The INSPIRE Journal

Volume 7 Number 2
April 1999

New Features in This Issue!

In addition to the usual reports on VLF observations, announcements of future observing schedules and articles by INSPIRE participants, Volume 7 Number 2 of *The INSPIRE Journal* includes several new features that will become part of future editions.

The INSPIRE Archive

Special articles from the past will be reprinted so newer members of INSPIRE can enjoy them. This issue features an article written by one of the cofounders of INSPIRE, Michael Mideke. "A Beginner's Guide to Natural Radio Phenomena" (Page 24 et seq.) originally was included with the first RS4 receiver kits delivered in late 1991. Michael is one of the most dedicated and experienced natural VLF observers and this article features a wealth of his valuable insight. The article is reprinted exactly as it first appeared, so it must be noted that some of the events that are referred to as "in the future" (INSPIRE's participation in the SEPAC experiments carried out on STS-45 in the spring of 1992, for example), have already occurred. In addition, some of the reference materials may be out of date or in other forms by now. The science in the article is excellent. Enjoy!

The Radio Jove Project

Soon the Radio Jove receiver kit will be available. More information on this project and how you can get involved is included in the article on Page 8.

Looking Back on INTMINS

The first installment of this retrospective look at INTMINS appears on Page 10. All participants in INTMINS are encouraged to contribute their thoughts to future articles.

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Volume 7 Number 2
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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:

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Radio Jove Note

An article called "An Introduction to Radio Jove" appears on Page 8 of this issue. This is a follow-up to the article "Radio Jove Science Education Project" which appeared in the last issue of the *Journal*. The current article contains more details about Jupiter radio astronomy and the Radio Jove receiver kit. Radio Jove has received funding through a NASA grant and, as a feature of the grant proposal, the project is aimed at schools. Since there is no provision for involvement of individuals not connected with a school in the basic grant, INSPIRE has contracted for the production of some extra kits to be made available to those who might not otherwise qualify. The kits sold by Radio Jove will have the costs partly subsidized by the grant; those sold by INSPIRE will be priced higher since the cost is not supported by the grant. The unsubsidized price is expected to be about $100-$120; the subsidized price will be about $50 and will only be available to the first 100 schools that apply.

MIR Status: An Update

The status of the MIR Space Station has been the subject of much speculation over the past several months. At one time it was announced that MIR would be returned to the atmosphere to burn up as early as this spring. The Russian Space Agency would like to keep MIR in operation into the future, but lack of funding makes this unlikely. The cost to maintain MIR in operation and manned for the next three years was estimated at $250 million. At one time an anonymous donor was reported to be ready to provide the funds, but that source of funding has failed to materialize. The United States is said to be pressing the Russians to retire MIR and apply their resources to the International Space Station. MIR is now in its 13th year of a 5-year planned life. There have been some well publicized problems in the past couple of years, but the establishment and maintenance of a constantly manned presence in space by the Russians is a scientific and technological achievement of which they are justly proud. During all of this time of triumph and turmoil, the Russian Space Agency has provided INSPIRE with an opportunity to do some space science from the surface of Earth by providing the instrument for the INTMINS observations for the past 4 years. At this point it looks like MIR will come down some time in late summer unless the necessary funding is found. It will be a sad time, but looking forward to future cooperation among the space programs of the world should provide the proper perspective to the event: MIR is a pioneer and has served us all well.

Larry Kramer's URL

The last issue of the *Journal* featured Larry Kramer's (Team 19) website. A small omission was that the URL was not included in the description. It is:

http://home.pon.net/785/

Looking Back on INTMINS...

The article on Page 10 consists of the responses of three INSPIRE participants to an invitation to write on the topic "Looking Back on INTMINS...". All INSPIRE participants are encouraged to submit their thoughts on this topic for publication in future issues of the *Journal*.

Mike Aiello's Website:

http://www.marymt.edu/~aiello/vlf.html

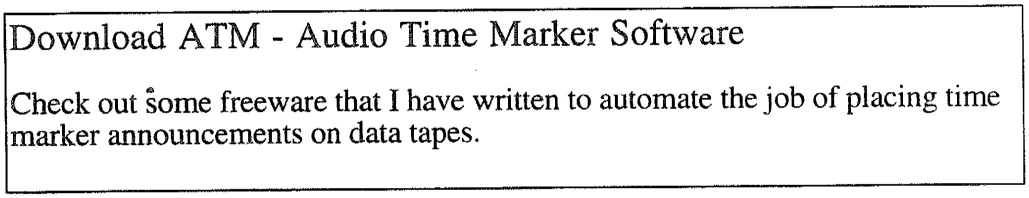
The featured website for this issue of the *Journal* is Mike Aiello's site. Mike's site starts with the INSPIRE logo and goes on to describe INSPIRE and Mike's participation.

NASA INSPIRE TEAM 4

INSPIRE, which stands for Interactive NASA Space Physics Ionosphere Radio Experiments, is educational outreach program whose primary purpose is to promote and support involvement of students in space research.

The site includes a map of Mike's observing site overlooking the Hudson River in New York.

Also included is a link to download Mike's ATM time marking software.



Download ATM - Audio Time Marker Software

Check out some freeware that I have written to automate the job of placing time marker announcements on data tapes.

Mike's site concludes with a nice set of links to other VLF-related and space-related sites.

INTMINS-April/99
Operations Schedule

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

The April/99 INTMINS Operations schedule will be finalized soon. Operations will occur on the last two weekends: April 17-18 and April 24-25. Data gathered will be analyzed and reported on in the November 1999 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 104 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 105 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. 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.

INTMINS Schedule

The operation schedule had not been determined by press time. The schedule will be printed separately and mailed included with the *Journal* .

Coordinated Observation Schedule
April/99

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. Unfortunately, coordinated observations in November revealed mostly quiet natural VLF conditions. (See "Report on Coordinated Observations 11/98" Page 79 in this issue of *The INSPIRE Journal* .)

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 EDT), at 8 and 9 AM CDT and at 10 AM (9 AM MDT).
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/98:

Saturday, April 24 and Sunday, April 25

An Introduction to Radio Jove

By: Jim Thiemann
Chuck Higgins
Goddard Space Flight Center
Greenbelt, Maryland

What is Radio JOVE?

Radio JOVE (http://radiojove.gsfc.nasa.gov/) is an educational project intended to get students involved in science by encouraging them to listen to a radio. Not only would they listen. but they would also help to build the equipment and use it to listen to the unique radio sounds of both Jupiter and the Sun, and possibly collaborate in research on the solar system. Jupiter generates natural radio emissions and these emissions have been observed by dedicated ground-based radio telescopes since the 1950's. The Sun is also a strong natural radio source. Strange and exciting phenomena such as predictable radio noise storms dependent on the rotation of Jupiter and the orbital position of its moon, Io, are still not well understood. Several spacecraft have monitored these radio emissions, such as Voyager, Ulysses, and Wind and now Galileo is in orbit around Jupiter, returning important new information. Solar radio bursts, however, are not predictable, but have been correlated with high sunspot activity. We are approaching the years of maximum solar activity (2000-2001) and associated radio bursts should be more frequent.

In mid to late 1999 scientists and observers around the world will collaborate as a part of International Jupiter Watch (IJW - http://www-ssc.igpp.ucla.edu/IJW/) and monitor Jupiter closely as Galileo crosses the orbit of Io several times. Ground-based observations are important at wavelengths not observable by Galileo and give a different perspective on the sources. Widely scattered observations help to overcome the variable filtering effects of the Earth's ionosphere. Thus students using simple, inexpensive radio receivers can participate in the scientific process by collecting, comparing, sharing, and analyzing data. Radio observations of Jupiter must be made at night when the Sun's effects on the Earth's ionosphere fade away, but the equipment can also be used for daytime observations of solar radio phenomena.

The project will adopt the successful approach used by the Interactive NASA Space Physics Ionosphere Radio Experiments (INSPIRE - http://image.gsfc.nasa.gov/poetry/inspire) program for involving students in ionospheric observations through the building of special Very Low Frequency (VLF) receiver kits and making their own measurements. We hope that many of the schools that are participating in INSPIRE will expand their activities to this new area.

What are the program objectives?

1) To acquaint students with the science of radio astronomy and the excitement of being involved in the scientific process.
2) To learn electronics through construction of inexpensive kit-based radio receivers suitable for hands-on learning of radio astronomy as a science curriculum support activity.
3) To collaborate with other schools and the science community through a web site that teaches about radio astronomy and is a coordination point for Radio JOVE data sharing in conjunction with the International Jupiter Watch program.
4) To enable, through the World Wide Web, observation and usage of data from a professional radio telescope observing Jupiter and the Sun.
5) To develop educational resources for teaching and understanding the science of ratio astronomy.

How does it work?

The Radio JOVE project is centered around the development of low cost radio receiver/antenna kits which can be assembled by science classes and used to collect planetary or solar radio astronomy data. It is intended for high school level classes, but may be appropriate for college or even middle school levels. The students build the kit using basic electronic tools under the supervision of the teacher. They also construct the special antenna needed to receive the planetary or solar emissions. The antenna requires construction of a basic structure using wood or pipe, ropes, stakes, etc.

Once the kit is completely assembled and tested the students determine a good time to observe Jupiter based on predictions supplied on the Radio JOVE website. Note that Jupiter radio signals can only be received at night and the conditions are often best in the hours just before dawn. Also, the antenna needs to be set up in a location that is as free from electrical interference as possible. This may be possible near some schools, but it is recommended that observing be done in nighttime field trips to locations away from power lines and other sources of interference. If nighttime viewing or field trips are a problem, daytime viewing of the Sun at an outdoor location near the school may provide the equivalent observing experience.

The kits cost approximately $100. The kit contains:

1) All parts for the JOVE receiver and a few tools (other tools are required);
2) Complete step-by-step instructions for assembly;
3) Antenna parts including cable, wire, and connectors;
4) Complete step-by-step instructions for antenna assembly and setup;
5) CD ROM with chart recorder software and general information;

Discounts will be offered on the first 100 kits ordered by schools. The materials for supporting the antenna are not included in the kit nor are the tools that are necessary to put the kit together, such as a soldering iron, wire clippers, and other typical tools for putting together electrical kits. Many schools may have these materials and tools already, but, if they do not, we estimate they will cost about $60. Recommendations for these tools and materials are in the kit.

In order to be able to analyze the data and share it with others there is also the need to capture the radio data and this can be done by feeding the output of the receiver into a tape recorder or directly into a computer. On a field trip it may be more convenient to use the tape recorder than to carry along a computer, even if you have a laptop. Small tape recorders can be purchased for this purpose, but they must not have an automatic gain control (automatic volume adjustment) or the control must be capable of being switched off since such a control makes it difficult to measure the relative strength of the signals. The cost of recorders sufficient for this purpose is about $70 (Radio Shack Models CTR 69 and CTR 117 are both priced at $70). Software is supplied with the kit that simulates a standard professional chart recorder for plotting the data using a standard 486 or higher model personal computer. The computer will also need a sound card. The software is contained on a CD that is sent with the kit.

A central web site will accept files of data from observing groups around the country and make them available for schools and scientists to see and hear. The site also contains general information and activities relevant to the understanding of radio astronomy and, in particular, how to order, build, use, and understand the data from radio receiver kits. These web pages are currently under construction and will be fully developed by the summer of 1999.

How can my school participate?

Fill out the inquiry form on the last page of this edition of the *Journal* and send it to the indicated address. We will get back to you as soon as possible about your request and what will be done from that point.

If you are not associated with a school, you may still fill out the form. The price for the kit, when determined, will not be discounted to those not associated with schools. This is because of conditions placed on the grant support for this project. The undiscounted price will probably be between $100 and $120. The discounted price will be about $50.

Looking Back on INTMINS ...

by: Dean Knight, Sonoma, CA
Jack Lamb, Belton, TX
Bill Pine, Ontario, CA

With the approach of the end of the MIR Space Station, we also approach the end of the INTMINS operations. Several participants have contributed thoughts on the value of the INTMINS operations and the future of this type of scientific investigation. Similar contributions are solicited from any other INSPIRE participants. Another article "Looking Back on INTMINS..." will be published in the nest *INSPIRE Journal* .

Dean Knight, Sonoma Valley High School, Sonoma, CA

If I were to list the primary contributions of INTMINS, it would be a statement that included two parts: one for my students and one for international cooperation.

First and foremost is that for my students. The chance for the students to do real science in a relaxed, fun, exciting situation that involves a bit of hiking (both daytime and night), a bit of involvement with technical apparatus (other than a TV or computer), a bit of camaraderie (quite a bit), a bit of careful observation, a bit of new ideas (both up on the mountain-our radio site- and back in the classroom), a bit of continuity (we have been involved with this for a while, and this year we had a group of senior students who had been involved as freshmen as well as present freshmen students who had participated with their older brothers or sisters several years back), and a bit of a chance for students to claim on resumes that they have been involved in an international physics study. (There have also been a few perks for the school to be involved in such a project--actually at this point it may surprise some that this is our last year with the project as it is now configured--hard to believe!) Needless to say, I hope that every effort will be taken to continue the study in a meaningful international way.

The second part (the international cooperation one) has advantages that speak for itself. YES, I think an experiment like INTMINS should be included in the International Space Station. but I hope we don't wait until the Station is available- we need to occupy the intervening years with another project. Coordinated observations are, of course, a possibility, but I personally would like to see a project that would continue to more directly involve the Russians. I really think this is important. Maybe there is something significant that can be done. Thanks for keeping the project going.

Jack Lamb, Belton, TX

So far, I think INTMINS' contribution to science has been minimal since I am not aware of any discoveries that resulted from our work. The fact that we have worked with MIR in this study is a fine example of international cooperation in science. Perhaps it will lead to more such cooperation in the future.

My wife and I have enjoyed getting out to our quiet site to record the various operations. We wish we knew more about what we were doing, but we are happy to know we are contributing something to a project that we feel is very worthwhile. My grandson is not as excited about standing around listening to static. A few minutes is enough for him. He always brings a book to read while I stand around and listen to static. It is nice to have him there anyway in case something goes wrong.

