The INSPIRE Journal

Volume 9 Number 1

November 2000

Observation Opportunities Continue

The MIR Space Station is still up and functioning and INTMINS operations will continue, too. Some modifications in the scheduling process have been necessary due to the fact that MIR is not manned continuously. INTMINS operations will be held when possible while MIR is manned. Since it is not known when operations will be possible, planning methods have been adjusted. Specifically, in the future the INTMINS schedule will be sent to participants using email. This will allow planning to take place later than in the past and will probably make adjustments in the plans less necessary than in the past. If you would like to receive information about observing opportunities, send a message to:

pine@mail630.gsfc.nasa.gov

INTMINS schedules will be determined about two weeks ahead of the operations and communicated immediately. Since the advance time is less than the 4-5 weeks we have had to use in the past, adjustments in the schedule should not be necessary. (See Page 7)

With the launch of the IMAGE satellite, there are other observation opportunities that may be available in the future. IMAGE has an instrument on board that emits VLF radio waves. We will try to determine if the signals are detectable on Earth. (See Page10)

The Coordinated Observation program will also continue as in the past. (See Page 9)

An international team made observations during the Leonid meteor shower on November 1998. They report the first VLF radio signals from meteors. (See Page 27)

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The INSPIRE Journal
Volume 9 Number 1
November 2000

The INSPIRE Journal is a publication of The INSPIRE Project, Inc., a nonprofit educational/scientific corporation of the State of California. The purpose of the INSPIRE Project, Inc., is to promote and support the involvement of students in space science research. All officers and directors of the corporation serve as volunteers with no financial compensation. The INSPIRE Project, Inc., has received both federal and state tax-exempt status (FEIN 95-4418628). The *Journal* is published two times per year: November 1 and April 1. Submission deadlines: October 1 and March 1

Contributions to the *Journal* may be sent to:

Bill Pine - Science
Chaffey High School
1245 N. Euclid Avenue
Ontario, CA 91762

email: pine@mail630.gsfc.nasa.gov
billpine@earthlink.net
Fax: 909 931 0392

Observation Schedules to be Communicated by email

Since MIR is no longer manned continuously, the INTMINS operation schedule we have used in the past will need to be modified. We have been assured by our Russian colleagues that INTMINS operations can still be scheduled during times when MIR is manned. We will just have to be ready to plan operations on a shorter time schedule than in the past. In order to accommodate this, from now on we will use email messages to communicate the schedule. The schedule will be sent out about 2 weeks in advance. If you would like to receive notification of the schedule when it becomes available, send a message to:

pine@mail630.gsfc.nasa.gov

Write for *The INSPIRE Journal*

The procedure for contributing articles for *The INSPIRE Journal* could not be simpler! Just send it in! Any format is acceptable. Electronic format is easier to work with: a Word file on disk for either the PC or Mac platform. An email message will work, too. If that does not work for you, a paper copy will do. Any diagrams or figures can be scanned in.

What about topics? Anything that interests you will probably interest most INSPIRE participants. As long as the topic is related to natural radio or the equipment used, it will get printed. The deadlines for submissions are March 1 for the spring edition and October 1 for the fall edition. Don't worry about the deadlines, though. If you miss a deadline, you will just be very early for the next edition!

We at INSPIRE are looking forward to hearing from you.

New email Addresses for the *Journal*

The editor of The INSPIRE Journal can now be reached at the following email addresses:

pine@mail630.gsfc.nasa.gov

Subscription Information Included on the Address Label

You can determine the status of your subscription to *The INSPIRE Journal* by looking at the address label. In the upper right corner of the label is a 2-digit number that indicates the year your subscription will expire. All subscriptions expire with the November issue. If your label shows "00", then this issue will be the last under this subscription. If your label shows "01", then your subscription is good through the November 2001 issue. If you have any questions or if you feel that the information shown is incorrect, please contact the editor.

Antenna Design Documents and Other Materials Available

Fred Fields, a retired electronics engineer and current radio amateur, has made available copies of documents relating to low frequency (LF) and very low frequency (VLF) communications with an emphasis on antenna designs.

The following is a partial list of the documents:

1. Naval Shore Electronics Criteria; VLF, LF and MF Communication Systems; NAVELEX 0101,113; 1972

> Foreword
> This handbook presents ready-reference criteria for planning, engineering, installation and checkout of VLF, LF, and MF communications equipment installed on Naval shore stations ...

2. Personal communications concerning the US Navy radio station, NPL. Topics include the history, shutdown and demolition of the station.

3. A large ring binder consisting of articles from various publications on a variety of topics. Tabbed sections include:

   Broadcast band
   Whistlers
   Marine radio
   Physical waves
   LORAN
   OMEGA
   CONSOL/CONSOLAN
   SANGUINE – ELF communications
   Underground
   WWVL / WWVE
   Propagation
   Historical

4. Another ring binder containing the following tabs:

   VLF converter
   Lists of radio stations in the following frequency ranges:
   10-150 kHz, 150-415 kHz, 415-550 kHz
   TTY converter

5. Two articles on active antennas from 1983 issues of *Radio Electronics*.

Arrangements to obtain copies can be made by contacting the editor. Partial copies and samples can also be sent.

Observation Opportunities Using Space-based Platforms
Update on the Status of IMAGE and MIR

by Bill Taylor, Washington, DC
Bill Pine, Ontario, CA
The INSPIRE Project, Inc. Co-founders

Two opportunities for observing manmade VLF signals from space will be available to INSPIRE participants. One is a continuation of the INTMINS operations that have been conducted for the past four years. A significant change is required due to the fact that MIR will not be manned all of the time. To allow planning in a shorter time frame, operations will be planned for times when MIR is manned and the schedule will be communicated by email to participants. If you would like to receive the schedule, please send a message to:

pine@mail630.gsfc.nasa.gov

and your name will be added to the participant list. (Note: You do NOT have to be an active participant to be included on the email list!)

An additional observation opportunity has been added using the IMAGE satellite. IMAGE was launched in March and is currently gathering data about the magnetosphere and plasmasphere of Earth. ne of the instruments is being operated when IMAGE is at perigee to attempt to see if the VLF radio signal emitted by the instrument can be detected on the ground. See Bill Taylor's article on Page 10 for a description of how to determine observation times for your location.

The following is an update on the status of these two orbiting space platforms.

IMAGE

IMAGE was launched on March 25, 2000 into a polar orbit with an inclination to the equator of 90.01 degrees. Its closest approach to the Earth, perigee, is an altitude of 1000 km and its furthest, apogee, 46,004 km, or 7.2 Re (Re is Earth radii, about 6371 km). Its period is 14 hours, 16 minutes. The perigee is above the South Pole of the earth, so at northern latitudes IMAGE is at altitudes of a few thousand kilometers.

After about two months, the 500-meter tip-to-tip RPI (Radio Plasma Imager) antennas reached full extension and engineering tests began of the RPI. The data from these tests were somewhat useful for scientific research and slowly engineering testing has wound down and scientific studies have accelerated. A new set of onboard programs was uplinked to the satellite at the beginning of October. These programs were scientific and included programs to transmit VLF waves with the objective of testing propagation to the ground. These are the experiments that INSPIRE will support with observations.

Unfortunately, on October 3, 2000, the satellite suddenly started to wobble. Based on observations by some of the scientific instruments and measurements by the onboard star tracker, it has been concluded that about one half of one of the four 250-meter long antenna elements was lost. The most likely (although very unlikely) cause is the antenna being hit by a meteoroid.

Engineering will have to take over for a while to retune the antenna to be able to operate efficiently, even though one of its two elements is only half as long as it was! This may take a few months and propagation experiments will have to be delayed.

MIR

MIR (which means peace in Russian) has been in orbit 14 years, many years beyond its design lifetime. Over 20,000 space experiment sessions have been performed. As a result, MIR is considered a landmark on the road of scientific progress. Worldwide, the word MIR has become synonymous for the advancement of technology and the establishment of life in space in the late 20th century.

There have been reports that MIR may be deorbited early in 2001, but MIRCorp,

http://www.mirstation.com

the commercial operator of MIR, is determined that MIR will continue, and on October 3, announced that there would be an October 16 resupply mission to MIR.

Dr. Stas Klimov, the Russian Director of INTMINS, has assured us that when MIR is manned, we can plan operations of the plasma accelerators, for attempting reception by INSPIRE participants.

Future IMAGE and MIR operations

Since the exact schedules of operations of IMAGE/RPI and MIR/ISTOCHNIK and MIR/ARIEL are uncertain at this time and will probably change much more quickly that the twice yearly period of the *INSPIRE Journal*, INSPIRE has decided to notify participants by email of operations opportunities. Therefore, all observers must send a message to Bill Pine at:

pine@mail630.gsfc.nasa.gov

INSPIRE will then compile an email distribution list and will notify everyone on the list of upcoming observation opportunities.

INTMINS-April/2000 Operations Schedule

By Bill Taylor, Washington, DC
Stas Klimov, Moscow, Russia
Bill Pine, Ontario, CA

The November/2000 INTMINS Operations schedule will be finalized soon. Operations will occur at times consistent with the manned status of MIR. INSPIRE participants will be notified by email when the schedule is determined. If you would like to receive email notification of the schedule, send a message to:

pine@mail630.gsfc.nasa.gov

and your name will be added to the INSPIRE email list. Data gathered will be analyzed and reported on in the April 2001 issue of *The INSPIRE Journal.*

Gathering Data:

IMPORTANT NOTE: Data gathering procedures will remain the same as those used since April 1996.

Perhaps the most important ingredient in a successful data gathering session is what happens **before** you go out in the field. The following is the recommended procedure for data gathering including preparation prior to the date of the operation.

Step 0: Completely check out all equipment. A good method is to set up everything in your living room. All you will hear is household 60 Hz, but you will know the equipment is working. This is also a good time to fill out the log cover sheet (see Page 80 of the *Journal*).

Step 1: Define "T-time" as the starting time for operation of ISTOCHNIK. Convert the UT time to local time. Arrive at your site with time to spare.

Step 2: Start data recording at T minus 12 minutes. Prior to this time place a brief voice introduction on the tape identifying the observers and the operation number.

Step 3: Place time marks on the tape at: T-12, T-10, T-5, T, T+3, T+8, T+13, and near the end of the tape. Use UTC times only. Note that this schedule brackets the scheduled time of operation of ISTOCHNIK with time marks. Use 60 minute tapes and place one operation per side.

Step 4: Keep a written log (see Page 81 of the *Journal*) of time marks and descriptions of everything you hear.

Step 5: Review your tapes and revise your logs if necessary.

Step 6: Mail your tapes and logs to Bill Pine at the address shown on Page 2 of the *Journal.*
Your tapes will be returned to you.
Send in copies of your logs since they will not be returned.
You will receive a copy of the spectrograms made from your data.
Your data will be incorporated in the data analysis report article in the *Journal.*

Mode of Operation:

The two instruments on MIR are Ariel and ISTOCHNIK. Ariel is a plasma generator and operates for 5 minutes, alternating between axes. ISTOCHNIK is a modulated electron gun that accelerates a beam of electrons and emits them into space. The electron beam is turned on and off at frequencies of either 10 hertz or 1000 hertz (1 kHz), which should cause the radiation of electromagnetic waves in the VLF range at those two frequencies. ISTOCHNIK operates for a total of 2 minutes on the following schedule:

ISTOCHNIK mode:
10 seconds modulate at 10 Hz
10 seconds modulate at 1000 Hz
10 seconds modulate at 10 Hz
10 seconds modulate at 1000 Hz
repeat for 2 minutes of operation

On each pass, Ariel will either operate first or last, whichever gives the most coverage over INTMINS observers. Since the signal from ISTOCHNIK is more powerful, it is the one most likely to be detected. For that reason, the schedule emphasizes the operation of ISTOCHNIK.

Notes on Time Marks and Logging;

The purpose of putting time marks on the data tapes is twofold:

1. The obvious need to know what time is represented in each part of the tape,

2. also to provide a means of synchronizing the tape with actual time. Battery operated recorders tend to run slower as the batteries wear out. Some recorders run fast or slow because of the particular motor being used. By timing (with a stopwatch) the actual times between time marks, the speed of the analysis recorder can be adjusted to synchronize the data tape with actual time. This has the effect of adjusting the frequencies on the spectrogram to the proper values since incorrect tape speed on the data recorder will cause the frequencies to be out of position.

When time marks are put on the tape, they should include an announcement of the UT time and a mark (either by voice ("mark") or by WWV tone or some other means). Try to minimize the interruption to the data flow when putting on the time marks. This takes practice! Also, put the time marks on at least as often as is called for by the instructions. It is better to have more time marks than are called for than to have too few.

The purpose of the data log is to record the contents of the tape. The time of each time mark should be recorded. Anything else of interest should be noted on the log with the time indicated.

Tapes with incomplete or missing time marks and poor logs are nearly impossible to analyze. Your help in following good time mark and logging procedures is much appreciated.

Coordinated Observation Schedule
November/2000

By Bill Pine Ontario, CA

In response to requests in the INSPIRE Survey for observation opportunities at more convenient times, the INSPIRE Coordinated Observation Program was established in April/98 in conjunction with the INTMINS observations. The purpose of the coordinated observations is to provide an opportunity for INSPIRE observers to make recordings of natural VLF radio and to compare the resulting data. Ideally, a coordinated session would result in everyone hearing whistlers. Whistlers were not detected last April, but interesting signals were heard nonetheless.

Since Coordinated Observations do not rely on platforms in orbit, the procedure for Coordinated Observations will not change.

The procedure to use for coordinated observations will be as follows:

1. Use the Data Cover Sheet and Data Log as with the INTMINS observations.
2. Record for 12 minutes at the start of each hour that you can monitor on the specified days. Keep a detailed log of all signals that you hear and indicate any items of interest. When you submit your tapes, spectrograms will be made of any parts of the tape that you indicate.
3. Place a time mark on the tape on the hour and each two minutes for the next 12 minutes. Use Coordinated Universal Time (UTC) for all time marks.
4. Record at 8 AM and 9 AM **LOCAL** time.
5. In addition, record on other hours to compare results with those in neighboring time zones. For example, an observer in the Central Time Zone might record at 7 AM (8 AM EST), at 8 and 9 AM CST and at 10 AM (9 AM MST).
6. Use 60 minute tapes (30 minutes per side) with two sessions per side. It is preferred that you record on one side of the audio tape only.
7. Label all tapes and logs to indicate the sessions monitored and send to:

   Bill Pine
   Chaffey High School
   1245 N. Euclid Avenue
   Ontario, CA 91762

8. Your tapes will be returned with spectrograms of your data. An article reporting on the results will appear in the next *Journal*. .
9. SPECIAL NOTE: If you are hearing whistlers, replace the data tape after 12 minutes with a "Whistler" tape and continue recording with time marks every two minutes. If we get whistlers, this would be a good opportunity to try to determine the "footprint" of a whistler (the "footprint" is the geographical area where a whistler can be detected).

Specified Coordinated Observation Dates for November/2000:

Saturday, November 18 and Sunday, November 19

Propagation Experiments from IMAGE to the Ground

By Bill Taylor
Co-Founder, The INSPIRE Project
Washington, DC

Introduction

IMAGE (Imager for Magnetopause-to-Aurora Global Exploration) is the first MIDEX or Medium-sized Explorer. It was launched on March 25, 2000 to study the global response of the Earth's magnetosphere to changes in the solar wind. IMAGE will use radio imaging, neutral atom, and ultraviolet techniques to: (a) identify the dominant mechanisms for injecting plasma into the magnetosphere on substorm and magnetic storm time scales; (b) determine the directly driven response of the magnetosphere to solar wind changes; and, (c) discover how and where magnetospheric plasmas are energized, transported, and subsequently lost during substorms and magnetic storms.

The radio plasma imager (RPI) will transmit and receive pulses from 3 kHz to 3 MHz allowing relative motions of the satellite and plasma to be determined to a resolution of 400 m/s and a time resolution as good as 4 s. A suite of three neutral atom imagers (NAI) will provide energy- and composition-resolved images at energies from 10 eV to 200 keV with a time resolution of 300 seconds. Two ultraviolet imagers, covering wavelength ranges from 120-180 nm (FUV) and 30.4 nm (EUV), provide coverage in the far and extreme ultraviolet.

One of the objectives of the RPI is to measure propagation of the radio waves that RPI emits. Planned observing instruments are INSPIRE receivers, other radio receivers on the ground, and radio receivers on satellites. Starting in August, RPI has been transmitting from 3-15 kHz for approximately the 2.5 hours closest to the Earth.

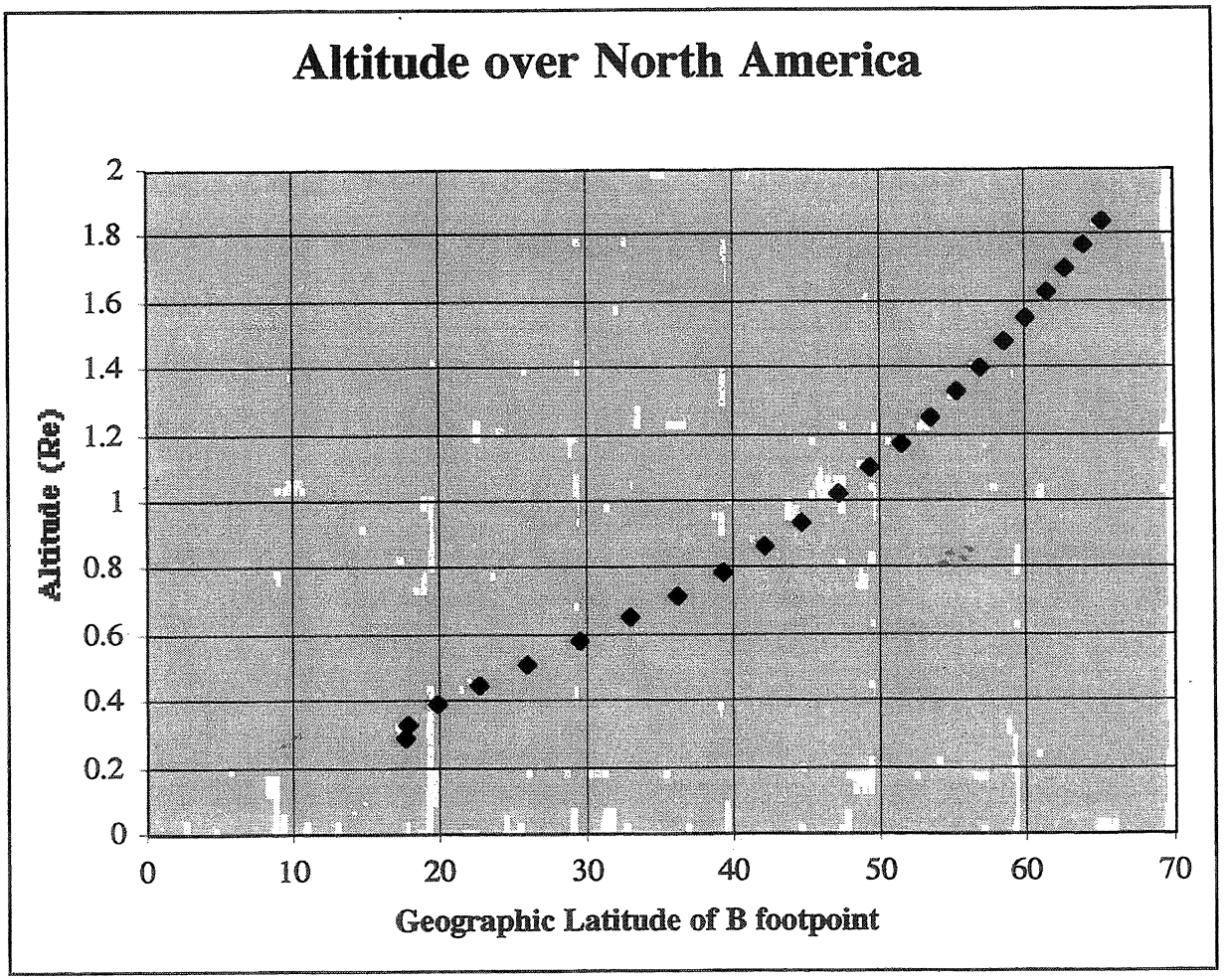
On August 3, 2000, the WIND satellite received signals from RPI at a frequency of 828 kHz during a special experiment when WIND and IMAGE were aligned.

This article is designed to lead INSPIRE observers through the simple process of determining when they should observe. I will show what I did to be prepared for observations I made in Washington, DC on August 12, 2000. The only thing required is access to the internet and the World Wide Web.

IMAGE Orbit

IMAGE is in a polar orbit with an inclination to the equator of 90.01 degrees. Its closest approach to the Earth, perigee, is an altitude of 1000 km and its furthest, apogee, 46,004 km, or

7.2 Re (Re is Earth radii, about 6371 km). Its period is 14 hours, 16 minutes. The perigee is above the South pole of the earth, so at northern latitudes IMAGE is at altitudes of a few thousand km. Figure 1 shows the altitude of IMAGE as a function of the geographic latitude of the B footpoint. The B footpoint is the point where the magnetic fieldline that passes through IMAGE reaches the surface of the earth.



SSCWeb Tabular Data

To find the best times for INSPIRE observers to record data go to the NASA/Goddard Space Flight Center web site for the National Space Science Data Center's Satellite Situation Center:

http://sscweb.gsfc.nasa.gov/

and Figure 2 shows what you will see.

Welcome to the Satellite Situation Center (SSCWeb) System and Services

The Satellite Situation Center Concept

SSCWeb

[Navigation Tips | Models and Regions of Geospace | SSCWeb User's Guide]

Locator Graphics

Query

Locator Tabular

Locator Tutorial

Query Tutorial

Users of Locator Graphics

SSCWeb Facilities Interface

Figure 2. The main page of SSCWeb.

The first thing to do is to click on Locator Tabular. You will get Figure 3.

SSC Locator Form

Standard Interface

Spacecraft/Time Range Selection

View Available Spacecraft and Times

Satellites	Time Range
DMSP-10 DMSP-11 DMSP-12 DMSP-13 DMSP-14 DMSP-8 DMSP-9 Equator-S FAST Freja Geotail GMS-3 GOES-10 GOES-11 GOES-6 GOES-7 GOES-8 GOES-9 Hawkeye IMAGE	**Valid Date/Time Formats:** Date: yyyy ddd; yyyy/mm/dd; yyyy-mmm-dd Time (Optional): hh.hhhh; hh:mm:ss; hh:mm Start Time (inclusive) 2000 214 00:00 Stop Time (inclusive) 2000 244 23:59 Display 1 out of every 1 points.

Command Menu

REQUIRED SETTINGS — Output Options	2 *INPUT SUMMARY* — Input Summary
1 *OPTIONAL SETTINGS* — Filtering Options; Output Units/Formatting	3 *EXECUTION OPTIONS* — Submit query and wait for output; Prepare query to be saved locally

Interface Style: Standard | Advanced

Undo changes just made - this page only | Clear entire form (all input settings, all pages)

Figure 3. The top Locator Tabulator form.

Click on IMAGE in the Satellite box, fill in the time period of interest, I chose August, 2000, and click on the Output Options box. You will get Figure 4.

SSC Locator Form

Standard Interface

Output Options

	X Y Z	LAT LON	X	Y	Z	LAT	LON	LOCAL TIME
GEI/TOD	☐	☐	☐	☐	☐	☐	☐	
GEI/J2000	☐	☐	☐	☐	☐	☐	☐	
GEO	☐	☑	☐	☐	☐	☐	☐	☑
GM	☐	☐	☐	☐	☐	☐	☐	☐
GSE	☐	☐	☐	☐	☐	☐	☐	☐
GSM	☐	☐	☐	☐	☐	☐	☐	
SM	☐	☐	☐	☐	☐	☐	☐	☐

Additional Options

Regions	Values	Distance From
☐ Spacecraft Regions	☑ Radial Distance	☐ T95 Neutral Sheet
☐ Radial Traced Footpoint Regions	☐ B Field Strength	☐ P93 Bow Shock
☐ North B Traced Footpoint Regions	☑ Dipole L Value	☐ RS93 MPause
☐ South B Traced Footpoint Regions	☐ Dipole Inv Lat	☐ B GSE X-Y-Z

B Field Trace Output Options

	Footpoint Latitude	Footpoint Longitude	Field Line Length
GEO NORTH	☑	☑	☑
GEO SOUTH	☐	☐	☐
GM NORTH	☐	☐	☐
GM SOUTH	☐	☐	☐

Command Menu

1 *REQUIRED SETTINGS*
[Spacecraft/Time Range Selection]

OPTIONAL SETTINGS
[Filtering Options]
[Output Units/Formatting]

2 *INPUT SUMMARY*
[Input Summary]

3 *EXECUTION OPTIONS*
[Submit query and wait for output]
[Prepare query to be saved locally]

Interface Style [Standard] [Advanced]

Figure 4 The second page of the Locator Tabular.

Click on the boxes with checks in them in Figure 4 and click on Filtering Options. You will get Figure 5.

SSC Locator Form

Standard Interface

Go to the command menu

Filtering Options

● Must pass all specified range filters
○ Must pass at least 1 specified range filter

Spacecraft Location Filters

Distance Units are in	● R_E - Earth Radii ○ Km - Kilometers
Lat/Lon units are in	degrees.
Valid local time formats (24 hour clock):	hh.hh hh:mm:ss hh:mm

		Return:		Return values that are...	
		Min	Max	greater than:	less than:
GEO	X	☐	☐		
	Y	☐	☐		
	Z	☐	☐		
	LAT	☐	☐		
	LON				
	Local Time				

Additional Location Filters

Distance Units are in ● R_E - Earth Radii ○ Km - Kilometers

	Return:		Return values that are...	
	Min	Max	greater than:	less than:
Distance From Center of the Earth	☐	☐		4
Dipole L value	☐	☐		

Figure 5. The third page of the Locator Tabular. Command Menu has been cut.

Enter 4 in the upper right hand box of the Additional Location Filters to get only the low altitude information, and click Submit query and wait for output. You will get 341 kB of data. This can be reduced by changing the number in the Display 1 out of every ___ points box in Figure 3. Five is a good number.

You will get the output shown in Figure 6, in which I have just included the headers and the first few lines of the table:

SSC Locator Form

Standard Interface

Output is sent as generated; please allow server to complete transfer if full time range is desired.

LOCATOR_GENERAL OUTPUT:
User: websrvr
Date: Mon 14-Aug-2000 (227) 14:02:33
Status: request completed successfully

GROUP 1	Satellite	Resolution	Factor
	image	120	1

Start Time	Stop Time
2000 214 0.00000	2000 244 23.98333

Coord/ Component	Output	Min/Max Markers	Range Filter Minimum	Filter Maximum	Mins/Maxes
GEO Lat	YES	-	-	-	-
GEO Lon	YES	-	-	-	-
GEO LT	YES	-	-	-	-

Addtnl Options	Output	Min/Max Markers	Range Filter Minimum	Filter Maximum	Mins/Maxes
dEarth	YES	-	-	4.00	-
L_Value	YES	-	-	-	-

Perform the following magnetic field traces:
North trace for GEO footpoint; Output: lat, lon, arclen.

