A simple and low-cost system, based on *Digital Radio Mondiale* standard, for the imaging of *sporadic-E* in the ionosphere

***Piero Tognolatti*[1], *Emidio Di Giampaolo*[2]**

[1]Department of Electrical and Information Engineering, University of L'Aquila, Italy
P.le E. Pontieri 1, I-67100 L'Aquila, Italy email: tognolatti@ing.univaq.it

[2]Department DISP, "Tor Vergata" University of Rome, Italy
Via del Politecnico 1, I-00133 Roma, Italy email: digiampaolo@disp.uniroma2.it

Abstract

This paper proposes a new, low-cost method which allows a continuous monitoring of sporadic-E in the ionosphere. It is based on the channel impulse-response estimation obtained as a by-product from the reception of DRM – Digital Radio Mondiale, a new standard for LF, MF and HF digital broadcasting – signals. At the University of L'Aquila, Italy, some preliminary observations have been carried out receiving, at night-time, DRM signal that Vatican Radio broadcasts at 1611 kHz from S. Maria di Galeria, Rome. These observations have clearly shown the capability to detect sporadic-E. The low-cost of the proposed sensor suggests a spatial-sampling around the broadcasting station, in order to "image" the occurrences of sporadic-E.

1. Proposed method and preliminary results

Digital Radio Mondiale (DRM) is a digital sound broadcasting system to replace existing analogue AM broadcasting in the bands below 30 MHz (long-wave, medium-wave and short wave – LF, MF, HF –) [1]. It provides near-FM sound quality and also provides data content for display on a DRM receiver. The DRM system uses COFDM (Coded Orthogonal Frequency Division Multiplex) with a bandwidth of 9 or 10 kHz. Its standardization and regulation by ETSI and IEC can be found in [2, 3]; also ITU has considered the use of DRM on LF, MF and HF bands. DRM reception can be easily obtained using a simple RF front-end and a Personal Computer on which a proper code, e.g. "DREAM" [4] or "DIORAMA" [5], performs channel and audio decoding – a framework known as Software Defined Radio. A by-product of channel decoding is the impulse-response estimation. When DRM signal broadcasted in Medium Frequency band are received at nighttime, when there is no *D*-layer absorption, channel impulse-respond (IR) shows the possible presence of sporadic-*E* (*Es*) patches located at an altitude of about 110 km. Groundwave (*GW*), *Es* and *F*-layer contributions can be easily detected in the IR, where they appear as multipath. Using *GW* for synchronization, the virtual height *h'* can be computed for each ionospheric contribution. The need of *GW* reception constrains to use MF rather than HF bands. The cost of this kind of sounder is extremely low; this is a common feature for most "passive radar" techniques [6, 7]. A simple front-end that output low-IF (12 kHz) quadrature signals to the stereo audio input of a Personal Computer is available at less than 150 US$ [8]. At University of L'Aquila first experiments were run in summer 2004, when a couple of superheterodyne receivers were used to detect *Es* occurrences in Central Italy. Transmitting station was "Vatican Radio" which broadcasts DRM programs on several bands; among them MF (1611 kHz). Fig. 1 shows locations of involved stations. In Fig. 2 nighttime ionosphere sounding can be seen, where the occurrence of *Es* appears for some time to only one of the receiving stations. It is worth to note that, for a single-hop echo, sounded region has to be located at the middle of the path between TX and RX. By the use of several receiving stations, e.g. as depicted by smaller yellow circles in Fig. 1, a sampled image of *Es* patches can be obtained and input to a proper image reconstruction and/or motion detection algorithm. Collecting data on *Es* can help to a better understanding of *Es* related phenomena [9-11]. Figs. 3 and 4 show a comparison between proposed methods results and conventional ionograms taken at a nearby ionosonde station of the Italian "Istituto Nazionale di Geofisica e Vulcanologia" (INGV). A good agreement between data produced by the proposed method and ionograms is there shown. Proposed method, even if is able to collect just few data on ionosphere, has the advantages to run continuously and to allow a low-cost displacement of a network of sensors. It has also a potential in educating students on ionosphere. Each school or university that has a nearby DRM broadcaster can run its own basic ionosphere sounding.

