SINGLE-DISH HIGH SENSITIVITY DETERMINATION OF SOLAR LIMB EMISSION AT 22 AND 44 GHz

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ABSTRACT

A large number of solar maps were obtained with the use of the Itapetinga 14-m (45-ft) antenna at 22 GHz and 44 GHz in the 1978-1982 period. A statistical study of these maps, reduced using original techniques, permitted the establishment of the solar radius with great accuracy (<1.5 arc s r.m.s.) at the two frequencies. It has been found that 22 GHz and 44 GHz radiation originates at 16 000 km and 12 500 km, respectively, above the photosphere. Excess emission due to active regions was clearly identified at lower solar latitudes above and below the equator, extending up to 26 000 km and 16 500 km above the photosphere at 22 GHz and 44 GHz, respectively.

DISCUSSION

During 1978-1982 the Itapetinga 14-m (45-ft) radome-enclosed antenna was intensively used in a large number of solar runs in connection with SMY and real-time operations with SMM satellite measurements and by other observatories. Each observing session (a few days up to two months) was carried on at 22 GHz and 44 GHz linear polarization, simultaneously, or at 22 GHz, right- and left-handed polarization. Only one run was carried on at 22 GHz, two orthogonal linear polarizations (May 1980). Details on the experimental setup are given elsewhere (Kaufmann et al., 1982). During each run, at least one full-Sun map was obtained per day. Every full-Sun map was obtained in a timescale relatively short (6 min) compared to timescales required by other large antennas (1 to 2 hr). The sensitivity attained was very high: 10 to 20 K in antenna temperature. The antenna half-power beamwidth was 4 arc min at 22 GHz and 2 arc min at 44 GHz, but the spatial definition of "hot spots" of more than 15 percent above the quiet Sun was better than 15 arc s.

The present study was based on 353 full-Sun maps obtained at 22 GHz, and 79 maps obtained at 44 GHz. Each map was obtained using the drift-scan technique, with scans in right-ascension separated by 2 arc min in declination. For the study of the solar limb, we determined one isotherm contour corresponding to the antenna temperature that was one-half of the value of the most probable antenna temperature found in the solar disc (assumed as representative of the quiet Sun). An arbitrary circle was adjusted by least-squares fit to the points that generated that contour, and the center of the radio-Sun was determined. With this technique we eliminate uncertainties due to any systematic pointing error. The radius was then determined as the mean distance from the center to the coordinates defining the isotherm contour previously established.

This method was found to be highly accurate. In terms of solar photospheric radius $R_\odot$, we obtained

– Solar radius at 22 GHz: $(1.02305 \pm 0.00082)\ R_\odot$

– Solar radius at 44 GHz: $(1.01922 \pm 0.00135)\ R_\odot$

or, correspondingly, the height above the photosphere of the 22 GHz emission was of 16 000 ± 600 km, and at 44 GHz it was of 12 500 ± 1000 km, determined from 353 maps and 79 maps, respectively. The corresponding accuracy was of less than 1.5 arc s r.m.s. These results have greater accuracy and are consistent with measurements obtained by various authors at frequencies above 10 GHz (Figure 1). It was possible to determine, for example, the apparent variation of the solar radio-radius with the variation of the distance of the Earth to the Sun (i.e., the variation of the apparent size of the optical solar disc), as shown in Figure 2.

The solar limb features were analyzed in terms of departures from the mean solar radio-radius, as it was described before. In Figure 3 we show the mean departures for 353 maps at 22 GHz, in solar heliocentric polar coordinates. It consists of one point every 0.5 deg (720 points over 360 deg). The principal findings were the following ones:

– The contribution from active regions clearly concentrate around 18 deg North and South, at both East and West limbs. A clear minimum occurs at the solar equator.

– The active regions' emissions at 22 GHz extend up to 26 000 km above the photosphere (or up to 10 000 km above the radio-radius at 22 GHz).

– A "darkening" was noticed to be more pronounced at the south solar pole. No physical interpretation has been attempted yet. It might be meaningful to point out that for the 353 maps used in this study, the southern pole was towards the Earth for most of them, with a mean inclination of -1.2 deg for all the collection.