Magnetic field model:
Internal: IGRF
External: Tsyganenko 89C Kp: 3-,3,3+
Stop trace altitude (km): 100.00

Output - File:
lines per page: 0

Formats and units:
Day/Time format: YYYY DDD HH:MM

Degrees/Hemisphere format: Decimal degrees with 2 place(s).
Longitude 0 to 360, latitude -90 to 90.
Distance format: Earth radii with 2 place(s).

image Time yyyy ddd hh:mm	GEO Lat	geoLT Long	hh:mm	NorthBtrace GEO Lat	Long	ArcLen	Radius (RE)	DipL-Val
2000 214 00:00	24.07	243.55	16:14	42.73	247.64	0.95	1.83	2.5
2000 214 00:02	27.60	243.09	16:14	45.43	247.29	1.01	1.90	2.8
2000 214 00:04	30.86	242.62	16:14	47.94	246.95	1.07	1.98	3.2
2000 214 00:06	33.88	242.15	16:15	50.26	246.62	1.14	2.06	3.6
2000 214 00:08	36.68	241.69	16:15	52.42	246.31	1.21	2.13	4.1

Figure 6. The first part of the tabular output of SSCWeb. GeoLT is the solar time, approximately local time. Radius means the distance from the center of the earth to the satellite in earth radii. NorthBtrace GEO means the geographic latitude and longitude of the magnetic field line that passes through the satellite, where it passes through the surface of the earth. ArcLen is the distance along the magnetic field from the satellite to the surface of the earth.

Low altitude passes are clustered into 5 groups of longitude around the earth. The passes in each group are separated by about one hour less than three days, and advance eastward about 9.5 degrees in longitude in those three days. A particular place on the earth will have a close pass approximately every 18.4 days. Figure 7 shows the B footpoints of a group over North America during July and August, 2000.

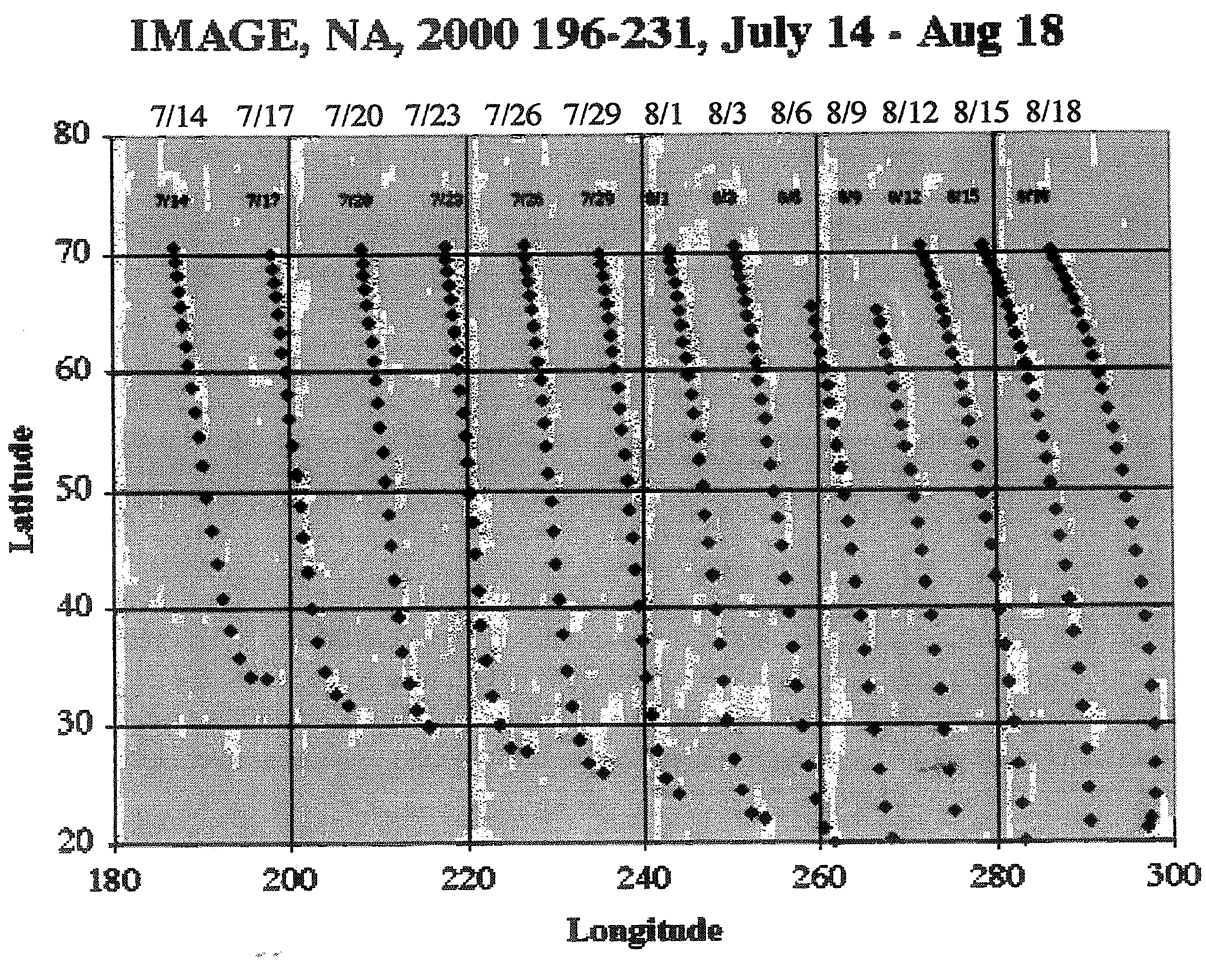


Figure 7. The footpoints of a group of low altitude IMAGE passes over North America.

To see when there is an appropriate pass two criteria could be used. The first is when the spacecraft is overhead. The second is when the magnetic field line that passes through the spacecraft is near. If the waves travel in a straight line, the first criterion would be best. VLF waves, 3-15 kHz in this case, in the ionosphere are traveling in the whistler mode and waves in the whistler mode tend to follow the magnetic field line, so the second criterion is probably better.

Washington, DC, where I live, is at approximately 77 degrees west longitude (= 283 degrees east longitude, the way SSCWeb denotes longitude) and 39 degrees north latitude.

There was a good pass for me on August 12, 2000, Day 225 at about 20:40 UT. I've included the SSCWeb for about 40 minutes below:

Time			GEO		geoLT	NorthBtrace GEO		Radius			
yyyy	ddd	hh:mm	Lat	Long	hh:mm	Lat	Long	ArcLen	(RE)	DipL-Val	
2000	225	20:20	-28.84	286.40	15:26	18.96	284.19	1.20	1.26	1.4	
2000	225	20:22	-21.30	285.98	15:26	17.58	283.91	0.95	1.30	1.3	
2000	225	20:24	-14.26	285.54	15:26	18.24	283.58	0.81	1.35	1.4	
2000	225	20:26	-7.73	285.10	15:26	20.41	283.18	0.74	1.40	1.4	
2000	225	20:28	-1.72	284.65	15:27	23.43	282.75	0.73	1.46	1.5	
2000	225	20:30	3.81	284.20	15:27	26.83	282.29	0.74	1.53	1.6	
2000	225	20:32	8.87	283.74	15:27	30.30	281.82	0.77	1.59	1.8	
2000	225	20:34	13.51	283.28	15:27	33.68	281.34	0.81	1.67	2.0	
2000	225	20:36	17.77	282.82	15:27	36.89	280.85	0.86	1.74	2.2	
2000	225	20:38	21.68	282.35	15:27	39.89	280.37	0.92	1.81	2.5	⇐
2000	225	20:40	25.28	281.89	15:28	42.68	279.88	0.98	1.89	2.9	
2000	225	20:42	28.60	281.42	15:28	45.26	279.40	1.05	1.96	3.3	
2000	225	20:44	31.68	280.96	15:28	47.65	278.92	1.11	2.04	3.7	
2000	225	20:46	34.53	280.49	15:28	49.87	278.45	1.18	2.12	4.2	
2000	225	20:48	37.18	280.02	15:28	51.93	277.98	1.25	2.19	4.8	
2000	225	20:50	39.66	279.55	15:28	53.83	277.52	1.32	2.27	5.5	⇐
2000	225	20:52	41.97	279.09	15:28	55.62	277.07	1.39	2.35	6.3	
2000	225	20:54	44.14	278.62	15:28	57.27	276.62	1.46	2.42	7.2	
2000	225	20:56	46.18	278.15	15:29	58.82	276.17	1.53	2.50	8.2	
2000	225	20:58	48.10	277.69	15:29	60.27	275.73	1.60	2.57	9.4	
2000	225	21:00	49.91	277.22	15:29	61.62	275.29	1.67	2.64	10.7	

By the overhead criterion, the best time would be centered around 20:50 UT. The satellite is at an altitude of 1.27 Re or 8091 km.

By the field line criterion, the best time would be centered around 20:38 UT. The distance along the field line to the satellite at that time is 0.92 Re or 5861 km.

I recorded data from about 20:30 to 21:00 UT.

SSCWeb Graphics

Another way to get orbital data from the SSCWeb is from the Graphics section, which can be found by clicking on Locator Grpahics on the main SSCWeb page shown in Figure 2. What you get is shown in Figure 8.

SSC Locator Graphics Form

Standard Interface

Spacecraft/Plot Type Selection

View Available Spacecraft and Times

Satellites	Plot Type
DMSP-10 DMSP-11 DMSP-12 DMSP-13 DMSP-14 DMSP-8 DMSP-9 Equator-S FAST Freja Geotail GMS-3 GOES-10 GOES-11 GOES-6 GOES-7 GOES-8 GOES-9 Hawkeye IMAGE	○ Orbit Plot ● Mapped Projection Plot ○ Time Series Plot

Time Range Selection

Please use time ranges of less than 30 days.

Time Range Specification

Start Time (inclusive)	Stop Time (inclusive)	Valid Date/Time Formats:	
2000 225 20:22	2000 225 21:00	Date	yyyy ddd yyyy/mm/dd yyyy-mmm-dd
		Time (Optional)	hh.hhhh hh:mm:ss hh:mm

Figure 8. The main page of the Locator Graphics part of SSCWeb.

I decided to make a plot above of the projection of the magnetic field line for the pass discussed. Scroll down and click on "Plot Options" and you will get Figure 9.

SSC Locator Graphics Form

Standard Interface

Mapped Projection Plot Options

Plot Parameters	Selections	Other Options
Spacecraft Track	○ Radial ● B Trace North ○ B Trace South	
Coordinate System	● GEO with Continents ○ GEO without Continents ○ GM without Continents ○ SM (Radial & Cyl. only)	
Projection	**Equatorial** ● Cylindrical ○ Mercator ○ Molleweide **Polar** ○ Stereographic ○ Orthographic ○ Azimuthal	**Map Limits** Min Lat: 20.0 Max Lat: 70.0 Min Lon: -170.0 Max Lon: -60.0 **Polar Map Orientation** ○ North Pole ○ South Pole Longitude plotted as vertical down: 0.0

Plot Title: Mapped Plot

Command Menu

1	*REQUIRED SETTINGS* Spacecraft/Plot Type Selection *OPTIONAL SETTINGS* Other Options	2 *INPUT SUMMARY* Input Summary
3	*EXECUTION OPTIONS* Plot Prepare query to be saved locally	

Interface Style Standard | Advanced

Undo changes just made - this page only | Clear entire form (all input settings, all pages)

Figure 9. The second page of Locator Graphics.

I confined the plot to the US. Make your choices on this page and click on Plot. You will get Figure 10.

SSC Locator Graphics Form

Standard Interface

LOCATOR_GRAPHICS_GENERAL OUTPUT:

MAPPED_IMAGE

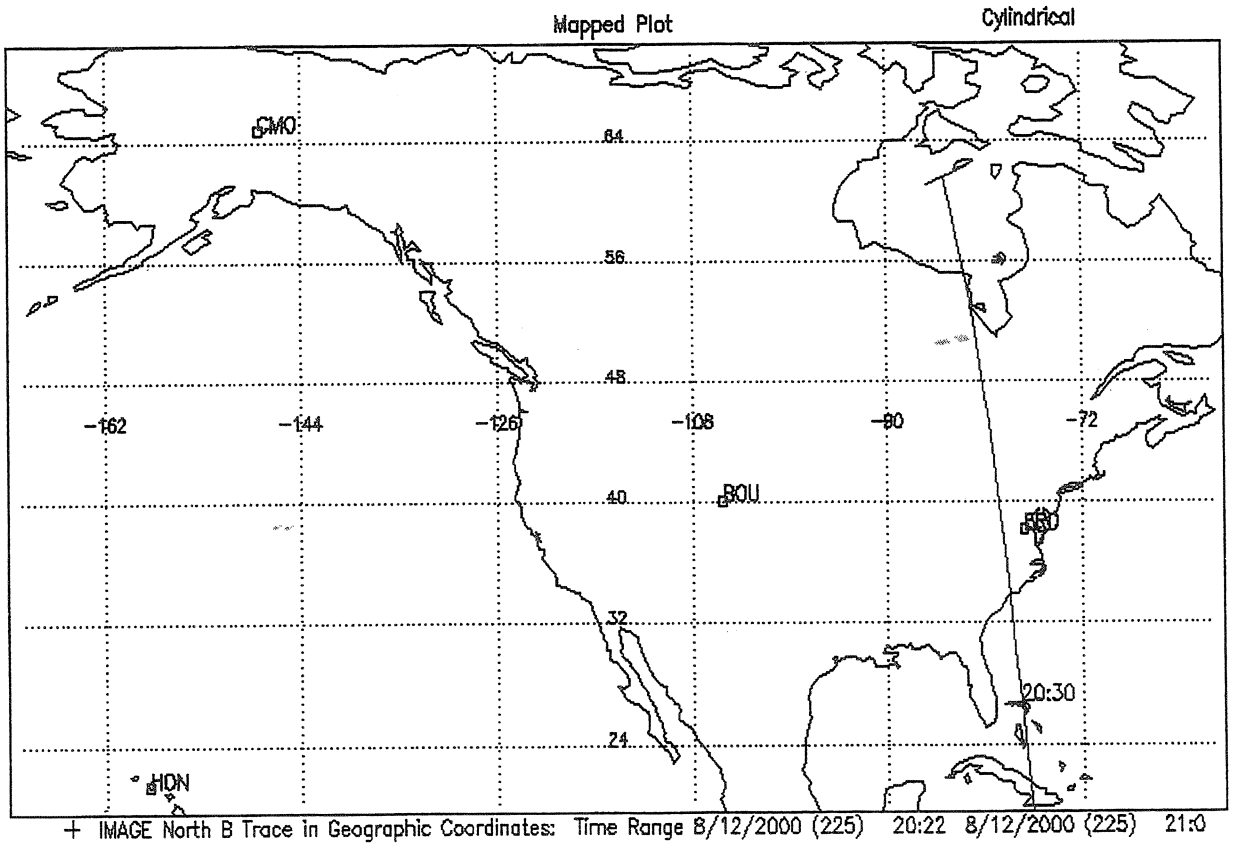


Figure 10. The path of the B footpoint of a low altitude pass over North America on August 12, 2000.

This is the pass that I recorded.

A Triggered Emission
September 17, 2000

By Shawn Korgan
Team 32
Gilcrest, CO

It's 11:00 o'clock in the evening and once again I'm off to my favorite quiet spot in the Rocky Mountains - Trail Ridge Road, at an elevation of over 12,000 feet. I realize I have a two-hour drive ahead of me so I begin to relax and enjoy the ride. As I do so, my thoughts begin to wander back to the previous month.

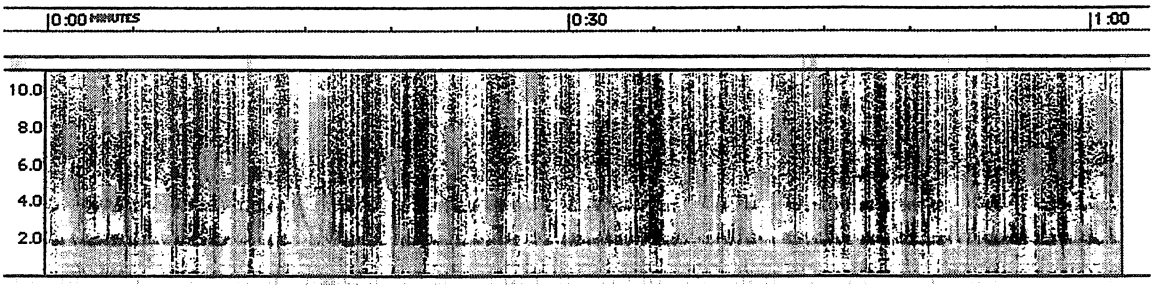
It was then that I received an email from Steve Ratzlaff informing me of an upcoming coordinated listening session being conducted by Mark Karney (naturalradio@norwest.net) via *The LOWDOWN*, a monthly publication on low-end radio frequencies (including periodically Natural Radio articles.) I'm always ready for a coordinated listening session when it comes to natural radio, so I am naturally excited to hear that one is occurring in the month of September. In the next few days I send off my subscription for *The LOWDOWN* so I will not miss any of the last-minute details. (It's a good thing that I did because at the last minute the dates were changed to include Sept. 16th and 17th and to exclude the dates of Sept. 30th and Oct. 1st.)

I reach my destination around 12:45 a.m. (6:45 GMT) in the morning and begin to set up the equipment. First I begin by running the 400-foot longwire antenna and then by interconnecting the VLF receiver, tape deck and WWV receiver. This being done, I flip on the VLF receiver to check the conditions. At the moment things sound rather calm, so I decide not to record. As I'm sitting there listening, all of a sudden a loud wavering tone, some sort of periodic emission, is heard. It lasts approximately five seconds in duration and is not heard again the rest of the evening. I decide from that point on that tonight I will record even when there is nothing spectacular going on -- I had already missed one good event.

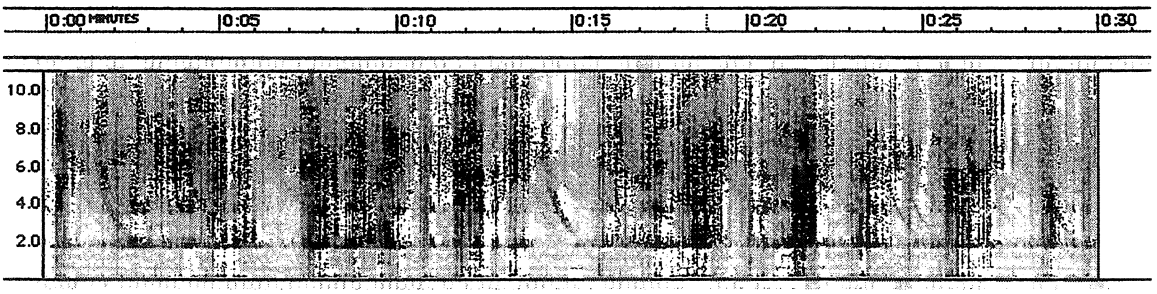
I notice faint whistlers beginning around 7:00 GMT. These whistlers continue to strengthen as the first coordinated listening session of the evening draws closer. At 8:55 GMT I begin recording for the coordinated listening session. I am recording simultaneous WWV audio on one track while at the same time recording the live VLF feed on the other. By 9:00 GMT there are numerous loud whistlers occurring. This is always a good sign during a coordinated listening session!

At 9:02:34 GMT I hear a strange emission that instantly commands my attention. It is one of those VLF events that sounds a little unusual, a little out of the ordinary and unlike all the rest of the activity occurring that evening. I think to myself, if this is all the activity I catch this evening it was worth it to hear just that one odd-sounding event. I thank God for the catch and continue to monitor under the beautiful Milky Way / star-studded heavens, enjoying both the beauty and the sounds of nature.

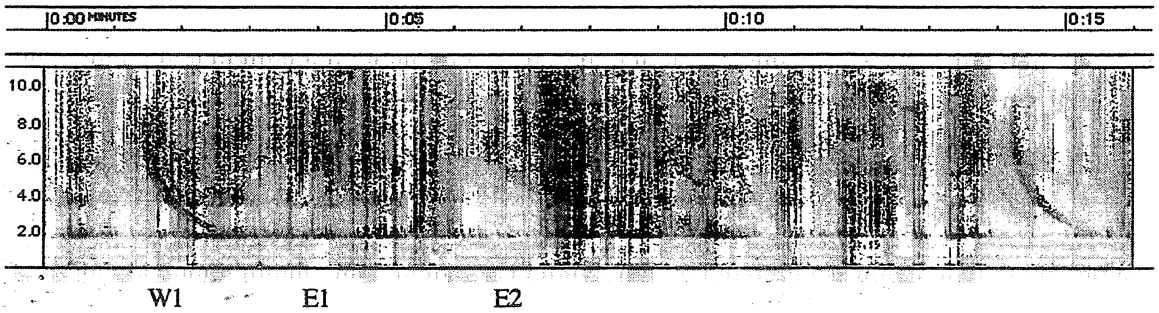
Conditions continue to get even better as the night progresses. By the time the 10:00 GMT listening session rolls around, there are now whistlers occurring with multiple echoes along with periodic emissions and bits of chorus. Things get even better when, by 11:30 GMT, I begin to hear multi-path whistlers. Can things continue this way? Sure enough, by 13:06 GMT faint sounds of a coming whistler storm are captured on tape. By around 13:35 GMT a full-blown whistler storm is in progress. The whistler storm is still in progress as I'm leaving for work at 14:45 GMT. Talk about a night!



Spectrogrsam of the first minute after 1000 UT. Ten whistlers were logged during this interval.

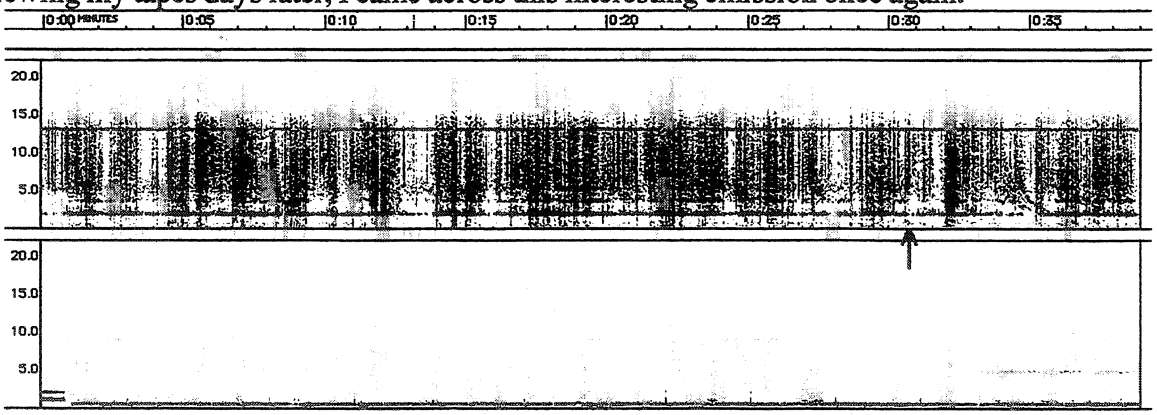


First 30 seconds. Six whistlers. The first is the strongest.



First 15 seconds. Two echoes (E1 and E2) follow the first whistler (W1).

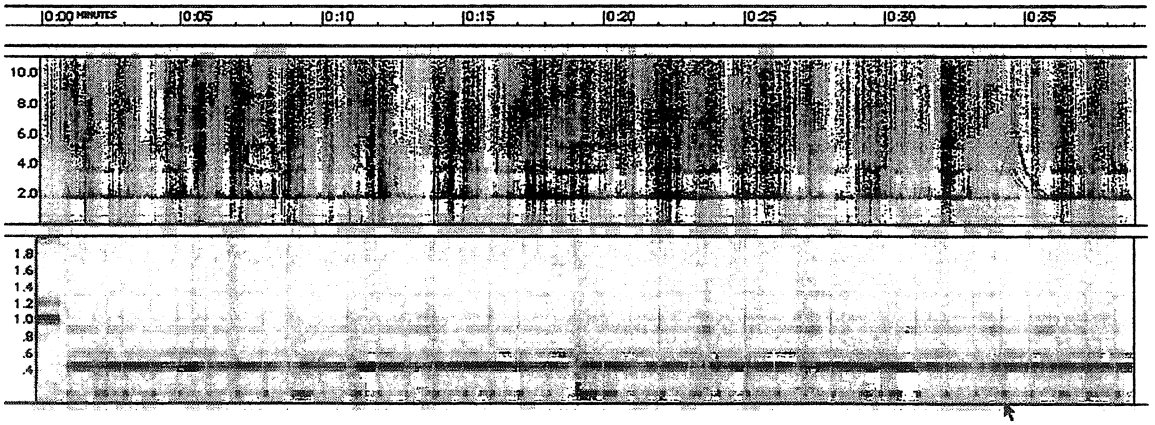
Now let's back up to that event captured at 9:02:34 GMT on Sept. 17th. As I was reviewing my tapes days later, I came across this interesting emission once again.



Spectrogram showing natural radio on the top track and WWV on the bottom track.
The dash at the beginning of the WWV track is the 0902 UT WWV tone.
The arrow points to the "interesting emission".

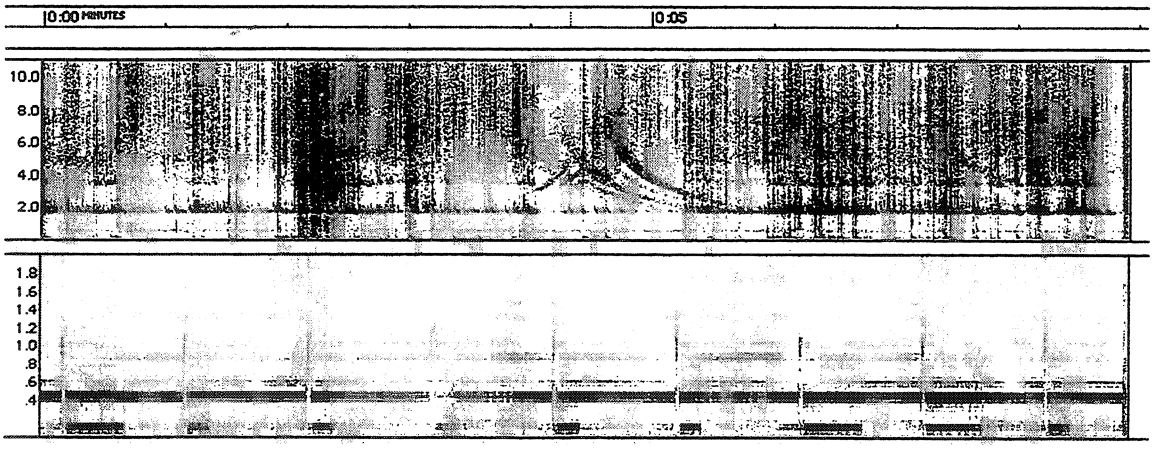
The event reminded me of how some of the triggered emissions sounded that I had heard previously on tape recordings created by the Navy's NAA transmitter in the 1950's. I listened a little closer and noticed that I could hear a faint bubbling sound around 1 kHz, beginning

approximately 0.8 seconds before the "triggered emission" occurred. After taking a quick break to listen to this recording again, I can better describe this bubbling sound as being centered around 600 hertz instead of the assumed 1 kHz. Basically it sounds like a string of fast-rising and descending notes (around 10-15 per second) centered around 600 hertz. It almost sounds like someone yodeling way off in the background. (I had to throw that in - it's hard to describe exactly.)



