counterpoise line. Shortly thereafter, the noise disappeared. I did not record much in the way of the crackling, popping, whining type sounds as I figured it was useless noise disturbing my aurora recordings. Looking back, I wish I had recorded further examples of this noise. The reasons will be noted in the remainder of this article.

Here are the facts. Our VLF receivers in Alaska were prone to some type of electrical charge which was particularly noticeable from wires which had been laid along the top of the snow as opposed to upon the pavement. The effects of this charge were noticeable upon both a long wire e-field receiver and upon a large loop receiver. The effects of this mysterious charge were not immediately noticeable upon connecting our antenna lines to our VLF receivers. Our receivers would function normally for a short amount of time before beginning to experience the abnormal crackling, popping, hissing and finally whining and screeching type sounds.

Continuing, aurora was visible each time we experienced these problems with our equipment although the problems were not experienced throughout the entire duration of the aurora. Both a loop receiver and a e-field receiver began to experience this noise at the same time on the first evening we attempted to record the northern lights. First the noise developed in the loop receiver and then shortly thereafter it was noticeable in both receivers. (It is also interesting to note that Bill Pine had experienced problems the day previous with his handheld VLF-3 receiver not functioning for a short time.) Moisture between input connections as the source of the noise was ruled out on Monday night when I eliminated all coax lines and simply connected the two insulated wires feeding in opposite directions (over 700 feet apart from each other) directly to the inputs of the e-field receiver. Both a VLF-3 receiver and the SK-1 receiver revealed the same noise.

It is also interesting to note that I have used long wire antennas (up to 1000 feet in length) for over five years on Trail Ridge Road in the Rocky Mountains (at an elevation of over 12,000 feet) and have never experienced the problems we experienced while in Alaska (the popping, crackling and whining type sounds characteristic of electrostatic charge buildup upon electronic equipment).

After arriving home, it was discovered that the front-end chip in the loop receiver had indeed been damaged. I hooked the small loop antenna to the receiver and still, nothing but white noise was noticeable in the receiver's output. The receiver was perfectly dry both inside and outside. Replacing the unprotected front-end IC chip with a new one fixed the receiver! This was proof positive in my mind that the front-end chip of the loop receiver had been damaged by some type of static electricity. But what on earth had created such a large buildup of electrostatic charge on a lonely road over twenty miles from power lines? For the answer, I believe one has only to look upward into the sky during a display of the northern lights!

It was at this point that it began to dawn on me that we had actually recorded audio examples of the sounds of coronal discharge, the leading explanation for the audible sound generation mechanism of the northern lights!

Could the source of this charge be the DC "voltage" counterpart to the high "current" produced by the aurora? Is the electrostatic charge we experienced upon our VLF receivers the source of the audible sounds people claim to hear from the aurora? These are questions which remain to be entirely answered.

The intriguing part is that the "noise" we experienced on our VLF receivers is identical to nearly all of the testimonies regarding the audible sounds heard during auroral displays, a crackling, popping, hiss or screeching type sound, etc.

After arriving back home and re-reading personal testimonies from people who claim to have actually heard sounds during auroral displays (refer to www.members.tripod.com/~auroralsounds/aslist.html), I came across the following amazing similarity to our own experience while in Alaska.

Colin Graham, Inuvik, N.W.T (observer #93 on the above web page) reports audibly hearing crackling and popping type sounds in conjunction with a bright auroral display! The most intriguing part of this testimony is that this group heard "similar" noises coming from their audio amplifier as they had audibly heard from the aurora with their ears! By the way, what are VLF radios? Audio amplifiers! Here is another group (other than ourselves) which experienced audio amplifier interference during the northern lights. Remarking upon the incident, he mentions that the noises in their audio equipment "repeatedly had a similar sound [to what they had heard with their ears from the northern lights] transmit through our equipment and it was not any of our instruments." Continuing, "it was intermittent and sometimes 'burst' through the sound system and then we would stop playing and turn off all the stage gear and you could still hear the sound in the main sound system. After complete diagnostic of the system we determined it was not our equipment, lighting or sound system; it was a mystery sound."

Could electrostatic discharge or coronal discharge (also referred to as brush discharge) actually explain the sounds heard during displays of the northern lights?

"Professor Chant's theory was enthusiastically embraced by two American researchers, S. M. Silverman and T. F. Tuan, who in 1973 wrote a comprehensive 110-page paper on the subject. It is a mine of information. The brush discharge theory is supported to some extent by D.E. Olsen, who measured a jump in the geoelectric field from the fair-weather value of around 100 volt per metre to over 10,000 volt per metre during an intense aurora. This is approaching the electric field strength needed to excite an audible brush discharge under suitable conditions…." http://users.hunterlink.net.au/~ddcsk/aurora1.htm

Add to this the fact that during a bright aurora display in Colorado on October 29, 2003, I felt a profound static charge in the air. During the peak of this auroral display, there were two bright red patches to both my East and West while directly in front of me were bright white and green curtains rising to almost directly overhead. What a sight! Patches of light were moving very slowly from one side of the aurora to the other. This was the best auroral display I have ever experienced with what I recently witnessed in Alaska being second best.

