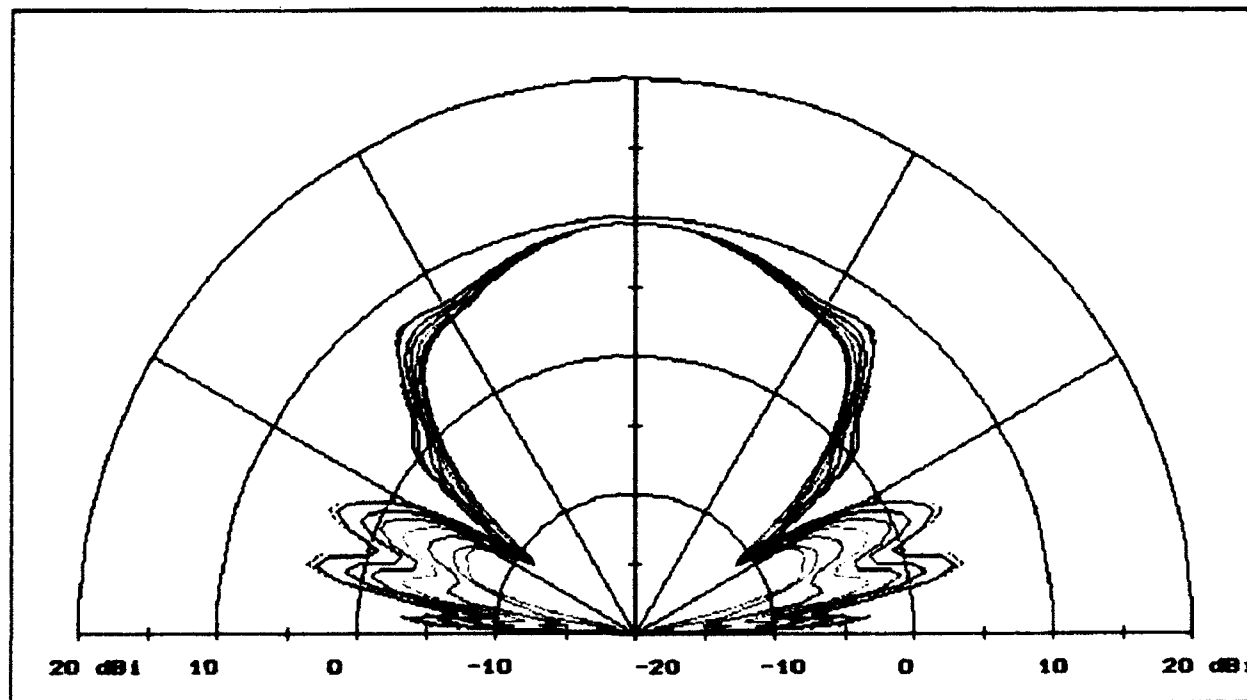


Figure 2-10. Radiation Pattern of 14 Element Yagi for 425 MHz.

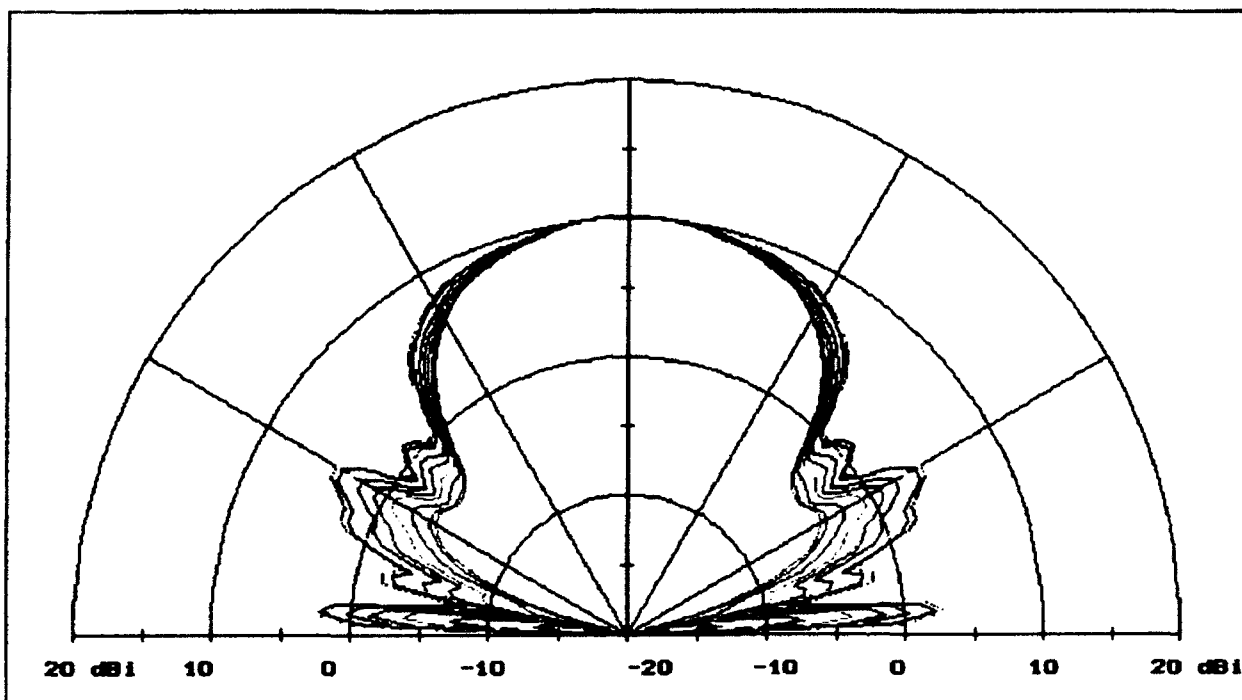


Figure 2-11. Radiation Pattern of 14 Element Yagi for 430 MHz.

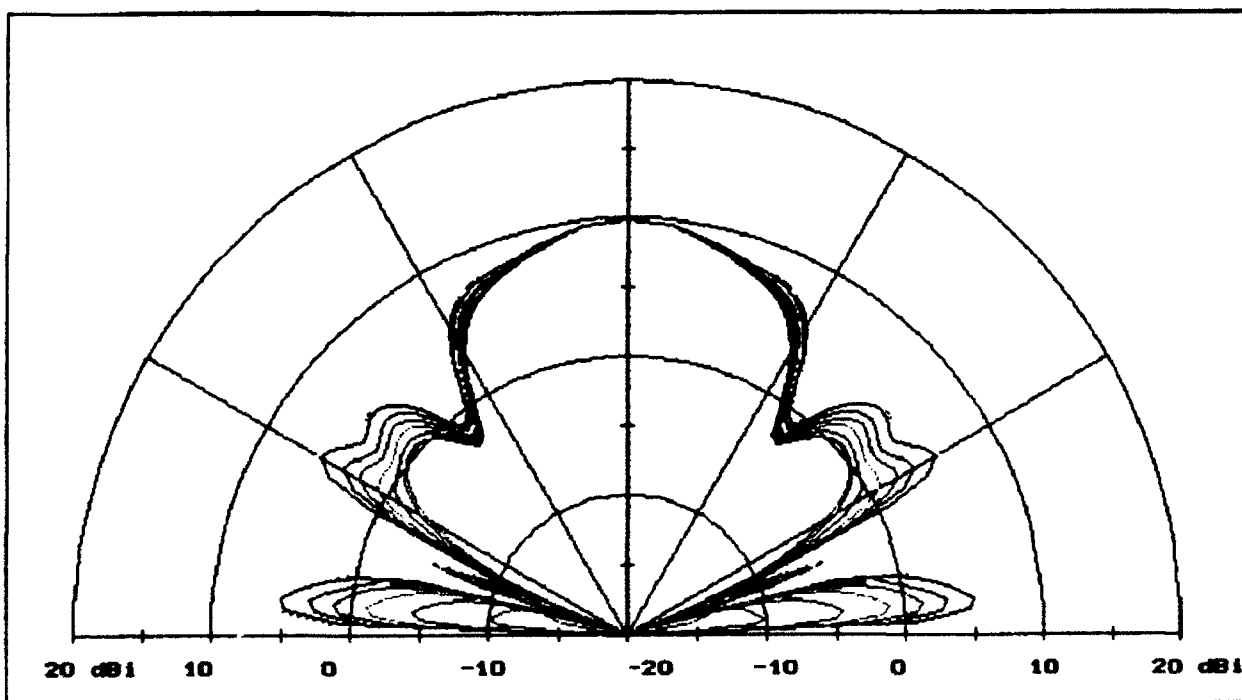


Figure 2-12. Radiation Pattern of 14 Element Yagi for 435 MHz.

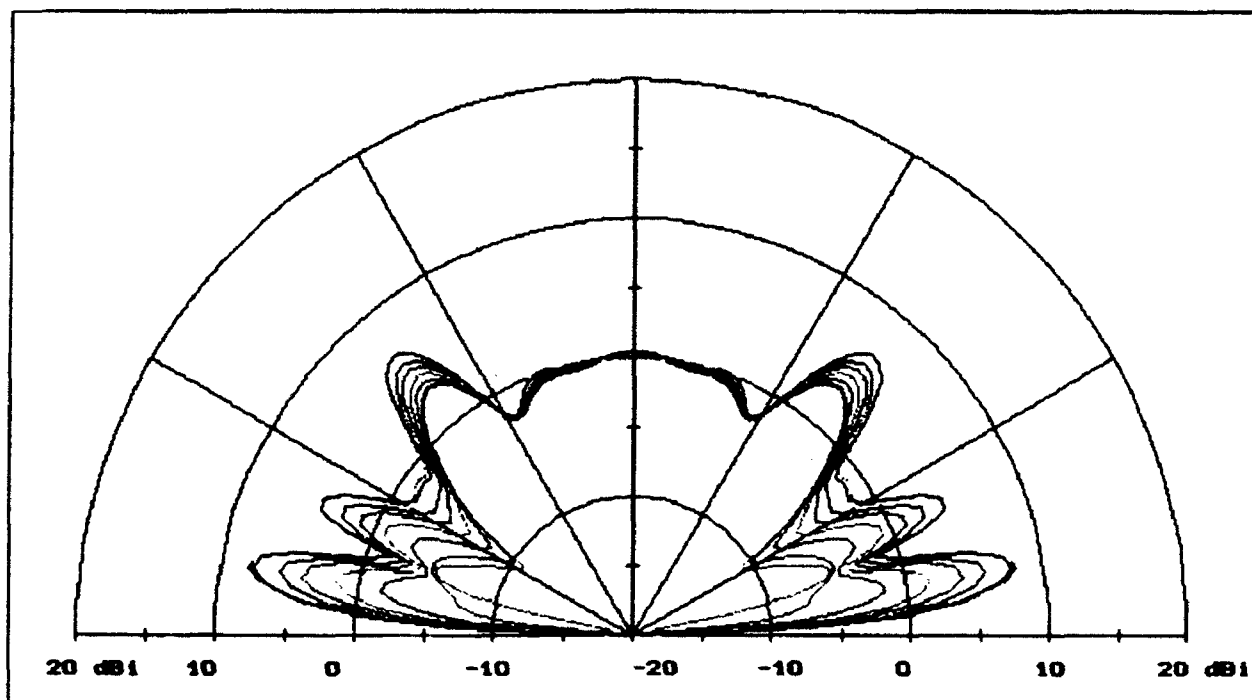


Figure 2-13. Radiation Pattern of 14 Element Yagi for 440 MHz.

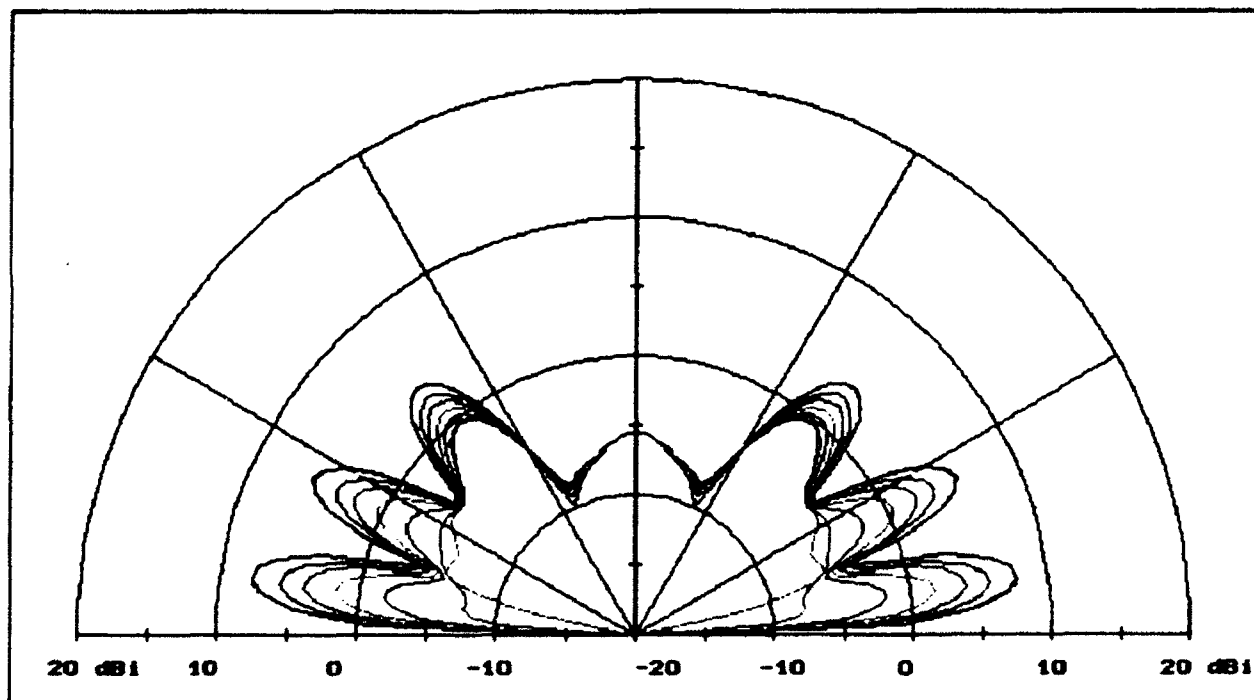


Figure 2-14. Radiation Pattern of 14 Element Yagi for 445 MHz.

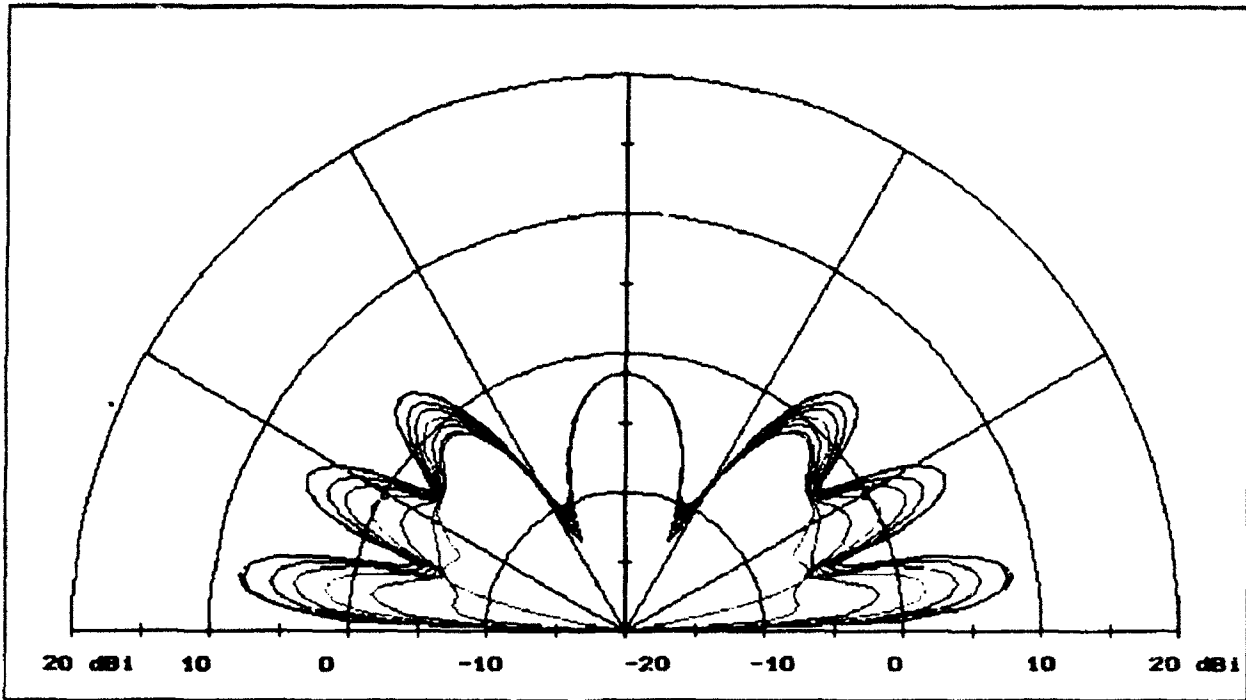


Figure 2-15. Radiation Pattern of 14 Element Yagi for 450 MHz.

HF antenna.

The antenna used for the HF measurements was a short (1.45 meter) monopole with a preamplifier, a so-called 'Active antenna', using the ground as a counterpoise. The preamplifier has a high input impedance compatible with the short monopole, and a 50 Ohm output compatible with the spectrum analyzer. The antenna is shown in Figure 2-16.



Figure 2-16. Active Antenna Used for HF Measurements.

3. Calibration procedures for the VHF and UHF antennas.

The VHF and UHF antennas were calibrated using a source with a known Excess Noise Ratio, ENR. The ENR is usually given in dB above 290 K. Such a noise source can be used to determine both the system gain and noise figure through a two stage calibration. First, a calibration is performed with the noise source, substituted for the antenna, turned on. This calibration presents the system with a source temperature determined by the noise source ENR. Then a second calibration is performed with the noise source still mounted onto the preamplifier input, but turned off. This calibration presents the system with a source temperature equivalent to the ambient temperature T_{cold} of the noise source, 290 K in a laboratory environment.

The system sensitivity can now be determined from the first calibration. The source temperature is calculated from:

$$T_{hot} = 290(1 + 10^{ENR/10}) \text{ K},$$

and the source power as:

$$P_{source} = kT_{hot} B$$

where k is Boltzmann's constant (1.38^{-23}) and B is the system noise bandwidth.

The system noise temperature T_s and thus its noise figure can be determined from:

$$T = (T_{hot} - Y T_{cold}) / (Y - 1)$$

where Y is the ratio P_{hot} / P_{cold} of the power measured with the spectrum analyzer when the noise generator is turned on and off respectively. A computer program has been written to perform such computations. An example of a calibration of the 40 - 50 MHz system and the associated system temperature is shown in Figure 3-1. It is seen that the system temperature varies between 300 and 800 K. The variation is due to impedance mismatches in the cable connecting the preamplifier to the spectrum analyzer. The lowest expected galactic noise temperature at 50 MHz is approximately 4000 K. Thus the contribution from the measurement system is insignificant.

450 MHz calibrations

A calibration performed at 420 - 450 MHz is shown in Figure 3-2. The system temperature is in the range 600 - 1000 K. This by far exceeds the expected galactic noise temperature of 50 - 100 K. Thus very low level signals can still be seen with the system, but not the diurnal variation of the galactic noise.

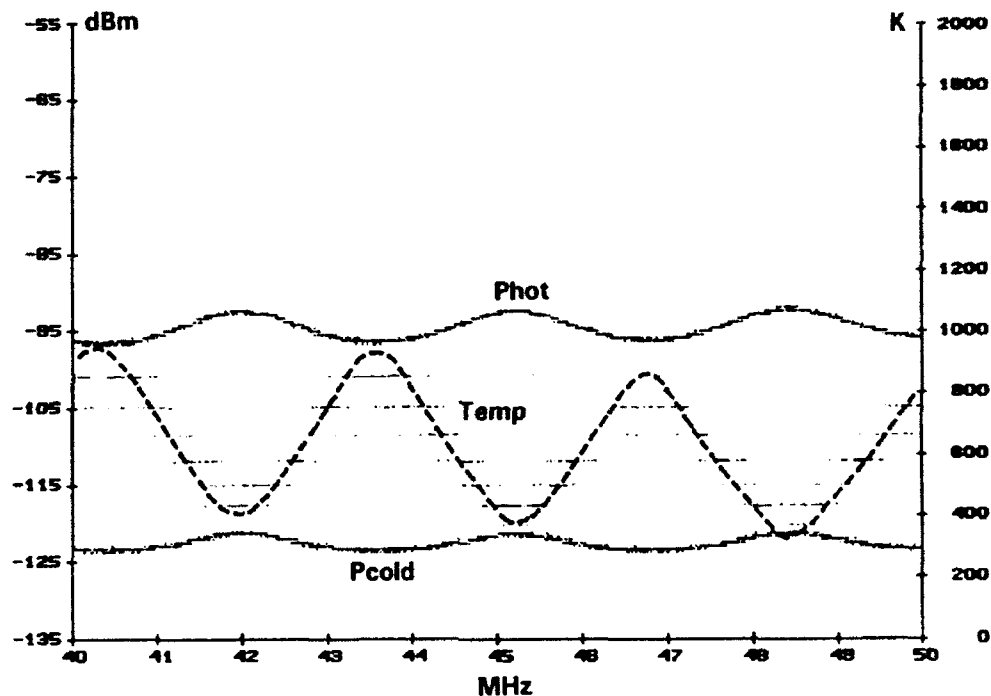


Figure 3-1. Calibration at 40 - 50 MHz. The Curves Show P_{hot} , P_{cold} , and the System Temperature (Temp).

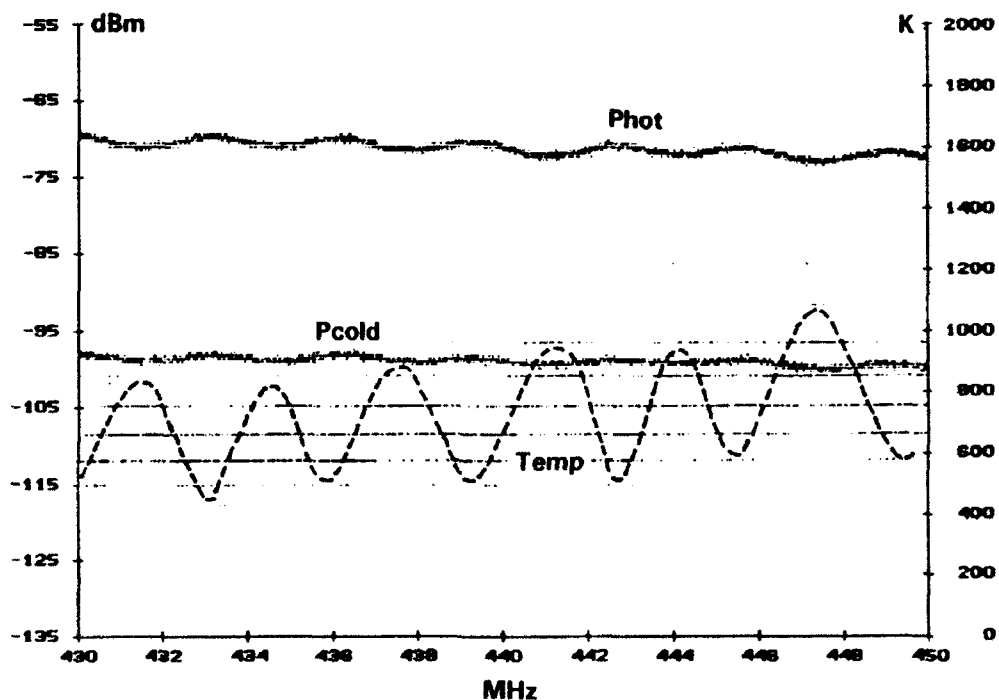


Figure 3-2. Calibration at 430 - 450 MHz. The Curves Show P_{hot} , P_{cold} , and the System Temperature (Temp).

4. Calibration of the HF Antenna.

The radiation pattern of the active HF antenna is omnidirectional, with a main lobe extending from approximately 15 to 65 degrees elevation. An example of the radiation pattern at 6 MHz is shown in Figure 4-1. It has not been attempted to derive the relationship between the ambient E-field strength and the output power of the antenna into a 50 Ohm load. Rather, a simple calibration establishing the relationship between the antenna voltage at the base of the whip and the output power into a 50 Ohm load was performed using a network analyzer. The input power was 100 microvolts.

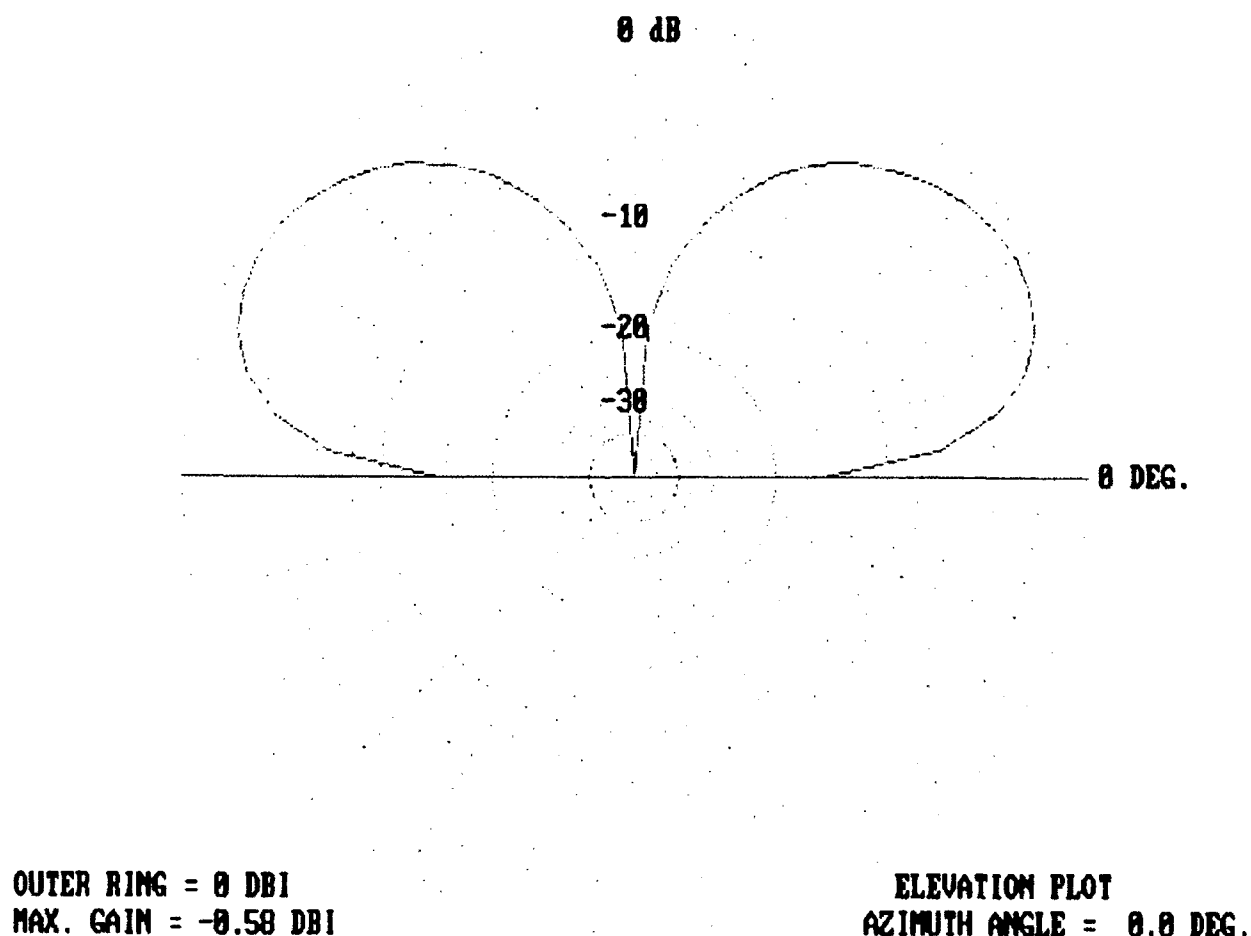


Figure 4-1. Computed Radiation Pattern for the Active HF Antenna at 6 MHz.

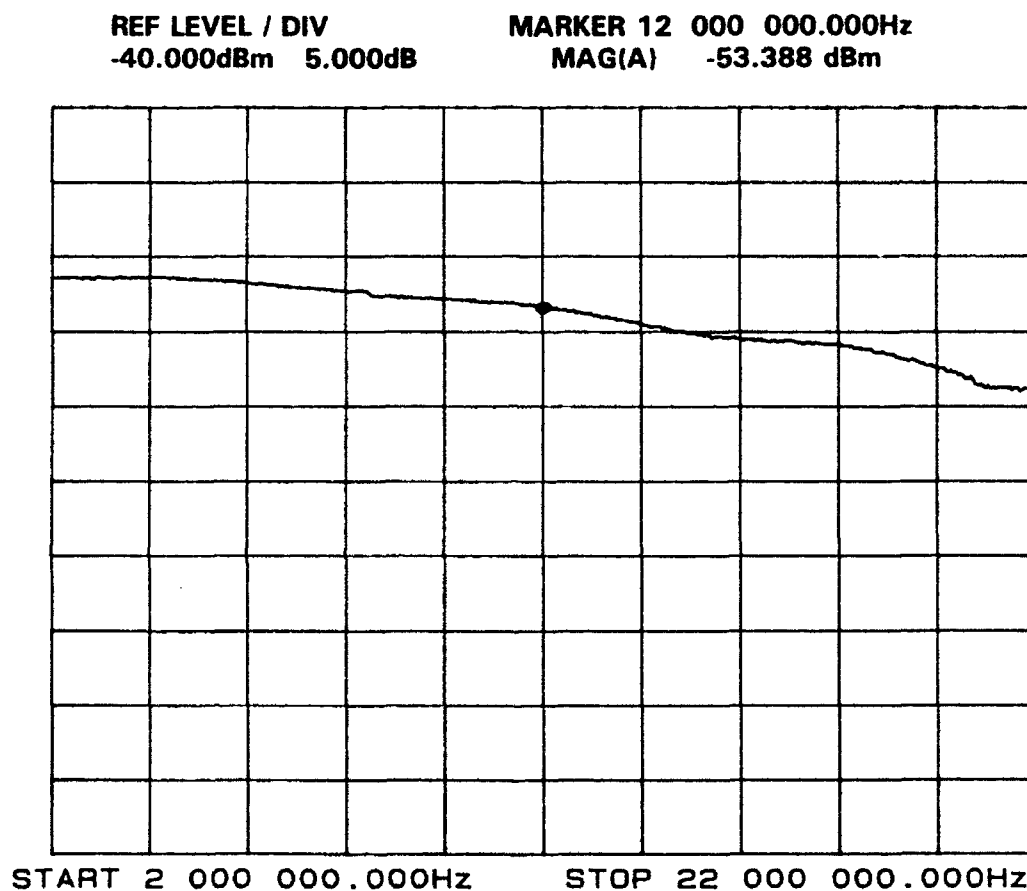


Figure 4-2. Calibration Curve for the HF Antenna. The curve shows the power in dBm at the spectrum analyzer for a 100 microvolt input signal.

5. Prediction of the Diurnal Galactic Noise Variation.

The diurnal variation of the galactic noise at a given frequency can be predicted when the radiation pattern of the receiving antenna and the distribution of galactic noise sources are known. The distribution of galactic noise sources at 136 Mhz, presented by Taylor, Ref.1. was used for the predictions in this report. The distribution is presented in Figure 5-1. as a galactic noise map.

The galactic noise power is presented as equivalent temperature in Kelvin (K). The noise power at other frequencies and in a given bandwidth can be obtained as:

$$P_n (\text{freq}) = (136/\text{freq}) T_n^{2.3} P T k B \text{ (Watts)}$$

where freq is the frequency in MHz, k is Boltzmanns constant:

($1.38 \cdot 10^{-23}$) and B is the receiver noise bandwidth in Hz. The quantity T_n is the noise temperature present at the antenna terminal. T_n is computed from:

$$T_n = \frac{\int T(\psi, \phi) G(\psi, \phi) \sin(\phi) d\phi d\psi}{\int G(\psi, \phi) \sin(\phi) d\phi d\psi}$$

where ϕ is the elevation, ψ is true azimuth $G(\psi, \phi)$ is the antenna gain in the direction ψ, ϕ and $T(\psi, \phi)$ is the Galactic noise temperature in the direction ψ, ϕ .

ψ and ϕ must be computed to orient the galactic noise map correctly with respect to the antenna aperture. This is done by computing the projection of the antenna aperture on the galactic noise map in right ascension and declination for the time of day and date. A computer program has been written to perform such calculations. Figure 5-1. presents the galactic noise map with the projection of the aperture of the discone antenna situated at Gulkana.

The computed diurnal variation of the galactic noise seen by the Discone antenna situated at Gulkana is presented in Figure 5-2., for the frequencies 30, 35, 40, 45, and 50 MHz. The date is August 15. It is seen that the noise power decreases with frequency as expected, and the diurnal variation is similar at the different frequencies. This should also be expected since the antenna radiation pattern varies very little with frequency in the range 30 MHz to 50 MHz.

The computed diurnal variation of the galactic noise power for the UHF Yagi antenna pointed at zenith at Gulkana on March 8 is presented in Figure 5-3. It is seen that the diurnal variation is different for the various frequencies. This is to be expected as the radiation pattern of the Yagi antenna varies with frequency. The diurnal variation will not be detected, as the system temperature is much larger than the galactic noise temperature.

The diurnal variation of the noise has not been computed for the HF antenna, since these computations are not relevant for the current noise survey.

Ref. 1.

Taylor, R.F., 136 MHz/400 MHz Radio-Sky Maps. Proceedings of the IEEE, vol 61, no. 4, pp 469-472, April 1973.

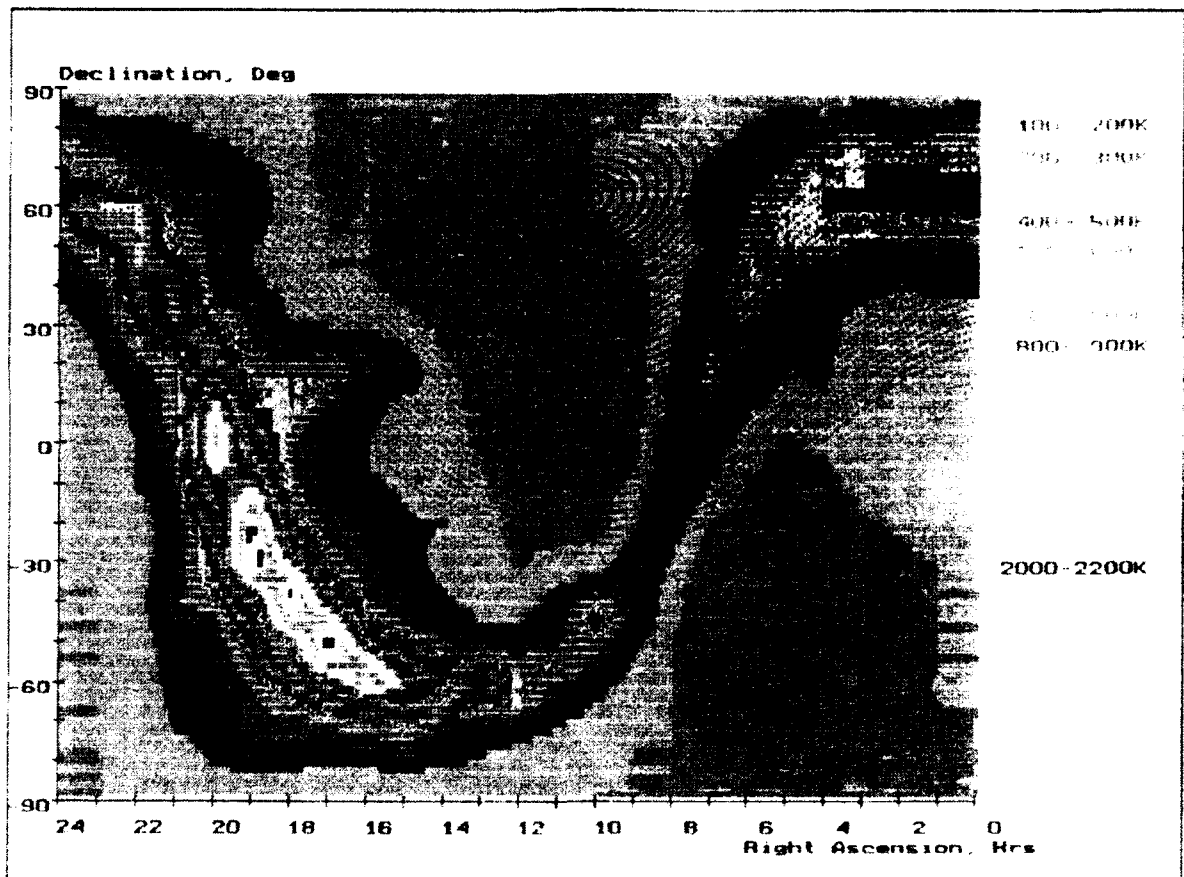


Figure 5-1. Galactic Noise Map with a Projection of the Discone Antenna Aperture at Gulkana.

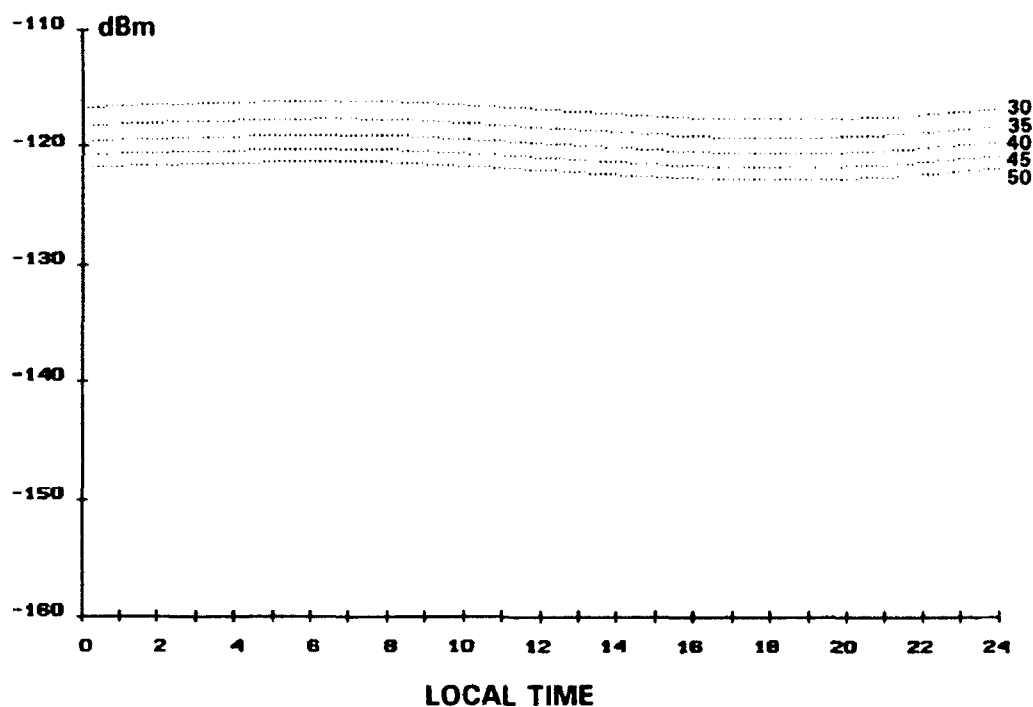


Figure 5-2. Computed, Diurnal Variation of the Galactic Noise Power in a 10 kHz Bandwidth, 30-50 MHz, August 15.

