AHMADU BELLO UNIVERSITY, ZARIA

DEPARTMENT OF ELECTRICAL ENGINEERING

DIURNAL AND SEASONAL VARIATIONS OF MEDIUM WAVE RADIO SIGNAL AT ZARIA

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Being a thesis submitted in partial fulfillment
for the award of M.Sc.(Eng) Degree

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DECLARATION

I hereby declare that this thesis has been composed by myself and that it is a record of my own research work. It has not been accepted in any previous application for a higher degree. All quotations are distinguished by punctuation marks and the sources of information are specifically acknowledged by means of references.

GBADE O. AFOLABI

Date: 15 - 11 1983

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ABSTRACT

This research was undertaken to investigate diurnal and seasonal variation of Medium Wave in Zaria. The effect of the seasons on signal strength and consequently of harmattan was examined.

The more common analysis of evaluating several medians was used. Medians were evaluated for periods of one hour, one day, one month, one season and for the whole period of measurement. The hourly medians were evaluated *on* a daily and monthly basis.

Some problems common to Medium Wave broadcasting in Nigeria in particular were enumerated and suggestions made *on* how to overcome them.

A comparison was made between theoretical distributions and the probability distribution of the received signal. All the results were obtained from the Computer and put in graph form from which some conclusions were arrived at.

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DEDICATION

Dedicated to my Father and Mother

CHAPTER ONE

INTRODUCTION

There has been a lot of work done on Medium Wave propagation, however, most of this work was carried out in the temperate regions of Europe, Australia and U.S.A. The need to study the propagation conditions of Medium Wave signals in the Tropical zone has long been recognised. Broadcasting transmitters, receivers and standards of broadcasting in the tropics have been based on data analysis in the temperate regions, it being assumed that the temperate region results can be applied to the tropics. There is therefore, a need for extensive data analysis to investigate propagation conditions in the tropics.

The medium frequency broadcast band is the most extensively used and is increasingly used in Nigeria. As will be further discussed in chapter 3, there are over 19 Medium Wave broadcast stations in Nigeria, most of them having their primary coverage area overlapping that of another station. It is therefore of primary interest to Nigeria to investigate Medium Wave reception by extensive data analysis. This need has motivated this work.

The main objective of this work was to analyze field strength measurements to find out:

1. The effect, if any, of harmattan dust particles on Medium Wave propagation.
2. Diurnal and seasonal variation of Medium Wave signals in Zaria.
3. To compare the signal level of ground wave field strength with measurements done in the past.

For effective planning of Medium Wave broadcast stations, certain factors affecting propagation of signals need to be known. They include the ground constants - ground conductivity and dielectric constant-, absorption of radio signal caused by vegetation and the physical factors in the atmosphere. The latter factors can be determined only by extensive data analysis of measured signals.

Here at Ahmadu Bello University, some work has been done on ground conductivity measurements. Ezeadubu (1982) conducted ground conductivity measurements of several parts of the Northern States of Nigeria using the ground wave attenuation method. He found out that most of the Northern States have an average ground conductivity of 3 m mho /m. He measured the ground wave signal strength of Rima Radio station among others and found that the ground wave signal did not vary appreciably during the 5 months (March - July) period of measurement.

Pindar (1980) conducted some ground wave measurements for five stations including Rima Radio Sokoto station. He investigated the variation of the ground wave signal with time and distance. His measurements were made in a shorter period than that of Ezeadubu and his conclusion that the ground wave signal does not vary with time of day agreed with that of Ezeadubu. Badmos (1979) also conducted some field strength measurements of both ground wave signals (MW), skywave signals (S.W.) and microwaves. He investigated, among others, ground wave variation of field strength with distance and time. He measured field strength signals of another set of stations both near and far from Zaria. He found out that nearer stations had a steady ground wave signal during the day and night and stations further away had a larger range of variation at night.

In his paper "Some Results of Radio Wave Measurements" Bajoga (1981) highlighted results of ground wave and sky wave measurements in Zaria. He stressed the need for further investigation into the results obtained so far especially the variation of received signals in the Medium Wave band at night from distant stations. The results obtained were for short periods of measurement and statistical analysis of extensive data are necessary for results to be conclusive.

In other parts of the country, some work has also been done on propagation of radio waves. In the first National Symposium on Broadcasting in Nigeria held at University of Ife, Ile-Ife, in September 1978, Oyinloye (1978) reviewed radio propagation studies within the last twenty-five years. He showed that most of the work done on ionospheric propagation was done at University of Ibadan with the use of the MK II Union ionosonde. Received echoes of pulses sent into the ionosphere were measured. Information was thus provided on the E and F regions of the atmosphere. He also indicated that a lot of research had been done on the maximum usable frequency and radio absorption characteristics. Owolabi (1978) discussed some engineering design aspects essential for planning of Medium Wave broadcasting systems. The design of the transmitting aerials for good area coverage and maximum use of transmitter powers were treated. Furthermore, design of microwave links for Broadcast relay systems were discussed.

Maska (1982) proposed a new broadcast system for Kaduna State radio at 639 KHz for better coverage of Kaduna State. In his design he tried to maximize transmitter power and produced propagation curves for the proposed frequencies of transmitters.

To provide further information useful for designing better broadcast systems, this project was undertaken.

Intermittent measurements were started with the Radio Kaduna broadcasting station on 639 KHz. The transmitter is at Jaji, a distance of 38 km from Samaru, Zaria. The signal level was practically constant during the day and at night. In late May 1982, Rima Radio Sokoto began to be recorded along with Radio Nigeria Kaduna. It was decided to stick to only one station, Rima Radio Sokoto, because initial measurements showed variations of the received signal at night. The measurements were taken between June 1982 and June 1983. From November 1982 onwards, the field strength measurements were restricted to the Rima Radio station with intermittent measurements of Radio Nigeria Kaduna.

Rima Radio broadcasts on 558 KHz Medium Wave with a transmitter power of 25 KW located at Shuni, Sokoto State. Shuni is a distance of 322 km from Zaria. The main scope of the work became very complicated when on December 10, 1982, Radio Nigeria Calabar began test transmission on the same frequency of 558 KHz with a transmitter power of 50 KW. Although Calabar is over 600 km (straight line distance) from Zaria, the signal strength of the Calabar station completely drowned the Rima Radio signal at night. During the day, the Rima Radio signal was the only signal received.

The angle of seperation between Calabar - Zaria and Sokoto - Zaria line of sight is 45^{o} *. This very close angle of seperation made it impossible for available equipment to separate the two signals. A loop antenna supplied with the field strength meter proved inadequate. With a more sophisticated directional antenna that can receive in only one direction, such seperation can be possible. Figure 1.1. illustrates the relative positions of Calabar, Zaria and Sokoto. The line of sight angle of seperation is also shown.

It was necessary to take measurements of the two signals at night without seperating them. However, during the day with the sky wave signal of Radio Nigeria Calabar absent, the Rima Radio station was recorded without interference.

The field strength measurements recorded thus comprised Rima Radio signal during the day and both Rima Radio and Radio Nigeria Calabar signals at night. The signals were analyzed seperately as far as possible and a comparison of single signal measurements was made with that of two signals. This will be further discussed in chapter 3.

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* Oxford Atlas of Nigeria (C) 1968, Oxford University Press.



Scale 1: 6,300,000

Kuhn and Taumer* (1974) proposed a theoretical distribution that approaches a Rayleigh or log-normal distribution as two values in the formula approach 0 respectively. It was found that in the G D R, measurements taken approach a Rayleigh or log-normal distribution only in marginal cases. It was also the objective of this research to investigate the statistical distribution of the Medium Wave signal measured by comparing it with the Rayleigh and Gauss distributions.

The results of Medium Wave propagation measurements undertaken in the Northern part of Nigeria have only been for a short period of time (for ground wave signals) and diurnal and seasonal variations of received signals have not been undertaken. Also the sky wave signal in the Medium wave has not been studied here in Zaria. Extensive data based on a period of thirteen months was analyzed. This made it possible for diurnal and seasonal variation of the Medium Wave signal to be investigated. The received ground wave signal was compared with past measurements for any long term variation. The effect of power of transmitter and transmitter - receiver distances on the received signal and finally seasonal variations of received signal were analyzed.

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* See "Some New Results of Propagation Measurements and Their Application for Planning Transmitter Networks" IEEE Transactions on Communications Vol. Comm - 22, No.9, September 1974, pgs. 1396 & 1397.

CHAPTER TWO

PROPAGATION OF MEDIUM WAVE SIGNALS

Medium Waves occupy the frequency spectrum of 300 KHz - 3 MHz. Part of this band in the range 525 KHz - 1.6 MHz, is used for broadcasting, It is important to note that Medium Waves propagate as both ground and sky waves. In Nigeria, Medium Wave propagation is very popular and is becoming more widespread in area of coverage. These two modes of propagation will be discussed in this chapter.

2.1 GROUND WAVE PROPAGATION

Ground wave propagation is the dominant mode of Medium Wave propagation. As the frequency of transmission increases, the ionospheric wave becomes more significant during the day. For the frequency of 558 KHz, ionospheric waves are not significant during the day. Ground waves can be divided into two types: surface waves and space waves. Surface waves propagate close to the earth's surface. Space waves propagate higher and farther than surface waves and can be direct ray or reflected ray.

For an isotropic transmitter in free space, the electric field strength can be expressed in terms of its effective radiated power as

$$E = \frac{300\sqrt{F}}{r} \quad mV/m \qquad .... \quad (2.1)$$

An attenuation factor A to take care of all losses in the actual medium is usually introduced. A is given by[2]

$$A = \frac{2 + 0.3p}{2 + p + 0.6p^2} - \sin b\,(P/2)^{\frac{1}{2}} \exp\left(\frac{5p}{\delta}\right) \quad \ldots \quad (2.2)$$

where p is a distance figure depending on the permittivity (ε) conductivity (σ) and frequency. Introducing A into equation (2.1)

$$E = \frac{300\,A\sqrt{P}}{r_{km}} \text{ mV/m} \quad \ldots \quad (2.3)$$

Equation (2.3) is the standard equation for calculating the electric field strength of a transmitter of effective radiated power P at a distance of r_{km}. This equation assumed a flat earth. The assumption is true for any distance

$$d \leqslant \frac{80}{f^{\frac{1}{3}}} \quad \ldots \quad (2.4)$$

where f is the frequency of transmission in MHz and d is in km.

At larger distances the presence of the direct and reflected rays make the received signal to be more complex than as depicted in equation (2.3). The interference caused by the existence of the direct and reflected rays can either be constructive or destructive. This interference is negligible when compared with interference between ground and sky waves, which will be discussed later in the chapter.

The effect of the earths curvature is that it greatly limits the area of coverage of the ground wave signal which is only slightly difracted on the earths surface.

The area where the signal strength of a station is higher than noise for all the time can be defined as primary coverage area. A minimum signal of 3 mV/m should be present.(8) The design engineer does not want interference and so relies mainly on the ground wave signal. In the primary coverage area, the ground wave should be the dominant mode of propagation most of the time. This is to ensure that the signal strength received is above noise.

2.2 MEDIUM WAVE PROPAGATION IN NIGERIA

Medium Waves are commonly used in Nigeria and therefore needs some attention. State Radio stations are not allowed to broadcast outside their state boundaries. At present most states have their own Medium Wave broadcast systems. The F.R.C.N. (Federal Radio Corporation of Nigeria) also has broadcast stations in many of the State capitals. The need to keep within primary area of coverage by the use of appropriate transmitter powers, location of transmitters and design of antenna is very great. This is in order to avoid needless interference between adjacent stations. The proper allocation of

frequency is also very important. It cannot be assumed that stations that are far away cannot interfere with each other. This has been demonstrated in the case of the Radio Nigeria Calabar station and the Rima Radio station. Both stations operate on the same frequency of 558 KHz and at night, the interference here in Zaria is very bad. It is therefore important for a lot of measurements to be conducted in different parts of the country in order to correct the many problems existing in our Medium Wave broadcast systems. New stations being set up should also be monitored as to their power transmission and frequency of broadcast and also conforming to the coverage areas assigned.

2.3 SKY WAVE PROPAGATION

Medium Waves propagate at night as both ground and sky waves. This fact justifies the discussion here of sky wave propagation. Sky waves are propagated over large ranges due to single or multiple reflection in the ionosphere. A brief description of the ionosphere especially with respect to Medium Wave propagation will be discussed.

2.3.1 The Ionosphere

The ionosphere is the region of the atmosphere where free ions that affect radio propagation exist. It can be

divided into layers or regions depending on the ion concentration. These layers are named D, E and F. The E and F layers can be further divided into E_1, E_2 and F_1, F_2 respectively. Figure 2.1 is a schematic diagram of the ionospheric layers and their respective heights. The seperation between the layers are gradual and not abrupt as suggested in the figure.

These layers vary diurnally and seasonally. The D layer is most significant here because it exists during the day and disappears at night. The main ionising agent is the sun. It emits electromagnetic waves, X-rays and streams of electrons all of which contribute to the ionisation of the atmosphere. The density of ionisation and consequently the ionospheric layers vary with the sun spot and time of day. The ionisation of the atmosphere takes place from the top downwards to the earth but because of the low air density at higher altitudes, the maximum ionisation density is somewhere within the atmospheric layer. During the day with the presence of the sun the D layer exists but at night it disappears. This layer absorbs Medium Wave signals very strongly when it is present and in most cases the signal is completely absorbed and does not propagate.

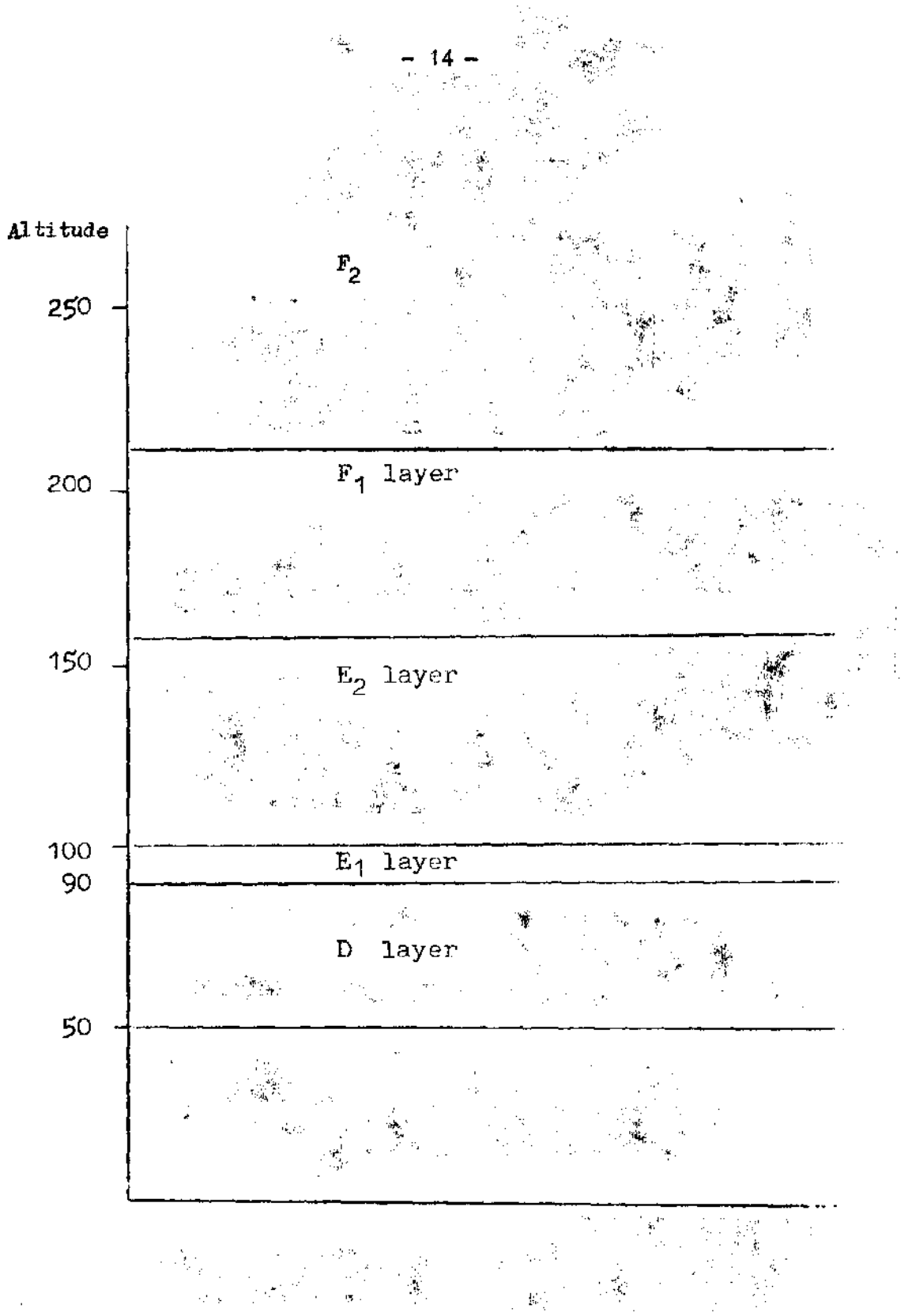


Figure 2.1 Ionospheric layers of Earths Atmosphere

2.3.2 Refraction and Reflection in the Ionosphere

The lack of definition of the ionospheric layers is responsible for a lack of defined point of reflection in the atmosphere. As shown in Figure 2.2 a radio wave entering the ionosphere is reflected back to the earth. The reflection follows a curved path. A wave will be reflected back to the earth only if the conditions of increase of electron density at point of reflection and angle of incidence are satisfied. This shows that not all waves incident in the ionosphere will propagate. However, the above conditions can be satisfied by Medium Wave signals and this will be examined next.

2.4 MEDIUM WAVE PROPAGATION IN THE IONOSPHERE

As was mentioned earlier, the D layer disappears during the night making ionospheric propagation possible. During the day the D layer absorbs the Medium Wave signal such that only the ground wave is present. Even when this is not the case, the sky wave signal is usually negligible. At night both ground and ionospheric waves are present. At close distances to the transmitter the ground wave dominates. This has been verified by measurements taken here in Zaria. At very large distances (over 400 km) usually the only wave present is the ionospheric wave. In between is a region where both ground and sky waves are present and this can be a nuisance because of rapid

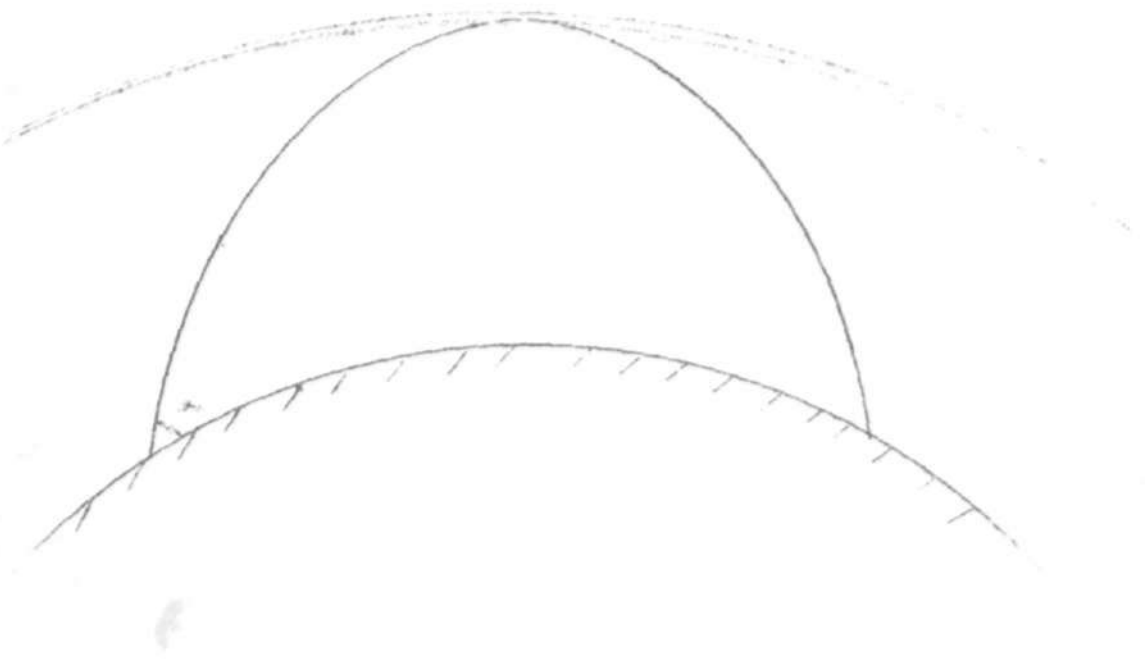


Figure 2.2: Return of a Radio Wave to Earth

fading caused by interference of the two signals. Medium Wave transmitter stations are designed such that this region is outside the primary coverage area. In Zaria, the Rima Radio station (322 km away) is received as both ground and sky waves and the Radio Nigeria Calabar station only as sky waves (over 600 km away).

With the absence of the D layer at night, the Medium Wave signal is reflected in the E layer and received at distances far larger than during the day. The existence of the ground and sky wave signal causes fading which can be reduced by anti fading aerials. All these problems of interference enumerated and those of frequency allocation as well as interference between nearby stations were encountered during the research investigation.

In summary Medium Wave signals are used extensively in Nigeria. There are problems of interference and especially frequency allocation due to the existence of several stations. With proper monitoring of old and new stations, these problems can be reduced. Also by careful design of antennas, the sky wave component of the wave can be reduced and this will reduce interference between ground and sky waves. It is hoped that the results of the investigation in the later chapters will contribute to better broadcast systems.

CHAPTER THREE

FIELD STRENGTH MEASUREMENTS

3.1 MEASURING SITE

The field strength measurements were carried out in a hut[4] at the outskirts of Ahmadu Bello University Main Campus away from residential buildings. The flat roof building is at the centre of a circular area of 35 meters radius. This area has a special earthing system[4] of copper wires soldered to copper plates on the top edge of the building and this plate is connected to earthing poles 2.5 meters high at the periphery of the circular area. The roof was also solidly earthed at the four corners of the building. With this set up, the rod antenna on the top of the roof can be considered as real earth.

The hut was supplied with a 240 volt underground line with provision for standby generator supply. This hut housed the field strength meter, strip chart recorders and other equipment discussed in the next section.

3.2 MEASURING EQUIPMENT

The following is a list of the equipment housed in the measuring hut:

1. Rohde and Schwarz field strength meter type HFH.
2. Hewlett Packard strip chart recorders.

3. Servomex electromechanical a.c. stabilizer.
4. Phillips a.c. stabilizer.
5. Standby Honda generator.
6. 45 AH Varta Battery.

3.2.1. Field Strength Meter

The Rohde and Schwarz Electric field strength meter used has the following main specifications:

1. Indicating meter range: linear 0 - 20 dB
   logarithmic 0 - 40 dB
   0 - 60 dB

2. Frequency range : 0.1 to 30 MHz in 10 subranges

3. Measurement range : 0 to 120 dB referred to 1 μV switchable in 10 dB steps

4. IF Bandwidth (3 dB down): ± 100 Hz
   ± 500 Hz switch selected
   ± 4 KHz

5. Image rejection : 50 to 70 dB depending on frequency

6. Output for recorder : - 3 V + 10% for full scale deflection on meter 500 kohms

7. Error of indication : ± 2 dB

The field strength meter was connected to the strip chart recorder and antenna matching unit as shown in

figure 3.1. The logarithmic indication ranges were used because they are better suited for largely varying signals characteristic of Medium Wave signals at night. The meter was set to 558 KHz permanently. This corresponds to the Rima Radio station with the Radio Nigeria Calabar station interfering at night. Intermittent readings from Radio Kaduna at 639 KHz were also taken at the start of the measurements in June and July 1982. Even before the uncontrolled interference from Radio Nigeria Calabar, a nearby station at 545 KHz, Radio Nigeria Kano with an average signal strength of 80 dB interferred with the Rima Radio readings. The bandwidth was then changed from 4 KHz to 500 Hz to reduce this undesirable interference.

The main problem encountered with continuous measurements was the public power supply. Initially the equipment was set up relying only on the public electricity supply which was greatly inadequate. The supply was cut often and for extended periods of time making continuous measurements practically impossible. A Honda generator was later (in November 1982) attached to the measuring hut and this was used as much as possible when the public supply was off. Also, because of the distance of the hut from the main campus, a 45 AH battery was purchased and used to run the equipment for a short time after the electricity supply was off before the

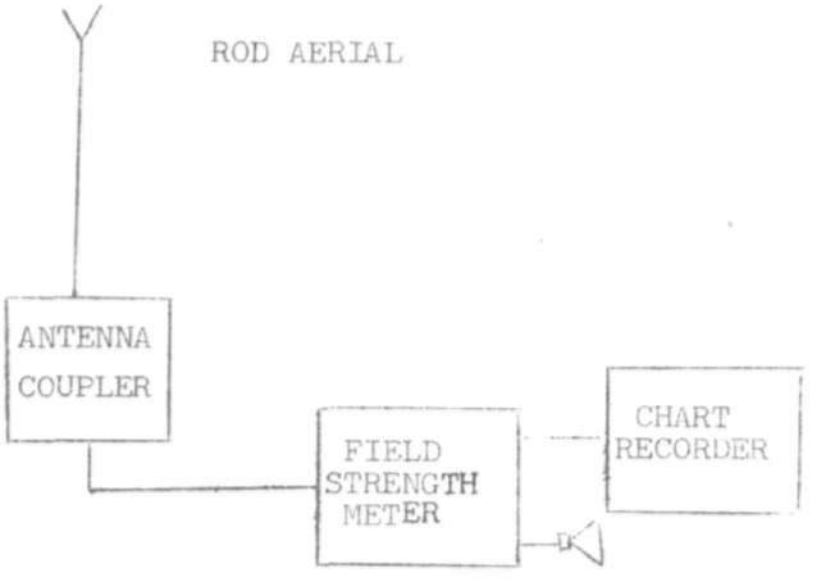


FIG. 3.1 Block Diagram of Measuring Equipment Set Up

generator is switched on. This arrangement reduced the number of breaks in the measurement.

3.2.2. Strip Chart Recorders

Two strip chart recorders were used during the course of the research. The first one, Hewlett Packard model 3055A chart recorder was purchased in 1974 and prior to the measurements had run over 3.78 km of recorded paper.(4) Very early in the research, this chart recorder had to be changed for a better model 7155B also manufactured by Hewlett Packard. This was necessary because the gears of the first chart recorder had worn out and the speed of paper was no longer accurate.

The HP 3055A chart recorder is an ink/pen recorder using millimetric recorder paper of width 28 centimeters and length 36 meters. The recorder could be set at speeds from 2.5 cm/hr to 5 cm/sec. When the recorder was used, it was set to 15 cm/hr or 30 cm/hr.

The HP 7155 chart recorder is a disposable pen recorder using a paper of 12 centimeters width and 22 meters length. The speed of recorder paper is a range from 2 cm/hr to 0.1 cm/sec or 6 cm/min. The speed of paper was set at 0.4 cm/minute. This speed was found most convenient both for unattended recordings and economical use of chart recorder paper. It also

On the 40 dB range, full scale deflection represents 3 V that is

40 dB -- 3 V

and 80 dB -- 6 V

The maximum level of 80 dB corresponds to 6 volts output. A scale of 0.5 volts/cm means the 6 volts output would cover 12 cm. This is the width of paper. Any other scale would either lead to the signal shooting past the paper or to inadequate use of paper. Figure 3.2 shows the graph recorder paper and the staircase discussed above.

The Rima Radio signal was recorded in the months of June 1982, November 1982 and the first 10 days of December 1982 without interference. Thereafter, the Radio Nigeria Calabar station began test transmission and this station started interfering with the Rima Radio Station. Since the two stations were transmitting at the same frequency of 558 KHz, the only way of seperating the signals was before it goes into the receiver. A directional loop antenna provided with the field strength meter proved inadequate to do this because the line of sight propagation of both stations with respect to Zaria were almost parallel. Lack of a sophisticated antenna made it impossible to seperate the two signals. The field strength recordings from December 10, 1982 till the end

of June 1983 were made up of Rima Radio station during the day (ground wave signal) and both Rima Radio and Radio Nigeria Calabar stations at night. Since the phases of the signal on arrival could not be predicted, there was no way of knowing when the interference was constructive or destructive. Sound monitoring however showed that the Radio Nigeria Calabar station completely suppressed the Rima Radio signal most of the time. The Rima Radio signal was heard only briefly (not more than ten seconds) about every 3 minutes. Despite this, it was decided to normalise the received data only on the basis of the 25 KW transmitter of the Rima Radio station. The consequence of this is seen in a comparison of the Monthly hourly medians for November 1982 and December 1982 on pages 55 and 57. The extended period of missing data in the month of April 1983 (see table 4.2 on page 37) was due to temporary incapacitation caused by a bicycle accident while coming from the measuring hut at night. All other causes of missing data were power failure and equipment malfunctions.

3.4 RIMA RADIO AND F.R.C.N. CALABAR RADIO TRANSMITTERS

Rima Radio Sokoto has two transmitters each of 25 KW located at Shuni, near Sokoto. Only one of these two transmitters is in use. The other one is kept as standby in case of any breakdown . The primary area of

coverage is limited to Sokoto State. The closest town to the Kaduna - Sokoto border is Gusau, a distance of 160 km (straight line) from Shuni. The relative positions of Sokoto, Shuni, Zaria and Calabar can be seen in Figure 1.1 on page 7.

Radio Nigeria Calabar has a 50 KW transmitter and full broadcast started in March 1982. Calabar is a straight line distance of 690 km from Zaria.

The following assumption were made in the analysis:

(1) The transmitter power of Rima Radio station is constant and effective radiated power is 25 KW.

(2) Omnidirection antenna with a gain of unity is used.

(3) Receiver station (Zaria) is in the far field thereby neglecting aerial height effects.

The consequence of 1) above is that there will be an increased signal due to the FRCN Calabar station at night. Assuming a constant effective radiated power of 50 KW, the power increase can be taken into consideration. This will be further discussed in Chapter 5.

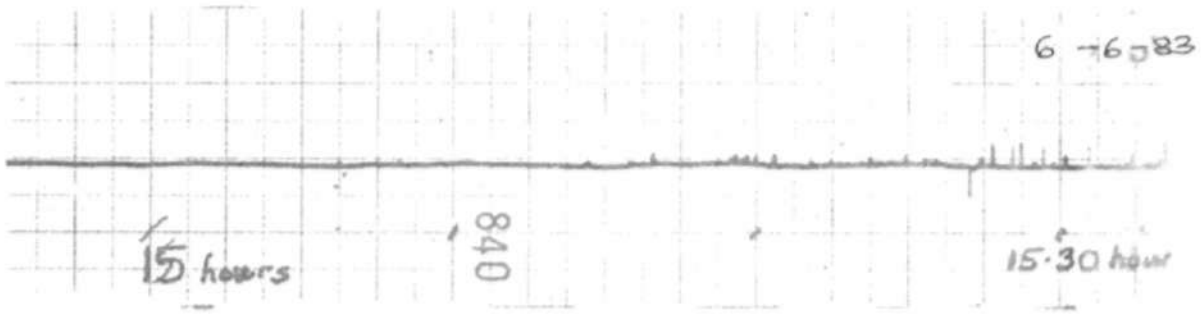
The expected signal of the Rima Radio station was estimated using the CCIR curves in Recommendation 368 - 2 of the XIIIth Plenary Session, Geneva 1974 Vol. 5. A ground conductivity of 3 mmho/m and permittivity of 4

were assumed. Assuming a flat earth, the signal for effective radiated power of 1 KW at the Sokoto - Kaduna border is 38 dB and for effective radiated power of 25 KW is 52 dB. This is 8 dB less than the 1 mV/m signal strength stipulated at the border of the primary coverage area of a transmitter. The signal strength of the Rima Radi station in Zaria is 23 dB.

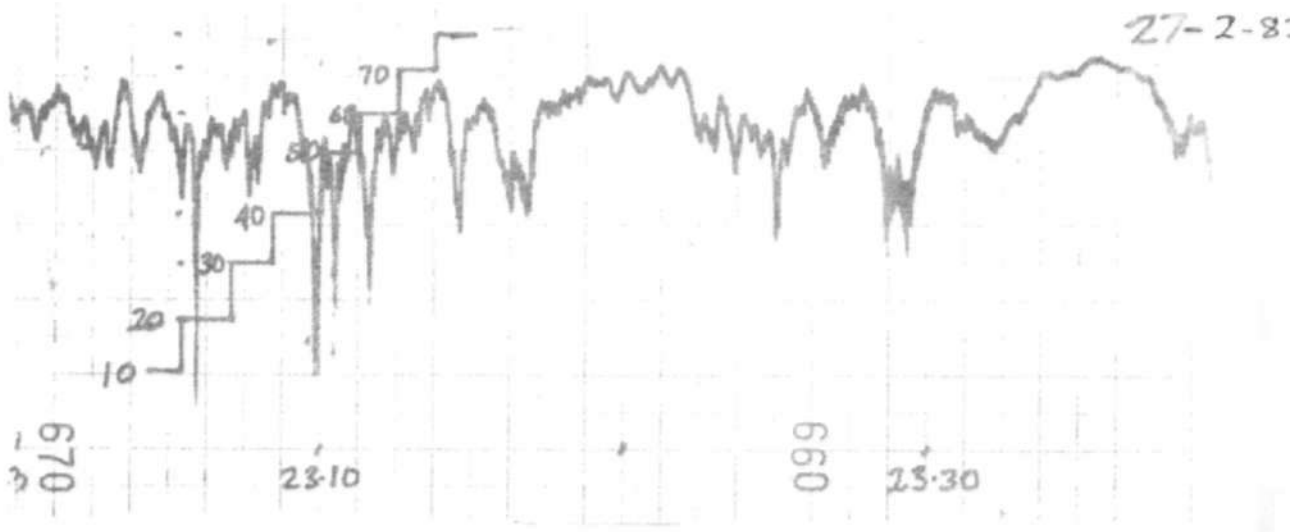
3.5 DATA CONVERSION FROM ANALOG TO DIGITAL FORM

The analog data sample is shown in Figure 3.2. It shows the chart recorder output at different periods of the day. This analog data needed to be digitized for computer analysis. To do this, a scale was constructed from the chart recorder staircase. A sample of this scale is shown in Figure 3.3. Each staircase was divided into 5 divisions which corresponds to 2 dB steps. This scale constructed on tracing paper was then placed on the chart recorder paper and signal levels read every 2 minutes. This corresponds to every 0.8 cm. This 2 minutes interval was considered sufficient for a close digital form of the analog data without loss of information and redundancy in the digitization. A close look at the sample readings verifies this.