During this Colorado aurora the air gained some type of static charge to it as suddenly every breath I took made my nostrils feel like they were full of static electricity! This charge was also felt slightly upon the hairs within my ears! This was very annoying to me at the time although I did not recognize the significance of the experience. I should note that I was sitting in my car when this static type charge began to be experienced. I would assume the vehicle should have shielded me from any type of change in the charge of the air but this was not the case. It was as if my body suddenly had a different charge from my surroundings.

Recognizing this was a very bright auroral display and that many people claim to have heard sounds from the northern lights, I stepped out of the car for a while during part of the brightest display in an attempt to "hear" the northern lights with my ears. Unfortunately, I did not hear anything even though it was absolutely quiet. The static charge I felt began suddenly as the aurora became very brilliant and began stretching to what appeared to be almost directly overhead. The charge dissipated and became unnoticeable as the aurora faded away.

On the VLF group e-mail reflector (http://groups.yahoo.com/group/VLF_Group), I had the following comments to make upon this experience at the time. "On October 29th [2003] when the brightest auroras I have ever seen were occurring in Colorado, I very distinctly felt a static charge on my body (or in the air). This lasted between fifteen minutes to half an hour during the duration of the brightest portion of the aurora. I especially noticed [sensed] the static electricity feeling by the tiny hairs within my nose and ears.... I've never heard of anyone experiencing anything similar to this but thought I would pass it along." VLF reflector group message 2750.

Our experience with coronal discharge upon our VLF receivers in Alaska along with the feeling of static electricity during the brightest aurora display I have ever seen leads me to highly believe that coronal discharge is indeed responsible for the sounds of the northern lights! Could there be any more convincing evidence?

While we were in Alaska, Ron Franklin (the owner of the Chatanika Lodge we were staying at) mentioned that he occasionally hears more than the standard popping, crackling and rustling type sounds from the aurora. He has also heard the aurora occasionally screech like a bobcat which he said can make a person's hair stand on end! This type of sound would occur during higher amounts of coronal discharge. Coronal discharge produces a popping, crackling type sound during slower discharge rates. This popping, crackling sound can be steady in rate/speed or it can vary in rate/speed creating a type of rustling sound. During slightly higher discharge rates the popping, crackling sound turns into hiss, frying and hum type sounds. And finally, during high discharge rates sizzling, screeching, squeaking and squealing type sounds are heard. Again, these sounds can vary in speed, pitch or duration corresponding to the discharge rate. If the discharge rate varies widely, a mixture of the above sounds might be heard. Add to this the fact that Ron has smelled ozone (or something very similar to it) in the air as audible sounds of the aurora are occurring. Ozone is generated during coronal discharge!

Coronal discharge, as I basically understand it, occurs as electrical charge upon an object is released into the surrounding air generating ozone and frequently noise as it does so.

After adding up all the facts, it is easy to come to the conclusion that the noise we experienced in Alaska upon our VLF receivers was coronal discharge! This alone could explain what burned out the front-end IC chip in the loop receiver while only aurora was visible overhead.

In closing, I believe good hearing is a requirement to hear audible sounds from the aurora as coronal discharge is often a soft, subtle type sound. I believe we actually obtained more on this expedition than we bargained for and we did not even realize it at the time. It's science! You have to love it!

The upcoming thirty minute radio documentary entitled "Songs of the Sky" will focus on the sounds heard using simple VLF receivers from the northern lights and upon reports that sounds from the northern lights can also be heard audibly without the aid of a radio receiver including personal testimonies and a brief mention of possible explanations for this unusual and as yet unexplained phenomena. Another twist in the documentary will focus on legends and myths from Alaskan natives regarding the northern lights.

Kate Bissell is the producer of this radio documentary which is tentatively scheduled to air on BBC Radio 4 stations across the United Kingdom May 31st at 8:30 p.m. BST (British Summer Time GMT +1 / UTC+1).

You will want to tune into this fascinating broadcast live on the internet May 31st at www.bbc.co.uk/radio4/. Simply click on the "Listen Live" button to hear the broadcast. If you miss the broadcast click on the "Programme Finder" to locate the broadcast.

Thanks to Bill Taylor and Bill Pine from the INSPIRE project and to Kate Bissell from the All Out Production Company for making this expedition possible!

SOME ANTENNA OBSERVATIONS Part 1

Robert Bennett
Las Cruces, NM

For almost a year, the author has been collecting data to determine the performance of various antennas for use with the VLF-3 INSPIRE Receiver. The goal is to determine which antenna is "best" for my particular location and noise environment, (*these results may not generalize to other locations and environments*). This paper is divided into two parts. In Part 1, results relating to about half the antennas tested will be presented. The rest will be presented in Part 2.

Antennas Considered. The antennas considered for use generally have to meet three criteria.

First, the materials to construct the antennas have to be readily available and the design must not require professional machine shop work.

The second restriction is that the antenna materials have to be inexpensive. I set a limit of $50 per antenna, although most of the prototypes were quiet a bit less than this.