2. References

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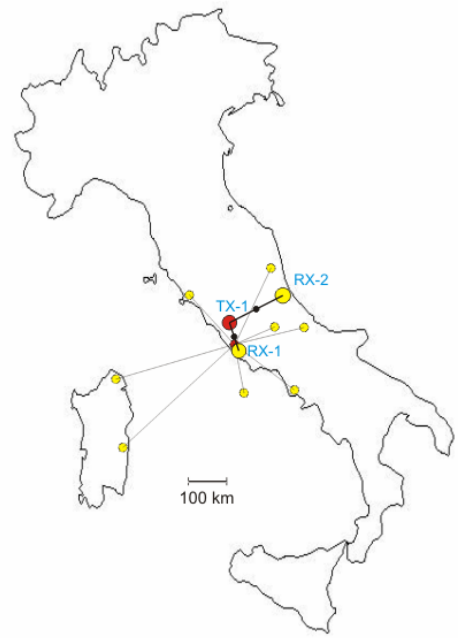

Fig. 1. First experiments of the proposed method were run in year 2004, involving stations labeled TX-1 (Vatican Radio Broadcast from S. Maria di Galeria, next to Rome) RX-1 in Anzio and RX-2 in Giulianova, next to Pescara. Next trials will involve the RAI station which recently started broadcasting DRM at 846 kHz and several RX stations (small red and yellow spots). Among them the ones in Sardinia island will exploit groundwave propagation over Tyrrhenian sea at low attenuation rate.

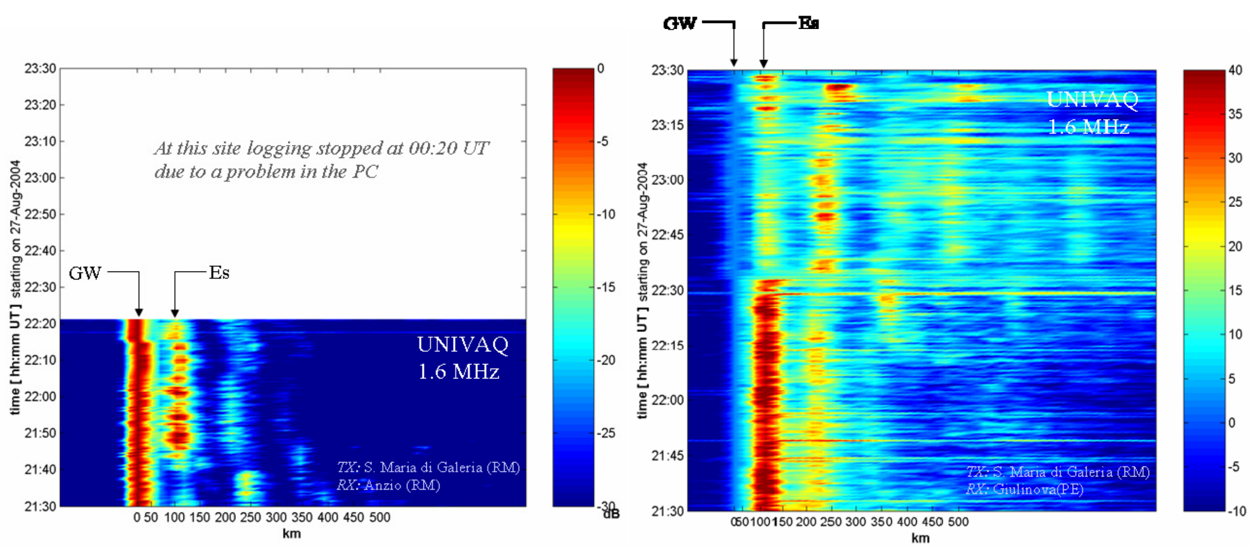

Fig. 2 Simultaneous nighttime ionosphere sounding by two station. Left plot refers to RX-1, while the right one to RX-2. Transmitting station was TX-1, broadcasting DRM at 1611 kHz. It can be easily observed that in time interval [21:30, 21:40] station RX-2 observes a strong *Es* echo, while station RX-1 didn't. Please note that station RX-2, due to the great distance from TX, receives a very weak groundwave (*GW*) signal with respect to *Es* one; that signal was however strong enough to achieve time synchronization. This activity was supported by University of L'Aquila (UNIVAQ).

