STUDIES IN COSMIC RADIO NOISE AT BANGALORE

Some Special Features

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ABSTRACT

A brief description of the different techniques now being employed at Bangalore for conducting a radio survey of the sky at 28.6 Mc/s and 62 Mc/s and for making observations on the disturbed sun at these frequencies is given. Some special features noticed during the work and relating to the ionosphere, the brightness temperatures at the frequencies employed and solar radio emission are indicated in the paper.

INTRODUCTION

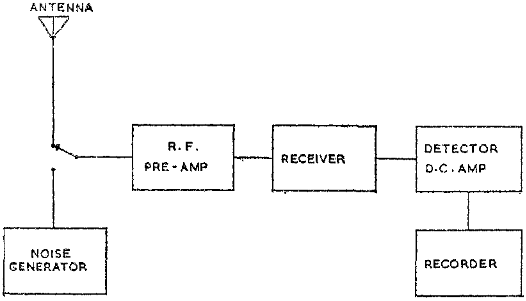
Radio surveys[1] of the sky have been carried out, using various types of antenna systems with varying resolving powers, at several frequencies ranging from about 1 Mc/s to 30,000 Mc/s or more. Narrow beam surveys have been carried out by Brown and Hazard[2] at 158.5 Mc/s, Kraus and Ko[3] at 250 Mc/s and many others at higher frequencies. Surveys at the lower frequencies, except those by Mills[4] at 85 Mc/s and Shain[5] at 19.7 Mc/s are only broad-beam surveys. It is therefore difficult to obtain the value of the spectral index of the background radiation at frequencies below 158.5 Mc/s with any high degree of accuracy. Another serious defect inherent in a comparison of the existing surveys is that no two surveys with sufficiently narrow beams have been carried out with identical aerial characteristics such as resolving power and gain. It is desirable that detailed and accurate survey work should be done at a large number of frequencies to cover the entire radio spectrum. It would also be advantageous to carry out surveys at two different frequencies with comparable aerial characteristics.

A detailed survey of the sky at 28.6 Mc/s and 62 Mc/s is in progress with the above objectives in view at the Radio Astronomy station of the Indian Institute of Science, Bangalore, (lat. 12°58′ N, long. 77°35′ E). The choice of frequencies was governed by various factors. Firstly, a survey of the sky at or near the lower frequency chosen has not so far been undertaken, the nearest being those by Blythe[6] (38 Mc/s; HPBW $2\frac{1}{2}^\circ$ by 3°) and Shain (19.7 Mc/s; HPBW $1^\circ{\cdot}4$ by $1^\circ{\cdot}4$). Blythe's beamwidth becomes larger and larger as the equatorial regions are reached and attains a value of $7^\circ{\cdot}4$ at the largest tilt angle. Shain's survey covers only the area lying between the declinations -12° to -43° and gives no information about the areas covered by our survey.

Secondly, unlike in most other countries where radio astronomy work is being done, in India the frequency region chosen is substantially free from nearby amateur transmitting stations, and hence observations reasonably free from interference can be obtained. Thirdly, the requirements of the radio receiver will not be too stringent with regard to its internal noise characteristics as the cosmic noise at this frequency is quite intense. Simultaneously with this programme, studies of enhanced solar radio emission and of the characteristics of the ionosphere have also been undertaken. It is proposed to give in this paper a brief description of the different techniques now being employed for the 28.6 Mc/s background survey and report on the results obtained so far in relation to some special features.

EXPERIMENTAL DETAILS

The survey at 28.6 Mc/s is being carried out with a broad-side array of 30 full wave dipoles and associated receiving and recording equipment. A block diagram of the set up is given below.



The aerial array consists of three rows of ten full-wave dipoles each. The ten dipoles are spaced half-wavelength apart in the E-W direction, each dipole being stretched in the N-S direction. They are all connected together in phase by means of a two-wire transmission line of characteristic impedance 600 ohms. The three rows of dipoles are situated side-by-side in the N-S direction, as a result of which there are ten columns of three collinear full-wave dipoles each. The physical length of the full-wave dipoles is shorter than the actual length (Smith[7]) and this enables the three dipoles to be located λ apart. The aerials are located about $0.2\,\lambda$ above a flat ground. The aerial pattern has been calculated in the E-W and N-S directions. The first nulls occur at

11°·5 on either side of the zenith in the E - W direction and 19°·5 in the N - S direction, the half power beam widths being 10°·7 and 16°·7 respectively.

