The INSPIRE Journal

Volume 8 Number 1

November 1999

Whistlers Explained!

Whistlers were first observed early in this century after the advent of radio. Whistlers presented many questions for scientists:

Where do they come from?
Why do they sound the way they do?
Where has the signal traveled?

As scientists slowly unraveled the mysteries involved the answers were found. It was determined that lightning provides the signal that eventually becomes a whistler. Lightning consists of a broad band of frequencies being emitted at once. Dispersion of the signal results in the higher frequencies arriving before the lower frequencies.

The third question proved hardest to answer. The problem was that there were no known paths for the signal that were long enough to provide the observed dispersion. Multiple bounces between the Earth and the ionosphere simply could not provide a long enough path. In the early 1950s, the answer was found by Dr. Owen Storey. In January of 1956 an article appeared in *Scientific American* describing Dr. Storey's discovery. *Scientific American* has graciously given INSPIRE permission to reprint the article and it appears on Page 4. Dr. Storey, while semi-retired, is still active in the field of space plasma physics.

Table of Contents

The INSPIRE Journal
Volume 8 Number 1
November 99

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

Contributions to the *Journal* may be sent to:

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

email: pine@ndadsb.gsfc.nasa.gov
pinebill@aol.com
Fax: 909 931 0392

Write for *The INSPIRE Journal*

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

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

We at INSPIRE are looking forward to hearing from you.

Back Issues Available

Back issues of *The INSPIRE Journal* are available for purchase. The price is $1 per issue with a $5 minimum order. Use the address found on the Order Form (Page 75 of this issue). Dates for previous volumes are:

Volume 1 Number 1	November 1992
Volume 1 Number 2	April 1993
Volume 2 Number 1	November 1993
Volume 2 Number 2	April 1994
Volume 3 Number 1	November 1994
Volume 3 Number 2	April 1995
Volume 4 Number 1	November 1995
Volume 4 Number 2	April 1996
Volume 5 Number 1	November 1996
Volume 5 Number 2	April 1997
Volume 6 Number 1	November 1997
Volume 6 Number 2	April 1998
Volume 7 Number 1	November 1998
Volume 7 Number 2	April 1999

Indicate the issues you would like and make the check payable to "The INSPIRE Project".

Coordinated Observations – April/2000

Next spring the major emphasis will be on Coordinated Observations. Since there will probably be no more INTMINS Operations, Coordinated Observations will take place on the last **two** weekends of April. Procedures will be the same as in the past:

1. Record for 12 minutes at 8 AM and 9 AM **local time**. Record at those times for neighboring time zones if possible. Record additional time if you hear whistlers.
2. Place time marks on the tape every 2 minutes.
3. Keep a log of what you hear.
4. Use 60-minute tapes and label each.
5. Send your data to:

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

Storey, L.R.O., *Whistlers*, Scientific American, January, 1956, p. 34-7.

WHISTLERS

They are musical sounds that may be heard in a radio receiver tuned to very low frequencies. Originating in the atmosphere, they provide a new method for exploring its outlying regions.

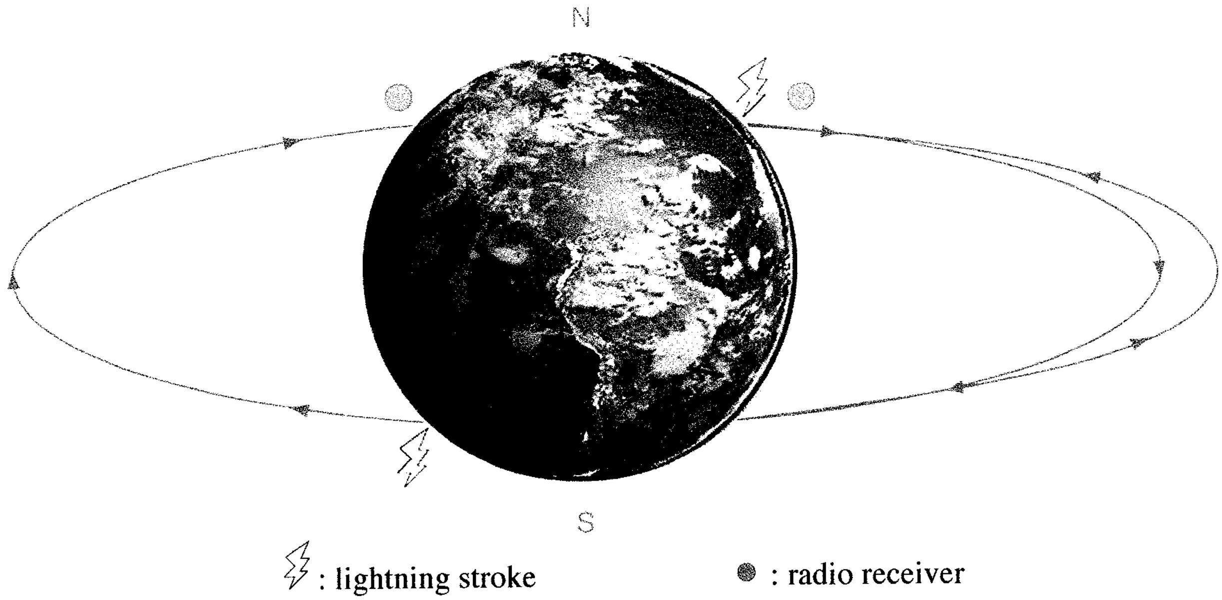
By L. R. O. Storey

As plans go forward for launching the first man-made satellites of the Earth, we have suddenly become confronted with a compelling need to know more about the outer reaches of our atmosphere. Where does the Earth's atmosphere end and space begin? What is the upper air composed of? What is its temperature, its density, its physical condition?

Up to about 200 miles the atmosphere has been thoroughly explored by radiosounding [see "The Ionosphere," by T. N. Gautier; **Scientific American**, September]. But beyond that the atmospheric "country" is still largely unknown. The ionosphere thins out so that it no longer reflects radio waves back to us. We have had no other instrument that could probe the outer regions. Recently, however, it was discovered that Nature herself is continually sounding the outer atmosphere in a way that we can follow, and thereby hangs the tale of this article.

The tale begins with an accidental observation on the battlefield during World War I. Behind the German lines the physicist Heinrich Barkhausen (discoverer of the Barkhausen effect in magnetism) was "wire tapping" Allied field telephone conversations at a distance with some ingeniously simple equipment. Two prods, stuck in the ground several hundred yards apart, picked up minute electric currents leaking into the ground from the Allied telephone wires; these signals were conveyed by cables to a sensitive amplifier, and Barkhausen was able to hear the telephone talk with headphones. During his eavesdropping he occasionally heard curious whistling sounds which completely swamped the military chatter. He was sufficiently impressed with the phenomenon to report it later in a paper: "A very remarkable whistling note is heard in the telephone. At the front it was said that one hears 'the grenades fly.' " Barkhausen's first reaction was that the whistles probably originated in his apparatus, but when all attempts to eliminate them failed, he decided that they must be coming from the atmosphere. He was right. It was to be many years, however, before much further attention was paid to them or anyone really understood what they meant.

In the form of static on the radio from a nearby thunderstorm, atmospheric radio signals are familiar enough. But the whistles Barkhausen heard were not in the ordinary broadcasting wavebands. They were low-frequency (long-wave) signals below the lowest broadcasting frequencies. Radio engineers now know that off this end of the broadcast spectrum various odd atmospheric signals are there for the hearing. Hearing is the right word, for the frequencies of these waves are so low that they fall within the sound range – the range of the human ear. To hear them we need only the simplest of apparatus: basically just an aerial to pick up the atmospheric electrical oscillations and an audio amplifier like the one in a phonograph to convert the oscillation directly into sound.



The curved lines represent Earth's magnetic field lines. The arrows indicate the direction of travel of the radio waves. The left show lightning originating in the Southern Hemisphere which is received in the Northern Hemisphere as a short whistler. On the right is lightning in the Northern Hemisphere which is heard, after the radio signal makes a round trip, as a long whistler.

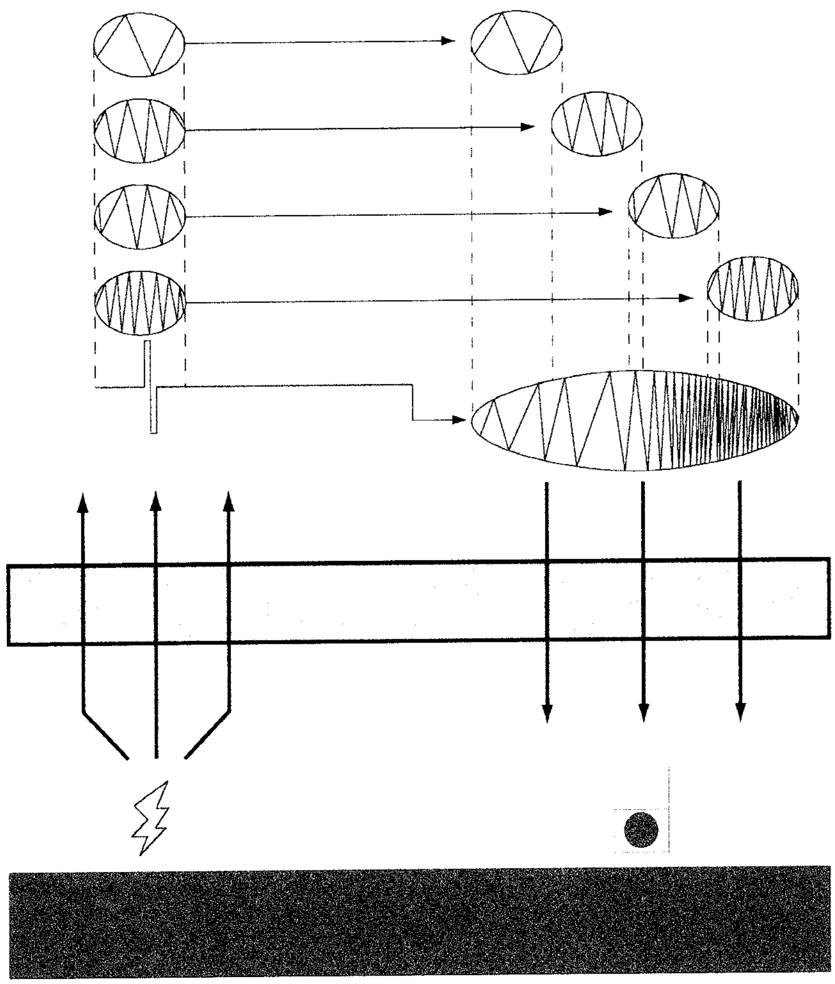
And what do we hear when we turn the amplifier on? Well, most of the time just the same clicks as in the broadcast bands. But now and again we are favored with relatively musical noises, which have acquired quaint onomatopoetic names. There is the "tweek" or "chink" – a brief, metallic note produced by waves bouncing up and down between the earth and the ionosphere. There is the "dawn chorus" – an unexplained twittering noise which occurs during a magnetic storm. And there are Barkhausens's whistlers.

Starting above the upper limit of hearing, the whistling tone falls steadily in pitch, at first rapidly, then more slowly at the lower frequencies. The sound sweeps down through several octaves in a second or two.

Whistlers were studied to some extent in the 1920s and 1930s, notably by E. T. Burton and E. M. Boardman at the Bell Telephone Laboratories and by T. L. Eckersley of the Marconi Wireless Telegraph Company in England. These workers noted that a whistler often (though not always) appeared about a second after a loud atmospheric click. Apparently whistlers were connected in some way with the clicks. The source of the clicks themselves was in doubt at the time, but in any case there was a promising lead to investigate. It seemed that the whistler might be an echo of the click, returning from the ionosphere. The question was: How could a click be converted into a whistler?

Barkhausen and Eckersley independently conceived an explanation which experiments later proved correct. It was clear that a click must be composed of a number of different frequencies, for the same click could be detected all over the broadcast band, and indeed in the range of sound waves as well. It was also known that radio waves of different frequency travel at different speeds through the ionosphere. Suppose that, as a click moved through the ionosphere, its component frequencies were spread out, the highest frequency traveling fastest and the lower ones strung out behind. If the click traveled far enough so that its frequencies were well separated, an observer should receive a drawn-out signal – a whistling tone of steadily falling pitch.

