Some ISR History (US) and a few tidbits

Why VHF to UHF frequencies?

To determine Te/Ti, want to retain double humped spectral shape (related to Debye length) – sets minimum wavelength:

$$\lambda_D = \sqrt{\frac{\varepsilon_0 k_B T_e}{n_e q_e^2}}$$

Region	Height, km	N, m-3	Te, K	Minimum wavelength, cm
E	120	1E10 1E11	300 300	25 10
F1	200	1E11 1E11	2000 3000	25 15
F2	300	1E11 1E12	2500 2500	25 7.5
Topside	1000	1E10	3000	95

Cosmic background noise:
Bigger or smaller as RX frequency goes up?

Spectral width:
Bigger or smaller as center TX frequency goes up?

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F2	300	1E11 1E12	2500 2500	25 7.5
Topside	1000	1E10	3000	95

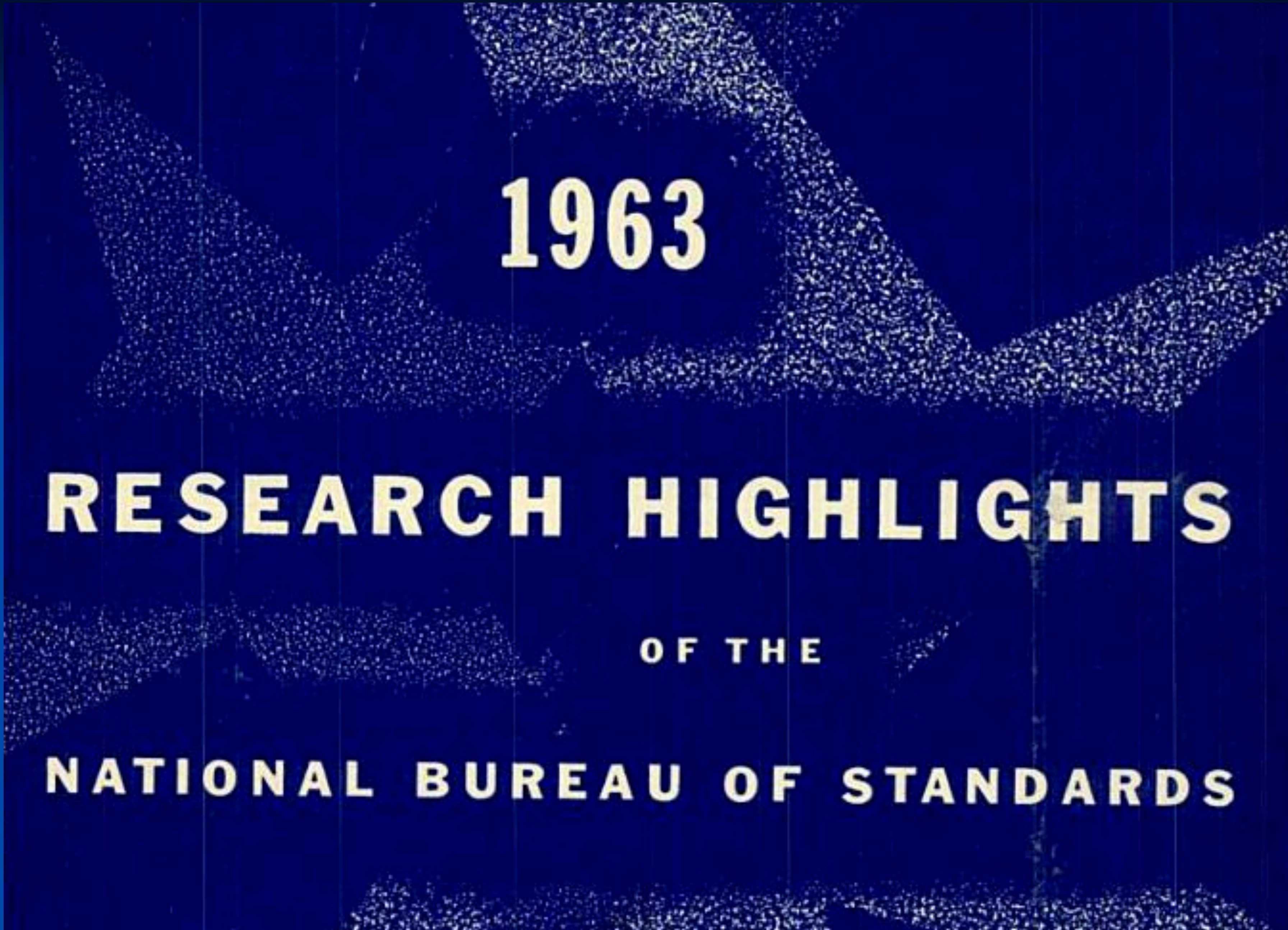
Cosmic background noise:
SMALLER as RX frequency goes up

Spectral width:
BIGGER as center TX frequency goes up

Result:
Meter scale wavelengths ideal for ISR probing to ~1000 km

Incoherent Scatter Radars


Jicamarca Radio Observatory near Lima, Peru
Constructed 1959 -1960 by K. L. Bowles (National Bureau of Standards, Transmission/
Propagation division)
50 MHz center frequency


1963

RESEARCH HIGHLIGHTS

OF THE

NATIONAL BUREAU OF STANDARDS

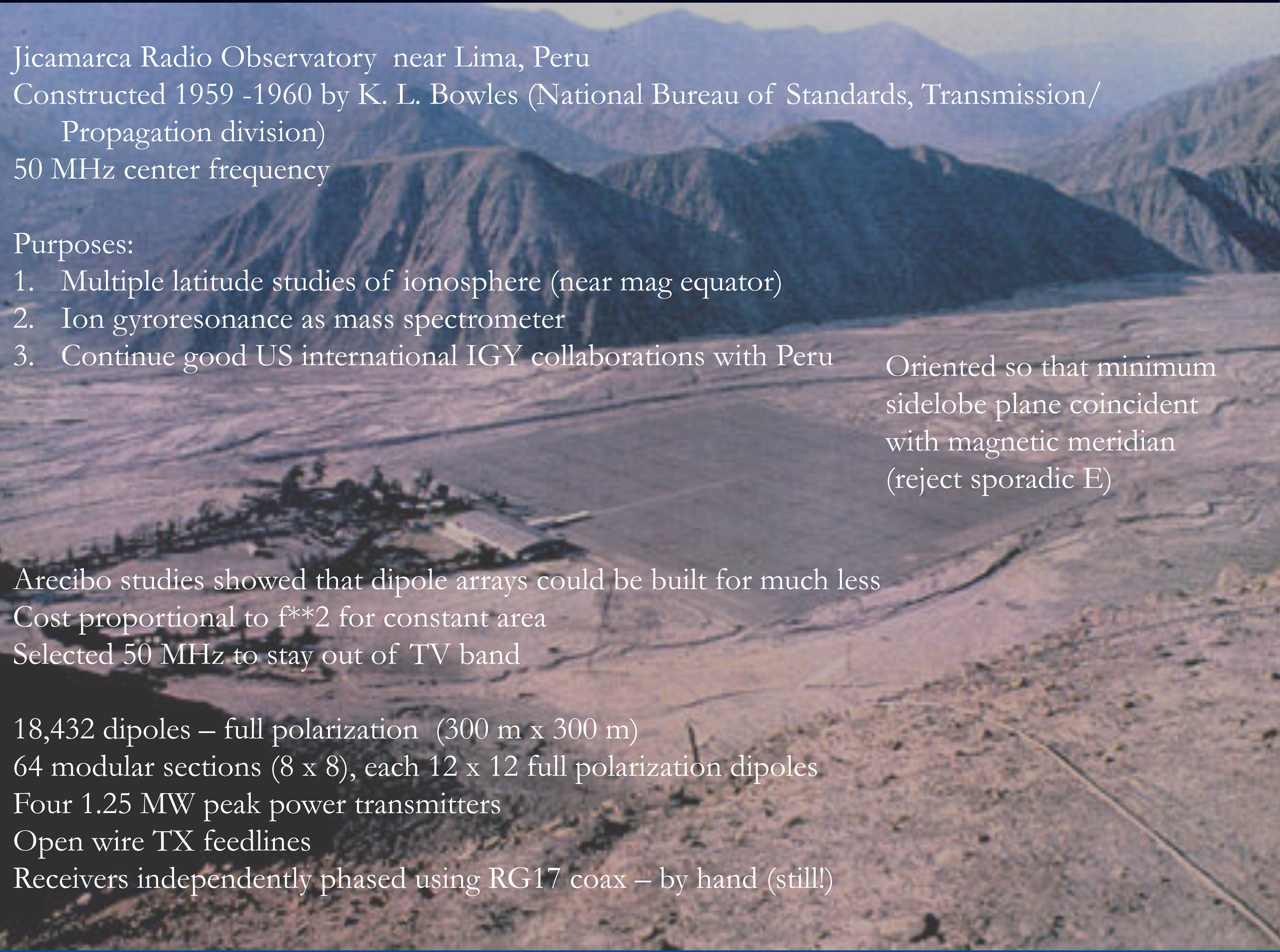
SPECIAL CENTRAL MISSIONS

Radio Propagation. Within the Federal Government, the NBS Central Radio Propagation Laboratory (CRPL) has been given the central responsibility for collecting, analyzing, and disseminating information on the propagation of radio waves at all frequencies along the surface of the earth, through the atmosphere, and in outer space. To carry out this responsibility, it conducts research on the nature of the waves, the media through which they are transmitted, and the interaction of the waves with the media.