The balanced output of each row of ten aerials is taken from corresponding points on each transmission line and after conversion to a single-ended voltage with the use of a half-wave balun, the output is taken into the laboratory using equal lengths of low loss 56 ohms cable. Thereafter, suitable phase differences are introduced between the three cables so that the direction of maximum sensitivity may be swung to either north or south as desired. However, the side lobes set a limit to the maximum tilt obtainable by this method because they grow in importance as the main lobe is swung further and further, till they become comparable with the main lobe at about 30°. The output from the cables is fed to a matching net work which couples this output to the R. F. Preamplifier. The matching network consists of a double tuned transformer with adjustable capacitive coupling also available between primary and secondary. By adjusting the variable capacitors in the primary and secondary as well as the coupling capacitor, matching is achieved.

The pre-amplifier consists of a broad-band single stage 6 AC 7 amplifier followed by a cathode follower. This arrangement gives sufficient RF gain as well as a reasonably low noise characteristic. The band width of the amplifier is about 2.5 Mc/s, centred on 29 Mc/s. This is followed by a communication receiver whose output, after passing through a variable attenuator, is further amplified and rectified. The time constant of this final detector can be varied by switching in or out various capacitors in parallel with the detector load resistance. The D. C. voltage developed across this load is amplified by a D.C. amplifier which drives a 0-1 mA Evershed recording milliammeter. The power supplies to all the circuits are regulated at the A.C. end by means of a constant voltage transformer and at the D.C. end by the use of voltage regulating circuits. Periodical records taken over several hours with the aerial disconnected show no appreciable variations in recorded current level, indicating that within the sensitivity of the equipment, variations in gain due to various factors are negligible.

Daily calibration of the equipment is carried out by means of a standard noise generator. This consists of a CV2171 tungsten filament diode working under conditions of saturation. The calibration is used to reduce the recorded currents to corresponding equivalent antenna temperatures.

RESULTS

Some of the results that have been obtained so far will now be outlined. Detailed discussion of these and other observations will be given in subsequent papers.

(*a*) *Ionosphere*:—The cosmic radio radiation passes through the ionosphere before reaching the aerial array. All observations are therefore influenced by the ionospheric conditions which may cause refraction, diffraction and absorption. Shain[8] in his early work indicated that if the observing frequency is more than three times the critical frequency of the F_2 layer of the ionosphere, the ionospheric effects are not significant. Most of the observers who have so far dealt with this aspect of the ionosphere have worked at stations far removed from the geomagnetic equator. Our station, on the contrary, is located within the tropical region and close to the geomagnetic equator. It is a noteworthy observation of the present work that this criterion does not hold good and absorption due to the ionosphere is present all the time though in varying degrees. It has, however, been found that it is a minimum in the early hours of the morning before sun rise. Portions of two records taken on two different days (18th/19th July 1960 and 18th/19th December 1960) separated by five months are given in Figs. 1 and 2 respectively. It can be seen that the relative magnitudes of the two peaks which occur at about RA 19 hrs and RA 6 hours corresponding to the passage of the galactic equator across the zenith are different. In Fig. 1, the peak at 19 hrs. has not been appreciably affected by the ionosphere whereas the peak at 6 hrs. has been absorbed to an appreciable extent. Thus there is a marked difference between their relative intensities. On the contrary, in Fig. 2, the peak at 19 hrs. which on 18th December occurs during the day time has been absorbed to an appreciable extent whereas the peak at 6 hrs. has been relatively less affected. The difference between their intensities is accordingly much less significant. These results show in a very convincing manner that there is a marked ionospheric absorption at frequencies as high as 28.6 Mc/s.

Figs. 3 (*a*) and (*b*) are portions of two records taken at 62 Mc/s during corresponding time intervals on successive days (3rd January and 4th January 1961). The peak in Fig. (*a*) is sharper relatively to that in Fig. (*b*) and there are other noticeable differences between the two records. It seems that these differences have to be provisionally attributed to the effect of the ionosphere and the fact that the records relate to noon time supports our conclusion.

