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DSN Observations of Titan

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When using DSS 14 in a monostatic configuration, radar observations of Titan show that Titan is a diffuse reflector with a relative radar cross section of 0.14 ±0.03. No hot spots were observed.

I. Background

Last summer, there was a favorable opportunity to observe Titan with the Goldstone radar. Detection of radar echoes and the study of their characteristics are expected to be very helpful in the design of the Cassini radar instrument and in planning for its data-acquisition scenarios.

Previous observations by Muhleman, Grossman, Butler, and Slade [1], using the Goldstone transmitter and the Very Large Array receivers, revealed reflectivities of 0.38, 0.78, and 0.25 percent on successive nights. Later measurements have shown that the hot spot may be variable in time and/or location.

A campaign was undertaken to use the upgraded Goldstone radar, in the monostatic mode, to observe such areas on Titan.

II. The Experiment

Sixteen nights at DSS 14 were initially scheduled for this experiment. This would have enabled the examination of each 22-deg time zone of longitude around Titan. An observation night consisted of one 2.5-hour period for transmission followed by an equal period for reception. The signal to noise ratio for a hot spot was expected to be greater than 10 for a single night's observation.

Each observation started with an antenna-pointing test using Saturn as a radiometric source. After verification that Saturn increased the system temperature by 1.6 kelvins, the antenna was swung to nearby Titan and transmission was started.

Frequency hopping was used, so that every 30 seconds the transmitter would jump 10 kHz in frequency. After three hops, the transmitter would return to the original frequency. This technique permits accurate background removal, which is required for detection of weak signals.

During the receive time, the signals were filtered to 40-kHz bandwidth, digitally sampled, Fourier transformed to 39-Hz resolution, detected, and summed. The summed power spectra for each hop period were stored on floppy disks. The above procedure was performed on-line with the newly installed orbital debris equipment.

A daytime test run, using the planet Mercury as a reflector, proved that all systems were working. Even so, all 16 nights of observing time were wasted. The problem, which will be described subsequently, was in the pointing of the antenna.

Because of the importance of Titan data, six additional nights of observations were scheduled. Five of these nights produced useful data. The (weighted) average radar characteristics were as follows:

Radiated power = 468 kW

Antenna diameter = 70 m

Antenna efficiency = 0.68

System temperature = 18.0 kelvins

Range to Titan = 9.22 AU

Wavelength = 3.5 cm

Figure 1 presents the results: one spectrogram for each night of successful observation. The spectrograms have been smoothed to a final resolution of 235 Hz. For clarity, the vertical scales are different for each night. A dotted reference curve shows the echo expected from the average relative cross section (0.35) reported by Muhleman, et al. [1].

The bottom curve of Fig. 1 is the weighted average of the other five observations and represents all the results of the experiment. It constitutes a weak (5.0σ) detection of Titan, and gives a radar relative cross section of 0.14 ± 0.03.

Titan appears to be a diffuse scatterer, with most of the disk contributing to the echo. There was no visible specular component, no central peak in the spectrogram, such as exists for the terrestrial planets. Neither was there any evidence of the sought-after hot spots.

III. Problems

The support given to this experiment by the Goldstone Radio Science group and the DSN personnel was excellent. There were, however, problems encountered whose solution would improve certain hardware and/or software deficiencies.

(1) For 15 of the scheduled nights, the antenna was off-point because the command "PLAN" was absent from the control stream. This command works like "Simon Says"; although the antenna moved away from Saturn when the coordinates were changed, it did not then move to Titan since Simon didn't say to do so. There was no feedback to the experimenters, so there was no way they could know a problem existed.

(2) On one of the remaining nights, the antenna was off-point because the time was entered with four digits instead of six. Once again, since there was no feedback about what the machine was actually doing, no one could know that the problem existed.

(3) On two occasions, the antenna went to brake, causing minor outages.

The Goldstone Solar System Radar would benefit from some provision for the experimenters to monitor the actual pointing of the antenna.

Reference

[1] D. O. Muhleman, A. W. Grossman, B. J. Butler, and M. A. Slade, "Radar Reflectivity of Titan," *Science*, vol. 248, pp. 975–980, May 25, 1990.

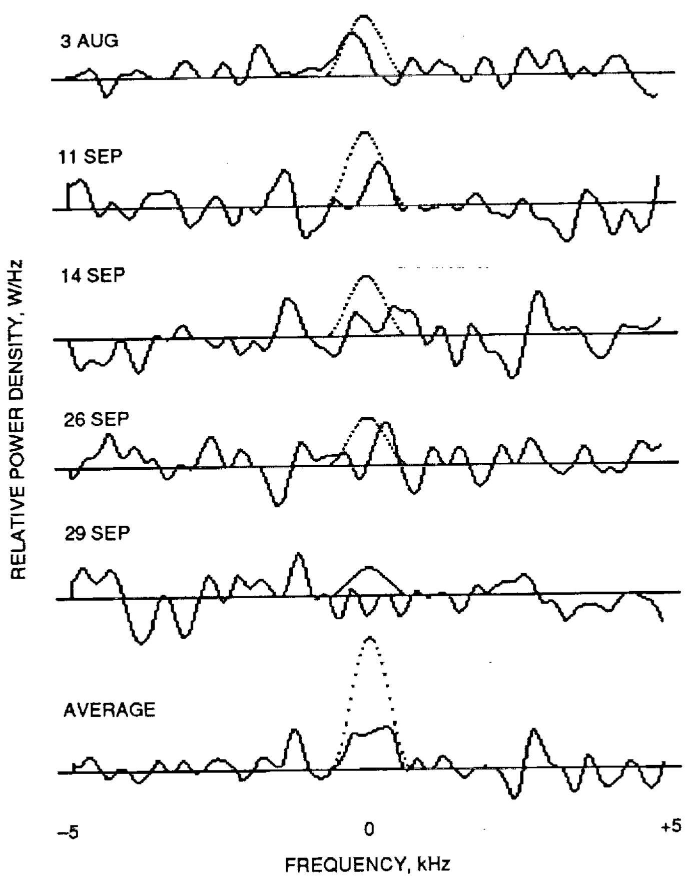

Fig. 1. Spectrograms for each night of successful observation.