The value of INTMINS is not entirely clear to me. It has certainly been a valuable experience for me and, hopefully, for all other participants to be part of a team that spans the globe. It is interesting to see the graphs of our data we send in. I am beginning to understand what the dark marks mean. I hope we discover something dramatic (maybe even useful) before MIR burns up in the atmosphere next year. INTMINS should certainly be included in the International Space Station so we can continue our research. Hopefully, the novelty of the new space station will attract more members for our team.

I mentioned a global team above, but have noticed, in particular, that there are no Russian observers as far as I know. I hope that will change soon. I wonder if we would benefit from observers in the southern hemisphere? Now that we are on line, perhaps we can make ourselves known to more people in the world so that they can consider joining us.

I hope there reflections on the past and wishes for the future are helpful for your retrospective article in the April, 1999 issue of *The INSPIRE Journal*.. I am looking forward to reading it.

Bill Pine, Chaffey High School, Ontario, CA

I have been involved with natural VLF radio observations for the past 10 years. I have taught physics for the past 25 years, so I am in a position to compare the physics curriculum with and without VLF radio observations. Even though the radio observations occur outside the normal school day and outside the formal physics curriculum, participation in INSPIRE activities has had a positive impact on both my students and me. INTMINS, as the latest example of INSPIRE activities, is a prime example of that positive influence. There are many good things about being involved in something like INTMINS:

1. Spending time off campus with students allows everyone to get better acquainted - both with the teacher and with each other. Lasting friendships have been forged between students who might not otherwise have even met. The times riding up the mountain and back down are very pleasant and the feeling of accomplishment after successfully meeting an operation schedule is something to be proud of.

2. Meeting a schedule like that of INTMINS is an important activity for students (and teacher). In the school system, the emphasis seems to be less on encouraging students to be responsible and more on constantly giving them second chances. With INTMINS, if the team is late, MIR does not wait! Your “second chance” may not come for another six months. Students do a pretty good job of meeting their time obligations, but when they do not, they find that the “bus” has left and they miss out. This is a good experience for them especially since the only consequence is that they miss out.

3. Finally, INTMINS has a positive impact on physics enrollment and attitude. Each year several students who might not have taken physics otherwise enroll in physics. The enthusiasm and positive attitude of the students involved in INSPIRE is a good example for other students to follow - and some of them do!

I don’t know what the physics program at Chaffey High would be like without INSPIRE and INTMINS, but I strongly believe that it would not be as good.

What are your thoughts “Looking Back on INTMINS ...” ?

All INSPIRE participants are encouraged to share their thoughts to be published in future issues of *The INSPIRE Journal* .

HESSDALEN'S LIGHT REPORT

By: Flavio Gori
Florence, ITALY

In Europe there are many people involved in strange phenomena, both in optics and electromagnetic radio waves fields. Probably there are some more areas but we can talk about these two. Some would say that it is a classical way at the end of one millennium, as the end of the world and the like. While there are many of these phenomena, unfortunately we can't say that all are studied by serious researchers and scientists. This allows people to say anything they want as if personal thinking may be the reality. I understand that not always what some persons may believe. is the truth and it may not always be appropriate to give their views strong importance, but sometimes the number of persons who can supply important support is enough to propose a scientific explanation for the phenomena.

That's what happened in a valley on the Scandinavian peninsula in the southeast of Norway. The subject of our story this month is not far away from the small town of Trondheim and about 30 kilometers northwest of the town of Roros. The valley is about 2 kilometers long and, in the beginning of the reported lights, about 150 people were living there. The phenomenon. which often tended to occur at very low altitude, had been showing a large variety of displays: multicolor and multiform lights, pulsating and flashing lights, lights whose regime of motion was rapidly oscillating, fast-moving or fixed lights, lights which were turned on for over an hour. lights which were "reacting" after a laser beam was pointed toward them. Apparent dimensions of the luminous phenomenon ranged from point-like or strongly illuminated Venus-like objects to very extended Moon-like objects, and its distance was very often estimated to be 1-3 kilometers, so that, from reference points (such as trees or houses) whose distance was known, it was possible to estimate an intrinsic diameter which was ranging from 1 to 10 meters. The existence of a very large number of witnesses convinced some scientists that a serious study should be soon attempted. All this is because in the years 1981, 1983 and 1984 a luminous phenomenon appeared in the valley and was so repetitive and seen by a number of persons who were able to support their words with strong evidence, or so it was believed by scientists who went there to study the phenomenon. This led to the formation of Project Hessdalen which was a group which included Norwegian engineers and scientists constituting a "working committee", together with external consultants operating in the astrophysical and geophysical branches.

An analogous measurement campaign had been carried out at Piedmont - USA in the years 1973-1981 when a very similar phenomenon could be monitored by physical scientists. Observations in the Hessdalen area started 21 January 1984 and ended the 26 February of the same year and the following instruments were employed: seismograph, radar, EM antenna connected to a spectrum analyzer, magnetometer, laser, Geiger counter and IR viewer; moreover a grating was added to conventional cameras. All of these instruments, except for gratings, Geiger counter and IR viewer, could provide some meaningful measurements. All the instruments were installed in two stations placed inside the Hessdalen valley. Technical personnel were constantly at the sites to monitor instruments and the ongoing situation in real time.

A total of 188 sightings could be reported, of which at least 58 couldn't have an explanation in terms of known objects. About 70% of the most reliable reported luminous phenomena were moving along a north-south direction. Radar, radiometric and magnetometric measurements and laser-pointing tests showed such a peculiar behavior that couldn't be clearly explained, at that time, in terms of known laws of physics, geophysics and atmospheric physics. In particular, the laser, once pointed to some specifically pulsating objects, seemed to cause a doubling of the objects' pulsation rate. This is still now a mystery which, later, suggested physicists to investigate on possible kinds of photon-photon interaction, but, still now, no satisfactory explanation has been furnished. Unfortunately such object reactions to the laser beam acquired only the value of a visual report. Both instrumental measurements and simple visual observations were accurately reported by "Project Hessdalen" researchers.

Twelve years later a computer analysis of the available data has been attempted in order to study the time-variability of the phenomenon in many of its aspects, including possible correlation between the different aspects of the phenomenon and finally possible correlation with daily solar activity. The character of this study can only take into account the phenomenon as a group of points in time. Such an analysis has regarded only data whose quality can allow a scientific approach. A physical analysis of every single sighted object is not possible because the obtained photographic and spectrographic data don't contain sufficient information: photographs are often of very good quality but the only possible computer analysis which is applied to them can serve to demonstrate that a given object is real but still not allow the investigation of its intrinsic nature. Obtained grating-spectra of the objects were very few and in most cases signal to noise ratio was judged too low in order to allow a consistent analysis. The study of the intrinsic nature of the objects will be, hopefully, the subject of future systematic instrumental investigations which have been already planned and partially tested and which invoke the use of up-to-date technology. Being involved in radio waves, it is obvious that my principal interest is radio related and here you will hear about the kind of radio waves research carried out in the Norwegian valley.

The following the instruments were used. As you can see, there were very good tools.

1. Hewlett-Packard spectrum analyzer
   sections 8544L-RF, 8552A-IF, display 1415
   operating in the range 150 kHz-1250 Mhz.
2. Singer NM-25T radio interference and EM field detector,
   operating in the range 150 kHz-32 Mhz.
3. Wide-band antenna (home-made conical spiral type).

Even if the spectrum analyzer was not running all the time and even if the screen was not monitored in a continuous way, two types of recordings could still be reported:

1. A single-frequency component, whose frequency could range from 130 to 1115 Mhz and whose amplitude could range from 12.5 to 22.5 dB. The signal was characterized by a single spike whose amplitude was going up and down: this kind of signal was called "Type 1".

2. A signal characterized by several simultaneous spikes with almost equal amplitude, with 80 Mhz between each, all over the frequency band from 100 kHz to 1250 Mhz. The amplitude of the spikes was oscillating up and down: in the down phase it was about 5 dB over the noise, in the up phase it was 25-30 dB over the noise. This kind of signal was called "Type 2".

Comparing data, it is possible to notice that Type 2 signals occurred a few hours before or after the luminous phenomenon, while some of the Type 1 signals seemed about to coincide with it.

Recordings of radio events which are suspected to be related to UFOs have not been a unique prerogative of the Project Hessdalen Norwegian team. During an observational and, partly, instrumental campaign carried out in the period 1973-1980 at Piedmont (USA), physicist Harley Rutledge and his collaborators, using a spectrum analyzer could record similar spike-like radio events which were presumably associated to luminous phenomena. Anyway, even if very numerous and good estimations of distance and size of luminous phenomena could be done, the number and the quality of reported radiometric data at Piedmont were respectively much lower and worse than the ones obtained in 1984 at Hessdalen. Furthermore, astrophysicists George Smoot and Giovanni De Amici of the Lawrence Berkeley Laboratory (USA), using a small dish for radioastronomic research, recorded accidentally and repeatedly strong unexplained radio spikes during a mission in Antarctica, which was devoted to the measurement of the 2.7° K background cosmic radiation. Unlike the Hessdalen and Piedmont cases, in this specific case no luminous phenomenon was reported about to coincide with radio-spikes. This last, was from a book written by G. Smoot and Keay Davidson in 1994 and named "Wrinkles in Times". Very interesting also to understand how these strange spots may appear and look like. This research is carried out by a Norwegian University and is headed by Dr. Erling P. Strand. One of his colleagues is Dr. Massimo Teodorani from Italy, an astrophysicist living in Cesena, a central eastern Italian town. These two researchers are the authors of the report largely quoted in this article of mine, as indicated in the footnote below. They have been working on the Hessdalen phenomenon since 1994 and are still working on it. Their new campaign will begin in few months, though the one I'm reporting on here is still in progress as data treatment.

As I reported some years ago for the Ostina phenomenon (maybe someone will remember in the 2/95 Journal), light spots in the atmosphere may be studied also by Natural Radio tools such as the WR3 as well as Inspire receivers. I wonder if Hessdalen phenomenon may be detected by very low frequency radio receivers and antenna or, better, a radio/antenna net positioned in the Valley, connected with portable computer (such as PowerBook) with FFT sonogram software (with log scale and real time feature), or Spectrum Analyzer. It should be fine to establish such a network, thinking to the phenomenon's and Valley 's geography. In the next Journal I'll try to explain what I'm planning to do. (Are there any Norwegian Inspire members?).

In my conversation with Teodorani I usually ask why there are no VLF/ULF research programs in the Hessdalen site. Being an optic researcher, he is not able to answer in detail. Maybe it would be interesting ask to Strand or someone else familiar with radio waves why this is. I'll do it as soon as I can.

This article is just the first part. The second one will be here in the next Inspire Journal.

Note.
Technical data are from:
The Hessdalen luminous phenomenon: a data analysis.

The author thanks Massimo Teodorani for his kind permission to reproduce their work.

An Example of Data Analysis on a PC

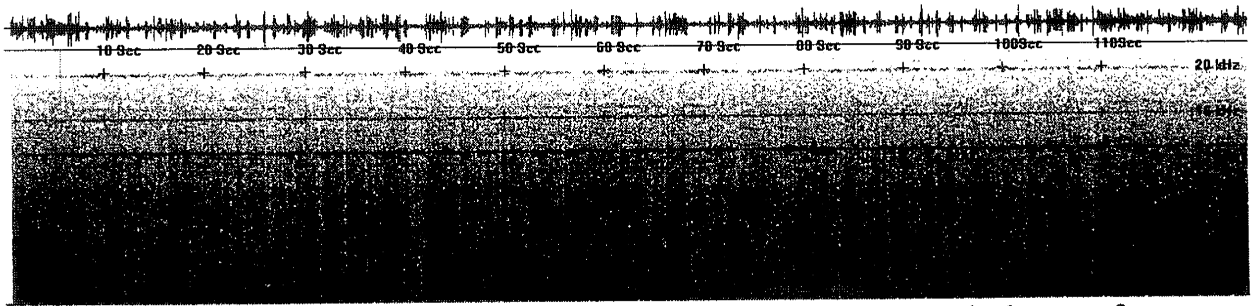
By: Robert Bennett
Las Cruces, New Mexico

(*Editor's note: The following was not originally submitted as an article, but rather as a communication to the data analyst. The analysis was so well done that it seems appropriate to make a full-fledged article out of Bob's work.*)

As far as the mechanics of monitoring, everything went well with only a few minor problems. The weather even cooperated, it was warmer than normal this time of year in southern New Mexico, the ground was still a little wet from rains during the previous weeks and this helped prevent blowing dust, a constant problem for me normally. I had a cable connector fail on one mission (I had a spare), and ran down the batteries in all three of my flashlights during one evening (the result of buying discounted batteries that were alleged to be fresh).

Attached to this note are my logs for the Nov. 98 monitoring sessions. (See Pages 20-23 for sample copies of logs.) I have also sent in my audio recordings and two Iomega ZIP Disks with the results of my reduction of the audio recordings

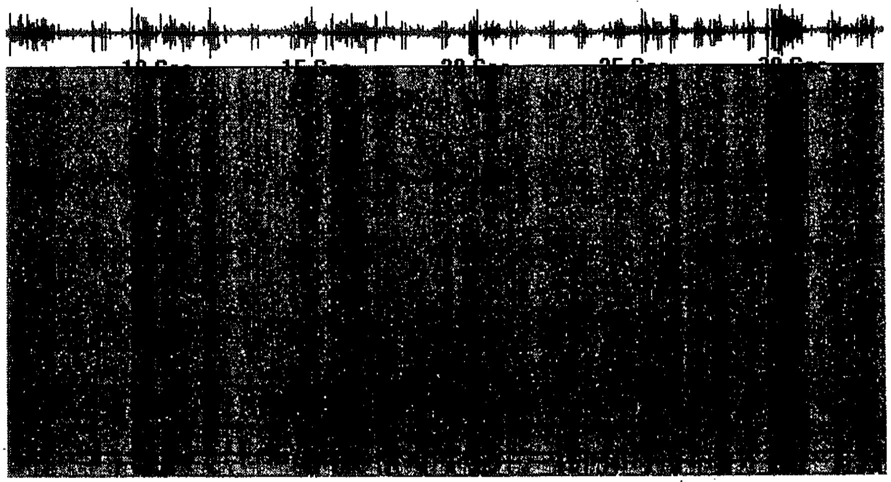
The wave and spectrogram files on the disk can be decoded as follows. Each file starts with the mission number and the extension gives the type file. For example, 22-2.WAV is the audio recorded during the two minute of the ISTOCHNIK Mission. The resulting spectrogram for the entire two minutes is file 22-2.BMP. The spectrogram of the first 30 seconds or so of this period will have an "A" appended in the file name, e.g. 22-2A.BMP. Other items on the tape that were of interest to me are recorded with an "X" in the file name (for example 22-2x1.wav is file from an antenna test.



