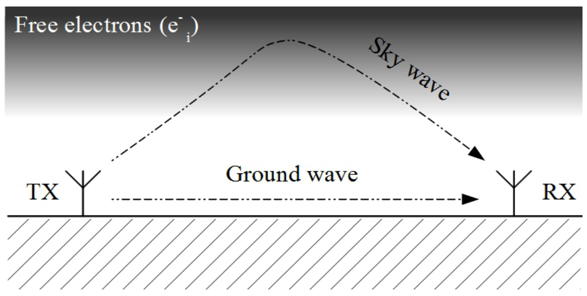
Evidence for VLF radio waves propagation perturbations associated with single meteors

Jean-L. Rault
International Meteor Organization Radio Commission, f6agr@orange.fr

Evidence is given in this presentation that under some circumstances, a single meteor, when entering the Earth atmosphere, is capable of disturbing the propagation of VLF (Very Low Frequency) electromagnetic waves in the Earth ground-ionosphere waveguide.

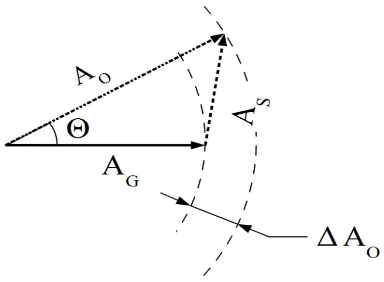
VLF waves propagation

Natural and man-made VLF (Very Low Frequency) electromagnetic waves propagate on Earth at very long distances, thanks to a natural low attenuation waveguide. The ground and the lowest layer of the ionosphere behave like a two parallel plates low attenuation waveguide.

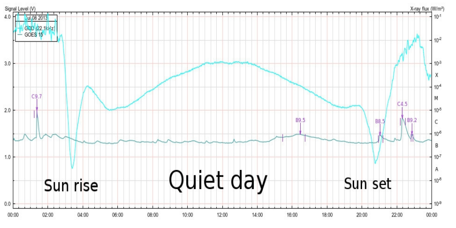


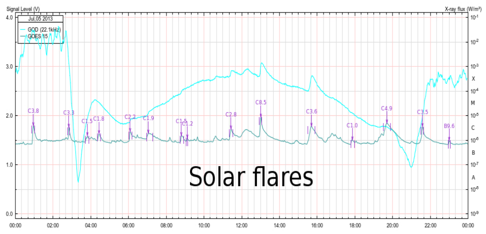
VLF waves propagation disturbances

According to the ray tracing method commonly used to describe VLF radio propagation on short to moderate distances (<2000 km) [1], the amplitude of a VLF radio wave at a given observation location is the vectorial sum $\vec{A}_O=\vec{A}_G+\vec{A}_S$. Vector lengths of $\vec{A}_G$ and $\vec{A}_S$ represent respectively the amplitude of the ground wave propagating along the Earth surface, and of the sky wave reflected from the D or E layer of the ionosphere. The angle between the two vectors represents the phase (delay) between the ground wave and the sky wave components.

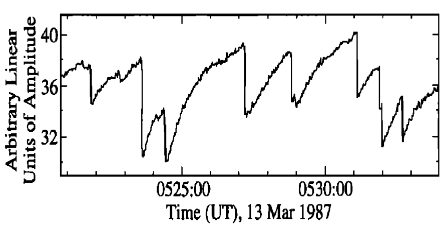


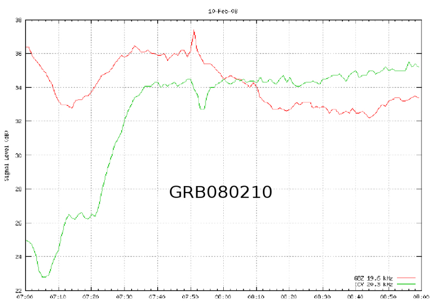
The amplitude and the phase of the sky wave $\vec{A}_S$ at the observation location depend on the altitude and on the density of free electrons of the D or E layer of the ionosphere. Various natural phenomenons such as solar flares, polar cap absorption events, X rays and γ rays radiated by distant stars, and lightning create long duration or short transient VLF propagation disturbances by modifying the ionospheric D or E layer parameters [2].





