Geofísica Internacional (2004), Vol. 43, Num. 2, pp. 193-198

A commercial radio receiver for lower ionosphere monitoring: Initial results

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Received: March 31, 2002; accepted: August 1, 2002

RESUMEN

Hemos usado un receptor comercial de radio controlado por una computadora para medir la intensidad de las señales en el rango de las altas frecuencias, con el objeto de estudiar los efectos de los eventos geofísicos en las radio-comunicaciones y probar este sistema para el monitoreo ionosférico. El sistema se instaló en el Observatorio Espacial del Sur (OES/CRSPE/INPE) localizado en São Martinho da Serra (29.43°S, 53.8°W, B = 23350 nT) en el sur de Brasil y ha probado que puede detectar eventos de radio-absorción ionosférica. El experimento consiste en un radio receptor comercial con una computadora de interfase en serie, que hace posible controlar la recepción de frecuencias y conocer la intensidad recibida. Este reporte describe el sistema y presenta resultados iniciales obtenidos principalmente sobre absorción de eventos asociados con ráfagas solares de las clases C y M. Los resultados preliminares indican que este equipo de bajo costo se puede usar para estudiar la variación diaria de la ionización de la baja ionosfera y los eventos de absorción ionosférica. Además, las mediciones a largo plazo dan información estadística sobre la magnitud y tiempo de la desaparición de señales; esto se puede usar para planear los contactos entre diferentes emisoras de radio.

PALABRAS CLAVE: Ionosfera, absorción, desaparición de señales.

ABSTRACT

A commercial computer controlled radio receiver has been used to measure signal strength of High Frequency (HF) signals in order to study the effects of geophysical events on radio communications and to test the system for ionospheric monitoring. The system was installed at the Southern Space Observatory (OES/CRSPE/INPE) in São Martinho da Serra, Brazil (29.43°S, 53.8°W, B = 23350 nT). Initial results show that this system is able to detect ionospheric radio absorption events. The commercial radio receiver has a computer serial interface, to control the reception frequency in order to acquire the values of the received signal strength. We describe the system and some initial results on radio absorption events associated to C and M classes of x-ray solar flares. The results suggest the possibility of using this low-cost system to study the daily variation of the lower ionosphere ionization and to study events of ionospheric absorption. Long period measurements give statistical information about the magnitude and time scale of fading, that can be used for planning radio links.

KEY WORDS: Ionosphere, absorption, fading.

INTRODUCTION

The HF range of radio waves has been largely used in maritime and aeronautical fixed systems as well as by broadcasting stations. The lower frequencies in the HF band propagate mainly by ionospheric reflection (sky waves). For communication planning, information on the mean value of the received signal strength is insufficient. Fading caused by ionospheric absorption has an important influence on the performance of radio systems. It is essential to know the magnitude and rapidity of fading in order to specify the transmitter power required, the necessary protection ratio to guard against interference and an efficient diversity or coding system (Davies, 1990).

Absorption fading events are fluctuations in signal amplitude caused by changes in D region absorption. Such changes in the signal amplitude can be associated to x-ray solar flares and they can last from about 1 minute to more than 1 hour (ITU, 1998). According to Campbell (1997), a solar flare can be defined as the transient brightening of a small region on the solar surface observed in the Hα emission line. Microwave and broadband radio-wave bursts, ultraviolet emissions, X-rays, and particle ejections are associated with more active flare events. Flares are classified by area and x-ray output. The order of magnitude of the peak burst intensity, in watts per square meter for a band of x-ray emissions from 0.1 to 0.8 nanometers, classifies the flare magnitude (in increasing magnitude) into B, C, M or X flares. Also, there is a number that indicates a level within the order of magnitude (Campbell, 1997).

In this report we present initial results of signal strength measurements made with a commercial computer controlled radio receiver used to monitor the lower ionosphere. We define the lower ionosphere as the ionospheric region which includes the D and the initial portion of the E layer. Broadcast amplitude modulated (AM) stations, which are numerous in Brazil, provide HF beacon signals.

SYSTEM DESCRIPTION

The system we have developed consists of a commercial radio receiver with a serial RS-232 interface to control the receiver from a personal computer. A control and acquisition computer program was developed to change automatically the reception frequency of the radio receiver and to record the value of the received signal strength. The signal strength values acquired in a 0.1 Hz sampling rate are sent from the receiver to the computer by the serial interface. The values of the signal strength are in arbitrary digital units corresponding to 40 different levels of a Signal Meter (S-Meter) built in the receiver. Then, the digital values are received by the computer and recorded in daily text data files. In a posterior data reduction procedure we convert the raw digital data to S-Meter values and to dBm units. The logarithm of the received power to 1 miliWatt ratio multiplied by 10 is defined as dBm. The conversion of arbitrary units to dBm is based in a conversion table given by the radio receiver user's manual. (JRC, 1996). Figure 1 shows the diagram block of the system.

