

# **Investigation and Development of Data-Driven D-Region Model for HF Systems Impacts**

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Quarterly Report: June 1 to August 31, 2002

Prepared by:

J.V. Eccles, D. Rice, and J.J. Sojka  
Space Environment Corporation  
221 N. Spring Creek Parkway, Suite A  
Providence, UT 84332

R. D. Hunsucker  
RP Consultants  
Klamath Falls, OR

## **Investigation and Development of Data-Driven D-Region Model for HF Systems Impacts**

### **1. PROPOSED WORK**

Space Environment Corporation (SEC) and RP Consultants (RPC) are to develop and validate a weather-capable D region model for making High Frequency (HF) absorption predictions in support of the HF communications and radar communities. The weather-capable model will assimilate solar and earth space observations from NASA satellites. The model will account for solar-induced impacts on HF absorption, including X-rays, Solar Proton Events (SPE's), and auroral precipitation. The work plan includes:

1. Optimize D-region model to quickly obtain ion and electron densities for proper HF absorption calculations.
2. Develop indices-driven modules for D-region ionization sources for low, mid, & high latitudes including X-rays, cosmic rays, auroral precipitation, & solar protons. (Note: solar spectrum & auroral modules already exist).
3. Setup low-cost monitors of existing HF beacons and add one single-frequency beacon.
4. Use PENEX HF-link database with HF monitor data to validate D-region/HF absorption model using climatological ionization drivers.
5. Develop algorithms to assimilate NASA satellite data of solar, interplanetary, and auroral observations into ionization source modules.
6. Use PENEX HF-link & HF-beacon data for skill score comparison of assimilation versus climatological D-region/HF absorption model. Only some satellites are available for the PENEX time period, thus, HF-beacon data is necessary.
7. Use HF beacon monitors to develop HF-link data assimilation algorithms for regional improvement to the D-region/HF absorption model.

## 2. PROGRESS DURING THE FIRST QUARTER

The main goals for this first quarter were associated with the deployment of the low-cost HF monitoring experiment to maximize the data acquisition over the duration of the contract. We held weekly review meetings at Space Environment Corporation to review the progress of the work. Weekly reports are attached. In what follows, we highlight some of our accomplishments. A quick outline of the efforts is:

- ◆ finalize the most useful configuration for the low-cost HF monitoring experiment,
- ◆ order equipment necessary for the experiment,
- ◆ started software development work for data acquisition,
- ◆ deploy the equipment in Klamath Falls, Oregon.

Don Rice traveled to Klamath Falls, OR for a Team Meeting (July 8,9) with Bob Hunsucker of RP Consultants (RPC) to discuss measuring D-region absorption and other HF parameters using an HF monitoring system and to deliver the HF receiver. Don Rice also delivered and installed the Linux PC with modem to be used for data collection and archive. The antenna had been ordered but had not arrived for deployment.

Don Rice traveled to Klamath Falls, OR for a second Team Meeting (August 4-6) with Bob Hunsucker to deploy the BWG 1.8-30 MHz antenna and feedline. The receiver was connected and tested.

### 2.1 HF Monitoring Experiment Design

Space Environment Corporation (SEC) engineer, Don Rice, and Bob Hunsucker of RP Consultants (RPC) collaborated extensively in defining the most useful and cost efficient system to monitor D region absorption.

The NCDXF/IARU beacons identified in the proposal provide low power (100 W) signals on 14.100, 18.110, 21.150, 24.930, and 28.200 MHz. The specifics of Western Hemisphere beacons are:

<b>Beacon</b>	<b>Latitude</b>	<b>Longitude</b>	<b>Distance, SEC</b>	<b>Distance, RPC</b>
4U1UN, New York	40°45'N	73°58'W	3200 km	4000 km
VE8AT, Nunavut	79°59'N	85°57'W	4400 km	4500 km
W6WX, California	37°09'N	121°54'W	1000 km	500 km
KH6WO, Hawaii	21°38'N	157°55'W	4800 km	4100 km
YV5B, Venezuela	10°25'N	66°51'W	5600 km	6500 km

There are two shortcomings with these beacons. One is that the distances are long enough to require multiple ionospheric hops for reception. The other is that the frequencies are high enough that D region effects are reduced; lower frequencies would provide more insight into D

region influence. D region absorption is proportional to  $1/f^2$ , but the beacon frequencies still can be used if proper ray tracing is done to interpret the absorption effects. Solutions to monitor D region absorption are:

- ◆ Use NCDXF/IARU beacons with ray tracing to estimate D region pierce points and resulting absorption.
- ◆ Use time standard stations WWV (Fort Collins, Colorado) and WWVH (Hawaii) as beacons. These stations broadcast on 2.5, 5, 10, 15, 20, and 25 MHz. The signals are coded such that the WWV and WWVH broadcasts can be separated using signal processing.
- ◆ Establish a beacon at Logan, probably in the 75-m amateur radio band (3.5-4 MHz.) This operation requires an FCC license, and issues related to potential interference with other SEC instruments need to be resolved.

Figures 1 and 2 indicate the location range and bearing of WWV and WWVH broadcasts with receivers at Klamath Falls, OR and Bear Lake Observatory, UT. Klamath Falls was measured to have GPS coordinates of 42.17342°N, 121.84977°W, and 1320m elevation.

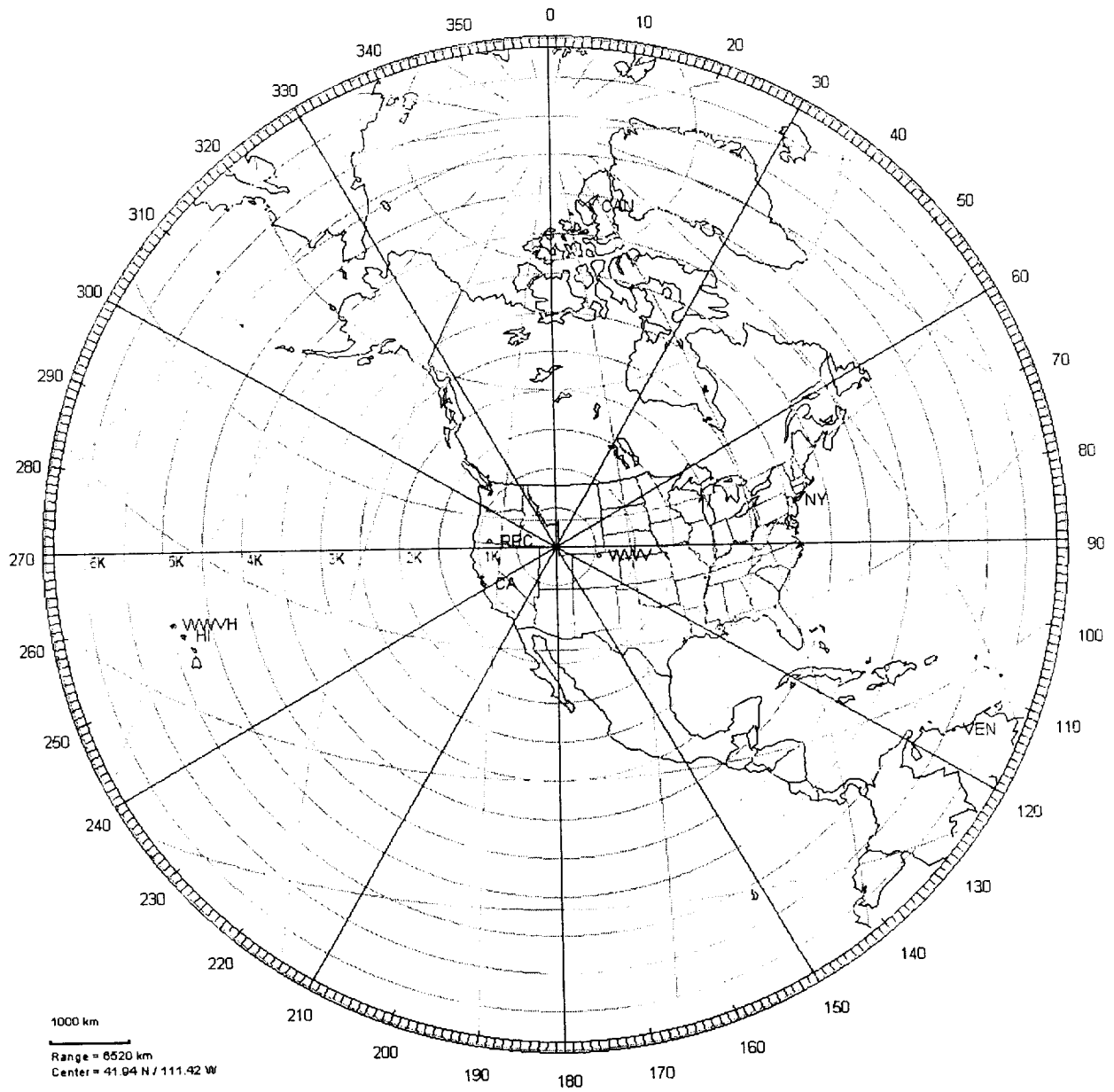


Figure 1. Plot of Range and Bearings (500-km circles) to Bear Lake Observatory, Garden City, UT. Time signals come from WWV in Colorado and WWVH in Hawaii. HF Beacons to be received are 4U1UN (NY), VE8AT (CAN), W6WX (CA), KH6WO (HI), YV5B (VEN).

