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El Campo Solar Radar System

Second Semiannual Report
July 1 to December 31, 1965
DSR Project 4539

CSR PR-4539-2

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SECOND SEMIANNUAL REPORT

For the Period

July 1 to December 31, 1965

on

NASA Grant NGR-22-009-064

EL CAMPO SOLAR RADAR SYSTEM

DSR Project 4539

To The

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Office of Grants and Research Contracts

Submitted by: J. V. Harrington
Principal Investigator

CSR PR-4539-2

During the period covered by this report the principal effort has been the performance of daily solar radar experiments. The problems associated with changes in experimental procedure and with improvements in the transmitter, antenna, receiver, and data processor are continual ones. For example, during the spring of 1965 the receiving bandpass was increased to 200Kcps so that the wide Doppler spectra of the solar echoes could be more faithfully studied. This increased bandpass demanded more of the magnetic tape recorder in order for the spectra to be faithfully reproduced. Many attempts were made to improve the quality of the tape recording and the characteristics of new tape machines were investigated, with the conclusion that analog recording of a weak wideband signal buried in 20 decibels of noise will involve an appreciable loss of signal-to-noise ratio even for the most advanced tape machines. The tentative conclusion is that the best way to study the echo spectra is to perform the signal integration for the various segments of the spectra in real time as the signal is received.

The solar echo at times shows weak scatterers two to three or more solar radii in front of the sun's center. The bulk of the echo energy is returned from a coronal height of about 1.3 to 1.5 solar radii, and these main echo components have a much broader Doppler spreading and larger Doppler shifts than the weak components from two to three solar radii heights. These high-corona echoes are very interesting, and a study of them is considered very important because of their unusual Doppler characteristics and because they imply irregularities having ionization densities several hundred times the mean coronal density. For these resons considerable effort was expended during this report period in studying these high-corona echoes. A separate bank of integrators was used to study these echoes in real time because they are weak and, as mentioned, there is a loss of sensitivity through tape recording. Various solar models designed to explain these echoes have also been investigated. It has been found that these echoes are present at many range intervals simultaneously, that is they are not present at one range one day and at some other range another day. Furthermore, when they appear at earlier range intervals than the main echo, they also appear at later range intervals. These later range intervals undoubtedly represent reflections from the limbs and from coronal regions at greater distances than the center of the sun. This suggests that the disturbances responsible for these echoes are present simultaneously all over the sun. Could they be some type of sound waves traveling around the periphery of the corona? Do they represent the solar wind velocities at two to three solar radii? If they do represent solar wind velocities, then the solar wind velocity at that location is less than predicted by Parker. A statistical study of the occurrence of these echoes has shown that they have a strong tendency to appear on days when the main echo is larger than average.

During this report period most of the solar echo data obtained since 1961 was punched on IBM cards. Various analyses of data were then made using the computer facilities at the nearby Wharton County Junior College. For example, one program computed and normalized the cross section, range depth, and mean range of all runs. The cross sections were then averaged for three-month periods and plotted along with a three-month running average of the sun spot number. In a general sense the cross section increases with sun spot number, but there is not a strong correlation with the short period variations. The average cross section for this report period was about $1.2\pi R_o^2$ for energy received in a wide band, where R_o is the photospheric radius. This cross section is not so large as expected on the basis of the increase in sun spot number since 1964. The average cross section in 1961 was about $20\pi R_o^2$.

The average range depth and mean range of the echoes have also been found to vary with sun spot number. The three-month averages of range depth are fairly well correlated with the three-month averages of cross section. The range depth is defined as twice the second moment about the mean of the distribution of echo energy with radar range. The average range depth for this report period was about 0.55 solar radii, and the average range depth in 1961 was about 1.4 solar radii.

The mean range was computed as the centroid of the distribution of echo energy with radar range. This centroid was then related to the center of the sun, assuming that the additional radar group delay time was 1.6 seconds, the computed value for the central ray using the Baumbach-Allen model. Actually this group delay is not constant but varies with coronal density. The mean range for this report period was about 1.07 solar radii from the sun's center toward the earth. The mean range in 1961 was about 1.22 solar radii. In general the mean range varies with sun spot number, but the correlation is not so high as is the correlation of range depth and cross section with sun spot number. The correlation would probably be higher, and the change in mean range with time would be greater, if a more accurate account could be taken of the additional group delay. On the basis of a given model, it would be possible to determine the variation of coronal ionization density from radar data.

During this report period work was done on three papers which are soon to be presented for publication in the Astrophysical and Astronomical Journals. The first paper will present the solar radar results obtained at El Campo since 1961; the second will present the 1964 Venus radar experiment performed at El Campo; and the third will discuss the effective size of the sun in occulting radio energy from the galaxy. The third paper will be based on occultation experiments performed at El Campo during December of each year when the sun was on the galactic equator, and will also be based upon the results of Taurus occultation observations made at El Campo in June. For point sources the occulting zone of the sun is about three or four degrees in diameter, but for a large distributed source the effective occulting zone is not this large because of the energy mirrored in the corona. For a constant galactic background the effective occulting zone is only about one solar diameter for a wide range of frequencies. The effective occulting zone is based on net loss of galactic energy due to the presence of the sun.

During July and August 1965, the two linearly-polarized El Campo arrays were connected to produce the two circularly polarized components of echo energy and solar noise. The results of these experiments are that the echo energy is approximately evenly divided between the two circular components. Perhaps with a narrow antenna beam that could resolve a small region of the sun one component might predominate when there were strong magnetic fields.

Other accomplishments during this reporting period include:

(1) A monitoring of Jupiter at 38Mcps (no bursts were observed);

(2) Various theoretical investigations pertaining to the solar reflection process; and

(3) A drawing of a sky map of contour lines of constant galactic temperature at 38Mcps from cosmic noise data received at El Campo.

The present opinion as to the type of reflectors responsible for the solar echo is that the irregularities are caused by some type of hydromagnetic shocks which are propagating at various directions in the corona, but predominately radially outward. These shock front velocities are from 100 to 200km/s, and are probably responsible for coronal heating. The shocks vary in number and in intensity with time but are always present. The coronal shell throughout which most reflections take place is probably less than one-tenth solar radii thick. The cross section increases when the number density and ionization density of the shock fronts increase.

Additional facilities recommended for future solar radar experiments are:

(1) An antenna that would allow more than one experiment per day to be performed;

(2) An increase in system sensitivity by at least ten decibels;

(3) An antenna with an angular resolution of at least one-fourth degree; and

(4) A bank of real time integrators for spectral studies.