The system has been operating since middle October 2000 at the Southern Space Observatory (29.43°S, 53.8°W, B = 23350 nT) in the Brazilian South region. The main geophysical feature of that region is the anomalous weak geomagnetic field. This region of weak geomagnetic field is called South Atlantic Magnetic Anomaly (SAMA). Satellite based and ground-based measurements have shown that high-energy particles can precipitate in the SAMA region (Nishino *et al.*, 2001; Kohno *et al.*, 1990; Abdu *et al.*, 1973). Makita (1996) reported the necessity of more ground-based observations in this region for a better understanding of the particle precipitation processes and upper atmosphere effects caused by particle precipitation.

The observation site where the system is installed is located far away from artificial noise sources and its antenna has a free area of view. There are several other instruments, which are available for data comparison such as riometer, imaging riometer, VLF receivers, magnetometers and Muon detector. The combination of data from all these instruments may give a picture of the space weather effects over the lower ionosphere.

MEASUREMENTS

We have carried out signal strength measurements from signals transmitted by four AM radio stations in Brazil. The locations of these radio stations are shown in Figure 2, while Table 1 gives information about the operation frequency, name and location of such stations. The signal strength values of these signals are recorded in daily text files at a sample rate of 10 seconds. These radio stations were chosen after a 1-week campaign of measurements carried out in early October 2000. During this campaign we tuned several frequencies transmitted by several radio stations and we have chosen the stations with better audible signal-to-noise ratio during nighttime period.

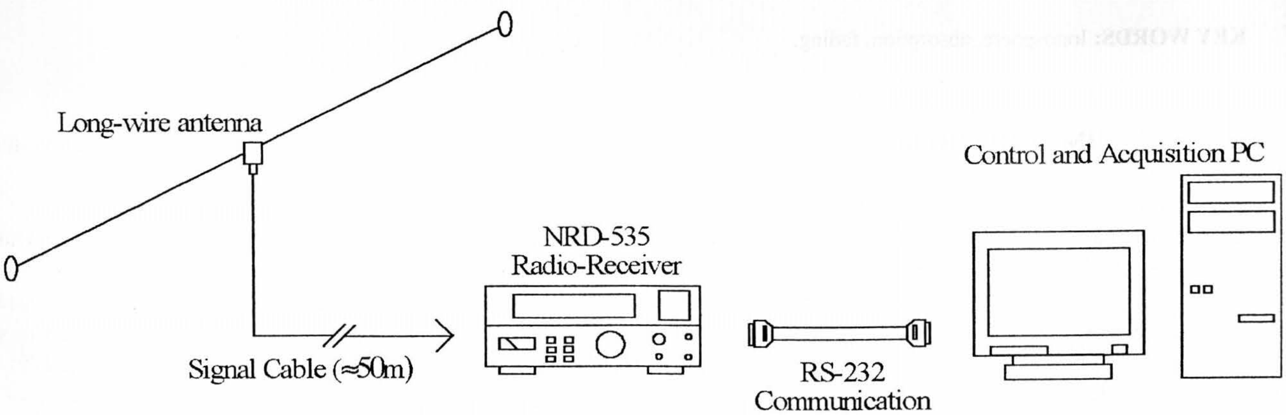

Fig. 1. Block diagram of the system. Long wire antennae were not appropriate for AM signal reception, but the reception level has been satisfactory in this case.

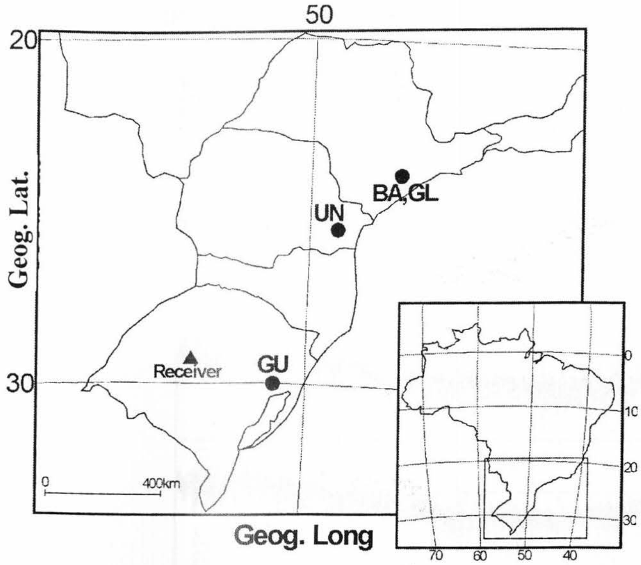

Fig. 2. Locations of the transmitter stations where signals have been monitored by the instrument described in this report.