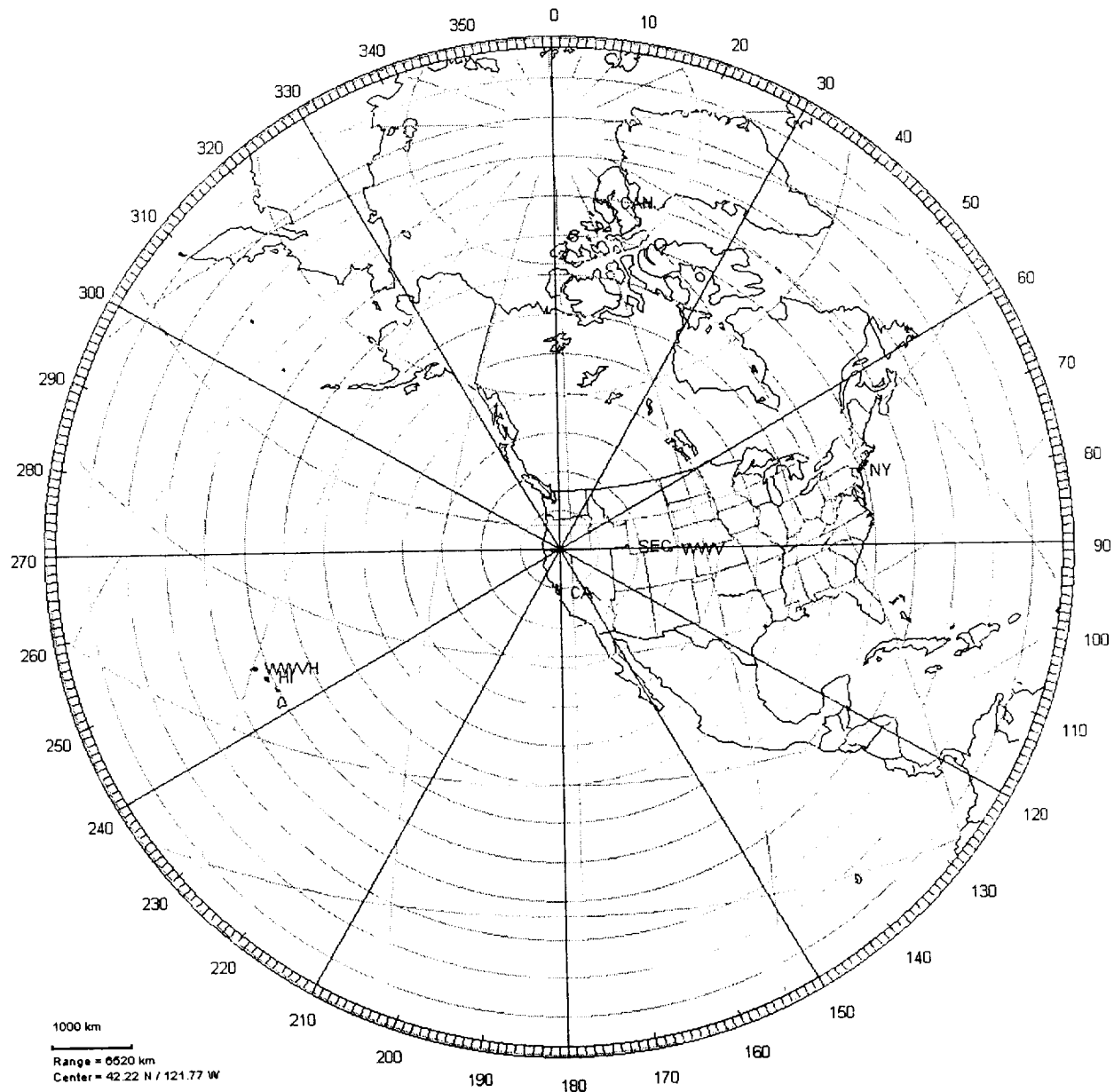


Figure 2. Plot of Range and Bearings (500-km circles) to RP Consultants in Klamath Falls, OR. Time signals come from WWV in Colorado and WWVH in Hawaii. HF Beacons to be received are 4U1UN (NY), VE8AT (CAN), W6WX (CA), KH6WO (HI), YV5B (VEN).

## *2.2 HF Absorption Monitoring Equipment*

Two PCs were purchased by SEC and configured with sound cards and Linux. The PC for Logan has a network card and will allow direct data collection. The PC for Klamath Falls has a modem card and a CD recorder to allow remote access via dial-in and periodic data dumps onto inexpensive CD-R media. Bob Hunsucker indicated that he already has a monitor and no room for a second one so a monitor switch is used between the LWS PC and an existing PC.

Two receivers (Icom R75 with high-stability option) and antennae (Barker and Williamson folded dipole, inverted V configuration) were purchased by SEC for Klamath Falls (OR) and Bear Lake Observatory (UT). SEC will use other existing equipment to implement the beacon near 3.75MHz. SEC rented test equipment (oscilloscope, signal generator, and frequency counter) to perform calibrations on the receivers and antennae before putting them into service. Figure 3. and 4. are schematics of the two HF monitoring systems being deployed at Klamath Falls and Bear Lake Observatory.

A site map of Bear Lake Observatory (BLO) (Figure 5.) shows the layout of SEC instruments (magnetometer, GPS Scintillation monitor antenna, and ionosonde antenna) in relation to the BLO facility and other instruments. The mast holding the CADI (Canadian Advanced Digital Ionosonde) antenna will be used to hold the BWD-1.8-30 FDMK antenna for the monitoring experiment. Sufficient quiet time between ionosonde soundings will be created to monitor HF signals of interest.

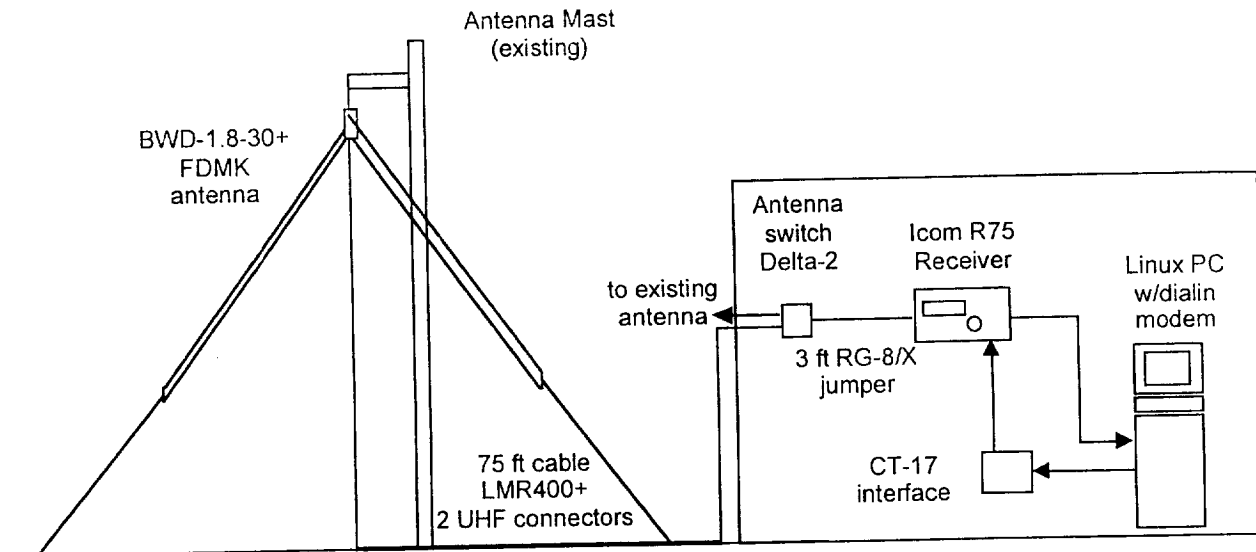
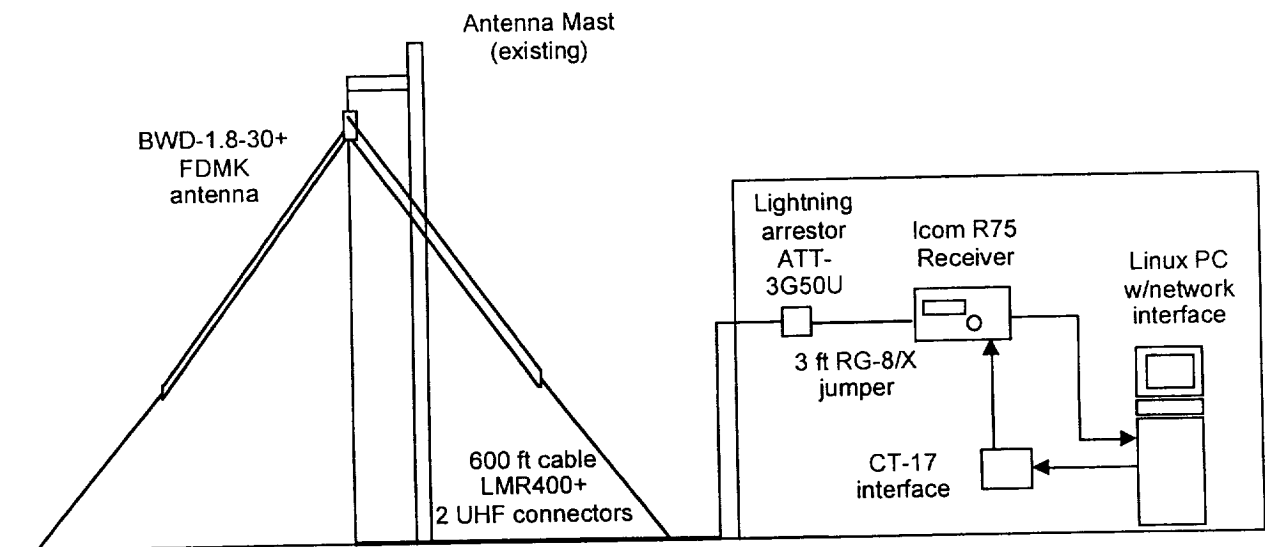


Figure 4. System Diagram of the monitoring system at Klamath Falls, OR. The system will monitor NCDXF/IARU beacons (14-28 MHz) and WWV (2.5, 5, 10 MHz). PC controls receiver via CT-17 interface and processes audio signal to determine signal strength.



Note: Use Icom 718 transceiver instead of R75 for beacon operation.)

Figure 5. System Diagram of the monitoring system at Bear Lake Observatory near Garden City, UT. The system will monitor NCDXF/IARU beacons (14-28 MHz) and WWV (2.5, 5, 10 MHz). PC controls receiver via CT-17 interface and processes audio signal to determine signal strength. Operation is same as Oregon site but may be modified to operate as a beacon on 1.8 or 3.5 MHz if the transceiver is purchased.



