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IONOSPHERIC FIELD STRENGTH MEASUREMENTS NEAR GEOMAGNETIC ANOMALY REGION

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The first results of the measurement of radio wave field strength in MF and HF bands near the geomagnetic anomaly region are given. The observed values are compared with some models adapted by CCIR. In MF band a median value of 40.86 dB was observed at Gaspar at midnight for a reference sunspot number R=O, after applying correction for receiving and transmitting antenna gains. This value is the same as the value observed for other circuits in Brazil but less compared to the value obtained using the models of CCIR.

Os primeiros resultados das medidas de intensidade de campo de ondas de rádio em frequências altas e médias, perto da região de Anomalia Geomagnética Brasileira, são divulgadas neste trabalho. Valores medidos foram comparados com alguns modelos adaptados pelo CCIR. Em frequência média um valor mediano de 40,86 dB foi observado em Gaspar, SC, por volta da meia-noite, para uma época referencial de manchas solares R=O, após aplicação de correções para ganho de antenas receptoras e transmissoras. Este valor é o mesmo que foi observado em outros circuitos no Brasil, porém, é menor comparado com o valor obtido pelos modelos CCIR.

INTRODUCTION

The measurement of field strength of ionospheric wave using a signal received from a distant cw transmitter is a powerful tool in applied radio propagation work. This method determines the true absorption of radio waves in ionospheric layers, particularly in the D and E regions. The method also serves for the evaluation of correctness of the theoretical models adopted, to know the loss in transmission and to observe the day-to-day and seasonal variation in absorption of the transmitted wave.

The CCIR has adapted various theoretical methods to determine the skywave field strength and transmission loss for different frequency ranges (CCIR, 1986a, b, c, d) for different regions of the Globe. These methods are subject to regional geographic influences and in order to adopt them for frequency planning purposes, they should be compared with the results obtained from local circuits at different epochs of the year and at different phases of solar cycle. Few field strength measurements have been made in Brazil so far on routine basis and particularly such measurements are lacking in the Brazilian Geomagnetic Anomaly Region. In the present work the preliminary results of field strength measurements carried out in the MF and HF ranges near the center of the geomagnetic anomaly region are given and are compared with some theoretical models and the results obtained by other circuits in Brazil.

THE EXPERIMENT

A program of field strength measurement was started by Fundação Universidade Regional de Blumenau (FURB), Blumenau, in collaboration with the Ministry of Telecommunications (MINICOM) at Gaspar near Blumenau, SC, in October 1985. Gaspar, with geographic latitude of 26°S 54' and longitude 49°W, is situated very near the center of Brazilian Geomagnetic Anomaly region (25°S, 48°W).

The A3 method adopted is quite simple in that a rod antenna is used along with a radiofrequency field intensity meter to measure and register the strength of a signal transmitted by a distant transmitter as a constant wave. An electromagnetic field intensity meter model NM-17/27 of Singer Instruments of Ailtech, a Division of Cutter Hammer of United States of America is used at Gaspar with a 9 – foot rod antenna and coupler, model 93049-1. The coupler, the rod antenna and the ground plane are calibrated for use over the frequency range of 150 KHz to 32 MHz and the calibration curves are supplied by Ailtech. The instrument is a programmable, precision, field intensity meter which can be operated from internal rechargeable batteries or mains. This instrument has an exceptional gain flatness of a maximum of ± 2 dB, which permits X-Y plotting of signal amplitude and frequency information without extreme deviations from calibration curve in either automatic or manual modes. An X-Y recorder is connected to the equipment, the Y- output voltage of which is proportional to the signal level as indicated in the output meter. The X- output voltage, which is proportional to the frequency applied, can be used to monitor the frequency in an automatic or semi-automatic mode, when different frequencies are monitored. At present the X- output is not being used.

The calibration of the signal is done by applying different fixed voltage levels, from 0.01 to 1.0 V, whenever initial pen position is changed or the monitoring frequency is changed. Using the calibration scale, the readings in divisions on the recording paper are converted to RMS values of the ionospheric field intensity in dB (dB over 1μV/m). A constant speed of 30 cm per hour is used for the recorder to register the field intensity which gives adequate resolution to study variations of field strength in about a minute.

The present results are based on the measurement at two frequencies, monitored for one month, one in the HF range at 6090 KHz transmitted by Radio Bandeirantes of São Paulo (Geographic latitude 23° 40'S, longitude 46° 40'W) at 9.7 KW power and the other in MF range at 600 KHz transmitted by Radio Gaucha at Porto Alegre (geographic latitude 30° 6'S and longitude 51° 19'W) at 100 KW power.