The VLF spectrogram is shown with a 0-11 kHz frequency range;
the WWV track uses a 0-2 kHz range.
The arrow points to the location of the faint "bubbling" sound.

This faint bubbling sound that begins immediately before the triggered emission on Sept. 17th sounds very similar to the VLF emissions that were created by the NAA CW transmissions, which made them also sound nearly like a steady tone in the 1950's. This was proof enough to me already that this was indeed a triggered emission. I had an even bigger surprise awaiting me that would throw all doubt out of my mind that this was a triggered emission I had captured.



About 7 seconds centered on the triggered emission.
The dash at the bottom left of the WWV track is the 0902:30 tick

After arriving home from work later that same day, I decided I needed to create some logs of the activity I had heard from this day of coordinated listening sessions. Mike Mideke had already sent me his logs of the activity he had heard, and I wanted to pass along my logs as well. This time I was monitoring the WWV track alongside with the VLF audio track so I could mark down the exact time that whistlers were being heard for comparisons of our logs at a later date. I was in for a surprise when I arrived at the point where the triggered emission occurred. Not only did I hear the triggered emission this time, but I also heard a transmission on the WWV station I was monitoring. It keyed up at exactly the same time the bubbling sound begins in the VLF audio track (approximately 0.8 seconds before the triggered emission occurred.) This transmission consisted

of an 8-second data signal followed by a CW identifier "WPC," which made the overall transmission time twelve seconds in duration. Now I found out I had not only the triggered emission on tape, but also the signal that triggered the emission with its Morse code identifier!

A little more research using audio filters and spectrographs showed that the signal was indeed transmitted by WPC. I thank Mike Mideke for the wonderful spectrographs he provided. A little research on the WPC transmitter showed they were licensed to 27 different frequencies in the HF radio spectrum. The station is run by the United States Coast Guard and sends out signals to commercial ships, military vessels and yachts worldwide. They boast about their "global coverage" using "very advanced proprietary technology" that relies on "using the earth's ionosphere" instead of "satellites" and their corresponding "mammoth capital investment." Again, from an email dated Sept. 26, "We provide commercial service on 27 frequencies for vessels all over the world using as our infrastructure nature's own ionosphere instead of a satellite structure costing many billions of dollars to put up." The station is located in Gladstone, New Jersey and transmits with one thousand watts of power. So, how did I happen to hear this signal on my WWV receiver?

That's easy to explain. All radios have mixers that mix different frequencies together to arrive at the signal you want to hear and to allow you to tune up and down in frequency. After being mixed, the signal is sent through filters to filter out the unwanted frequencies while leaving in place the desired frequency. If the unwanted signals from the mixing process are strong enough, they will bleed through the filter(s) and be heard along with the station that you are monitoring. A little research proves that this is what happened on Sept. 17th with my WWV receiver. My receiver has an IF (intermediate frequency) of 455 kHz. Usually, "images" (duplicates of the same signal which are heard elsewhere because of the mixing process of the radio receiver) occur at twice the IF (intermediate frequency). Looking at the frequencies licensed to WPC, one stands out in particular - 5910.5 kHz! Everything adds up now. I was monitoring WWV at 5000 kHz. Add to this twice the IF (910 kHz), and you come up with 5910 kHz. Further listening with this short-wave receiver used on Sept. 17th showed that all stations with any decent strength can be heard at their actual frequency and also at 910 kHz below their actual frequency. So, in summary, what I heard that night was the 5000 kHz WWV signal and the 5910.5 kHz WPC signal combining together into one signal at 5000 kHz in my receiver through the receivers' internal mixing process.

In closing, I would have to say that research is underway! If what was heard was in all actuality a triggered emission by an "HF" radio station, which very strongly appears to be the case, it could potentially mean another breakthrough in the field of research dealing with the ionosphere and the frequencies affecting the ionosphere. WPC uses a "log periodic antenna" to broadcast many of their transmissions. On the spectrographs, the triggered emission looks like two quick risers, which are then blended into two descending whistlers. One note that may be of interest is that on this particular night for several hours starting from the time of the triggered emission and continuing for several hours onward, the lightning crashes that appeared 5-10 dB louder in the WWV receiver while remaining at the same decibel strength as all the other crashes in the VLF receiver, seemed to be having really great affects on the VLF activity in the way of nice, loud-sounding whistlers. Again, I would have to say research is underway!

Instrumental Detection of Meteor-produced VLF Electromagnetic Radiation

Z. Andreic[1] D. Vinkovic[2], S. Garaj[3], G. Zgrablic[4],
D. Kovacic[5], S. Gradecak[4], N. Biliskov[6], and N. Grbac[7]

1 Rudjer Boskovic Institute, Dept. of Materials, Science, Thin Films Laboratory, Bijenicka 54, 10000 Zagreb, Croatia, E-mail: andreic@rudjer.irb.hr
2 Department of Physics and Astronomy, University of Kentucky Lexington, KY 40506, USA, E-mail: dejan@pa.uky.edu
3 Institut de Génie Atomique, Département de Physique, Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne - EPFL, Suisse, E-mail: slaven.garaj@epfl.ch
4 Department of Physics, Faculty of Science, University of Zagreb, Bijenicka 32, 10000 Zagreb, Croatia
5 Cognitive Neuroscience Sector, International School for Advanced Studies (SISSA), via Beirut 4, 34014 Trieste, Italy
6 Department of Chemistry, University of Zagreb, Strossmayerov trg 14, HR-10000 Zagreb, Croatia
7 Department of Mathematics, Bijenicka 30, HR-10000 Zagreb, Croatia

Abstract

In November 1998 a Croatian Physical Society expedition to Mongolia was undertaken. The goal was to try to record VLF emissions and electrophonic sounds (if any) of Leonids during the anticipated Leonid storm. We obtained some instrumental recordings of very-low-frequency electromagnetic radiation (VLF) which we attribute to a meteor. The detected VLF signals were coincident with the light maximum of meteors in question, and the meteors involved in these events were quite small (-5 mV and -8 mV) which implies much lower brightness limit (about –5 mv) for the VLF producing meteors than previously suggested. It is, however, not excluded that this limit depends on weather conditions. In the best recording (the -8m meteor), a 0.7 s long sequence of 8 short VLF impulses with amplitude of about 10-2 V/m, starting 0.1 s before the visual maximum of the meteor, was registered. The amount of gathered data is huge, and we are still at the analysis of it.

Introduction

The meteor--related electrophonic sounds are defined as sounds heard simultaneously with the appearance of a bright meteor. Although their existence and possible relation to "electric matter" (Bla1784) was recognized already in the 18th century, they are still a mysterious natural phenomenon. The fact that puzzled so many scientists is that any sound produced by the meteors would travel to the observer on the ground within a few minutes, as the meteors usually burn--out at heights of around 100 km. Moreover no audible sound from that height can reach the ground as the sound wave will be totally reflected back into the ionosphere on the denser layers of the atmosphere near the ground level. So the electrophonic sounds must have a different origin. A distinction to a normal sonic boom produced by very large meteors should be made here. The sonic boom is generated when a large and solid meteoroid, usually of stone or iron type, penetrates into the lower atmosphere, while the smaller meteors, to which our study is directed, disintegrate at heights between 80 and 100 km.

The first plausible mechanism of the origin of electrophonic sounds was suggested by Keay in 1980 (Kea80) and theoretically modeled by Bronshten (Bro83) (KB-theory hereafter). According to their theory, a bright fireball can under special conditions produce ELF/VLF radio waves The low frequency end of electromagnetic spectrum is divided into ULF (frequencies below 30 Hz), ELF (30--3000 Hz) and VLF (3 kHz--30 kHz) bands). This electromagnetic radiation can then be converted into sound by an ordinary object in the observer's vicinity. The main conclusions of this theory are that very bright bolides are needed to generate VLF, and they set the lover limit to -12 m (about equal to the brightness of a full Moon). Keay also tried to do some laboratory experiments on generation of sound by VLF fields on mundane objects that have clearly demonstrated the ability of VLF radiation to produce audible sound (Kea91). In 1991, he pointed to the first known detection of a meteor VLF by Japanese observers (Kea92a) which was published in Japanese (Wat88). Soon after, he refined the KB theory (Kea92b) and predicted that VLF can be generated in the moment of the explosive disintegration of a bolide, but also a little bit earlier. In cooperation with Ceplecha he tried to predict the average number of electrophonic sounds that should be heard by a single person (Kea94a). The calculation was based on data presented by Ceplecha (Cep92,Cep94). The results predict that a person who would spend every night outside has a once in a lifetime chance of hearing an electrophonic sound, with a comment that this is a very optimistic prediction as today many such events would be masked by man-made sounds and would so pass unnoticed. Recently Keay attempted to give a review of this field (Kea95) but misses some Russian references.

Expedition to Mongolia

To collect a significant sample of bright meteors, an exceptionally high meteor rate is needed. The predicted Leonid meteor storm of 1998 was expected to be such an event. The storm was predicted to happen over East Asia on the night of November 17/18 (Jen96). Historical records from the great Leonids meteor storm in 1833. suggest that large Leonids are capable of producing electrophonic sounds (Olm1833). Considering these facts, our observing campaign was located in Mongolia, lasting from Nov. 10 until Nov. 24, 1998. Here is a rather lengtly, but a very interesting recollection on the voyage itself, extracted from the diary of Dejan Vinkovic:

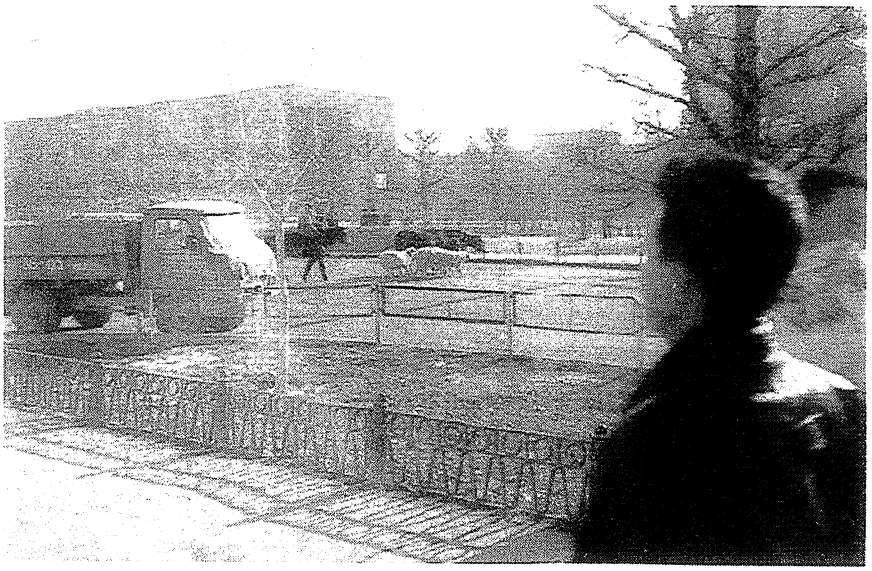


Figure 1:

Ulan-Bator has a lot in common with big towns of the former Soviet Union

"Imagine a huge land, empty land. Without people and roads, with deserts, mountains, wild animals, ... And one town in the middle of that. Small, smoggy town, mixture of people, cattle and cars... with nuclear power plants!! That's Mongolia and Ulan-Bator.

The first impressions of Ulan-Bator: streets are crowded and everything is strange and interesting. But people are friendly and curious on us. It is warm! Where is this "-30C"?! Is my investment into the low-temperature clothes a loss of money?
The first two days we spent in observing Ulan-Bator through the eyes of tourists: photo and TV cameras, getting excited about things which are ordinary for people there, talking with kids on the main square, etc.. At the evenings we were preparing the equipment, and had briefings about the current problems and how we would perform the experiments. Then we went to the astronomical observatory, where we supposed to have two gers, at least 2km away from the observatory to avoid electric installations because they are producing a ELF/VLF (extremely/very low frequency) radio noise. We would like to perform two experiments: detection of the ELF/VLF emission from the meteors, and detection of the electrophonic sound, which is probably somehow related to ELF/VLF electromagnetic waves. But, first we found that there was only one ger. Moreover, our Mongolian hosts thought that it would be nice for us to have electric bulb in the ger, so the ger was in the observatory complex, surrounded by electricity, impossible for any kind of experiments!

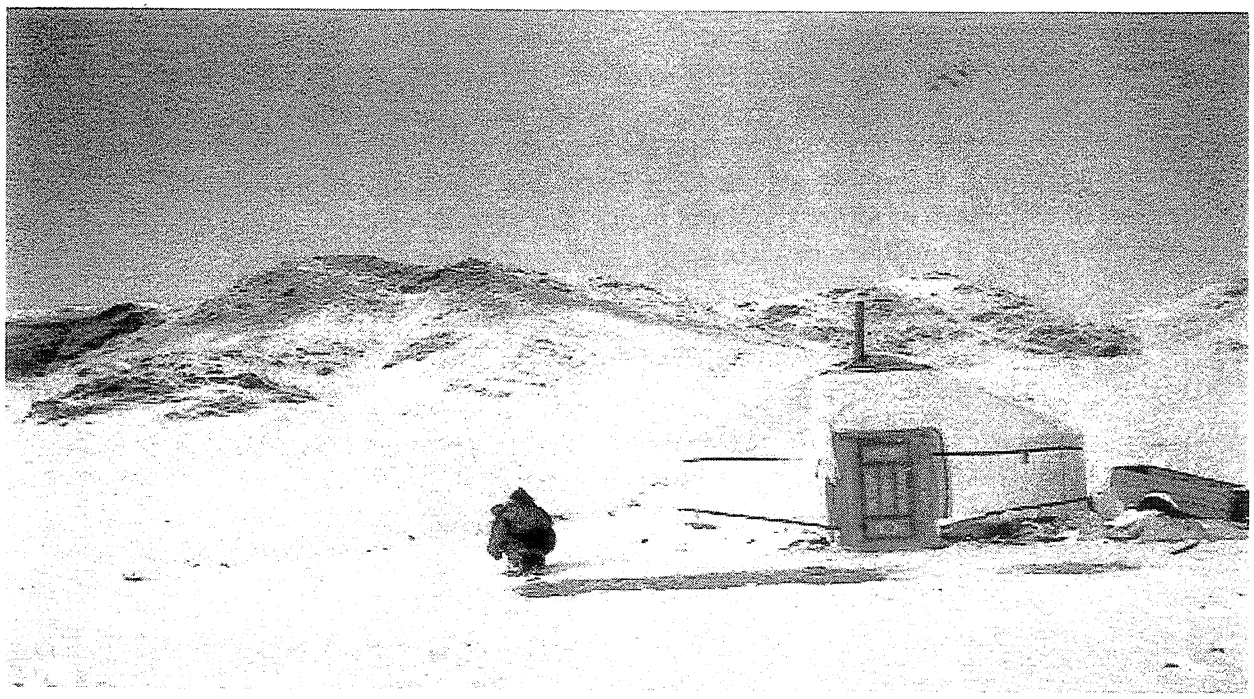


Figure 2: The first snow in the Mongolian wilderness. Believe it or not, people are driving cars there, even when there are no roads around. But the ground is smooth and frozen.

We thus had to move our gear somewhere where we wouldn't see civilization. During the day we found the place, and next day we were moving there. At least, we learned how to set up a ger. Weather is still nice, warm. But Americans at the observatory told us that a cold Siberian air was coming, with the snow in front of it. Americans are part of the large Canadian-American

expedition. There is a German team ,too, and a few people from Slovakia and Yugoslavia. Crowded place!

The first night in countryside: snow storm! The ger is really overcrowded: 13 people all together! Mongols said that another ger should come in the following days. Anyway, everybody is in a good mood. But temperature is falling down ... fast. Sky is suddenly full of clouds and snow storm starts! Next morning everything is covered by snow. And it is cold ... now I do not regret spending money on warm clothes anymore... First tests of our equipment are carried out in days before the anticipated meteor storm. Temperature outside is -25C !! Cool!! Every night the sky is partly cloudy. We are worried about the sky at the night of maximum, although Americans are saying that weather will be good, and we relied on it. Then the last night before the predicted maximum came and we made the last tests of complete practice for tomorrow. There are two of us outside, freezing on almost -30C, and making visual observations and comments which are recorded with the video signal from a small camera. There are also two microphones specialized for electrophonic sounds, and two ELF/VLF antennas. Everything is going smoothly. Taurids are active. There is also a small activity of Leonids. But, the Leo constellation is still under the horizon, and activity will be probably a little bit larger after the midnight, when the Leo is rising. At about 11pm, we noticed a few very nice Leonids. Good. If we already see higher activity, then we can expect show tomorrow. Actually, the show has already begun! The number of Leonids is slowly increasing. All of them are bright. Magnitude zero or brighter. But, the Leo is rising and Leonids are flying more often.

Suddenly, we realize that something strange is happening! These meteors have become fireballs, and now we can see huge explosions every 10 minutes. And there are no small meteors!! The excitement is rising. At 3am we are watching incredible show: explosions every few minutes. The most of them have beautiful trails and colors. We are just standing and waiting for another flash from the sky. Sometimes they are so bright that you can see shadows on the ground. Slaven and Neven claim that they heard an elecrophonic sound. But we are skeptical. Until something turns night into day! A huge bolide appears on the north horizon, and we hear a "pop" sound! Now we are sure that they exist, and hope that everything is on tapes. This incredible show was going on and on ... We have a tape where we're dancing in front of camera, when the Sun and Moon are rising behind us, and meteor is falling near by the Moon! When the Sun rose, they were still falling on the blue sky! This was indication that they are visible in Europe, too.

The setup of the equipment

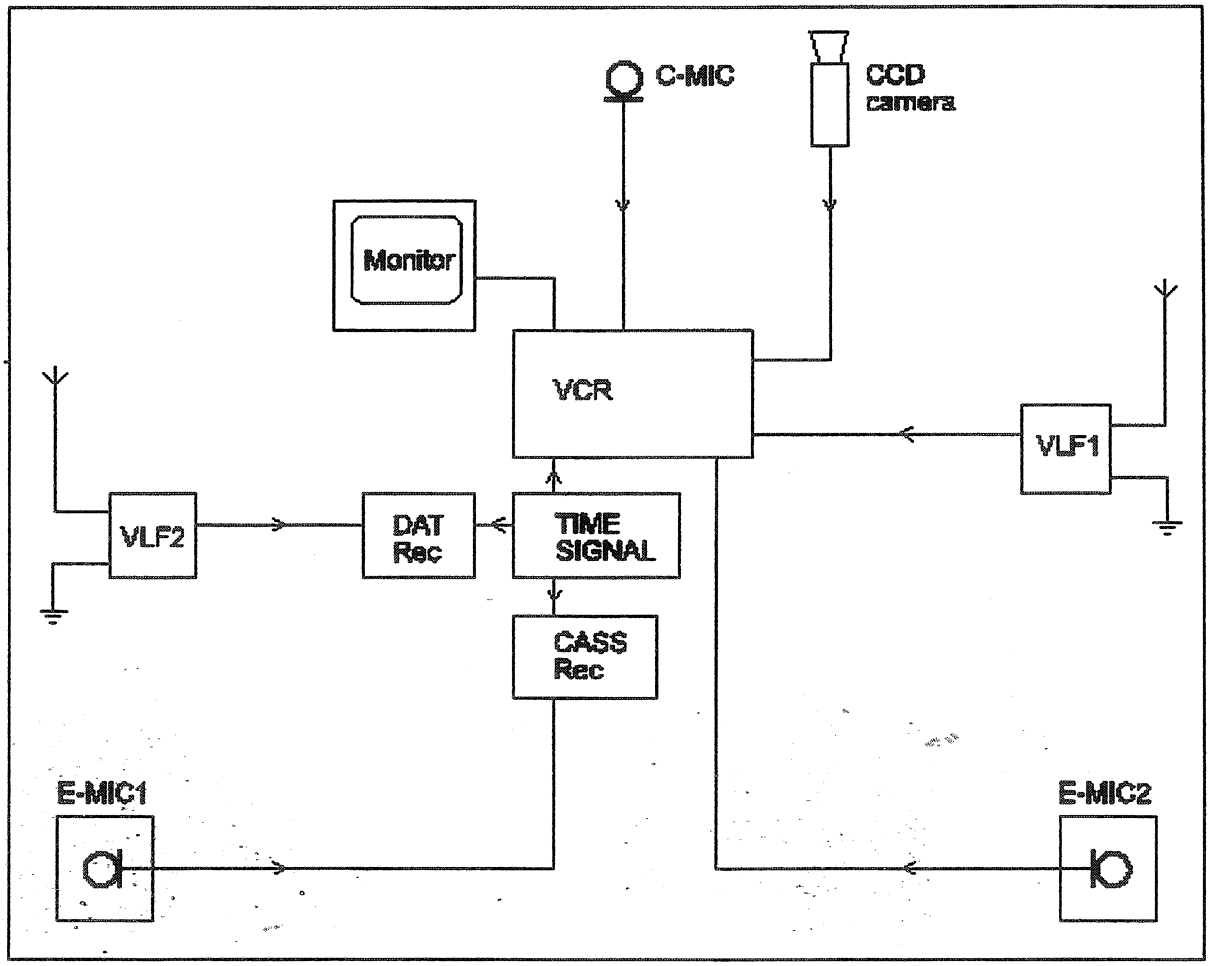


Figure 3: The schematics of recording setup used in our experiment. Video signal from a CCD camera is recorded on a professional VHS video-recorder with 4 sound channels. An accurate time signal is recorded on one of these channels to provide absolute time reference for other channels. The other channels are used for an VLF detector (VLF1), observers comments (C-MIC) and a separate environmental sound microphone (E-MIC2). A digital sound recorder (DAT) supported spare VLF detector and a cassette recorder supported a spare environmental sound microphone (E-MIC1).

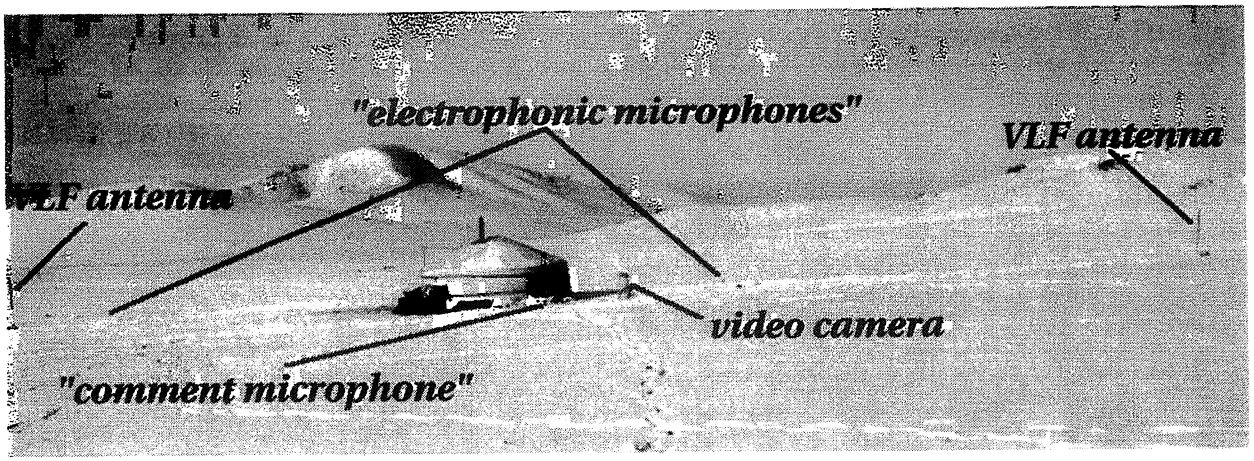


Figure 4: The observing site and the position of the microphones and the antennas around it. At the moment when this picture was taken, there was about 15 cm of snow and the temperatures were very low already.

On the observing site was almost no vegetation, and the relatively flat ground was covered with snow. The humidity was extremely low, and the temperature during the observations was between -20° C and -30° C. The scheme of experimental setup is shown on the Fig. 4. We used two separated and locally grounded VLF receivers (INSPIRE RS4) with whip antennas. To avoid local interference, the antennas were well separated from each other and from visual observers. Microphones in another part of experimental setup were used to monitor environmental sound. A CCD video camera with a sky coverage of 55% and a limiting magnitude of about 0 m was placed near the visual observing site. Absolute time signal from Taskent radio station at 5.000 MHz was recorded simultaneously with other signals on each recorder used. Simple photometry was performed on the video frames, each one with 0.04 sec exposition (25 frames/sec frame rate). A dark frame was created by averaging six frames at 0.5 sec before the frames with visible meteors. After the dark frame had been subtracted from the frames with meteors, a simple integration of the remaining pixel values was performed, and Sirius was used for calibration of magnitude scale. The two main sources of error associated with this procedure are the outermost contour used for the integration and the comparison of the resulting intensity with Sirius. Due to the low S/N of the Sirius image, this was the principal source of error which was estimated to about ± 0.5 m. Overall synchronization accuracy between different recording channels was found to be better than ± 0.02 s. In total, 5.5 hours of observations on the night of Nov. 16/17, 1998. were logged in. In addition to the two ELF/VLF signals from meteors known before, we obtained several new recordings, with an order of magnitude better time correlation with video and sound signals than before. No electrophonic sound was detected for these events. The most interesting VLF signal is shown on the Fig. 5.

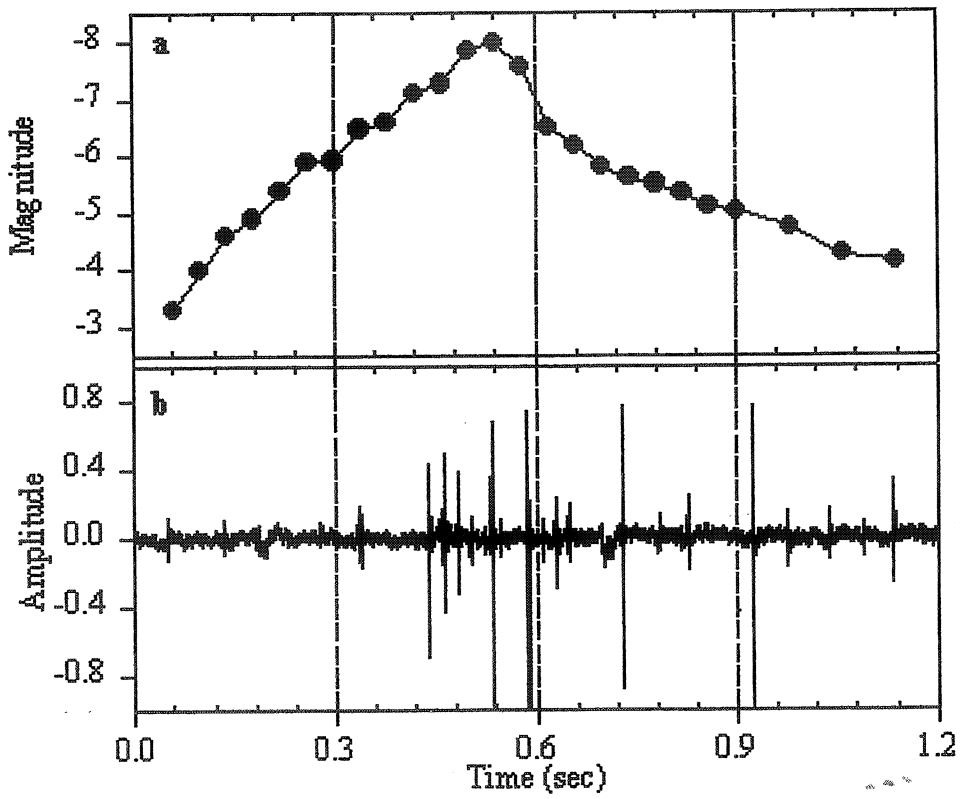


Figure 5: Recorded ELF/VLF emission from a -8 m (+- 0.5 m) meteor. Upper panel shows the meteor brightness recorded by video, and the lower panel is the signal at ELF/VLF channel during that event (amplitude is given in arbitrary units). Time 0.0sec = 21h 44m 35.1s UT (Nov.16.1998.). The synchronization accuracy between video and ELF/VLF channel is +- 0.02 sec.

