CHAPTER III

CONTENTS

25 Mc/s COSMIC RADIO NOISE RECORDING EQUIPMENT AT AHMEDABAD

1. GENERAL DESCRIPTION.

2. ANTENNA.
   a) POWER GAIN OF A HALF-WAVE DIPOLE.
   b) RECEIVING AERIALS.
   c) DIRECTIONAL AERIAL USED FOR COSMIC RADIO NOISE MEASUREMENT AT AHMEDABAD.

3. RECEIVER: ITS FUNCTIONS AND LIMITATIONS.
   a) RECEIVER USED FOR RECORDING COSMIC RADIO NOISE RECORDING ON 25 MC/S AT AHMEDABAD.
   b) CHANGES MADE IN THE ORIGINAL CIRCUIT OF THE RECEIVER.
   c) OPERATING CONDITIONS OF THE RECEIVER.

4. DESCRIPTION OF DIODE NOISE GENERATOR.

5. DESCRIPTION OF D.C. AMPLIFIER.

6. PEN RECORDER.

7. NOTE ON STABILISED POWER SUPPLIES.
   a) STABILISED POWER SUPPLY REQUIREMENTS.
   b) DESCRIPTION OF STABILISED D.C. FILAMENT POWER SUPPLY FOR RECEIVER.

8. SAMPLE RECORDINGS OF COSMIC RADIO NOISE ON 25 MC/S AT AHMEDABAD.
CHAPTER III

25 Mc/s COSMIC RADIO NOISE RECORDING EQUIPMENT AT AHMEDABAD

1 - GENERAL DESCRIPTION

Fig. 1 shows the block diagram of cosmic radio noise recording equipment, designed and constructed by the author as part of the research programme in ionospheric physics in the Physical Research Laboratory, Ahmedabad.

It is a total-power type radiometer operated on 25 Mc/s on the lines of the instrument used by Shain and Mitra\(^9\) for their work on ionospheric absorption on 18.3 Mc/s.

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Fig. 1. 25 Mc/s Cosmic noise recording equipment at Ahmedabad.
The equipment consists of a directional antenna connected to a communications-type receiver whose output, after second detection, is fed to a d.c. amplifier. After d.c. amplification, the output is recorded on a 0-1 mA recording milliammeter. The output of the receiver is calibrated manually every day against the noise generated in a pure tungsten-filament type noise diode. The filament and high tension supplies are stabilised electronically to ensure good stability. A cold resistor of 100 ohms is automatically substituted for the aerial for a period of 2 min at intervals of 45 min by means of a d.p.d.t. relay actuated by a geared-down synchronous motor. With this arrangement it was possible to make corrections for the unavoidable changes in the receiver noise level. The same cold resistor was used to load the impedance of the diode noise generator.

2 - ANTENNA

a) POWER GAIN OF A HALF-WAVE DIPOLE

Even the simplest aerial, the Hertzian dipole, radiates more energy in certain directions than in others; and a half wave aerial is still more directional. In discussing the directional characteristics of aerials, it is usual to express the degree of beaming in terms of the power gain. The absolute power gain of an aerial is defined as its gain over
a perfect all round isotropic radiator. Such a radiator is a purely theoretical concept and cannot be realised in practice, since owing to the transverse nature of e.m. waves, it is impossible to devise a source which radiates uniformly through a complete solid angle $4\pi$. However, for purposes of calculation it provides a satisfactory standard. The absolute power gain of a Hertzian dipole is 1.5, while that of a half-wave aerial is somewhat higher having a value of 1.64.

