Large-Scale Galactic Surveys at 8000 KMc

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On the basis of 5 observing nights with the 85-ft. telescope at Green Bank, using the 8000 kMc TWT Ewen-Knight receiver, we come to the conclusion that surveys of extended regions in the Milky Way are impracticable since a large amount of telescope time will have to be devoted to such a programme. It is also concluded that the use of MASERS or other low-noise devices will make such a survey possible in a limited amount of time.

These conclusions were reached on the following grounds:

A. Receiver noise level

The receiver may be assumed to have a 6000°K noise temperature. With its 1000 Mc bandwidth and a 10 sec time constant, this results in r.m.s. noise of $6000/\sqrt{(10^9 x 10)} = 0.06$°K. Assuming a ratio peak-to-peak/r.m.s. = 5, the peak-to-peak noise is expected to be 0.3°K. Over periods of a few hours in good weather conditions on the air, and for very long times on dummy load, this value is indeed reached. The receiver thus is reaching its theoretical sensitivity.

B. Influence of radiation by the atmosphere on the zero level.

The following data were taken from MIT series 13, Ch. 8, by J.H. van Vleck, E. M. Purcell and H. Goldstein. Table of atmospheric attenuation at 3.75 cm, in db/km.

O II			0.009 db/km
Water Vapor	7.5 g/m^3	1% water molecules	0.002
Rain	0.25 mm/hr	drizzle	0.001
	1	light rain	0.008
	4	moderate rain	0.03
	16	heavy rain	0.2
Clouds and fog	0.032 g/m^3	visibility 2000 ft.	0.001
	0.32	400	0.01
	2.3	100	0.07

From this table we may now calculate a model atmosphere under average conditions.

		max.	min.
O II 22 km	elevation about 30°	0.2 db	0.2 db
Water Vapor 1 km	37 g/m^3	0.01	0.002
Dense Clouds 1 km	2.3 g/m^3	0.07	0
Moderate rain 1 km	4 mm /hr	0.03	0
Total, at elevation 30°		0.31 db	0.20 db

We thus see that the attenuation may vary from 0.2 to 0.3 db, in cases of heavy rain even to 0.5 db. Under cloudy conditions, with no rain, one might expect short-time variations of the order of 0.04 db, under rainy conditions, variations of 0.03 db, with heavy rain 0.1 db. If we now assume an air temperature of 300°K, we have short-time variations of 2.8, 2.1 and 7°K in the sky brightness temperature, or about 1 to 3°K in antenna temperature. This is actually observed to occur over periods of the order of 4 minutes. Changes in the humidity, or light cloud, might give 0.005 db variations, which is 0.35°K in T_b or 0.15°K in T_a. The variations due to the weather might tend to be smoothed out if a wider beam is used.

In these calculations, it is assumed that $T_b = \varepsilon T$ where ε is the fractional attenuation, T is the air temperature, and $T_a = 1/3\ T_b$ (antenna efficiency of the order of 30%).

C. Influence of the radiation from the Sun, entering in the side lobes.

The side lobe pattern of the antenna is unknown as yet, but it may be assumed that side lobes which are 50 to 60 db down occur over the whole sky. Assuming a temperature of 10,000°K for the Sun at this frequency, a 50 db side lobe still gives rise to a 0.1°K signal. One might therefore expect the zero line to show fluctuations of this order during the day, if the antenna is used for sweeping. Just after sunrise, fluctuations of the order of 1°K are observed, probably due to spillover effects.

D. Expected radiation from the Milky Way.

At this wavelength, practically all radiation has a thermal origin. Calculations from 22-cm observations have shown that if most of the sources of thermal radiation are faint emission regions, with $N = 5 - 10\ cm^{-3}$, the sky along the ridge of the Milky Way is filled homogeneously, and the brightness temperature at 3.75 cm may be calculated from the 22-cm thermal brightness temperature by multiplying by $(3.75/22)^2 = 0.03$. Taking into account the antenna efficiency of 30%, the reduction factor from T_b at 22 cm to T_a at 3.75 cm is 0.01. The galactic ridge between ℓ = 320 and ℓ = 5 has on the average T_b = 10°K, with a top of 15°K at ℓ = 355, so that we may expect ridge temperatures of T_a = 0.1°K. Nearby bright sources, with diameters of 10 pc and distances of 2000 pc (apparent diameter0°.3) will all be resolved by the 0°.1 beam. The relation between emission measure E and brightness temperature T_b at 3.75 cm is $T_b = 5.6 \times 10^{-5}$ E. A nebula with $N = 30\ \mathrm{cm}^{-3}$ and a diameter of 10 pc has $E = 10^4$ and thus T_b = 0.6°K, T_a = 0.2°K. It will also have this T_a, or about this, if it is at 6000 pc distance. Then at 22 cm wavelength, it has T_b = 15°K, but since it is only 0°.1 in diameter, it is observed with an apparent T_b = 0.5°K, which was undetectable at the time of the 22-cm Dwingeloo survey (limit about 2°K or so; τ = 1.5 sec!). Thus, with a sensitivity of 0.1°K, the average bright source would be detectable to about 10 kpc distance.

E. Time needed for a galactic survey.

We expect to be able to identify a source or a rise in level if it has an amplitude of the order of the peak-to-peak fluctuations. Under dry and clear sky conditions at night this is 0.3°K in 10 sec (see A). Under rainy and cloudy conditions, we have fluctuations of the order of 1°K over 4 minutes. It seems possible to reach about the 0.3°K sensitivity if we make sweeps not longer than 4 minutes. To reach 0.1°K we have to make 10 sweeps, which take, with setting, 50 minutes. To survey an area of 1° x 1° at intervals of 2/3 beamwidth, we thus need 12.5 hours. To cover the galactic ridge between ℓ = 330 and ℓ = 10, an area of 2° x 40°, with a sensitivity of 0.1°K would take 1000 hours or 125 nights of 8 hours (observation in the daytime is slightly more difficult due to the Sun. See C). It would be impossible to detect the galactic ridge. This calculation is based on an excellent performance of the receiver, very tiresome observations, lengthy reductions (averaging 10 measurements for one sweep), and not too many rainstorms.

F. Possibilities of a low-noise amplifier.

A MASER or other type of low-noise amplifier will give an input temperature of about 100°K. With a bandwidth of 10 Mc and a 10 sec time constant, its r.m.s. noise will be $100/\sqrt{(10^7 \times 10)}$ = 0.01°K, so that we can reach in the same time a 6 times higher sensitivity, or the same results in 1/36 of the time, which for the above example is 4 nights. The best compromise would probably be a 2 times faster sweep rate, so that in 4 minutes 2 degrees are swept, and a 2 times smaller time constant. In that case, one sweep would be sufficient to obtain 0.1°K.