During 1963, ground-based studies of the ionosphere in the vicinity of the earth's equator were made by a scatter radar technique at the Jicamarca (Peru) Observatory of CRPL and of the Instituto Geofisico de Huancayo (Peru). This observatory, located on the magnetic equator near Lima, employs a 6-million-watt transmitter and a 22-acre antenna to transmit a very-high-frequency radio wave of extremely short duration to great heights. The antenna is also used to detect the faint reradiation of the pulsed radio wave by free electrons in the upper atmosphere. The primary function of the installation is to study the distribution of electron density with height out to 6,000 miles or more above the earth's surface.

In cooperation with the Instituto Geofisico de Huancayo, the Jicamarca Observatory made a series of measurements of the synchrotron radiation that was emitted by the manmade belt of high-energy electrons which formed as a result of the high-altitude nuclear detonation occurring above Johnston Island in the Pacific on July 9, 1962. From these measurements, made at 30 and 50 megacycles per second, the number, energy spectrum, and decay rate of the electrons were derived—information that will help improve understanding of the physics of the upper atmosphere. The extremely high radar sensitivity available at Jicamarca also made possible the detection of radar echoes from Venus when the planet was observable from Lima during the first week of December 1962.

(NBS, 1963)



Jicamarca Radio Observatory near Lima, Peru

Constructed 1959 -1960 by K. L. Bowles (National Bureau of Standards, Transmission/ Propagation division)

50 MHz center frequency

Purposes:

1. Multiple latitude studies of ionosphere (near mag equator)
2. Ion gyroresonance as mass spectrometer
3. Continue good US international IGY collaborations with Peru

Oriented so that minimum sidelobe plane coincident with magnetic meridian (reject sporadic E)

Arecibo studies showed that dipole arrays could be built for much less

Cost proportional to f**2 for constant area

Selected 50 MHz to stay out of TV band

18,432 dipoles – full polarization (300 m x 300 m)

64 modular sections (8 x 8), each 12 x 12 full polarization dipoles

Four 1.25 MW peak power transmitters

Open wire TX feedlines

Receivers independently phased using RG17 coax – by hand (still!)