A meteor with visual magnitude of -8 mv was observed close to the horizon and the final part of the trajectory is partially obscured by a hill, but the light maximum is clearly visible on the video. About 0.1 s before the visual maximum, a sequence of 8 short pulses of VLF radiation appeared, with a total length of 0.7 s and amplitude of about 10-2 V/m. More rigorous discussion of this first results can be found in our article published in Fizika (Gar99).

Conclusions

A vast amount of experimental data (the complete data set spans about 35 CD ROMs of video and audio data) was gathered the night before the anticipated Leonid storm. The preliminary analysis has given us some examples of VLF radiation from meteors and, for the first time ever, detections of electrophonic sounds The VLF observing group remains active and more observing sessions will be caried on on favourable occasions. An indication that electrophonic sounds are maybe produced by ULF instead by VLF waves exists, so we are planning to use receivers that are sensitive in the ULF region also. We recently expanded our activities by starting the Global Electrophonic Fireball Survey (GEFS, accessible at http://gefs.ccs.uky.edu) reporting network. The purpose of the GEFS is to collect these reports and provide a more systematic approach in the study of this phenomenon with a possibility for more extended activities.

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References

(Bla1784) C. Blagden, An account of some late fiery meteors, with observations, Phil. Trans. Roy. Soc. 74, 201-232 (1784)
(Kea80) Keay C.S.L., Anomalous sounds from the entry of meteor fireballs, Science 210, 11-15 (1980)
(Bro83) Bronshten V. A., A magnetohydrodinamic mechanism for generating radiowaves by bright fireballs, Solar System Research 17, 70-74 (1983)
(Kea91) Keay C S L, Ostwald P M, A laboratory test of the production of electrophonic sounds, J. Acoust. Soc. Am. 89, 1823-1824 (1991)
(Kea92a) Keay C S L, Meteor fireball sounds identified, Asteroids, comets, meteors 1991, Lunar and Planetary Institute, Houston, 1992
(Wat88) Watanabe T, Okada T, and Suzuki K, Meteor and radio wave, HAM Journal (Japan) 54, 109-115 (1988) (in Japanesee)
(Kea92b) Keay, C.S.L., Keay C S L, Electrophonic sounds from large meteor fireballs, Meteoritics 27, 144-148 (1992)
(Kea94) Keay C S L, Ceplecha Z, Rate of observation of electrophonic meteor fireballs J. Geophy. Res. E 99, 13163-13165 (1994)
(Cep92) Ceplecha Z, Influx of interplanetary bodies onto Earth, Astron. Astrophysics 263, 361-366 (1992)
(Cep94) Ceplecha Z, Impacts of meteoroids larger than 1 m into the Earth's atmosphere, Astron. Astrophysics 286, 967-970 (1994)
(Kea95) Keay C S L, Continued Progress in Electrophonic Fireball Investigations, Earth, Moon, Planets 68, 361-168 (1995)
(Jen96) Jenniskens P, Meteor stream activity. III.: Measurements of the first in a new series of Leonid outburst, Meteoritics and Planetary Science 31, 177-184 (1996)
(Olm1833) Olmsted D, Observations on the Meteors of November 13th, 1833., The American Journal of Science and Arts, 25(2), 363-411 (1834)
(Gar99) Garaj S, Vinkovic D, Zgrablic G, Kovacic D, Gradecak S, Bilickov N, Grbac N and Andreic Z, Meteor-produced VLF Electromagnetic Radiation, Fizika A8, 91-98 (1999), pdf or ps version can be downloaded at http://fizika.hfd.hr/fizika_a/av99/a8p091.htm (if it does not work, go to http://fizika.hfd.hr/fizika_a/ and search on the table of contents by title)
(WGN2000) Vinkovic D, Andreic Z, Garaj S, Kovacic D, Mladinov M, Zgrablic G, lobal Electrophonic Fireball Survey, WGN, the Journal of the IMO, 28, 48-53, (2000)

Whistler Analysis Using the TI-83+ Graphing Calculator

By: Mark Spencer
Coleville, CA 97107
wa8sme@gbis.com

ABSTRACT

This article covers three topics. First, a procedure for using the TI series of graphing calculators (specifically the TI-83 plus) to analyze whistler-generated data is presented. This process uses the curve fitting, data manipulation, and calculus capabilities of the graphing calculator to accurately analyze whistlers and to extrapolate data from the received whistlers outside of the frequency range that was audible and visible upon reception. A wide frequency range whistler is used to test the procedure to demonstrate the validity of extrapolating data from the "typical" whistler. Second, a process using the graphing calculator to analyze whistlers based on the dispersion models presented in Robert Helliwell's book *Whistlers and Related Ionospheric Phenomena* will be presented. Calculation of the time location of the source lightning strike of a whistler will be compared to actual received data. Finally, a graphing calculator program that produces predictions of low-frequency and high-density models of whistlers will be presented. Received whistler data is overlaid on the two models to illustrate how graphing calculator technology can be used to compare real world data to theoretical predictions. The article concludes with a few observations and generalizations about whistler behavior that resulted from this project and the author's novice study to date.

Introduction

I have been listening to whistlers for only a very short period of time. The experience has been very rewarding and the auditory beauty of the sounds generated by natural phenomena have generated a new appreciation for our complex world. I have been fortunate to hear examples of almost all of the various signals that are by-products of lightning strikes. Though many of my peers and acquaintances have looked at me with suspicious accommodation when I replay the "neat" things that come over the low-frequency airwaves, my enthusiasm to learn more about these audio pearls of nature has not been dampened.

I will freely admit that I became frustrated by the apparent superficial depth of coverage given to whistlers in contemporary publications. Fortunately an e-mail reply to a rhetorical question I posed in a recent article in the *Inspire Journal* proved to be the catalyst I needed to begin a serious study of the whistler phenomena. The e-mail hinted that I should seek out the book by Robert Helliwell, *Whistlers and Related Ionosheric Phenomena*. During an Internet search I found three copies of the book available, two in major university libraries and one in the Library of Congress. I live in a very rural, frontier county of California and my request for an inter-library book loan from the Library of Congress raised many doubtful eyebrows, and that was

before the librarians even looked at the title of the book. The quest was well worth the effort and I would recommend that anyone serious about studying whistlers get their hands on this book.

I want to caveat the remainder of this article up front: there is nothing that follows that I would consider original research. All that follows is based on the content and work presented in Helliwell's book and I give him and other contributors to his book full credit. I hope that you will indulge this one, all encompassing footnote.

There are three parts to this article. First, a procedure for entering time and frequency data taken from received whistler plots into a TI-83 plus graphing calculator will be presented. Once the data is entered into the calculator's lists, curve fitting and discrete analysis of the curve can be performed to get a mathematical snapshot of the whistler. The whistlers that I receive at my latitude (38 degrees north) generally have a frequency range from 500 Hz to 5,000 Hz. I found this frequency range a little shy of the range I needed for a comprehensive analysis of a whistler and I was looking for a reliable way to extrapolate data from a whistler that was outside of the actual received range. I also needed a way to determine the slope of the whistler at a specific frequency (find the derivative of the whistler curve). This procedure allows me to do that.

The second part of the article builds on the process developed in the first part to apply the data received from a whistler to a mathematical model to determine the time of the lightning strike that created the whistler. The model was tested numerous times with collected data. In most cases the spherics were so numerous within a reasonable time of predicted strike that it was difficult to confirm with certainty that the predicted strike was in fact the strike that created the whistler. Fortunately I have had a few very quite days when I could determine a definite correlation between the predicted strike and an actual strike that preceded the whistler. These occurrences allowed me to validate the utility of the model.

The third part of the article tests two mathematical models for whistlers presented in Helliwell's book, the low-frequency model and the high-density model. A program that displays both models on the calculator screen is presented. Actual whistler data can then be overlaid on the models for comparison.

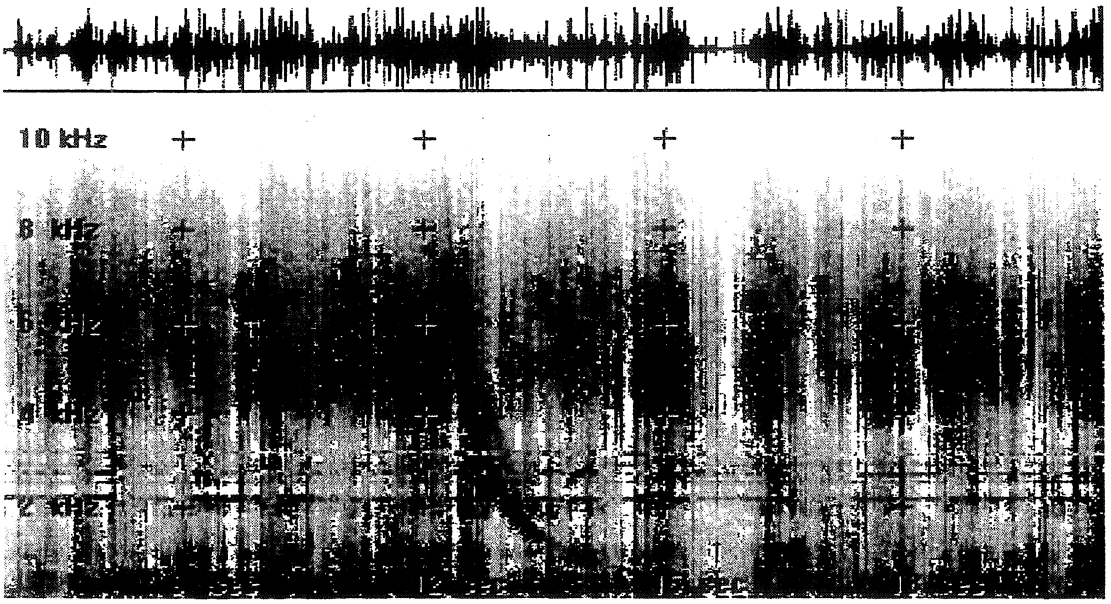
I have attempted to provide enough step-by-step procedures for the graphing calculator neophyte. The procedures could be readily adapted to other calculators than the TI-83 plus.

Part 1: Entering whistler data into the graphing calculator.

The overview of this procedure is as follows:

1. Extract time and frequency data from the whistler using the Spectrogram program.
2. Enter the data into the graphing calculator lists.
3. Normalize the time data to around 1 second.
4. Perform a curve fit of the data using the graphing calculator power curve fit function.

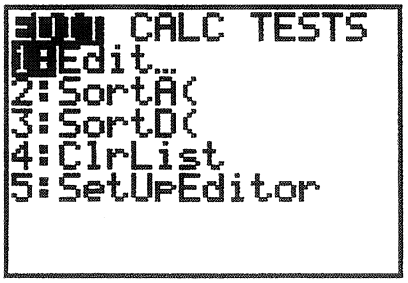
For demonstration purposes I have chosen one particularly good whistler that I collected that had a very distinct signature on the Spectrogram presentation that allowed me to precisely extract time and frequency data. This particular whistler also had a wider than the normal frequency range, from about 10,000 Hz to about 600 Hz, which allowed me to test the validity of the concept of extrapolating data from the fitted curve that was outside the range of the actual received time and frequency of typical whistler. The whistler being used is depicted in figure one. If you would like a copy of the wave file of this whistler please submit a request via e-mail.



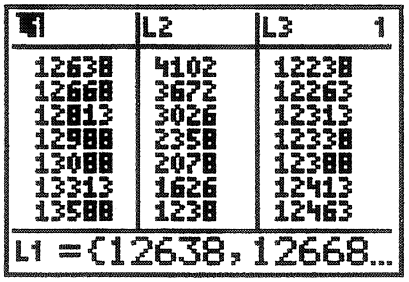
Step 1. The time and frequency data that I pulled from this whistler is listed in table 1. I have split the data extracted from this whistler into a high-frequency set (first two columns) and a low-frequency set (last two columns). The demonstration analysis will treat the low frequency data set first, do a curve fit using this data, then overlay the high frequency data on the curve to see how valid the curve fit using the low-frequency data is, and finally, the total data set will be used to provide a comparison of the curves.

Data Table for Whistler 04301130z at 12 seconds			
Time (ms)	Frequency (Hz)	Time (ms)	Frequency (Hz)
12238	10089	12638	4102
12263	9443	12688	3672
12313	8452	12813	3026
12338	7720	12988	2358
12388	7009	13088	2078
12413	6363	13313	1626
12463	5696	13588	1238
12488	5330	13963	937
12563	4641	14313	722
		14688	571

Step 2. After you have turned on your calculator press the **[STAT]** key, you should see the following screen:



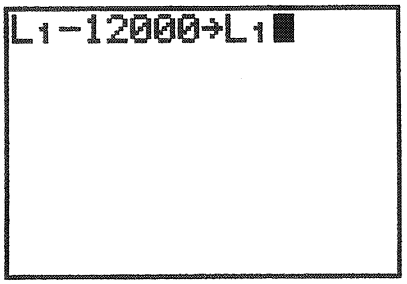
Press **[ENTER]** to select **Edit** and the lists will be presented. If the lists **L1**, **L2**, **L3**, and **L4** are not empty, you should empty them by using the arrow keys ([◀] [▲] [▶] [▼]) to highlight each list to be cleared in turn as shown here for **L1**, pressing the **[CLEAR]** key and then **[ENTER]**, will clear the list. Repeat this process for **L2**, **L3**, and **L4**.



Enter the time and frequency data that you extracted from the whistler into **L1** and **L2**, if you would like to follow along with my example, enter the low-frequency time in **L1** and the frequency in **L2** and the high-frequency time in **L3** and frequency in **L4** as shown here.

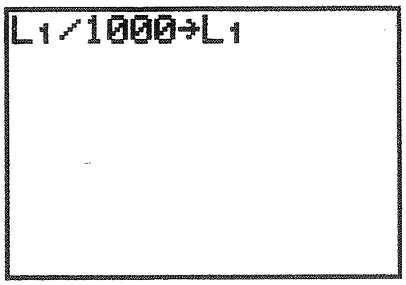
Step 3. I have developed the habit of normalizing the time data to a range that makes the remaining calculations more consistent. If you choose to use the actual time data from Spectrogram in milliseconds, the time numbers will get pretty large and may be outside of the capabilities of the calculator. I subtract some number that will normalize the time data to approximately 1 second (1000 milliseconds) (in this case subtract 12000 ms from each time list **L1** and **L3**) and then divide the time list by 1000 to convert the times into seconds as follows:

Press **[2ND] L1 [-] 12000 [STO→] [2ND] L1 [ENTER]**



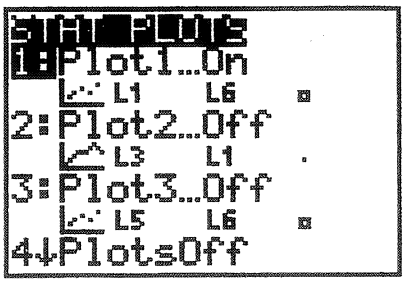
Repeat this process to normalize time list **L3**.
Now divide the time lists by 1000 to convert the time into seconds as follows:

Press **[2ND] L1 [÷] 1000 [STO→] L1**

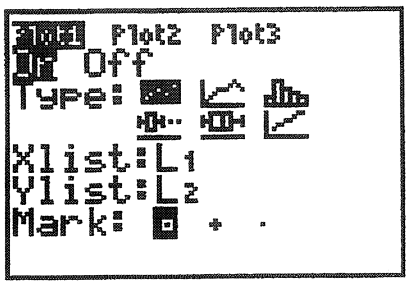


Again repeat this process to convert list **L3** to seconds

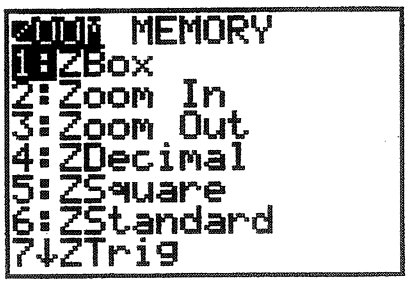
Step 4. Confirm that the data you entered into the calculator lists looks reasonable by displaying a plot of the data, your calculator plot should mirror the plot displayed by the Spectrogram software. Press the **[2ND] [Y=]** (for **STAT PLOT**) keys to obtain this screen:



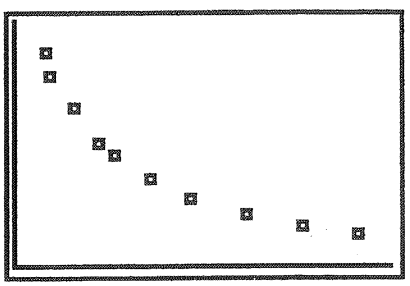
Select **PlotsOff** and press **[ENTER]** twice to turn off all plots (this avoids confusion later). Press the **[2ND] [Y=]** (for **STAT PLOT**) keys again and select **Plot1** (**[ENTER]**). Select the options as shown on this screen (**On**, **scatter**, **Xlist L1**, **Ylist L2**, **Mark** is the **square**).



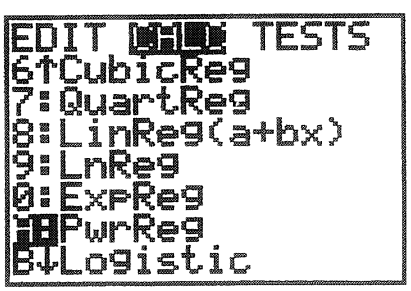
After the plot parameters are selected, press the **[ZOOM]** key to obtain this screen.



Scroll down with the **[▼]** key or press **9** to perform a **ZoomStat** operation. You should have a screen that looks like this, if the plot does not resemble the whistler presented by Spectrogram, check your data:



It is time to fit a curve to the data. Press the **[STAT]** key to obtain this screen and cursor over to **CALC** and cursor down to highlight **PwrReg**.



Press **[ENTER]** to call the **PwrReg** procedure and enter **L1** for the independent, and **L2** for the dependent variables as shown.

```
PwrReg L1,L2
```

Press [ENTER] to obtain the algorithm for the curve that fits the data.

```
PwrReg
 y=a*x^b
 a=2266.211098
 b=-1.344603447
 r²=.9976883801
 r=-.9988435213
```

You can write this algorithm down but that would be very tedious and error prone. The following keystrokes will enter the algorithm into one of the functions automatically:

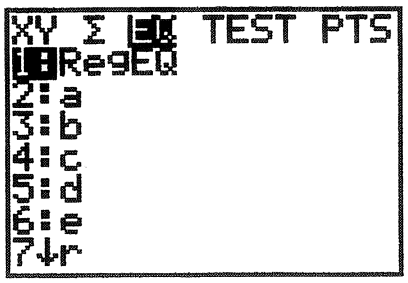
Press [Y=] and ensure the Y1 is cleared, if it is not press the [CLEAR] key and it will be cleared.

```
 Plot1 Plot2 Plot3
\Y1=
\Y2=
\Y3=
\Y4=
\Y5=
\Y6=
\Y7=
```

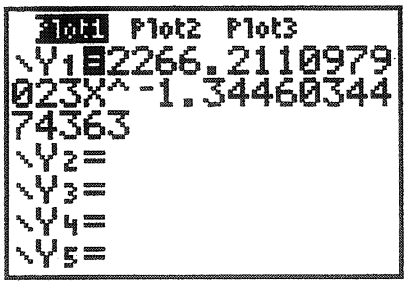
Press the [VARS] key and select **Statistics**:

```
VARS Y-VARS
1:Window...
2:Zoom...
3:GDB...
4:Picture...
5:Statistics...
6:Table...
7:String...
```

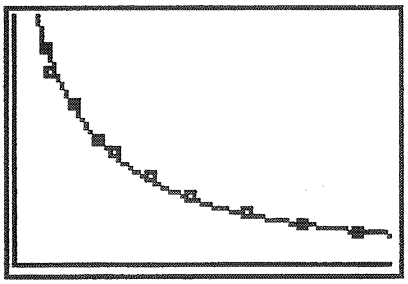
Press [ENTER] and select **EQ** and **RegEQ**:



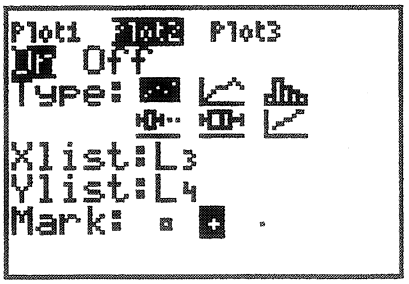
Press **[ENTER]** and the algorithm for the fitted curve will be entered into **Y1** and **Y1** will be turned on as shown (the = will be bold):



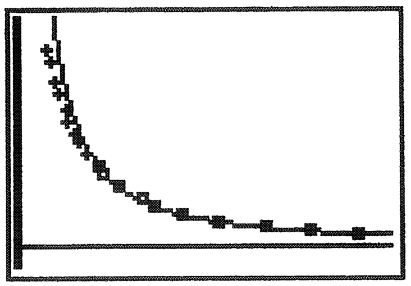
Now when you press **[ZOOM] 9** (to display **Plot1**) the fitted curve will be overlaid on top of your data and you can confirm the quality of the fit.



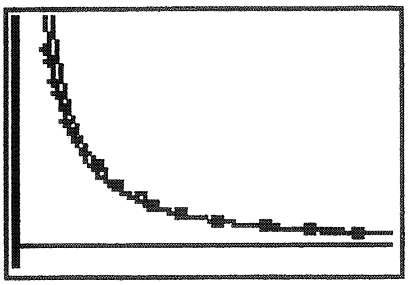
Now the high-frequency data will be added to the plot. Turn on the display of the high-frequency data by pressing **[2ND] [Y=]** and selecting the following parameters for **Plot2**:



Press **[ZOOM] 9** to obtain the display of the combined high and low-frequency data points and the curve that is based on the low-frequency component of the data.

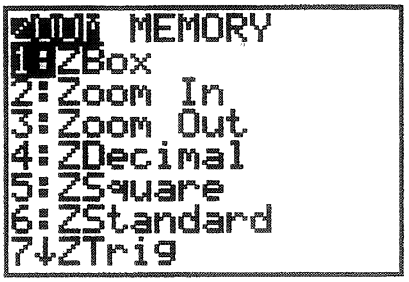


The curve derived from the low-frequency data seems to be a reasonable fit for the total data though there is some departure from the high-frequency data points. To take a more quantitative look at this departure, create a listing of the total data from table 1 in lists **L5** and **L6**, do a curve fit of that data following the same procedures as before except put the curve into **Y2**, and display the data and the two fitted curves:

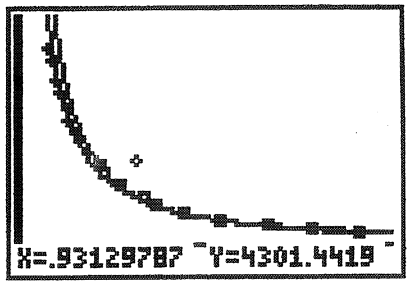


There seems to be fairly good correlation between the curves developed from the low-frequency data alone when compared to the curve developed from using all of the data. The frequency of 5,000 Hz is of particular interest in part 2 of this article. This frequency was chosen by Stanford University researchers as the reference point for calculations and models to determine the time of the lightning strike that created the whistler and also for comparing the slope of various whistlers to help determine the whistler type. The frequency was chosen because whistlers are generally strongest and most pronounced at this frequency. Therefore we will use the frequency of 5,000 Hz to test the validity of this curve fitting process by taking a more detailed look at the two developed curves at this frequency.

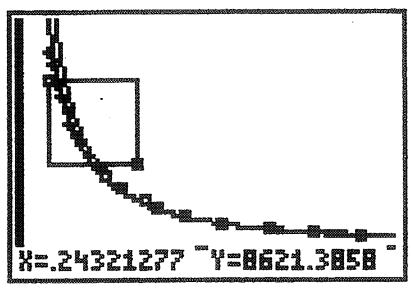
Zoom in around the area of 5,000 Hz by pressing **[ZOOM]** and selecting **ZBox**:



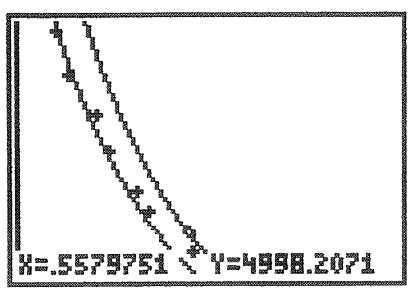
Press [ENTER] and your plot display returns with a crosshair that will be used to select the corners of the zoom box and a display of the X (time) and Y (frequency) coordinates of the crosshair. Our area of interest is around 5,000 Hz so place the crosshair to a time on the right side of the curves and a frequency less than 5,000 Hz as shown.



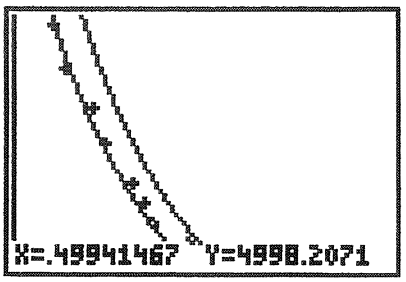
Press [ENTER] and move the crosshair to the upper left hand corner of the zoom box, to a time on the left side of the curves and a frequency greater than 5,000 Hz as shown. You will note that while you move the crosshair, the zoom box is depicted on the display.



Press [ENTER] again to display the magnified area of the display. Note that the X and Y coordinate values of the crosshair location are depicted at the bottom of the display. Move the crosshair to a point on the low-frequency curve at frequency of approximately 5,000 Hz, in this case 4998.2 Hz. Note that the time of arrival of this frequency is listed in X as .5579751 (.5580) seconds.



Now move the crosshair to the curve derived from all of the data at the same frequency using the [◀] key. The time of arrival of the 4998 Hz frequency on this curve is .4994147 (.4994) seconds.



The time difference of arrival between the two curves is .0586 seconds. This difference is comparable to the accuracy of the time and frequency measurement technique used to extract the data from the Spectrogram program plot. There appears to be a reasonable expectation that the curve fit method does provide an opportunity to extrapolate data outside of the collected frequency range. Though the fitted curves are not perfect, they are usable.

Part 2: Using whistler dispersion to calculate the time of the source lightning strike.

Armed with the analytical tools provided by the graphing calculator, we are now ready to tackle a mathematical model that will allow us to calculate the time of the lightning strike based on the arrival time of a specific frequency and the dispersion of the whistler wave form.

