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HF BACKSCATTER ECHOES FROM WHITE SANDS SPREAD F EXPERIMENT (U)

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Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York

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HF BACKSCATTER ECHOES FROM WHITE SANDS SPREAD F EXPERIMENT (U)

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Raytheon Company

[redacted]

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PUBLICATION REVIEW

This technical report has been reviewed and is approved.

RADC Project Engineer

RADC Contract Engineer

ABSTRACT (U)

(S) A series of experiments were run during the period 5-16 October 1970 in which HF radars at the White Sands Missile Range (WSMR) were used to search for direct backscatter from ionospheric irregularities produced by the Boulder heater. The observations were made from White Sands because radars at this location view the heated volume normal to the earth's magnetic field. If the irregularities are field aligned (as might be expected from the similarity between the range spreading seen on Boulder ionograms and that due tothe field-aligned irregularities responsible for natural "spread-F") then they will be aspect sensitive and the radar cross-section will be greatest looking normal to the field.

(S) Direct echoes from the heated volume were unquestionably observed. Returns were found at radar frequencies up to 30 MHz (the highest frequency available) at times when the local plasma frequency over Boulder was as low as 5 MHz at the layer peak. These echoes occured at the expected range and were well correlated in time with the turn-on and turn-off of the heating transmitter. The results varied greatly from day to day for reasons that are not yet understood. When a direct echo was observed it grew continuously while the heater was on and died rapidly when it was turned off (lasting about 10 seconds at 30 MHz and 100 seconds at 13 MHz). Typically the direct returns exhibited doppler spectra a few Hertz wide with a net doppler offset of a few Hertz (at 30 MHz), implying a relative velocity between scatterers of a few tens of meters per second and a net southward drift of comparable magnitude.

(S) The strength and wavelength dependence of the returns (for the one case studied in detail) required a root-mean-square electron density fluctuation of about 12% and a correlation length of about 0.8 meters if the scatterers occupied a

cylindrical volume 100 kilometers in diameter and 100 kilometers in length, had a Gaussian autocorrelation function, and were isotropic. These requirements are not so severe as to rule out isotropic scatterers and so it can not be concluded that the observed irregularities were field aligned. However much weaker electron density fluctuations and a smaller scattering volume would be required if the scatterers are in fact field aligned. Further measurements will be required to resolve this question.

(S) In addition to direct echoes from the heated volume,perturbations in the ground backscatter returning through the heated volume are also seen. These perturbations are definitely heater related but have received little study as yet.

CONTENTS (U)

I. INTRODUCTION AND EXPERIMENTAL CONFIGURATION (U)

(S) The White Sands Spread-F Experiment was done by Raytheon during Project Ivory Coral over the two week period from October 5 through October 16, 1970. During this time, six ionospheric heating experiments were performed by ESSA of Boulder, Colorado, using the Platteville, Colorado, ionospheric heating transmitter (referred to in this report as the Boulder Heater). The HF pulse transmitting and receiving equipment, operated by Raytheon on a previous experiment at White Sands, was re-configured for backscatter sounding toward the heated region. The purpose was to directly illuminate the heated volume using two 100 Kw peak power pulse transmitters at different frequencies and to obtain both direct return and ground backscatter return echoes from the volume. The directly illuminating rays, when operating sufficiently high in frequency to avoid significant refractive bending in the ionosphere, perpendicularly intersect the earth's magnetic field lines at approximately 300 kilometer above the Boulder Heater. The perpendicular aspect geometry was considered important to obtain a detectable scattering cross-section from field aligned scatterers which may be underdense to the operating frequency for a 180^{o} scattering angle. It was also of interest to obtain bending ray coverage in the heated volume which would be provided by ionospherically reflected one hop ground backscatter on a frequency which would place the backscatter skip distance at twice the Boulder range from White Sands.

(S) The pulse backscatter soundings were operated bistatically from the Paxton Siding transmitting site and Twin Buttes receiving site located south of Alamogordo, New Mexico at the eastern edge of the White Sands Missile Range.

(S) cont.

Both systems were operated from standard reference oscillators permitting coherent and synchronized transmission and reception. The antennas used for transmitting were log periodic beams horizontally oriented above ground and boresighted on a 7 degree true North bearing. Antennas at heights of 40 and 60 feet above ground were used at Paxton Siding to transmit the higher and lower frequencies respectively. At Twin Buttes, the receiving log periodic was at a 50 foot height and used throughout the tests for all frequencies. Maximum antenna gains ranging from 9 to 11 db over an isotropic radiator (including transmission line losses) and horizontal half power beamwidths of 65° are typically obtained with the log periodic arrays. The vertical elevation look angles of approx-imately 14.5 and 15.5° were considered optimum to illuminate the heated region from the White Sands sites for ordinary ray and extraordinary ray heating respectively. The corresponding range delays of 6.5 Ms (980 Km slant range) and 6.2 Ms (930 Km) were anticipated for direct returns for the two heating polarizations. For the ground backscatter returns, the operating frequencies were chosen to place the backscatter skip distance at approximately 1800 Km for ordinary ray and 1700 Km for extraordinary ray heating. A ground scattered return via the heated volume would therefore appear at the backscatter return leading edge with a range dely of 12 to 13 milliseconds or twice that of the direct return. Figure 1 shows the geometry profile for the White Sands Spread-F Experiment.

(S)

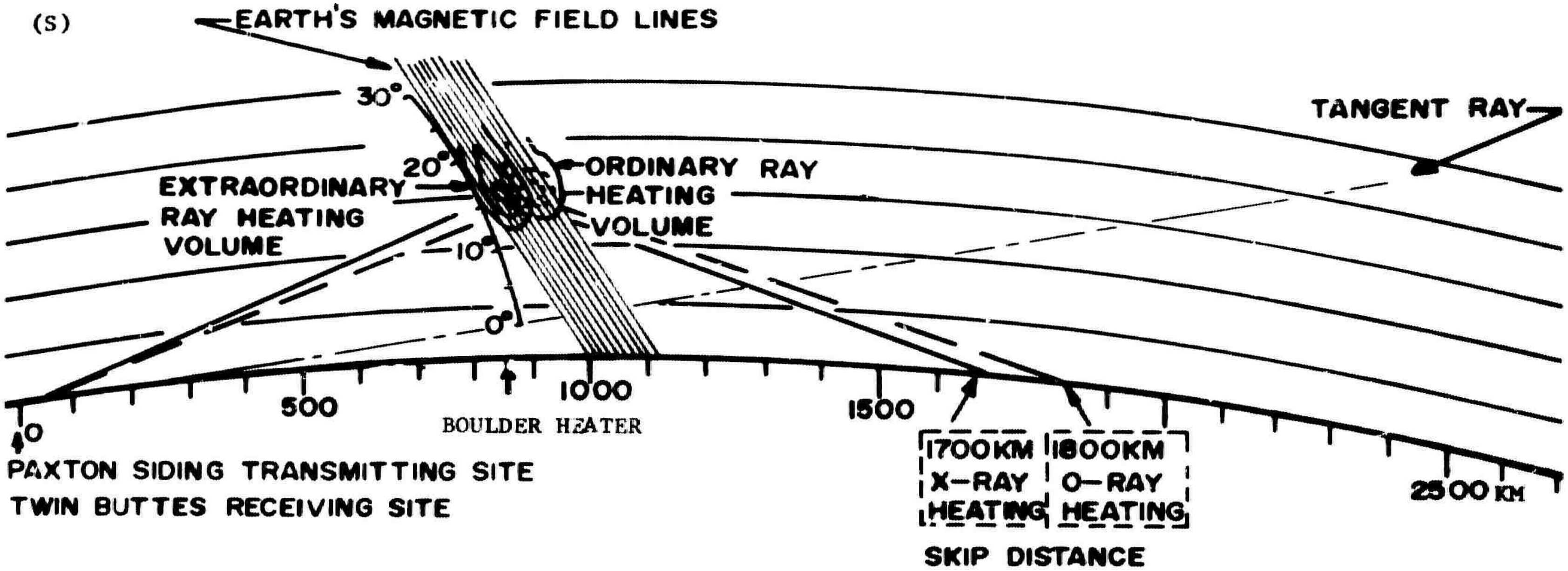

FIGURE 1

Geometry of the White Sands Spread-F Experiment
October 5-16, 1970 (U)

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II. OBSERVATIONS AND RESULTS (U)

(S) During each of the six dates of heating experimentation several heating cycles were attempted as well as different heater frequencies and wave polarizations. The purpose was to test the effectiveness of the different techniques and to examine the time of day which yielded best results. Much of the data presented in this report is of a preliminary nature in order to view the results obtained at White Sands and to examine areas that need further exploration and analysis. Due to time limitations in making this data report available to the experimental and theoretical community most of the detailed explanations of the figures and processing technique are omitted at this time. A few points which should be noted in the figures, however, are presented in the following sections.

A. Backscatter Range Delay Versus Time Records (U)

(S) Figures 2 to 7 show the first 15 milliseconds of the pulse backscatter returns on the two frequencies transmitted from White Sands as a function of GMT for the 6 dates of experimentation. The receiver 15 KHz IF outputs were tape recorded in 45 minute segments. The data gaps in time are therefore attributable to either no data recording, equipment difficulties or frequencies of operation being changed. In Figure 2 on the 6th of October, a note is indicated where the pulse repetition frequency (PRF) was changed from 40 to 20 pulses per second. The return indicated at the 5 to 9 millisecond range delay prior to this time is not related to the Boulder heater cycle. This return is produced by 2 hop F region ground backscatter which overlaps the adjacent pulse period to which it should be associated (at 30 to 34 Ms). From this time on, a 20 pps repetition rate was utilized for the backscatter experiment

(S) cont.

thereby permitting a full 50 Ms of unambiguous time period between transmitted pulses. A transmitted pulse width of 500 microseconds was used for all tests except the 6th of October for which 100 microseconds was used.

(S) The transmission cycle of the Boulder heater is indicated at the top of each of the figures. For each day of operation except that of 6 October, the heater transmitting polarization was that of the ordinary ray. On the 6th of October the extra-ordinary mode was used. When both backscatter frequencies are shown, the upper record (higner frequency) and lower record can be cross examined for echoes, frequency dependence, and backscatter structure perturbations produced in the ionosphere. Some of these effects correlate directly and others last beyond the heating interval for periods ranging from minutes to perhaps an hour. Several of the obvious effects (but by no means all effects) have been selected for further processing to examine the echoes in more detail. In the following figures, the selected time intervals are analyzed particularly for received power, spectral power distribution, and characteristics within the scattered return.

B. Doppler Spectral Variation with Sample Depth (U)

(S) The records in Figures 8, 9 and 10 show how the integrated spectral shape changes with an increasing depth of sampling in the direct returns of 17 October 1970 (GMT date). These spectra are obtained with a total analysis frequency range of 10 Hz and a frequency resolution bandwidth of approximately 1/8 Hz. The records are obtained by sampling the coherently detected echo with narrow (40 microsecond) or "discrete" gates and processing the sampled (boxcar) waveform through a Federal Scientific UA-6A spectrum analyzer and digital averager. In general the spectrum shows a broadening with more power

(S) cont.

and hence provide "a selective skip distance shortening" phenomena for ray paths through the heated region (on the 13th and 17th of October). All of the four records were obtained on 13 MHz where ray bending would be anticipated in the heated region. The last ground backscattered echo on the 17th of October (Figure 17) differs from that obtained on the 13th of October (Figure 16), the range delay was only 9 Ms as opposed to 12 Ms. It is believed that this return is scattered from within the heated volume at an angle directly toward the earth below rather than obliquely to twice the range to Boulder. In this case the scattering at the earth is specular.

(S) It is interesting to compare the direct echo with the 9 Ms echo on the same frequency. The 9 Ms echo lasts to the end of the recording period in contrast to the o Ms direct echo (Figure 13). The spectral variations within the time period of heating correlate well between the two returns, however, the 9 Ms echo exhibits a more negative net Doppler shift. After the heating stops, the 9 Ms echo spectrum appears to stabalize. Finally the 9 Ms ground scattered echo exhibits an overall broader spectrum than that of the direct return.

(S) One further observation is worthy of note. The 12 Ms ground back-scattered return (via the heated region) on the 13th of October (Figure 15) exhibits the most diffuse spectral spread of any echo. The spectrum of this return spreads over the entire 10 Hz frequency range (one half the pulse repetition frequency) thereby making it impossible to estimate the total spectral width.

(S) cont.

at lower or negative Doppler frequencies as the sampling point moves further into the received pulse group. The spectrum obtained from the gate placed in the noise serves as a noise baseline for a reference.

C. Received Power and Spectral Variation with Time (U)

(S) Figures 11, 12 and 13 give an indication of how the received power of the echo changes or builds up with time. It should be noted that the ratio of the Boulder Heater frequency to local (ordinary ray) critical frequency approached unity at about 0220 GMT on Figures 12 and 13. The increased spectral spreading, therefore, is a function of the height (or depth) of heating within the ionosphere as both the 30 and 13 MHz echoes exhibited proportionate broadening.

(S) Several other interesting effects are noted in the Spectral data and power records of Figures 12 and 13. The net Doppler frequency shift of the return, which should be an indication of the ionospheric drift velocity, is proportionate to the operating frequencies. The shorter term (few minutes) cyclic variations in the spectrum during the heating cycle is correlated and proportionate on the two frequencies. Finally, the received power appears more than one order of magnitude larger on the 13 MHz frequency than on 30 MHz.

