# A search for lunar radio Cerenkov from high-energy neutrinos

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or

# "Daddy, did you find any timrons?"

by

**Tim** and **Ron**

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# A search for lunar radio Čerenkov emission from high-energy neutrinos

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**ABSTRACT**

A search for Čerenkov emission in the radio-frequency range resulting from the particle cascade of an ultrahigh-energy neutrino on the near surface of the Moon is described. The expected pulse of 1-ns duration, dispersed by propagation through the Earth's ionosphere, with an amplitude of approximately 400 Jy was not detected in approximately 10 h of observations.

**Key words:** methods: observational – Moon – cosmology: observations.

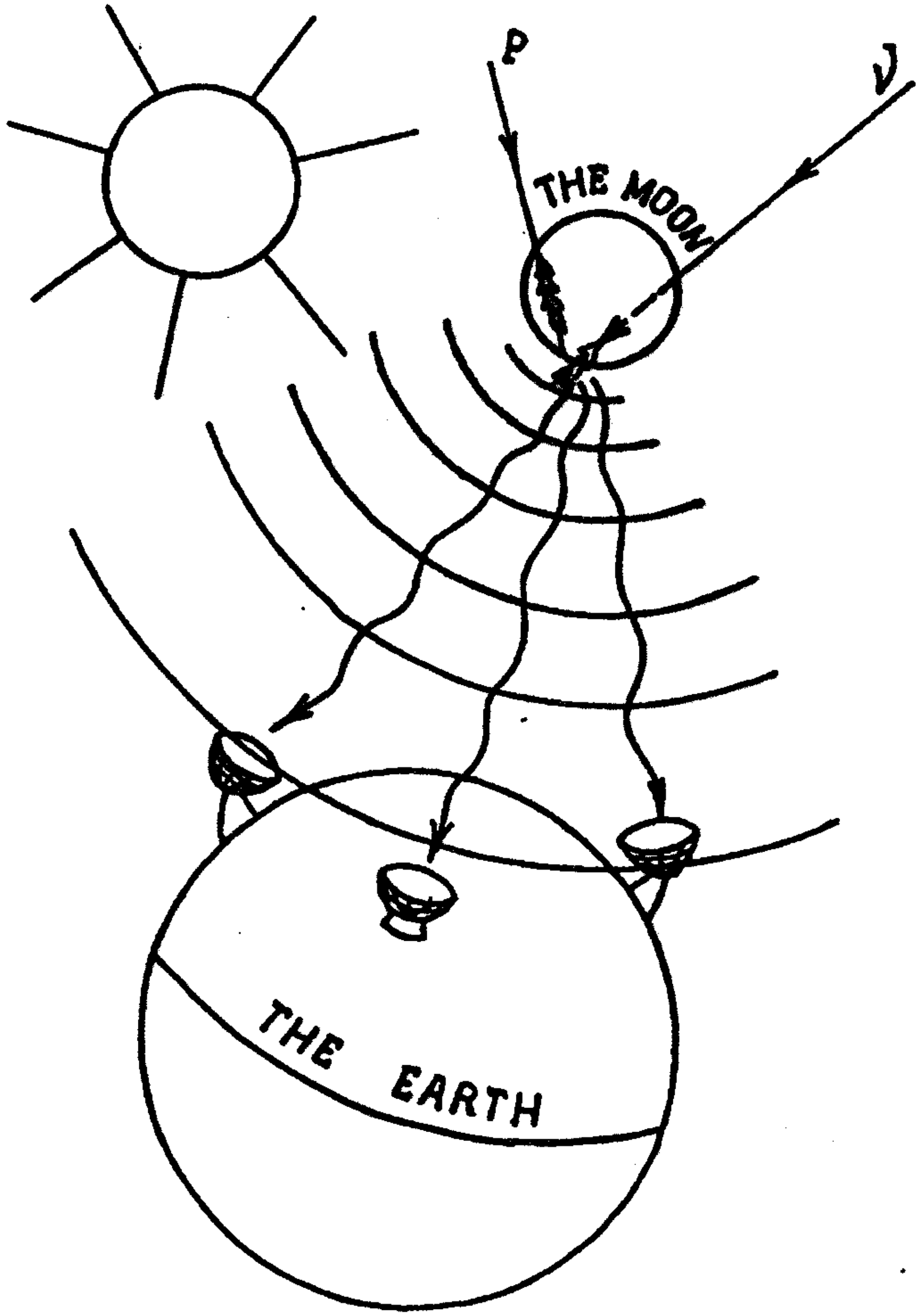



Fig.1 - A scheme of RAMHAND - Radio Moon Hadron and Neutrino Detection

# Neutrino detectors

| | |
|---|---|
| • Homestake Gold Mine (Solar neutrinos) | $V = 400\ m^3$ |
| • Existing Extensive Air-shower Arrays. | $A = 10\text{–}20\ km^2$ |
| • Proposed Extensive Air-shower Arrays. (Fly's Eye*, EAS-1000, etc.) | $A = 100\text{–}1000\ km^2$ |
| • Underground Water Detectors. (Kamiokande, etc.) | $V = 10^3 - 10^4\ m^3$ |