Very low frequencies in the range of whistlers do not travel at a consistent velocity. When these frequencies travel over great distances through a non-vacuum, non-homogeneous medium, the higher frequencies travel at a greater velocity and therefore arrive before the lower frequencies, which produces the whistler effect. The concept that different frequencies of a wave travel at different velocities is defined as the dispersion of the wave. Dispersion of a wave is a function of the length of the path and the electron density along the path (longer paths and/or higher electron density, the greater the dispersion). For the sake of this article I am going to ignore other factors that contribute to the dispersion of the wave such as heavy ion density, which arguably has a negligible contribution to wave dispersion of the frequencies being considered here.

Mathematically, dispersion is defined by:

$$D=t\sqrt{(f)}$$

Where **D** is the value of the wave dispersion, **t** is the time delay from the source of the frequency (the lightning strike), and **f** is the discrete frequency of the wave. The fact that a whistler is defined by this mathematical function can be verified by graphing the whistler data extracted from a collected whistler as $1/(\sqrt{(f)})$ versus **t**. This graph should reflect a straight line with a slope of **D**.

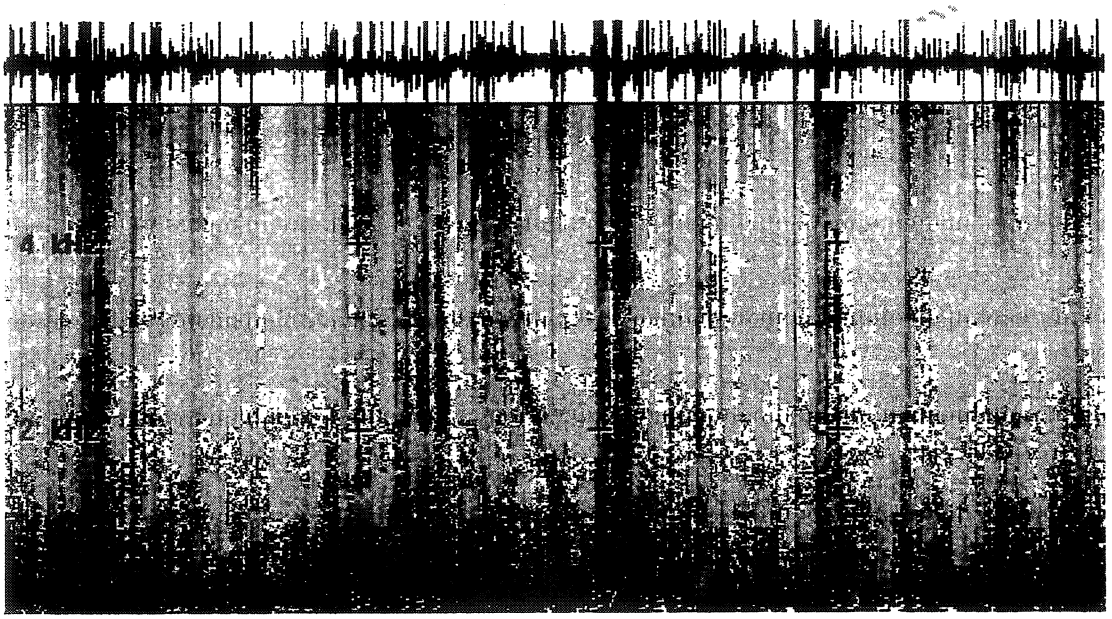
In the analysis that follows, I will use the example set by Stanford University researchers who used a standardized frequency of 5,000 Hz because the waves seemed to be strongest at this frequency; however, other convenient frequencies can be used.

If the source time is missing, dispersion can be estimated from the slope of the whistler curve at a specific frequency. Assuming that the dispersion is constant at a given value of $t\sqrt{f}$ then:

$$D = -2f^{3/2}dt/df$$

Where **dt/df** is the derivative (slope) of the whistler curve at the discrete frequency **f**. This gives the dispersion of the wave as a function of the slope and can be used when the time of origin of the source lightning strike cannot be determined otherwise.

I am fortunate to have an excellent location within 15 minutes drive of my home to collect whistler signals, and I receive numerous whistlers on virtually every excursion. Many times there are so many spherics associated with the whistlers that it is difficult to pick out the one strike that could be associated with a particular whistler but there have been enough quiet opportunities that I have been able to correlate collected whistlers with their probable source spheric to test the dispersion mathematical model. That process follows.



The whistler that I am using for this analysis is depicted in figure 2. A copy of the wave file is available for the asking via e-mail. One note of interest: I discovered that the Spectrogram software does not load the wave file at the same starting time each time a specific wave file is loaded and displayed. Therefore if you are going do this dispersion analysis to calculate the time of the source strike and then look for the source strike on the Spectrogram screen, you will need to use the same depiction of the whistler as the one that the data is extracted from so that the time reference is the same.

The data extracted from this whistler is contained in the following table.

Data Table for Whistler 06031030z at 85 seconds	
Time (ms)	Frequency (Hz)
85863	4275
85938	3456
86038	2918
86163	2358
86288	1906
86538	1303

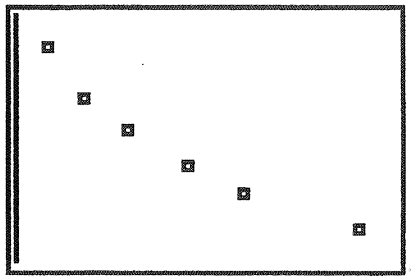
Table 2.

There are a number of calculations that will be accomplished based on the data and the resulting fitted curve. It is helpful to keep an organized log of the calculations so that the accumulation of data can be used later for further analysis. The table that I developed to help organize the calculations is at Appendix 1. I will refer to that table during the following calculations. The example table includes the results of this example calculation and the calculations using the whistler data from Part 1.

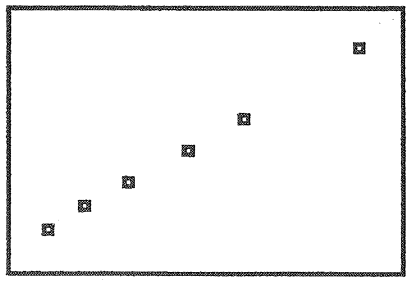
The overview of this procedure is as follows:

1. Enter whistler data points into calculator lists.
2. Normalize the time data to around 1 second.
3. Display the data to confirm data entered correctly.
4. Create a list of $1/(\sqrt{(f)})$ and display a plot of this list versus time, check for a linear relationship.
5. Fit a curve to the data and expand the display window to include the discrete frequency of interest (i.e., 5,000 Hz).
6. Determine the slope of the curve at the discrete frequency (**df/dt**).
7. Calculate the inverse of this slope (**dt/df**).
8. Calculate the dispersion of the wave.
9. Calculate the time from the arrival of the discrete frequency to the source strike.
10. Convert the source strike time to the Spectrogram plot time reference and look for the source strike on the display.

After entering the identification data on the specific whistler being analyzed into the ID columns of the log, the data points are entered into the graphing calculator as outlined in Part 1 of this article. Using the data in Table 2, the following plot depicts the data for this whistler.

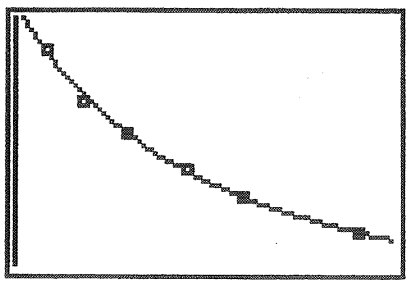


To test whether the whistler follows the inverse square model, enter the inverse square root of the frequency into one of the lists and then plot the data. Press **1[÷][2ND] [x²]** (for square root) **L?** (list where frequency data is stored) **[STO→] L?** (list where square root data is to be stored for plotting) **[ENTER]**. The plot appears as follows.

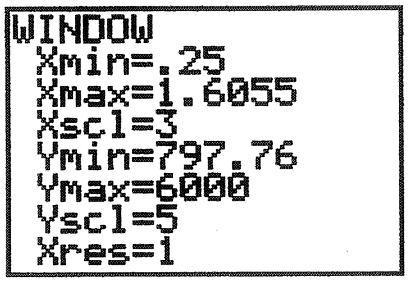


This plot is approximately linear and verifies that the whistler follows the inverse square of the frequency model.

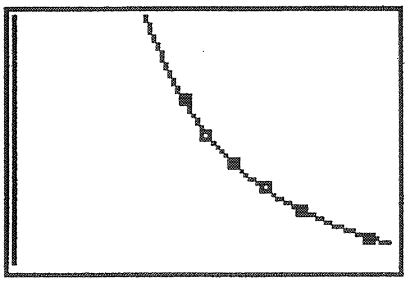
Now performing a curve fit on the whistler data results in this plot.



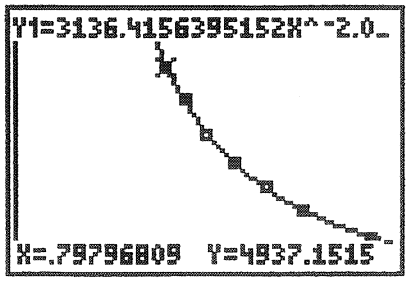
I chose this whistler because it was typical of the frequency range of the whistlers received at this latitude. The data point of the maximum usable frequency was approximately 4,300 Hz, a little short of the standard 5,000 Hz that is being used for the remainder of the calculations. This is where using the fitted curve allows us to extrapolate data outside of the received range of the whistler. To do this, the plot of the curve needs to be expanded to include frequencies greater than 5,000 Hz. Press **[WINDOW]** to obtain the display parameters. Change the **Xmin** (time) and the **Ymax** (frequency) as shown to expand the display to frequencies above 5,000 Hz.

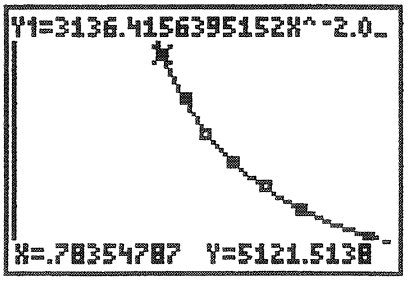


Now press [GRAPH] instead of [ZOOM] 9 to accept the modified display parameters. Pressing [ZOOM] 9 at this point would return the display parameters to the best-fit parameters based on the list data.

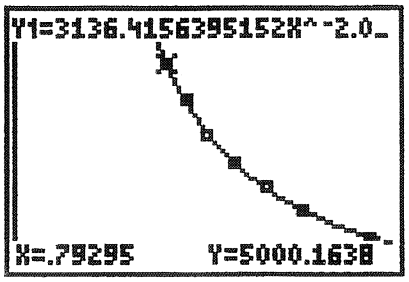


Pressing the [TRACE] key and then the [▲] key puts the calculator into the trace mode and tracing the curve as opposed to the actual data. Using the [◀] and [▶] keys move the crosshair to either side of the 5,000 Hz frequency coordinate as listed at the bottom for Y=, take note of the time of arrival (X=) of the points on either side of the 5,000 Hz frequency point. Here the right hand point is at frequency 4937 Hz arrived at .7980 seconds and the left hand point is at 5121 Hz at .7835 seconds.

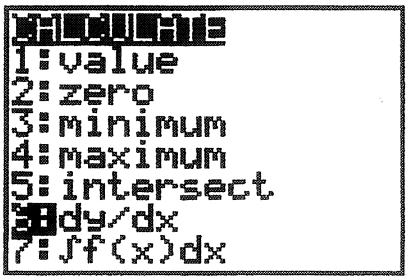




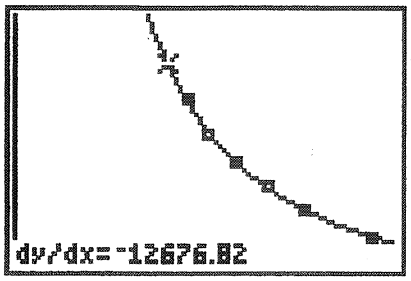
The following steps will take some trial and error to zero in on the time of arrival of the 5,000 Hz frequency. While still in the trace mode enter values between .7980 and .7835 seconds until you get as close to 5,000 Hz as possible. Here the arrival time of the 5,000 Hz frequency was a time of .79295 seconds.



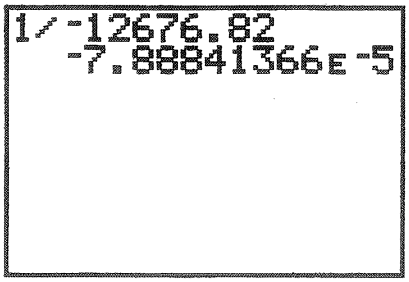
Note this time of arrival for the next step, determining the slope of the curve at 5,000 Hz. Press **[2ND] [TRACE]** to enter the CALC menu and select **dy/dx**.



Press **[ENTER]** and you will return to your data and curve plot. Enter the time of arrival for the 5,000 Hz frequency (.79295) and press **[ENTER]**. The derivative result will be displayed at the bottom. Enter this number in the appropriate column on the whistler analysis data sheet attached.



Next find the inverse of this slope (**dt/df**) and enter it into the data table.
Press **1/-12676.82 [ENTER]**.



Calculate the dispersion at 5,000 Hz by the following keystrokes. Press –
2(5000[▲] (3[÷] 2)) [2ND] [-][ENTER].

```
1/-12676.82
   -7.88841366E-5
-2(5000^(3/2)Ans
        55.77950789
```

The dispersion returned is 55.77; enter that number in the appropriate column. Next calculate the time of the strike before the arrival of the 5,000 Hz frequency by calculating the dispersion divided by the square root of the frequency. Press **[2ND] [(-)][÷][2ND] [x²] 5000 [ENTER]**

```
Ans/√(5000)
        .7888413656
```

The time of the strike before the arrival of the 5,000 Hz frequency was .7888 seconds. Add the time of the 5,000 Hz frequency (792.95milliseconds) to the time that you subtracted from the list time to normalize the data, in this case 85000 milliseconds, and finally subtract the strike time of arrival just calculated (788.8 milliseconds). The result is the time of the strike relative to the Spectrogram time reference, in this case 85004 milliseconds. You will note in the Spectrogram plot that there is a distinctive spheric at 84988 milliseconds. The difference between the calculated time of the source strike and the received time of the probable source strike is only 16.5 milliseconds. Record these values in the calculation log. I have also included in the log the calculations for the whistler that was used in Part 1 of this article.

I have tested this model for determining the time of the source strike numerous times and it appears to be a useful model when the source strike is not readily available. There should be some time delay between the source strike and the reception of the source strike depending on the distance the receiver is away from the strike.

Part 3: Testing the low frequency and high-density models.

One of the fascinating things revealed during my study of Helliwell's book was the description of nose whistlers. Nose whistlers have a definite frequency at which the time delay of the wave's travel at the nose frequency is a minimum. Frequencies above the nose frequency are more

delayed, and as described earlier, the frequencies below the nose frequency are also more delayed. Helliwell provides excellent illustrations of nose whistlers. The program described here will produce graphic displays of nose whistlers and low-frequency model whistlers (the type normally seen) based on the gyro frequency of the electrons caught up in the magnetosphere. Apparently all whistlers are nose whistlers; just the lower frequency components are more readily received at the lower latitudes. After reading about nose whistlers, I reviewed my collection portfolio and I believe I have seen just the first hint of the nose in some of the whistlers that I have received at this latitude.

Helliwell presents two mathematical models of whistlers that I thought would be interesting to test using the graphing calculator. The first is the high-density approximation model:

$$T = \frac{1}{2\Lambda^{1/2}(1-\Lambda)^{3/2}} \text{ sec}$$

The second model is the low-frequency approximation model:

$$T = \frac{1}{2\Lambda^{1/2}} \text{ sec}$$

Where T is the time of arrival from the source strike of a discrete frequency and:

$$\Lambda = \frac{f_o}{f_h}$$

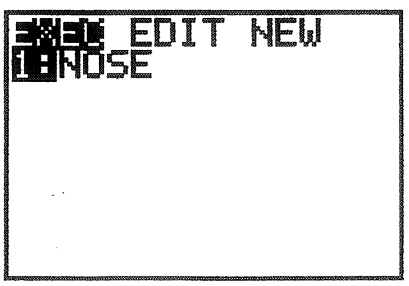
f_o is the discrete frequency, f_h is the electron gyro frequency.

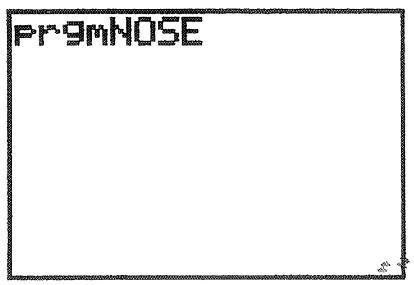
The TI-83plus program at Appendix 2 produces graphic displays of these two models given the gyro frequency. If we take the equation for the low-frequency model and rearrange it to solve for the gyro frequency, we can enter the time delay of the 5,000 Hz signal as calculated by the procedure in Part 2 of this article and solve for the gyro frequency.

$$f_h = 4T_o^2 f_o$$

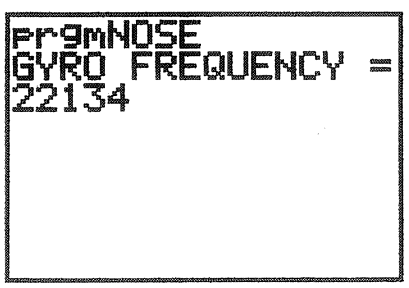
Where T_o is the time of arrival of the discrete frequency (5,000 Hz). Using the time of strike calculated in Part 2, the gyro frequency is 12444. Using the time of strike calculated for the whistler presented in Part 1, the gyro frequency is 22134 Hz. Both of these values are entered into the calculation log at Appendix 1.

After you have debugged and entered the NOSE program into the graphing calculator, call and run the program. Press **[PRGM]**, select **NOSE**, and press **[ENTER]**.

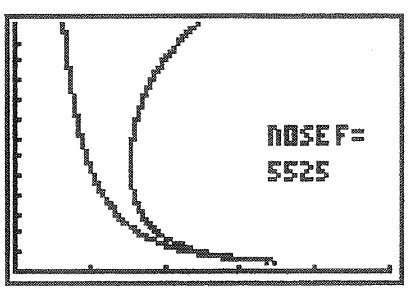




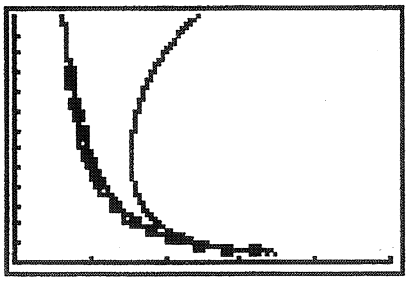
Press **[ENTER]** again to run the program. The program will ask for the gyro frequency, enter the gyro frequency for the whistler analyzed in Part 1, 22134 Hz.



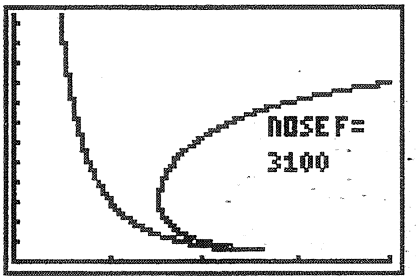
Press **[ENTER]** to continue the program. It will take a few moments so be patient. The display will look like this when the program is finished. The nose frequency will also be displayed.



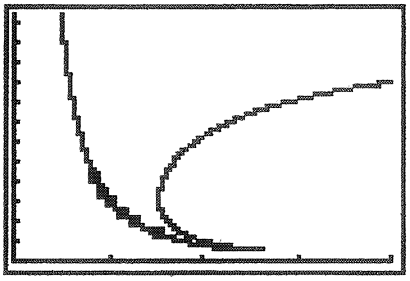
Obviously the nose frequency model is a little shy of being close, this whistler had a frequency range up around 10,000 Hz with no indication of nosing over. If you put the time normalized data for the whistler into lists L5 and L6, you can overlay the data on top of the mathematical models. This is what I have done here. There is a good correlation between the actual data and the low-frequency model.



Now try the whistler from Part 2. Run the **NOSE** program and enter the gyro frequency of 12,444 Hz. The mathematical predictions are depicted this way.



Again the high-density model does not appear to fit the whistler profile. Overlaying the time normalized data on top of the model produces this display.



The low-frequency model seems to provide a better fit for the actual data.

Using the high-density model to determine the gyro frequency is not as clean and simple using the graphing calculator. You would need to enter the algorithm of arrival time versus the gyro frequency based on a discrete frequency and use the trace function to solve the equation. In most

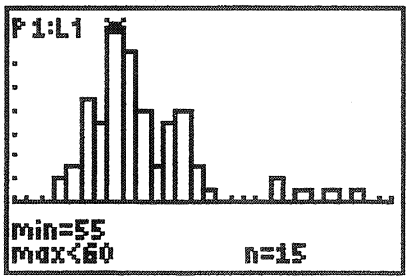
cases the minimum of this algorithm was above the arrival time of the discrete frequency and therefore was not applicable.

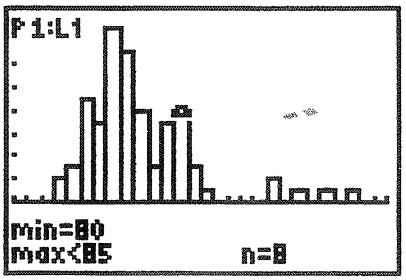
It would appear from the whistlers that are received at my latitude, that the low-frequency model provides a better predication.

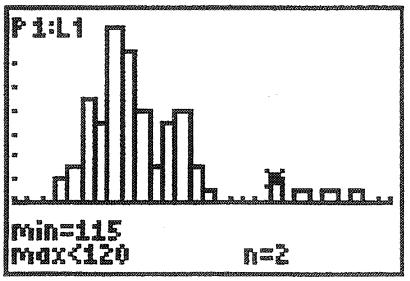
Concluding thoughts and speculations.

I have analyzed approximately 100 whistlers using the methods and procedures presented here. From this limited database I would like to present an observation. It would appear that strikes that produce tweeks do not produce whistlers. I speculate that this is because most of the energy of the strike is trapped and ducted beneath the ionosphere and insufficient energy escapes the ionosphere out into the magnetosphere to produce detectable whistlers.

I have also taken a look at the distribution of the dispersions of the whistlers that I have analyzed. The followung displays are TI-83 plus generated histograms of that distribution.







From the histograms it can be seen that there is a major cluster of dispersions that center around 55, there is a minor cluster centered around 80, and a very minor cluster centered around 115. If I assume that the first major cluster is made up of double hop whistlers, the added dispersion for each hop would be 27.5. Taking the center dispersion of 55 and adding 27.5 for one additional hop results in a dispersion of 82.5, remarkably close to the center of the minor cluster at 80. Finally, the very minor cluster at dispersion of 115 appears to be echoes of the major cluster at 55 (55 * 2 = 110). I do not know what to make of this limited data set yet, but I am working on it.

Where next?

Some of the things that I will be looking at in the future include:

1. Continue to gather data from whistlers to add to the database and the picture being developed.

2. Do some analysis of echo trains. I have received one at this location and I have the wave file of the super train received recently in Colorado.

3. Most of the whistlers I have received and analyzed were collected during the prime collection window. I am going to expand my collection opportunities to include less than optimal time. I hope that the distribution of dispersions as a function of time of day will give an indication of the changes in the magnetosphere as a function of time of day. I must admit that this may try my patience waiting for whistlers to occur when the ionosphere is fully ionized.

Conclusion

I hope that you have found some of the material presented here of use and perhaps interesting. I know that some of my founding assumptions will be criticized and perhaps I have oversimplified the whistler phenomena, but I had fun crunching the numbers and trying to make some sense out of what is being given to us by whistlers. Happy listening and whistle while you work…or is it work while you're whistling?

Appendix 1

File I.D.	Time	df/dt (slope) at 5000 Hz	dt/df (slope) at 5000 Hz	Dispersion	Time of strike from 5000 Hz	Calculated time of strike	Time of strike on plot	Strike Time Differences	gyro freq.	Nose freq
06031030z	85	-12676.8	-7.888e-5	55.78	.7888	85004	84988	-16.5	12444	3100
04301130z	12	-9594.75	-1.052e-4	74.39	1.052	11498	11463	20	22134	5525

Appendix 2

File Name: NOSE.8XP Type: Program Protected: No
Comment:Program file dated 06/04/00, 18:07

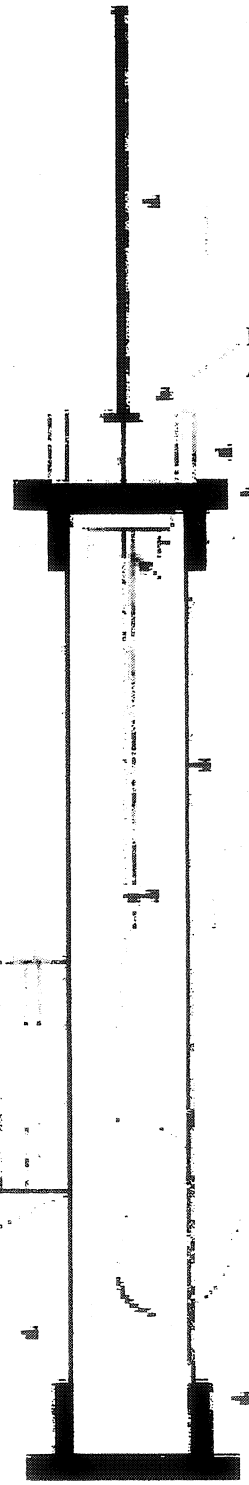
```
Input "GYRO FREQUENCY =",H
1 Part ( (H-475) /25) -1→D
If D≥500 : 500→D
[)→dim ( L1 )
D→dim ( L2 )
D→dim ( L3 )
475→F
For ( C, 1 , D, 1 )
F+25→F
1/(((2*√(F/H))*(l-(F/H) ) ^ (3/2)))→Z
F→L1 (C)
Z→L2 (C)
I/(2*√(F/H))→Z
Z→L3 (C)
End
0→Xmin
0→Ymin
F→Ymax
round(max( L3 ),0)+2→Xmax
I000→Yscl
1→Xscl
FnOff
Plotsoff
PIot 1 ( xyLine, L2 , L1 , - )
Piot 2 ( xyLi ne, L3 , L1 , - )
PlotsOn (1,2)
DispGraph
min( L2 )→M
For ( C, l, D, l )
If L2 (C)=M:L1(C)→N
End
Text(25,64,"NOSE F=")
Text(34,64,N)
```

An INSPIRE Antenna and Ground Rod

By Carl Chernan
Tarentum. PA

BM List:

1. 1 ea. Radio shack Antenna #270-1408A
2. 1 Section 3/4" - 36" Long PVC Pipe
3. 1 ea. Hubbell Strain Relief Connector
   Aluminum - 3/8" NPT Hub Size
   Grainger PN. 5D712
4. 1 ea. 3/8" Conduit Retaining Nut
5. 2 ea. 3/4" PVC Pipe Caps
6. 1 ea. 3/8" Rubber Grommet
7. 10' #20-22 Flex Stranded Wire
8. 1 ea. Insulated Spade Lug
9. Misc. - Tools, soldering iron, solder, PVC Pipe Cement, Electric Drill, RTV Silicone



Radio Shack Telescoping Antenna
Part # 270-1408A

Insert Antenna Through Rubber Grommet
And Leave 5 3/4" Of Antenna Exposed

Hubbell Strain Relief Connector
Grainger PN 5D712 3/8" NPT Hub Size

3/4" PVC Pipe Cap (Cement this end)
3/8" Conduit Retaining Nut

Fill this area with RTV silicone. Do NOT let antenna touch the inside wall of the strain relief connector.