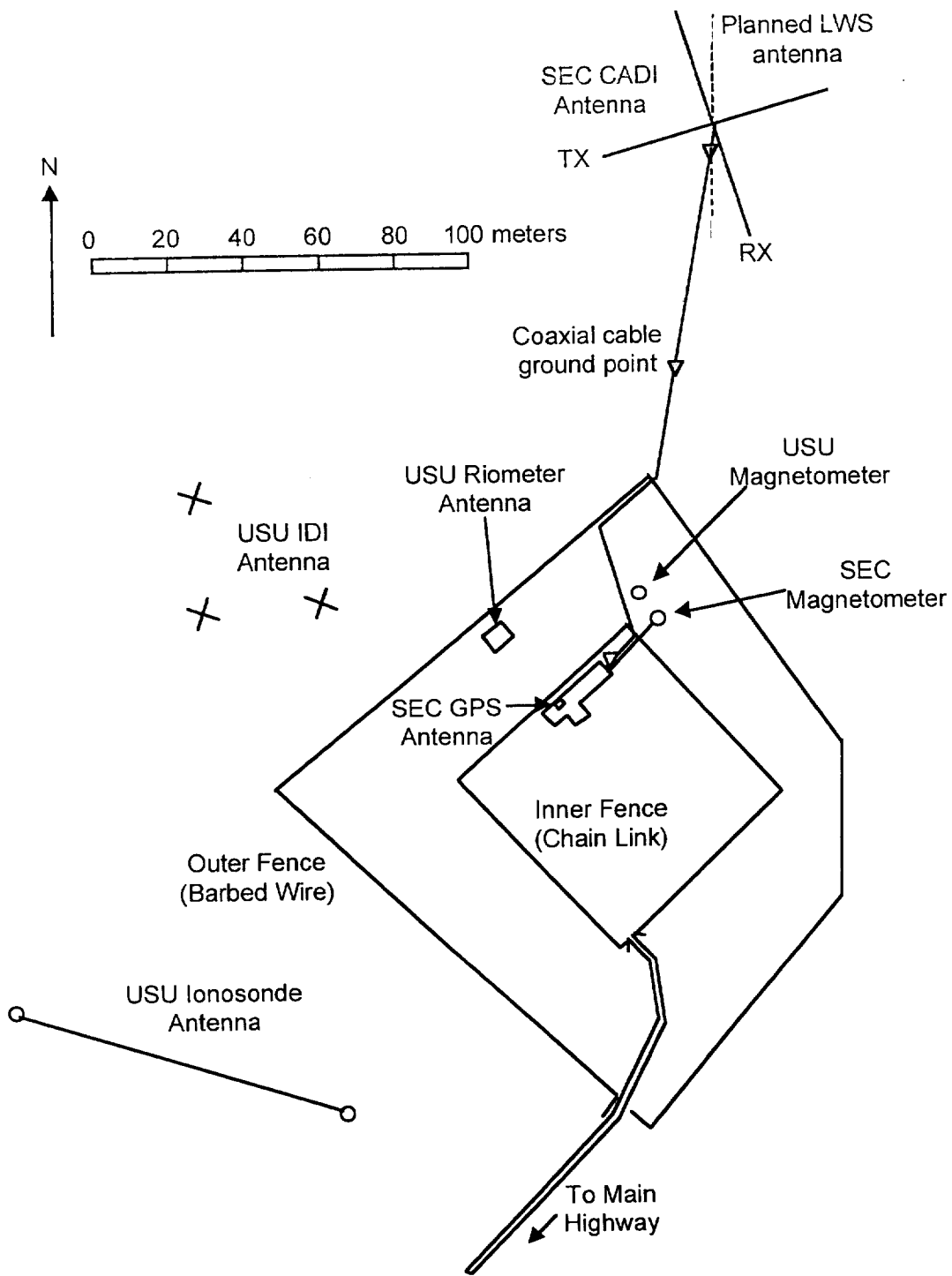


Figure 5. Site map for Bear Lake Observatory near Garden City, UT.

### *2.3 Software Development Status*

The Linux PC at Klamath Falls and BLO was put together to allow for remote upgrades, operation, and archiving via INTERNET connections from Space Environment Corporation's main office in Providence UT. The modem on Klamath Falls computer was configured for dial-in operation and file transfers were tested. After some difficulties with the integrated sound hardware, a working configuration with a SoundBlaster PCI card was achieved, and the receiver audio can be captured and displayed on a simple spectrum analyzer application. This analyzer software has been modified to identify the beacon signals and estimate the signal power. The software modification is not completed for yet for autonomous operation.

The control interface between the PC and the receiver turned out to be a little simpler than expected (simpler than that of other Icom radios) and a simple program has been developed to change the receiver's frequency and operating mode (AM, CW.) Other receiver parameters (preamplifier, noise blanker, etc.) need to be controlled but that should be straightforward. Software has been installed to generate Morse code signals for testing the Linux signal processing software, since receiving actual signals near the development PCs with the limited indoor antenna available is difficult.

### *2.4 HF Beacon Design*

It is important to establish a short hop beacon for local D Region absorption estimates. This will help interpret absorption longer path transmissions with multiple hops. A local beacon could be generated by SEC's CADI transmitter, though software ability provided by the CADI manufacturer may not provide for our requirements. We are pursuing with the manufacturer for such a possibility. We are also pursuing a second beacon activity using Don Rice's Icom transmitter to generate a beacon on a campaign basis near 3.75 MHz. A request for transmission authorization will be submitted.

### *2.5 D-Region Model*

All the necessary publications for Dr. Swider's D Region model were received from Dr. Swider. The software and test runs are now available to begin the D-Region modeling effort. However, the spending levels incurred by the equipment purchases and deployment have not permitted allocation of first quarter funds to the modeling effort. This will begin in the second quarter.

### *2.6 RP Consultant's Effort*

Bob Hunsucker has aided in the planning of the two monitoring sites and has begun analysis activities associated with the effort. He has provided June and July monthly reports and a first quarterly report to SEC to document his consulting effort. These are attached.

RPC's  
First Quarterly Report

August 13, 2002

Dr. Vince Eccles  
Space Environment Corporation  
221 N. Spring Creek Parkway, Suite A  
Providence, Utah 84332

Dear Vince;

Here is my first quarterly report on the DDDR Project. I'll return from the URSI-GA on August 25<sup>th</sup>, so please contact me if there are questions on this report.

Sincerely,



Dr. Robert Hunsucker  
Senior Partner, RPC

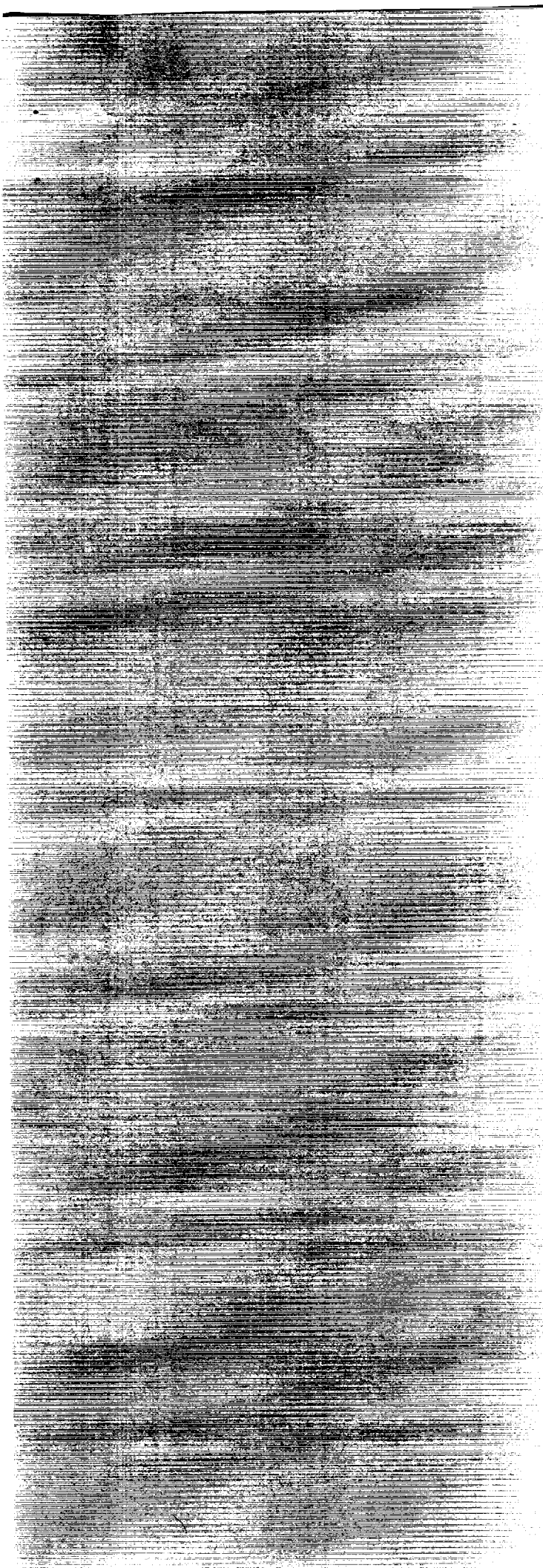
**First RP Consultants Quarterly Report on SEC/DDDR Program**

**(Covering Period June through August 2002)**

**Submitted by Dr. Robert Hunsucker, Senior Partner, RPC-Klamath Falls, OR 97601**

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- III.) First Team Meeting in Klamath Falls, OR – Comments on measuring D-region Absorption and other HF parameters using the SEC/RPC HF Monitoring System – July 9, 2002.**
- IV.) Second DDR Team Meeting – August 6, 2002.**



Absorption Theory and Measurement applied to the SEC/LWS-NASA HF Monitoring Program.

R.D.Hunsucker  
RPC-Klamath Falls, OR

July 2002

This is a short summary of ionospheric absorption theory and measurement techniques applicable to the SEC/ RPC-LWS/NASA monitoring and modeling effort. Most of the material is abstracted from the references listed at the end of this report.

The *attenuation* of radio waves can be described by,

$$E = E_0 \exp (- \kappa L) \text{----- 1.)}$$

where E = field strength of attenuated wave  
E<sub>0</sub> = " " " unattenuated wave  
κ = absorption coefficient of medium  
L = length of path

The absorption coefficient, κ, can be interpreted as the imaginary part of a generalized complex wave number.

In the ionosphere the absorption can be expressed as,

$$A \approx \kappa \int_{L_1}^{L_2} N \nu / [ \nu^2 + ( \omega \pm | \omega | )^2 ] dL \text{----- 2.)}$$

This expression holds for non-deviative absorption and for  $\mu^2 \gg \chi^2$ ,

where μ = the complex refractive index  
χ = Absorption index  
κ = absorption coefficient per unit length =  $e^2 / (2\epsilon_0 mc)$   
ω = the angular frequency of the signal  
ω<sub>L</sub> = the longitudinal angular frequency

Non-deviative absorption occurs in regions where  $\mu \approx 1$ , but where the product Nμ is large, typical of absorption of HF waves in the D region.

Deviative absorption occurs near the top of the trajectory or anywhere along the path where marked bending takes place and can be expressed as,

$$\kappa \approx \nu / [2c (1 \pm Y)] \cdot (1/\mu - \mu) \text{----- 3.)}$$

where  $Y = (e/m) B_0$

Total Absorption.

In order to obtain total absorption we need to integrate over the ray path,  $L$ , so the *total absorption* is given by

$$\Lambda = 8.68 \int_L \kappa \, dL \text{ (dB)} \text{-----} 4.0$$

$\kappa$  is in nepers per unit length.

It is sometimes convenient to utilize an *amplitude reflection coefficient*,  $\rho$  in the calculation of ionospheric absorption, so if  $E_I$  is the amplitude of the incident electric field and  $E_r$  is the amplitude of the reflected field, then

$$\rho = E_r / E_I = e^{-\int_L \kappa \, dL} \text{-----} 6.)$$

so,

$$- \ln \rho = \int_L \kappa \, dL \text{-----} 7.)$$

and we can write

$$\alpha = 20 \log \rho = - 8.68 \ln \rho \text{ (dB)} \text{-----} 8.)$$

We must also, however, make allowance for spatial spreading of the antenna beam, focussing and retardation of the wave.

Table 1 (from Davies, 1969) Gives the Total Absorption in Model Ionospheric layers

Electron-density profile	Collision profile	Type of absorption	Absorption	Comments
$N = N_0$	$\nu = \nu_0$	Nondeviative	$\int \kappa \, ds = 1.2 \times 10^{-7} f^{-2} N_0 \nu_0 T$	(1) $T$ is slab thickness
Parabolic [eqn. (5.11)]	$\nu = \nu_0$	Deviative and nondeviative	$\int \kappa \, ds = \frac{y_m \nu_0}{2c} \left( \frac{1+x^2}{2x} \ln \frac{1+x}{1-x} - 1 \right)$	(2) $x = \frac{f}{f_c}$ , $f_c$ is critical frequency
$N = N_0$	$\nu = \nu_0 e^{-z/H}$	Nondeviative	$\int \kappa \, ds = 1.2 \times 10^{-7} f^{-2} N_0 \nu_0 H (1 - e^{-T/H})$	(3) $z = \frac{h - h_0}{H}$ ; $H$ is scale height; $T$ is slab thickness
Chapman [eqn. (2.47)]	$\nu = \nu_0 e^{-z/H}$	Nondeviative	$\int \kappa \, ds = 4.13 \nu_0 H c^{-1} \left( \frac{f_c}{f} \right)^2 \cos^{3/2} \chi$	(4) Double traverse
$N = a(h - h_0)$	$\nu = \nu_0$	Deviative and nondeviative	$\int \kappa \, ds = \frac{2 \nu_0 f^2}{3 cka}$	(5) Wave reflected, $k = 80.5$



## Methods of Measuring Absorption.

Rawer (1976) has given in considerable detail, descriptions of the "URSI Techniques for Measuring Absorption" and we herewith list some of the salient features of the methods which apply to our monitoring program.