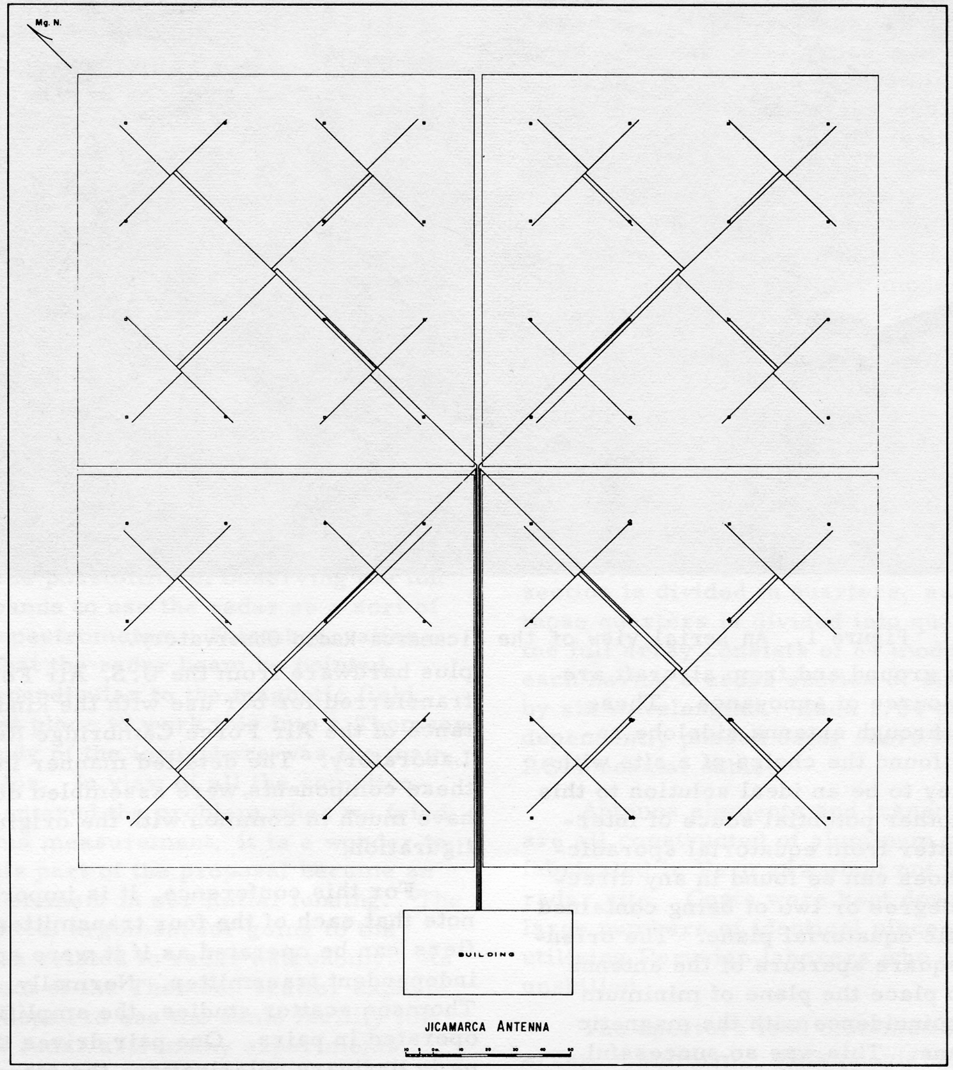
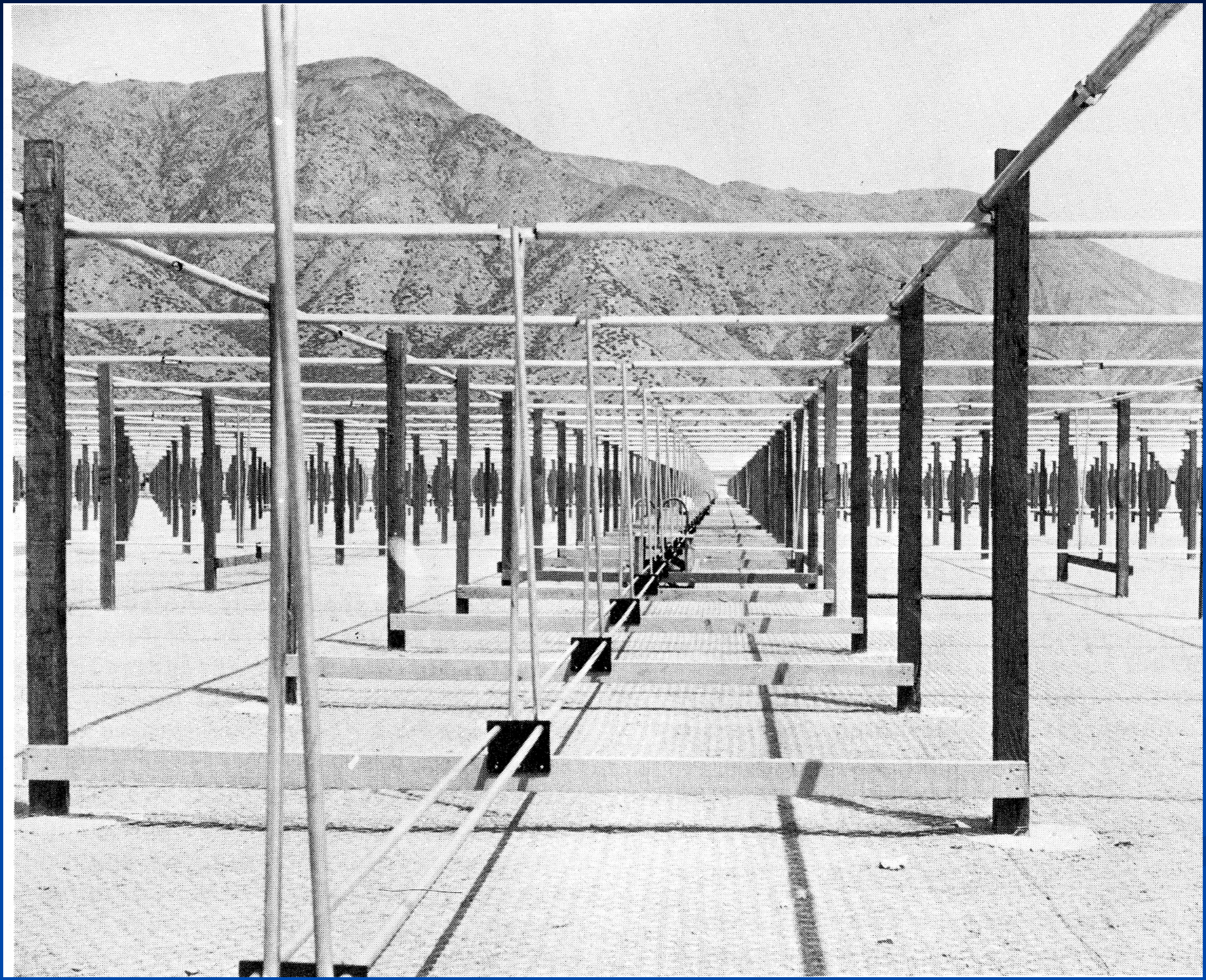
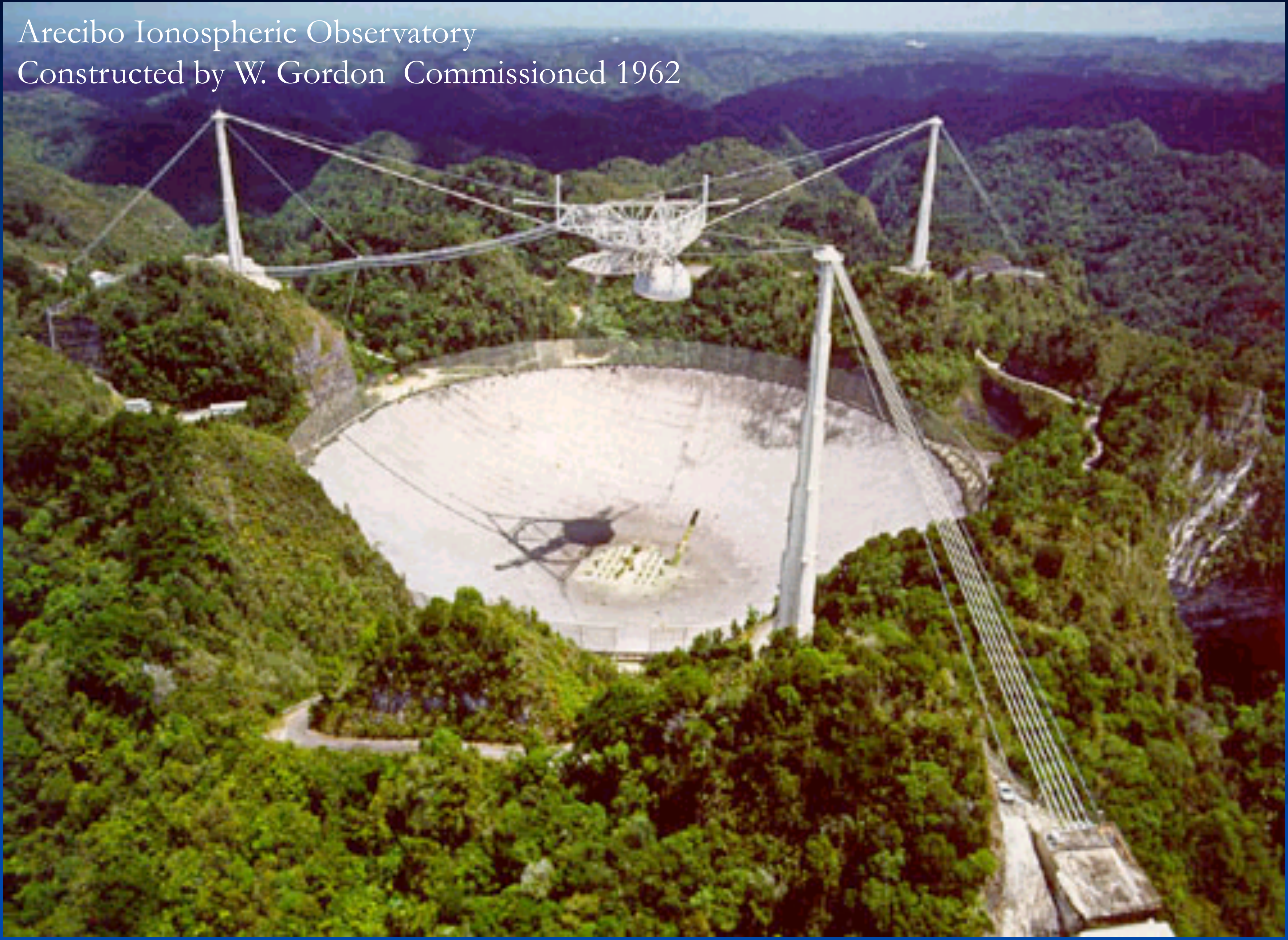


Figure 2. A schematical view of the antenna power distribution network.




