POSSIBILITIES FOR CONTINUUM RADIOASTRONOMY AT IAR

Dr.Dan Harris

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I. Introduction.-

by Dan Harris

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The 100' paraboloid antenna of the IAR while not amongst the largest in the world is a sizable telescope capable of a wide variety of useful studies in the continuum. The fact that it has not been so used is directly traceable to the very limited support available: both in the technical field of the electronic engineers needed to build and maintain the necessary receivers and in the astronomical field of the necessary personnel to investigate and devote the time necessary for the experiments.

In the following I will first consider aspects of the continuum receiver from the point of view of the "user" which have arisen in the first attempts to convert the present (1969) line receiver to use in the continuum. The next section deals with the capabilities of the present 1420 parametric receiver coupled with the 100' antenna. The final section gives an evaluation of our potentialities in the various fields of current research in the continuum.

II. The Receiver.

The two quantities which any receiver must minimize are the noise fluctuation and the instability in level or gain. The first of these, expresed in equivalent temperature at the receiver input of a black body or resistive load is given by:

$$\Delta T = \frac{T_s}{\sqrt{\tau \Delta f}}$$

when T_s = Total system Temperature

τ = Effective time constant

Δf = Band pass of the receiver

At 1400 MHz, current receivers have temperatures of the followi order of magnitude:

Cristal Mixers:	300°K	"Conventeal" receiver
Non- Degenerate Parametric:	100°	As in use at IAR
Degenerate "	50°	Impossible for line work
Cavity Maser	30°	Need Liquid Helium
Travel Wave Maser	10°	

The system temperature of course is considerably higher than the receiver temperature. Spillover (ground radiation) usually amounts to 30°K and other effects such as losses in cables (20°), directional couplers (30°), Dicke insertion loss (20° or more), and noise from the comparison level (40°) are sufficient to give us a temperature in excess of 250°K.

Equation (1) refers to a total power system but the difficulties of minimizing the instabilities of a total power system often results in the use of a Dicke system as described by Filloy in another article. In this case a factor of 2 in signal to noise is sacrified to achieve the stabilities inherent in the switched system. This factor of 2 comes from two $\sqrt{2}$'s. One of these arises because the signal is being observed for only one half of the time: the other comes from the synchronous detector where the difference is taken of the two incoherent noise sources (the signal and the comparison). In practice, the improvement in signal to noise ratio of the total power system over the Dicke system is more than a factor of two because of the Dicke insertion losses and excess temperature introduced by the comparison level. Al IAR we have in operation a Dicke system with a gain modulator and the rest of the discussion will be based on this receiver even though it is clear that a stable total power system would be far preferable for continuum work.

The chief difficulties encountered in attempts to use the line receiver for continuum observations comes from instabilities. (The only factor of equation (1) at our disposable is Δf ,and steps are being taken to use a Δf of 8 MHz instead of the present $\Delta f = 4$ Mc). As will be shown in the next section, the class of instabilities which cause us the must dificulties are in the range of 30^{s} to 5 minutes. The shorter variations are attenuated by the time constant or are not present; the longer period variation while sometimes present, will not produce artificial sources. Variations of the receiver output which can not be attributed to the sky or interference have an amplitude from 0.5 to 3°K.

The gain modulator protects that part of the receiver between the Dicke switch and the synchronics detector from linear gain variations. Thus the observed variation must come from (a) the "unprotected part" of the receiver, or (b) a malfunction of the switching components (Dicke switch, gain modulator, or synchronous detector)or (c) non-linear gain variations. The only element which has so far been found to contribute to the instabilities is the unprotected back end i.e. the D.C. amplifier and time constant. This difficulty has now been avoided by lower impedance circuitry which is not as sensitive to line picks up as was the previous system. The immediate problem facing us now is the isolation and rectification of other sites of instabilities. Only then will it be advantageous to try and reduce the system temperature.

III. Capabilites of the Receiver and Telescope

In the absence of instabilities, all radio telescope operation is confusion limited given enough integration line. By successive observations of the same signal (a source) ΔT in equation (1) can be made arbitrarily small as $\tau \to \infty$ .The confusion limit of the telescope is set by its beamwidth and by the number of sources of given intensity in the sky. It has been a general practice to take the confusion limit as the intensity of that source for which there is one source for every 20 beamwidths. For a 100' dish at 1400 Mc with a beamwidth between half power points of 30',(6.10^{-5} steradians), twenty beamwidth is 10^{-3} steradians and from source counts we find that the confusion limit is 0.4 f. U.