File 21-2.BMP Operation 21-2. On the GRAM display screen, at the top is the waveform graph and below is the frequency-time plot. Time is shown across the top of the spectrogram; frequency is shown to the right. There is a grid mark (+) at each 4 kHz and 10 seconds.

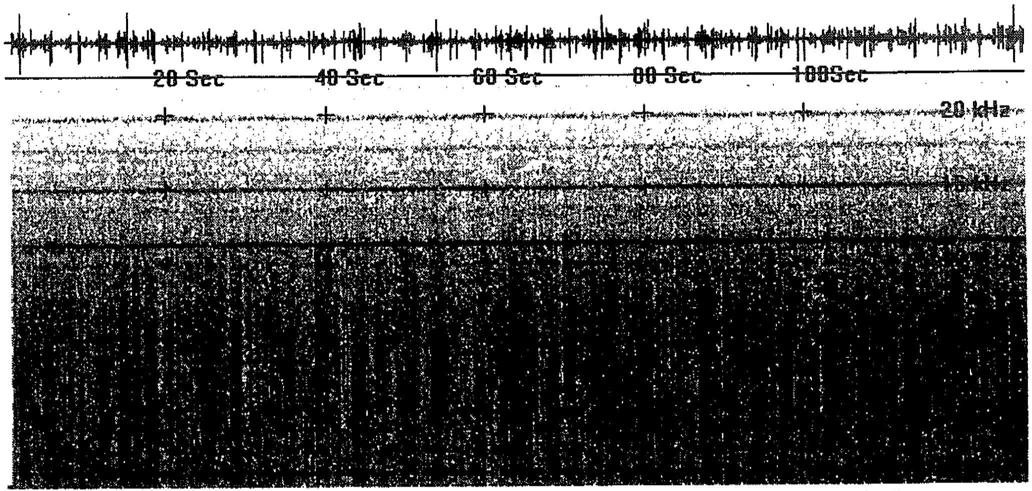
I recorded missions 21-2, 21-3, 21-4, 28-9, 29-1, 29-2, 29-3, and 29-4. I was not able to monitor during the coordinated monitoring periods on 29 November because of rain. In general, I found the November monitoring sessions to provide some of the highest intensity activity I have seen in natural radio signal monitoring. The sferic levels were always high, I estimate between 8 and 10 on a scale of 1 to 10. The tweeks were frequent and intense, almost always having a chirp tail on them. I thought I recorded one weak whistler; however, I could not find it on the spectrogram after processing.

I did not detect the ISTOCHNIK signal during these observations. This is not a surprise since one look at the spectrograms tells why. I have a LORAN Station about 40 miles from my monitoring location. The Loran pulses produce spectral components (or lines) right on top of the ISTOCHNIK frequency of 1 kHz. The Loran component is much stronger than I would expect the Inspire signal to be.

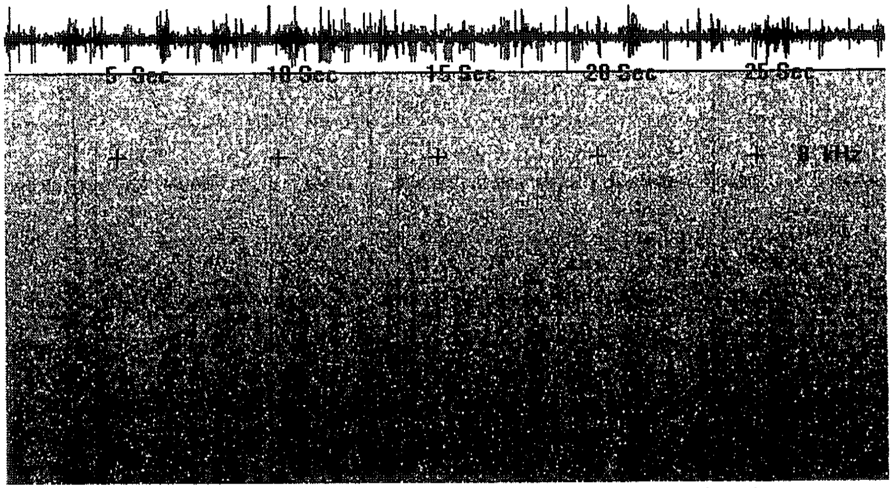


File 21-2A.BMP Approximately the first 30 seconds using 0-5 kHz frequency range. The horizontal rows of dashes are from the LORAN station. Notice the row of dashes at 1 kHz.

I noticed several interesting things. First, the 60 cycle hum levels varied quite a bit on me. The recordings on 21 November had no evidence of hum. The recordings on the rest of the days had some minor hum present. Also, during recording on 28 November, I noticed what seems to be varying levels of hum, amplitude would seem to increase for several seconds then decrease. The random noise level (hiss on the tape) increased as the nights wore on. The recordings made early in the evening show lower levels than those made late at night. The increase seems to be most noticeable in the 4-8 kHz band. I included a spectrogram of the increased levels on the Zip disk (files 22-3x1.BMP, 22-3x2.BMP and 22-3x3.BMP).

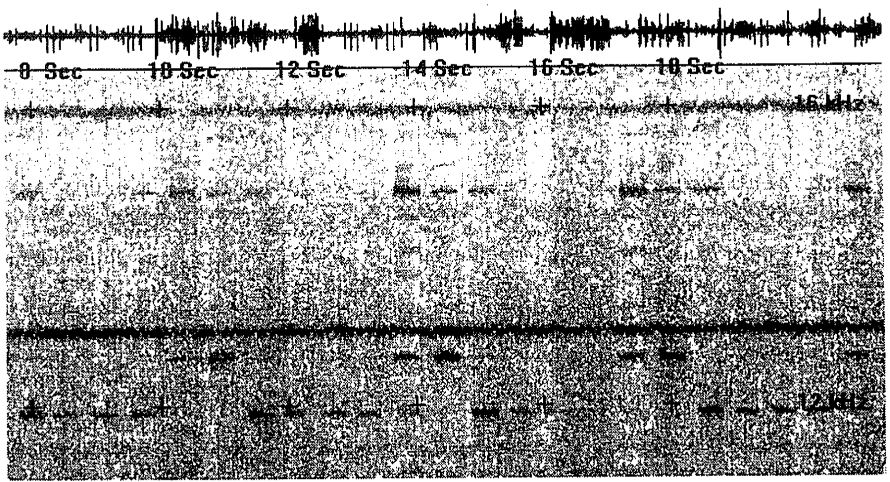


File 22-3x2.BMP Hum shows up as horizontal bands below 8 kHz.



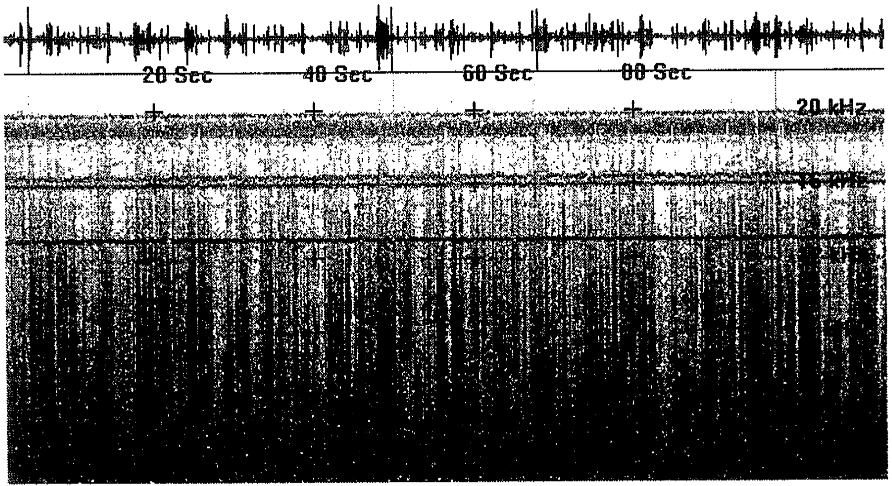
File 22-3x3.BMP Closeup of 4-8 kHz band showing hum.

I recorded the Russian Alpha system during every session. I enclosed a good example of a spectrogram showing the structure of these signals (file 21-2b.BMP).



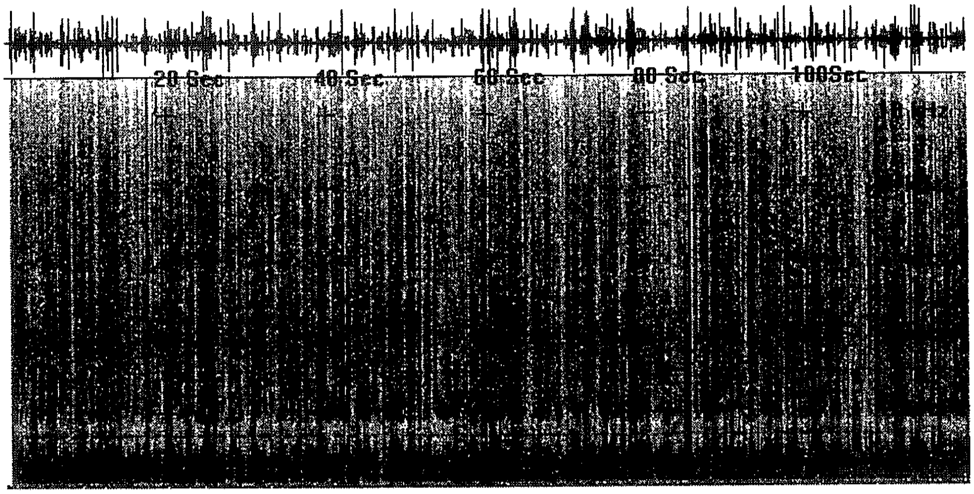
File 21-2b.BMP Dashes are from Russian Alpha navigation stations. There are three stations transmitting patterns of dashes at frequencies between between 11.905 kHz (the lowest row of dashes) and 14.881 kHz.

I found communications signals at 13.1, 16.0, 19.8, and 21.4 kHz.

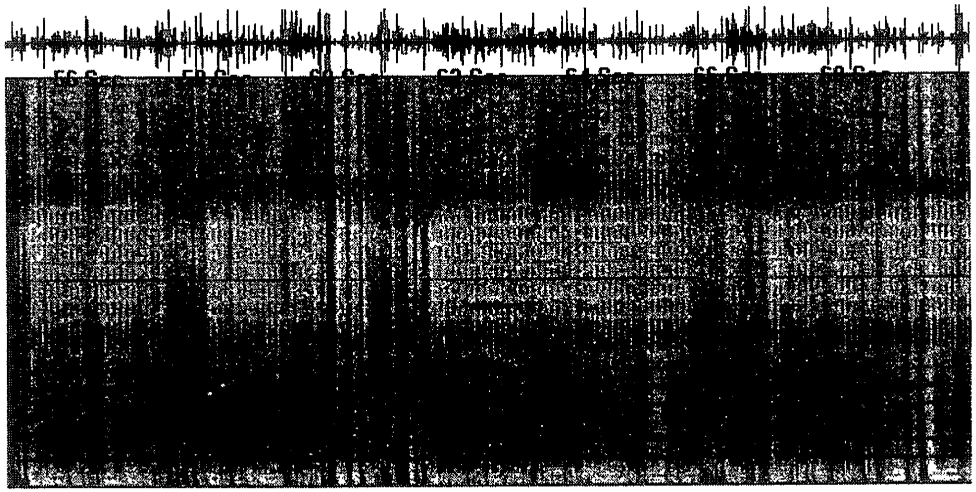


File 28-9.BMP Horizontal lines indicate communications signals at several frequencies above 12 kHz. A cursor function included in the GRAM software allows precise determination of times and frequencies.

Also, on 29 November, I noticed two steady signals at 1384 and 1503 Hz. The signals were not present in all the recordings and I am not sure what they are.



File 29-1.BMP



File 29-1A.BMP Horizontal lines show the steady signals.

Finally, I conducted several antenna experiments during these sessions. Details can be found in my hand written logs and sample spectrograms are included on the Zip disk.

(Note: The following pages show copies of Bob's logs for Operation 22-2 including his antenna tests.)

DATA LOG COVER SHEET

OBSERVER: Robert Bennett
DATE: 22 NOV 98.

****

OPERATIONS DETAILS

Type Operation: ISTOCHNIK 22-2.

Tape Start Time: 0252 UTC — **Local Time** 1952 MT.
Operation Start Time: 0304 UTC → 0302 — **Local Time:** 2004 MST, Sat. 21 NOV 98.
Operation Stop Time: 0306 UTC → 0304 — **Local Time** 2006.
Tape Stop Time: 0317 UTC — **Local Time** 2017.

T-Time Correction = -2 min

****

EQUIPMENT

Receiver: VLF-2.
Recorder: Marantz CP 430.
Antenna: Several used see next Page.

WWV Receiver: Yupiteru MVT 7100
WWV Antenna: 10' whip.
WWV Frequency: 5.00 MHZ.

Misc: Limiter on recorder was "on" to prevent recorder motor damage.

****

SITE INFORMATION

Location: 32 deg, 34 min N LAT: 106 deg, 41 min W LON: Elevation: 4290 Feet
Site Description: Desert valley between two mountain ranges.
Temp: 34 F. **R.H.** 66 %.
Local Weather: No wind, no rain in about a week but ground still has moisture in it. dew point occurred in this mission, everything has water film on it.

Name and Address: Robert Bennett
[redacted]
Las Cruces, NM 88012
[redacted]

Page 1 of 4.

22 NOV 98

Antenna Experiments.