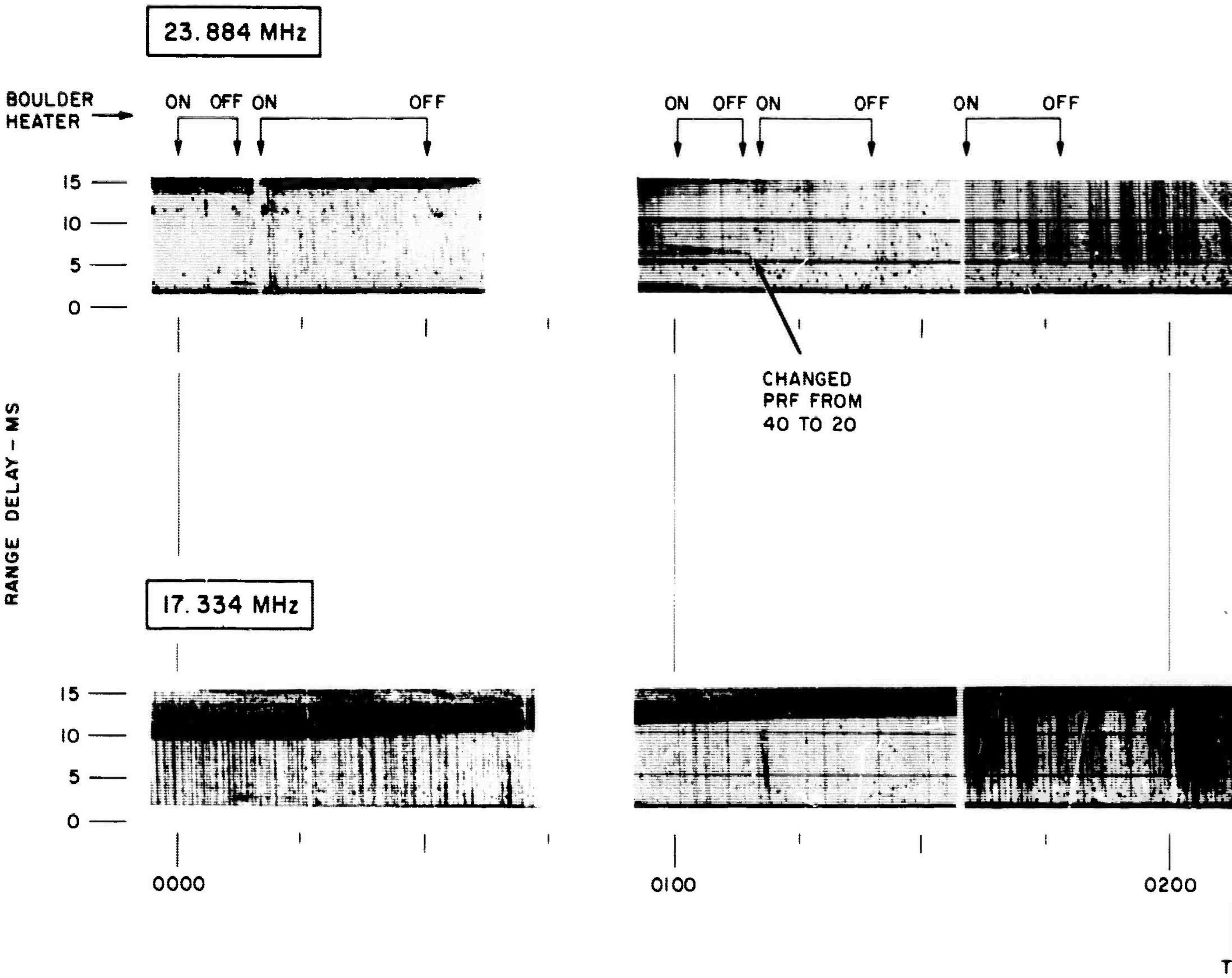
D. Power Spectrum of Additional Echoes (U)

(S) Four other selected returns have been analyzed and are shown in Figures 14 through 17. Two of these correspond to direct backscattered returns (at 6 Ms) obtained on the 6th and 13th of October. The other two are attributed to ground scattered returns which traverse the heated volume

E. Doppler Distribution Changes With Time (U)

(S) The final three records (Figures 18, 19 and 20) are included (from preliminary data reduction) to show one further interesting characteristic of the power spectra of the direct echoes (17th of October 1970). The peak spectral buildup with time throughout the heating interval appears to be accompanied by a spectral broadening. The spectral power density plots were obtained from consecutive 5 minute integration periods using a single discrete sample gate in the center of the direct echo. It appears that the spectrum becomes nearly flat topped as time progresses. The distribution of scatterer velocities, therefore, appears to widen as time progresses.

WHITE SANDS SPREAD F EXPERIMENT NO. I - N



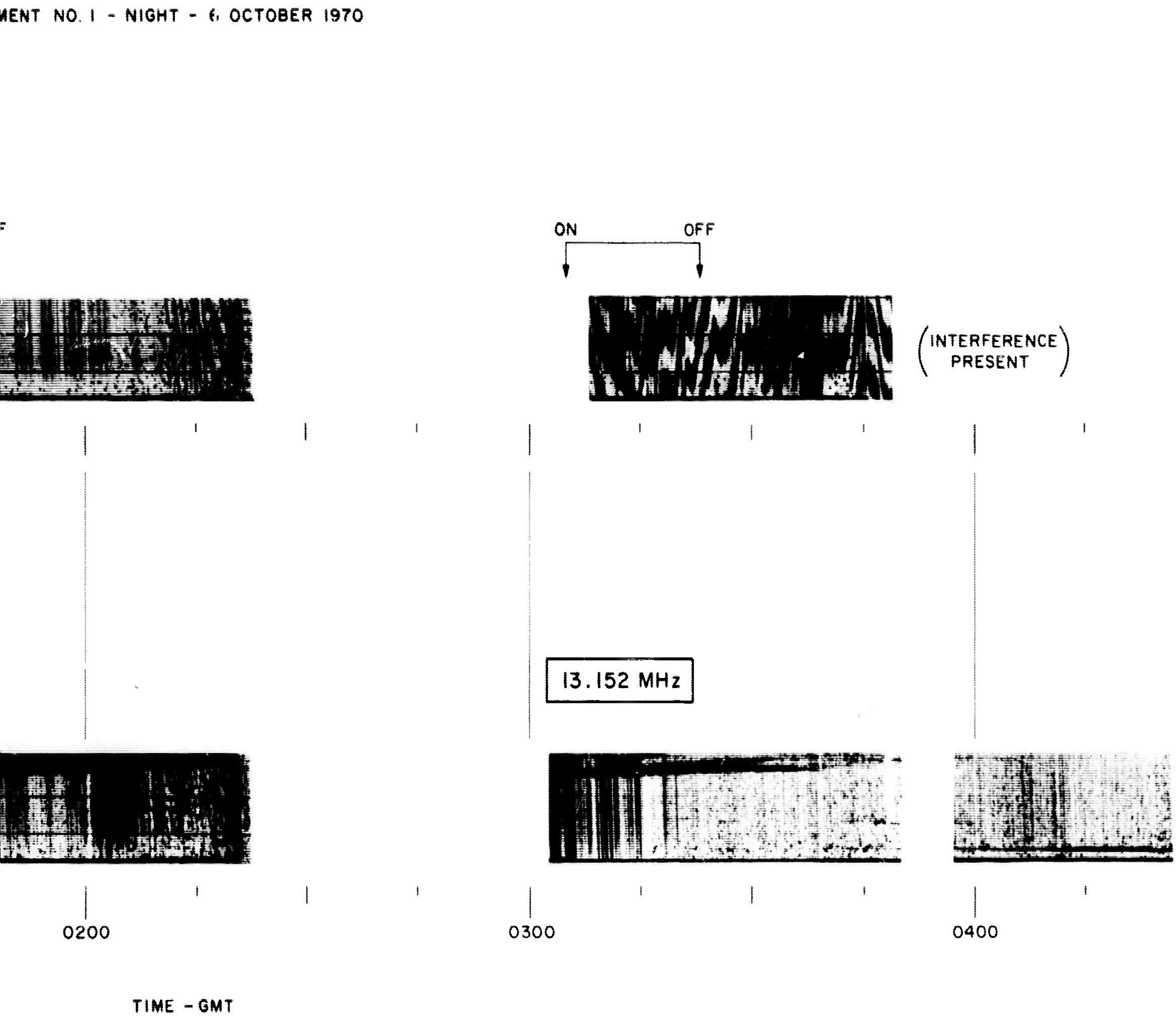
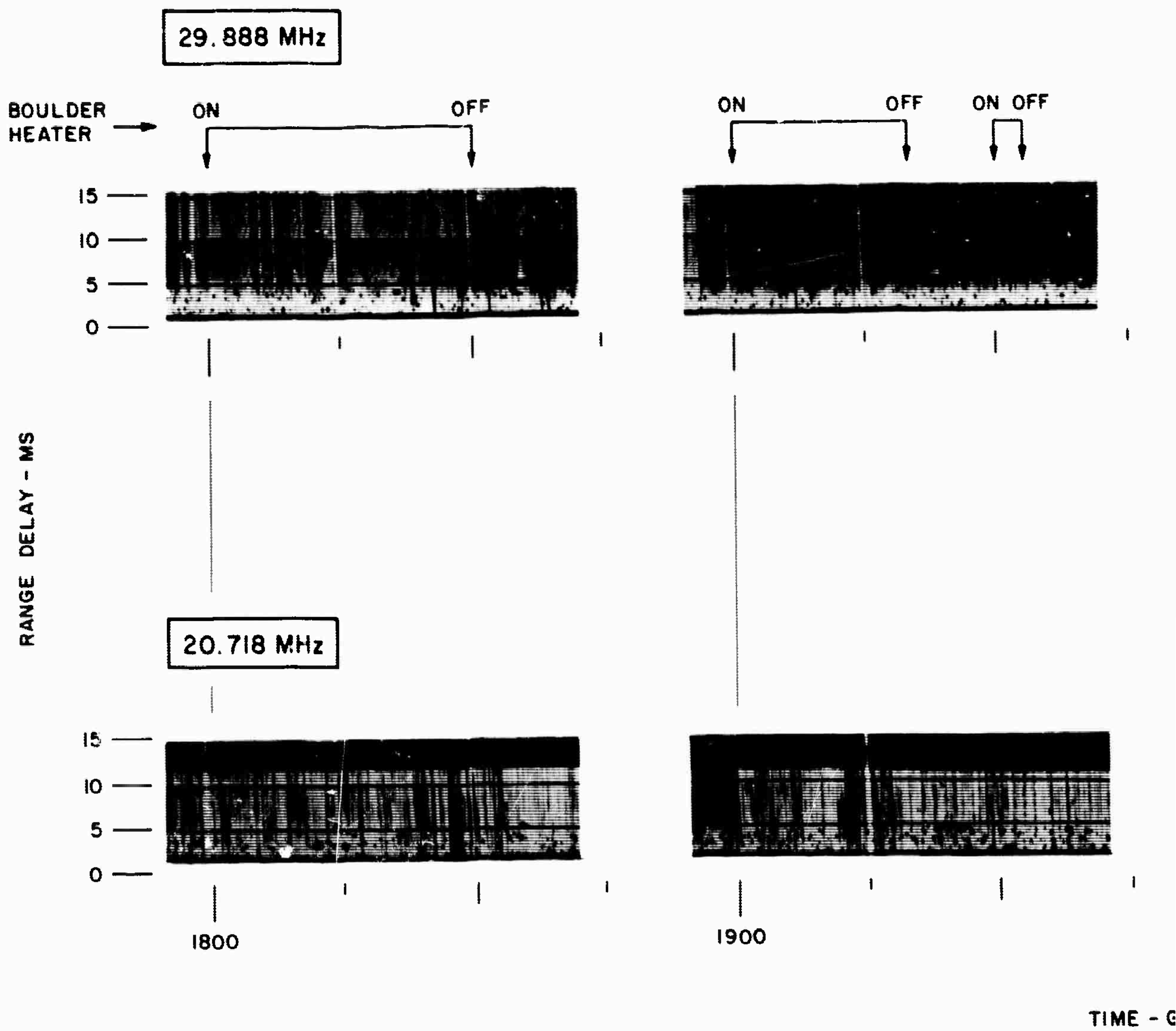


Figure 2. Backscatter Range Delay Records from White Sands Towards the Boulder Heated Region - 6 October 1970. (S)

WHITE SANDS SPREAD F EXPERIMENT NO. 2 - DAY



SPREAD F EXPERIMENT NO. 2 - DAY - 8 OCTOBER 1970

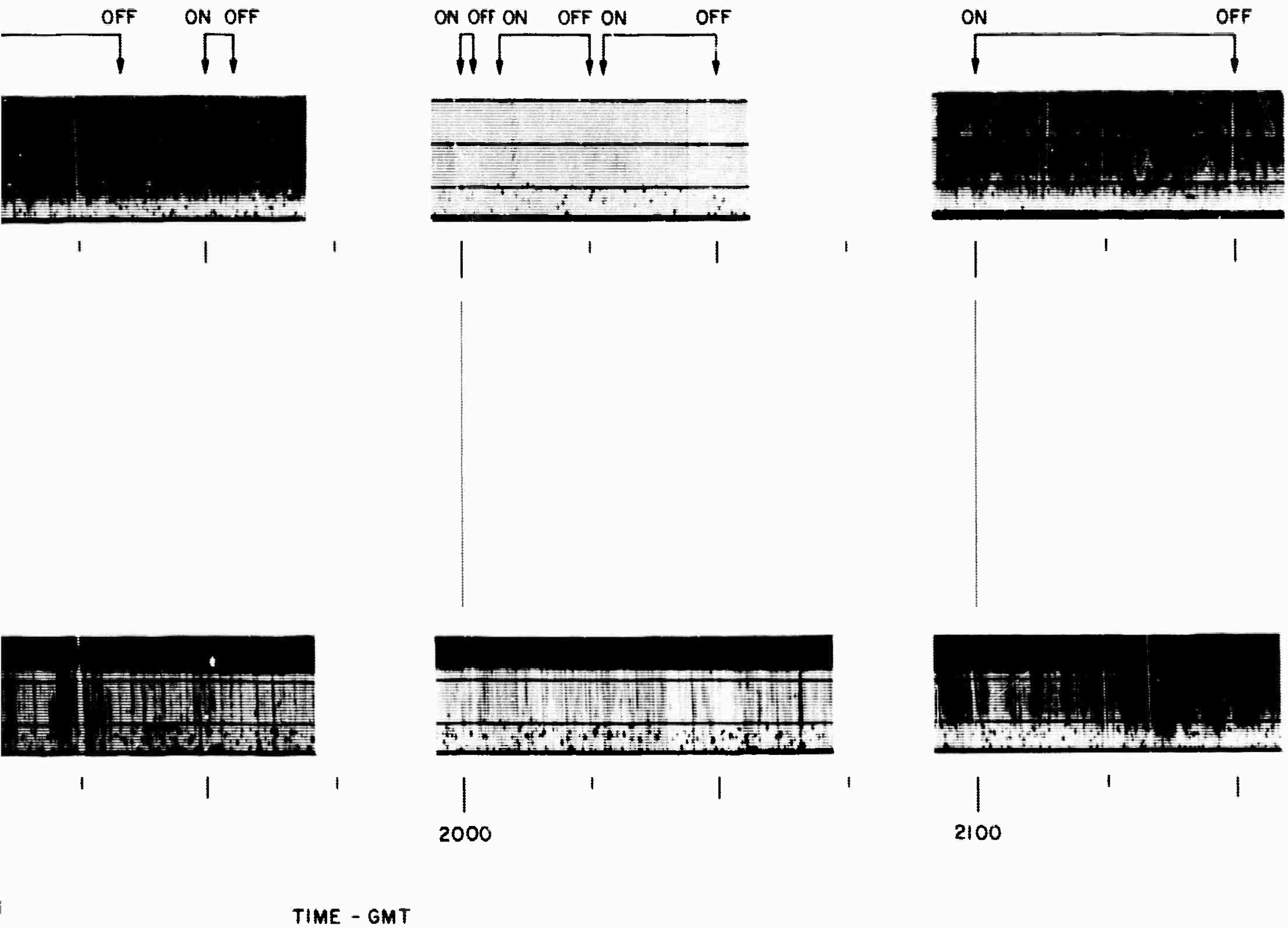
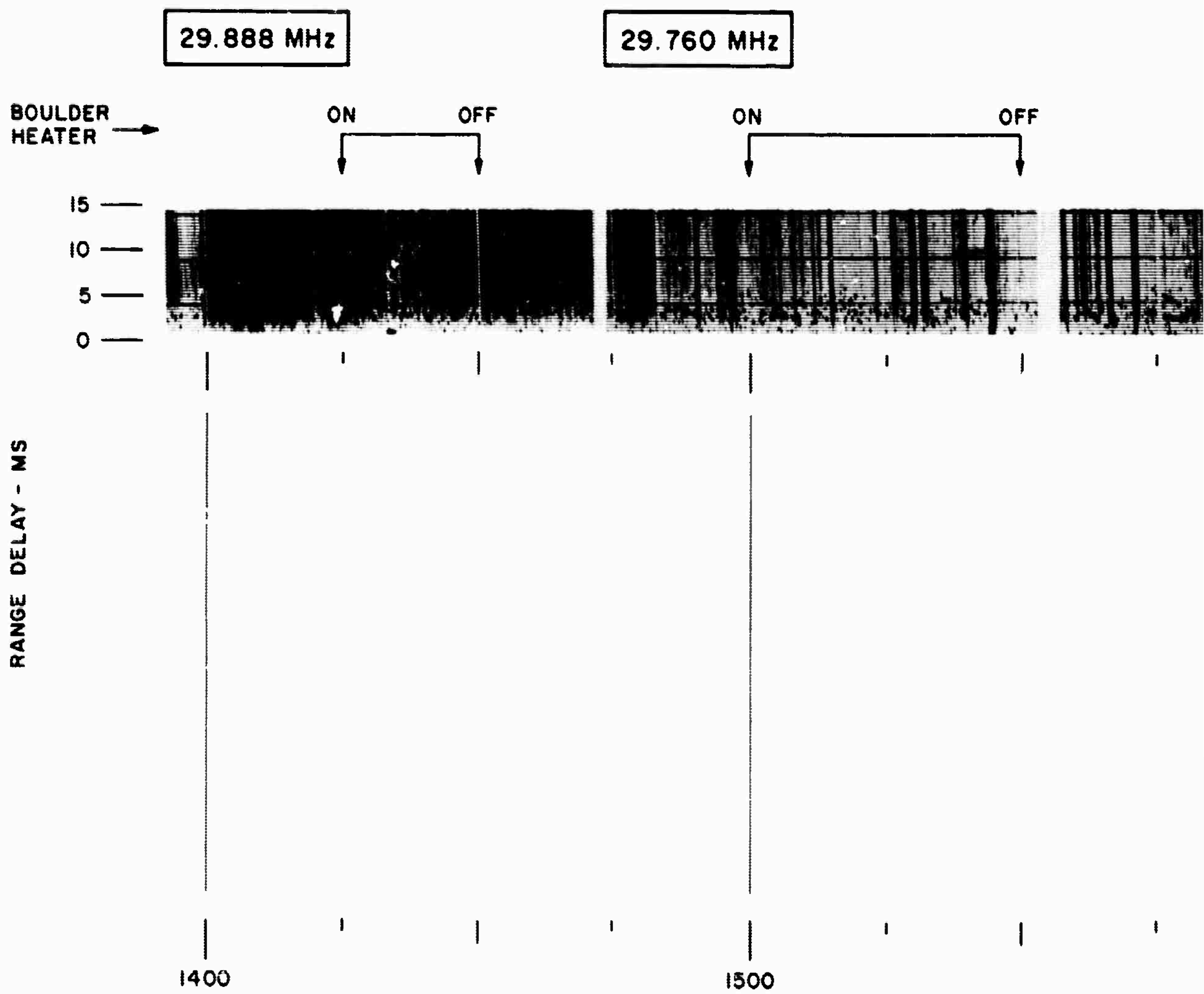