The third restriction is that a single person must be able to assemble and erect the antenna. Also, the antenna has to fit in the bed of my truck. This means that each piece of the antenna can be no longer than 6-feet.

Given the above constraints, I ended up evaluating the following antennas. A detailed description, including sketches and photographs, is in the appendix.

a. Vertical monopole (whip), 6-Feet in length, mounted on a wood support that elevates the base of the antenna about 3-Feet above ground level. The antenna has two feeder connection points, one for an open wire line and one for a coax cable.

b. Sloping Long Wire Antenna, 120-Feet in length. A 20-foot telescoping mast supports the taller end. The lower end is 3-Feet above ground. The antenna is made of 14-guage stranded, insulated, electrical cord.

c. Vertical Monopole, 4-Feet in length and mounted atop a 20-foot PVC pipe mast. The antenna is fed with RG-59 Coax cable. I used a 50-Foot length of coax so that the antenna can be located well away from the monitoring position.

d. 500-Foot Long Wire Antenna. Made of insulated wire and supported above ground by throwing on top of low bushes.

e. 1000-Foot Long Wire Antenna, same as above except longer.

f. Ferrite Loop Antenna.
g. Box loop antenna.
h. "Tree" antenna.
i. "Wet Sand" antenna. The tree and wet sand antennas were the subjects of extensive discussion on the VLF Group (VLF_Group@yahoogroups.com).

Evaluation Technique. The 6-foot vertical whip was selected as the reference antenna. The general technique was to first connect the reference antenna to the VLF-3 receiver and record from 15 to 30 Minutes of natural radio signals. The VLF-3 was adjusted for maximum gain and the recorder gain adjusted so that its level meter was in the green zone and slightly below the red line (recorder saturation). Next, the reference antenna was replaced with the antenna to be evaluated and an additional 15 to 30 minutes of natural radio recorded. All recorder and VLF-3 settings were held constant.

Usually a second "run" with the same antennas but with the VLF-3 antenna attenuator in the "in" position was made.

Most of the experiments were conducted at night, between the hours of 2000 and 0100 local time. However, some of the experiments were repeated to obtain data during the daytime. The daytime periods varied but usually occurred between 0800-1000 and 1500-1700 local time.

Spectrum analysis programs (SpectraPlus and Gram) were used to analyze the data on the tapes.

RESULTS

The following charts show the results. Figure 1 is the performance of the reference antenna with the VLF-3 antenna attenuator "out" then "in". This figure clearly shows the presence of Loran when the antenna attenuator is out. The Loran signal appears as peaks in the spectrum at multiples of 1 kHz. The Loran signal is completely eliminated by placing the attenuator in the "in" position. However, the penalty one pays for eliminating Loran is a 6-10 dB decrease in signal level at all frequencies.

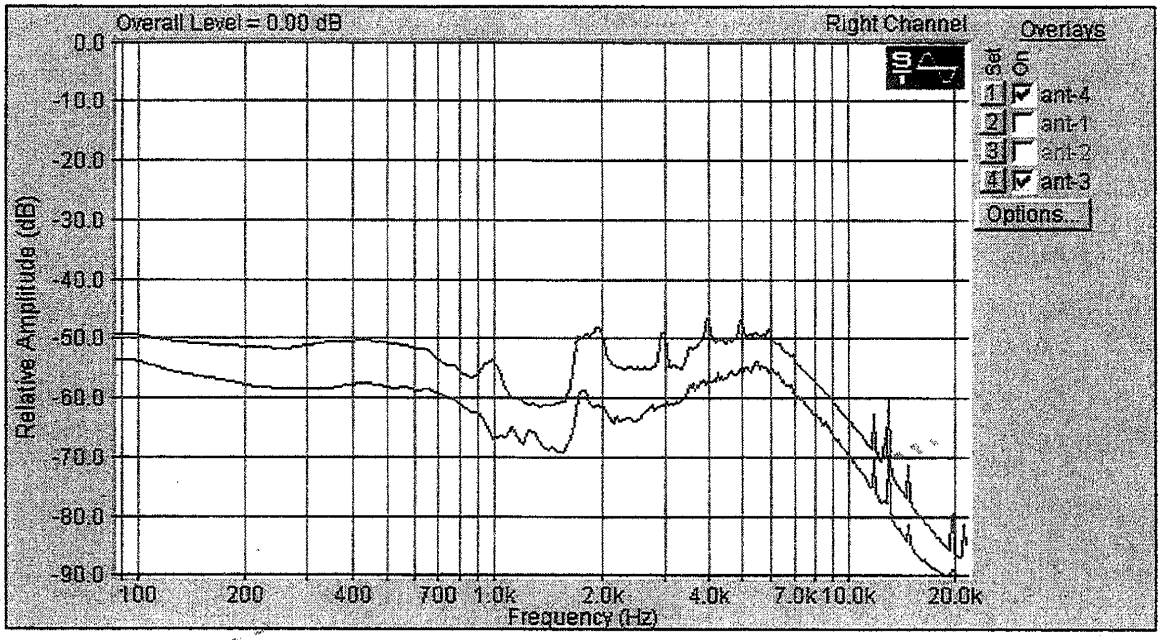

Figure 1 Reference Antenna. Top trace is with VLF-3 Attenuator "out". Bottom trace is with attenuator "in".