Method A1 (Pulse Reflection Method) - Essentially a high power pulsed "radar" with carefully calibrated parameters (2-3 MHz).

Method A2 (Cosmic Noise Absorption)

Method A3a ( Oblique Incidence Field strength Observations on Frequencies > 2 MHz).

Method A3b( Oblique Field Strength Measurements on Frequencies < 2MHz in the MF Broadcast Band.

The Partial Reflection Method.

### Techniques applicable to our monitoring program.

Method A2 - The Riometer – Detailed descriptions are given in the References. This Technique utilizes a carefully calibrated total power receiver to measure the variation in the amplitude of extraterrestrial radiation – calibrated with an internal noise source. Data analysis is based on obtaining a good "quiet-day curve". The operating frequency is a compromise between the sensitivity to absorption and is limited by HF propagated interference (usually in 20-40 MHz range). Riometers are mainly deployed in the auroral and polar cap regions. If a Riometer is deployed at BLO, an operating frequency of 25 MHz is recommended for this part of the solar cycle.

Method A3 – Applies directly to our HF monitoring program. A useful technique for long-term monitoring of midlatitude ionospheric absorption. Must use the "skywave" and reject the groundwave. Receiver bandwidth must be appropriate for rejecting interference and must have adequate sensitivity and stability. Rawer's manual emphasizes that a *single-hop* E-mode is preferable, with typical geometry as shown in Figure 1, and that the maximum distance for accurate results is ~ 500 km.

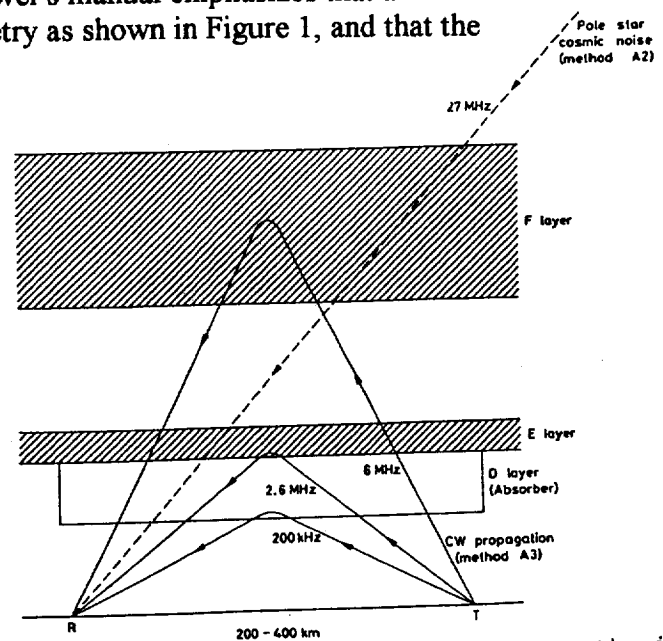


Fig. 1 Ray geometry for measurement of absorption in the ionosphere, methods A2 and A3

The relative strength of different modes and the effects of the receiving antenna elevation polar pattern and polarization are discussed in Rawer (1976) pp. 125-129. The *dominant mode* must be identified and other modes rejected, also the nighttime signal should be used for calibration. Rawer (1976) also has an extended discussion (pp. 131-146) on antenna and receiver calibration.

### Some Space Weather-Absorption Considerations

The NOAA Space Environment Center in Boulder, Co calculates realtime D-region "background Absorption" from GOES x-ray data interpreted by empirical relations outlined as follows:

They define a "Highest-Affected-Frequency as the highest subpolar frequency experiencing 1 dB of absorption at vertical incidence as

$$\text{HAF} = 10 \log (\text{flux}) + 65 \text{ ----- } 9.$$

where: HAF = Highest Affected Frequency (MHz) ----- 10.  
flux = X-ray flux in  $\text{Wm}^{-2}$

the frequency is degraded  $\propto \cos^{0.75X}$   
where X is the solar zenith angle.

They then calculate absorption by

$$A = (\text{HAF})^2 / f^2 \text{ ----- } 11.$$

where A = absorption in dB  
f = the operating frequency in MHz

It might be worthwhile comparing the absorption values we obtain from the monitoring program with the NOAA/SEC empirical data.

### **Summary:**

**I believe that monitoring the 2.5 and 5.0 MHz WWV transmissions from Ft. Collins, CO to Klamath Falls (1401 km) could produce relatively quantitative absorption data using adequately "robust" statistical analysis. The dominant mode for each frequency would be determined by our receiving antenna, the great-circle distance and the ionospheric reflection height (the CADI data could be used for the latter for raytracing). Our absorption measurements probably would also be enhanced by establishing our own beacon on an 823 km path from Logan to KF (f=3.75 MHz) or possibly on a shorter path.**

4.)

The nighttime skywave WWV 2.5 and 5.0 MHz signals could provide the calibration for absorption measurements by establishing a "quiet-day" hourly median signal strength curve selected from the magnetically quietest 10 or 12 days of the month. The solar zenith angle variation at the midpoint of the path could also be utilized to detect seasonal variations of absorption. The difference in dB between the hourly median "quiet day" nighttime signal strengths and the daytime hourly median signal strengths should be a measure of the absorption.

The 2.5 and 5.0 MHz signal strength ratios obtained above should differ by a  $1/f^2$  if they really measure absorption. It should be remembered that we are really measuring *attenuation* by this technique – which includes absorption, spatial spreading of the beam and the reflection coefficient ( $\rho$ ) of the E or F- layer, however *absorption* is considered in the literature to be the dominant component. Plots of the realtime signal strength at 2.5 and 5.0 MHz should show inflection points near sunset and sunrise at  $h \approx 75$  km.

We will need to utilize online Space Weather data to determine solar disturbance effects on our absorption values.

#### References:

Davies, Kenneth (1969) Ionospheric Radio Waves. Blaisdell Publ Co., Waltham, MA, Toronto, London. (L.OC. Number 68-11726); Chapter 6.

Hargreaves, J.K. (1992) The Solar-Terrestrial Environment. Cambridge Univ.Press, Cambridge, New York. (ISBN 0 521 32748 2); Sects. 3.5.1 and 7.1.4.

Hunsucker, R.D. (1991) Radio Techniques for Probing the Terrestrial Ionosphere. Springer-Verlag; Heidelberg, Berlin, London, New York (ISBN 3-540-53406-7), Sects. 2.2.2 and Chapt.7

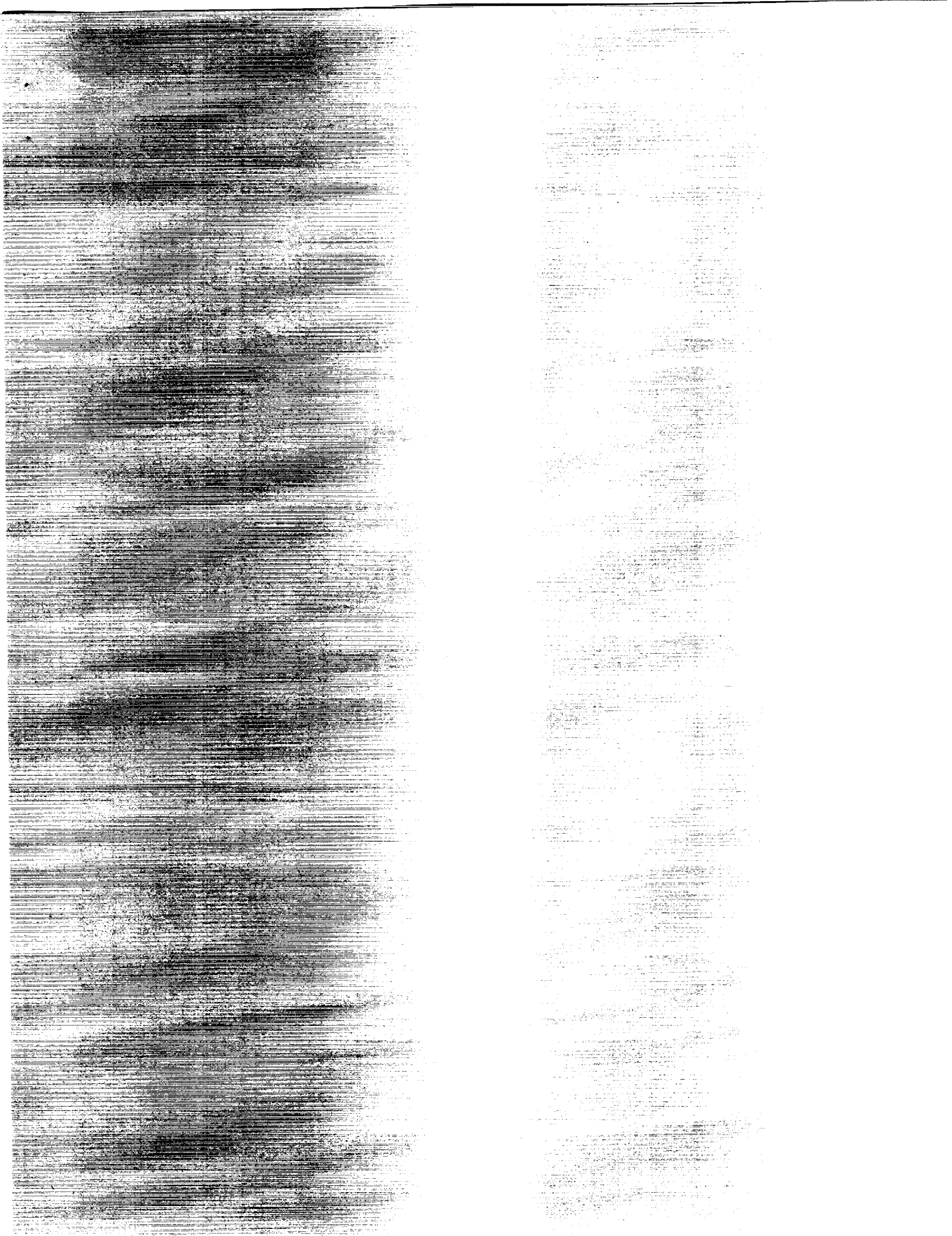
Rawer, K. (1976) Manual on Ionospheric Absorption Measurements. Rep. UAG-57; World Data Center A for Solar-Terrestrial Physics; Boulder, CO.