During this mission, I experimented with Four different antennas.

ant-1

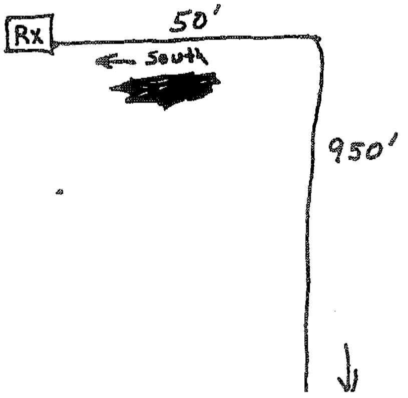
6' vertical whip mounted on a fence post. The bottom of the whip is about 5' above ground.

ant-2

120 Ft Longwire. Feed end is about 3' above ground and distant end is about 20' above ground. Orientation is North-South.

ant-3

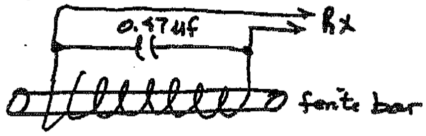
1000' surface mounted insulated wire. The wire was deployed in an "L" configuration and was laid along the dirt trail used to access my monitoring site.



22 Nov 98

ant-4

Ferrite loop antenna tuned to 1.0 KHz.



The Loop was orientated N-S and was mounted on a 2' high PVC pipe.

General observations.

The recording level meters on the Marantz gives an integrated or average signal level in DB. The following were observed during the testing:

	Antenna	recorder level in DB
#1	120' LW	0 to -2 db
#2	6' whip	-2 to -4 db
#3	1000' LW	steady at about -4 db
#4	Ferrite loop	-20 db
1+2+3	sum	0 to -2 db

The best signal level seems to be provided by the 120' L.W., followed by the 6' whip. The others are worse.

Date: 22 Nov 98

APE RECORDER COUNTER	TIME UT	EVENT	SFERIC LEVEL	COMMENTS
0-10		Voice Announcement		
10-28		level adjustments	9	
30	0246	WWV		On 120' L.W. Ant
#1				lot of strong tweeks
68	0248	WWV		60∿ present but weak
103	0250	WWV		
107-109		Antenna change to 6' whip		6' Whip Ant
				60∿ hum has on
			8	6' Ant.
134	0252	WWV Suggest Tape start		Loran about same
2 164	0254	WWV		
178	0255	WWV		
179		antenna change to 1000' L.W.	6	Loran stronger
192	0256	WWV		Sferics lower?
		The tweeks seem to "ring" more on the 1000' L.W.		
218	0258	WWV		1000' L.W.
243	0300	WWV		
245-251		change back to 120' L.W. for mission		
268	0302	WWV Corrected T-Time	9	120' L.W.
291	0304	WWV T-Time		60∿ hum seems to
313	0306	WWV mission End		have decreased
335	0308	WWV		
341-347		change Antenna #1 + #2 + #3		Combined Antennas
356	0310	WWV		The 1000' L.W. seems to
3				Act as a filter to remove
376	0312	WWV		Some Natural Radio Signals
396	0314	WWV		
397		Change Ant to Ferite Loop		#4 Loop Ant
406		End of Recording and Tape		almost No Signal

A BEGINNER'S GUIDE TO NATURAL VLF RADIO PHENOMENA

How to Hear and Record Them

By Michael Mideke
Ragged Point, CA

The emergence of new technologies has a way of revealing unexpected aspects of the natural universe. The telephone, which effectively shrank our world by superimposing its electronic dimension upon our existing physical space, has played a coincidental role in showing us the same world larger, more mysterious, more wonder-filled than we'd imagined.

The story goes back to the earliest long telephone lines, clear back to the 1880s and operators who reported strange chirps and whistles that had no obvious connection with the telephone system and its traffic. It was a mystery, but one which attracted little serious attention until much later, when it emerged to complicate life in the entrenched battle-fields of World War I Europe.

Though primitive by today's standards, there was a mature telephone technology when the war began, and that technology soon found its way into the trenches. Electronic Counter Measures arrived immediately thereafter in the form of high-gain vacuum tube amplifiers which each side employed to intercept "leakage" from the other's communications. The general idea was to run wires from widely separated ground stakes to the input of a sensitive amplifier sampling stray or induced currents from the enemy's telephone system. For the most part, this worked well enough to be worth the trouble but now and then eerie descending whistling tones appeared in the monitors' headphones. Some likened them to the sound of phantom shells passing over-head. At times the cacophony of these "whistlers" became so thick that eavesdropping efforts were completely foiled.

The German scientist H. Barkhausen became quite intrigued with these peculiar sounds. His initial assumption was that they were an artifact of the amplifiers, but his attempts to reproduce the whistler phenomenon in the laboratory were fruitless. About this time he did make basic discoveries relating to electronic oscillators. and it is interesting to speculate that his pursuit of whistlers may have played this. Barkhausen's next conclusion about whistlers was that they were a natural phenomenon which could not be explained on the basis of current knowledge. It was a fascinating puzzle, and over the years he and other researchers pecked away at it, arriving by late 1920s at fairly general agreement that lightning was responsible. A correct interpretation, but the 'how" of it remained elusive until the 1950s.

What does the sudden flash and roar of lightning have to do with these musical electromagnetic signals that glide from as high as 30 kHz down to less than 1000 Hz? How can the one event lead to the other? The key lies in the nature of electrical sparks.

Lightning is a spark discharge - a huge spark, embodying peak currents of thousands of amperes, potentials on the order of 250 million volts. Any electrical spark is a source of electromagnetic energy. Not only light but ultraviolet, infrared and radio. The latter is the basis of Heinrich Hertz's experimental verification of Maxwell's equations, and the source of whistlers.

Rather than being a coherent signal confined to a particular frequency or band of frequencies, lightning's radio emission is a broad spectrum burst - all frequencies appear in it at once, from hundreds of Hz through hundreds of MHz. On our conventional AM and short-wave radios we hear these bursts as the snap and crackle of static. Were you to line up several radios tuned to different frequencies, chances are good they would all register the same static bursts at the same time. (The experiment is not guaranteed to produce this result because radio waves propagate quite differently at different frequencies - radios- tuned to widely separate parts of the spectrum might be responding to static from completely different areas of the world.)

A large percentage of lightning's effective radio energy is concentrated in the 1 to 30 kHz region loosely defined as the VLF or Very Low Frequency region. (See Figure 1.) At these frequencies the static bursts propagate with particular efficiency in the "waveguide" formed by the earth's surface and the ionosphere (See Figure 2). Tuning

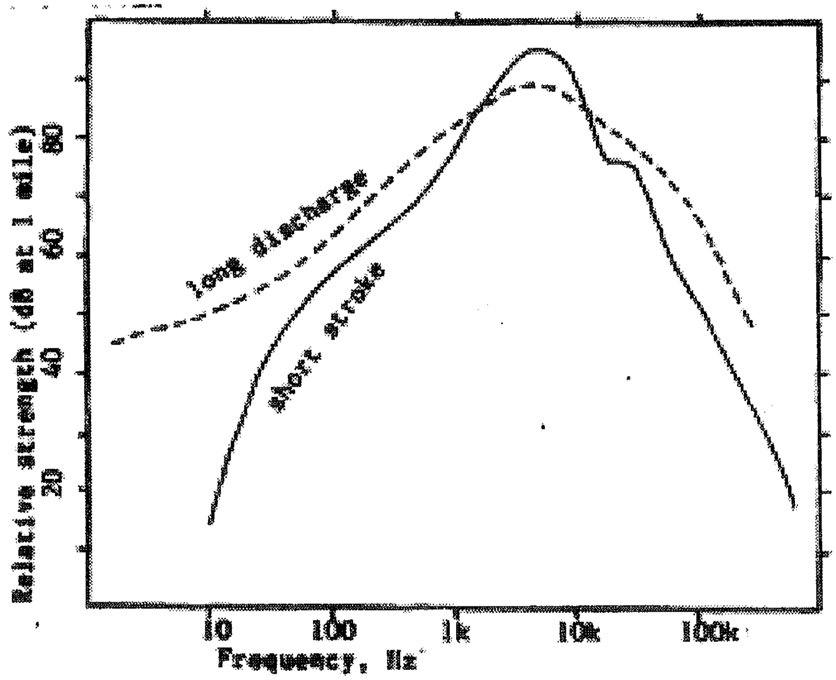


Figure 1. Lightning's radio energy in the ELF-VLF region. After Watt, VLF RADIO ENGINEERING

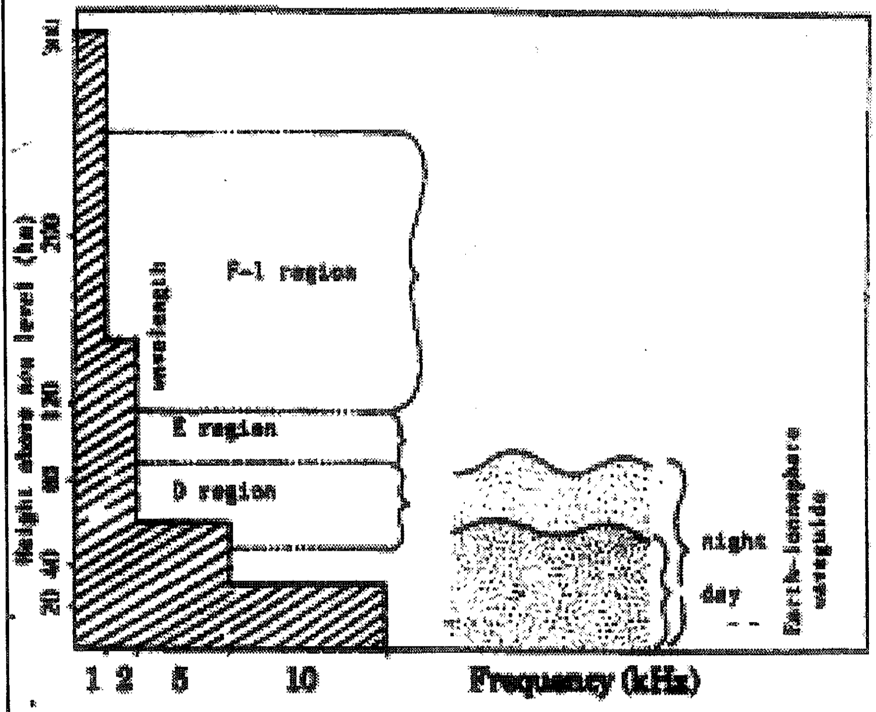


Figure 2. Frequency vs. wavelength, seen in the perspective of ionospheric regions. Signals whose wavelength exceeds twice the waveguide height will not propagate in higher wavetude modes. The earth-ionosphere waveguide operates as a variable passband filter when propagating the lightning spectrum.

through most of this frequency range, you will hear static that sounds pretty much like what you hear on your AM receiver. But If you tune below about 5 kHz you'll discover that sometimes (not always by any means), the crackle becomes a liquid musical "pinging", each pop of static producing a rapid descending note. These sounds are called tweeks. Typically, they drop a few hundred Hz in a fraction of a second, then cut off abruptly.

The mechanism of tweeks is quite well understood. When radio signals pass through a non-vacuum medium, those of higher frequencies usually travel faster than those of lower frequency. Since an impulse of lightning static starts out as high and low frequencies produced simultaneously, propagation in the earth-ionosphere waveguide necessarily sorts its frequency components; the highs arrive first, the lows later. The signal becomes dispersed over time; thus is referred to as dispersion. The degree of dispersion or "tweeking" is an indication of how far signals have traveled. Because of the nature of "waveguide" propagation, this is not necessarily an indication of point-to-point geographic distance.

Tweeks are generally heard at night (though they will often tend to appear late in the afternoon), and winter is probably their best season. If you spend long enough listening to static and tweeks below 10 kHz you are almost certain to hear a few whistlers come howling through. These too are descending notes, but they occupy seconds rather than milliseconds, and they can be extremely loud, commanding the listener's attention in no uncertain terms!

Beginning with Barkhausen, early researchers toyed with the idea that whistlers, like tweeks, are dispersed lightning static. There was a great deal to recommend this explanation, but also one bad problem - nobody could find signal paths on earth that were anywhere near long enough to account for the huge amount of dispersion seen in whistlers. Propagation around and around the world was hypothesized, as were strange radio-reflective clouds somewhere out in space. But these theories didn't fit the observed phenomena very well. Since they seemed to resolve far fewer questions than they raised, nobody was very happy with them as explanations for whistlers.

Whistler research lapsed into a sort of limbo from the mid 1930s through WW-II. Whistlers remained: "Natural Phenomena, cause and mechanism unknown."

The war engendered unprecedented technological leaps. New techniques for recording and spectrum analysis emerged from the conflict to play central roles in the

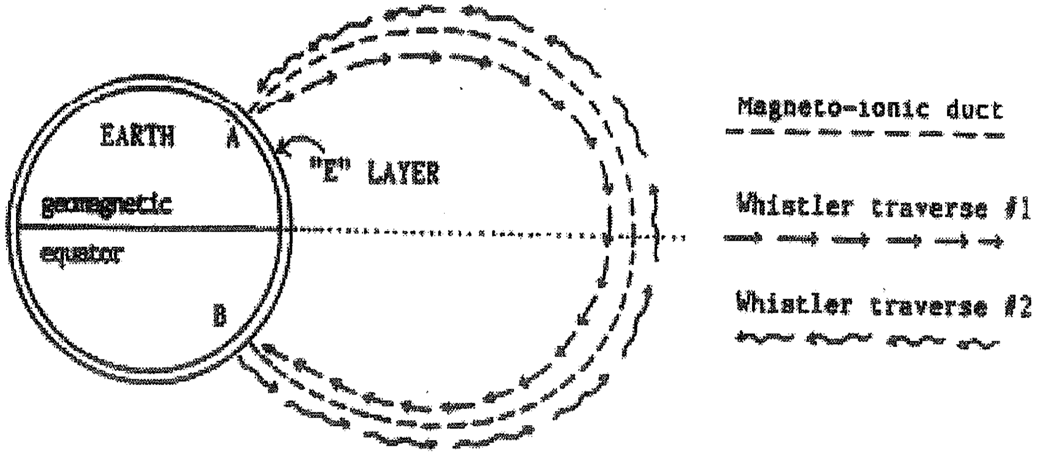


Figure 3. Whistler paths (after Helliwell). A lightning impulse near A propagates between earth and the E region of the ionosphere until it is trapped by a duct. The signal is then ducted to B in the conjugate region of the opposite hemisphere. A single hop whistler emerges into the earth-ionosphere waveguide at B. A reflected signal may be returned to A to be heard as a two hop whistler.

unraveling of whistler mysteries during the 1950s. L.R.O. Storey, R.M. Gallet, R.A. Helliwell, M.G. Moran and others were successful in applying new tools and careful observation techniques to whistler research. In the process, they developed a new view of earth's near-space environment and laid foundations for the field of magnetospheric physics.