In Figure 4 similar data are shown for 44 GHz, for the solar limb departures from the mean radio-radius. The plot is considerably noisier than the 22-GHz plot due to the smaller number of maps used in the statistics (79). The 44-GHz emission due to active regions are suggested at the East and West limbs, extending up to about 16 500 km above the photosphere (or up to 4000 km above the radio-radius at 44 GHz). A depression or "darkening" is indicated near the NE limb, for which no explanation has been found. The south pole limb seems to be slightly "darker" than the north pole limb (the mean inclination was +2.0 deg for the 79 maps).

Finally, from the data shown in Figures 3 and 4, we confirm that the best estimate of the solar radius can be obtained at limb coordinates corresponding to 45 deg West and East of the poles, when the reference solar radio-radius is not established in advance (Furst, Hirth, and Lantos, 1979).

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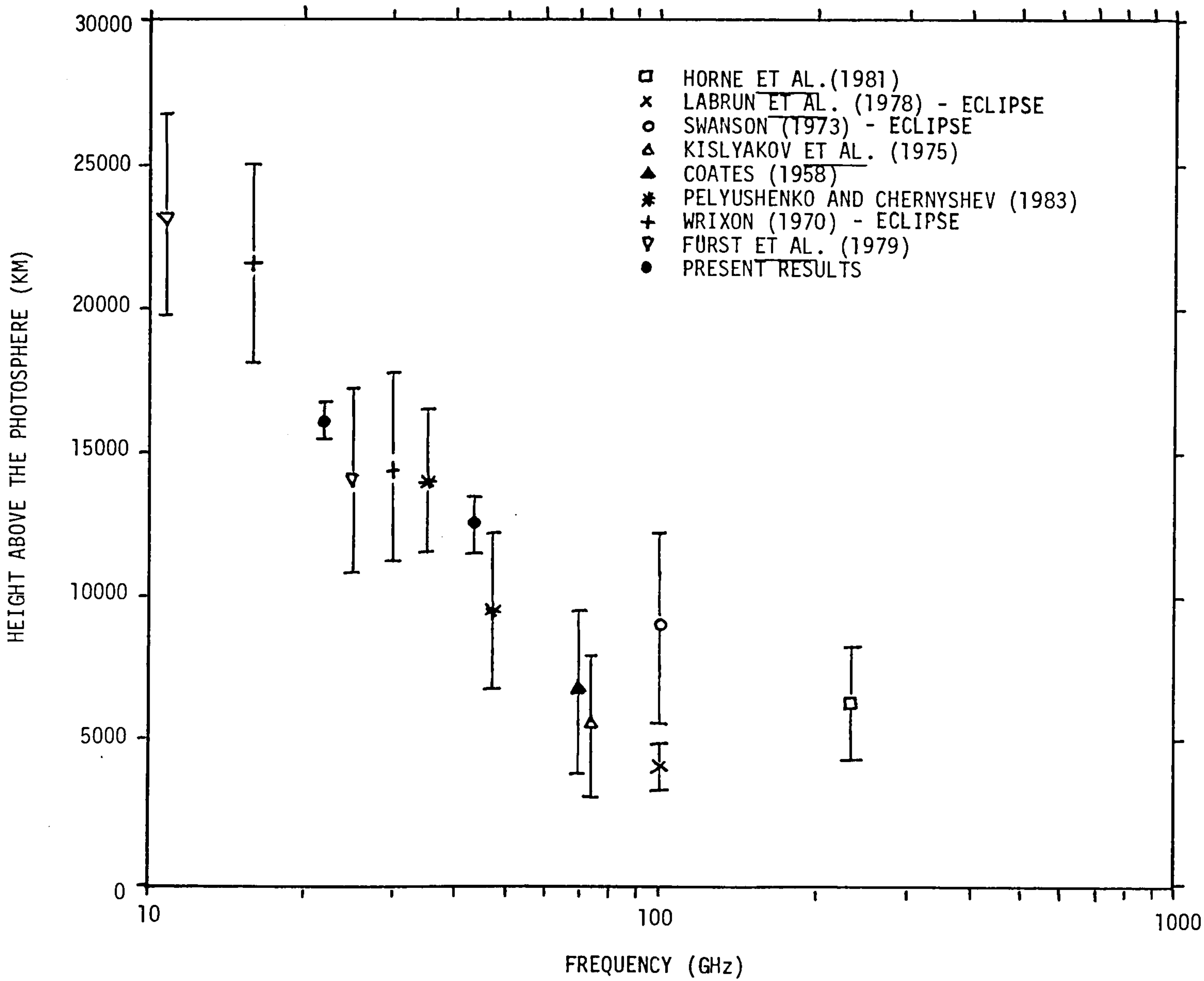

Figure 1. Some determinations of the height above the photosphere of radio emission at frequencies above 10 GHz, reported by various authors, indicated at the top-right corner, using different techniques. The present results are considerably improved in accuracy, and fit well to the general trend in the range 10 to 70 GHz.