| • Optical Deep Water Muon and NeutrinoDetector (DUMAND) | $V = 10^7\ m^3$ |
| • Antarctic Ice - radio antennas in or on ice | $V = 10^9 - 10^{10}\ m^3$ |
| • <u>Moon</u> | $A = 10^7\ km^2$<br>$V = 10^{14}\ m^3$ |

* Fly's Eye has seen < 1/yr events for $10^{20}$ eV hadrons

# Objective:

Test the hypothesis that $E > 10^{20}$ eV neutrino interaction cascades in the near 10 m of the Moon produce of radio Cerenkov emission.

# Strategy:

Look for short, dispersed radio pulses.

Use existing equipment where possible.

# Observational Parameters:

**Telescope:** Parkes 64-m telescope, New South Wales, Australia

**Time:** Full Moon to avoid daytime terrestrial interference. 10 hr over 3 days, 17-19 Jan 1995.

**Receiver:** SETI, 1.2 – 1.9 GHz

**Frequency:** 1425 MHz (±250 MHz)

**Bandwidth:** 475 MHz to get 2-ns time resolution

**Beamwidth:** 13 arc min
(Moon ~ 30 arc min, hence reduced sensitivity at Moon's limb.)

# Sensitivity:

## System Noise:

450 Jy (1 Jy = $10^{-26}$ W/m$^2$/Hz)

## Expected Flux:

4200 Jy for $E_\nu = 10^{20}$ eV neutrino event.

## Trigger Detectors:

Square law (power) detectors.

Two 100-MHz bands, 100 MHz apart.

Coincidence of two pulses (duration 7.5 ns < t < 20 ns) required, with 10 ns delay of higher frequency channel.

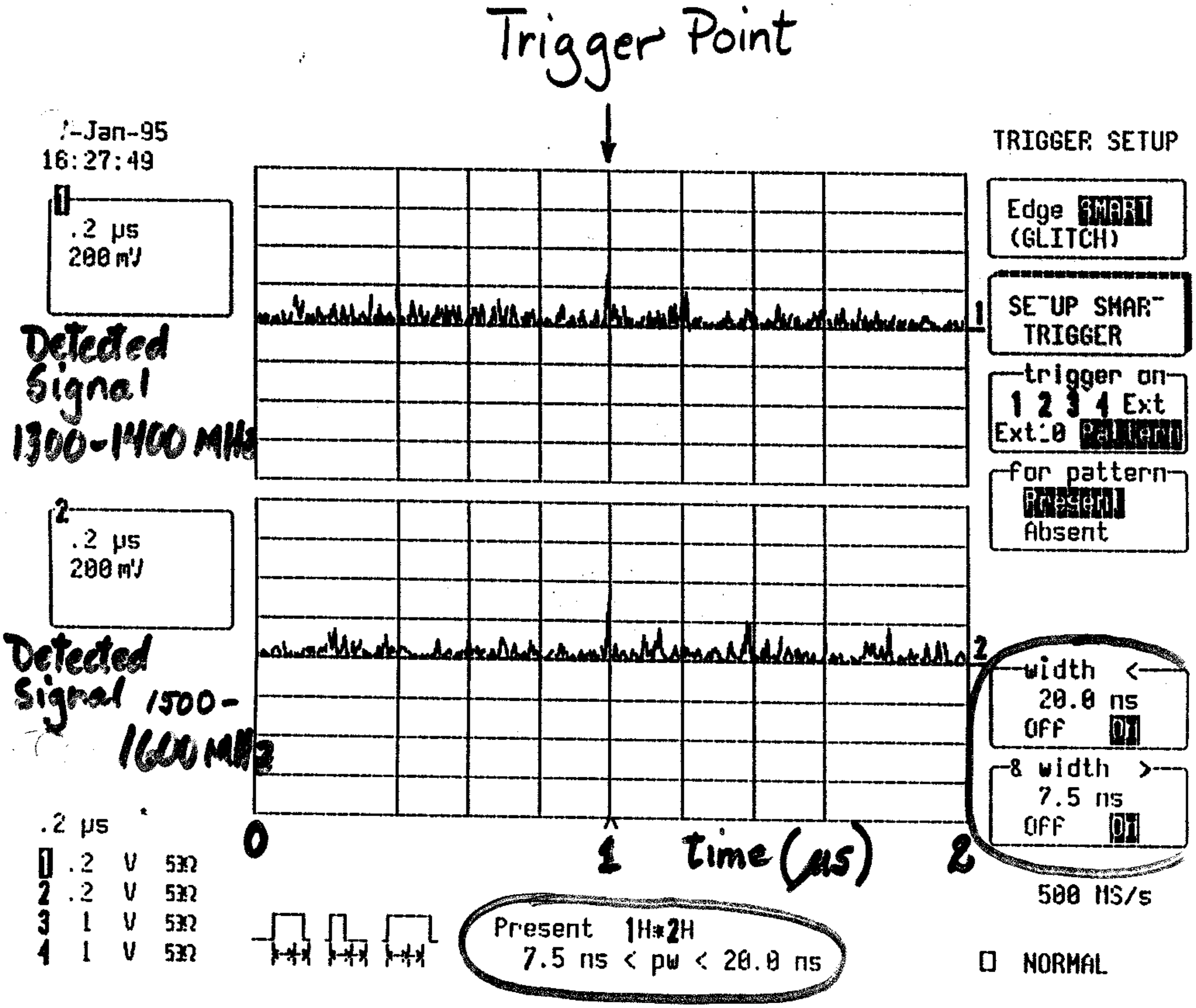
# Sampling:

## Two circular polarizations

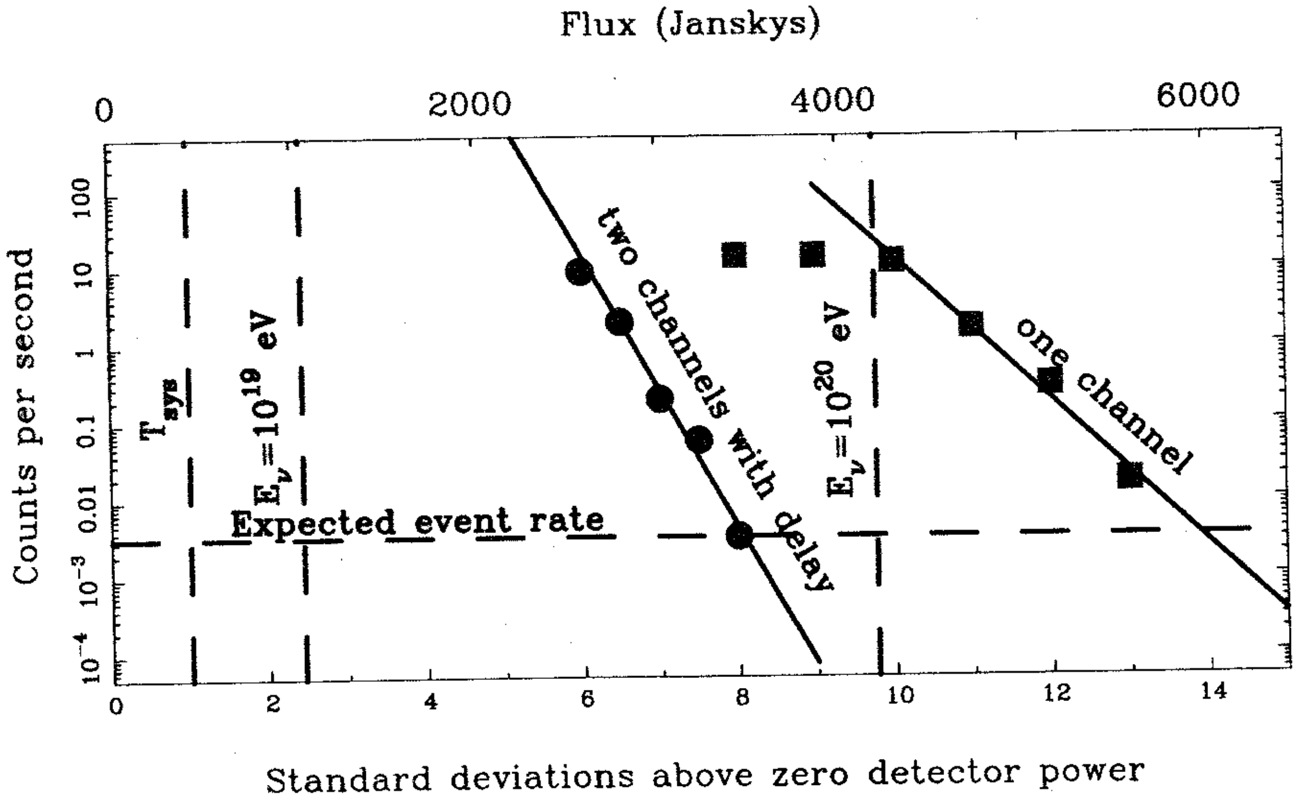
**Total Bandwidth:** 2 x 500 MHz

**Quadrature Sampling:**

2 ns/sample, 8 bits/sample
500 samples/event (1μs per event)
(250 samples before trigger,
250 samples after trigger.)