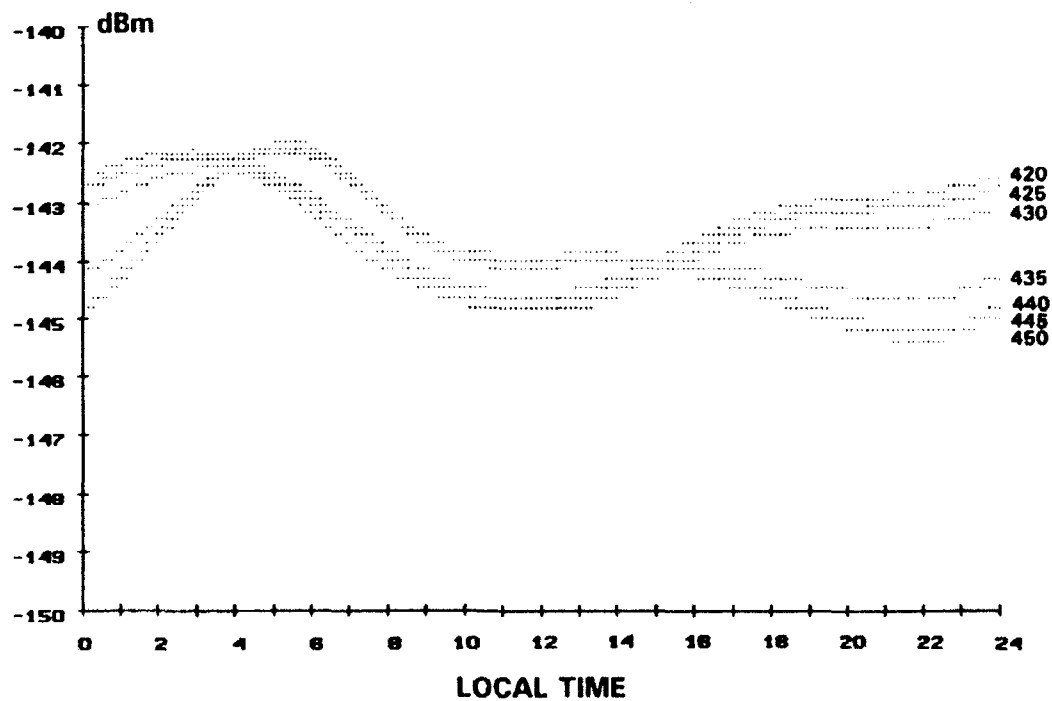


Figure 5-3. Computed, Diurnal Variation of the Galactic Noise Power in a 10 kHz Bandwidth, 420 - 450 MHz, March 8.

6. Site Surveys.

This section presents the data acquired during the site surveys at the HAARP site at Gulkana, at three sites at Elmendorf AFB, at Galena AFB, Kotzebue and Cape Lisbourne. A short discussion of the results are included with each site description.

6.1 Data Presentation and Analysis.

The acquired data can be displayed in three different formats:

The first format plots all acquired spectra throughout a full day on top of each other. This presentation gives an impression of the total number of allocated channels, and also shows the existence of any large, broad band noise events.

The second format shows the signal and noise level for a particular frequency as a function of time of day for a particular day. This presentation is useful to monitor a specific channel, and to examine any diurnal variation that may show the dynamics of the galactic noise, or noise and interference in general.

The third format shows a time-frequency plane occupation chart covering the use of the spectrum as a function of frequency and time of day. The signal levels can be color coded in accordance with the legend printed on the right side of the plot. This presentation is specially suited to search for allocated frequencies in the spectrum, and to examine the time dependence of the spectrum usage. This presentation can also be shown in one color only, suppressing the signal amplitude information. The amplitude information available from the cumulative spectrum presentation in the single color format is better suited for photocopying.

Measurements performed at the HAARP site at Gulkana over the frequency range of 30 to 50 MHz are presented in section 6.2 as an introduction to the data presentation and as an example of a quiet site. The spectrum analyzer resolution bandwidth was 10 kHz and an averaging video filter with a 300 Hz bandwidth was used for all the noise surveys presented in this report. The time between individual scans of the spectrum was approximately 1.5 minutes throughout.

6.2 Gulkana HAARP site 30-50 MHz.

The HAARP site at Gulkana contains a power plant under construction, and an office building powered by a small generator. The terrain is reasonably flat as far as could be determined due to the snow and tree covered surroundings. Noise and interference was measured during two campaigns at Gulkana. The first campaign in March 1992 investigated noise and interference at 30 - 50 MHz and 410 - 450 MHz. Special emphasis was put on the 35 - 40 MHz range intended for an imaging riometer for HAARP. The frequency range 40 - 50 MHz is of special interest for meteor scatter communication. The measurements in this range were intended to examine the noise and interference environment at a expected quiet site before making measurements at Elmendorf AFB. The measurements at 410 - 450 MHz examined the frequency range of interest for an incoherent scatter radar proposed for HAARP.

A second campaign took place in August 1992 to repeat the measurements of interest for the imaging riometer, and examine the signal levels and their frequency distribution in the 2 - 22 MHz HF band since the proposed HAARP transmitter will operate in the range 2.8 - 10 MHz. We were very kindly received at the site, and given the most expedient, competent, and cordial help with the installation of the noise survey equipment, including the fabrication of an antenna mount for the discone antenna. The antennas were set up in the parking lot, Figure 6.2-1., and the spectrum analyzer and computer were placed in the office building.



Figure 6.2-1. Gulkana HAARP Site 30 - 50 MHz.

Cumulative spectra, time series for 38.2 MHz, and time-frequency charts for the first campaign are presented in Figures 6.2-2. to 6.2-9. Similar presentations for the second campaign are found in Figures 6.2-10 to 6.2-15.

The cumulative spectra from the March campaign show activity in the frequency range 30 - 43 MHz. A cluster of occupied frequencies are seen at 35 MHz, 40.5 MHz and 42.5 MHz. Most of the spectrum from 44 to 50 MHz is unoccupied. The galactic noise temperature decreases with frequency to the power 2.3. This translates to a steadily declining value of the noise baseline if the site is galactically noise limited. A 5 dB decrease should be seen in the range 30 to 50 MHz, and a decrease of 2.5 dB should be seen in the 35 to 45 MHz range. Other factors, however, influence the absolute calibration, in this case especially the impedance differences between the antenna, the input of the preamplifier, and the noise calibrator. The noise calibrator provides an ideal 50 Ohm resistive broad band impedance, but both the antenna and the preamplifier have impedances with frequency dependent reactive components. This means the antenna is not a direct substitute for the calibration generator and will generate a frequency dependent calibration offset. This offset can be seen as a varying baseline in the cumulative spectra from the first campaign.

The baseline on the cumulative spectra from the second campaign has less variation because a different preamplifier with a lower Q input impedance was used. Still, the noise baseline decreases with decreasing frequency in the range 35 to 40 MHz. This is due to the cut off frequency of 30 MHz for the discone antenna. A correctly declining noise baseline will be seen in later noise surveys from Galena AFB, Kotzebue and Cape Lisbourne. These surveys were conducted in the frequency range 40 to 50 MHz with a low Q input preamplifier.

Future surveys should be conducted with even more broad band front end components, incorporating the calibration noise source permanently into the antenna - preamplifier circuit. The necessary bandlimiting to eliminate the very large signals present in the HF band is provided by the discone antenna, which has a very sharp lower frequency cut off at 30 MHz.

The diurnal variation of the signals encountered at 38.2 MHz are shown below the cumulative spectra. The predicted galactic noise level is also presented on the graphs. Little interference at 38.2 MHz was observed during both campaigns, except for a few short lasting signals in the time period 1330 to 1700 on March 6, and a enhanced noise level during the early hours of August 14. A small, but consistent diurnal variation in the background noise, in good agreement with the predicted levels, is observed. The dip around 1800 - 2100 shows the diurnal dip in the galactic noise level. This dip is very small due to the use of an omnidirectional antenna at high latitude. It does signify, however, the site is galactically

noise limited at this particular frequency and time in history. Some caution is necessary in determining if the measured noise levels represent the galactic background. Alaska is situated under the auroral oval, and ionospheric absorption and noise bursts are commonplace. As explained in the following paragraph on wide band interpretations, some of the variations observed on March 5 are characteristic of auroral absorption events.

The time - frequency charts present the occupancy of the RF spectrum vs. time and frequency. Color coding of the signal levels have been retained for the days March 6 and August 14. The signal levels less than approximately 6 dB above the background noise have been suppressed, so that noise bursts and frequency use can be distinguished from the background noise. The signal level on the color plots are in dBm referred to the antenna terminals.

It is seen that the spectrum usage at 30 - 44 MHz occur predominantly at 0700 - 2200 local time. The sources of the signals at 40 - 44 MHz are most likely users of cordless telephones returning from work. The sources in the 34 - 36 MHz range are most likely dispatch services or other mobile users. The rest of the spectrum is virtually unoccupied throughout the day and night except for signals continuously present at 42, 43, 48, 49, and 50 MHz. The sources of these signals are not known. The data collected in March show a larger spectrum occupancy than does the August data, especially in the 34 - 40 MHz range where signals are absent in the August data.

It is concluded the HAARP site is at present very quiet, galactically noise limited throughout most of the 30 - 50 MHz frequency range. Exceptions include a number of legitimate users. The frequency range 38.0 - 38.5 MHz proposed for the HAARP imaging riometer was found to be unoccupied most of the time examined.

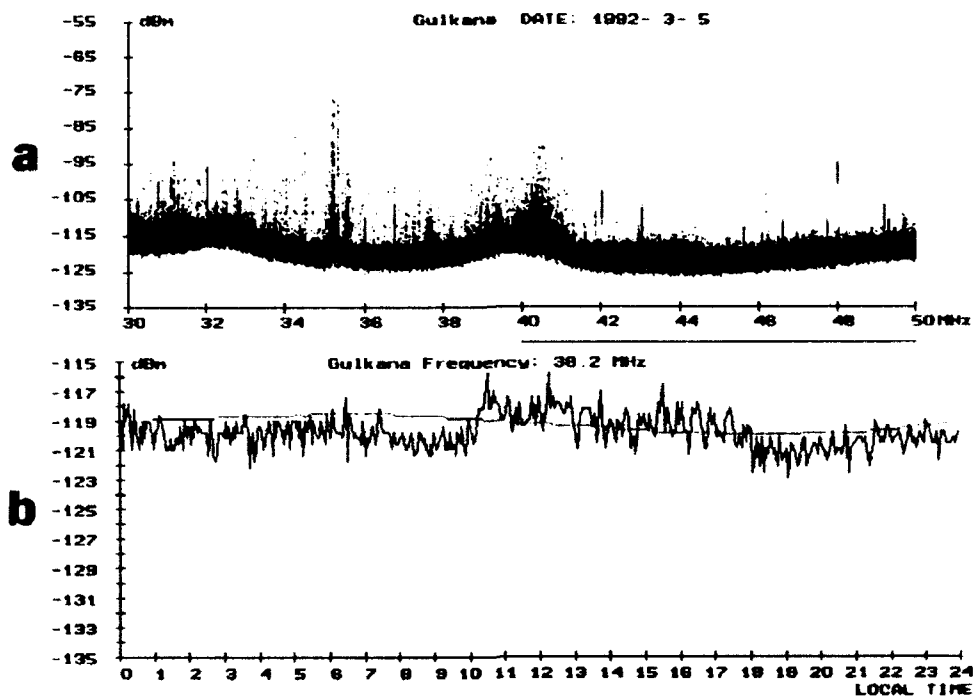


Figure 6.2-2. Gulkana 5 March 1992.
 a. Cumulative Spectra 30 - 50 MHz.
 b. Time Series for 38.2 MHz.

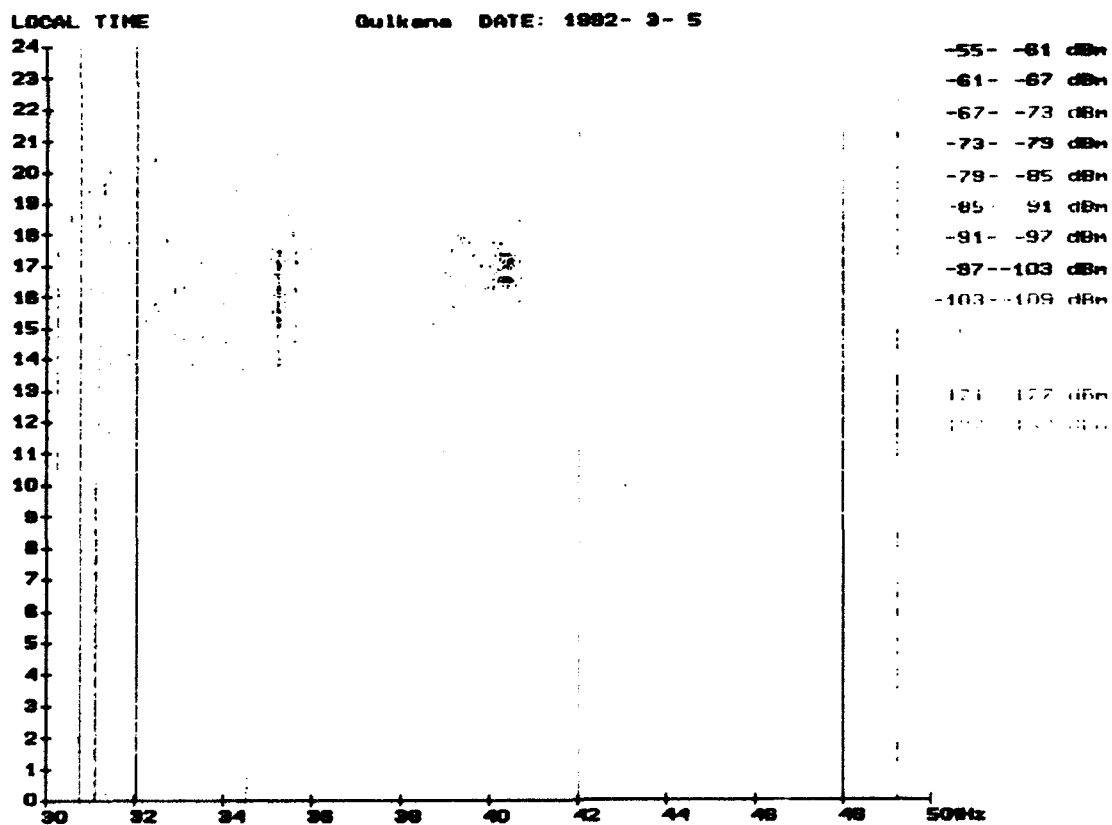


Figure 6.2-3. Gulkana 5 March 1992. Time - Frequency Chart.

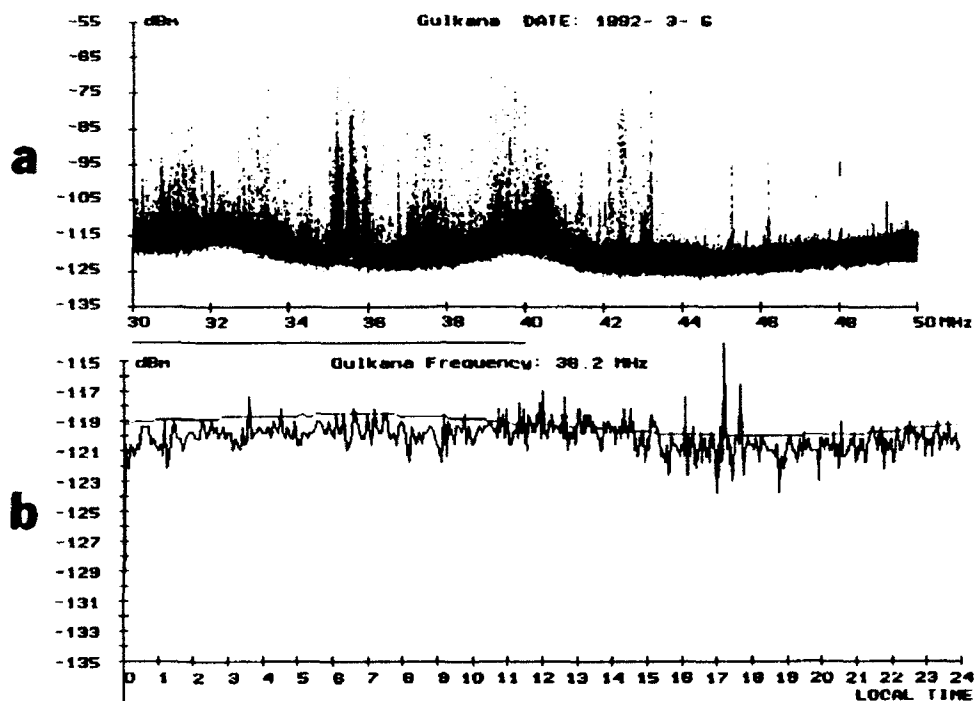


Figure 6.2-4. Gulkana 6 March 1992.
 a. Cumulative Spectra 30 - 50 MHz.
 b. Time Series for 38.2 MHz.

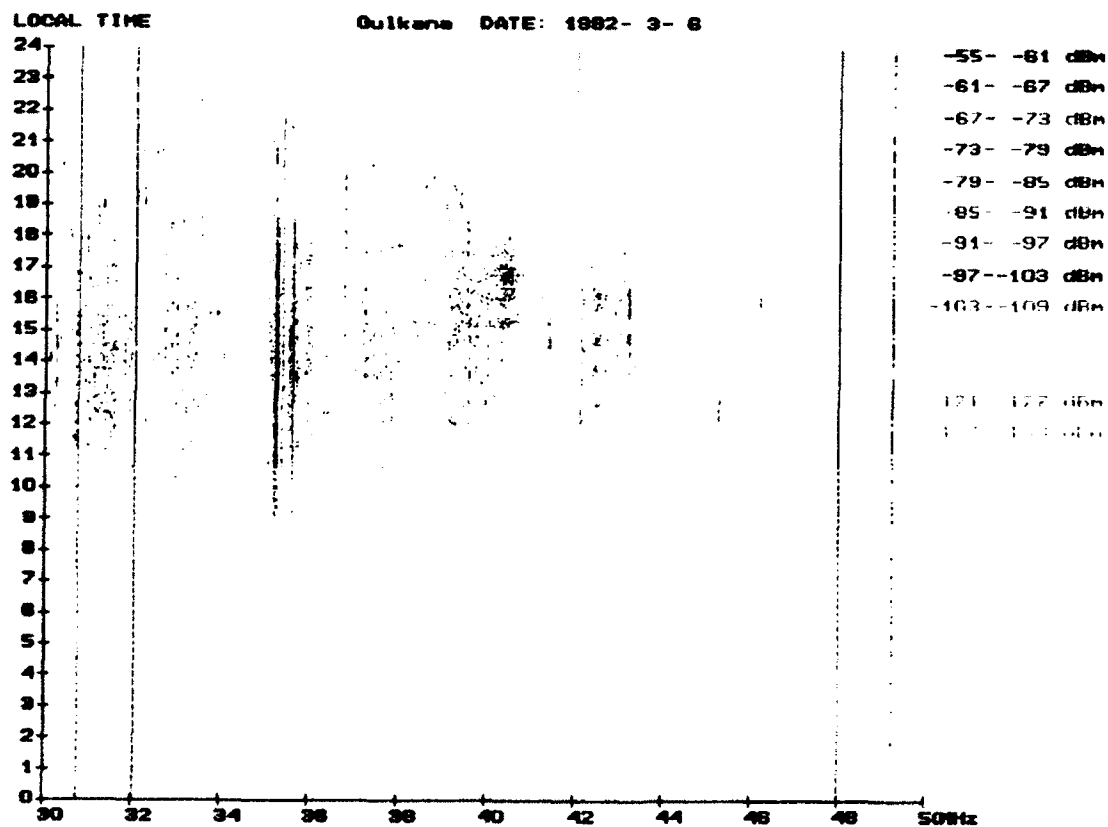


Figure 6.2-5. Gulkana 6 March 1992. Time - Frequency Chart.

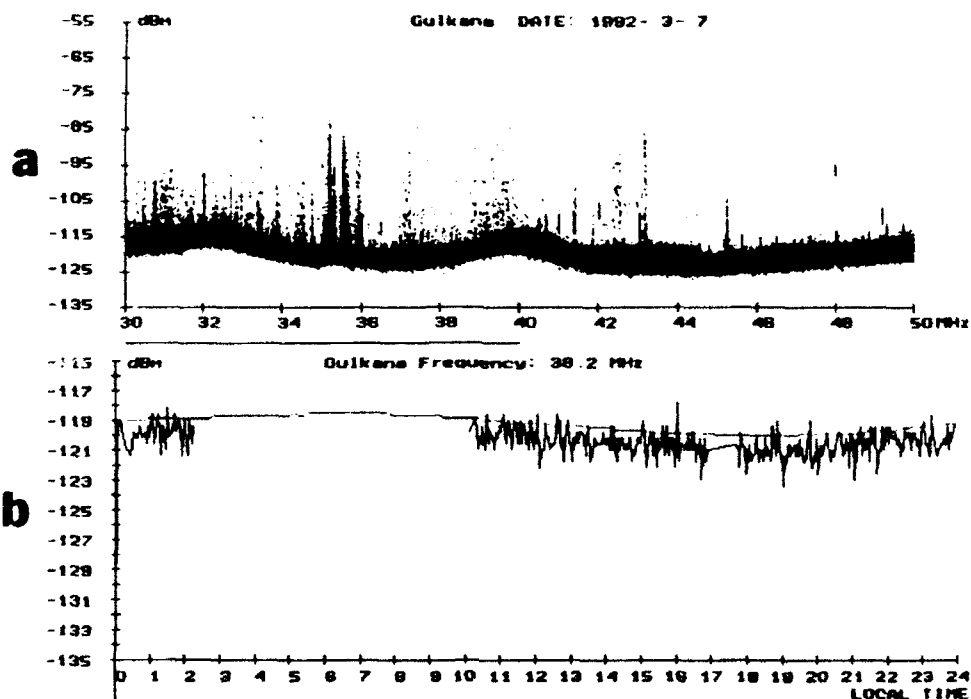


Figure 6.2-6. Gulkana 7 March 1992.
 a. Cumulative Spectra 30 - 50 MHz.
 b. Time Series for 38.2 MHz.

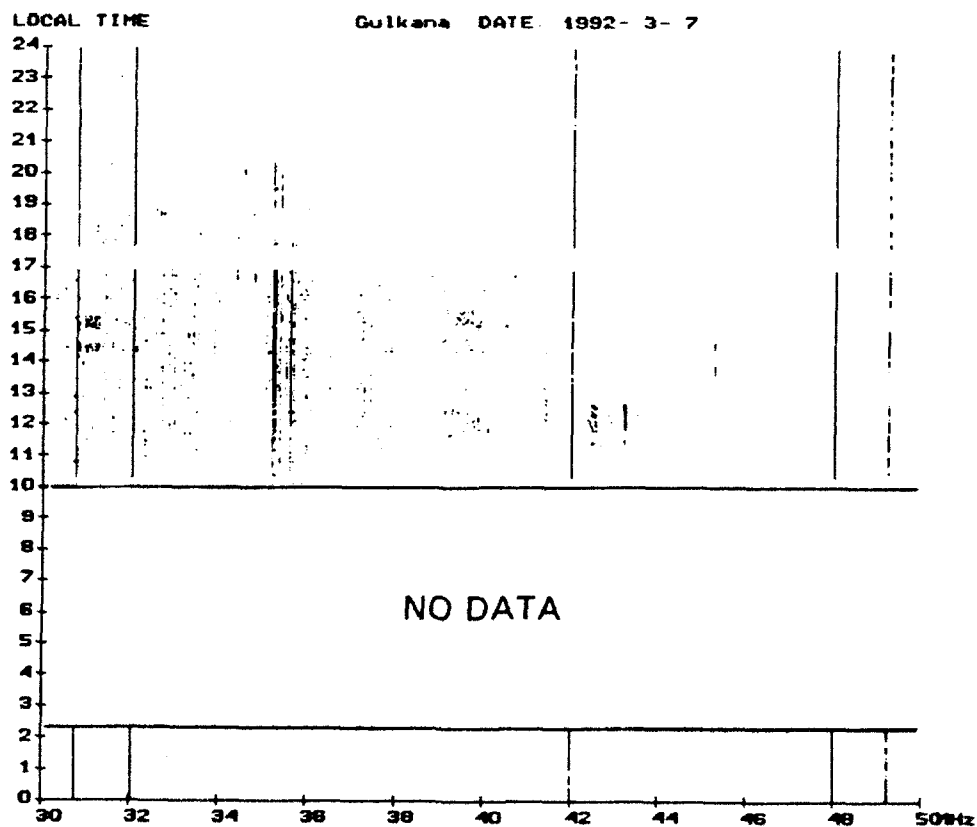


Figure 6.2-7. Gulkana 7 March 1992. Time - Frequency Chart.

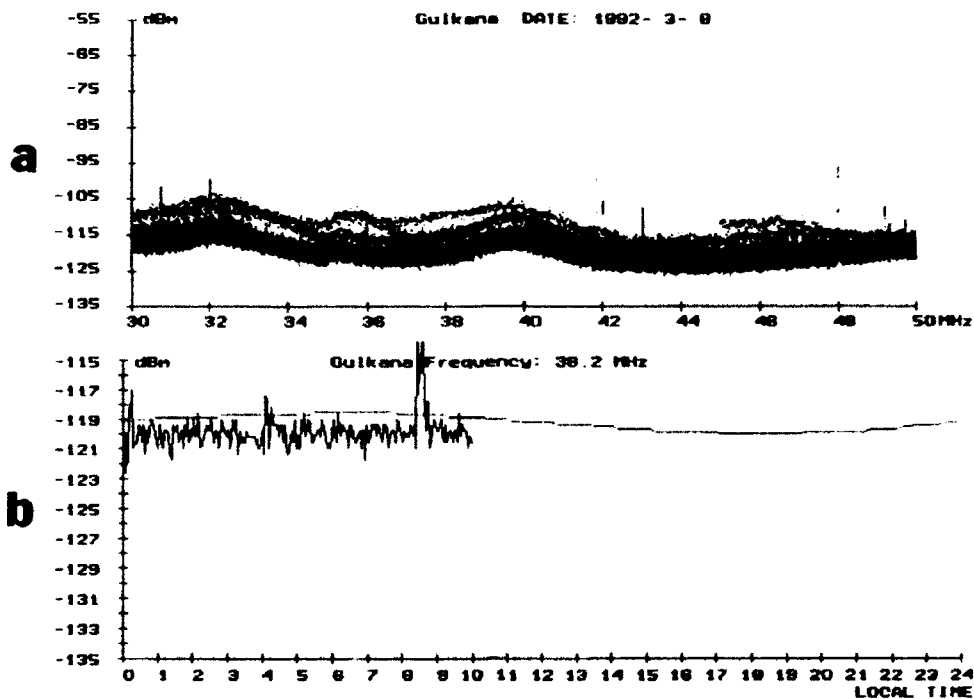


Figure 6.2-8. Gulkana 8 March 1992.
 a. Cumulative Spectra 30 - 50 MHz.
 b. Time Series for 38.2 MHz.

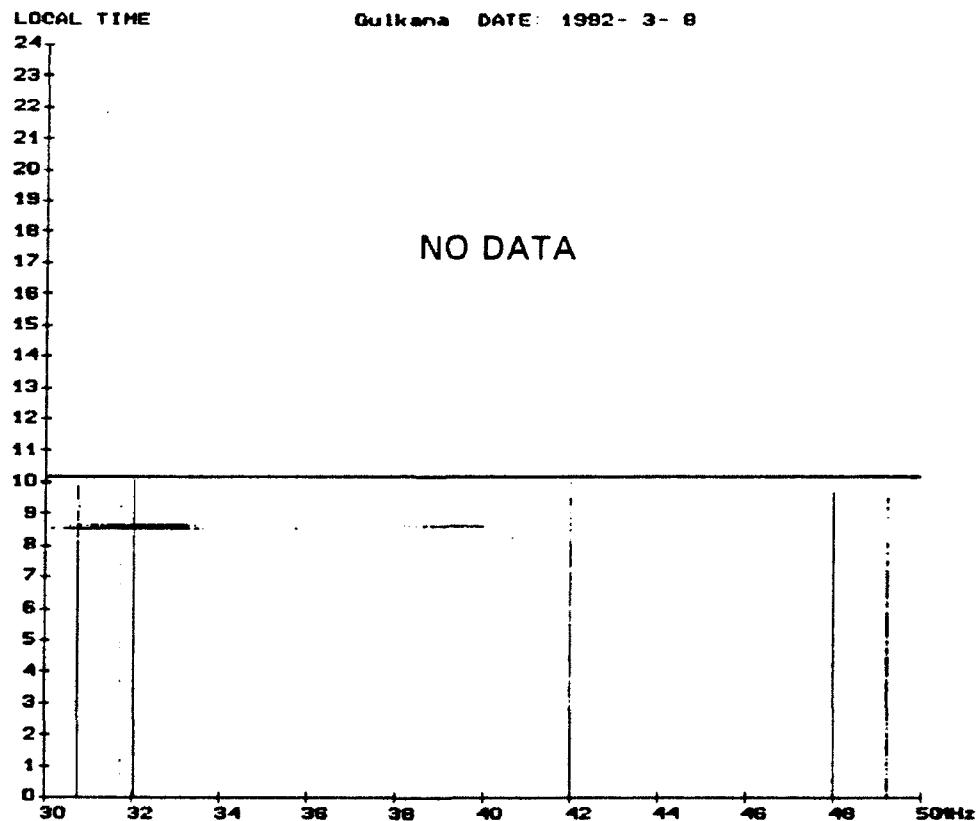


Figure 6.2-9. Gulkana 8 March 1992. Time - Frequency Chart.

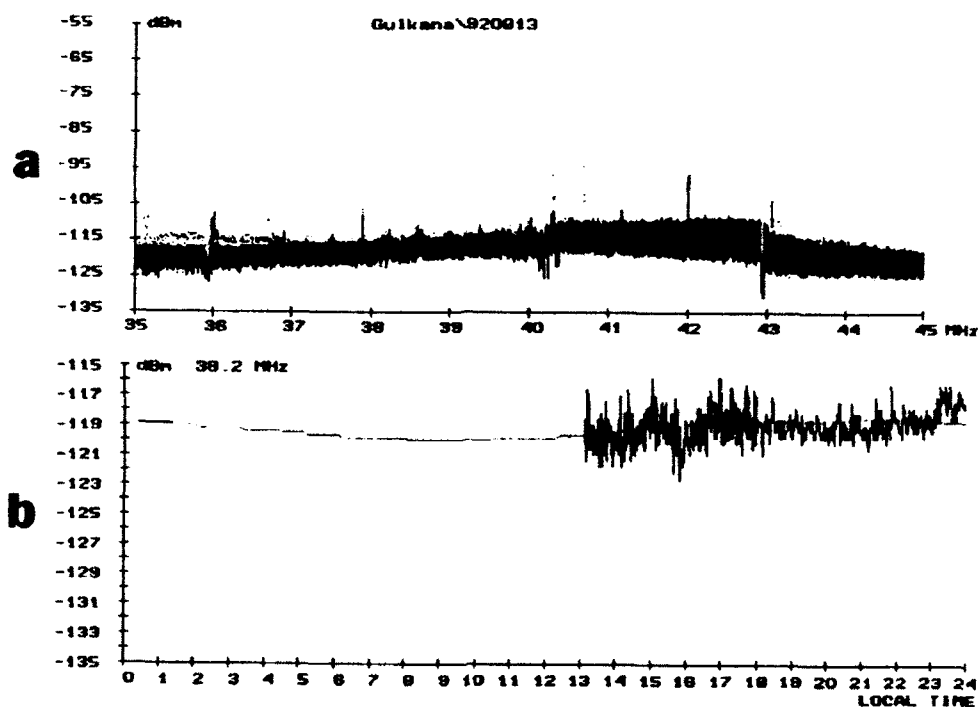


Figure 6.2-10. Gulkana 13 March 1992.
 a. Cumulative Spectra 30 - 50 MHz.
 b. Time Series for 38.2 MHz.

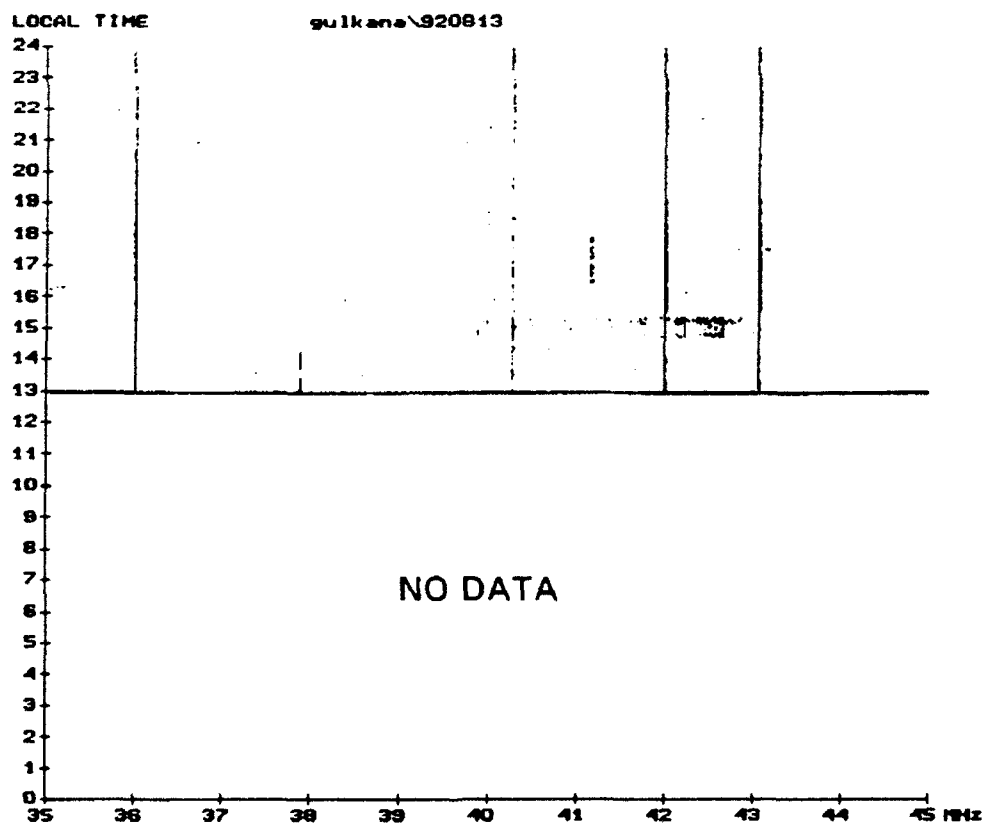


Figure 6.2-11. Gulkana 13 March 1992. Time - Frequency Chart.

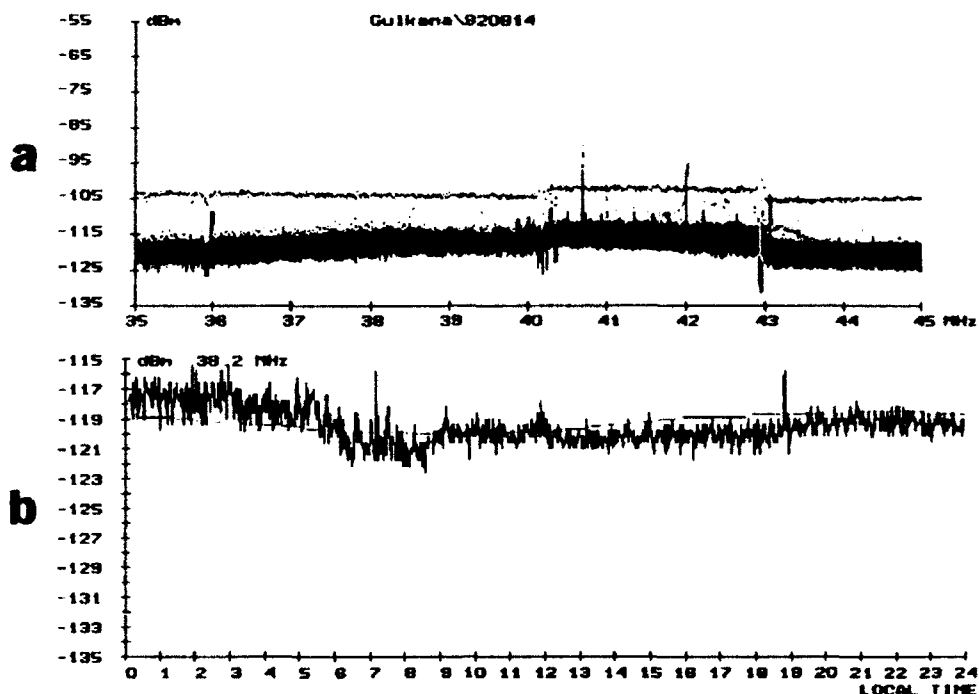


Figure 6.2-12. Gulkana 14 March 1992.
 a. Cumulative Spectra 30 - 50 MHz.
 b. Time Series for 38.2 MHz.