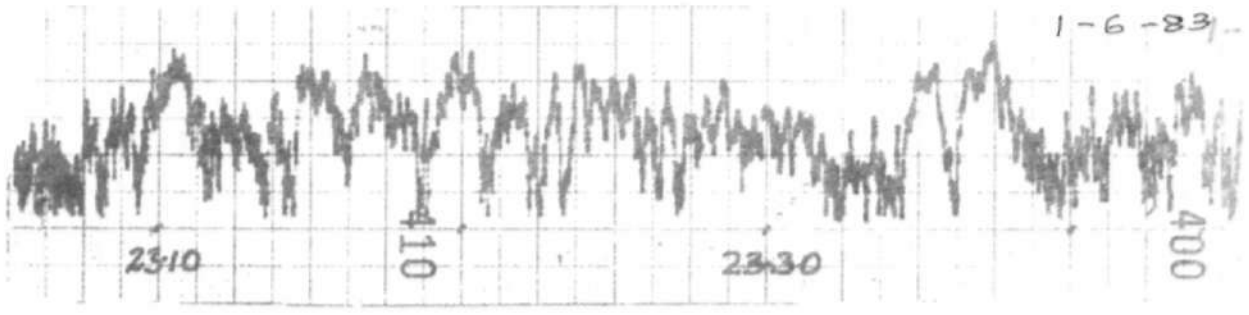
The middle value of the analog data was recorded. During the night the variation of the signal was such that the record of two values of signal levels were



(a) Recordings of signal variation on 6 June 1983 between 2.40 p.m. and 3.30 p.m. Constant level signal, typic of ground wave signals during the day.



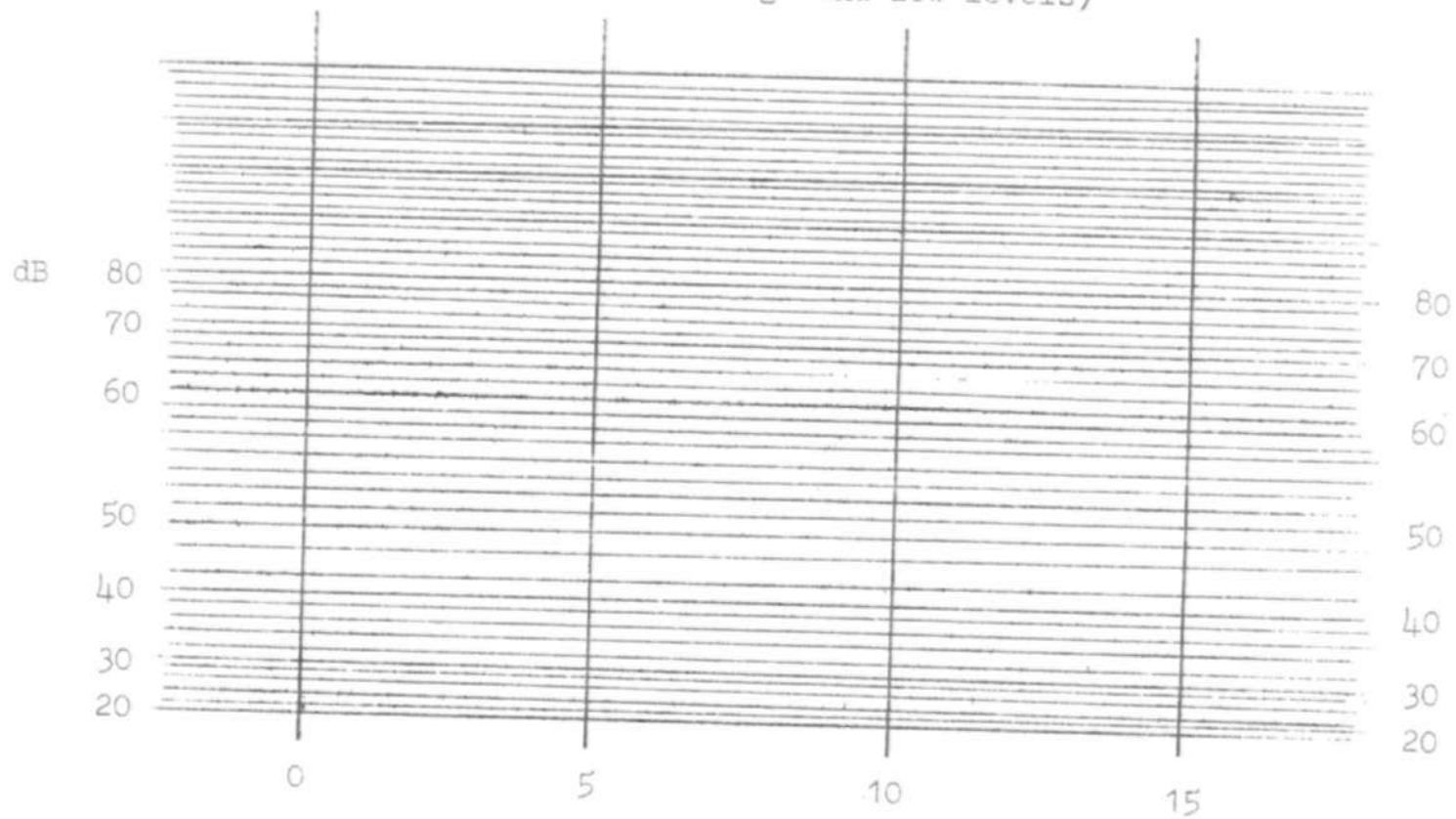
(b) Recordings of signal variation on 27 February, 1983 towards midnight. High level, slowly varying signal.



(c) Recording of signal variation on 1 June 1983. Low level signal with moderate variations.

Fig. 3.2: Recordings of received Signal Variation

Fig. 3.3 dB Scale
(Can be adjusted for high and low levels)



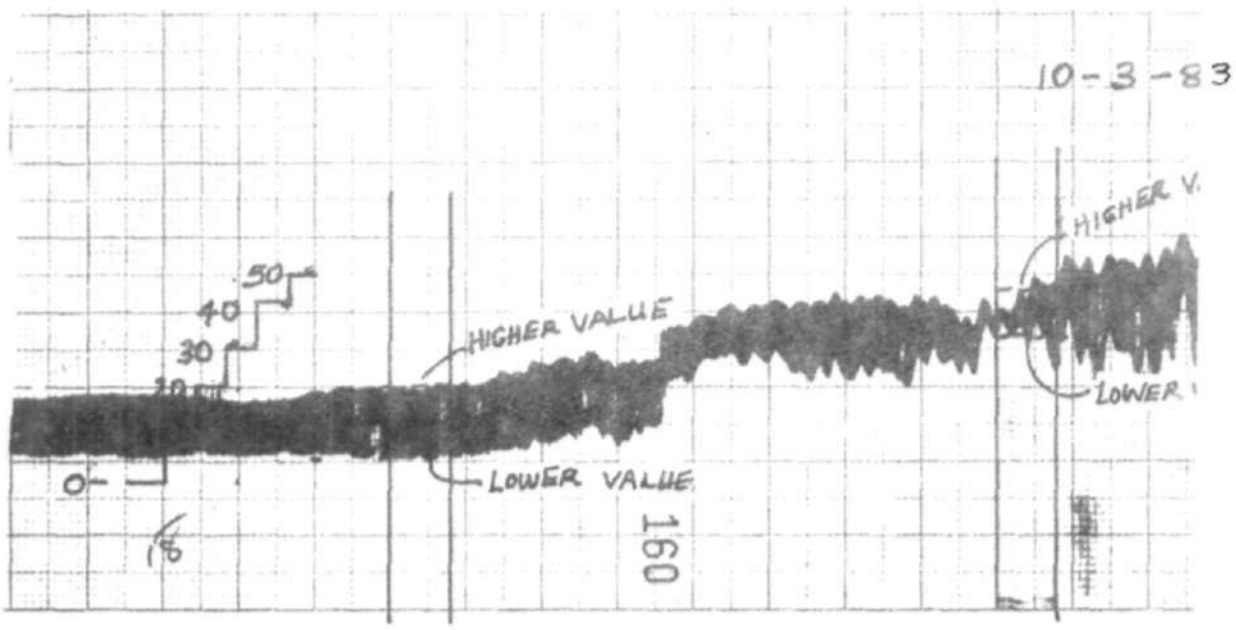
more accurate. The mean of these two values was then the median value of the signal within the two minutes interval. An example of this is illustrated in Figure 3.4. The evening period shows two levels of signal within the 0.8 cm (2 minute) interval. The mean of these two values is taken as the median level of signal within the interval. The data conversion from analog to digital form produced a maximum of 300 readings per day of measurement.

3.6 DATA COMPILATION

The data was fed into the computer in such a way that it could be read correctly in SPSS*. The computer programs and format can be found in Appendix 2. The data for any particular month was entered at the same time with days of the month as column and time of the day as rows. The two pairs of digits read from the analog output were entered side by side in 4 spaces and a space used to seperate data of different days. The matrix for any particular month contained 300 rows but the columns varied as the days of the month varied (31 days, 30 days or less). All data unavailable was recorded as 0.

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* SPSS - Statistical Package for the Social Sciences.



Signal level verification. Illustrates transcription of ana
data to digital form. The Lower and Higher Values of Re
can be seen.

Fig. 3.4

A Fortran program was then written called (program One). This program was used to standardize all the data. The mean of the pairs of numbers entered was found and converted to equivalent decibel levels assuming a 1 Kilowatt transmitter, The power of transmitter used is that of Rima Radio Sokoto which is 25 KW. The results were then written on a file called 'month input'. This file was used as input data for the SPSS programs written. After this procedure the data of any particular month was then in a standard form suitable for analysis.

CHAPTER FOUR

ANALYSIS OF FIELD STRENGTH DATA

The more common analysis of computing the median values of the data was employed. This corresponds to the middle number of an orderly set of data. The median value is an actual value of one of the ordered set of numbers which makes it preferable to a mean value. Moreover, the median value is the number or level of signal exceeded 50% of the time or the 50th percentile. Whereas a sharp burst of the signal would considerably affect the mean value for any specified length of time, it is only if the duration is comparable with the time interval chosen that a median value will be affected. It is also known that design of Medium Wave Stations is based on annual medians. For the above enumerated advantages, the median values for various time intervals were evaluated.

The median values evaluated are as follows:

1. Monthly hourly medians from 2.00 p.m. to 12.00 m.n. for all the months.
2. Daily medians of signal level for all the days data was collected.
3. Monthly median for each month.

4. Seasonal and annual medians.

5. Daily hourly medians.

SPSS and Fortran programs (see appendix 2) were written in order to evaluate each of these medians.

4.1 Monthly hourly medians

This is the median of all the data for a particular hour of a certain month. For example, the data for a time period of one hour from 5.00 - 6.00 p.m. for a particular day of the month was added to those of other days of the same month for the same period of time. The median of such data is the median value of field strength signal from 5.00 p.m. - 6.00 p.m. for that month.

This was done for all the hours of measurement and for all the months. The result is tabulated in Table 4.1.

4.2 Daily medians

The daily median is the median value of all the data collected for a particular day of a given month. It must be noted that it is difficult to interprete the median of a particular day except by comparison with other days of the month. This is because of the interference of the chosen Rima Radio Station by the

TABLE 4.1

MONTHLY HOURLY MEDIANS OF SIGNAL LEVEL FOR JUNE 1982, NOVEMBER 1982 - JUNE 1983

Time (p.m.) \ Month	JUNE 1982	NOV. 1982	DEC. 1982	JAN. 1983	FEB. 1983	MAR. 1983	APR. 1983	MAY 1983	JUNE 1983
2.00 - 3.00	33.5	28.6	32.5	34.2	25.4	24.4	24.9	22.9	22.0
3.00 - 4.00	34.5	29.6	32.6	33.7	30.4	23.4	21.8	22.9	22.0
4.00 - 5.00	35.0	29.5	32.7	33.5	30.5	21.3	21.9	23.1	22.4
5.00 - 6.00	35.7	30.7	33.1	34.1	30.6	21.7	21.6	23.7	22.2
6.00 - 7.00	36.5	31.2	43.2	43.7	40.1	30.7	28.2	30.3	25.6
7.00 - 8.00	37.8	31.8	45.5	44.7	41.0	35.8	33.8	37.9	34.3
8.00 - 9.00	39.6	32.2	47.4	46.6	40.2	35.6	33.0	39.3	36.1
9.00 - 10.00	41.3	33.4	48.4	49.4	45.0	36.3	35.1	39.3	36.6
10.00 - 11.00	43.6	36.8	42.3	44.0	43.0	36.5	25.3	39.0	36.0
11.00 - 12.00 (m.n.)	43.4	42.1	41.8	42.7	41.2	36.8	35.1	36.9	35.6

Radio Nigeria Calabar Station at night. Furthermore, the day signal was fairly constant for any particular day. It can therefore be seen that an increase or decrease in the number of hours the signal was recorded during the day would affect the daily median because the additional data would be single valued. However, a graph of the daily medians is still informative and will be discussed in greater detail in the next chapter.

Table 4.2 contains the daily medians for the whole period of measurement.

4.3 Monthly, Seasonal and Annual Medians

All the data of a particular month was arranged as a single set of data using a Fortran program called program Two. A single median value of this set of data was computed and called the median for that month or monthly median. This is the 50th percentile. Also the frequency distribution table of the set of data for a given month was plotted to give the cumulative frequency distribution from which any percentile can be found. This frequency distribution table is part of the output of the SPSS program run. This median value is very useful in the design of Medium Wave transmitter stations and will be discussed in greater detail in the next chapter.

TABLE 4.2

DAILY MEDIAN OF GLOBAL LEVEL IN AF ABOVE 1 kW/m

MONTH \ DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
OCT. 1982	37.4	35.9	33.4	27.6	39.	35.3	34.2	*	*	*	37.2	41.4	36.1	36.4	39.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
NOV. 1982	3.9	34.9	*	31.8	28.9	29.4	36.2	27.9	*	*	32.7	30.2	33.0	43.3	*	*	34.0	32.9	*	*	*	28.5	27.2	20.1	7.3	30.9	41.2	39.3	30.3	31.2	*
DEC. 1982	30.1	*	30.7	31.5	30.2	*	32.2	35.2	33.9	33.5	43.2	39.4	*	33.7	33.2	*	52.2	39.4	34.3	42.0	44.2	35.0	46.5	43.3	33.5	36.9	40.8	40.2	38.2	37.4	36.0
JAN. 1983	33.2	*	42.9	*	46.4	36.1	46.3	35.4	36.7	*	42.3	34.9	*	38.4	25.9	49.7	*	*	40.6	39.9	33.3	39.8	32.5	31.5	*	37.6	42.9	37.5	36.4	43.9	37.2
FEB. 1983	40.6	40.5	41.4	37.4	41.7	33.8	33.9	31.4	34.4	*	*	*	*	37.3	32.2	35.1	21.9	35.2	*	*	*	*	*	20.5	31.2	30.9	35.0	21.0	*	*	*
MAR. 1983	*	*	32.0	29.2	27.9	30.6	28.2	*	14.8	31.7	28.1	26.6	31.1	30.8	31.7	33.7	37.3	41.6	28.2	29.3	29.6	34.5	30.3	25.5	24.0	30.9	25.7	24.5	26.9	24.4	27.3
APR. 1983	28.4	34.6	30.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	31.0	27.7	24.3	*	34.3	7.4	7.0	34.0	16.5	31.9	*
MAY. 1983	*	*	21.3	41.9	34.0	31.4	25.0	34.7	31.9	37.9	25.9	21.3	*	41.9	33.8	35.4	32.6	39.5	32.1	36.0	36.9	33.3	40.2	30.9	30.7	32.0	26.8	*	*	38.0	26.7
JUNE 1983	27.7	31.5	34.6	29.8	25.7	25.2	27.4	29.0	*	*	29.8	36.1	24.7	29.5	28.0	30.1	32.9	36.1	*	*	*	*	*	*	*	*	*	43.9	33.7	*	*

* Missing Data

All the data from the months of November 1982 to April 1983 were appended and a single median value evaluated, called the dry season median. This is a season median. The same was done for the wet season months of June 1982 and May and June 1983 to get the wet season median.

In addition to the seasonal medians the data for the whole period of measurement was analysed to get a single median, the annual median. This result was also used to investigate the type of statistical distribution obeyed by the data collected. The results of these medians are contained in table 4.3.

4.4 Daily hourly medians

The daily hourly medians or daily signal variations can be said to be the most detailed result but not necessarily the most informative. Median values of a particular hour of a single day was evaluated. This was done for each of the hours of recording and for the whole days of measurement. In order to derive maximum information from these median values, a set of graphs were drawn showing the daily variation of signal level for a particular hour during a certain month. This was also compared with other hours of the month. This daily hourly median is very important to this analysis because

TABLE 4.3

MONTHLY, SEASONAL AND ANNUAL MEDIANS

	JUNE 1982	NOV. 1982	DEC. 1982	JAN. 1983	FEB. 1983	MAR. 1983	APR. 1983	MAY 1983	JUNE 1983	WET SEASON	DRY SEASON	ANNUAL
MEDIAN	36.4	31.1	35.0	37.4	35.2	30.1	27.6	32.7	29.7	31.4	33.6	33.8
No. OF DAYS MEASUREMENT WAS TAKEN	12	23	30	25	20	28	12	26	28	56	148	204

it seperates the data both on a daily basis and on an hourly basis. This is very desirable as it gives a lot of insight into the composition of the received signal. More importantly, the variation of the day signal can be studied seperately (This is the Rima Radio Station ground wave signal) from the night signal which is a mixture of both stations. The results of these graphs are discussed in chapter 5. Tables 4.4 to 4.12 contain the daily medians for each of the months recorded. These tables are contained in appendix 1.

Some further statistical analysis (mean, standard deviation) was performed on some of the evaluated medians to facilitate interpretation of results and to expose any trends in the data.

The results of the analysis carried out are contained in the tables in this chapter. The discussion of these results is contained in chapter 5. To facilitate ease of discussions and conclusions, the relevant graphs of the tables are included in chapter 5. Some of the graphs of the daily hourly medians are included with the tables in appendix 1.

CHAPTER FIVE

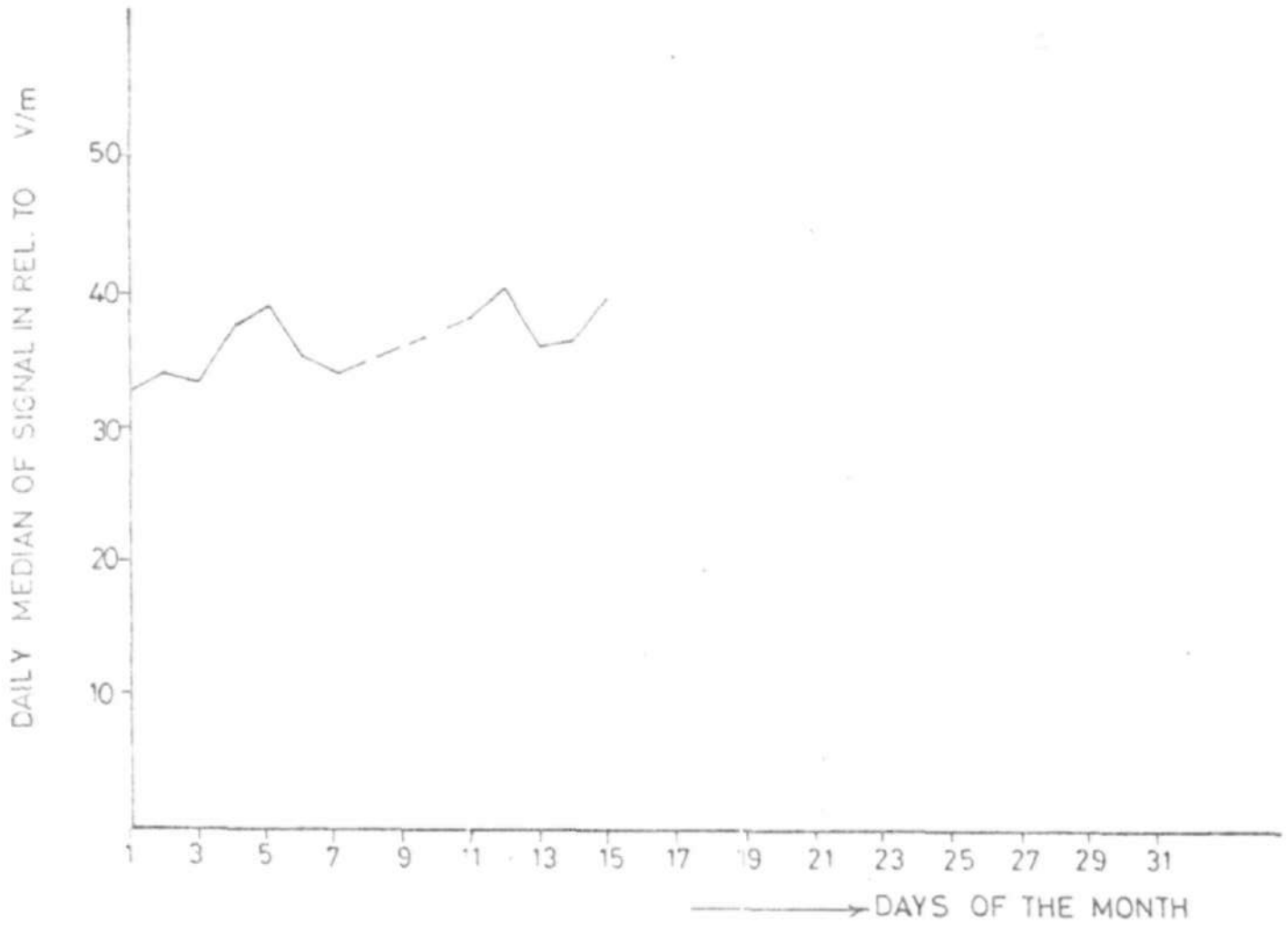
DISCUSSION OF RESULTS AND CONCLUSIONS

All graphs plotted from results of the data analysis are discussed in this chapter. As was stated in chapter four, various median values were evaluated and tabulated. The graphs of these tabulated data are shown in graphs 1 to 45. Some further statistical analysis was also compiled to expose any trends in the results. The result of the measurements was also analysed to see the type of distribution it obeys.

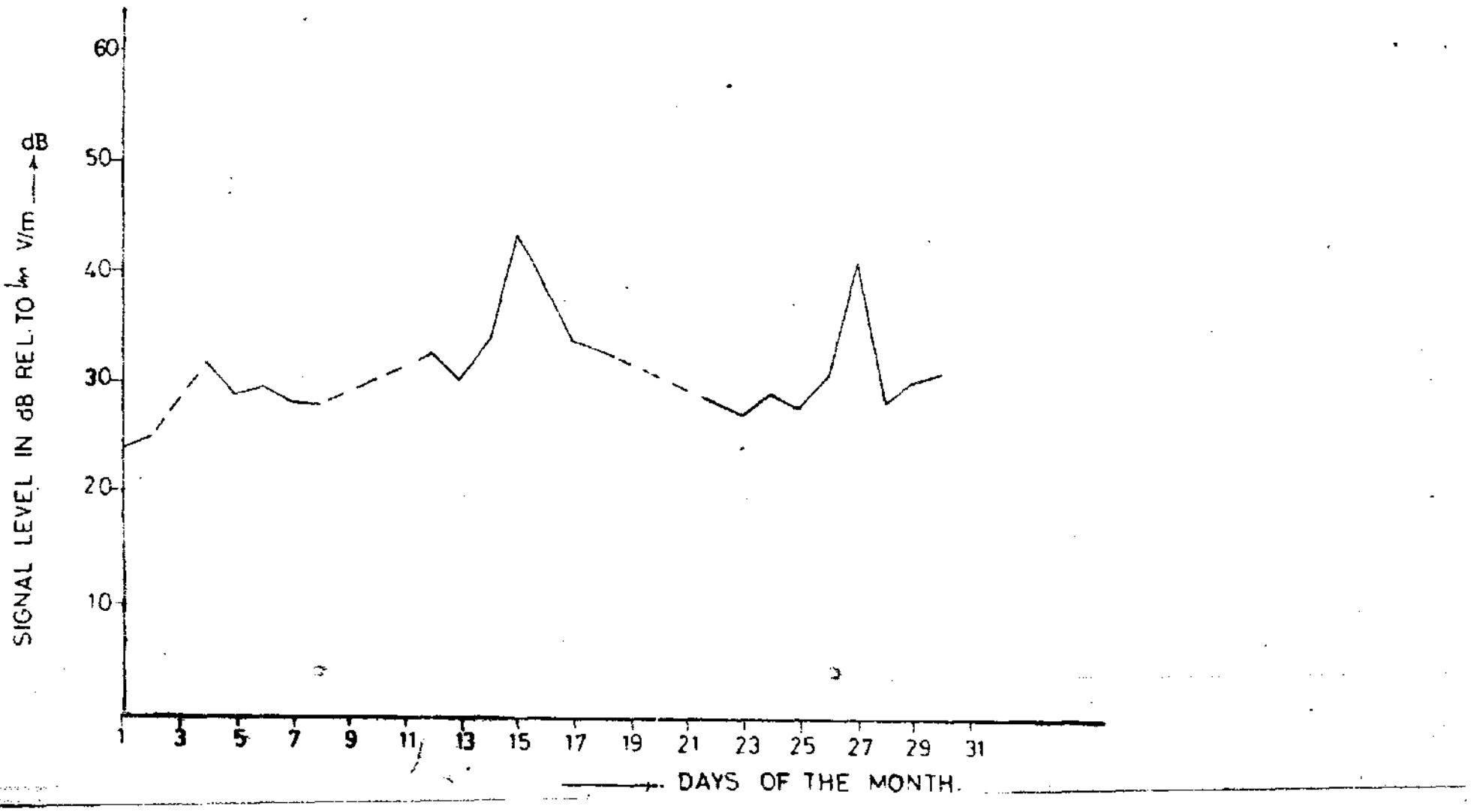
5.1 DAILY MEDIAN

Graphs 1 - 9 show the daily medians for all the months. The median of a particular day of the month was plotted as ordinate with the days of the month as abscissae. Graph 1 shows the daily medians of the month of June 1982. The minimum median level is 32.5 dB while the maximum is 40.5 dB. This is a range of 8 dB. A close look at the graph also shows that there is no sharp change in the median level of consecutive days. This is not the case with Graph 2 which shows the daily median variation for the month of November 1982. From Day 14 to Day 15, the level of the signal jumps from 34 dB to 43 dB, a difference of 9 dB. There is also a jump of the signal level from Day 26 to Day 27, from

GRAPH 1. DAILY MEDIAN OF SIGNAL LEVEL IN JUNE 1982



GRAPH 2. DAILY MEDIAN OF SIGNAL LEVEL for NOVEMBER 1982

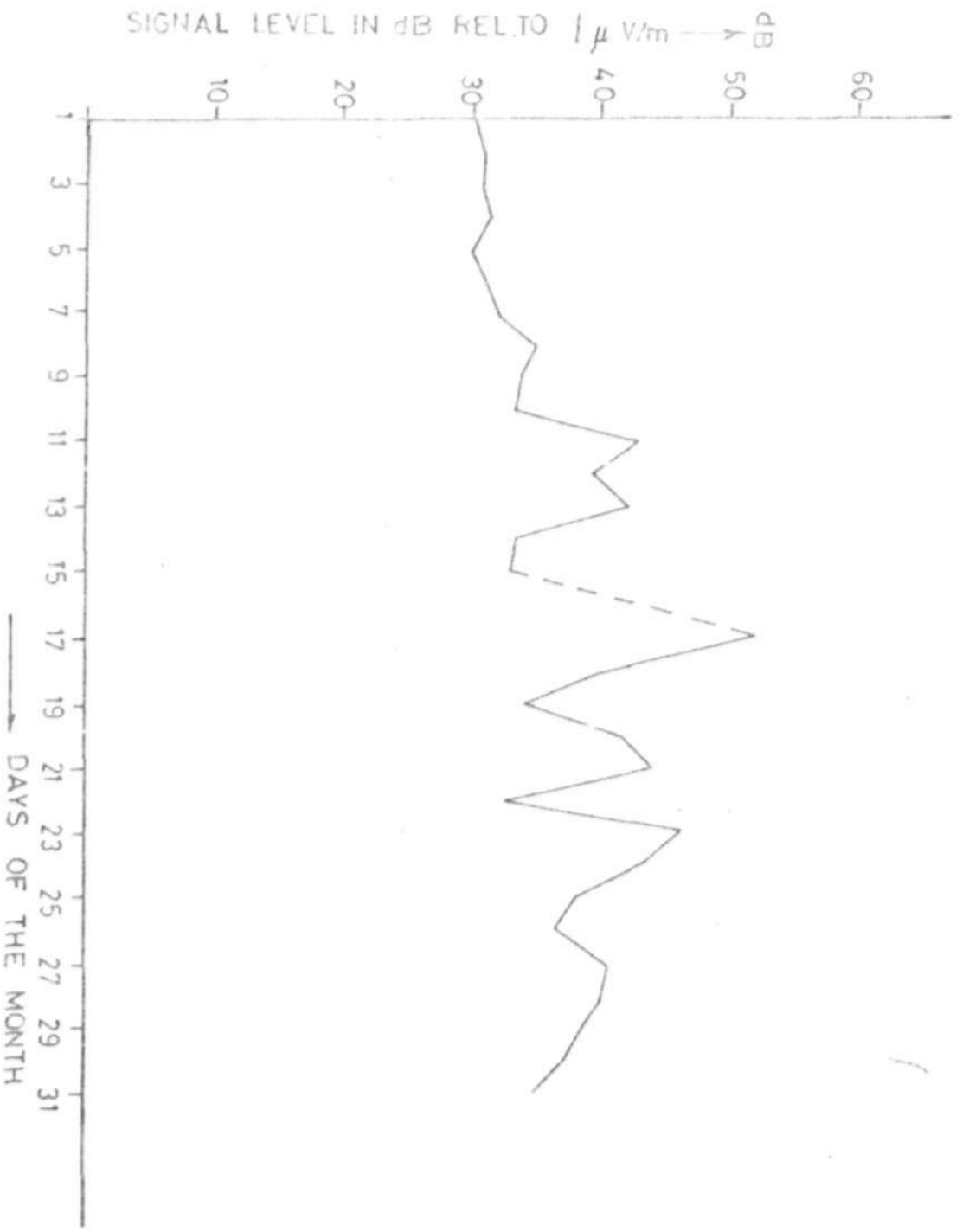


31 dB to 41 dB; a difference of 10 dB. This shows that although propagation conditions were fairly stable for the greater part of the time, some irregular behaviour was present.

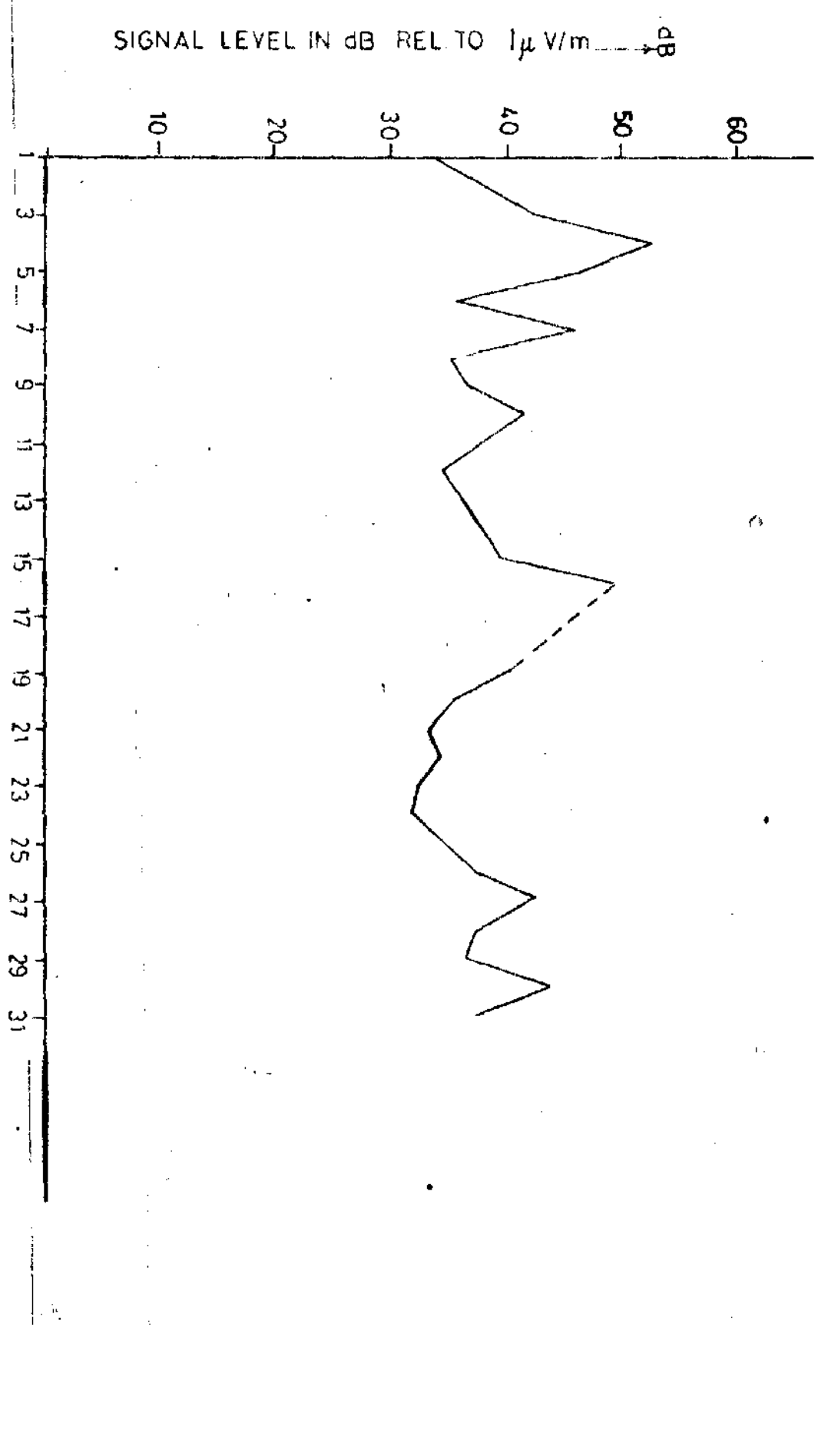
Whereas graphs 1 and 2 represent field strength data for only one station, the Rima Radio Sokoto station, Graph 3 shows the daily median variation for both Rima Radio and Radio Nigeria Calabar stations. From Day 10 to Day 11 there is a jump from 33.5 dB to 43 dB. This sharp rise makes the shape of the graph different from the shape of the graph before the 10th of the month. The mixing of the two signals was accountable for this. It can also be seen that the daily median levels are much more unpredictable with a range of 19 dB whereas for the first 10 days the range is only 5 dB.