36" Length of 3/4" PVC Pipe
Schedule 40 (Main Body)

Cut 1/4" x 1" Slot Top and Bottom.
Both sides - front and back

Solder point for the antenna lead wire to the bottom part of the antenna

3/4" x 5" PVC Pipe
Antenna Lead Wire Holder

Half loop the wire and tape in place to prevent the wire from pulling out.

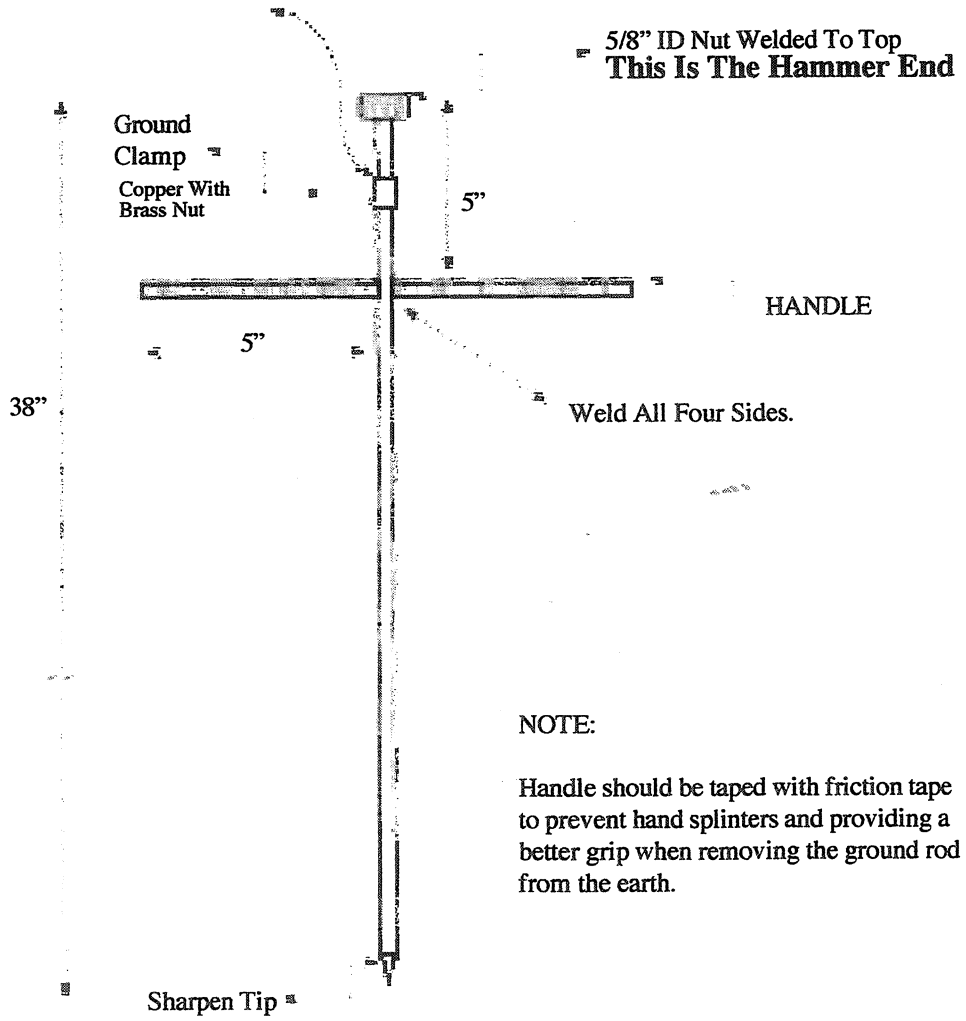
To VLF2 Receiver Antenna + Terminal.
Use approximately 8-10 feet of #20-22 flexible stranded wire. Terminate the end of the wire with an insulated spade lug.

Cement to side of antenna.

3/8" Grommet

3/4" PVC Pipe Cap (Bottom)
Slip fit only (Do NOT cement)

Ground Rod



NOTE:

Handle should be taped with friction tape to prevent hand splinters and providing a better grip when removing the ground rod from the earth.

INTMINS OBSERVERS

Roster Update

The following is a roster of INTMINS observers including first-time observers. Team number assignments are permanent and will be used to refer to teams in the future. (Unless noted otherwise, all longitudes are West and latitudes are North.)

Team #	Observer	Location	Longitude/Latitude
1	John Lamb, Jr.	Belton, TX	97° 27' 50" / 31° 7' 45"
	University of Mary Hardin-Baylor		
2	Stephen G. Davis	Fort Edwards, NY	73° 29' 30" / 43° 18' 00"
3	Don Shockey	Oklahoma City, OK	97° 40' 5" / 35° 43' 30"
4	Mike Aiello	Croton, NY	73° 46' 45" / 40°
5	Jean-Claude Touzin	St. Vital, Quebec	79° 10' / 48° 55'
6	Bill Pine	Ontario, CA	117° 41' / 34° 14'
	Chaffey High School		
7	Dean Knight	Sonoma, CA	122° 33' / 38° 21'
	Sonoma Valley High School		
8	Mike Dormann	Seattle, WA	123.4° / 47.2°
9	Robert Moloch	Greentown, IN	85° 58' / 40° 28'
	Eastern Elementary School		
10	Bill Taylor	Washington, DC	77° 2' / 38° 54'
	INSPIRE		
11	Mark Mueller	Brown Deer, WI	87° 56' / 43° 10'
	Brown Deer High School		
12	Jon Wallace	Litchfield, CT	73° 15' / 41° 45'
13	Bill Combs	Crawfordsville, IN	86° 59' / 40° 4'
14	John Barry	West Lebanon, IN	87° 22' / 40° 18'
	Seeger High School		
15	Robert Bennett	Las Cruces, NM	106° 44' / 32° 36'
16	Leonard Marraccini	Finleyville, PA	80° 00' / 40° 16'
17	Kent Gardner	Fullerton, CA	117° 48' 30" / 34° 12' 13"
18	David Jones	Columbus, GA	77° 07' / 35° 00'
19	Larry Kramer / Clifton Lasky	Fresno, CA	119° 49' / 37° 01'
20	Barry S. Riehle	Cincinnati, OH	84° 15' / 39° 7'
	Turpin High School		
21	Phil Hartzell	Aurora, NE	98° 0' / 41° 0'
22	Rick Campbell	Brighton, MI	83°50'2.7" / 42°16'43.7"

23	Jim Ericson	Glacier, WA	121° 57.91' / 48° 53.57'
24	Paul DeVoe	Redlands, CA	116° 52' / 34° 10'
	Redlands High School		
25	Norm Anderson	Cedar Falls, IA	92° 15' / 42° 20'
26	Brian Page	Lawrenceville, GA	83° 45' / 34° 45'
27	Ron Janetzke	San Antonio, TX	98° 47' / 29° 35'
28	Thomas Earnest	San Angelo, TX	100° 25' / 31° 16'
29	Janet Lowry	Houston, TX	95° / 29°
30	Linden Lundback	Watrous, Sask,	105° 22' / 51° 41'
31	Lee Benson	Indianapolis, IN	86° 3' / 39° 23'
32	Shawn Korgan	Gilcrest, CO	104° 67' / 40° 22'

European observers:

Team #	Observer	Location	Longitude/Latitude
E1	Flavio Gori	Florence, IT	11° 50' 18" E/ 43° 50' 18" N
E2	Silvio Bernocco	Torino, IT	7° 12' E / 44° 54' N
E3	Fabio Courmoz	Aosta, IT	7.7° E / 45.7° N
E4	Joe Banks	London, UK	0° / 50° 52' N
E5	Renato Romero	Cumiana, IT	7° 24' E / 49° 57' N
E6	Marco Ibridi	Finale E., IT	11° 17' E / 44° 50' N
E7	Alessandro Arrighi	Firenze, IT	10° 57' 50" E / 43° 43' 21" N
E8	Zeljko Andreic	Zagreb, Croatia	
	Rudjer Boskovic Institute		
E9	Dr. Valery Korepanov	Lviv, UKRAINE	24° E / 50° N
	Lviv Center of Institute of Space Research of NASU		
E10	Sarah Dunkin	London, England	0° 02' E / 51° 40' N
	University College London		

INTMINS – April/2000 Data Analysis Report

by Bill Pine
Chaffey High School
Ontario, CA

The April/2000 INTMINS observations marked the eleventh session in an ongoing series of operations conducted with the cooperation and assistance of the Russian Space Agency (IKI) and ENERGIA, the Russian space engineering organization. INTMINS is an attempt to detect manmade VLF radio waves emitted by instruments on the MIR Space Station.

INTMINS Status Report

A limited number of operations was scheduled for April 2000. Paritipation was also limited.

The bottom line of the analysis remains unchanged: the VLF signal from the pulsed electron beam was not detected on the ground. This is not an unsurprising result since theoretical calculations of the signal of the power of ISTOCHNIK when propagated to the ground place the signal strength at just about the same as the background of natural VLF. We will continue with INTMINS as long as the Russian Space Agency (IKI) and MIR are able to provide observing opportunities for us. It is beginning to look like (even to an optimist!) the beam strength of ISTOCHNIK is inadequate to propagate a VLF signal to the ground that can be detected by our receivers. In the future, perhaps on the International Space Station, maybe a more powerful electron gun will be available for us to use in this ongoing investigation.

Data Analysis Procedure

The data analysis procedure used consisted of the following:

1. A sound file was created of the 2-minute period of ISTOCHNIK operation.

2. A spectrogram image was made of this file using a frequency range of 0-22.05 kilohertz so that the 12-15 kilohertz range could be examined for the presence of Russian Alpha navigation signals. The 1 kilohertz region of the spectrogram was examined for the 10 seconds on, 10 seconds off signal from ISTOCHNIK.

3. A one-minute portion of the file was cropped, enlarged and an image made using a 0-11.025 kilohertz frequency range. Again the 1 kilohertz region of the spectrograph was examined.

4. Finally, a 30-second portion was cropped, enlarged and an image made. A final examination of the 1 kilohertz region was made.

5. Additional sound files and spectrogram images were made of items of interest noted in the logs.

INTMINS-April/00 Operations Summary

(NOTE: All times are UT on the date indicated.)

European Passes

Pass	ISTOCHNIK Start Time	Path during ISTOCHNIK Firing	Number of Observers Recording Data
E22-1	0555	Croatia	
E28-1	2159	Northern Italy	
E28-2	2337	Croatia	
E29-1	0245	Russia, south of Moscow	
E29-5	2212	Russia, south of Moscow	
E30-1	0119	Croatia	

North American Passes

Pass	ISTOCHNIK Start Time	Path during ISTOCHNIK Firing	Number of Observers Recording Data
22-2	1016	WA	
22-3	1331	NE, IA, MO, IL	1
22-4	1505	NM, TX	2
29-2	0400	MO, IL, IN	1
29-3	0528	So CA	1
29-4	0704	OR, WA,	
30-2	0239	NC, VA, DC, MD, NJ	2
30-3	0415	QC	1
30-4	0541	No CA	
30-5	1033	AR, MS, AL	
30-6	1205	AZ, NM, TX	

Summary of European Passes Recorded

Team/Pass	E22-1	E28-1	E28-2	E29-1	E29-5	E30-1

NONE

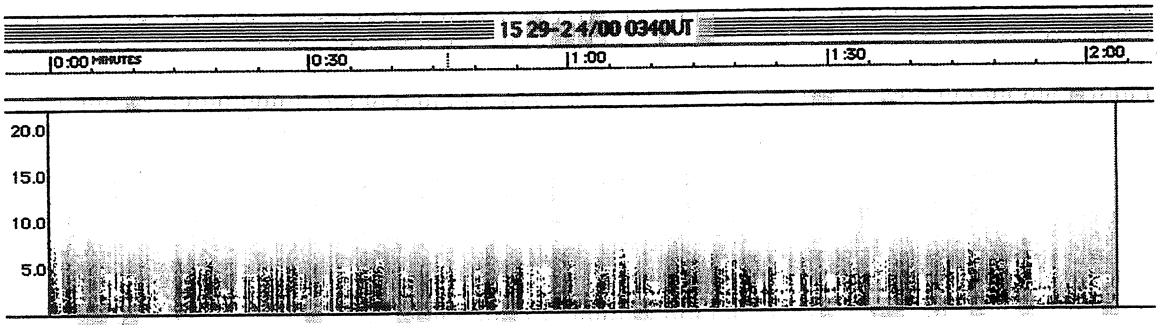
Summary of North American Passes Recorded

Pass	4/22			4/29			4/30				
	2	3	4	2	3	4	2	3	4	5	6
Team											
7									x		
15				x	x	x		x	x		

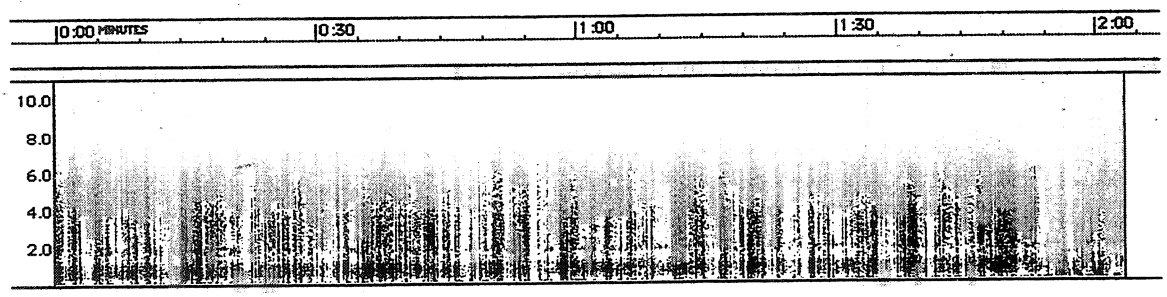
INTMINS Data

The following spectrograms are taken from data tapes submitted by INSPIRE observers. The first view shown will be that of the entire two-minute interval analyzed. At the top of the image is the sound filename, which consists of the Team Number, operation number, and the start time of the operation. Subsequent views will be of portions of the first. Use the time scale at the top to determine the length of the view. Unless otherwise noted, the start time of the cropped view is the same as the start time of the operation.

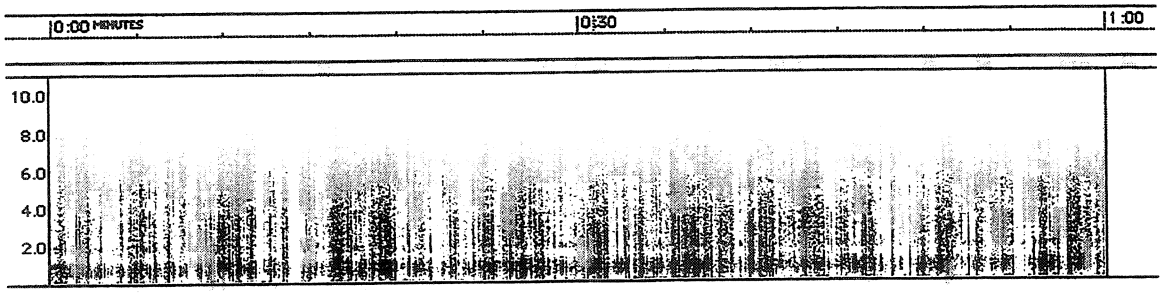
29-2



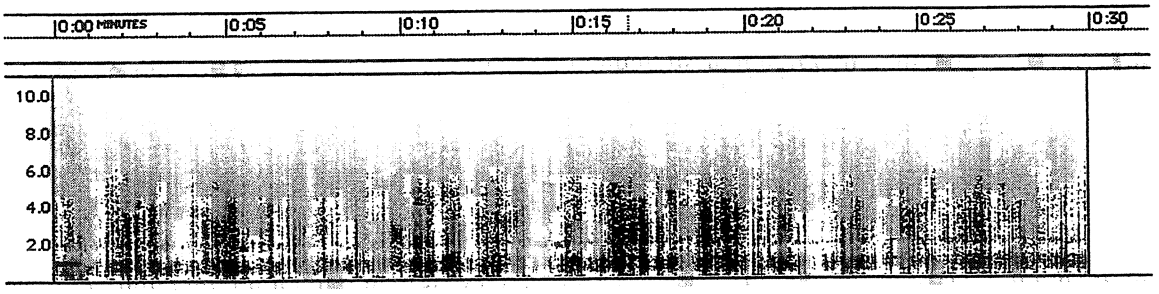
Team 15 Robert Bennett, Las Cruces, NM. This spectrogram shows intense, dense sferics. For this first view, a 0-22 kHz frequency range is used, the maximum range the software allows.



The same time interval as the first spectrogram, using a 0-11 kHz frequency range. The VLF2 receiver is designed to filter frequencies above 10 kHz, but the presence of signal above 10 kHz indicates very strong sferic signals at those frequencies.

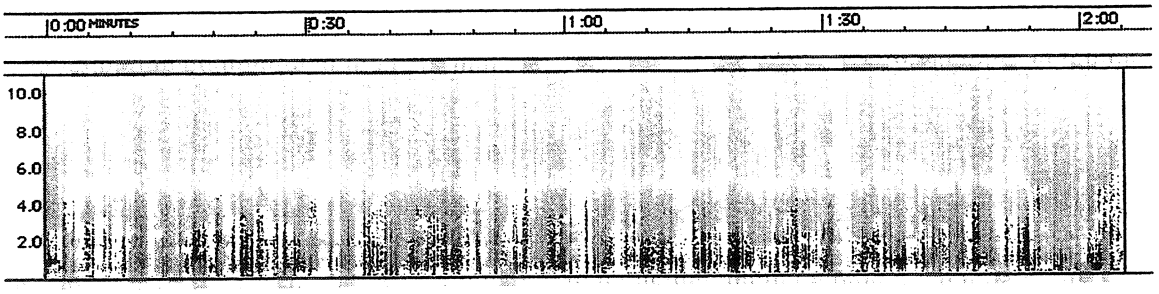


The first minute.

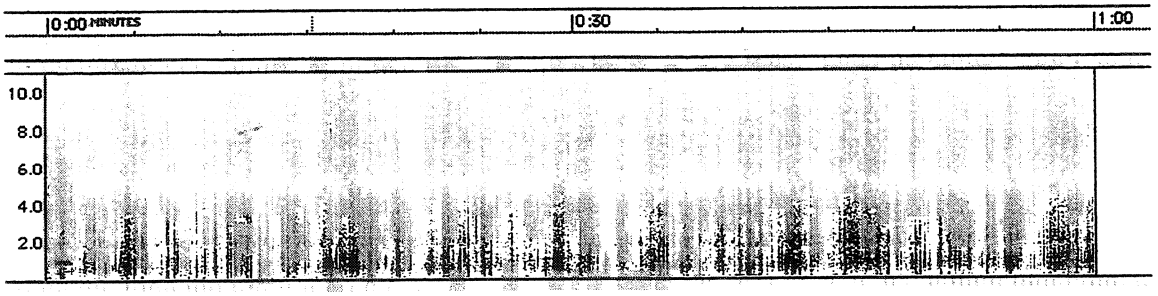


The first 30 seconds.

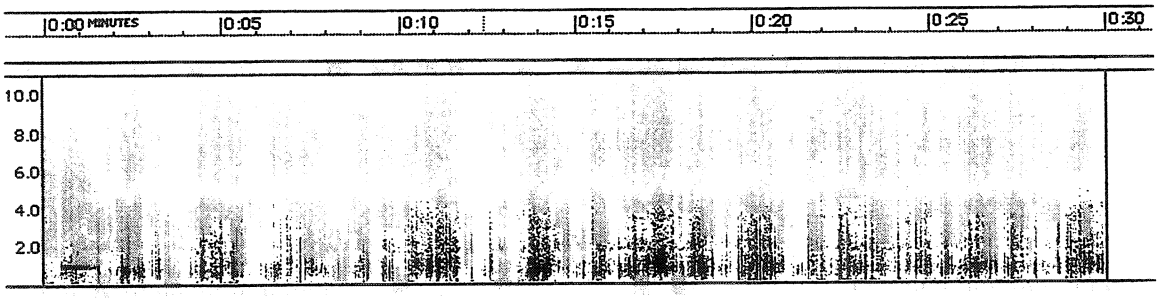
29-3



Team 15 Robert Bennett, Las Cruces, NM One orbit later (88 minutes), conditions are the same.

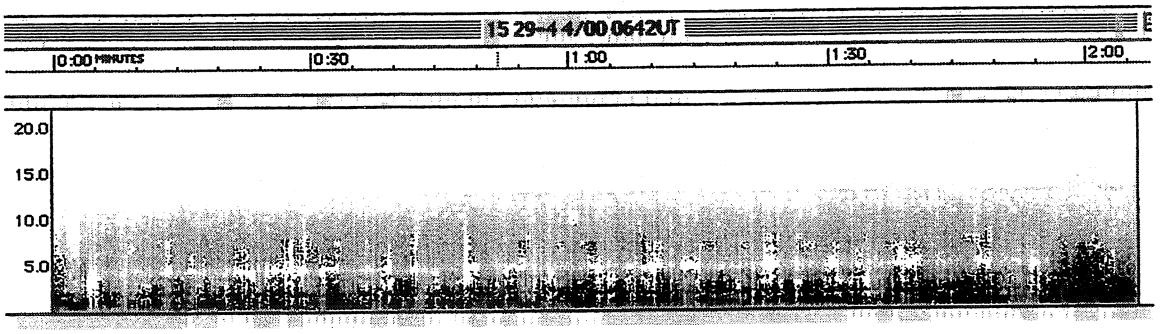


The first minute.

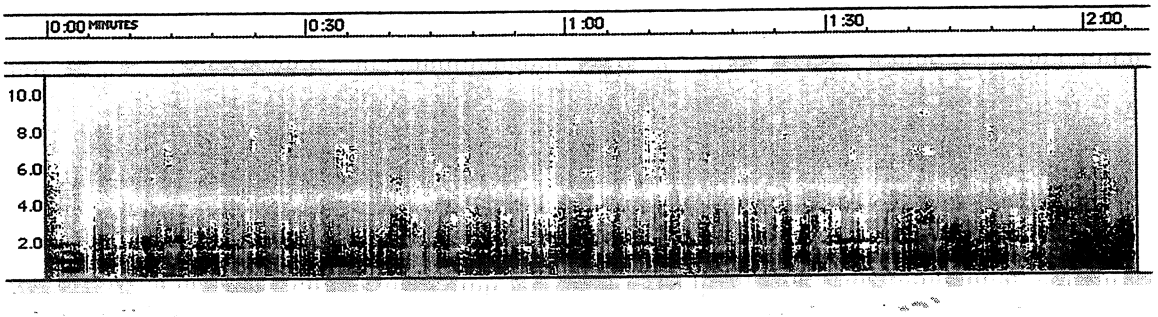


The first 30 seconds.

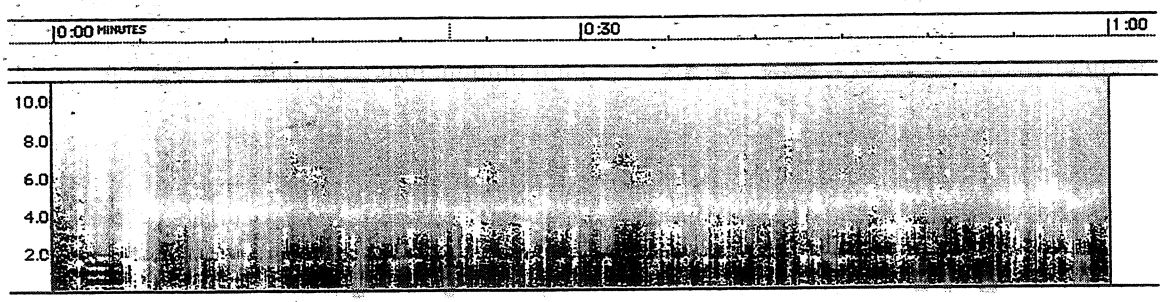
29-4



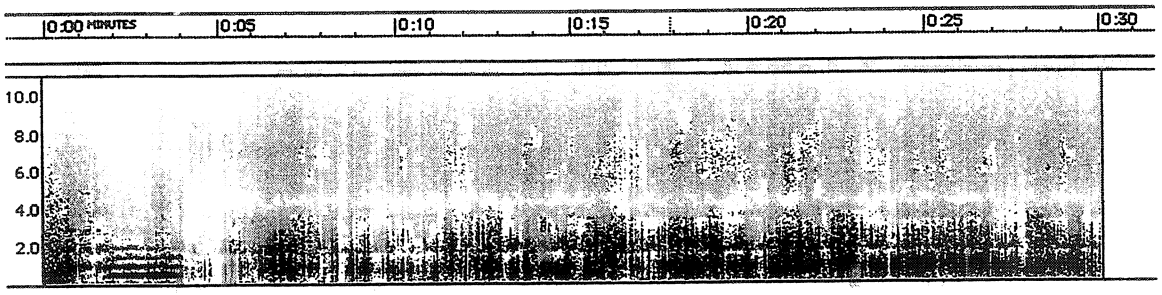
Team 15 Robert Bennett, Las Cruces, NM One orbit later, conditions are the same.



0-11 kHz.

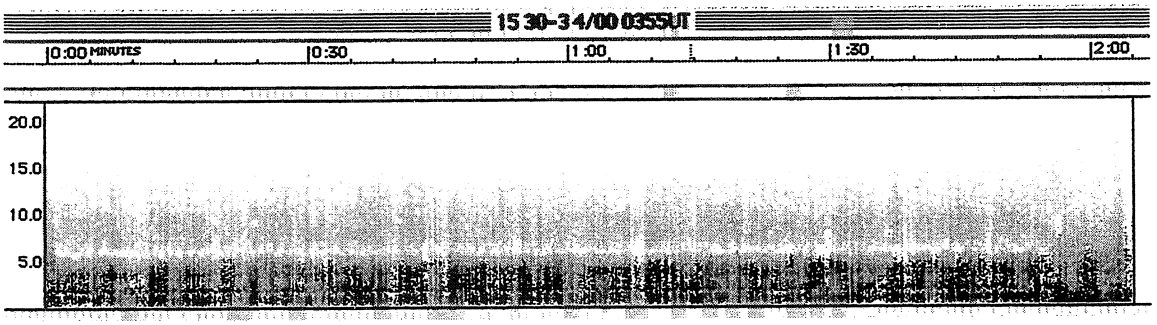


First minute.

