Solar Radar Experiments

Paul Rodriguez
Plasma Physics Division
Naval Research Laboratory
Washington, DC 20375
phone: (202) 767-3329 fax: (202) 767-3553 e-mail: paul.rodriguez@nrl.navy.mil
Award # N0001498WX30228

LONG-TERM GOAL

My long term goal is to develop the techniques to be used to reliably detect coronal mass ejections (CMEs) from the sun which are directed at the earth. The radar detection technique could provide several days advance notice of possible strong geomagnetic storms at earth.

OBJECTIVES

I wish to establish whether the Doppler shift of the radar echo can be measured and from that the earthward-directed velocity determined. The frequency of the radar signal that is launched from earth is such that CMEs would be detected in the range of 1 to 5 solar radii. The CME is detected while still in the solar corona and, based on the typical velocities of CMEs, will take several days to reach the earth's orbit. Such advance warning time makes it possible for space-based and ground-based systems that are vulnerable to geomagnetic storms to take some protective action.

APPROACH

Experiments have been conducted using Russian and Ukrainian research facilities that are close equivalents to an operational solar radar. The Russian facility is the SURA ionospheric heater, which is used as the radar transmitter at about 9 MHz and with total power of about 750 kW. The Ukrainian UTR-2 radio astronomy receiving array is used as the receiver of solar coronal echoes. The facilities are separated by about 1000 km; thus, they are used in bistatic mode. In order to investigate the effect of the earth's ionosphere on the transmitted and echo signal, we have also conducted experiments of direct transmission to the NASA WIND satellite and reflection from the moon.

WORK COMPLETED

Three summer campaigns, each of about two weeks duration in which about ten daily experiment have been conducted. The experiments are constrained by the elevation of sun in the sky, which must be above about 50° in the sky in order for the sun to be in the beam of the SURA transmitter. These requirement limit experiments to several weeks in summer.

The dates of the campaigns are:

- 9-12 July 1996
- 19 July – 25 August, 1997
- 10 June – 25 July, 1998.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
1998		**00-00-1998 to 00-00-1998**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Solar Radar Experiments	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Plasma Physics Division,Washington,DC,20375**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

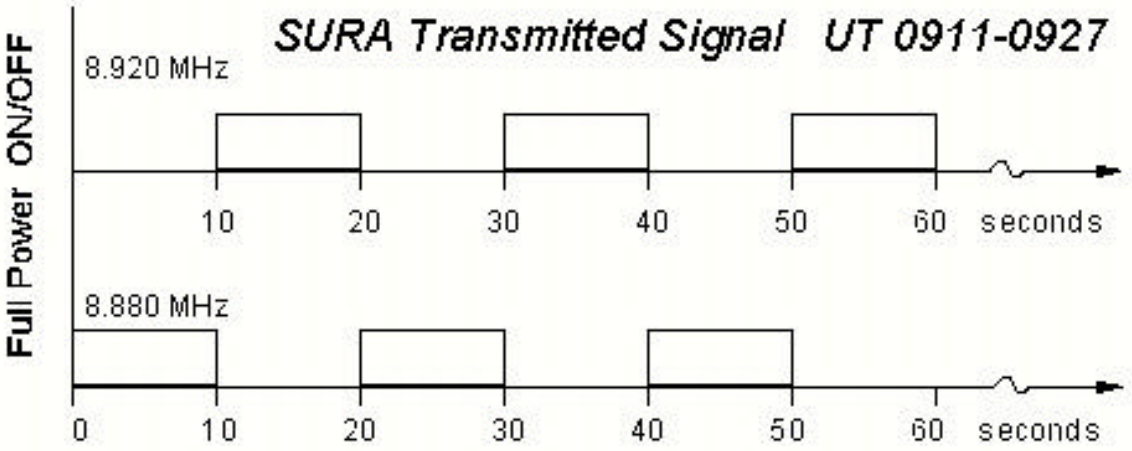
Because the solar echo signal is necessarily weak, data analysis has had to contend with relatively low signal-to-noise ratios (typically ~ 1 dB). The analyses must therefore rely on integration techniques. In addition, we have tested various transmission coding approaches to help discriminate against background noise. The frequency of transmission (~9 MHz) is on the lower limit of the range of frequencies that should be used with solar radars; however, at present the SURA facility cannot transmit at higher frequency.