The data obtained at each minute has been corrected for the receiving antenna gain. At Gaspar a monopole antenna of 2.75 m is used for receiving the signal. For HF transmission of 6090 KHz a correction of 12.2 dB and for MF transmission of 600 KHz a correction of 23 dB is applied as per the calibration curves of the antenna supplied by the manufacturer.

MEDIAN FIELD STRENGTH VALUES

The field strength measurements, namely, the A3 absorption experiment, was started at Gaspar in the month of October 1985, but during the initial months when the tests were being carried out the data was intermittent and the calibration was not done on all records. Beginning from May 1986, the data collection is continuous and the calibration is done regularly. Preliminary analysis has been done using 30 days data in May-June, 1986.

Fig. 1 gives the median values of hourly medians obtained during one month, irrespective of the frequency used. The high frequency of 6090 KHz was used mainly during daytime and the medium frequency of 600 KHz was used during the night, though there was some overlap at times. Fig. 2 shows the average field strength during the day. A diurnal variation is seen, the minimum being around 11:00 UT corresponding to 08:00 LT and a maximum intensity around 21:00 UT i.e. about 18:00 LT. During this period the sunrise occurred between 09:46 UT and 10:01 UT and the sunset between 20:29 UT and 20:37 UT. The minimum thus occurred well after the sunrise and the maximum immediately after the sunset, showing that the diminution of electron density after the sunset is very rapid and the post-sunrise build up is very slow. Figs. 3 and 4 show the field intensity for the HF and MF bands separately. The average of the median of HF band is 54.96 ± 6.61 dB and that of MF band 58.34 ± 10.54 dB.

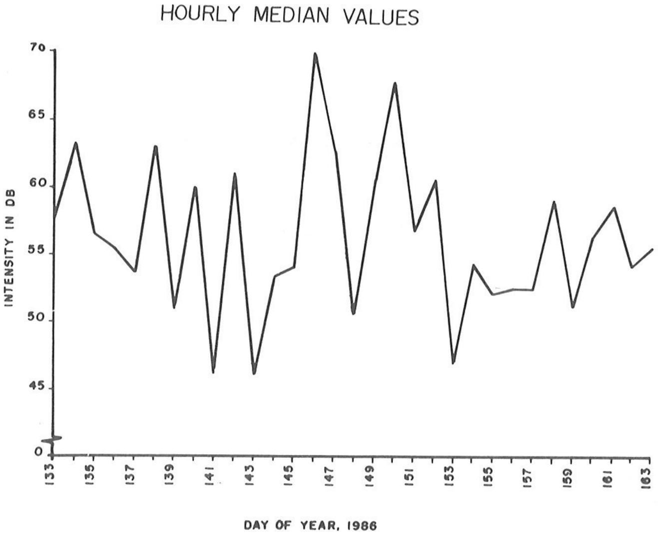

Figure 1 – Hourly median values of field strength at Gaspar, SC, Brazil, for different days in May-June, 1986, irrespective of frequency used.

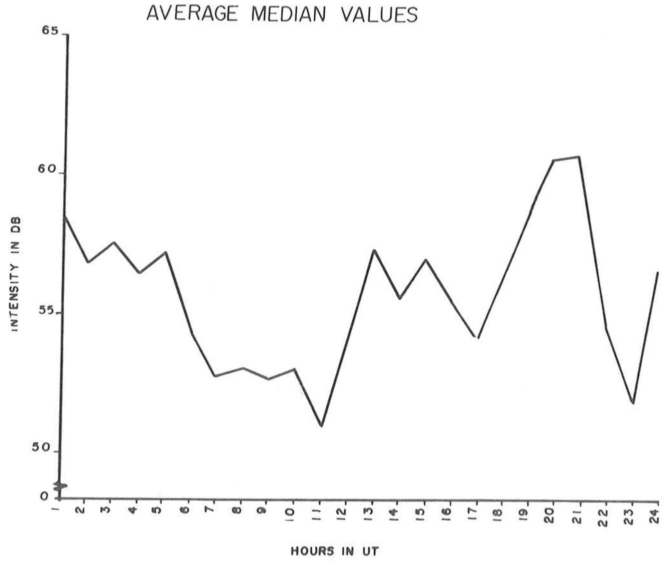

Figure 2 – Diurnal variation of average median values of field strength at Gaspar, SC, for May-June, 1986.