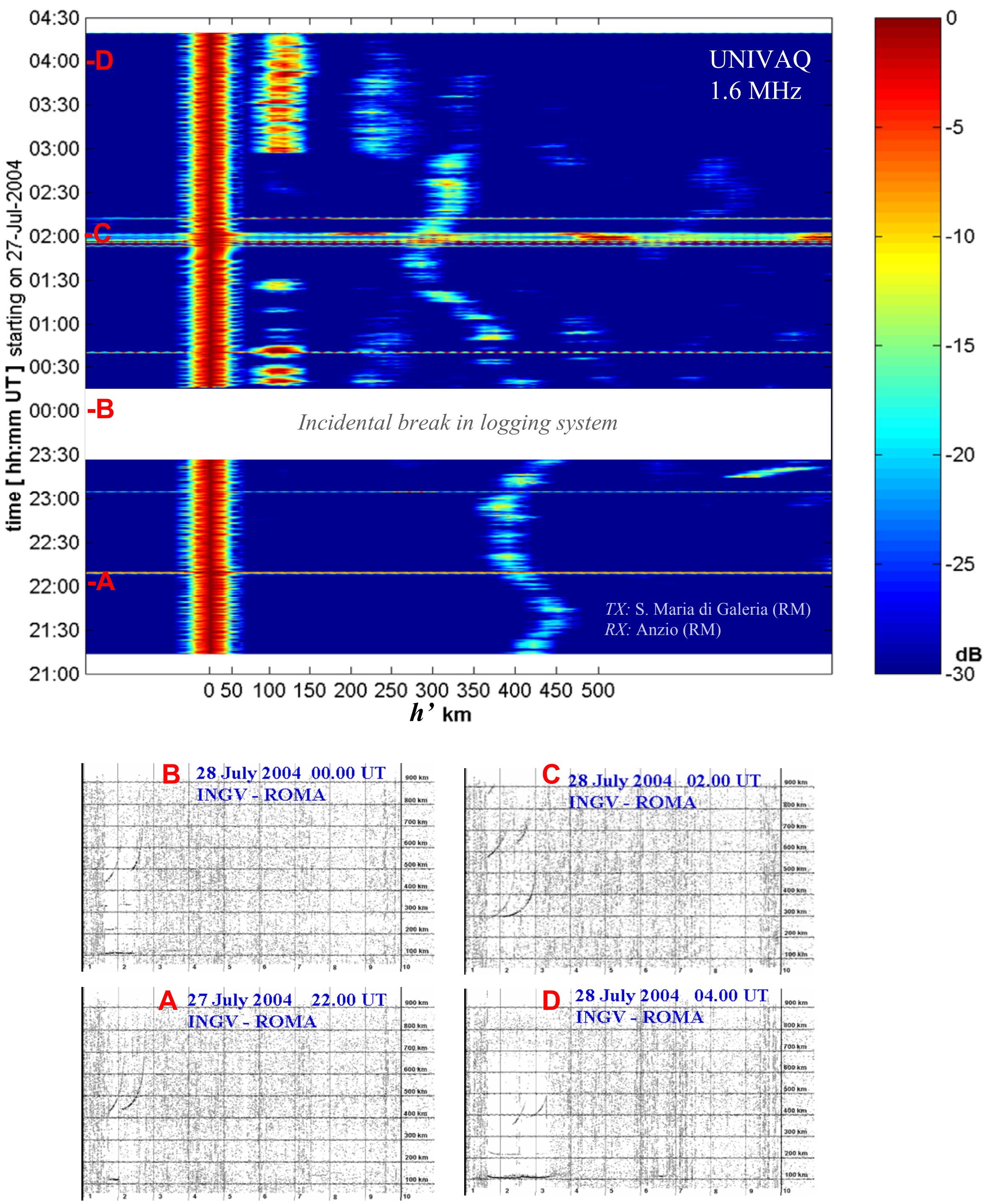

Fig. 3 Ionosphere virtual heights *h'* vs. time, as acquired by proposed method on July 27, 2004 (top color plot). Receiving station was at Anzio (RX-1 in Fig. 1), while transmitting station was Vatican Radio, broadcasting DRM at 1611 kHz (site TX-1). At time spots A-D it is possible to make a comparison with ionograms taken at INGV-Rome, which was running, in those days, an old-type ionosonde (bottom plots). From them it is possible to see an echo coming from *h'*≈110 km only at time spots A, B and D. Same behavior can be observed in the color plot. Fluctuating value of *h'F* can be observed by both methods, too.