b) RECEIVING AERIALS

According to the reciprocity theorem the aerial has similar directional characteristics for both transmission and reception. The energy delivered to the receiver is abstracted initially from the incident e.m. waves. It is evident, however, that the whole of this power cannot be delivered into the receiver for during the absorption process an alternating current is set up in the aerial, and this inevitably gives rise to a radiation field. The aerial therefore behaves partly as an absorber and partly as a scatterer of the incident radiation. It is usual to consider the collecting area $S$ as being made up of two parts, the equivalent absorbing area $S_A$, and the equivalent scattering area $S_S$, whose sizes are such that a fraction $S_A/S$ of incident power enters the receiver, while a fraction $S_S/S$ is retransmitted. The relative values of $S_A$ and $S_S$ depend on the parameters of the circuit. The first
amplifying stage of the receiver has a finite electrical resistance which causes an impedance to the flow of current between the input terminals. If this impedance is very high the amplitude of the current in the dipole will be small and \( S_A \) and \( S_s \) will both tend to zero. If, on the other hand, this impedance is so low as to approximate to a short circuit, the value of \( S \) will tend to become maximum, but almost all the power will be reradiated, so that while \( S_s \) will be large, \( S_A \) will be again very small. For any receiving system, there is an optimum condition between these two extremes for which the power transfer into the receiver is maximum. When the input resistance of the receiver is matched to this value, the system is said to be matched. It can be shown that when the incident radiation falls on to a matched aerial from the best direction of reception \( S_A = S_s = G \frac{\lambda^2}{4\pi} \) where \( G \) is the absolute power gain. If the input terminals of the aerial are short circuited, \( S_A = 0 \) while \( S_s = G \frac{\lambda^2}{4\pi} \). For a matched half-wave aerial, \( S_A = 1.64 \frac{\lambda^2}{4\pi} \).

c) DIRECTIONAL AERIAL USED FOR COSMIC NOISE MEASUREMENTS ON 25 Mc/s AT AHMEDABAD

Fig. 2 shows a schematic diagram of the directional aerial used by the author in conjunction with a communications receiver for the cosmic radio noise observations on 25 Mc/s at Ahmedabad. It is a broadside collinear array consisting of 16 half-wave dipoles spread in E-W direction in 4 rows and 4
the beamwidth of our aerial to half power points is about 30° in E-W and 40° in N-S planes. The power gain of an array over a single dipole is equal to the number n of half-wave aerials and the absolute gain, G, is equal to 1.64 x n. If a conducting screen is placed behind the screen, the whole energy is concentrated in one direction and the gain is increased by a factor of 2 for a separation of 0.2λ between dipoles and reflecting screen. The absolute gain of the array then becomes 3.28 x n. The power gain of the broadside-collinear array used at Ahmedabad is thus equal to 3.28 x 16 = 52.48 or 17.2 db over an isotropic radiator.

The impedance of a thin full-wave dipole fed at the centre is about 2000 ohms, hence four full-wave dipoles in parallel give an impedance of about 500 ohms (balanced). It should be noted that the antennae may be considered to be in parallel, since they are spaced at intervals of λ/2 along the feeder; also the feeder is twisted round between each full-wave dipole so as to obtain correct phase relationship for broadside radiation. The problem remains of matching the aerial impedance of 500 ohms to the transmission line whose characteristic impedance is 95 ohms, and the transmission line impedance to the receiver input impedance which is of the order of 100 ohms (balanced). The transmission line used for connecting the aerial to the receiver was a shielded twin-wire solid-dielectric low-loss radio frequency cable whose Z₀ = 95 ohms. This could be directly matched to the receiver.
input impedance. The transmission line was matched to the aerial impedance of 500 ohms in the following manner: A quarter wave stub of twin-wire, shorted at the far end was connected in parallel with the aerial feed points and the optimum position for connecting the transmission line to the stub was found by sliding it along the length of the stub. The total length of the cable between the aerial and receiver was about 50 feet.

3 - RECEIVER : ITS FUNCTIONS AND LIMITATIONS

The purpose of the receiver is to convert the minute signals delivered to it by the aerial into a form capable of actuating the output meter. For the measurement of solar and cosmic radio waves, this requires a high degree of amplification. Since the output is usually recorded on a recording milliammeter some amplification is done at the signal frequency but it is usual to employ the superheterodyne system in which the greater part, or all the amplification occurs at a lower frequency known as the intermediate frequency. The intermediate frequency signal is then rectified to produce a unidirectional signal. A rectifier is a nonlinear device and its output is not in general simply related to the input. It is, therefore, necessary to rely on calibration to establish the significance of a given reading in the output meter. The rectified signal is smoothed, partly by circuit arrangements and partly by the output meter.
The resultant smoothed signal, which is relatively constant, is what is indicated on a receiver output meter. If the changes in output are not sufficiently prominent on the record, further amplification (d.c. amplification) may be employed. The usual method is to amplify the difference between the detector output voltage and a suitable steady comparison voltage. Since both receiver noise and cosmic and solar noise have random waveforms, the powers are additive and the desired signal is only recognizable through the increase in the mean level which it causes. In normal radio practice signals much greater than the receiver noise level are common, though in some applications signals right down to noise level are utilized. The receivers used in radio astronomy may be required to operate with much smaller input powers. There, the wanted signal is commonly only a small fraction of the noise generated within the receiver itself.