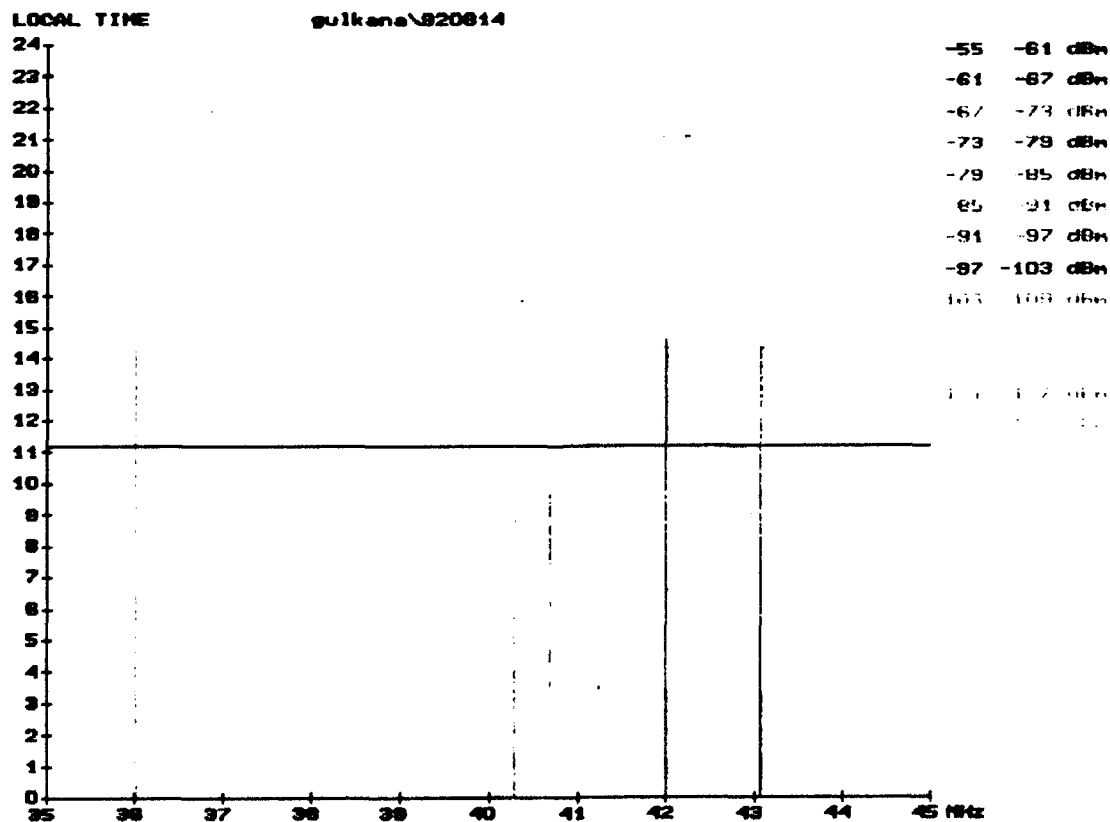


Figure 6.2-13. Gulkana 14 March 1992. Time - Frequency Chart.

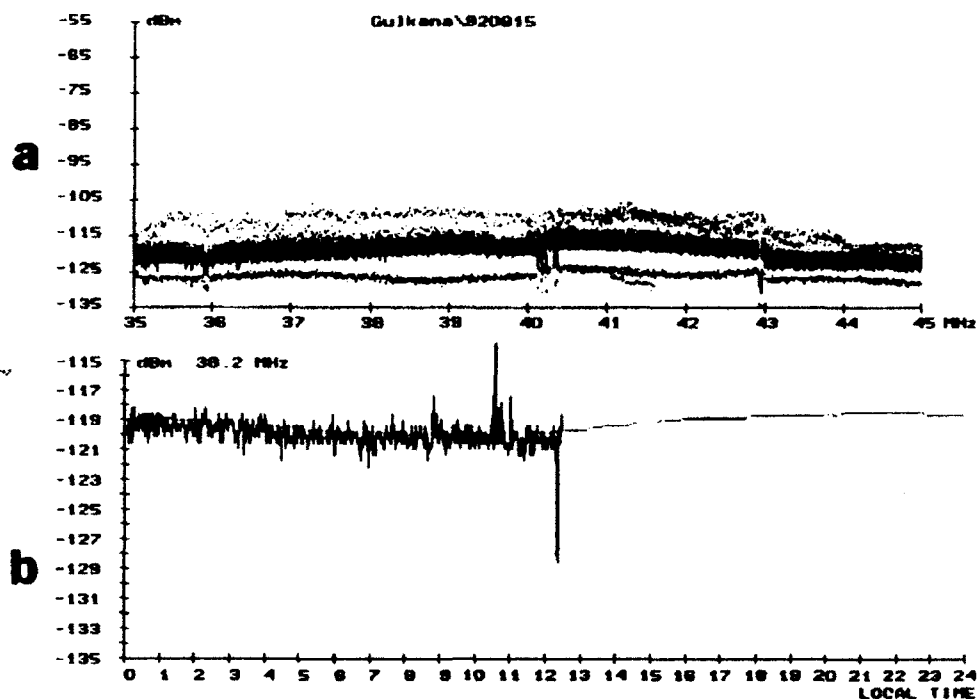


Figure 6.2-14. Gulkana 15 March 1992.
 a. Cumulative Spectra 30 - 50 MHz.
 b. Time Series for 38.2 MHz.

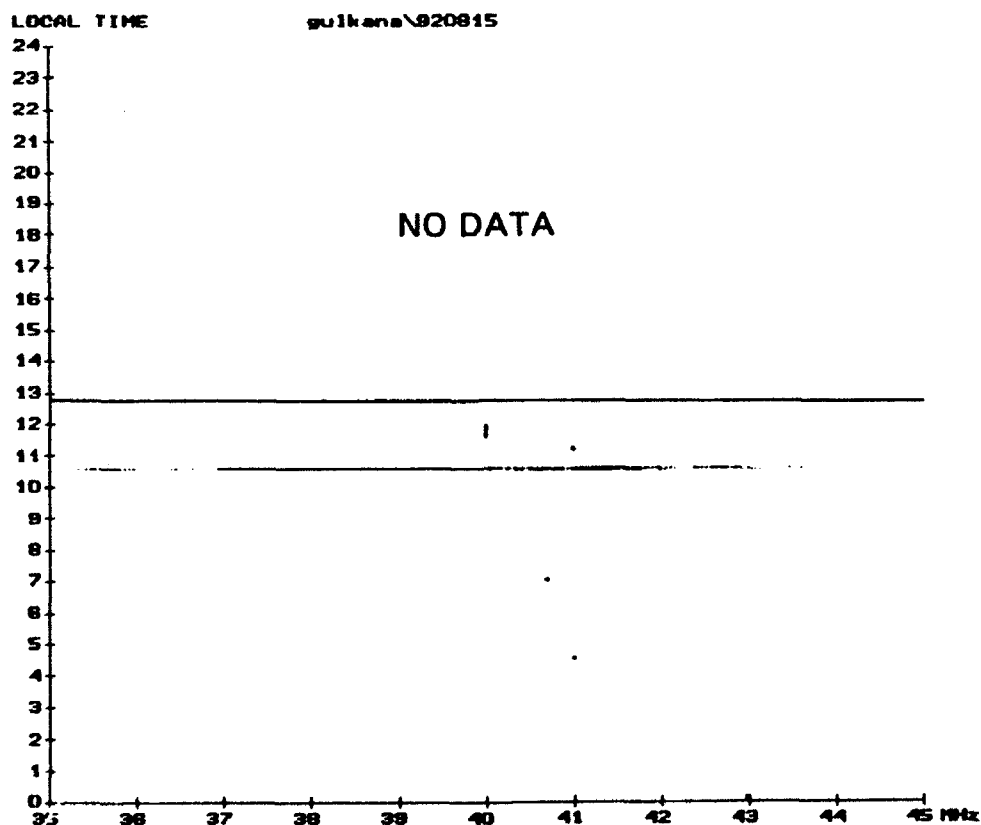


Figure 6.2-15. Gulkana 15 March 1992. Time - Frequency Chart.

Wide Band Interpretations at 38.2 MHz.

The projected imaging riometer for HAARP will have a RF bandwidth of 500 kHz. The wide bandwidth is necessary to fulfill requirements for resolution and sampling interval. This prompted interest in interpreting the noise survey data in terms of wider bandwidths than the 10 kHz used for the data acquisition. The following Figures, 6.2-16. to 6.2-22. contain time series of the total power recorded in 50, 10 kHz wide channels centered at 38.2 MHz, the frequency of the imaging riometer.

The noise level in the first time series recorded in March agree well with the predicted noise levels during the night hours, but a number of absorption events are seen at noon and in the afternoon. Two discrete events are seen on March 5. The following three days had both absorption events and a number of short lived noise bursts. It is not known if these are of solar origin or due to interference.

The second time series taken in August shows an increased and uneven noise level except for the night of August 14 - 15 where the measured noise agrees well with the prediction. A long lasting noise event followed by absorption, lasting from 2300 August 13 to 0900 August 14 is seen. The origin of the noise events are not known, except for the three very short lasting, strong noise bursts on the August 14 and 15, caused by local interference (the custodians vacuum cleaner). Solar noise, ionospheric noise, or ionospherically propagated signals are all possible causes for the unknown interference.

Presence of such low level noise events and absorption emphasize the difficulty in relying solely on the presence of a regular galactic noise level variation to determine whether or not a site is galactically noise limited. This is especially true in the Auroral zone, therefore in Alaska. Longer term measurements will be needed to determine the level of interference a 500 kHz wide riometer receiver will be subjected to at the Gulkana site. It is suggested to place a single, wide band riometer receiver at the site during the construction years to evaluate the noise and interference environment over a longer timespan.

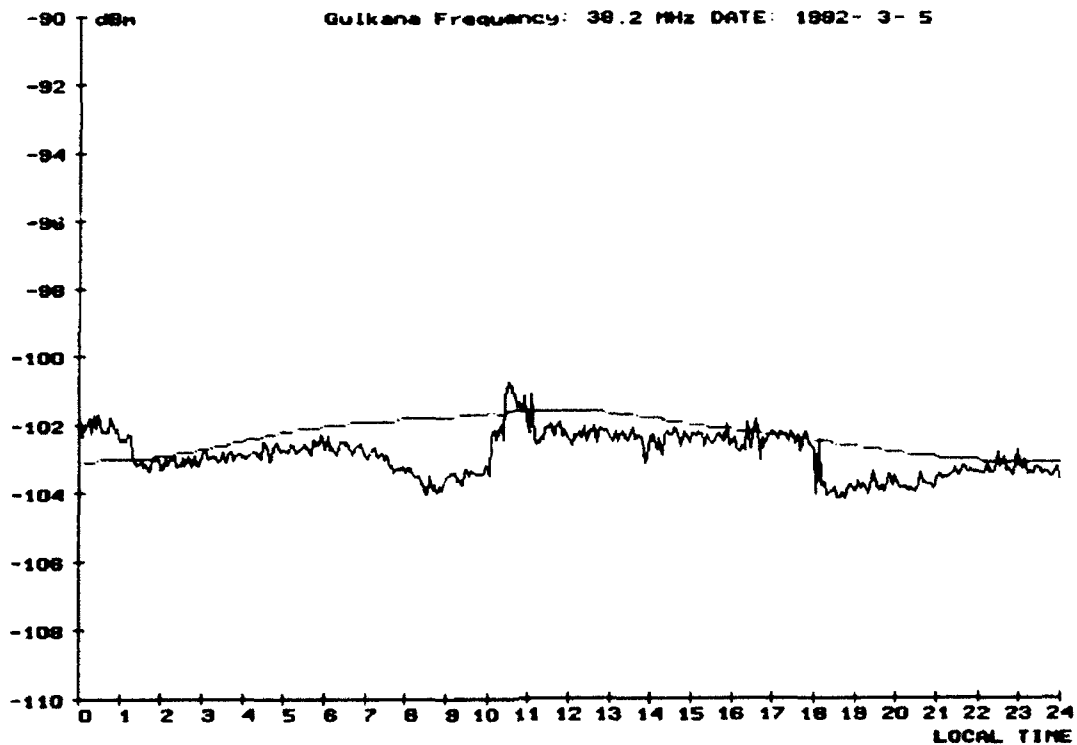


Figure 6.2-16. Gulkana 5 March 1992.
Time Series for 38.2 MHz, 500 kHz Bandwidth.

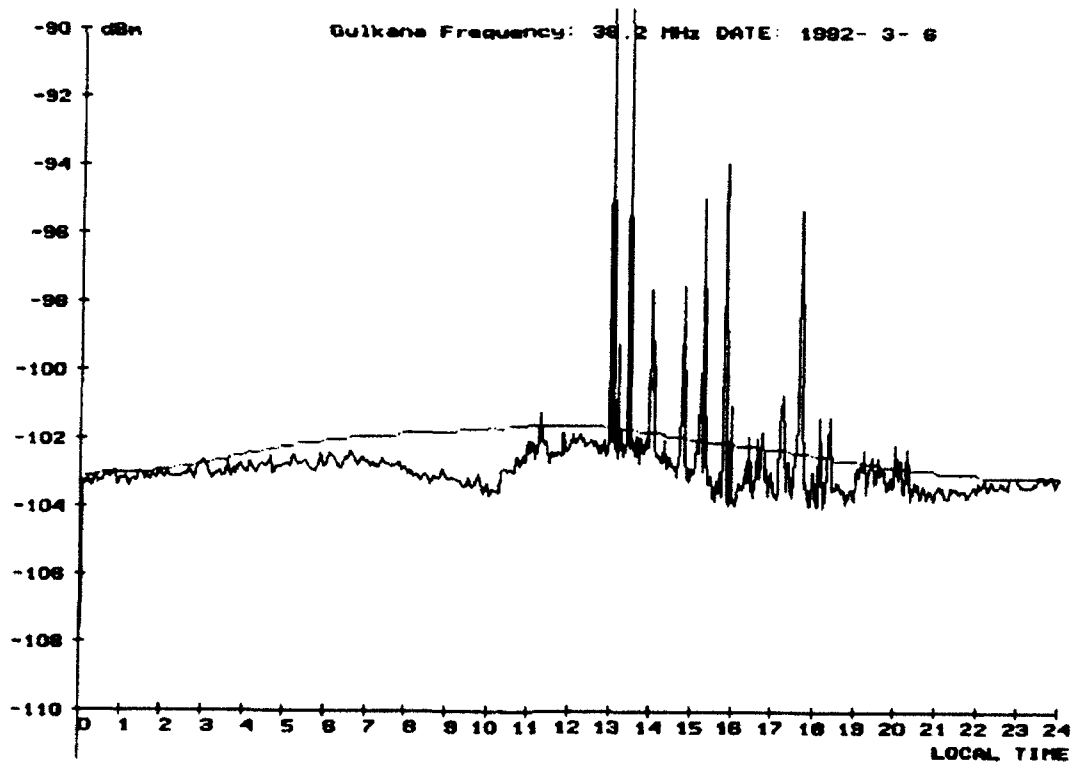


Figure 6.2-17. Gulkana 6 March 1992.
Time Series for 38.2 MHz, 500 kHz bandwidth.

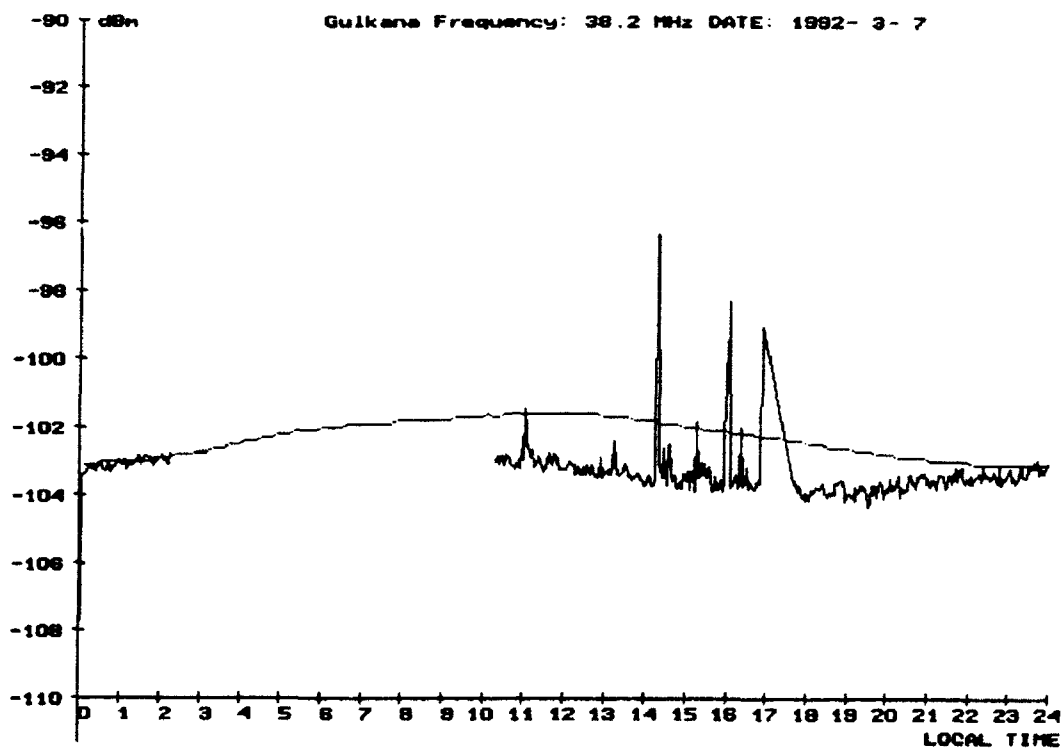


Figure 6.2-18. Gulkana 7 March 1992.
Time Series for 38.2 MHz, 500kHz bandwidth.

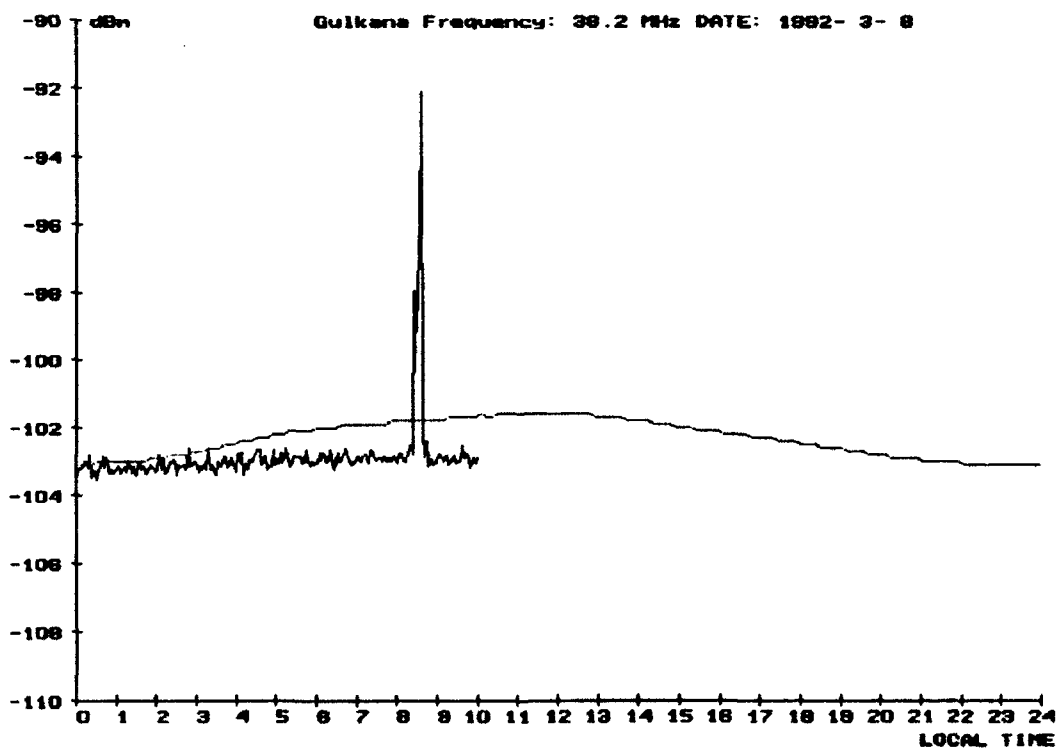


Figure 6.2-19. Gulkana 8 March 1992.
Time Series for 38.2 MHz, 500 kHz bandwidth.

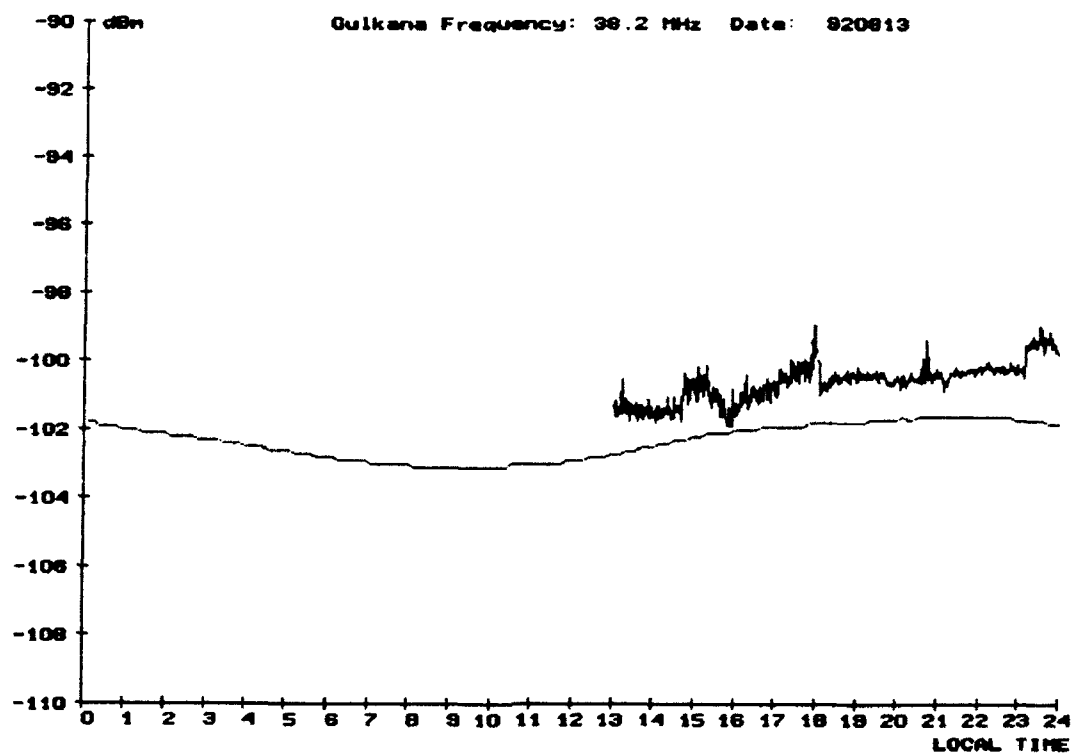


Figure 6.2-20. Gulkana 13 March 1992.
Time Series for 38.2 MHz, 500 kHz bandwidth.

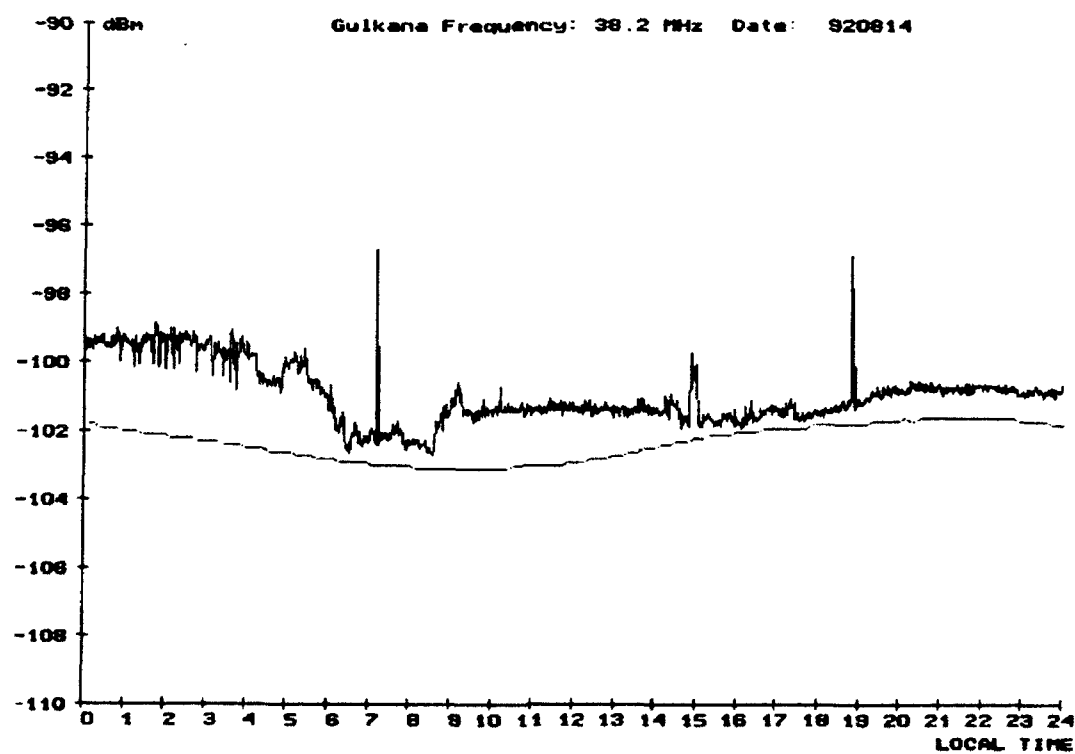


Figure 6.2-21. Gulkana 14 March 1992.
Time Series for 38.2 MHz, 500 kHz bandwidth.

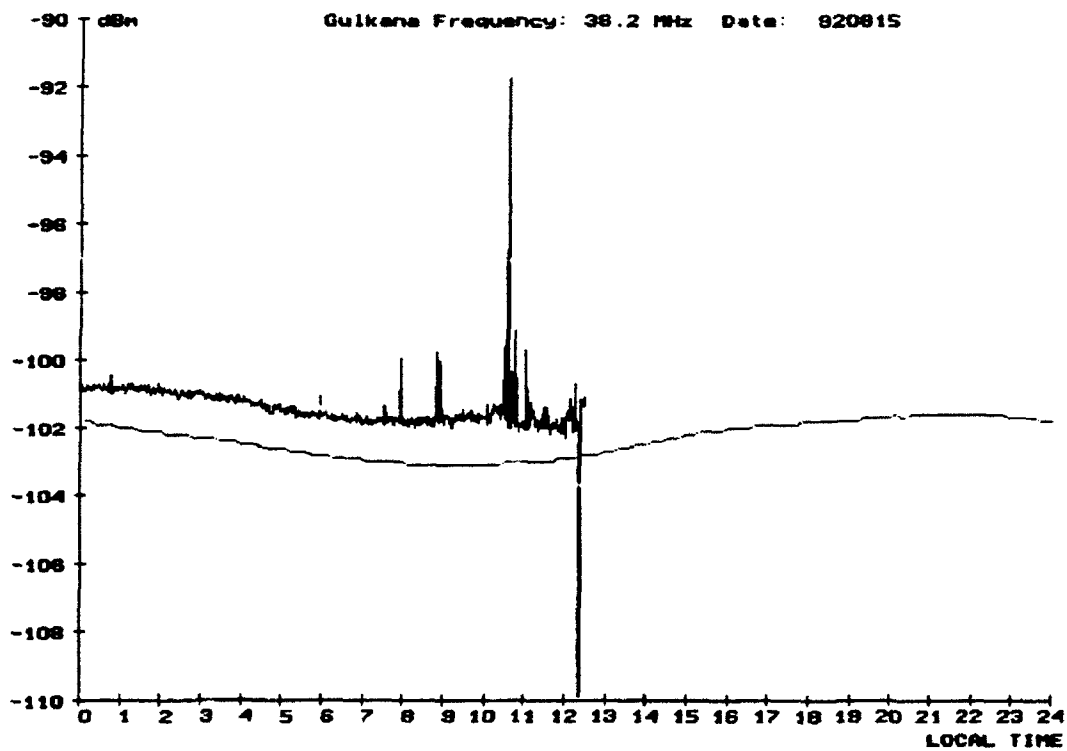


Figure 6.2-22. Gulkana 15 March 1992.
Time Series for 38.2 MHz, 500 kHz bandwidth.

Gulkana HAARP Site 410 - 450 MHz.

A noise survey covering the frequency range 410 - 450 MHz was performed at Gulkana, to determine the general spectrum occupancy and interference level at the site. A 14 element Yagi antenna aimed towards zenith, in conjunction with a low noise preamplifier was used to drive the spectrum analyzer. The noise survey was performed in two independent series. The first series covering 410 - 430 MHz was taken on March 4 and 5, and the second series covering 430 - 450 MHz was taken on March 7 and 8. Cumulative spectra, time series for 420 and 440 MHz respectively, and time frequency charts for the two series are found in Figures 6.2-23. to 6.2-30.

The cumulative spectra show a uniform, frequency independent noise baseline of approximately -134 dBm, or a 290 K system temperature. The expected galactic noise temperature at 430 MHz for a narrow beam antenna pointed to the Galactic North Pole is in the order of 50 K. From this a receiver system temperature of approximately 250 K or a 2.6 dB noise figure can be deduced. Thus, the even noise floor is predominantly caused by receiver noise and no diurnal variation should be expected. This is confirmed by the time series for 420 and 440 MHz.

The cumulative spectra show essentially no spectrum usage in the 410 to 430 MHz range except for one signal at 430 MHz. The 430 - 450 MHz range has a few signals in the 432 to 442 MHz range. These are most likely amateur radio repeaters. A signal at 449 MHz is also seen. The time frequency charts show that the only consistent frequency use occur in the amateur radio band 432 - 442 and at 430 and 449 MHz. A signal at 430 MHz is present for a few minutes every hour, its origin is unknown.

It is difficult to elaborate more on the findings of this noise survey. Line of sight propagation is the only way signals and noise can reach a receiver at 440 MHz. The line of sight coverage area for land based emitters is limited primarily by terrain features and antenna height. The Gulkana site is situated far away from urban areas where UHF frequency usage is more extensive. Also, the low altitude of the antenna and its main lobe pointed towards zenith did effectively limit the line of sight area coverage of the survey system. Furthermore, mobile radio telephones in rural areas of Alaska operate at low VHF frequencies in order to obtain better area coverage than is possible for 400 MHz systems commonly used in urban areas. Thus, little spectrum usage and man made noise was expected at Gulkana, and this was indeed confirmed by the noise survey.

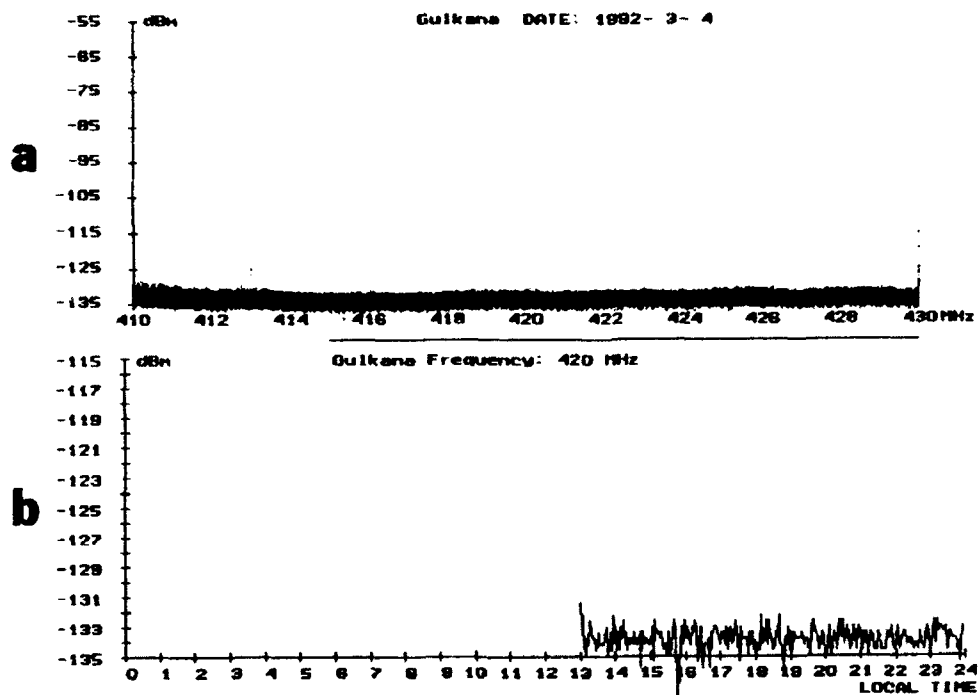


Figure 6.2-23. Gulkana 4 March 1992.
 a. Cumulative Spectra 410 - 430 MHz.
 b. Time Series for 420 MHz.

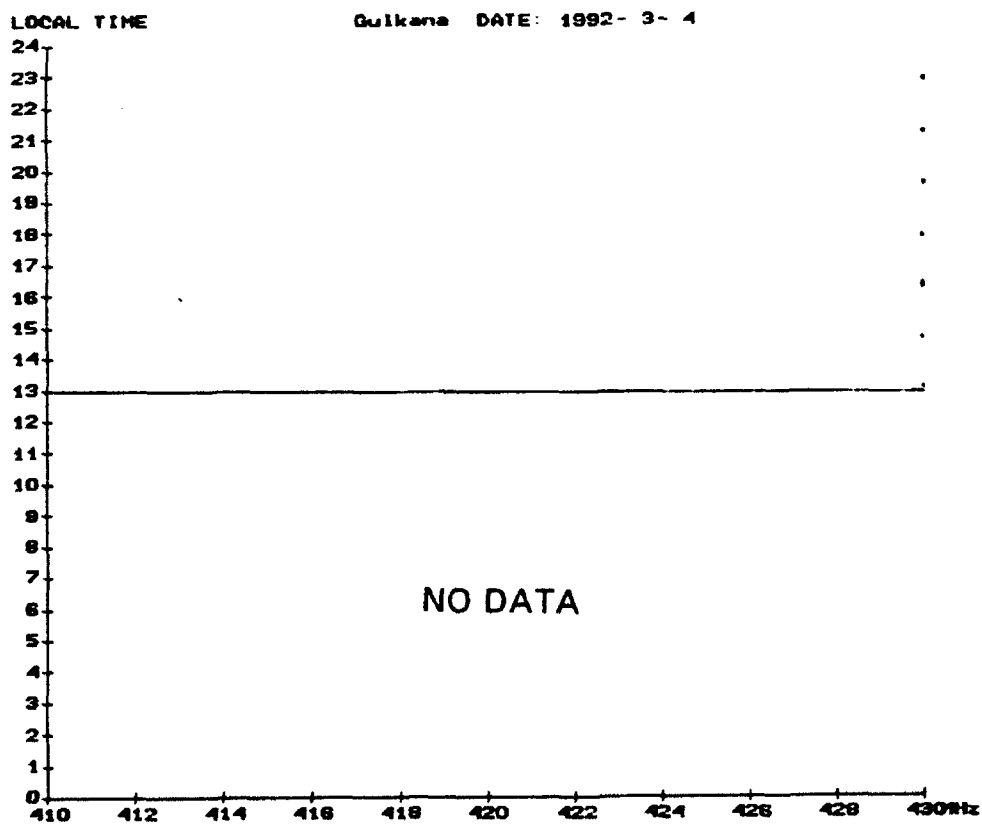


Figure 6.2-24. Gulkana 4 March 1992. Time - Frequency Chart.

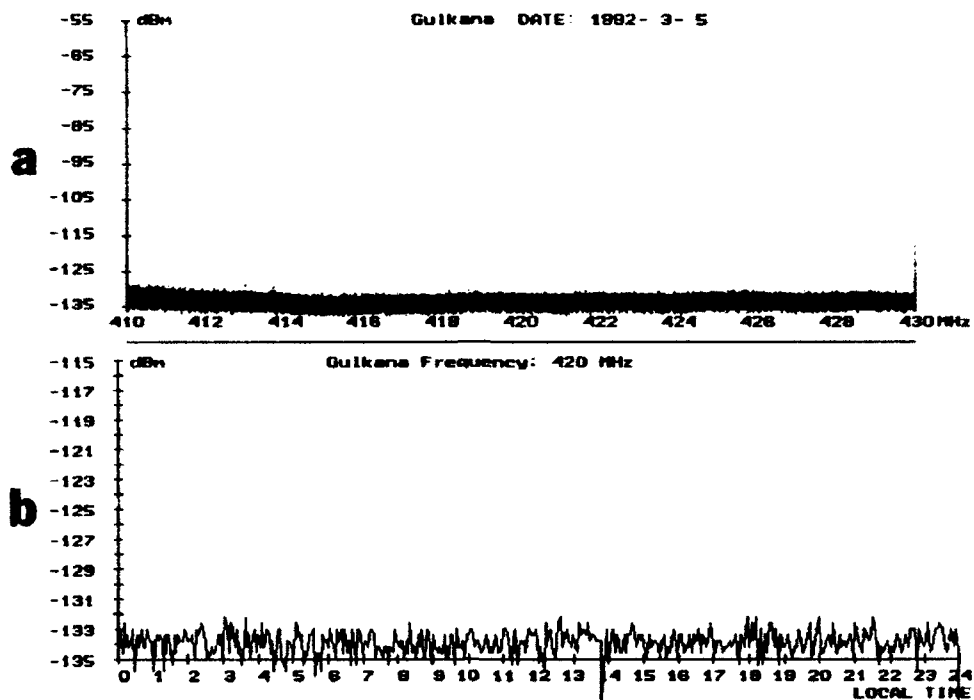


Figure 6.2-25. Gulkana 5 March 1992.
 a. Cumulative Spectra 410 - 430 MHz.
 b. Time Series for 420 MHz.