Other material on Ionospheric Absorption can be found in:

Hunsucker, R.D. and J.K.Hargreaves (2002-November) The High-Latitude Ionosphere and its effects on Radio Propagation. Cambridge Univ.Press; Cambridge, London, New York.

Schunk,Robert W. and Andrew F. Nagy (2000) Ionosphere: Physics, Plasma Physics and Chemistry. Cambridge Univ.Press; Cambridge, London, New York ( ISBN 0521632374).

<http://www.sec.noaa.gov/radiusers/absorption> (see the "Documentation")



More Comments on measuring D-region Absorption from our HF monitoring.

R.D.Hunsucker  
RPC/KF

July 5, 2002

## OUTLINE

### 1.0) Introduction:

The purpose of the HF Monitoring program is to provide estimates of the diurnal, seasonal, sunspot cycle and "storm-time" variation of D-region absorption for the SEC Ionospheric Model and to validate selected predictions. The data will also provide good quality data for validation of predicted values of MUF on selected paths. We will concentrate of midlatitude data at first, but also include data on trans-auroral, equatorial and polar HF paths.

Signal strengths will be recorded at the Klamath Falls field site of WWV transmissions from Fort Collins, CO on 2.5, 5.0 and 10 MHz, as well as transmissions from the 14 HF beacons on frequencies of 14.100, 18.110, 21.110, 24.930 and 28.200 MHz operated by IARU/NCDXF. It is also tentatively proposed to operate a dedicated beacon on 3.75 MHz over a short path in Utah.

Since D-region absorption is  $\propto 1/f^2$ , our measurement of the amplitudes of the 2.5 and 5.0 MHz signals from WWV at Klamath Falls may be the most useful of our efforts, but we need to estimate the probable mode structure for each analysis case. This would be based on raytracing using our modeled antenna vertical pattern and on the daily E-layer parameters from the Logan CADI.

2.0) Details of Monitoring program. (Description of transmissions, characteristics of path, sampling frequency, etc.)

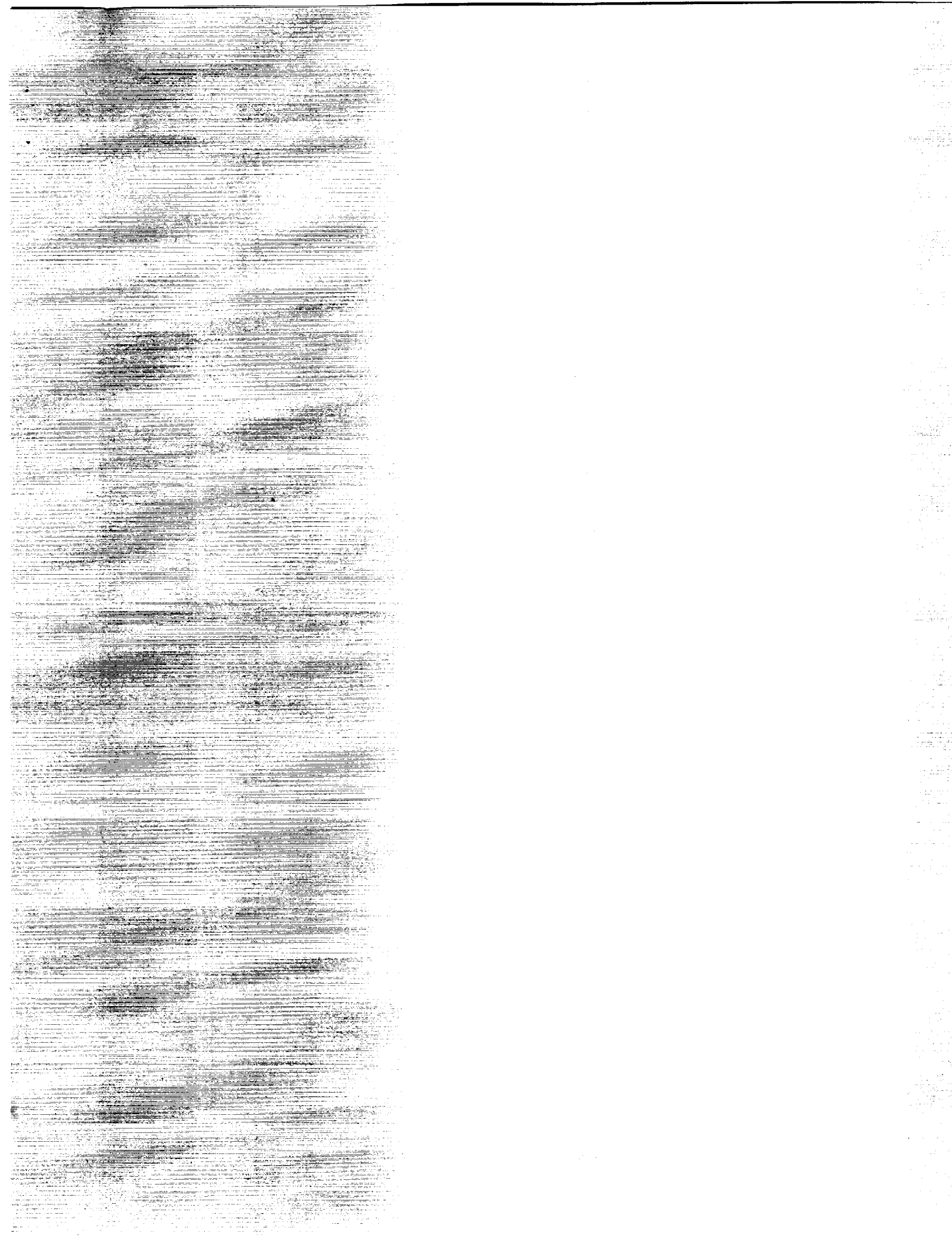
- 2.1) WWV Reception on 2.5, 5.0, 10.0 and 15.0 MHz.
- 2.2) IARU HF Beacon reception (path selection for 1<sup>st</sup> year).
- 2.3) Possible new beacon on 3.75 MHz ("NVIS path").

3.0) Interpretation of data.

4.0) Quantitative determination of D-region Absorption in a form which can be assimilated by the SEC computer model and validation of model predictions.

5.0) Utilization of the HF MUF data for PRISM, etc validation....

6.0) Other technical considerations of the monitoring program.  
(What has been accomplished on first KF site visit – present status)



Second DDDR Team Meeting

R.D.Hunsucker  
RPC/KF

D.D.Rice  
SEC/Logan

August 6,2002

Donald Rice and Robert Hunsucker participated in the second DDDR team meeting at the RPC site in Klamath Falls, OR on 4 - 6 August 2002. A Tower Climber from "Big Mack's Tree Service" of Klamath Falls assisted in the erection of the BWG 1.8-30 MHz antenna and feedline. Impedance as a function of frequency of the BWG 1.8-30 MHz were also made. The ICOM IC-R75 receiver was also installed and tested on the new antenna. WWV and Beacon transmissions were received at signal strengths over "S9". A station ground system was also installed.

Control and calibration software developed at SEC was installed on the RPC Linux PC. The audio cable and control (serial) cable were connected between the receiver and the PC, and a sample data set acquired to verify proper operation. The Linux PC was relocated into the equipment rack with the Icom receiver.

The PC/receiver system does not yet have the software in place to acquire data automatically but the hardware configuration is now complete.

It was noted that the Sunspot cycle 23 maximum is giving indications that it may be broader than average cycles, so the frequencies from 20 – 15 MHz may be received well through the Fall of 2002.

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R.D. Hunsucker

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D.D.Rice

First Team Meeting in Klamath Falls, OR - Comments on measuring D-region Absorption and other HF Parameters using the SEC/RPS HF monitoring System.

R.D.Hunsucker  
RPC/KF

D.D.Rice  
SEC/Logan

July 9, 2002

Introduction:

The purpose of the HF Monitoring program for the LWS/NASA program is to provide estimates of the diurnal, seasonal, sunspot cycle and "storm-time" variation of D-region absorption for the SEC Ionospheric Model and to validate selected predictions. The data will also provide good quality data for validation of predicted values of LOF/MOF on selected paths. We will concentrate of midlatitude data at first, but also include data collection on trans-auroral, equatorial and polar HF paths.

Signal strengths will be recorded at the RPC Klamath Falls field site of WWV transmissions from Fort Collins, CO on 2.5, 5.0, 10, 15 and 20 MHz, as well as transmissions from HF beacons on frequencies of 14.100, 18.110, 21.110, 24.930 and 28.200 MHz operated by IARU/NCDXF. It is also tentatively proposed to operate a dedicated beacon on 3.75 MHz.

Since D-region absorption is  $\propto 1/f^2$ , our measurement of the amplitudes of the 2.5 and 5.0 MHz signals from WWV at Klamath Falls (and measurements of signal amplitudes of suitably located MF Broadcasting stations) may be the most useful of our efforts, but we need to estimate the probable mode structure for each analysis case. This would be based on raytracing using our modeled antenna vertical pattern and on the daily E-layer parameters from the Logan CADI.

2.0) Basic features of Monitoring program. (Description of transmissions, characteristics of path, sampling frequency, etc.)

- 2.1) WWV Reception on 2.5, 5.0, 10.0, 15.0 and 20.0 MHz.
- 2.2) IARU HF Beacon reception (path selection for 1<sup>st</sup> year).
- 2.3) Broadcast Band (550 – 1600 kHz) skywave reception.
- 2.4) Possible new beacon on 3.75 MHz.
- 2.5) Path characteristics vs. URSI Technique descriptions.



3.0) Interpretation of data. A discussion of the essentials of ionospheric absorption theory and techniques for measuring absorption is being prepared (RDH) and will be submitted to Dr. Vince Eccles of SEC as part of the RPC July monthly report.

4.0) Quantitative determination of D-region Absorption in a form which can be assimilated by the SEC computer model and validation of model predictions. This will be a joint effort by SEC and RPC personnel.

5.0) Utilization of the HF MUF data for PRISM, etc validation. The Maximum-Observed-frequency (MOF) and Lowest-observed-Frequency (LOF) on our monitored paths as a function of time, season, solar flux and geomagnetic activity should provide excellent validation data for selected extant HF Propagation Prediction Programs (PRISM, VOACAP, ICEPAC, etc.)

6.0) What has been accomplished on first KF site visit, and present status of equipment. Installed Linux PC and tested modem and CD-R operation; acquired a 500 VA UPS. PC will be left turned off until operational software is installed. B&W antenna has not arrived (ordered 10 June 2002) so installation is pending; got GPS coordinates for antenna and measured SWR of existing antennas at frequencies of interest. LPA is currently stuck pointing east and will require maintenance. Made copies of reference materials (Rawer manual, invoices, etc.)