The sensitivity of a receiver is not limited by any inability to obtain more amplification but by electrical noise generated in its valves and resistors. The excellence of a receiver in respect to the generation of internal noise is specified by either of two parameters: by the "noise factor" N or by the "noise temperature", T_R. We define gain factor, "g" in terms of the differential ratio of output P to input p i.e. \( g = \frac{dP}{dp} \) and shall take P as the power delivered to the detector and p as the available power at the aerial terminals. Now for a given input power p, the output is greater
than gp because of the noise generated in the receiver, say
\[ P = g(p + p_r), \]
where \( p_r \) is the receiver noise referred to the input terminals. It simply adds to \( p \) since it is a random noise. Both the noise factor and the noise temperature are essentially measures of \( p_r \) in terms of thermal agitation. The receiver noise temperature \( T_R \) which is a direct measure of \( p_r \) is obtained by writing
\[ p_r = K T_R \Delta f \]
where \( K \) is Boltzmann's constant \(( = 1.37 \times 10^{-23} \text{ Joules per deg.})\) and \( \Delta f \) is the integrated noise acceptance band of the receiver. The noise temperature, so defined, is simply the effective temperature of an aerial which would yield as much noise as the receiver generates.

The noise factor is a ratio relating \( p_r \) to the available power from an aerial at ambient temperature \( T_0 \). In this case,
\[ p = K T_0 \Delta f. \]

\( N \) is defined by
\[ N = \frac{\text{Total noise power}}{K T_0 \Delta f} = \frac{K T_0 \Delta f + p_r}{K T_0 \Delta f} \]

Therefore
\[ p_r = (N - 1) K T_0 \Delta f. \]

and
\[ T_R = (N - 1) T_0. \]

To give an idea of the orders of magnitude for a typical receiver, \( \Delta f = 1 \text{ Mc/s} \), and \( N = 10 \), for \( T_0 = 300 \text{ deg. Kelvin} \) so that \( p_r \approx 4 \times 10^{-14} \text{ watts} \) and \( T_R = 2700 \text{ deg.} \).
a) RECEIVER USED FOR RECORDING COSMIC RADIO NOISE ON 25 Mc/s AT AHMEDABAD

A Hammarlund Super-Pro Receiver, Model SP-400-SX, was adapted for cosmic radio noise work on 25 Mc/s at Ahmedabad. It is an 18-tube superheterodyne receiver originally meant for amplitude-modulated (AM) or continuous wave (CW) code signals within the range 1.250 to 40 Mc/s. This coverage is obtained in five-selected bands. An extremely wide range of selectivity is provided by a variable-selectivity crystal filter and variable-selectivity I-F transformers. Either manual or automatic sensitivity control can be selected and a noise limiter circuit is provided.

(i) **Antenna Circuit**: The antenna is coupled to grid of the 1st R-F amplifier through an input transformer having an untuned primary and tuned secondary. The terminals of the primary coils are ungrounded. This symmetrical arrangement of antenna primary coils permits full advantage to be taken of the noise reducing properties of a balanced transmission lines lead-in. The impedance of the input circuit is approximately 100 ohms.

(ii) **R.F. Amplifiers**: There are two conventional grounded cathode stages of R.F. amplification preceding the first detector or mixer.

(iii) **H.F. Oscillator**: The H.F. Oscillator operates at a frequency 465 Kc/s lower than the signal on 20-40 Mc/s band.
(iv) **Mixer**: The 1st detector or mixer employs a 6L7 pentagrid mixer. Its injection grid (grid No.3) is coupled to the H.F. oscillator cathode and its signal grid (grid cap) is coupled to the plate of second R.F. amplifier tube by means of a second R.F. transformer.