Because of the different path lengths of the two signals, there is interference, especially at night. Since the ionosphere is not stable, the phase difference of these two signals will be varying continuously. There is also interference between the ground and sky waves of the Rima Radio Station. This gives rise to a very complex signal indeed. The large variations between daily medians are therefore due to both propagation conditions and destructive / constructive interference. The same trend was observed for all the succeeding

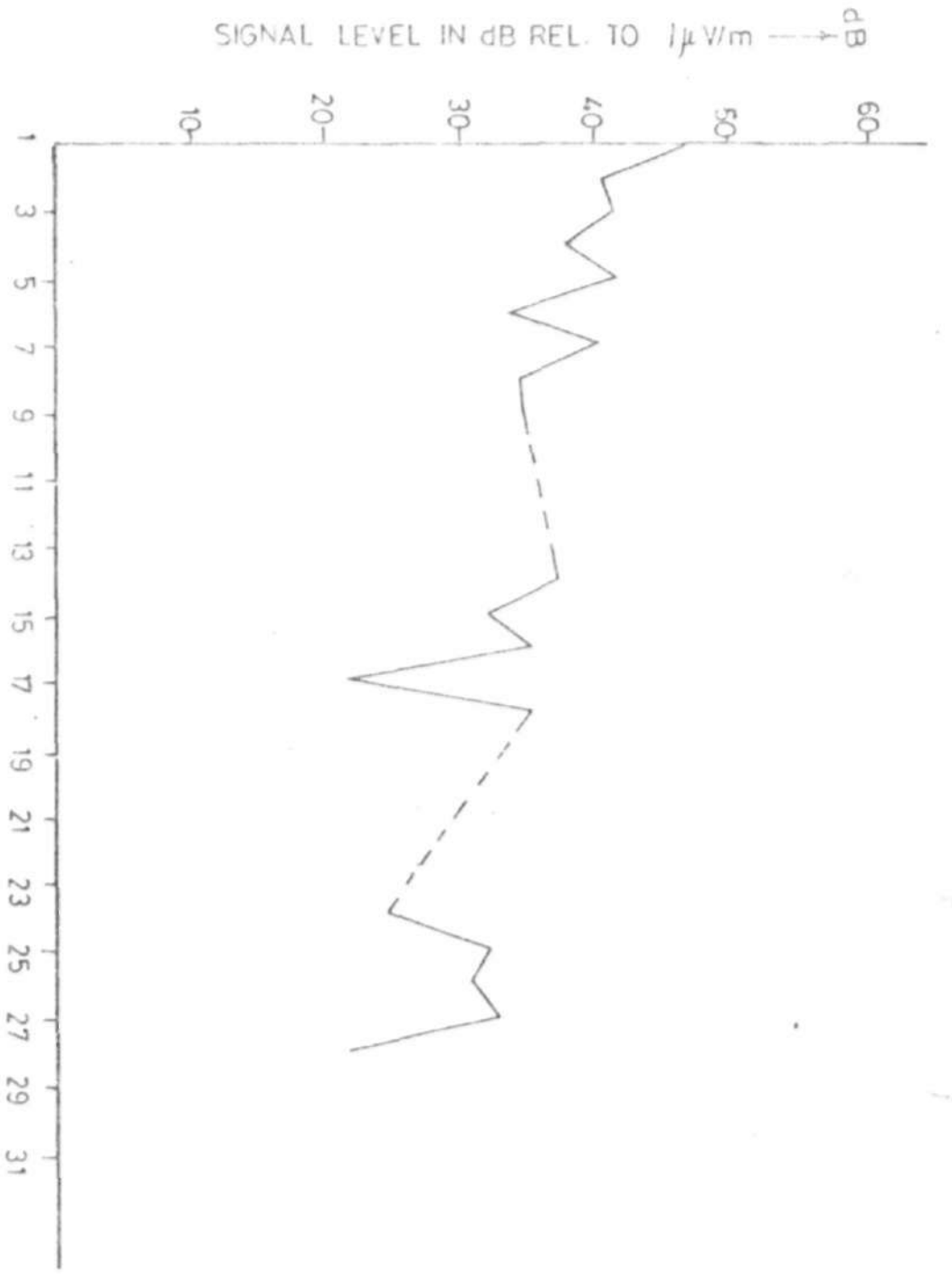
GRAPH 3. DAILY MEDIAN OF SIGNAL LEVEL FOR DECEMBER 1982



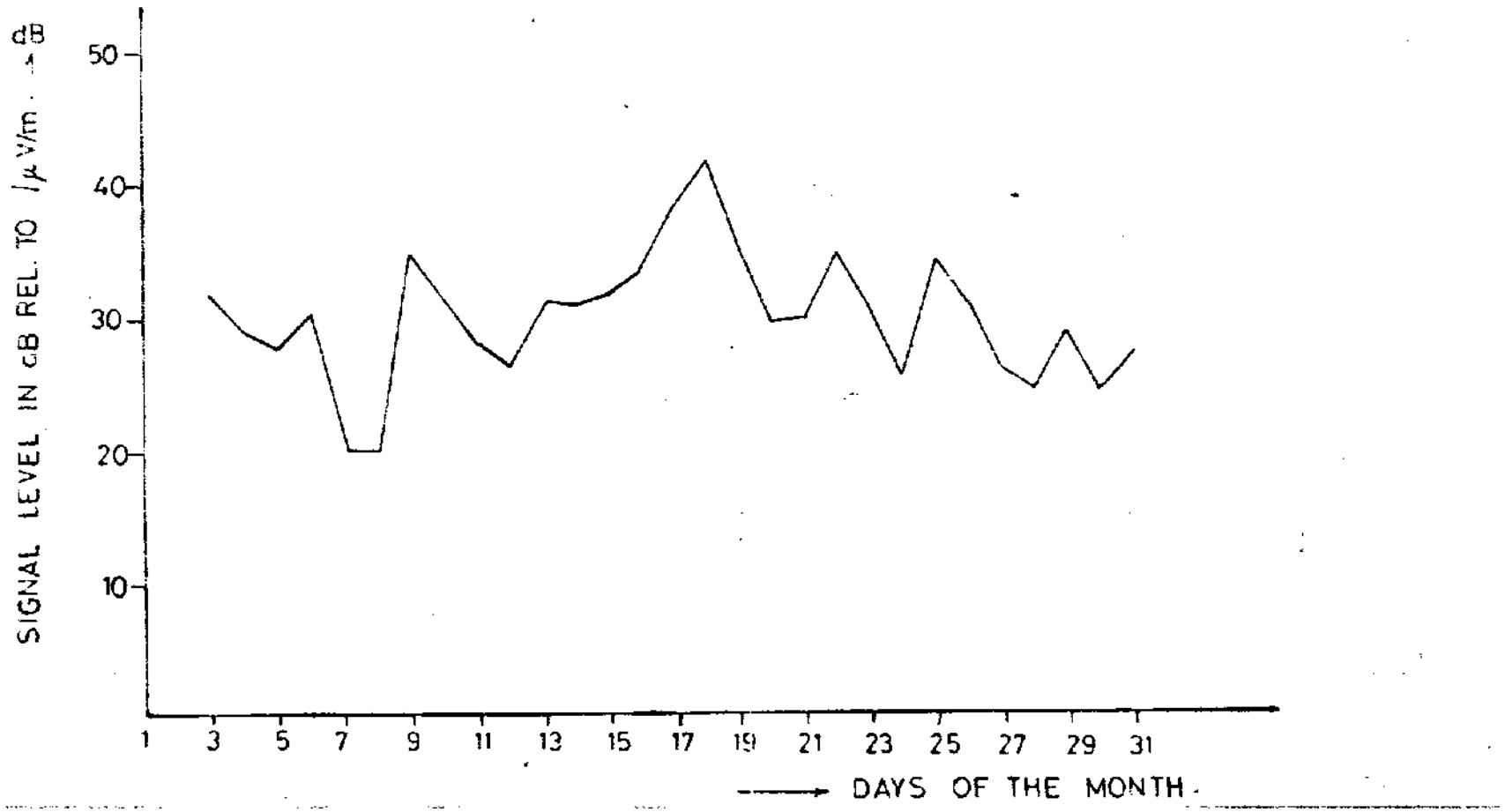
GRAPH 4. DAILY MEDIAN OF SIGNAL LEVEL FOR JANUARY 1983

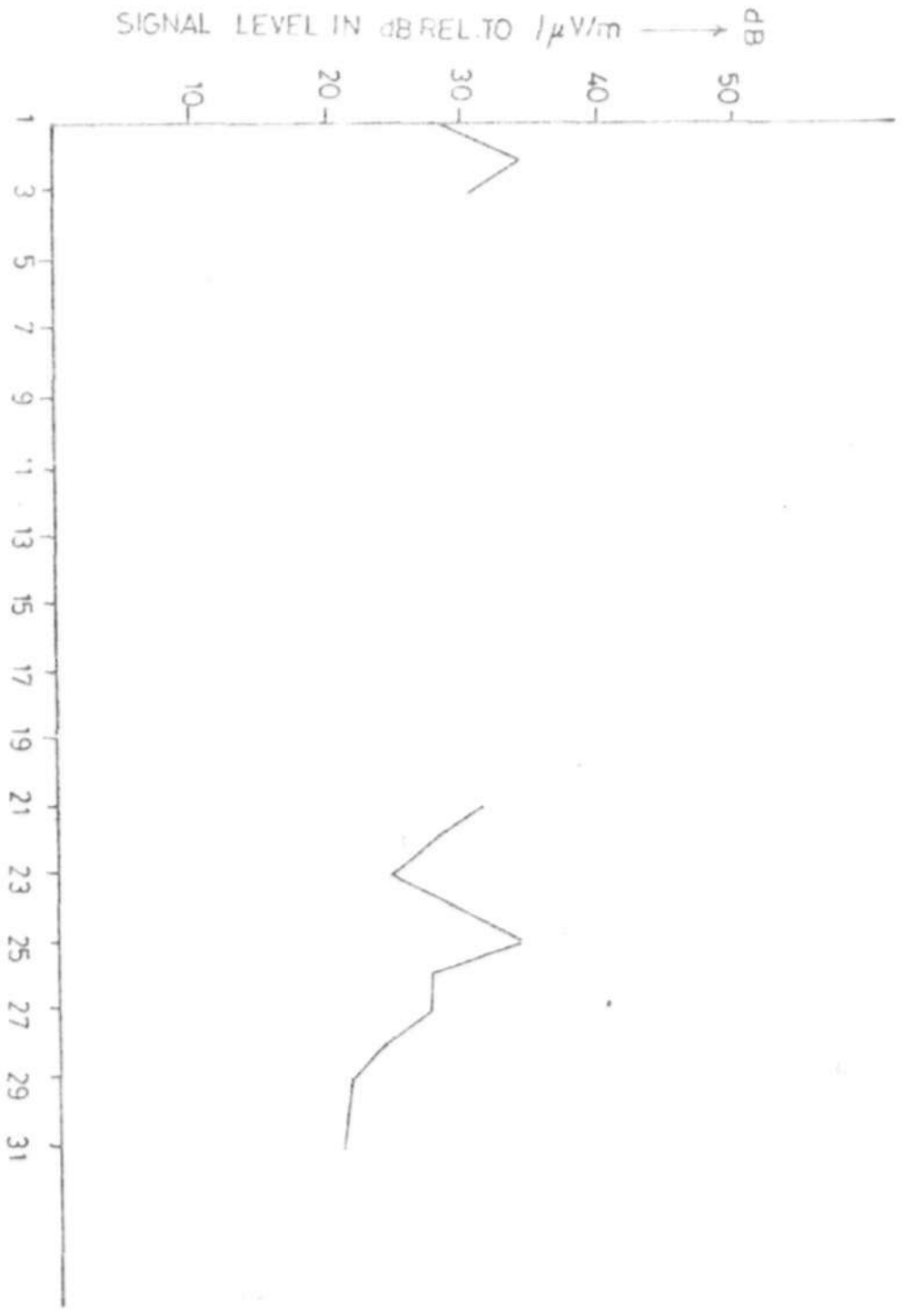


GRAPH 5. DAILY MEDIAN OF SIGNAL LEVEL FOR FEBRUARY 1983



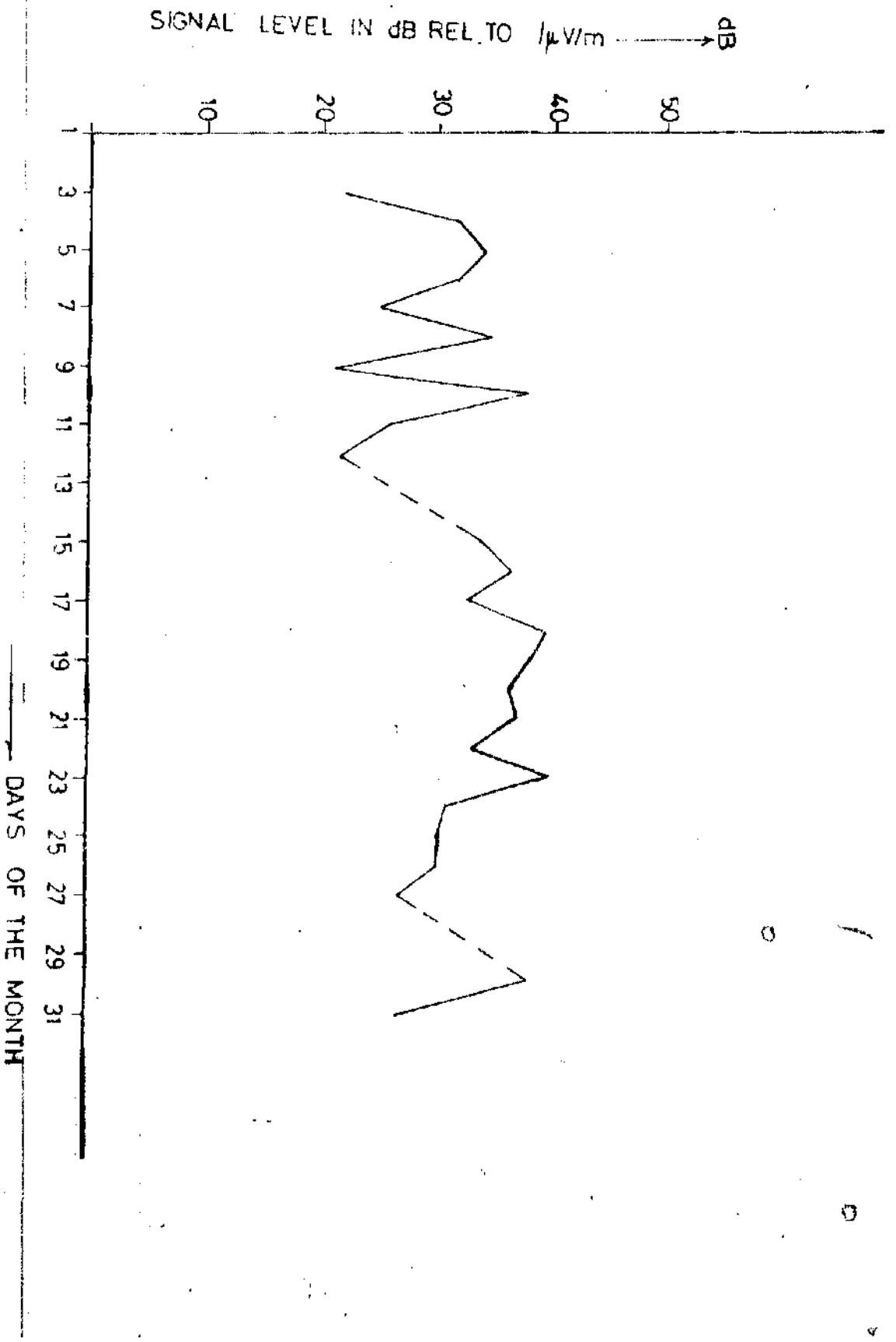
GRAPH 6. DAILY MEDIAN OF SIGNAL LEVEL FOR MARCH 1983



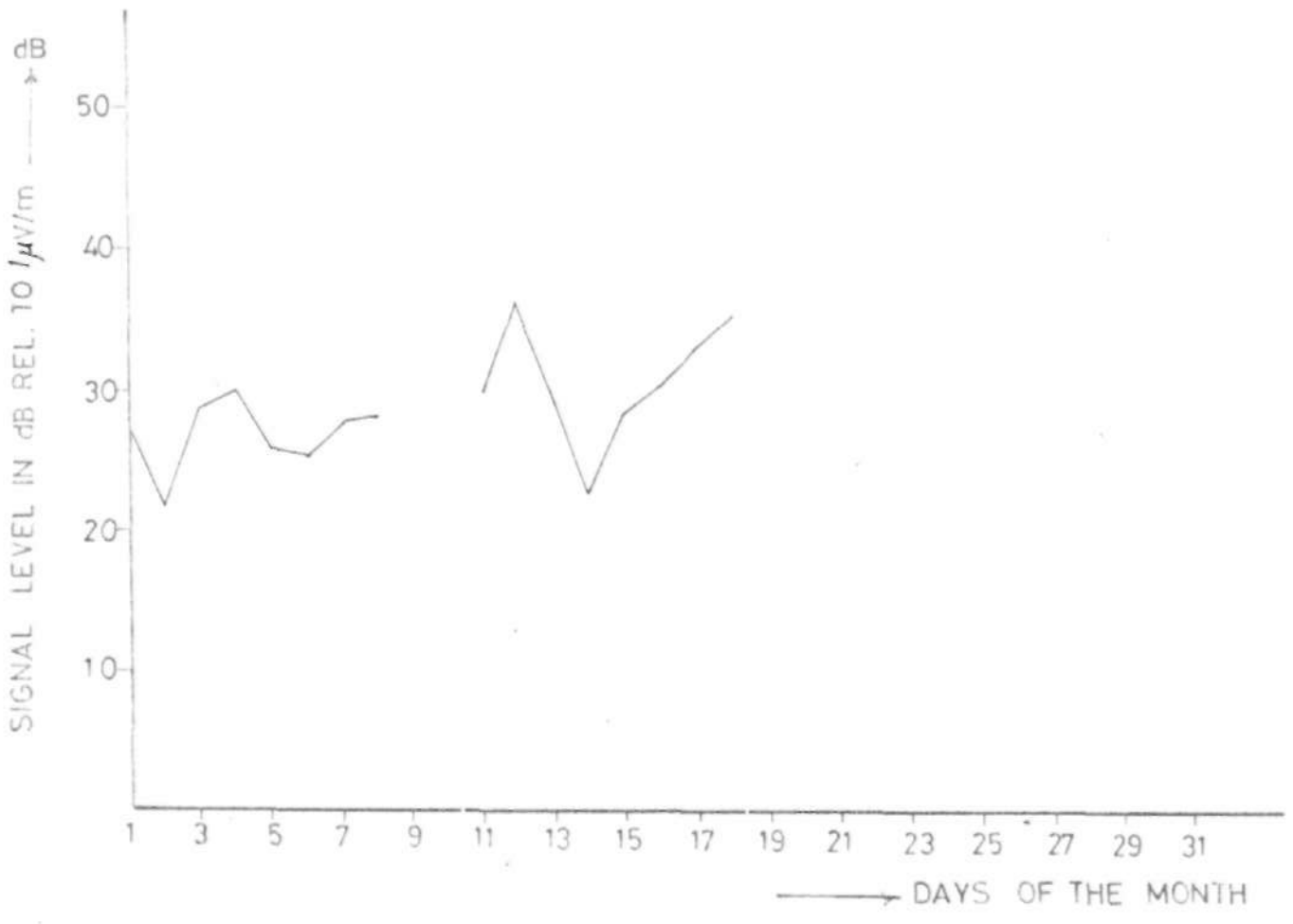


GRAPH 7. DAILY MEDIAN OF SIGNAL LEVEL FOR APRIL 1983

GRAPH 8. DAILY MEDIAN OF SIGNAL LEVEL FOR MAY 1983



GRAPH 9. DAILY MEDIAN OF SIGNAL LEVEL FOR JUNE 1983



months as can be seen from Graphs 4 - 9.

A comparison of the daily median variations for the months of June 1982 and June 1983 proves to be interesting. For the month of June 1983 (Graph 9) the signal varies from a minimum of 22 dB to a maximum of 38 dB giving a range of 16 dB. This is double or 100% greater than that of June 1982 when only one signal was present. Furthermore, both graphs show a gradual rise of 0.4 dB per day. The average signal level for June 1982 where only one signal existed is about 5 dB higher than that of June 1983. This may not be significant but the difference is consistent for the two months.

The above discussion leads to the following conclusions.

i. There is less correlation during the months of December 1982 to June 1983 than from June 1982 to December 1982. This may be due to the existence of two signals from different stations from December 1982 to June 1983.

ii. There is a gradual rise of the daily median signal in the month of June (0.4 dB/day). There is also a drop of about 0.6 dB/day consistently on the average in the month of February.

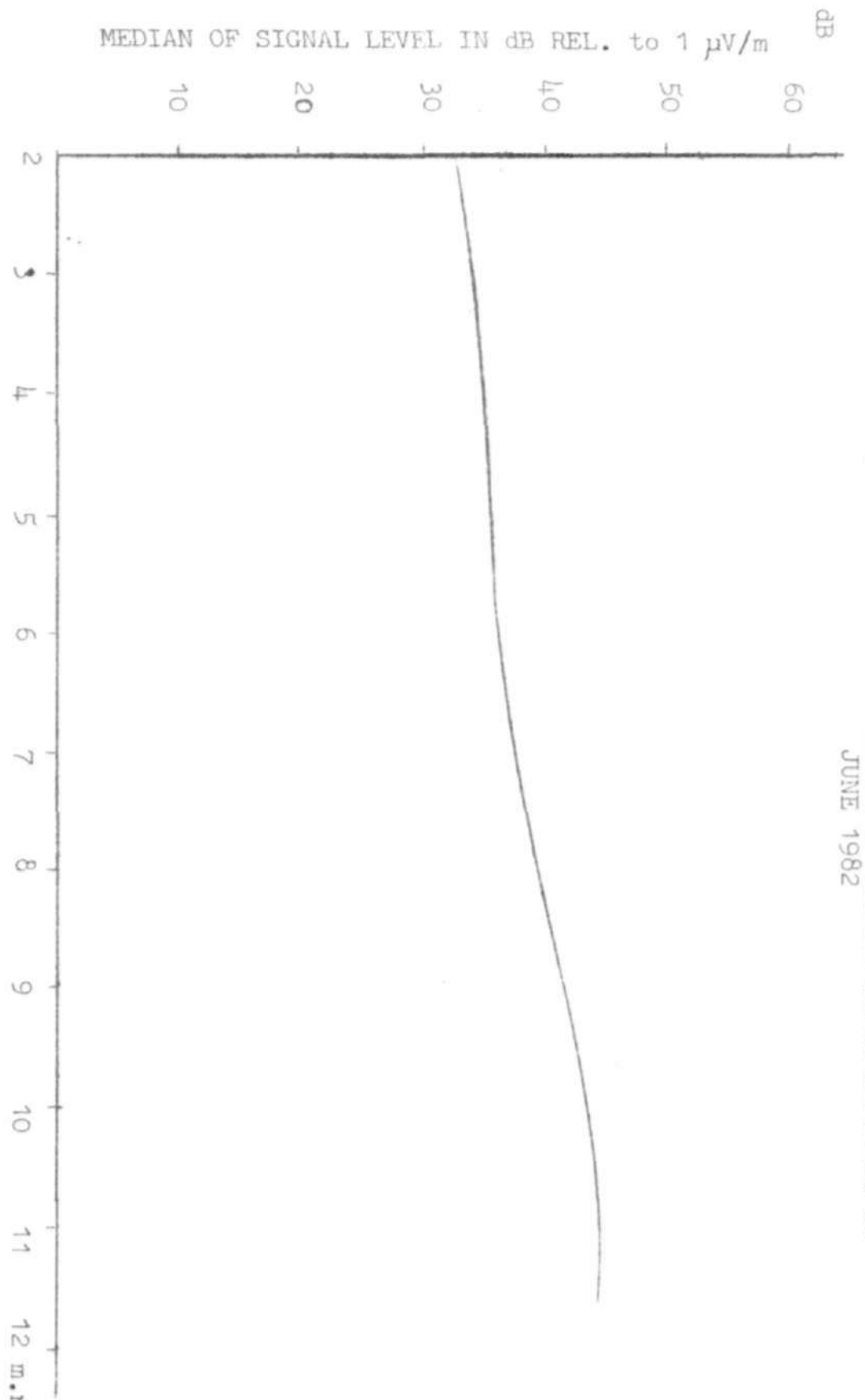
iii. There is no significant difference in the nature of the daily median signal levels for the period of measurement.

5.2 Monthly Hourly Median

Graphs 10 - 18 show the monthly hourly medians for the data collected. The graphs show the median of a particular hour (say 3.00 - 4.00) for a period of one month. The graphs show the median values as ordinate and time (hour) as abscissa.

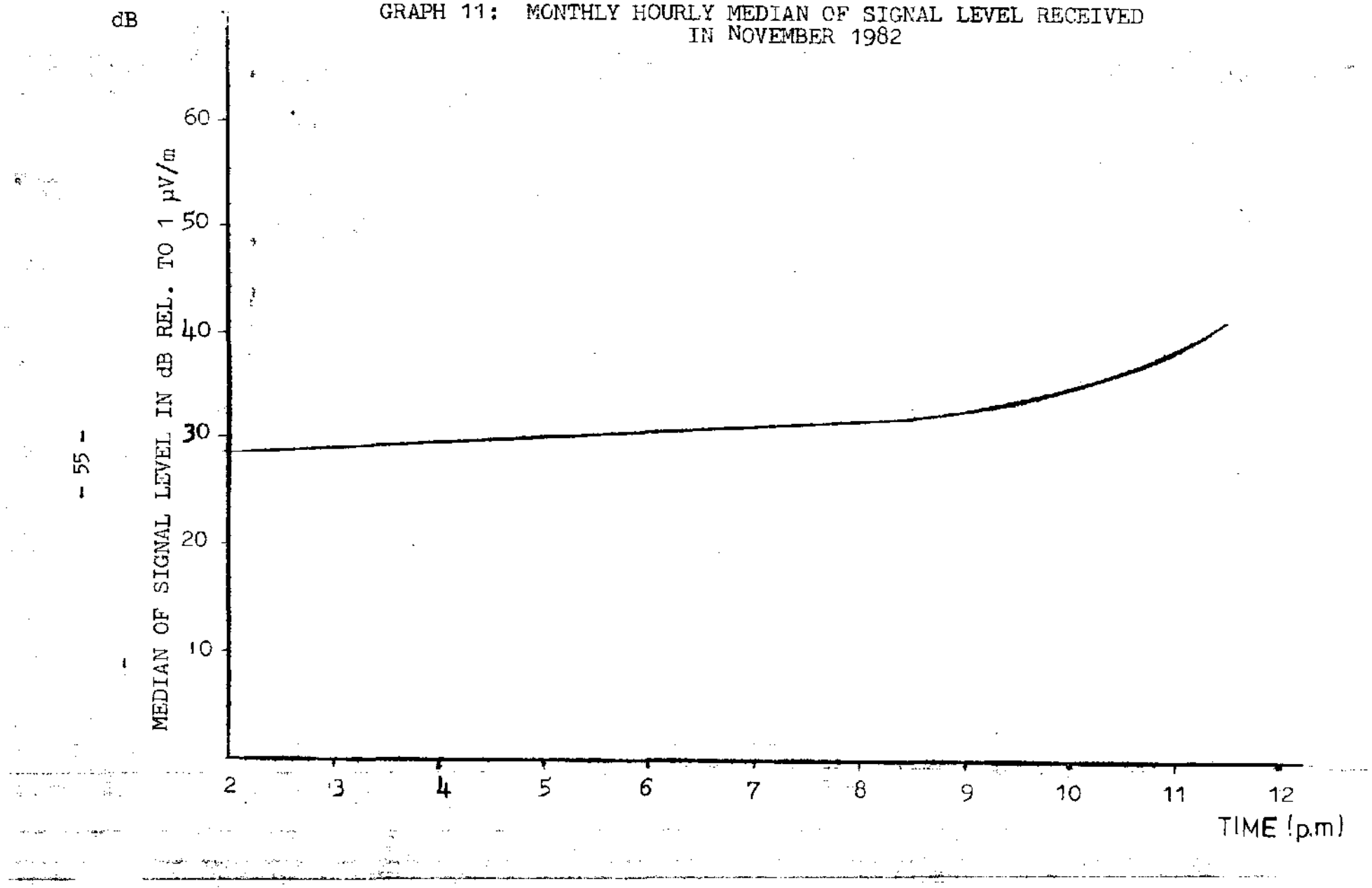
Graphs 10 and 11 show the hourly medians for the months of June 1982 and November 1982. During the day, there is a fairly steady signal level but towards sunset there is a gradual rise in the signal level. This rise continues towards midnight. For the month of June 1982 the rise rate is uniform at about 0.6 dB/hour and drops somewhat at about midnight. For the month of November 1982, the rise rate is not uniform and increases towards midnight. The total increase in the signal level from daytime to midnight was the same for both months. This value of 10 dB is significant.

Although the daily medians revealed the presence of an interfering signal and when it started (day of year) the hourly medians give a better insight into this. Graphs 12 - 18 show the hourly medians for the months of December 1982 to June 1983. The graphs have the same general shape. However, it is interesting to note a few points:



GRAPH 10: MONTHLY HOURLY MEDIAN OF SIGNAL LEVEL RECEIVED IN JUNE 1982

GRAPH 11: MONTHLY HOURLY MEDIAN OF SIGNAL LEVEL RECEIVED IN NOVEMBER 1982

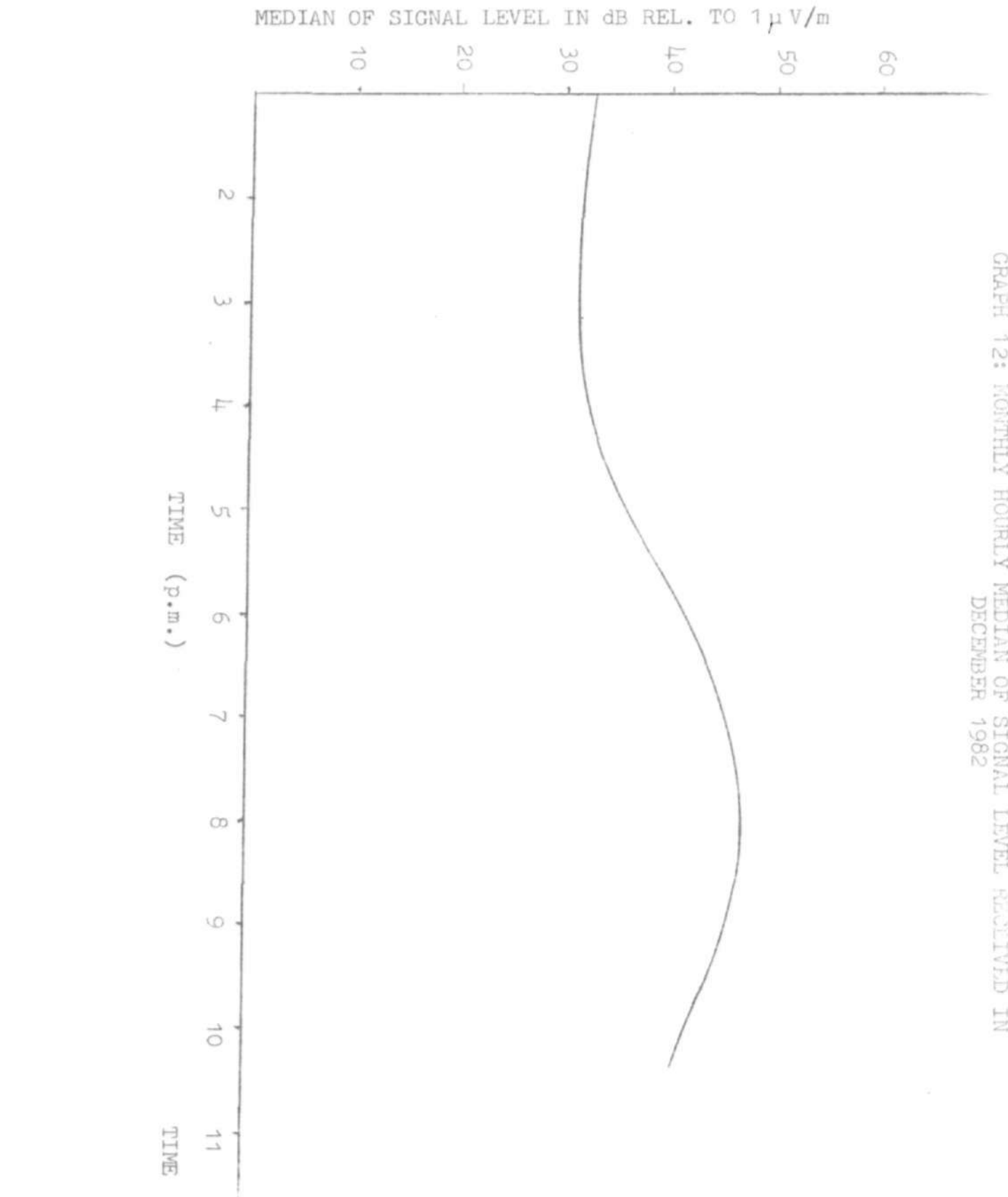


1. During the day when only the ground wave Rima Radio signal is present, the signal level is fairly constant at about 30 dB for the months of December to February and 23 dB from March to June. This is a difference of 7 dB on the average.

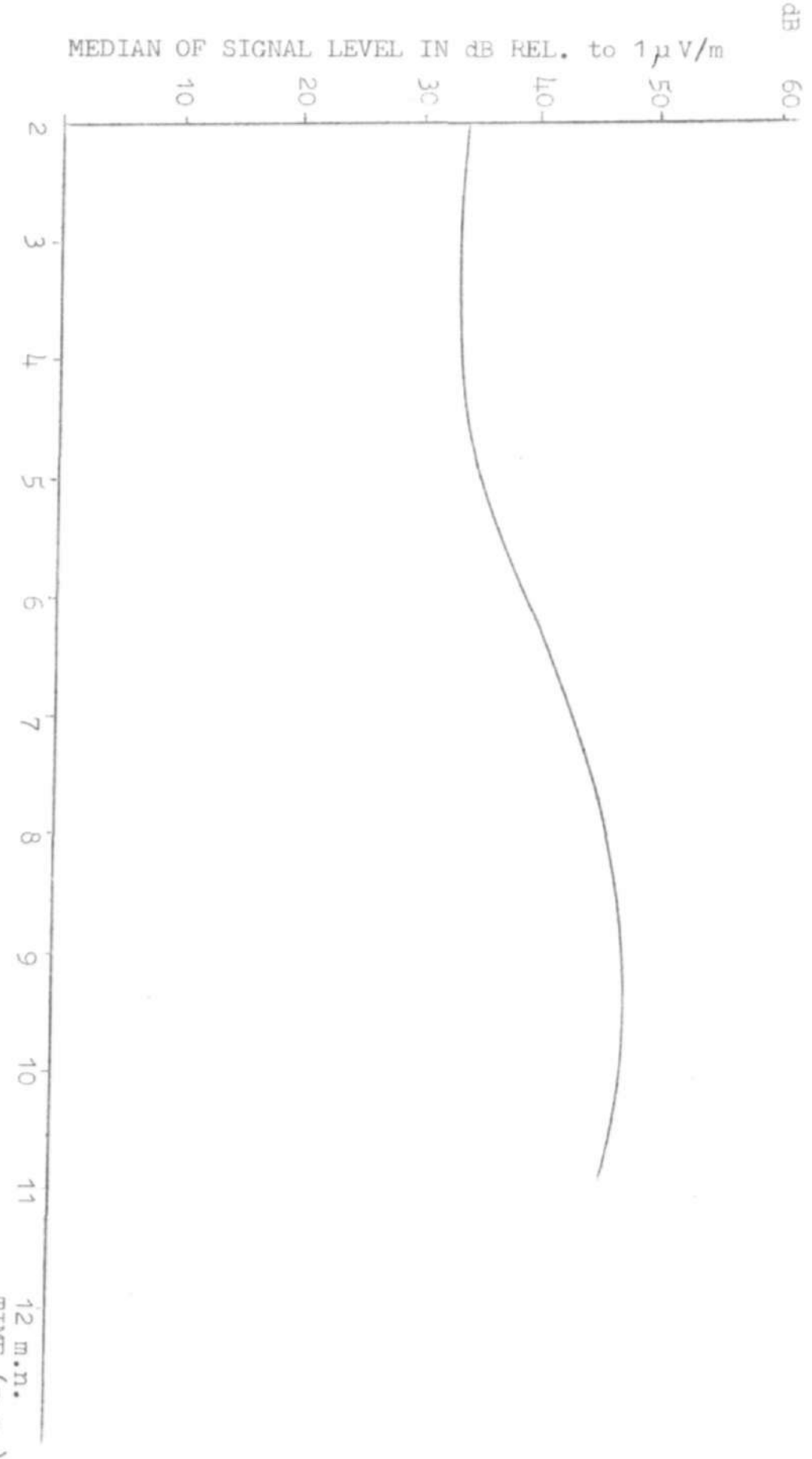
2. Towards sun set the level of the signal drops slightly (between 4.30 p.m. and 5.30 p.m.) and rises sharply thereafter till about 7.00 p.m. when the rise rate drops gradually.