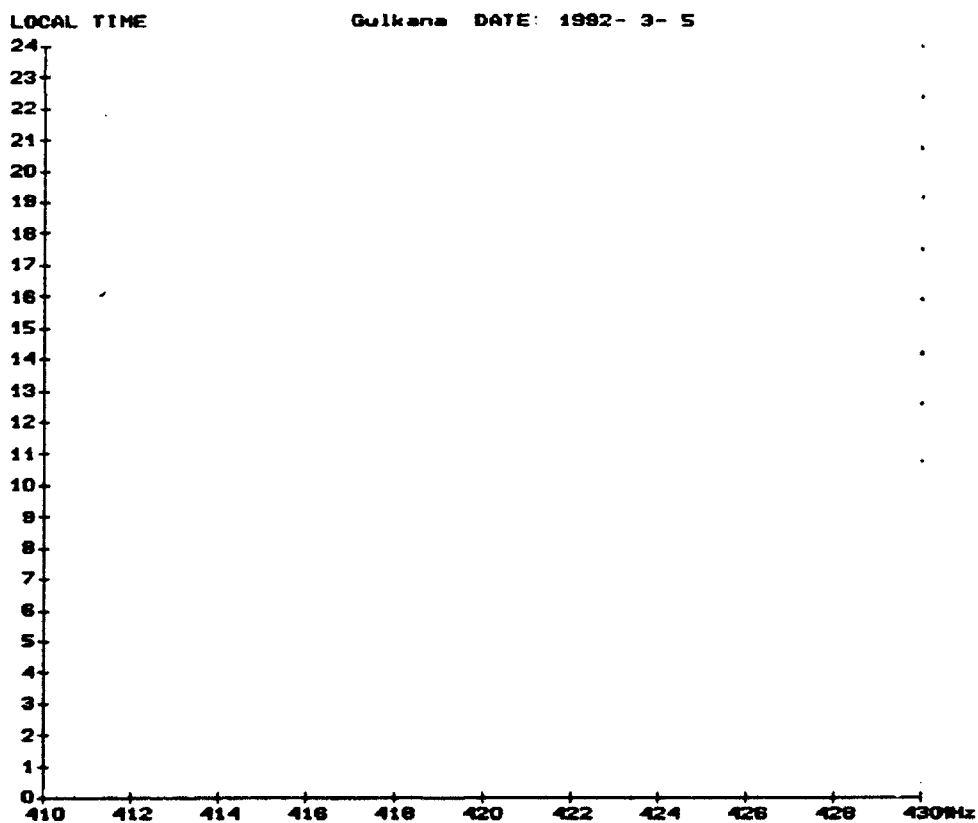


Figure 6.2-26. Gulkana 5 March 1992. Time - Frequency Chart.

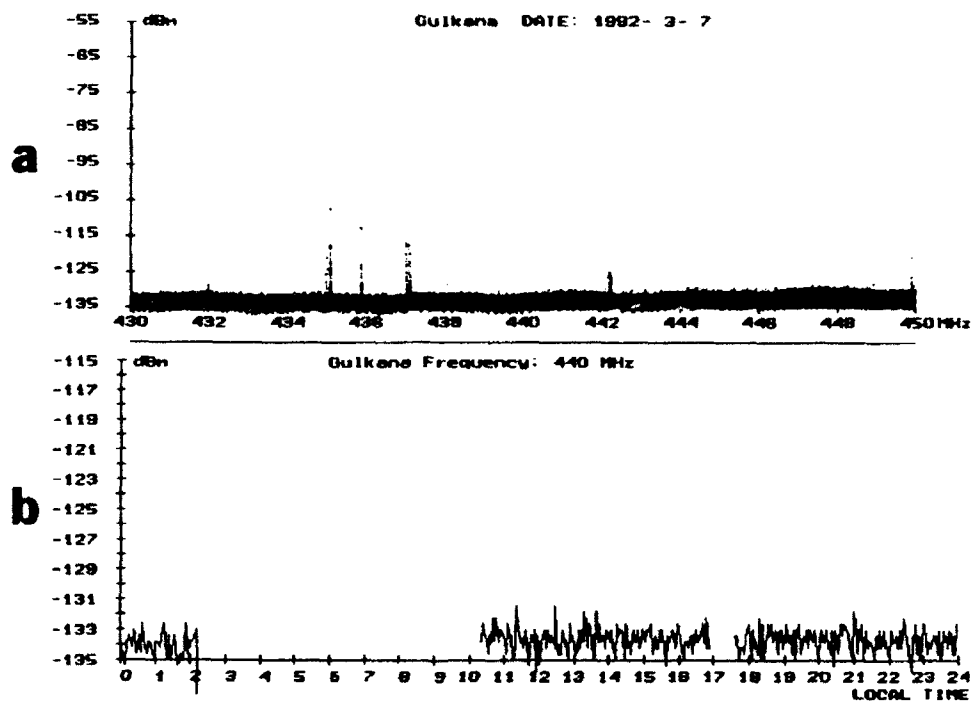


Figure 6.2-27. Gulkana 7 March 1992.
 a. Cumulative Spectra 410 - 430 MHz.
 b. Time Series for 420 MHz.

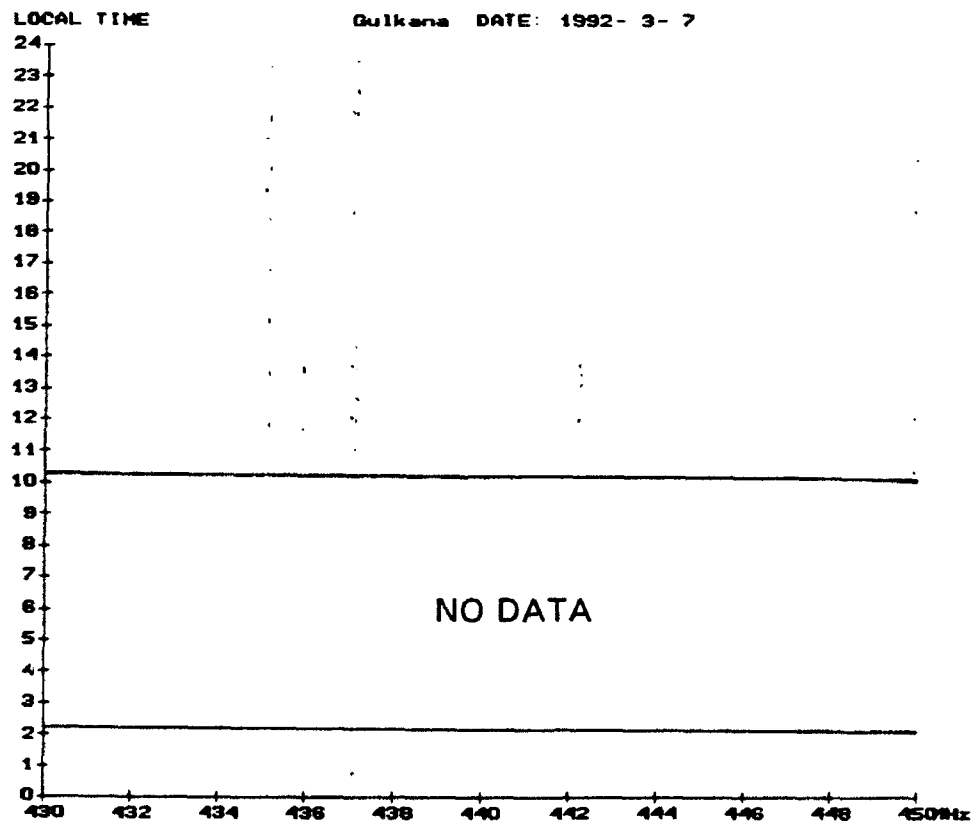


Figure 6.2-28. Gulkana 7 March 1992. Time - Frequency Chart.

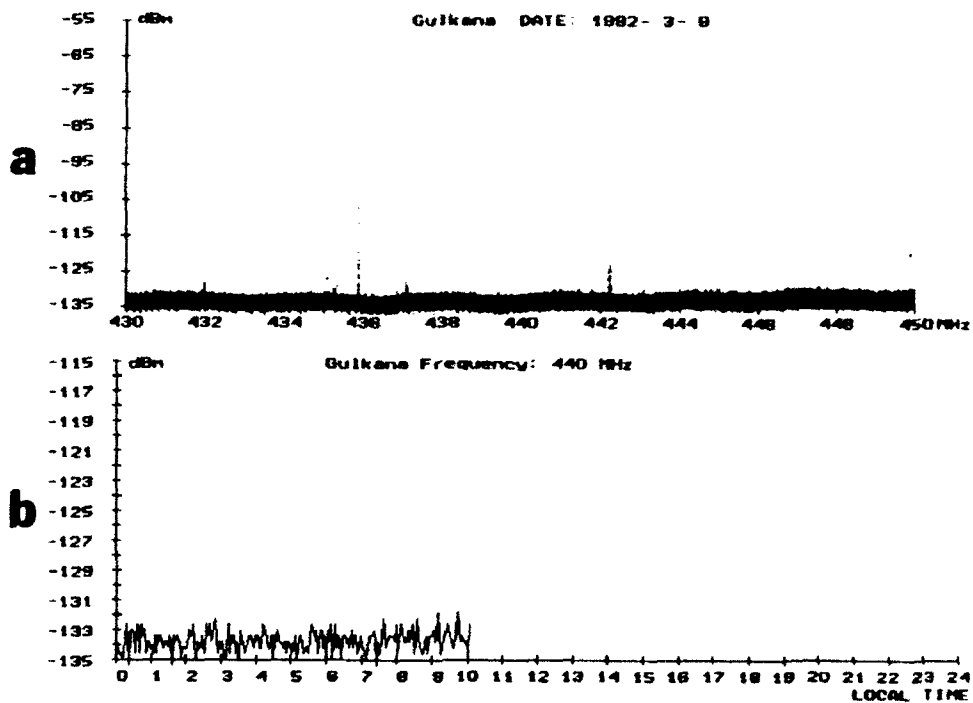


Figure 6.2-29. Gulkana 8 March 1992.
 a. Cumulative Spectra 410 - 430 MHz.
 b. Time Series for 420 MHz.

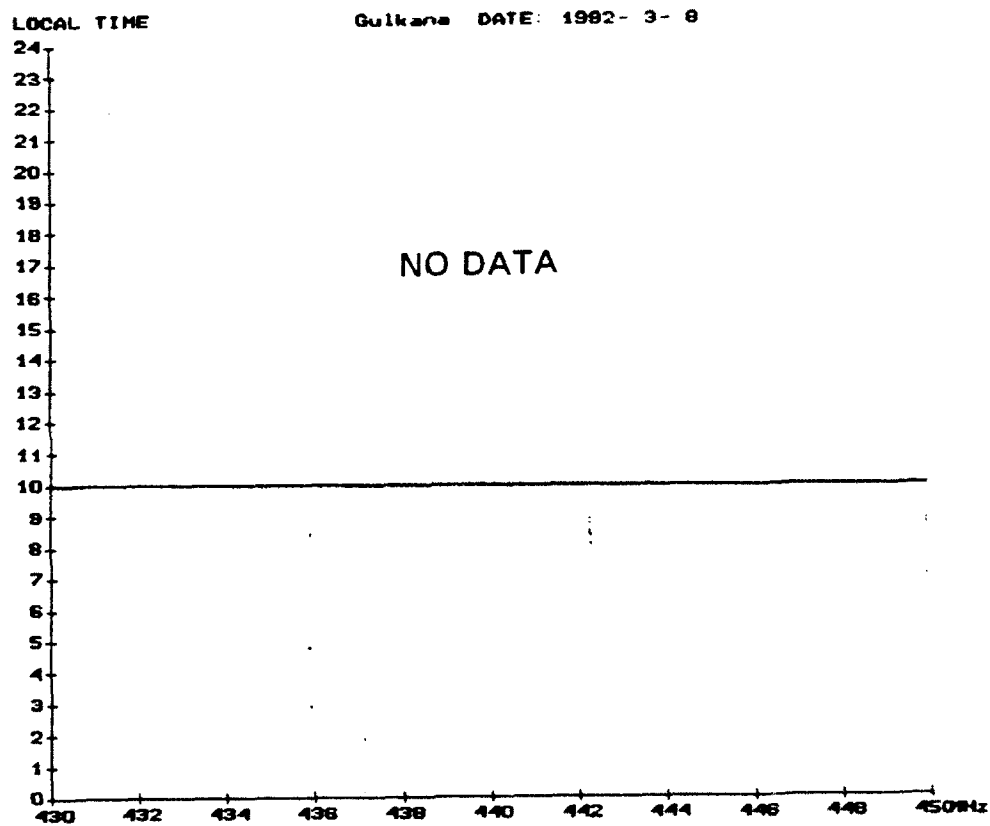


Figure 6.2-30. Gulkana 8 March 1992. Time - Frequency Chart.

Gulkana HAARP Site 2 - 22 MHz.

The results of the HF noise survey at Gulkana are presented in Figures 6.2-31. to 6.2-38. The cumulative spectra found in Figures 6.2-31. to 6.2-33. show a very large dynamic range, exceeding 70 dB for the signals present. Thus, the voltage at the base of the whip antenna ranges from several millivolts to less than a microvolt. Also, the pattern of frequency allocation at HF is illustrated. Bands of very high signal levels at 4, 6, 7, 9.5, 11.5, 13, 15, and 17.5 MHz are allocated for broadcasting world wide. Broadcasters use large transmitter powers, and correspondingly large signals are present throughout, especially in the range 8 - 16 MHz where long paths to some regions of the Earth are always open. Bands with lesser signal strengths allocated to government, maritime and other mobile users, as well as amateur radio are found between the broadcast bands.

The spectrum above 17 MHz has less use than the lower frequencies. This is due to fewer allocations above 18 MHz and also to the propagation constraints imposed by the ionosphere's F-layer at frequencies above the MUF-F2.

The time frequency charts, with signal levels exceeding approximately 0.5 microvolt at the base of the whip show diurnal variation of the received signal levels. Strong signals are present throughout the day in the broadcast bands between 10 and 18 MHz. At lower frequencies, strong signals are present during the night hours, whereas few signals are present during the daylight hours. The lack of signals is not caused by ionospheric absorption, but rather by the appearance of the ionosphere's E-layer at approximately 100 km. It is a well known phenomenon at high latitudes that the E-layer blocks long distance propagation paths at frequencies below the MUF of the E-layer. The time variation of the frequency range affected is a measure of the critical frequency of the E-layer. This, in turn, is directly dependent on the solar zenith angle. The low level interference seen in the 2 to 14 MHz range on August 14 between 0845 and 1730 hrs was caused by radiation from the computer monitor in the survey equipment. The interference disappeared when the monitor was switched off.

The diurnal variation is typical for a summer day at high latitude, and it will vary with the seasons. The influence of the E-layer and the signal levels at the higher HF frequencies will diminish during the winter months as the critical frequencies of the E- and F-layers decrease.

The time series for 5.2, Figure 6.2-37., and 15.2 MHz, Figure 6.2-38, show the diurnal variation of signal levels for a frequency affected by the E-layer during daytime (5.2 MHz), and a frequency above the MUF of the E-layer, (15.2 MHz). The high frequency has large signal levels throughout the day, as broadcasts from different parts of the earth propagate into Alaska, whereas the low

frequency has high level signals from 2300 to midnight and from midnight to 0600. During the daylight hours, only background noise and interference from the computer monitor is seen. The low noise and interference levels emphasize the usefulness of the low HF frequencies for short range skywave communication at high latitude during daylight hours. The spectrum occupancy at temperate latitudes especially in Central Europe is far greater in this frequency range and does not offer the same advantage as at high latitudes.

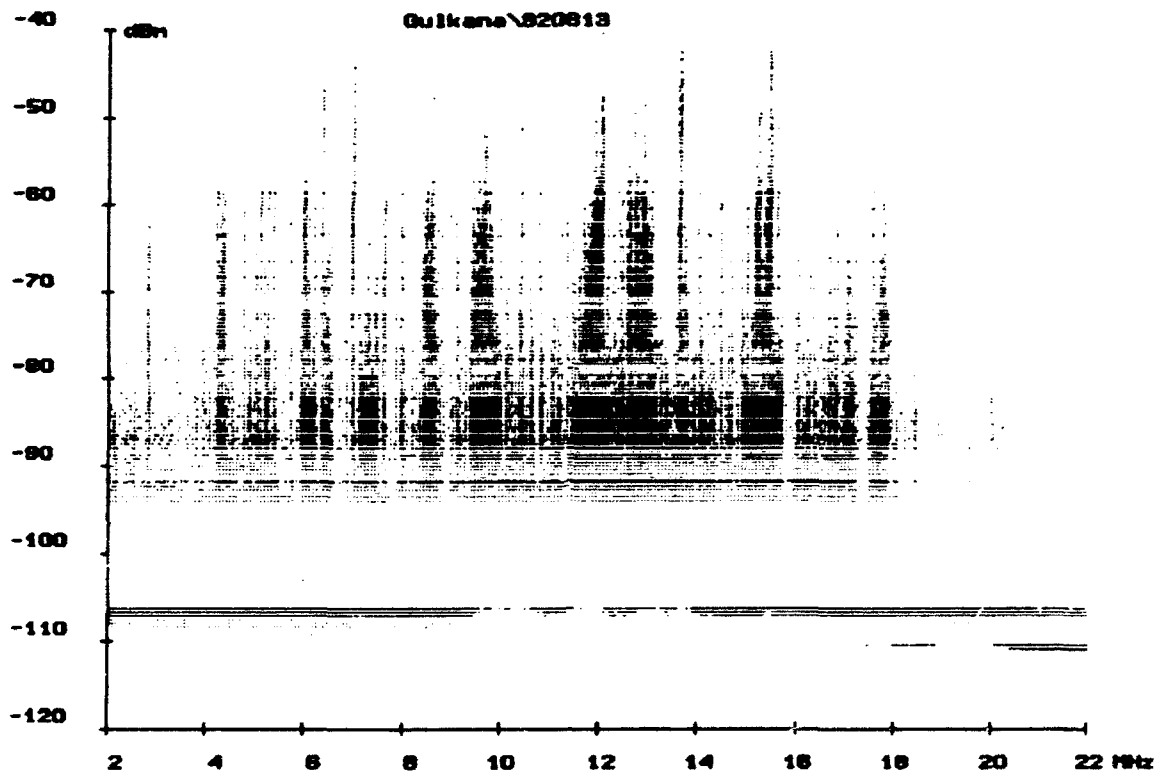


Figure 6.2-31. Gulkana 13 August 1992.
Cumulative Spectra 2 - 22 MHz.

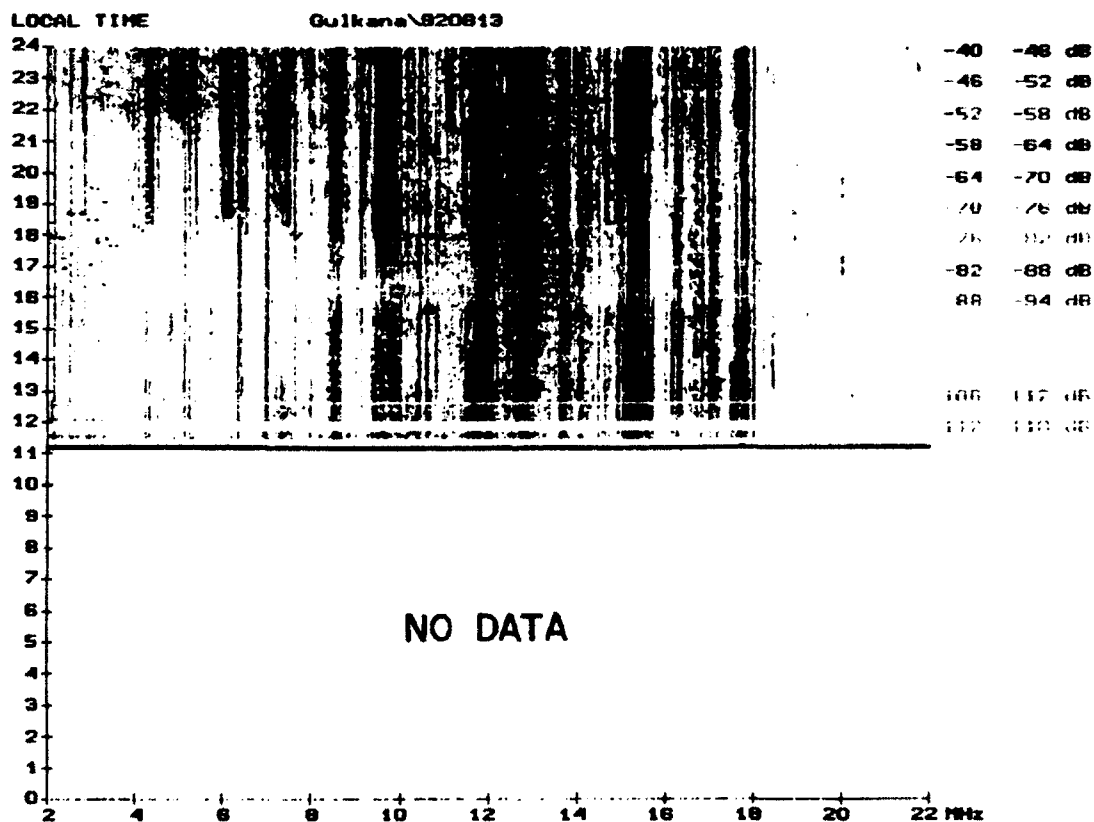


Figure 6.2-32. Gulkana 13 August 1992. Time - Frequency Chart.

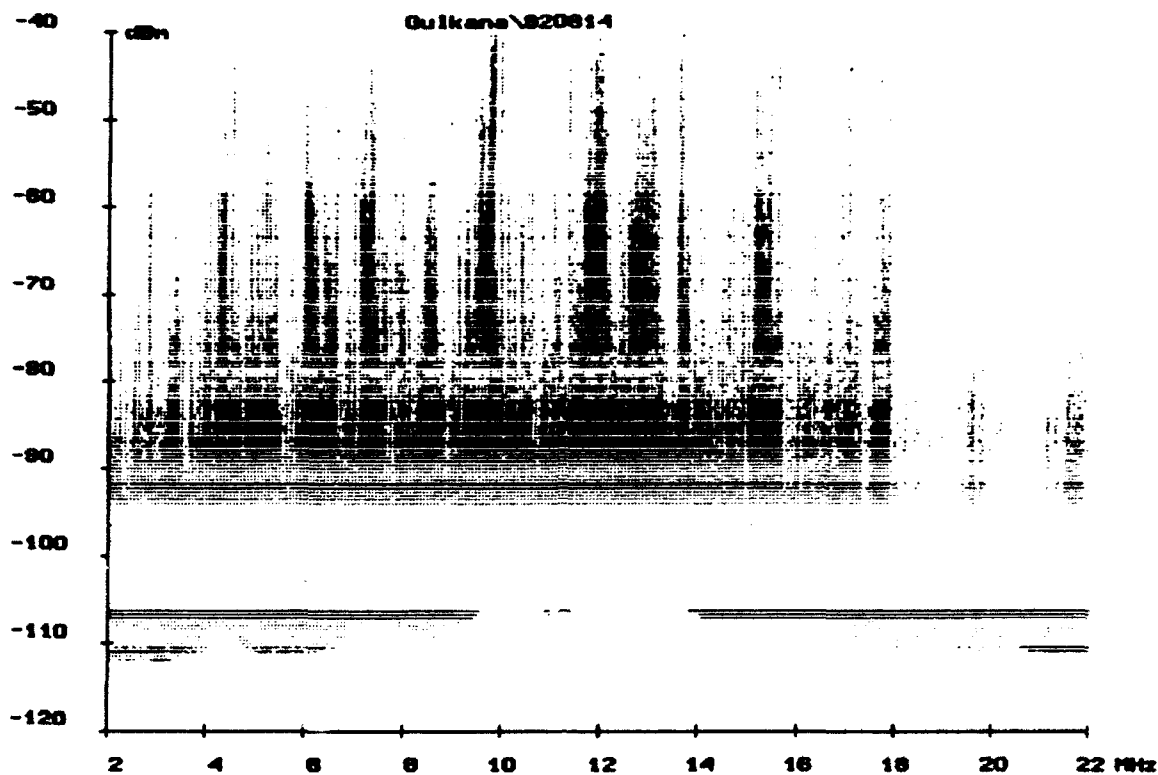


Figure 6.2-33. Gulkana 14 August 1992.
Cumulative Spectra 2 - 22 MHz.

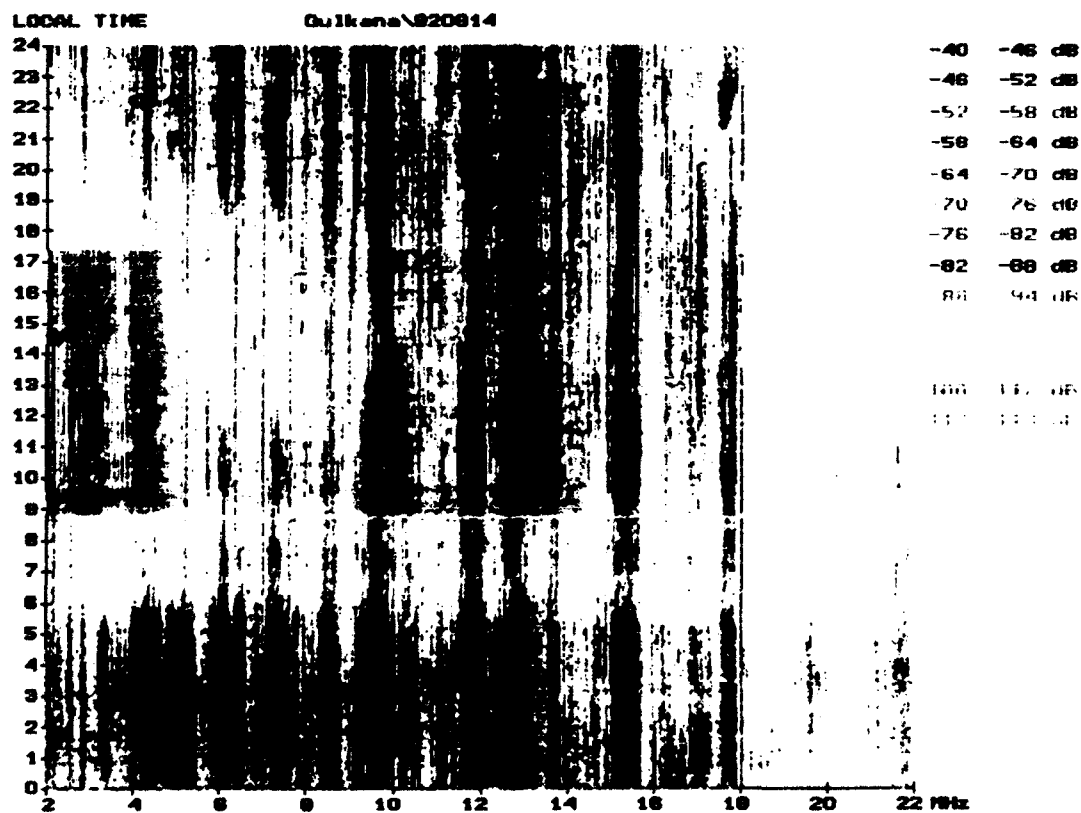


Figure 6.2-34. Gulkana 14 August 1992. Time - Frequency Chart.

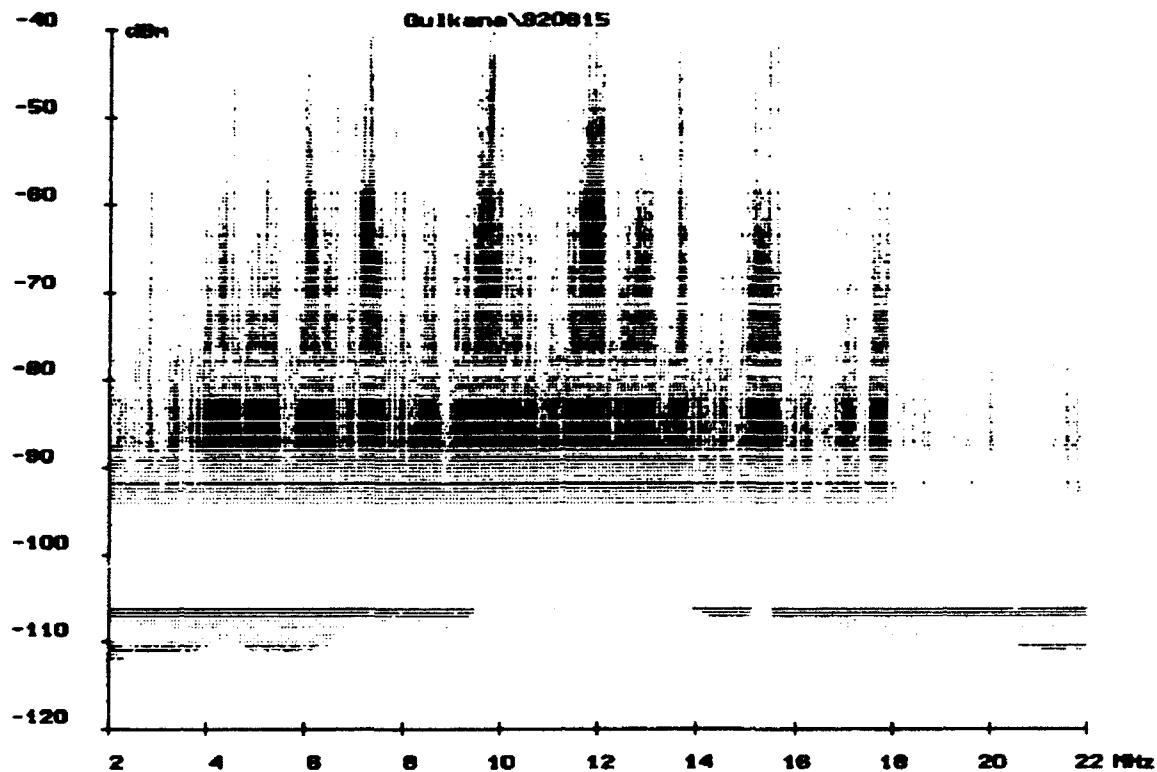


Figure 6.2-35. Gulkana 15 August 1992.
Cumulative Spectra 2 - 22 MHz.

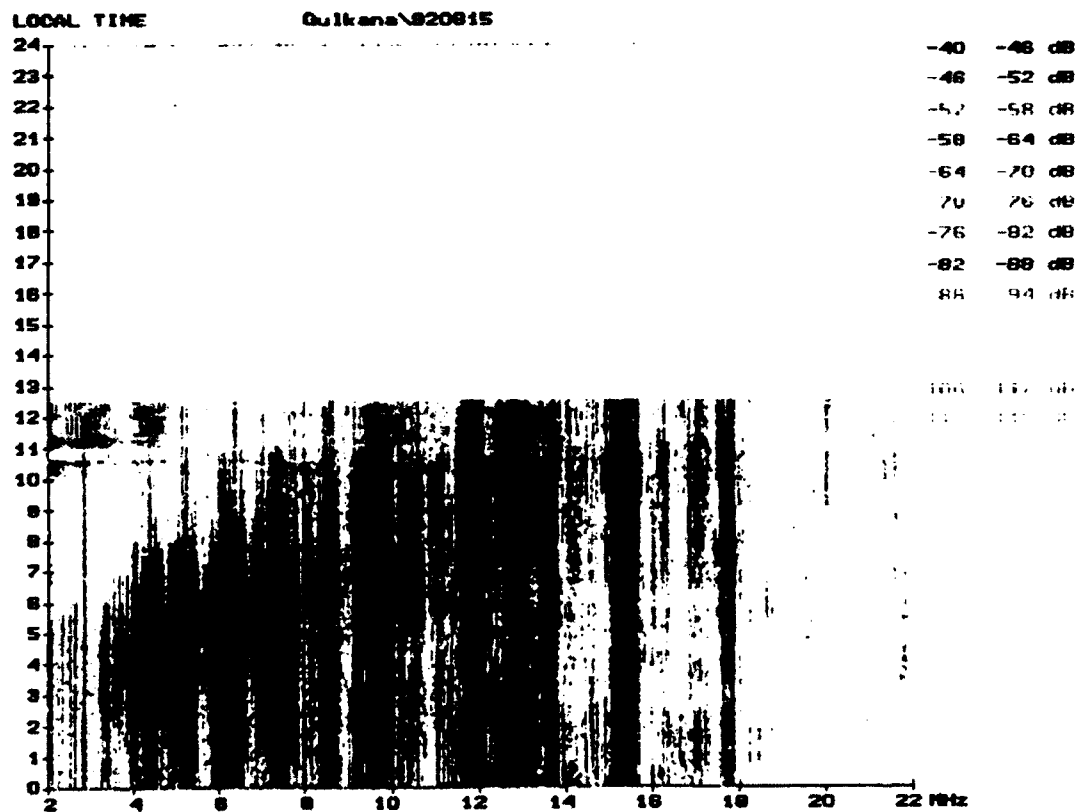


Figure 6.2-36. Gulkana 15 August 1992. Time - Frequency Chart.

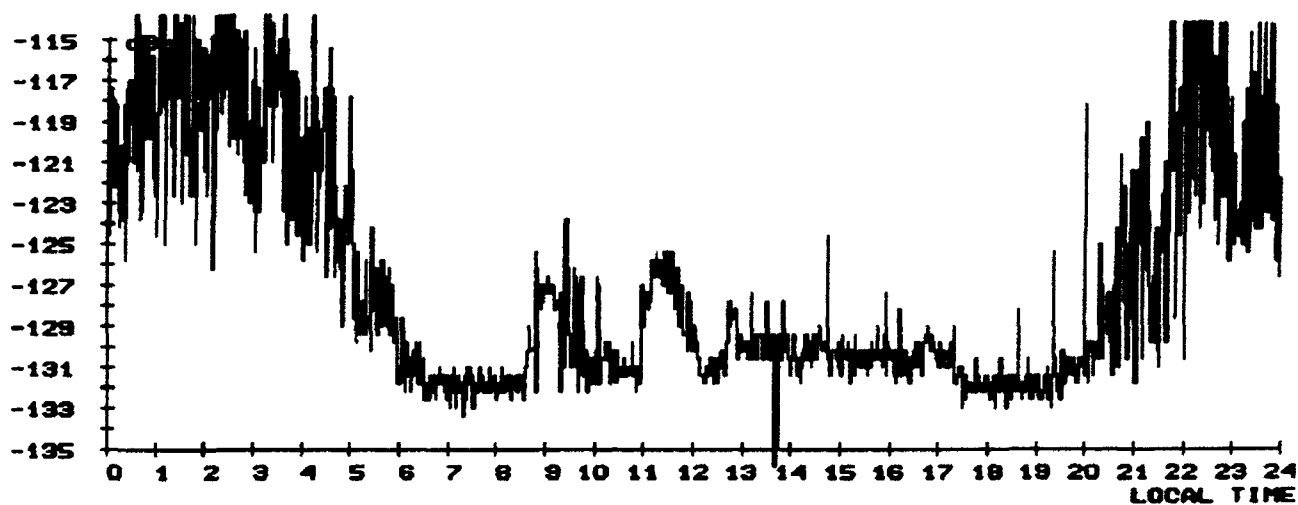


Figure 6.2-37. Gulkana
Time Series for 5.2 MHz.

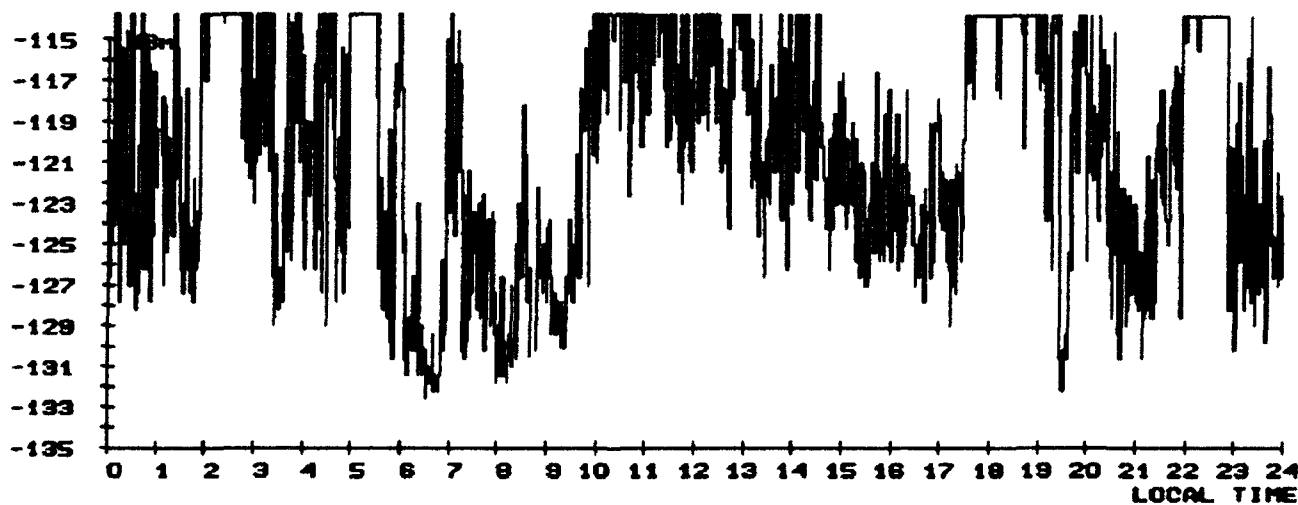


Figure 6.2-38. Gulkana
Time Series for 15.2 MHz.

6.3 Elmendorf AFB. Meteor Scatter Site (MSS).

The current meteor scatter site at Elmendorf AFB is situated on a hilltop off the base proper. The hill has a flat top and slopes into gullies on all four sides. The meteor scatter communications equipment is situated in a trailer placed on the hilltop, and four antenna systems pointing to four different sectors are placed on the hill side slopes. The Alascom service technician at the site helped us locate power for our noise equipment, and determine that the power from the site's transmitters did not produce levels damaging to our equipment. The MSS equipment was under repair and only operating during part of the two day survey period. Also, our equipment had a software problem requiring site visits in the late evening to prepare the instruments for over night data collection. We found it was not possible to gain access to the site, even with Air Force personnel supervision, without paying Alascom \$600 for a minimum 4 hour technician call out. After two days of work to resolve the issue, we left the site, with less data than anticipated due to the access restrictions. Future surveys at this site must be prepared well in advance, so that all parties will be informed and feel comfortable with the work to be performed. Figure 6.3-1. shows the discone antenna situated outside the meteor scatter station.

Cumulative spectra, time sequences at 45 MHz, and time frequency charts are shown in Figures 6.3-2. to 6.3-7. The cumulative spectra show more spectrum occupancy than at Gulkana, and also an elevated, fluctuating background noise level. The noise found in the 46 to 47 MHz range originates from the meteor burst transmitter at the site. The origins of other noise contributions are unknown.

The diurnal variation at 45 MHz shows large noise events, exceeding the background noise by 6 to 10 dB and lasting several hours in the afternoon of March 10. Such noise events are clearly detrimental to the operation of a communication system. Due to the lack of sufficient day time data, it is difficult to evaluate if the diurnal, galactic noise variation is present. During the night time, however, the measured noise level conforms well with predictions at 45 MHz.