From the measurement of signal strength that has done by the radio receiver we can produce graphs like that shown in Figure 3. This graph shows the daily variation of the signal strength for the four frequencies monitored by the radio receiver on December 10, 2000. This day was considered solar and magnetically quiet. The geomagnetic kp index did not exceed 3 and moderate or strong x-ray solar flares were absent.

Table 1

Amplitude Modulated (AM) radio station which transmissions have been used as beacon signals

	Frequency (MHz)	Radio Station	Location (City – State)
Frequency #1	15.400	Globo (GL)	São Paulo – SP
Frequency #2	9.645	Bandeirantes (BA)	São Paulo – SP
Frequency #3	9.565	Universo (UN)	Curitiba – PR
Frequency #4	6.000	Guaíba (GU)	Porto Alegre - RS

During the data analysis we observed that the 6 MHz signal showed a systematic daily variation and we studied this signal in more detail. In Figure 4 is shown the variation of the 6 MHz signal strength for five consecutive days. It is possible to observe that the time variation of signal strength does not change very much from day to day. During the period around 03 to 07 UT, the signal suddenly falls to about -105 dBm. It occurs because the radio station transmitter is turned off during that period of time. Figure 4 also shows a fading event on October 21 around 18:15 UT. The signal strength fell from about –76 dBm to about –105 dBm and only returned to the normal level about 19:10 UT. It means that the signal was completely lost and only returned to its normal level 55 minutes after the sharp decreasing of the signal strength.

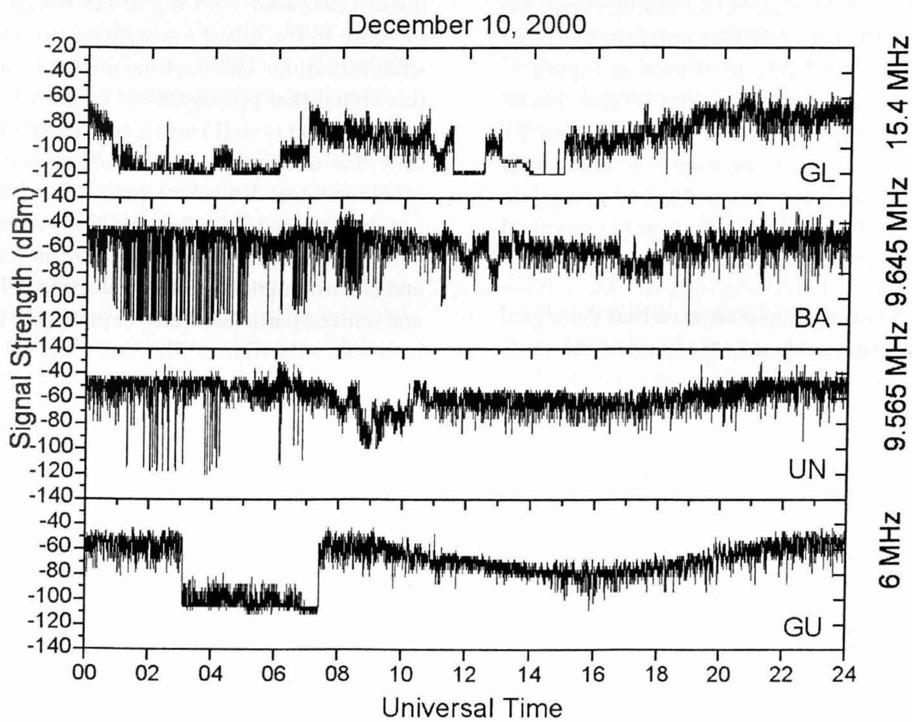

Fig. 3. Example of daily variation of signals monitored by the radio receiver described in this report for December 10, 2001. This graph shows the typical daily variation of the monitored signals.