Exemples of solar effects on the VLF propagation [3]





Lightning induced electron precipitations [4]

Gamma ray burst [5]

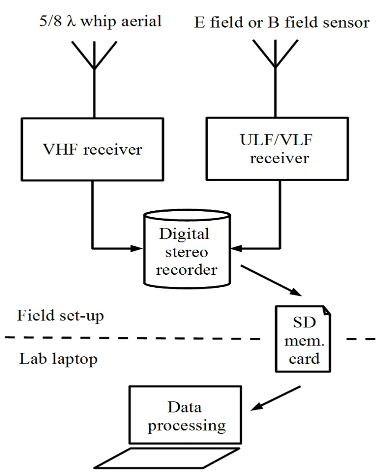
Searching for VLF disturbances induced by meteors

VLF phase [6] and amplitude [7] transient variations occurring during meteor showers were reported in the past, but these variations were observed on a statistical basis and at large time scales only (i.e. averaged values), but were not directly linked to any single meteors.

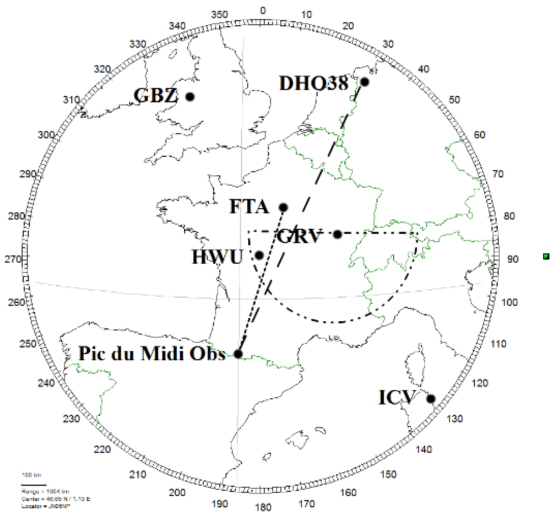
Observation of a first transient VLF disturbance induced by a single meteor

In the framework of a joint radio/video meteor observations campaign, VLF/VHF radio and video data were synchronously recorded at the Pic du Midi observatory during the 2010 Geminids meteor shower [5].

The radio set-up consisted mainly of an home-made e-field ELF/VLF broadband receiver (5 Hz to 24 kHz pass-band), a VHF commercial receiver dedicated to meteor pings detection and a digital hifi stereo recorder. Five military communications VLF transmitters (GBZ, DHO38, FTA, HWU and ICV) were monitored simultaneously 24 hours a day. Meteors were detected in VHF forward scatter mode, using the french military Graves (GRV) radar as targets illuminator (See map below).



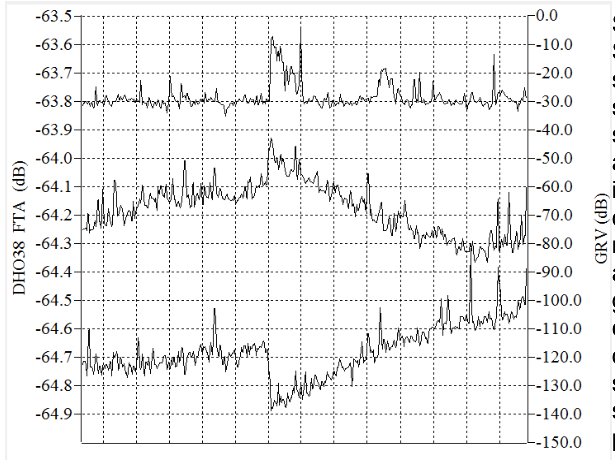
Short amplitude transients on the amplitude of the german VLF transmitter DHO38 and of the french VLF transmitter FTA were serendipitously observed when a large meteor entered the atmosphere on december 13 at 23h13m44s UT. No visible transients were observed at the same time on the amplitudes of GBZ, HWU or ICV.



On the plot below, the upper trace shows successive meteor echoes, detected in forward VHF scatter mode.

The middle trace shows a constructive interference between $\vec{A}_S$ and $\vec{A}_G$ detected on FTA, and the lower trace shows a destructive interference on DHO38.