The time frequency charts show the noise present at 45 MHz in the afternoon is broad band, covering the full spectrum examined. The origin of this noise source is unknown, but it is conceivable that it is at or very close to the site, and it can be found and removed. The signals in the 46 to 48 MHz range are partly due to the meteor scatter transmitters at the site, but some contribution at 48 MHz from other sources is likely.

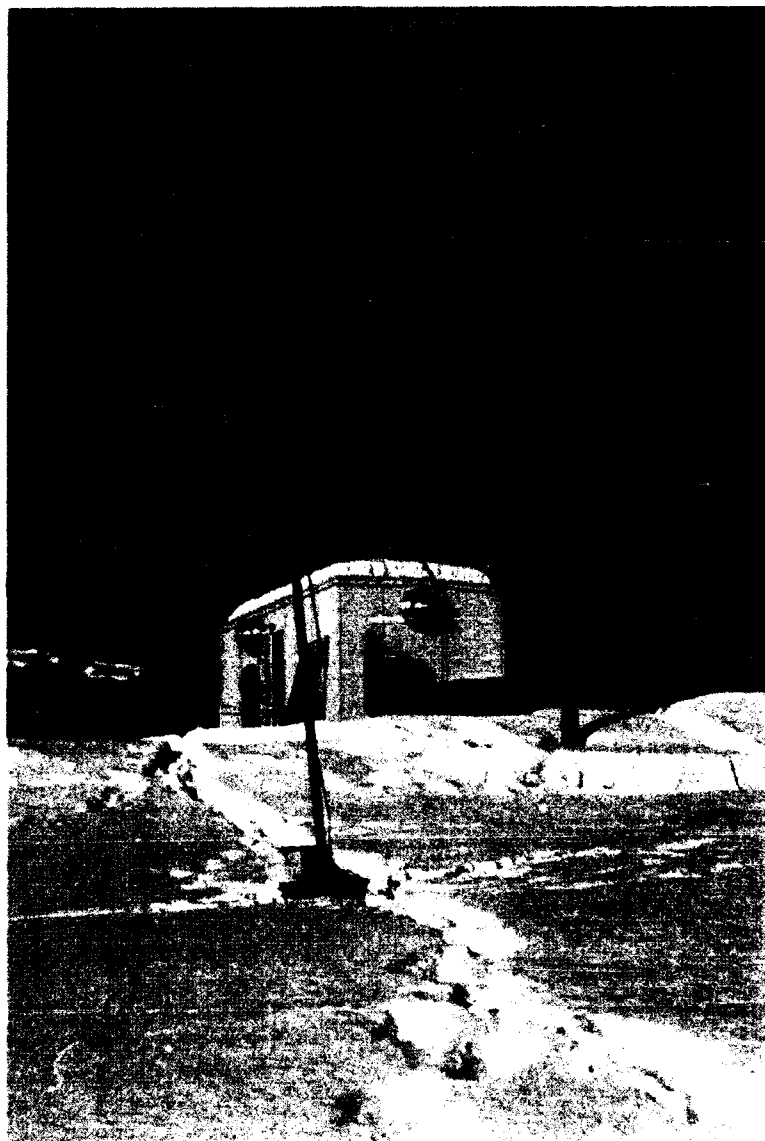


Figure 6.3-1. Meteor Scatter Station at Elmendorf AFB. The survey antenna is located close to the building.

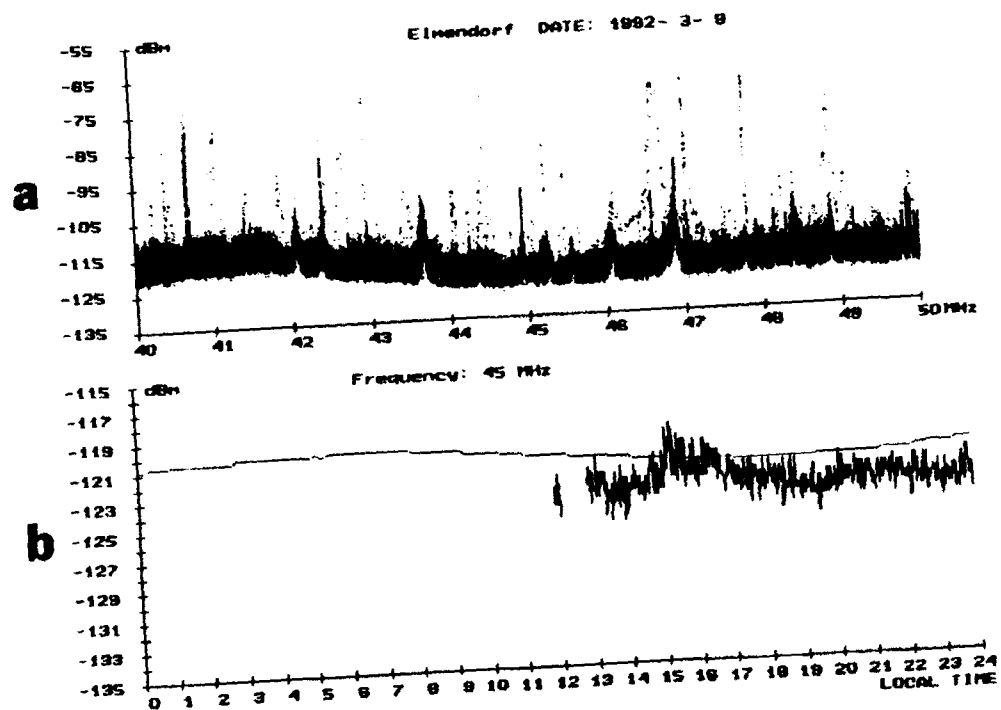


Figure 6.3-2. Elmendorf MSS 9 March 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

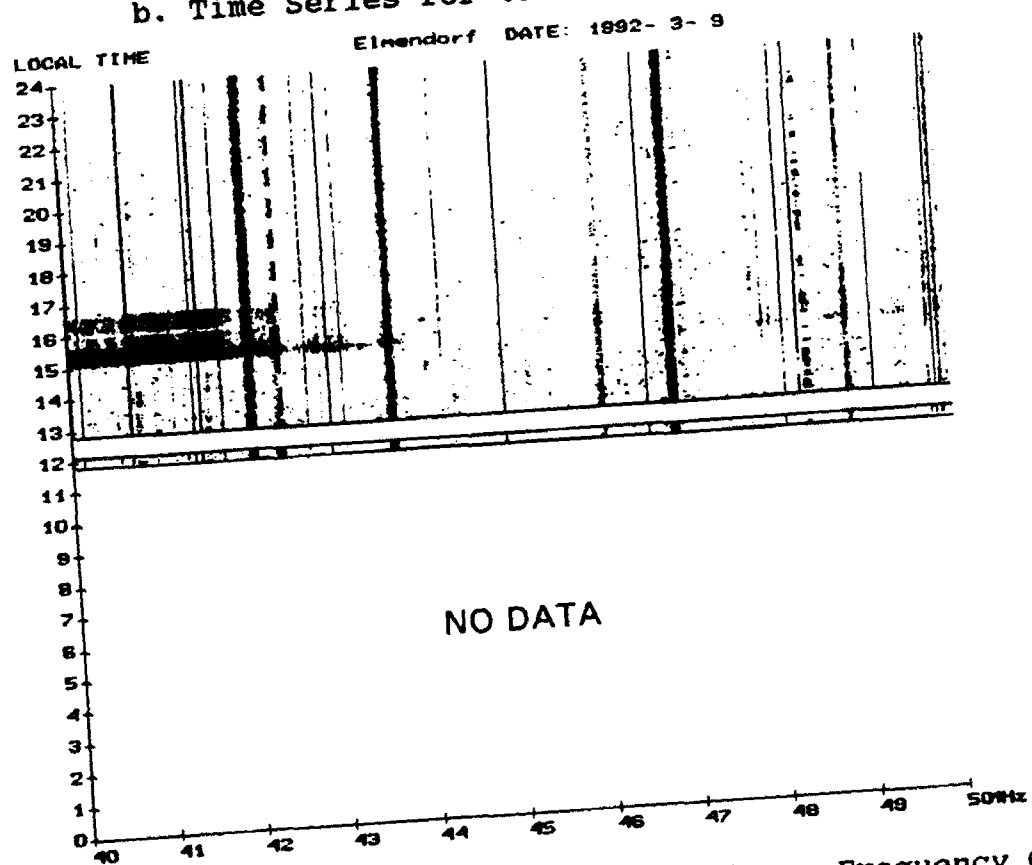


Figure 6.3-3. Elmendorf MSS 9 March 1992. Time - Frequency Chart.

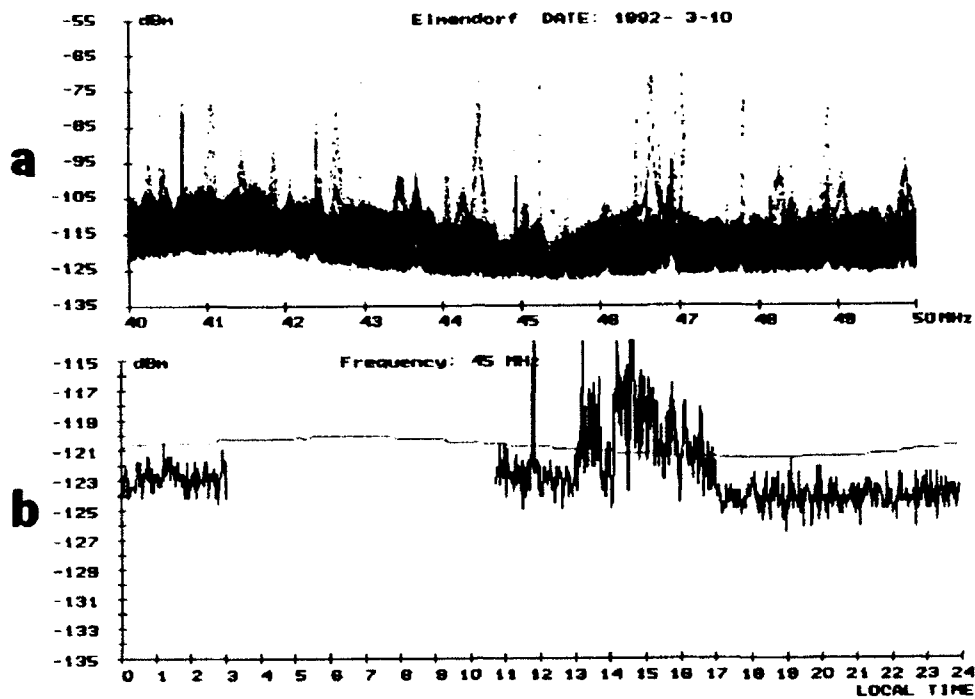


Figure 6.3-4. Elmendorf MSS 10 March 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

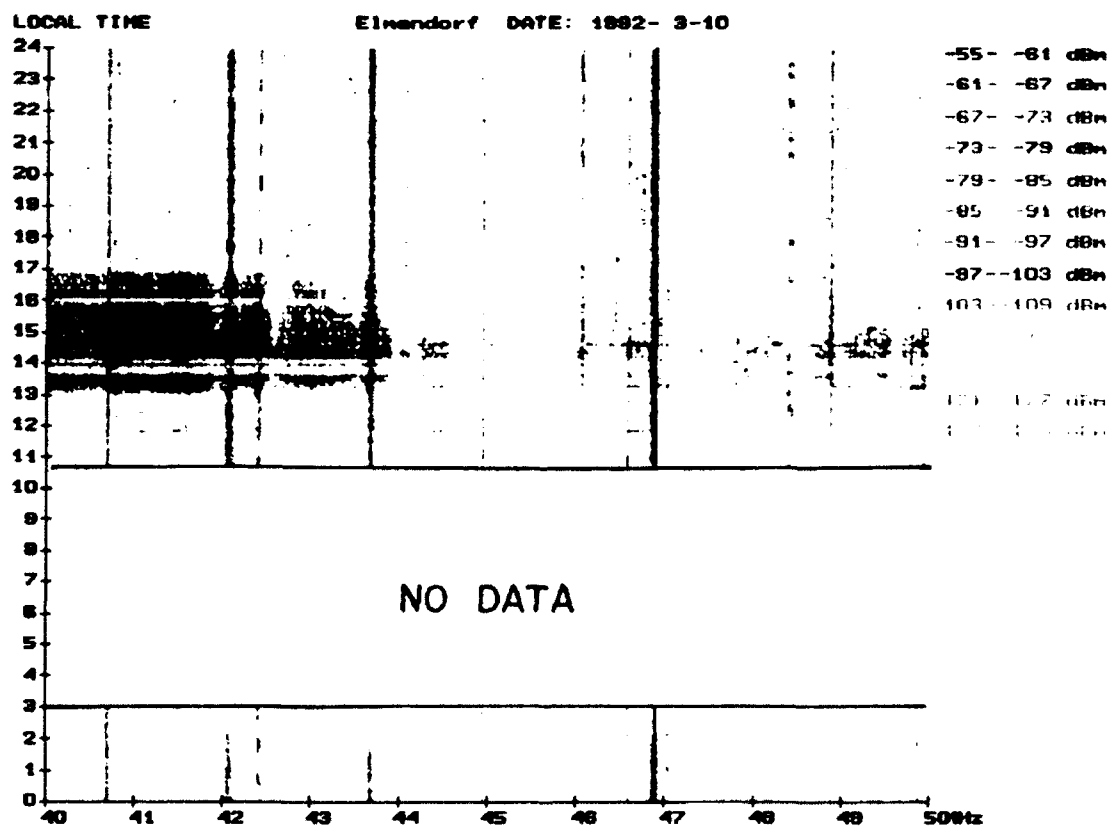


Figure 6.3-5. Elmendorf MSS 10 March 1992. Time - Frequency Chart.

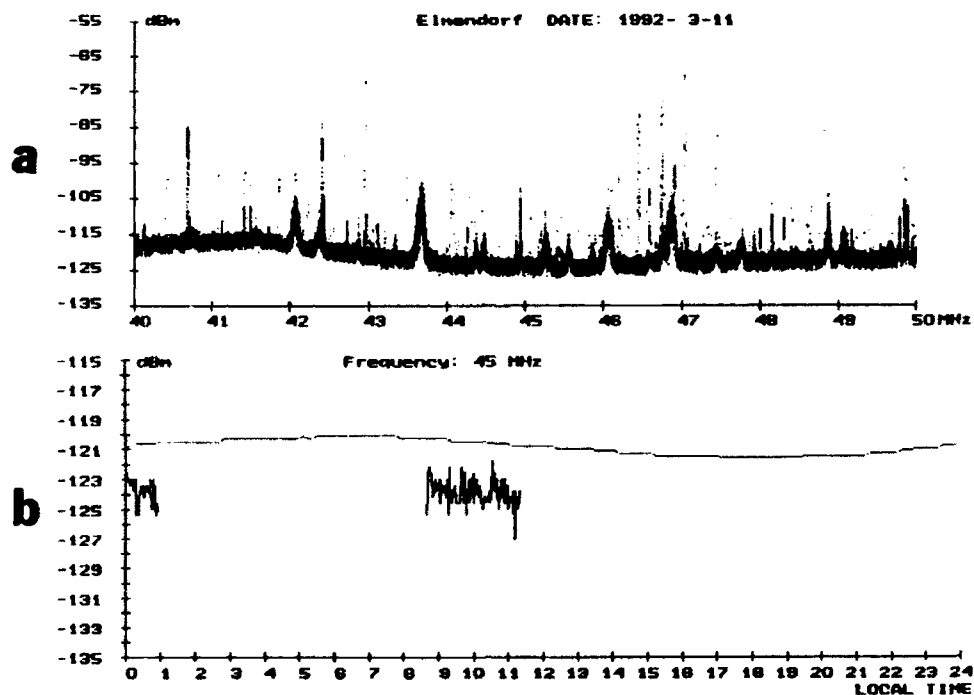


Figure 6.3-6. Elmendorf MSS 11 March 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

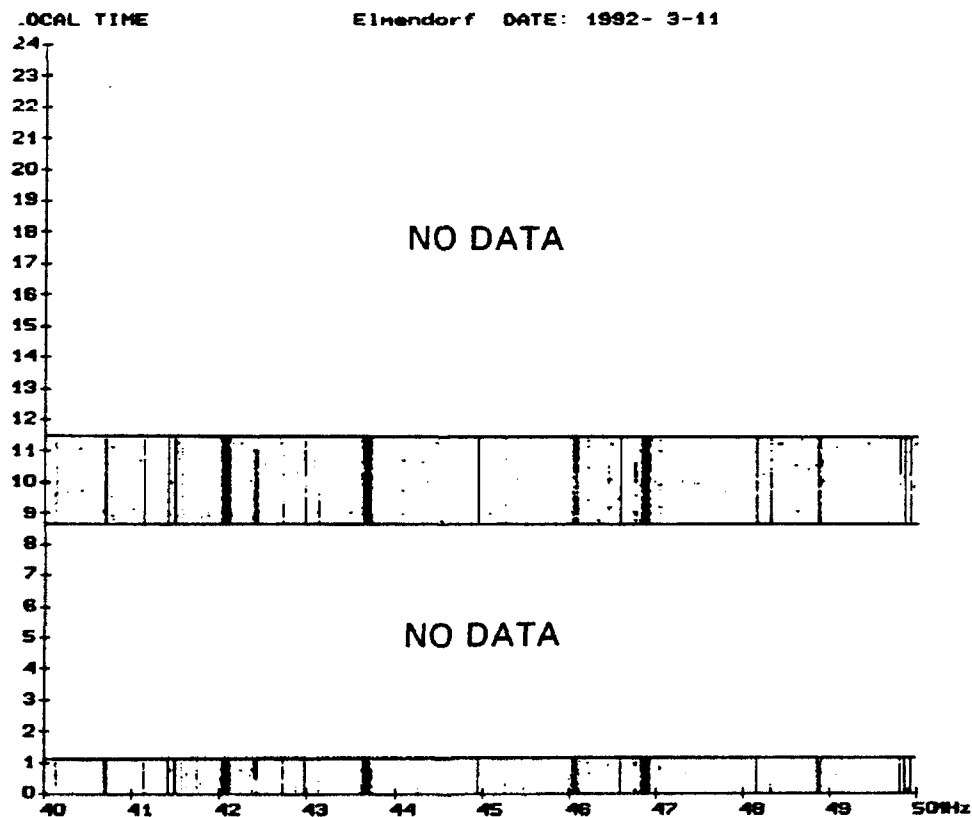


Figure 6.3-7. Elmendorf MSS 11 March 1992. Time - Frequency Chart.

6.4 Elmendorf AFB. MC3 Site.

The MC3 site is situated next to the satellite communications facility on Elmendorf Air Force Base proper. The surrounding terrain is completely flat except for the nearby buildings. The horizon is defined by the mountain ranges east of Anchorage, and the far distant mountains north and west of the city. For meteor scatter antenna installations the terrain features are ideal. The site is however, situated very close to potential and future sources of RFI that could prove detrimental to the operation of a meteor scatter link.

We were informed by the Communication Squadron staff that any antenna installation on this site would be prohibitive due to concerns over the appearance of the base. Especially arrays of antennas for high performance meteor scatter links would present rather insurmountable complications, even if the electromagnetic environment at the site was found suitable for a meteor scatter receiving station.

At present the MC3 site is a dumpster storage area. Figure 6.4-1. shows the antenna area and a skyscraper in downtown Anchorage. We set up in the area close to an existing building, where power was made available to us by BCE. We were soon visited by a representative from the neighboring facility, worried by the prospect of transmissions from our equipment. After a presentation about our measurement setup, and assurances we did not intend to transmit signals from the site during the investigation, we were able to commence data acquisition.

Cumulative spectra, time sequences at 45 MHz, and time-frequency charts are shown in Figures 6.4-2. to 6.4-7. The cumulative spectra show very heavy spectrum usage at this site, especially in the 44 to 50 MHz range. Lower usage is found in the 40.5 to 42 MHz range. Signals exceeding the noise level by 30 - 40 dB is the norm, rather than the exception.

The diurnal variation of the signal level at 45 MHz shows something resembling the diurnal galactic noise low in the evening hours, but the high occurrence of noise spikes indicate the site is more prone to interference from vehicles and other short lived sources of electrical noise. On the evening of March 12 a number of signals or noise bursts were present during the evening hours. Thus the site is not galactically noise limited at this frequency.

The time-frequency plots show that a large number of the signal sources found in the 40 - 50 MHz spectrum operate continuously, and there are few if any clear frequencies in the 44.5 to 50 MHz range. The frequency range 42.5 to 44.5 MHz shows few signals present and absence of broad band noise sources. Thus the site at present is less bothered by broad band noise sources than anticipated when looking at the number of facilities close by.

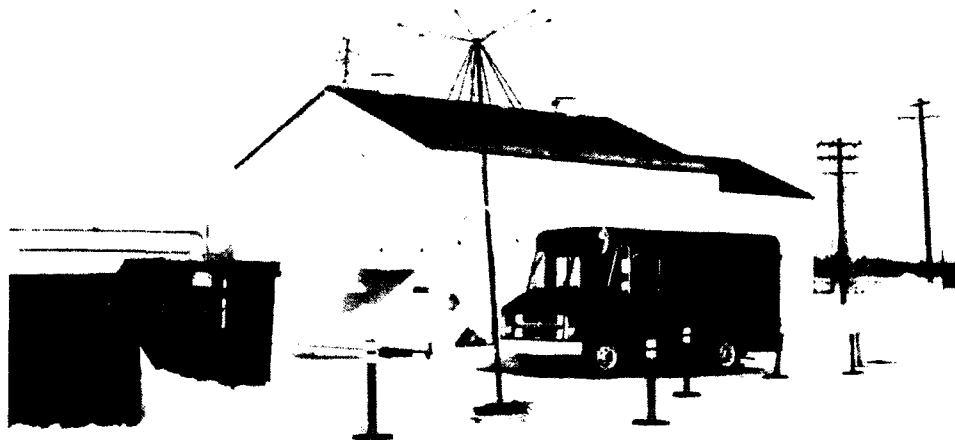


Figure 6.4-1. Antenna Installation at the MC3 Site at Elmendorf AFB.

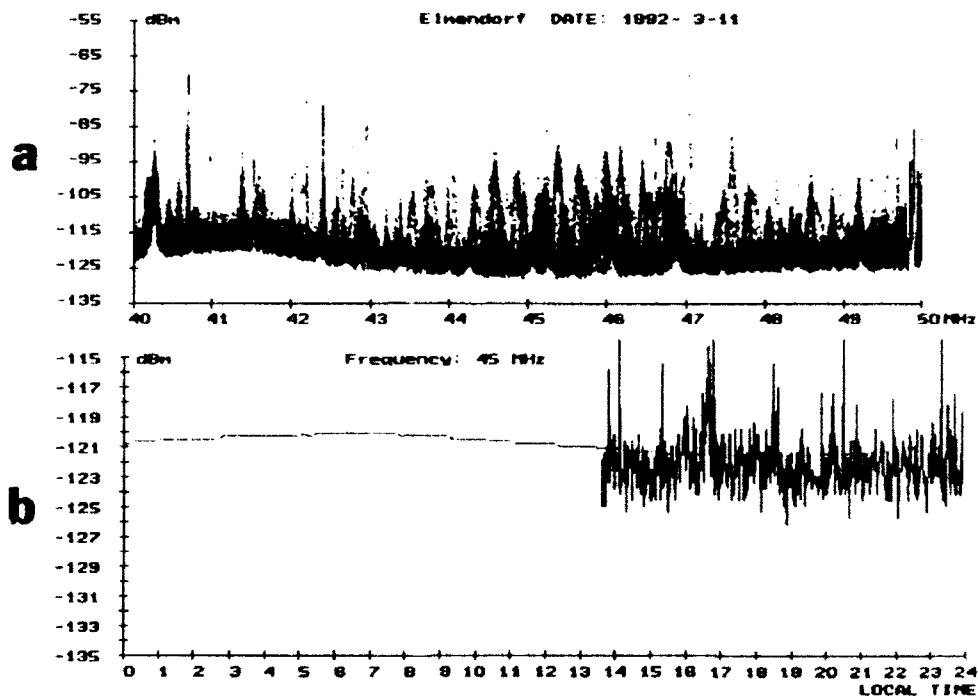


Figure 6.4-2. Elmendorf MC3 11 March 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

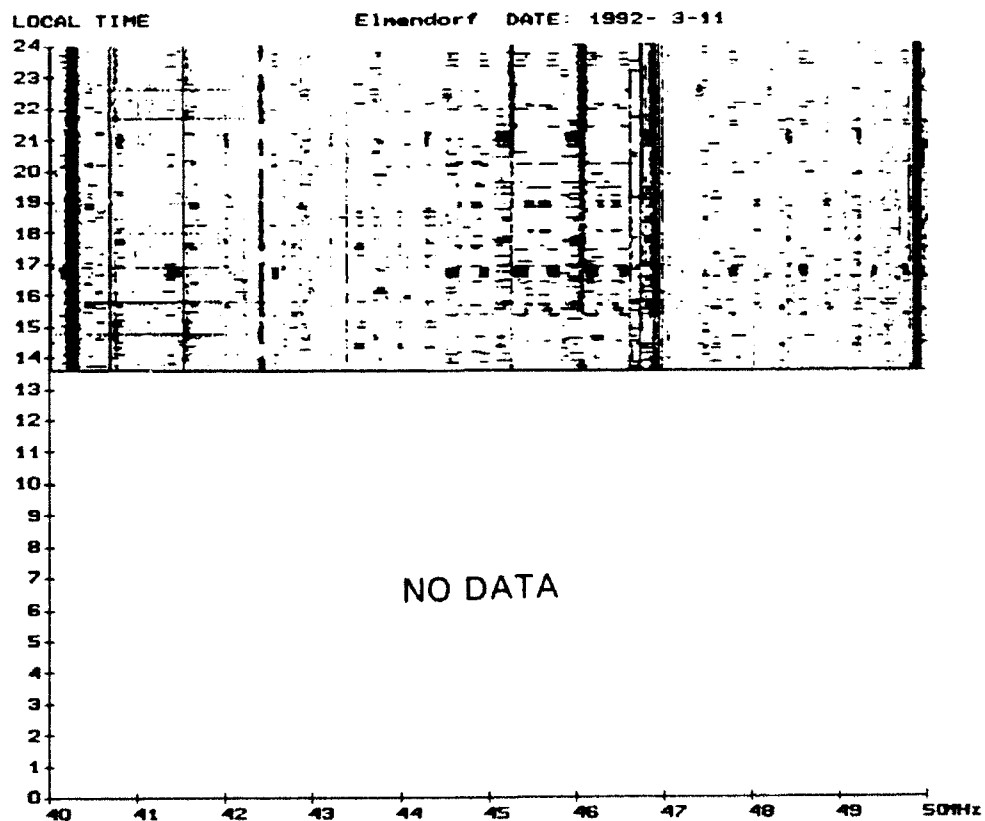


Figure 6.4-3. Elmendorf MC3 11 March 1992. Time - Frequency Chart.

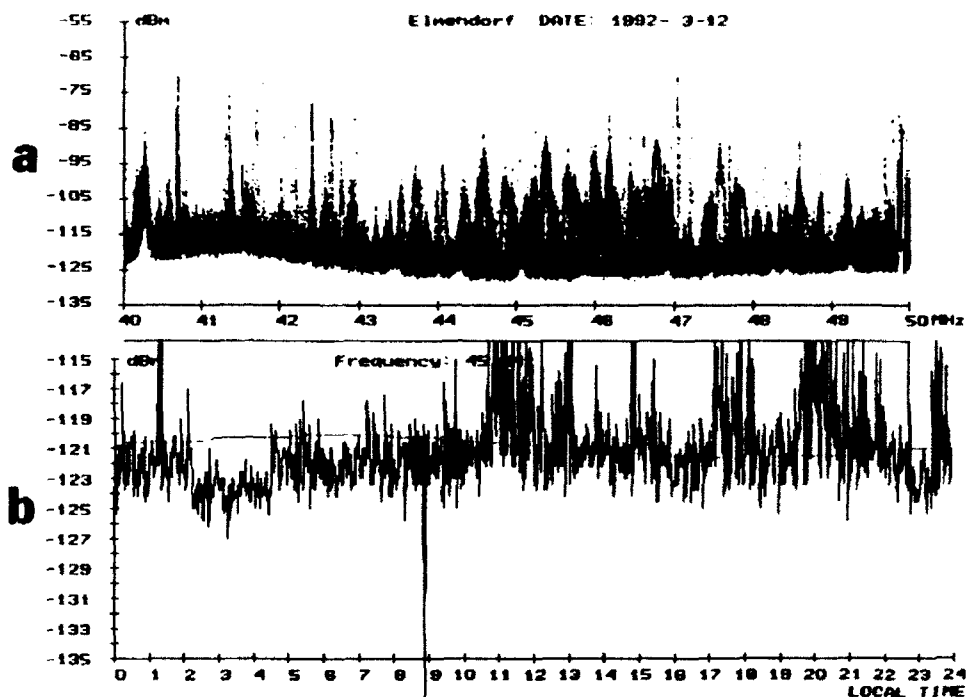


Figure 6.4-4. Elmendorf MC3 12 March 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

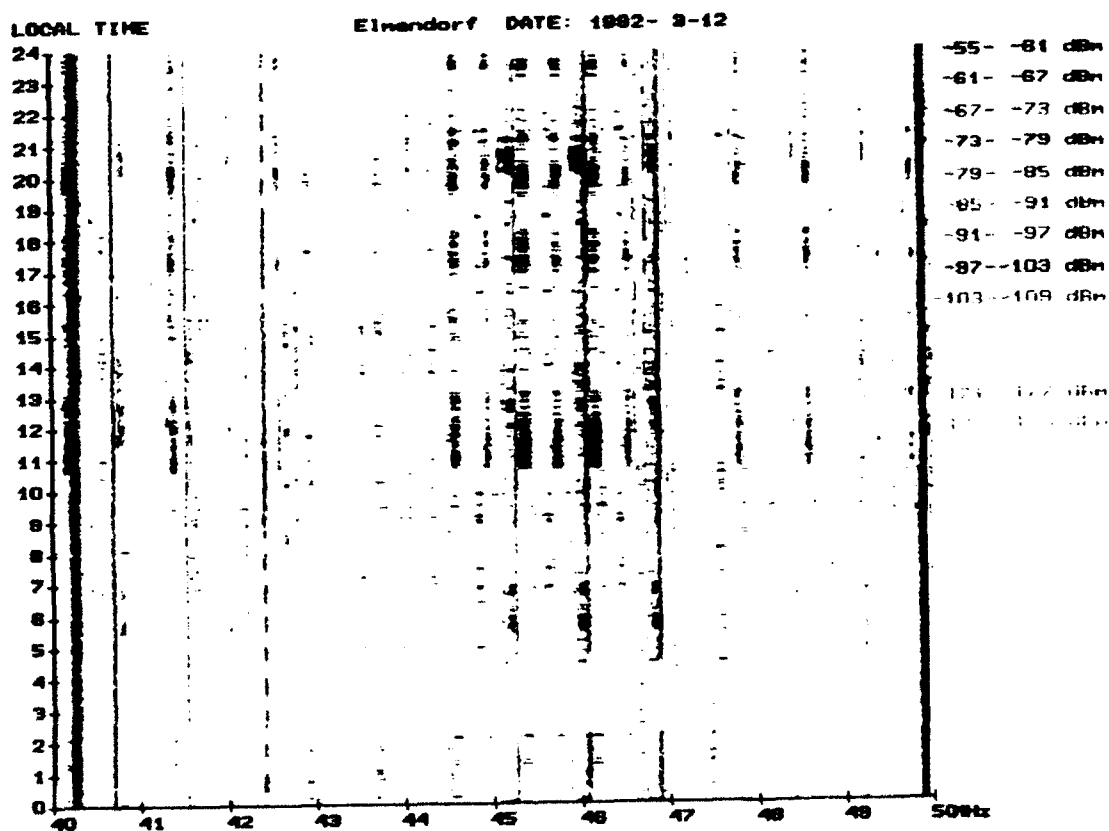


Figure 6.4-5. Elmendorf MC3 12 March 1992. Time - Frequency Chart.

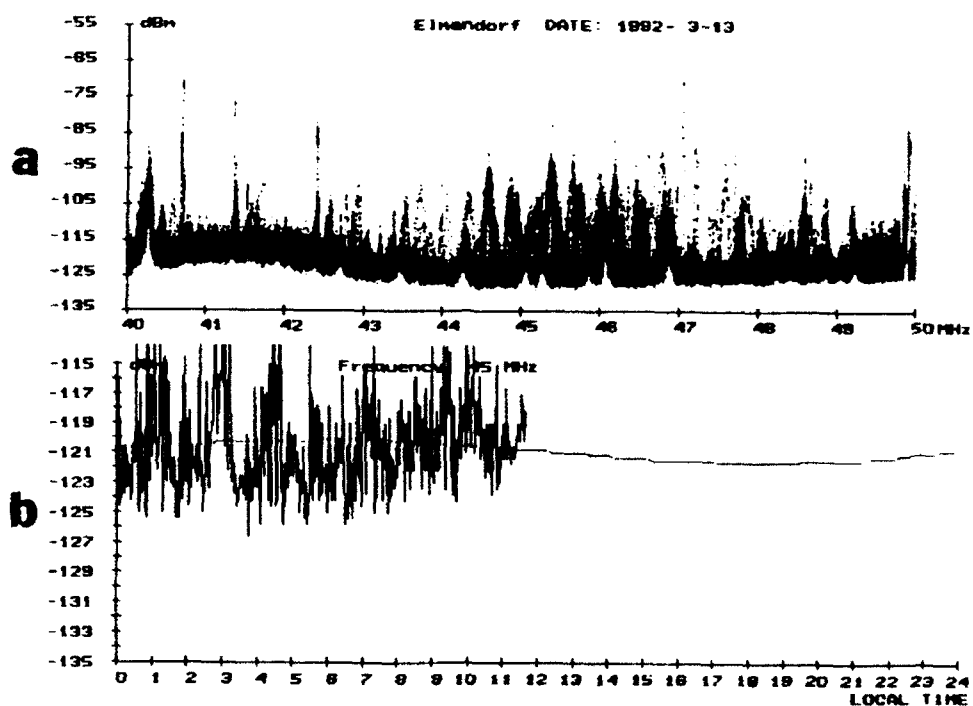


Figure 6.4-6. Elmendorf MC3 13 March 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

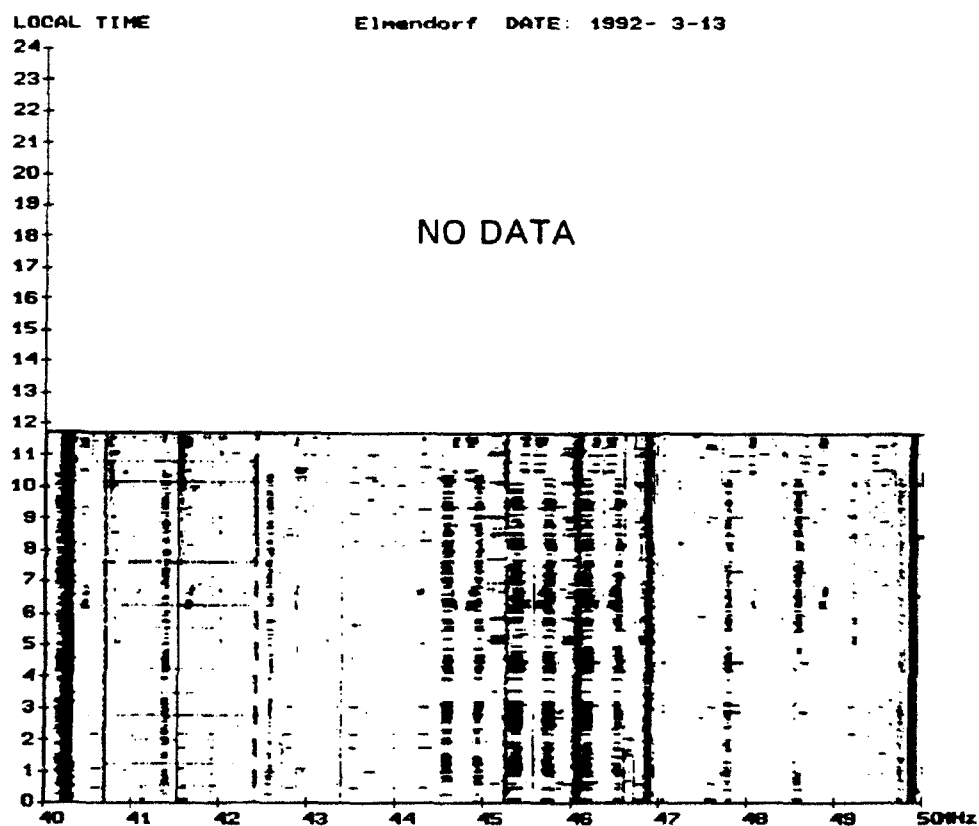


Figure 6.4-7. Elmendorf MC3 13 March 1992. Time - Frequency Chart.

6.5 Elmendorf AFB. VHF Site.

This site is an abandoned VHF air radio site located off the main base. The site has a building, in somewhat tough shape, and eight antenna towers in a circular clearing in the forest. The terrain is flat but rough, with terrain features of 1 to 2 feet according to information from AF personnel. The site was covered by 5 feet of snow during the tests. We set up in the van in the plowed driveway leading to the building where power was made available by BCE. The terrain W and NW of the site is a flat cleared field used for model air plane flying, control frequencies being mostly in the 72-75 MHz. range. Figure 6.5-1. shows the site and the measurement setup.

Cumulative spectra, time series at 45 MHz, and time-frequency charts are shown in Figures 6.5-2. to 6.5-7. The cumulative spectra show fewer occupied frequencies as compared to the MC3 site, but the presence of broad band noise bursts during March 14 should be noted. Also a number of broadband sources are seen in the 44 to 48 MHz range.

Little diurnal variation is seen at 45 MHz. Large noise bursts are seen during the afternoon and early evening hours, and noise depressions are seen around noon. The noise levels are markedly lower at this site than at either the meteor scatter or MC3 sites. It is not known if the depressions are due to ionospheric absorption or terrain features. Comparison of system calibrations performed at all three sites confirm that the calibration did not change between sites.