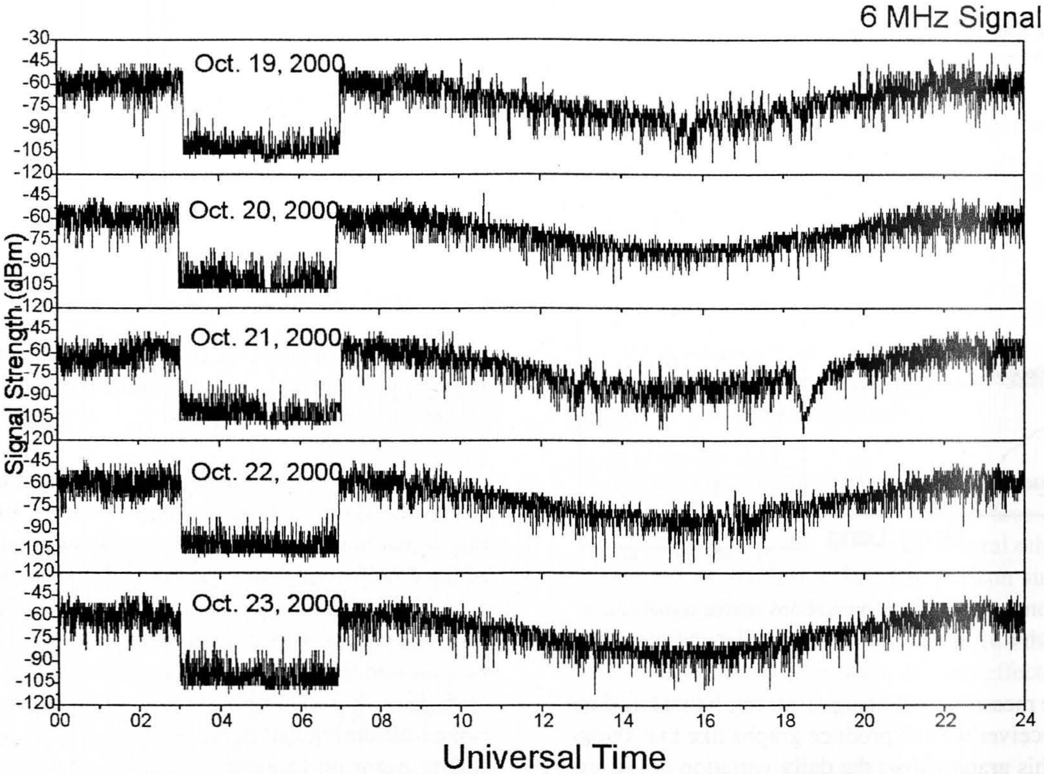

Fig. 4. Daily variation of the 6 MHz signal strength for five consecutive days. The variation of signal strength is almost the same for all days except for October 21, 2000 when a fading event occurred around 18 UT. From around 03 to 07 UT the radio station transmitter is turned off and the signal falls to noise background level.

In order to investigate the October 21 fading event, we have simultaneously plotted the 6 MHz signal strength and x-ray data from GOES 10 satellite as shown in Figure 5. This figure also shows the computed values of absorption. The absorption curve is the subtraction of the October 21 signal strength variation from an average signal strength variation. The simple average curve was obtained using data from 8 days around October 21. The curves were smoothed before the subtraction to remove the noise.

From Figure 5, it is possible to observe that the signal strength has an immediate response to the burst of the x-ray solar flux started around 18 UT. The increase of x-ray flux causes an increase of ionization in the lower ionosphere that consequently causes a sudden decrease of the 6 MHz signal strength by ionospheric absorption of radio waves. The peak of absorption reached 27 dBm around 18:30 UT and exponentially returned to a 0 dBm level of absorption. Data from imaging riometer (30.8 MHz) installed at the same place of HF radio receiver for October 21, 2000 event also showed strong absorption swings during 19 to 20 UT.

DISCUSSION

As expected, further analysis of the monitored 6 MHz signal shows that during daytime the signal strength is much lower compared with nighttime because of the ionization increase in the lower ionosphere, principally in D layer by solar radiation. The daytime attenuation is about 27 dB for this signal that propagates in a path of about 300 km. This phenomenon is well known and occurrs because during daytime, the collision frequency of electrons and neutral particles increases due solar ionization and nondeviative absorption takes place. In a didactic way, when the ionization occurs the energy of the radio wave is transformed into heat and electromagnetic noise by electron collisions with neutrals and ionized particles. It also explains the fading events caused by x-ray solar flares. The x-ray bursts increase drastically the ionization of the D layer.