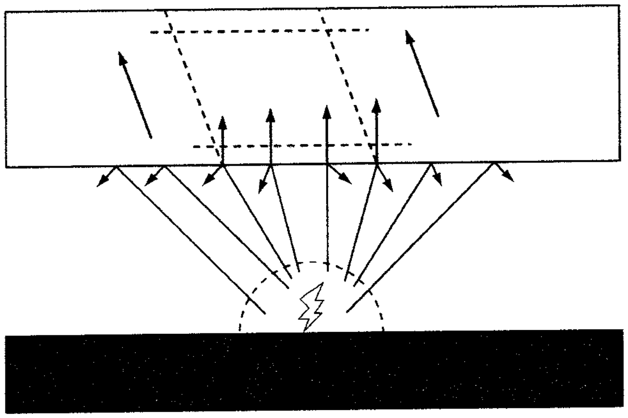
Eckersley proceeded to translate this conception into



The radio signal from the lightning stroke at the left is heard immediately by the receiver at the right as a click (as illustrated by the rectangular waveform above the lightning stroke) composed of the variety of waveforms shown above. In the ionosphere (gray area) shorter wavelengths (higher frequencies) travel faster than longer (lower) which results in a whistler heard seconds later at the same receiver.

numbers and equations. He calculated that a certain type of radio wave should pass through the ionosphere without being reflected by it, that it would be slowed in the ionosphere to one twentieth or less of its usual velocity, and that its speed should depend on several factors: its frequency, its direction of travel in relation to the Earth's magnetic field, the strength of the magnetic field and the density of the electrons in the region through which it was passing. Considering frequency alone, the speed of waves of this kind through the ionosphere should vary in proportion to the square root of the frequency: e.g., a wave of four times the frequency of another wave should travel with twice the speed, other things being equal. Thus in the case of the click traversing a given path through the ionosphere, the velocities of the component frequencies should have the simple square root ratio. This means that the time taken by the various frequencies to cover the course should vary inversely with the square root of the frequency.

To check this prediction, all one needs to do is to separate the frequencies in a whistler with a frequency analyzer and determine whether the several frequencies' times of arrival after the click do in fact obey the postulated ratio. Eckersley found that they did almost exactly.



The lightning stroke causes a radio disturbance that travels outward in all directions. When the signal encounters the ionosphere, some is reflected and some is refracted. The refracted waves are formed into a beam (horizontal dashed line) which then follows the Earth's magnetic field (up to the left).

The next important question was: How long is the path traveled by the whistler? The answer, of course, lies in the amount of dispersion of the frequencies (the length to which the whistling tone is drawn out). But it is impossible to make an exact estimate of the travel distance from this, because the dispersion also depends in part on the average electron density and magnetic field strength along the route, which are unknown quantities. However, we can compute very roughly the minimum distance whistlers must travel. Leaving the variation of the magnetic field out of the account and assuming the highest possible electron density throughout the route (equal to that of the densest layer in the ionosphere), one calculates the path length for whistlers showing a typical amount of dispersion. The answer is the astonishing figure of 15,000 miles. Apparently the whistlers go far beyond what has previously been thought to be the limits of the Earth's atmosphere.

When I began to look into whistlers in the Cavendish Laboratory at the University of Cambridge in 1950, there seemed to be two problems outstanding: firstly, what caused the clicks and secondly, where the path went and how the waves were reflected at the end of it.

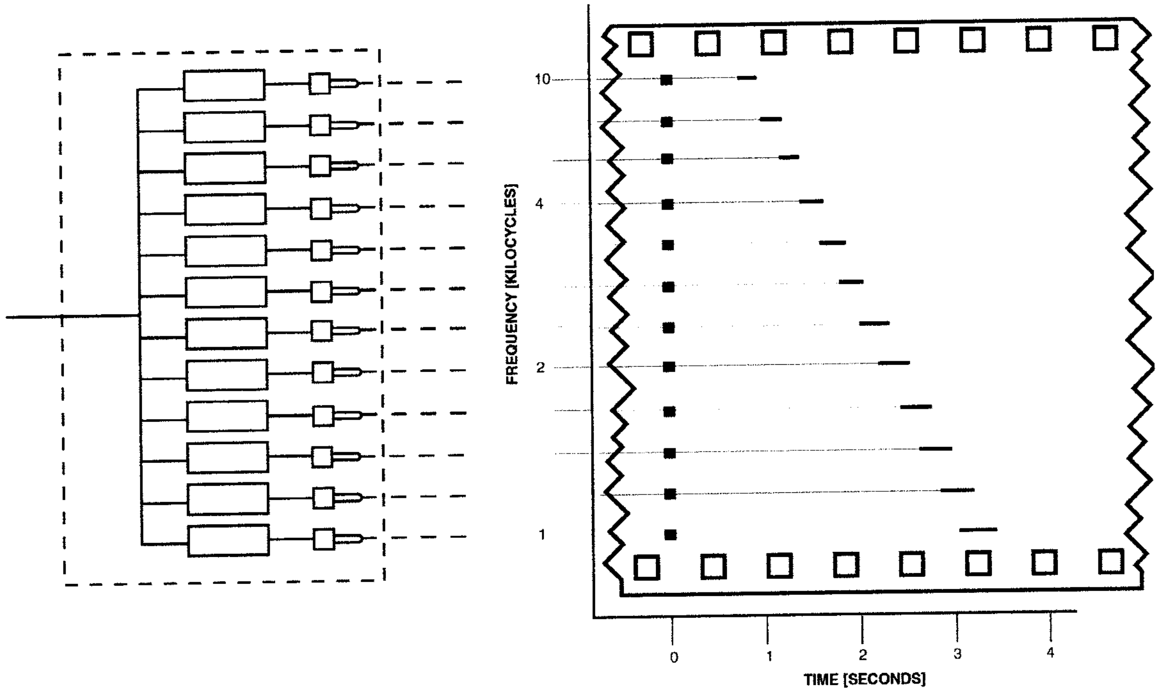
It appeared highly probable by this time that the clicks originated in lightning. To study them we enlisted the help of the British Air Ministry Meteorological Office which has a "Sferic" organization that monitors atmospherics to locate thunderstorms. Four widely-spaced stations in the United Kingdom pinpoint the sources of atmospheric clicks. We arranged to receive a telephone signal from these stations the moment the position of a click was fixed. We recorded these signals, noted whether a whistler followed each click, made a map of the fixes and later were able to correlate the loudness of each whistler with the distance of the click source from our receiver.

These observations and analysis of the wave forms left no doubt that the clicks were produced by lightning strokes. From lightning within 600 miles of us we invariably received loud whistlers; from points farther away the whistlers steadily grew weaker, until, beyond 1,200 miles, we seldom received any at all. That is to say, we could detect no echo from a click that originated more than 1,200 miles from us.

This was most curious. One would expect waves to spread out widely, yet here were waves which traveled at least 15,000 miles and after journeying that great distance returned as an echo to a limited area no more than 1,200 miles in radius. What mechanism in the atmosphere could focus them in this manner?

Let us try to trace their journey. When a lightning stroke occurs, it sends out radio waves in all directions, and some go upward to the ionosphere. When the radio rays traverse the boundary between ordinary air and the ionized region, they are bent, just as a ray of light is refracted when passes from air to some other medium. Whatever the angle at which the radio waves strike the ionosphere, all of them are bent toward the vertical. As we have already noted, the refractive (slowing) effect of the ionosphere on these waves is very pronounced. Consequently the rays coming from all angles are concentrated in a narrow vertical beam.

As it rises into the ionosphere, however, the beamed pulse of energy does not continue in the vertical direction. It follows the lines of the Earth's magnetic field,



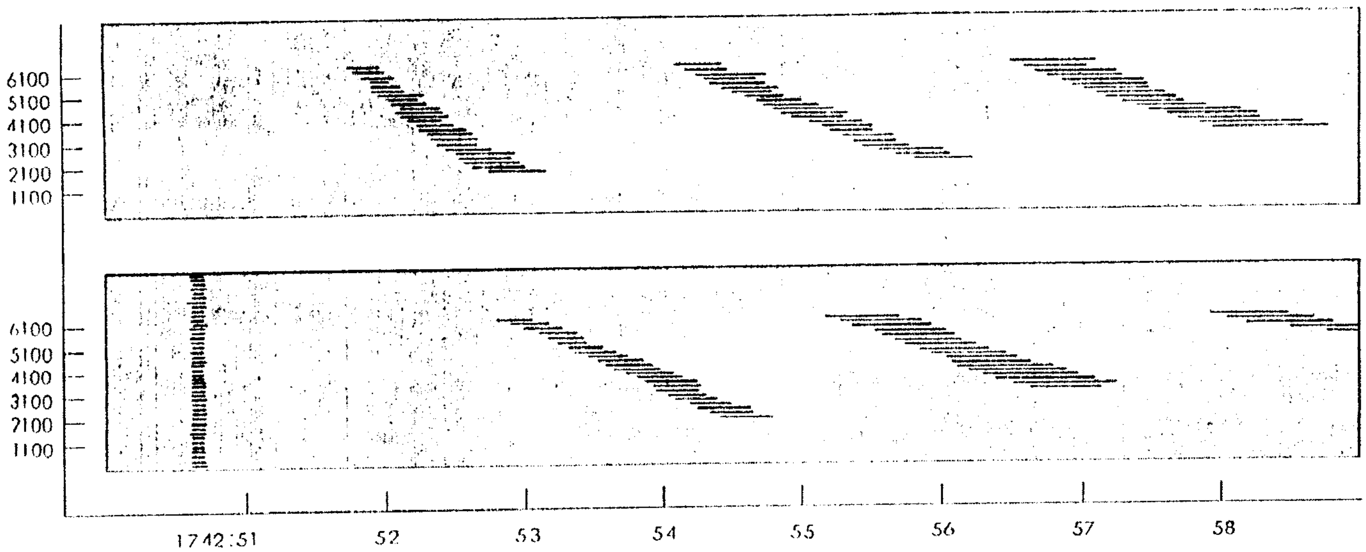
Sound spectrograph consists of a set of filters (rectangles) which each pass a narrow band of wavelengths. Each filter is connected to a small neon lamp (squares). A strip of photographic film is passed under the set of lamps. The click of nearby lightning appears on the film as a vertical row of spots (at 0 seconds). A whistler creates the diagonal row of marks as the higher frequencies arrive first followed in turn by the lower frequencies.

because this is the direction in which the waves travel fastest. And as it goes, the pulse or click is drawn out into a whistler.

If it is indeed true that the whistler follows a line of magnetic force, then we have some notion where the path will go. From the Earth's surface in England a line of magnetic force sweeps southward around the globe, crosses the magnetic equator at a height of about 7,000 miles and comes down to Earth again in the Southern Hemisphere. A whistler traveling this path might be reflected from the ground and return along the same line of force to the area in England from which it came.

The thought sends us back immediately to our records and our listening posts, and a fresh look at the evidence soon confirms the reasoning. Firstly, there is the hitherto puzzling fact that sometimes a whistler is heard without any preceding click. We can guess now that such a whistler comes directly from the Southern Hemisphere – not an echo but a single trip passage from a Southern lightning flash. The click itself, traveling in the lower atmosphere, is unheard because it is absorbed before it reaches us. If the whistler has made only one journey through the ionosphere, it should only be half as drawn out as one preceded by a click (which makes the round trip). Measurements confirm the prediction.

Secondly, almost from the beginning it was noticed that sometimes a single click fathers not one but a train of whistlers, each weaker than the one before. They follow one another at short, regularly-spaced intervals. Quite evidently these must be reverberations of the same echo, bouncing back and forth like a tennis ball between the two hemispheres. That this is the case has been verified by the finding that the lengthening of the successive whistlers is proportional to the number of trips: when they follow a click, the dispersion ratios are 2:4:6:8; when no click is heard,



SPECTROGRAPH RECORDS of an experiment by Millett G. Morgan and G. McK. Allcock are depicted in this drawing. The lower record was made in New Zealand on August 28. At its left is a click; at its right are a long whistler and two echoes. The upper record was made simultaneously in the Aleutian Islands. It shows a short whistler and two echoes from the same click. The numbers at the left give the frequency in cycles; those at the bottom, the time in seconds after 17 hours, 42 minutes, 51 seconds Greenwich Mean Time.

indicating that the signal started in the other hemisphere, the ratios are, as expected, 1:3:5:7.

Last summer, in a direct test, individual whistlers were actually caught bouncing back and forth by observers who made synchronized recordings at the two ends of a line of magnetic force – one in the Aleutian Islands, the other in New Zealand [see illustration above]. On each successive trip the whistler was drawn out further by the predicted amount.

