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Final Technical Report

ONR Contract No. N00014-88-K-0687

Maintenance of the HIPAS Ionospheric Radio Frequency Heater at Two Rivers, Alaska

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During this contract period, the work performed at the HIPAS site can be divided into two categories. The first category is basic site maintenance and the second category is experimental and scientific endeavors.

Site Maintenance:

The harsh weather at the HIPAS site combined with the remote location greatly increase the sight maintenance requirements. There are further complicated by interference from animals and providing the security necessary to preserve the facilities.

During the contract period several important operations have been completed:

1. Critical parameters of the eight high power transmitters were modified so that these values can be read, displayed, and controlled digitally.

2. Various transmitter components were upgraded. For example, the capacitors in the power supplies were checked and replaced as needed. Additionally, all of the filtering circuits were checked and upgraded.

3. The diesel-electric generators were run once a week to thwart the build up of water and acid in the crankcase oil. Concurrently the transmitters were all run and checked against high voltage and rf short circuits and malfunctions.

4. The coaxial transmission lines (between the transmitters and the antennas) and the antenna baluns were pressurized slightly over ambient to prevent any internal build up of water or ice which could short out the lines. The air pressure in the systems is periodically monitored to prevent failure.

5. Distilled water in the transmitters (this evaporatively cools the 4CV 100,000 transmitter tubes) was monitored to prevent freezing.

6. The glycol heat exchanger lines and radios were maintained to insure that the glycol water mixtures are correct.

7. Commercial electrical lines throughout the site were maintained and fuses replaced as needed.

8. Roads to and around the facility were kept open and in good order. This involves plowing during the winter and grading/graveling after the sprint thaw.

9. Site vehicles were inspected and maintained. Electrical heaters are used to keep lubricants from freezing.

10. The sites' two wells, pipes, and sanitary lines have to be monitored during the winter to guard against freezing and rupture. Critical locations have been wrapped with heater tape and remote reading thermometers.

11. The site is regularly patrolled to check building temperatures, and for damage from vandals or animals.

12. Antenna field must be cleared of brush.

13. Communications to the remote site (Gilmore Creek) have been improved with upgraded modems and computers.

14. Performance of the sites two ionosondes has been greatly improved. The reliability has been increased by overhauling the transmitters. The ease of use as been improved by interfacing the units with IBM PCs. Measures have been taken to protect the ionosonde antennas from moose and other animals.

Experimental and Scientific Program:

On the experimental program the large backlog of data from the Gilmore Creek site has begun to be analyzed. This data indicates that we can detect ELF signals (11-100Hz) 18 miles away. The ELF is generated by interaction of the HIPAS 2.85MHz radio bean and the polar electroject. The signals were detected by a three axis "Schumann Receivers" developed by Dave Sentman of UCLA's Institute of Geophysics and Planetary Physics. The received data has been stored on optical disks and tapes.

Similar ELF data has been recorded at Table Mountain, California, as well as at a new station at Northwest Cape Australia, which was able to detect the HIPAS signal.

Additional scientific work has been performed in cooperation with Pennsylvania State University. This work is summarized in the following report.

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Appendix I

FINAL TECHNICAL REPORT

CONTRACT ONR-TPSU-UCLA-0677-387

OPERATION OF HIPAS FACILITY
FOR COOPERATIVE EXPERIMENTS WITH
PENNSYLVANIA STATE UNIVERSITY

SEPTEMBER 15, 1986 - SEPTEMBER 30, 1989

Submitted by

The Regents of the University of California
University of California, Los Angeles
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PROJECT REVIEW

During the period fom 9/15/86 to 9/30/90, UCLA's Plasma Physics Laboratory was under subcontract to The Pennsylvania State University, to collaborate with Professor A.J. Ferraro to conduct research on polar VLF excitation and generation. The whole program was under the sponsorship of the U.S. Congress Universities Research Initiative (URI), which was administered by the U.S.Navy's Office of Research, Washington D.C. UCLA's contributions to the URI initiative were its very high power radio frequency array 35 miles east of Fairbanks, Alaska; called HIPAS, which stands for HIgh Power Auroral Stimulation and UCLA's ionosonde diagnostics.