The time frequency plots show a number of continuously operating transmitters in the 40 - 47 MHz range, and a large, diffuse patch of broad band noise in the afternoon in the range 40 to 44 MHz. The noise was present during both days of the test. Also broad band noise covering the whole spectrum examined was present in the noon to afternoon period. The site seems to have the greatest potential as a new meteor scatter site of the three examined, both due to the flat area available for antennas and the slightly better noise and interference environment.



Figure 6.5-1. Measurement Setup at the VHF Site, Elmendorf AFB.

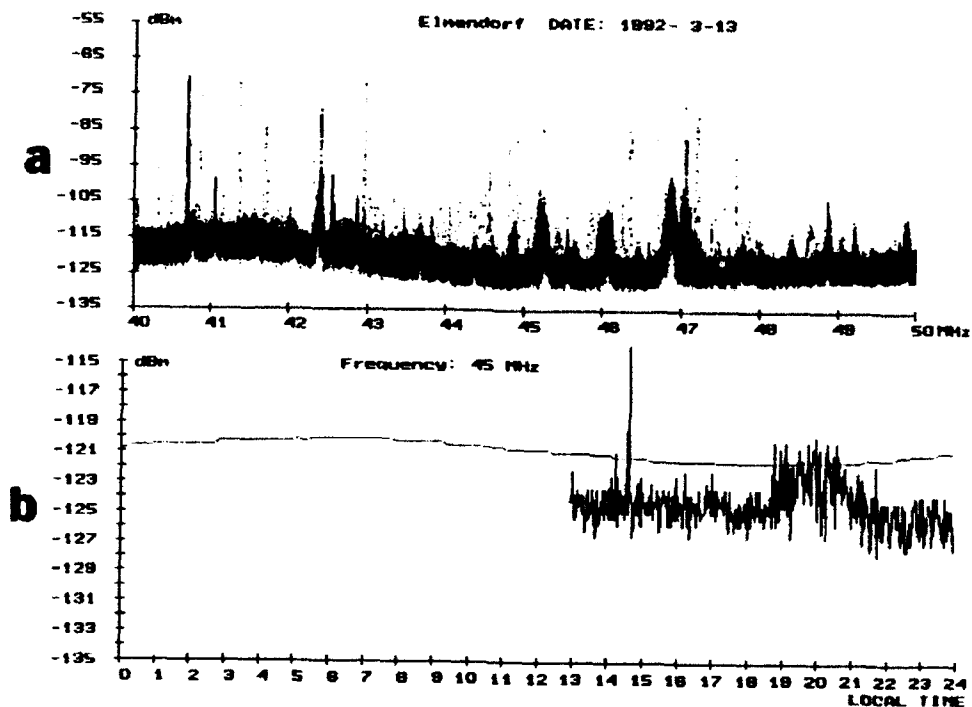


Figure 6.5-2. Elmendorf VHF 13 March 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

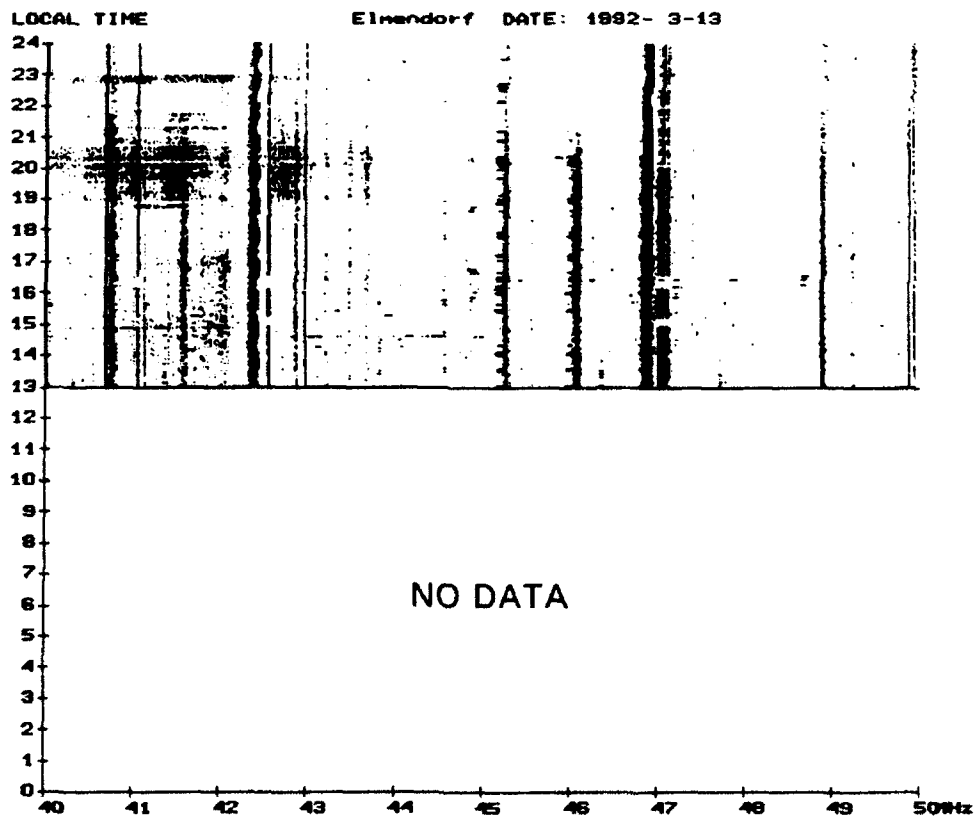


Figure 6.5-3. Elmendorf AFB 13 March 1992. Time - Frequency Chart.

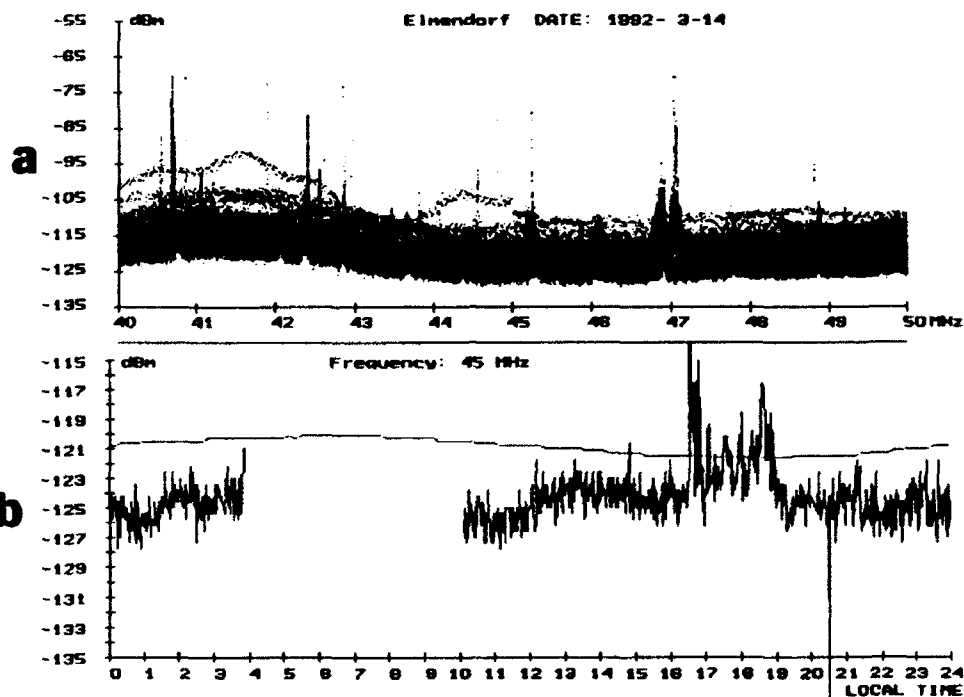


Figure 6.5-4. Elmendorf VHF 14 March 1992.
a. Cumulative Spectra 40 - 50 MHz.
b. Time Series for 45 MHz.

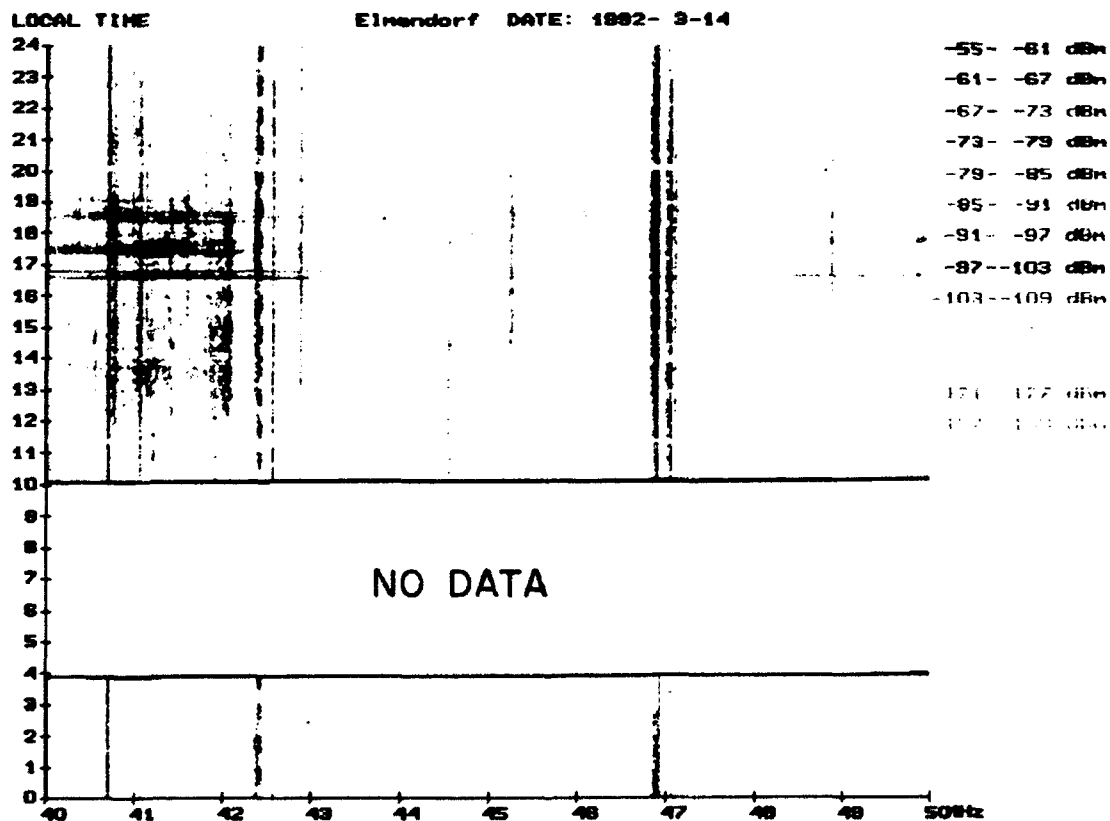


Figure 6.5-5. Elmendorf VHF 14 March 1992. Time - Frequency Chart.

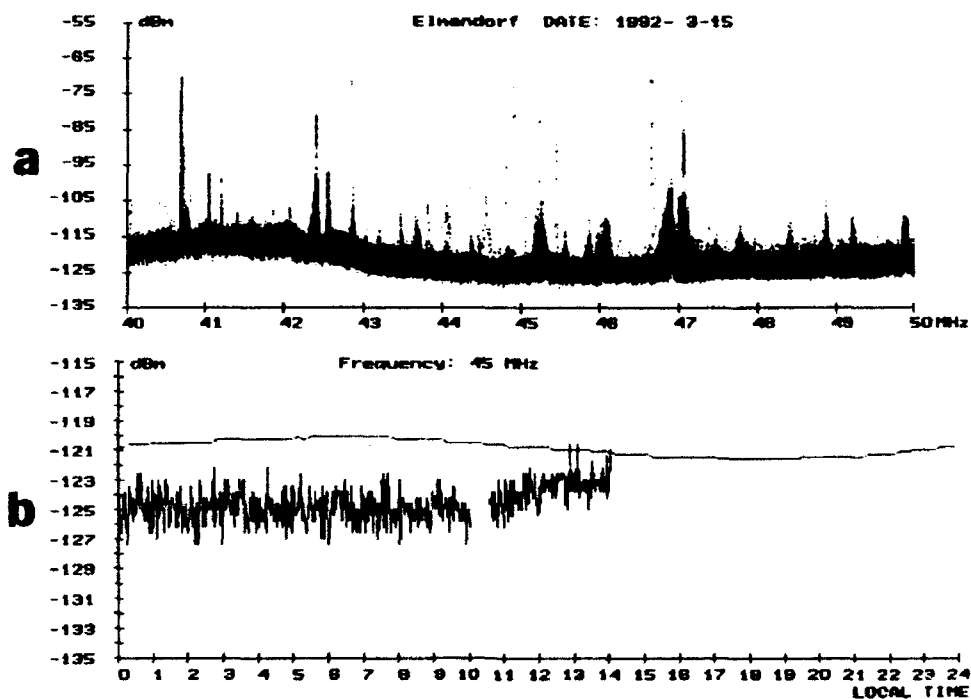


Figure 6.5-6. Elmendorf VHF 15 March 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

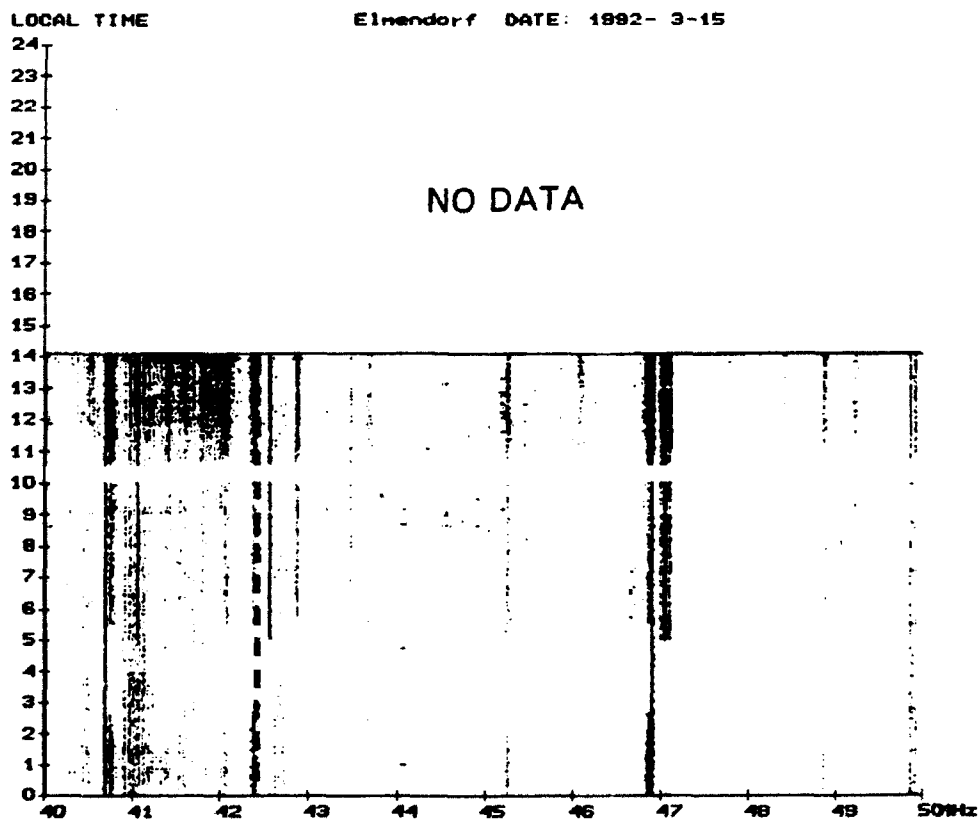


Figure 6.5-7. Elmendorf VHF 15 March 1992. Time - Frequency Chart.

6.6 Galena AFB. Meteor Scatter Site.

The meteor scatter site in Galena was the first of three stations in the meteor scatter network outside Elmendorf AFB to be surveyed. Preparations for the surveys included improvements to the RF equipment, as well as software updating. Also, a significant effort was made to arrange for site access and the necessary support. A noise survey is a small scale effort and can be difficult to fit into the existing logistics framework more geared to massive military needs. Future efforts at these sites should be arranged well in advance (6 months) to ease the problems with access clearance, support, etc. It is hoped the travel and accommodation information included with each site survey description may be of value for later efforts.

Galena is a small air force base located on the Yukon River NW of Anchorage. The airport is serviced by Mark Air using commuter type aircraft. While it is possible to pay for excess baggage to transport the instrumentation, the airline has a limit of 3 pieces of luggage per passenger which cannot be exceeded. Excess pieces will be forwarded when the opportunity arises, in our case the next day. Galena has a local community as well, with a few residents, a couple of restaurants, and a small shop. Access to the air base is by prior permission only. We were very well received at the air base. A short meeting with the base commander and the deputy base commander gave us the opportunity to explain our mission. We were given a van for transportation and introduced to the Alascom technician in residence. The accommodations are luxurious, the VOQ being exclusively suite type quarters. Meals are available at the bases dining hall and club. The dining hall is as expensive as the club, in contrast to other Air Force installations. Meals can also be had at the local restaurants approximately 4 miles from the base. Also, travel orders must be stamped explicitly for access to the base exchange, otherwise benign purchases such as shoelaces and postcards will not be possible. The Galena area is large and transportation is necessary if work has to be performed outside the base proper.

The Alascom technician was extremely helpful and guided us to the meteor scatter station, located 7 miles outside the base and approximately 200 meters from the main road. The area is heavily wooded, and the station is somewhat concealed by the growth. The antenna foreground is flat until the river bank, and becomes flat again on the other side of the river. We set up the measurement system outside the meteor scatter station and placed the antenna on the access road. Figure 6.6-1. shows the meteor scatter station and the measurement setup. Measurements commenced on July 31 at 1700 and ended August 3 at 0700. The measurements were continuous except for 1400 to 2030 on August 1, when the antenna had fallen over.



Figure 6.6-1. Meteor Scatter Station at Galena. The measurement equipment is set up next to the station and the antenna placed on the access road.

Spectra, time sequences for 45 MHz, and time frequency charts are shown in Figures 6.6-2 to 6.6-9. The cumulative spectra show a evenly declining noise baseline, as would be expected for the galactic noise background. A second, lower baseline is also seen. This baseline is associated with the operation of the meteor scatter transmitter. The signal from the transmitter overloads the preamplifier used for the noise survey, and a depressed baseline results simultaneously with the recording of the transmitter spectrum. The low peaks on the time series at 45 MHz are also due to the operation of the transmitter. A rather small amount of spectral lines denoting occupied frequencies are seen, but wide band, low level noise or interference exceeding the base line by 2 - 4 dB is seen in the 43 to 49 MHz range. The origins of all signals except the meteor scatter transmitter are unknown.

One of the broad band noise signals happen to cover 45 MHz. The time sequences for this frequency show an invariant noise level 4-5 dB above the predicted noise level. No diurnal variation is seen. Thus this frequency is not galactically noise limited. Although the background noise level is slightly higher at Galena than at Kotzebue and Cape Lisburne, the data shows that the frequency range 40 to 43 MHz is almost free from noise and interference. Consequently galactically noise limited frequencies may be possible in this range, but a more detailed examination of the spectrum is needed to determine this.

The frequency-time charts, color coded for August 2 show the continual presence of both discrete spectral lines and broadband noise sources. The very strong periodical signals in the 40.5 to 42 MHz range originate from the meteor scatter transmitter. The spectrum occupancy and interference level are markedly higher than at Kotzebue and Cape Lisburne.

It must be concluded that the meteor scatter site at Galena is not in general galactically noise limited. However, a search for and elimination of nearby interference sources combined with a more detailed search for quiet frequencies may enable galactically noise limited frequencies to be obtained.

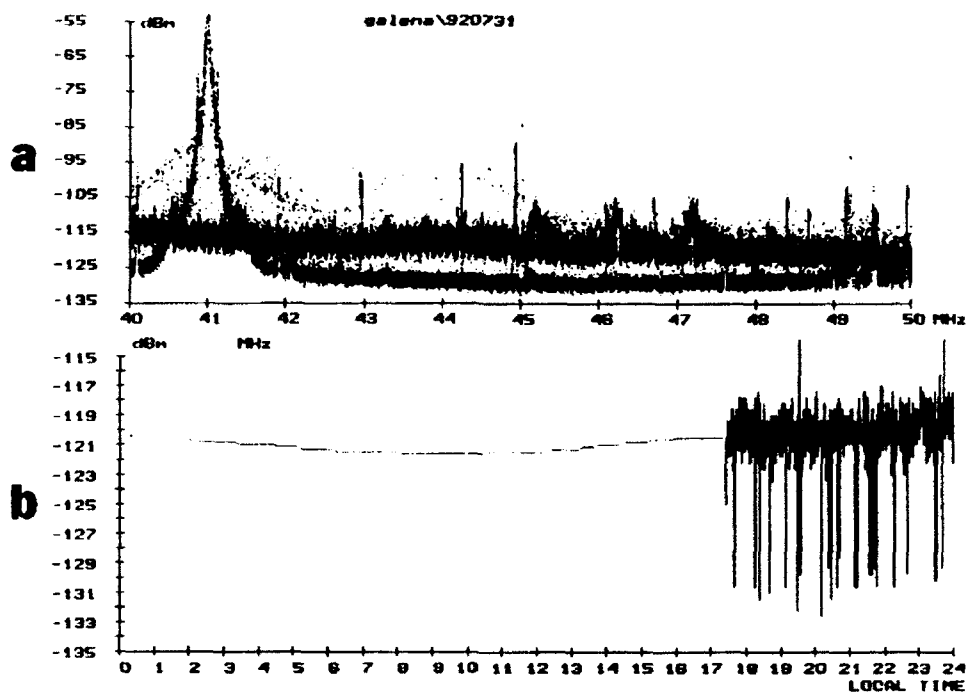


Figure 6.6-2. Galena AFB 31 July 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

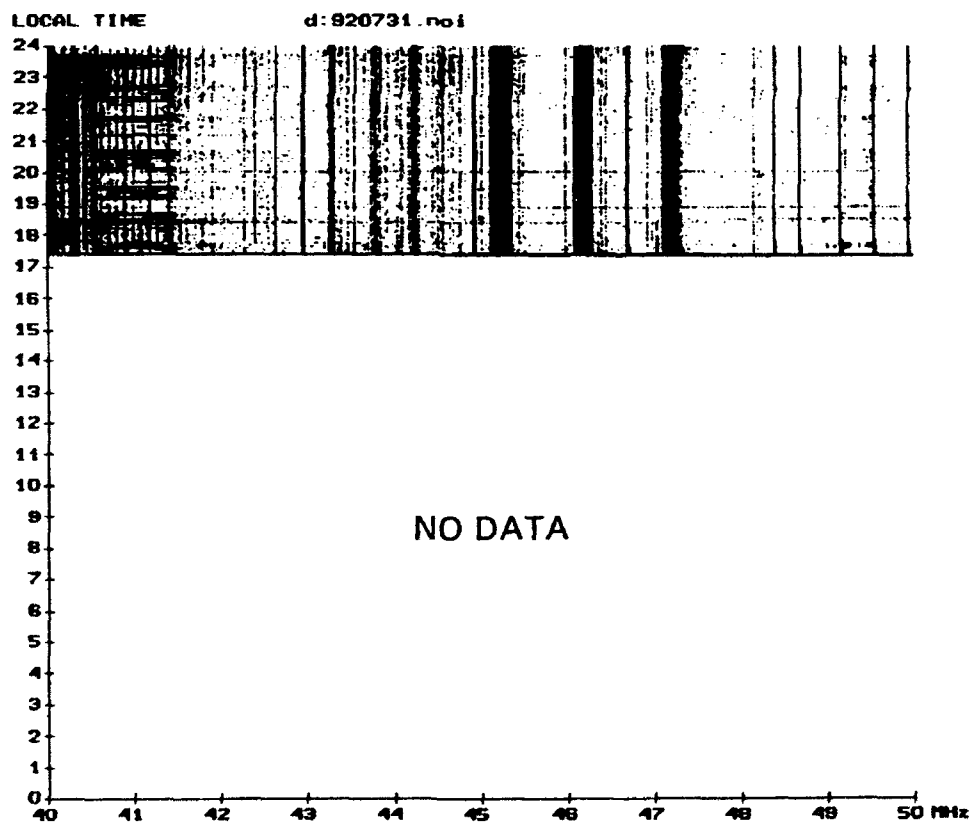


Figure 6.6-3. Galena AFB 31 July 1992. Time - Frequency Chart.

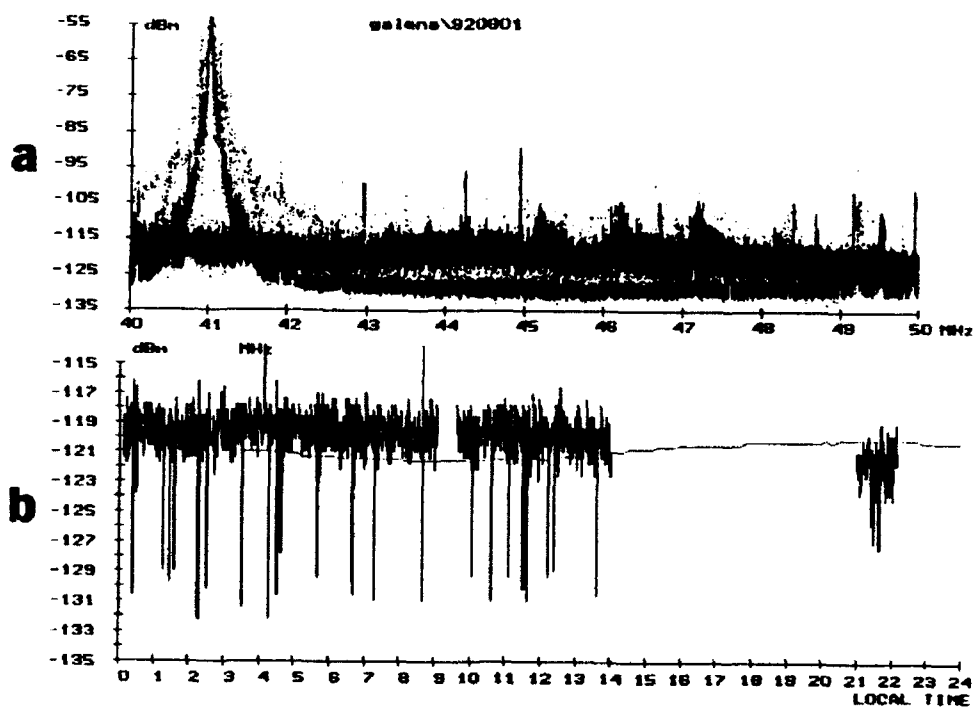


Figure 6.6-4. Galena AFB 1 August 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

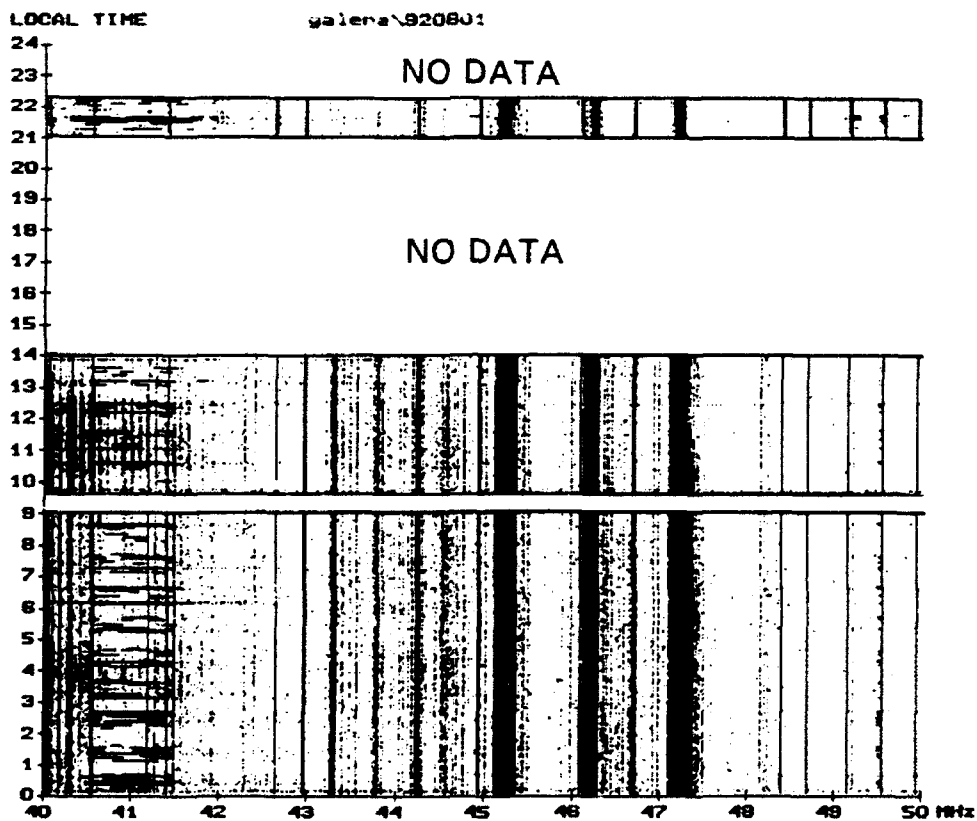


Figure 6.6-5. Galena AFB 1 August 1992. Time - Frequency Chart.

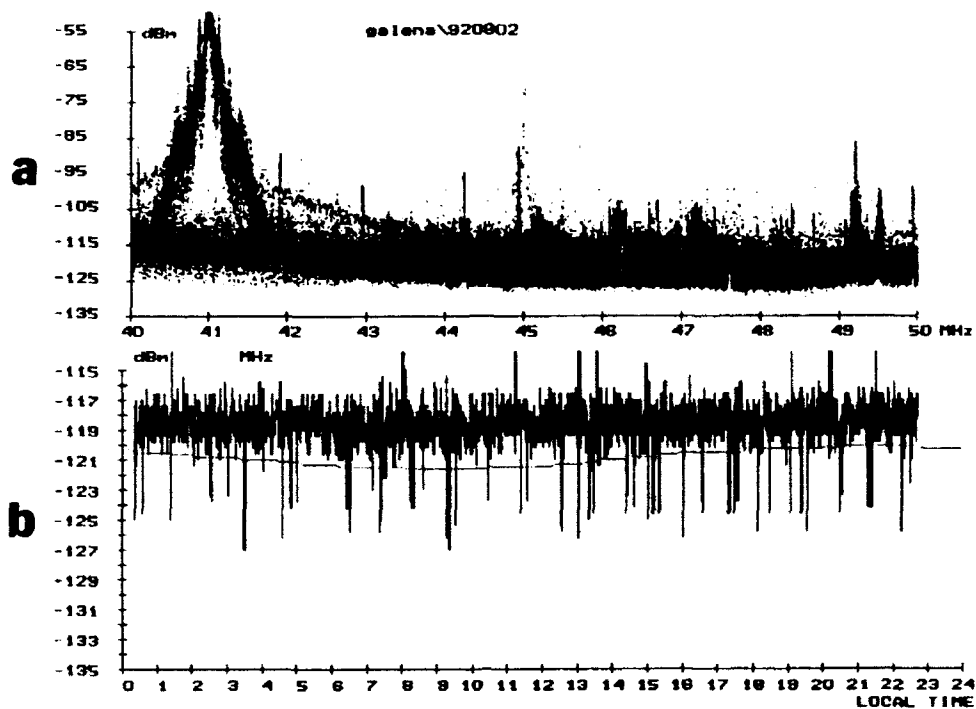


Figure 6.6-6. Galena AFB 2 August 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

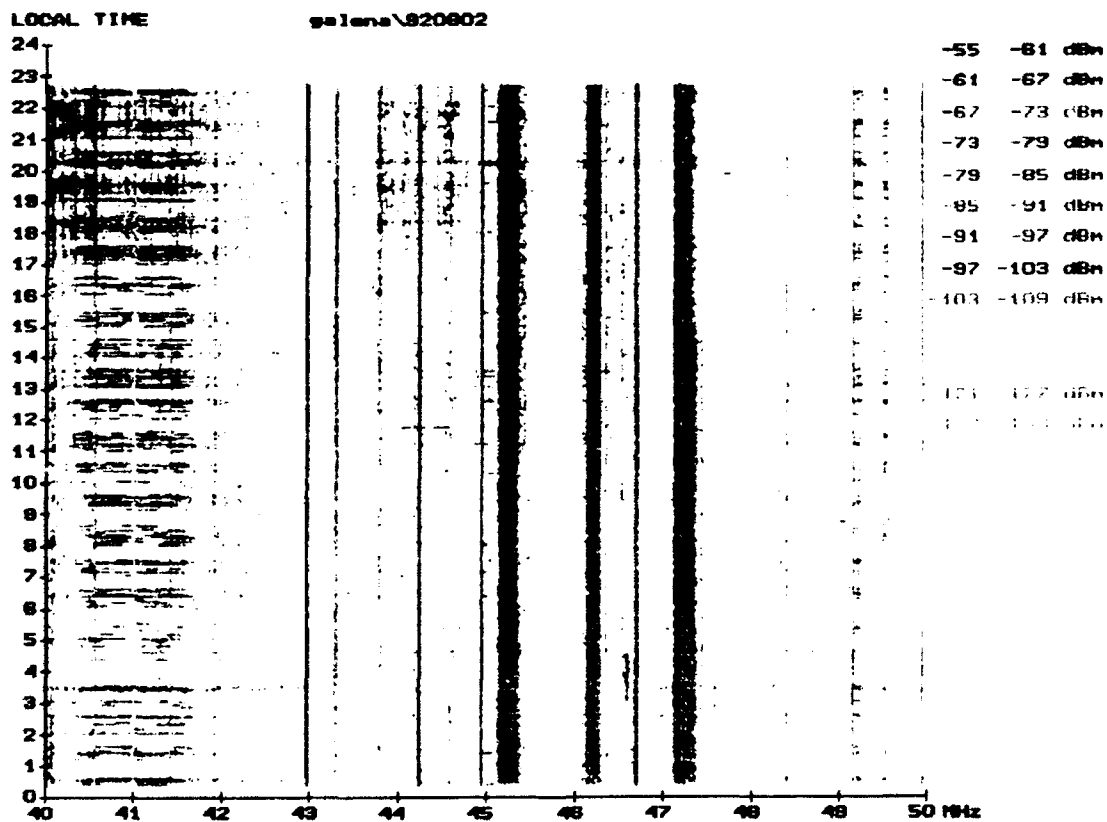


Figure 6.6-7. Galena AFB 2 August 1992. Time - Frequency Chart.

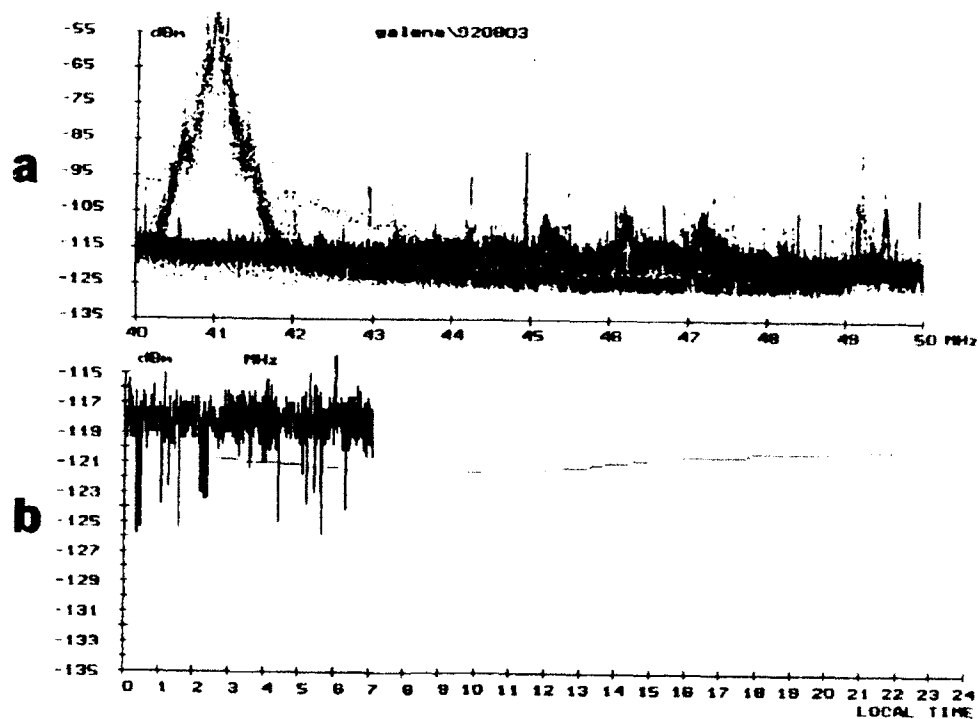


Figure 6.6-8. Galena AFB 3 August 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

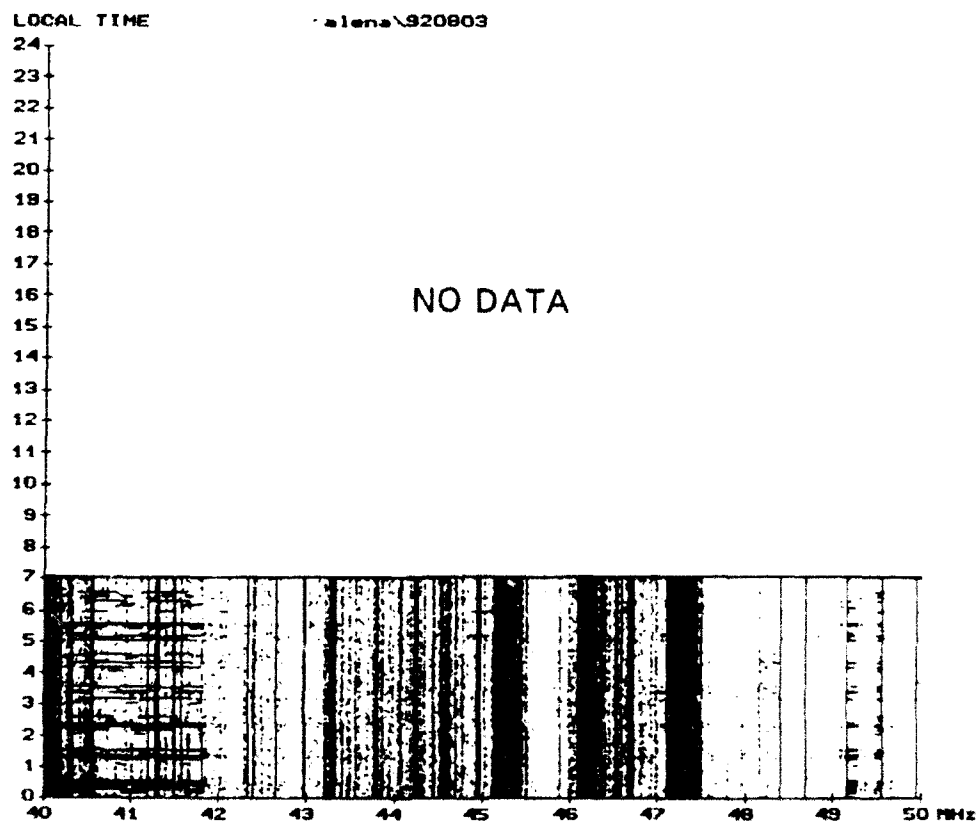


Figure 6.6-9. Galena AFB 3 August 1992. Time - Frequency Chart.