`The biggest surprise is what whistlers tell us about the height of the atmosphere. It must extend out to at least 7,000 miles – several times farther than had previously been thought. The atmosphere was supposed to end at about 1,500 miles. But now it appears, from the dispersion of whistlers, that 7,000 miles out there must still be about 400 electrons per cubic centimeter. This may mean various things. If we suppose that the electrons come from ionization of gases typical of our atmosphere (oxygen and nitrogen), then to produce this ionization the temperature of the outer atmosphere would have to be at least 7,000 degrees – a figure far too high to be believed. J. W. Dungey of the University of Pennsylvania has suggested instead that the ions may come from outside the atmosphere: that in its passage through space the Earth picks up ionized hydrogen and holds it by the force of its magnetic field. Some recent estimates put the hydrogen content of "empty" space near Earth's orbit as high as 600 particles per cubic centimeter, so Dungey's theory seems reasonable. But the issue is far from settled.

The only certain thing is that whistlers still have much to tell us. During the forthcoming International Geophysical Year observers all over the world will be listening for these strange messages from the outer atmosphere.

The April 99 Monitoring Sessions

By - Robert Bennett
Las Cruces, NM

(Editor's note: The following was received from Robert Bennett as a field report of his April/99 observations.)

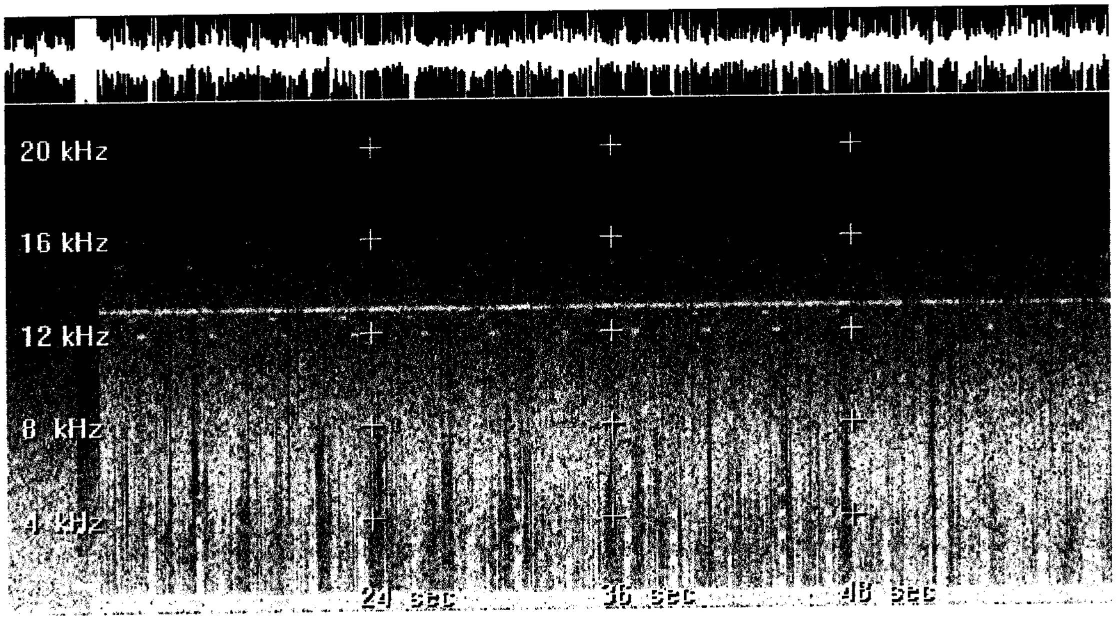
The audio recordings for the April monitoring session are enclosed. I have also enclosed ZIP disks containing WAVE and BMP files produced when I analyzed the recordings. The following paragraphs contain the results of my analysis. While I did not detect the ISTOCHNIK signal, I did find some interesting and unknown (at least to me) signals. If you have any idea what they are, I would like to know.

I also used a commercial software program (SPECTRAPLUS) to analyze some of the missions. This program provides a different view of the data. Instead of a frequency versus time display as provided by GRAM, this program gives a power density versus frequency display (that is, the signal is integrated over time). I have included plots from the program in this note.

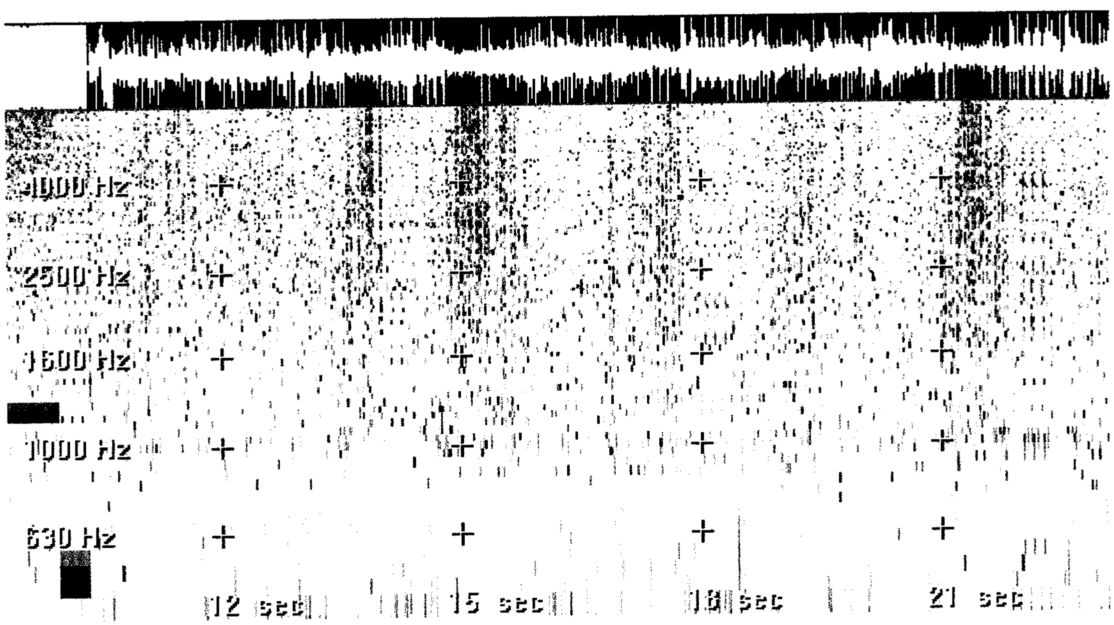
MISSIONS ON 17 APRIL 1999.

On 17 April, I was able to monitor and record missions 17-5, 17-6, and 17-7. The 17th was a very nice day for outdoor activities. The weather was dry, temperature in the mid 70's F, and no wind. However, I noticed that natural radio levels were abnormal this day. First, the levels were much higher than I normally observe during spring daytime in the desert. Also, I observed many bursts of noise and the noise levels in the lower part of the spectrum were quite high. I have never observed this noise activity before. Radio Station WWV said that the solar activity was low and the geomagnetic field unsettled. There was a magnetic storm at 2200Z on 16 April. Could the storm account for the noise activity? All recordings on 17th were made with a 120 ft longwire antenna orientated toward 175 degrees.

Mission 17-5.

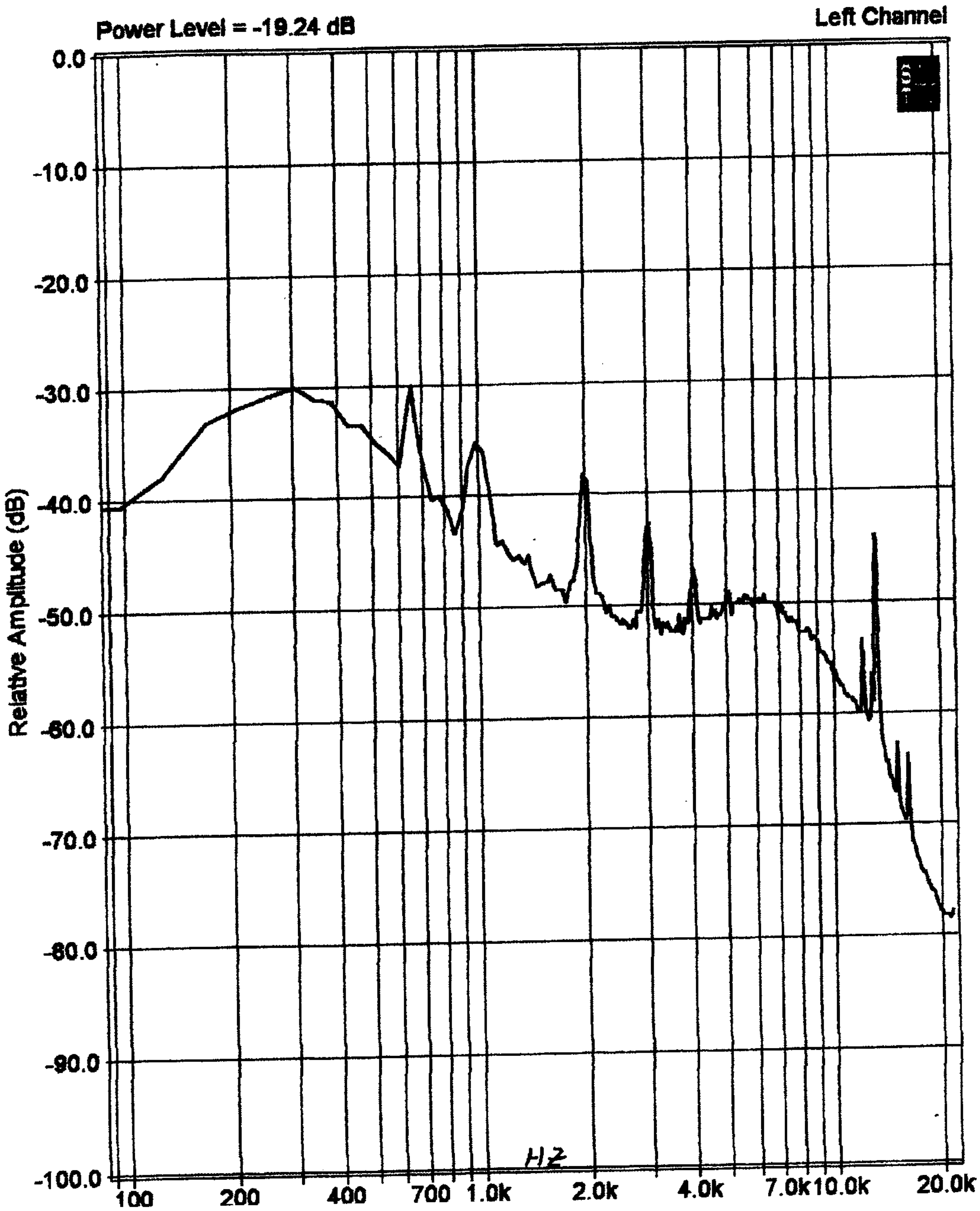


The above image shows the Loran signals very clearly as vertical sets of dots. The Russian Alpha signal is evident as dashes between 12 and 16 kHz as is a communications signal near 13 kHz. Also note the 60 Hz hum product near the bottom of the figure. There is no evidence of the ISTOCHNIK signal.



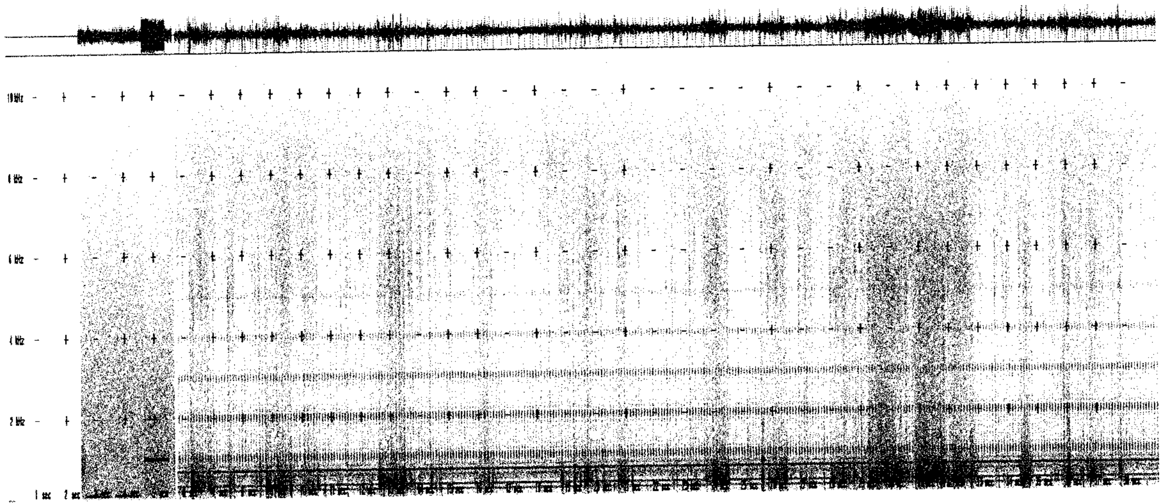
This image is the first few seconds of the operation in high resolution. Note the hum near 630 HZ and the high noise levels below 1 kHz.