Figure 3. Backscatter Range Delay Records from White Sands Towards the Boulder Heated Region - 8 October 1970.(S)

WHITE SANDS SPREAD F EXPERIMENT N



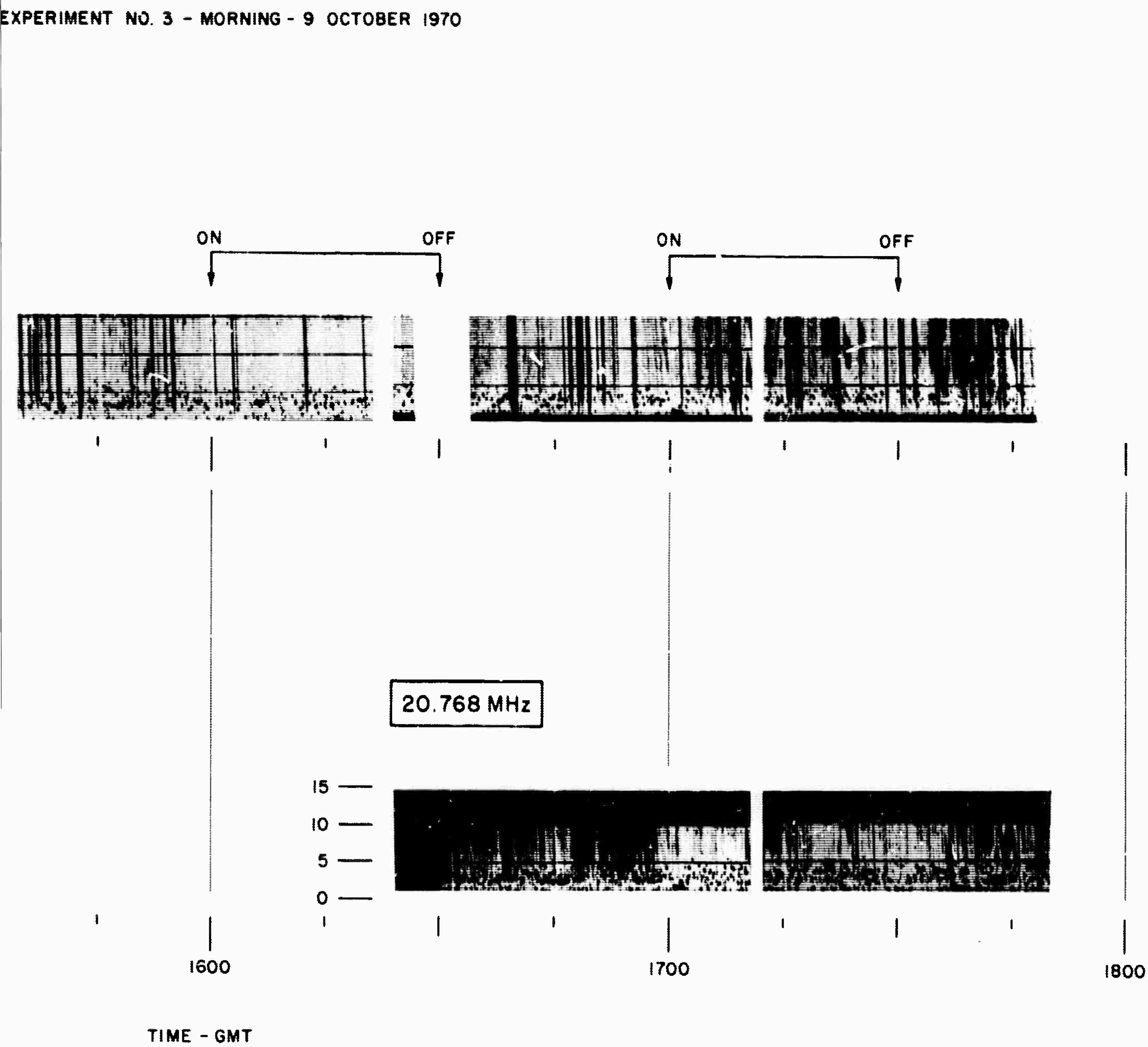
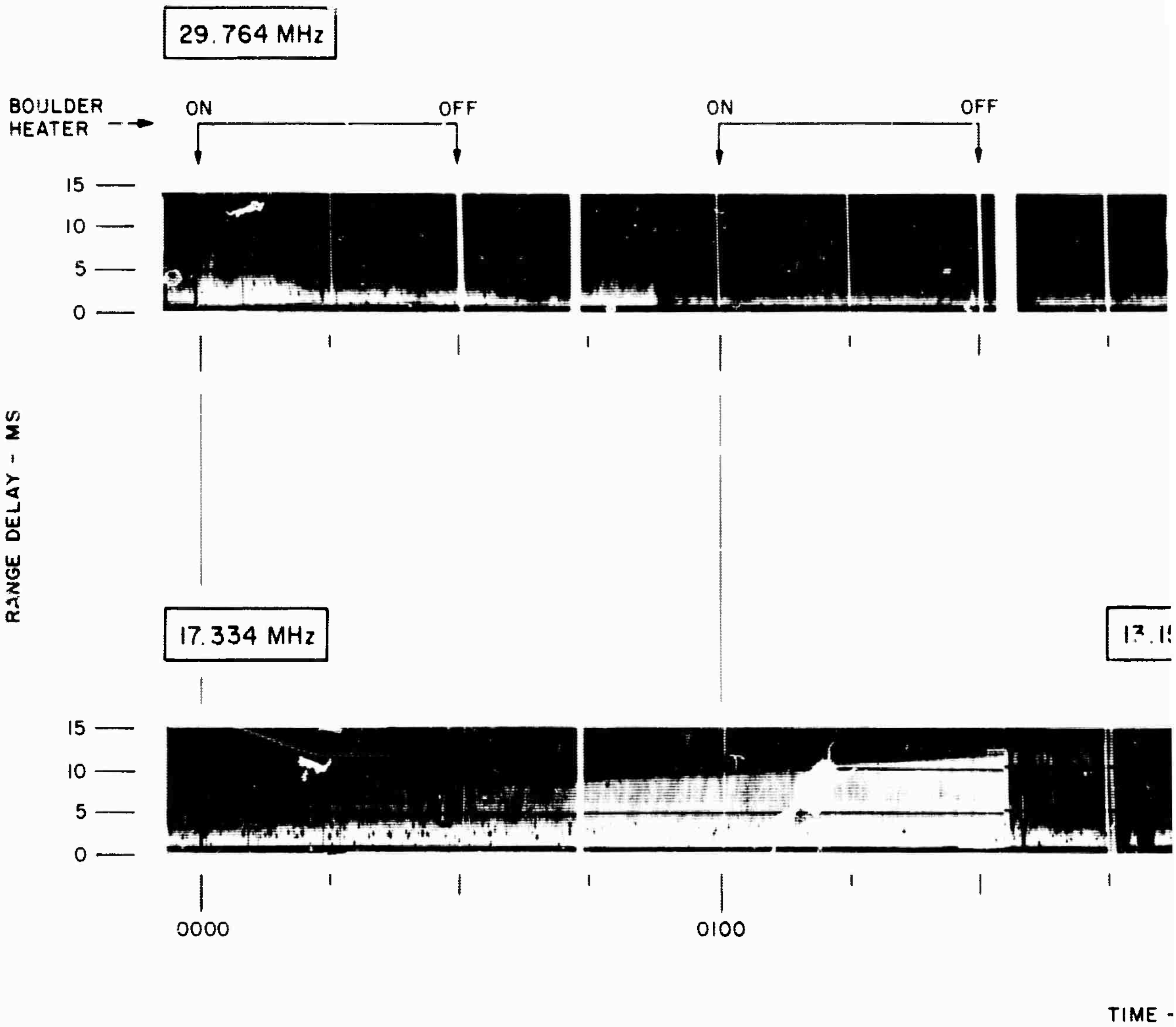


Figure 4. Backscatter Range Delay Records from White Sands Towards the Boulder Heated Region - 9 October 1970. (S)

WHITF SANDS SPREAD F EXPERIMENT NO.



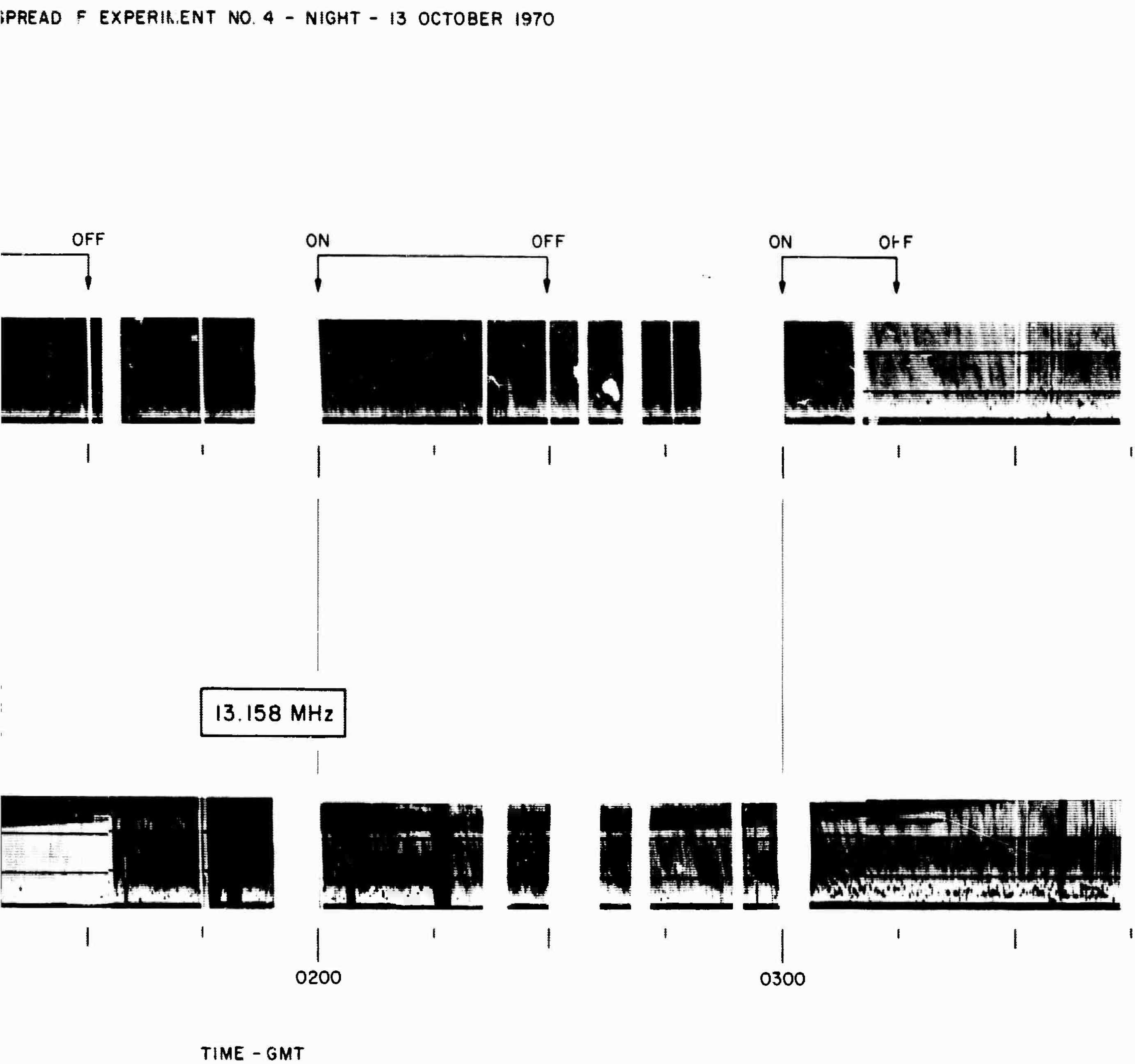
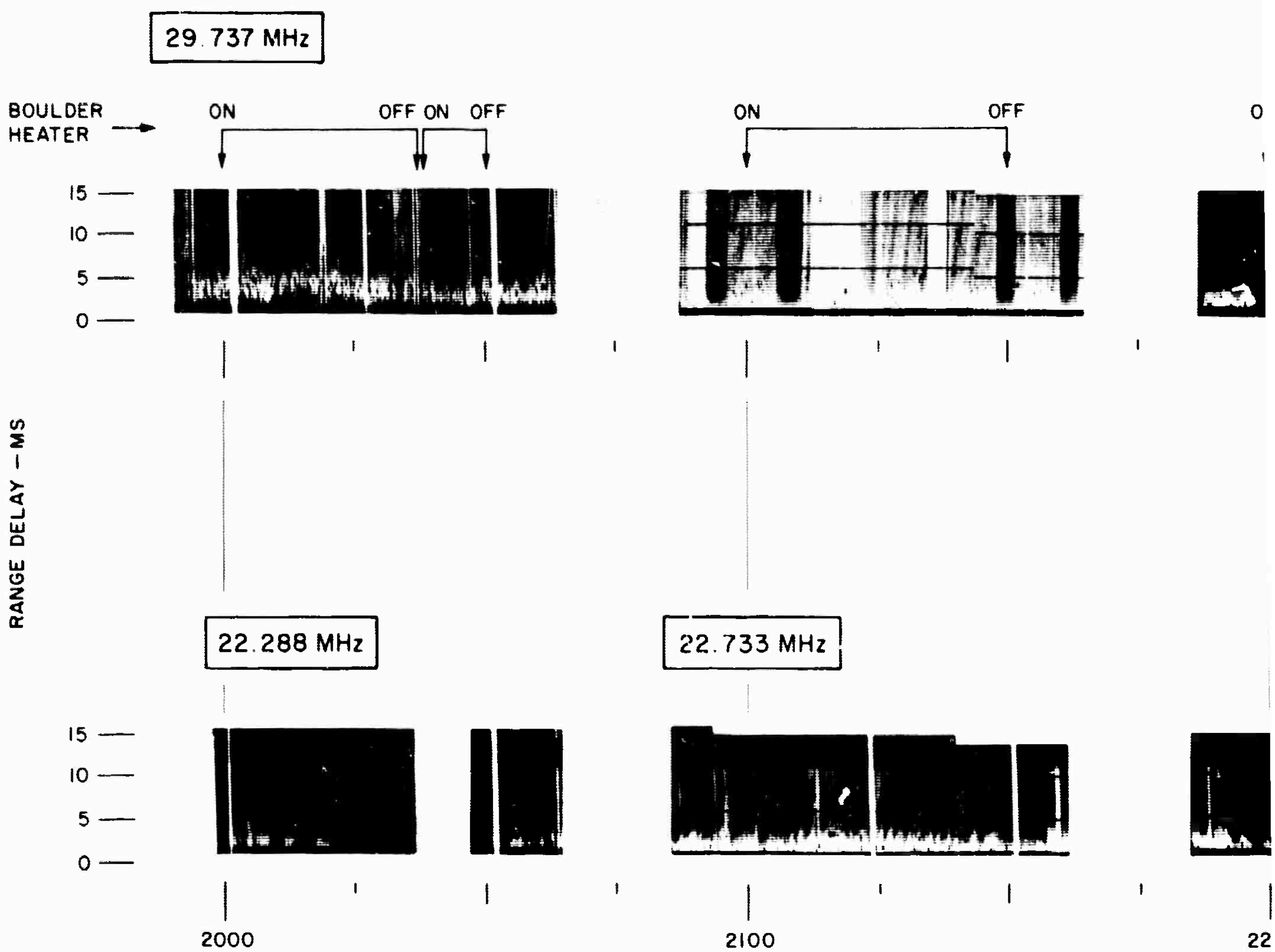