Four separate campaigns were conducted over the course of the URI/PennState subcontract; namely,

I	June 15-25, 1987
II	October 13-23, 1987
III	July 11 -22, 1988

and

IV	July 12- Aug 8, 1989

The four campaigns are summarized in Table I, which emphasizes the operation of the HIPAS radio frequency heater; namely, the campaign dates, the durations of uninterrupted operation, the total power radiated (ie 8x100KW means 8 transmitters at 100KW each or a total radiated power of 800KW), and comments on the over all operation during the specified period of operation.

Prior to the first campaign, the total radiated power was brought up to 800 KW at 3.345 MHz under the advice of John Carroll (the orginal Platteville chief engineer) who came and worked at the site. The sytem was next retuned to 2.85 MHz, which is close to the electron cyclotron frequency, and which should efficiently couple to the electrojet to generate VLF and ELF. This meant retuning both the transmitters, baluns, and antennas. The antennas were tuned by the addition of "end-straps" which were a pair of cables attached to the ends of each antenna and spread in angle and anchored to the ground to control both the impedance and frequency of a dipole. This method of antenna tuning was the contribution of Mr. William Harrison, a consultant to HIPAS. The baluns were tuned by replacing the coaxial cable that acted as capacitive ends loads by high voltage variable vacuum capacitors which could be continously tuned. The tops of the baluns were covered by large plastic boxes to protect the antenna connections from the elements, principally ice during the winter, but rain during the summer. The coaxial feed lines were also pressurized to a few inches gauge to thwart any intake of mosture laden air into the coaxial lines and baluns, with resultant build up of ice during the winter. Initially, this air was dried with commercial "Dri- Rite". Later a refrigeration type of drying sytem was added. The pressurization of the transmission lines and baluns with dry air soon showed that the system could be operated during the winter at temperatures as low as -40^{o}F.

TABLE I

TRANSMITTER PERFORMANCE SUMMARY

CAMPAIGN	DATES	TIMES	DURATIONS (hours)	POWERS	REMARKS
I	6/15/87	0600-0900	3	8x100KW	10°C ambient
	(Monday)	1530-1830	3	"	rain
	6/16/87	0700-1030	3.5	8x100KW	
		1800-2100	3		23°C
	6/17/87	0400-1600	12	8x100KW	Coolant problems
	6/18/87	0300-1100	8	8x100KW	
		1700-2300	6		22°C
	6/19/87	0600-1200	6	8x100KW	
	6/22/87 (Monday)	1000-1230	2.5	8x100KW	stopped due to arc in #0
		2030-2400	3.5		
	6/23/87	1230-1600	3.5		
		1900-2200	3		
	6/24/90	0800-1424	6.4	8x100KW	#6 out, insulator
		1424-1500	0.6	6x100KW	failure, #7 off for balance
		1500-1524	0.4	8x100KW	repaired
		1524-1600	1.0	4x100KW & 4x 70KW	generator overheated
	6/25/90	0630-1100	4.5	8x100KW	
		2200-2400	2	8x100KW	trips due to air in water interlocks
		TOTAL hours	73.1		
II	10/13/87	1300-1900	5	8x100KW	
	10/14/87	1300-1500	2	"	
		1500-1600	1	8x 40KW	fly over
		1620-2000	3.3	8x100KW	
	10/15/87	0800-1400	6	8x100KW	1°C ambient
	10/16/87	0000- 600	6	8x100KW	
	10/19/87	1530-2200	6.5	8x100KW	
	10/20/87	0830-1200	-	-	interlock problems
		1330-1730	4	8x100KW	
	10/21/87	1530-1830	3	8x100KW	
		2000-2400	4	7x100KW	#6 off line
	10/22/87	1500-2300	8	8x100KW	
	10/23/87	1900-2300	4	8X100KW	
		TOTAL hours	50.3		

(continued)