The next figure is a plot produced by SpectraPlus. It is a spectrum analyzer like display showing signal amplitude (actually power) versus frequency. The Loran pulse signals are the peaks at 1, 2, 3 and 4 kHz. The spike between 600 and 700 HZ is a harmonic of the AC power line frequency. Note the communications signals between 10 and 20 kHz.



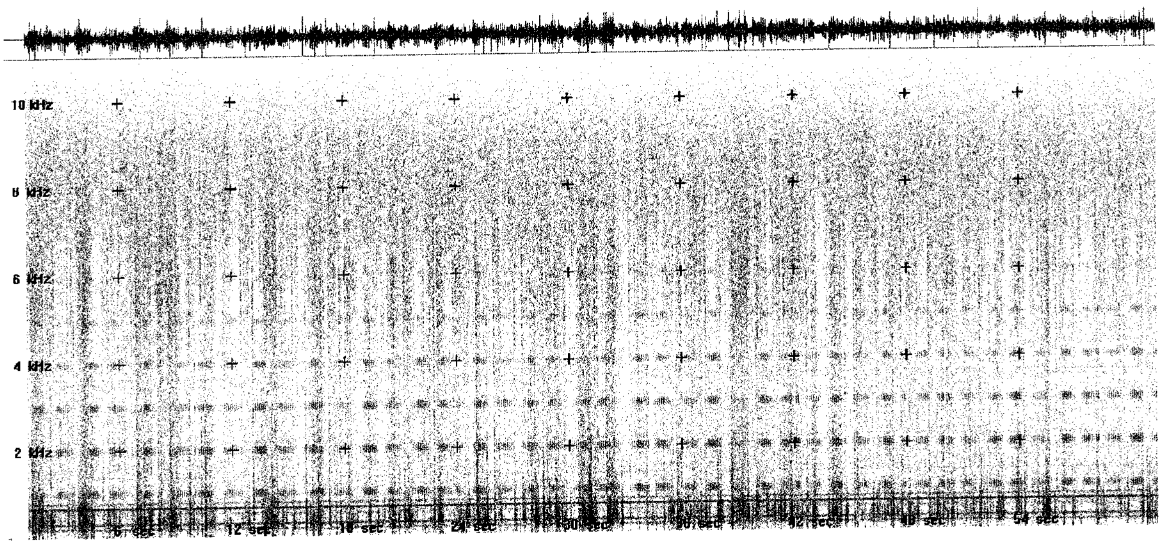
Mission 17-6.

There isn't anything new on these plots that isn't evident on the ones for the previous mission. No evidence of ISTOCHNIK. The following is typical. It shows strong Loran, Alpha and noise bursts. The communications signal is not evident this time.



Mission 17-7.

This mission is much the same as the previous ones except that the natural radio emission levels seem to have dropped some. Also, I didn't detect Alpha or the communications signals in the plots. This mission takes place later in the day and the drop in levels is what I normally observe as the day progresses. I selected the following image because it has some "insect noise" on it. Otherwise it is identical to the others for this mission. No indication of ISTOCHNIK. This figure shows Loran and the noise bursts.

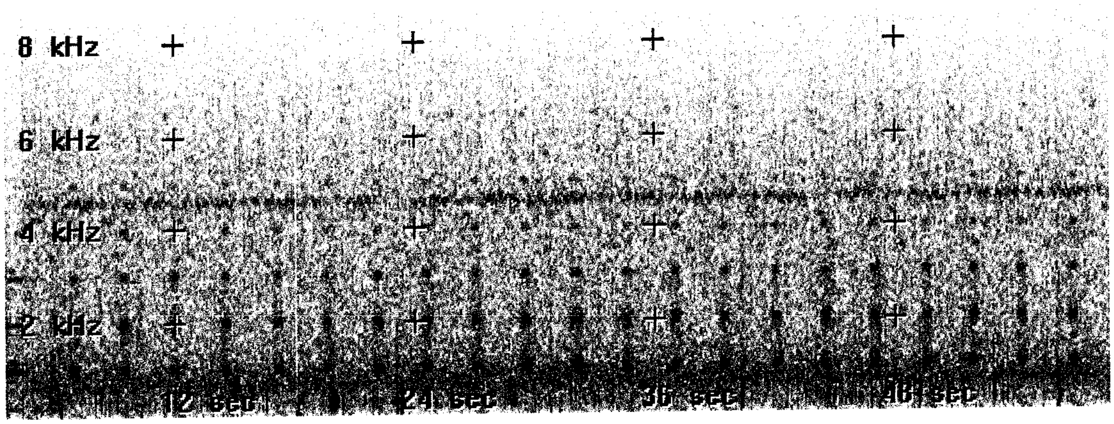


MISSIONS ON 18 APRIL.

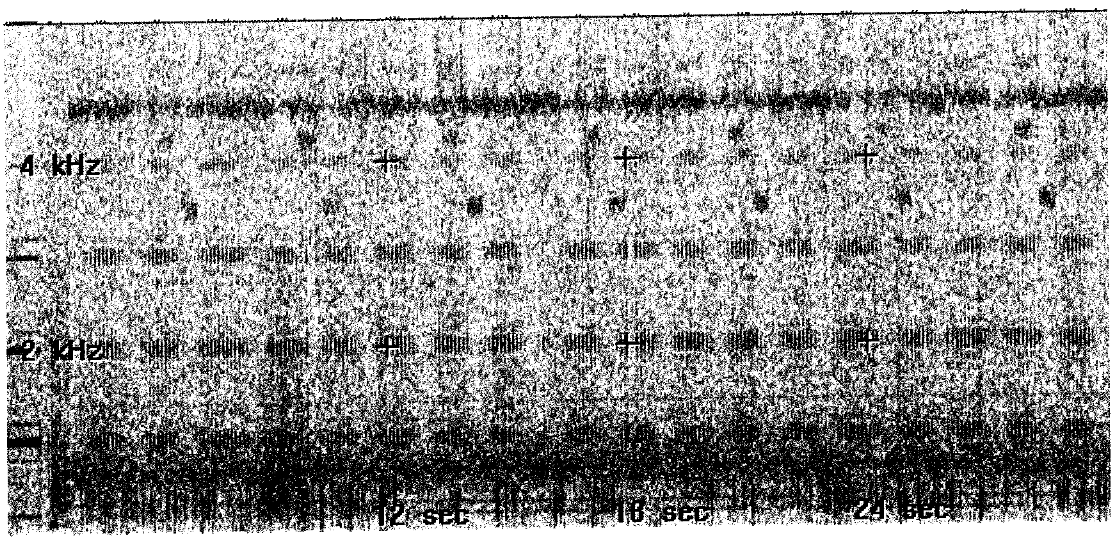
On the 18th I was able to monitor missions 18-4, 18-5, and 18-6. This day was also nice for outdoor activities. It was cool in the early morning and warmed up to about 70 degrees by mid morning. Conditions were dry, thin cloud cover, and no wind. I used the same longwire for these missions as I did on the 17th.

Mission 18-4.

Signal levels did not seem as strong as on the previous day. Loran is ever present; however, the communications signal near 12 kHz appears absent along with the Alpha signals. Note the presence of the signal near 5 kHz. This signal was present all the time during this mission and I don't know what it is.

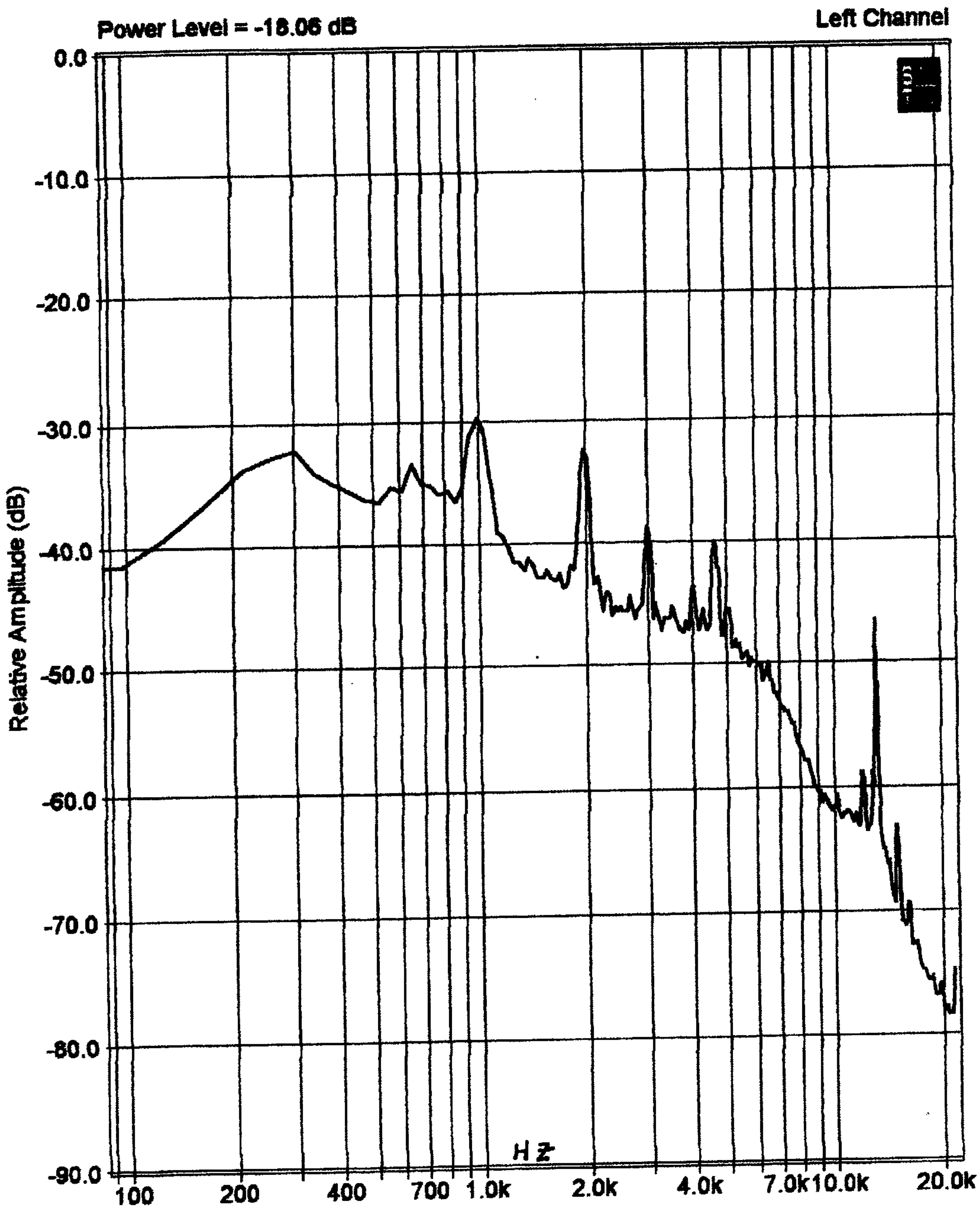


The following image is a higher resolution look at the strange signal.