Figure 5. Backscatter Range Delay Records from White Sands Towards the Boulder Heated Region - 13 October 1970 (S)


29.737 MHz
BOULDER HEATER
ON
OFF ON
OFF
ON
OFF
O
15
10
5
0
RANGE DELAY — MS
22.288 MHz
22.733 MHz
15
10
5
0
2000
2100
22

EXPERIMENT NO. 5 - DAY - 15 OCTOBER 1970

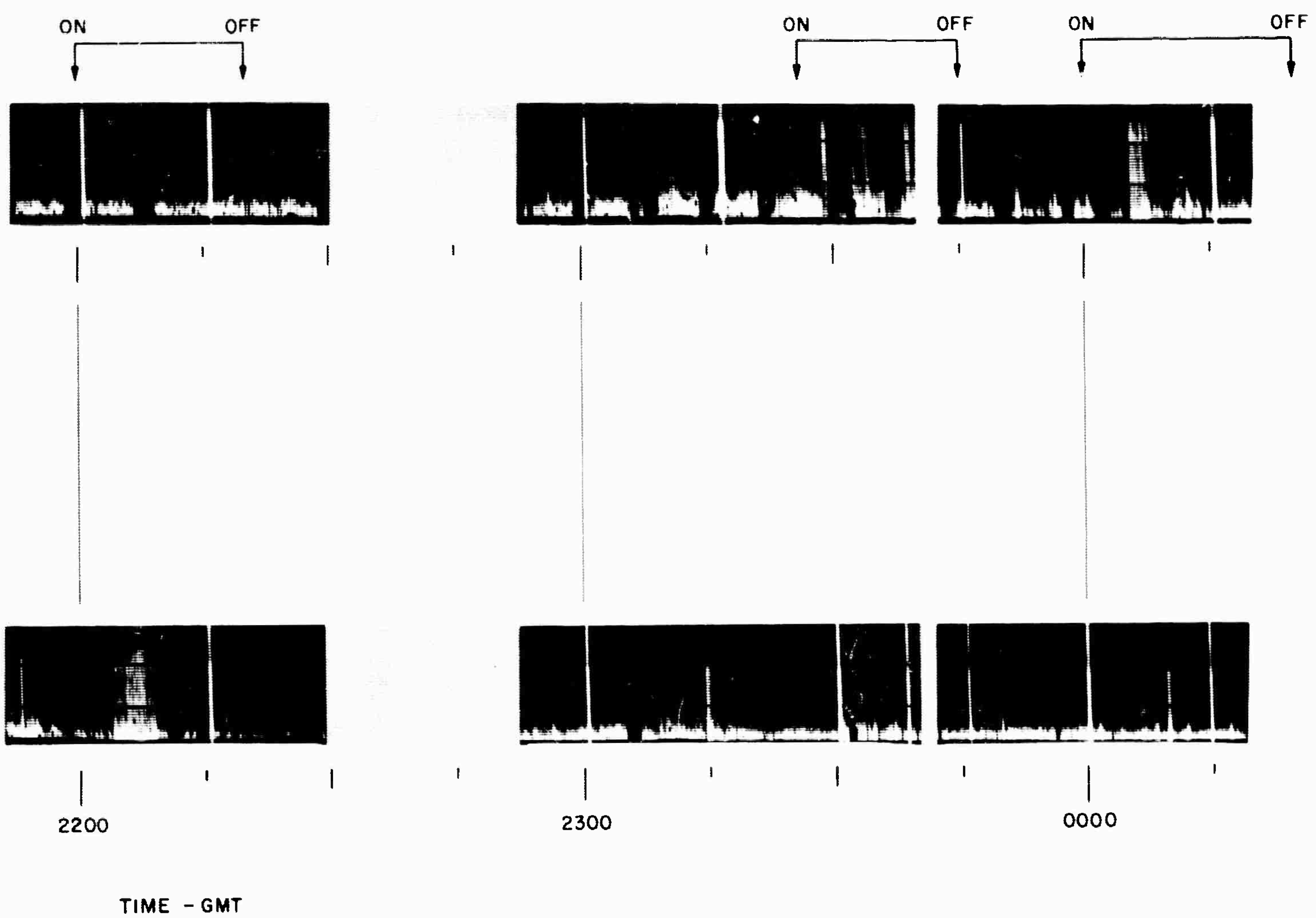


Figure 6. Backscatter Range Delay Records from White Sands Towards the Boulder Heated Region - 15 October 1970. (S)

WHITE SANDS SPREAD F EXPERIMENT NO. 6 - NIG

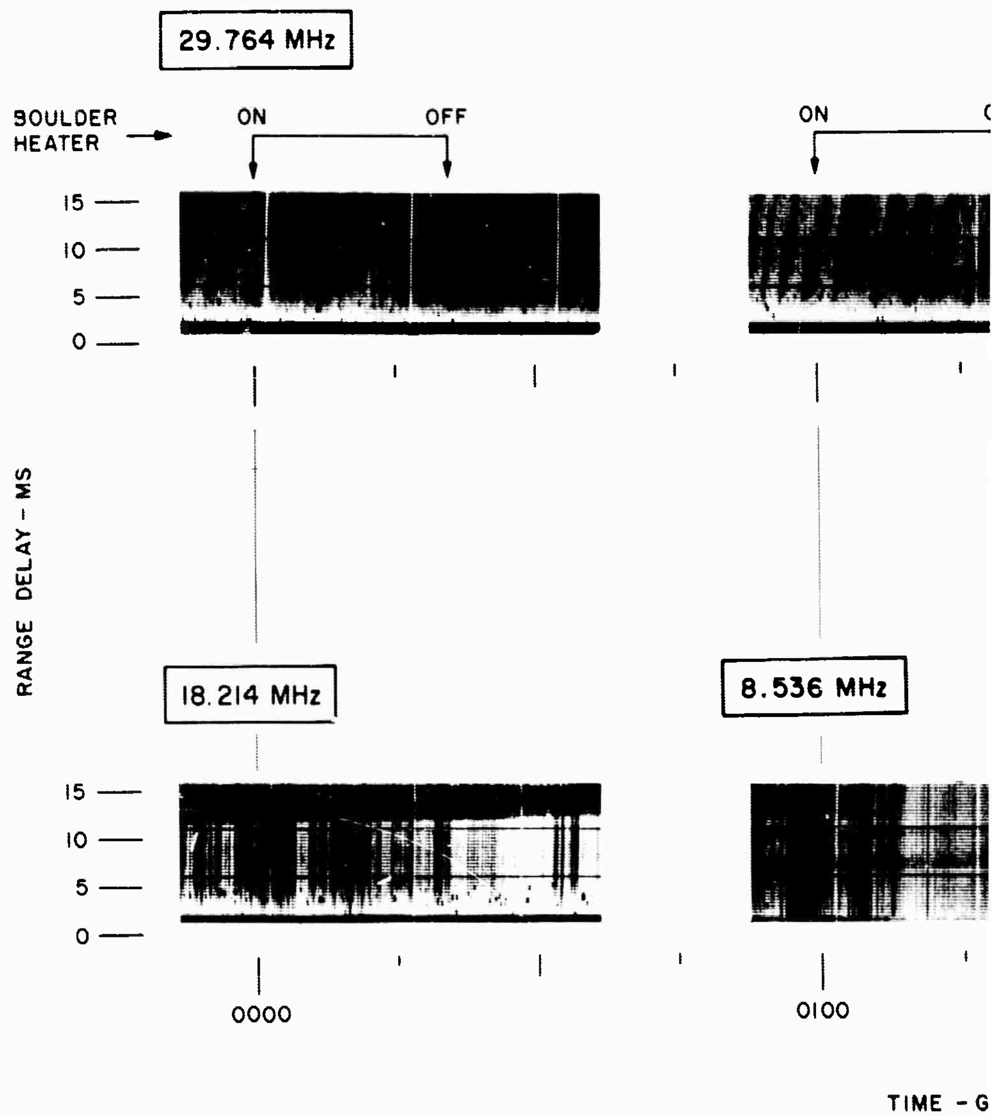


Figure 7.

WHITE SANDS SPREAD F EXPERIMENT NO. 6 - NIGHT - 17 OCTOBER 1970

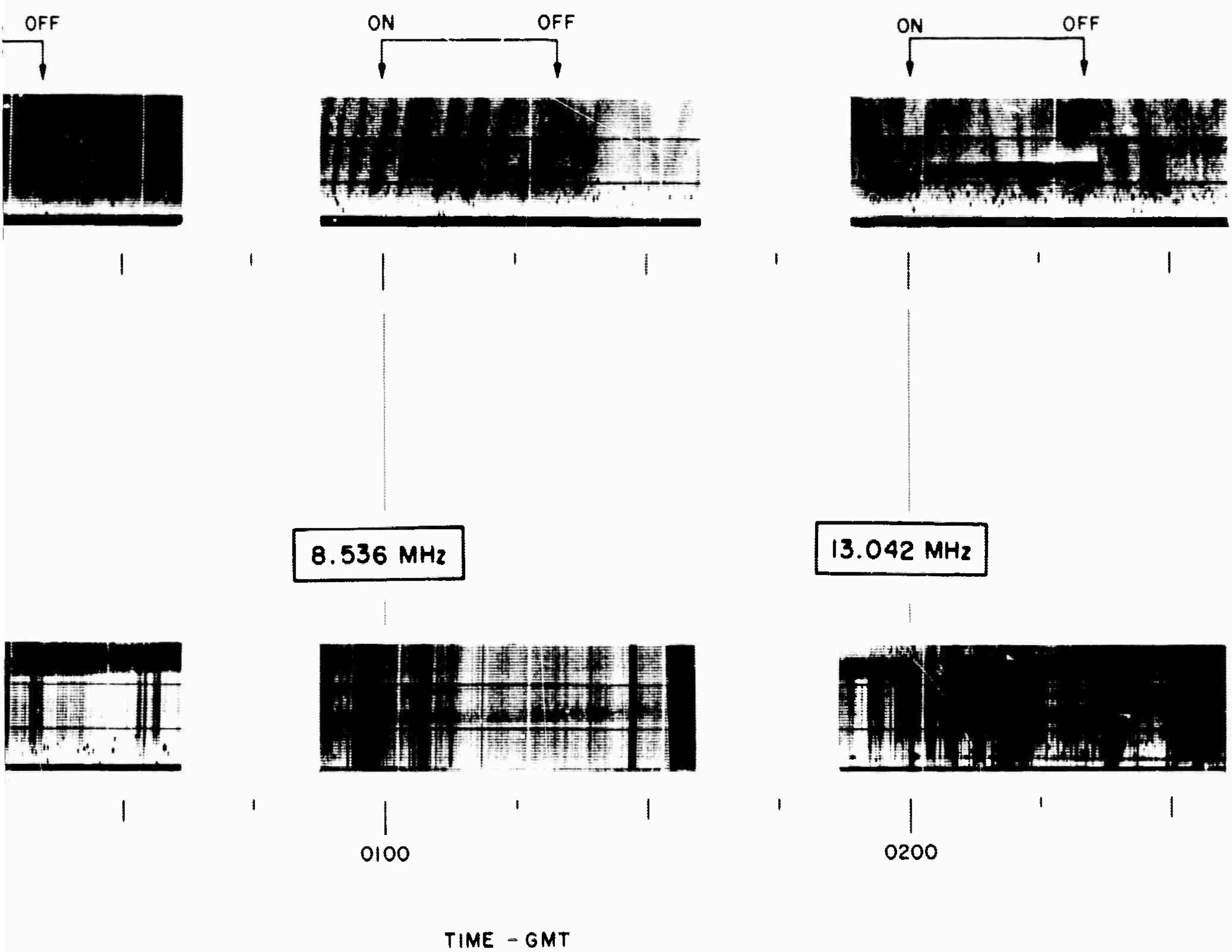


Figure 7. Backscatter Range Delay Records from White Sands Towards the Boulder Heated Region - 17 October 1970. (S)

