# Optical identification of the 1.35-cm radio granulation with features in the chromospheric network

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Simultaneous observations have been made of the brightness distribution across the quiet sun at 1.35-cm wavelength with the RATAN-600 radio telescope, and of the chromospheric network in the Ca II *K* line. Bright radio granulation features coincide with bright nodes in the network, while distinct dark features in the radio granulation correspond to dark inner fields of the network.

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Radio observations in the centimeter and millimeter wavelength ranges carried out in the past few years have revealed regular inhomogeneities in the radio brightness distribution over the disk of the quiet sun. These have been given the conventional name "radio granulation." At 8-mm wavelength, structure of this kind has been detected from observations of the transit of Mercury over the solar disk,[1] using the RT-22 radio telescope of the Crimean Astrophysical Observatory. At shorter wavelengths, 2.3 and 4.1 mm, similar inhomogeneities have been examined with the RT-25 radio telescope.[2] Radio granulation has been observed in the centimeter range at Bonn with the 100-m reflector,[3] at $\lambda$ = 2.8, 1.8, and 1.25 cm.

From the inception of solar studies with the RATAN-600 radio telescope,[4,5] radio granulation parameters have been measured at a number of wavelengths from 2 to 6 cm.

The 5-min oscillations of individual features on the surface of the quiet sun observed[6] at the U.S. National Radio Astronomy Observatory at $\lambda$ = 3.75 and 11 cm also appear to be associated with radio granules.

Most authors of the papers we have mentioned consider, on the basis of the characteristic scales of the phenomenon, that the radio granulation is related to the chromospheric network (the supergranulation). Severnyi's group[1] has also identified smaller scales. However, because of the procedural difficulties arising mainly from inadequate resolution, the complicated shape of the radio telescope beams, insufficient collecting area of the antennas, and the limited amount of observational material available, it has not been practicable to make a direct identification of specific radio granules with features in optical images of the sun, or even to ascertain the extent to which the optical and radio features of the chromosphere are correlated. The chief aim of the work reported in this letter has been to compare the radio granulation with the structure of the chromosphere.

In order to enhance the resolution provided by the RATAN-600 radio telescope, we have utilized the shortest wavelength recorded by the receivers, $\lambda$ = 1.35 cm; with the sun at 65° altitude the beam then measures 9" × 54" at the half-power level. A tracing of the radio emission was made with the north section of the radio telescope by a single scan across the computed center of the solar disk. However, during subsequent adjustments of the antenna with respect to cosmic sources a correction to the focus position was established, indicating that the actual center of the beam during the observations of the sun was directed 30" north of the center of the disk. The beam was referred to the true horizontal with a precision of ≈ 2". Since the parameters of the RATAN-600 at 1.35-cm wavelength have not yet been adequately investigated, we refrained from an attempt to calibrate the contrasts of the features. The reproducibility of the computed beamwidth (in the central horizontal section) was verified against point cosmic sources.

Optical observations of the sun at the RATAN-600 site immediately next to the feed of the radio telescope were organized by a group from the solar physics departments of the Shternberg Astronomical Institute and the Moscow branch of the All-Union Astronomy and Geodesy Society. The field horizontal solar instrumentation was based on a chromospheric telescope with a Halle polarizing interference filter admitting the Ca II K line.[7] A passband of 1.2 Å was used. The diameter of the image of the solar disk on the film was 18 mm, and the resolution reached 4". Atmospheric scintillation of the image limited the resolution. Three joint observing sessions of the sun were conducted, on July 21 and 28 and August 3, 1976. The sun was quiet on these dates. According to the Solnechnye Dannye reports, there were no active formations at the center of the sun on July 21. A small group of low-intensity faculae was observed in the west, and in the east, nearly at the limb, faculae of moderate intensity.

