Use of a DRM Modulation to study the ionosphere

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Abstract

The aim of this article is to introduce a technology of investigation of the ionosphere based on the reception of a numerical broadcasting fixed link at 6.085 MHz using the DRM (Digital Radio Mondiale) modulation properties as an opportunistic ionospheric sounder. The analysis used tools are Dream and SpectrumLab software. Observations are accomplished at the same time in narrow band (2Hz) and in wide band (10 kHz). They are presented by dopplergram. Different ionospheric characteristic events are observed in narrow band (typical figures at the opening and at the closing of the link, scattering, absorption, gravity waves) and in large band (selective fading, scattering, absorption). Different typical examples are presented.

1. Introduction

The ionosphere is this region of the upper atmosphere where charges, either positive or negative, are present in quantities large enough to influence the trajectory of radio waves and permit radio communications between two points on the surface of the Earth. The existence of these charges results from the ionisation by the solar rays of the components of the overall neutral atmosphere. To better understand the ionospheric characteristics and its different layers (D, E and F layers) different sounding means have been developed: vertical sounding, bottomside or topside, backscatter or incoherent scatter soundings, riometer, low and very low receiver.

Here we present a new ionospheric investigation method based on the reception of a digital broadcasting fixed link at 6.085 MHz using the DRM (Digital Radio Mondiale) modulation proprieties [1] like an opportunist sounder of the ionosphere. The SpectrumLab software [2] is used as an analysis tool. The observations are realized in narrow band (2 Hz) in one hand and in wideband (10 kHz) on the other hand. Different ionospheric characteristic events are outlined either in narrow band (sunrise and sunset effects, diffusion, absorption, ionospheric gravity wave) or in wideband (selective fading, diffusion, absorption).

2. The experiment

2.1 The studied ionospheric link

Ismaning in Germany (48°13’ 11" N, 11°04’ 47" E) and Keranstraou-Ploumilliau in France (48°42’ 18" N, 3°32’ 06" O) is the used link. The distance between the transmitter and the receiver is equal to 1120 km.

The transmitter emits a power of 50 kW at the frequency of 6.085 MHz. The reception of the radio electrical field of such link is conditioned to the reflection of the wave on the ionosphere at mid path (case of a single hop). This reflection requires a sufficient electronic concentration.

It is therefore apparent that, in order to maintain an ionospheric link, the frequency cannot be too small, as the wave would then be absorbed, nor too high, for reflection would no longer be possible in this case. The two frequencies thus defined are referred as the lowest useful frequency (LUF) and the maximum useful frequency (MUF) respectively. Hence, in order that a frequency be usable, the following relation must be satisfied: LUF<f<MUF. The frequency of the received wave “fr” is lightly different from the emitted frequency “f” due to the movement of the different layers inside the ionosphere: it is due to the doppler effect.

In addition to these effects due to large gradient and to medium and small scale irregularities of the Total Electronic Content (gravity wave) phase and amplitude fluctuations of the received signal are added.

2.2 Digital Radio Mondiale

It is an open worldwide digital broadcasting standard for short, medium and long waves (f<30 MHz) with a very large coverage (several thousand km). The receiver system is light and simple (compact receiver, wire antenna). It gives numerous advantages in comparison with traditional analogical broadcasting: improvement of the sound quality, identification of received stations, weaker emit power, etc.

The receiver bandwidth is equal to 10 kHz. Data rates range between 8 Kbit/s and 20 Kbits even 72 Kbits when using several channels.

For transmission, the used modulation is a QAM (Quadrature Amplitude Modulation) constellation associated to an OFDM (Orthogonal Frequency Division Multiplexing) code allowing a very good robustness of the signal. The principle consists to obtain a uniform spectral density by dividing the numerical signal total flux on numerous sub-carriers modulated individually in QAM modulation.

On the other hand these sub-carriers phases are orthogonal to reinforce the diversity of the signal in comparison with the propagation echoes.

In DRM the signal is transmitted with redundancy on all sub-carriers and with an error corrective code in order to be able to correct it in case of hole of the pass-band passer-by resulting from negative interferences or frequency shift due to Doppler effect.