This may be compared with the signal -to- noise detection limit set by the noise level of one drift curve. Since the beamwidth is 30', the time elapse between half-power points of the antenna diagram will be $2^{\text{min}}. \cos \delta$ (δ = declination) and the longest time constant we can use without serious attenuation will be $\sim 25^{\text{sec}}$. Thus

$$\Delta T = \frac{300^{\circ}}{\sqrt{8.25.10^{6}}} = 0.02 \ {}^{\circ}\text{K rms.}$$

To detect a source we require a signal at least twice the peak to peak noise or 6 x rms noise i.e. Tmin = $0^{\circ}.12$ K. which is very close to the antenna temperature produced by a 1 f.u. source. This, however, applies to a total power receiver, so that the practical limit for us set by noise is 2 f.u. This is a factor of 5 greater than the confusion limit and it is obvious that there is much to be gained in reducing the system temperature and going to total power operation. If the factor of 5 were to be obtained in integration time only, it would require 25 observations instead of one; which is prohibitive.

The gain of the antenna as used above (1 f.u. produces o.14 °K antenna temperature) is found by comparison of a 13 °K effective temperature [redacted] signal injected before the Dicke swith with sources of known intensity. The calibration signal was in turn calibrated against a resistence in an alternately hot and cold bath.

IV. Posible Experiments.

A) Survey of the southern sky.

This project is suggested for the zone between -20° and -60° declination. The purpose of the survey would be to detect sources with flat radio spectra which have thus far been missed at lower frequencies. The only published survey in the southern hemisphere which includes spectral information comes from Parkes (Australia). Although their original flux density limit at 408 MHz (The search frequency) was 4 f.u., this has been reduced to 2.8 f.u. by a later scale change of 0.7. Figure one shows the range of spectra for sources we may expect to detect which have not already been catalogued by Parkes. 0.7 is the mean spectral index for all sources and it is clear that with our present limit of 4. f.u., any observations to detect new sources are useless. If we can realize the 2 f.u. limit calculated above, then we would begin to detect new sources with spectral indexes less than 0.27. However, to obtain a reasonable return (i.e. 20 new sources in the 2.8 steradious between -20° and -60° Dec) we must rearch the 1 f.u. detection limit.

Such a survey has already been completed for the northern sky by both the Dutch (Davis, M.M. 1967, BAN 19, 201) and the Canadian (Galt and Kennedy, 1968, A.J. 73, 135). In both cases a 25 meter antenna was used in conjunction with a parametric amplfier at 1400 Mhz.

B) Pulsars

This is certainly a possibility, although a great deal of additional instrumentation would be necessary and every effort to obtain the lowest possible system temperature should be made. The pulsar signal are very week at high frequencies such as 1400 MHz, and it should be noted that Arecibo, for example, has the advantages of 50 times our collecting area plus an average 10 x stronger signal (at 100 MHz) giving a 500 x advantage in antenna temperature plus the capabilites of a large on line digital computer, magnetic tape recorders, ecc, ecc. The strongest southern pulsar at 1400 MHz gives an average pulse energy of $0.12.10^{-26}$ Jm^{-2} $(c/s)^{-1}$

C) Variable Radio Source

Given below are typical variations found in flux density

Source	Time scale	22 cm		11 cm	
	(years)	flux density	%	flux density	%
3C-120	2	4-5.5	25	3-6	100
3C-273	5	40-46	10	34-40	17
3C-279	5	8-11	30	13-12	8
3C-454.3	5	13-11	18	10-13	30
3C-345	5	6.5-7	8	5.5-8	50

Thus, this would be a possible project since the change to be measured are sometimes longer that our detection limit. Even so, this would be very difficult except in the care of a strong source like 3C-273.

D) Polarization

Typical values of polarization are:

22 cm $<$ 5% 11cm $<$ 10%

Polarization, like source variability, necessitates a measure of a small fraction of an already weak source. Both of these effects increase with radio frequency, and although marginally practicable at 22 cm, they may become attractive at 11 cm.Of the two, polarization is probably being done better in Australiaa than would be possible at

E) <u>Interplanetary Scintillations</u>

This field is not practicle for I.A.R. The effect is strongest at low frequencies. Hence, at 22 cm. it could be observable only close $(1^\circ - 10^\circ)$ to the sun and in fact, we do not find any suitably strong, small diameter source that close to the southern ecliptic. The problem is complicated by the necessity of using a very short time constant $(\tau \sim 0.^{s}1)$ and thus not being able to integrate. Further more, one is againg looking for fractional variations in the source intensity (~70%, depending on the distance from the sun).

F) <u>Galactic Sources - HII Regions and Supernova Remnants</u>

This would be possible as the sources are strong. However, most of this work has already been done in Australia with a higher resolution

G) <u>Source Spectra</u> (<u>Catalogued Sources</u>)

Already done by the Australians

H) <u>Very long Baseline Interferometry</u>

This needs rather complicated recording and timing apparatus. However, the antenna and receiver are adequate. Since the telescope will not reach the horizon we would be limited to observatories toward the north (or south). In view of the equipment cost ecc, the best we could do would be to cooperate with a group already working in this field.

I) <u>Lunar Occultation</u>

Once our sensitivety reaches 1.f.u., there will be a good possibility of a study of source structure and position by means of lunar occultation. This will require a minimum of extra equipment such as accurate timing facilities. The time constant will have to be ~5 second rather than 25, but this will dimish the signal to noise ratio only by 2.5 and sources > 5 f.u. should be workable.