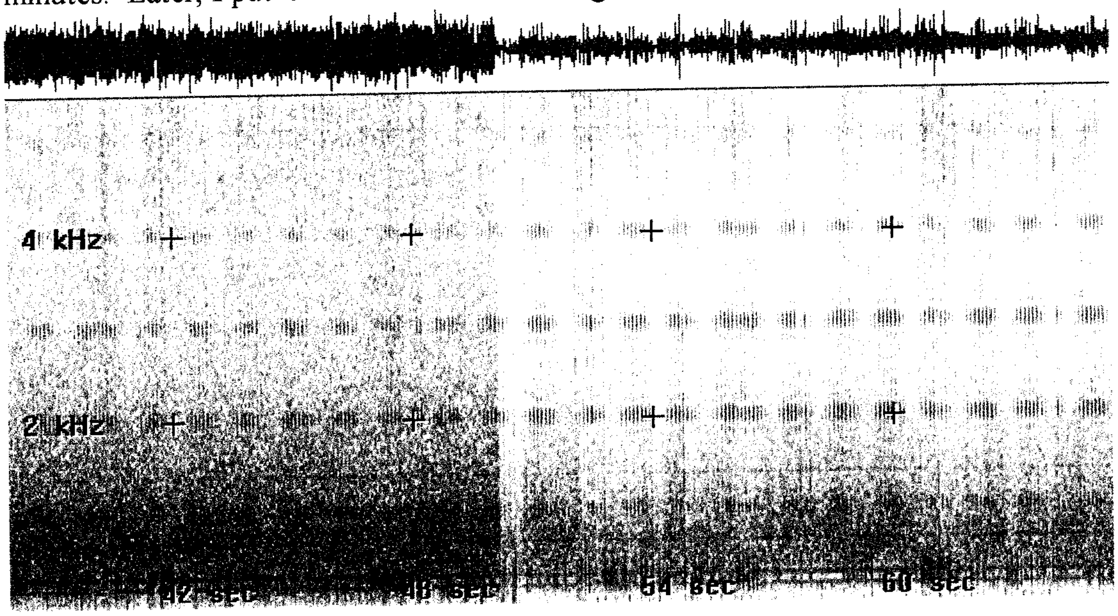
This figure shows that there is a steady signal at 4630 HZ, and a pair of periodic pulse signals at 4230 and 3500 HZ. The pulse repetition interval between the two signals is about 550 MS, and the two-signal group repeats every 3550 MS. Again, I have no idea what this signal could be. Also, note the high noise levels between about 500 and 1260 HZ.

The next figure is a plot from SpectraPlus. The chart shows a spectrum analyzer like display. Also, the signals at 1, 2 and 3 kHz are the components of the pulsed signal transmitted by Loran. Compare this chart with the one for mission 17-5. The unknown signals I discussed above are very evident between 4 and 6 kHz. Notice the presence of many communications signals between 10 and 20 kHz.



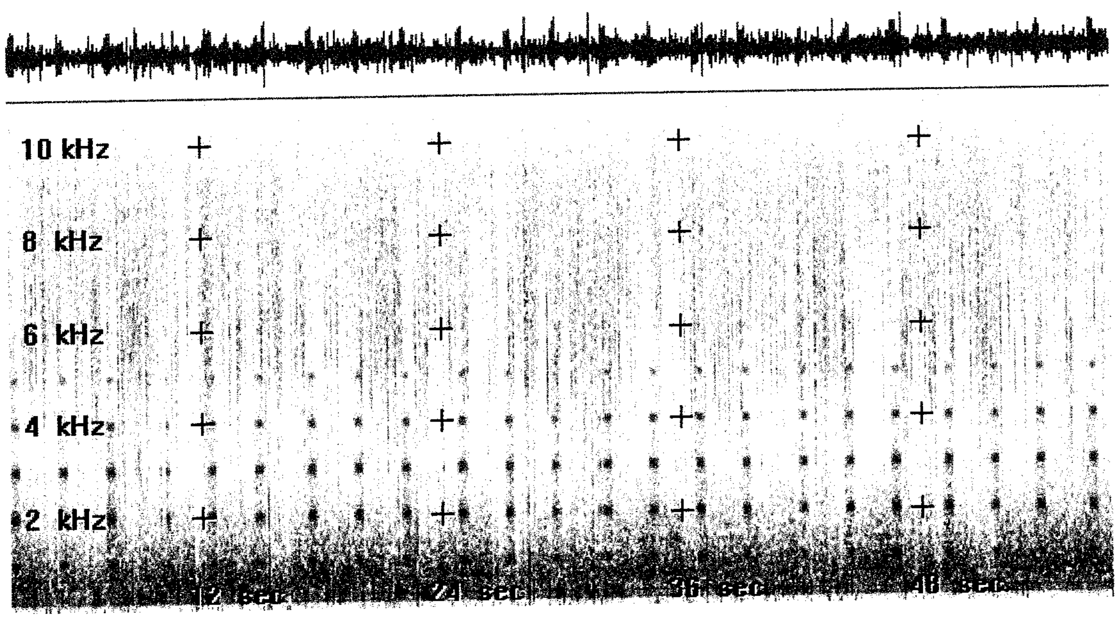
Mission 18-5.

In this mission, I started recording with the recorder limiter "out" and recorded for several minutes. Later, I put it "on" because of bad signal overload.



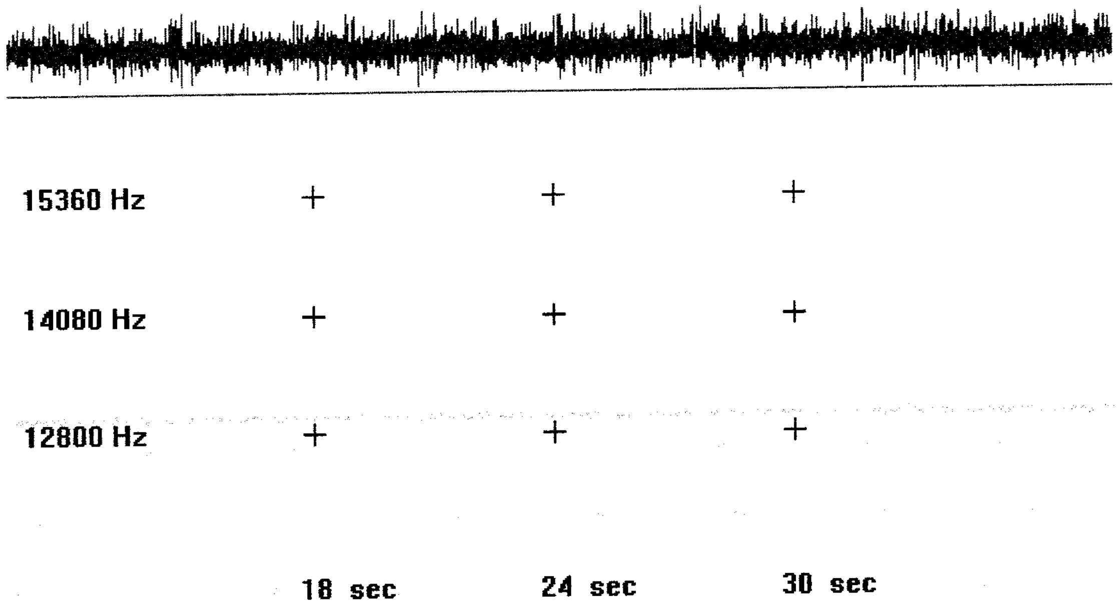
The above figure shows the effect of the recorder limiter. It was out in the first part of the recording up to about time 50 Sec then turned on. After the limiter was turned on, note the appearance of the faint signals at 1411, 3564 and 3693 HZ. The recorder was in saturation with limiter off and the above signals were not evident.

The next figure is during the ISTOCHNIK operation. Loran is very evident as is the unknown signal near 4 kHz. The intense low frequency noise is still present.

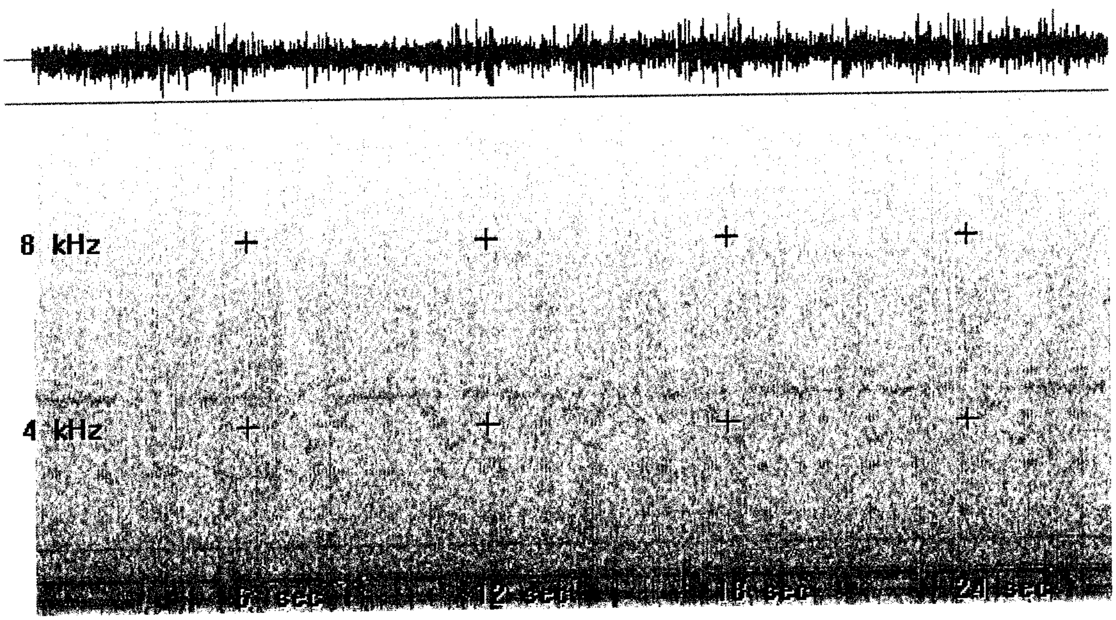


Mission 18-6.

The following image covers the high frequency end of the recording. This image, which used 2048 pts FFT and 50 MS resolution, gives a good view of the signals between 10 and 20 kHz. Note the presence of both a steady communications signal and Alpha signal pulses (dashes).



The next image is for the ISTOCHNIK operation for the first 30 seconds. The image is a 1024 PTS FFT with 50 MS resolution.

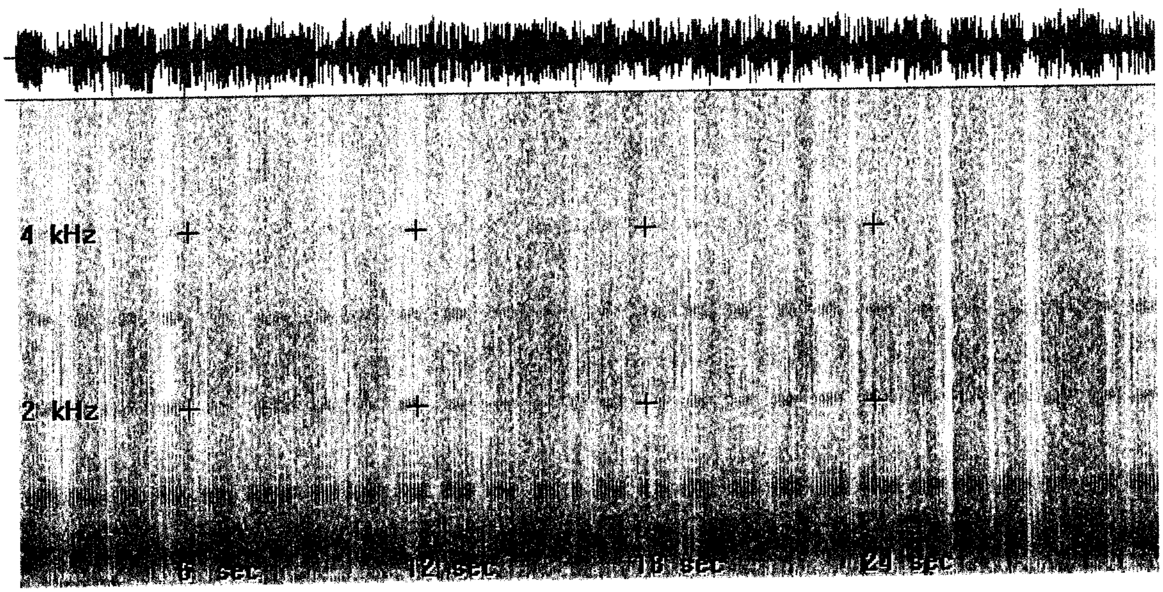


MISSIONS ON 24 APRIL 1999.

24 April was a difficult day for outdoor monitoring. A cold front passed through the area during the evening of the 23rd. The morning of the 24th was overcast, cool, with high winds and threatening rain. The wind and blowing dust/sand got steadily worse until I was forced to move my monitoring setup into the cab of my truck. Also, my long wire was unusable later in the morning due to the high wind and I was forced to use a 6' whip antenna. The wind started at about 20-25 MPH with gusts to 35 MPH and by noon when I was forced to leave the field, the wind was gusting to 50 MPH. I was forced to leave not because of the wind but because it started to rain. My monitoring site is about 4 miles off a gravel secondary road and the access is by a dirt trail. The 4-mile trail is impassable when wet. I managed to record missions 24-5, 24-6, 24-7 and 24-8. Mission 24-8 was a complete washout as my receiver decided to fail during the mission.

Mission 24-5.