This sudden increase of averagely 10 dB is due to the presence of the Radio Nigeria sky wave signal. Audio monitoring revealed that before 5.00 p.m. only the Rima Radio ground wave signal was present. However, from 5.00 p.m. to 7.00 p.m. the signal from Radio Nigeria Calabar station gradually increases until 7.00 p.m. when this is the only station audible. Thereafter, the Rima Radio station is heard intermittently. It seems, therefore, that for most of the time, there is only the sky wave signal of the Radio Nigeria Calabar station present at night.

In the months of December 1982 to June 1983, the signal level is constant between 8.00 p.m. and midnight, except for January 1983 and May 1983 when there is a drop in signal level towards midnight (11.00 p.m. to 12.00 p.m.) The shape of the monthly hourly medians for June 1982 and

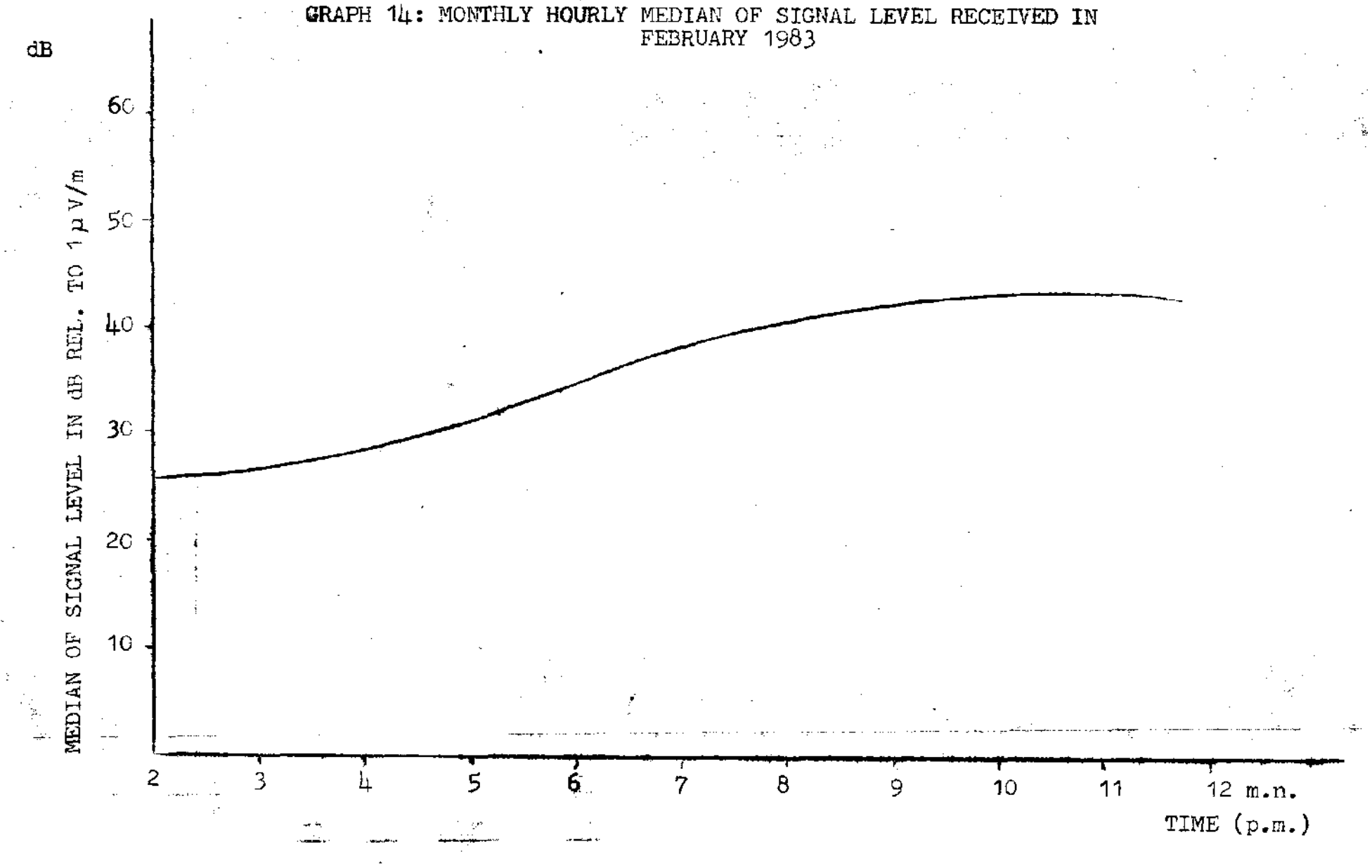


GRAPH 12: MONTHLY MEDIAN OF SIGNAL LEVEL RECEIVED IN DECEMBER 1982

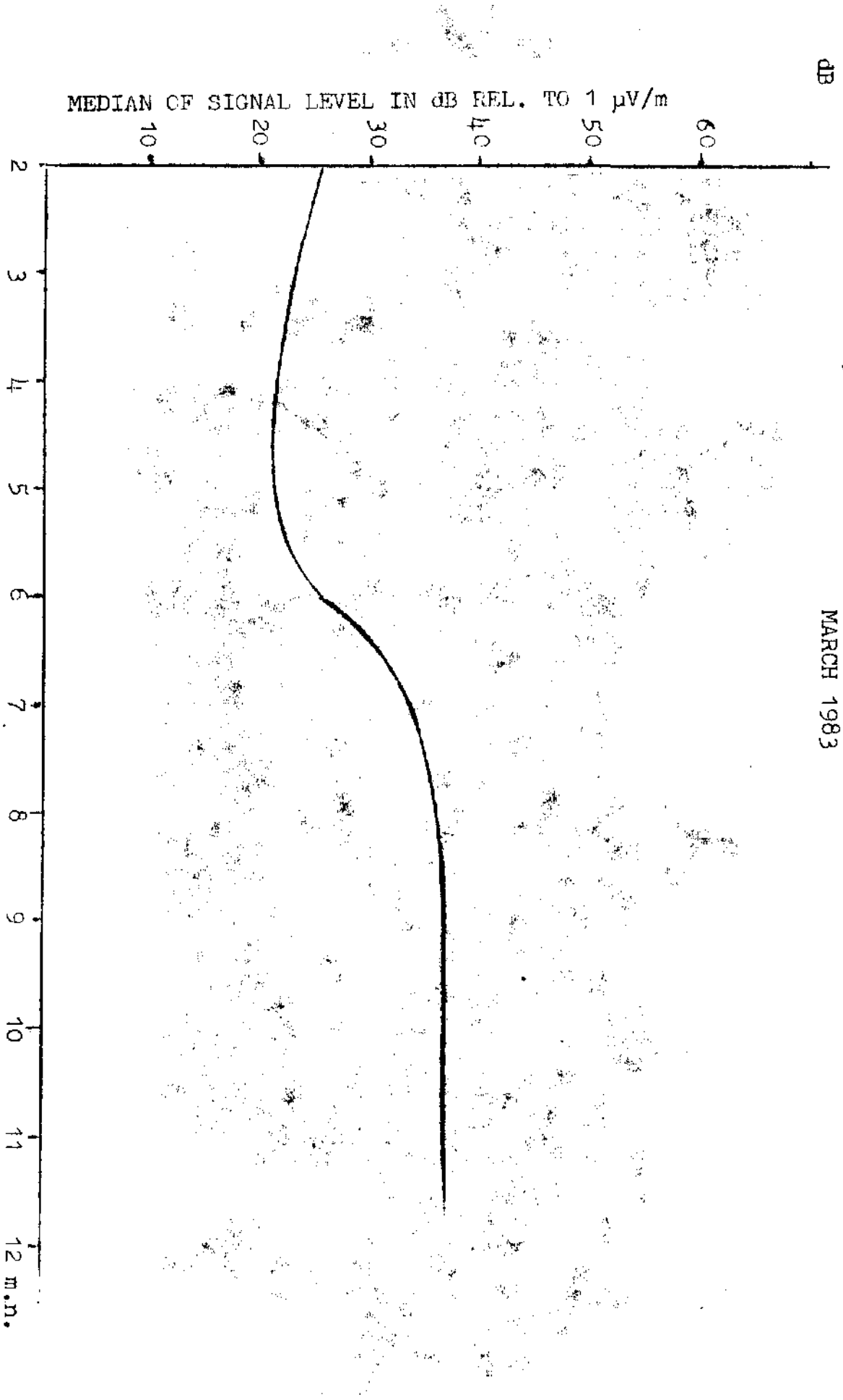


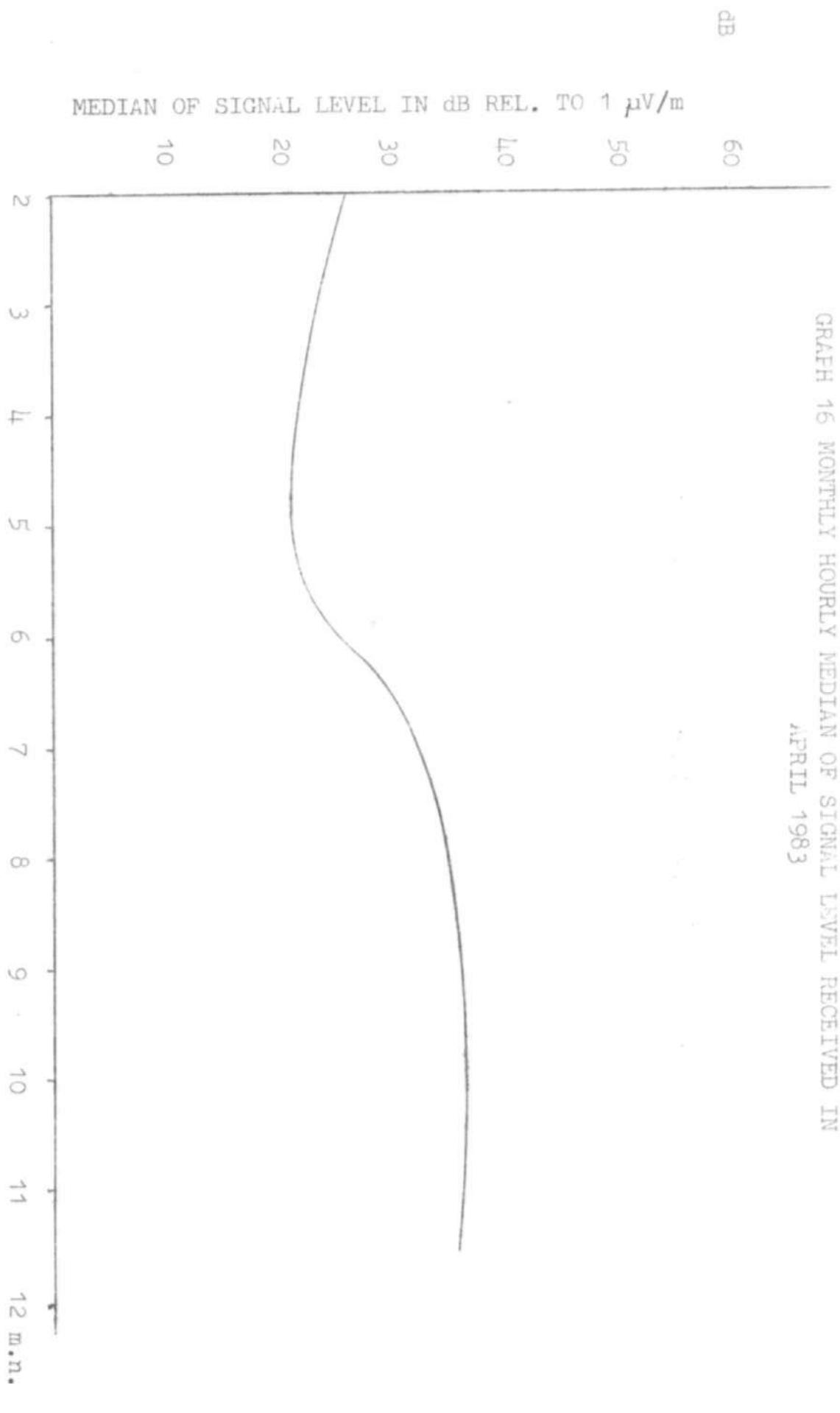
GRAPH 13: MONTHLY HOURLY MEDIAN OF SIGNAL LEVEL RECEIVED IN JANUARY 1983

GRAPH 14: MONTHLY HOURLY MEDIAN OF SIGNAL LEVEL RECEIVED IN FEBRUARY 1983



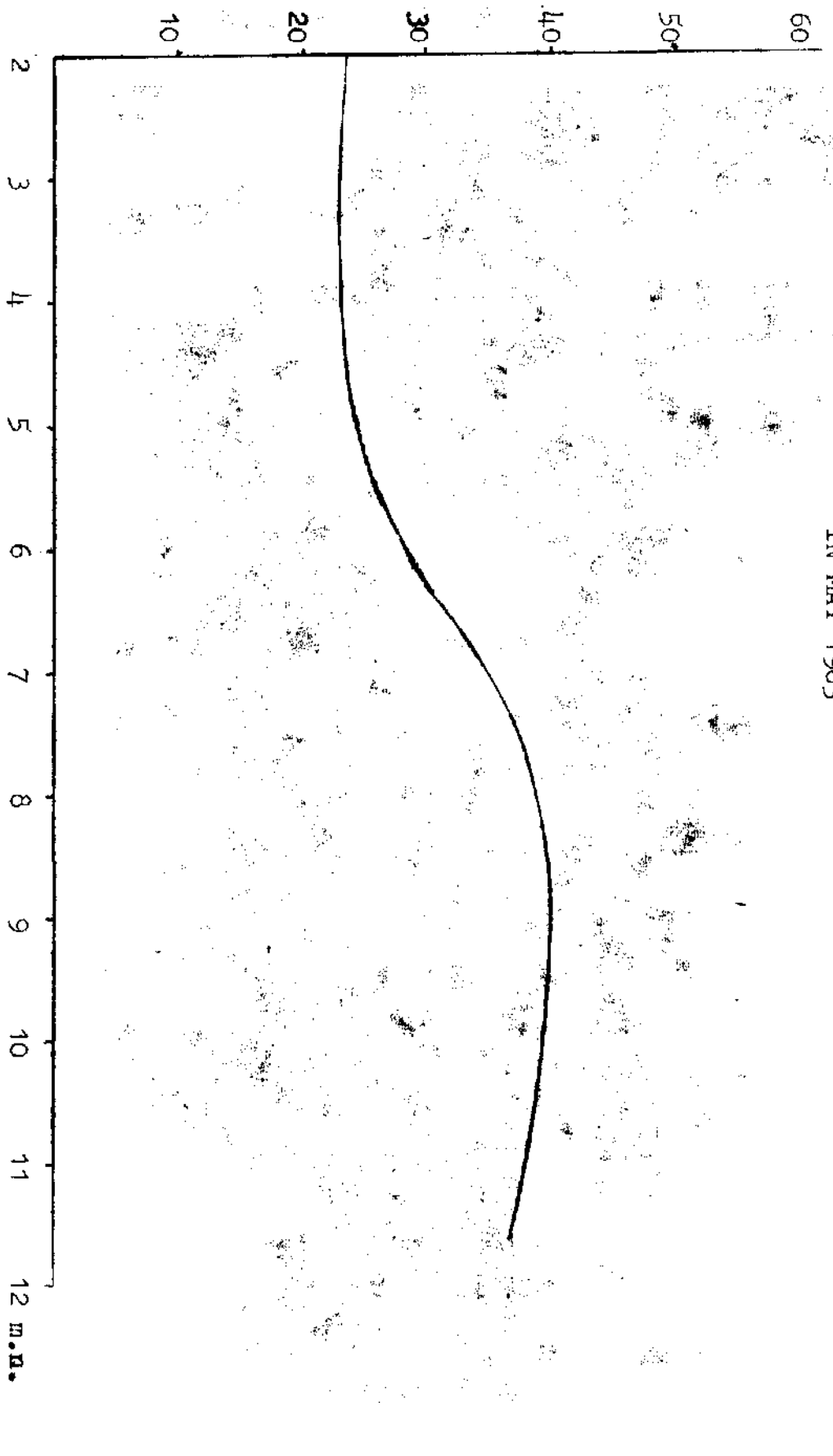
GRAPH 15: MONTHLY HOURLY MEDIAN OF SIGNAL LEVEL RECEIVED IN MARCH 1983



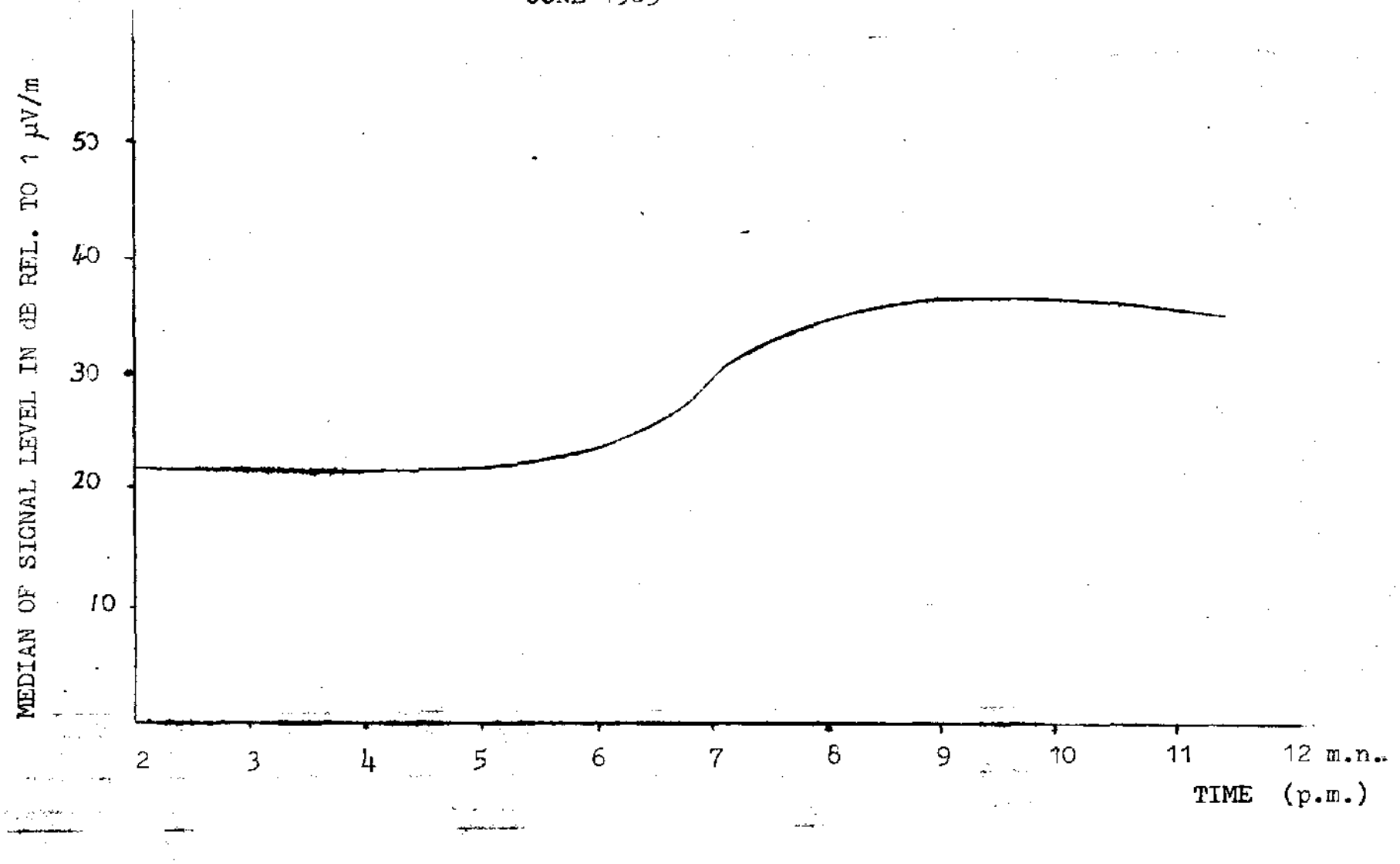


GRAPH 16 MONTHLY HOURLY MEDIAN OF SIGNAL LEVEL RECEIVED IN APRIL 1983

GRAPH 17 MONTHLY MEDIAN OF SIGNAL LEVEL RECEIVED IN MAY 1983



MONTHLY HOURLY MEDIAN OF SIGNAL LEVEL RECEIVED IN JUNE 1983



November 1982 is seen to be different from those above. The signal level actually rises appreciably within the same period (8.00 p.m. - midnight) by 5 dB in June 1982 and 7 dB in November.

A study of the monthly hourly medians as discussed above leads to the following conclusions:

1. During the day, only the ground wave signal is present. It is constant at a certain level during a particular month. This agrees with the theoretical predictions of Medium Wave signals.

2. At night, the sky wave becomes the dominant mode of propagation. This results in a rise of 10 dB on the average in the signal level from 7.00 p.m. to 12.00 m.n. This also agrees with theory; the depletion of the E layer which absorbs medium wave signals during the day is gradual towards sunset. Hence an increase in the signal level is expected towards midnight. If the extra power of 50 KW from the Radio Nigeria Calabar station is taken into account, there will still be an increase in signal level of at least 4 dB, assuming the signals add. This shows that the rise in signal level at night cannot be attributed only to the existence of a second signal.

3. The propagation conditions of a purely sky wave (transmitter over 600 km from receiver) is fairly stable during the night whereas a nearer station experiences greater signal level changes.

5.3 Daily Hourly Medians

The analysis of field strength data did not stop with monthly hourly medians. The hourly medians were also evaluated on a daily basis. These proved to be the most detailed of the medians evaluated. In order to utilise these results fully, the daily variation of signal levels was plotted for particular hours of the day. Three hour slots were plotted - 15 - 16 hours, 18 - 19 hours and 21 - 22 hours. These three slots are representative of the different propagating conditions as discussed in the last section. These were plotted as ordinate with the days of the month as abscissa. The results are contained in graphs 19 - 27. Some statistics of the computed results, namely, the mean and standard deviations of these hourly slot medians were also evaluated. The results of this computation are shown together in table 5.1. For ease of reference, it was decided to include these results together with the tables in appendix I. (See pages 96 - 123).

HOUR 15 - 16

This hour is typical of the propagation during the day. The power of transmitter of the Rima Radio station

TABLE 5.1

MEAN AND STANDARD DEVIATION OF DAILY VARIATION OF SIGNAL LEVEL FOR JUNE 1982 - JUNE 1983

MONTH	15 - 16		18 - 19		21 - 22	
	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$
JUNE '82	2.1	34.2	3.8	37.3	5.8	40.8
NOV '82	2.48	29.4	3.0	31.0	6.73	34.9
DEC '82	1.09	32.3	7.32	42.6	6.4	47.3
JAN '83	2.28	32.8	4.98	42.8	5.2	48.5
FEB '83	5.5	27.5	5.6	39.5	7.2	45.1
MAR '83	3.0	22.65	3.97	30.6	4.14	36.2
APR '83	1.35	21.5	2.89	27.6	3.15	35.1
MAY '83	2.2	23.2	4.3	30.7	4.0	39.3
JUNE '83	2.19	22.5	4.48	25.8	2.54	36.8

was constant at 25 KW. The mean of the signal level during this time slot for the period of measurement varied greatly. The dry season months of November to February show a higher mean of about 30 dB than that of March to June which has an average of 22 dB. There is a fairly high degree of correlation for all the months as shown from the table of standard deviations. The only month which is an exception is the month of February 1983 which has a standard deviation of 5.5 (table 5.1). The month of December 1982 has the least standard deviation of 1.09. This shows a very stable ground wave signal during the day in a typical dry season month.

HOUR 18 - 19

There is an obvious increase in scatter of the medians in this time slot when compared with that of 15 - 16. The highest occurs in December with a standard deviation of 7.32. This was the month when the interference from Radio Nigeria Calabar started. At the start of the interference on December 10, the signal level was measured and was found to be high as 75 dB at night whereas it was typically 50 dB prior to that. This accounts for the large disparity in the standard deviation between the two time slots. The other months show a slight increase in the standard deviation.

HOUR 21 - 22

This time slot is dominated by sky waves and in particular the Radio Nigeria Calabar station, over 600 km away. There was an increase in the standard deviation when compared with the 18 - 19 time slot except for the months of December and May where there was a slight drop. The results also reveal that the mean level of signal increases towards midnight as was indicated earlier. The month of February had the highest scatter with a standard deviation of 7.2 while the month of April 1983 had the least of 3.15.

From the above discussions, it is seen that the day time ground wave signal was fairly constant during the period of measurement.

A comparison of Graphs 19 and 20 with Graph 21 shows a sharp difference in shapes. Although there is on the average a rise from 3.00 p.m. to 10.00 p.m. during the month of December the rise is conspicuous. It is observed that the day time signal has a very high degree of correlation. During the night taking the later part of the month the signal varied between 40 dB and 55 dB a range of 15 dB. This range is typical for the dry season months. The month of May for example, (typical wet season month) has a range of 26 dB. There is seen to be an appreciable difference in range of variation of signal level at night.

The analysis leads to the following conclusions:

1. The day time ground wave signal has a high degree of correlation for all the months, especially the dry season months .

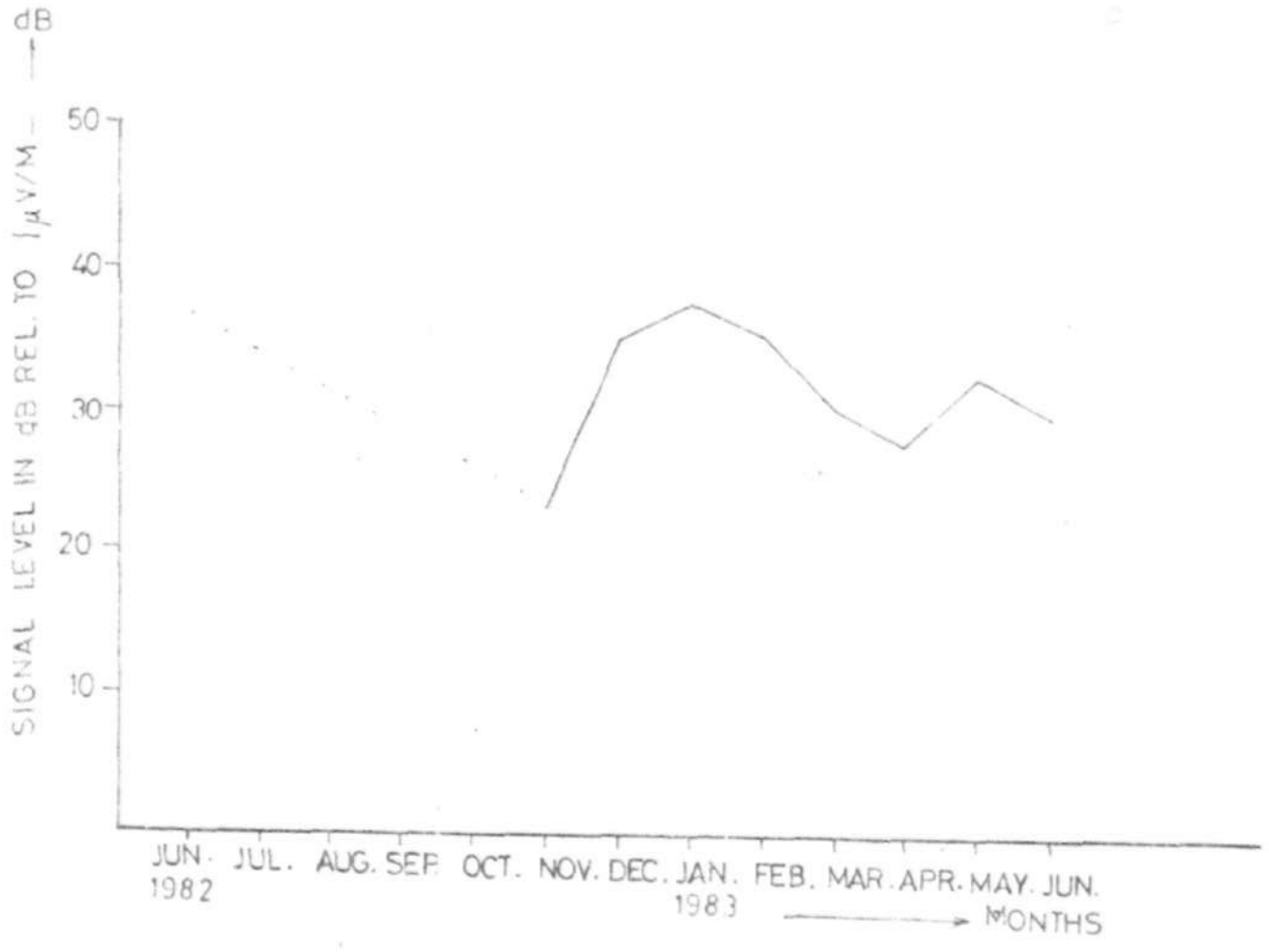
2. The instability of the ionosphere is greater during the wet season than during the dry season hence greater variation in the hourly median values especially at night. It is to be noted however, that the high range of 26 dB in May 1983 can also be due in part to interference caused by the existence of two signals.

5.4 DAY / NIGHT MEDIANS

In order to verify the conclusions arrived at from a study of the monthly hourly medians and daily hourly medians, another set of medians was computed. The period of measurement for a particular day was divided into two parts. One period from 2.00 p.m. to 6.00 p.m. to represent DAY median and from 6.00 p.m. to 12.00 midnight the NIGHT median.

The results are contained in graphs 28 - 36. The graphs reveal a high degree of correlation for the day time ground wave signal and a higher variation for the night time. The existence of two signals during the night makes it difficult to interpret . However, in the month of November

GRAPH 37. VARIATION OF MONTHLY MEDIANS
FOR THE PERIOD JUNE 1982 — JULY 1983



5.6 CUMULATIVE DISTRIBUTIONS

The analysis and discussions done so far are on the 50th percentile. This is the most informative of the percentiles but other percentiles are also useful. The cumulative distribution of the two minute medians was therefore computed for each of the months and also for the seasons. Graph 38-46 (pgs. 78-86) show the cumulative distribution with signal level relative to 1 $\mu V/m$ in dB as ordinate and percentiles as abscissa. Table 5.2 and Graph 47 contain the distribution for the whole period of measurement with signal level relative to annual median as ordinate and the percentile on a Gauss scale as abscissa.

Table 5.3 shows the cumulative distributions for all the months and also for the wet season, dry season and the whole period of measurement. Table 5.4 is a comparison of the results obtained during the nine months measurements were taken. The computed range, interquartile range and measure of scatter are included. A few things can be noted from Table 5.4.

1. The dry season months of December to February recorded the highest signal levels with the levels exceeding 60 dB 0.1, 0.6 and 0.8% of the time respectively.

2. The months of March to April recorded the lowest signal, the signal falling below 15 dB for 0.6, 0.2 and 0.7% of the time respectively.

TABLE 5.2

PROBABILITY DISTRIBUTION OF FIELD STRENGTH DATA

	% level was Exceeded	5	10	20	30	40	50	60	70	80	90	95	97	99
WET	Level in dB	45	42	39	36.5	34	31	27	24	22	21	20	19.5	18.5
	Level in dB rel. to Med.	14	11	8	5.5	3	0	-4	-7	-9	-10	-11	-11.5	- 12.5
DRY	Level in dB	51	48	42	38	35	33	32	30	28	27	20	19	18.0
	Level in dB rel. to Med.	18	15	9	5	2	0	-1	-3	-5	-10	-13	- 14	-15
ANNUAL	Level in dB	50	46	42	38	35.5	34.5	32	30	26	22	20.5	19.5	18.0
	Level in dB rel. to Med.	15.5	11.5	7.5	3.5	1	0	- 2.5	- 4.5	-8.5	-12.5	-15.0	-16.0	-17.5

TABLE 5.3

CUMULATIVE DISTRIBUTION OF THE TWO MINUTE MEDIANS OF SIGNAL LEVEL

SIGNAL LEVEL IN dB rel. to 1 μV/m	JUNE 1982	NOV. 1982	DEC. 1982	JAN 1983	FEB 1983	MAR 1983	APR 1983	MAY 1983	JUNE 1983	WET SEASON	DRY SEASON	ANNUAL
69												
68					0.0							
67				0.0	0.1							
66				0.1	0.2							
65				0.1	0.2							
64				0.1	0.3							
63	0.0		0.0	0.2	0.5							
62	0.0		0.0	0.3	0.6							
61	0.0		0.0	0.4	0.7							
60	0.0		0.1	0.6	0.8							
59	0.1		0.1	0.9	1.1						0.0	
58	0.1	0.0	0.5	1.2	1.5						1.0	
57	0.2	0.1	0.8	1.8	1.8						1.0	1
56	0.4	0.2	1.5	2.4	2.2				0.0		1.0	1
55	0.7	0.4	2.3	3.6	2.8				0.2		2.0	1
54	1.0	0.4	3.3	4.8	3.9	0.0	0.0	0.2			2	2
53	1.4	0.6	4.9	6.6	4.2	0.1	0.1	0.4	0.0		3	2
52	2.1	1.0	7.9	8.4	5.0	0.1	0.1	0.5	0.0	0.0	4	3

5

TABLE 5.3 (CONTD.)

SIGNAL LEVEL IN dB rel. to 1 μV/m	JUNE 1982	NOV. 1982	DEC. 1982	JAN. 1983	FEB. 1983	MAR. 1983	APR. 1983	MAY 1983	JUNE 1983	WET SEASON	DRY SEASON	ANNUAL
51	3.0	1.5	9.2	11.1	6.2	0.2	0.1	0.8	0.1	1.0	5	4
50	4.7	2.2	11.9	13.4	7.3	0.4	0.1	1.0	0.2	1.0	7	5
49	5.8	3.0	14.7	15.9	8.5	0.6	0.2	1.5	0.3	1.0	8	6
48	7.4	3.5	17.9	18.6	10.3	0.8	0.4	2.3	0.5	2.0	10	8
47	8.8	4.1	21.1	21.7	12.6	1.2	0.4	3.3	0.7	2.0	12	9
46	10.9	4.9	24.0	24.5	14.6	1.8	0.6	4.6	1.1	3.0	14	11
45	13.6	5.7	27.5	27.2	17.3	2.6	1.0	6.6	2.0	5.0	16	13
44	16.6	6.4	29.2	29.7	19.9	4.0	1.5	8.5	3.0	6.0	17	15
43	20.3	7.6	31.5	32.6	22.7	5.2	2.2	11.0	4.5	8.0	19	17
42	23.7	8.7	33.8	35.2	25.6	6.9	3.3	14.0	5.9	11	21	19
41	27.5	10.0	35.9	37.8	29.0	9.4	4.6	17.5	8.9	14	24	22
40	31.3	11.3	39.2	40.4	32.5	12.3	6.8	20.6	11.2	17	26	24
39	35.1	12.9	40.3	43.5	35.7	15.1	9.7	24.6	14.9	21	29	27
38	39.3	15.0	42.3	46.0	39.1	18.2	12.2	28.2	18.1	24	31	30
37	44.6	17.1	44.4	49.8	42.1	22.0	14.8	32.0	22.6	28	34	4
36	49.8	19.3	46.4	54.2	45.6	25.9	17.7	36.1	25.6	32	37	37
35	60.3	21.6	48.8	61.9	49.2	30.1	22.1	40.8	30.6	37	41	42
34	71.7	25.6	51.8	69.7	53.0	33.9	25.5	44.4	34.7	41	46	47
33	79.2	30.2	57.3	78.5	60.4	38.2	30.1	48.0	39.2	45	51	52
32	84.3	37.7	78.0	84.1	64.2	41.5	33.3	51.1	42.0	47	60	59

TABLE 5.3 (CONTD.)