As it turned out, the long dispersive whistler paths were found neither in terrestrial propagation nor in the depths of space - rather, they were traced to an intermediate region known as the magnetosphere. This is the region where earth's magnetic field interacts with the continuous (but varying) influx of charged particles known as the solar wind.

The solar wind consists of charged particles (electrons and ions) moving outward from the sun. Solar wind, magnetosphere and ionosphere are plasmas, hot, partially ionized gases. These charged particles in motion develop magnetic fields. Since magnetic fields are subject to interactive forces of attraction and repulsion, as the solar wind particles encounter earth's magnetic field both particles and the planetary field are perturbed. Energy is transferred, distorting the geomagnetic field into its now familiar teardrop shape, and solar wind particles are captured in spiraling courses aligned with the field. The plasma densities and the dimensions of the magnetospheric plasma environment happen to be suitable for the effective propagation of radio energy at whistler frequencies.

Broad spectrum VLF radio energy generated by lightning bursts under some circumstances escapes the earth-ionosphere waveguide to encounter field-aligned discontinuities (generally described as "ducts") in the magnetospheric plasma. The ducts extend between northern and southern hemispheres, arching to their maximum distance (several earth radii) from earth over the equatorial regions as shown in Figure 3. Field-aligned ducts within magnetospheric plasmas do in fact yield paths long enough to account for the dispersion of whistlers.

Simultaneous monitoring in northern and southern hemispheres has revealed that specific static impulses m one hemisphere do correlate with whistlers heard in the conjugate region of the opposite hemisphere. Moreover, whistlers may rebound back and forth along a duct (or even multiple ducts) many times, generating progressions of echoes that become ever longer in duration, lower pitched.

Scientists were quick to realize that the study of whistler dispersion could yield valuable data about the characteristics of the magnetosphere. Every whistler is a magnetospheric probe!

BASIC GUIDE TO WHISTLERS, EMISSIONS AND ASSOCIATED PHENOMENA

STATIC - Static is the impulsive crackling and popping of lightning generated broad spectrum radio bursts. Static can be heard throughout the radio spectrum. Its character varies according to the structure of the lightning producing it, distance from the receiver and the paths over which it propagates. Static impulses are also referred to as sferics.

TWEEKS - Tweeks are sferics subjected to dispersive distortion by subionospheric propagation, They are sharp falling notes with a duration of 25 to 150 milliseconds.

WHISTLERS - Whistlers are descending tones generated through the propagation of sferics over very long paths formed by field aligned plasmas (ducts) m the magnetosphere. Whistler's magnetospheric propagation is between magnetic conjugate regions in northern and southern hemispheres. Terrestrial reception of whistlers results from subionospheric propagation of these signals.

Whistler duration ranges from a fraction of a second to several seconds. The frequency range of whistlers can extend from above 30 kHz to below 1 kHz but those readily heard with simple equipment will mostly lie between 1 and 9 kHz, with their maximum energy usually concentrated between 3 and 5 kHz. Whistlers are categorized according to hops. One hop equals a single traverse between conjugate regions. A one hop whistler is generated by lightning in the opposite hemisphere from the listener. It has traversed the magnetosphere just once and as a consequence, it tends to be a high pitched whistler of short duration. Since the causative sferic is very far away, it is rarely heard in association with single hop whistlers.

Two hop whistlers are produced by lightning in the same magnetic hemisphere as the listener. The signal has traveled to the opposite hemisphere and echoed back to the region of its origin. Subject to roughly twice the dispersion of a single-hop whistler, its duration is much longer than its one-hop cousin. Causative sferics can often be heard in very distinct association with 2-hop whistlers. Delays of 1.5 to 3 seconds between sferic and whistler are typical.

Odd order hops (1, 3, 5, etc.) indicate opposite hemisphere lightning while even order progressions (2, 4, 6, etc.) follow from same hemisphere lightning. On occasion, whistlers generate multiple echoes or progressions known as echo trains. While trains exceeding about a dozen echoes are uncommon, progressions of more than 100 have been observed on rare occasions.

Whistler notes range from extreme] pure tones to breathy, diffuse swishes. The breathy quality is described as diffuseness. It results from whistler mode excitation of multiple ducts, with slightly different travel time for each duct serving to spread or diffuse the signal.

Whistlers were the first studied and most easily understood class of magnetospheric radio events but they are far from being the only ones that can be observed by a patient listener using basic tools.

VLF EMISSIONS - VLF emissions are naturally occurring phenomena found in the same frequency range as whistlers. In his book WHISTLERS AND RELATED IONOSPHERIC PHENOMENA, Robert Helliwell divides VLF emissions into 7 basic categories:

HISS - Hiss, as the term suggests, is a hissing sound. Unlike white noise, it is more or less band-limited. Its center frequency and bandwidth can vary widely with different conditions. Hiss may be stable in amplitude and frequency for minutes or hours. Or it may show distinct short-term fluctuations which may or may not be periodic in nature. Hiss is often found in conjunction with other emissions.

DISCRETE EMISSIONS - Discrete emissions are brief, transient events. They may be pure or fuzzy tones which rise ('risers") or fall ("falters') in frequency. Sometimes falters abruptly turn about and rise in frequency as 'hooks". Other descriptive terms that come to mind are 'chirps', "croaks", "honks" and "barks".

PERIODIC EMISSIONS - When clusters of discrete emissions form regularly spaced repeating patterns they are known an periodic emissions. They may be singular or multiple, relatively frequency stable or drifting.

CHORUS - Multiple closely spaced or overlapping events are known an chorus. Chorus may resemble the sound of birds at sunrise but often it is reminiscent of croaking frogs or seals barking. Chorus is frequently found rising out of the upper edge of a band of hiss.

QUASI-PERIODIC EMISSIONS - These are events consisting of discrete emissions. periodic emissions or chorus which appear at long but fairly regular intervals - on the order of tens of seconds. They are less regular than periodic emissions.

TRIGGERED EMISSIONS - Sometimes one magnetospheric event triggers another. Triggered emissions are those which appear to be clearly associated with a triggering source. Whistlers, discrete emissions. manmade VLF signals and atmospheric nuclear explosions may all serve as triggers. Whistlers and other signals may also be seen to modify the spectrographic signatures of other events in the same duct.

THE ORIGINS OF VLF EMISSIONS

VLF emissions appear to arise from interactions above. the equatorial region that involve incoming solar wind particles. the planetary magnetic field and plasma resident on the field lines. At whistler and emission frequencies the magnetosphere has the potential to perform as an amplifier. (Gains of 20 to 50 dB have been observed.) This amplifier is subject to instabilities which are regulated by (among other things) the time constants of whistlers and other signals echoing back and forth along magnetospheric ducts. To take a simplistic view, the whole system can be considered as a gigantic electronic synthesizer programmed by solar and terrestrial processes. The resulting music can be complex, sustained and hauntingly beautiful.

ARTIFICIALLY STIMULATED EMISSIONS (ASES)

In the 1950s and 60s, powerful military VLF Morse Code transmissions were observed to stimulate emissions resembling elements of the rather mysterious "chorus" phenomenon. This led to the idea that it might be possible to perform active experiments in order to better understand the actual mechanisms involved in the production of whistlers and emissions, thereby refining our knowledge of the magnetosphere.

Research employing a powerful VLF transmitter at Siple Station, Antarctica, was carried out in the 1970a and 80s. Transmissions from Siple generated a variety of magnetospheric phenomena that were heard by a monitoring station in the magnetic conjugate region near Roberval, Quebec, and by a variety of satellite monitors operating within the magnetosphere. These experiments in the controlled excitation of events within the magnetosphere succeeded in greatly advancing scientists' understanding of the interactions taking place in the near space environment. They have also suggested many avenues for future research.

With the magnetosphere well established as the sensitive region within which the mechanisms governing whistlers and emissions operate, there has been considerable interest in discovering the effects of stimulation applied directly to that region. During 1989-90, the Soviet satellite ACTIVE attempted to accomplish this by passing large 10.5 kHz currents through a 20 meter loop antenna. Unfortunately, the loop apparently accidentally deployed in a very inefficient configuration. Several months of monitoring by NASA, Soviet observers and private experimenters in the US found no effects, either on the ground or in space. These joint experiments were nonetheless successful in that they provided the occasion for participation by a number of amateurs and high school groups. Had ACTIVE performed as hoped, their data would have made a valuable contribution to the research.

School and amateur participation will continue in the spring of 1992, when the Space Shuttle based ATLAS 1 (ATmospheric Laboratory for Applications and Science) will deploy a VLF modulated electron beam instrument known as SEPAC (Space Experiments with Particle ACcelerators). The SEPAC electron beam will be modulated at frequencies between 50 Hz and 7 kHz as researchers attempt to analyze its propagation and interactions with magnetospheric plasmas. The high school and amateur ground stallion program, INSPIRE (Interactive NASA Space Physics Ionosphere Radio Experiments) will provide a large network of ground stations to determine the “footprint” and other characteristics of the SEPAC signal.

Not only has the past four decades of active and passive whistler research enormously enhanced our understanding of the vast interactions taking place in the magnetosphere, it has given us glimpses of similar processes on other worlds. Whistler-like signals have been heard in the vicinity of Jupiter, Saturn and Neptune. Even Venus and Mars make odd noises on VLF. It appears that planets having magnetic fields and turbulent atmospheres are likely to produce whistlers and related phenomena. The coming decades should signal the emergence of a new branch of science devoted to the analysis of planetary electromagnetic signatures at VLF and ELF. But as we speculate along these lines we should remember that we've only begun to understand the complexities of our own world’s natural electromagnetic environment.

For the amateur observer, pursuit of whistlers represents a unique combination of challenges and rewards. Highly sophisticated receiving and recording equipment is not required - the basic tool kit needn't cost a fortune, and the parts of that kit which need to be constructed (or

commissioned) by the user are not particularly complicated. Even a rank beginner at electronic construction can build a workable whistler receiver. The greater challenge probably lies in seeking out radio quiet locations far from power lines and waiting patiently (or returning again and again)
until something happens.

The rewards are inextricably bound up with the challenges. There is a genuine thrill to hearing these things for the first time (or the first hundred times!), particularly if one accomplishes the feat with tools built "from scratch". With increasing experience it becomes apparent that the variety of natural VLF radio phenomena is enormous. Many listening expeditions will be duds, but of those that produce results, no two are likely to be the same. If one makes recordings, the task quickly evolves from a quest to collect samples of the various phenomena to an ongoing process of gathering better samples. With over 60 hours of whistler tape on the shelf, I foresee no end to that particular process!

The scientifically inclined amateur will find numerous areas that invite research, including topics and phenomena that have been touched upon only lightly, if at all, by professional researchers. For instance, the possibilities of a large network of coordinated monitors have never been explored simply because there has never been a large number of monitors.

There is a great deal to be done in the area of electronic design and signal processing. Prototype 'comb filters' have been developed to remove power frequency harmonics from receivers, but there is clearly more to be done in this area if the whistler hunter is to be freed from the necessity of going far from the power lines to do his thing. An alternative approach to the power line interference problem lies in the development of remote receiving and recording systems that can be automated or remotely controlled. Impressive hardware and software for spectrum analysis exist in the professional world, and the well-to-do amateur can certainly acquire a rudimentary signal analysis capability "off the-shelf". However, the field is wide open for development and innovation.

RECEPTION BASICS

Whistlers and other VLF phenomena that can be detected by simple receivers occur at frequencies ranging from a few hundred Hz to above 10 kHz. These frequencies are readily accessible to human hearing but even so, whistlers and emissions are not directly audible. This is because they are electromagnetic events which do not produce the mechanical vibrations in the air that our ears detect as sound. In order to hear whistlers we must convert their electromagnetic activity to acoustical vibration. Conversion is accomplished with a transducer - a loudspeaker or headphone that uses electrical energy to move a sheet or cone of material that in turn pushes and pulls air molecules to produce sound.

In theory. all that is needed is to connect a transducer, such as set of headphones, between an antenna and the ground. But in practice, unless the antenna is miles long, the amount of energy that can be intercepted from whistlers is too small to make much in the way of sound. The problem is resolved by placing an amplifier between the antenna and the transducer. While this is quite straightforward, manmade interference immediately above and below the frequencies of interest dictates careful control of amplifier characteristics if satisfactory reception and recording is to be achieved.

INTERFERENCE FROM THE LOW SIDE - Modern civilization runs on AC (Alternating Current) electrical power. Practically all inhabited areas are heavily threaded with wires of the electrical power grid. These power lines deliver electricity at frequencies of 50 and 60 Hz, the frequency depending upon the part of the world in which you reside. This system presents the whistler hunter with a serious problem: the flow of alternating current in power lines induces alternating electric and magnetic fields in the vicinity of the lines. These fields are readily intercepted by the sensitive antennas and amplifiers used for whistler reception. They are heard as a humming sound. overwhelmingly strong in the vicinity of power lines, progressively weaker as distance from the source is increased. The hum consists of a combination of the fundamental 50 or 60 Hz note with numerous harmonics at multiples of the fundamental frequency. Hum harmonics may extend up to several kHz but the lower frequencies are generally strongest.

To reduce the effects of hum it is helpful to incorporate a high-pass filter in the receiver to attenuate frequencies below about 1 kHz. Since the worst hum often lies below 1 kHz and most whistler activity is above that frequency, this is a quite workable compromise. Where power line interference is very severe, it may be necessary to raise the high pass frequency as high as 5 kHz. Since this sacrifices much interesting whistler spectrum, the better solution is to find a more nearly interference free site. Highpass filtering is not a cure-all. Operation too close to power lines will still result in hum dominating the receiver. Given quiet conditions and a large antenna, power line harmonics extending to several kHz will be heard from almost anywhere you can go. But once you are one or several kilometers from their source they will be weaker than most natural radio activity. Even a few hundred meters may be sufficient to hear activity.

