



HAL
open science

Sub-ionospheric VLF/LF waveguide anomalies over Europe

Hans U. Eichelberger, Mohammed Y. Boudjada, Konrad Schwingenschuh, Patrick H. M. Galopeau, Alexander Rozhnoi, Maria Solovieva, Pier F. Biagi, Viktor Fedun, Bruno P. Besser

► **To cite this version:**

Hans U. Eichelberger, Mohammed Y. Boudjada, Konrad Schwingenschuh, Patrick H. M. Galopeau, Alexander Rozhnoi, et al.. Sub-ionospheric VLF/LF waveguide anomalies over Europe. URSI GASS 2021. Proceedings, Aug 2021, Rome, Italy. insu-03597698

HAL Id: insu-03597698

<https://insu.hal.science/insu-03597698v1>

Submitted on 4 Mar 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Sub-ionospheric VLF/LF waveguide anomalies over Europe

Hans U. Eichelberger⁽¹⁾, Mohammed Y. Boudjada⁽¹⁾, Konrad Schwingenschuh⁽¹⁾, Patrick H. M. Galopeau⁽²⁾, Alexander Rozhnoi⁽³⁾, Maria Solovieva⁽³⁾, Pier F. Biagi⁽⁴⁾, Viktor Fedun⁽⁵⁾, and Bruno P. Besser⁽¹⁾

(1) Space Research Institute, Austrian Academy of Sciences, Graz, Austria, <http://www.iwf.oeaw.ac.at>

(2) LATMOS-CNRS, UVSQ Université Paris-Saclay, Guyancourt, France

(3) Schmidt Institute of Physics of the Earth, Russian Academy of Sciences, Moscow, Russia

(4) Department of Physics, University of Bari, Bari, Italy

(5) Department of Automatic Control and Systems Engineering, The University of Sheffield, Sheffield, UK

Extended Abstract

Ground based long-term sub-ionospheric VLF/LF amplitude and phase measurements of propagation paths along spatially far away distributed transmitter and receiver facilities provide a powerful tool to characterize waveguide parameters and their variations under various endo- and exogenic dynamics. This monitoring service is usually one component of multi-parameter seismo-electromagnetic investigations. Figure 1 shows the dense web-like structure of the radio links with a focus on Europe, details and performance of the receiving facilities are given in [1, 2].

The VLF/LF waveguide extends from the Earth's surface up to the D/E-region (day/night) of the ionosphere with a variety of natural and man-made electromagnetic sources in the lithosphere, atmosphere, and ionosphere. Our primary objective are soundings of waveguide modifications related to seismic activity determined via regular VLF/LF amplitude and phase measurements at the receiver stations. We show results from earthquakes with magnitude $M_w \geq 5.5$ where VLF/LF radio link crossings are available (observations over Southern Europe during the last years) and we explore coupling mechanism within the waveguide boundaries, among them acoustic waves and atmospheric gravity waves. In general, numerous amplitude and phase anomalies with a suitable S/N ratio are available, but it is mandatory to probe the full power of combined links in the network in order to disentangle the sources. The study also explore the impact and potential of complementary investigations from ground and space.

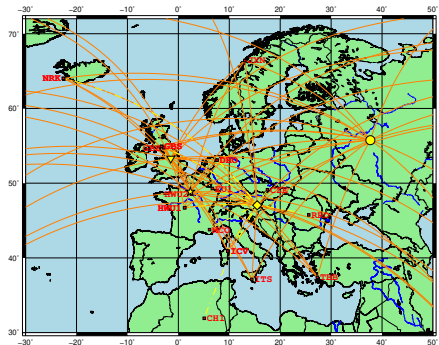


Figure 1. Map of the European part of the VLF/LF receiver network (three operational stations, one planned; symbols in yellow) showing the great circle paths (orange lines) to the transmitters (red squares) in the northern hemisphere. Additional receivers which further intensify the net – mainly in Southern Europe, the INFREP system [2] – are not shown, except the Graz station with paths to ten transmitters (yellow dot-dot-dash lines).

References

- [1] K. Schwingenschuh, G. Prattes, B. P. Besser, K. Mocnik, M. Stachel, Ö. Aydogar, I. Jernej, M. Y. Boudjada, G. Stangl, A. Rozhnoi, M. Solovieva, P. F. Biagi, M. Hayakawa, and H. U. Eichelberger, “The Graz seismo-electromagnetic VLF facility,” *NHESS*, **11**, 2011, pp. 1121–1127, doi: 10.5194/nhess-11-1121-2011.
- [2] P. F. Biagi, T. Maggipinto, F. Righetti, D. Loiacono, L. Schiavulli, T. Ligonzo, A. Ermini, I. A. Moldovan, A. S. Moldovan, A. Buyuksarac, H. G. Silva, M. Bezzeghoud, and M. E. Contadakis, “The European VLF/LF radio network to search for earthquake precursors: setting up and natural/man-made disturbances,” *NHESS*, **11**, 2011, pp. 333–341, doi: 10.5194/nhess-11-333-2011. <http://www.infrep-network.eu/> as of Feb. 2020.