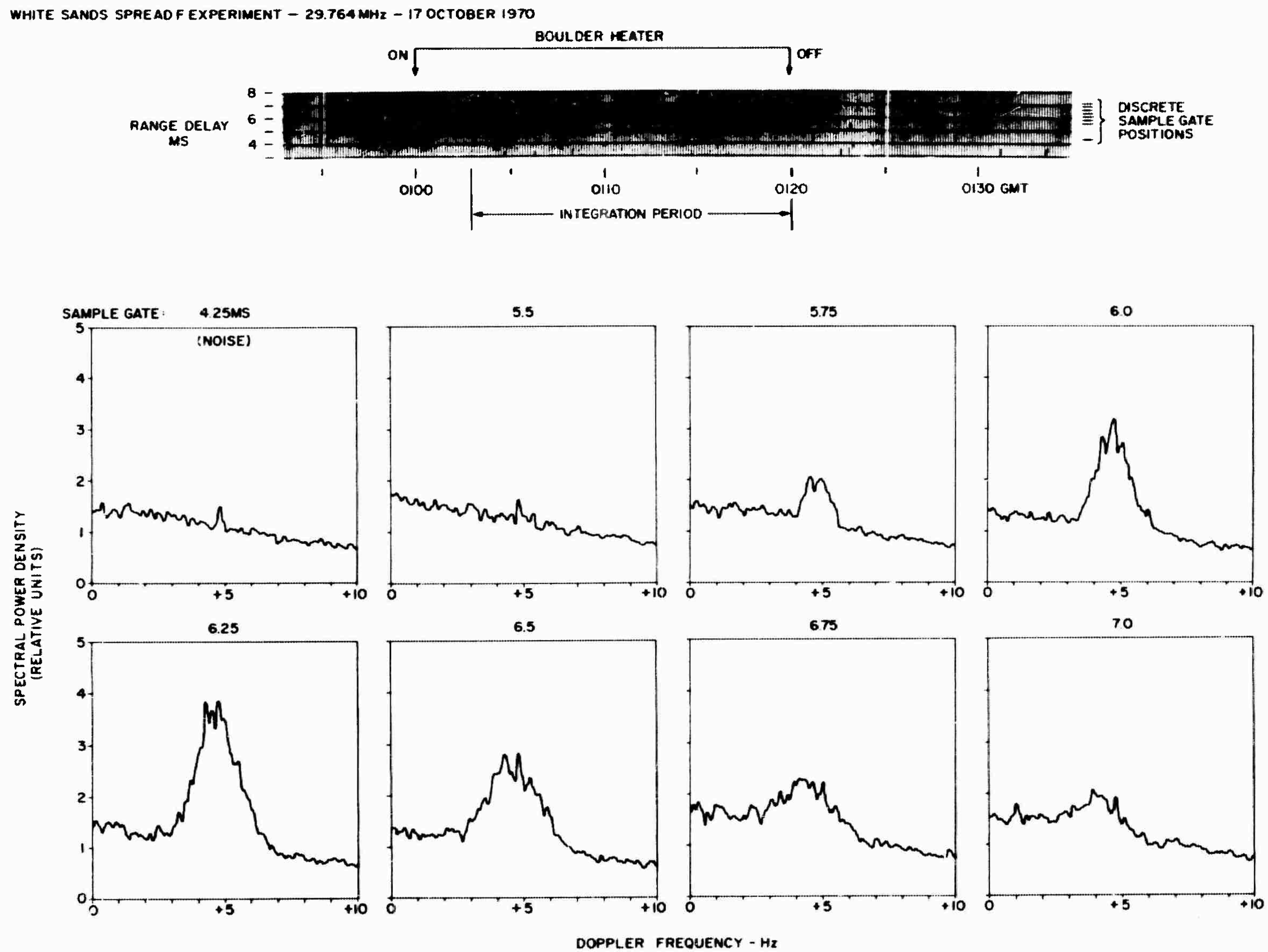


Figure 8. Integrated Power Spectrum at Discrete Range Delays in the 30 MHz Direct Backscatter Return on 17 October 1970 (0100 to 0120 GMT). (U)

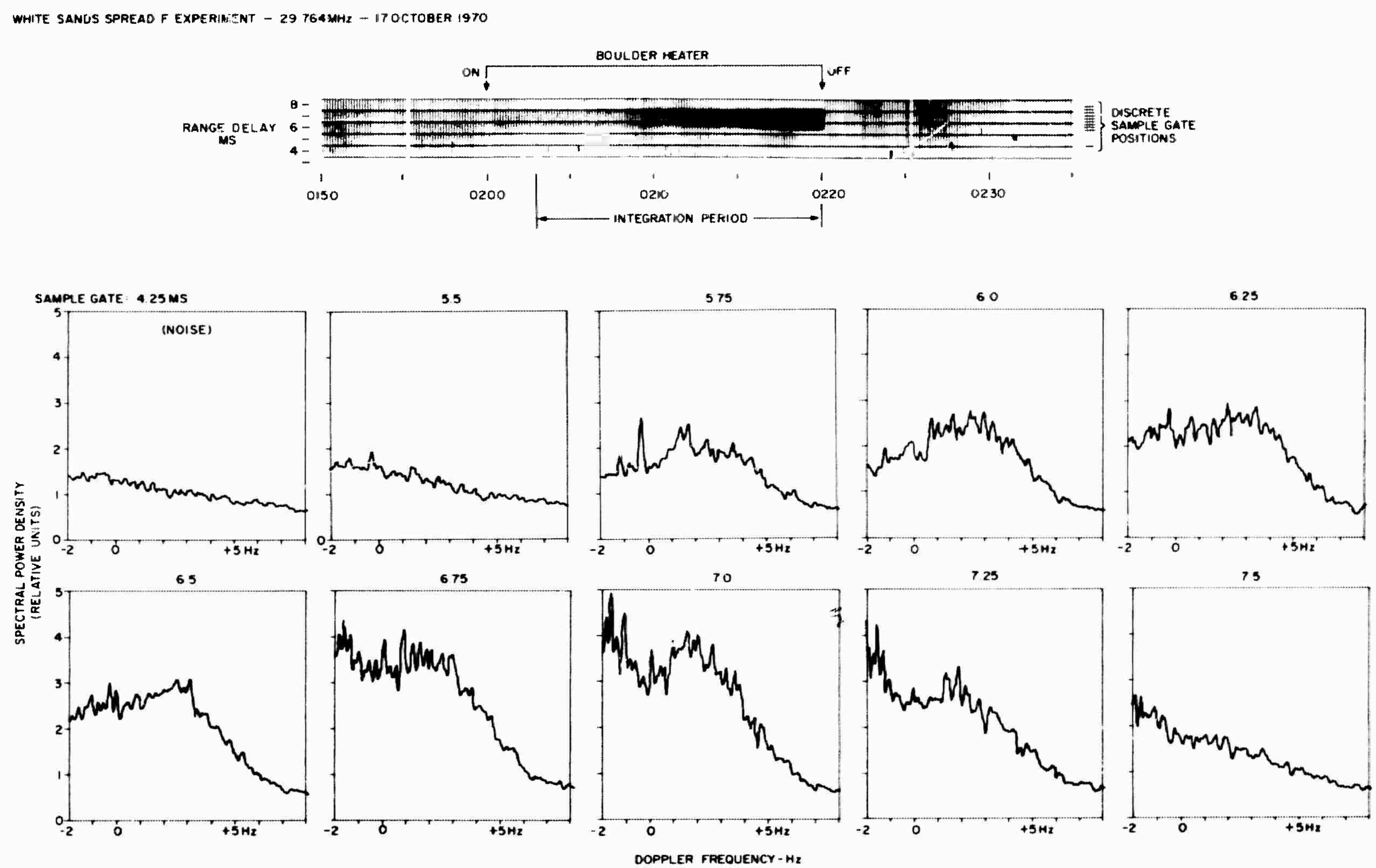


Figure 9. Integrated Power Spectrum at Discrete Rang^ Delays in the 30 MHz Direct Backscatter Return on 17 October 1970 (0200 to 0220 GMT). (U)

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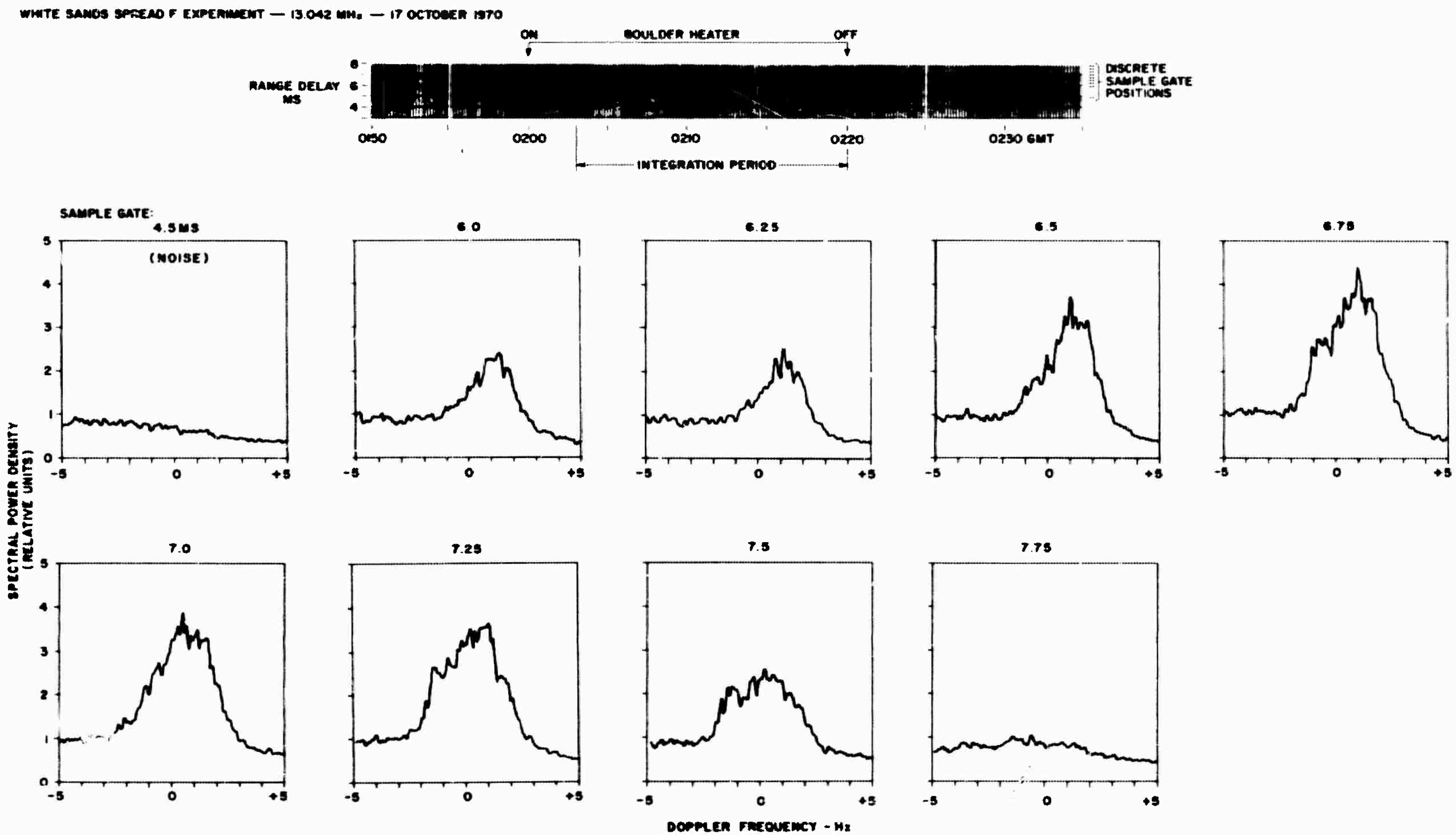


Figure 10. Integrated Power Spectrum at Discrete Range Delays in the 13 MHz Direct Backscatter Return on 17 October 1970 (0200 to 0220 GMT). (U)

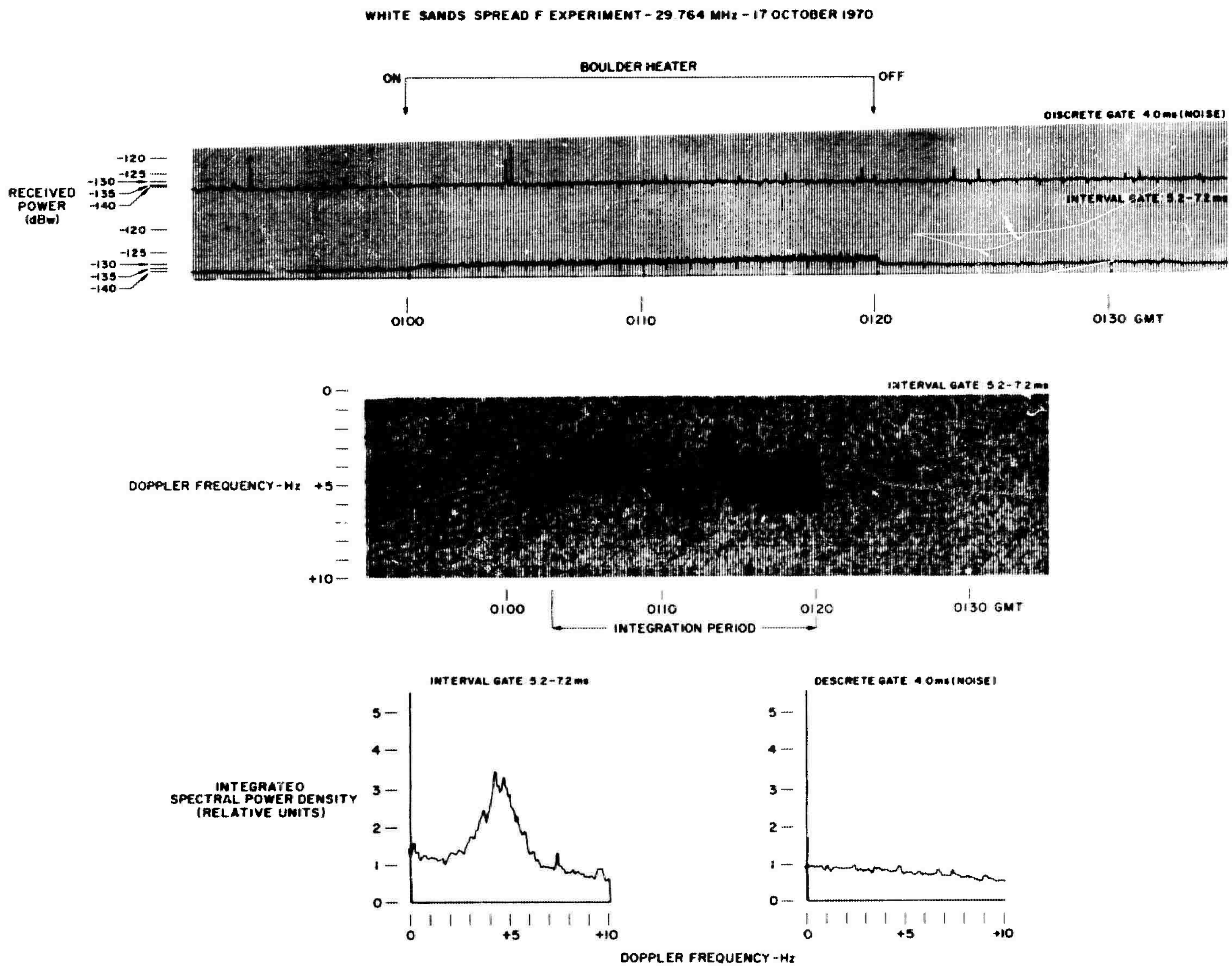


Figure 11. Total Received Power Versus Time and Integrated Spectrum of the Direct Backscatter Return at 30 MHz on 17 October 1970 (0100 to 0120 GMT). (U)