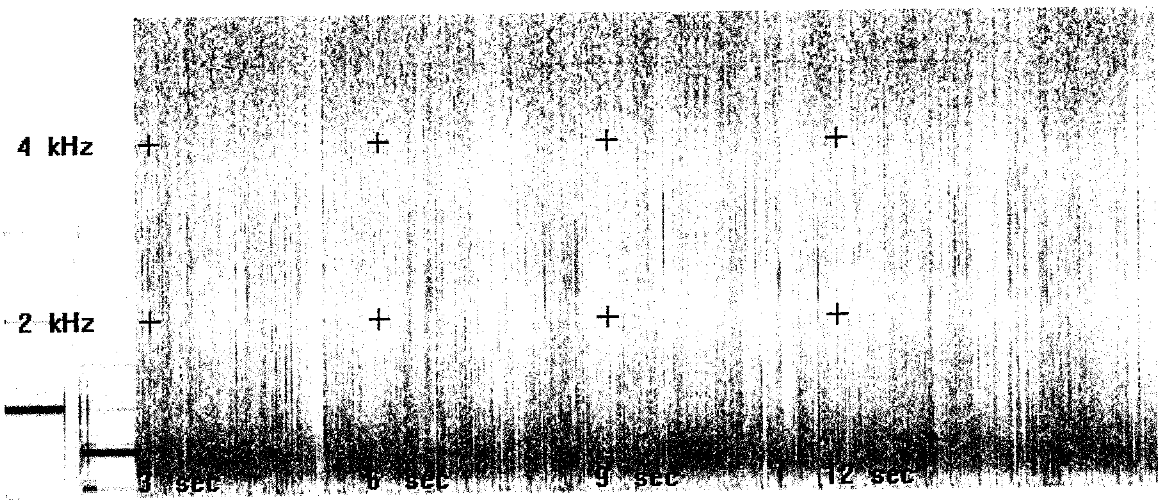
I was able to use the 120-foot longwire on this mission. The following figure shows the first 30 seconds of the operation using 1024 PTS FFT with 50 MS resolution



As can be seen in the figure, there isn't much out of the ordinary. There is intense natural radio activity and LORAN pulses but little else.

Mission 24-6.

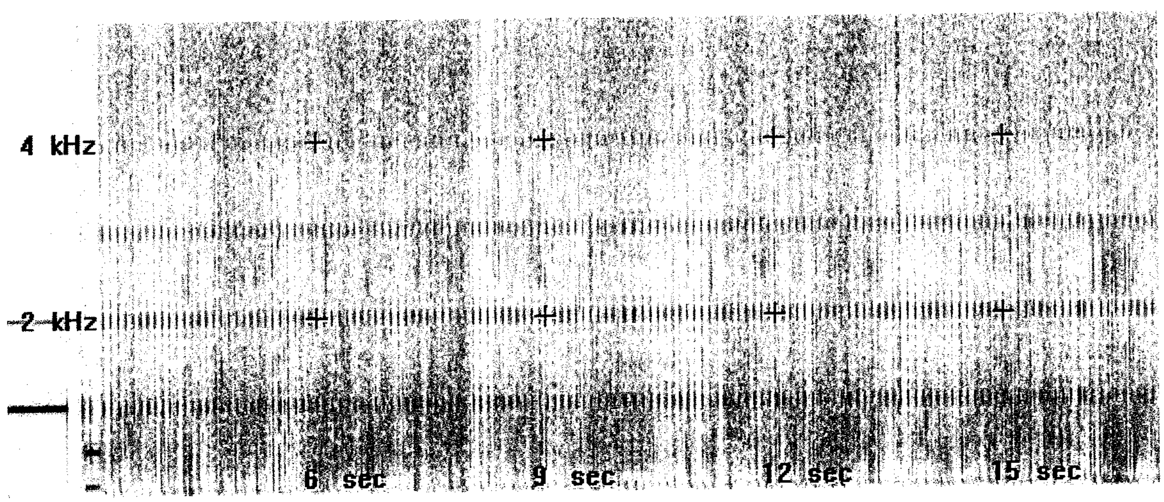
Mission 24-6 seemed to have lower LORAN levels than before. I am not sure if the levels are really lower or I was seeing the beginnings of the receiver failure. The following figure shows the first 12 seconds of the ISTOCHNIK operation using 1024 PTS FFT and 25 MS Resolution.



This image shows intense activity and an almost complete absence of Loran. The natural radio noise was strong enough to suppress the Loran signal. This is further illustrated with the SpectraPlus output shown on the next page. Note the complete absence of the Loran signals and the communications signals between 10 and 20 kHz. There is a strange "hump" in the spectra at about 5 kHz. This has the appearance of a noise-modulated signal. I suspect but haven't been able to prove, that my VLF-2 receiver is thermally unstable. It was in direct sunlight in my truck most of the morning and its case got very hot to the touch. I believe that one of the transistors went into thermal runaway and started oscillating at about 5 kHz and was being frequency modulated by the input natural radio noise.

Mission 24-7.

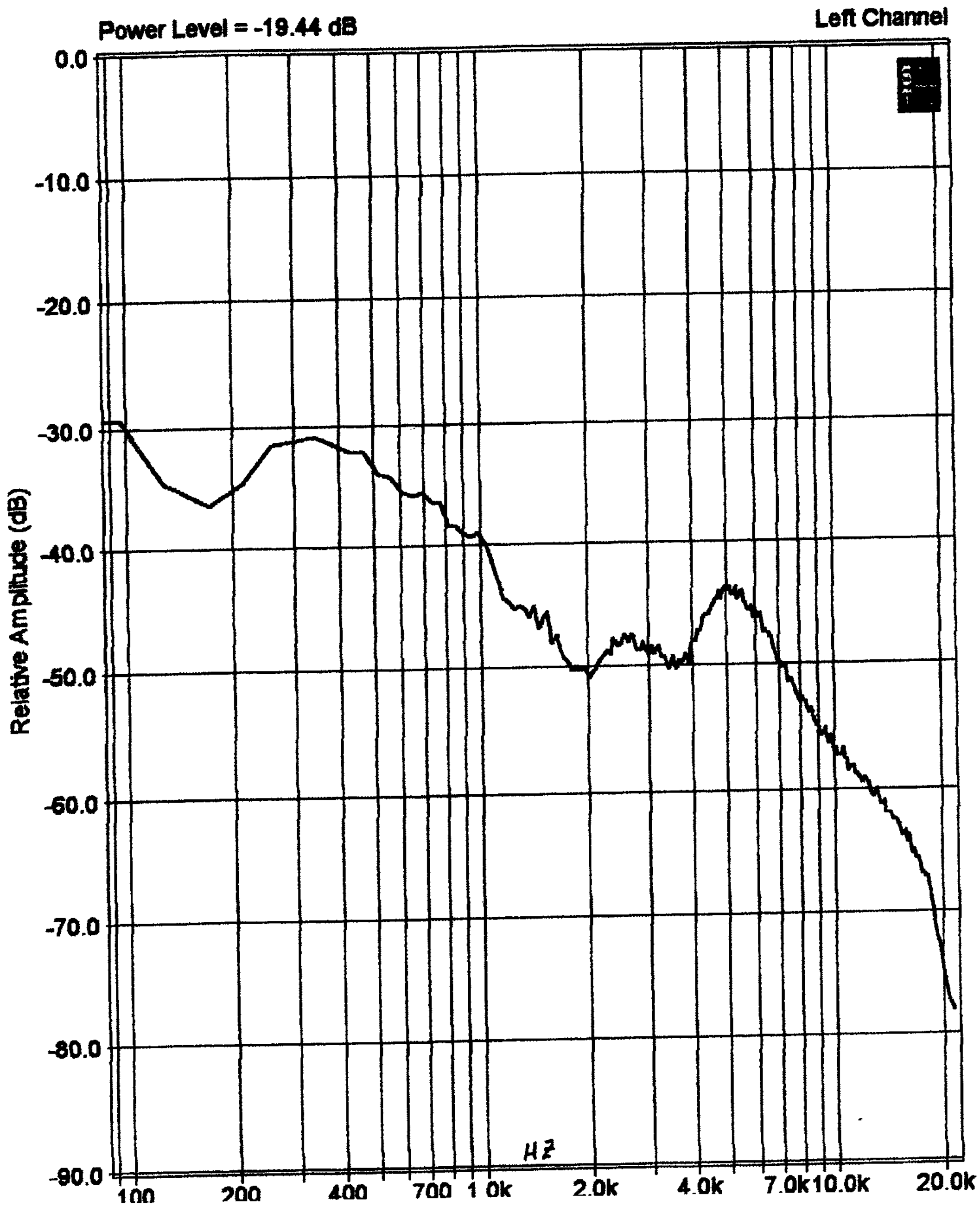
I changed to my backup receiver (RS-6) before this operation. I was using a whip antenna. The recordings seem more normal that the previous mission. There isn't anything of great interest in these files. The following image will serve as an example.



Mission 24-8.

This mission was recorded with the RS-6 and a whip antenna. The recording session started OK then after about one minute of recording, all output from the receiver was lost. The operation was a complete wash-up.

SpectraPlus Plot for Mission 24-6



INTMINS OBSERVERS

Roster Update

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

North American observers:

Team #	Observer	Location	Longitude/Latitude
1.	John Lamb, Jr. University of Mary Hardin-Baylor	Belton, TX	97° 27' 50" / 31° 7' 45"
2.	Stephen G. Davis	Fort Edwards, NY	73° 29' 30" / 43° 18' 00"
3.	Don Shockey	Oklahoma City, OK	97° 40' 5" / 35° 43' 30"
4.	Mike Aiello	Croton, NY	73° 46' 45" / 40°
5.	Jean-Claude Touzin	St. VitalQuebec	79° 10' / 48° 55'
6.	Bill Pine Chaffey High School	Ontario, CA	117° 41' / 34° 14'
7	Dean Knight Sonoma Valley High School	Sonoma, CA	122° 33' / 38° 21'
8	Mike Dormann	Seattle, WA	123.4° / 47.2°
9	Robert Moloch Eastern Elementary School	Greentown, IN	85° 58' / 40° 28'
10	Bill Taylor INSPIRE	Washington, DC	77° 2' / 38° 54'
11	Mark Mueller Brown Deer High School	Brown Deer, WI	87° 56' / 43° 10'
12	Jon Wallace	Litchfield, CT	73° 15' / 41° 45'
13	Bill Combs	Crawfordsville, IN	86° 59' / 40° 4'
14	John Barry Seeger High School	West Lebanon, IN	87° 22' / 40° 18'
15	Robert Bennett	Las Cruces, NM	106° 44' / 32° 36'
16	Leonard Marraccini	Finleyville, PA	80° 00' / 40° 16'
17	Kent Gardner	Fullerton, CA	117° 48' 30" / 34° 12' 13"
18.	David Jones	Columbus, GA	77° 07' / 35° 00'
19.	Larry Kramer / Clifton Lasky	Fresno, CA	119° 49' / 37° 01'
20.	Barry S. Riehle Turpin High School	Cincinnati, OH	84° 15' / 39° 7'
21.	Phil Hartzell	Aurora, NE	98° 0' / 41° 0'
22.	Rick Campbell	Brighton, MI	83°50'2.7" / 42°16'43.7"
23.	Jim Ericson	Glacier, WA	121° 57.91' / 48° 53.57'
24.	Paul DeVoe Redlands High School	Redlands, CA	116° 52' / 34° 10'
25	Norm Anderson	Cedar Falls, IA	92° 15' / 42° 20'
26	Brian Page	Lawrenceville, GA	83° 45' / 34° 45'
27	Ron Janetzke	San Antonio, TX	98° 47' / 29° 35'
28	Thomas Earnest	San Angelo, TX	100° 25' / 31° 16'
29	Janet Lowry	Houston, TX	95° / 29°
30	Linden Lundback	Watrous, Sask	105° 22' / 51° 41'

European observers:

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

New Observers (11/97):

31 Lee Benson — Indianapolis, IN

Longitude: 86° 3' W
Latitude: 39° 23' N
North Central Camp Atterbury, 50 miles S. of Indianapolis
Receiver: INSPIRE VLF-2
Recorder: Sony TCS-580V Stereo
Antenna: 4 ft. shielded loop, Top 11' AGL, 2nd part, 12 ft vert wire
WWV: Sony ICF-SW7600G

32 Shawn Korgan — Gilcrest, CO

Longitude: 104° 67' W
Latitude: 40° 22' N
Open area, 50 ft from paved road, one mile from power lines
Receiver: TL071 op-amp (home made)
Recorder: Sharp RT-22
Antenna: 8 foot whip mounted on car
WWV: PRO-60

INTMINS - April/99
Data Analysis Report

by Bill Pine
Chaffey High School
Ontario, CA

The April/99 INTMINS observations marked the ninth session in an ongoing series of operations conducted with the cooperation and assistance of the Russian Space Agency (IKI) and ENERGIA, the Russian space engineering organization. INTMINS is an attempt to detect manmade VLF radio waves emitted by instruments on the MIR Space Station.