Figure 2 shows the results obtained using the 120 Foot long wire antenna. These results are interesting and were unexpected. The figure shows that the long wire provides about 10 dB more signal across the band than did the reference antenna. Loran is present when the VLF-3 attenuator is "out" and not present when the attenuator is "in". However, note in figure 2 that the level differences with the attenuator "in" versus "out" are not significant in the bands of interest for natural radio, 1 to 10 kHz. This result was not expected!

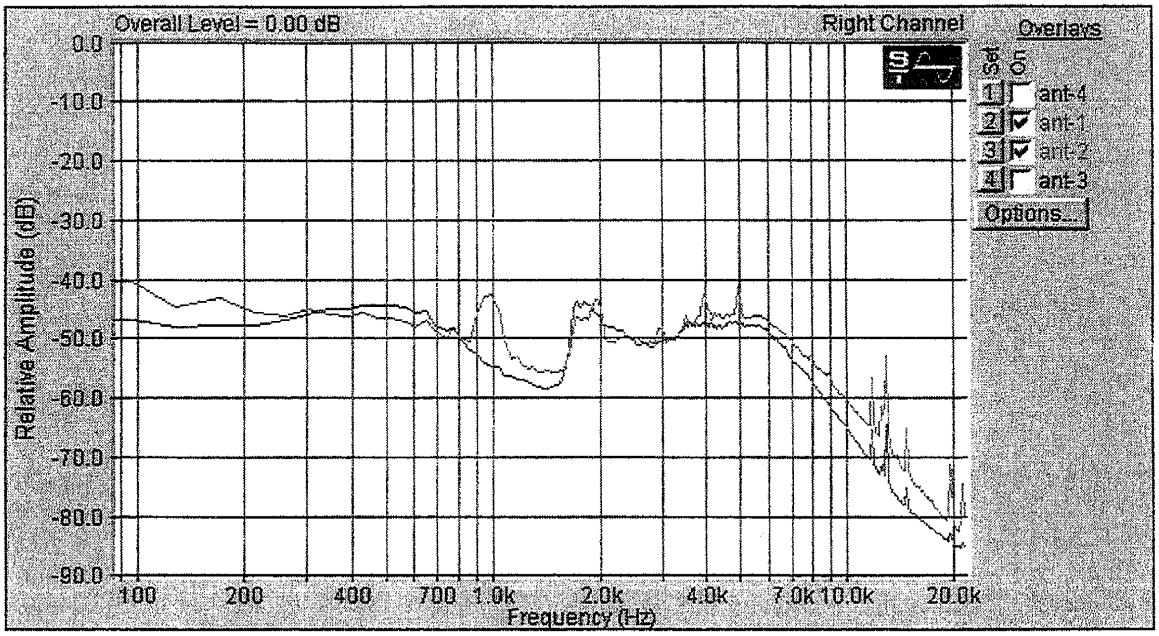

Figure 2 Comparison of 120 Foot Long wire antenna with VLF-3 attenuator "out" (top trace) and "in" (bottom trace)

Figures 3 and 4 show plots of the reference antenna and the 120 Foot Long Wire on the same chart. The difference between the signal pick up by the two antennas is very clear in figure-3 but less pronounced in Figure 4. Figure 4 clearly shows Loran pick up by both antennas and the long wire provides several dB more Loran signal than does the reference antenna.