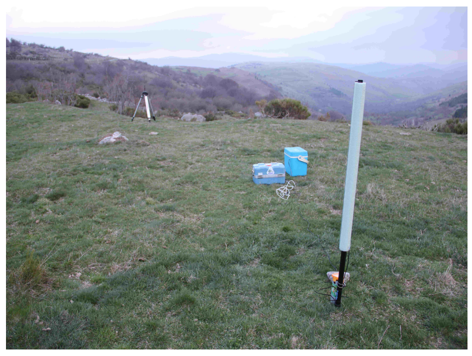
The horizontal time scale on the figure below is 10 s/div, and the vertical VLF amplitudes scale are 0.1 dB/div.



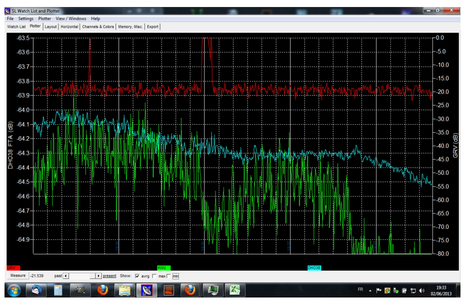
Such "M-SID" (Meteor induced Sudden Ionospheric Disturbance) seem to be faint and rare. They are supposed to be created by a sudden variation of density and/or altitude of the lower region of the ionosphere, this variation being due to the appearance of a large meteor overdense trail (presenting a free electrons line density greater than 2×10^{14} electrons/meter) . Until now, all the observed transcients present a similar shape, starting with a steep slope and followed by a progressive recovery (about 60 seconds long) .

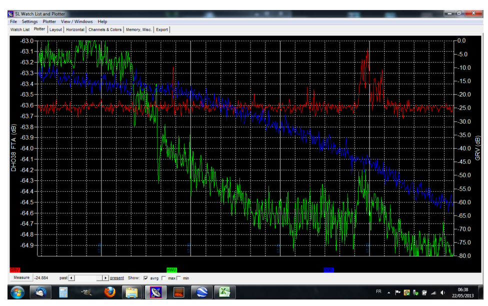
Observation of further meteor transient VLF disturbances

During the 2013 Lyrids meteor shower, a campaign dedicated to the observation of potential VLF meteor perturbations was performed in a remote area located in Lozère, France. About 50 large overdense meteors echoes were manually analysed and several new meteor-induced VLF amplitude disturbances were found. Former various VHF/VLF records performed mainly during Geminids 2008, 2009, 2010, 2011, 2012, Leonids 2009, 2012, Perseids 2009, 2010, 2011, 2012 are waiting for manual analysis ...



From left to right: VHF aerial, electronics container and ELF/VLF aerial



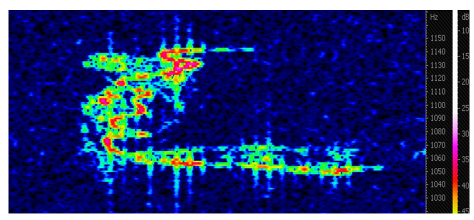


Green: HWU transmitter (France)

Pale blue: DHO38 tranmitter (Germany)

Dark blue: GBZ transmitter (UK)

Red: VHF meteor pings



Spectral analysis of the above meteor echo

Acknowledgments

Warm thanks to François Colas and Jérémie Vaubaillon from IMCCE for inviting the author to participate at several observation campaigns at Pic du Midi observatory and Haute-Provence observatory.

References

[1] Delcourt J.J., (2000), Ionosphère région D, Lavoisier, ISBN 2-7462-0656-0, 141-142
[2] Barr R. et al., (2000), Journal of Atmospheric and Solar-Terrestrial Physics, 62, 1689-1718
[3] Loudet L. (2013) http://sidstation.loudet.org/data-fr.xhtm
[4] Lev-Tov S.J. (1995), Journal of Geophysical Research, Vol. 100 NO A11, 21,375-21,3
[5] Godet J.P. (2008) Private correspondance
[6] Chilton, C.J., (1961), Journal of Geophysical Research 66, 379-383
[7] De S.S.,(2006), Indian Journal of radio & Space Physics, Vol.35 dec, 396-400
[8] Rault J.L., (2010), WGN, the Journal of the IMO 38:2, 67-75