6.7 Kotzebue. Meteor Scatter and Army National Guard Sites.

Kotzebue is a town and administrative center with approximately 4000 residents. Access to Kotzebue is by a variety of airlines from Anchorage, Fairbanks, and other locations in Alaska. Originating as a fishing village, Kotzebue is located on the beach between the ocean and a shallow lagoon. The surrounding terrain is flat tundra with no obstacles on the horizon. Accommodations can be had in two places, at Drakes Camp or at the tourist hotel. We stayed at Drakes Camp, a very basic, but adequate and friendly place. Accommodations are in double rooms with two baths shared by all 12 guests. The camp has a common kitchen where meals can be prepared. The camp is the place to meet both travelers and local residents, drawn there by the affordable prices and the friendly hosts. If one need to do any desk related work, the camp is not so suitable due to the very social atmosphere and the eternal TV. The tourist hotel is more expensive and lacks local flavor, but is a viable alternative if space and quiet is needed for desk work. Kotzebue has a couple of restaurants, a pizza bar, and a couple of markets. We rented a car from Drakes Camp. The first car offered was a beat up truck on its last legs, as are most vehicles in Kotzebue. This broke down after 10 minutes, so we were offered the hosts car, a newer pickup in good condition. Rental prices are comparable to regular car rentals in the big cities.

The meteor scatter station is located by itself approximately 3 miles out of town between the radar station and the town. There are no other installations except power lines within 1 - 2 miles in any direction. Figure 6.7-1. shows the meteor scatter station relative to the radar station and downtown Kotzebue. However, the meteor scatter site is also a favorite berry picking, picnicking, and target practice area. This, along with the rain pouring down made the site unsuitable for unattended tent measurements. We visited the local FCC station, which is always manned and explained our predicament. We were kindly permitted by the station master to set our tent up in the stations courtyard. We also visited the Army National Guard facility located somewhat closer to the meteor scatter station. Here, we received a kind welcome and were allowed to set up the instrumentation in the garage. We chose the Army National Guard location due to its proximity, and thus hopefully more similar noise environment to the meteor scatter station. We were given all possible help by MSGT Bahma of the National Guard. The measurements began at midnight August 5 and ended at 0730 August 7. Figure 6.7-2. shows the antenna placed outside the National Guard facility and the measuring equipment in the garage.

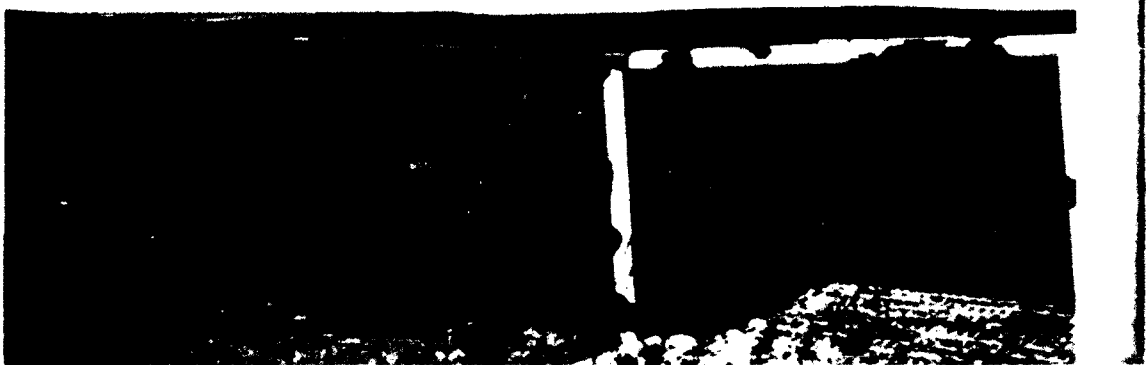
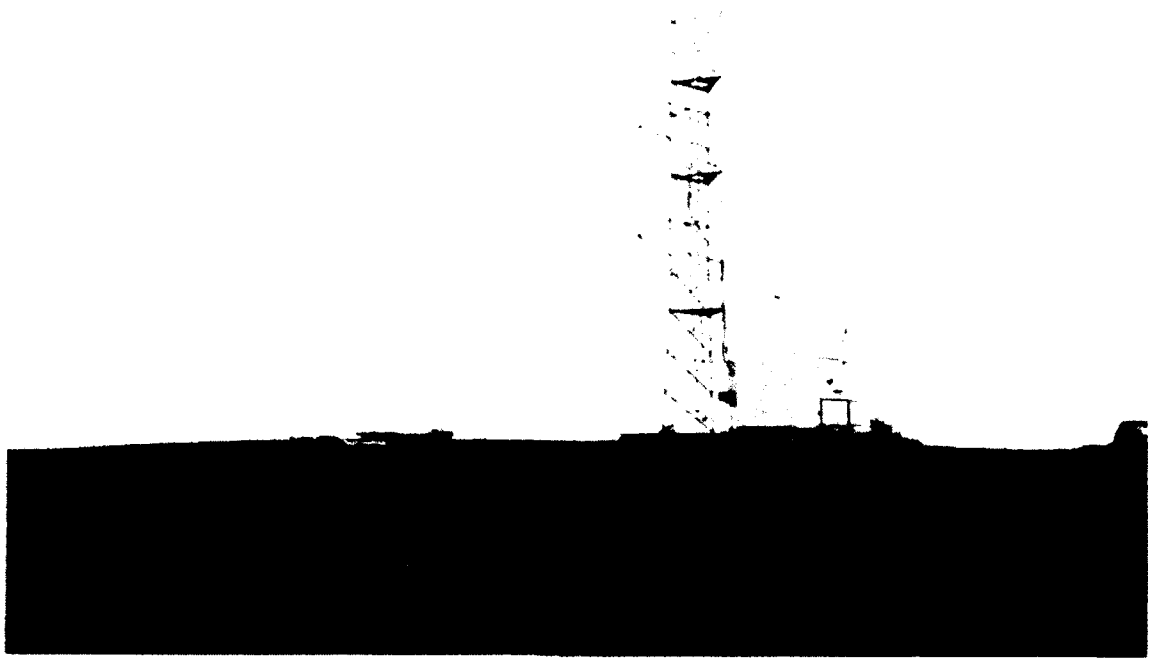


Figure 6.7-1. Location of the Meteor Scatter Station Relative to the Radar Station and Downtown Kotzebue. (Note the flat foreground terrain)

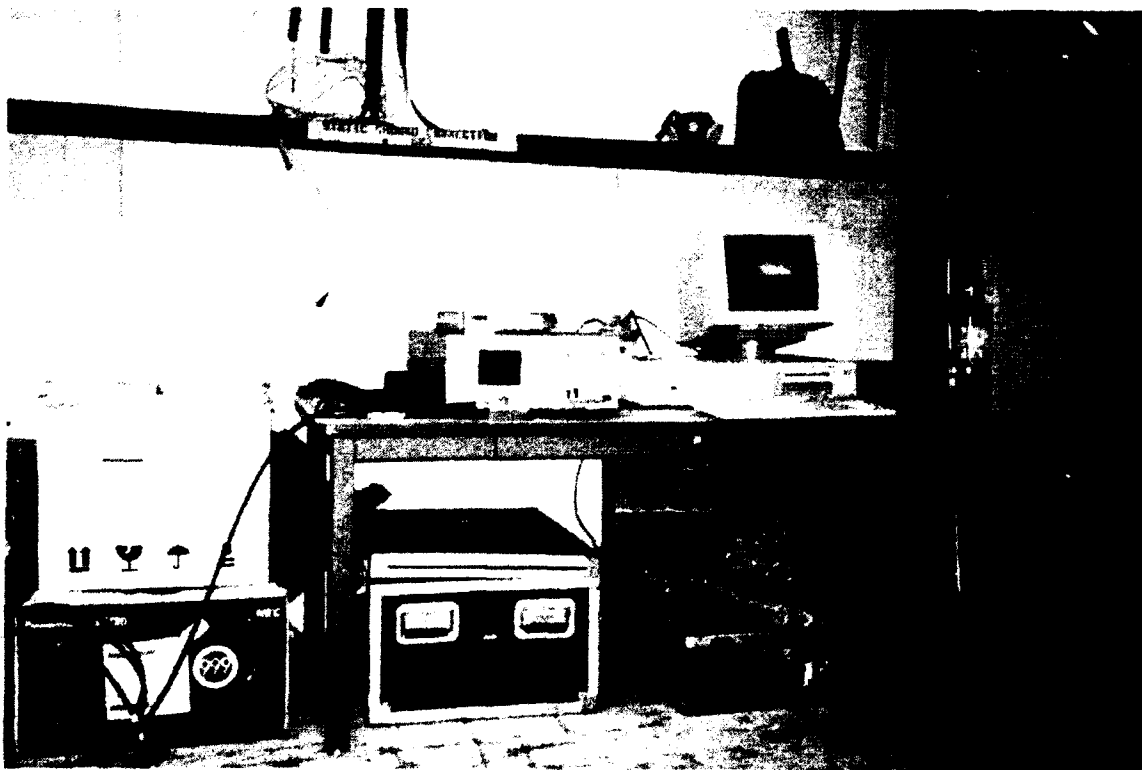
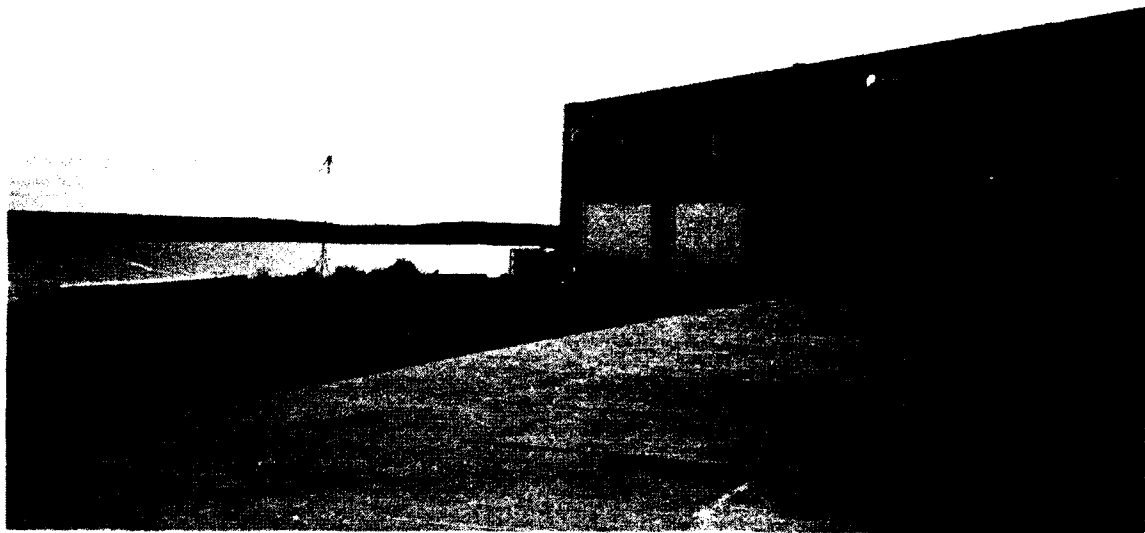


Figure 6.7-2. Measurement Set Up at the Army National Guard Facility in Kotzebue. The antenna is situated outside the parking area, and the measurement equipment inside the garage.

Spectra and time-frequency charts from the measurements at Kotzebue are presented in Figures 6.7-3 to 6.7-8. The cumulative spectra show a noise baseline decreasing evenly with frequency with relatively few spectral lines of any magnitude, therefore few frequencies are in use. Also, wide band noise events of limited duration, as well as a wideband noise component, are seen on August 6. A very strong spectral line at 41 MHz probably originates from the meteor scatter transmitter. The origin of the other very strong line at 50 MHz is not known.

The time scans at 45 MHz show little deviation from the predicted noise level, except for a few hours during the day when the noise is slightly enhanced. The short lived noise spikes can be attributed to vehicles, aircraft and occasional use of the radio equipment at the National Guard facility.

The frequency - time charts, color coded for August 5, show very little spectrum use, and it must be concluded that the Army National Guard facility in Kotzebue is essentially galactically noise limited. No noise or interference exceeding the galactic background was found during night hours, and only some slight enhancement of the background was found during daytime.

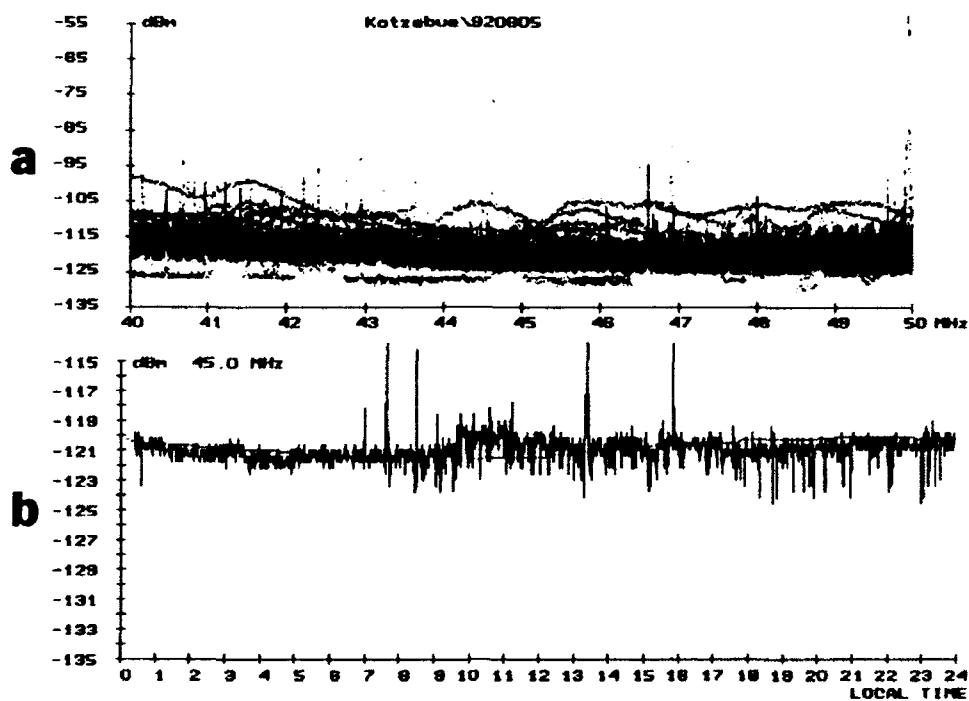


Figure 6.7-3. Kotzebue 5 August 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

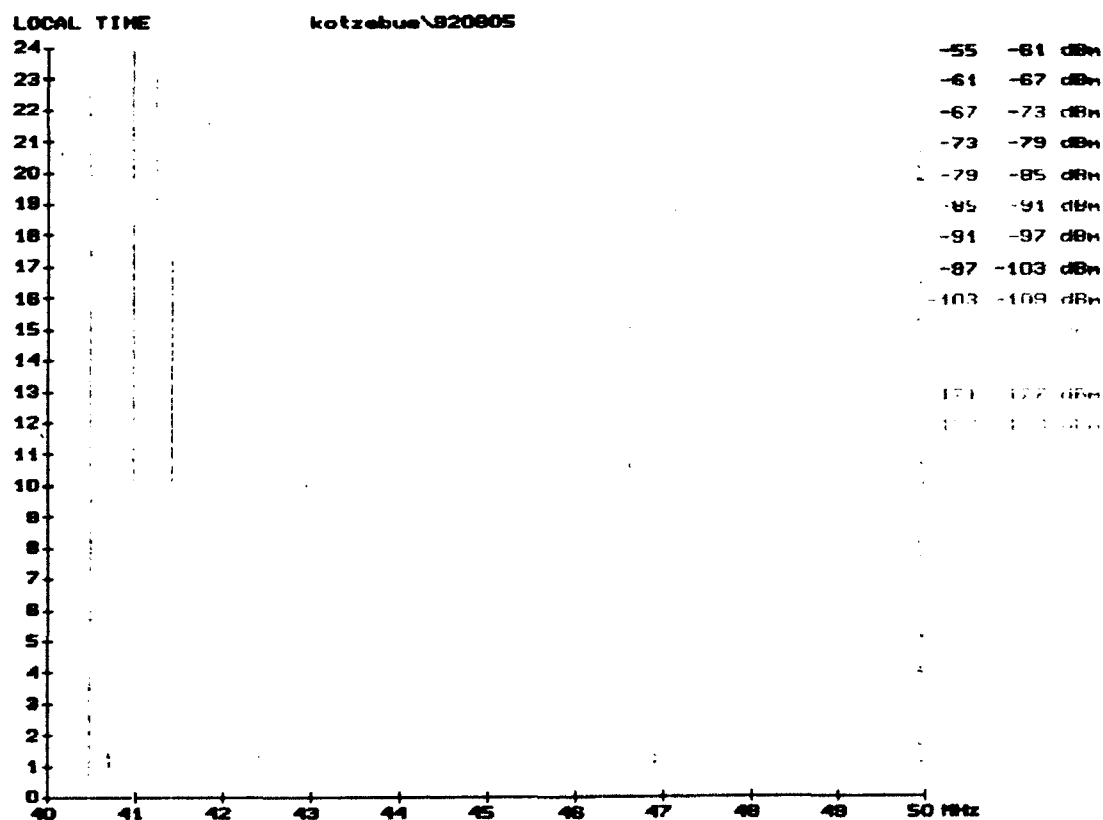


Figure 6.7-4. Kotzebue 5 August 1992. Time - Frequency Chart.

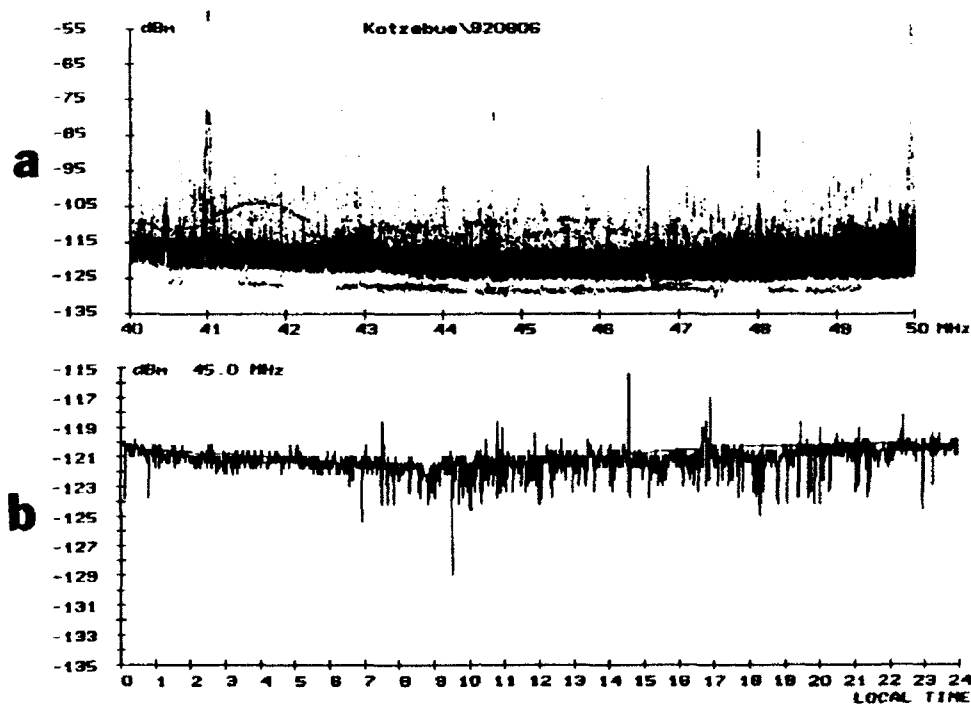


Figure 6.7-5. Kotzebue 6 August 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

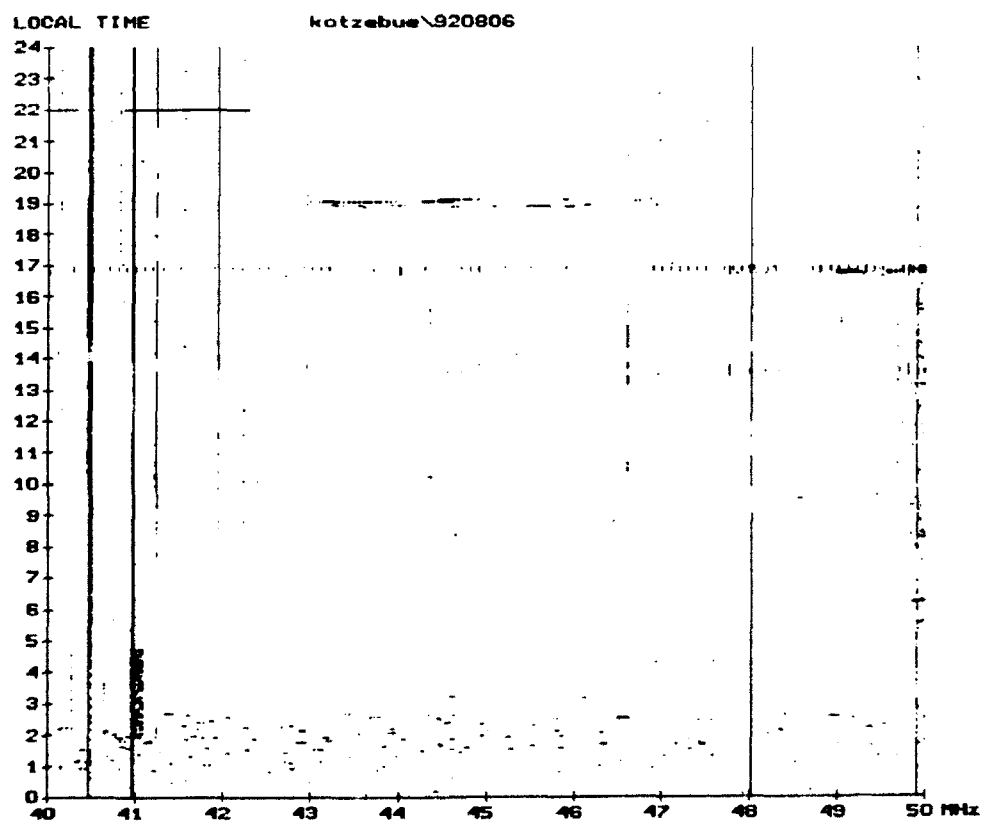


Figure 6.7-6. Kotzebue 6 August 1992. Time - Frequency Chart.

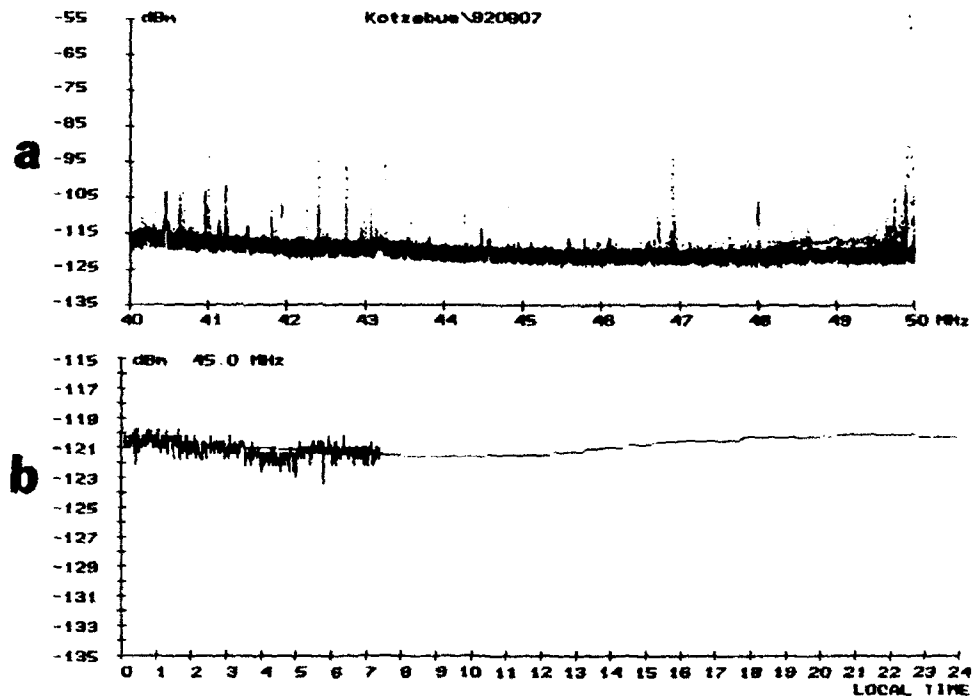


Figure 6.7-7. Kotzebue 7 August 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

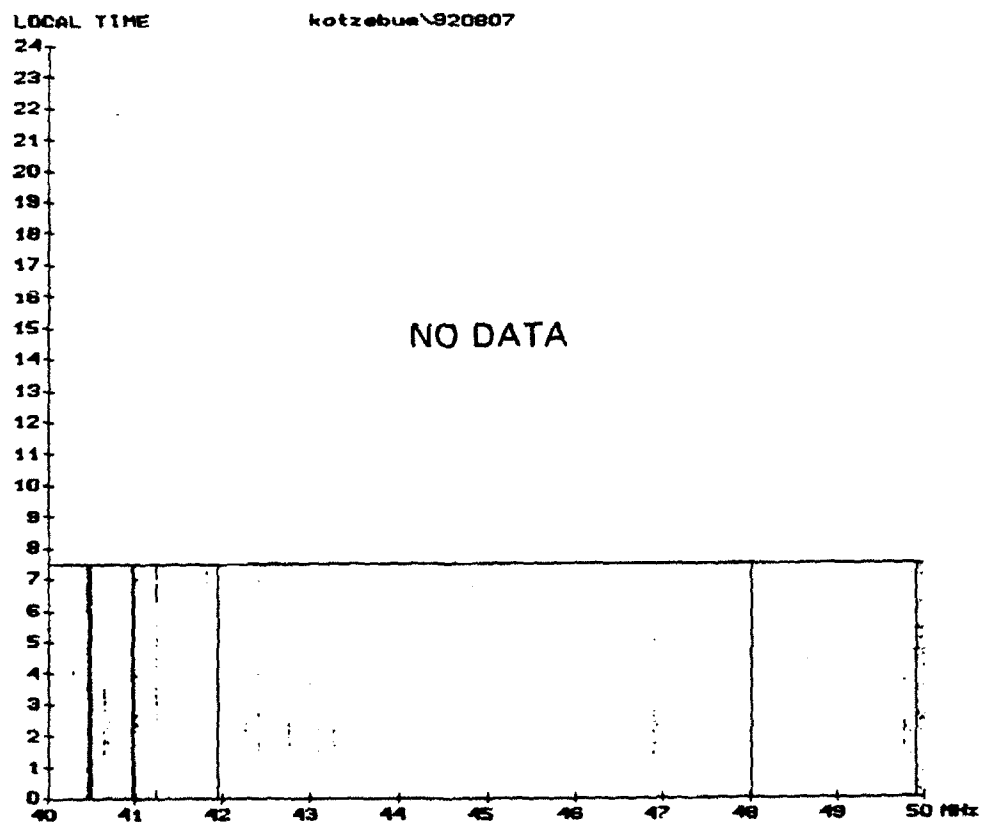


Figure 6.7-8. Kotzebue 7 August 1992. Time - Frequency Chart.

6.8 Cape Lisburne. Meteor Scatter Site.

The Cape Lisburne meteor scatter station is located near the north-western corner of Alaska, the manned radar station is located on the north shore. Access is by permission only and transportation is by chartered airplane from Kotzebue. There are no other facilities or settlements near the site. The Alascom satellite ground station and the meteor scatter facility are both located approximately 0.5 miles from the station complex. The horizon is unobstructed to the north of the site over the ocean, but is limited to the south by a range of mountains. The meteor scatter station is located so the direction to Elmendorf is through a valley in the mountains. The foreground is thus reasonably flat for approximately 1 mile in front of the antennas, and then gently sloping up through the valley, Figure 6.8-1.

We arrived in the early evening and were well received at the station. We were allowed to set up in the yard of the station complex for a night of measurements. The measurement equipment was set up in the station wood shop as shown in Figure 6.8-2. The next morning the equipment was moved to a location just outside the meteor scatter facility and two days of measurements were performed in this location, Figure 6.8-3. and Figure 6.8-4. Both the station personnel and the Alascom representative in residence were most helpful during the stay. Accommodations at the station are very good, with comfortable rooms where it is possible to do desk work. Meals are available in the station's dining room. The bill must be settled in cash prior to departure.

Spectra and time-frequency plots are found in Figures 6.8-5. to 6.8-12. The first nights measurements in the station courtyard lasted from 2100 on August 8 to 0430 on August 9 when the antenna fell over. The measurements were resumed at 0900 and continued through 1330 on August 11. During this period, the equipment failed between 0145 and 0830 on August 10, caused by rain water in the preamplifier. The cumulative spectra from the first nights measurements show the noise floor evenly decreasing with frequency, and a number of narrow band signals exceeding the background noise by up to 40 dB. The cumulative spectra for the rest of the period when measurements were performed next to the meteor scatter station and in the near vicinity of the satellite ground station show the same spectral lines and also a large number of spectral lines with less amplitude in the frequency range of 43 to 50 MHz. The signal from the meteor scatter transmitter can be seen at 41 MHz. The background noise is larger than at the courtyard site by 1 to 2 dB, and shows an increase during the daytime on August 10. This is most clearly seen on the time scans of the 45 MHz signal. The time scans also show that the background noise at 45 MHz is very close to the predicted galactic levels.

The time-frequency charts, color coded for August 9, support these findings. The spectrum occupancy increased significantly when the

measurement system was moved from the courtyard to the meteor scatter station. Signals occurring every hour in the range 40 - 42 MHz are noted at both locations. The sources of spectral lines and the noise increase are not known, but it is suspected that some signals originate from the meteor scatter facility and the satellite ground station. Measurements show however, the noise is less at this location than at Galena.

It can be concluded the meteor scatter site at Cape Lisburne was galactically noise limited within 1 to 2 dB during the measurements, and frequencies free from noise and interference can be found.



Figure 6.8-1. Cape Lisburne Station. The courtyard, meteor scatter and satellite ground stations are marked.



Figure 6.8-2. Noise Measurement Equipment in the Wood Shop at Cape Lisburne.

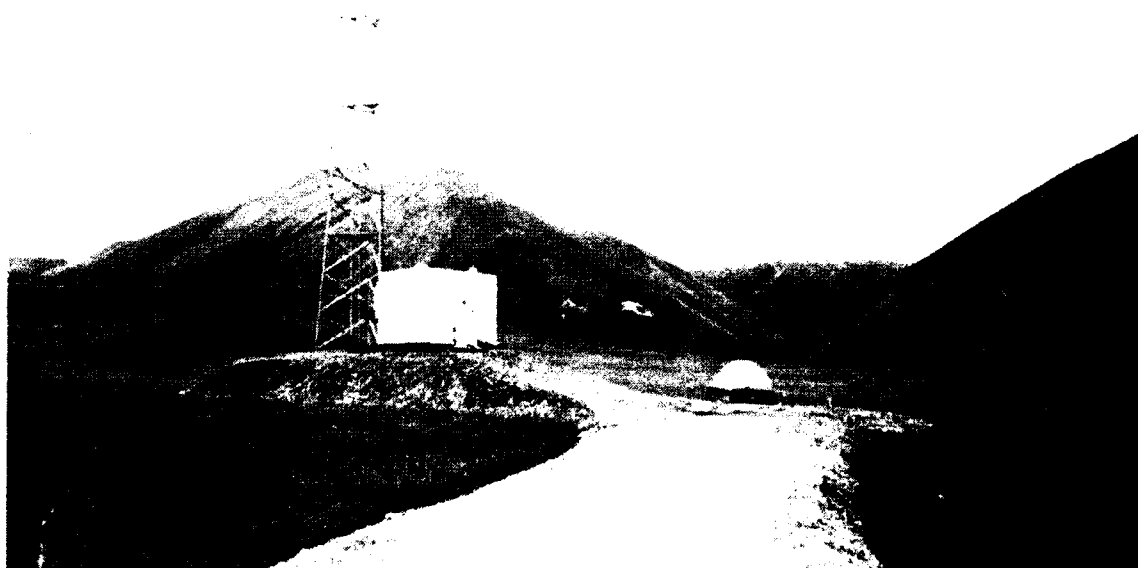


Figure 6.8-3. Meteor Scatter Station at Cape Lisburne with Measurement Set-up.



Figure 6.8-4. Meteor Scatter Station and Satellite Ground Station at Cape Lisburne.

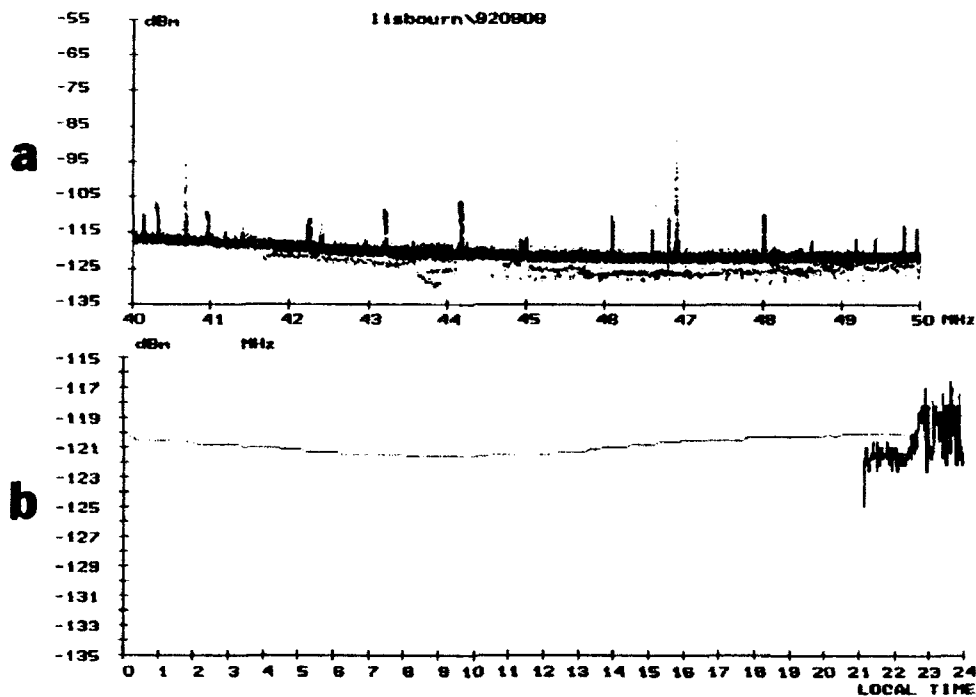


Figure 6.8-5. Cape Lisburne 8 August 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

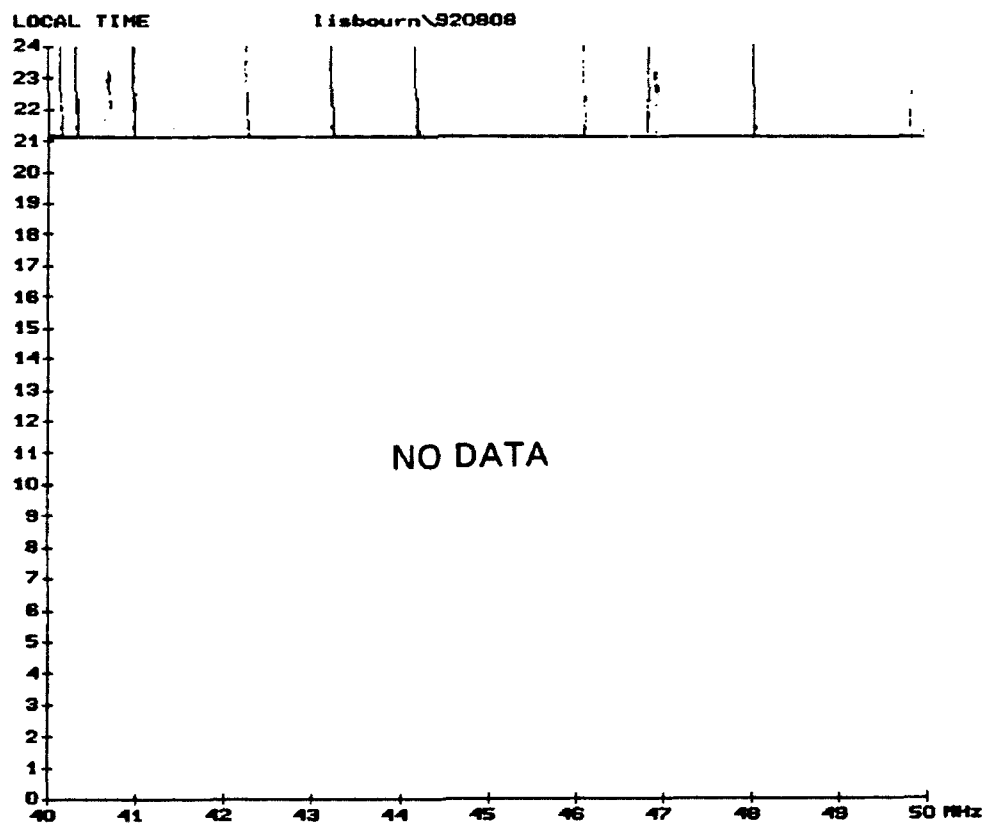


Figure 6.8-6. Cape Lisburne 8 Aug. 1992. Time - Frequency Chart.