(v) **I.F. Amplifier**: The intermediate frequency amplifier has three stages consisting of three coupling transformers and three pentode amplifier tubes of the remote cut-off or super-control type. The first two transformers are identical and have tuned primaries as well as tuned secondaries. The secondary coils are fixed in position, while the primary coils are mounted on sliding rods permitting them to be moved back and forth with respect to secondaries, thus changing the degree of inductive coupling between them.

(vi) **Second detector**: The second detector is a small twin diode operated with both plates and both cathodes connected in parallel.

The following tubes are used in the circuit:

<table>
<thead>
<tr>
<th>Valve type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>6K7</td>
<td>1st and 2nd R.F. amplifier, and 1st I.F. amplifier.</td>
</tr>
<tr>
<td>6L7</td>
<td>Mixer.</td>
</tr>
<tr>
<td>6J7</td>
<td>H.F. oscillator.</td>
</tr>
<tr>
<td>6SK7</td>
<td>2nd and 3rd I.F. amplifier.</td>
</tr>
<tr>
<td>6H6</td>
<td>2nd detector.</td>
</tr>
</tbody>
</table>
The above is the description of the relevant portions of the Hammarlund receiver.

b) CHANGES MADE IN THE ORIGINAL CIRCUIT OF THE RECEIVER

The following alterations or additions were made in the original circuit to adapt the above receiver for cosmic-noise work:

(1) Since only R.F., Mixer, I.F. and 2nd detector stages were utilised for amplification and detection of cosmic radio noise, it was convenient to divide the receiver circuitry into two parts. Circuitry from antenna terminals to the 2nd detector formed part (1). Part (2) included the remaining circuits such as audio amplifiers, AVC, BFO, Noise Limiter etc. Of these audio section was used to identify aurally interference due to man-made or natural signals. AVC and BFO circuits were not used at all.

(2) Since the original AC and DC power supplies were unregulated, a highly stabilised high tension supply unit for plate, screen and bias voltages was built. Mains supply for these supplies was taken through a constant voltage transformer.

(iii) Filaments of the valves from 1st R.F. to 2nd detector, which were originally in parallel, were connected in series and the filament heating power was taken from a separate stabilised d.c. supply of 63 volts. All these valves require heater current of 300 mA.
(iv) The output was taken after second detection across its load resistance and fed to a d.c. amplifier for further amplification.

(v) Since pulsed transmitter of ionospheric recorder and the present equipment were installed in the same hut, to avoid their interaction, an arrangement was made to paralyse the receiver and shorting the recording milliammeter for the duration of transmission.

(vi) A one revolution per minute synchronous motor was geared down to perform one revolution per 45 minute and it operated a d.p.d.t. relay to replace the aerial periodically by a cold resistor of the same impedance as that of a matched aerial. This cold resistor is also used as a load for the noise-diode.

c) OPERATING CONDITIONS OF THE RECEIVER

<table>
<thead>
<tr>
<th>Control</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate voltage</td>
<td>250 Volts.</td>
</tr>
<tr>
<td>Screen &quot;</td>
<td>105 &quot;</td>
</tr>
<tr>
<td>Bias &quot;</td>
<td>-50 &quot;</td>
</tr>
<tr>
<td>Filament &quot;</td>
<td>+63 &quot;</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>5 Kc/s</td>
</tr>
<tr>
<td>AVC or Manual</td>
<td>Manual</td>
</tr>
<tr>
<td>Crystal select</td>
<td>Off</td>
</tr>
<tr>
<td>Phasing</td>
<td>On arrow</td>
</tr>
<tr>
<td>Limiter</td>
<td>Off</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>10</td>
</tr>
<tr>
<td>AM or CW</td>
<td>AM</td>
</tr>
</tbody>
</table>
4 - DESCRIPTION OF DIODE NOISE GENERATOR

The complete radiometer includes a standard noise source which could be connected in the place of the aerial and used to calibrate the receiver output. This source may be a standard signal generator or a so-called "noise generator", of which there are two common forms, the variable temperature resistor and the saturated diode. The noise generator has the marked advantage over the signal generator that the spectrum over a small interval is identical with that of the waves to be measured. Thus the form of the frequency response of the receiver does not affect the relative readings. In each case the impedance of the calibrating source is made identical with that of the aerial so that the receiver operates under identical conditions. The most direct way of using the calibrating source is to calibrate the receiver output directly at suitable levels.