SIGNAL LEVEL IN dB rel. to 1 μV/m	JUNE 1982	NOV. 1982	DEC. 1982	JAN, 1983	FEB. 1983	MAR. 1983	APR. 1983	MAY 1983	JUNE 1983	WET SEASON	DRY SEASON	ANNUAL
31	94.2	47.8	87.5	88.2	69.7	45.0	37.9	53.3	45.1	50	67	65
30	97.7	54.5	93.6	90.6	73.9	48.7	41.6	55.4	47.6	52	71	69
29	98.5	64.9	97.4	95.9	75.8	53.0	45.6	57.3	50. 9	55	76	73
28	99.0	74.9	99.0	97.5	76.6	55.5	48.1	59.1	53.2	57	79	75
27	99.3	85.5	99.4	99.4	77.3	60.6	50.5	61.1	55.4	59	83	78
26	99.6	92.3	99.6	99.8	78.0	62.2	52.1	65.9	60.2	64	84	80
25		94.8	99.7	100.0	79.3	66.2	55.4	69.0	67.2	68	86	83
24		96.5	99.8		85.3	68.0	57.4	71.7	68.7	71	88	84
23	99.8	98.0	99.9		87.6	74.6	61.6	79.1	70.6	76	90	87
22	99.8	99.0	99.9		88.1	77.9	70.1	87.0	75.5	82	91	90
21	99.9	99.3	99.9		93.5	82.1	82.2	91.1	92.8	92	94	94
20	99.9	99.4	99.9		95.4	84.7	85.0	97.0	95.0	96	95	96
19	99.9	99.8	100.0		97.9	94.2	87.3	98.0	99.4	99	97	98
18	99.9	99.9			99.3	96.0	87.9	98.7	99.8	99	99	99
17	99.9				99.9	98.6	99.6	98.9		100	100	100
16	100.0				100.0	99.4	99.8	99.3				
15						99.9		99.5				
14								99.7				
13								99.9				
12								99.9				
11												

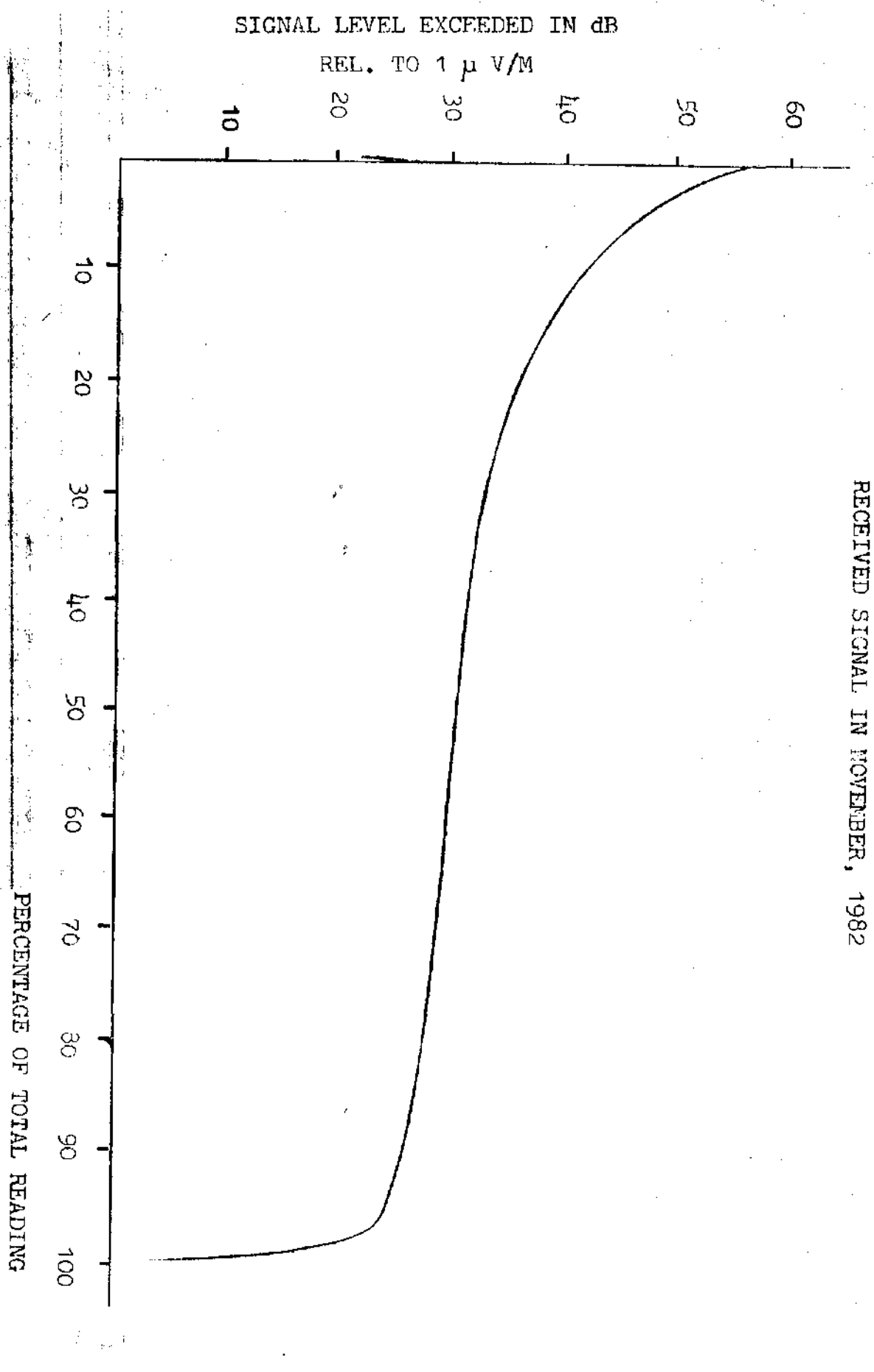
TABLE 5.4

CUMULATIVE DISTRIBUTION OF MEDIAN SIGNAL LEVELS IN dB RELATIVE 1 μV/m AND MEASURE OF SCATTER

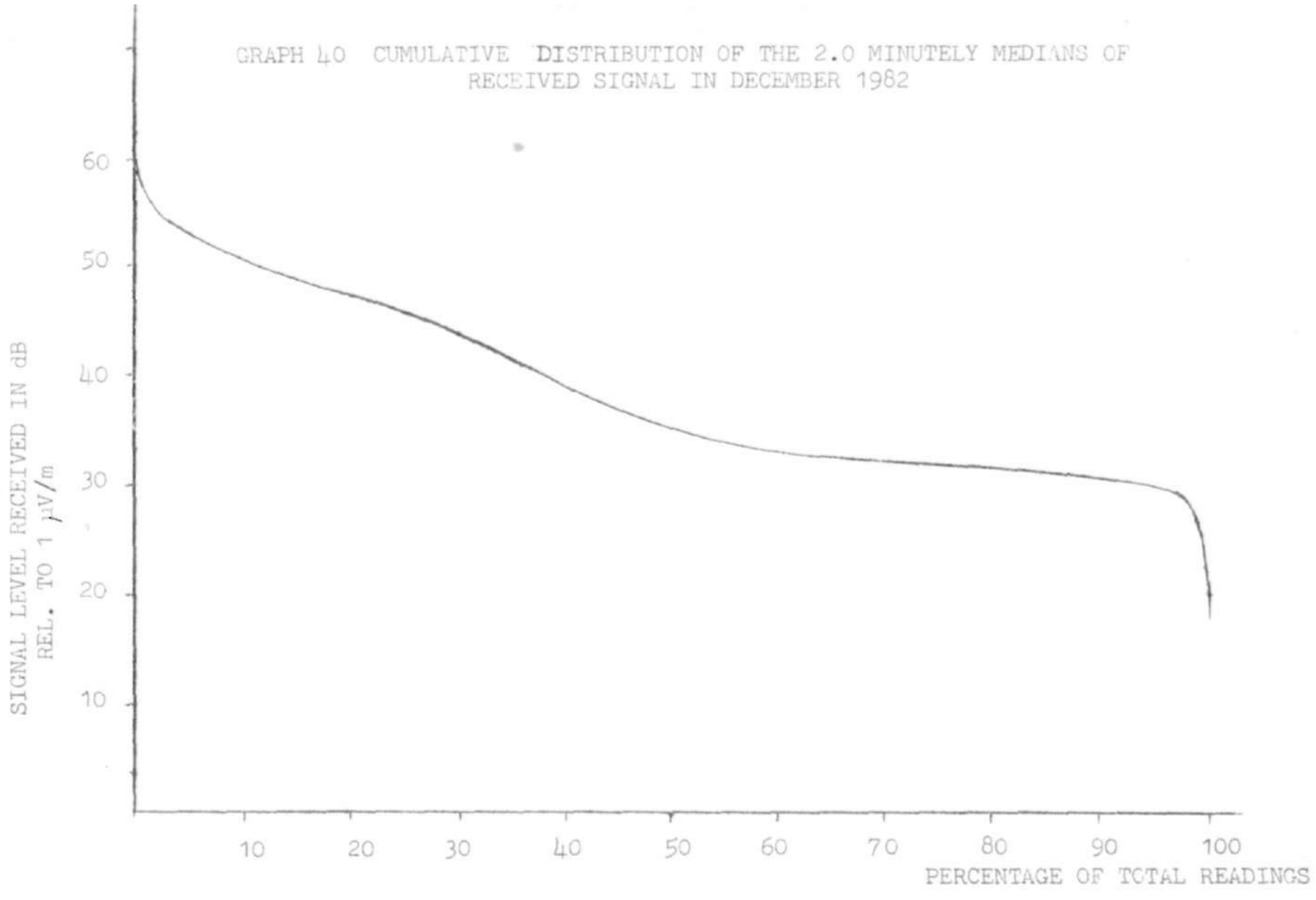
MONTH	60 dB	50 dB	40 dB	30 dB	20 dB	15 dB	RANGE (dB)	SEMI-INTER QUARTILE RANGE	MEASURE OF SCATTER
JUNE 1982	0	4.7	31.3	97.7	99.9	100	46	3.9	.085
NOV. 1982	0	2.2	11.3	54.5	99.4	100	40	3.2	.08
DEC. 1982	0.1	11.9	39.2	93.6	99.9	100	42	7.7	.18
JAN. 1983	0.6	13.4	40.4	90.6	100.0	100	41	5.9	.14
FEB. 1983	0.8	7.3	32.5	72.9	95.4	100	51	6.4	.13
MAR. 1983	0	0.4	12.3	48.7	84.7	99.4	38	7.8	.21
APR. 1983	0	0.1	6.8	41.6	85.0	99.8	38	7.5	.20
MAY 1983	0	1.0	20.6	55.4	97.0	99.3	44	7.5	.17
JUNE 1983	0	0.2	11.2	47.6	95.0	100	34	7.1	.21

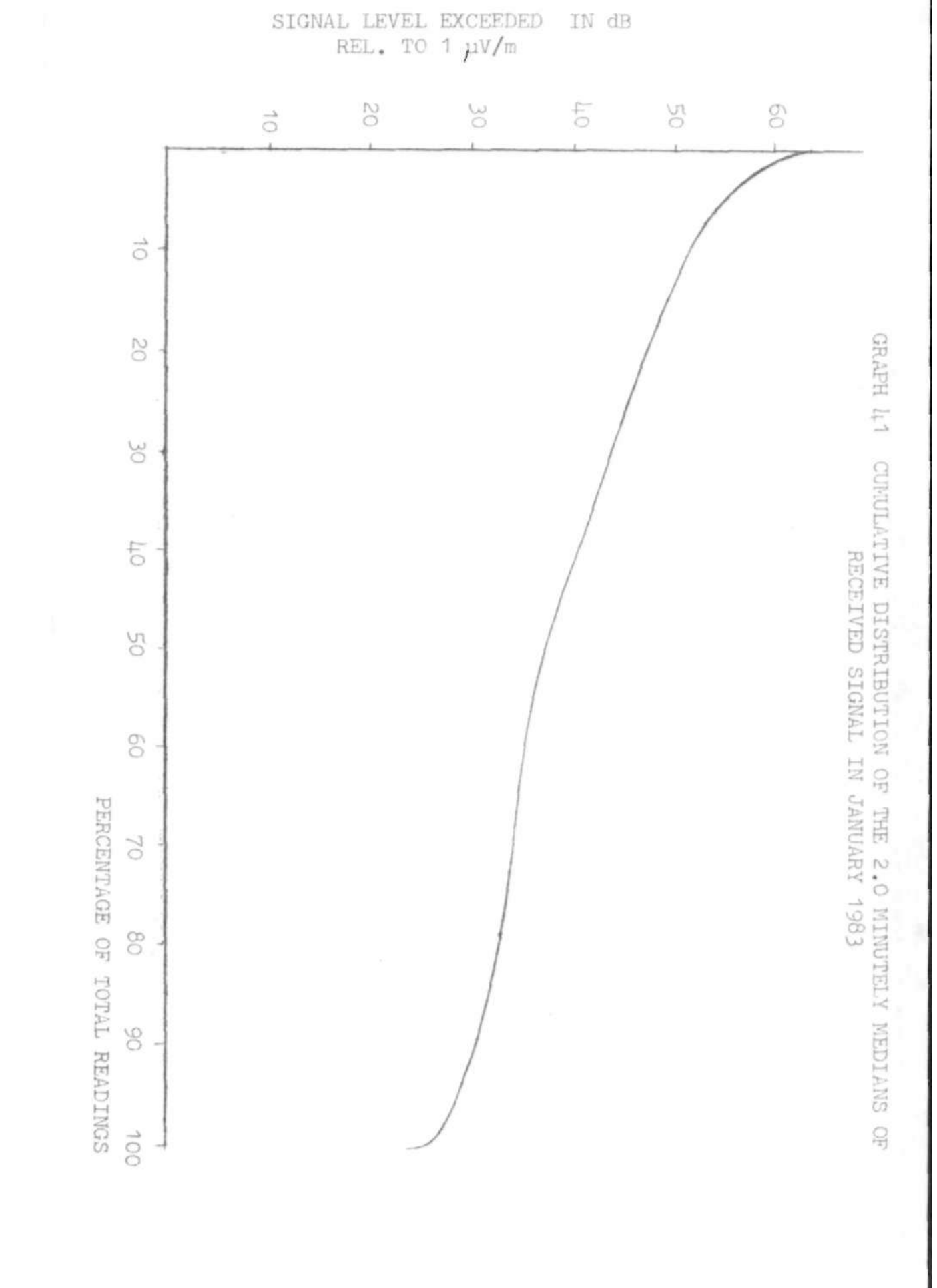
$$\text{MEASURE OF SCATTER} = \frac{\text{SEMI-INTER QUARTILE RANGE}}{\text{RANGE}}$$

GRAPH 39 CUMULATIVE DISTRIBUTION OF THE 2.0 MINUTELY MEDIANS OF RECEIVED SIGNAL IN NOVEMBER, 1982

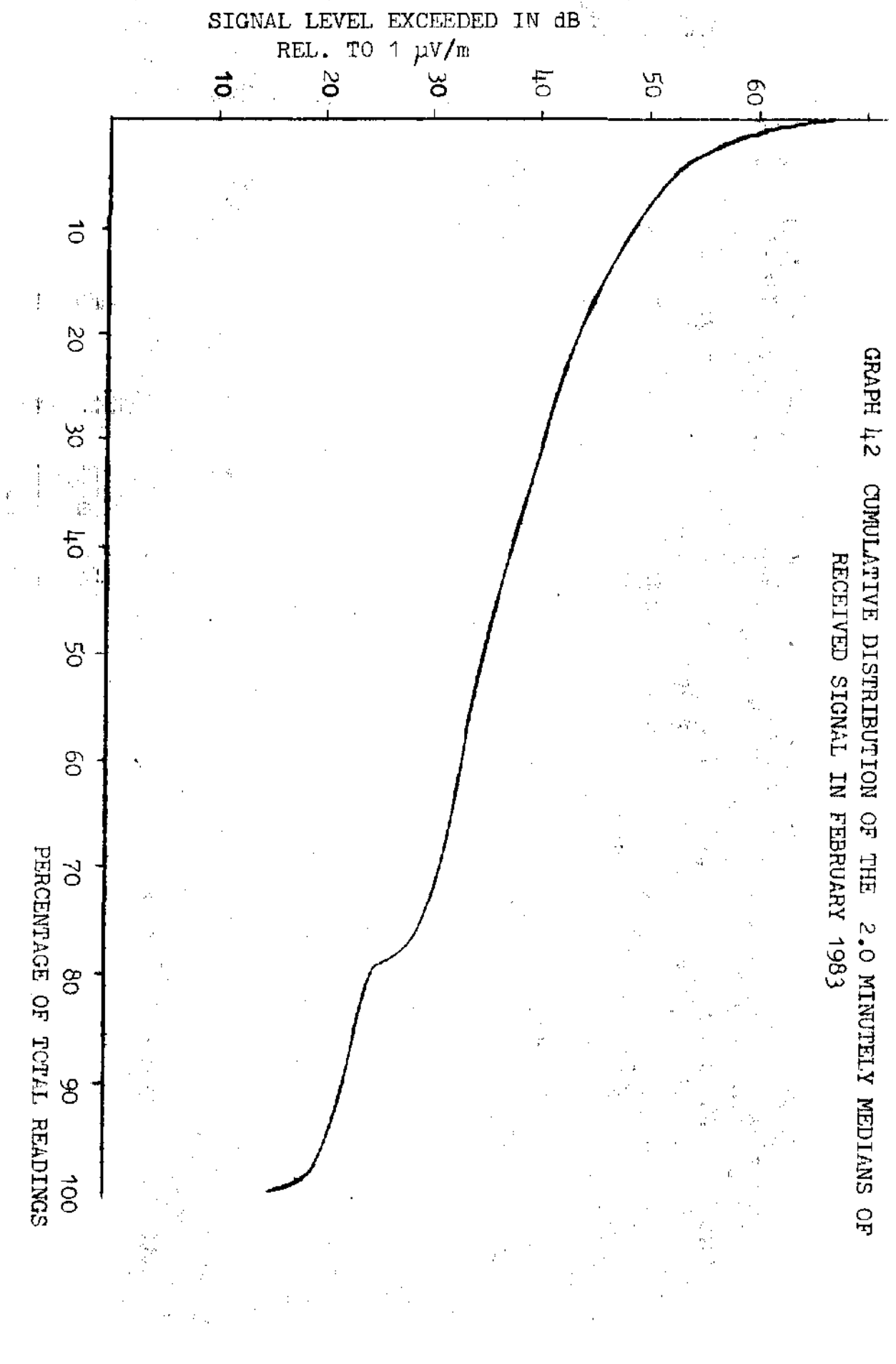


GRAPH 40 CUMULATIVE DISTRIBUTION OF THE 2.0 MINUTELY MEDIANS OF RECEIVED SIGNAL IN DECEMBER 1982



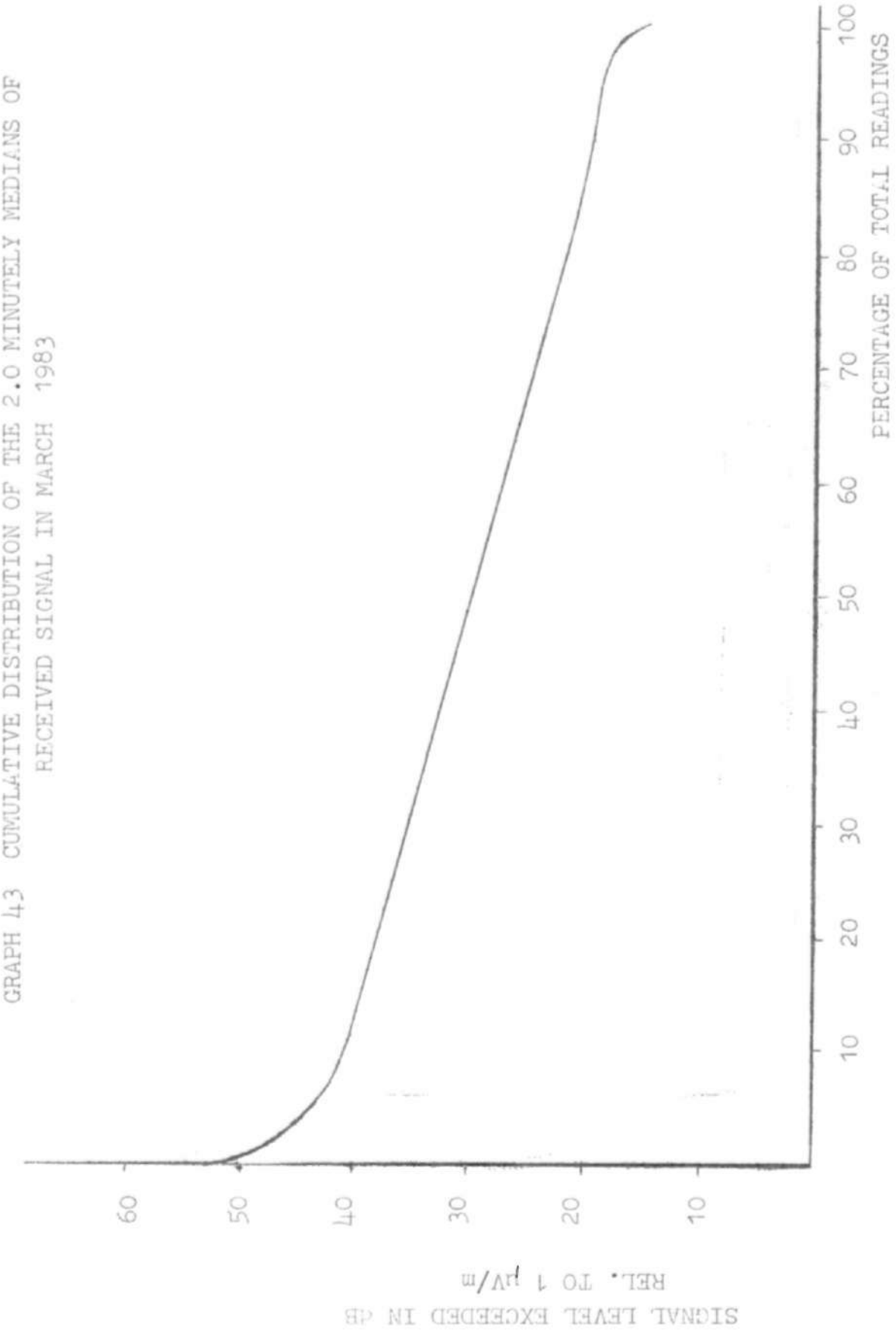


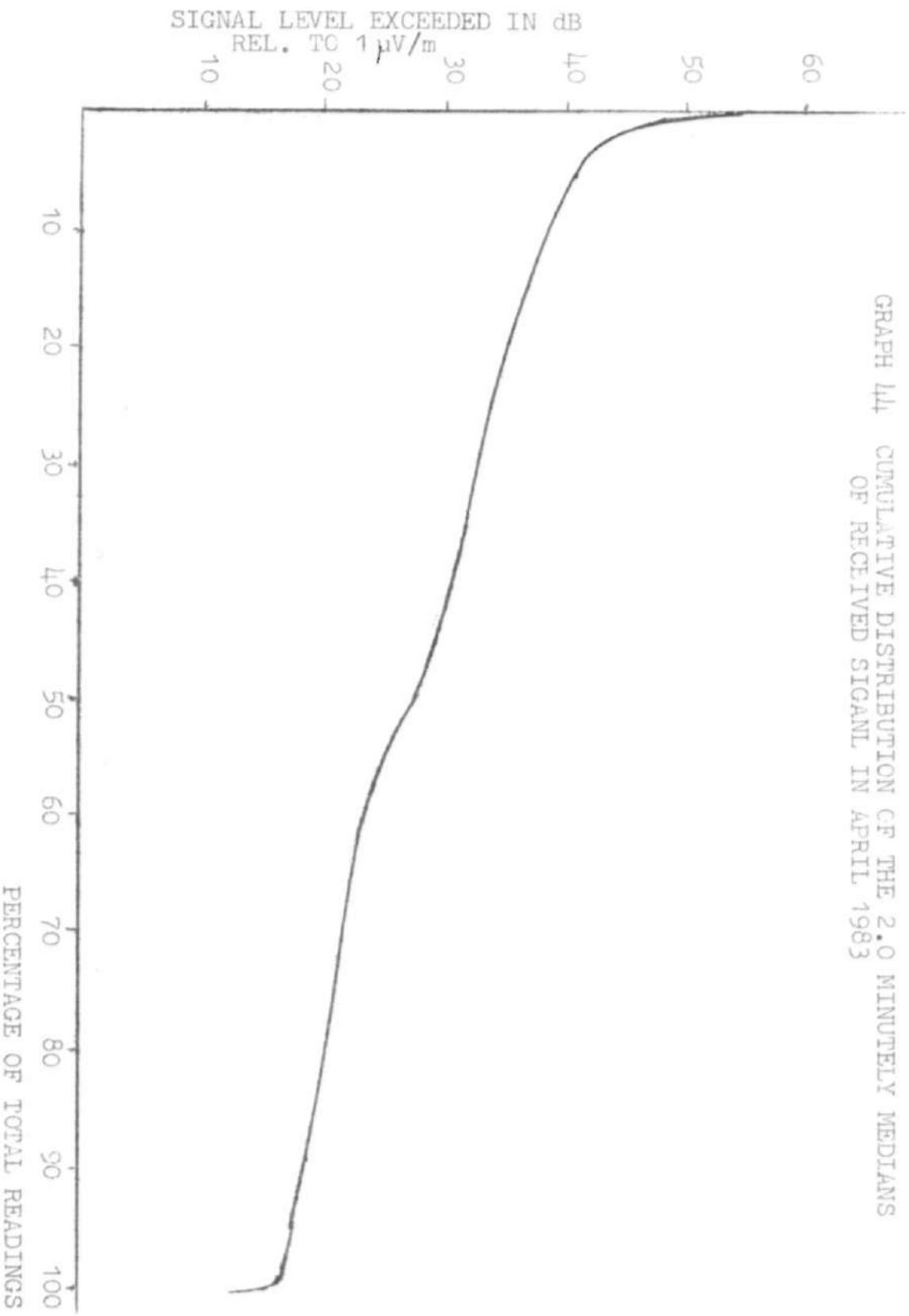
GRAPH 41 CUMULATIVE DISTRIBUTION OF THE 2.0 MINUTELY MEDIANS OF RECEIVED SIGNAL IN JANUARY 1983



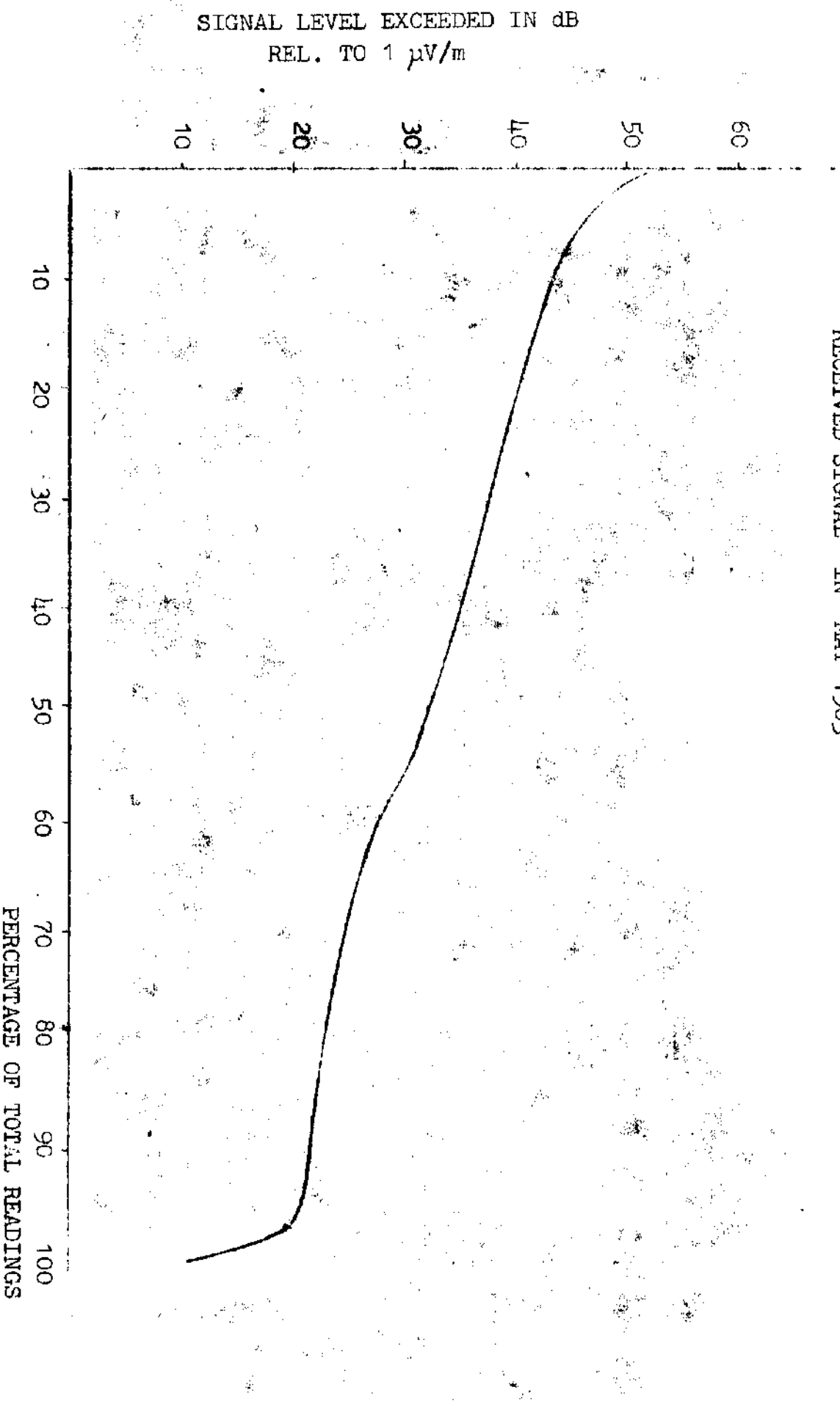
GRAPH 42 CUMULATIVE DISTRIBUTION OF THE 2.0 MINUTELY MEDIANS OF RECEIVED SIGNAL IN FEBRUARY 1983

GRAPH 43 CUMULATIVE DISTRIBUTION OF THE 2.0 MINUTELY MEDIANS OF RECEIVED SIGNAL IN MARCH 1983



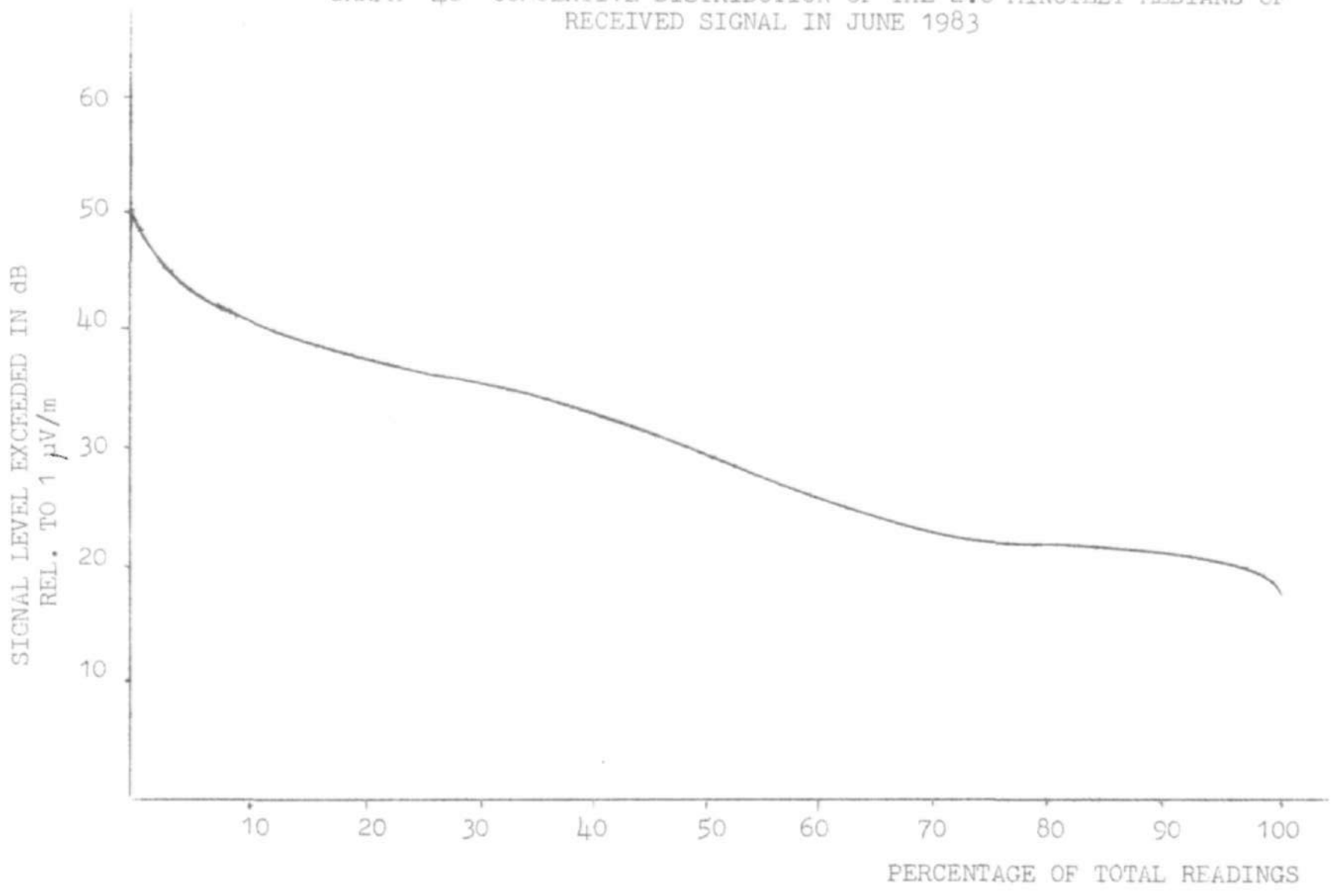


GRAPH 44 CUMULATIVE DISTRIBUTION CF THE 2.0 MINUTELY MEDIANS OF RECEIVED SIGANL IN APRIL 1983



GRAPH 45 CUMULATIVE DISTRIBUTION OF THE 2.0 MINUTELY MEDIANS OF RECEIVED SIGNAL IN MAY 1983

GRAPH 46 CUMULATIVE DISTRIBUTION OF THE 2.0 MINUTELY MEDIANS OF RECEIVED SIGNAL IN JUNE 1983



3. The month of February, a typical dry season month has an unusually large range and also the highest range of 51 dB whereas other months in the dry season have a range of about 40 dB. No explanation was found for this exception.