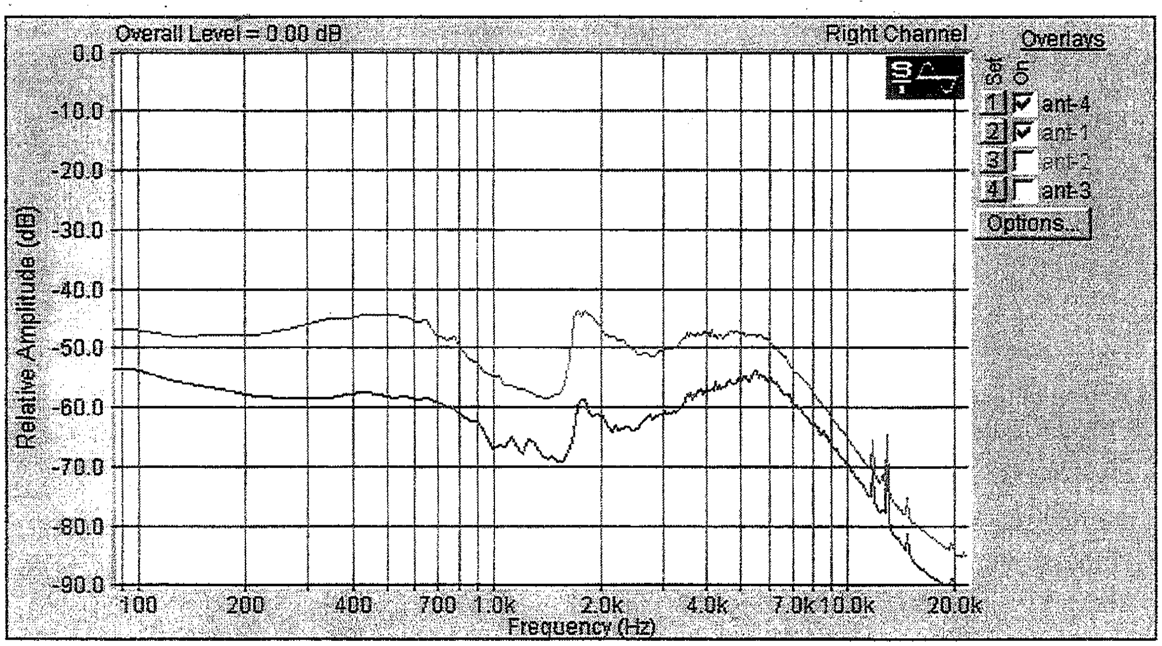

Figure 3 Comparison of 120-foot long wire (top trace) with 6-Foot Vertical reference (bottom Trace) with VLF-3 attenuator "in".

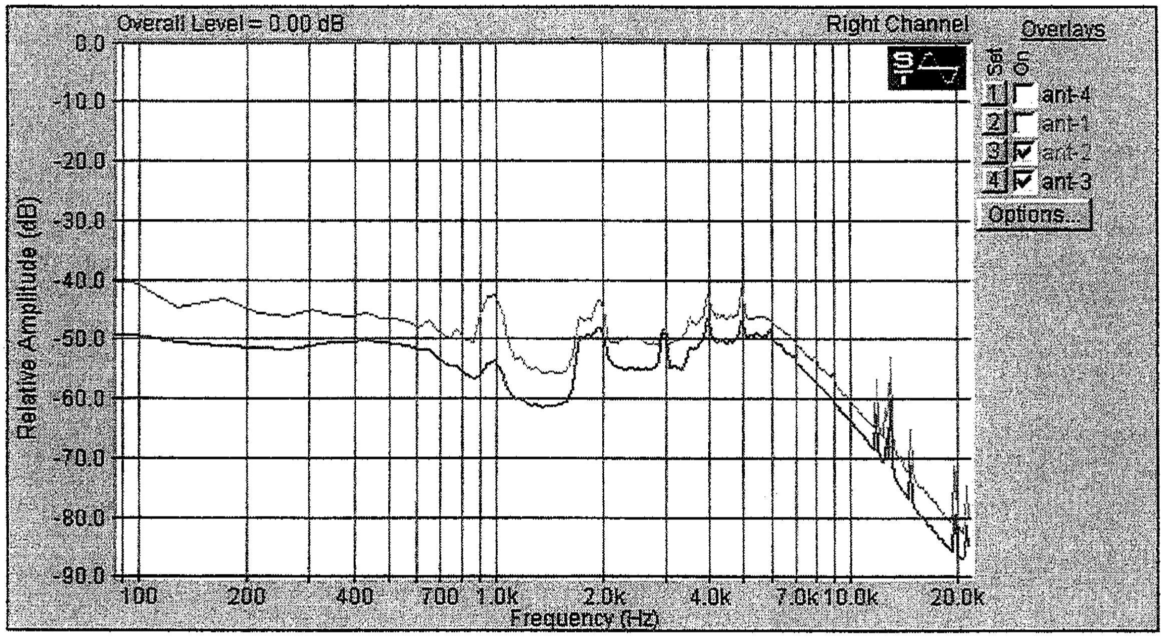

Figure 4 120-Foot long wire (Top trace) versus
6-Foot Whip (bottom Trace) with VLF-3 attenuator "out".

The 120 foot long wire antenna also picked up more 60~ power line interference than the 6 foot whip. Figures 5 and 6 show this effect. Figure 5 is for the long wire and clearly shown stronger 60~ harmonic interference than the 6 foot whip in Figure 6. The interference appears as horizontal lines in the charts.

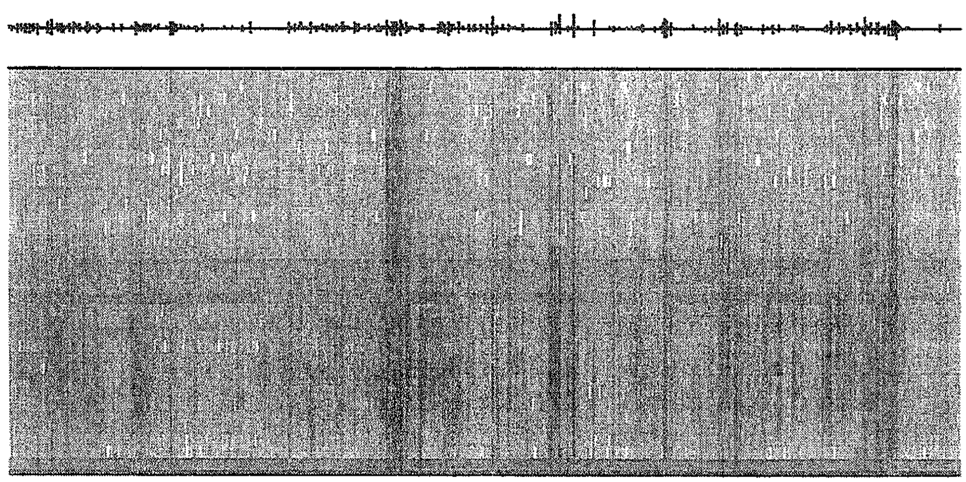

Figure 5 120- Foot Long wire. GRAM spectra of the 0 to 1 kHz portion of spectrum.