TABLE I
(CONTINUED)

CAMPAIGN	DATE	TIMES	DURATION (hours)	POWERS	REMARKS
II	7/11/88	1100-1600	5	8x100KW	#5 off 15 minutes
	(Monday)	1900-2200	3	"	80°F ambient
	7/12/88	1800-2230	4.5	"	Power out at UA
	7/13/88	1100-1200	1	7x100KW	#6 off (meter shunt bad)
		1200-1400	2	8x100KW	
		2000-2400	4		77°F thunderstorm
	7/14/88	1800-2400	6	"	86°F thunderstorm lightening
	7/15/88 7/16/88	2040- 0302	6.3	"	beautiful sunset at 0019
	7/17/88 7/18/88	2100- 0220	5.2	"	
	7/18/88 7/19/88	2100- 0300	6	"	
	7/19/88 (Tuesday)	1800-2400	6	"	85°F ambient 2 frequency mod 2.85 &2.8525 MHz
	7/20/88	0900-1500	6	"	
	7/21/88	0300-0500	2	"	oil hose broke on diesel generator
		0545-9000	3.2	"	
	7/22/88	0000-0600	6	"	52°F ambient, rain at 0432
		TOTAL hours	65.2		

(continued)

TABLE I
(CONTINUED)

CAMPAIGN	DATES	TIMES	DURATIONS (hours)	POWERS	REMARKS
IV	7/12/89	0000-0600	6	8x100KW	rotating and
	7/13/89	0000-0345	3.75	"	scanning beams
		0345-0400	0.25	6x100KW	0 & 7 off due to
		0400-0630	2.5	8x100KW	interlock problem
	7/14/89	0000-0300	3	"	64°F ambient
	7/14/89	2100-	5	"	90°F ambient
	7/15/89	0200			
	7/15/89	2000-2230	2.5	"	74°F ambient
		2230-2300	0.5	6x100KW	0 & 7 off line
	7/16/89	2300-0100	2	8x100KW	
	7/17/89	2100-2400	3	"	63°F
		0000-0245	2.75	8x120KW	
	7/18/89	0245-0300	0.25	8x100KW	74°F
	7/18/89	2140-	4.75	"	delayed by #4
	7/19/88	0230			FCC Anchorage called
	7/19/89	2130-	4.5	"	#6 interlock delay
	7/20/89	0200			
	7/20/89	1900-2330	4.5	"	55°F
	7/21/89	2330-0300	3.5	8x120KW	78°F
	7/21/89	1900-0300	8	"	
	7/31/89	2100-	6	8x100KW	65°F ambient
	8/01/89	0300			
	8/01/89	2100-	6	"	"painting"
	8/02/89	0300			
	8/02/89	2100-	6	"	66°F ambient
	8/03/89	0300			
	8/03/89	2100-	7	"	
	8/04/89	0400			
	8/04/89	2100-	6	"	59°F ambient
	8/05/89	0300			
	8/06/89	2100-	6	"	78°F ambient
	8/07/89	0300			
	8/07/89	2100-	6	"	75°F ambient
	8/08/89	0300			
	8/08/89	2000-2130	1.5	7x100KW	#1 off line
		2130-0200	4.5	8x100KW	Finis
		TOTAL hours	104.5		

The second diesel generator was brought on-line and the two diesels were actually run in parallel (ie synchronized). Although interesting as an exercise in power generation, parallel operation was abandoned in favor of the simpler arrangment in which one diesel drove four transmitters while the other drove the other four. This arrangment avoided the problem and dangers of loss of generator synchronization. With the two diesels operational, all eight transmitters could be run at 100KW each for long durations.

The original Henry Radio radio frequency amplifiers that drove the Platteville transmitters were replaced by ENI (Model 240L, 50 Watt) broadband units, which were much more reliable.

During the first campaign, 73 hours of operation were delivered. On one day, (6/17/87) the system suported the Penn State experiments continously for 12 hours. Occationally, transmitters would stop when interlocks over reacted, but generally the transmitters could put were back on-line within minutes.