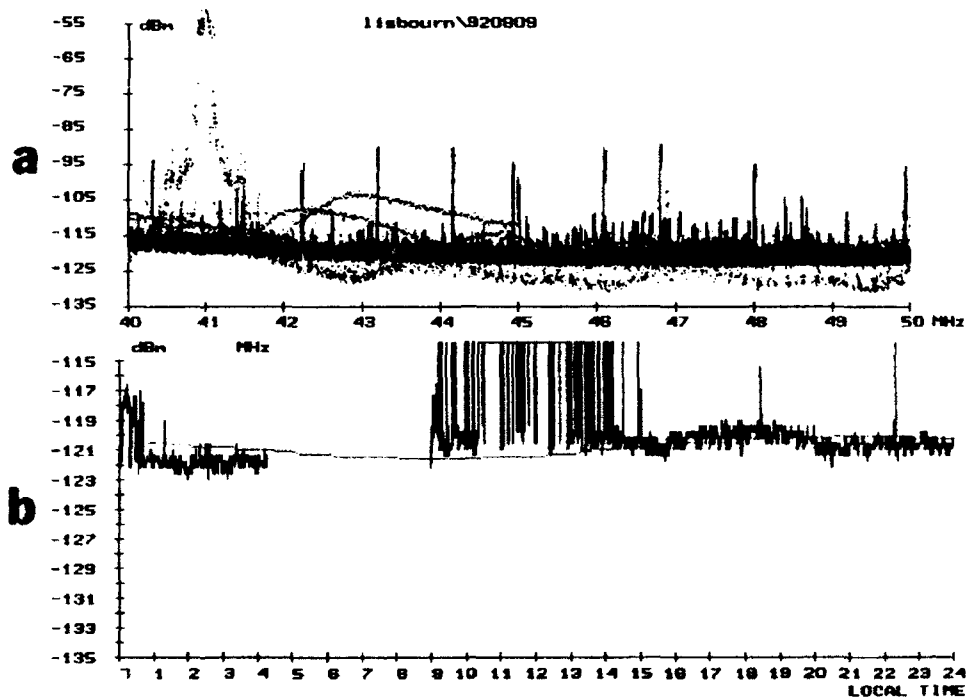


Figure 6.8-7. Cape Lisburne 9 August 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

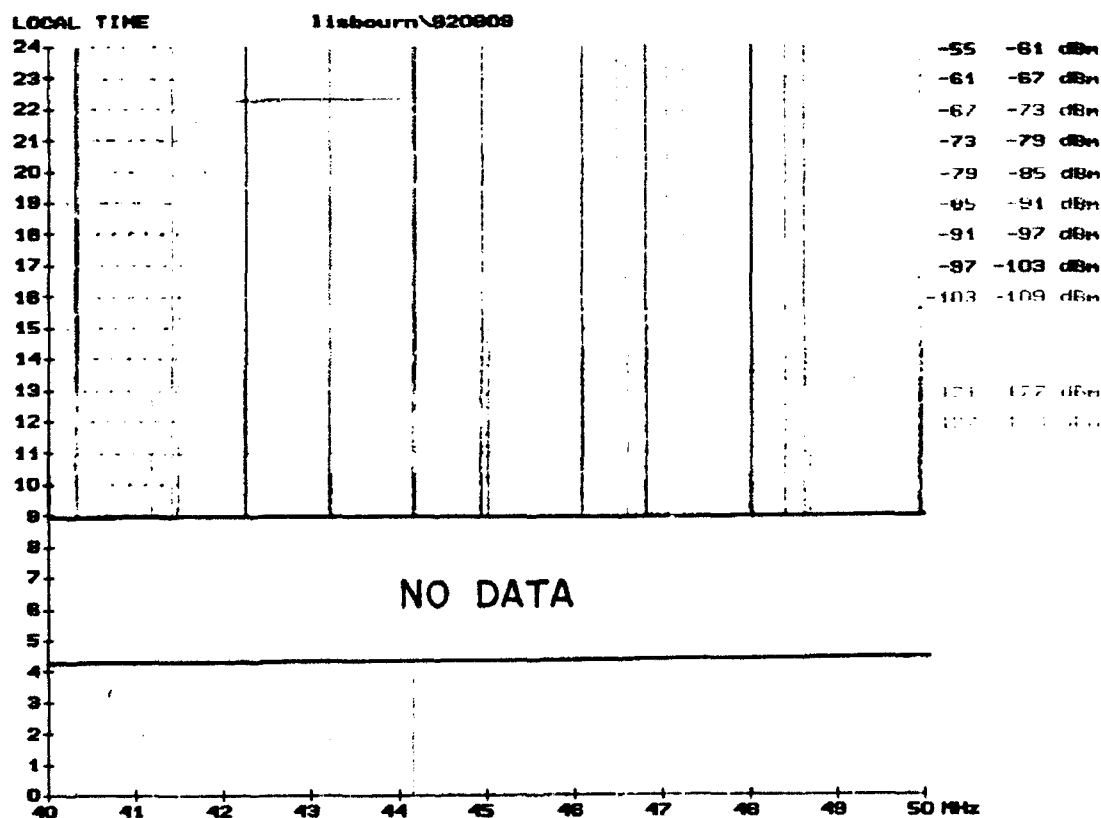


Figure 6.8-8. Cape Lisburne 9 Aug. 1992. Time - Frequency Chart

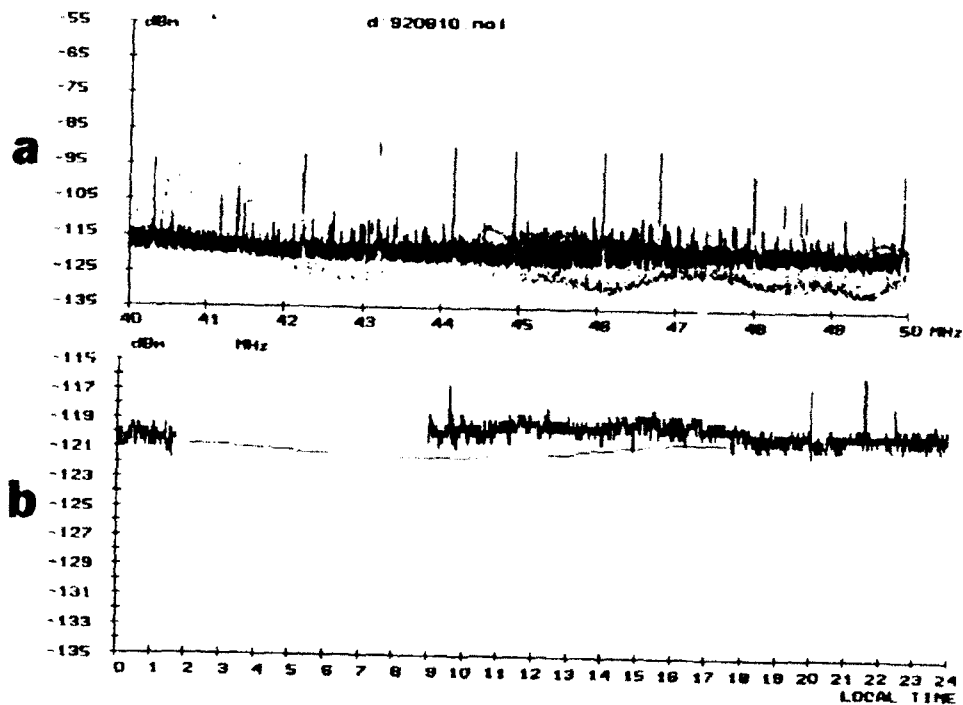


Figure 6.8-9. Cape Lisburne 10 August 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

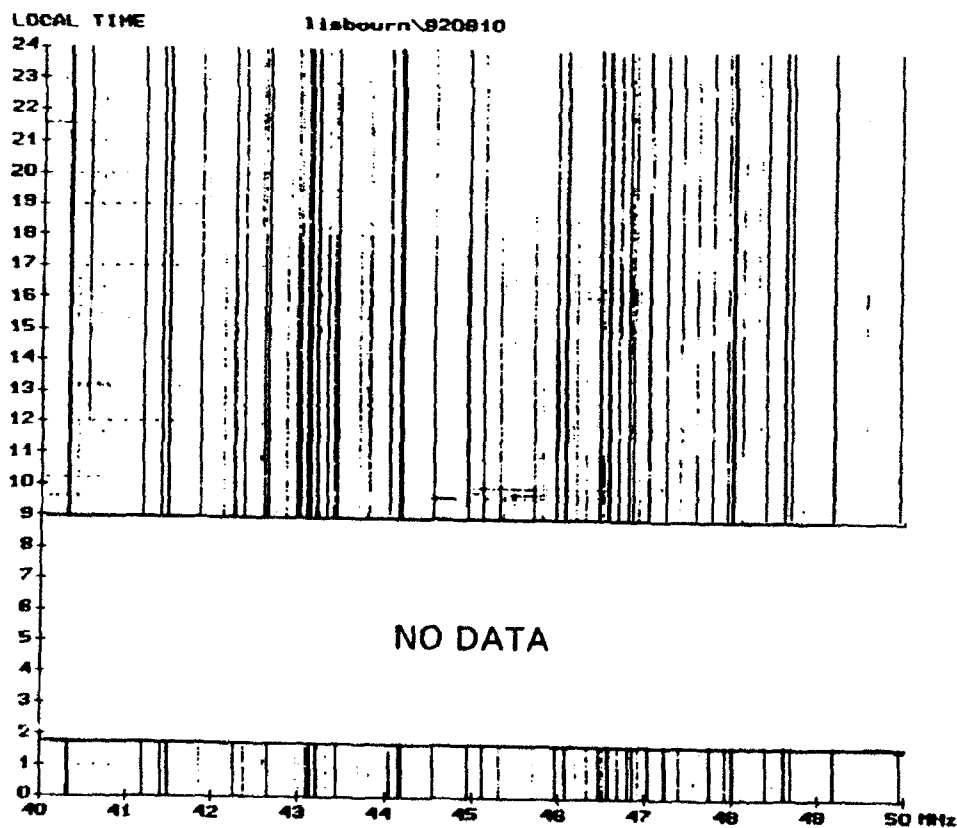


Figure 6.8-10. Cape Lisburne 10 Aug. 1992. Time - Frequency Chart.

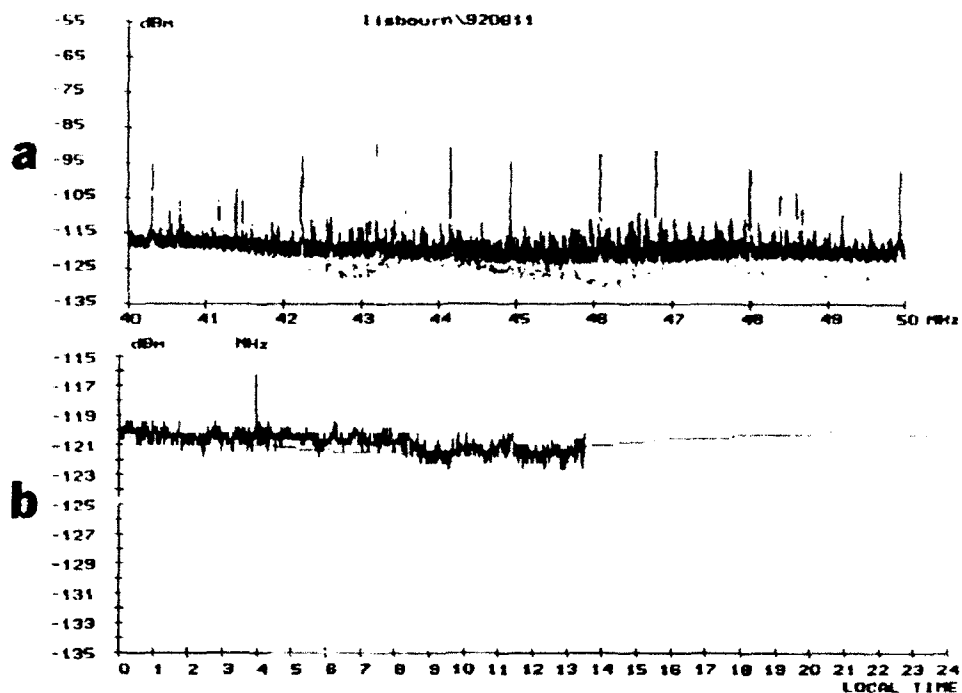


Figure 6.8-11. Cape Lisburne 11 August 1992.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

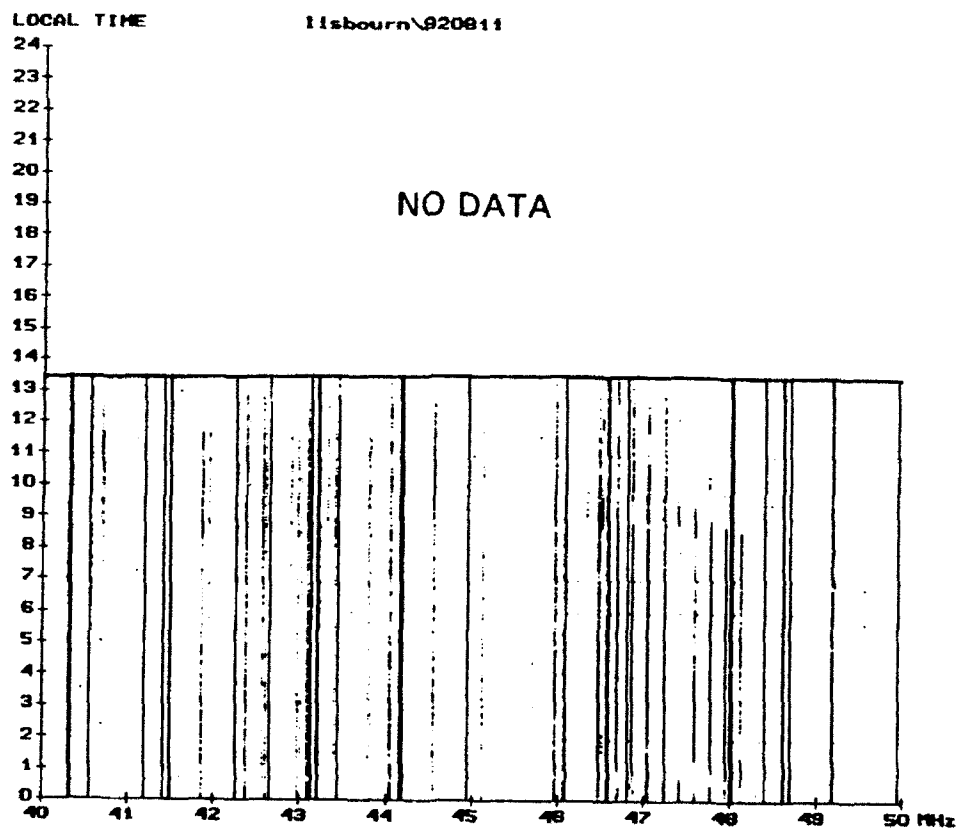


Figure 6.8-12. Cape Lisburne 11 Aug.1992. Time - Frequency Chart.

6.9 Naval Research Laboratory, Washington DC and Pomonkey, MD.

Limited noise surveys at 40 - 50 MHz have been performed at the Naval Research Laboratory (NRL) in Washington DC and at the NRL site at Pomonkey, Maryland. These surveys were performed as part of a feasibility study to measure the meteor scatter channels dispersion characteristics using the NRL channel probing facility and a PL diagnostic meteor scatter link. The link was composed of a transmitter at Sudbury, MA, and a receiver at NRL or Pomonkey respectively. The results are included in this report as examples of an extreme urban site and a rural site on the East Coast of the United States. Photographs of the two sites are not available.

The noise survey at NRL was performed with a 5 element Yagi antenna pointing NE towards Sudbury in combination with a broadband preamplifier. The selectivity of the antenna provided the necessary band limiting. The antenna was mounted on a 20 foot tower on top of a building centrally located in the NRL laboratory complex. This particular building and supposedly others in the vicinity house a large number of PC computers and other modern day office equipment, causing expectations of a high noise levels.

The NRL site at Pomonkey is a receiver site situated in a rural area of Maryland. A small airport and a some towns are situated 2 to 4 miles from the site. Several radio towers, presumed to be used by police, fire departments, and other dispatch services, are found within a few mile radius of the NRL site. The noise survey at Pomonkey was performed with the discone antenna placed on a lawn, 100 feet from a small building housing the measuring equipment. The set up was similar to the one used in Alaska, except a 40 - 50 MHz band limited preamplifier was used.

The results of the two surveys are shown in Figures 6.9-1. to 6.9-6. The survey at NRL lasted from February 3 at noon to February 4 at 0830. The survey at Pomonkey lasted from 1430 to midnight on February 4. This survey was terminated early by a power line glitch at Pomonkey. The cumulative spectra and time series at 46.7 MHz from NRL show a very high level of spectrum occupancy, noise and interference throughout the 40 - 50 MHz frequency range. The noise at 46.7 MHz exceeded -95 dBm for a prolonged period during the afternoon on Feb. 4., and a period of 5 hours between 0100 and 0600 on Feb. 4, defining the noise floor at approximately -104 dBm. When comparing the time series at 46.7 MHz at NRL with the time series from Pomonkey it should be noted that the Y-axis scales differ by 20 dB for the 2 locations. The levels presented from NRL are in the range -95 to -115 dbm, whereas the levels presented from Pomonkey are in the range -115 to -135 dBm. The expected galactic noise floor for an antenna pointed North at mid latitudes is in the -121 to -124 dBm range. Thus the noise at NRL is 17 to 20 dB above the galactic noise at best. The time frequency charts show the highest levels of noise and interference to be present during the evening hours between 1900 and 2300. This may

imply that a large part of the interference originates from consumer electronics in nearby residential areas as well as from the use of computers during work hours at NRL. The site must be considered an example of a very noisy urban environment and not well suited for meteor scatter communication systems.

The cumulative spectra for the Pomonkey site show much less spectrum occupancy and noise than at NRL in Washington DC. The uneven baseline is due to the frequency dependent mismatch between the antenna and the band limited preamplifier. The data shown is absolutely calibrated, but the response of the amplifiers two pole band pass filter increases the noise floor at frequencies less than 44 MHz. The time series for 46.7 MHz show the expected noise level of approximately -125 dBm during most of the late evening hours. The signals present in the afternoon and occasionally during the evening hours are due to a local dispatch radio transmitter, possibly operated by the police or fire department. The frequency of 46.7 MHz is allocated for diagnostic meteor scatter links in the CONUS, but this frequency is not suitable for operation at Pomonkey due to the local transmitter. However, the 44 to 45 MHz range was seen to feature both low noise and low interference from other users. A frequency in this range may be useful for meteor scatter studies. The time frequency chart shows that a few signals were continuously present and the majority of the intermittent signals disappeared after 1730. Thus, they may be attributed to electrical equipment used during work hours. Again, the 44 - 45 MHz range was seen to be virtually unoccupied, and should be examined in more detail for a suitable frequency for a meteor scatter link.

A diagnostic meteor scatter link receiver was operated at 46.733 MHz with a signal bandwidth of 1 kHz and 130 kHz. At NRL in Washington DC only one meteor trail return was received, whereas at Pomonkey a steady stream of signals were received, interrupted only by the local transmitter when the 130 kHz receiving bandwidth was used.

In conclusion, the Washington DC NRL site is not suited for meteor scatter. The Pomonkey site while not entirely quiet, is probably usable for meteor scatter communication providing a frequency not in use locally can be found and allocated.

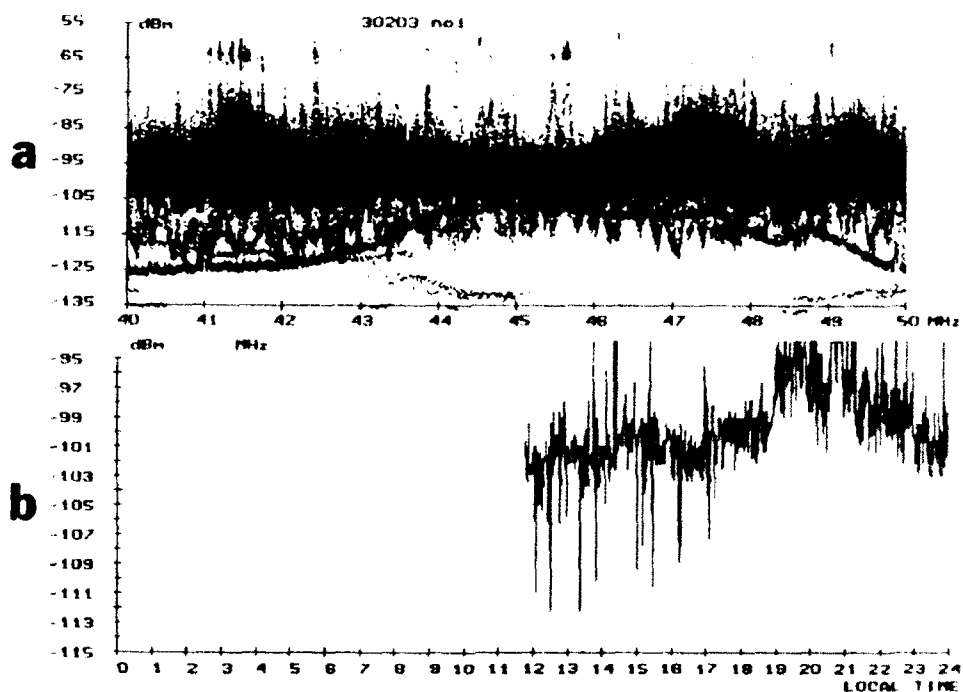


Figure 6.9-1. NRL 3 February 1993.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

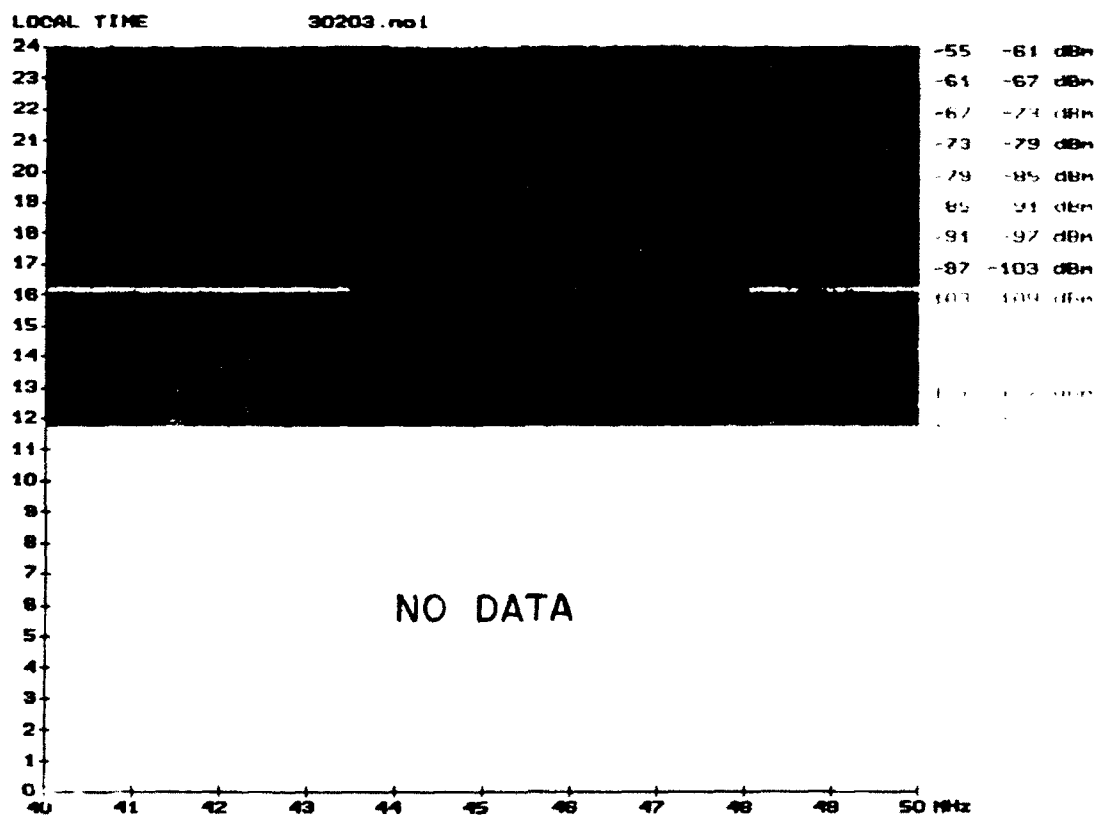


Figure 6.9-2. NRL 3 February 1993. Time - Frequency Chart.

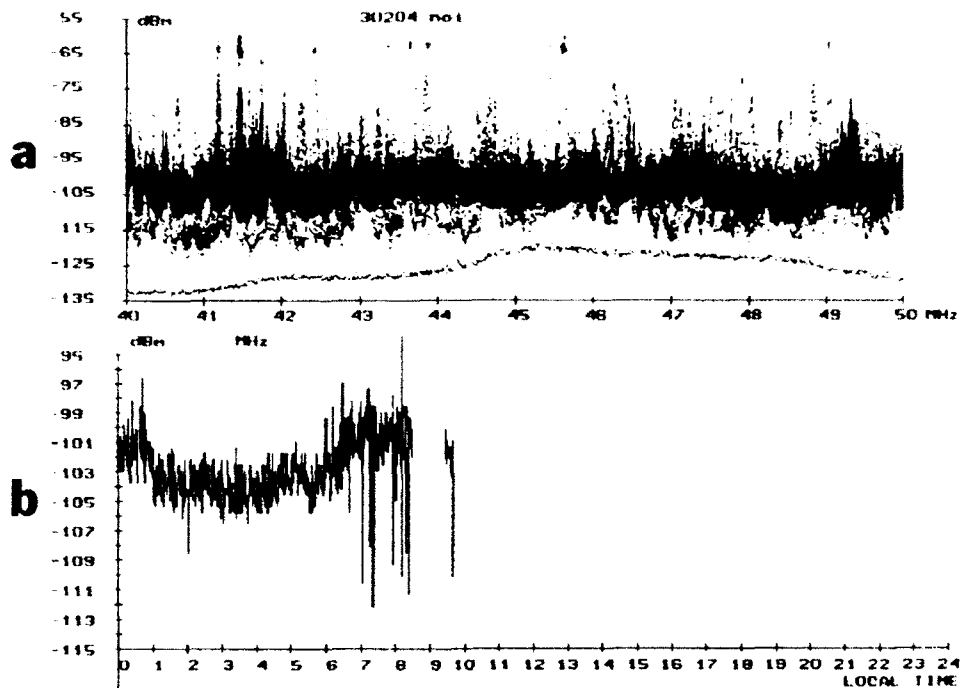


Figure 6.9-3. NRL 4 February 1993.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

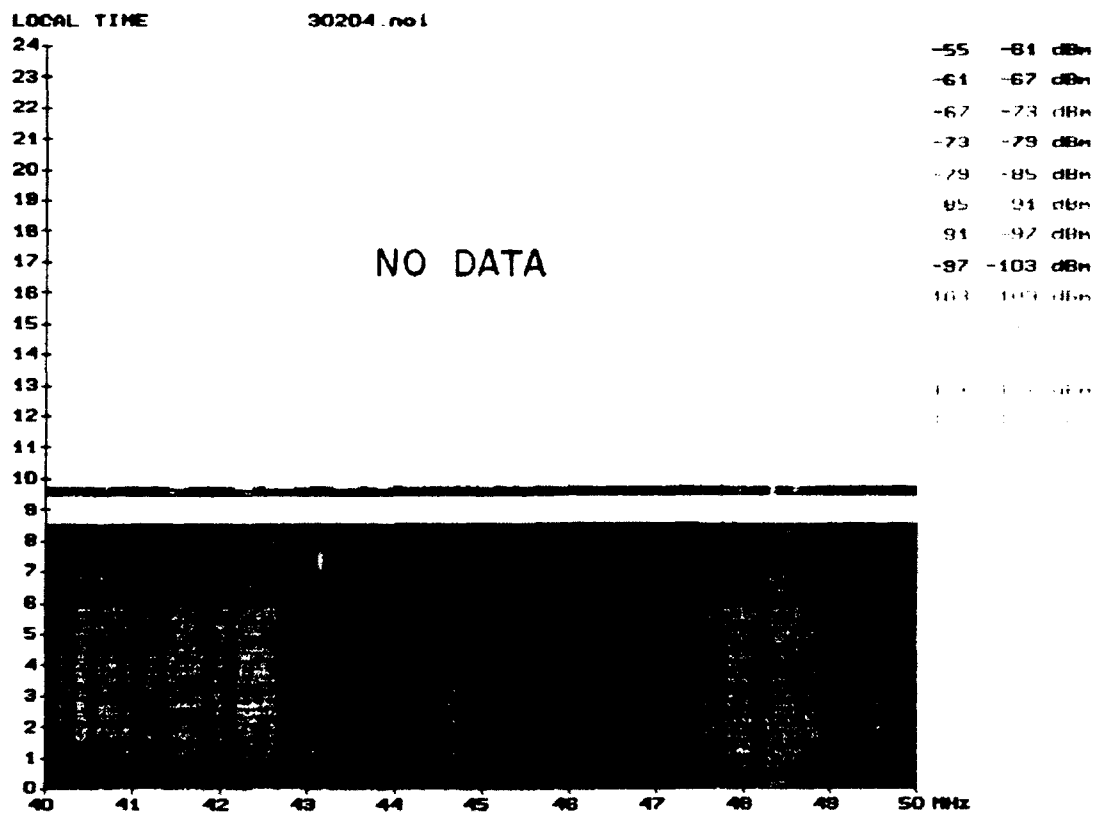


Figure 6.9-4. NRL 4 February 1993. Time - Frequency Chart.

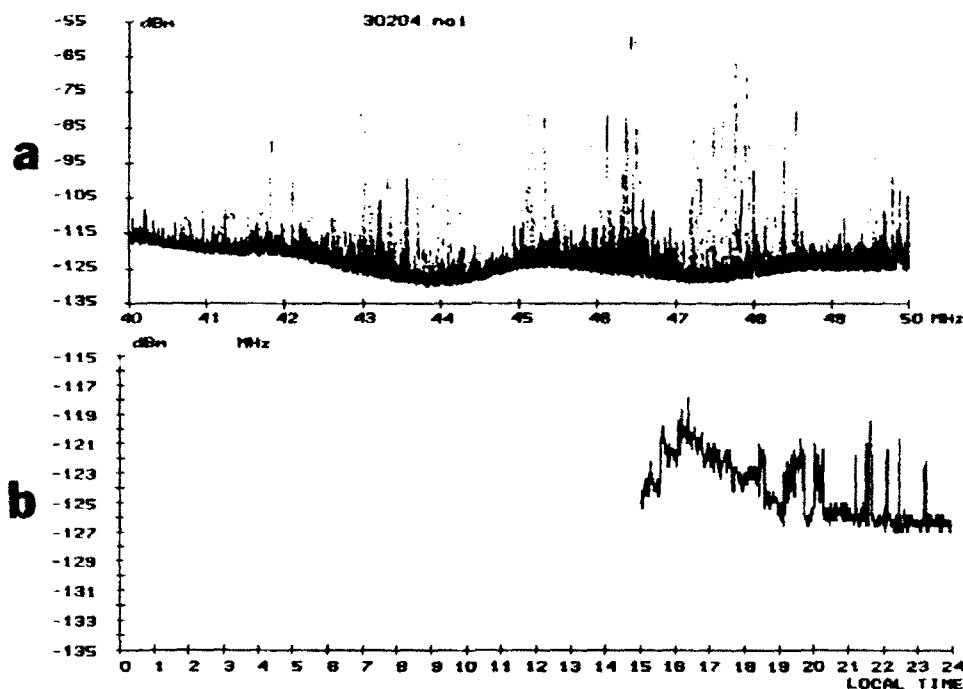


Figure 6.9-5. Pomonkey 4 February 1993.
 a. Cumulative Spectra 40 - 50 MHz.
 b. Time Series for 45 MHz.

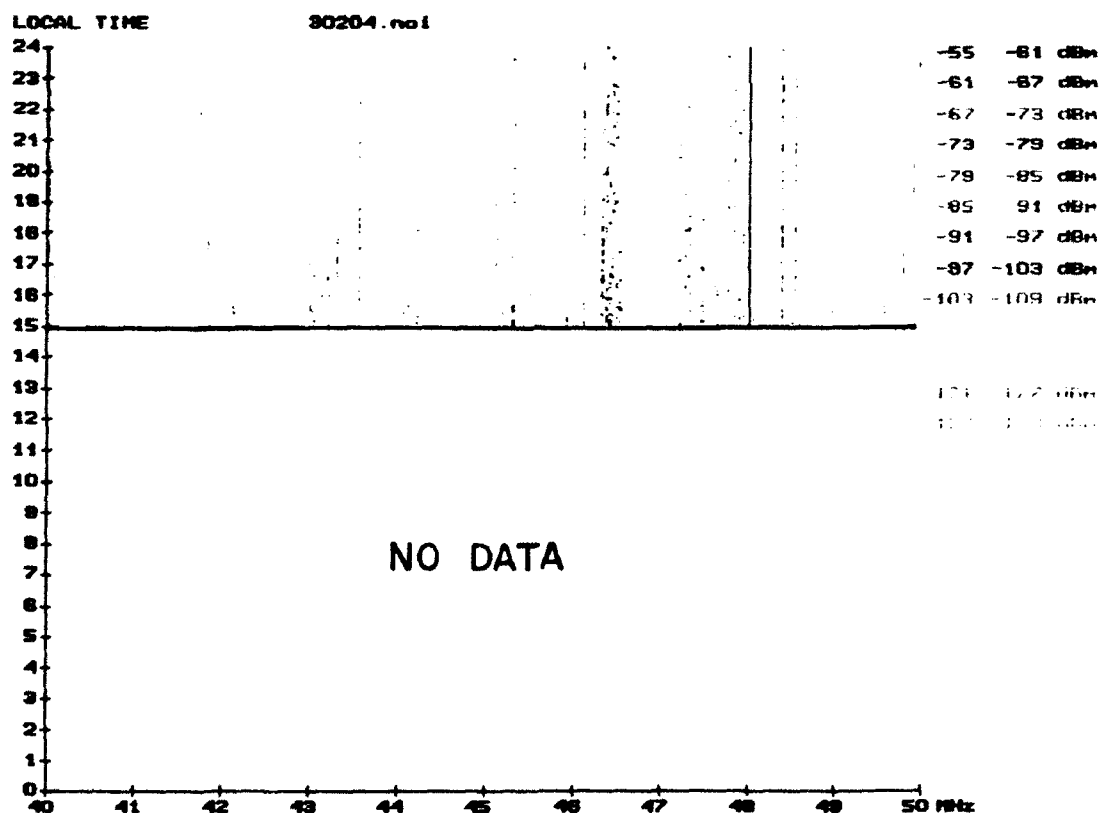


Figure 6.9-6. Pomonkey 4 February 1993. Time - Frequency Chart.

7. Summary.

* The noise surveys performed have determined the proposed HAARP site at Gulkana to be essentially galactically noise limited in its current configuration (between 30 and 50 MHz) except for limited usage.

* The 410 - 450 MHz spectrum is virtually unoccupied at the Gulkana site, except for a few signals in the amateur radio band 432 to 438 MHz.

* The HF spectrum usage at the Gulkana site follows the expected patterns for a high latitude location in summer. Very strong signals are present throughout the night, and the presence of the ionosphere's E-layer suppresses long distance propagation into the site of low HF frequencies during daylight. Consequently the site is relatively quiet at frequencies less than 5 or 6 MHz during the day.

* None of the meteor scatter sites surveyed at Elmendorf AFB were found to be galactically noise limited, and all three sites had large parts of the spectrum occupied by other users.

The current meteor scatter site (MSS) was disturbed by strong, broad band noise events in the afternoons, and the spectrum usage was found to be quite heavy throughout. The terrain at the site is suited for a meteor scatter terminal, provided the antennas are deployed on the flat part of the hilltop.

The MC3 site on the airbase has good terrain features, the foreground being flat and unobstructed by trees. The site had the heaviest spectrum usage of all the sites, and a high frequency of noise spikes probably due to local traffic. The broad band background noise level was fairly low at 42 - 44 MHz. This signifies that whatever unoccupied frequencies can be found may be good for meteor scatter communication. It should be kept in mind that the MC3 facility may radiate sufficient noise in the future to preclude the site from usage, and it may prove difficult to find and remove future noise sources due to the many facilities found nearby. The site may also have some environmental restrictions.

The VHF site at Elmendorf AFB has a suitably flat foreground extending from north through west and could be a suitable meteor scatter site due to terrain and environmental factors. The site was not galactically noise limited, but the background noise levels were the lowest found at Elmendorf AFB. A source search would have to be performed to identify and evaluate the possible elimination of the broad band noise sources present before any decision could be made to locate a meteor scatter terminal at the site.

Further evaluation is necessary at all three Elmendorf AFB sites to determine the impact of future installations and identify the broad band noise sources.

Noise surveys were performed at three meteor scatter sites at distances of 300, 600, and 1000 km from Elmendorf AFB: Galena AFB, Kotzebue, and Cape Lisburne.

* The meteor scatter site at Galena AFB is not in general galactically noise limited. However, a search for and elimination of nearby interference sources, combined with a more detailed search for quiet frequencies may enable galactically noise limited frequencies to be identified.

* A noise survey of the meteor scatter site in Kotzebue was not practical, and the survey was performed at the nearby Army National Guard station. The Army facility in Kotzebue is essentially galactically noise limited. No noise or interference exceeding the galactic background were found during night hours, and only slight enhancements of the background were found during daytime.

* The meteor scatter site at Cape Lisburne was galactically noise limited within 1 to 2 dB during the survey, and frequencies free from noise and interference can be found.

Noise and low level signals were found at all three remote meteor scatter sites. It was observed at Cape Lisburne that such noise and signals can originate from the meteor scatter facility itself or from other nearby communication facilities, such as satellite ground stations. We suggest the present meteor scatter sites be subjected to a source search within the facilities themselves to eliminate any interfering noise and signals from the receiver passbands.

* Further noise surveys were performed at the Naval Research Laboratories in Washington DC and Pomonkey, MD. The Washington DC site is not suited for meteor scatter due to the extremely high levels of noise and interference, 20 dB above the galactic background. The Pomonkey site is not entirely quiet, but is usable for meteor scatter communication provided a frequency not in use locally can be found and allocated.

February 25 1993.

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M. Sc. E.E.