Associated to the DREAM software [3] which demodulate the DRM flux and the SpectrumLab software which allows the frequential analysis of the received signals composition, distorted during their propagation in the ionosphere, the receiver allows, in narrow band, the analysis of one DRM modulation pilot (750 Hz for instance) and the analysis in broad band on 10 kHz.

2.3 The used software

2.3.1 Dream software

It is an Opensource software. It can be used to decode DRM broadcasts by simply connecting them to a computer via a sound card. It extracts the principal characteristics from the DRM signal: station determination, physical and logical code, pilot signals, …, etc. [3]. The pilot signals at 750, 2250 and 3000 Hz are very stable references. Their amplitudes have a higher level and are not amplitude modulated. They used the phase information of frequency pilots to decode the DRM signal. These pilot signals are used as input signal by the sound card. Measurements of their perturbations are used as measurement to see the movements and the modifications of the ionosphere through the Spectrumlab software.

2.3.2 Spectrumlab software

The Spectrumlab software is a spectral analyzer device. It identifies, typically by means of Fourier transform, a frequency domain representation of a time domain of a received signal distorted during it passage through the ionosphere. The sound card digitalizes the input signal and the Spectrumlab software output restitutes the level of the signal in the frequency domain in function of the time.

2.4 The receiver

The receiver consists of 2 parts : an narrow band (2 Hz) and a wide band (10 kHz) receiver system.. With the first one we can record and observe gravity waves, frequency shifts (upward and downward of the ionospheric layers and with the second we can record and observe selective fading, multipath interferences, day/night transition, etc. These different records give a temporal representation of the reflecting layer of the electromagnetic wave which provides the radioelectrical link between the emitter and the receiver.

3. Results

We present hereafter some typical results observed in narrow band (2Hz) and in broad band (10 KHz).

3.1 Narrow band

The examples presented hereafter visualize the received signal intensity in the temporal (unit=5mn) frequency (2 Hz) domain. The narrow band spectral analysis (dopplergram) allow to put in evidence the upward and the downward movements of the reflecting layers of the different radioelectrical waves which provides the radioelectrical link between the emitter and the receiver and their variations. These movements and these height movements are due respectively to the ionisation created by the sun and to the passage of gravity waves [4]. During the daytime, gravity wave effects can be observed as roughly sinusoidal variations with a period of 20-30 minutes.

Figure 1 gives an example observed at the opening hour of the link. They show the start of morning F layer single hop propagation. Theirs forms result from the interference between ordinary, extraordinary and eventually Pedersen waves. We can see the role of the ionisation and the magnetic field in the separation of ordinary and extraordinary wave. Note that ordinary and extraordinary become viable 5 to 10 mn apart. Figures 2 shows an example of an complex phenomena, …, etc.