4. The measure of scatter is higher (0.18 to 0.21) for the months two signals existed than for months when only one signal (NOV., JUNE) was recorded.

5. The dry season months have a lower measure of scatter than the wet season months.

5.7 SUMMARY OF CONCLUSIONS

The need for stations working in same or adjacent frequency channels to determine the minimum geographical seperation and maximum transmitter powers to avoid interference resulting from long distance ionospheric propagation has been stressed for some years now. In Nigeria in particular and developing countries in general, more attention needs to be focussed on this. The scope of this research work was complicated early in the research period because of long distance ionospheric interference. When two stations transmit on the same frequency the interference of the signal from the two stations is a big nuisance and is very difficult to remove. This is particularly true of medium wave signals at night.

The handicap of the interfering ionospheric signals notwithstanding some useful results and consequently conclusions were arrived at. They are as follows:

1. The graph of daily medians reveals that there is no significant variation in the shape of the graphs during the period of measurement, (June 1982 to June 1983).

2. There is an average spread of 10 dB in the signal level. However, the signal level shows a downward trend in the month of February of - 0.6 dB/day and an upward trend of 0.4 dB/day in the month of June 1983.

3. Due to the presence of an interfering signal at night there is less correlation during this period when compared with the period of single signal measurements.

4. The monthly hourly median graphs reveal a rise of 0.6 dB/hour on the average from sunset to midnight. For any particular day, the level of received signal does not vary with time.

5. The daily hourly median graphs confirm the conclusions reached in 3 and 4. It also revealed that the level of signal during the harmattan was higher than during the wet season with a high correlation during the day. There is a greater spread during the night and the signal level is significantly lower during the wet season.

6. As a result of 5) above, there does not seem to be a reduction in signal level due to harmattan dust. Rather the stability of the atmosphere, giving rise to specular reflection rather increases the level of the received signal during harmattan.

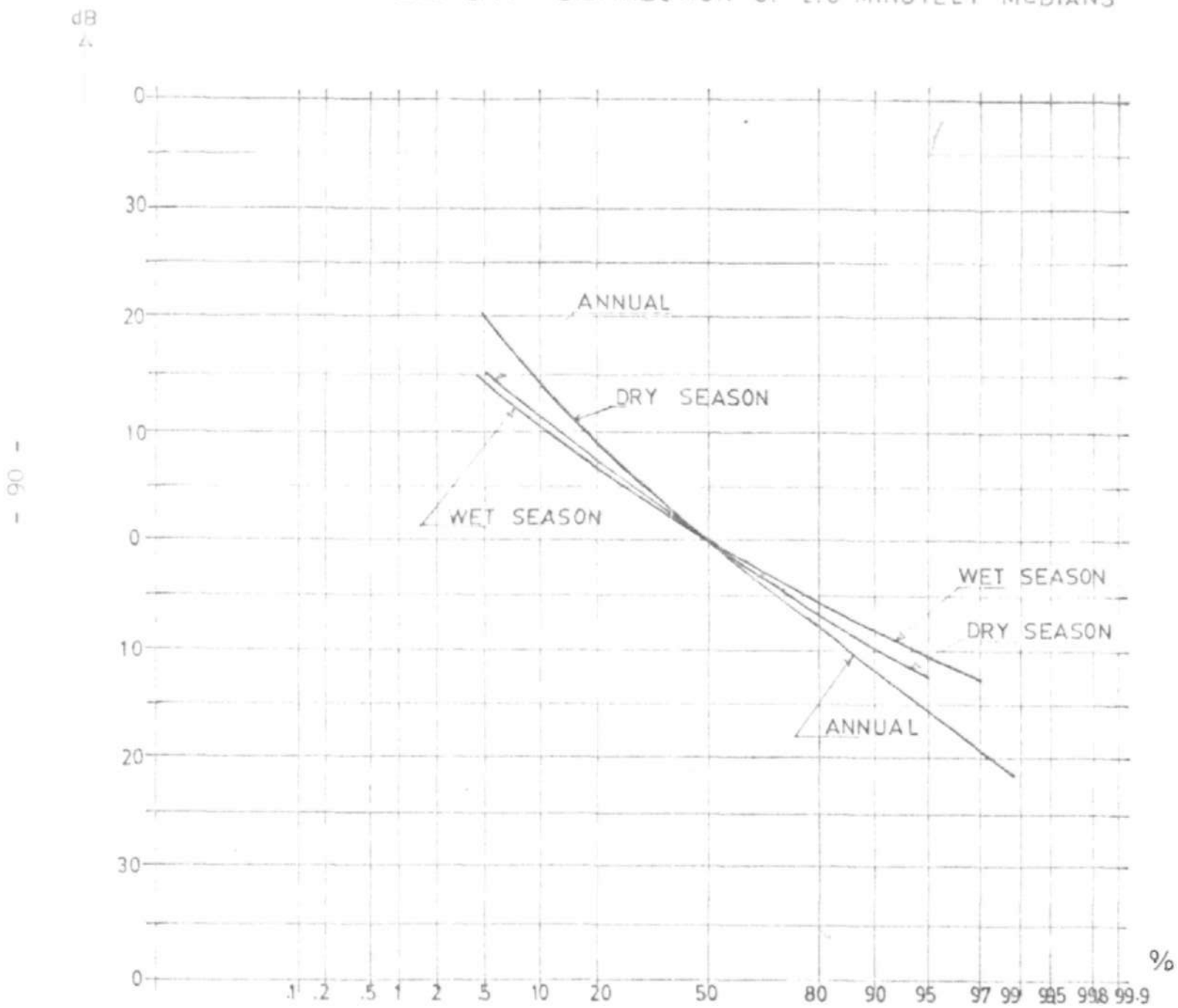
7. The sky wave night time signal is 10 dB higher than the ground wave day time signal. The reduced correlation and fluctuation of the signal during the night however, causes the sound quality to deteriorate. This shows that an increased signal strength due to sky wave signals is undesirable for medium wave transmission.

8. The difference between the wet season and dry season medians of 33.6 dB and 31.4 dB are not statistically significant. The annual median represents readings taken for a period of 204 days and has a value of 33.8 dB.

9. The probability distribution approaches a log-normal distribution. This is characteristic of slowly varying signals.

The CCIR recommendation 216 of the XIIIth Plenary Session, Geneva 1974 states that for good reception, the median value of the wanted signal should be 40 dB greater than the median value of the unwanted signal

GRAPH 47 PROBABILITY DISTRIBUTION OF 2.0 MINUTELY MEDIANS



for 90% of the hours and days. The research work has revealed that a lot of the protective laws regarding medium wave transmission with respect to frequency allocation, maximum power of transmitters for good area coverage and no interference are seriously inadequately adhered to.

The monthly medians are very useful in the design of medium wave transmitters. It was discovered that during the period of measurement, the largest difference in decibel between any two medians was 10 dB. The average rise rate is 5 dB/month. This shows that propagation conditions are fairly stable and good reception should be possible throughout the year with a fixed power of transmitter. This is the usual practice.

5.8 RECOMMENDATION FOR FURTHER WORK

The period of measurement of this work was 204 days within a thirteen month period. It is therefore recommended that readings be continued to be taken over a period of years in order to compare results of different years.

Also, there was not much work done on fading of the signal. The graph paper recordings show a slowly varying signal for most of the period of measurement. It would be seen that this was due to the high signal level and

consequently high signal to noise ratio. With a lower signal typical of rural area broadcast, the fading is likely to be much more significant especially at night.

It is known that the ionospheric signal becomes more dominant as the frequency increases (in the Medium Wave band). It would be interesting to see the effect of a higher frequency of transmission on the nature of propagation. It is therefore recommended that more work be done in the upper range of the medium wave band.

Although it was found out that harmattan does not seem to have an appreciable effect on the level of signal received, it would seem more work is advisable in that area. Firstly the presence of two signals made interpretation of results difficult. It also made it difficult to compare results critically. Secondly it is known that the harmattan is not uniform over the years, hence some data analysis taken over a period of years would be informative.

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Appendix I

TABLE 4.4

DAILY HOURLY MEDIAN FOR JUNE 1982

Time \ Day	1	2	3	4	5	6	7	11	12	13	14	15
2.00 - 3.00	31.9	30.9	31.9	32.0	37.7	32.8	31.9	35.8	35.7	34.9	34.9	33.9
3.00 - 4.00	31.9	31.0	31.9	33.3	39.0	34.0	32.9	35.9	35.9	34.9	34.9	34.9
4.00 - 5.00	31.9	31.4	32.6	36.5	41.5	35.1	33.2	37.1	37.6	35.9	34.9	34.9
5.00 - 6.00	31.9	34.0	32.1	39.1	43.9	36.0	33.8	37.7	39.9	34.8	35.9	36.0
6.00 - 7.00	31.4	34.4	33.1	40.6	43.7	35.8	33.7	37.5	43.4	37.1	36.3	40.4
7.00 - 8.00	34.1	33.7	35.4	38.4	37.0	38.1	35.2	38.4	42.2	46.4	37.4	50.2
8.00 - 9.00	37.0	36.9	41.7	*	33.9	38.9	38.9	43.4	46.0	36.8	42.4	50.4
9.00 - 10.00	42.7	34.2	42.4	34.4	33.3	32.9	43.5	48.4	48.7	38.9	48.9	41.2
10.00 - 11.00	44.1	41.9	46.9	41.7	38.4	33.4	47.4	*	44.1	40.8	52.9	45.9
11.00 - 12.00	46.4	42.7	45.0	43.0	43.1	35.7	47.9	*	42.2	36.9	50.1	45.4

* Missing Data

TABLE 4.5

DAILY HOURLY MEDIAN FOR NOVEMBER 1982

Time \ Day		2	4	5	6	7		12	13	14	15	16	17	20	23	24	25	26	27	28	29	30
3.00 - 4.00			27.6	27.0	27.9	27.9		31.9	34.0	31.9	31.9	*	32.8	27.1	26.9	28.9	23.0	28.0	27.9	27.1	28.4	29.6
4.00 - 5.00		28.2	31.7	26.3	28.2	29.0		30.2	30.7	32.3	32.6	*	33.0	28.1	27.2	29.1	26.4	28.9	*	27.9	30.3	30.2
5.00 - 6.00		24.1	31.9	26.7	28.3	28.7		30.9	30.3	32.1	33.9	37.0	33.1	28.5	27.7	28.3	28.5	28.4	*	27.9	30.4	30.1
6.00 - 7.00		26.9	29.2	*	33.6	27.9		33.6	31.2	33.0	*	*	33.6	28.3	28.3	*	30.7	29.8	*	29.9	*	31.2
7.00 - 8.00		*	33.0	30.2	28.4	34.3		31.8	34.9	33.8	*	34.7	32.0	28.3	27.5	*	*	28.9	*	28.3	32.2	33.9
8.00 - 9.00		*	34.4	26.6	26.9	*		31.0	*	*	*	37.5	*	32.4	*	*	*	30.2	*	31.9	33.7	32.9
9.00 - 10.00		29.3	33.6	28.8	29.5	*		32.9	*	*	44.9	40.2	*	31.9	*	*	*	36.9	*	30.8	*	32.4
10.00 - 11.00		34.4	33.4	37.0	29.2	*		34.0	*	39.7	45.4	40.4	*	*	24.9	29.9	*	46.1	32.9	38.9	*	32.6
11.00 - 12.00		*	*	31.7	30.6	*		40.6	*	38.4	50.4	37.9	*	*	24.9	35.4	*	46.6	*	*	*	34.1
12.00 - 13.00		*	*	40.4	34.4	44.3		45.8	*	47.9	50.2	40.4	*	*	27.4	*	*	47.4	42.9	*	*	38.8

TABLE 4.6

DAILY HOURLY RESULTS FOR OCTOBER 1962

Hours \ Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2.00 - 3.00	29.6	29.9	29.4	30.4	29.9	32.6	30.9	32.9	32.9	33.9	*	32.9	32.7	32.9	31.6	30.9	31.3	31.4	31.6	31.6	32.9	*	.4	.7	32.9	32.9	32.7	32.9	31.6	32.8	33.0
3.00 - 4.00	29.9	30.2	29.9	31.2	30.2	33.1	30.9	33.0	32.9	33.9	*	31.6	32.6	33.0	32.4	*	31.7	32.4	32.6	32.2	33.0	*	.6	31.7	32.8	32.9	32.2	33.5	33.9	32.8	33.9
4.00 - 5.00	30.1	30.9	*	31.4	30.1	33.6	31.6	33.1	33.0	33.4	*	32.8	.6	33.2	33.4	*	31.6	32.6	32.6	32.7	*	33.4	.3	32.8	32.5	33.0	33.4	33.6	32.3	33.9	
5.00 - 6.00	31.7	31.2	*	32.6	32.9	35.1	32.0	33.9	33.9	35.6	31.4	33.4	33.2	33.8	32.6	*	32.0	32.9	33.6	34.7	35.9	36.4	37.7	36.2	32.5	32.9	33.1	33.4	34.7	33.2	
6.00 - 7.00	32.1	30.4	*	31.4	*	32.2	33.8	*	32.9	33.9	37.4	33.4	38.7	46.2	31.9	*	31.4	33.4	33.4	33.7	*	31.7	34.9	47.4	46.1	44.4	41.3	47.4	46.1	43.4	
7.00 - 8.00	*	33.0	43.9	45.9	49.6	36.0	36.2	35.9	36.6	40.4	41.2	45.2	50.2	47.3	45.2	*	46.7	44.4	46.9	36.9	*	37.4	51.7	47.4	43.9	42.1	47.6	45.7	*	41.2	
8.00 - 9.00	*	31.4	*	*	*	36.2	*	47.2	37.2	*	46.4	46.5	51.0	53.4	45.4	51.0	44.4	45.4	46.8	40.2	*	50.2	55.4	51.6	48.7	49.4	47.2	42.9	46.7	44.4	
9.00 - 10.00	*	35.4	*	38.4	*	39.4	*	47.9	43.4	*	50.2	52.4	53.4	**	46.4	54.1	49.4	45.4	51.4	46.9	*	51.4	44.7	51.6	49.4	50.7	50.4	49.6	46.0	48.6	
10.00 - 11.00	*	37.1	35.0	34.4	*	41.0	37.6	46.1	41.4	*	54.3	50.6	43.5	*	39.1	51.2	46.7	34.5	48.4	47.1	*	42.7	-	*	36.2	50.8	49.4	47.4	47.2	47.6	
11.00 - 12.00	*	33.2	35.7	46.7	*	49.2	48.4	50.7	41.0	*	50.6	41.0	41.0	*	*	52.6	42.4	39.2	46.9	47.4	*	45.0	*	*	*	42.7	45.7	39.2	*	*	

* Missing Data

TABLE 4.7

DAILY HOURLY MEDIAN FOR JANUARY 1983

Time (P.K) \ Day of Month	1	3	4	5	6	7	8	11	14	15	16	19	20	21	22	23	24	26	27	28	29	30	31
2.00 - 3.00	*	*	*	*	35.9	*	34.9	*	35.4	34.1	33.9	*	*	33.6	28.3	29.7	*	29.9	30.0	37.7	35.5	35.6	*
3.00 - 4.00	30.4	*	*	*	35.9	*	34.8	*	34.0	34.0	*	*	33.8	33.7	29.2	28.9	*	29.9	30.8	35.3	35.0	34.0	33.4
4.00 - 5.00	32.6	*	*	*	*	*	34.9	*	33.2	34.1	*	*	34.0	32.4	29.9	29.7	30.8	29.0	30.9	35.7	34.4	36.2	35.4
5.00 - 6.00	31.6	*	*	*	*	*	34.5	*	32.8	34.7	*	*	34.0	*	30.6	28.0	32.3	32.4	30.9	34.8	36.1	34.4	36.4
6.00 - 7.00	44.7	*	*	48.7	*	*	*	*	46.1	45.4	*	*	34.5	*	*	38.3	*	44.4	31.3	*	46.2	45.0	41.9
7.00 - 8.00	34.2	*	48.7	49.9	*	*	*	*	51.9	51.6	*	46.9	38.4	*	36.9	40.0	*	*	47.2	*	*	47.4	*
8.00 - 9.00	*	51.6	52.9	46.9	49.9	47.3	43.9	*	49.7	49.4	*	*	*	*	40.3	36.1	*	*	47.9	*	*	48.2	*
9.00 - 10.00	*	53.9	*	51.2	*	50.4	48.7	51.8	50.9	52.2	41.4	46.9	48.3	*	40.3	35.4	*	*	51.9	*	50.6	48.0	53.7
10.00 - 11.00	*	47.9	*	42.4	*	45.9	48.0	37.9	54.9	*	48.4	41.1	46.2	*	40.0	32.1	*	40.6	43.4	40.4	43.9	48.4	47.4
11.00 - 12.00	*	41.4	*	40.4	*	39.7	50.9	41.0	50.9	34.4	57.4	36.9	50.4	*	38.8	34.6	*	44.0	44.2	41.9	44.6	47.0	39.6

* Missing data

TABLE 4.8

DAILY HOURLY MEDIAN FOR FEBRUARY 1983

Time (P.M) \ Day of Month	1	2	3	4	5	6	8	9	14	15	16	18	25	26	27	28
2.40 - 3.00	*	30.2	33.9	34.2	32.2	33.6	32.7	33.9	30.7	20.2	22.7	24.8	20.9	21.4	22.0	20.5
3.00 - 4.00	*	31.2	32.7	35.5	32.0	31.4	34.5	34.0	31.0	19.2	24.4	22.9	23.6	24.6	22.4	20.8
4.00 - 5.00	37.0	31.3	31.8	36.9	33.9	32.7	32.3	34.0	34.9	19.2	24.7	24.9	24.9	21.8	23.1	19.7
5.00 - 6.00	35.4	32.0	33.4	39.1	32.0	33.0	34.7	36.7	35.4	21.2	25.6	26.0	24.6	23.8	23.9	19.0
6.00 - 7.00	46.4	*	41.4	45.6	44.4	41.1	39.8	48.1	*	33.6	40.4	37.4	36.4	37.2	32.2	28.7
7.00 - 8.00	47.9	42.7	52.2	42.5	47.9	*	*	*	*	*	35.6	36.4	33.7	42.4	35.9	32.6
8.00 - 9.00	53.1	49.1	46.9	37.4	48.1	*	*	*	50.9	37.2	37.8	42.7	31.2	41.4	39.7	32.5
9.00 - 10.00	53.9	44.8	46.9	30.2	51.5	*	*	*	53.4	52.4	40.5	46.0	38.4	43.6	39.0	*
10.00 - 11.00	54.1	43.8	44.4	39.8	48.1	*	*	*	55.7	55.1	41.1	46.4	42.4	34.9	39.4	*
11.00 - 12.00	46.0	42.4	44.3	37.4	41.8	*	*	*	55.8	57.7	38.7	46.7	42.1	28.4	41.2	23.9

* Missing data

30 JAN 1984
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TABLE 4.9

DAILY HOURLY MEDIANS FOR MARCH 1983

Time (P.M) \ Day of Month	3	4	5	6	7	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2.00 - 3.00	20.3	20.0	22.6	22.3	19.9	21.9	18.0	23.9	17.9	20.2	19.7	20.9	29.8	30.4	29.9	28.8	29.4	27.4	27.8	26.2	24.4	28.9	28.1	27.7	21.8	20.9	*	20.0
3.00 - 4.00	20.2	19.7	21.2	19.9	18.3	22.4	21.3	*	19.6	20.2	19.9	21.1	27.5	29.6	24.0	27.7	25.4	26.2	24.4	25.6	19.4	22.3	20.2	25.7	22.9	21.3	*	22.8
4.00 - 5.00	21.7	20.3	20.2	20.1	16.4	23.5	20.3	*	17.9	19.9	19.4	21.7	23.5	25.8	25.6	24.1	23.4	21.7	21.9	19.9	17.7	20.9	19.3	24.5	20.7	20.0	*	18.4
5.00 - 6.00	22.6	19.5	23.8	23.1	*	24.0	21.9	18.2	18.0	20.1	23.0	22.4	22.7	27.8	24.5	19.4	21.7	20.4	23.6	19.8	16.4	20.9	19.2	23.4	23.1	20.1	15.8	18.5
6.00 - 7.00	35.4	31.4	30.9	34.1	*	31.4	29.4	30.4	30.4	37.2	30.9	33.1	29.4	37.2	36.9	28.7	29.4	26.9	28.4	24.1	21.4	28.4	29.4	35.7	31.9	29.9	29.4	23.4
7.00 - 8.00	32.2	33.7	36.4	36.8	31.8	39.4	36.9	29.7	30.4	38.2	36.4	37.8	36.6	40.6	44.7	37.3	33.9	33.1	40.6	34.3	29.6	36.4	35.6	*	36.9	38.4	28.9	29.7
8.00 - 9.00	34.3	31.4	29.2	38.1	34.9	40.2	35.7	29.4	31.0	36.9	37.0	32.1	39.9	41.2	45.1	38.4	27.7	31.6	41.2	35.2	*	41.4	39.4	*	36.2	36.4	*	32.1
9.00 - 10.00	35.0	31.4	30.0	38.1	37.1	40.7	38.4	31.4	28.9	34.4	34.9	35.4	40.9	41.6	46.3	38.9	33.7	33.9	39.4	33.2	31.3	40.3	38.0	*	36.7	34.9	*	32.9
10.00 - 11.00	39.1	39.1	30.9	33.7	*	41.4	36.9	26.4	32.3	38.2	37.2	36.4	38.1	42.1	49.6	38.7	32.9	35.8	40.8	33.1	30.2	41.0	33.1	*	*	32.6	*	33.4
11.00 - 12.00	34.8	33.1	30.9	36.7	*	37.2	34.3	26.9	28.3	36.9	35.9	36.4	39.7	42.1	48.4	39.4	37.4	36.4	40.4	37.4	33.4	39.8	32.2	*	*	*	*	33.5

* Missing data

TABLE 4.10

DAILY HOURLY MEDIAN FOR APRIL 1983

Time \ Day	1	2	3	21	22	23	25	26	27	28	29	30
2.00 - 3.00	21.9	28.8	22.9	*	19.9	21.9	*	19.9	22.9	19.8	21.9	19.6
3.00 - 4.00	22.6	22.9	22.8	19.9	19.9	21.2	*	19.9	23.1	19.9	22.1	21.9
4.00 - 5.00	25.5	21.2	22.7	20.4	19.4	21.9	22.4	19.9	25.6	23.4	19.8	20.9
5.00 - 6.00	23.0	21.8	22.9	21.8	19.9	20.4	21.9	19.9	22.1	20.5	16.9	19.9
6.00 - 7.00	29.7	30.9	28.4	27,4	23.7	25.1	33.4	25.4	24.9	27.1	*	27.1
7.00 - 8.00	35.1	39.7	34.4	32.6	28.8	32.2	33.9	34.9	33.4	31.4	*	*
8.00 - 9.00	32.1	41.7	36.8	37.6	30.8	33.4	30.4	32.1	31.4	30.7	*	*
9.00 - 10.00	33.7	40.2	34.1	35.9	34.1	35.4	40.4	33.7	33.0	30.2	*	*
10.00 - 11.00	31.7	40.2	37.4	37.4	36.4	34.2	41.4	33.2	36.1	31.4	*	*
11.00 - 12.00	30.0	39.2	35.4	*	34.8	*	40.9	39.1	32.4	*	*	*

* Missing Data

TABLE 4.11

DAILY HOURLY MEDIAN FOR MAY 1983

Time (P*S) \ Day of Month	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	31
2.00 - 3.00	21.9	25.9	22.9	23.5	23.9	25.9	21.3	*	22.9	20.9	*	*	*	20.9	*	*	*	18.9	20.9	*	20.9	22.9	22.9	23.2	22.5
3.00 - 4.00	20.4	25.9	23.9	22.9	20.3	26.1	20.9	*	22.5	20.9	*	26.1	25.5	22.9	*	*	*	20.6	26.2	*	20.9	23.8	22.9	22.9	21.9
4.00 - 5.00	21.1	27.3	23.9	22.9	24.7	26.9	20.4	*	23.4	20.9	*	17.4	23.1	14.9	*	*	21.1	27.3	26.9	*	20.9	23.4	19.4	22.9	22.9
5.00 - 6.00	21.5	25.6	23.4	23.0	24.6	27.8	*	*	25.4	21.2	*	23.1	25.5	18.4	*	*	24.4		26.4	*	21.4	23.7	22.3	*	24.7
6.00 - 7.00	*	30.2	33.9	28.4	36.2	38.0	*	33.9	26.4	24.1	37.4	30.4	26.9	34.4	38.7	32.7	35.5	31.4	26.4	*	28.7	31.4	29.7	22.9	30.1
7.00 - 8.00	*	38.7	39.4	37.7	36.2	48.4	*	40.9	33.4	33.8	42.6	41.9	43.6	42.4	37.4	42.4	40.0	41.0	38.8	*	35.0	37.4	34.6	31.3	34.4
8.00 - 9.00	*	38.4	43.9	38.9	35.2	43.7	*	40.7	34.4	35.4	41.0	40.4	44.1	43.4	40.4	41.4	39.9	43.0	34.7	*	36.4	38.7	35.4	32.7	*
9.00 - 10.00	*	37.6	43.4	42.4	44.1	*	*	35.9	*	*	43.9	35.4	43.5	37.4	42.2	38.6	39.7	43.9	36.4	41.4	35.6	36.8	33.2	29.6	40.4
10.00 - 11.00	34.9	39.9	47.7	46.4	*	38.9	*	32.4	40.4		48.2	41.9	37.4	39.4	43.1	36.2	37.6	39.1	36.4	43.3	37.7	35.2	34.4	29.4	40.8
11.00 - 12.00	33.9	38.1	41.8	44.1	*	*	*	*	*	*	34.4	36.7	38.7	*	*	36.2	35.7	36.9	38.4	38.4	40.7	30.4	35.4	31.7	34.9

* Missing data

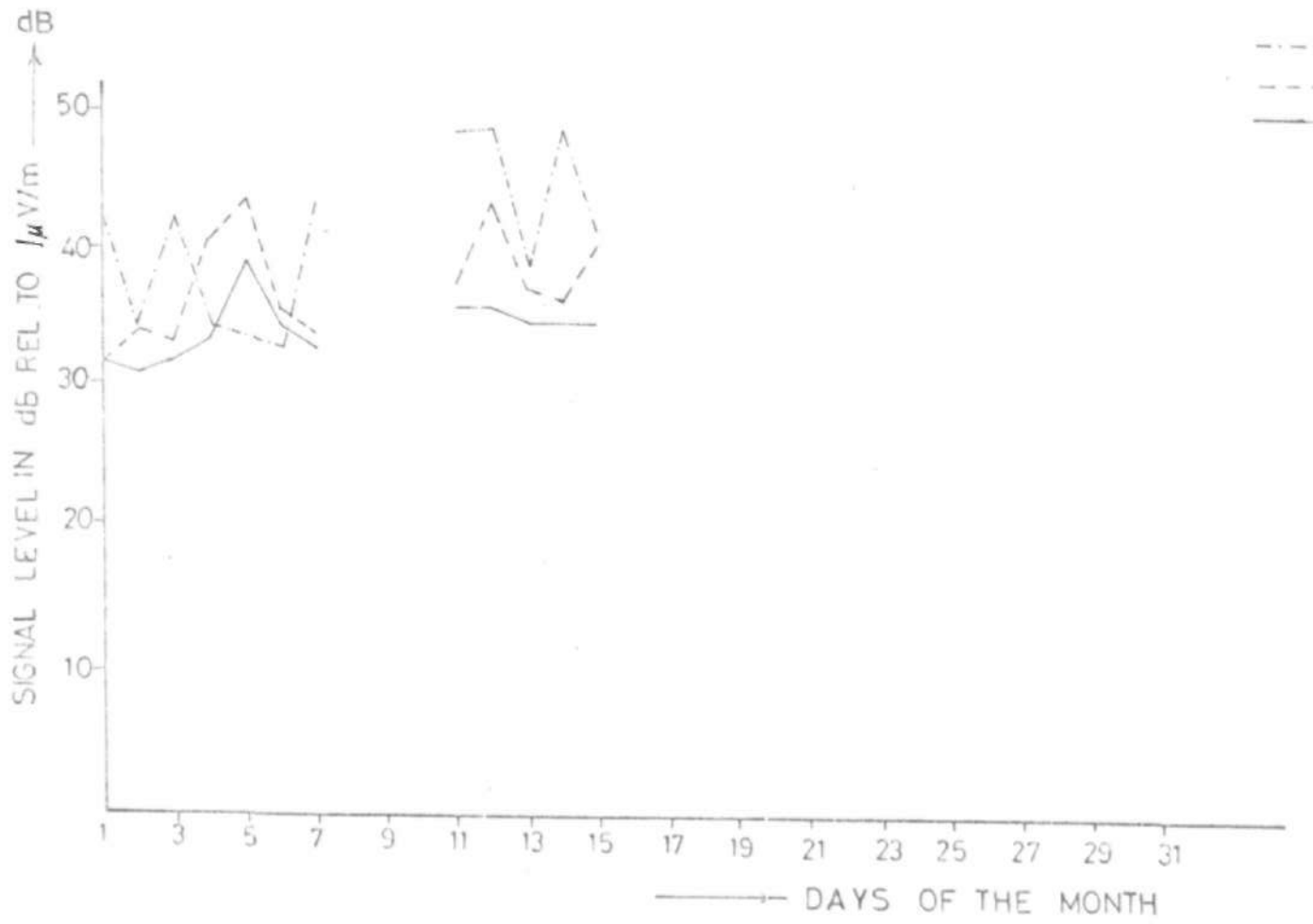
TABLE 4.12

DAILY HOURLY MEDIAN FOR JUNE 1983

Time (P:M) \ Day of Month	1	2	3	4	5	6	7	8	11	12	13	14	15	16	17	18	29
2.00 - 3.00	20.9	20.2	21.9	21.6	21.9	22.4	21.9	22.8									26.9
3.00 - 4.00	20.2	20.3	25.7	21.9	21.9	22.4	21.9	21.4									26.9
4.00 - 5.00	19.9	22.7	23.4	21.9	21.9	21.9	*	*	*	*	21.9	22.9	21.9	26.7	25.9	25.9	26.9
5.00 - 6.00	19.9	22.3	22.2	21.9	21.9	22.3	*	*	*	*	21.2	21.6	21.7	25.9	25.8	26.1	27.1
6.00 - 7.00	23.4	*	26.4	26.7	22.1	22.3	*	*	*	34.7	21.3	19.6	22.0	26.7	27.4	29.6	33.4
7.00 - 8.00	32.4	*	35.4	34.4	34.4	35.4	*	36.2	32.4	35.8	30.7	27.4	29.2	33.4	38.1	36.2	43.7
8.00 - 9.00	33.8	*	37.7	36.9	38.4	34.7	35.2	37.0	34.0	34.1	35.4	32.2	29.4	38.4	39.2	40.4	45.4
9.00 - 10.00	33.7	*	36.2	39.9	37.9	35.5	35.7	36.1	33.9	40.2	36.2	*	33.4	35.4	*	40.4	41.2
10.00 - 11.00	34.4	*	37.7	40.7	37.4	35.9	31.7	27.2	27.5	36.0	35.4	*	32.1	*	40.0	40.2	36.2
11.00 - 12.00	37.9	*	*	40.6	36.7	35.6	26.5	25.7	23.4	36.7	34.7	*	32.1	*	35.8	41.8	37.9

* Missing data

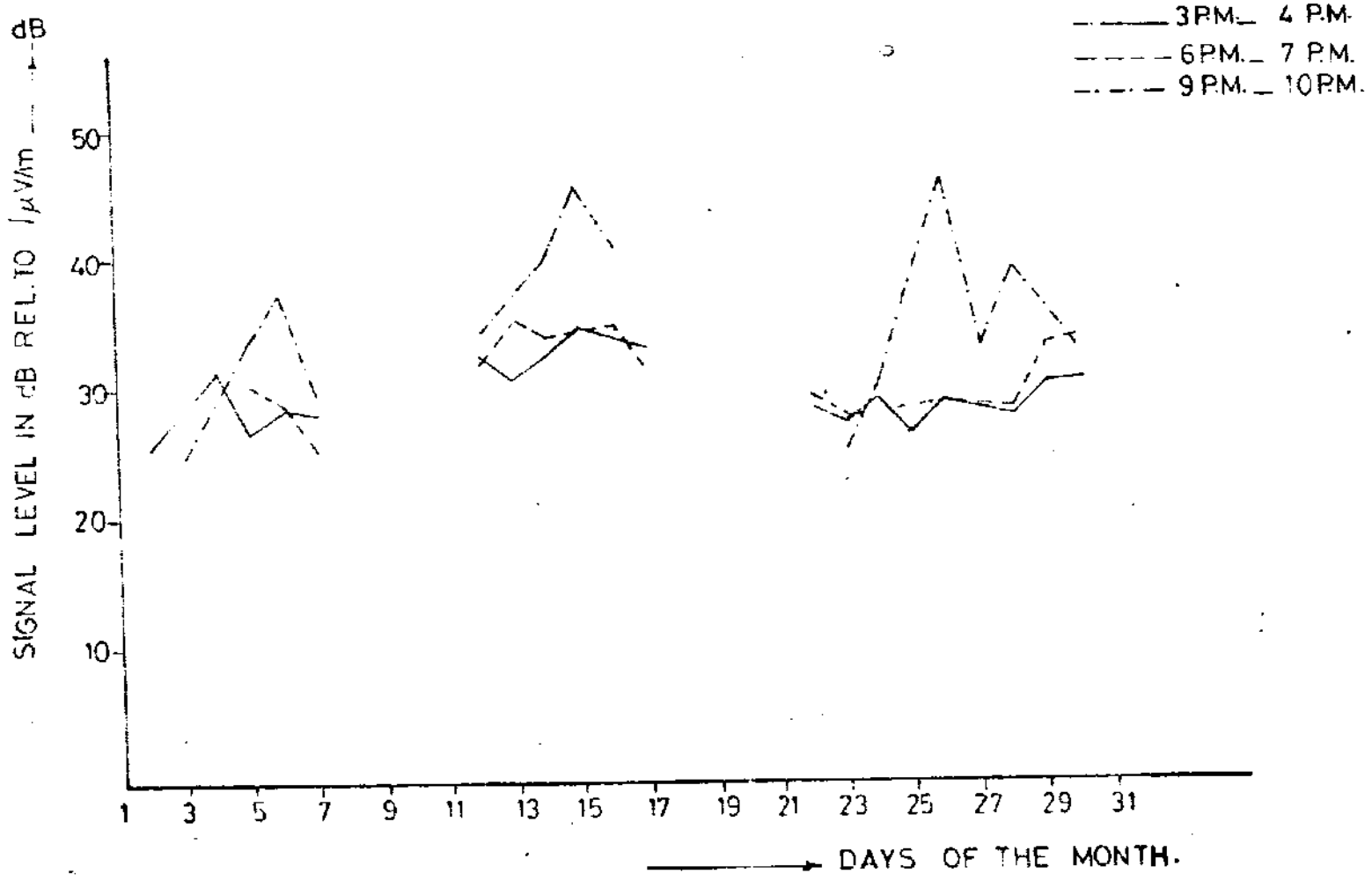
GRAPH 19. DAILY VARIATION OF SIGNAL LEVEL IN JUNE 1982
FOR THE PERIOD 3PM._4PM., 6PM._7PM, 9PM._10PM.