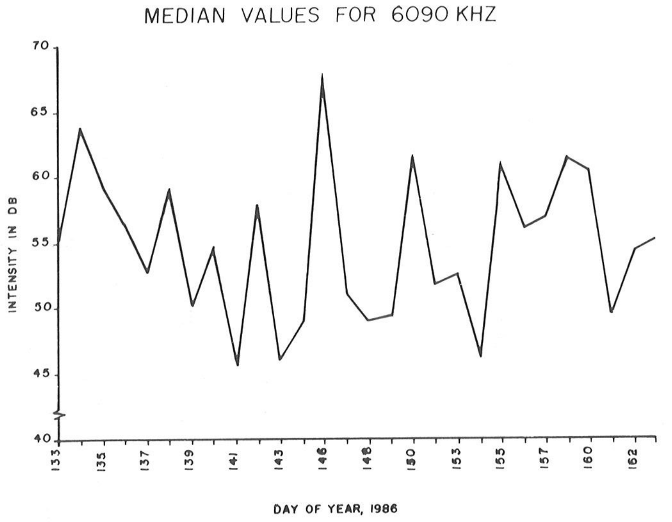

Figure 3 – Daily median values of field strength for a frequency of 6090 KHz (HF). The values are mainly day-time values.

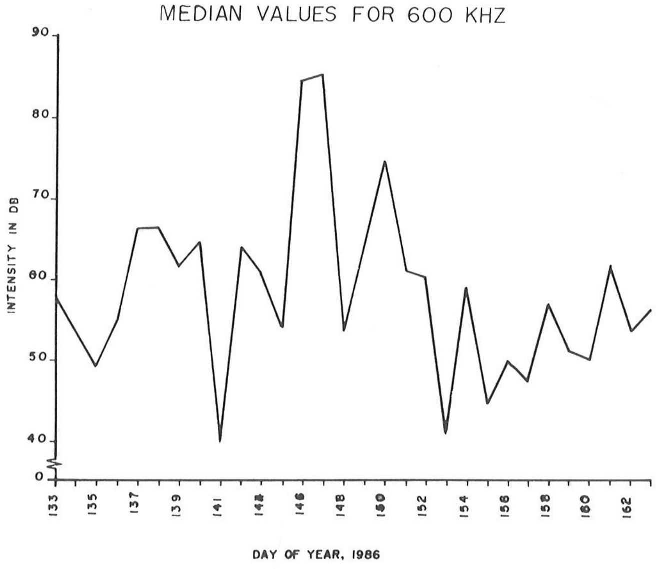

Figure 4 – Daily median values of field strength for a frequency of 600 KHz (MF). The values are mainly night-time values.

CORRECTION FACTORS

In order to compare these values with results obtained by other groups, corrections should be applied so that the median corresponds to an isotropical transmitting aerial radiating a power of 1 KW. The correction should also be applied so that the deduced median corresponds to a referred sunspot activity level, say R=0.

If the observed median is designated as F' (50) to give the average median of the day, we can write (Ebert, 1962a)

$$F'_0 = F'(50) - \Delta(50) - \Delta A - \Delta P - \Delta R \qquad (1)$$

where F'_0 refers to the field intensity at midnight for an isotropic transmitting aerial giving an unatenuated field strength of 3 x 10^5 μV/m at a distance of 1 km and the solar activity corresponds to a sunspot number R=0. F' (50) is the observed uncorrected median of the day, $\Delta(50)$ is the correction to be added to the observed median so as to make it valid for daily median at midnight. ΔA is the correction to be applied to the field strength of an isotropic aerial whose unatenuated field strength is 3 x 10^5 μV/m at a distance of 1 km, in order to obtain the field strength of a vertical aerial of height ℓ, installed on a perfectly conducting ground and radiating a power of 1 KW, ΔP is the power radiated by the aerial, expressed in dB, referred to 1 KW and ΔR is the correction to be applied so as to make the median valid for sunspot number R=0.

If we refer the above equation for local midnight, we can write it as

$$F'_0 = F'_{2400}(50) - \Delta A - \Delta P - \Delta R \qquad (2)$$

which gives

$$\Delta(50) = F'(50) - F'_{2400}(50) \qquad (3)$$

The observations show that for HF band

$$F'^{6090}_{2400}(50) = 50.345 \text{ dB}$$

and for MF band $F'^{600}_{2400}(50) = 58.804$ dB

Thus the correction factors become

$$\Delta^{6090}(50) = 54.96 - 50.345 = 4.615 \text{ dB}$$

and

$$\Delta^{600}(50) = 58.34 - 58.804 = -0.464 \text{ dB} \qquad (4)$$

The correction factors ΔA and ΔP depend on the transmitting aerial, its radiation pattern and the radiating power. If E_{00} is defined as the field strength in the horizontal plane, at a distance of 1 km, of an aerial installed on a flat perfectly conducting ground with a radiating power of 1 KW and $E_{0\varphi}$ as similar field strength measured in a direction of an elevation angle φ, then the characteristic function of the radiation, Q, which defines the vertical radiation pattern, is given by (Ebert, 1962b)