Arecibo Ionospheric Observatory
Constructed by W. Gordon Commissioned 1962

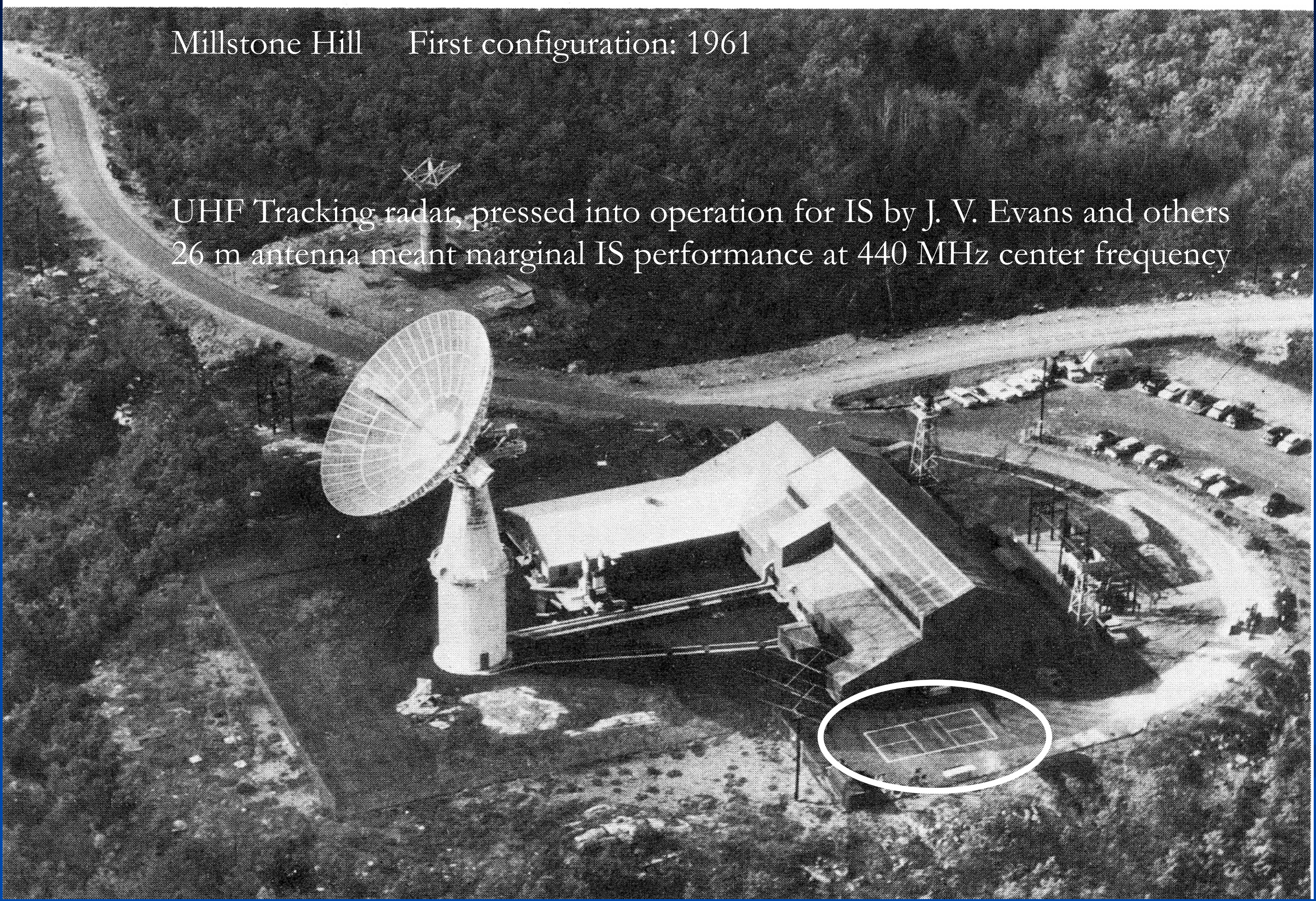

Arecibo Ionospheric Observatory
Constructed by W. Gordon Commissioned 1962
300 m spherical reflector (70 degree cap)
62 dB gain
430 MHz frequency
2.5 MW peak power (nominal)
Original platform weight 700 tons
Maximum steering angle 18 – 20 degrees

Arecibo Ionospheric Observatory
Constructed by W. Gordon Commissioned 1962

Mortality rate in construction: zero
(insurance companies: one death for every $4M in 1960 dollars – AO was ~ $10 M)
Platform motion with original cable systems: 6 mm per degree centigrade
Competing ideas for platform suspension:
Rigid feed supports (but 214 m long trusses – thermal expansion about 18 cm!)

Millstone Hill First configuration: 1961

UHF Tracking radar, pressed into operation for IS by J. V. Evans and others
26 m antenna meant marginal IS performance at 440 MHz center frequency



1960-1961

JOURNAL OF GEOPHYSICAL RESEARCH VOLUME 65, No. 5 MAY 1960

Ionospheric Backscatter Observation at 440 Mc/s[1]

V. C. PINEO, L. G. KRAFT, AND H. W. BRISCOE

Lincoln Laboratory, Massachusetts Institute of Technology
Lexington 73, Mass.

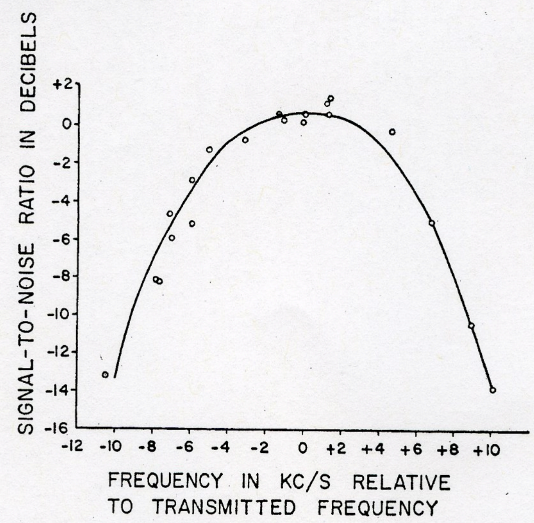


Fig. 3. Frequency spectrum of vertical-incidence backscatter from a height of about 315 km, observed at 440 Mc/s during the period 1400 to 1530 hr, 75° west time, February 5, 1960.

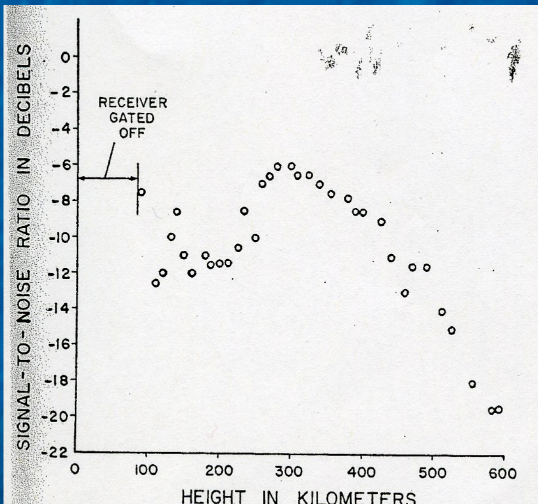


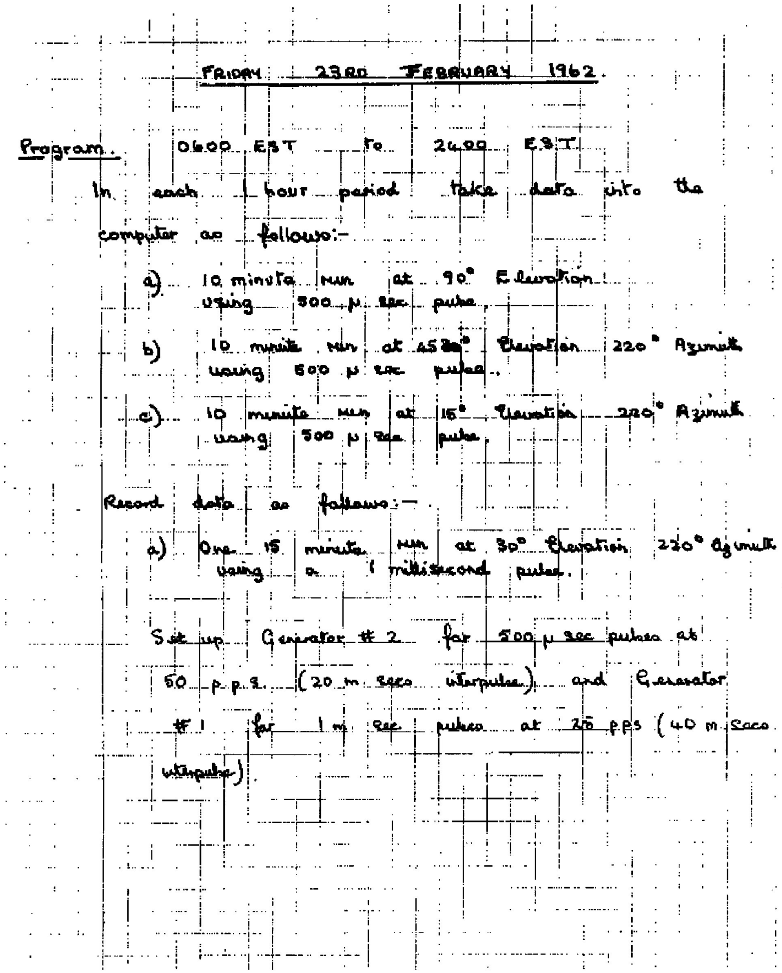
Fig. 2. Signal-to-noise ratio vs. height of oblique-incidence backscatter (elevation angle of antenna beam = 15°), observed at 440 Mc/s during the period 1415 to 1419 hr, 75° west time, February 8, 1960.

800 Hz filter scanned across the signal – requires > 1 hour to measure spectrum

"There has not as yet been any attempt to relate the experimental results presented here to electron temperatures or other parameters of the ionosphere"

1962-1975 – Radar System

First Page of Millstone Hill Backscatter Log



FRIDAY 23RD FEBRUARY 1962.

Program. 0600 EST to 2400 EST

In each 1 hour period take data into the computer as follows:-

a) 10 minute run at 90° Elevation using 500 μ sec pulse

b) 10 minute run at 45° Elevation 220° Azimuth using 500 μ sec pulse.

c) 10 minute run at 15° Elevation 220° Azimuth using 500 μ sec pulse.

Record data as follows:-

a) One 15 minute run at 30° Elevation 220° Azimuth using a 1 millisecond pulse.

Set up Generator # 2 for 500 μ sec pulses at 50 p.p.s. (20 m secs interpulse) and Generator #1 for 1 m sec pulses at 25 pps (40 m secs interpulse).