CONCLUSIONS

In this report we have shown some measurement results of HF radio signal strength. We have used signals transmitted by AM broadcasting radio stations as beacon signals and we have used a commercial HF radio receiver controlled by computer to acquire the strength of those signals. The system operates automatically and acquires the signal strength in a 0.1 Hz sampling rate. It has shown to be able to monitor the ionization daily variation of the lower ionosphere and also able to detect fading events caused by x-ray solar flares.

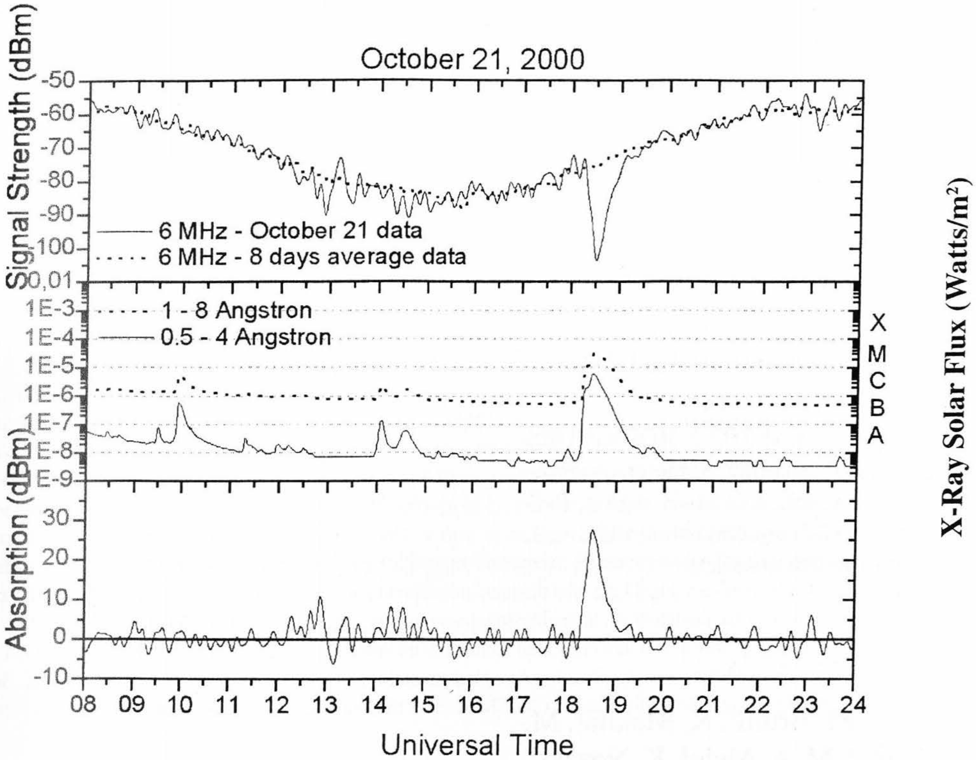

Fig. 5. Further analysis of the x-ray solar flare event of October 21, 2000. The top panel shows the 6 MHz signal strength and a average curve obtained for reference. In the middle panel is showed the x-ray solar flux data from GOES 10 satellite and the bottom panel shows the absorption curve that is the subtraction of the October 20 curve from the average curve.

Mostly observed fading events were caused by C (10^{-6} W/m^2 $\leq$ Peak Flux $\leq$ 10^{-5} W/m^2) and M (10^{-5} W/m^2 $\leq$ Peak Flux $\leq$ 10^{-4} W/m^2) classes of x-ray solar flares and the signal strength may take more than one hour to return to its normal level.

From the practical point of view, we showed the effects of x-ray solar flares over lower HF radiocommunication signals. From the measurements it is possible to observe that the stability of radio links in HF range is highly dependent of the solar activity and a long period of observations can give us statistical information about the relation between the x-ray solar flare and radio absorption magnitudes. This information would be useful for planning of radio links.

We have installed a similar system at Manaus (03,01°S, 60,01°W, B=27168.7 nT) in Brazil in order to compare the effects of x-ray solar flares outside of SAMA region. Further investigation is needed to find correlation between magnetic storms and ionospheric absorption caused by particle precipitation in the SAMA region using the imaging riometer (Nishino *et al.*, 2001).

ACKNOWLEDGEMENT

We thank the students of the Laboratory of Aeronomy at CRSPE/INPE and specially Mr. Ivan Shieffelbein for instrumentation maintenance and data transferring. This work was supported by Takushoku University – Japan and INPE. The x-ray solar flux data were taken from the Space Environment Center web site, Boulder, CO, National Oceanic and Atmospheric Administration (NOAA), US Dept. of Commerce.

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