The noise source in most general use is the temperature limited diode in which the anode current has a random or noise component \( i_n \) given by

\[
i_n^2 = 2eIB,
\]

where \( e \) is the charge of an electron, \( I \) is the anode current and \( B \) is the bandwidth. If \( i_n \) flows through \( R \), the noise power available from the terminals of the resistance, additional to its thermal noise is therefore

\[
(\frac{1}{2} i_n)^2 R = \frac{eIBR}{2}.
\]
The impedance of the diode is in parallel with \( R \) but is usually of the order of at least 20,000 ohms in normal circumstances. If \( R \) corresponds to the aerial impedance, \( \frac{1}{2} e I B R \) can be substituted for \( P_s \) in the equation

\[
N_T = \frac{P_s}{m K T B}
\]

where \( P_s \) is the noise power required to double the receiver noise.

Taking \( T = 290^\circ \) and \( m = 1 \), we have

\[
\frac{e}{2 m K T} = 20
\]

and the noise factor is given by \( N_T = 20 I R \), \( I \) being in amperes and \( R \) in ohms. Alternatively expressed in decibels

\[
N_T = 10 \log_{10} 20 I R.
\]

\( I \) is adjusted by varying the filament current and an important point to be remembered is that the anode voltage must be sufficient to ensure that the current remains temperature-limited even at the maximum value required. Failure to attend to this point usually reveals itself by a decrease of noise with increase of anode current. Oxide-coated cathodes are unsatisfactory under temperature-limited conditions. Thoriated filaments have been used successfully but it is safest to employ pure tungsten.

Fig. 3 shows the circuit arrangement of the balanced noise generator constructed by the author, using a Marconi type CV-172 pure tungsten filament noise diode, to calibrate
daily the cosmic noise recordings on 25 Mc/s at Ahmedabad. It has been mentioned previously that there is a provision to substitute the noise generator instead of the aerial by means of a d.p.d.t. relay. The output impedance of the noise generator is 100 ohms balanced, same as the aerial impedance. The noise-diode assembly and its power pack are built on two separate chassis and a d.c. milliammeter is incorporated to measure the diode plate current in the power supply circuit. Since the noise-diode is operated under temperature limited condition, the filament voltage is adjusted for changing d.c. plate current from 0 to 25 mA in steps of 5 mA by means of a rheostat in series with the primary of the filament transformer. The mains-supply is taken through a constant voltage transformer.

**Fig.3.** Balanced noise generator used for calibrating cosmic noise recordings on 25 Mc/s.
The rated maximum anode current for CV172 is 30 mA but higher currents for short periods, if some reduction of the valve life is acceptable. The filament voltage for CV172 should not exceed 7 volts. A safe plate voltage to ensure saturation up to 50 or 60 mA is 100 volts.

5 - DESCRIPTION OF D.C. AMPLIFIER

In a direct coupled amplifier, the input, output and interstage couplings are conductive i.e. they are either direct connections or resistive networks. No "blocking" condensers or coupling transformers are employed. Thus d.c. signals may be amplified, whereas the bandpass characteristics of other types of amplifiers drop to zero gain at zero frequency. The fact that the conductive coupling must be used throughout, results in several special problems of design and stability. One obvious design problem arises because plate potentials are considerably higher than grid potentials. It is therefore necessary to have the cathode of a following stage at this higher potential from the ground, or to use a device to lower this potential by the correct amount. Since batteries are impractical here, a negative supply voltage and a resistance divider are generally required, with resulting decrease in gain. The "zero adjustment" problem is the most difficult one resulting from conductive coupling. If the effects of noise and pickup are neglected, a non-conductively
coupled amplifier gives zero output for zero input regardless of circuit parameters such as resistor values, supply voltages and tube characteristics. This is not true of a direct-coupled amplifier; the d-c output at a given d-c input (e.g., zero) depends on all these things. A certain output current or voltage is usually required for a specified input. In order to meet this requirement some kind of 'zero' adjustment is needed to compensate for variation of the above parameters.