23 Feb, 1962

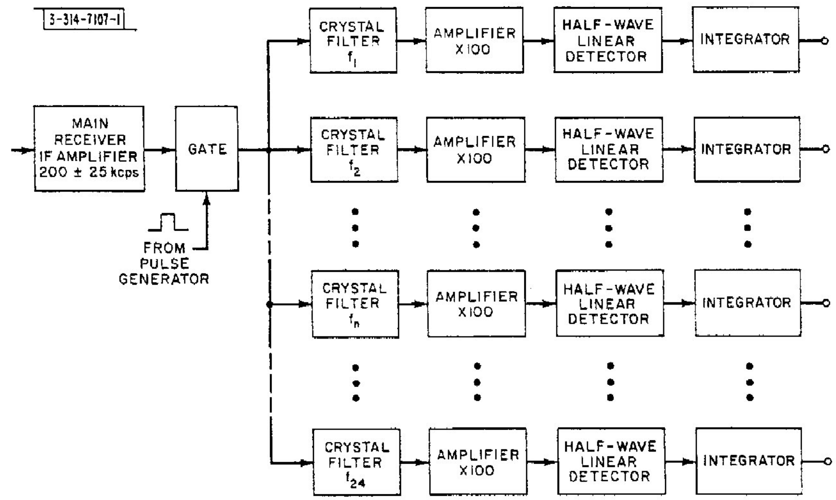


Fig. 30. Block diagram of the new spectral analyzer.

- 1962 – Analog integrator output stored on paper tape
- 1964 – Signal stored on magnetic tape for later processing
- 1968 - Analog integrators replaced by real-time integration in the new SDS 9300
- 1970 – Two-pulse measurements of the E region begin
- 1970 – I arrive at Millstone

1962-1975 - Science

- 1962 - J. V. Evans, Diurnal variation of the temperature in the F-region
- 1964 – J. V. Evans, Ionospheric temperatures during the launch of a NASA rocket
- 1965 – J. V. Evans, An F-region eclipse
- 1967 – J. V. Evans, Midlatitude F-region densities and temperatures at solar minimum
- 1968 – J. V. Evans, Sunrise behavior of the F layer at midlatitudes
- 1970 – J. V. Evans, Comparison of radar and optical measurements in the F-region
- 1971 – J. V. Evans, Observations of F-region vertical velocities at Millstone Hill
- 1972 – J. V. Evans, Measurements of horizontal drifts in the E and F regions at Millstone Hill
- 1973 – J. E. Salah and J. V. Evans – Measurements of thermospheric temperatures by incoherent scatter radar
- 1974 – M. Mendillo and J. V. Evans – Incoherent scatter observations of the ionospheric response to a large solar flare
- 1974 – R. J. Cicerone – Photoelectrons in the ionosphere: radar measurements and theoretical computations
- 1975 – J. E. Salah, R. H. Wand and J. V. Evans – Tidal effects in the E-region from incoherent scatter radar observations

1969-1974
Upper Atmosphere Observatory

Transmitters (2)

No. 1 Frequency ~400 MHz
Peak power ~5 MW
Average power ~300 kW
Maximum pulse length ~2 msec

No. 2 Frequency ~1200 MHz
Peak power ~10 MW
Average power ~300 kW
Maximum pulse length ~2 msec

Antennas (3)

Main antenna Diameter ~300 ft
Type: parabolic reflector
Motion: transit in magnetic north-south plane
Surfact tolerance: 0.25 in. rms

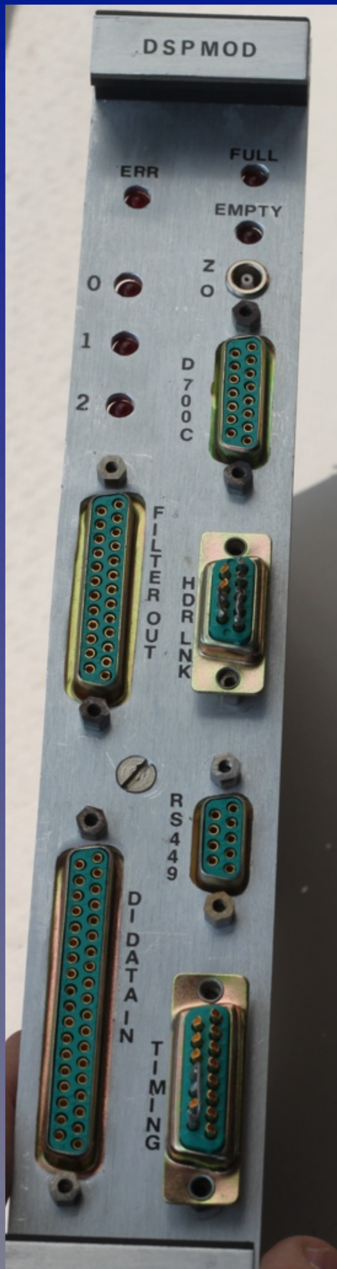
Receiving antennas (2) Diameter ~150 ft
Type: Parabolic reflector
Motion: fully steerable
Surface tolerance: 0.25 in. rms

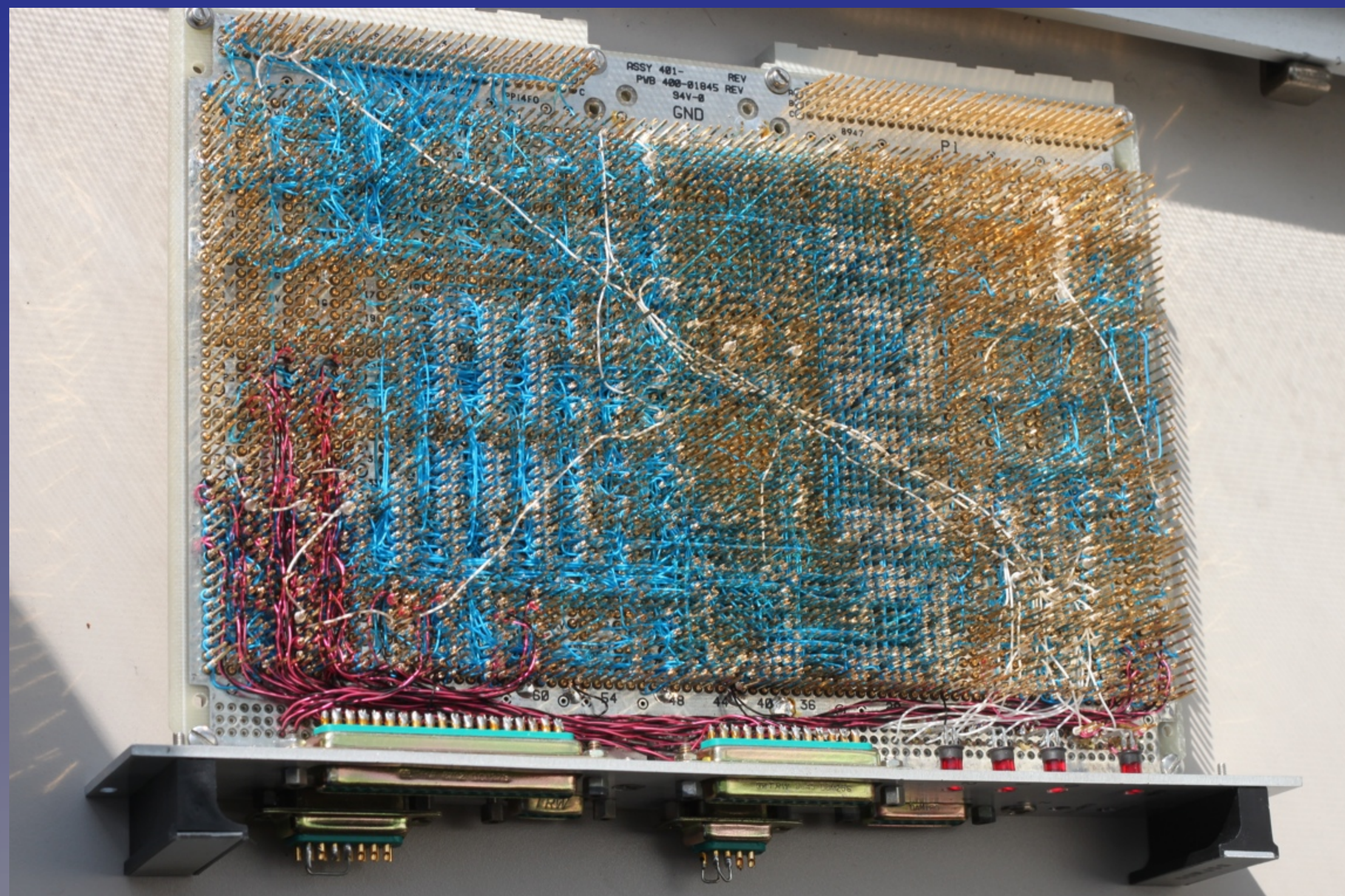

Millstone Hill current configuration
68 m Zenith antenna cost (1961):
$200K (Evans, 1967)
$400K (Lincoln property value)
46 m MISA acquired and installed 1978
SRI designed: AN FPS-50 system
at Sagamore Hill, MA
2.5 MW peak TX power
MISA beamwidth at UHF well
matched to L band beamwidth