Refraction due to vertical and horizontal inhomogeneities and also diffraction can be observed in the case of point sources. These effects cause a shifting of the apparent position of the source and variations in both amplitude and phase of the incoming radiation (scintillation). With the present broad beam survey, diffraction is not easy to observe but refraction some times results in spurious peaks. Fig. 4 shows a record taken from 19.30 hrs. to 24.00 hrs. on 22nd August 1960. The dotted line indicates the quiet day curve for the same portion of the sky. It may be noted that there are a large number of irregularities in the record. Analysis of these will yield information regarding the nature of the inhomogeneities, the characteristics of their movements and also any correlation with other terrestrial and solar phenomena. This phenomenon has been observed mostly in the early hours after sun-set.

An unusual phenomenon which seems to have much to do both with the frequency of observation as well as the low geographic and geomagnetic latitude of the observing station is the recording of a sort of noise storm resulting in both noise bursts and enhancement of base level just before and about the time of sun rise. On several occasions such increases in the noise level have been recorded. Fig. 5 is a record obtained between 0.30 hrs. and 6.05 hrs. on 23rd June 1960. The dotted line indicates the quiet day curve for the same portion of the sky. Appreciable increases comparable to the galactic maximum (M) over the quiet day curve are easily noticed. The fact that these are related to a purely terrestrial event such as sun rise shows that their origin is connected with the planet itself. Tentative indications are that a certain amount of correlation exists between this emission and some geomagnetic features. The origin of this noise seems to be due to the sudden local increases in the electron and ion density in the ionosphere coupled with more than usual velocities for these particles. Pawsey[9] has suggested the possibility that the ionosphere probably acts as an emitter on some occasions. The phenomenon is being investigated and further results will be published later.

(*b*) *Radio Survey*: A survey of the sky consists in determining the distribution of brightness in the sky at a given wavelength, brightness being defined as the flux density received per unit solid angle of the source and expressed as watts per square metre per cycle per second per steradian. In radio astronomy, however, it is usual to express brightness as an equivalent black body temperature (T) such that if the particular part of the sky were radiating as a perfect black body, it would have to be at the temperature T to emit with the given brightness. As the wavelengths involved are quite long, Rayleigh Jeans law of radiation can be used to connect the brightness with the equivalent black body temperature. It is obvious that this "brightness temperature" T will vary from point to point in the sky and will be a function of right ascension (α) and declination (δ). The aerial beam collects power from the sky with differing sensitivities in different directions and the actual power received at any moment will be determined not only by the distribution in the sky over the area covered by the aerial beam but also by the power sensitivity pattern of the aerial array. The actual power received by the aerial array can therefore be converted into a hypothetical equivalent antenna temperature T_A such that the actual power received would be the same if the particular area of the sky were uniformly at this hypothetical temperature. Thus what is observed is the variation of T_A with right ascension at a given declination. By tilting the beam north or south, different declinations can be covered. In the case of narrow beam surveys T_A has been rightly assumed to approximate closely to the actual brightness temperature T but in the case of broad beam surveys, methods involving successive approximation had to be devised to obtain T from T_A. As these methods are not wholly satisfactory, a method based on slightly different considerations is being developed to reduce T_A to T.

Approximate calculations have already established the following features:

(1) Comparison with the surveys of Hey, Parson and Philips[10] at 64 Mc/s and Kraus and Ko at 250 Mc/s shows that the brightness varies according to the law $T \propto \lambda^{2\cdot5}$, generally confirming the value of 2.5 for the spectral index obtained by the workers at other wavelengths.

(2) Ionospheric absorption is about 1.5 db even during the early hours before sun rise and generally higher at other times of the day.

(3) In certain regions of the sky the observed brightness is less than that computed from other surveys using the value of 2.5 for the spectral index. This is assumed to be due to absorption by ionised hydrogen clouds concentrated in those regions.

(*c*) *Solar Radio Emission*:—No emission has been recorded in our aerial array from the quiet sun. Assuming the area of the sun to be about one square degree[11] and the minimum background temperature to be about 18,000°K, will lead to the conclusion that the brightness temperature of the sun at this frequency does not exceed 1,000,000°K.