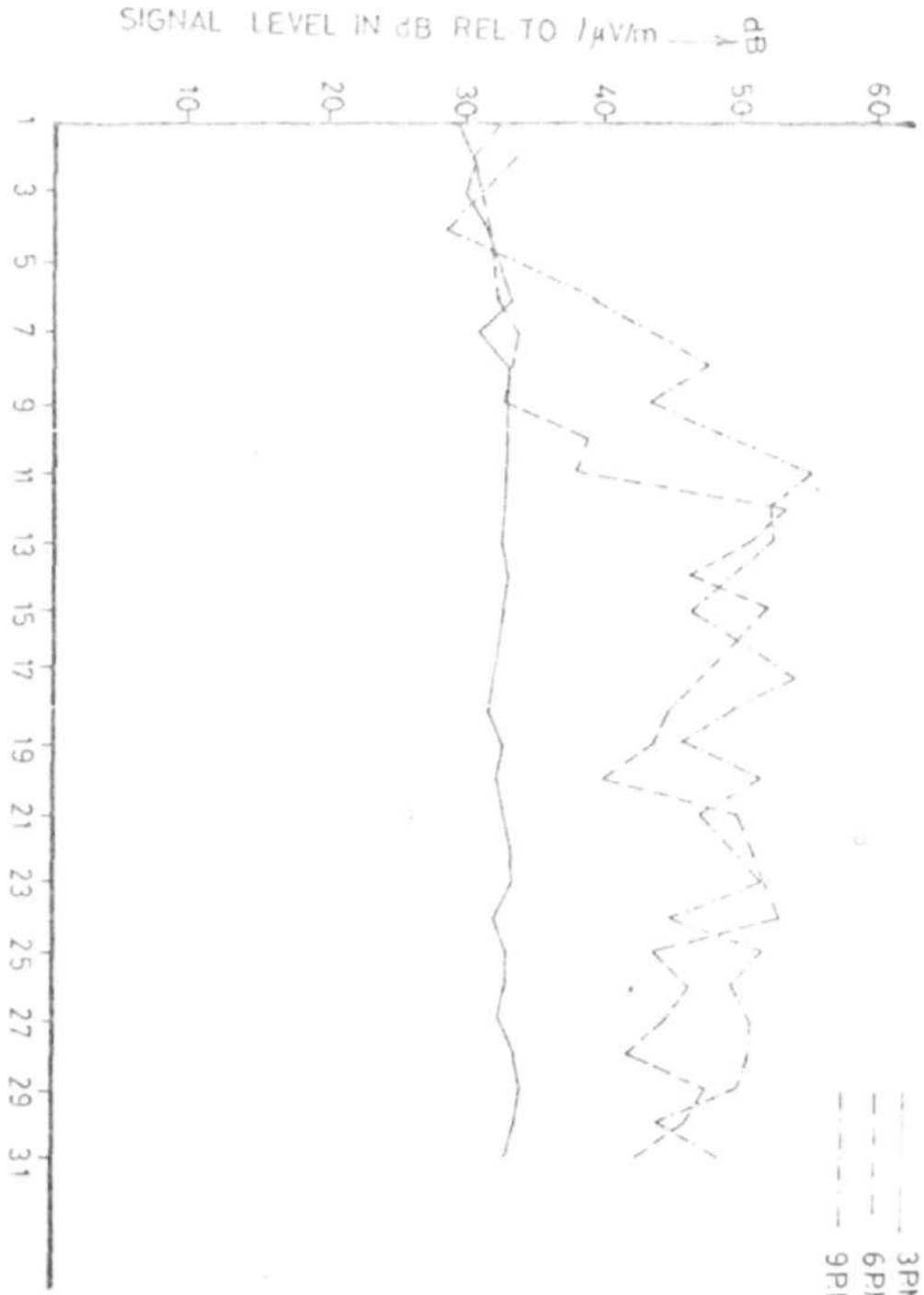
KEY:

-·-·- 9PM._10PM.
- - - 6PM._7 PM.
——— 3PM._4 PM.

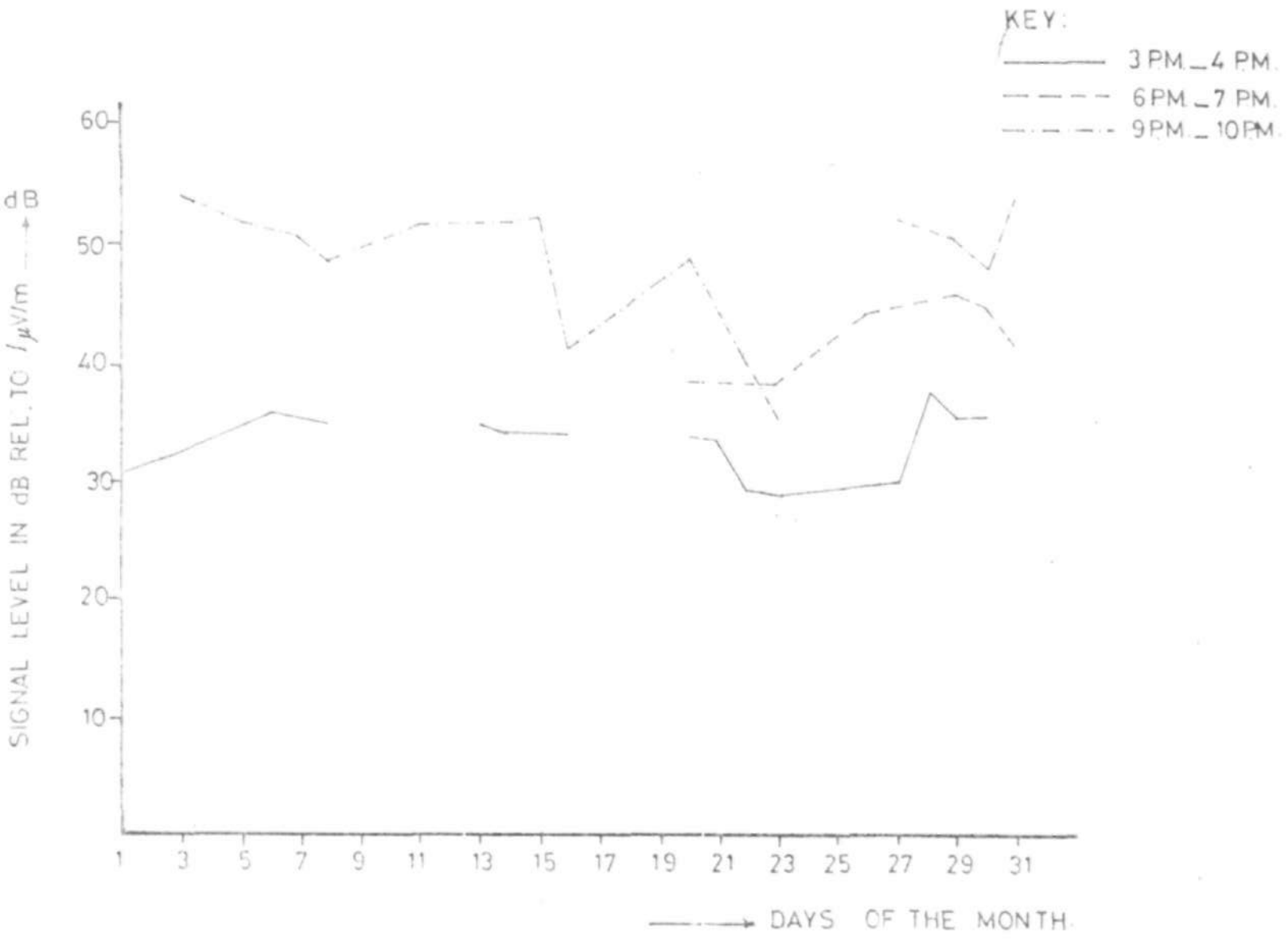
GRAPH 20. DAILY VARIATION OF SIGNAL LEVEL IN NOVEMBER 1982 FOR THE PERIOD 3 P.M._ 4 P.M., 6 P.M._7 P.M.• 9P.M._10P.M.



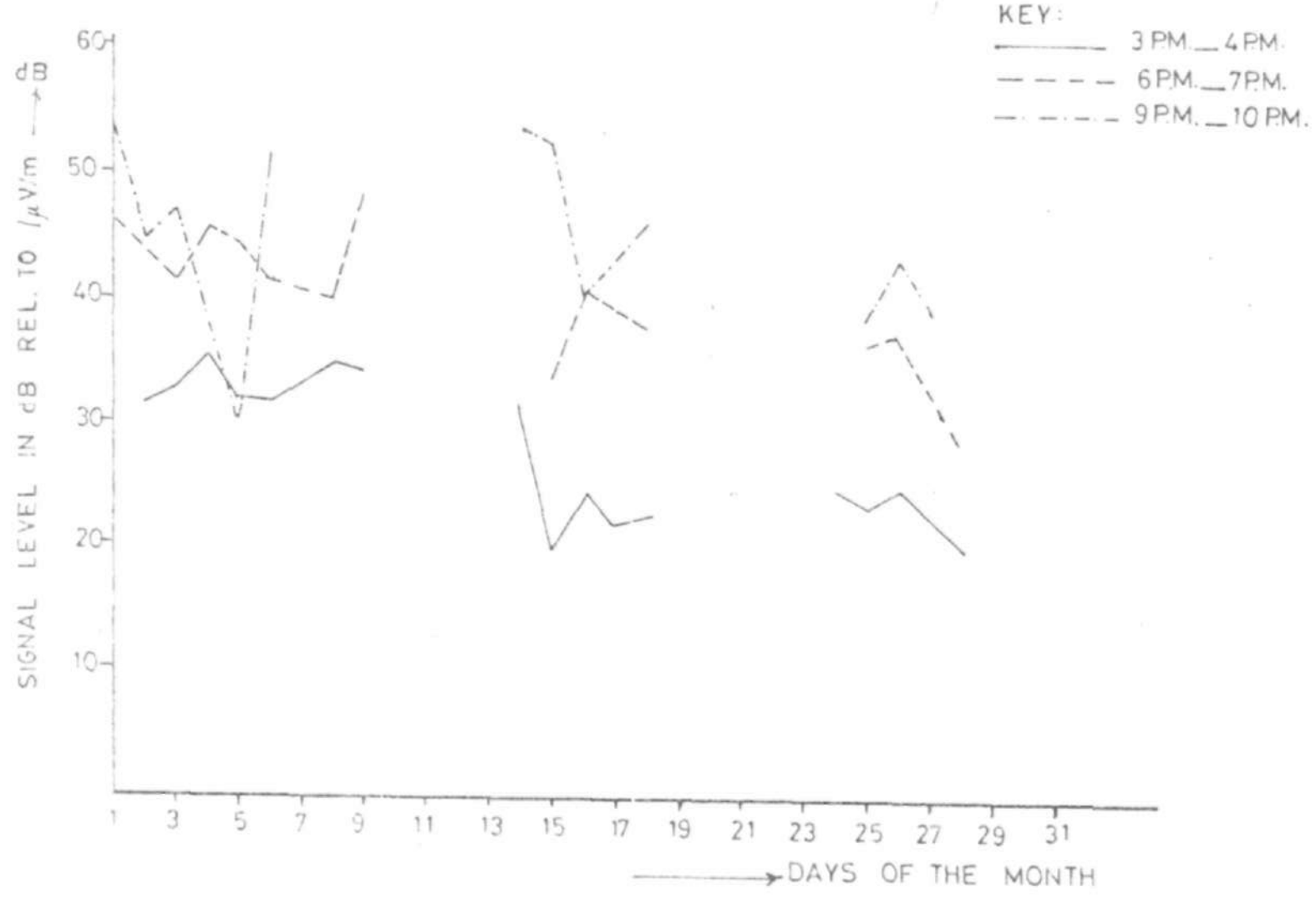
GRAPH 21. DAILY VARIATION OF SIGNAL LEVEL IN DECEMBER 1982
FOR THE PERIOD 3PM_4PM, 6PM_7PM, 9PM_10 PM.



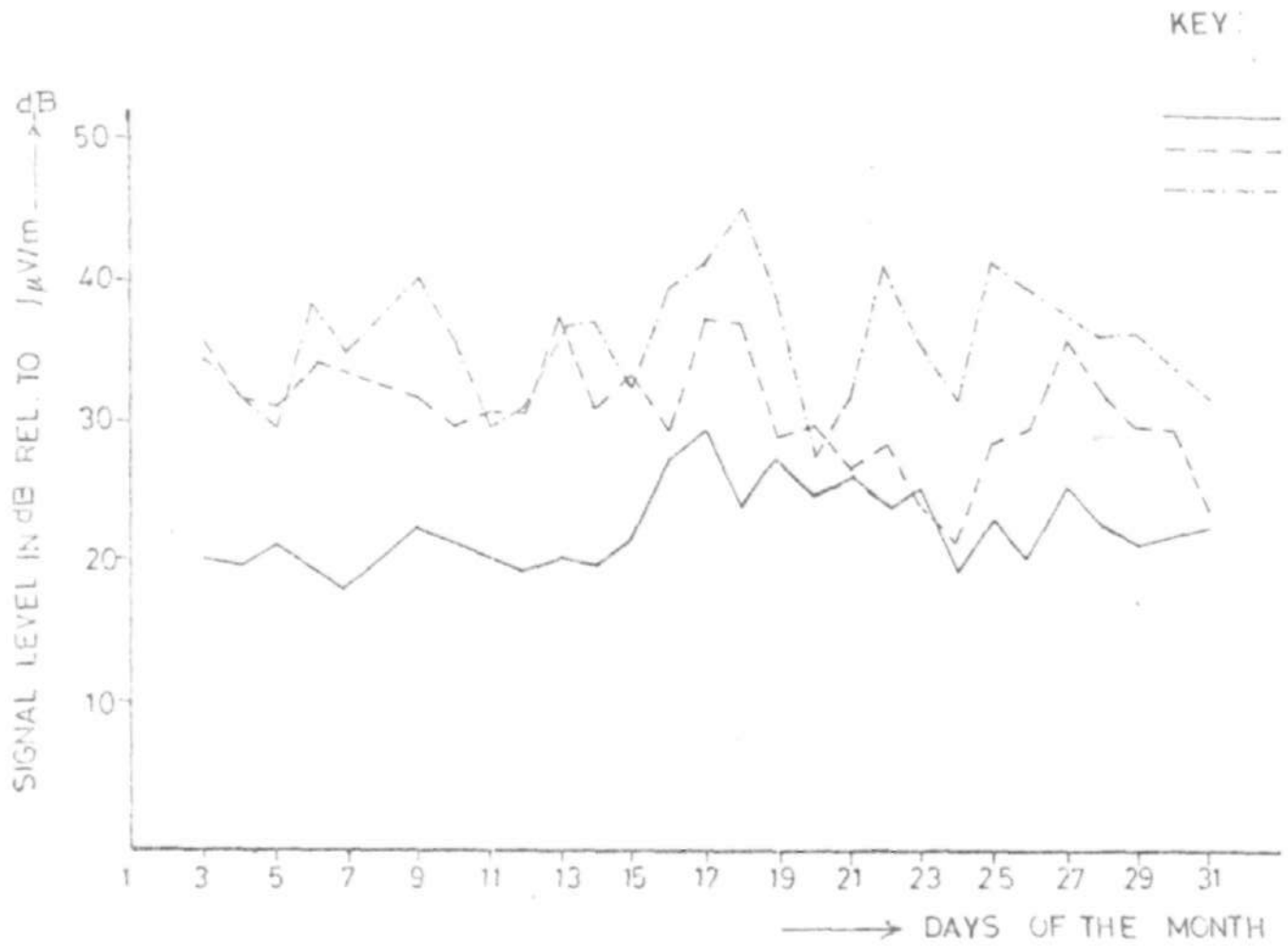
GRAPH 22. DAILY VARIATION OF SIGNAL LEVEL IN JANUARY 1983
FOR THE PERIOD 3 PM_4 PM, 6 PM_7 PM, 9 PM_10 P.M.



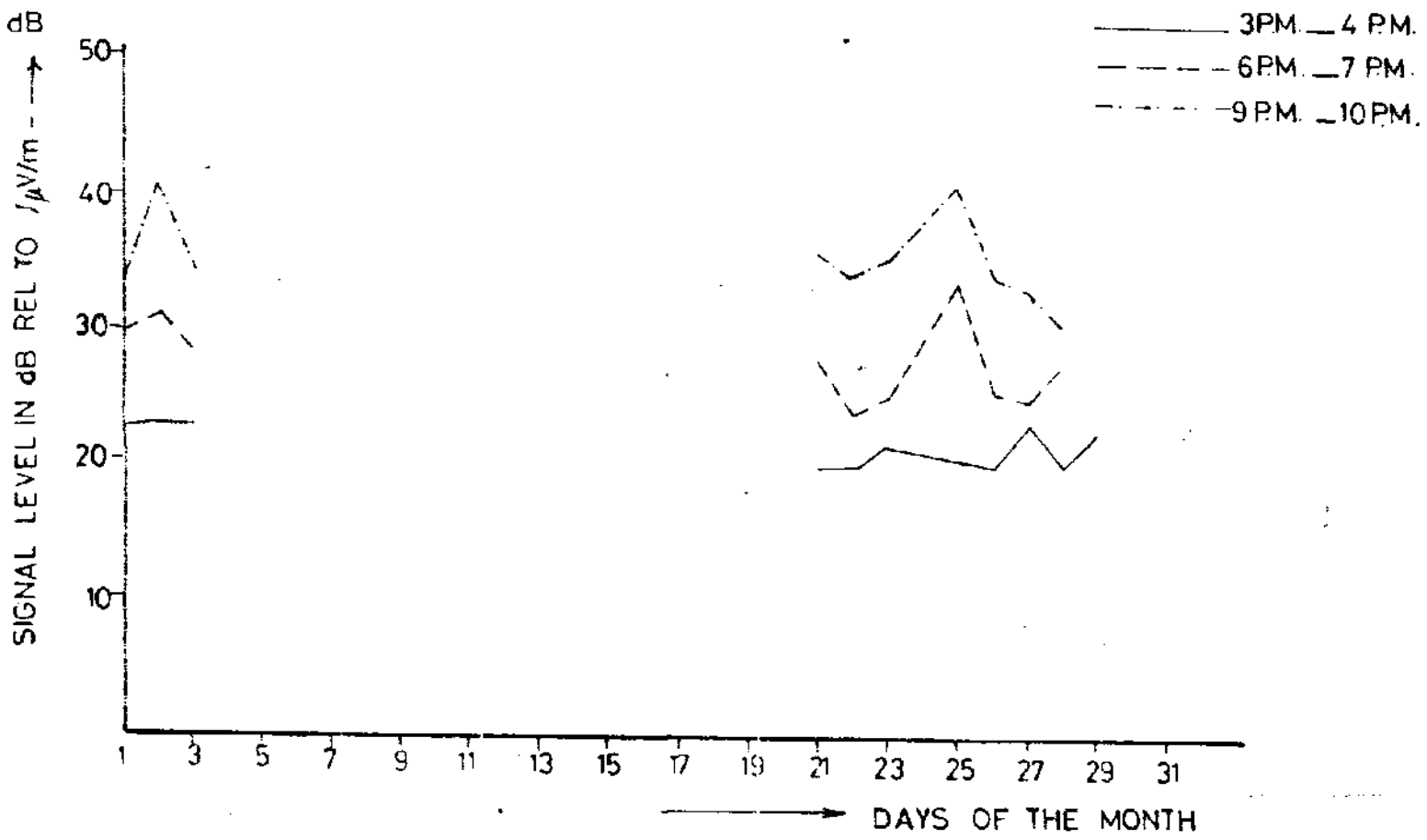
GRAPH 23. DAILY VARIATION OF SIGNAL LEVEL IN FEBRUARY 1983
FOR THE PERIOD 3 P.M._4 P.M., 6 P.M._7 P.M., 9 P.M._10 P.M.



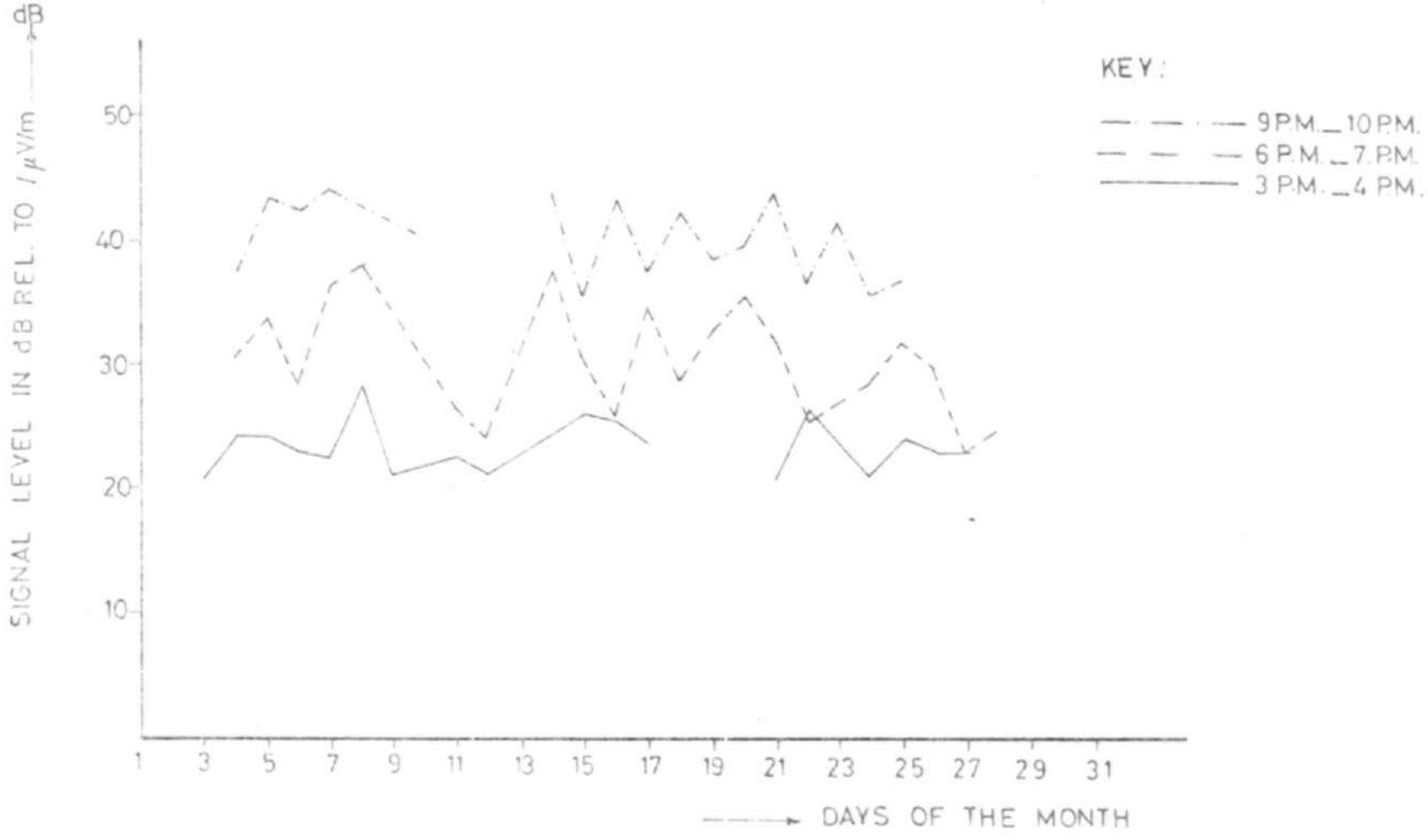
GRAPH 24. DAILY VARIATION OF SIGNAL LEVEL IN MARCH 1983
FOR THE PERIOD 3 P.M._4 P.M., 6 P.M._7 P.M., 9 P.M._10 P.M.



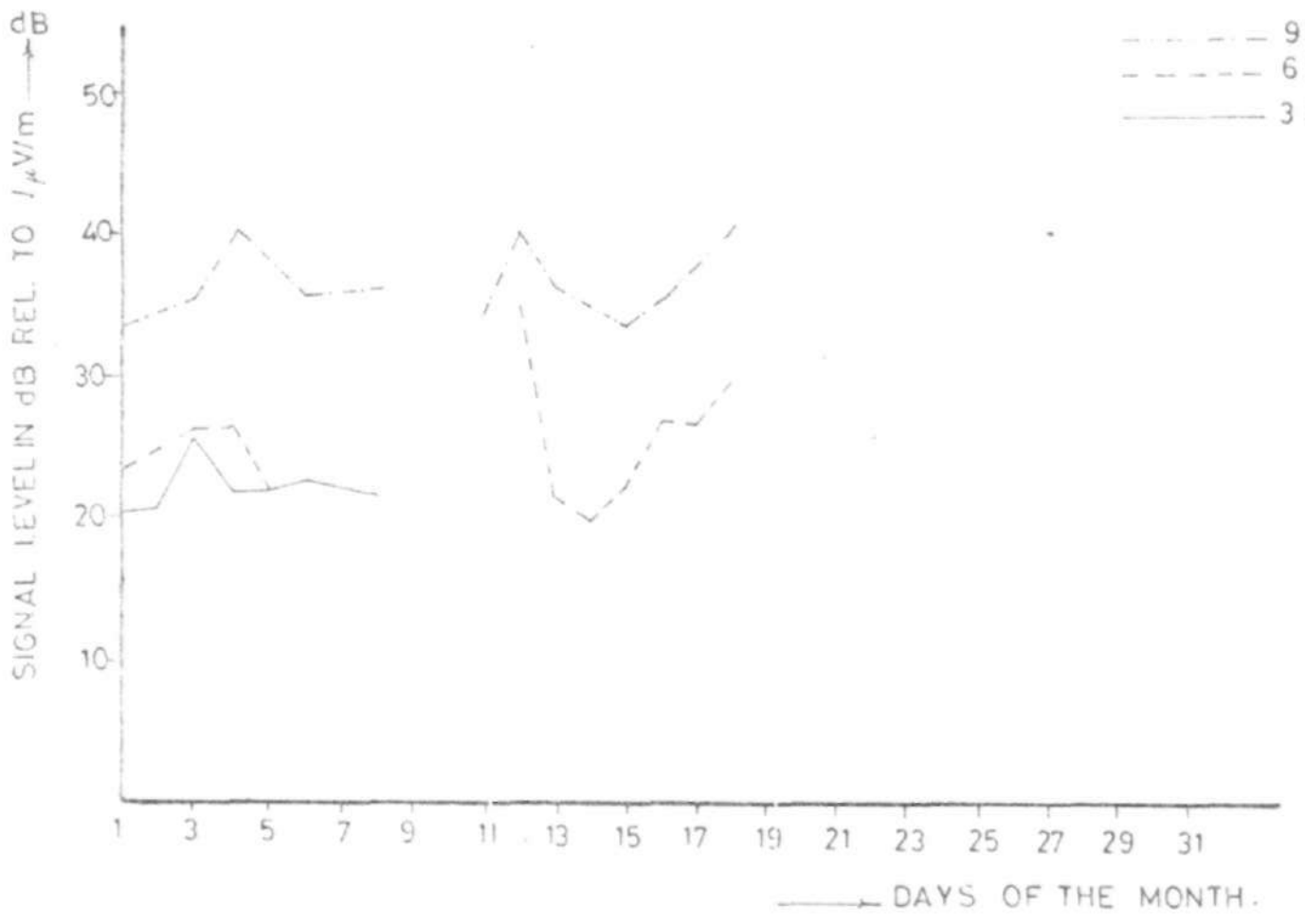
GRAPH 25. DAILY VARIATION OF SIGNAL LEVEL IN APRIL 1983
FOR THE PERIOD 3PM._4PM, 6PM_7PM.,9PM_10PM.



GRAPH 26. DAILY VARIATION OF SIGNAL LEVEL IN MAY 1983
FOR THE PERIOD 3 P.M._4 P.M., 6 P.M._7 P.M., 9 P.M._10 P.M.

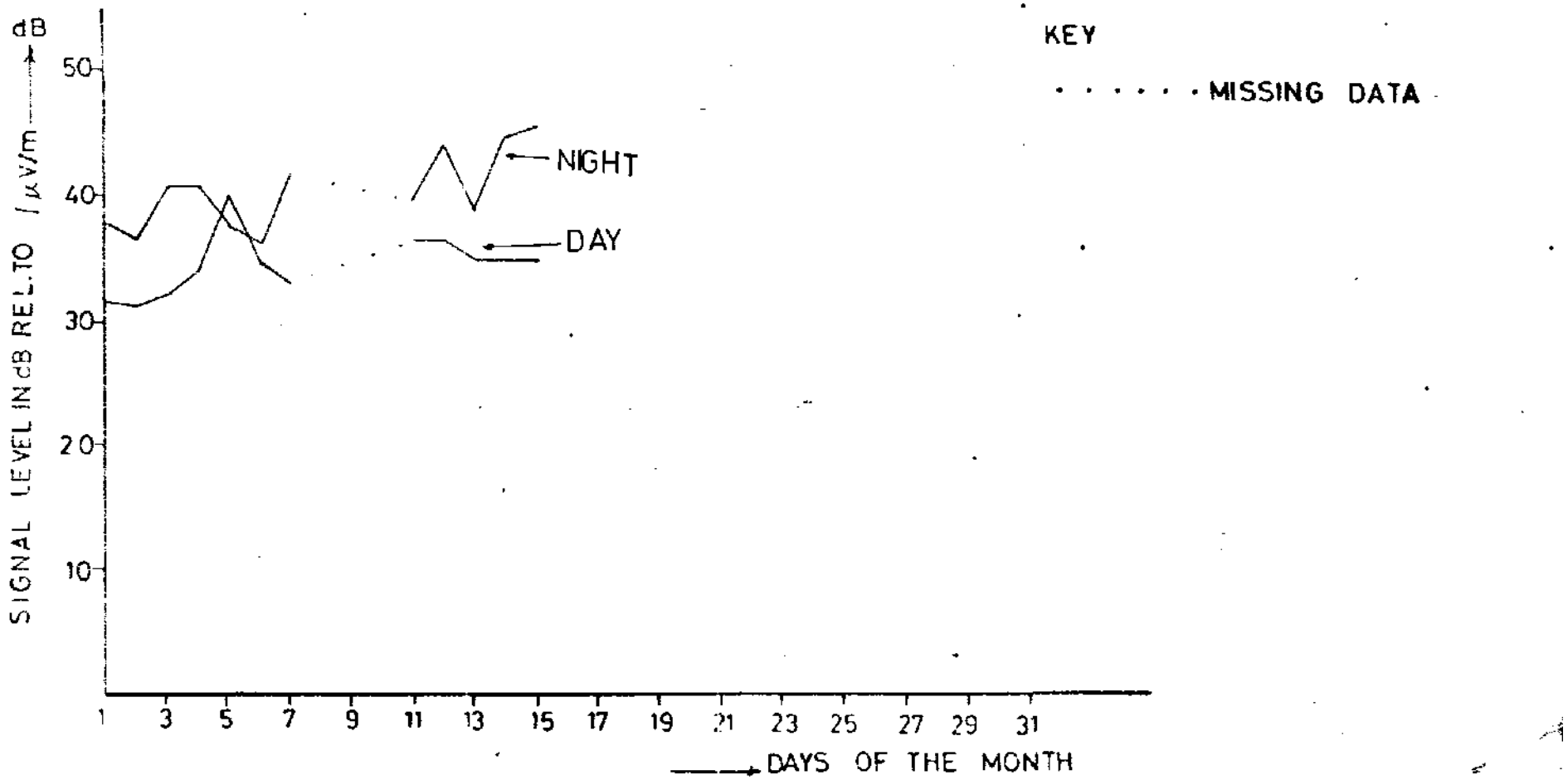


GRAPH 27. DAILY VARIATION OF SIGNAL LEVEL IN JUNE 1983
FOR THE PERIOD 3 P.M._4 P.M., 6 P.M._7 P.M., 9 P.M._10 P.M.