The HIPAS heater is described in a paper that has been accepted for publication in Radio Science in 1990. It is attached as Appendix I, and is a very complete description of the HIPAS heater during all of the campaigns. Noteworthy of the array is the fact that each antenna is driven from a single Platteville transmitter and each can be individually controlled in phase, permitting the RF beam pattern to be scanned or pointed or defocused. Another feature of the array are the crossed radiating dipoles which produce either right or left circular polarized patterns depending on how the antennas are connected to their balun terminals. The circular polarization of the radiating beam is described in considerable detail the Appendix I paper.

At the onset of the first campaign, any polarization change had to be made by climbing the antenna towers and changing the antenna connections by hand, which meant that half a day was typically needed to change the polarization of the the array. By the time of the third campaign switches had been installed on the tops of each antenna, so that the change could be made from the ground. The polarization can now be changed in less than five minutes. The polarization switches were of HIPAS design and were fabricated both at the site and with the aid of the UCLA Physics Department machine shop.

During the first two campaigns the array was phased or pointed manually, via delay boxes with switches that set the delays on the inputs to the individual Platteville amplifiers and associated antennas. The beam was pointed by pre calculation of the array pattern. Two operators, working furiously, could reset the direction of the beam in about 2 minutes. By the time of the third campaign, voltage variable phase shifters had been installed and the pointing or dephasing was controlled by a personel computer (PC). A beam forming time of 10 milliseconds was achieved with this first PC controlled system. The system was as shown in Figure 4 of the Appendix I paper. At the onset of the last campaign an even faster system had been installed with 15 microscond beamforming times. The new sytem permitted "painting" experiments.

To phase the array properly each antenna has to be sampled and compared with the others. The base of each antenna (see also Figure 4, Appendix I) has a sampling loop which is now connected to a 1000 foot long piece of RG-9U coaxial cable. The cables ends are all brought to a distribution panel at the control console; there the phases are compared with either an oscilloscope or vector voltmeter. The excess cable on each run are left wound on the cable spools to serve as chokes to keep RF induced on the outerbraid from interfering with the phase measurments (on the center conductors). The longer cables to the most distant antennas (ie, #'s 1, 2, 6, & 7)are finished by by winding ends on magnetic cores. The phasing cables were orginally RG-58U coax which was too light weight. Many were broken, RF burned, and poorly spliced. They were all replaced with the forementioned RG-9U cables with end chokes.

During the first campaign, harmonics of the radiating HF were found to interfere with television reception of channel 2 within the local community of Two Rivers, Alaska. The problem was solved by series resonant "traps" across the main tank circuit of the Platteville transmitters. The traps were tuned while monitoring televison reception at the bunk house, one half mile away. There was no problem in subsequent campaigns

We also procured a broadband isotropic RF radiation safety monitor (ie NARDA Model 8616 with 8662B Efield (0.3-1000MHz) and 8652 H field (0.3-30 MHz) probes). The monitor was used to carefully survey the site for unsafe levels of radio freuqency radiation, especially when the array was radiating a the megawatt level. At 3 MHz the US standard for whole body radiation, averaged over 0.1 hours, is 100 mW/cm^2. This corresponds to approximately 500 volts/meter amplitude. This standard was not exceeded beyond 100 feet of any antenna when the array was radiating at a megawatt. During operation, access roads into the antenna field are barricaded, a flashing light on the top of the generator building is activated, and the antenna field surveyed from control room for inadvertent intrusion.

Between the third and fourth campaign, Dr. Michael McCarrick of this laboratory moved with his family to the HIPAS site, for the purposes of better cooordinating the scientific work at the facility. It was during his tenure at HIPAS that diagnostics were set up at the NOAA, Gilmore Creek, approximately 35 kilometers North West of HIPAS, the fast beam switching system was installed, and the array was completely controlled by computers. With an ionosonde at NOAA, ionograms could be recorded while the heater was operating. During this same period special ELF detectors, developed by Dr. Dave Sentman of UCLA Space Sciences Group under a contract with the US Air Force, were installed at the NOAA site. With these special detectors, we were able to detect heater induced ULF excitation at 11 Hz, between the first two (7 & 14 Hz) Schuman earth E&M resonances.