INTMINS Status Report

The orbit of MIR remained stable during the time between the establishment of the operation schedule and the operations themselves. No modification of the start times was necessary.

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

Data Analysis Procedure

The data analysis procedure used consisted of the following:

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

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

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

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

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

INTMINS-November/98 Operations Summary

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

European Passes

Pass	ISTOCHNIK Start Time	Path during ISTOCHNIK Firing	Number of Observers Recording Data
E17-1	0824	Central ITALY	0
E17-2	1004	RUSSIA, South of Moscow	0
E17-3	1133	ENGLAND	0
E17-4	1309	ENGLAND	0
E18-1	0853	RUSSIA, South of Moscow	0
E18-2	1028	RUSSIA, South of Moscow	0
E18-3	1201	CROATIA	0
E24-1	0622	West-Central ITALY	0
E24-2	0935	CROATIA	0
E24-3	1109	Northern ITALY	0
E25-1	0510	Central ITALY	1
E25-2	0650	RUSSIA, South of Moscow	1
E25-3	0819	ENGLAND	0
E25-4	0959	South of CROATIA	0

North American Passes

Pass	ISTOCHNIK Start Time	Path during ISTOCHNIK Firing	Number of Observers Recording Data
17-5	1425	TX, OK	4
17-6	1558	So. CA	4
17-7	1742	QUEBEC	3
17-8	2054	VA, NC, SC	0
17-9	2220	WA, OR	1
18-4	1318	VA, DC, MD, DE	4
18-5	1448	AZ, NM	2
18-6	1621	No. CA	4
18-7	1757	WA	1
18-8	1942	PA, MD	1
18-9	2116	MO, MS, AL, FL	1
24-4	1226	IA, WI	1
24-5	1355	No. CA	4
24-6	1532	WA	2
24-7	1716	PA, MD	1
24-8	1847	WY, NE, KS	2
25-5	1249	SD, MN	2
25-6	1427	QUEBEC	3
25-7	1602	QUEBEC	1
25-8	1737	IA, IL, IN	1
25-9	1912	TX	3
25-10	2043	CA	2

Summary of European Passes Recorded

Team/Pass	E17-1	E24-1	E24-3	E25-1	E25-2
E1				x	x
E5	x	x	x	x	

Summary of North American Passes Recorded

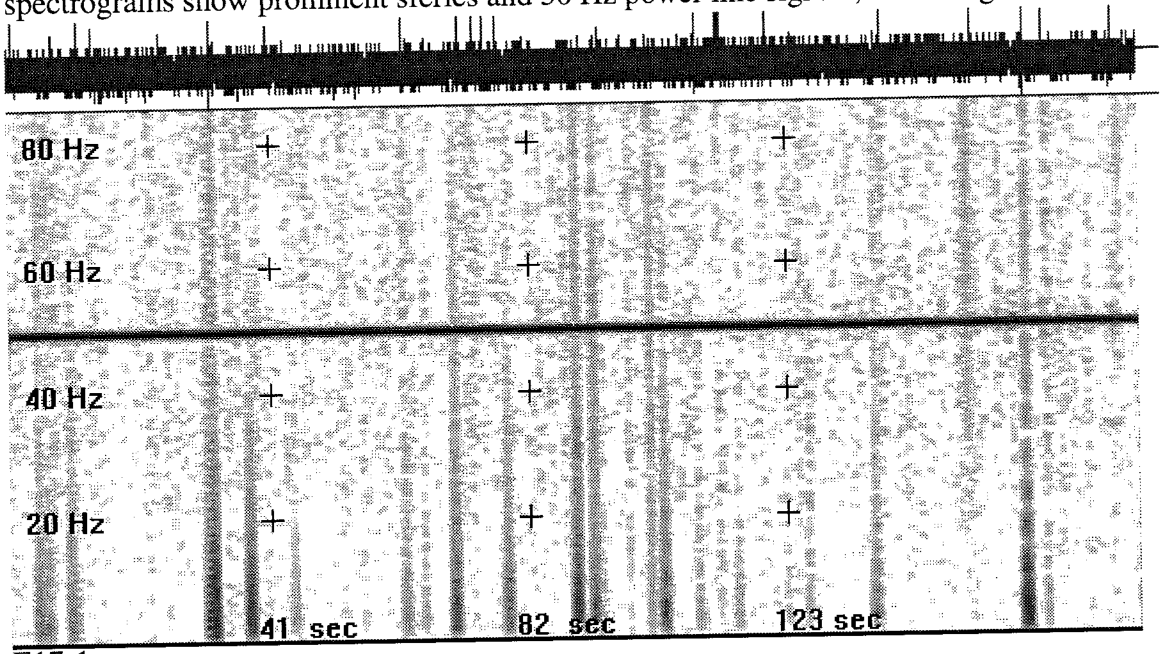
Pass	4/17					4/18						4/24					4/25					
	5	6	7	8	9	4	5	6	7	8	9	4	5	6	7	8	5	6	7	8	9	10
Team																						
1	x																				x	
5			x															x	x			
6		x						x					x									x
7		x						x					x									x
15	x	x	x			x	x	x					x	x	x	x						
16						x				x												
18						x					x										x	
21													x			x						
25												x										
27	x																					
28	x																				x	
30		x	x		x			x	x					x			x	x				
31																				x		
32						x	x										x	x				

INTMINS Data

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

E17-1

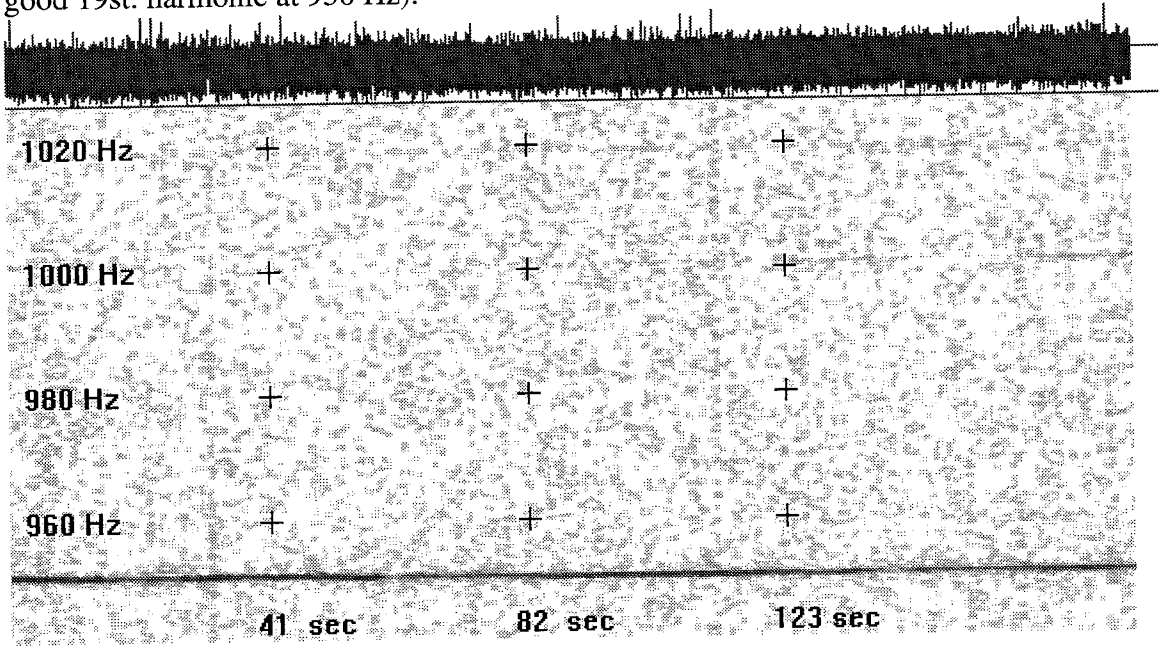
Renato romero, Team E5, submitted spectrograms of his data. He looked at the 10 Hz range and the 1 kHz range for the signals from Ariel and ISTOCHNIK, respectively. His spectrograms show prominent sferics and 50 Hz power line signals, but no signals from MIR



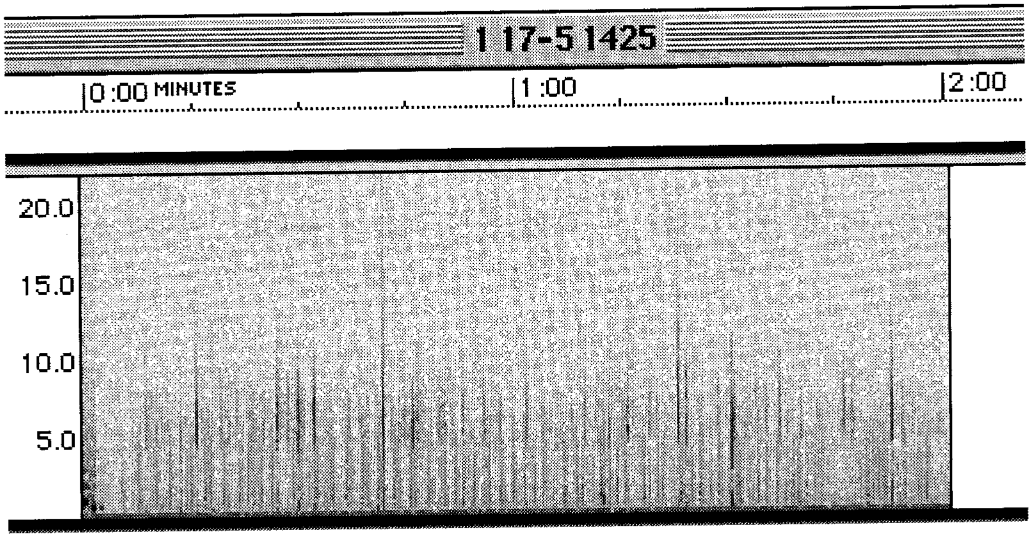
E17-1

Europe 5, R. Romero ñ Pass 17/1 ñ 17/04/99 from 08:24:00 to 08:27:00
Spectrum analisys: 0 ñ 86 Hz
Nothing at 10 Hz, strong 50 Hz tone.

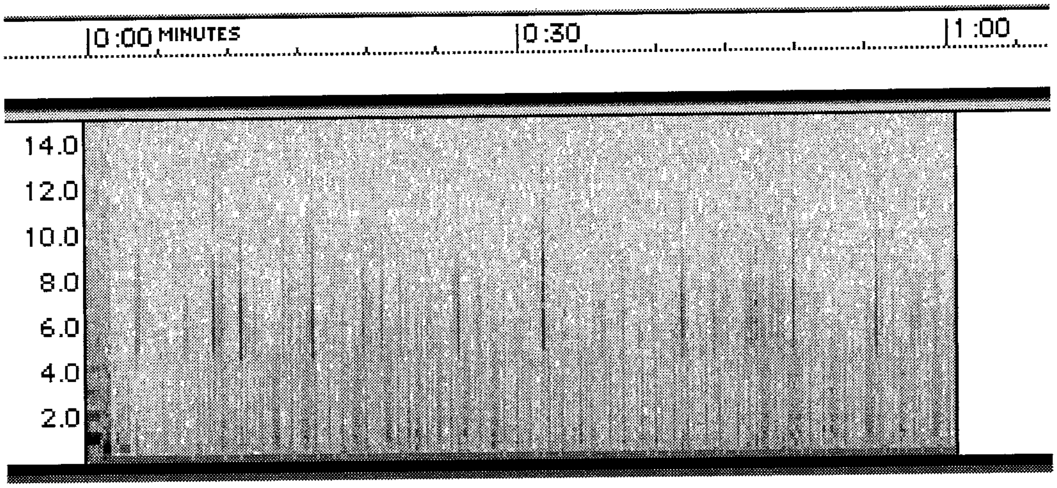
Europe 5, R. Romero ñ Pass 17/1 ñ 17/04/99 from 08:24:00 to 08:27:00
Spectrum analisys: 940 ñ 1030 Hz
Nothing at 1000 Hz (only a weak 20st.harmonic of 50 Hz at 1000 Hz at the end of sonogram, and good 19st. harmonic at 950 Hz).