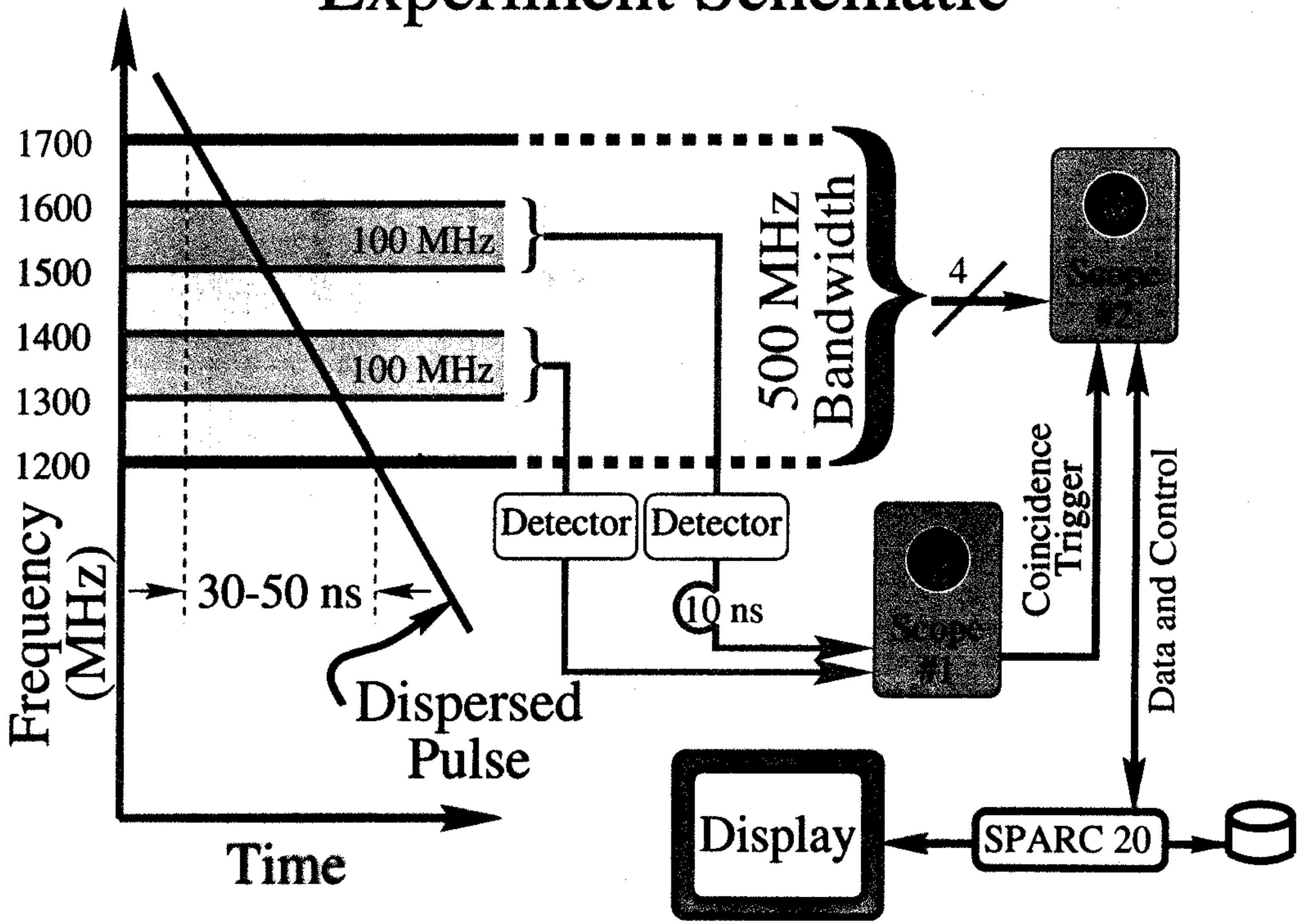


Trigger Point
/-Jan-95
16:27:49
TRIGGER SETUP
1 .2 µs 200 mV
Edge SMART (GLITCH)
SETUP SMART TRIGGER
Detected Signal 1300-1400 MHz
trigger on 1 2 3 4 Ext Ext/10 Pattern
for pattern Present Absent
2 .2 µs 200 mV
Detected Signal 1500-1600 MHz
width < 20.0 ns OFF ON
& width > 7.5 ns OFF ON
.2 µs
1 .2 V 50Ω
2 .2 V 50Ω
3 1 V 50Ω
4 1 V 50Ω
0
1
Time (µs)
2
500 MS/s
Present 1H*2H
7.5 ns < pw < 20.0 ns
NORMAL




