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Automatic ionospheric layers detection: Algorithms analysis

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Abstract

Vertical sounding is a widely used technique to obtain ionosphere measurements, such as an estimation of virtual height versus frequency scanning. It is performed by high frequency radar for geophysical applications called “ionospheric sounder” (or “ionosonde”). Radar detection depends mainly on targets characteristics. While several targets behavior and correspondent echo detection algorithms have been studied, a survey to address a suitable algorithm for ionospheric sounder has to be carried out.

This paper is focused on automatic echo detection algorithms implemented in particular for an ionospheric sounder, target specific characteristics were studied as well. Adaptive threshold detection algorithms are proposed, compared to the current implemented algorithm, and tested using actual data obtained from the Advanced Ionospheric Sounder (AIS-INGV) at Rome Ionospheric Observatory. Different cases of study have been selected according typical ionospheric and detection conditions.
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Keywords: Algorithm; Automatic echo detection; Ionospheric sounder

1. Introduction

A widely known technique to obtain ionosphere profile of virtual height (i.e. critical frequencies, structure and altitude of ionospheric layers) is the so called vertical ionospheric sounding and it is performed by an ionospheric sounder. This technique relies on reflection of radio waves from ionospheric plasma exhibiting plasma frequencies equal or higher to the radio frequencies employed for radio sounding. It uses radio waves in the high frequency (HF) range and reflected by the ionospheric layers acting like mirrors, with the corresponding echo delay related to the reflection virtual height of the reflecting layers (Davies, 1969; Reinisch and Galkin, 2011; Baskaradas et al., 2014, among others).

After a vertical sounding (within a frequency range) is performed by this HF radar a graphical representation of the ionosphere’s virtual height (ionogram) is obtained. Fig. 1 shows schematically processes to achieve an ionogram.

Ionosphere virtual height (h_v) is estimated by vertical sounding (Fig. 1a). For each transmitted frequency, the received signal is processed and echo (peak) is obtained as result (Fig. 1b). Moreover, for each peak, a point in the ionogram is set. Repeating this process for a given fre-

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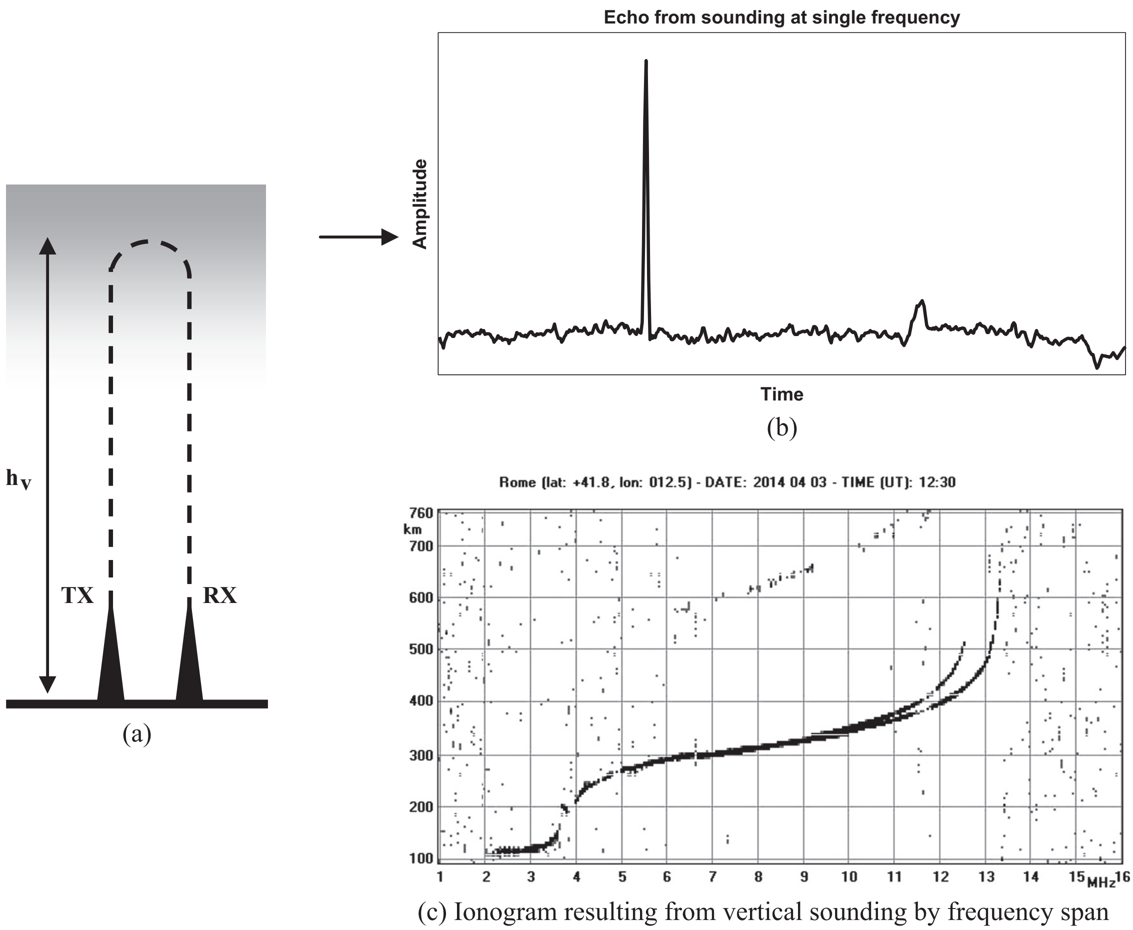

Fig. 1. (a–c) Scheme of complete ionospheric sounding and ionogram.

quency span, the radar is able to complete the whole ionogram (Fig. 1c).

As radar, the major function for an ionospheric sounder to carry out is target detection. From a geophysical point of view, the target corresponds to ionospheric layers. In terms of detection, the sounder must be able to decide whether a given measurement is the product of an echo from a layer or it is just noise. If detection is made properly, the resulting ionogram will be more reliable. This was a key motivational point for the study carried out in this work.

Since echo detection is the primary stage before ionogram interpretation, this operation must be as fit as possible to avoid misleading information. Suitable automatic detection parameters setting must be obtain according the target (ionosphere) characteristics and the actual signal scenario.

In Fig. 2, two raw ionograms (before scaling), with different detection settings, are shown. The bottom ionogram was measured one 1 min after the upper one, in quiet ionospheric conditions, which means that ionospheric conditions do not change significantly during this time (Rishbeth and Garriot, 1969). In the first one, not only the ionospheric layers can be seen but it has also plenty of noisy points, which introduces additional and mistaken information. This is obviously not a desired setting. In the second one, most of the noise does not appear. At first sight, this last one, offers a good detection parameters setting but with the decrease of the noise some important data regarding ionosphere's layers are not shown neither. For instance, in the second case, a second reflection from E layer is not visible, nether some important features of the F layer traces. Obviously a tradeoff between too much data (even with noise) and less information must be set. Thus, the automatic echo detection is a key point to get the important data from ionosphere and to avoid severe unreliable data.

The Advanced Ionospheric Sounder developed by the Istituto Nazionale di Geofisica e Vulcanologia (AIS-INGV) uses several tools and techniques to implement detection. This radar uses the spread-spectrum technique as many modern radars for geophysical applications (Barry, 1971; Poole, 1985; Bianchi and Altaldill, 2005, among others). The aim is to improve the range resolution, by transmitting low power, typical value is 500 W peak (approximately 15 W rms with 30 Hz of repetition frequency). As received signals are attenuated, noisy and delayed in time, several signal processing tools are used

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