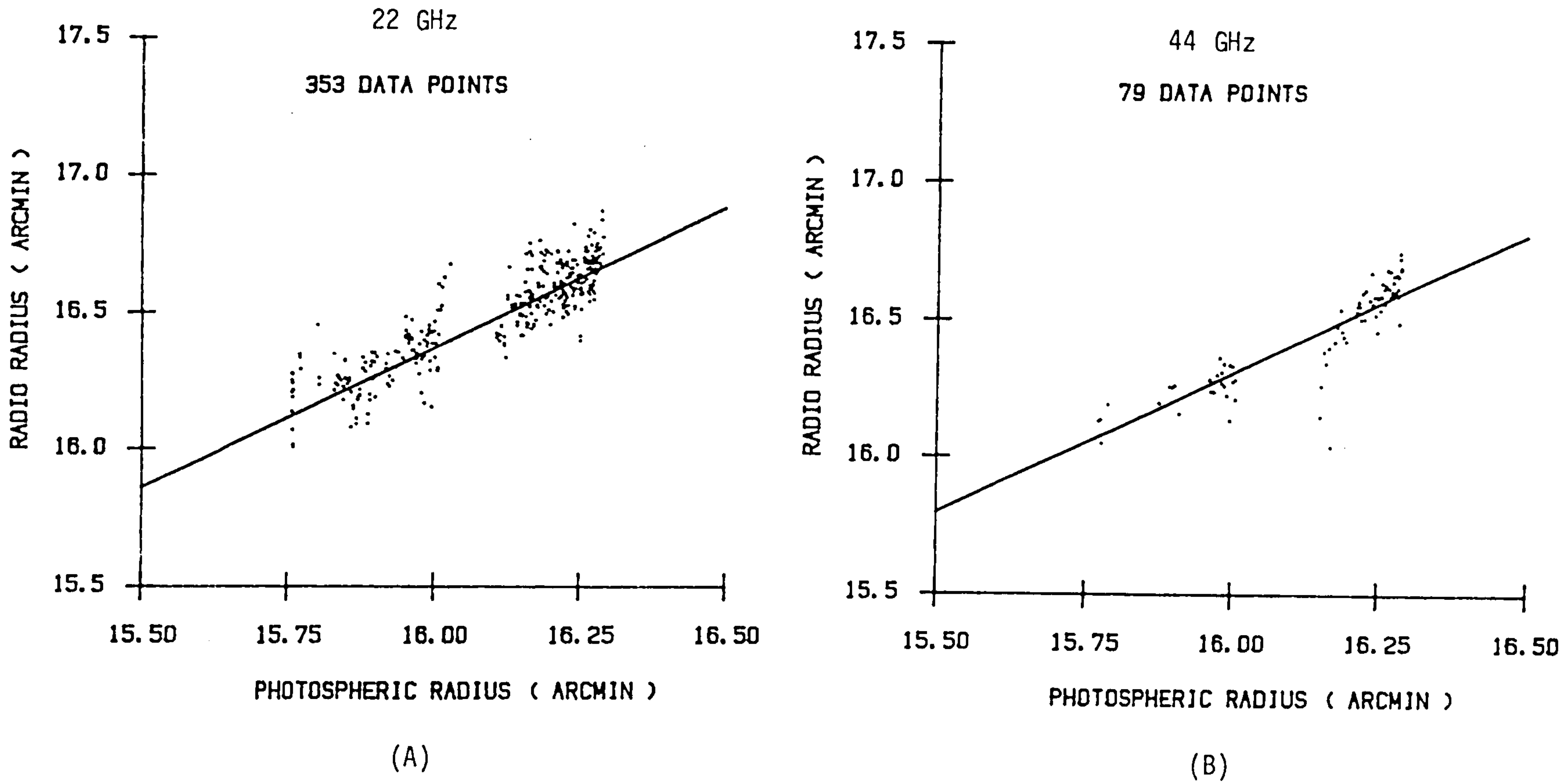

Figure 2. Plots of the measured solar radio-radius (ordinates) against the apparent optical disc radius (abcissae), for data obtained at 22 GHz (A) at 44 GHz (B).