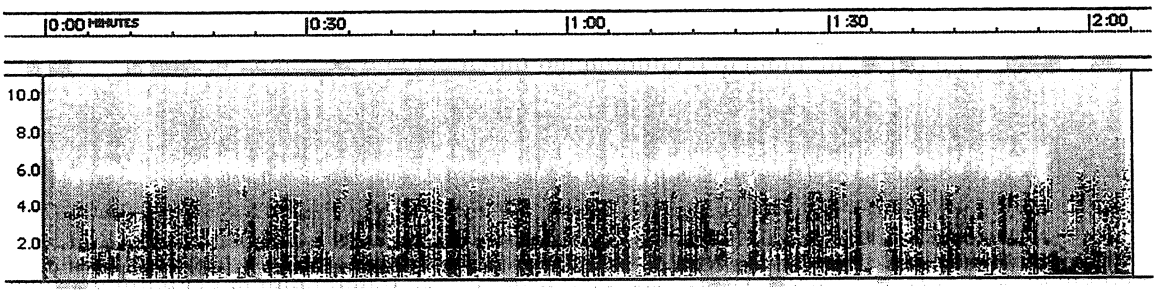


First 30 seconds.

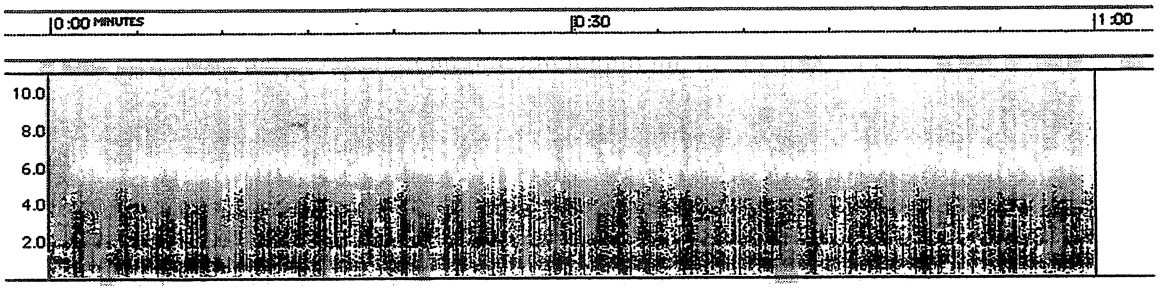
30-3



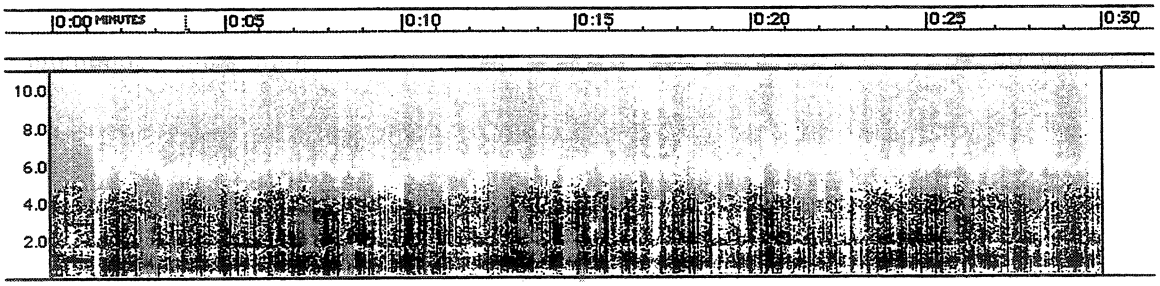
Team 15 Robert Bennett, Las Cruces, NM Dense sferics are present again on the 30th.



0-11 kHz



First minute.



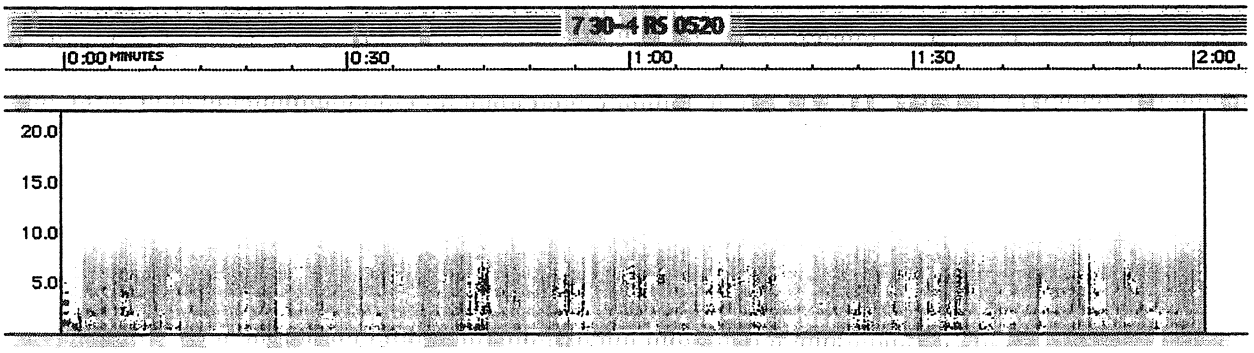
First 30 seconds.

30-4

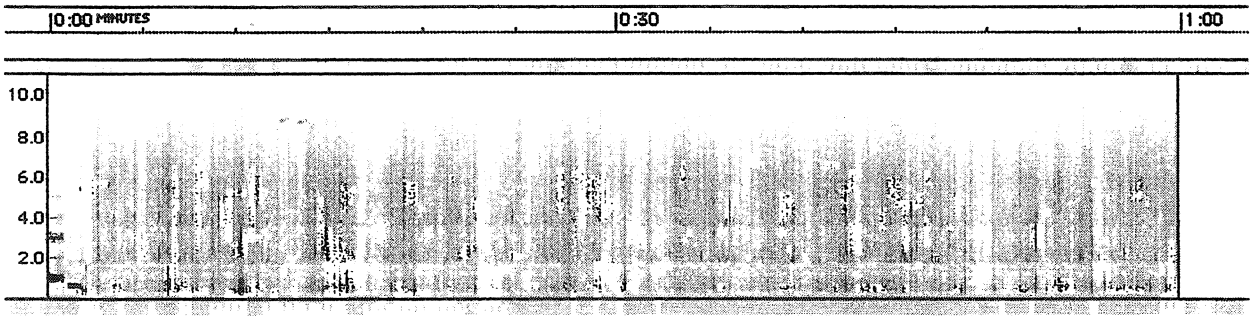
Team 7 Dean Knight, Sonoma Valley High School, Sonoma, CA

The Sonoma Valley High School team sets up three receivers. During the Operation 30-4 session, several whistlers were detected with each receiver. It is a little unusual to hear whistlers and tweeks at the same time. The sferic density was generally high during the recording time.

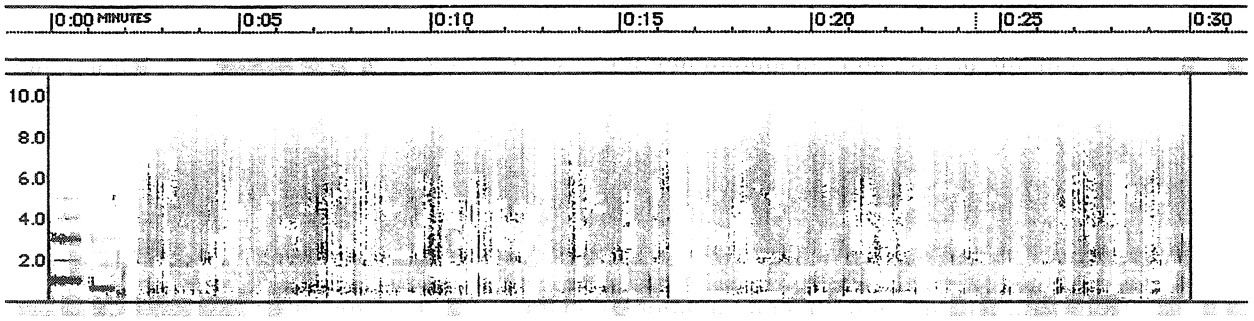
Receiver RS: Jenny Chesley



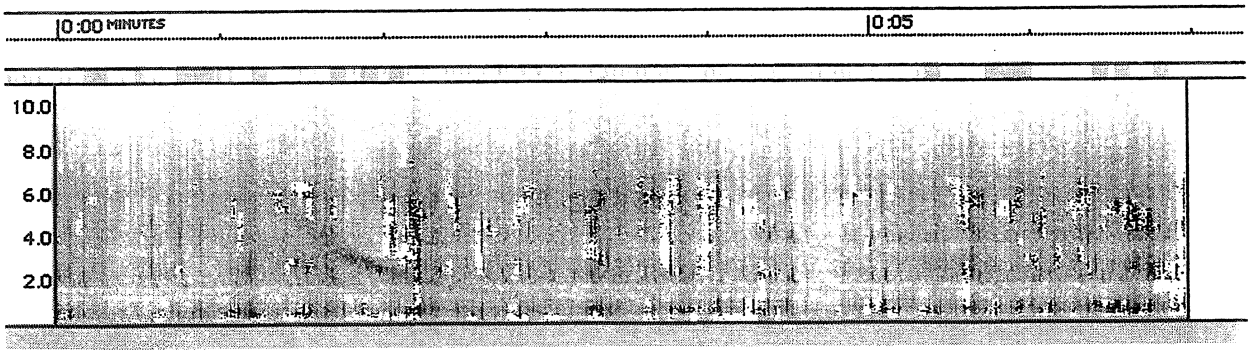
The spectrogram starts with the 0520 WWV dash.



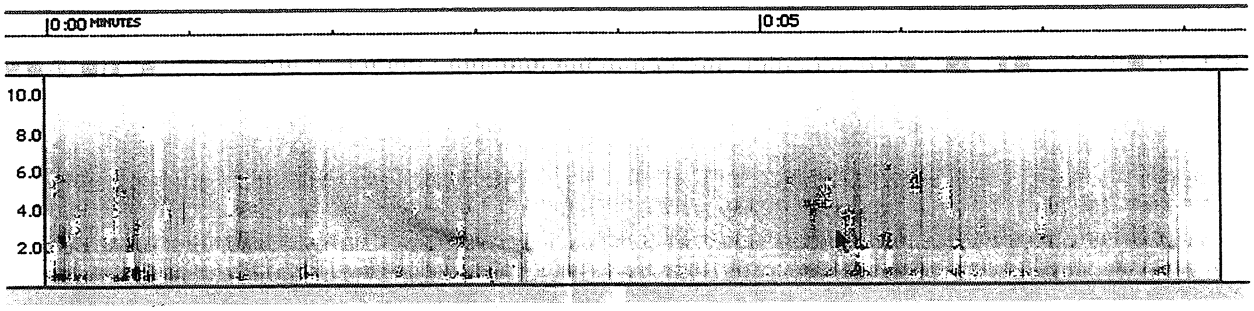
First minute, 0-11 kHz range. Tweeks show up as a horizontal band at about 2 kHz.



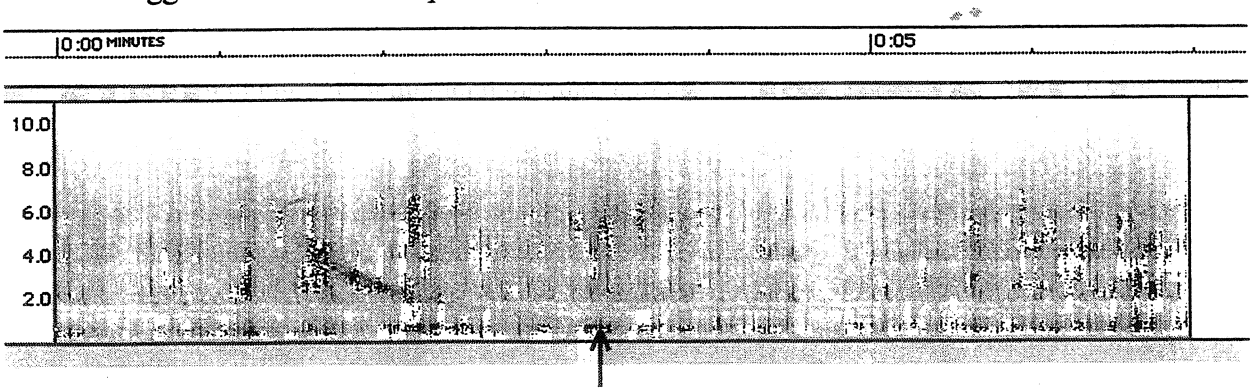
First 30 seconds.



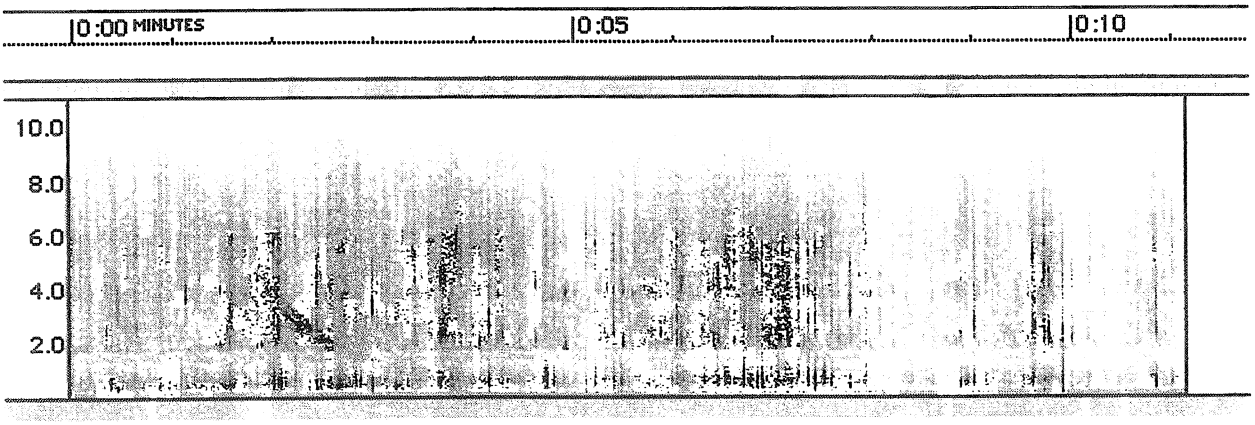
Whistler logged at 0532.



Whistler logged at 0530. Arrow points to what I think is a weak echo.

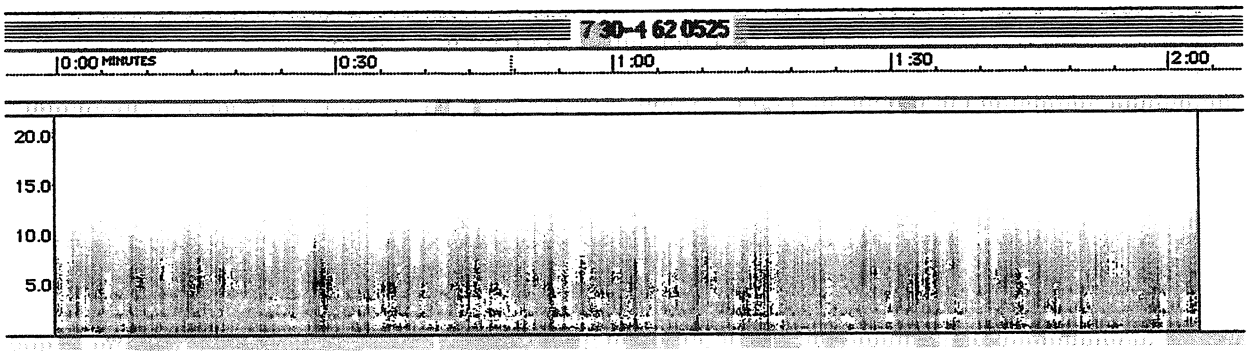


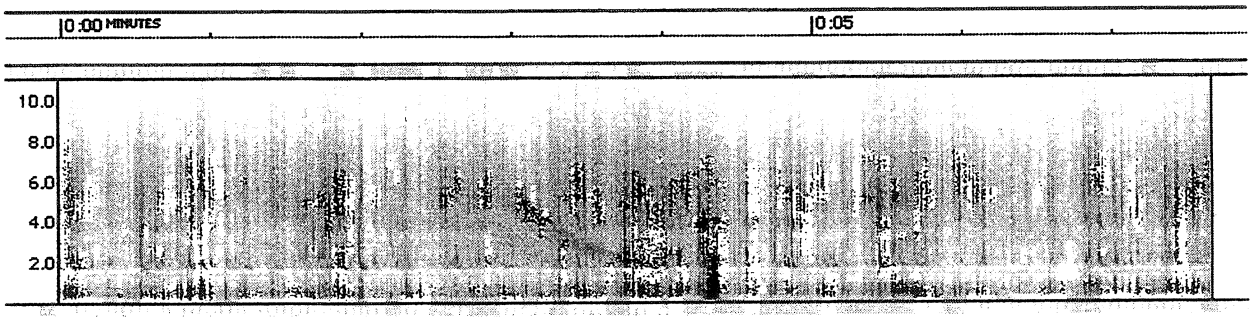
Whistler logged at 0532. Strong whistler and echo (arrow).



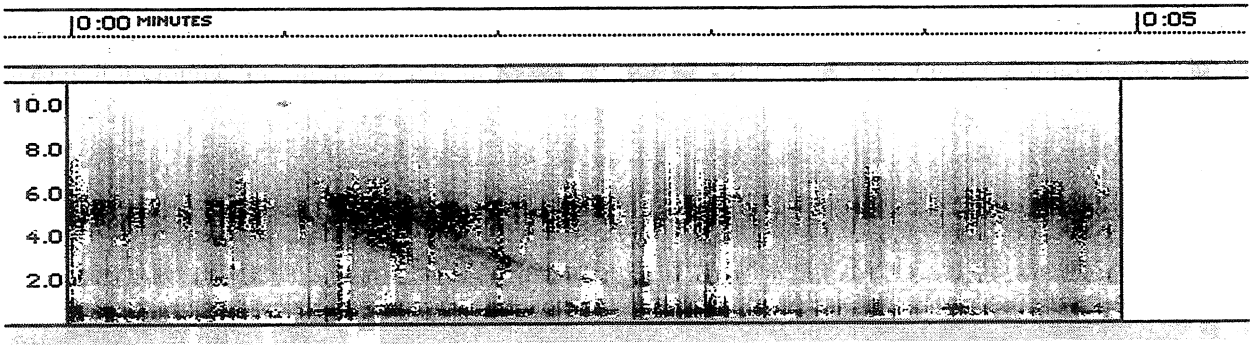
Whistler logged at 0535. The echoes for these whistlers are hard to hear since the general level of sferics and tweeks is so high.

Receiver #62 Megan Rea, Sacha Bendayan, Sacha Blackshear, Rachel Smith

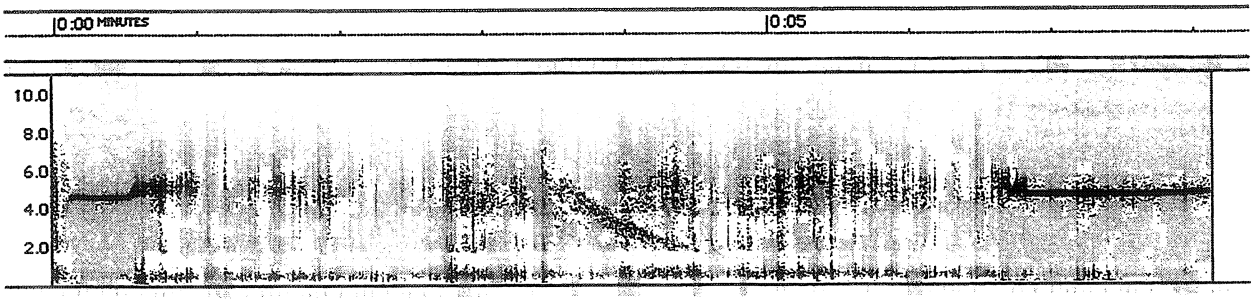




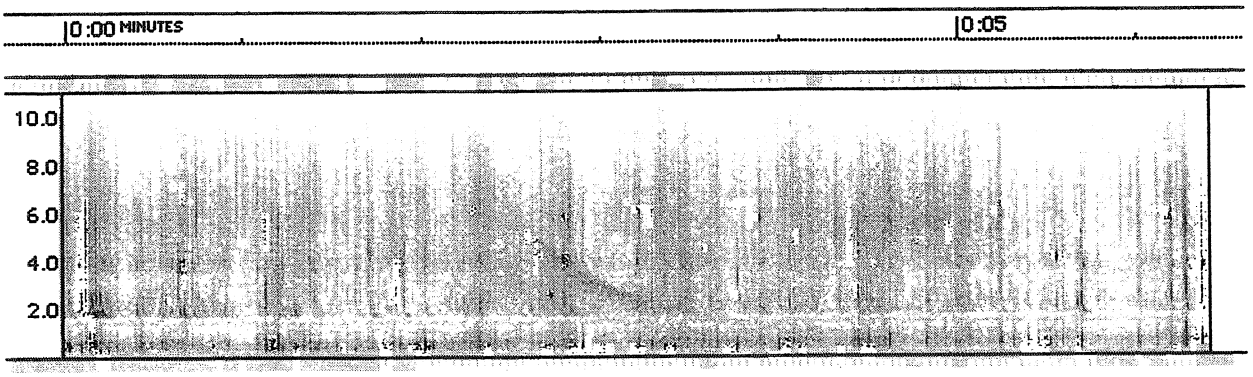
Whistler logged at 0514.



Whistler logged at 0530 UT.

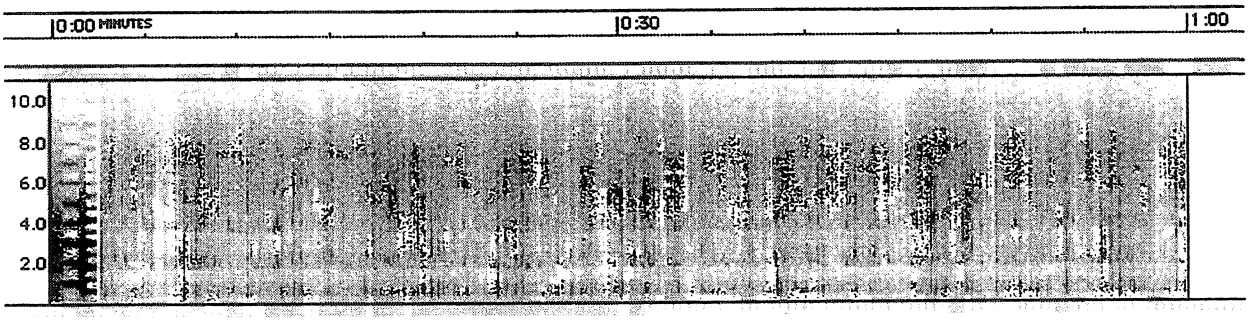


Whistler logged at 0532 UT. Horizontal signals at about 4 kHz are due to receiver oscillation.

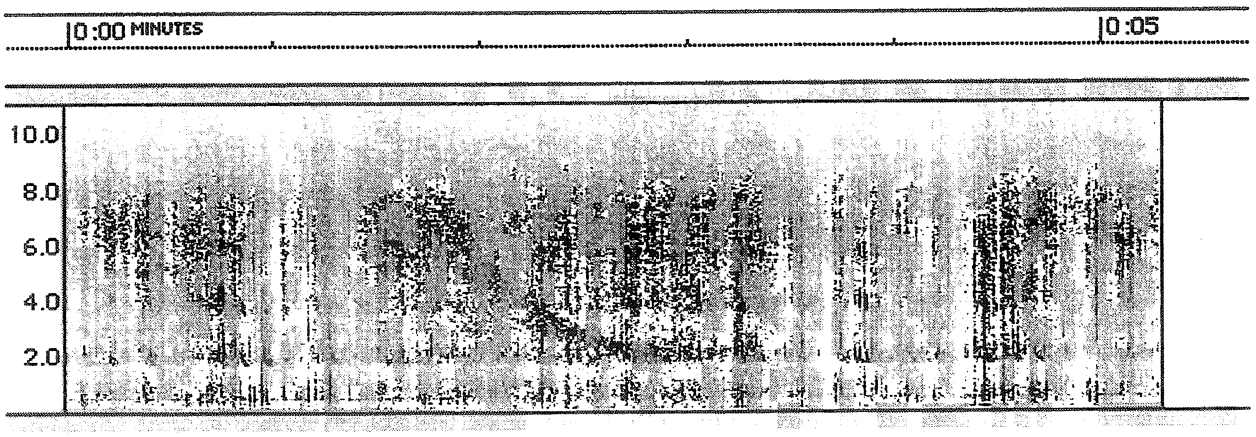


Whistler at 0535 UT.

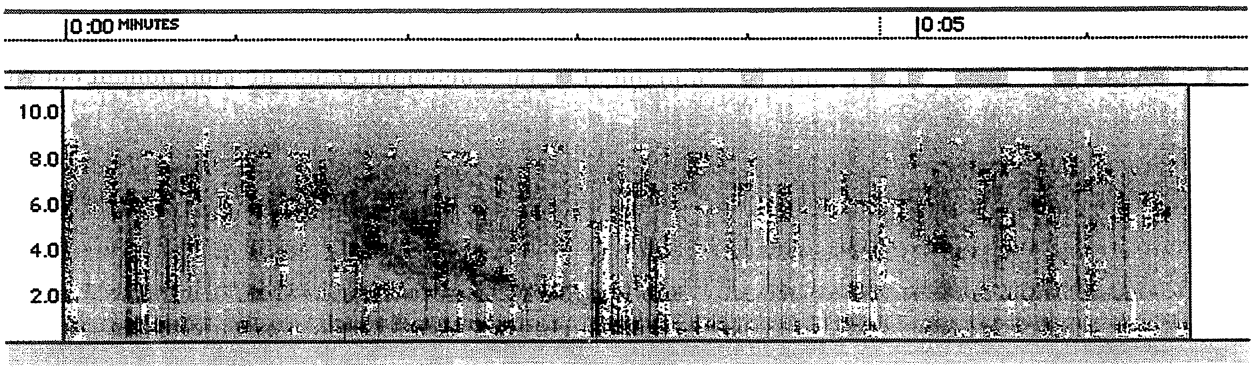
Receiver #65 Marisa Short, Alex Cali, Eric Israel, Lauren Klenow
Dana Peterson, Lauren Clementino, Maggie Sowell, Anna Hiser



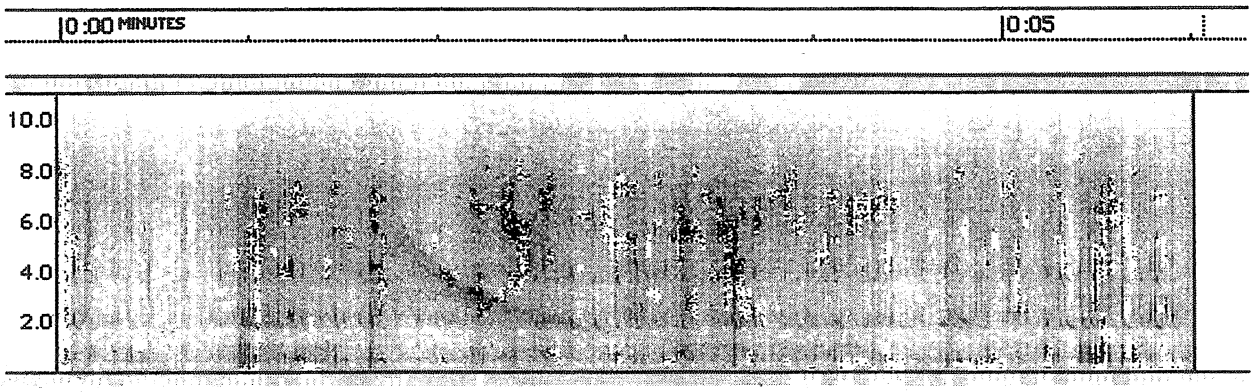
First minute of the operation. Note the harmonics of the 1 kHz WWV tone at the beginning. You can slso see the band of tweeks at 2 kHz with a harmonic at 4 kHz.