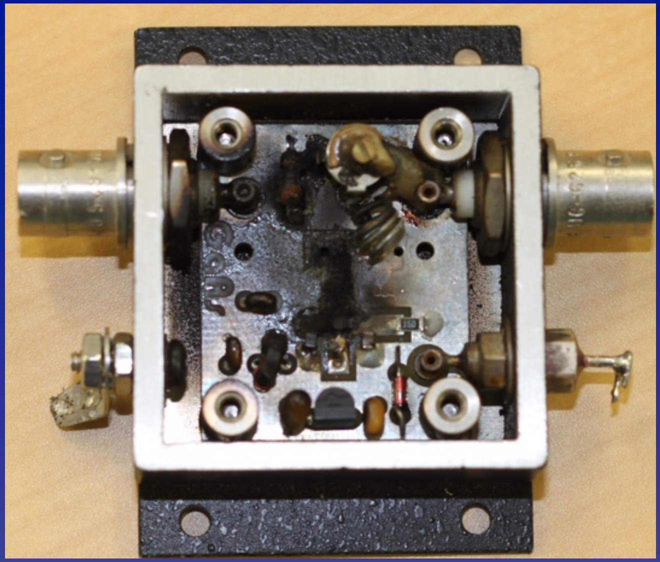

LITTON UHF 1.25 MW KLYSTRONS


UHF-1
TRANSMITTER
2.5 MW
UHF #1
Transmitter
2.5 Megawatts
Peak Power

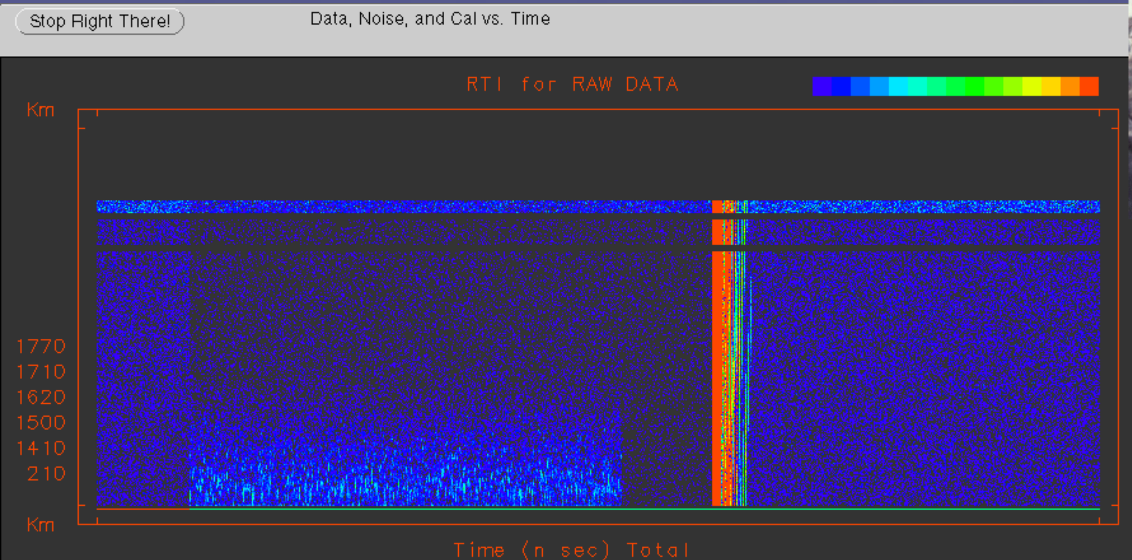
MIDAS-1 Electronics
1990 - 2001

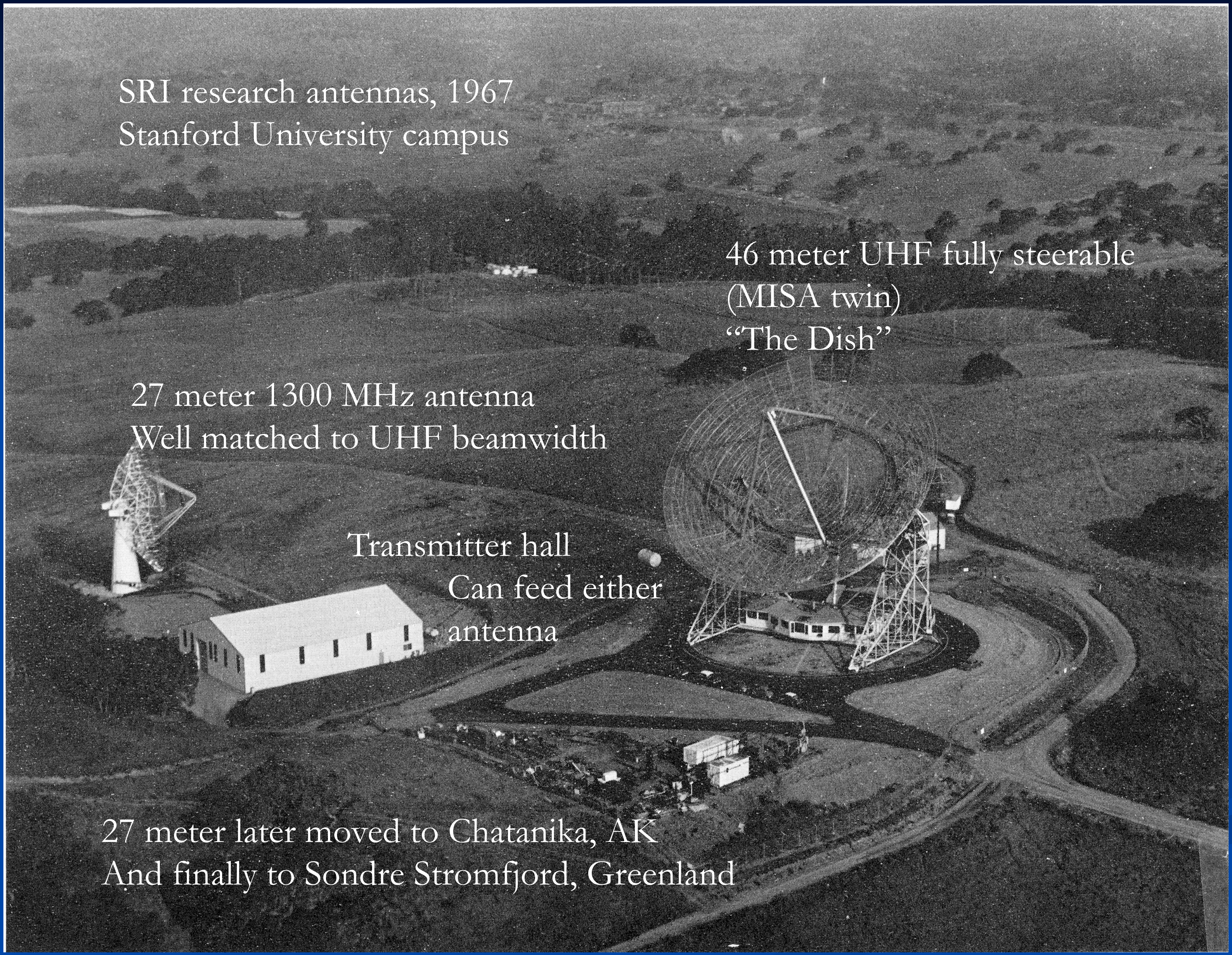


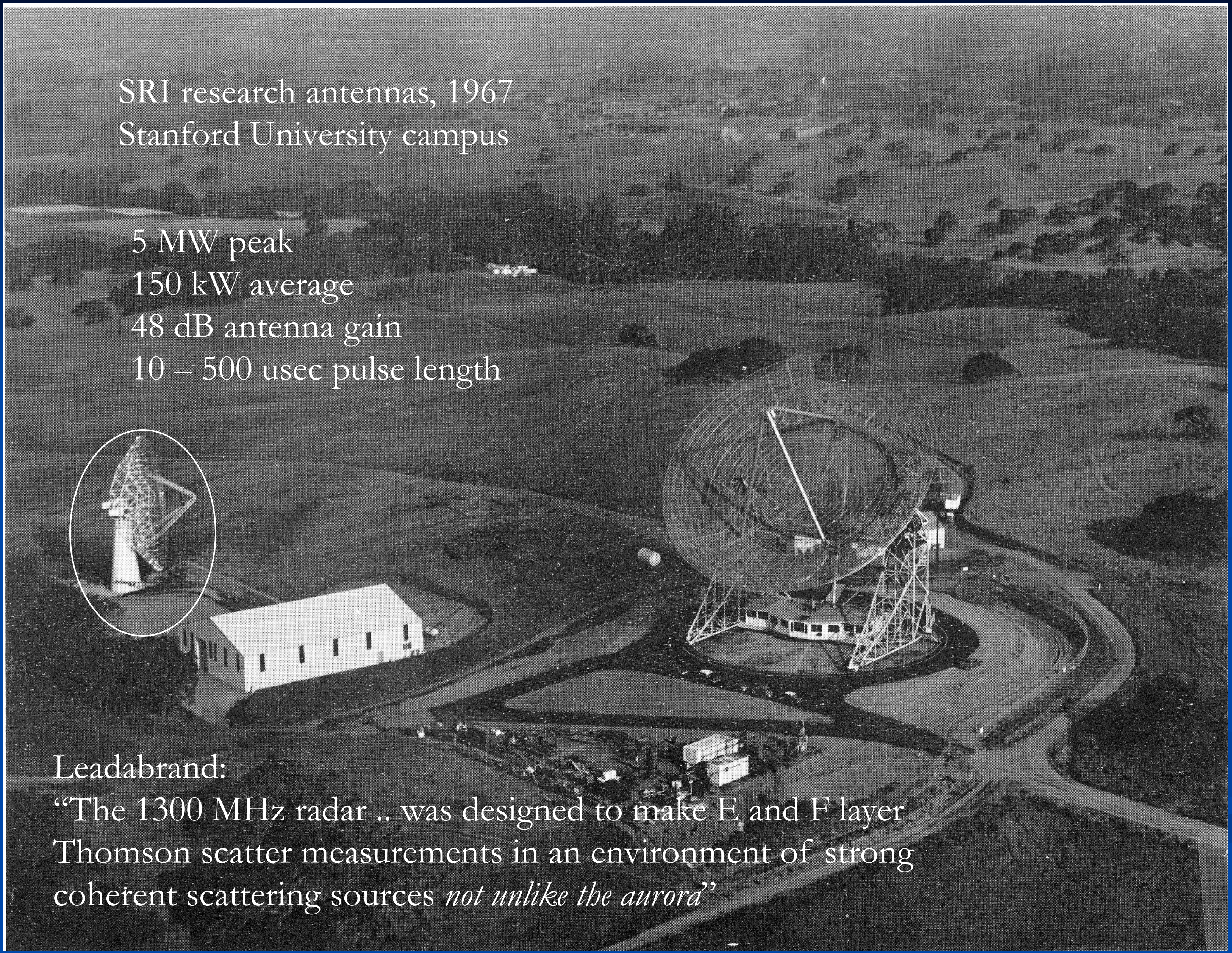




Keeping up with system 'firefights'




SRI research antennas, 1967
Stanford University campus
46 meter UHF fully steerable
(MISA twin)
"The Dish"
27 meter 1300 MHz antenna
Well matched to UHF beamwidth
Transmitter hall
Can feed either
antenna
27 meter later moved to Chatanika, AK
And finally to Sondre Stromfjord, Greenland


SRI research antennas, 1967
Stanford University campus
5 MW peak
150 kW average
48 dB antenna gain