On a number of occasions, however, radio emission from the disturbed sun has been recorded. All the usual types of bursts, outbursts and enhancement of the continuum have been observed. Polarisation characteristics of these various types have been studied by setting up a second system of aerials in the form of an interferometer with the aerials stretched in the E-W direction. Thus if there is any radiation from the sun polarised elliptically or in the extreme case linearly, there will be differences in the powers recorded by the broad side and interferometer arrays. Some very interesting features such as a noise outburst starting 30 to 100 secs earlier on one record than on the other have been observed. Figures 6 (*a*) and (*b*) are records relating to an enhanced solar radiation observed on September 2, 1960 with a broad side and an interferometer system respectively. Bursts marked A, B, C, D and E are seen to occur simultaneously on the two records. Burst marked F starts 90 seconds earlier in the interferometer record (F_2). This suggests that at the start of the burst, the radiation was highly elliptically polarised. Correlation of such enhanced emissions from the sun with other optical features has also been studied. A number of sudden cosmic noise absorptions have been recorded. Details of these observations will be given elsewhere.

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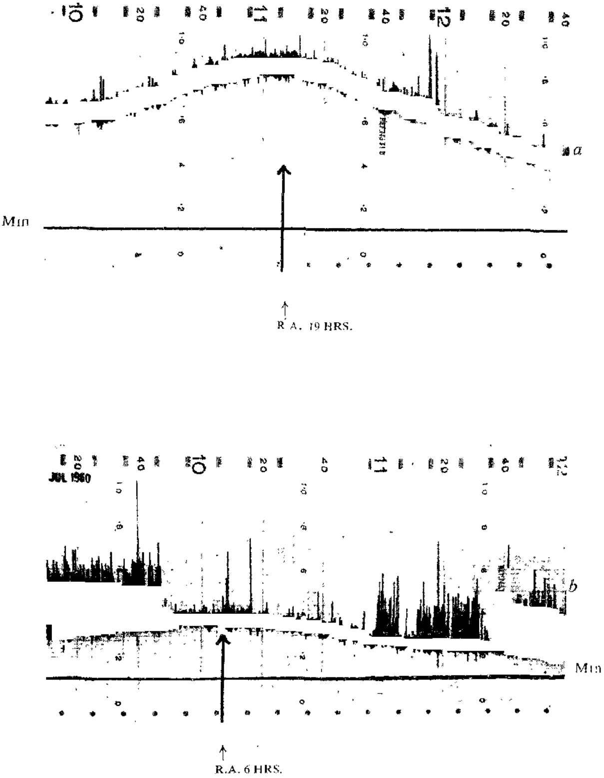
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FIG. 1

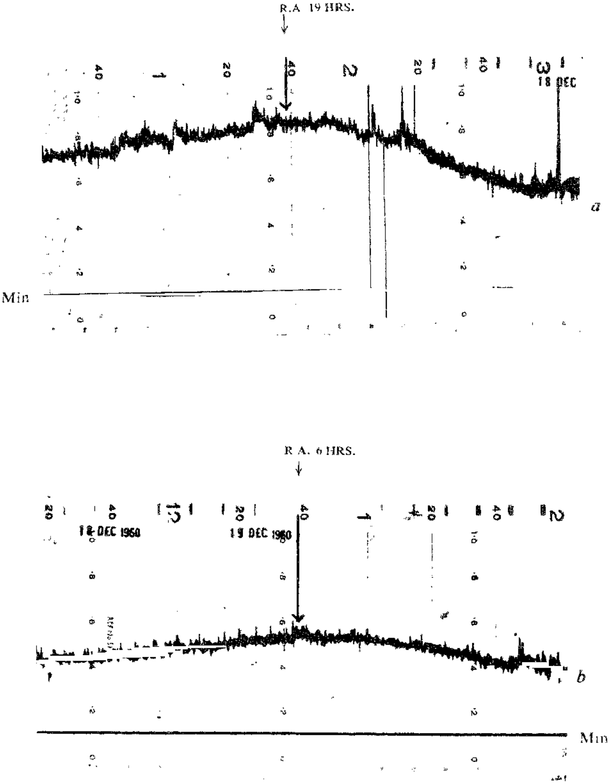
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FIG. 2