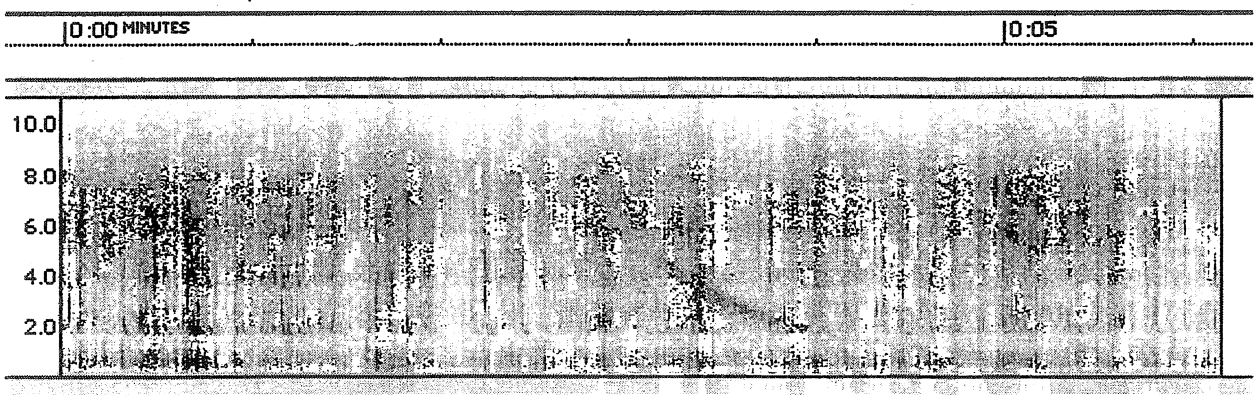
Whistler at 0514 UT.



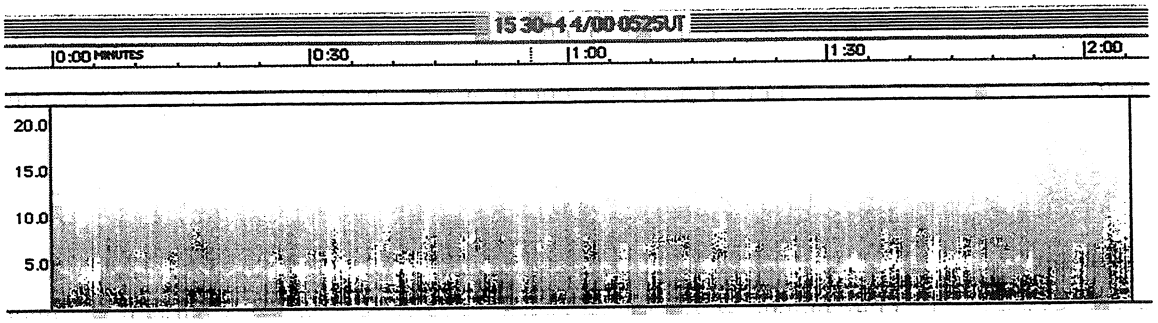
Whistler at 0530 UT



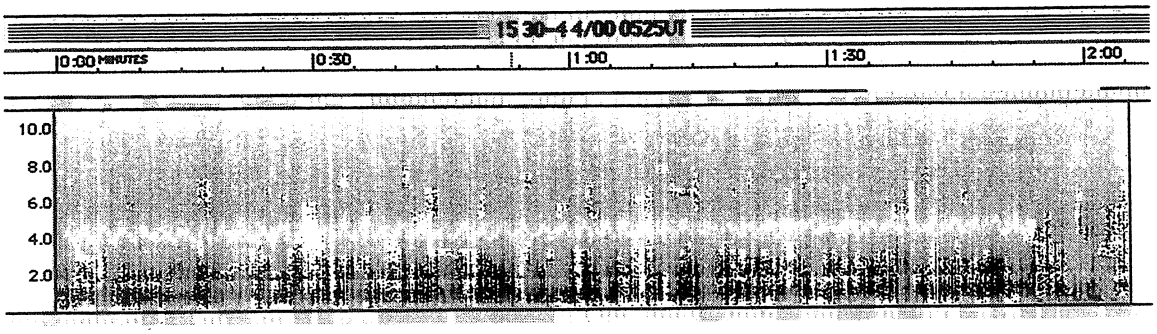
Whistler at 0532.



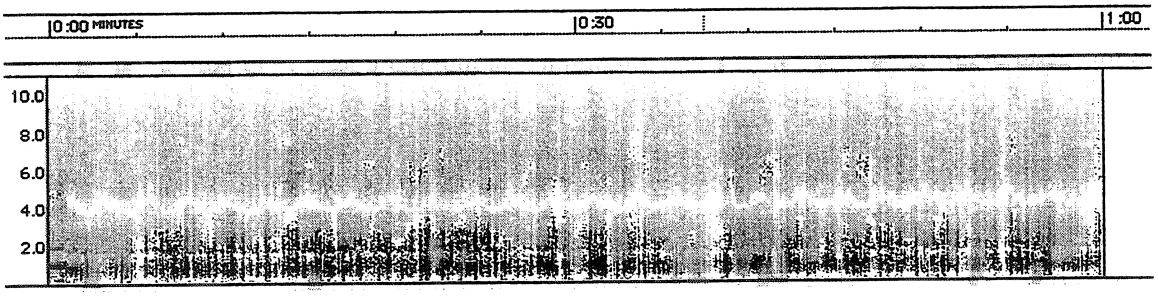
Whistler at 0535 UT.



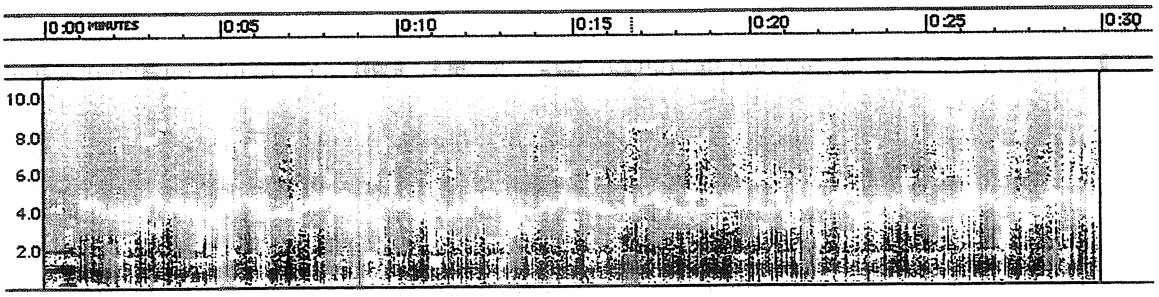
Team 15. Robert Bennett, Las Cruses, NM. Dense sferics, but no whistlers in New Mexico!



0-11 kHz.



First minute.



First 30 seconds.

Report on Coordinated Observations 4/2000

By Bill Pine
Ontario, California

The purpose of the Coordinated Observation Program is to provide an opportunity for INSPIRE participants to gather data at convenient times for purposes of comparing the resulting signals and attempting to interpret them. Since there is no manmade source of VLF that is being studied here, the signals of interest are those of natural origin. As in most natural radio listening, we would like to hear something "interesting". Most of the time that would be whistlers, but other sounds such as tweeks, chorus, triggered emissions and even hiss are also interesting. Observing whistlers, however, remains the prize for faithful listening. The problem with whistlers is that they are not the most common natural radio signal. Since coordinated listening schedules are determined arbitrarily and in advance of the listening sessions, it is only a matter of luck if whistlers are available to be detected. The experience of the author is that whistlers are heard about once every four or five morning sessions. When they are present, you will probably hear a lot of them until the rotation of the earth carries the ducting magnetic field lines into an unfavorable alignment. Conditions during April 2000 varied. There were some interesting signals observed including chorus. The following report includes sample spectrograms from contributing observers.

This table summarizes the sessions monitored by observers.

Date	4/29					4/30				
Time	1200	1300	1400	1500	1600	1200	1300	1400	1500	1600
Team										
26	E	E								
29							C	C		
30			M	M				M	M	
6				P	P				P	P

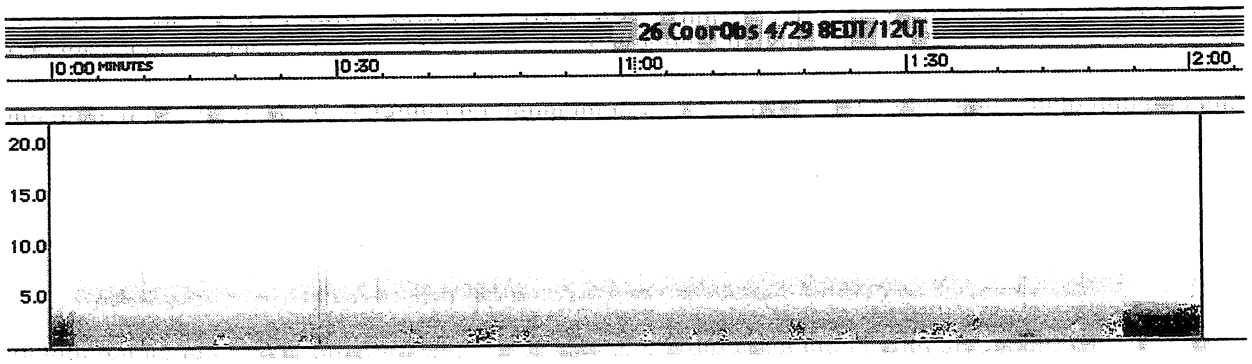
The times indicated are UT times.
The letter in the box indicates the time zone of the observer:
E = EDT = UT-4, C=CDT = UT-5,
M = MDT = UT-6 and P = PDT = UT-7

Observers:	Team 26	Brian Page, Lawrenceville, GA	(EDT)
	Team 29	Janet Lowry, Houston, TX	(CDT)
	Team 30	Linden Lundback, Watrous, Saskatchewan, CANADA	(CST)
	Team 6	Bill Pine, Chaffey High School, Ontario, CA	(PST)

For analysis purposes, a spectrogram was made of the first two minutes of each 12-minute hourly session. Additional spectrograms were made of any items of interest and of any segments requested by the observer. Time marks were placed on the tape every two minutes and a complete log was made of each session.

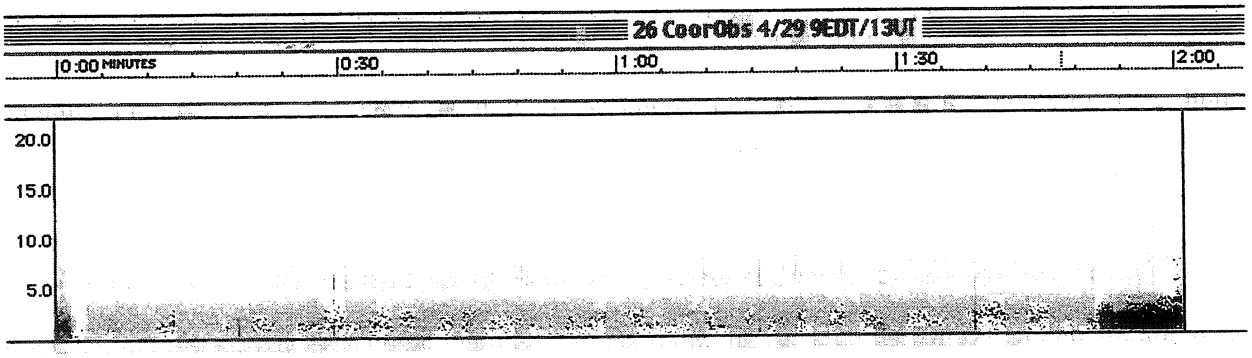
4/29/00 1200 UT

Brian Page led off at 8 AM EDT.



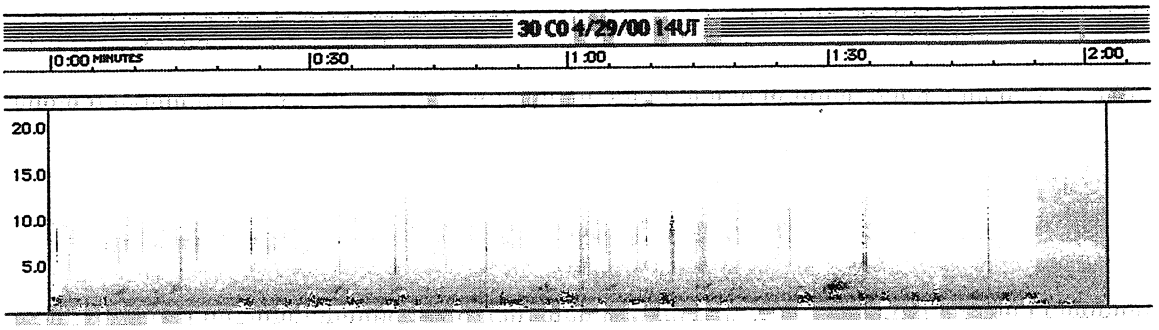
Team 26. Brian Page, Lawrenceville, GA. Quiet conditions, but sferics are present.

4/29/00 1300 UT

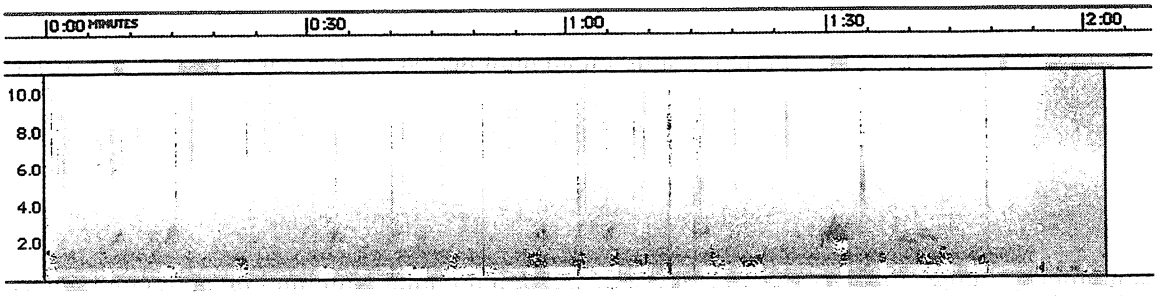


Team 2. Brian Page, Lawrenceville, GA. Conditions very similar to the previous hour.

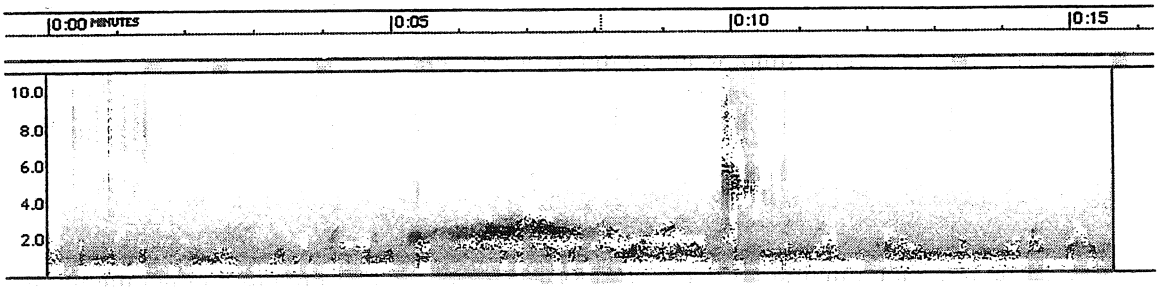
4/29/00 1400 UT



Team 30. Linden Lundback and Brian Cowan, Watrous, Saskatchewan, CANADA
First two minutes at 1400 UT on 4/29/00. Risers, a type of chorus, were prominent.

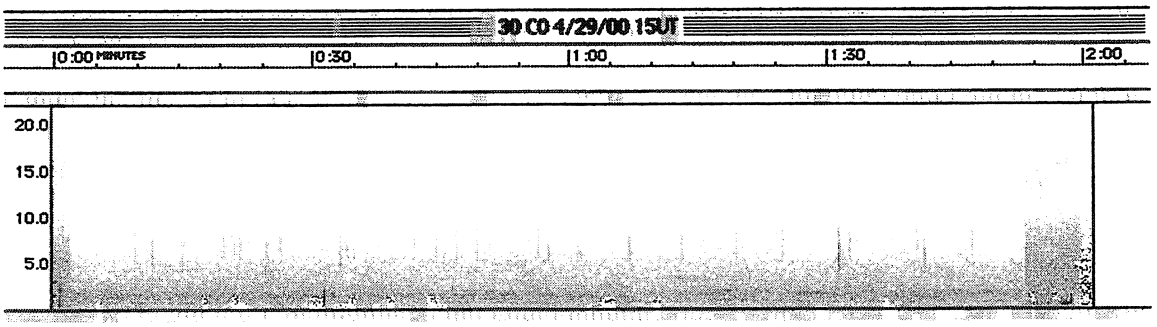


The same interval using a 0-11 kHz frequency range.
The risers are the dark smudges above 2 kHz.



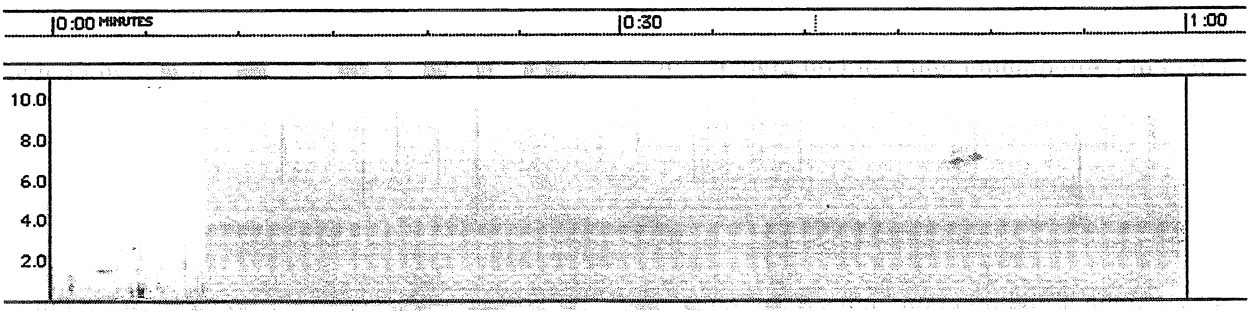
Close-up of the strong riser shown at about 1:30 above.

4/29/00 1500 UT



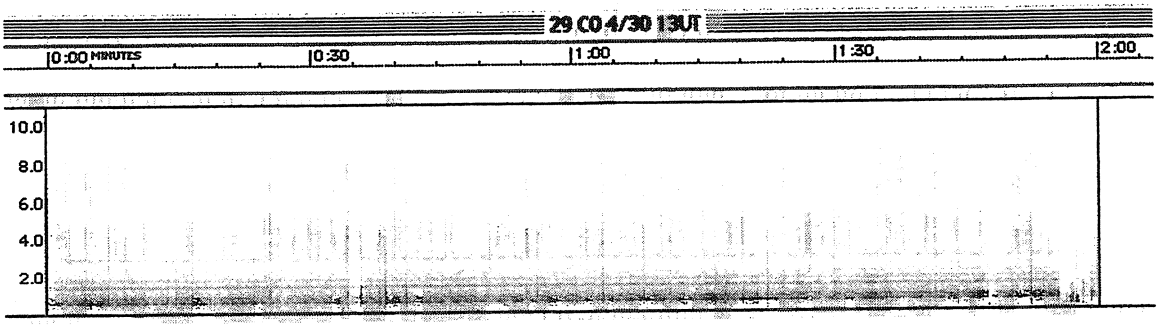
Team 30. Linden Lundback and Brian Cowan, Watrous, Saskatchewan, CANADA
Same site as the previous hour. Very quiet. What a difference an hour makes!

4/29/00 1600 UT



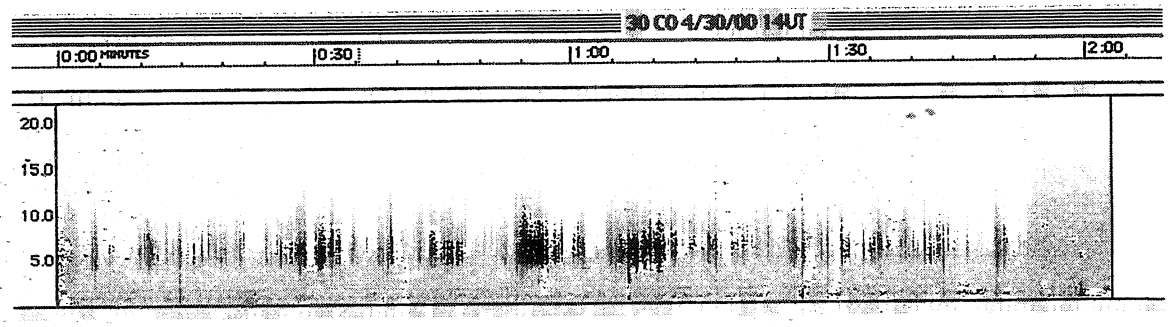
Team 6. Bill Pine, Chaffey High School, Ontario, CA
We tried a test of the DAN filter during a session conducted on campus. Switching in the DAN made a difference in the hum level, but hum still predominates in the recording. I think the problem was an electronic billboard on the side of the science building about 20 meters away. The signal did not sound like pure 60 Hz and the DAN was not able to remove the hum completely. The stronger sferics can be seen above the hum bands. Assisting in the data taking were Autumn Gomez, Miriam Aguirre and Jose Alvarado.

4/30/00 1300 UT

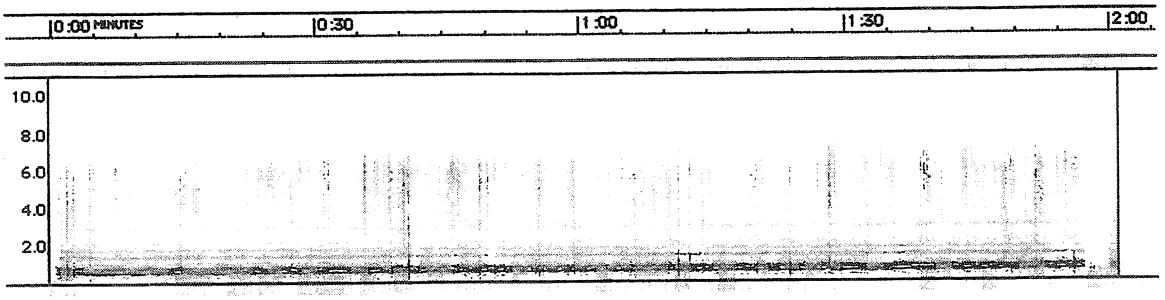


Team 29. Janet Lowry, Houston, TX
Janet tried a new site and noticed some hum. Sferics were easily audible on the tape and they appear prominently on the spectrogram. The hum appears as bands below 2 kHz.

4/30/00 1400 UT

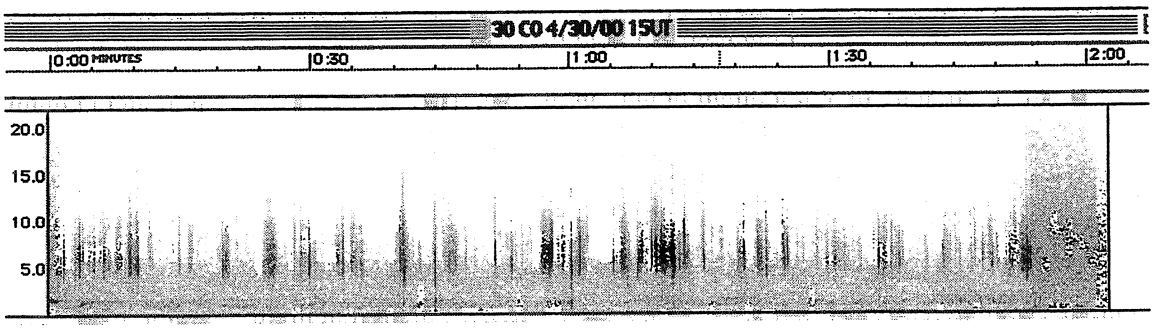


Team 30. Linden Lundback and Brian Cowan, Watrous, Saskatchewan, CANADA
Strong, dense sferics.



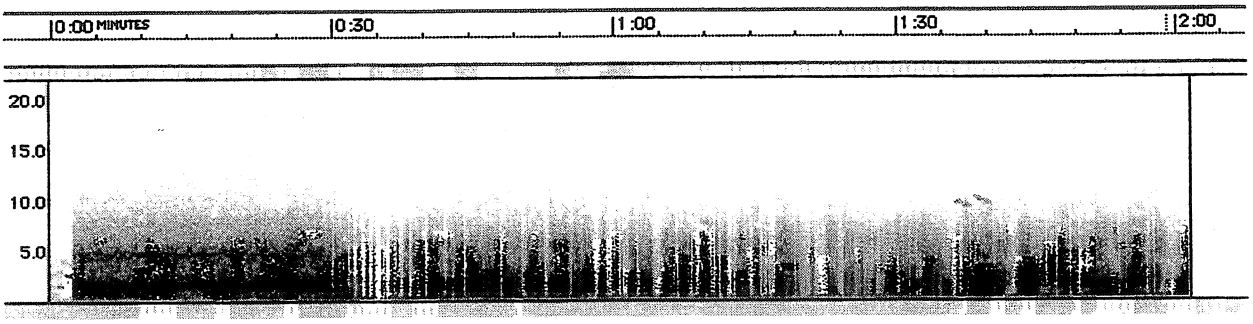
Team 29. Janet Lowry, Houston, TX
One hour later, the sferic density and strength were higher in Houston and the spectrogram looks very similar to the natural radio heard far to the north in Saskatchewan..

4/30/00 1500 UT



Team 30. Linden Lundback and Brian Cowan, Watrous, Saskatchewan, CANADA

4/30/00 1600 UT



Team 6. Bill Pine, Chaffey High School, Ontario, CA
Assisting in the data taking was Danica Cruz.

Data Log Cover Sheet (copy as needed)

INSPIRE Observer Team _____ Receiver _____

Operation _____

Date _____ Tape Start Time (UT) _____

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Operation details: Tape start time: _____ UT _____ local

Operation start time: _____ UT _____ local

Operation type: _____

Operation stop time: _____ UT _____ local

Tape stop time: _____ UT _____ local

Equipment: Receiver _____ WW V reception:

Recorder _____ _____

Antenna _____ _____

WWV radio _____ _____

Site description: _____

Longitude: _____° _____ ' W Latitude: _____° _____ ' N

Local weather: _____

Personnel: _____ _____ _____

_____ _____ _____

Team Leader address: Name _____

Street _____

_____

City, State, Zip, Country _____

INSPIRE Data (copy as needed)

INSPIRE Observer Team _____ Receiver _____

Operation _____

Date _____ Tape Start Time (UT) _____

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Code: S - sferics 0 1 2 3 4 5 M - Mark T - tweek W - whistler O - OMEGA C - chorus
L M H

Time	Entry		Observer
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____
_____	_____	S: 0 1 2 3 4 5	_____