Expanding the Reach of Ionosphere Real-Time Measurements: proposal of a virtual ionosonde concept

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Ionosphere is defined as the segment of earth's atmosphere that extends between approximately 60 and 1000 km where, among many other applications, radio transmission may reflect once proper conditions are present for a given frequency and position. [**1**] [**2**].

Oscillations on ionosphere properties are a key factor on most types of communications that travels within or across Earth's atmosphere as they alter propagation characteristics and its usage, like amateur radio and Global Navigation Satellite Systems (GNSS) for example.

The main agent of those fluctuations is the Sun through its flares and Coronal Mass Ejections (CMEs) [**3**] [**4**], what makes its comprehension a requirement to accessing and forecasting ionosphere status [**5**] [**6**]. Likewise, previous studies have demonstrated the effects of temperature in terms of thickness, density and altitude of the layer [**8**] [**9**] [**10**].

Therefore, on the 20th century, especially on its second half, telecommunications studies have increasingly focused on the ionosphere as humanity progressively turned dependent on propagation-related technology. As a result, models like the International Reference Ionosphere (IRI) have been developed to tackle the challenge of measuring, estimating and forecasting ionosphere state, generally using intensively data obtained from ionosonde networks.

The present research proposes the complementary use of automated RF transmissions between existing and future ionosonde stations to determine critical frequency in a wide range of additional world positions. From those real-time results it is proposed to infer other ionosphere properties on those locations, contributing to the layer's global model. The concept, called virtual ionosonde, would expand exponentially the reach of real-time measurements considering the combination of reflection coordinates possible between stations and could be additionally improved by periodically sampling those same positions using portable ionosondes.

References

[1] John M. Goodman, Ed., *The Effect of the Ionosphere on Communication, Navigation, and Surveillance Systems*., 1987.

[2] D. Bilitza et al., "International Reference Ionosphere 2016: From ionospheric climate to real-time weather predictions," *Space Weather*, vol. 15, pp. 418–429, Feb. 2017.

[3] N. Buzulukova, *Extreme Events in Geospace: Origins, Predictability, and Consequences*, Natalia Buzulukova, Ed. Amsterdam, Netherlands: Elsevier, 2018.

[4] Mirko Piersanti et al., "Comprehensive Analysis of the Geoeffective Solar Event of 21 June 2015: Effects on the Magnetosphere, Plasmasphere and Ionosphere Systems," *Solar Physics*, vol. 292, no. 169, September 2017.

[5] Francesco Berrilli et al., "The relativistic solar particle event of May 17th, 2012 observed on board the International Space Station," *Journal of Space Weather and Space Climate*, vol. 4, p. A16, 2014.

[6] Luca Di Fino et al., "Solar particle event detected by ALTEA on board the International Space Station," *Journal of Space Weather and Space Climate*, vol. 4, p. A19, 2014.

[7] G. Drukarev, "On the mean energy of electrons released in the ionization of gas," *Journal of Physics (URSS)*, pp. 81-84, 1946.

[8] G. V. Khazanov, "Kinetic theory of inner magnetospheric plasma," *Astrophysics and Space Science Library*, vol. 372, p. 584, 2010.

[9] R. W. Schunk and A. F. Nagy, *Ionospheres: Physics, plasma physics, and chemistry*. Cambridge, UK: Cambridge University Press, 2011.