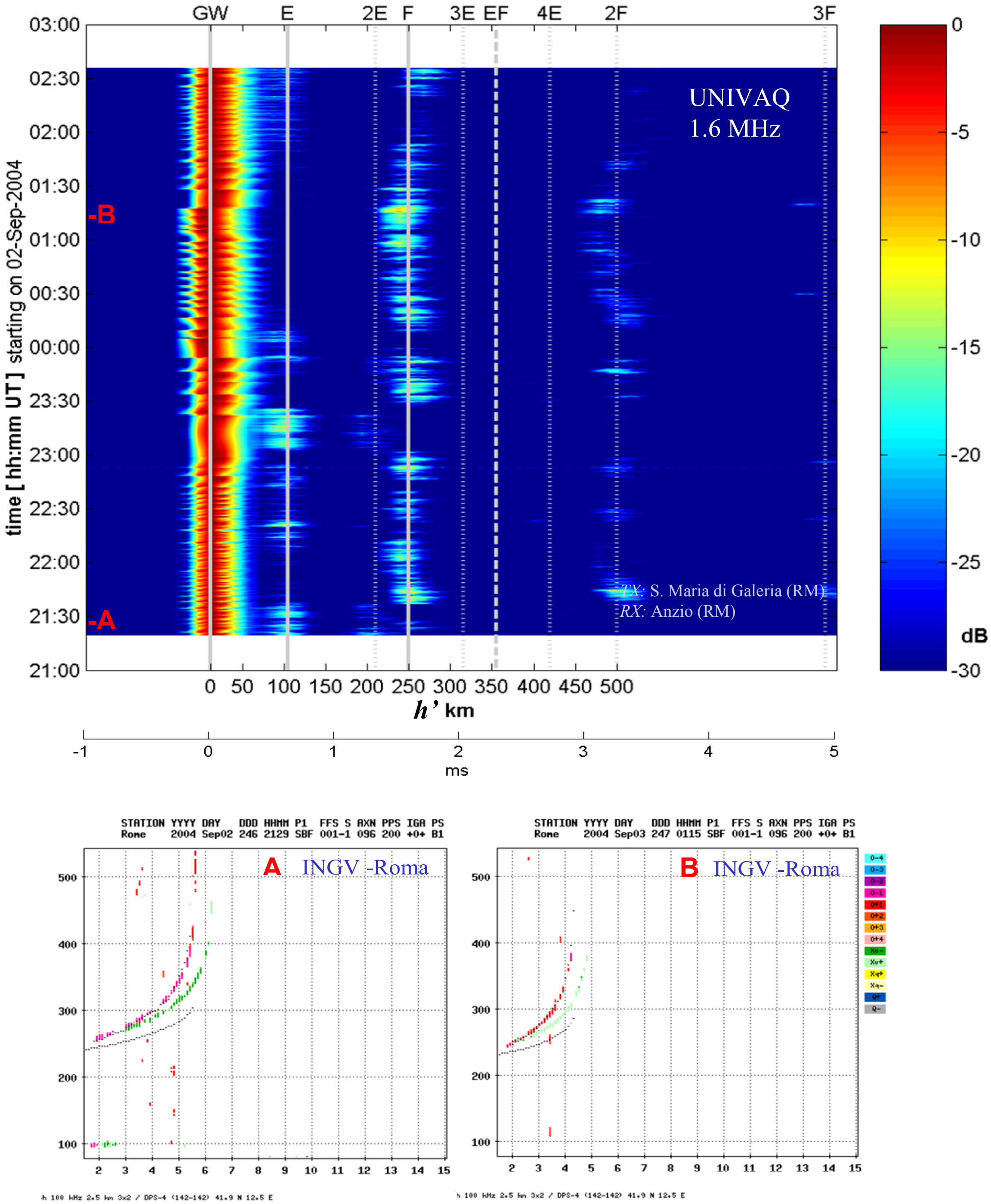

Fig. 4 Ionosphere virtual heights *h'* vs. time, as acquired by proposed method on September 02, 2004. Receiving station was at Anzio (RX-1 in Fig. 1), while transmitting station was Vatican Radio, broadcasting DRM at 1611 kHz (site TX-1). Vertical gray lines are added to help in classification of echoes. At time spots A and B it is possible to make a comparison to ionograms taken at INGV- Rome. Some multiple reflections (2E, 2F, 3F) can also be observed in the color plot.