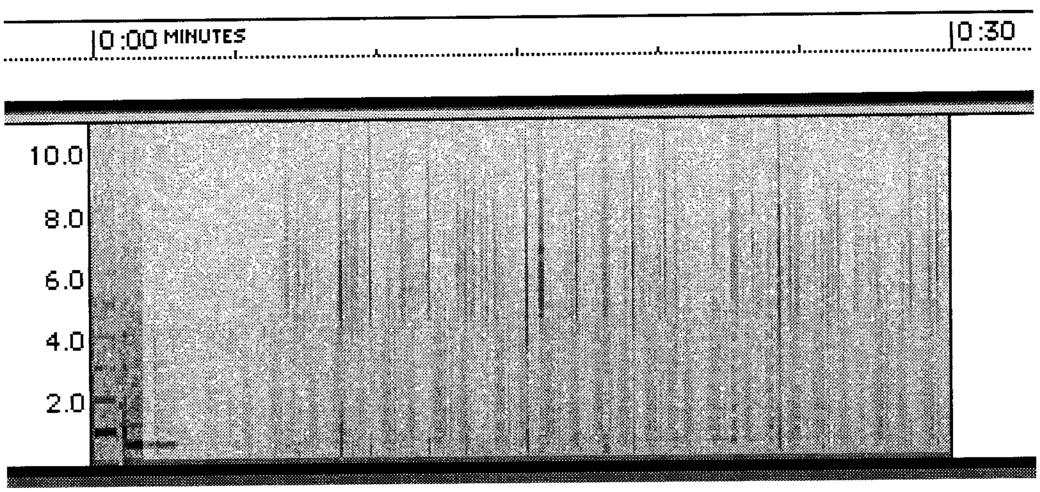


17-5



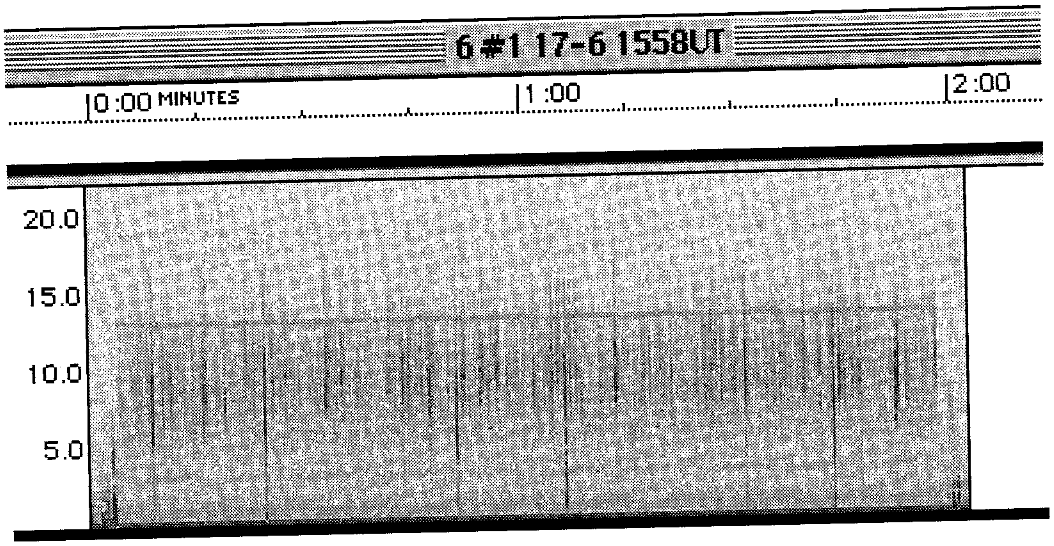
Team 1. Jack Lamb, Belton, TX
Good sferics shown. This was a quiet day in the middle of the country.



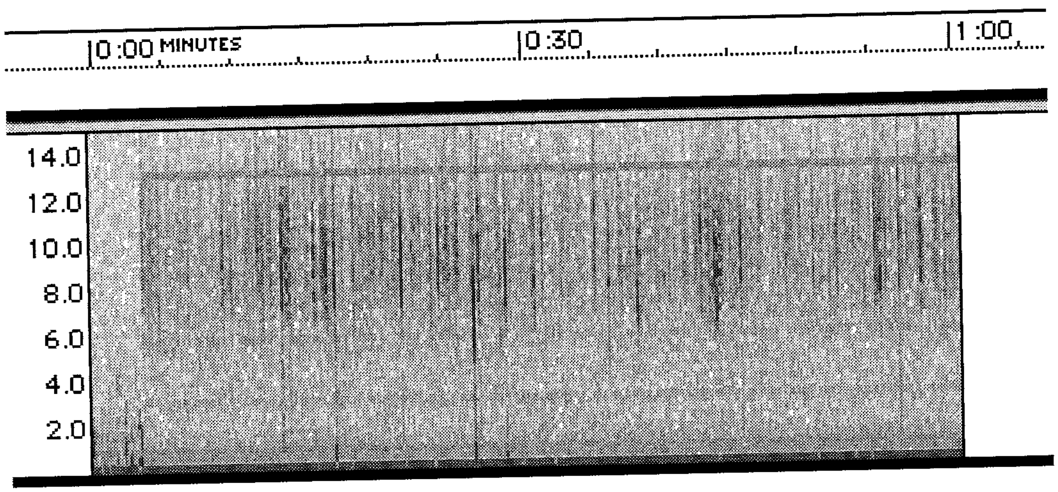


1425 UT WWV 1 kHz tone and several harmonics are present at the start.

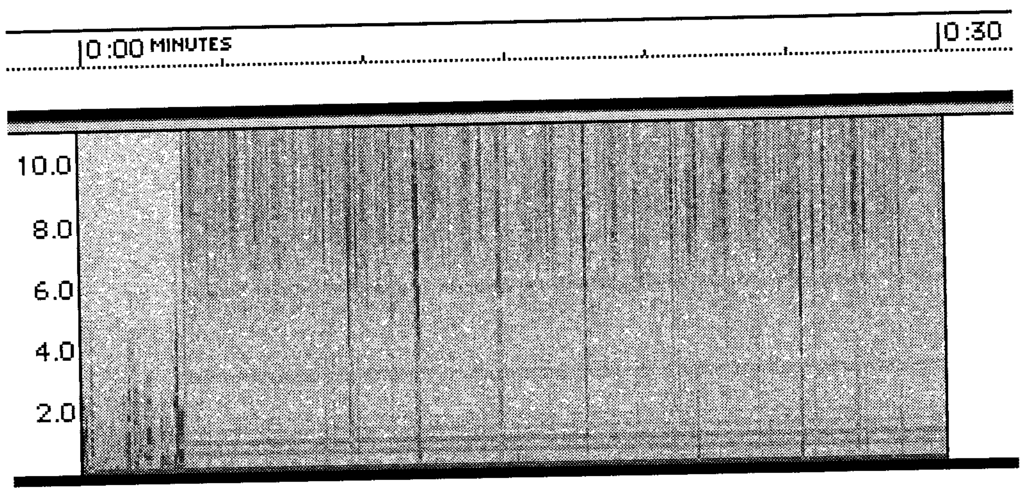
17-6

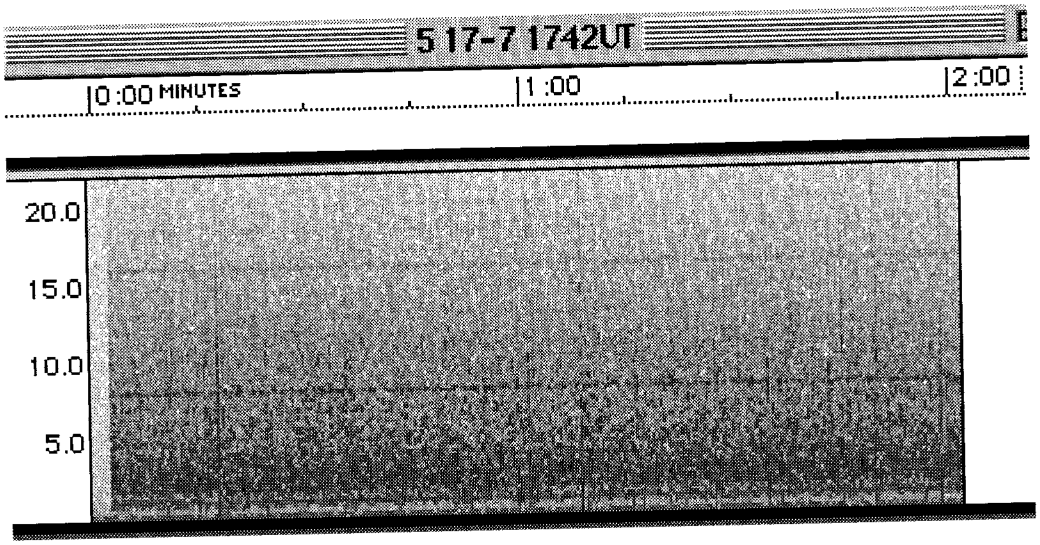


Team 6 Bill Pine, Chaffey High School, Ontario, CA
Receiver #1 is a B-field receiver with a 1 meter square loop with 90 turns, center tapped.
Quiet conditions.

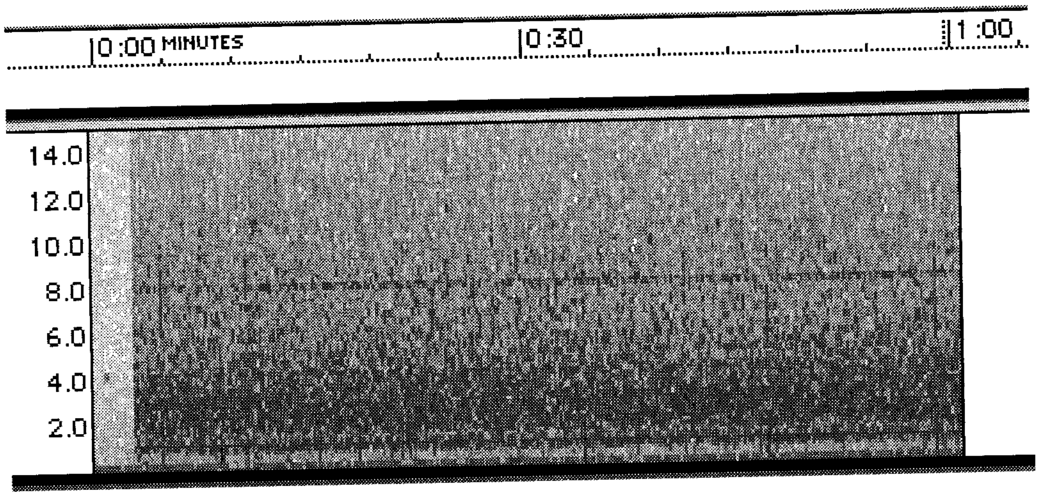


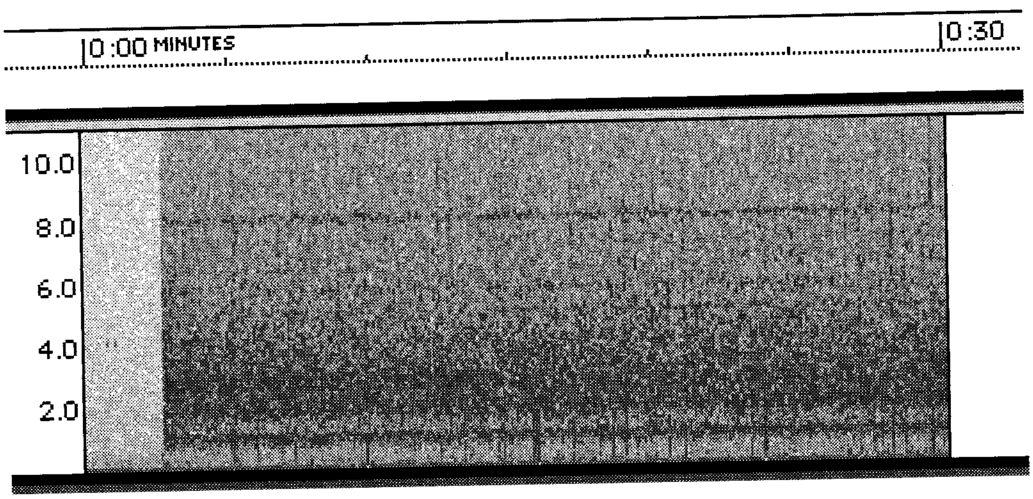
Strong sferics present, low density.





Team 5 Jean-Claude Touzin, St. Vital, Quebec, CANADA
Strong and persistent chorus was present during this session.





Chorus is not easy to see in spectrograms. This session had quite a bit of hiss-type noise that obscures the lower frequencies where chorus is found.