False alarm rates

# Experiment Schematic



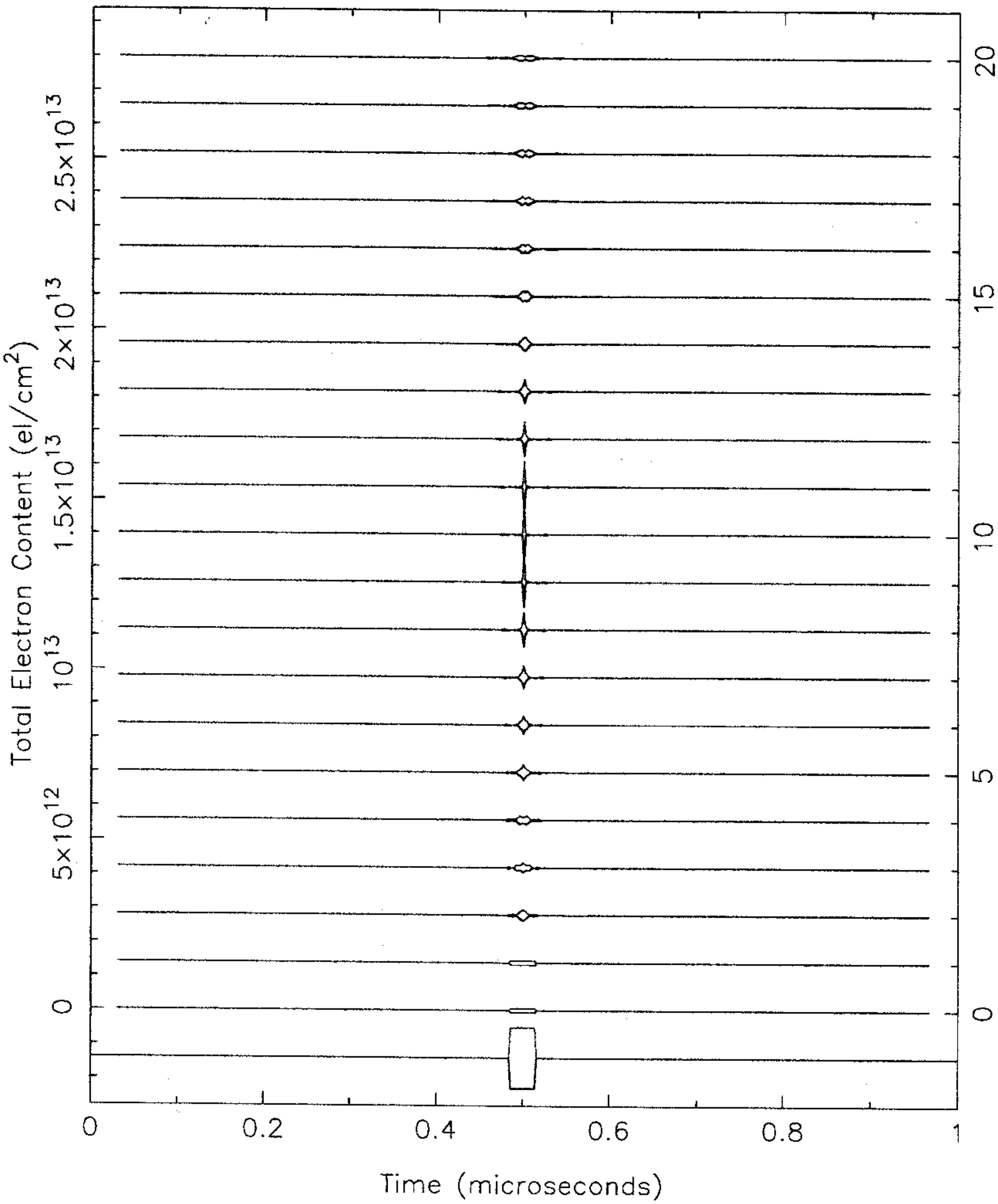
**Duration of dispersed impulse:**

$$\begin{aligned}
\tau_\mathrm{d} &= 0.012\ \Delta\nu\ \mathrm{STEC}\ \nu^{-3} \\
\Delta\nu &= \text{Bandwidth } (500 \times 10^6 \text{ Hz}) \\
\nu &= \text{Center Frequency } (1425 \times 10^6 \text{ Hz}) \\
\mathrm{STEC} &= \text{Slant Columnar Electron Content} \\
&= \text{Typically } 5 \times 10^{12} \text{ el/cm}^2 \text{ (night)} \\
&= \quad 15 - 25 \times 10^{12} \text{ el/cm}^2 \text{ (day)}
\end{aligned}$$

$$\begin{aligned}
\tau_\mathrm{d} &\approx 20\,\text{ns (night)} \\
&\approx 50 - 150\,\text{ns (day)}
\end{aligned}$$