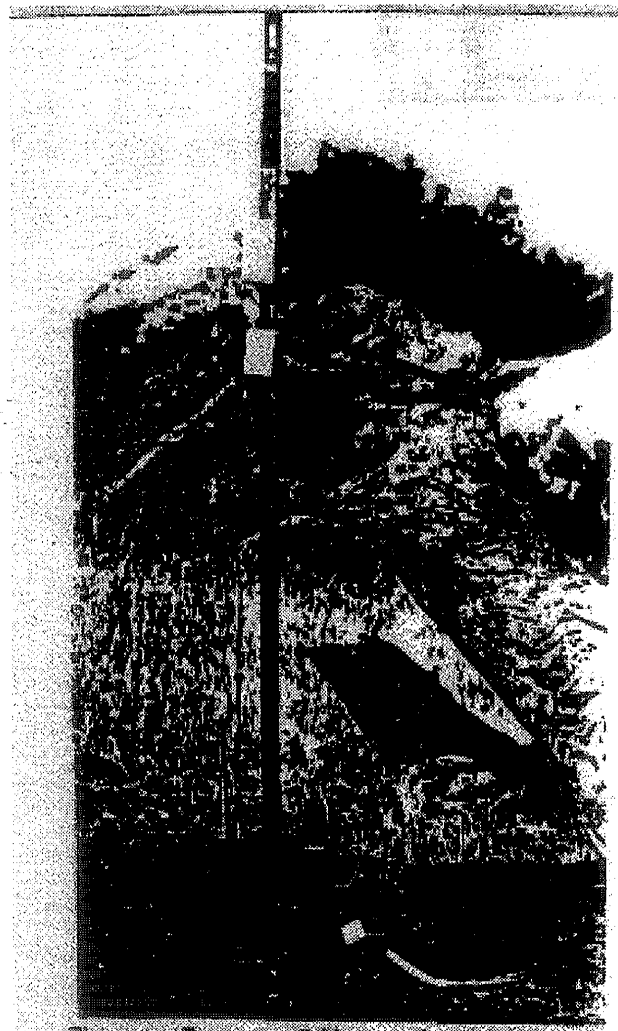


Figure 4a. Temporary field setup of an E-field whistler receiver, with monitor amplifier and whip antenna mounted on a piece of 1x2 lumber. The ground system, consisting of two rods fabricated from 1/2" conduit, is visible on the left.

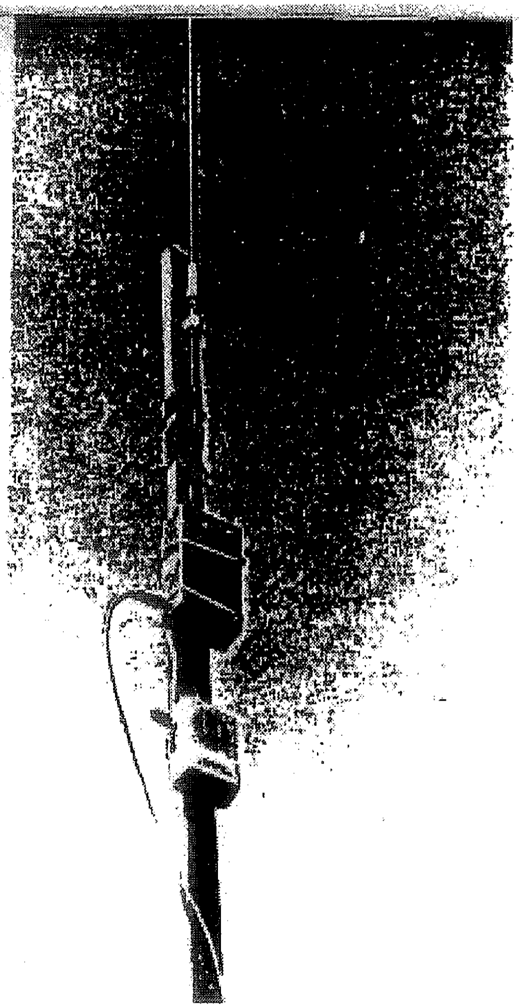


Figure 4b. Detail of whip antenna, E-field receiver and monitor amplifier mounted on 1x2 lumber.

INTERFERENCE FROM THE HIGH SIDE - Radio navigation and communications services utilize very powerful transmissions just above the frequencies where whistlers and emissions are most easily heard. The OMEGA navigation system's 10.2 kHz channel is the lowest of these interfering frequencies. If your ears have reasonably good high frequency response, you can hear OMEGA on 10.2 kHz and several higher frequencies. It sounds like a progression of high pitched dashes about 1 second long. Because the 8 stations of the OMEGA network are scattered all around the world, some of the dashes are much stronger than others.

If you find that you are hearing and recording pure OMEGA tones at 10.2 kHz and above. all is well. But if you hear or record them at a lower frequency, or if they have a warbling burbling character, overloading is taking place. Overload can happen quite easily because the manmade signals tend to be much stronger than the natural phenomena we are seeking. Cassette recorders are particularly prone to high frequency overload problems.

To minimize difficulties with high frequency overload it is useful to attenuate frequencies above about 9 kHz. This is accomplished with lowpass filters and by selection of component values that reduce high frequency response.

ANTENNA AND GROUND REQUIREMENTS - The following discussion pertains mainly to the use of whip and wire antennas which operate in conjunction with earth ground or a counterpoise to intercept the electric field component of radio signals. However, no discussion of VLF antennas would be complete without some mention of loop antennas. Loops have three great virtues. They are directional, allowing interference to be nulled and bearings to be taken on signal sources. Since they utilize the magnetic component of radio signals they are largely immune to desensitization by surrounding vegetation. Loops can be calibrates relatively easily, simplifying the business of making quantitative measurements under field conditions. On the minus side, effective loop receiver designs are more demanding and expensive than E-field receivers of comparable sensitivity. Loop antennas are a challenge to build and, when they are physically large enough to be highly sensitive at whistler frequencies they are also a real problem to transport. My recommendation to the beginner is to start out with E-field systems until you have defined a personal need for a loop.

E-field antennas (whips, wires and conductive objects insulated from ground) are heavily influenced by their relationship to ground, surrounding terrain and vegetation. In addition, every installation is subject to a critical threshold beyond which increasing antenna size or height will only result in overload of the receiver or recorder by signals outside the frequency range of interest. It is good to keep in mind that this threshold is subject to variations in propagation -
often a set-up that is perfectly clean by daylight will exhibit problems occasioned by propagation changes that begin around sunset.. For these reasons, only general guidelines can be given with regard to E-field antennas- the "fine tuning" must come from each user's experience.

The antenna should be small enough to avoid overloading under normal conditions and it should be large enough to provide an input that is usually strong in comparison to circuit and tape noise. Ordinarily this input level will be defined by substantial power line hum or a more or less continual crackle of static.

If you are operating in a clear area. as in the middle of a few acres of open field. on a hilltop or a ridge, your receiver will probably be happy with 6 foot whip such as Radio Shack's #270-1408. For the sake of sensitivity, it is important to keep the base of short whips at least a few feet above the ground. I've found the "walking stick' configuration illustrated in Figure 4 provides a very convenient way to carry and use sensitive E-Field receivers.

If you find yourself in woods or a close canyon the 6 ft whip will be virtually useless due to local attenuation of the electric field component. The solution is. to capture more signal by substituting a longer antenna made of wire. Somewhere between 30 and 200 feet should do the trick. Just about any sort of wire will work, as long as it is strong enough to avoid breakage. Wirewrap wire or plastic covered hookup wire is fine for temporary or portable installations. It is important to get the wire off the ground - the higher the better and probably the more nearly vertical the better, but there is no need to go to extremes. Unless the wire is strung along the top of an existing fence, always make the antenna high enough to clear people, horses, cattle and large wildlife. For a temporary installation it is fine to drape the wire over limbs and brush. However, the antenna will pick up noise from leaves and twigs blowing against it (or sometimes even moving nearby), so it is best to suspend the wire from just a few from just a few points and protect it from all unnecessary contact. This is true regardless of whether or not the antenna wire is insulated.

It should be noted that these antennas, minuscule in terms of the wavelengths were dealing with, function essentially as capacitors. Whips and wires are convenient to use, but any conductor that can be elevated above and well insulated from the ground will also work. I've found a 6" diameter copper sphere works about as well as a 4 foot whip mounted at the same height. My pickup truck, parked on a dry open ridge and used against a ground stake makes a more sensitive antenna than a 5 foot whip mounted several feet above the track bed.

GROUNDS - The ground connection does not have to be elaborate - you have a good enough ground when the receiver operates in a stable fashion. When the ground is missing or inadequate, the receiver will break into howling oscillation as the output level is advanced.

Buried pipes and metal fence posts sometimes provide convenient grounds. It's a good idea to carry a variety of clips and clamps for tying on to them. Don't neglect some sandpaper to clean up the contact points and extra wire to reach them. Serviceable ground stakes can be made from 1/2" electrical conduit or copper tubing. Cut the tubing in lengths of 14' to 24'. Use a hammer to mash one end flat for 3 or 4 inches, then use a hacksaw to cut a point at the end of the flattened section. Use a stainless steel hose clamp to attach your ground wire near the other end of the stake. In the field, one to four stakes of this type, hammered into the ground 10" to 12" will usually provide an adequate ground connection. For temporary and portable installations it is important not to drive the stakes to the point where they cannot be extracted. Permanent installations can incorporate one or more commercial ground rods, driven fully into the ground. If short stakes are used where the ground is sandy or very dry, it may be helpful to saturate the area around the the ground stakes with a few liters of saltwater.

COUNTERPOISE GROUNDS - Sometimes a direct earth ground is impractical. You may be situated on hard rock or ice. And of course if the receiver is mobile, ground rods are out of the question. The solution is to use a counterpoise to establish capacitive coupling to the ground. The counterpoise can consist of one or more wires with a total length several times that of the antenna. Counterpoise wires may be laid directly on the ground or suspended above it. Mobile communications systems use the vehicle body for a counterpoise, and you can do the same thing if you are operating from a car or truck. (Electrical noise will make the whistler receiver useless while the engine is running.) In general, the self capacitance of the counterpoise should be much greater than that of the antenna. When the whistler receiver is equipped with a short whip, the operator's body will often provide an adequate counterpoise. A finger ring improvised from copper wire or thin brass or galvanized strap and connected by a length of flexible wire to the ground terminal makes a convenient way to connect yourself to the receiver. If the earth ground connection is marginal, this type of body contact will usually clear problems.

FIELD TESTING THE RECEIVER - Once you have a receiver that proves itself by producing loud hums and buzzes when operated in your home or lab, it is time to do some field tests. Field-tests are important to make sure everything really is working properly, and to familiarize yourself with the equipment and procedures you'll be using later. It is also a good way to look for quiet monitoring sites.

The first criterion for a site is that it be some distance from any AC power line. Just how great this distance should be is a matter of debate, but 300 to 400 meters ought to be adequate for field testing.

For a full-scale field check, your kit should include receiver, antenna, ground stakes, monitor amp, headphones. recorder, spare batteries for everything. Take a full set of connecting cables and a couple of spares with whatever adapters are needed to replace lost or damaged cables. You will need microphone, recording tape and a notebook to keep track of your tests. Bring some spare wire and a few clip leads. Two or three "C' clamps may come in very handy, as will a basic tool kit consisting of hammer, wire cutters, a couple of screw drivers and a small adjustable wrench. (Yes, this seems like a lot of stuff, and later you may well decide to dispense with a quite a bit of it - but you can't try the things you didn't bring, so start out by erring on the side of excess.)

Having found a promising looking site, put up an antenna (try a whip if you are in the open, a wire if in the woods) and ground or counterpoise. Turn on the receiver and monitor. You should hear the click and crackle of sferics, their loudness and frequency depending upon the time of day and state of the weather within a few thousand miles. Unless the sferics are very strong and dense, you will probably hear the background hum of power lines as well. Depending upon the background level and the frequency response of your hearing, you may also hear the shrill tones of Omega as a series of dashes about 1 second long. With luck, you'll even hear whistlers or chorus, but don't count on it.

Make a test recording beginnmg with a microphone announcement describing the setup. Then try recording various receiver settings, cutting back to the microphone to provide running commentary on what you are doing. Ideally you should work with a recorder having an independent playback head, switching between tape input and output to arrive at settings where they sound identical. If this feature is not available, rewind and check the test tape immediately after recording. If the recording is distorted or noisy, or if things appear on the tape that are not heard on the direct monitor - try other settings, lengthen or shorten the antenna. Even if you don't fix the problem right away, these adjustments may give important clues as to its source. Take notes - things that seem obvious at the time tend to fade or become distorted in memory.

When you get home, review your tape and notes. Think about what could be improved on the next expedition.

WHISTLER HUNTING

Once the receiving system is working properly and you've gotten accustomed to setting it up, the time has come for more serious whistler hunting. The questions are 'When?' and "Where?'

WHEN? Whistlers and emissions may be heard at any hour of the day or night but odds are best around dawn. Atmospheric and manmade noise are usually at their lowest then and the magnetosphere seems to be especially sensitive as well. If you begin listening by the first glimmer of daylight and continue until the sun is above the horizon. chances are fairly good that you'll catch the day's best activity. But this is only a general rule. Sometimes nothing will happen at dawn and there will be a peak of activity at sunset or a few hours after dark.

Whistler and emission activity seems to occur in runs of about 3 to 7 days. There are also periods of days and even weeks with very little activity. At one extreme: more than 20 whistlers a minute. At the other: less than one per hour or none at all.

VLF emissions often appear during or shortly after magnetic storms. Magnetic storms are produced by interactions between earth's magnetic field and particles ejected from regions on the sun undergoing violent activity. Sometimes the activity persists through the sun's 27 day rotation period. This can lead to terrestrial magnetic storms and VLF emission events that follow the periodicity of roughly 27 days. Whistler activity also tends to be especially interesting during and after magnetic storms. Long spectacular echo trains are most common at such times.

WHERE? Locally speaking, the place to go is as far as you find it practical to get from AC power lines. Bear in mind that diminishing returns are involved here. If you're a kilometer from power lines you'll have a moderate hum level unless atmospheric noise (lightning static) is very strong. Doubling the distance to 2 kilometers will make a quite noticeable improvement as will doubling the distance to 4 kilometers. When you reach the point where you are unable or unwilling to go twice as far as you've already come it's time to unpack the equipment and do some listening!