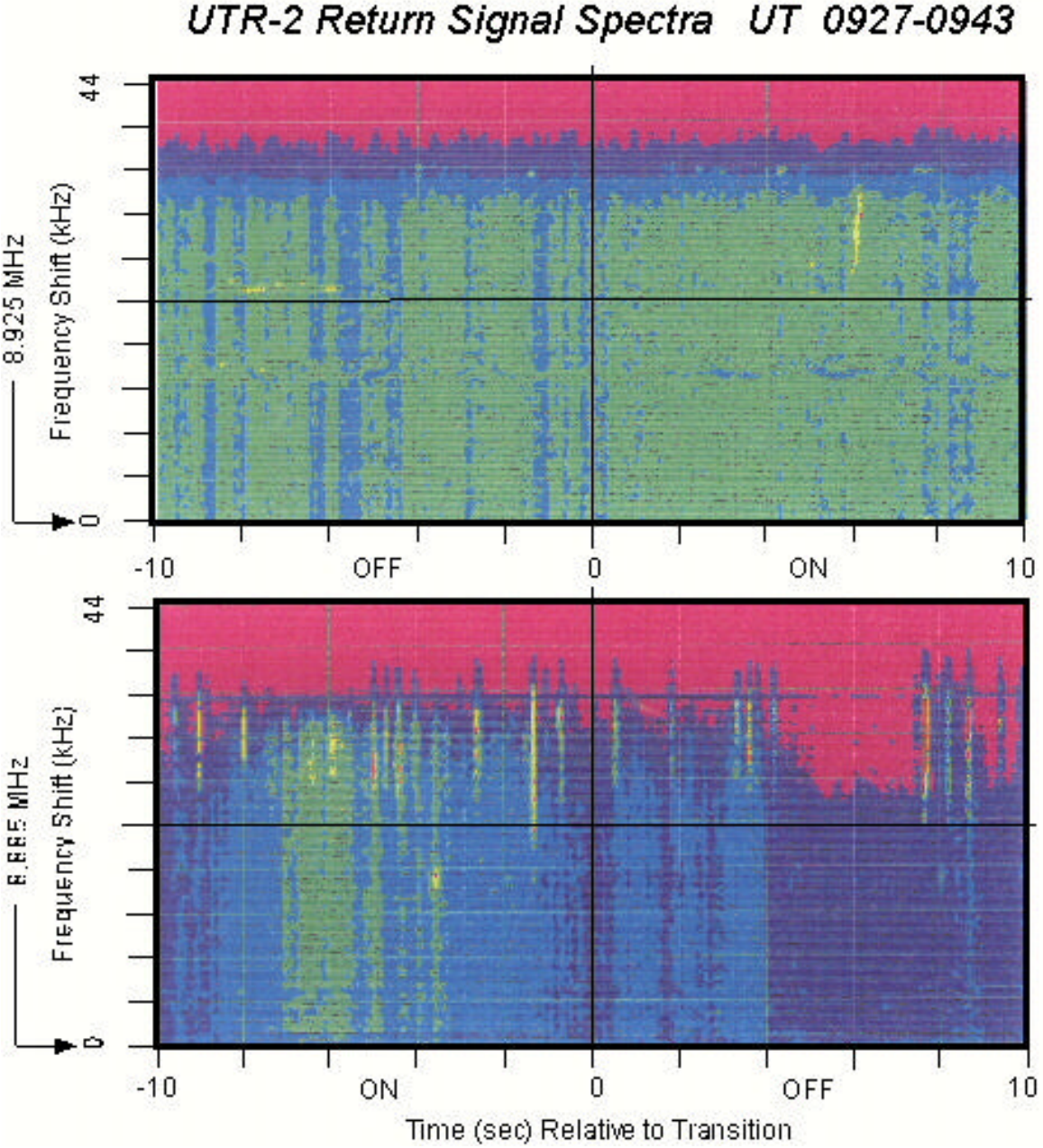
RESULTS

Thus far we have determined that in two cases, we have detected an echo signal from the solar corona. These cases have been when the background interference was relatively low.

In the figure below, we show the data from the experiment of 21 July 1996. The pattern of ON-OFF pulses at two frequencies transmitted for 16 minutes is shown in the upper part of the figure. The integrated spectrum of solar corona echo as detected in ~40 kHz bandwidth in the following 16 minutes is shown in the bottom part of the figure. The integrated spectrum power has approximately the same phase relationship as the transmitted pulses, thus identifying the echo signal.

Solar Radar Experiment 21 July 1996





IMPACT/APPLICATION

The means by which we have conducted these solar radar experiments is appropriate for the design and construction of a future solar radar facility in the United States. The information gained and experience acquired are important for determining the requirements of such a solar radar. The United States presently has no solar radar, although the technology is readily available.

TRANSITIONS

A US solar radar would provide an important component for Space Weather forecasting of solar-induced geomagnetic storms, thus providing significant advance (several days) warning to operators of space and ground systems such as communications satellites and electric power grids.

RELATED PROJECTS

Studies with the HAARP radar facility being constructed in Alaska are conducted with the WIND spacecraft to study the effects of HF propagation over long distances in the earth's magnetosphere. These experiments provide new information on wave-plasma interactions and also are assessing the possible use of HAARP as a solar radar.

REFERENCES

James, J. C., Radar studies of the sun, in Radar Astronomy, ed. J. V. Evans and T. Hagfors, McGraw-Hill Book Company, New York, 1968.

PUBLICATIONS

Rodriguez, P., High frequency radar detection of coronal mass ejections, in Solar Drivers of Interplanetary and Terrestrial Disturbances, Astron. Soc. Pacific Conf. Series, Vol. 95, ed. K. S. Balasubramaniam, S. L. Kiel, and R. N. Smartt, pp. 180-188, 1996.