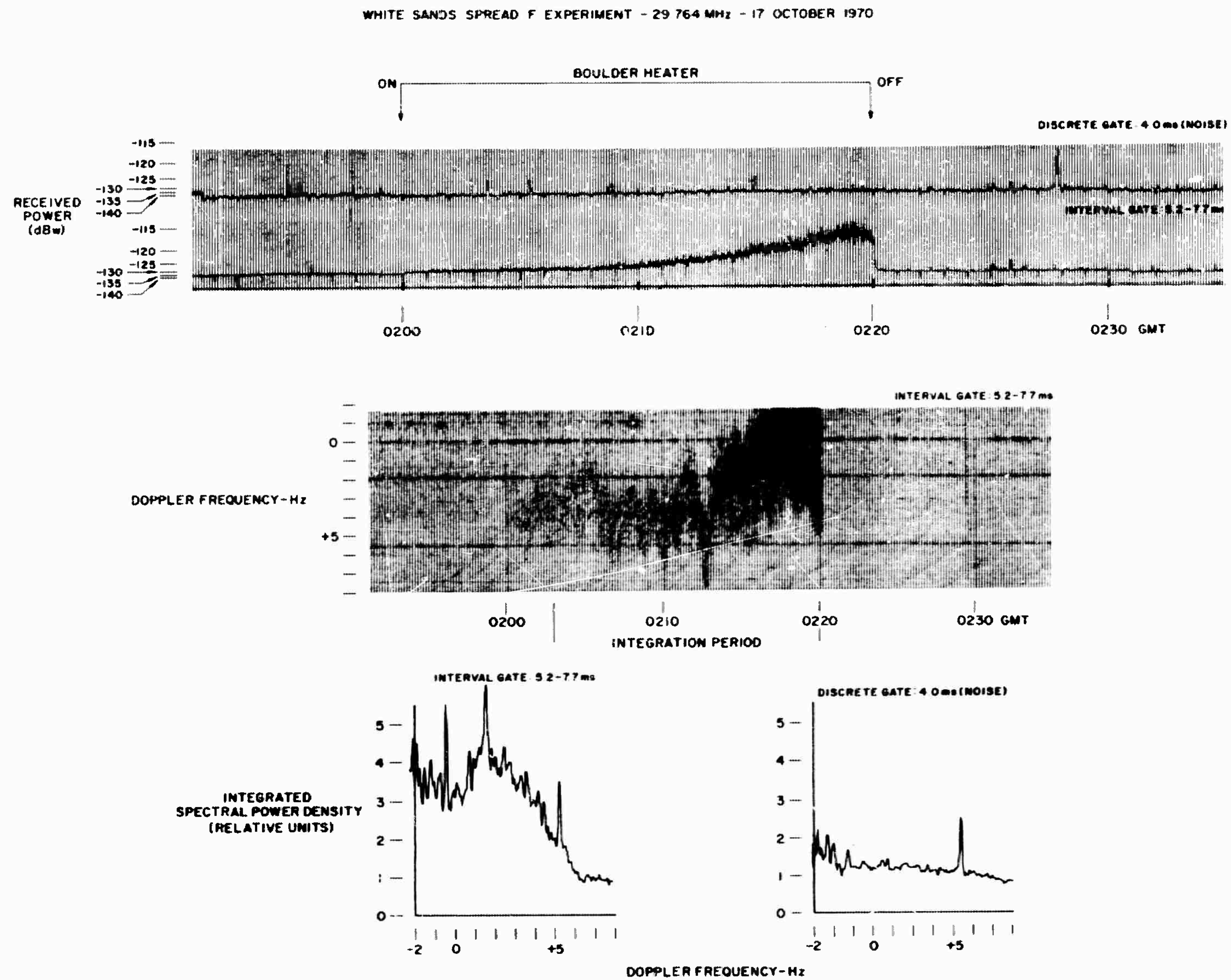


Figure 12. Total Received Power Versus Time and Integrated Spectrum of the Direct Backscatter Return at 30 MHz on 17 October 1970 (0200 to 0220 GMT). (U)

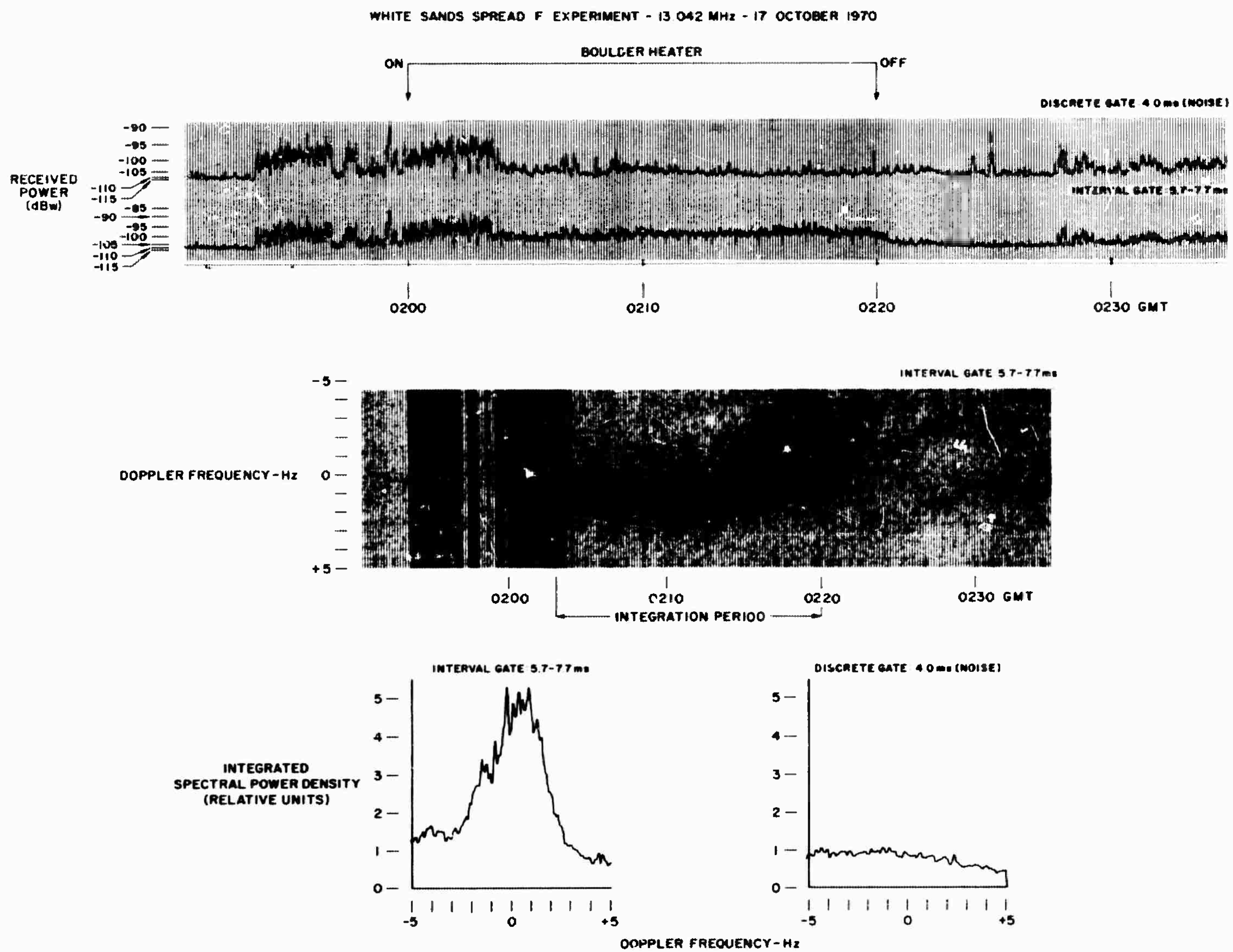
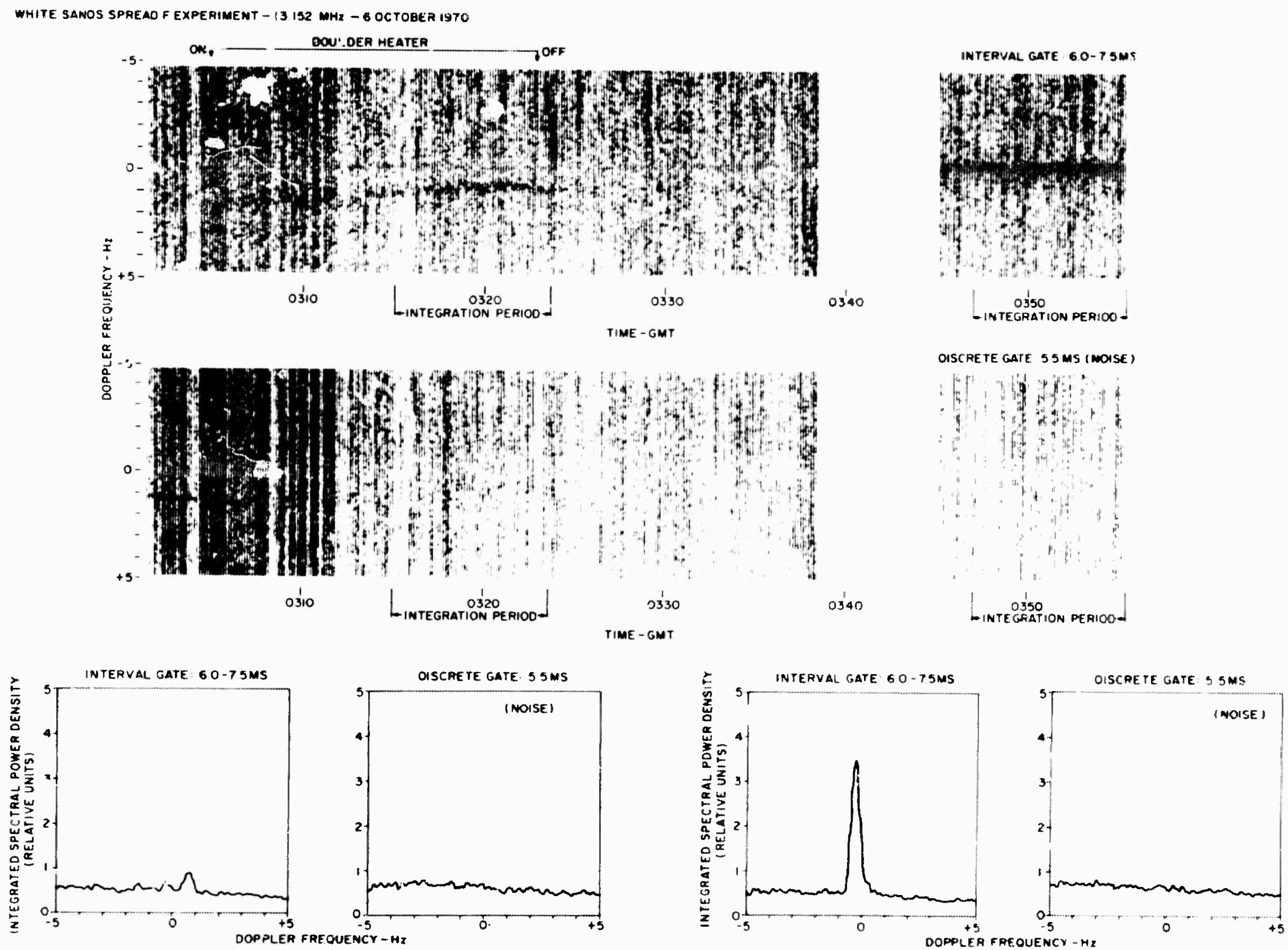


Figure 13. Total Received Power Versus Time and Integrated Spectrum of the Direct Backscatter Return at 13 MHz on 17 October 1970 (0200 to 0220 GMT). (U)



Figu: 14. Power Spec-rum of the 13 MHz Direct Backscatter Returns from the Heated Region - 6 October 1970. (S)

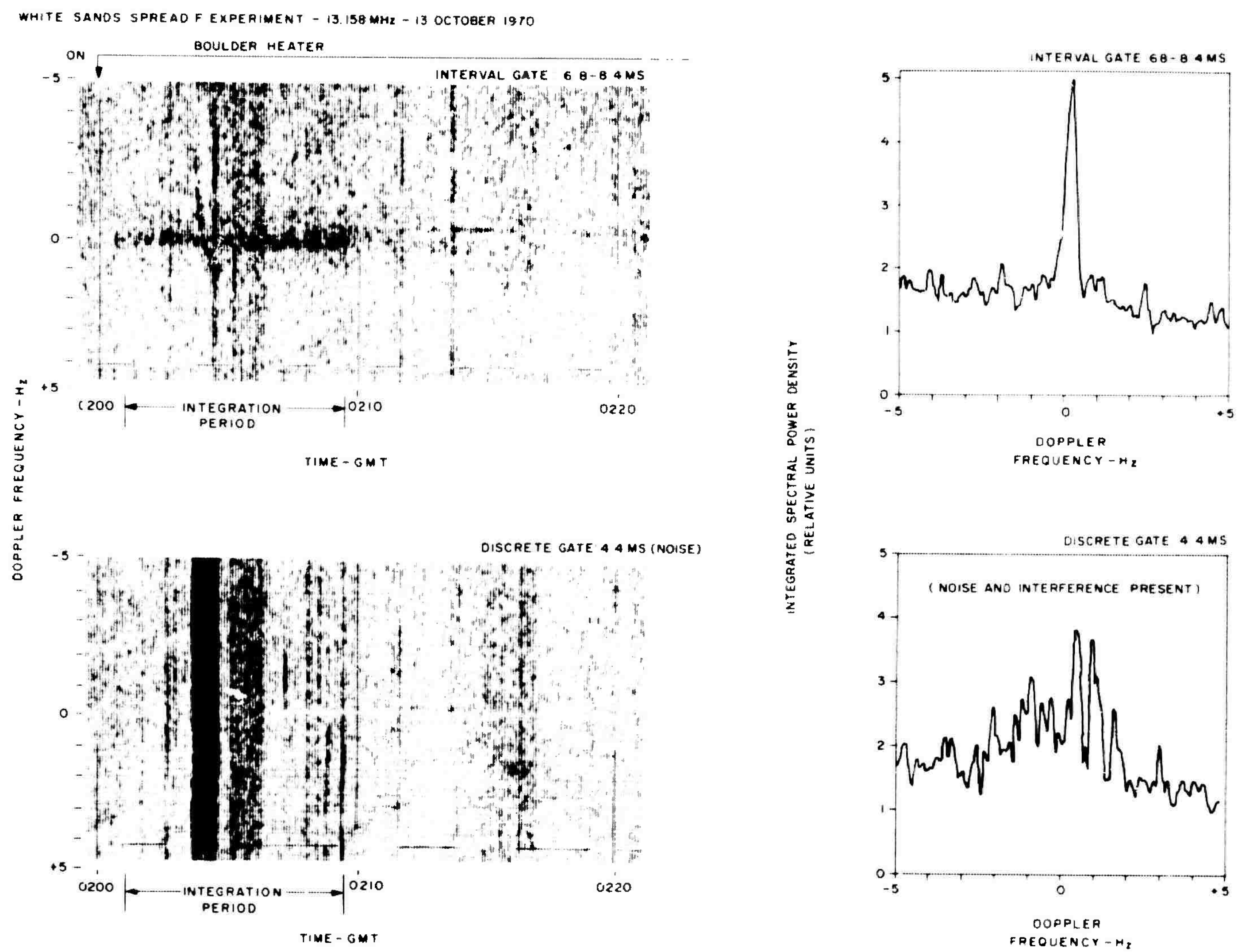


Figure 15. Power Spectrum of a 13 MHz Direct Backscatter Return from the Heated Region - 13 October 1970. (S)