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R.D.Hunsucker  
RPC

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D.D.Rice  
SEC



RPC's  
June and July Monthly Reports

*RP Consultants*

*Robert & Phyllis*

To: Dr. Vince Eccles

From: Dr. Robert Hunsucker


Subj: Monthly Report for June 2002

During this month, I have worked closely with Mr. Donald Rice of the SEC Staff on designing the HF Monitoring system for obtaining D-region absorption (and other HF) data for the SEC NASA/LWS program, "Investigation and Development of Data-Driven D-region Model for HF System Impacts". Specific actions were:

- 1.) Selection of specific HF transmissions to be monitored and qualitative examination of antenna takeoff angles and path characteristics.
- 2.) Specification and ordering an appropriate receiving antenna (covering the lower part of the HF bands) for the Klamath Falls (KF) and Logan (BLO) sites and characterizing the log-periodic antenna at KF for monitoring of the IARU/NCDXF beacons.
- 3.) Specification and ordering of the HF monitoring receiver based on performance and cost.
- 4.) Determining the best location for the B&W (lower HF) antenna at KF and preparing the site for erecting the antenna. This included removing two medium size Western Juniper trees, assembling a metal outrigger for the 60 ft tower to suspend the B&W antenna center and selecting proper ground anchors for the ends.
- 5.) Survey of the HF spectrum from 2.5 to 30 MHz at the KF field site. Results indicate a low-noise environment on the specified monitoring frequencies.
- 6.) Started a literature survey on the characterization of D-region absorption from HF measurements, HF prediction programs and ionospheric ray-tracing.
- 7.) Re-arranged part of the RPC office to accommodate new monitoring equipment and computer.
- 8.) All items necessary for completing the HF monitoring system at KF (except the B&W Antenna and the receiver have been received at this site.

Copies of discussion of some of the items above were also sent to Dr. Eccles this month.

Submitted 5 July 2002.

  
Robert D. Hunsucker, Ph.D.  
Senior Partner, RPC

To: Dr.Vince Eccles

From: Dr.Robert Hunsucker

Subj: Monthly Report for July 2002

As in June, I worked closely with Mr.Donald Rice of the SEC Staff on design of the HF Monitoring System and on planning data analysis. During Mr.Rice's visit (July 7-9) we installed some of the ancillary monitoring equipment at the Klamath falls site and planned the antenna installation. The BWD 1.8-30 MHz antenna arrived at this site and appears to be complete. A copy of a brief report describing our "First Team Meeting" was sent to Dr.Eccles on July 9, 2002.

I continued work on a report on "Absorption Theory and Measurement Techniques applied to the SEC/LWS/NASA HF Monitoring Program" and sent a Draft to Dr.Eccles on 19 July 2002.

Submitted on July 31, 2002.

Robert D. Hunsucker, Ph.D.  
Senior Partner, RPC

Weekly Reports

More Comments on the HF Monitoring Program of "HIDAVE"  
R.D.Hunsucker  
RPC/KF

June 3, 2002

As mentioned in my e-mail today, here are some more specific comments on HF monitoring. In general, I believe that monitoring all the WWV/WWVH HF transmissions and selected IARU HF beacons at Klamath Falls is the most cost-effective way to go. We might also want to monitor the 2.5 and 5.00 MHz WWV transmissions at Logan, because of the shorter propagation path. It would probably save us considerable effort and effort and funds to eliminate establishing our own beacons. Some more specific comments follow:

- The RPC site at Klamath Falls – Fortunately this is a relatively "low noise site" (not much RFI) and the log-periodic antenna is rotatable and covers ~ 7 – 30 MHz. It is an "M<sup>2</sup> Engineering, Model LPA 10-30 MHz" antenna (with a 7 MHz element added) with a claimed forward gain at mid frequency of ~ 6dB over a halfwave dipole and a front-to-back ratio of ~ 15 dB. The specified halfpower beamwidth is ~ 65° in the E and H planes. At its 60 ft height the "takeoff angle" is ~ 30° at 15 MHz and higher on the lower frequencies.
- There is ample room in a 6 ft high "relay rack" in the RPC office to mount the HF monitoring equipment, computer, etc. either on shelves or rack-panel mounting. It might be possible to construct a horizontal antenna for 2.5 and 5.0 MHz on the 1.6 acres of space. There are many Juniper trees of ~ 50 ht available for support, or there may be room for a "Beveridge" or longwire type antenna running E-W for ~ 300 ft....
- The calculated optimum takeoff angle for an antenna to monitor the 2.5 and 5.0 MHz transmissions from WWV for a one-hop or two-hop mode are 8° and 16° respectively, so designing an antenna for this site may be a problem.

Since we are primarily concerned with the effects of the D region, measuring the signal amplitude variation on the 2.5 and 5.0 MHz frequencies on relatively short paths is important. During quiet times at midlatitudes the behavior of the D layer depends primarily on the solar zenith angle, but during disturbed periods anomalous absorption may be present and difficult to measure at these frequencies. Perhaps the Riometer at Logan could provide useful supplementary data during the latter times. I think that you have a Chivers" Riometer and a 20 MHz version would be best, if available.

- I'm not sure if you plan to use your own HF Propagation Prediction Program, but I have pretty good versions of VOACAP, ICEPAC and PropMan available here. I don't know about "PRISM", but as I recollect, you have something better.... I'm enclosing a sample ICEPAC plot for the WWV-KF path.

June 2002

**To:** Jan Sojka, Vince Eccles  
**From:** Don Rice  
**Subject:** To Beacon, Or Not To Beacon

We need to order the radio for our side of the LWS monitoring setup as soon as possible so I can do the calibrations and other preparations together with the RPC radio and get that one shipped off to Bob Hunsucker.

It would be easiest, and cheaper, to get the same receiver that we purchased for RPC, the Icom R75. However, that would leave us without a dedicated transmitter for setting up a beacon. I think that is acceptable because, as we've discussed, WWV provides us with reliable signals on 2.5 and 5 MHz, bracketing our proposed 4 MHz frequency.

If we still want to operate a beacon for political expediency or just for fun, there are two solutions. One would be to try to operate the CADI transmitter as a beacon. I sent an inquiry about this possibility to SIL and haven't gotten a response back yet. The main concern would be duty cycle, since pulse-mode transmitters are typically designed to operate for a few ms per second and might melt down if run continuously for several seconds. We also need more details about the software interface for such operations.

The second, and immediately practical, solution would be to use my own transmitter (also an Icom model) as the beacon on a campaign basis. In particular, I probably won't have time to play with my radio when school is on so it could be dedicated to the task during the winter. That would also give us the flexibility to put the transmitter elsewhere, such as at the Providence office, allowing it to be monitored at BLO as well as in Klamath Falls. Locating it away from BLO would also eliminate interference concerns with the ionosondes. We would have to come up with a compatible antenna but there are various solutions to that problem.

The next problem would be selecting a beacon frequency. Since we have signals on 2.5 and 5 MHz, the midpoint between them would be 3.75 MHz, which is conveniently in the middle of the amateur radio 80 meter band (3.5-4 MHz.) There is no beacon segment specified in the ARRL band plan for 80 m, and 3.75 MHz is on the dividing line between the CW/data portion of the band and the SSB phone portion. Interference from amateurs might be a concern, but it is hard to say since amateurs can pick operating frequencies arbitrarily within their allocations.

Alternatively, we could set up on the edge of the band, 3.5 or 4 MHz. The 3.4-3.5 MHz band is allocated to aeronautical mobile and is probably best avoided. The 4-4.063 MHz band is allocated to fixed and maritime mobile operations, so I suspect that a 4 MHz authorization would not be hard to acquire (3.75 MHz should be easy to get.) I don't know that 4 MHz would offer any advantage in terms of interference over 3.75 MHz, so the main factor would be scientific preference. (Seems to me there's a gyrofrequency in that neighborhood, if that's relevant...)

### **My Recommendation**

We should purchase the same setup for BLO that we acquired for RPC, and also request authorization for either 3.75 or 4 MHz for future beacon operation using my radio or the CADI.



If you want to follow this path, it would be very helpful if one of you could order the radio in my absence to get things going. The particulars are:

Universal Radio Inc. <http://www.universal-radio.com> or 1-800-431-3939

1 #0175 Icom R75 receiver \$599.95 (\$799.95-\$200 discount)

1 #2137 Icom CR282 high stability option \$114.95

1 #4077 Barker&Williamson BWD-1.8-30 folded dipole antenna \$199.95

Other odds and ends would be needed for the beacon transmit operations but we can deal with those later.

If you want to discuss all of this I hope to check in at the office on Friday June 28 before taking off to Oregon.

**To:** Jan Sojka, Vince Eccles, Susan Sojka  
**From:** Don Rice  
**Subject:** Shipping Equipment to RPC

I've left some boxes to be mailed (Fed Ex'ed, whatever) to Bob Hunsucker. I would like to have them get to him around July 4 so they'll be ready when I drop by around July 8.

One question is whether the items need to be tagged or otherwise logged before they are sent off (thus I didn't tape the boxes closed.) Here's what I'm sending over there:

Linux PC w/ modem and CD burner  
Keyboard, mouse, and other stuff (separate box)  
Monitor switch  
AEA antenna analyzer (I'll bring it back with me)  
Antenna mounting kit (hasn't arrived yet; two are coming, one for BLO, one for RPC)

What I'm NOT sending:

17" monitor (Bob says he doesn't have room for it...we'll share his existing monitor)  
Icom R75 (need to do some calibrations, install options, etc.)

What I've had sent to RPC directly:

B&W antenna, 100 ft coaxial cable, antenna switch, jumper cable

I would really appreciate it if you could send it out by some appropriate means. Tag the items or log them in if necessary. I'm hoping to make it back to the office June 28 to see where things stand. Thanks!

**DDDR Project Under NASA/LWS Contract NASW-2108**  
**Weekly Report**

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**July 8-12 of 2002**

by Vince Eccles

Mike Howsden has rejoined our company as a part time programmer to be assigned as tasks arise. One of his tasks will be to scan in the B. Swider D region codes found in the documents; (1) "Computer Program for the Disturbed Steady-State Nighttime D-Region" and (2) "Steady-State Multi-Ion Disturbed D-Region Model". He has not started this effort but he received an outline of the work, tasks, required documentation of results, etc.

The June Monthly Report was written put together based on the monthly reports provided by Don Rice and Robert Hunsucker. The contract requires 5 copies of monthly progress reports. See attached "Reports of Work" from the NASA Contract NASW-02013.

## Project Status: July 12 2002

Don Rice

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### RIFS DAS

The data acquisition system behaved itself while I was away, with only a couple of outages caused by changing network addresses at SEC; no data were lost.

I haven't heard anything from the SUOMInet people about their installation plans and since I haven't been to BLO for a month I don't know if anything has changed out there. I should track down somebody (Pete Mace?) next week and see where things stand.

I also haven't heard from SIL in regards to CADI questions but I did get an response from John MacDougall. He said that they can extract the ordinary and extraordinary components given orthogonal receive antennas and two receivers, and didn't know of any problems working at higher altitudes (>510 km.) It appears that he is still using the DOS CADI software and isn't keeping track of what SIL is doing with the Linux version, so the difficulties I had with the higher altitudes might be due to the Linux software. He also had a pointer to his own CADI web pages:

<http://cadiweb.physics.uwo.ca>

which has PDF versions of various CADI papers that he has published.

### LWS

We now have both receivers but the antennas are back-ordered with an estimated ship date of July 19. There is considerable software development remaining but the key routines for control and acquisition seem to be working. The RF interference levels have risen considerably here so I need to find some solutions for testing the received signals.

After looking at the basic arrangement at Klamath Falls, I have a better idea of how things should go there. I made some measurements on the existing antennas but we are still waiting for the folded dipole to arrive.