Surprisingly good sites can often be found along public roads. Look for new roads and scenic routes that have been built away from power lines. Seek out rough terrain and complex shores that tend to separate roads from power lines. Elevated scenic outlooks sometimes diverge from the power lines. Even 1/2 km can make a big difference.

If you're into mountain climbing or backpacking, the place to listen is wherever you feel line stopping. Overnight camps are probably best because they get you set for the dawn window. If you have access to a boat and even a medium size body of water, by all means give it a try. Use a whip antenna with its base at least a couple of meters above the water (or the boat's structure if it is metal) and ground the receiver with about 30 meters of wire in the water. Excepting running lights and any other apparatus required by law to be kept on, turn off all electrical systems while monitoring.

In general, whistler reception is best at middle geomagnetic latitudes and worst in the equatorial regions. Whistlers and emissions can certainly be heard in fair number anywhere in the US. There do appear to be differences in the character and occurrences of whistlers heard in Eastern and Western North America. Amateur observations could readily address questions of how reception differs between the two coasts and how either coast may differ from mid-continent. While low latitude (below 20 degrees geomagnetic) reception of VLF phenomena is a good deal more challenging than reception at middle and high latitudes, this also represents an area where relatively little research has been carried out. Patient investigation of the tropical. VLF environment might yield some interesting surprises.

If you're fortunate enough to live some distance from the power grid, you could be in the enviable position of having first-rate listening with all the comforts of home. The receiving system outlined here is adequate to get you started but later you may want to go to a large loop system that can null either the distant power lines or your household's electrical noise. (With careful selection of the loop's location, you can do both.)

RECORDING

You don't have to record the VLF phenomena you hear, but if you don't, who's going to believe your wild tales of strange sounds overheard while everyone with an sense was sound asleep? Very little research can be accomplished in the absence recordings.

Unless quality portable reel-to-reel or digital tape equipment is available, the best way to get into whistler recording is with standard audio cassettes. Any cassette recorder having an external microphone input should work. Inexpensive machines tend to generate more noise and distortion than expensive recorders. Machines whose recording level is controlled automatically (practically all inexpensive recorders) tend to exhibit audible gain "pumping" in response to sferics. If the sferic density approaches the ALC (Automatic Level Control) time constant, the recorder will be effectively desensitized by transient peaks. So it is best, though by no means essential, to use a recorder that has manual level control and/or an input attenuator. In general it is best to leave peak limiters off for VLF recording - saturation by transient peaks costs less data than the post-peak desensitization imposed by a limiter. However, in monitoring 'live" reception, a limiter at the monitor input or output can be a real ear-saver.

I've had quite satisfactory results with Marantz PMD 430 recorders. At around $450, they represent about the last step before spending a lot more on "professional" equipment. A key feature on this machine is the third head, which allows real-time monitoring of what is actually going on tape - instant comparison between input and output for optimum adjustment of receiver and recorder. Monaural Marantz machines cost less and work fine, though you sacrifice the convenience of 2 channel operation by going mono. If you can possibly afford a 3-head machine, you'll find it well worth the price. On the other end of the scale, I've gotten usable tape on a recorder that cost under $30 at a Radio Shack sale.

Improved dynamic range and frequency coverage can be had with professional 1/4" tape equipment. Nagra is probably the best choice - but even used machines cost thousands of dollars. If your recorder is to be used exclusively for whistler work, it should be modified to provide flat frequency response. This will reduce problems with Omega and MSK overload, permitting extended high frequency coverage.

The Sony "Walkman" digital audio recorder is now around $650. I have no direct experience with this technology but in theory its extended frequency coverage and dynamic range should bypass many of the problems associated with analog recording of VLF phenomena.

RECORDING HINTS - Take spare batteries. Reserve used and questionable batteries for flashlights. Since you are going to a lot of trouble and some expense to record VLF phenomena, invest in good tape. This doesn't necessarily mean the most expensive tape you can find, but avoid the el-cheapos that are subject to mechanical failure and oxide shedding. I use TDK SA (Type II, chrome) tapes. They seem to be a little less vulnerable to high frequency distortion than quality "Type I" low bias tape. If your recorder is designed operate only with "Type I' tape, use it. "Metal" tape appears to provide no significant advantage over "Chrome". Unless there is an urgent need to produce very long continuous takes, don't use cassettes longer than 90 minutes. If you do wind up with longer cassettes, dub them immediately to 60 or 90 minute tapes, using the gentlest playback machine you can find.

If your recorder offers a tape noise-reduction system, don't automatically turn it on for VLF work. In my experience.(limited to Dolby B and DBX) the noise reduction simply introduces distortion. VLF is rarely quiet enough for the noise level of good tape to be a factor but Omega pulses modulating a noise-reduction may ruin otherwise good recordings.

Label cassettes and cassette boxes. Keep a log that includes the date and time of each take, along with remarks as to contents of the recording. It is extremely helpful to make a voice announcement at the beginning of each take, giving tape number, tape side and the sequential number of the take on that side. Example: Tape 26, Side A, Take 4. Or more simply, just- 26 A 4. You may think at the time you'll surely remember what you're doing, but will this really be the case a few sessions later? I experience great frustration when people send me field recordings that lack voice announcements between takes, forcing me to take great care to find the transitions from one take to the next and to keep count of all the takes so that I can be fairly sure that what I'm hearing corresponds to the notes I'm reading!

If you plan to dub and edit your field recordings you should aim for capturing the widest frequency range the system allows. You can take your time getting the sound you want through equalization during dubbing - the more you get on the original tape the more you have to work later. If the field recording is to be the end product, it makes sense to manipulate frequency response to emphasize the subject. If the recording is destined for spectrum analysis, don't mess with it - just go for as broad and flat as possible.

It is a good idea to log dates and times in UTC (Universal Time, Coordinated) rather than local time. This practice avoids ambiguities that can be terribly frustrating to anyone subsequently working with the recordings. It also means that your data can be easily examined in the context of other geophysical records kept in UTC. Where whistler recording is concerned, for all practical purposes UTC is the same thing as GMT (Greenwich Mean Time).

If you have a portable short-wave radio, it is always possible to find out the UTC time by tuning to stations WWV and WWVH on 2.5, 5, 10, 15 or 20 MHz. Time is announced on the minute and one or more frequencies are usually readable.

If you use a stereo recorder, you can run WWV on one track to provide an accurate time reference. Alternatively, if you are getting at least one 10.2 kHz OMEGA on tape, all you need is a WWV announcement on the head of a take. OMEGA dashes provide super-accurate markers as long as the tape is rolling. If you decide to use a two channel system. run tests to make sure there is no audible "bleedthru" from one track to the other. Also check for head misalignment by recording completely different material on the left and right channels of your field recorder. Then playback on a couple of good home machines to make sure their heads are tracking with your recorder. If the field recorder fails this test have it adjusted or refrain from two channel recording - use only one track or put the same information on both tracks.

When I find something especially unusual or interesting happening on VLF, I try to get the WWV announcement at 5 minutes past the hour and run tape of the VLF event for at least a minute thereafter. This particular time is chosen because at 5 past each hour, recorders on ELF/VLF receivers in Greenland, New Hampshire, Italy, California, Japan, New Zealand and Antarctica automatically roll to capture a minute of whatever is happening from 10 Hz through 32 kHz. This is part of an ongoing survey of radio noise conducted by Stanford University. I got into the 5 minutes past the hour routine while making site sensitivity comparisons with the CA receiver.

The Noise Survey receivers are not particularly sensitive or free of manmade noise, and they are very widely separated. Where weak VLF phenomena are concerned, they are probably of little use. But the network does establish a minute in each hour that is known to be monitored, and I urge amateur observers to take advantage of that minute. Don't necessarily stop recording at 6 past the hour - just get WWV at 5 past and run tape until you have a representative sample. This procedure improves the chances of getting simultaneous recordings. Simultaneous data are far more useful than scattered hunks of random data.

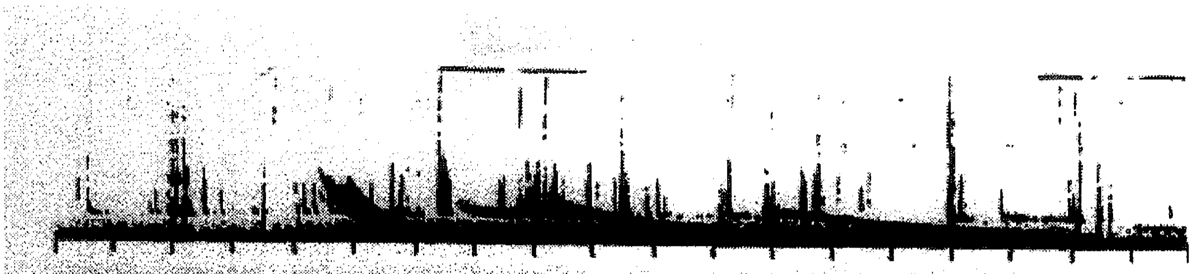


Figure 6. Spectrum analyzer view of tweeks and a multiflash whistler with echoes. Recorded by the author at San Simeon, CA on April 2, 1989. The waveguide cutoff frequency is apparent in the abrupt, uniform termination of the tweeks at about 1.8 kHz. 10.2 kHz OMEGA dashes appear at the top of the strip. The vertical scale is from 0 to 10 kHz and the horizontal scale is marked in seconds. Courtesy of STARlab, Stanford University.

SPECTRUM ANALYSIS - It is possible to tell a great deal about natural radio phenomena just by listening to them. A practiced listener will notice and describe things that utterly amaze the beginner. Much valuable data has been generated by trained listeners painstakingly logging the contents of recordings. But when it comes to measuring complex variations of signals immersed in a noisy interactive environment, the ear is a limited instrument. The whistlers won't sit still, there is nothing to hold on to! What is needed is some way to reduce these fleeting events to graphic representations that will sit still to be measured.

In the early 1950s. Owen Storey (then a graduate student at Cambridge University) felt this frustration so keenly that he built a primitive spectrum analyzer which was capable of creating frequency vs. time plots on a strip chart recorder. In present day terms this was an extremely low resolution instrument, but it was good enough for Storey to define the essential characteristics of whistlers. In so doing, he also defined the course of much of the research that has followed. Storey's tools were quickly made obsolete by a new generation of instruments designed for the analysis of speech characteristics. These devices, like Storey 's depended upon passing the signal through a comb of narrow filters - but instead of actuating pen and ink, the new machines left their mark on a moving strip of 35 mm

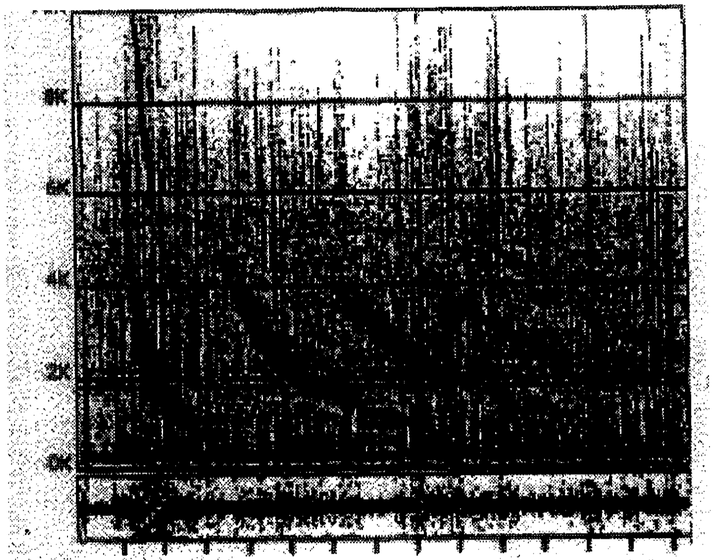


Figure 6. MacRecorder (tm) "sonogram" of whistlers recorded by the author at San Simeon, CA on March 14, 1989. Vertical scale is from 0 to 11 kHz and horizontal scale is marked in seconds. The narrow display at the bottom shows the amplitude of the wave as a function of time. In the "sonogram" black corresponds to maximum signal intensity.

photographic film or paper, each filter controlling a light source focused on a narrow section of the passing film. Figure 5 shows an example of such a spectrogram. In recent years VLF spectrum analysis has been revolutionized by digital technology. Now anyone with a sufficiently powerful personal computer can produce quite satisfactory frequency VS time plots (MacRecorder(tm) calls them "sonograms') from whistler recordings. Figure 6 shows a "sonogram" produced on a MacIntosh II with MacRecorder(tm). MacRecorder(tm) is a product of Farallon Computing, Inc. It uses an 8 bit analog to digital converter in conjunction with software to perform a variety of audio frequency analysis functions: waveform displays, frequency vs. amplitude plots and frequency vs. time plots. Several sound manipulation and editing functions are also included but these have little application to whistler work. Lack of an on-screen time scale and an expandable frequency scale is frustrating, but at less than 1/10th the cost of competing products, MacRecorder(tm) is worth a little hand labor. List price is around $250, with substantial discounts available. A new version is due in 1992. While many MacRecorder(tm) functions will work on a Mac Plus or Classic, the MacII is the smallest machine that will support sonograms. The smaller computers can produce what Farallon calls "spectrograms". These are frequency VS amplitude plots, with time incorporated as the "Z axis". They are not particularly useful for the interpretation of whistler type data.

Different organizations and authors use the words "spectrogram", " sonogram" and "sonograph" with various and sometimes conflicting meanings. When you encounter these terms it is a good idea to double-check on their utilization.

THINGS THAT CAN GO WRONG - Troubleshooting lists are always frustrating, and I'm sure this one is no exception. But it does cover many of the more likely problems. It MIGHT help solve something in a hurry!

Start by asking yourself some basic questions: Has each element in system worked in the past? (Don't forget cables and clipleads.) Do monitor, recorder and receiver work on their own? Have these devices previously worked properly when connected together? Try to localize the problem but remind yourself that your assumptions may lead you upstream or downstream of the real difficulty.

NO OUTPUT REGISTERS ON MONITOR OR RECORDER.-

1-Power off.
2-Battery dead or disconnected.
3-Connector not connected or connected to the wrong thing.
4-Damaged cable or connector.
5-Mechanical failure: open connection or short circuit.
6- Failure of electronic component.

FEEDBACK (HOWLS, SQUEAKS, SQUEALS):

1-Monitor, recorder, speaker, headphones or associated leads too close to antenna.
2-Ground missing or inadequate.
3-Bad connection to or in antenna.
4-Gain at monitor or recorder too high.