Fig. 4 shows a high gain d-c amplifier constructed by the author for use in the cosmic radio noise recording equipment on 25 Mc/s at Ahmedabad. The output of the receiver taken after second detection is too weak to be directly

![Diagram of DC Amplifier](image)

- A high gain d-c amplifier used for amplifying the output of second detector.
recorded on a 0-1 mA recording milliammeter and hence requires d-c amplification. Current feed back is employed, the current in the meter being measured by a stable resistance and a voltage proportional to it fed back to the auxiliary grid of the input differential amplifier. The second stage is a pentode amplifier with its cathode returned to a cathode follower. This arrangement permits differential input so that the full gain of the first stage is realised. It also allows input voltages at the plate level of the first stage; therefore, no dropping divider is needed at this point where the drift of such a divider would be felt very much more than after the second stage. Another feature permitted by the cathode follower in the second stage is the local positive feedback (by means of the 5.4 megohm resistor), which increases the linearity with overall negative feedback. Connecting the pentode screen and triode plate together prevents the common dropping resister from causing a reduction in gain; in addition the reduction in screen voltage produces higher gain in the pentode. The output cathode follower is designed to limit the current in the 1 mA meter at about 2 mA in either direction; the two limits result from the plate current cut-off and from grid current in the input resistance. The circuit may be used for full-scale input voltage as high as 10 volts, the limit depending on the value of the feedback resistor. The lower limit of full-scale input voltage is determined by the drift of the input tube. This limit is about 100 mV, and at
this scale factor the drift may be noticeable over a period of hours. In order to minimize this drift, the input tube was aged several hundred hours with the heater on. The d-c amplifier circuit described above has been found to give satisfactory service for the last four years. It has not given any special trouble except for the replacement of valves once in a few months. The only extra precaution that we have taken is to heat the filaments of d-c amplifier valves from a 6V accumulator battery instead of from filament transformer. Stability was better with this arrangement.

6 - PEN RECORDER

The output of the receiver after d-c amplification is fed to the pen recorder. It is a recording milliammeter with 0-1 mA full-scale sensitivity manufactured by Evershed & Vignoles Co., England. It has a synchronous motor drive and is operated at a chart speed of 1 inch per hour. Its time constant is of the order of 1 sec but is slightly variable with the damping arrangement provided in the instrument.

7 - NOTE ON STABILIZED POWER SUPPLIES

Considerable experience with different voltage-stabilizing circuits indicates that those of the simple
degenerative-type are the most generally satisfactory. A voltage-stabilised power supply accomplishes more than simply furnishing a d.c. voltage of a fairly stable value. It affords a low source impedance, considerably reducing the interaction between various parts of a circuit for which it furnishes plate power and the stabilizing circuit itself acts as an excellent filter for ripple voltages. In order to compare different power supplies, it is convenient to define the stabilization factor

\[ S = \frac{E_0}{E_s} \cdot \frac{dE_s}{dE_0} \]  

(1)

where \( E_s \) is the mains supply voltage and \( E_0 \) is the stabilized d-c output voltage; and to define the output or source impedance,

\[ R_o = -\frac{dE_o}{di_0} = \frac{e_o}{i_o} \]  

(2)

where \( i_o \) is the current supplied to the load. The most interesting property of the stabilizing circuit itself is expressed by the smoothing factor

\[ \chi = \frac{dE_o}{dE_1} = \frac{e_o}{e_1} \]  

(3)

where \( E_1 \) is output voltage of the transformer-rectifier-filter circuit preceding the stabilizing circuit. It is evident that the quantities defined in the equations (1) and (2) specify
the most important features of a voltage stabilised supply. The smoothing factor, defined in equation (3), enables an estimate to be made of the ripple voltage at the output, if the ripple voltage at the input of the stabilizing circuit is known.

The basic circuit of most stabilized supplies of the degenerative type is indicated in Fig. 5(a).

Fig. 5(a). Basic circuit of a stabilized supply of the degenerative type.

Fig. 5(b). A simplified equivalent circuit.

The circuit consists of a conventional transformer-rectifier-filter supply, indicated by the block T-R-F, followed by a triode connected in series with the positive supply bus. A fraction \( \beta \) of the output voltage is compared with a fixed voltage \( E \), obtained either from a VR tube or from a battery.
of dry cells. The difference between the two voltages is amplified by a difference amplifier of gain $G$ and is used to control the grid bias of the series triode, so as to afford a degenerative compensation for any change in circuit conditions that tends to alter the existing output voltage. All circuit voltages must be so arranged that d-c coupling can be used throughout the amplifier. Where this type of coupling results in a loss in gain, resistors can be bypassed by capacitors so that a greater degeneration is obtained for a-c signals in particular, for ripple voltages.