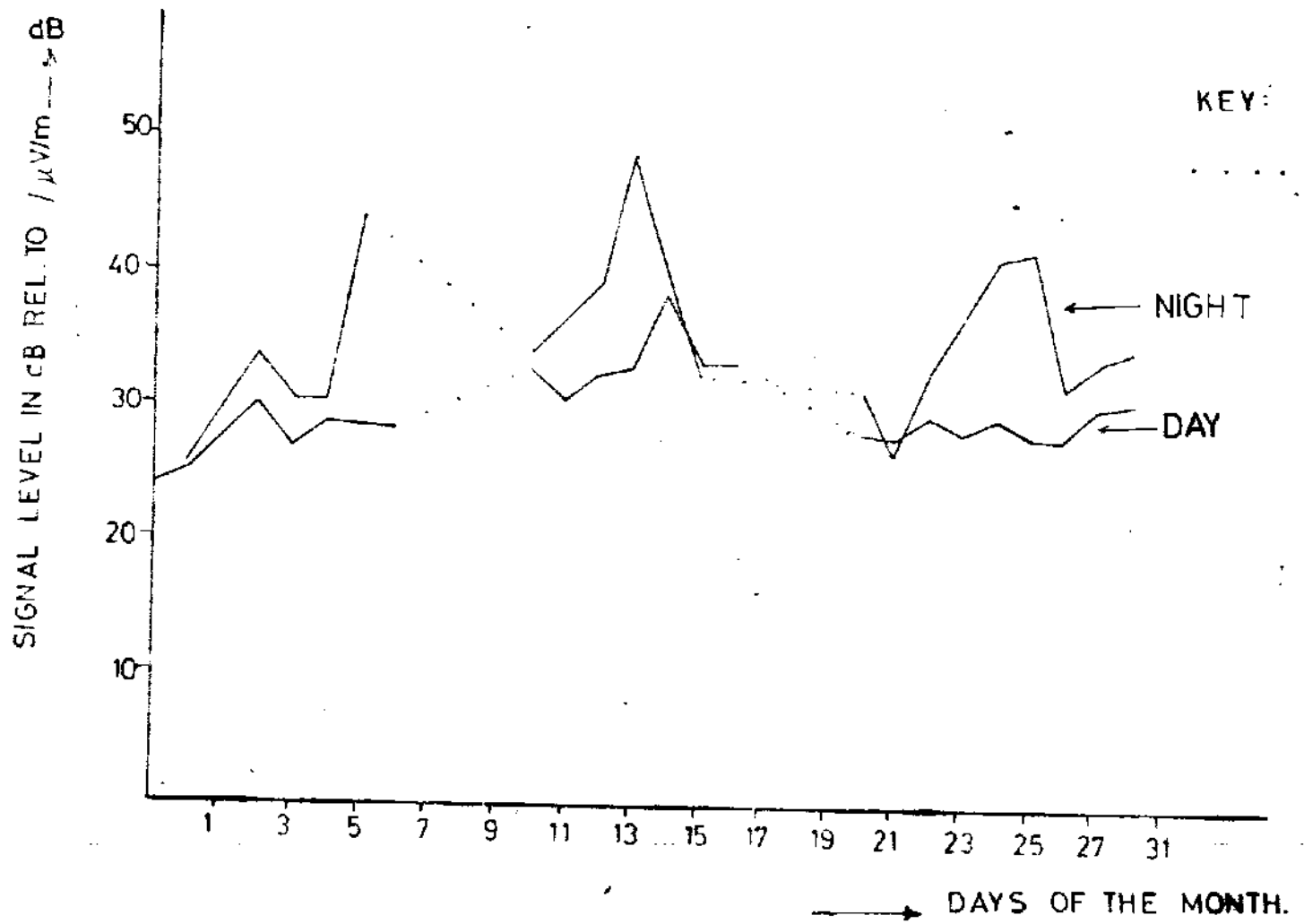


* Missing data

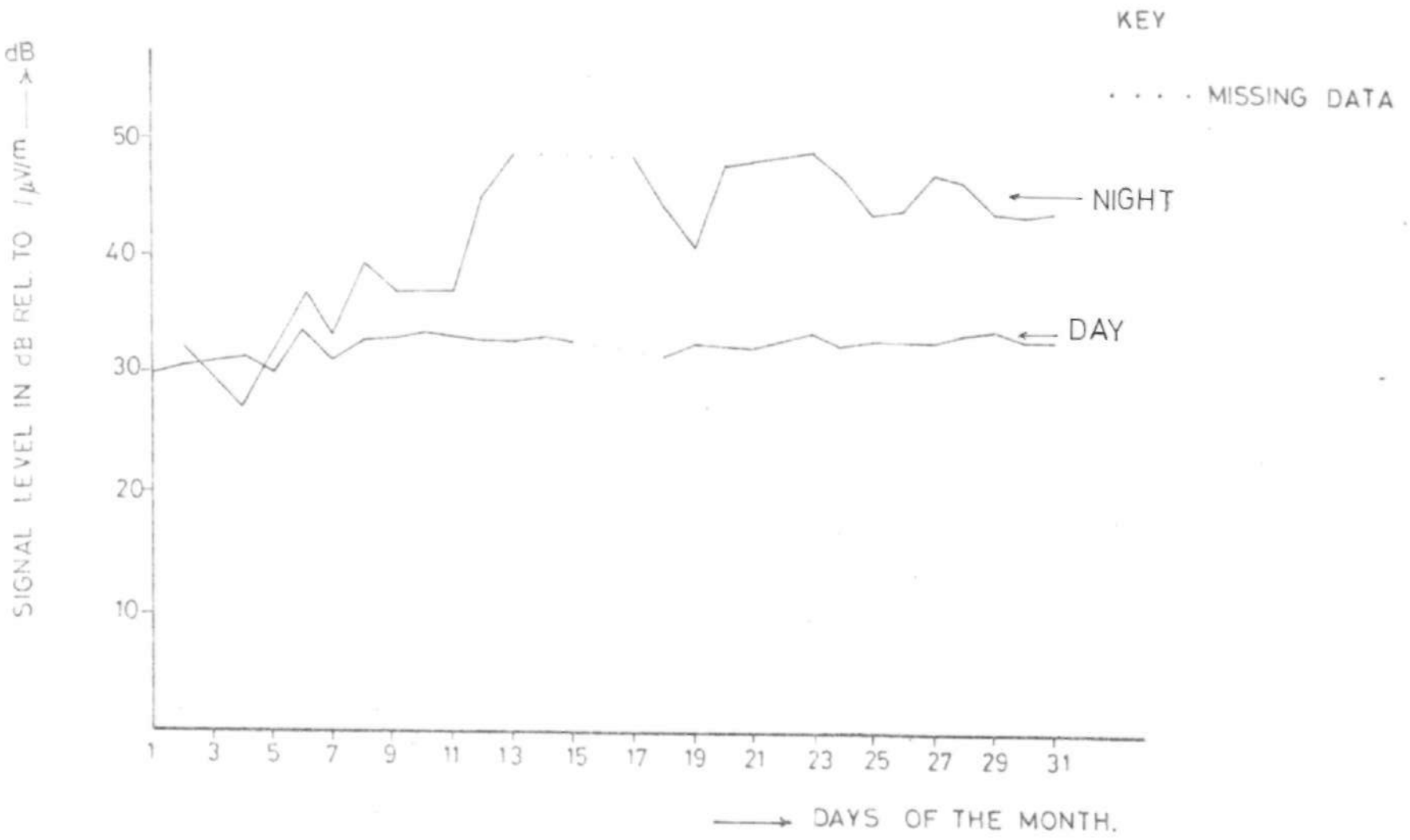
GRAPH 28. DAILY DAY AND NIGHT MEDIANS OF SIGNAL LEVEL IN JUNE 1982



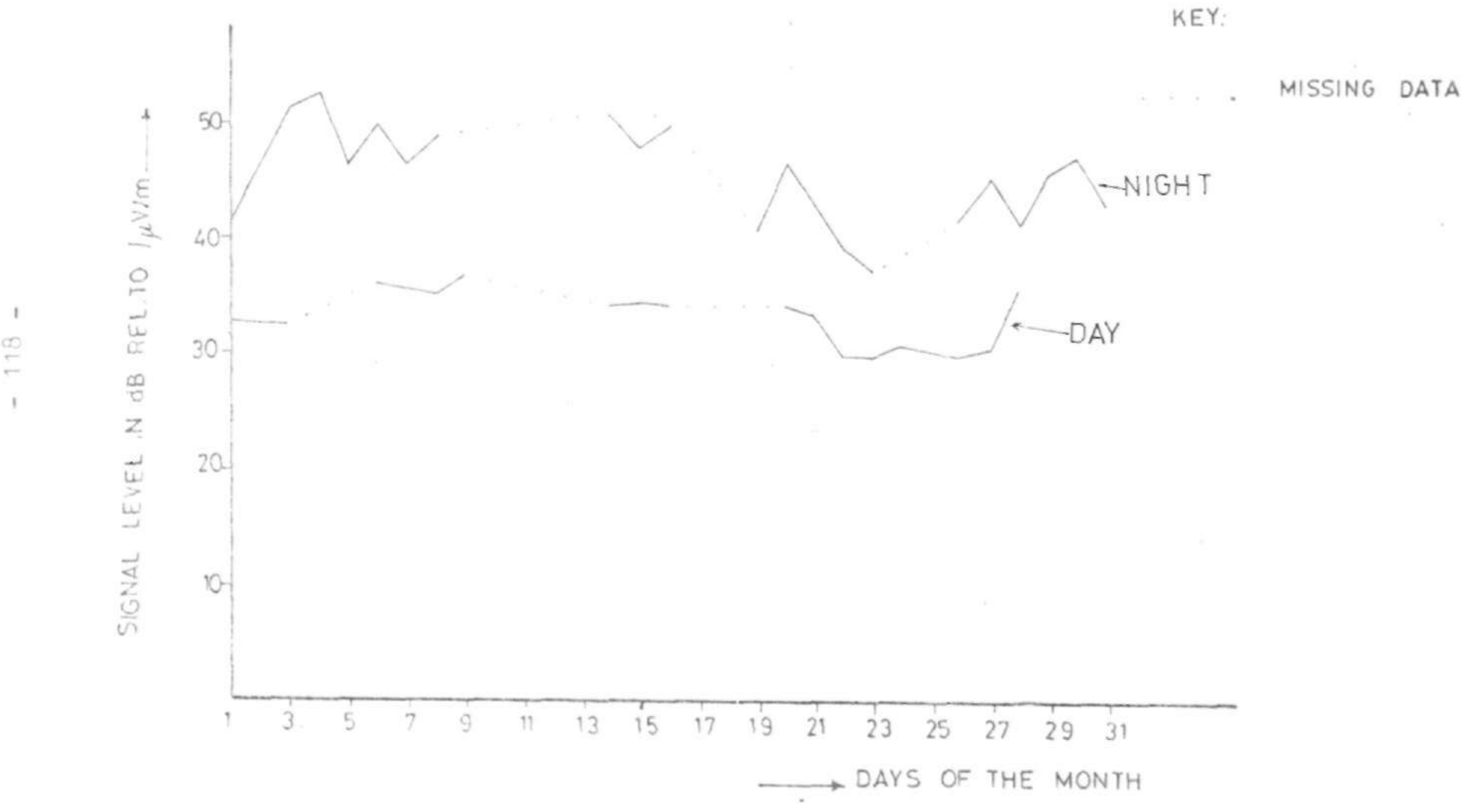
GRAPH 29. DAILY DAY AND NIGHT MEDIANS OF SIGNAL LEVEL IN NOVEMBER 1982



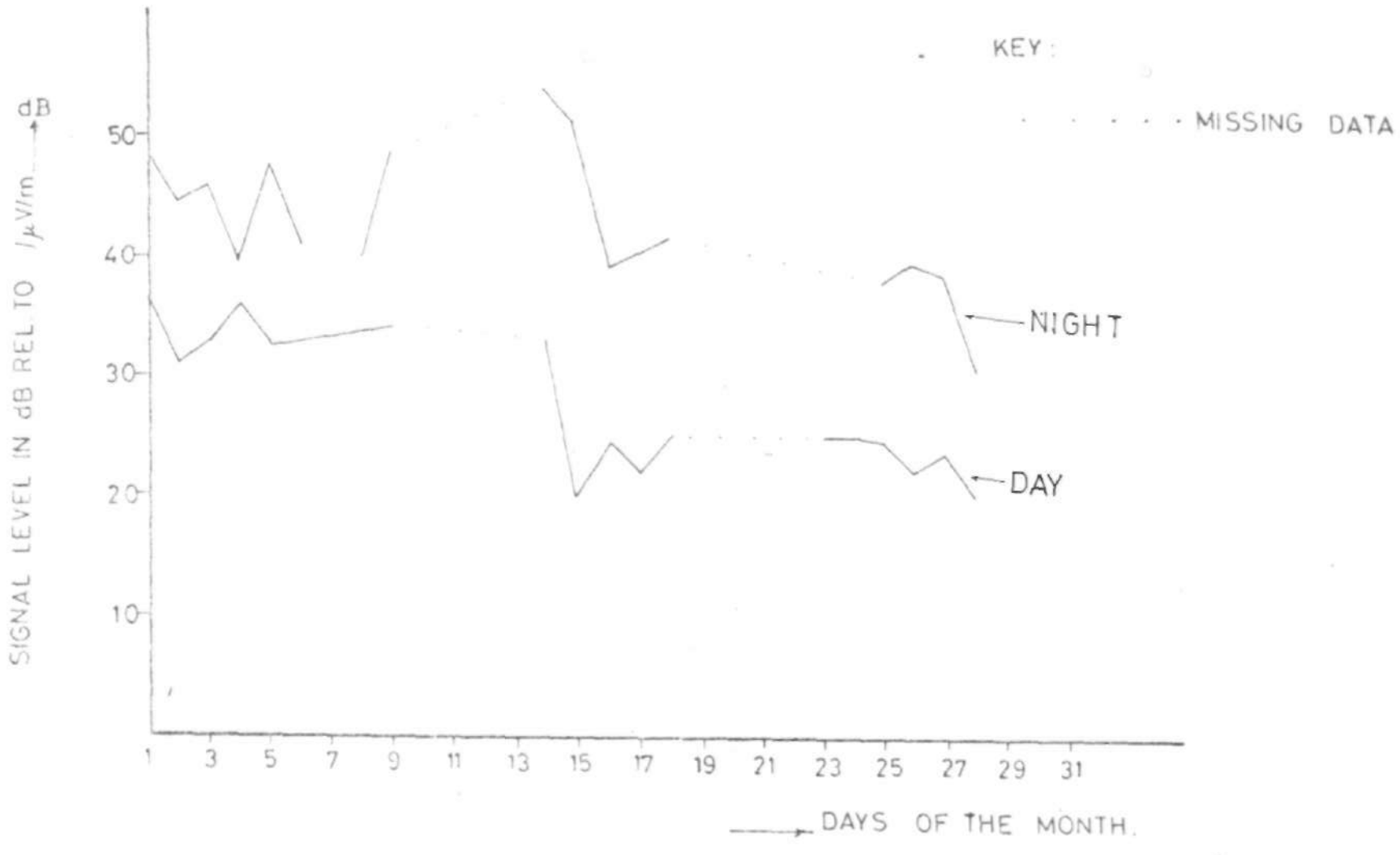
GRAPH 30. DAILY DAY AND NIGHT MEDIANS OF SIGNAL LEVEL IN DECEMBER 1982



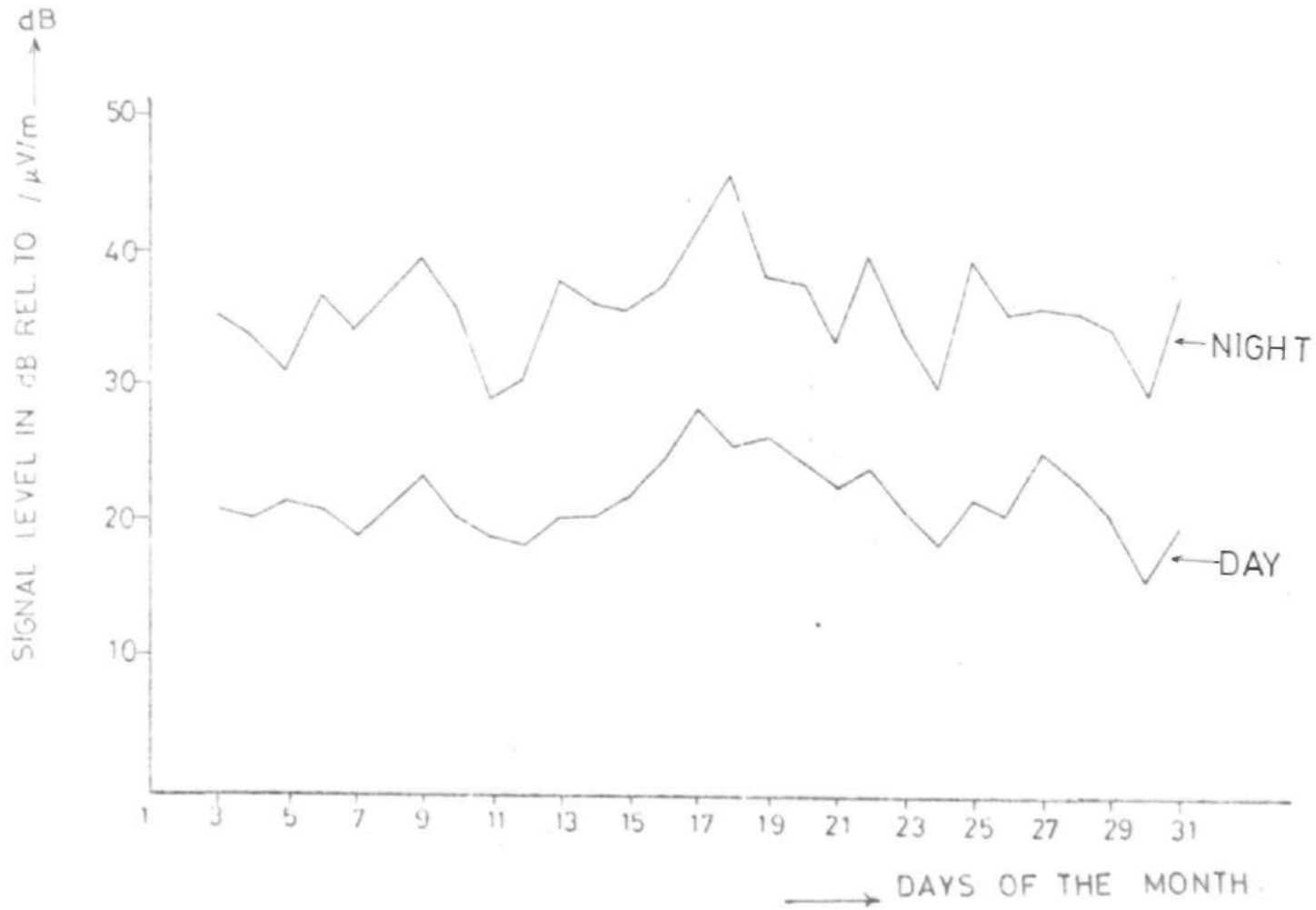
GRAPH 31. DAILY DAY AND NIGHT MEDIANS OF SIGNAL LEVEL IN JANUARY 1983



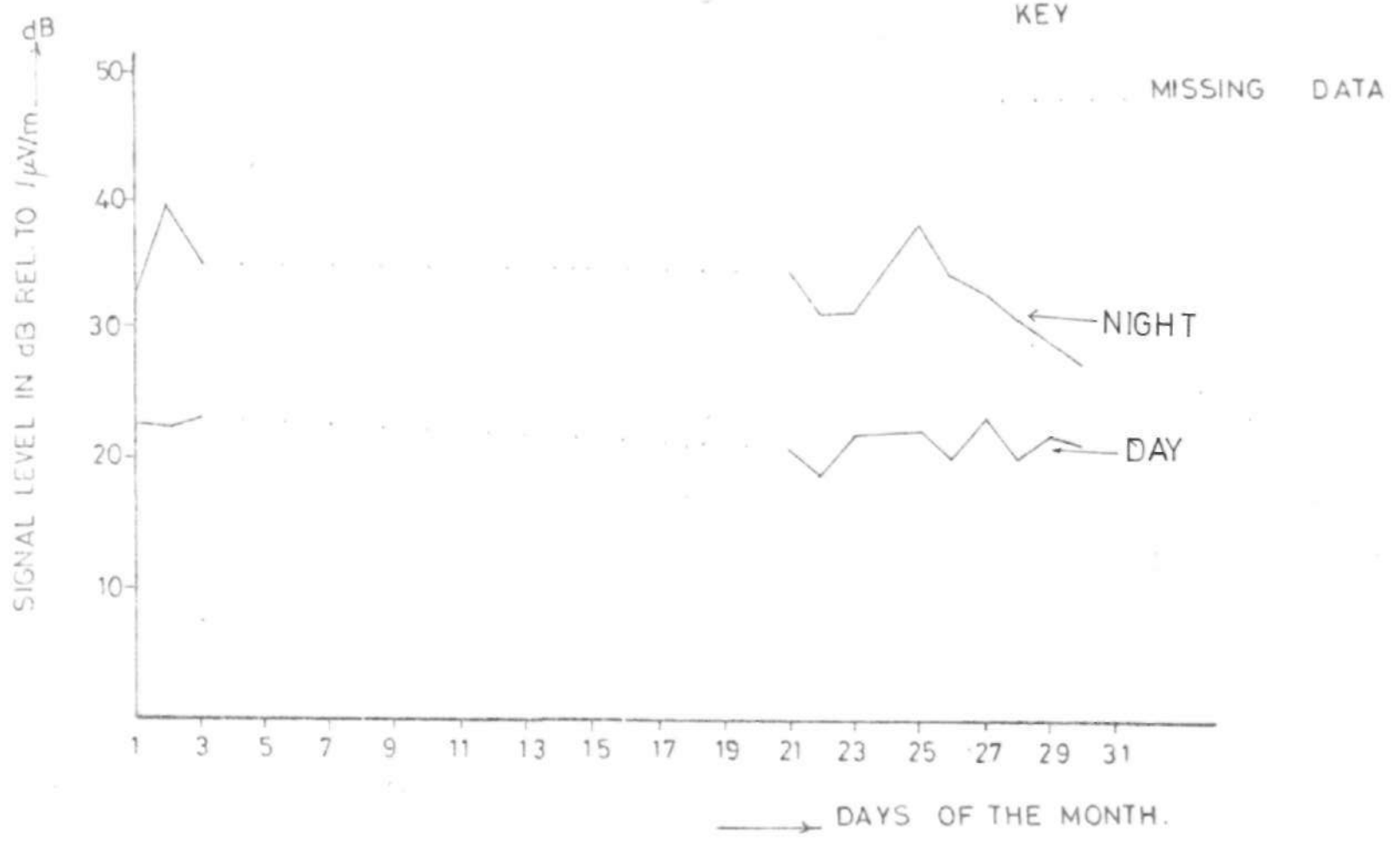
GRAPH 32. DAILY DAY AND NIGHT MEDIANS OF SIGNAL LEVEL IN FEBRUARY 1963



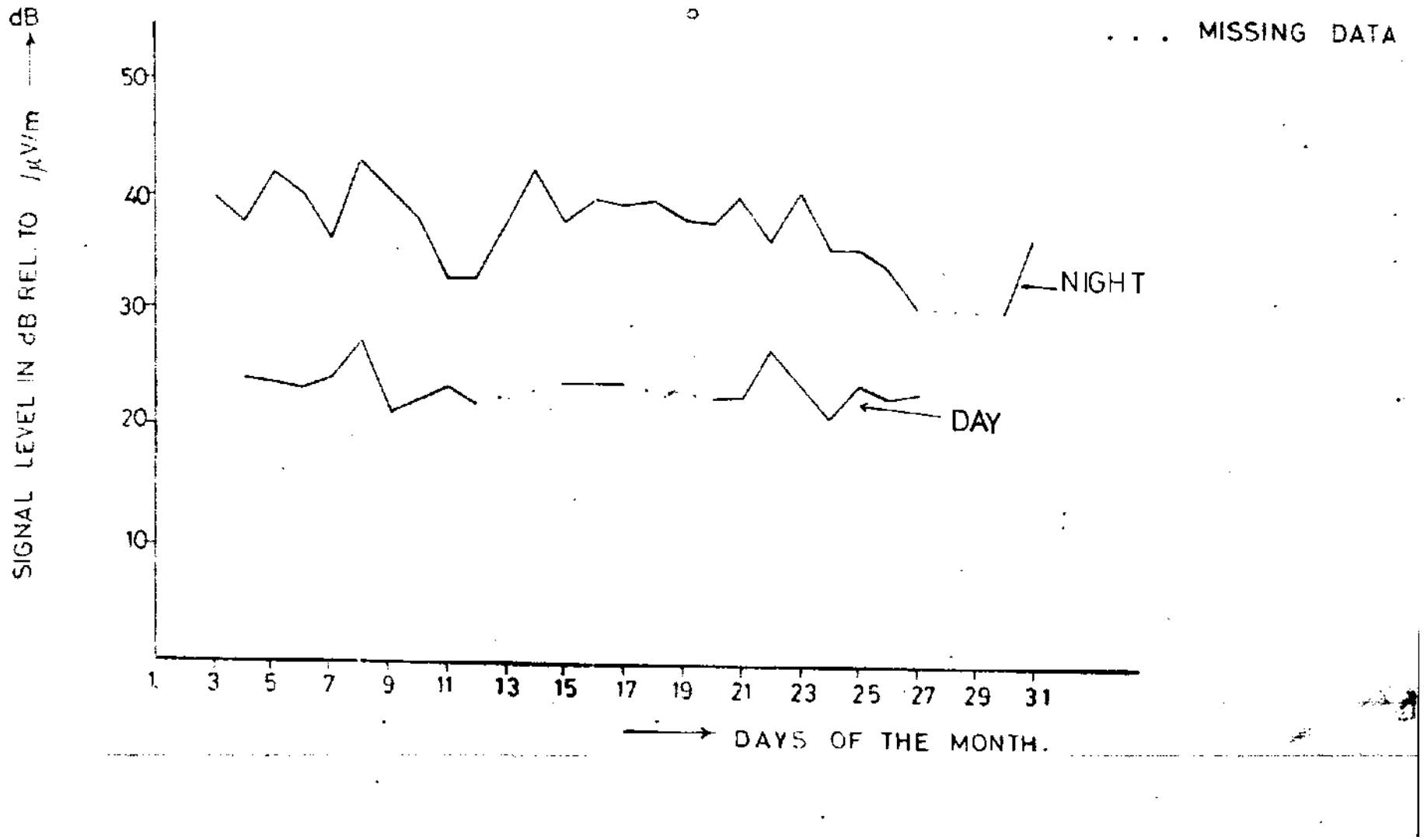
GRAPH 33. DAILY DAY AND NIGHT MEDIANS OF SIGNAL LEVEL IN MARCH 1983



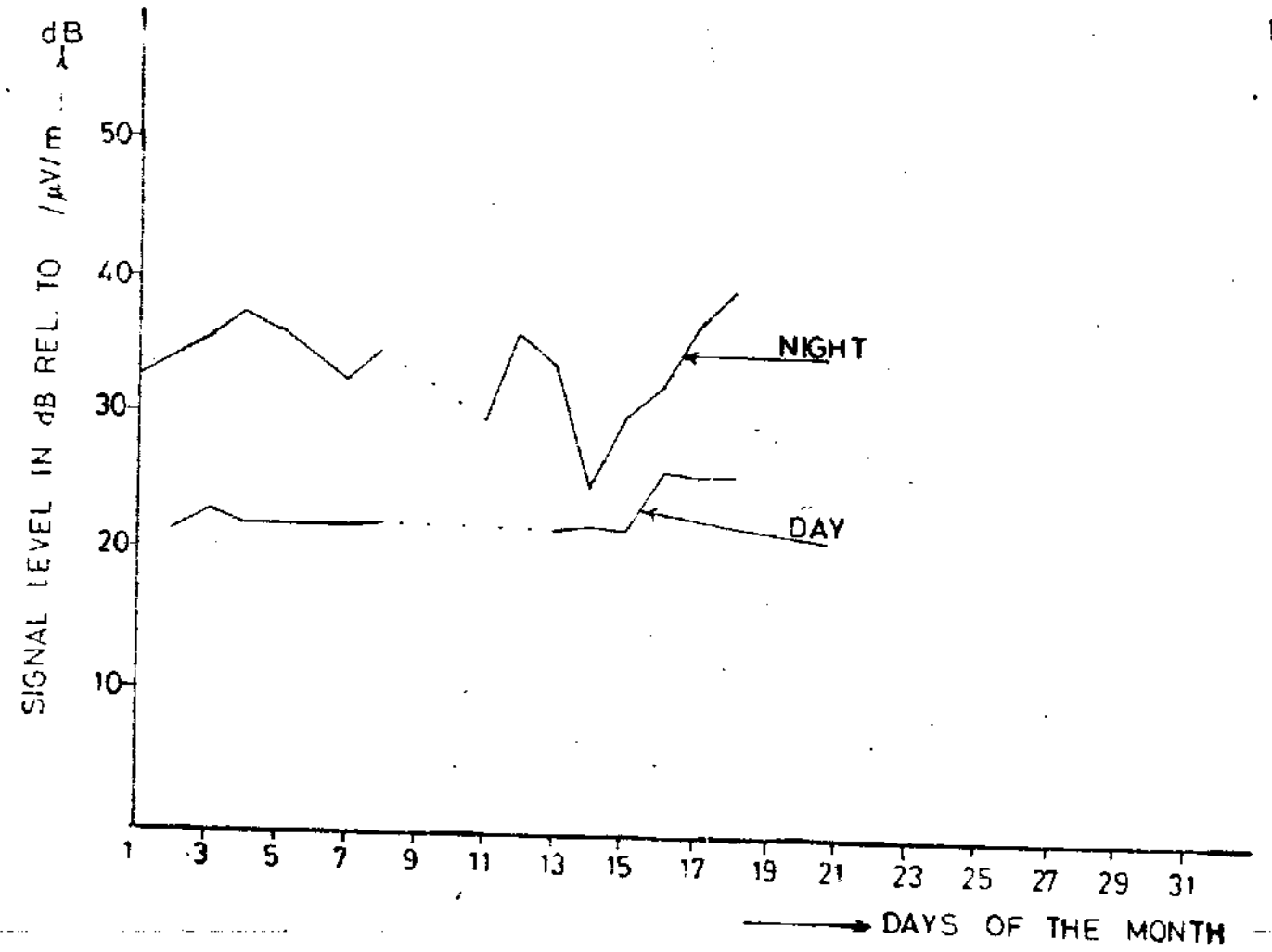
GRAPH 34. DAILY DAY AND NIGHT MEDIANS OF LEVEL IN APRIL 1983



GRAPH 35. DAILY DAY AND NIGHT MEDIANS OF SIGNAL LEVEL IN MAY 1983



GRAPH 36 : DAILY DAY AND NIGHT MEDIANS OF SIGNAL LEVEL IN JUNE 1983



Appendix II

Appendix 2

Computer Programs

A2.1 Program for Data Conversion

This program, named program One standardizes the raw data.

1. If finds the mean of the two values of Median values read from the analog data.

2. It normalises the signal level to effective radiated power of 1 KW.

The example given here is for the month of January 1983. The input file (Jan '83) contains the raw data. The output file is named JANINP (JANuary INPut). After running the program, JANINP will be created containing the normalised data and this serves as the input for the SPSS program.

In the program L1 and L2 are the two median values read, N is the number of days data was recorded. N changes for each month.

A2.2 Program for Finding Daily Median

This program finds the median of a set of data for 1 day. It is called daily median. It is run in a statistical package called SPSS - Statistical Package for the Social Sciences. Each line has two parts.

```
      PROGRAM CONV(INPUT,JANUARY,TAPE22=JANUARY,TAPE23=JANUARY)
      DIMENSION X1(31),Y1(31),RON1(31),X2(31),Y2(31),RON2(31)
      LOGICAL DEBUG
      DATA DEBUG /.FALSE./
      N=28
    5 CONTINUE
C     READ DATA AT A TIME OF ONE
      READ(INPUT=200,5,END=10) ID,(X1(I),Y1(I),I=1,N)
   15 FORMAT(1H ,1X,I2(I2,1X,I2,1X)/I2(I2,1X,I2,1X))
      IF(DEBUG) WRITE(6,20) ID,(X1(I),Y1(I),I=1,N)
   20 FORMAT(1X,'ADJUST'/1(I2,1X,I2,1X,I2(I2,A,I2,1X)/8(I2,1X,I2,1X,I2,1
C     FIND MEAN OF RADIANS AND RADIUS
      DO 40 J=1,N
      RON1(J)=(X1(J)+Y1(J))/2
      IF(RON1(J).LT.0.) RON1(J)=RON1(J)+2.*3.14159
      IF(RON1(J).EQ.0.) RON1(J)=0.
   40 CONTINUE
      WRITE(5,200) ID,(RON1(I),I=1,N)
  200 FORMAT(1X,I2,1X,I2F6.1/(1X,10F6.1))
      GO TO 5
   10 STOP
      END
```

Fig. A2.1 Program for Data Conversion

Fig A2.2 Program for finding

Fig. A2.2 Program for Finding Da

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ERSION 6.5J  ON APRIL 1, 1976


          RUN NAME          AFOLABI'S P
          PAGESIZE          NOEJECT
          FILE NAME         JAN83 DATA
          VARIABLE LIST     HOUR,DAY1,D
                            DAY19 TO DA
          INPUT MEDIUM      DISK
          INPUT FORMAT      FIXED(1X,F6
          N OF CASES        UNKNOWN
          MISSING VALUES    DAY1 TO DAY
          FREQUENCIES       GENERAL=ALL
          STATISTICS        ALL
          READ INPUT DATA

EOJECT

          FINISH
```

The first part is the control field and it starts on column 1. The second part is the specification field and starts from column 16. A complete description of SPSS is found in the SPSS manual reference 11.

A2.3 Program Transforming Data into a Column Matrix

This program is used to transform data into a column matrix for analysis. It is a Fortran program named program Two. The input data of an SPSS program is such that all the data of a particular variable is in the same column. The input into this program is the output of program One. For example, in the month of February, the output is named FEBCINP (FEBruary Column INPut). The program reads all the data at the input and writes it out in a column matrix by means of a write format.

HOUR is the number of rows in the data, N is the number of days reading was taken. The example shown is for the month of February 1983. This program transforms all the data of this month into a column matrix to find the median of the month.

The program is also used to transform all the data in a particular hour into a column matrix to find the median of that hour. For this run, the input file has to be edited in such a way that only the data in a particular hour remains. All the other hours are appropriately deleted. For example, to find the hourly median for the period 4.00 p.m. - 5.00 p.m.

```
1.    0000018          *
2.    0041218          PROGRAM TWO(FEBINP
3.    0041218          DIMENSION COL(9)5)
4.    0257238          N=19
5.    0257248          I=1
6.    0257258       30 CONTINUE
7.    0257368          READ (END=100,5,40
                       CHANGE TO COLUMN
8.    0257368          DO 50 J=1,N
9.    0257468          COL(I)=AOUR(J)
10.   0257418          I=I+1
11.   0257428       50 CONTINUE
12.   0257448          GO TO 30
13.   0257448      100 WRITE(6,30) (CO_(K)
14.   0257558       40 FORMAT(1X,F6.2)
15.   0257558          STOP
16.   0257568          END
```

Fig. A2.3 Program Transforming Data Int

data for the hours 2.00 p.m. - 4.00 p.m. and 5.00 p.m. - 12 midnight have to be deleted leaving only the hour of interest. This procedure has to be done for each hourly median evaluated for a particular month.

A2.4 Program for Finding Monthly, Seasonal and Annual Medians

This program is similar to that of A2.2. The differences are as follows: The variable list is changed to MONTH since only one median is to be evaluated. The Format is changed to read only one value for each line. This program is run each time the monthly median of any particular month is to be evaluated.

The same program is used to find the seasonal and annual medians except that the input differs. The output of program One for each of the months making up a season (Dry or Wet) or for the period of measurement have to be appended and converted into a column matrix with A2.3. The output after this run is now the input of A2.4 to evaluate a seasonal or annual median.

A2.5 Program for Finding Day and Night Medians

This program is similar to A2.2 for finding the daily median except that two additional statements are

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VERSION 6.51 OF APRIL 1, 1975


          RUN NAME          AFQ_ABI'S PROJECT
          PAGESIZE          NOEJECT
          FILE NAME         MONTH DATA
          VARIABLE LIST     DAYS
          INPUT MEDIUM      DISK
          INPUT FORMAT      FIXED(1X,F6.2)
          N OF CASES        UNKNOWN
          MISSING VALUES    DAYS(-1)
          FREQUENCIES       GENERAL=ALL
          STATISTICS        ALL
          OPTIONS           5,8
          READ INPUT DATA
          FINISH
```

Fig.A2.4 Program for Finding Monthly, Seasonal and Annual Medians

included,

1. A SUBFILE LIST statement to divide each day into 1 hour slots.
2. A RUN SUBFILES statement to run the subfiles singly or in groups. Further information on this process is available in the SPSS manual pages 67 - 69.(11) The run subfiles card is written such that it evaluates two medians for a particular day. One for the DAY and the other for the NIGHT.

Fig. A2.5 Program for Finding Day and Night Medians

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 RUN NAME          AFOLABI'S PROJECT
 PAGESIZE          NOEJECT
 FILE NAME         MAR83 DATA
 VARIABLE LIST     HOUR,DAY3 TO DAY7,DAY9 TO DAY31
 SUBFILE LIST      T14TO15 (30),T15TO16 (30),T16TO17 (30),T17TO18 (30),T18TO19 (30)
                   T19TO20 (30),T20TO21 (30),T21TO22 (30),T22TO23 (30),T23TO24 (30)
 INPUT MEDIUM      DISK
 INPUT FORMAT      FIXED(1X,F6.2,12F6.1/7X,16F6.1)
 MISSING VALUES    DAY3 TO DAY7,DAY9 TO DAY31 (0.0)
 RUN SUBFILES      EACH
 *REQUENCIES       GENERAL=ALL
 STATISTICS        1,3,9
 OPTIONS           7
 READ INPUT DATA
 *FINISH
```