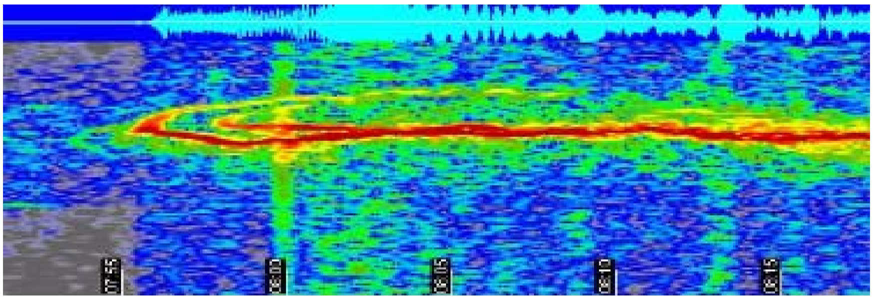

Figure 1: Start of morning F layer single hop propagation

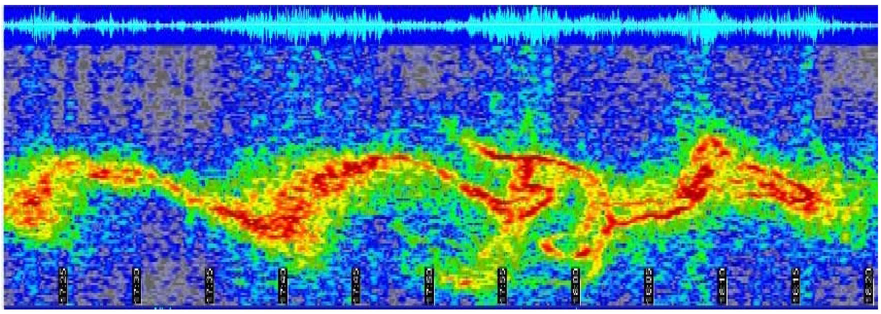

Figure 2: Complex event

3.2 Wide band

The examples presented hereafter show the received signal intensity in function of time (unit= 1mn) in a 10 kHz frequency band. Like solar glints on the sea surface waves, these spectrograms show signal intensity variations due to reflecting layer distortion. The wide band spectrum analysis at 10 kHz shows typical characteristics: selective fading, multi paths interference, day/night transition, etc. Figures 3 illustrates an examples of selective fading with increasing frequency observed at the opening (morning) F-layer single hop propagation. Figure 4 show an example observed during more complex phenomena due to combination of the previous effects showing the dynamic of the electromagnetic waves reflecting layers.

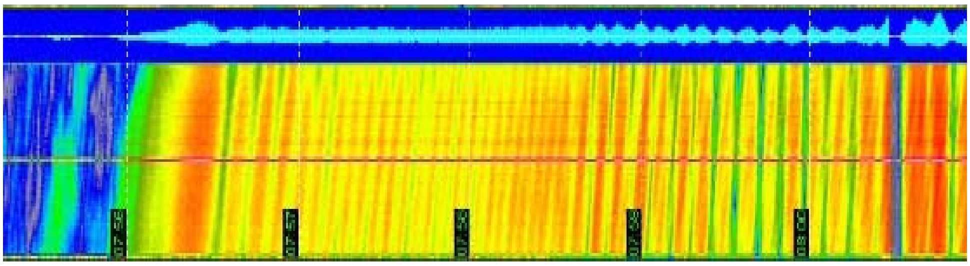

Figure 3: Selective Fading with an increasing frequency observed at the opening F-layer single hop propagation (morning)

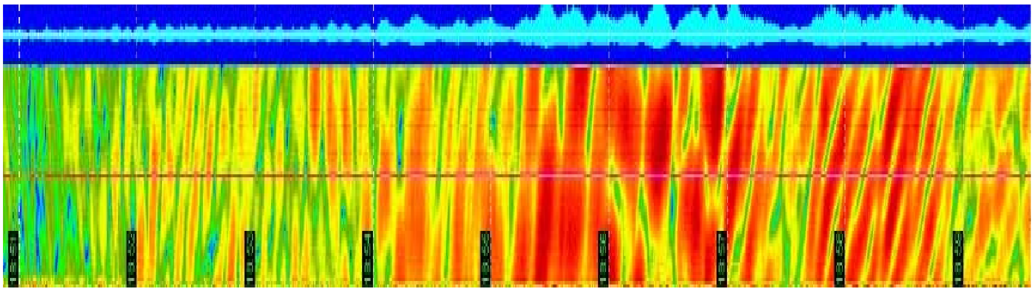

Figure 4: Complex event

4. Conclusion

The reception of a numerical broadcasting (Digital Radio Mondiale) link associated to decode software (Dream) and a spectrum analyzer (SpectrumLab) constitutes an opportunistic technology to investigate the ionosphere. The novelty lies in the use of amateur type devices (laboratory receiver, sound card, open source software) and the use of a broadcasting DRM emitter instead a deterministic sounder. It is the opportunistic aspect of the experimentation. Different characteristic events observed in the ionosphere in narrow band (sunrise effect, gravity wave travel) and in wideband (selective fading) have been presented. This method permits to observe passively the same events as the traditional observation methods (ionospheric sounders). Futures activities will carry more particularly on the following aspects: simulation of different signals interferences using SpectrumLab software, their comparison with observed phenomena and the promotion in radiocommunication course as an illustration of a very unpredictable radiocommunication channel.

5. References

1. DRM: http://fr.wikipedia.org/wiki/Digital_Radio_Mondiale

2. SpectrumLab : http://www.qsl.net/dl4yhf/spectra1.html

3. Dream: http://apps.sourceforge.net/mediawiki/drm/index.php?title=Main_Page

4. H. Sizun; « Perturbations ionosphériques itinérantes de moyenne échelle, étude et recherche de leur source », Thèse, Rennes, 1979.