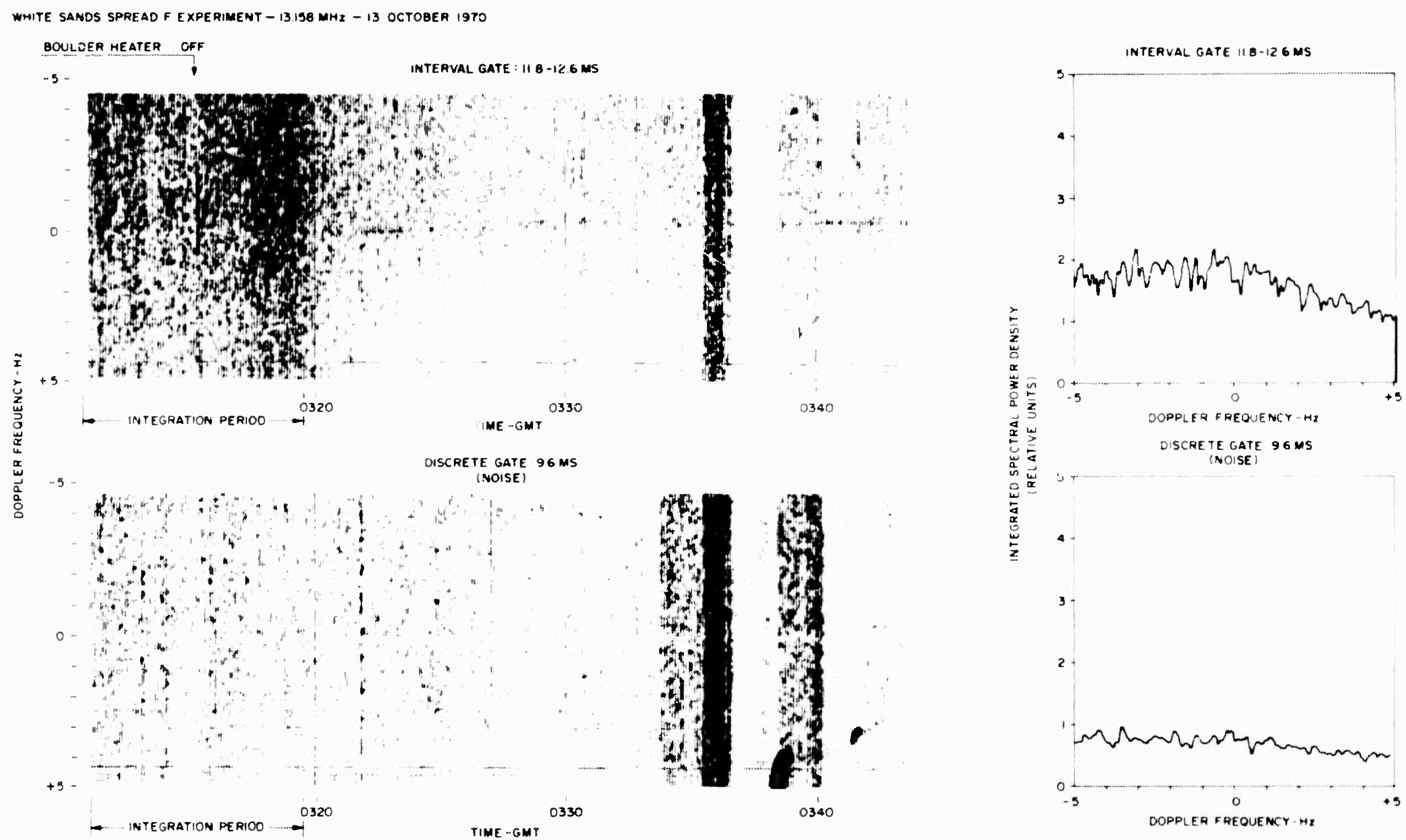


Figure 16. Power Spectrum of a 13 MHz Ground Backscatter Return (12 Ms) Supported by the Heated Region - 13 October 1970. (S)

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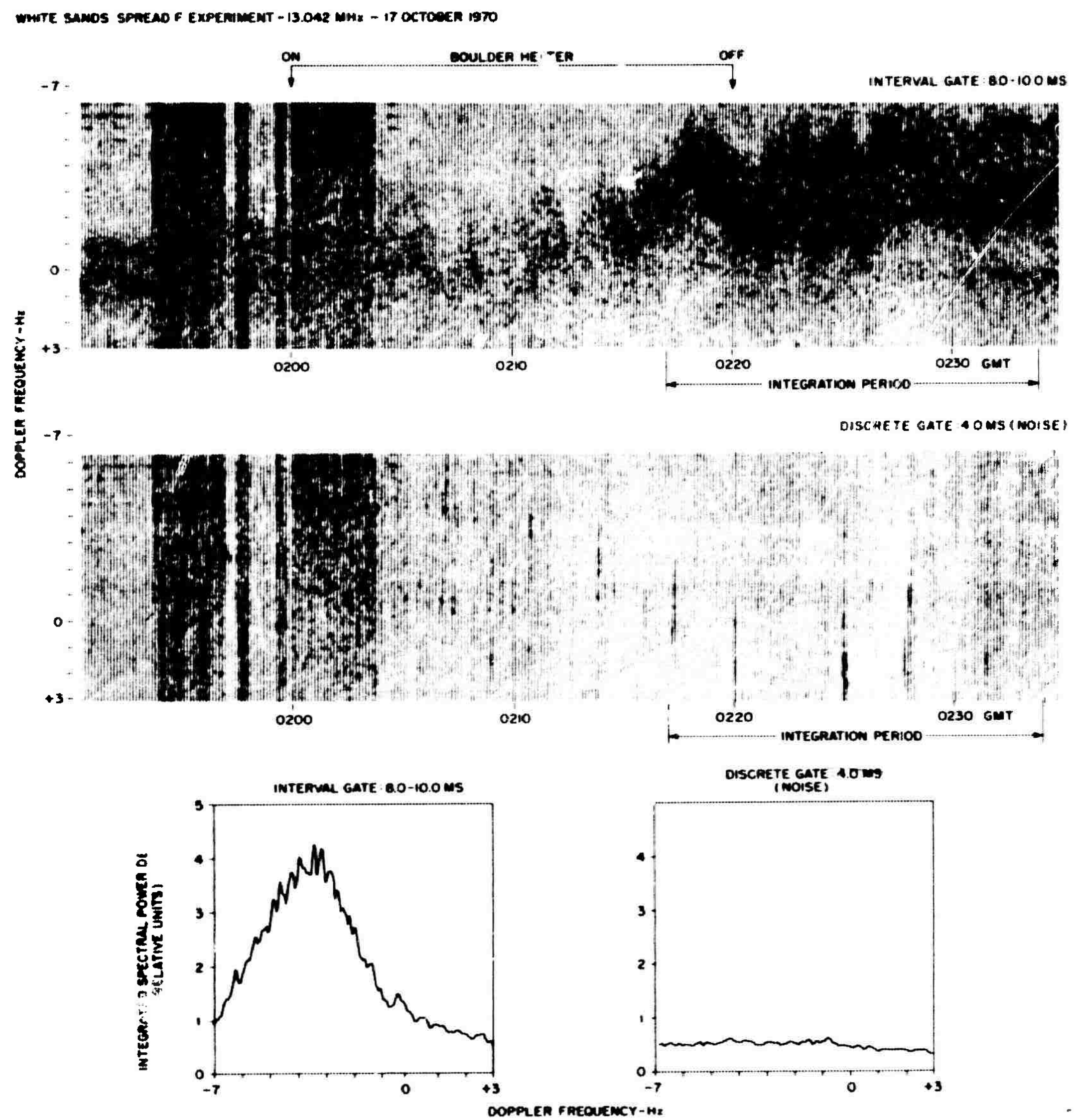

Figure 17. Power Spectrum of a 13 MHz Specular Ground Back-scatter Return (9 Ms) Supported by the Heated Region - 17 October 1970. (S)

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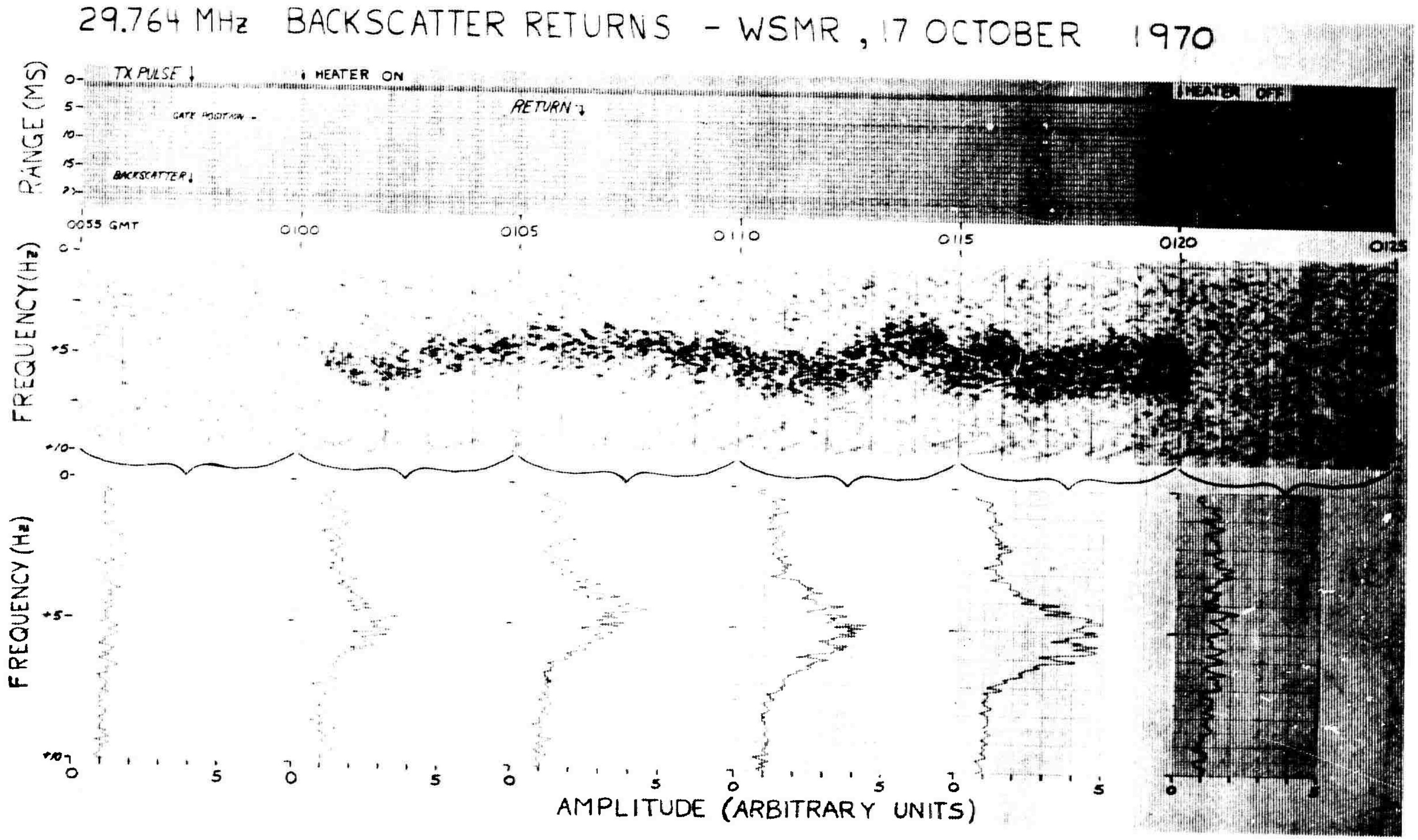

Figure 18. Variation of Spectral Characteristics with Time at a Discrete Range Gate, 30 MHz - 17 October 1970 (0100 to 0120 GMT). (U)

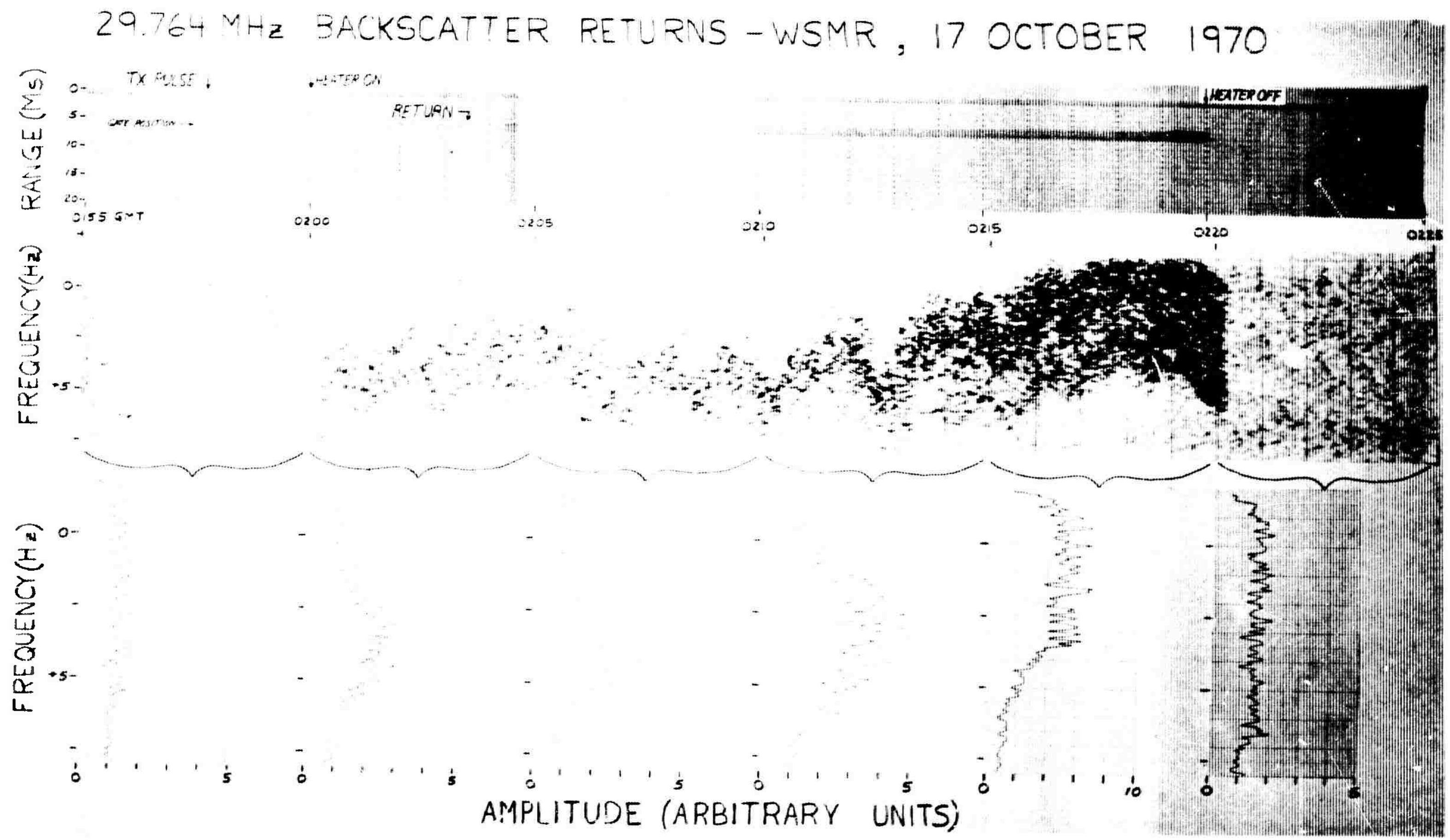

Figure 19. Variation of Spectral Characteristics with Time at a Discrete Range Gate, 30 MHz - 17 October 1970 (0200 to 0220 GMT). (U)