10 – 500 usec pulse length
Leadabrand:
"The 1300 MHz radar .. was designed to make E and F layer Thomson scatter measurements in an environment of strong coherent scattering sources *not unlike the aurora*"


Sondrestrom IS system today

And finally .. ISR Starts and Stops

- Mid 1950s: BMEWS network observes IS returns, discards them as ‘strange ubiquitous noise’
- France: St. Santin, (multi-static) 1963-1987
- UK: Malvern, (multi-static) 1968-1975
- MISCAT, Aberystwyth, UK, 1972 (multi-static--first ISR to measure three-dimensional drift velocities)

St. Santin bistatic ISR system (1963-1987)

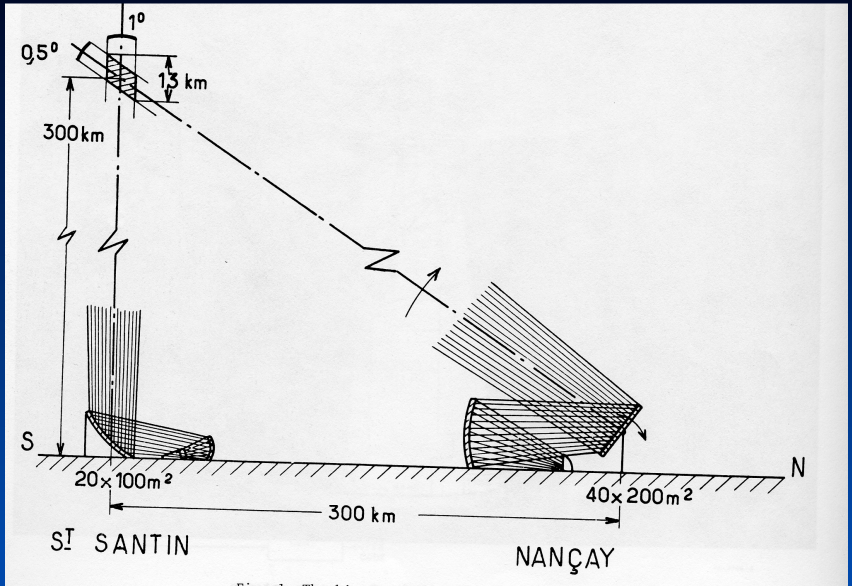
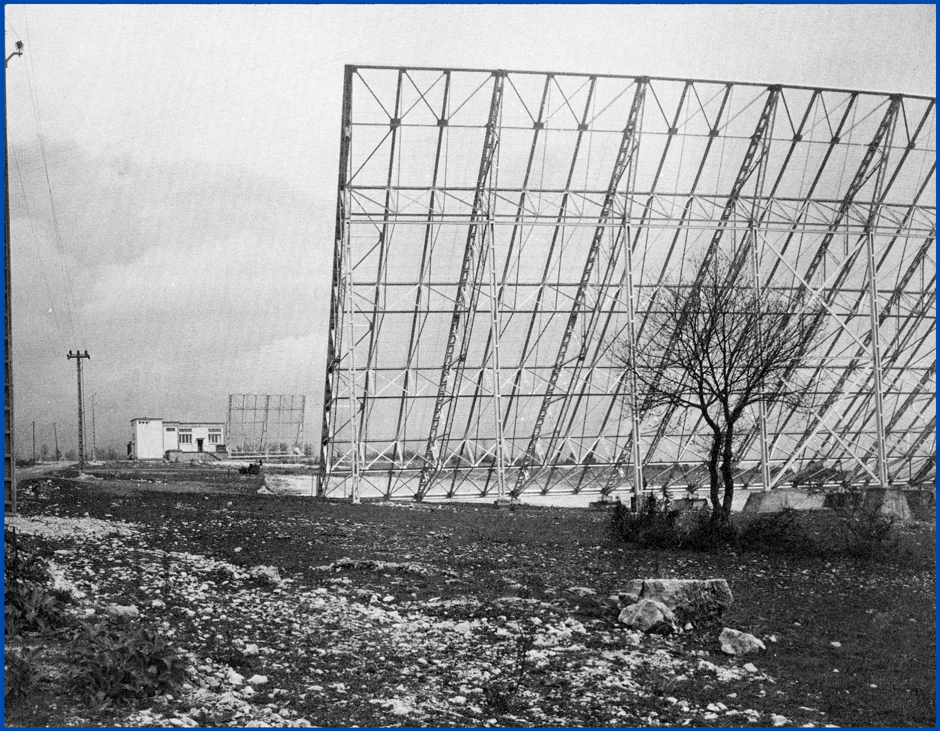


Fig. 1 The bistatic Thomson scatter system.