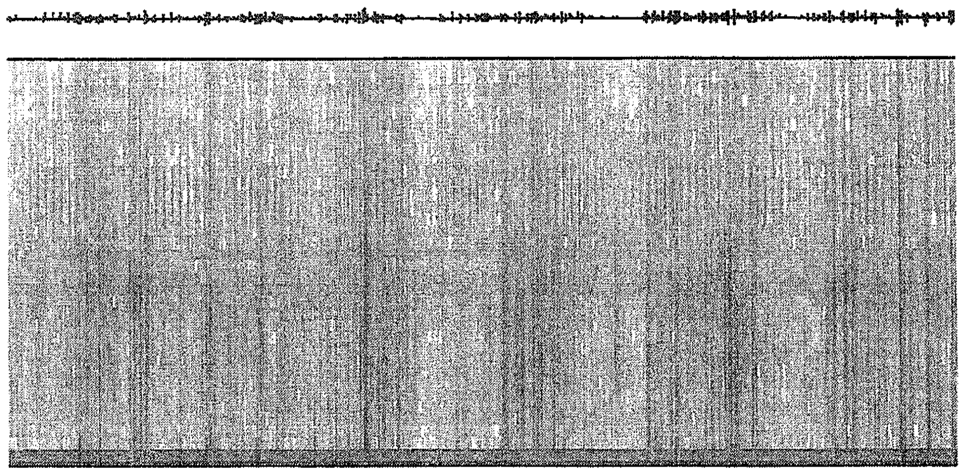

Figure 6 Reference antenna. Gram plot of 0 to 1 kHz portion of spectra.

The next antenna considered was the elevated 4-foot whip using a coax feed line. Figure 7 shows a comparison of the elevated whip with the reference antenna. In this experiment, the VLF-3 antenna attenuator was "out". Two things stand out in this chart. First, the natural radio signal levels are about the same for both antennas. Second, the elevated whip using a coax feed effectively removed the Loran signal, which is very clear in the trace for the reference antenna. The shunt capacitance of the coax is probably sufficient to attenuate the Loran signal without significantly affecting the natural radio signals.

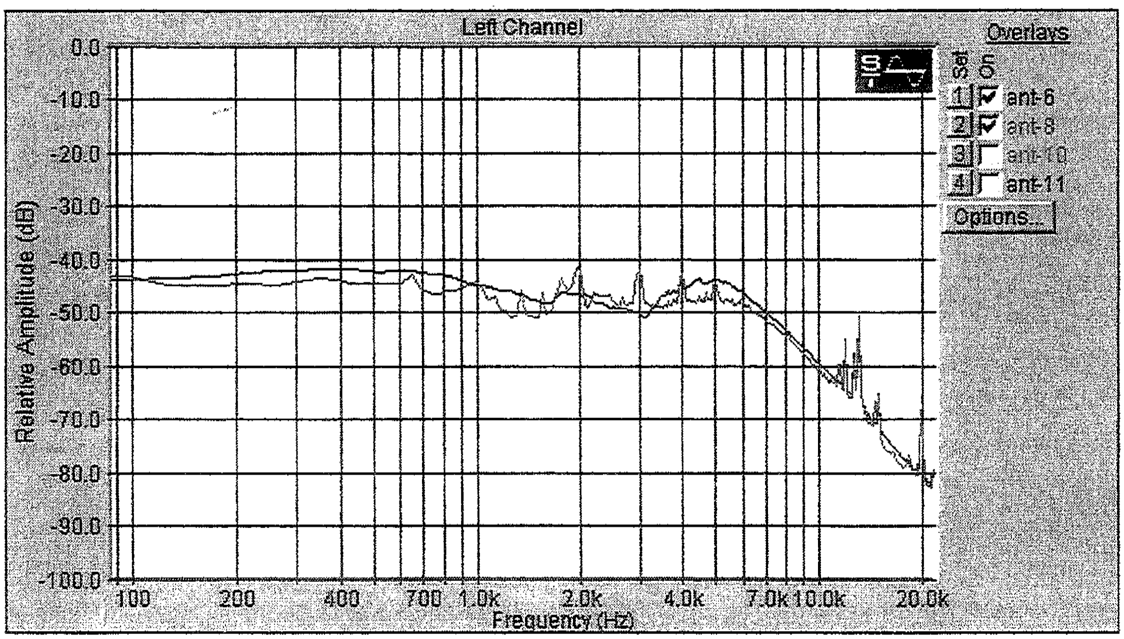

Figure 7 Comparison of reference antenna (bottom trace) with elevated whip fed with coax (upper trace). VLF-3 attenuator "off".