Data links were also set up between the PSU receiver site at the University of Alaska and the HIPAS transmitter control , which allowed instantaneous monitoring of the VLF resonance at the transmitter control center, and allowed an experimenter to see cause and effect in an on-line fashion. This was very important during the beam steering experiments. The same data line via IBM PC was also established between NOAA Gilmore Creek and the HIPAS control room allowing us to monitor the ionospheric conditions while the heater was running continuously.

The electric starting motors on the diesel generators were replaced by air starters, which are much more reliable: particularly since replacement electric motors are no longer available.

The reliablity of HIPAS depends on regular maintenance, especially during severe winter periods. The diesel generators are checked on a weekly basis and all the heating and cooling systems now have back ups. HIPAS weathered two severe winters (one where site temperatures dropped to $-70^{o}F$) and was able to run campaigns after each. We attributed this performance to the excellant on-site staff mebers, who were able to foresee potential problems and take action.

Reference to Table I, Campaign IV includes long-duration runs at total radiated power of one megawatt. The transmitters ran for a total of 104.5 hours with less than 1-2% down times.

Appendix II contains a copy of a paper written by R.G.Brandt for presentation at a special conference (May 1990) in Tromso, Norway on ionosphereic modification. It is an apt summary of the HIPAS's contribution to the four Penn State URI campaigns. Dr. R.G.Brandt is the Program Manager of the Office of Naval Research's which supported the entire project.

SUMMARY

In summary, the PSU and HIPAS staffs worked very well together during the four URI campaigns. HIPAS scientists would have liked to have had greater access to the data gathered during the campaigns, as well as participated in more post campaign discussions, as was orginally agreed upon the onset of the program. In reptrospect, the "opportunity" mode (in which experiments are conducted when conditions are favorable) would have been more preferable to the "campaign" mode (in which experiments are conducted during a block of time regardless of conditions), particularly due to the fact that the ionosphere is so variable.

During the URI program the HIPAS facility has been brought to a high degree of operational reliablity. It can now be operated any time of the year. In addition the facility has been instrumented to a stage that it can be controlled locally or remotely by computers. The invention of the "phase-modulation" technique by HIPAS sceintists made it possible to modulate the HF radiation at any low frequency without affecting the diesel power sources.

Abstracts of Published Papers

1. High Power Radiating Facility at HIPAS Observatory
2. Ionospheric RF Lidar
3. Observation of ULF Pulsation Electric Fields in the *D* Region Using the High-Power Auroral Simulation Heater Facility
4. Detection and Characterization of Geomagnetic Pulsations Using HF Ionospheric Heating
5. Determination of *D* Region Electron Densities from the ELF Frequency Stepping Experiment
6. Implementation of an ELF Array of Ionospheric Dipoles Using the High-Power Auroral Simulation Facility
7. Computer Simulation of ELF Injection in the Earth-Ionosphere Waveguide
8. A Diagnostic System for the Study of Extremely Long Wavelength Emission Produced by Ionospheric Modification
9. Mapping of the Polar Eletrojet Current Down to Ionospheric *D* Region Altitudes
10. Observations of ULF Pulsation Electric Fields in the *D* Region Using the High-Power Auroral Simulation Heater Facility

Radio Science, Volume 25, Number 6, Pages 1299-1309, November/December

Ionospheric RF lidar

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(Received July 7, 1989; revised October 31, 1989; accepted November 9, 1989.)