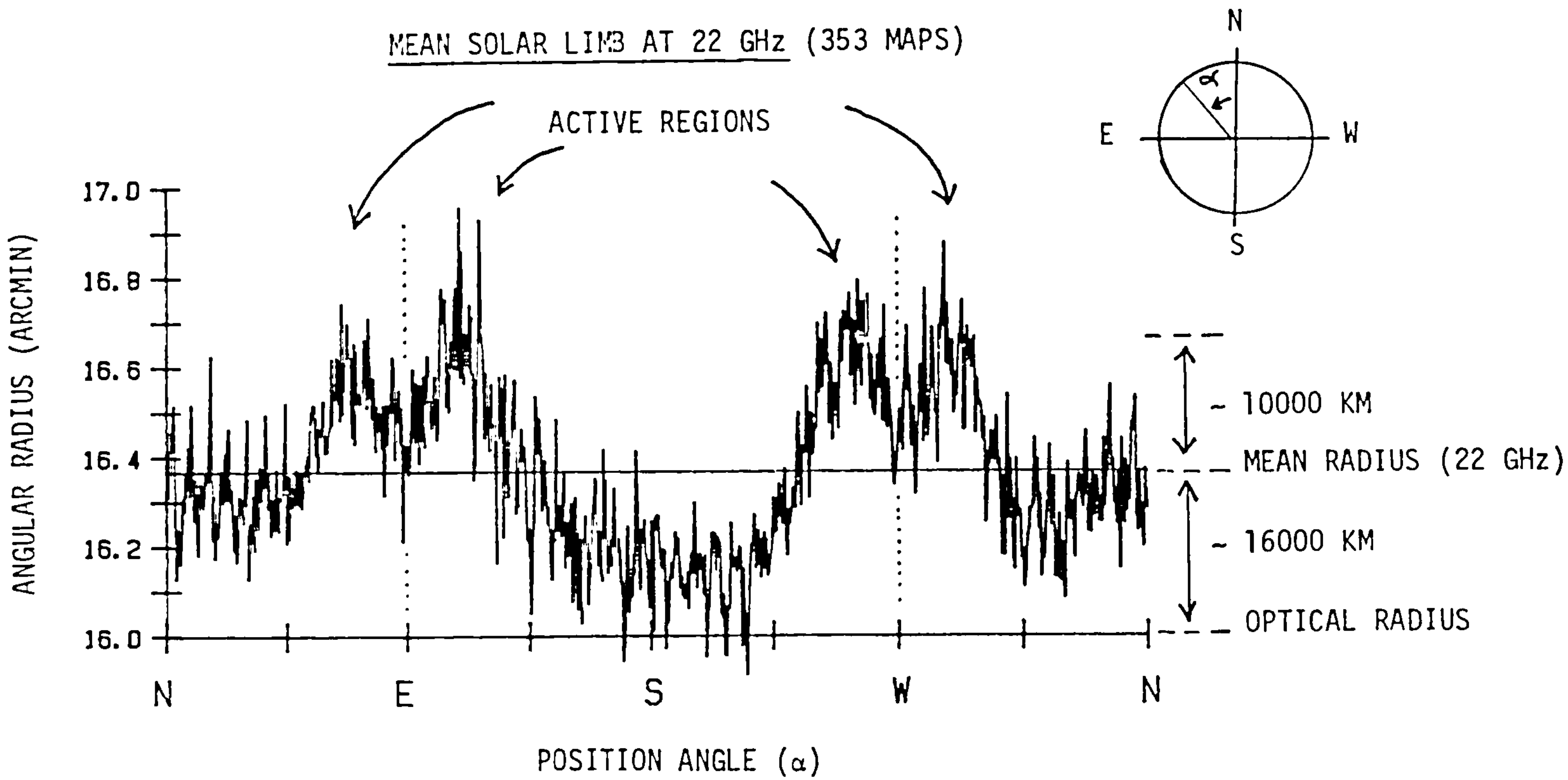

Figure 3. Mean departures from the mean solar radius at 22 GHz as a function of position angle referred to the optical disc set at 16 arc min. Active regions' contributions clearly concentrate at about 18 deg North and South of the equator, at both East and West limbs, extending up to 26 000 km above the photosphere. A "darkening" was evidenced on the southern polar limb, which might be attributed to a net negative inclination of the Sun for the 353 maps.