Figure 8 shows the effect of placing the VLF-3 attenuator "in". Note that the reference antenna curve does not show any trace of Loran. The elevated antenna trace remains free of Loran. However, note the differences in signal levels in the 10-20 kHz region. It seems that the VLF-3 attenuator in combination with the shunt capacitance of the coax is forming a low pass filter that has its cutoff point at about 6 kHz.

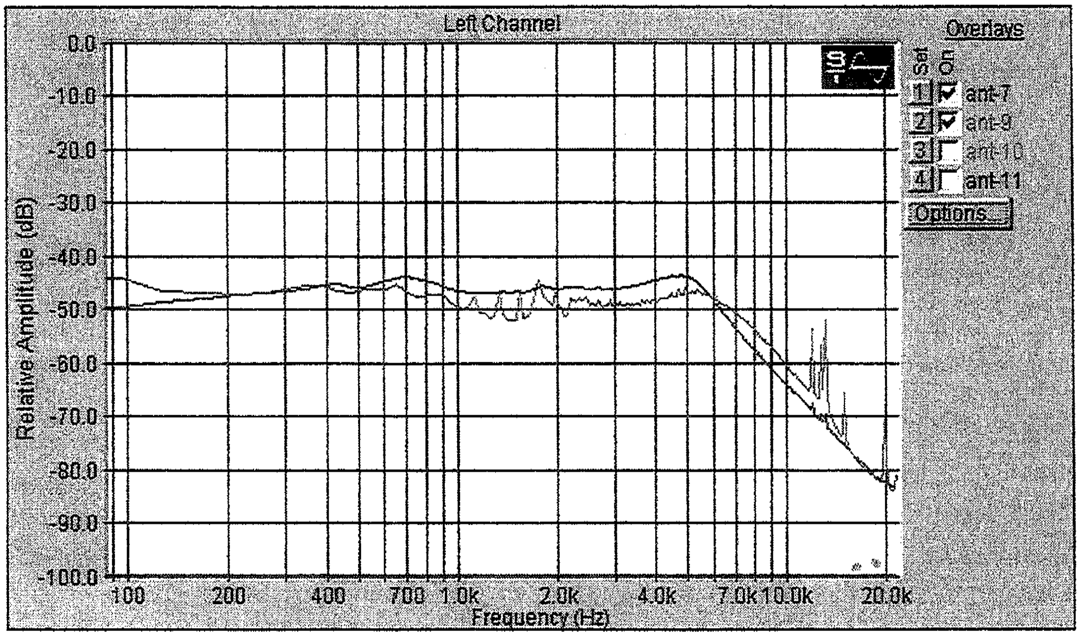

Figure 8 Reference Antenna (lower trace) and elevated whip (upper trace) with the VLF-3 attenuator "on".

Day versus night. Figure 9 is one example of the differences between daytime signal levels and nighttime levels. All the other experiments reveal the same trends so for the sake of brevity; only this example will be discussed. The data shows that nighttime natural radio levels (tweeks, sferics, whistlers, etc) are generally stronger than daytime levels but the differences are not constant. During some experiments the difference was only a dB or so and in others like the one presented, the levels differ by 10-12 dB. The manmade signals (Loran, plus communications and navigation signals between 10 and 20 kHz) are usually much stronger in the daytime than at night. Also, the daytime spectra usually shows stronger 60~ power line interference, normally odd harmonics. Note the spike in the daytime spectra at 660 HZ (11th harmonic).