The radiometer had a passband of 700 MHz and an rms sensitivity[1)] of 0.15°K (with an output device having a time constant of 1 sec). In recording low-contrast features on the sun, after the solar limb entered the antenna beam the signal was compensated by a noise generator and the low-frequency amplification was increased by an order of magnitude, furnishing a reliable record of signal variations amounting to about 0.1% of the antenna temperature of the quiet sun. To eliminate the smooth trend of the curve associated with the general radiation of the quiet sun and with features located above and below the main beam, the curve was rendered "stationary." For this purpose the observed curve was smoothed with a Gaussian weighting function and subtracted from the original curve, as was done in reducing earlier observations of radio

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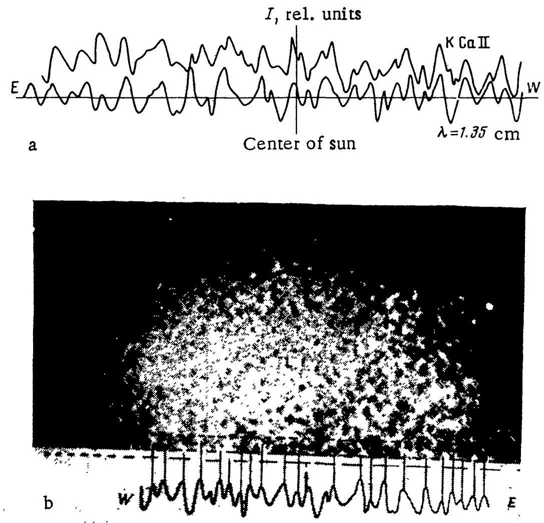


FIG. 1. a) Comparison between the radio granulation and the chromospheric network in the Ca II K line according to observations at 1976 July 21$^{d}$09$^{h}$-20$^{m}$ UT. Lower curve, radio tracing of a transit of the central part of the solar disk across the beam of the RATAN-600 at 1.35-cm wavelength. Upper curve, mean of three photometric scans of a spectroheliogram in the Ca II K line, taken along diurnal parallels through the center of the solar disk and 0'.5 to the north and south. Size of photometric slit: NS, 30"; EW, 4". Halfwidth of antenna beam, 9" x 54". b) Comparison of the preceding radio tracing with an image of the sun in the Ca II K line on July 21.

granulation[8] with the Ratan-600.

Figure 1 shows a typical comparison of optical and radio images. As a first step we intentionally refrained from seeking a simple correlation of brightnesses (or of areas or other quantities) with the radio brightness, but attempted to identify individual radio features with details in the optical image on the basis of an agreement of coordinates within the width of the antenna beam (as is the usual practice for other cosmic radio sources). In support of this approach we would point out that while the presence of a correlation of radio granules with the supergranulation and the chromospheric network is very likely, there is no reason to expect a direct proportionality between the radio brightness and the intensity of the calcium line emission. Since the resolution of the antenna permits discrimination, at least in part, of individual bright and dark features (the mean separation of the features, about 50", is five or six times the beamwidth), one should inquire what they correspond to in the more detailed optical picture rather than be limited to general statistical correlations of the brightnesses (these might even be absent). Furthermore, when the optical image is smoothed with a weighting function corresponding to the radio telescope beam, the contrast drops sharply. It is then difficult to determine the position of the optical peaks in the smoothed curve.

An inspection of all three pairs of radio and optical images leads to the following conclusions.

1. Practically all the bright details in the radio granulation correspond to the best defined and brightest nodes of the chromospheric network (in some cases a superposition of two or three features is unavoidable).

2. The converse is untrue: Many details in the optical structure which are just as bright do not correspond to reasonably well-defined radio granules.

3. The most distinct dark features in the radio granulation correspond to well-defined dark inner fields of the chromospheric network (centers of supergranules).

A test of the converse statement from our present observations does not appear feasible, in view of the inadequate vertical resolution of the radio telescope.

These results indicate that observations of the radio granulation afford an independent new method for studying the physical parameters of the solar atmosphere, particularly the structure of the chromosphere. A more detailed discussion of the observations described above, involving photometry of the photographs, will be given in a separate paper.

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[1)] When the antenna was pointed at the sun the width of the noise level increased by a factor of ≈ 4.

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