A new diagnostic consisting of a high-power radio frequency (RF) or microwave transmitter and a ground-based lidar (light detection and ranging) system is proposed for probing the ionosphere at heights of 80-200 km. The high-power transmitter creates energetic electrons in the ionosphere, which excite molecules to higher energy levels. These excited molecules become targets for a laser ranging system by resonantly absorbing and reradiating light at specific wavelengths. A laser pulse tuned to a specific transition wavelength is fired from a ground-based laser, and the reradiated light is detected by a ground-based light collector. A study of atmospheric species for ranging was performed, and the most suitable species were found to be N_2 and N_2^+. A laser whose output is matched exactly to the vibrational-rotational spectrum of ionospheric N_2 is proposed as the lidar master oscillator instead of a tunable dye laser.

Radio Science, Volume 25, Number 6, Pages 1423–1427, November–December 1990

Observations of ULF pulsation electric fields in the *D* region using the high-power auroral simulation heater facility

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(Received July 13, 1988; revised October 12, 1989; accepted December 19, 1989.)

During the two week interval from October 12 to 24, 1987, an experiment was conducted using the high-power auroral simulation (HIPAS) ionospheric heating facility near Fairbanks, Alaska. During the experiment the beam was modulated at ELF and ULF frequencies, and the data were recorded at the Geophysical Institute of the University of Alaska approximately 50 km from the HIPAS site. On several occasions naturally occurring ULF waves were present in the overhead ionosphere and were detected in the ELF polarimeter data and in the ground magnetometer data. The amplitudes of the ELF signals show high correlation with the magnitude of the naturally occurring ULF pulsations. Our analysis indicates that the ELF returns were produced by currents generated in the *D* region, near 75 km, where the bulk of the heater energy was deposited. The ULF pulsation signatures detected by the ground magnetometers reflect Hall currents flowing principally in the *E* region above 100 km. We believe that the correlation between ELF and ULF signals is produced as the naturally occurring ULF electric field penetrates to *D* region altitudes where it can drive currents in the heated ionosphere. It is the modulation of those currents by the heater beam which produces the ELF signals detected on the ground. ELF signal levels indicate pulsation fields of approximately 5 mV/m in the *D* region.

Radio Science, Volume 25, Number 6, Pages 1429–1438, November–December 1990

Detection and characterization of geomagnetic pulsations using HF ionospheric heating

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(Received July 13, 1988; revised June 8, 1989; accepted December 19, 1989.)

This paper describes the geomagnetic pulsations observed at the high-latitude ionosphere during the experiment dealing with the ionospheric generation of ELF/VLF electromagnetic waves. The experiments were conducted in June and October of 1987, and there was clear evidence of geomagnetic pulsations intermixed with the ELF/VLF signals generated. This was manifested in both the magnitude and phase data. This paper discusses the detectability of pulsations based on the ELF/VLF generation experimental technique and a method of characterizing the pulsation being observed. A simple simulation model is introduced to facilitate the interpretation of the data, and the procedure for characterizing the pulsation is described.

Radio Science, Volume 25, Number 6, Pages 1387–1395, November–December 1990

Determination of *D* region electron densities from the ELF frequency stepping experiment

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(Received July 13, 1988; revised January 3, 1990; accepted February 9, 1990.)

This paper describes the use of the generation of extremely low frequency (ELF) from heating of the *D* region of the ionosphere at high latitudes to estimate the degree of electron density ionization of the *D* region. In particular, the heating facility near Fairbanks, Alaska, known as the high-power auroral simulation (HIPAS) facility was used in this work. The theory of electron density synthesis is described, results of actual data presented, and electron densities determined. A new future ionospheric measurement technique is discussed.

Radio Science, Volume 25, Number 6, Pages 1397–1406, November–December 1990

Implementation of an ELF array of ionospheric dipoles using the high-power auroral simulation facility

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(Received July 13, 1988; revised December 27, 1989; accepted February 2, 1990.)

The feasibility of using the High-Power Auroral Simulation (HIPAS) facility for the creation of a linear array of ionospheric Hertzian dipole sources is investigated and presented as a possible ELF/VLF communication system, as well as an ionospheric diagnostic technique. Linear ELF arrays consisting of at least two elements can theoretically be used to monitor, in real time, the ionospheric conditions in the vicinity of the HIPAS facility. This provides a means of studying irregularities due to turbulence or wave structures within the *D* region. Several experiments have been proposed for far-field confirmation of ELF beam steering within the Earth-ionosphere waveguide, including varying the progressive phase and interelement spacing of an ELF array in a precise temporal sequence. The successful creation of two-element ELF ionospheric arrays using HIPAS is reported.