A return trip seems to be unavoidable, and I'm looking at August 5-9 as the tentative time for that, hoping that the antenna arrives and the software situation is under control. Based on our experience this trip, I would prefer to rent a vehicle and drive from Logan to Klamath Falls. That would make it easier to haul equipment, including sharp pointy tools, and would allow some flexibility in leaving whenever the job was done.

Whenever the antenna arrives here, we will have to mount it on the CADI antenna mast and anchor the ends. Hopefully cooler weather will also arrive (October?) We will also need to arrange for running the feedline into BLO, preferably keeping it away from transmitter coaxial cables in and around the building. Running the cable into BLO could be done anytime, e.g. if a crew was there installing SUOMInet hardware.

## **Project Status: July 26 2002**

Don Rice

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### **BLO**

I visited BLO for the first time in more than a month on July 19 and found the weeds have taken over the place. There is no sign of cattle this summer, which may be why the grass and weeds are so high. The vegetation is still green down towards the highway but is drying out on the hill top near BLO, so cutting back the weeds near the building would be a good idea for fire protection. I left a phone message for Shawna about the weeds. Other than that, there were no signs of anything going on at BLO this summer.

### **RIFS DAS**

I got an e-mail from Pete Mace about the SUOMInet preparations. He said they were testing the equipment and working on mounting hardware and would let me know when they were ready to install so we could move our GPS cable at the same time.

I cleaned up a few remaining glitches in the RIFS data plotting procedures left over from our move and configuration changes. Overall, the impact of the move on the RIFS DAS operation was rather small.

I've tried again to get the last software update working that SIL sent to us for the CADI earlier this year. I was able to get it running, but the dreaded noise floor problem returned and wouldn't go away, and the ionograms looked odd. After trying several modifications to the setup, I gave up and returned to the software version that we've been using.

I'm planning to make some measurements with the test equipment that we rented to see what the CADI is actually transmitting (power, bandwidth, pulse shapes) to see if that sheds any light on the low-altitude clutter that is often present during the day. I made some initial measurements with the oscilloscope and it can actually function as a crude spectrum analyzer, so I'm hoping for some enlightening results.

### **LWS**

I've installed the "high stability crystal" option in one of the Icom receivers, which required desoldering the original crystal, soldering in the new unit, and adjusting the frequency.

The antennas were finally shipped July 18; unfortunately, the one for us was sent to Klamath Falls with our street address, so the UPS person called me to find out where in KF "Spring Creek Parkway" was. They are sending it back over here so it should show up next week.

I now have software running which can change the receiver frequency and mode at given intervals, and have some basic signal processing software running that I'm using to measure signal levels for calibration purposes. There is still some work remaining before we can monitor signals, but the major modules are functioning.

# LWS DDDR Status: July 2002

Don Rice

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This month the software modules needed for HF monitoring were fabricated and used in determining the receiver transfer functions for the frequencies of interest. The remaining hardware items were also acquired.

## Visit to RPC, Klamath Falls

I visited RPC in Klamath Falls on July 8-9. GPS coordinates for RPC were obtained (42.17342° N, 121.84977° W, 1320 m elevation) and the Linux PC was installed with an uninterruptible power supply. Measurements of frequency response for two antennas already on site were made. The antenna purchased for this project did not arrive in time to be installed on this trip.

We decided to focus efforts on signals below 20 MHz, given the falling level of solar activity and greater sensitivity of lower frequencies to D region effects. Specifically, the 2.5 and 5 MHz WWV frequencies will be targeted and we will request authorization to establish a CW beacon on 3.750 MHz, located in the 75 m amateur radio band.

## Software Development

Software has been developed to control the Icom R75 receivers according to hourly schedule files. The receiver frequency, mode (AM, CW), attenuator, pre-amplifier, RF gain, and automatic gain control (AGC) can be set. Other parameters can be added to the control routine as required.

Software has also been tested which acquires audio samples from the receiver and produces a spectrum using an FFT routine. Sampling rate and resolution can be adjusted, but a 10 kHz sampling rate appears to provide adequate bandwidth and does not significantly impact the available CPU time.

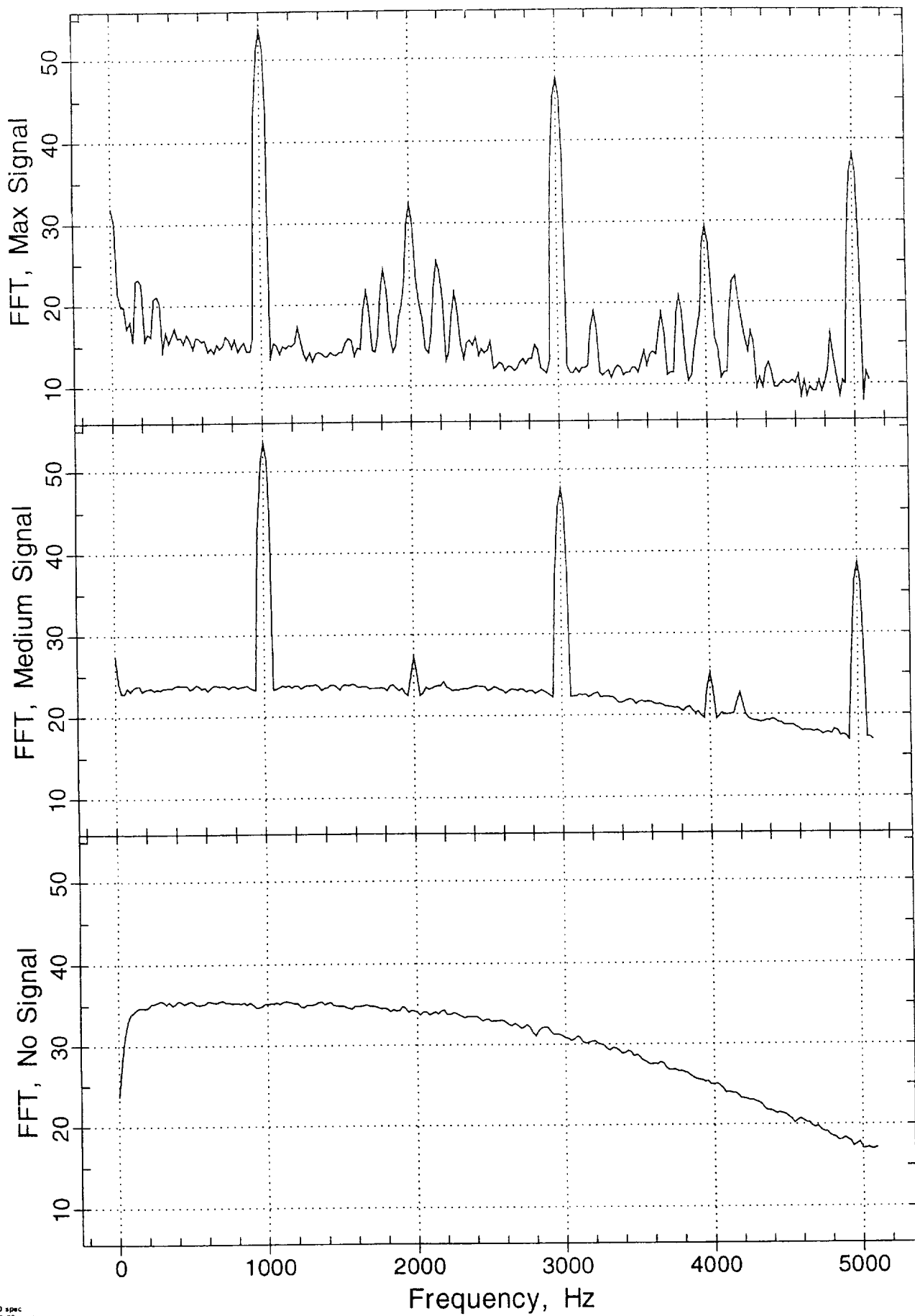
## Receiver Calibrations

The software modules described above were used to measure the transfer function of the receivers. A signal generator and attenuators provided signals with peak-to-peak amplitudes of 1  $\mu$ V to 10 mV, while the software set receiver parameters and recorded spectra.

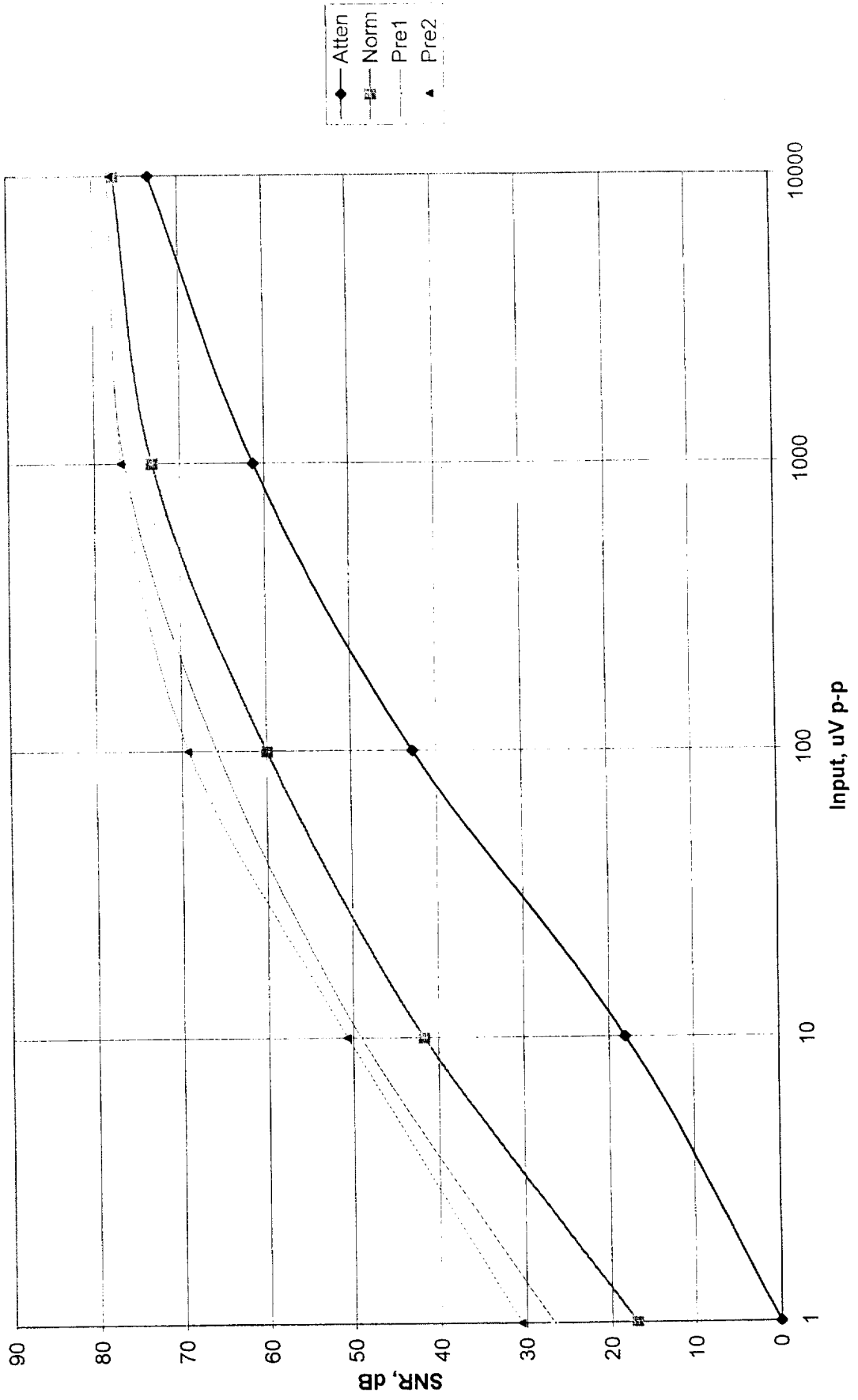
Sample results are attached. The spectra show that some distortion (harmonics) occurs, even at low signal levels, indicating that the audio signal needs to be reduced slightly. The receiver audio bandwidth and noise floor is clearly shown in the no-signal case. Signal-to-noise ratios are calculated and plotted, as are AGC values obtained by querying the receiver. AGC reduces the receiver gain according to signal strength to maintain constant output levels; its effect can be seen in the reduction of the noise floors in the audio spectra.