**Dedispersion processing gain:**

$$\begin{aligned}
g_\mathrm{d} &\equiv \frac{\text{de-dispersed pulse amplitude}}{\text{dispersed pulse amplitude}} \\
&\approx \tau_\mathrm{d}\,\Delta\nu \\
&\approx 10 \text{ (night)} \\
&\approx 25 - 75 \text{ (day)}
\end{aligned}$$




Moon
File: LL950117.0234

Freq: 1425.000 (1175.000–1675.000) MHz
Sample Rate: 500.0 MHz. ntb: 512 nsb: 512

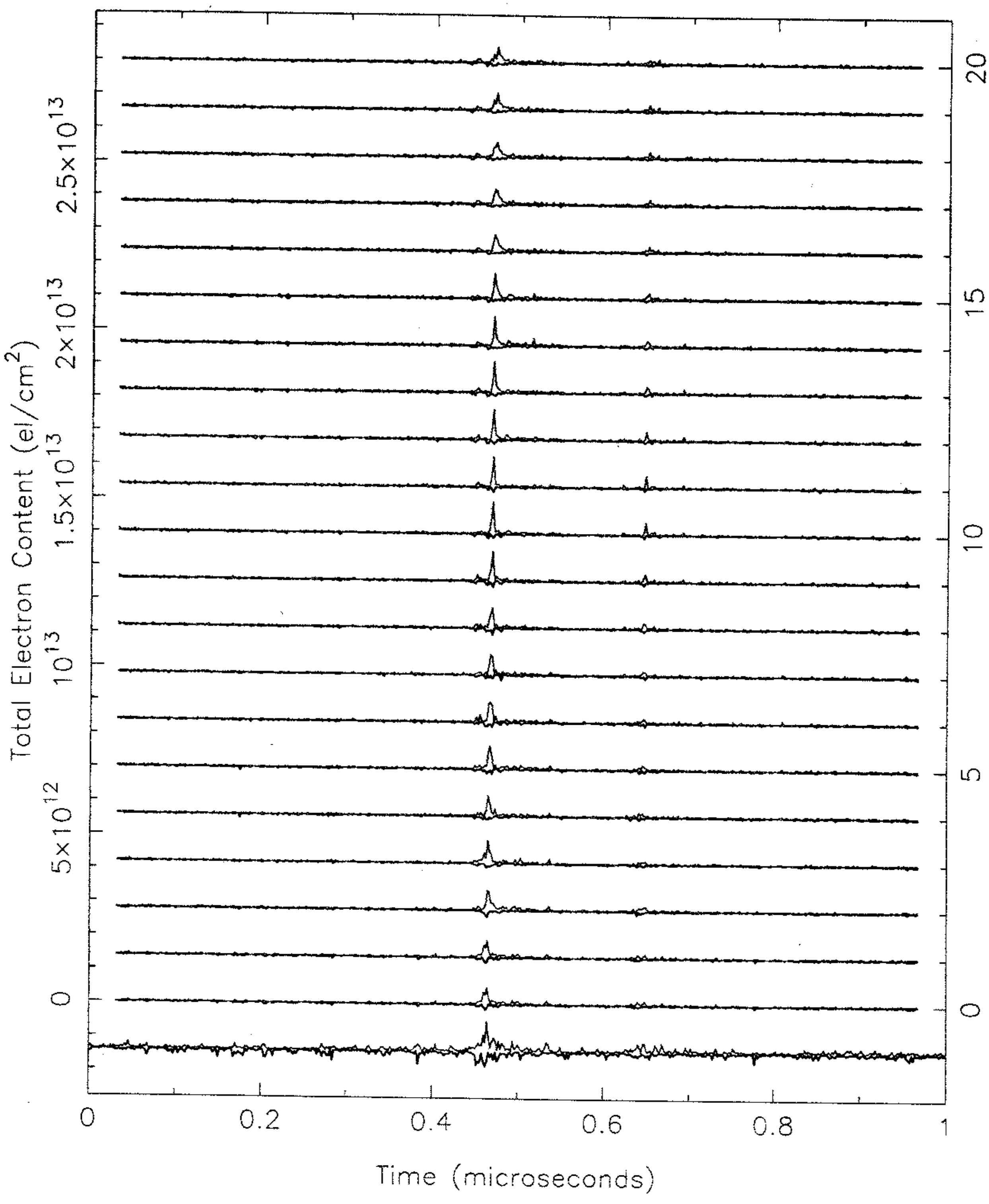
# Detection Criteria

**An event must meet of the following criteria:**

Must arrive the trigger time.

