FIRST SOLAR RADAR OBSERVATIONS IN MICROWAVES

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Abstract (Paper to be submitted to The Astrophysical Journal)
    A first solar radar experiment in microwaves has been carried out
with the 300 m dish in Arecibo.*The goal was to scatter the radio
waves at 2380 MHz on coronal Langmuir waves in the range from 170 to
270 MHz. The nonlinear interaction of these two wave modes produce a
radio signal in backward direction at the beat frequencies

$$\omega_r \pm \omega_L = \omega_s$$

$$\underline{k}_r \pm \underline{k}_L = \underline{k}_s \qquad .$$

Reception was at 2600 MHz with a bandwidth of 100 MHz. The transmitter
of 250 kW power was pulsed in periods between 0.5 and 1.5 s. The rec-
eived flux was Fourier analysed and searched for the transmitter period.

    The idea of the experiment was to probe source regions of type I
radio emission, which has been suggested to be caused by an enhanced
level of Langmuir waves. Since the beam size of the Arecibo instrument
is small compared to the solar disk (2.2' for transmission, 3.1' for
reception), information on the position of the source region is vital
to this experiment. It was kindly provided daily from Culgoora (court-
esy G. Nelson) and Nançay (courtesy P. Lantos). Since the type I
source region may be much smaller than its apparent size, there is no
certainty that in a particular experiment the target was hit. However,
we have a total of 12 runs with a possible hit which add up to a very
high probability that at least once a source was in the beam.

    The experiment has worked up to the expectations with a threshold
sensitivity (1 standard deviation) of the order of 1 Jy (10^{-23}erg/s cm
Hz) and on some occasions (over the limb) of a few mJy. However, no
echo has yet been detected. An upper limit on the level of Langmuir
wave energy can be derived using the wave-wave interaction coefficient
given e.g. by Kovrizhnykh (1966). With a source temperature of 5.10^6K
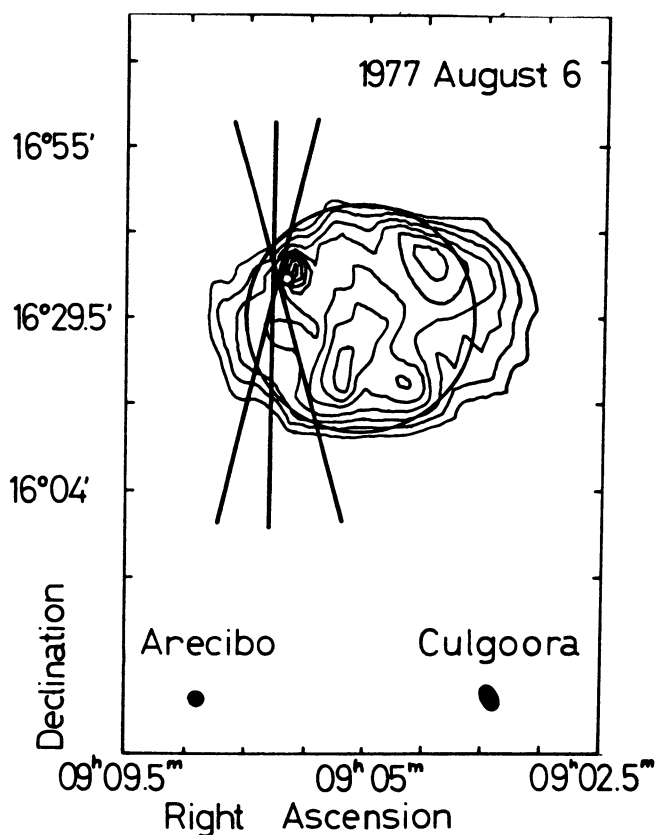
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Fig. 1: Example of microwave radar observation: Map of solar radio emiss-
ivity and position of radar pointing (circle). The large circle repres-
ents the photospheric disk. The heavy lines represent one-dimensional
type I burst positions at 1002, 1156, and 1408 UT measured by the
Nançay heliograph at 169 MHz. The different angles of these lines are
due to the changing aspect angle of the baseline on the sky. Isointen-
ity curves are from Culgoora at 160 MHz at 0004 UT the following day.
They are integrations of about 50 one second scans. The lowest level is
20% of the maximum, and the contours are in linear steps of 10%. The
100 % contour is just a point and is not plotted. Beam sizes are indic-
ated at the bottom. The radar measurement (receiving) was at 1737-1754
UT, about in the middle between the observations of Nançay and Culgoora.

and a size of 10^{28} cm^3 the upper limit of the wave energy density is
5.10^{-4}nKT (the thermal energy density) for 1 Jy sensitivity and assum-
ing an isotropic and flat Langmuir wave spectrum. First results will
soon be published (Benz and Fitze, 1979).

References
Benz, A.O., and Fitze, H.R.: 1979, Astron.Astrophys., in press.
Kovrizhnikh, L.M.: 1966, Soviet Physics-JETP 22, pp. 919-927.

* The Arecibo Observatory is part of the NAIC which is operated by
Cornell University under contract with the US National Science Found-
ation.

DISCUSSION

Kundu: Did you ever look at coronal holes with radar? I have
another philiosophical question to ask. Since you are the most experi-
enced person in radar experiments in this audience, what do you think
should be done to do solar radar experiments properly – so that we
understand better some of the solar phenomena.

Benz: Yes, we looked at coronal holes but with a different set-up
than described here. We received at the transmitter frequency. We have
not yet fully analyzed that data. In the part we studied there is no
echo.

I would (and have done it) propose to use a low frequency, say
50 MHz, and use an interferometer for reception. At this point spatial
resolution of the echo and comparison with passive solar emissions is
most important.

Pick: At metric wavelengths, type I burst source positions are
affected by ionospheric scintillations. This uncertainty is larger than
the Arecibo beam.

Benz: The beamwidth of the radar is 2.2' and thus probably more
than twice as large as the uncertainty due to the ionosphere. More
importantly, however, we have a total of about 25 different positions.
This makes the probability of having hit a source quite high, regardless
of what the ionosphere does.

Takakura: The upper limit of energy density of plasma waves which
you have given seems too high for the noise storm source, since much
weaker plasma waves could be enough to emit type I bursts.

Benz: High levels of Langmuir waves have been proposed by the early
plasma wave type I models, when Rayleigh scattering was proposed. I
agree with you that plasma wave type I models do not necessarily require
a level of 10^{-4} nKT. In fact, the model by Benz and Wentzel, presented
at this conference uses a level of 10^{-7} in burst sources and 10^{-9} in the
continuum source.

Papadopoulos: The formula you show is for homogeneous turbulence
everywhere. How much power you get depends on whether turbulence is
homogeneous or clumpy. Did you examine this?

Benz: No, I have not considered the possible influence of solitons
for calculating the level of Langmuir waves. The level I get is rather
small, and there may be no solitons in type I sources since we don't see
second harmonic radiation. However, I would certainly appreciate your
help in considering the effects of solitons.

S. S. Degaonkar: What is the line of sight velocity detected by
radar? To what does it correspond? And what is its interpretation?

Benz: The peak of the echo in decameter radar is often blue shifted
by about 10 kHz or, if interpreted as Doppler shifted, 100 km/s. However,
the echo does not return with the narrow bandwidth of the transmitter.
It is always spread by usually a halfpower width of the order of 30 kHz.
This cannot be explained by a Doppler shift.

Lin: I wonder if this technique has been used for ionospheric
studies?

Benz: Ionospheric radar experiments have shown echos from Langmuir
waves, the "plasma lines".