DISTORTION IN MONITOR OR RECORDER:

1-Excessive input level to recorder or monitor.
2-Excessive input to receiver.
3-Low battery.
4-Overloading from out-of-band signals.
5-Partial failure of connection or component.

HUM, BUZZ:

1-Too close to power lines, a generator or running vehicle.
2-Pickup from recorder motor.
3-Antenna too close to clock, motor or digital device.

VOICES, MUSIC:

1-Overload from Am or SW Broadcast signals.
2-Detection by rectification in antenna or ground system.
3-Pickup of audio frequency from nearby radios, entertainment systems or telephones.

TONES(ABOUT 1 SEC. LONG AT FREQUENCIES BELDW 10 KHZ)

1- Overload from OMEGA.

BURBLING SOUNDS:

1-Overload by MSK (Minimum Shift Keying) from military VLF -stations.

TICKING (10 HZ RATE):

1-Overload or detection in antenna or ground from 100 kHz Loran-C radionavigation.

RECORDING DISTORTED, MONITOR CLEAN:

1-Overload of recorder @ out-of-band signals.
2-Recorder batteries failing.
3-Incorrect tape bias.

SCRATCHING SOUNDS, WIND NOISE, INSECT NOISES:

1-Antenna rubbing its supports, moving in wind or somehow picking up signal from flying insects. The shorter the antenna the more of this sort of interference you'll experience. Its not a defect so much as a fact of life.

CURING DISTORTION AND OVERLOADING: First, try reduced setting of receiver output level, monitor gain and (if available) recorder level. If this fails to cure the problem, check or change batteries. If the batteries are OK, the distortion probably results from excessive input to the receiver.

To reduce receiver input you can shorten the antenna. If pruning the antenna is impractical, you can insert a variable resistor (500 K to 1 M) between antenna and receiver. Set the resistor just beyond the point where distortion disappears.

If you are working with a loop antenna, try rotating the loop to a position that reduces or eliminates the distortion. This may make AC hum worse. in which case it becomes necessary to choose the lesser evil. If the loop is a very one without a rigid frame, can also try reducing the loop's size - for instance, make it lower and narrower. If the loop is of the rigid portable type, in the unlikely event that rotating it fails to null the overload source you can try tilting it out of the perpendicular to reduce overall sensitivity.

Persistent overload from local sources may require the installation of filters or traps designed to eliminate the offending signal. Such measures should be applied as close as n practical to the receiver's input stage.

Overload conditions can change with propagation. Overloading is more likely during night than day and most likely of all around dawn, so it is good to have a "trimming' option handy.

PRECAUTIONS

Whistler hunting is a fairly safe activity, but there are a few precautions that should be observed. The dynamic range presented by natural radio sounds is enormous. Using headphones to listen to static crashes at high volume levels can cause permanent hearing impairment. So beware of turning up the level to hear more - it doesn't really help. Instead, what happens is that the ear-brain system is desensitized, leading you to turn up the volume some more in a vicious cycle that can take you over the threshold of ear damage. Instead of turning up the volume, take breaks from listening and turn the volume down a bit when you put on the headphones again.

Lightning in the vicinity of your monitoring site poses a hazard to you and your equipment. If lightning is visible or thunder audible it is a good idea to disconnect your equipment, ground the antenna and seek shelter. Don't under any circumstances do antenna work during thunderstorms!

Stay off of private property unless you have obtained permission to use it. Always clean up after yourself, removing antennas and ground stakes when monitoring is completed.

GLOSSARY

Not all of the following radio and radio-geophysical terms appear in the preceding text. However, you are likely to encounter them in other references, so they've been included for your convenience. Terms used as subject headings in the "Basic Guide to Whistlers, Emissions and Associated Phenomena" have not been repeated here.

ALPHA - A Soviet radionavigation system occupying 3 channels between 11.905 and 14.881 kHz, heard as a series of dashes about 0.3 seconds long.

B-FIELD - The magnetic induction field component of electromagnetic waves.

CONJUGATE POINT - In whistler work this refers to magnetic conjugates which are the points where a magnetic field line intersects the surface (or some defined level above the surface) in opposite hemispheres.

COUNTERPOISE - A large conductor substituted for or supplementing an earth ground connection.

CW- Common term for Morse Code.

DISCONTINUITY - A region where an abrupt change in a quantity occurs. In the case of whistlers, abrupt changes in electron density within the magnetosphere and aligned with geomagnetic field lines result in waveguide-like propagation of VLF radio energy.

DISPERSION --The separation of higher from lower frequencies that produces whistlers. When electromagnetic waves propagate through absorptive media such as the magnetosphere and the ionosphere, the highest frequencies travel fastest, the lowest most slowly. The longer and more absorptive the path the greater the dispersion.

DIFFUSENESS - The degree to which whistlers depart from a pure tonal quality to become breathy or "swooshy". Diffuseness is a result of multi-path propagation slightly offsetting signal components in time.

DUCT - In magnetospheric propagation ducts are assumed to be field aligned discontinuities in the plasma whose characteristics produce waveguide-like behavior at VLF frequencies.

E-FIELD - The electric field component of an electromagnetic signal.

ECHOES - Whistlers reverberating back and forth through the magnetosphere, becoming progressively dispersed and shifting to ever lower frequencies in the process. Progressions of several echoes are known as ECHO TRAINS. Echoes may be more precisely defined in terms of HOPS.

ELF - Abbreviation for Extremely Low Frequency. Formally defined as 300 to 3000 Hz but also frequently used as a generalization or to describe a different range of frequencies.

GEOMAGNETIC LATITUDE - Approximately, latitude in the geomagnetic coordinate system as defined by the geomagnetic poles. Tilted about 11 degrees with respect to geographic coordinates.

GEOMAGNETIC POLES - The poles of the best fit centered dipole model to the earth's magnetic field. Not identical to the magnetic poles.

GROUND-GROUNDING - Connection of a circuit to a large conductor the largest being the earth.

HERTZ - The frequency of a wave in cycles per second. Abbreviated Hz. One kilohertz (kHz) equals one thousand cycles per second, one Megahertz (MHz) is one million cycles per second.

HOPS - In relation to whistler mode propagation one hop is considered to be a single traverse of the magnetosphere. A one-hop whistler originates in the opposite hemisphere and has traversed the magnetosphere only once. A two hop whistler makes two magnetospheric passes, returning to its hemisphere of origin. In subionospheric propagation, hops are regarded as the ionospheric reflections between transmission and reception points on the surface.

IONS - Atoms or molecules that have acquired either a negative or positive charge.

IONOSPHERE - The region extending above about 60 km to beyond 100 km altitude, where the concentration of ions is large enough to influence radio propagation. It is divided into several regions: D (60 to 100 kin), E (100 to 150 km), F (150 to 1000 km). The F region is further divided into F1 and F2 regions, with F2 blending into the magnetosphere.

MAGNETIC STORM - Disturbance of the geomagnetic field, usually the result of interactions between charged particles from solar disturbances and the geomagnetic field.

MAGNETOSPHERE - Broadly defined this is the region of space within which the motion of charged particles is controlled by the geomagnetic field. However, this definition includes most of the ionosphere and common usage places the magnetosphere's lower boundary around the F2 ionospheric region.

MAGNETOPAUSE - The magnetosphere's outer boundary, extending to a geocentric distance of about 10 earth radii on the daylight side and beyond the moon's orbit on the night side.

MSK - Minimum Shift Keying. The modulation mode commonly employed by high power military VLF transmitters. Produces a burbling sound in conventional receivers or when overloading a whistler receiver.

OMEGA - A global radionavigation system occupying channels between 10.2 and 13.6 kHz. Heard as a series of 0.8 second dashes.

PLASMA - An ionized gaseous medium.

PLASMASPHERE - An approximately toroidal volume of space surrounding the earth where the density of the plasma is above about 100 particles per cubic centimeter, with its outer boundary (the plasmapause) aligned with geomagnetic field lines whose average equatorial crossing radius lies at about 4 earth radii.

PROPAGATION - Movement of electromagnetic waves through space. An important area of space physics research is concerned with propagation in the near space environment.

UTC TIME - Universal Time, Coordinated. Often referred to as UT. For most practical purposes identical to Greenwich Mean Time (GMT) or "Zulu" time.

VLF - Very Low frequency. Defined as 3 to 30 kHz but sometimes used with wildly different frequency ranges.

WAVEGUIDE - A device or physical arrangement which confines the movement of a wave to a particular path rather than allowing it to radiate in all directions. In the case of VLF radio waves, a waveguide is formed by the reflective properties of earth and the lower regions of the ionosphere.

WWV, WWVH - National Institute of Standards and Technology standard time and frequency transmissions on 2.5, 5, 10, 15 and 20 MHz. UTC time is given at the commencement of every minute.

RESOURCES

CONSTRUCTION

"GETTING STARTED IN ELECTRONICS" by Forrest M. Mims, III. Radio Shack (#276-5003) $2.49. A good introduction that will help you to build and understand the whistler receiver. Other, more specialized booklets by Mims will help the beginner to learn more about particular subjects. They are available at Radio Shack.

THE ARRL HANDBOOK FOR THE RADIO AMATEUR. 1216 pages from The American Radio Relay League. #1670.-$26.50 including postage. 225 Main Street, Newington, CT-06611. Though primarily devoted to Amateur Radio communications, the "Handbook" covers radio-electronic theory and construction practices with depth and clarity.

COMPONENTS

Many mail-order suppliers of inexpensive components have minimum charges of $50 or more not helpful if you just need a few- dollars worth of parts. A few sources are more friendly to small orders:

DC Electronics, P.O. Box 3203, Scottsdale, AZ 85271-3203. (Catalog free on request.) No minimum on prepaid orders- $15 minimum on phone orders. I think you. can find I everything to build a good whistler receiver at DC, and lots more besides.

JDR Microdevices, 2233 Branham Lane, San Jose, CA 95124. Catalog - mostly computer stuff but of components too. Wirewrap wire in 500 or 1000 ft quantities is usually a good deal here.

Fair Radio Sales, P.O. Box 1105, Lima, Ohio 45802. Great free catalog. Mostly military surplus, not much in the way of components but lots of test equipment and military communications stuff.

Longs Electronics, 2601 McDavid Court. Birmingham, AL 35210. Free Catalog. Good mail/telephone order source for bulk tape, audio equipment, Marantz recorders.

Mouser Electronics, 11433 Woodside Ave.. Santee. CA 92071 and 2401 HWY 287 North, Mansfield, TX 76063. Excellent catalog, almost everything you need to build anything electronic. High minimum charge but an outstanding stock.

REFERENCES ON VLF PHENOMENA

BOOKS

WHISTLERS AND RELATED IONOSPHERIC PHENOMENA Robert Helliwell, Stanford University Press, 1965. 343P. A good historical and theoretical background, with many excellent illustrations. Extensive bibliography. Out of print, check libraries. Interlibrary loan will get it for you eventually.

UPPER ATMOSPHERE RESEARCH IN THE ANTARCTIC, Edited by L.J. Lanzerotti and C.G. Park. Vol. #29 of the Antarctic Research Series, published by The American Geophysical Union, 1978, ISBN 0-87590-141-7.

VLF RADIO ENGINEERING, A.D. Watt. Pergamon Press, 1967. Extensive chapters on VLF propagation and atmospheric radio noise fields. Another "one of a kind" book - that is very hard to find.

PROBLEMS OF ATMOSPHERIC AND SPACE ELECTRICITY, Samuel C. Coroniti, ED. Elsevier Publishing Co. 1965. The entire proceedings of the Third International Conference on Atmospheric and Space Electricity. Lots of good background on thunderstorms and lightning.

ATMOSPHERIC ELECTRICITY. J. Alan Chalmers. Pergamon Press, 1967. Classic text on the atmosphere as an electrical environment, more good lightning background.

ARTICLES AND PAPERS

"Whistlers" L.R.O. Storey, SCIENTIFIC AMERICAN, Feb. 1956. pp. 34-37. Historical background with first-person perspective from the beginning of the modern phase of whistler research.

"Whistler Waves and the Magnetosphere" Helliwell, THE STANFORD ENGINEER, Oct. 1982. Good introduction to VLF research, with emphasis on Antarctic experiments.

"Sun Storms" Jay Stuller, AIR AND SPACE/Smithsonian, June/July 1991 (Vol. 6 N02) P. 50. Nice description of solar monitoring work at the Space Environment Services Center, Boulder, CO.

'The Dynamic Aurora", Syun-Ichi Akasofu. SCIENTIFIC AMERICAN, May, f989. Good reference on the structure and functioning of the Magnetosphere.

"Sounds of Natural Radio" Michael Mideke, THE LOWDOWN. June, Aug., Sept., Nov. 1989. Feb., March, Oct. 1990. April, June, July 199 1. This is an ongoing series, combining basic theory with accounts of professional research and amateur ventures into the realm of natural VLF phenomena.

PERIODICALS

THE LOWDOWN is a monthly Publication of The Longwave Club of America. 45 Wildflower Road, Levittown, PA 19057. $12 per year. Back issues are available for $1 each, membership not required for back issue service. If you are interested in monitoring and communications on longwave, THE LOWDOWN presents a good cross-section of amateur ties.

SPELEONICS A quarterly publication by the Communication and Electronic Section of the National Speleological Society. $4 for 4 issues in USA, Canada, Mexico. $6 elsewhere. Joe Giddens, P.O. Box 891: Camden. AR 71701. (Make checks payable to SPELEONICS.) The publication is devoted to underground communications, radio-surveying and other practical electrical stuff related to caving. Most of the action is below 100 kHz.

WESTERN UPDATE (The Western Newsletter For MF, LF and VLF Experimenters.) Available for 29 cent business size SASE's plus $1 per issue or $10 per year from: Jim Ericson. 226 Charles Street. Sunnyvale, CA 94086-6063. Mainly by and for "Lowfers' and "Medters" - folks who work with low powered communications systems in the lower part of the radio spectrum.

THE NORTHERN OBSERVER. Available for $15 (US) per year and 12 self addressed (not stamped) envelopes from: Herb Balfour, 91 Elgin Mills Rd., West. Richmond Hill, Ontario, L4C4M1, Canada. This is a Northeastern counterpart to WESTERN UPDATE, about monthly, and packed with information.