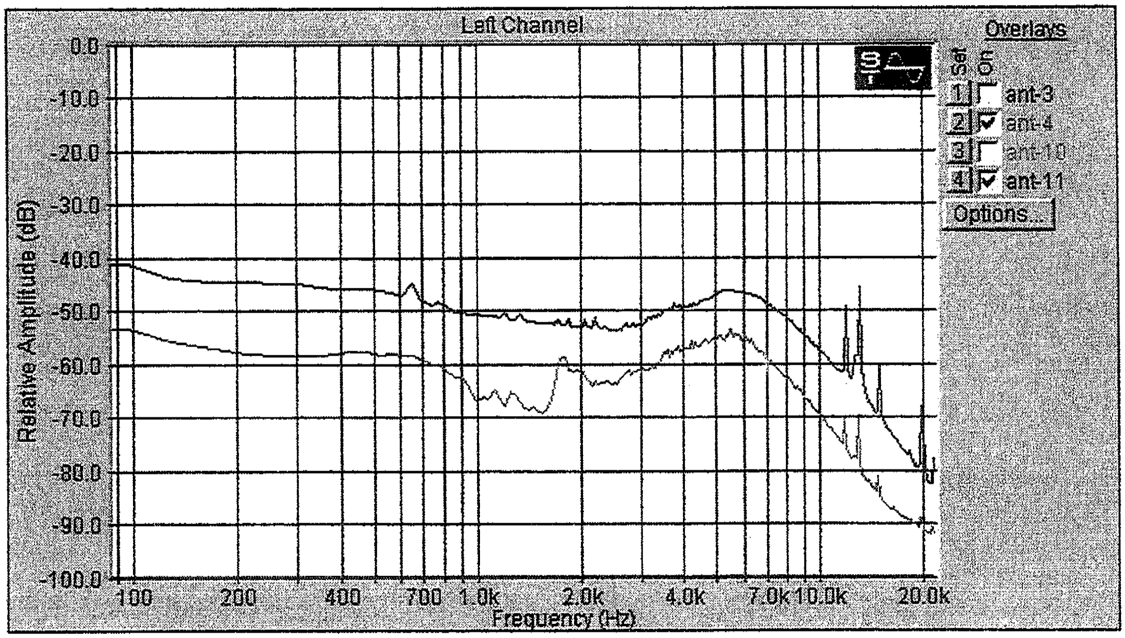

Figure 9 Day (top trace) versus Night (Bottom trace) signal levels using the reference antenna with VLF-3 attenuator "on".

The last experiment to be discussed is the 500-foot long wire antenna. The antenna was oriented generally in an East-West direction and supported by placing it in the tops of dormant creosote and mesquite bushes. The height above ground varied between 1 foot and 3 feet and care was taken to prevent the insulated wire from contacting the ground. Previous experimentation showed that if the wire is allowed to contact the Earth for any appreciable distance, then the levels of power line interference increase greatly. Figure 10 shows the results. This experiment was performed in the daytime and the VLF-3 attenuator is "in". Two things are immediately evident. First, the long wire provides more signal pick-up at frequencies below about 2 kHz than does the reference antenna. From 2-10 kHz, the antennas are about the same and above 10 kHz, the reference antenna is better. Second, the 500-foot long wire picks up substantially more 60~ interference than does the reference antenna. Note the strong 60~ odd harmonics at 300, 660, 780, 1500 and 2100 Hz.

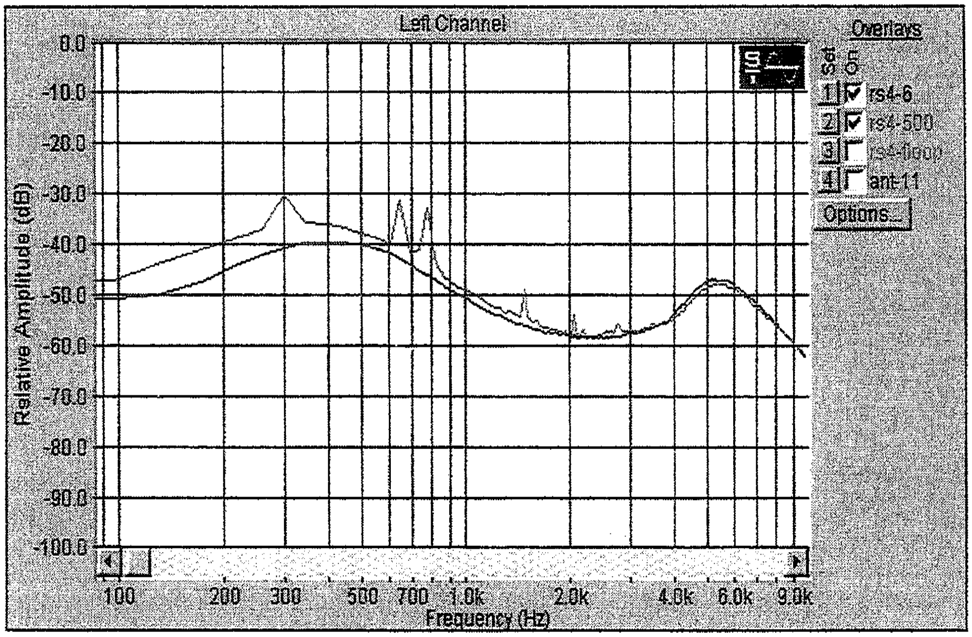

Figure 10 Comparison of a 500-foot long wire antenna (top trace) with the reference antenna (bottom trace).

CONCLUSIONS

From the information presented, the following conclusions can be drawn:

a. The antenna attenuator on the VLF-3 receiver will effectively eliminate Loran interference when using any of the experimental antennas.

b. Use of the VLF-3 attenuator is not without penalty. Its use can result in up to a 10-dB loss in receiver sensitivity.

c. The long wire antennas provide additional signal pick up but at the expense of increased 60~ interference.

d. An elevated whip antenna connected to the VLF-3 receiver (attenuator "out") with a coax cable feed provides about the same performance as the ground mounted 6-foot whip reference antenna with the VLF-3 attenuator "in". The appeal of the coax cable feed is that it can be used to attenuate Loran without using the VLF-3 antenna attenuator.

e. So far, the author has not found a compelling performance reason to replace the simple ground mounted 6-foot whip reference antenna with a more complex antenna.

f. The use of coax cable to eliminate Loran interference is attractive and can easily be applied to the reference antenna. This will be further investigated in the future.