935 MHz frequency
75 kW power – CW
52 m antenna
49 dB antenna gain

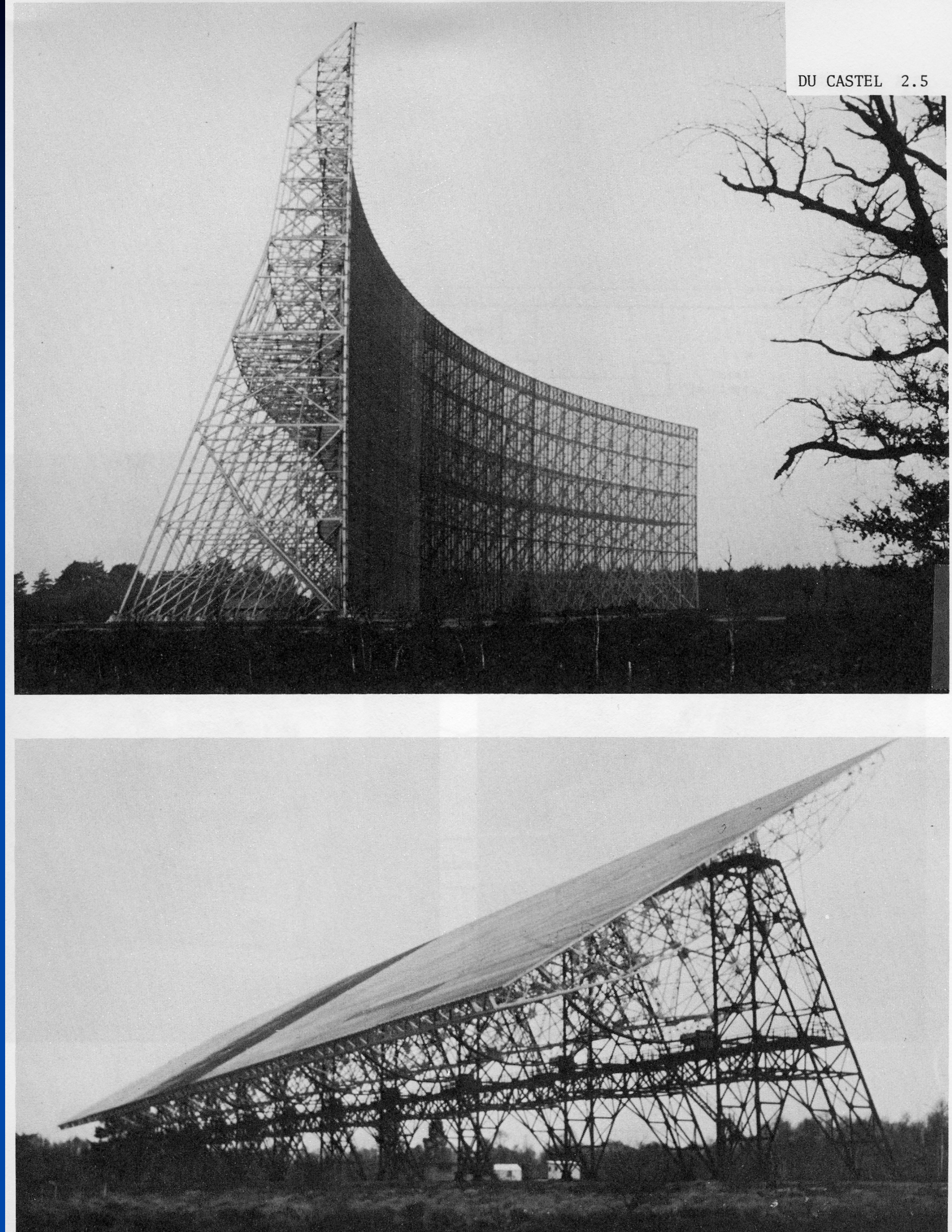


St. Santin transmitter facility

Nancay receiver

1967: used for IS measurements
“36 hours every fortnight”

Shunrong Zhang, John Holt have
the entire St. Santin IS dataset
available in Madrigal
(with an empirical model!)

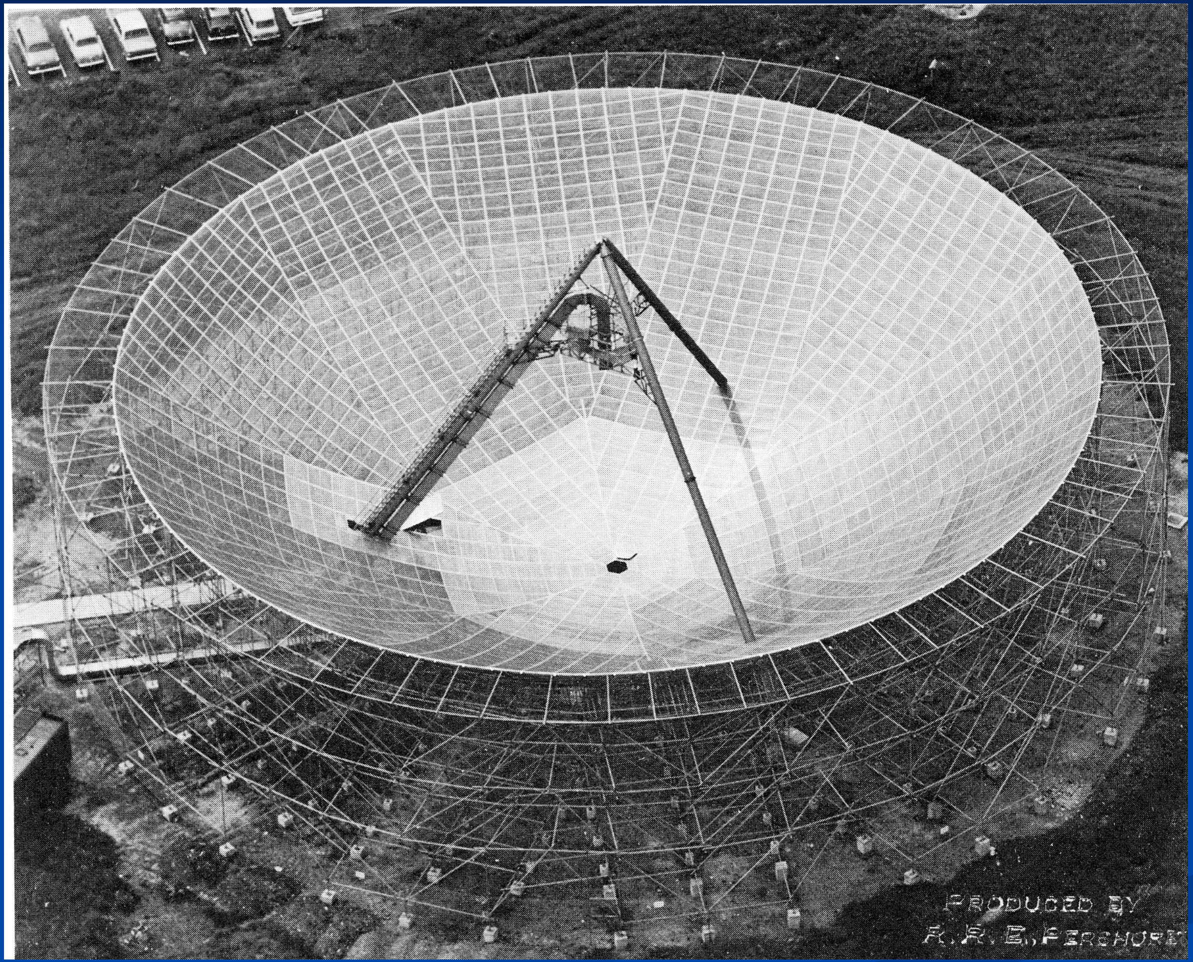


43 m vertical antenna
33 dB gain
400.5 MHz center frequency

15 MW peak power theoretical max!
(150 kW average power)

30 to 200 usec pulse length

Tony van Eyken may have the data…



Malvern ISR (UK, 1968-1975)