A simplified equivalent circuit is shown in Fig.5(b) where $R_1$ is the source impedance of the transformer-rectifier-filter combination, and $r_p$ and $\mu$ are the plate resistance and the amplification factor, respectively, of the triode. By means of a simple circuit analysis, it is found that

\[ S \approx \frac{E_0}{E_1} \beta G \]  
\[ R_o \approx \frac{R_1 + r_p}{\mu \beta G} \]  
\[ \alpha \approx \frac{1}{\lambda \beta G} \]

when $\beta G \gg 1$. In case of practical power supplies, the plate-load resistor of the final stage of the difference amplifier is often connected to the plate side of the series triode instead of to the cathode side. This arrangement is
chosen in order to maintain adequate gain for the difference amplifier as the grid bias of the series triode approaches zero.

a) STABILIZED POWER SUPPLY REQUIREMENTS FOR RECEIVER AND D.C. AMPLIFIER

| (i) Receiver          |  |  |  |
|----------------------|-----------------|-----------------|
| Plate voltage        | 250 volts       | 100 mA          |
| Screen voltage       | 105 volts       | 25 mA           |
| Bias for sensitivity | -50 volts       | 15 mA           |
| control              |                 |                 |
| Filament voltage     | 63 volts        | 300 mA          |

| (ii) D.C. Amplifier  |  |  |  |
|----------------------|-----------------|-----------------|
| Plate voltage        | 250 volts       | 25 mA           |
| Bias voltage         | -105 volts      | 10 mA           |
| Filament voltage     | 6 volts         | 1.2 Amp.        |

These were the power supply requirements for operating the receiver and d-c amplifier of cosmic radio noise equipment at Ahmedabad. Except for filament voltages, all the remaining voltages were obtained from the same stabilised power supply constructed by the author.

Fig. 6 shows the model 50 power supply circuit suitably modified to satisfy our requirements. (Elmore and Sands). The model 50 supply, when delivering a current of
100 mA to an external load, it has an rms ripple voltage of 1.5 mV and presents an output impedance of 0.5 ohm for slow changes in the load. The measured stabilization factor is about 1200. The difference amplifier in the stabilizing circuit is based on the double-triode amplifier followed by a single-triode amplifier. Both plates of 6SL7 difference amplifier are biased at approximately the same potential (200 volts) to obtain a symmetry in currents and voltages between the two halves of the amplifier. It may be shown that any change in the effective contact difference potential between grid and cathode, common to both tubes of the difference amplifier, suffers a degeneration of nearly $1/\mu$ in comparison with a signal impressed on the amplifier between grid and ground. For this reason the stabilized output voltage of the supply shows very little drift when the heater voltage is varied $\pm 10\%$. It will be noticed that the current for the VR tube is obtained from the output side of the supply. This arrangement ensures that the comparison voltage will not be subject to changes caused by a varying current through the VR tube. Another point worth noting in all the supplies is that the plate-load resistor of the amplifier stage that couples to the grid of the series triode is returned to the unstabilised side of the power supply. This enables the potential of the grid of the series triode to approach that of its cathode without causing the current through the amplifier stage to become very small and the gain, therefore, to become much reduced.
Fig. 6. Modified Model 50 stabilised power supply for receiver and d.c. amplifier.

b) DESCRIPTION OF STABILIZED FILAMENT POWER SUPPLY FOR THE RECEIVER

Fig. 7 shows the circuit diagram of a filament power supply designed and constructed by the author to give 63 V.DC and current 300 mA. Originally the filaments of the receiver valves were in parallel and heated by means of a filament transformer. Soon it was realised that for good stability a-c heating of the filaments had to be discarded. It was essential to heat them by a well-stabilized d.c. voltage. All the filament were connected in series. The sum of filament voltages of the
valves from 1st RF to 2nd detector was 50.4 volts and the heater current was 300 mA, same for all of them. It was necessary to raise this voltage to 63 volts for the proper operation of the amplifier tube 1N5GT in the regulating circuit. The excess voltage was dropped across a suitable resistor in series with the heaters. Special heavy duty transformers and filter-chokes were wound in the laboratory and it was decided to connect six 6L6 tubes in parallel as series valves so that 300 mA current could be drawn through them without exceeding their plate dissipation. A battery operated pentode 1N5GT was used as an amplifier tube, the plate of which was directly connected to the grids of 6L6's.