These data should allow the absolute signal strength at the receiver antenna terminal to be estimated based on measured audio signal and AGC levels.

# Receiver Signal Strength Data, 2.500 MHz AM

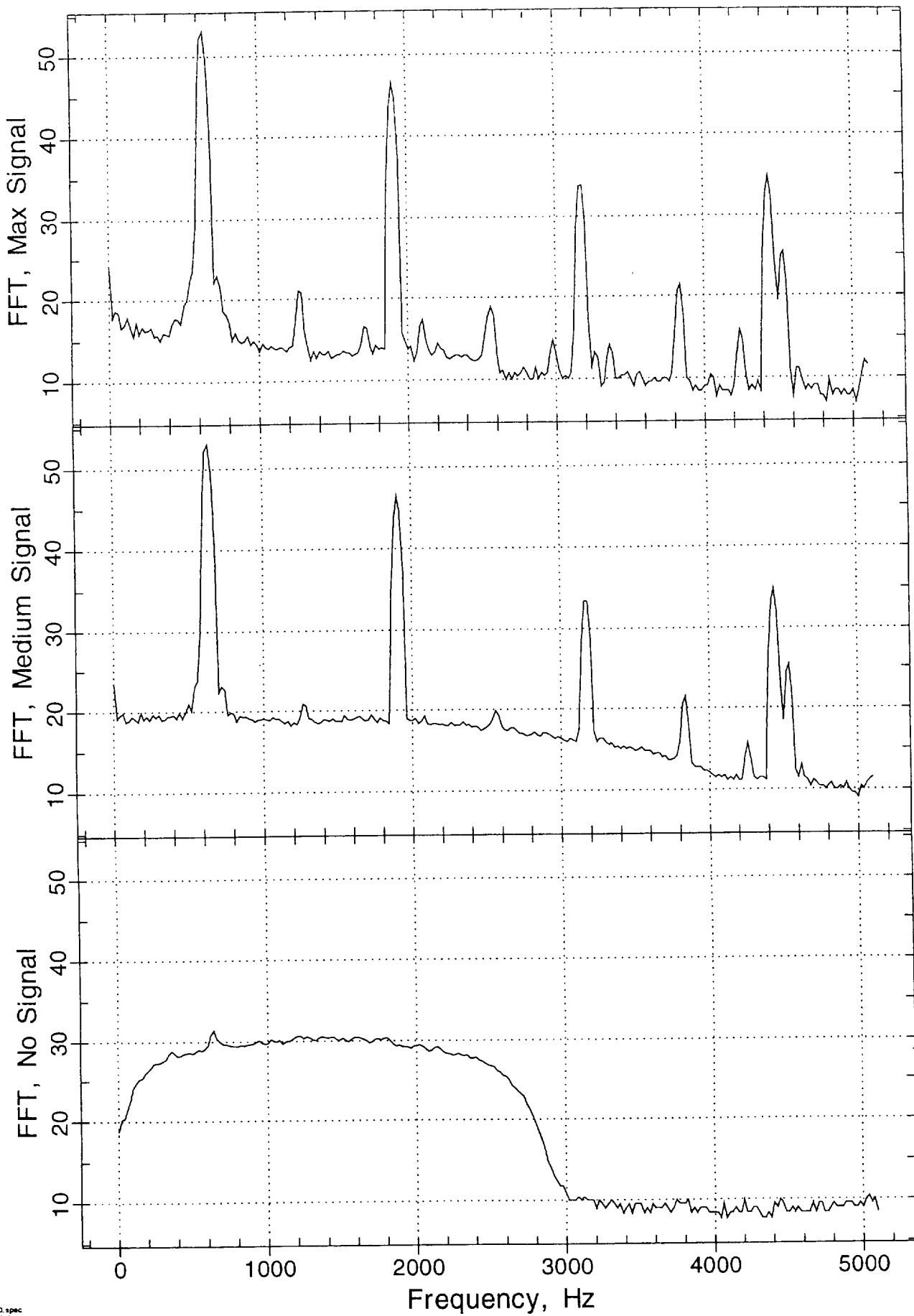


# Signal Strength, 2.500 MHz AM

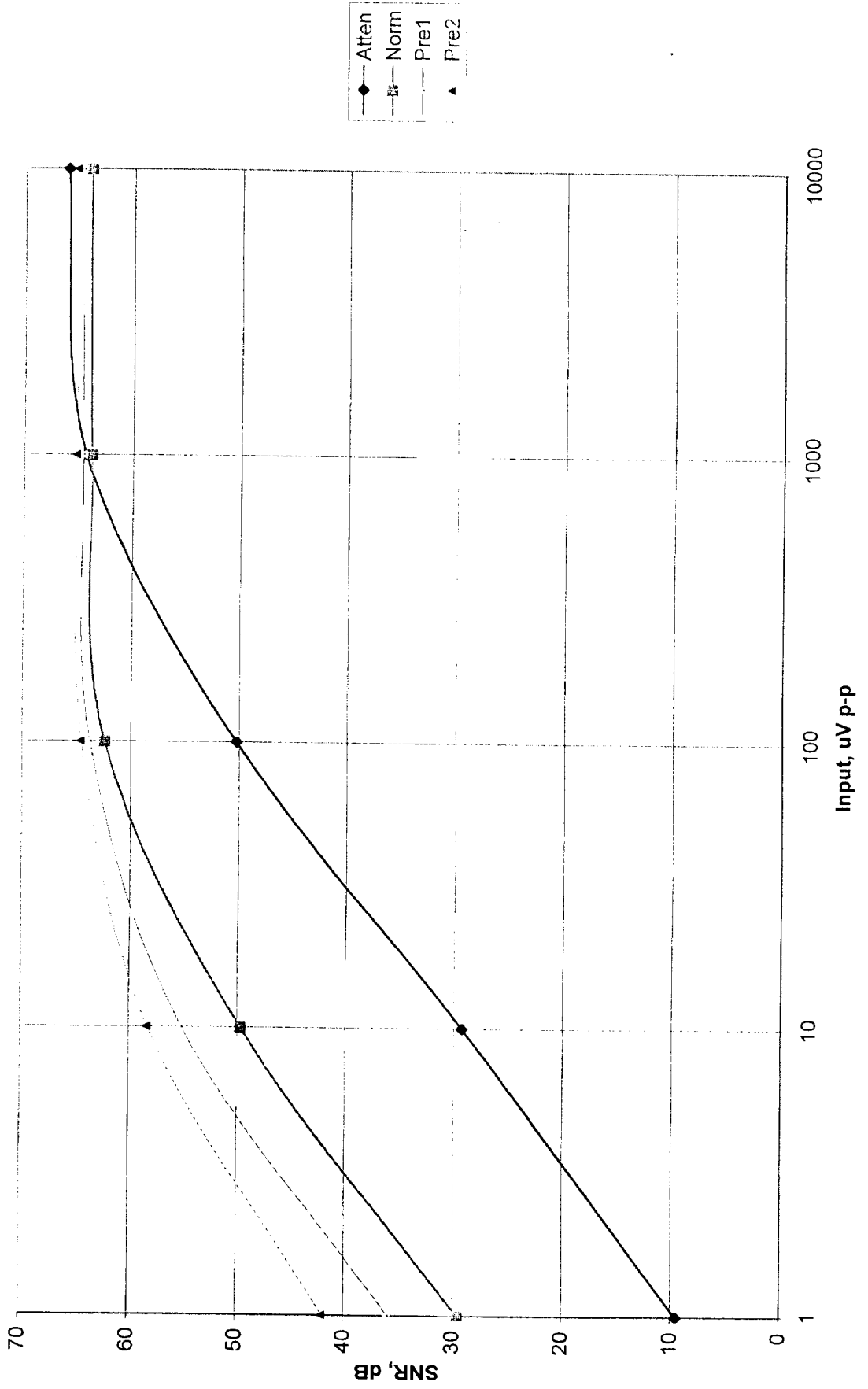




# Receiver Signal Strength Data, 14.100 MHz CW



# Signal Strength, 14.100 MHz CW



## **Project Status: August 16 2002**

Don Rice

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### **LWS/DDDR**

The trip to Klamath Falls during the week of August 5 was productive. We installed one of the Icom IC-R75 receivers and connected it to the PC which was installed on the previous trip. We also got the antenna mounted after some minor difficulties. An outrigger (5 ft angle iron) was clamped to the existing antenna mast at approximately the 40 foot level by a tree cutting service. The antenna was hoisted into place using a pulley, and the ends secured with screw eyes in convenient pieces of wood. We were able to achieve a good "inverted V" configuration and the guy ropes are attached at sufficient height to keep them out of the way. The feedline and a ground strap were brought into the RPC office and attached to the receiver.

We do not yet have monitoring software so the PC was left shut down. The receiver can be used for manual observations by Bob Hunsucker as desired.

I have made some improvements to the data acquisition software to eliminate the harmonics in the audio spectrum due to excessive audio signal levels. Test signals now produce much cleaner spectra, and the software now sets the PC audio hardware to a particular state rather than relying on default settings.

I have finished making the signal level measurements on the second (BLO) receiver, so the main task remaining is development of the data acquisition software. An initial version should be available by the end of September. We will also need to install the BLO antenna before we can set up the equipment there.

I have acquired an antenna for testing possible beacon operation. One thing that would be needed is cable access to the outdoors, i.e. a hole in the wall.

### **CADI**

I've plotted some of the receiver data for WWV frequencies. The plotting routine needs a little more work but it shows considerable variation between the different frequencies.

Next week I plan to take the test equipment out to BLO and perform some calibration measurements shown in the CADI manual to check receiver adjustments and the transmitter output power levels. I will also check the antenna frequency response to see what changes (if any) have occurred since I made the measurements in the spring when the ground was wet. That may give us some idea about the usefulness of putting in some ground radials under the antenna.

### **Miscellaneous**

Classes resume on August 26. I'm tentatively planning to make Tuesday and Thursday school days, and probably part of Monday as well.