Must appear in circular polarization channels.

Dedispersion reconstruction must produce an impulse with the dispersion value.

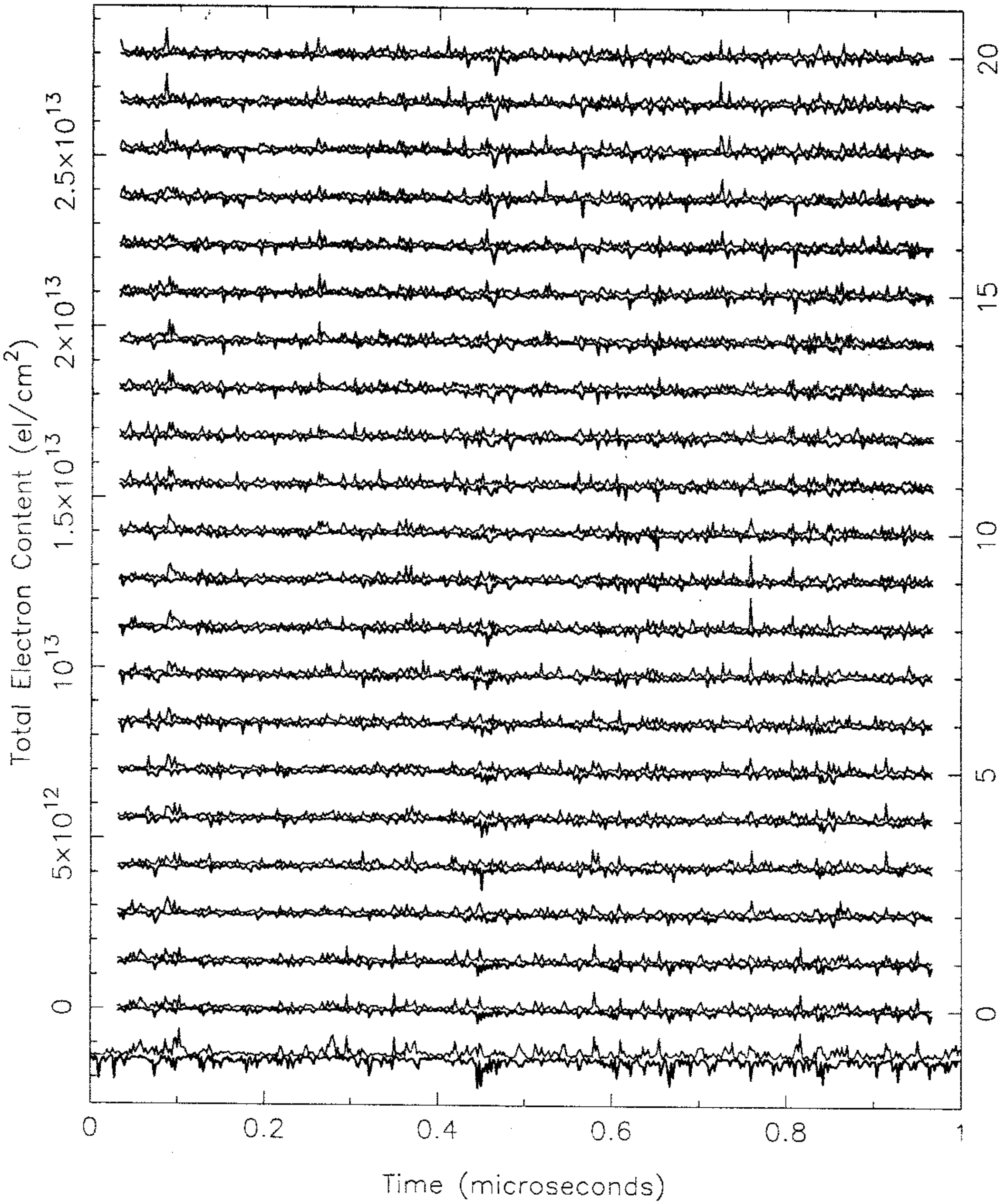



Moon

File: LL950117.0237

Freq: 1425.000 (1175.000–1675.000) MHz

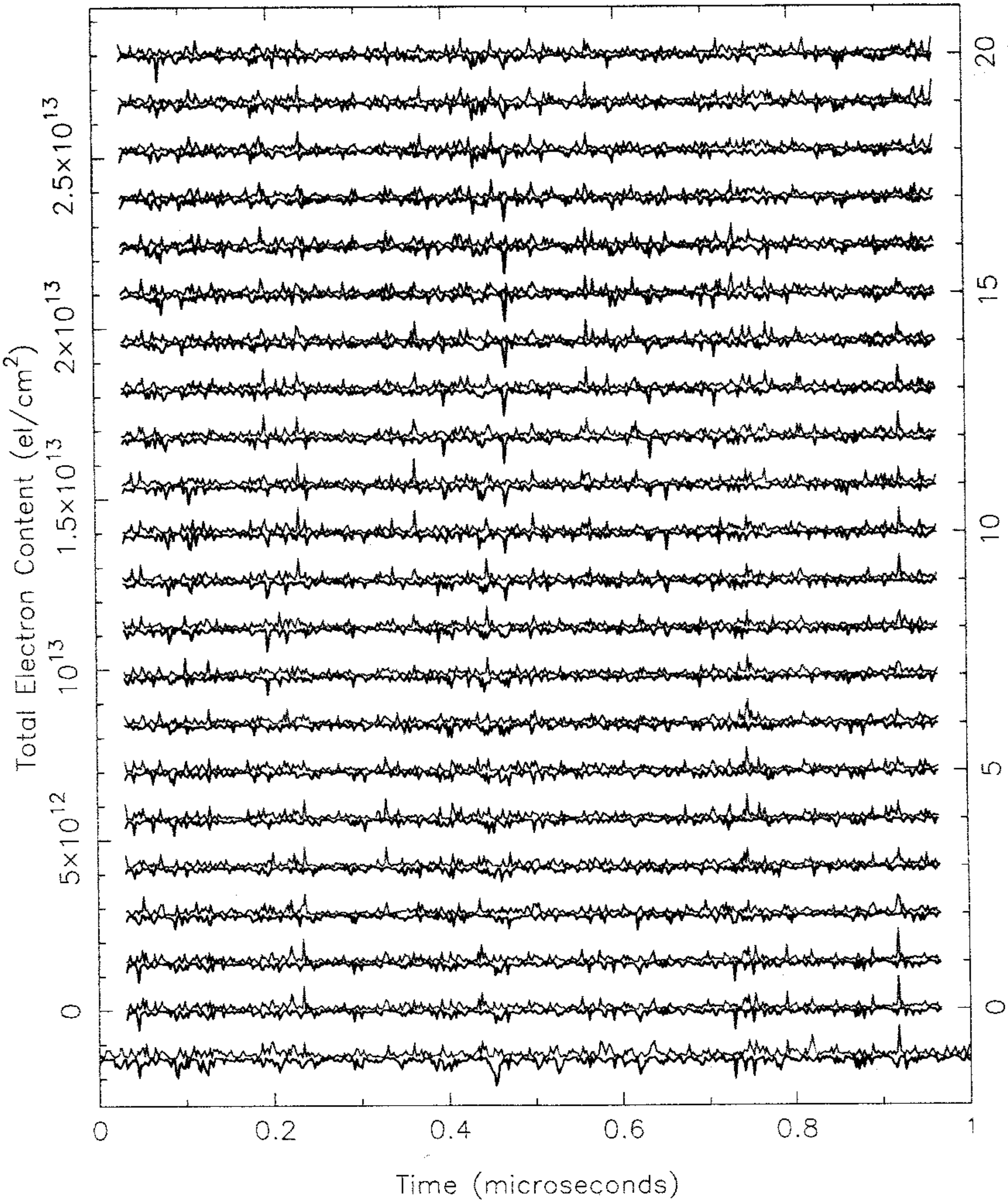
Sample Rate: 500.0 MHz. ntb: 512 nsb: 512




Moon
File: LL950117.0191

Freq: 1425.000 (1175.000–1675.000) MHz
Sample Rate: 500.0 MHz. ntb: 512 nsb: 512

15'5




Moon
File: LL950118.0044

Freq: 1425.000 (1175.000–1675.000) MHz
Sample Rate: 500.0 MHz. ntb: 512 nsb: 512

Strategy, phase 2:

- Anti-coincidence on terrestrial interference.

- Use full 500 MHz
(2 × 5 channels × 100 MHz) for incoherent dedispersion for trigger generation.

- Consider using 1400 MHz and 600 or 400 MHz. Dispersion delays 200–400 ns.

- Use spatial coincidence: two antennas with trigger communication.

- Match filter to expected waveform.

## Conclusions

If the flux of $10^{20}$-eV neutrinos was as high as predicted, we should have seen 20–25 events.

Therefore we can set some upper limits:
$E_\nu \leq 0.7 \times 10^{20}$ eV

or the flux of $10^{20}$-eV neutrinos is at least an order of magnitude less than the predictions.

Larger telescope??

Arecibo's 1.5-arcmin beam at $\lambda 21$ cm $\Rightarrow$ 1 event/30 hours

- Mark Lotter, Scientific Devices, Sydney, Australia, for loan of LeCroy 9354L oscilloscope.
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- Jiping Wu, Australian Ionospheric Prediction Service for STEC predictions.