$$Q = E_{0\varphi}/E_{00} \qquad (5)$$

For a given aerial the functions E_{00} and Q are related by

$$E_{00\,mv/m} = \sqrt{2/3} \times 300/\sqrt{\phi} = 245/\sqrt{\phi} \qquad (6)$$

where

$$\phi = \int_{o}^{\pi/2} Q^2 \, . \cos\varphi \, d\varphi \qquad (7)$$

Using these equations we see that when $\varphi = 0$ then $\phi = Q^2$

For an unloaded aerial of length ℓ, the value of Q is given by

$$Q = \frac{\cos(h \, . \sin\varphi) - \cos h}{(1 - \cos h) \, . \cos\varphi} \qquad (8)$$

where the electrical height of the aerial $h = 2\pi\ell/\lambda$, λ being the wavelength of transmission, and the elevation angle φ is given by

$$\varphi = \tan^{-1}\left[\frac{\cos(d/2) - 0.983}{\sin(d/2)}\right] \qquad (9)$$

Here d is the angular distance between the transmitter and the receiver and is given by

$$d = \cos^{-1}[\sin\theta_1 \, . \sin\theta_2 + \cos\theta_1 \, . \cos\theta_2 \, . \, . \cos(\mathring{A}_1 - \mathring{A}_2)] \qquad (10)$$

θ_1, $\mathring{A}_1$, θ_2, $\mathring{A}_2$ being latitudes and longitudes of transmitting and receiving stations respectively.

Table 1 gives the values of correction terms for Δ (50), ΔA and ΔP in dB for the high and medium frequency bands.

The data are not sufficient to get a relation between the twelve monthly mean of the sunspot number R_{12} and the field strength to evaluate the correction term ΔR. During May-June 1986 the solar activity is low and the mean of the twelve monthly running average R_{12} is 14.08. The relation between the daily sunspot number and the field intensity gives a large dispersion. If a smoothed daily sunspot number, as in the case of 12 month running mean sunspot number R_{12}, is considered with 27 day period to take account of the sunspots on the total area of the sun, the dispersion may become less, but the relation between this smoothed sunspot number and the intensity cannot still be obtained as the data is insufficient. However, in an earlier work Ebert (1962b) has given a relation between the field strength and the sunspot number for European sector with a correction factor $\Delta R = -0.0208 \, R_{12}$, where R_{12} is the 12-month running mean of sunspot number. If the same relation is adapted in the present case (till sufficient data is acquired), then one obtains the correction factor $\Delta R = -0.293$ dB.

Thus we obtain the following values for the daily median field intensity at high and medium frequencies over Gaspar:

$$F_0^{6090} = 54.96 - 4.615 + 1.76 - 9.87 + + 0.293 = 42.528 \text{ dB}$$

and

$$F_0^{600} = 58.34 + 0.464 + 1.76 - 20 + + 0.293 = 40.857 \text{ dB} \qquad (11)$$

DISCUSSION

In the present analysis no correction has been applied either for the ground conductivity or for magnetic activity of the Earth. Also the field intensity has been determined at the receiving station Gaspar, rather than the mid-path position. These modifications will be introduced when more data are analysed. The present work only gives the methodology adopted and shows the preliminary results.

In Figs. 1,3 and 4, it is seen that the intensity is high on DOY (Day Of the Year) 146 and 150. This is because the solar activity was high on DOY 145 (May 25, 1986) with two SN flares and three SID's

Table 1

Station	Transm. KHz	Latitude	Longitude	Power (KW)	Distance		Aerial HT. (m)	Δ A dB	Δ P dB	Δ (50) dB
					Degrees	KM				
Rádio Bandeirantes	6090	23 S 40'	46 W 40'	9.7	3.839	426.66	19.7	-1.76	9.87	4.615
Rádio Gaucha	600	30 S 06'	51 W 19'	100.0	3.814	423.76	230.0	-1.76	20.0	-0.464
Gaspar	RECEIVER	26 S 55'	48 W 56'	–	–	–	–	–	–	–

occurring during daytime (SGD, 1986a) and probably the charged particles from these flares or from the flare on DOY 146 (May 26), which had mass ejection (SGD 1986a), have arrived to ionospheric heights on DOY 150, about 90 hours later. The cosmic ray index from all neutron monitors located at high latitude stations shows a maximum flux for DOY 149 (May, 29, 1986) (SGD 1986b).