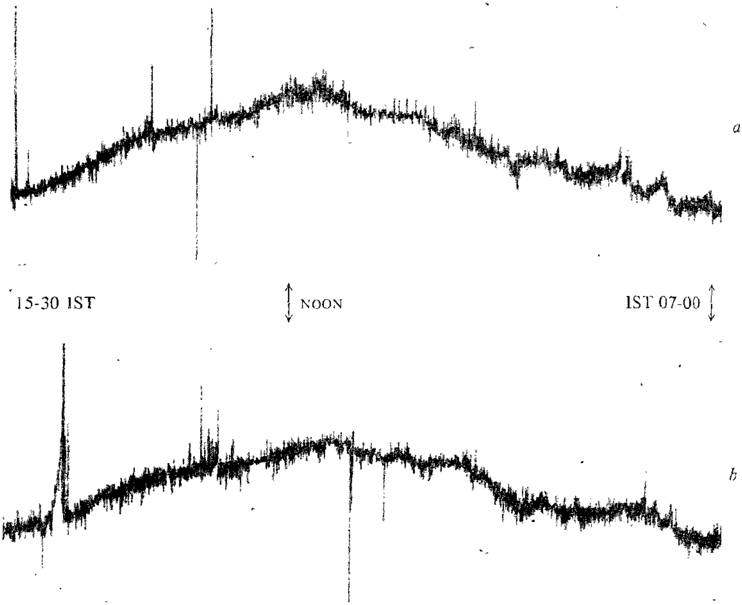

FIG. 3

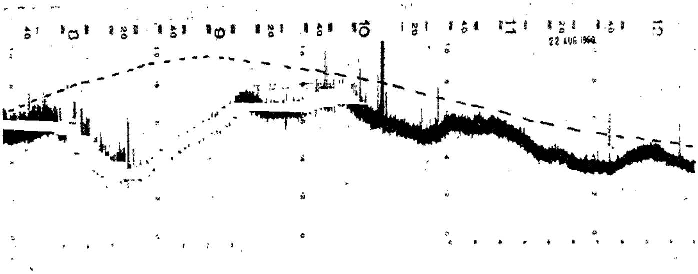

FIG. 4

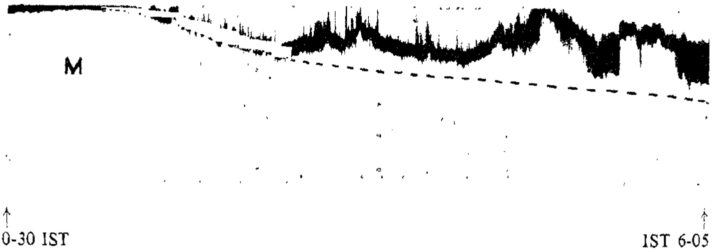

FIG. 5

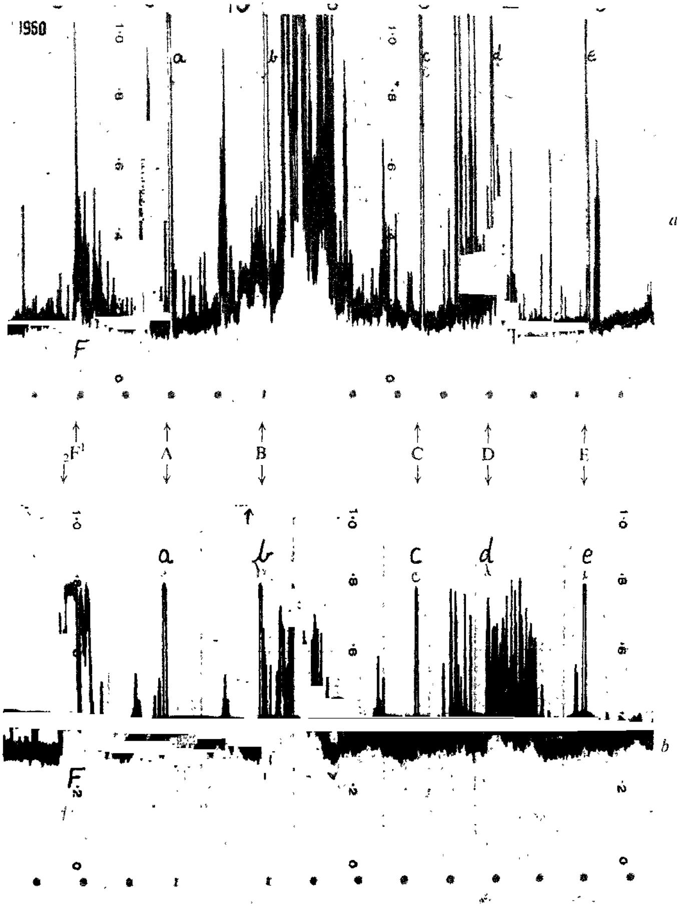

FIG. 6

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