Radio Science, Volume 25, Number 6, Pages 1363–1367, November–December 1990

Computer simulation of ELF injection in the Earth-ionosphere waveguide

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(Received July 13, 1988; revised June 16, 1989; accepted February 9, 1990.)

A computer model to simulate ELF injection from an ELF ionospheric source in the 60–90 km region of the ionosphere is described. Results are presented for the geomagnetic location of the high-power auroral simulation (HIPAS) facility. These results include the efficiency of the ELF source with altitude and a contour plot of the ELF magnetic field intensity on the ground below the source.

Radio Science, Volume 25, Number 6, Pages 1369–1373, November–December 1990

A diagnostic system for the study of extremely long wavelength emission produced by ionospheric modification

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(Received July 13, 1989; revised July 20, 1989; accepted December 19, 1989.)

This paper describes a diagnostic system developed for the study of radio signals at frequencies below 8 kHz. Of specific interest are emissions produced by high-frequency heating of the ionosphere which modulates natural ionospheric current systems. Dual receivers allow independent reception on orthogonal loop antennas, and microcomputer systems provide real-time data acquisition and processing of all experimental data. Provisions are also made for automatic control of modulating frequency applied to the heating transmitters; operating frequencies may be changed on a preset schedule in tandem with receiver tuning.

Radio Science, Volume 25, Number 6, Pages 1375–1386, November–December 1990

Mapping of the polar electrojet current down to ionospheric *D* region altitudes

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(Received July 13, 1988; revised November 20, 1989; accepted December 19, 1989.)

The high-power auroral stimulation (HIPAS) heating facility has been used to modulate *D* region ionospheric currents at high latitudes, producing extremely low frequency (ELF) radio wave emissions. The behavior of these ionospheric currents can be deduced from a comprehensive study of the ELF signals received at a local field site. This paper examines the mapping of the polar electrojet current from the *E* region down through the *D* region, where it can then be modulated by the heater beam. Results have been obtained using a simple Cowling model of the electrojet. These results indicate that for an electrojet flowing at an altitude of 110 km with a scale size in excess of 100 km, the mapping of the horizontal components of the current can be completely characterized in terms of the Pedersen and Hall conductivities. This is attributed to the fact that the mapping becomes independent of scale sizes which exceed 100 km. Several ionospheric heating experiments are proposed, including beam steering for localized ELF generation in the mapped region below electrojets.

Radio Science, Volume 25, Number 6, Pages 1423–1427, November–December 1990

Observations of ULF pulsation electric fields in the *D* region using the high-power auroral simulation heater facility

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During the two week interval from October 12 to 24, 1987, an experiment was conducted using the high-power auroral simulation (HIPAS) ionospheric heating facility near Fairbanks, Alaska. During the experiment the beam was modulated at ELF and ULF frequencies, and the data were recorded at the Geophysical Institute of the University of Alaska approximately 50 km from the HIPAS site. On several occasions naturally occurring ULF waves were present in the overhead ionosphere and were detected in the ELF polarimeter data and in the ground magnetometer data. The amplitudes of the ELF signals show high correlation with the magnitude of the naturally occurring ULF pulsations. Our analysis indicates that the ELF returns were produced by currents generated in the *D* region, near 75 km, where the bulk of the heater energy was deposited. The ULF pulsation signatures detected by the ground magnetometers reflect Hall currents flowing principally in the *E* region above 100 km. We believe that the correlation between ELF and ULF signals is produced as the naturally occurring ULF electric field penetrates to *D* region altitudes where it can drive currents in the heated ionosphere. It is the modulation of those currents by the heater beam which produces the ELF signals detected on the ground. ELF signal levels indicate pulsation fields of approximately 5 mV/m in the *D* region.