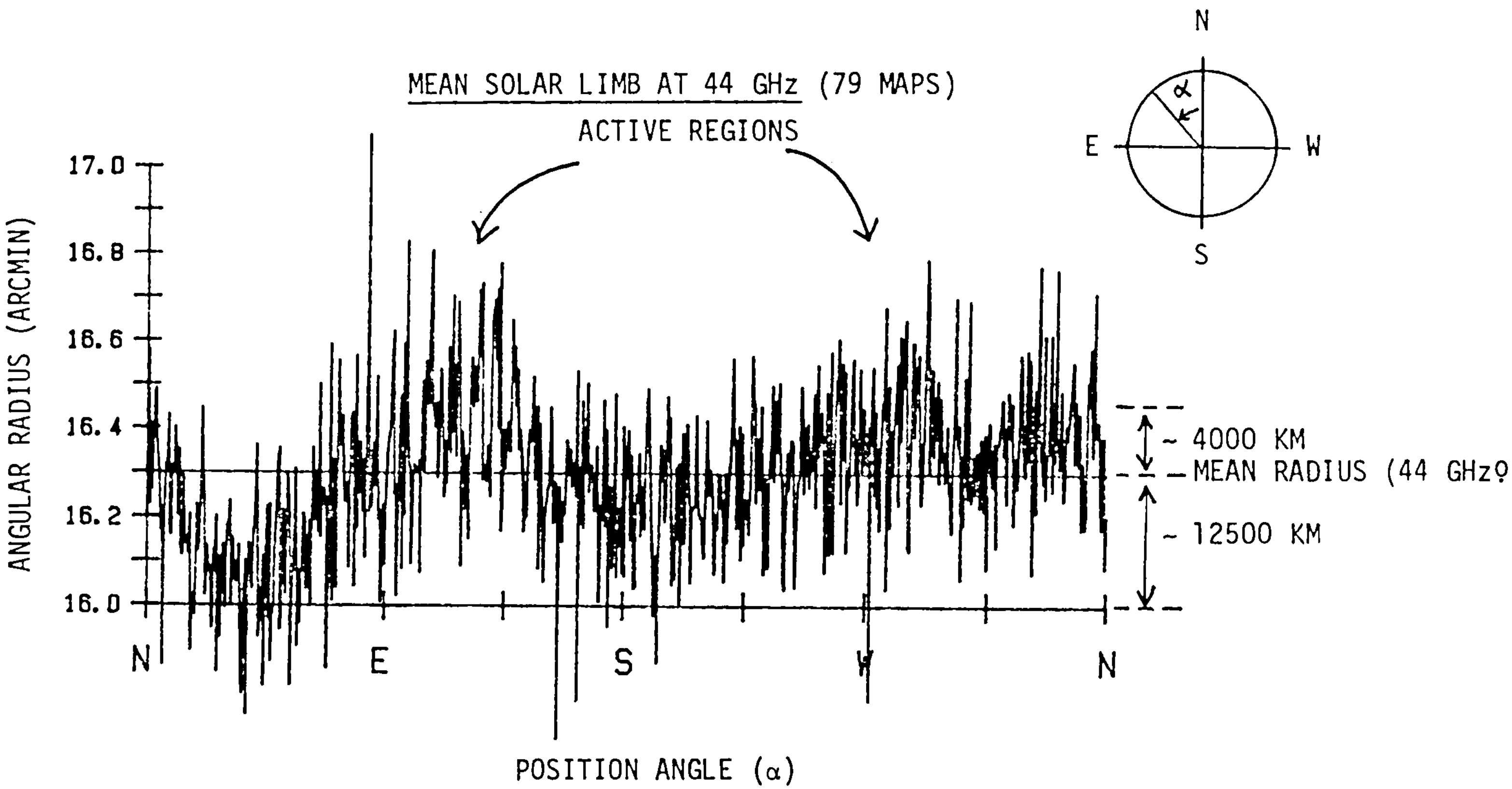

Figure 4. Mean departures, from the mean solar radius at 22 GHz, similarly to Figure 3. Data are "noisier" due to the smaller number of maps (79). Active regions are suggested to be concentrated at lower solar latitudes and extending up to about 16 500 km above the photosphere. A depression near the NE limb is of unknown origin.