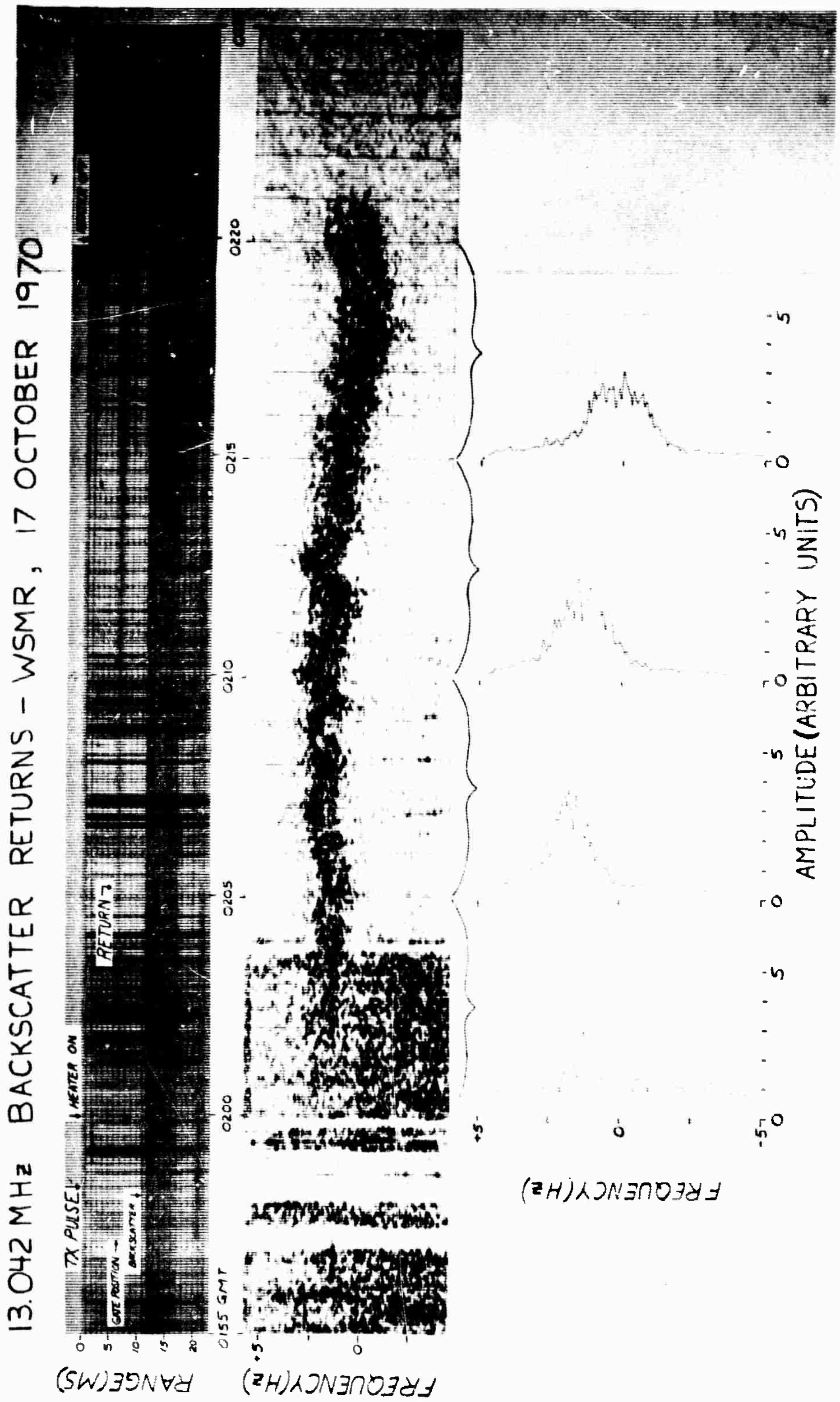

Figure 20. Variation of Spectral Characteristics with Time at a Discrete Range Gate, 13 MHz - 17 October 1970 (0200 to 0220 GMT). (U)

III. THEORETICAL CONSIDERATIONS (U)

A. Scattering Cross-Section (U)

(S) A theory of scattering from field-aligned irregularities has been given by Booker[1] and applied to the problem of understanding the radar characteristics of auroral reflections. In view of the success of the theory in auroral situations and the apparent similarity of the irregularities produced by the Boulder heater (i.e., "Spread-F" on ionograms, direct echoes at oblique incidence when looking normal to the magnetic field), the Booker theory has been applied below to the geometry of the WSMR observations. In this way estimates of physical parameters such as irregularity scale sizes and mean electron density fluctuation can be derived from the radar observations.

(U) Booker shows that for a volume contining random irregularities having a Gaussian autocorrelation function the backscattered power is

$$\sigma_B = (2\pi)^{3/2} \pi^2 (1/\lambda_N)^4 \overline{(\Delta N/N)^2} \, T^2 L \, e^{-\left(\frac{8\pi^2 T^2}{\lambda^2}\right)} e^{-\left\{\frac{8\pi^2}{\lambda^2}(L^2 - T^2)\sin^2\psi\right\}} \quad (1)$$

per unit volume, per unit solid angle, per unit incident power density, where

λ_N = wavelength corresponding to local electron plasma frequency

$\overline{(\Delta N/N)^2}$ = mean squared electron density fluctuation

T = fluctuation correlation distance transverse to magnetic field

L = fluctuation correlation distance along magnetic field

λ = radar wavelength

ψ = complement of angle between the direction of incidence and the axis of symmetry.

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[1] Booker, H. G., "A Theory of Scattering by Non-Isotropic Irregularities with Application to Radar Reflections from Aurora", J.A.T.P., 8, PP. 204 to 221, 1956.

(U) cont.

We want to integrate this backscattering coefficient over the volume containing irregularities in order to relate the measured radar cross-section to the physical properties of the scatterers.

(S) It can be shown that for the conditions of the present experiment,

$$\sigma = 4\pi \int_V \sigma_B \, dv \qquad (2)$$

where

σ = total radar cross-section

σ_B = volume scattering coefficient

V = the scattering volume contributing to the echo

We assume that the irregularities produced by the heater are contained in a cylinder of radius λ aligned with the earth's magnetic field. The radius of the cylinder is taken to be the half-power radius of the heater beam. The cylinder is unbounded along the field. It may of course be that the irregularities do not in fact extend indefinitely along the field but this is probably unimportant since only those irregularities near the layer peak will contribute significantly to the observed signal. This is so because the intensity of the scatter depends on the square of the ambient electron density (and is therefore greatest at the peak) and because only those irregularities near the peak satisfy the specularity conditions for radars located at WSMR. The geometry of the situation is shown in the sketch below:

(S) cont.

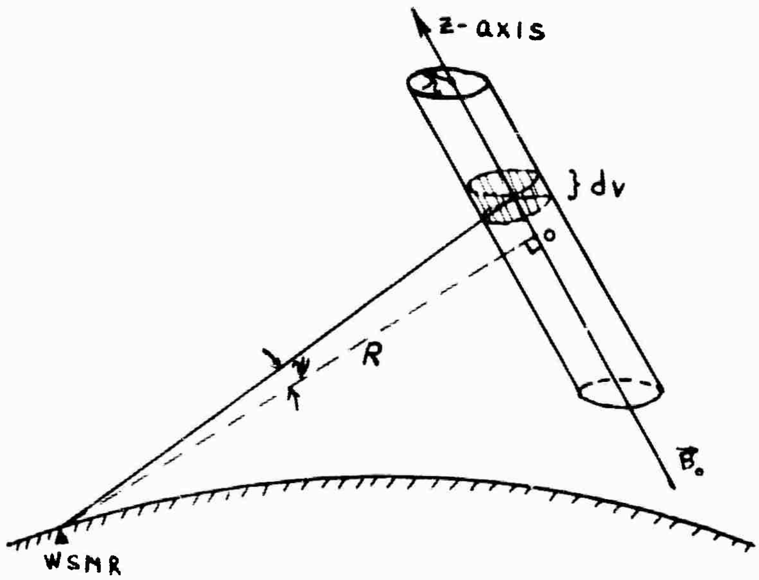

Figure 21. Scattering Geometry.(U)

We assume that $\overline{(\Delta N/N)^2}$, T, and L are constant throughout the volume but that λ_N and ψ vary along the cylinder (along the z-axis). The variation of $(1/\lambda_N)$ with z for a typical experiment is shown below (taken from an ESSA true-height electron density profile).

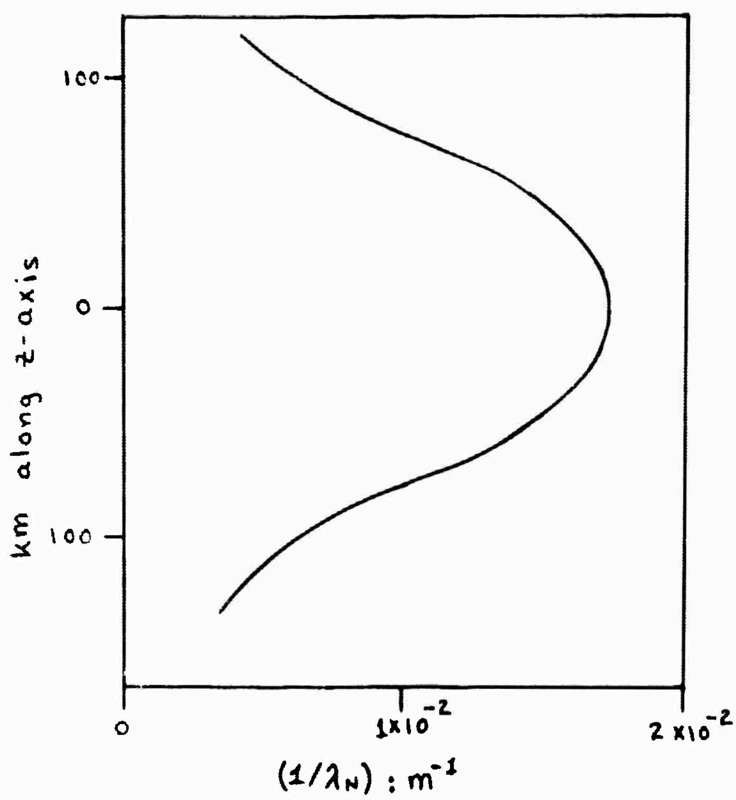

Figure 22. Variation of $(1/\lambda_N)$ Along Field Line. (U)

(S) cont.

In order to integrate σ_B analytically we model this curve as a Gaussian of the form

$$(1/\lambda_N) = (1/\lambda_{N_0})\, e^{-(z^2/h^2)}$$

where

$$\lambda_{N_0} = \lambda_N \text{ at the layer peak } (z=0)$$

$$h = \text{Gaussian scale distance}$$

Finally, since R << h we replace sin ψ with ψ and integrate σ_B to obtain

$$\sigma = \frac{8\sqrt{2}\,\pi^6 \lambda^2 \overline{(\Delta N/N)^2}\, T^2 L\, e^{-(8\pi^2 T^2/\lambda^2)}}{\lambda_{N_0}^4 \sqrt{(4/h^2) + 8\pi^2 (L^2 - T^2)/\lambda^2 R^2}} \qquad (3)$$

B. Numerical Example

(S) As a numerical example we consider the measurements made just prior to heater turn-off during the last cycle on the night of 16 October 1970. The two radar frequencies in use at the time were 13.042 MHz (hereafter associated with subscript 1) and 29.764 MHz (nereafter associated with subscript 2). In tabular form,

f_1 = 13.043 MHz	f_2 = 29.764 MHz
λ_1 = 23 m	λ_2 = 10 m
$\sigma_1 = 1 \times 10^9$ m^2	$\sigma_2 = 5 \times 10^7$ m^2

and typically,

L = 50 Km	(half the diameter of a 20° heater beam at 300 Km)
h = 100 Km	(Gaussian half-width from Figure 3)
λ_{N_0} = 57 m	(plasma wavelength from Figure 3)
R = 900 Km	(range from WSMR to heated volume)

(S) Since there are three unknows $(L, T, \overline{(\Delta N/N)^2})$ and only two observations (σ_1, σ_2) the unknowns can not be uniquely determined. However consider the special case i.. ..ich the scatterers are isotropic so that '. = T. Then equation (3) leads to

$$T^2 = \frac{\ln(\sigma_1/\sigma_2)}{8\pi^2(1/\lambda_2 - 1/\lambda_1)} \quad (4)$$

and

$$\overline{(\Delta N/N)^2} = \frac{\sigma_1 e^{+(8\pi^2 T^2/\lambda_1^2)}}{4\sqrt{2}\,\pi^6 h \lambda^2 (1/\lambda_{N_0})^4 T^3} \quad (5)$$

from which

$$T = 0.8 \text{ m}$$

and

$$\sqrt{\overline{(\Delta N/N)^2}} = 0.12$$

That is, in order to explain the observations on the basis of irregularities which are not field aligned, the scatterers would have to

a.) fill a cylindrical volume roughly 100 Km in diameter and 100 Km long

b.) have a correlation distance of about 0.8 meters

c.) have a root-mean-square electron density fluctuation of about 12%.

It is not obvious that these are unreasonable requirements and consequently it is perhaps premature to conclude that the WSMR observations demonstrate the existance of field-aligned scatterers in the heated volume. On the other hand, the observations could be more easily explained (smaller scattering volume and weaker mean electron density fluctuations) if the irregularities were in

(S) cont.

fact field aligned (L>>T). Additional measurements will be needed to settle the question.

IV. SUMMARY AND CONCLUSIONS (U)

(S) The WSMR series of experiments was designed primarily as a test of the hypothesis that ionospheric irregularities generated by the Boulder heater would produce detectable radar returns at frequencies well above the maximum ionospheric plasma frequency when viewed normal to the magnetic field.

1. The result of this test is positive: direct echoes from the heated volume have unquestionably been observed at frequencies up to 30 MHz (the highest available during the test series) at times when the maximum ionospheric plasma frequency was about 5 MHz.

2. The results vary widely from day to day and from heating cycle to heating cycle on the same day. Some days no echoes at all were detected while other days targets as large as 10^9 m^2 were observed. The following possible explanations are offered for this behavior:

   a. It may be that irregularities are generated only near the reflection height of the heater and are strongly field aligned. They would then be highly aspect sensitive and echoes would be observed at WSMR only if the reflection height of the heating signal were near the specular point for WSMR, i.e., near 290 Km. Since this height is also near the layer peak it implies that the heater would have to be operating near the critical frequency of the layer.

(S) cont.

In this case when the heater was operated well below the critical frequency for the layer, the scatterers would lie well below the specular point for WSMR and could not be observed due to aspect sensitivity. They could be observed, however, by a radar further north than WSMR for which the specular point would be lower in altitude.

b. It may be that irregularities strong enough to support direct backscatter are only produced when the heater operates near the critical frequency of the layer. In this case aspect sensitivity is not required to explain the absence of echoes at WSMR and direct echoes would not be observed from any location when the heater was operating well below the critical frequency of the layer.

c. It may be that refraction of the radar rays from WSMR to the heated volume is great enough and variable enough to explain the absence of echoes when coupled with high aspect sensitivity and/or variable height of generation.

d. It may be that ambient geophysical conditions (such as magnetic activity) make the ionosphere prone to irregularity generation on some days and not on others.

3. The direct radar returns occur at the range to the heated volume and turn on and off with the heater. The echo strength builds up steadily during the 20 minutes of heating. At 30 MHz the echo disappears after heater turn-off in about 10 seconds while at 13 MHz the echo disappears after about 100 seconds. The longer

(S) cont.

persistence of the lower frequency echo may be a consequence of the larger irregularity scale responsible for this return and the correspondingly longer time required for diffusion to smooth these fluctuations out.

At 30 MHz the doppler spectrum of the return is typically spread by a few hertz and has a net positive doppler shift of a few hertz. This is tentatively interpreted as implying a differential velocity between scatterers and a net southward drift of scatterers of a few tens of meters per second.

4. It has not been demonstrated that the irregularities responsible for the radar returns are field aligned. However in order to explain the strength and wavelength dependence of the echoes on the basis of isotropic scatterers, they would have to

a. occupy a cylindrical volume about 100 Km in diameter and 100 Km long,

b. have a Gaussian correlation function with a scale size of 0.8 meters,

c. have a root-mean-square electron density fluctuation of 12%.

While these requirements are not impossibly severe, the results could be explained by weaker scatterers in a smaller volume if the irregularities were field aligned.

(S) cont.

5. In addition to the direct returns there are also perturbations observed in the ground backscatter returning through the heated volume. These have received little study as yet.

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13. ABSTRACT

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(S) The results of direct HF backscatter echoes from six White Sands F Experiment are presented. The Spread F type conditions result from the heating of the F layer of the ionosphere through the utilization of a high power transmitter near Boulder, Colorado. Direct echoes from the heated volume were observed at frequencies as high as 30 Mhz and were well correlated with the turn-on and turn-off of the Boulder transmitter.

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