As mentioned earlier, a diurnal variation is seen in Fig. 2. It is also seen that a relatively higher intensity occurs around noon. Depending on the mode of propagation, the reflection of radio wave takes place at F layer during the night and at E layer during the day. At times the night reflection can occur at the sporadic E layer. However, in the absence of the knowledge of the presence of sporadic E layer, the night time reflections are considered to take place at F layer only, and a one-hop mode of propagation is presumed. When the E layer is well formed during the midday, it can act as a perfect mirror for the radio wave. The absorption near the reflection point would be less and also the path length of the radio wave in the ionosphere would be less at this time compared to that during the night. In this case the field strength would be high near the noon as seen in Fig. 2 between 1200 and 1600 UT. In the early hours of the day, however, the E layer is not well formed, and partial reflections may take place at lower heights while considerable reflection is still taking place at F layer. This phenomenon causes longer path length in the ionosphere inducing more absorption and consequently less intensity in the field strength as seen between 0600 and 1200 UT (0300 to 0900 LT).

Similar phenomenon is seen between 2100 and 2400 UT (1800 to 2100 LT) when the E layer is disappearing.

It may be worthwhile to compare these preliminary results with other results obtained in Brazil and elsewhere and also with theoretical models.

DENTEL of Brazil is monitoring various high frequency signals at different locations. The 6090 KHz signal from Radio Bandeirantes is also being monitored at different receiving stations. The field strength as observed by Gravatai, RS, a nearby receiving station with geographic latitude 29º 58' S and longitude 50º 52'W during May-June, 1986 is 41.45 dB ± 1.98 dB, (DENTEL, 1987) which compares well with the above value at Gaspar. In the medium frequency band University of Brasilia monitored various frequencies in 1983, including that of Radio Gaucha of Porto Alegre. The field intensity observed for 600 KHz was about 45 dB between 2000 and 2300 hours local time (Barreto & Mendes, 1986), which also compares well with the above value at Gaspar for 600 KHz.

CCIR adapted a theoretical formula (CCIR, 1986c) developed by Udaltsov & Shlyuger (1972) and other Russian workers for determining skywave field strength as a function of distance and frequency. This formula, valid for U.S.S.R. is given by

$$E_0 = 105.3 - 20 \log d - 1.9 \times 10^{-3} f^{0.15} d - 0.24 \times 10^{-3} f^{0.4} d(\tan^2\Phi - \tan^2 37^{\circ}) \qquad (12)$$

where

E_0 is the annual median field strength (dB (μ V/m)) for 1 KW e.m.r.p. for midnight local time, d is the ground distance, f the frequency in KHz and Φ the geomagnetic latitude at the path mid-point. The value obtained using this formula, which gives annual median field strength for midnight local time is 51.27 dB for medium frequency. A modified U.S.S.R. formula valid for other parts of Europe adapted by CCIR uses the slant distance p instead of d which is given by

$$p = (d^2 + 40.000)^{-1/2} \qquad (13)$$

and also uses the excess polarization coupling loss, Lp, which depends on the magnetic declination, dip angle and the path azimuth of the signal. This value, when computed for given conditions, is equal to 49.792 dB. These two values are slightly greater than the daily median value of 40.86 dB observed at Gaspar. This may be due to the fact that only one months's data in autumn has been used and the daily median instead of field strength at local midnight is considered in the present work.

Another CCIR method, the Cairo north-south curve method, is given by

$$E_o = E_c - L_p \qquad (14)$$

where

$$E_c = \frac{231}{3 + 0.001\, d} - 18 \qquad (15)$$

and Lp is the excess polarization coupling loss. From this we have for the same 600 KHz frequency a value of 49.46 dB which is also the annual median value, which is also about 8.6 dB higher than the value obtained at Gaspar (equation 11). According to the CCIR report (CCIR, 1986b), the median daytime field strength in Europe is 25 dB less than the night time value of E_o in winter and 30 dB less in summer, the spring and autumn daytime values being in between the summer and winter values. As the theoretical values obtained from equations 12 and 14 represent night time values, the above results are in accordance with the CCIR conclusion, but the difference may be much less in case of Brazil. These facts are encouraging and it is hoped that with more data available, an empirical equation or transmission curves can be constructed valid for the region.

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