Fig. 7. Stabilised D.C. filament power supply for the receiver.
The filament of the 1N5GT was heated directly from the stabilised output voltage with a proper voltage dropping resistor in series with it. A battery of dry cells (24 volts) was used as a reference voltage. The performance of this circuit has been satisfactory.

8 - SAMPLE RECORDINGS OF COSMIC RADIO NOISE ON 25 Mc/s
AT AHMEDABAD

Fig.3 represents three samples of cosmic radio noise records on 25 Mc/s made at Ahmedabad, by means of an equipment described above, during the IGY and IGC.

Fig.3(a) illustrates the cosmic-noise record on 1 and 2 July 1957. The chart speed has been one inch per hour. The times written on the upper and lower sides of the chart are 75° EMT and sidereal time respectively. The intensity of the cosmic-noise at a given time depends upon which portion of the sky the aerial is looking at and the ionospheric attenuation at that time. The presence of solar noise storm on 1 July 1957 is evident during noon hours from 1030 to 1330 hours. After 1400 hours, the record shows a broadening due to the atmospherics superimposed over the cosmic noise background. It is almost free from disturbance 2230 hours onwards. It is calibrated manually in terms of diode-noise generator current at 0815 hours and 1800 hours. It is clear that the receiver input/output characteristics are not linear. In order to
Fig. 8(a), (b) and (c). Illustrating sample cosmic-noise recordings made at Ahmedabad.
determine the intensity of cosmic-noise at a particular time, it is first necessary to count the number of divisions on the chart from the zero-level to the base of cosmic-noise level and then using a calibration curve relating chart divisions to the noise-diode current, the intensity of cosmic radio noise can be read on a linear scale. As has been explained earlier, zero-marks indicate the receiver noise level when the antenna is replaced periodically for a short time by a cold resistor of 100 ohms, so that if there be any drift in the instrument it can be corrected for. In this particular record the maximum amplitude occurred at about 1200 hours local time due to the solar radio bursts and at 0030 hours when the galaxy was overhead. The galaxy being a diffuse source of radio noise shows a broad maximum. The cosmic noise recording instrument was automatically paralysed for about 5 minutes every 15 minutes on 1 and 2 July in order to avoid pickup of strong radiation from the nearby pulsed transmitter used for vertical ionospheric soundings. Normally this is done for 5 minutes every hour. In the absence of such an automatic paralysing arrangement, the appearance of the cosmic noise recordings would have been spoilt.

Fig.9(b) shows a similar record but taken on 29 and 30 April 1958. This record shows a disturbance due to atmospherics from 1100 hour onwards on the 29th till about 0100 hour on the 30th April. After this the appearance of the
cosmic radio noise was smooth as indicated by the absence of spikes on the record. After sunrise, a weak interference due to atmospherics is evident. It is worth noting that the maximum due to galactic radiation, which occurred at midnight in the first week of July 1957, has now shifted to 05 hour local time in the last week of April 1958. This observed local time difference in the occurrence of the maximum in the cosmic radio noise is to be expected, since it depends upon the sidereal time and not on the solar time.

Fig. 9(c) shows a cosmic noise record on 27 and 28 September 1959. Due to the sidereal time dependence, the peak of the galactic radio noise has now shifted to evening between 1900 to 2000 hours. But its shape is distorted owing to rapid rise/ ionospheric attenuation after 1830 hours. This record also exhibits disturbance due to atmospherics but the cosmic-noise base-level can still be identified. In severe cases, one has to reject such records. This record became free from interference due to atmospherics and also from ionospheric attenuation after 2300 hours local time on 27 September 1959. Another smaller peak in intensity made its appearance between 05 and 06 hours. This second peak did not reveal itself in the last two records, since it was suppressed due to the daytime ionospheric attenuation.

From the above discussion of the cosmic noise records, one can conclude that the intensity of the cosmic noise as measured on the surface of the earth depends on: (1) its variation with sidereal time and (2) ionospheric transparency which on most days depends on the local time.