Pulse Dispersion into the Earth-Ionosphere Waveguide: Lightning Distance Estimation

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The aim of this work is to investigate the possibility of estimating the lightning distance in day time areas by using the waveform of the received ELF-VLF-LF signal. The propagation within the earth-ionosphere waveguide is presented with a ray model. The dispersion suffered by the wideband lightning radiated pulse is simply expressed. This in turn is used to estimate the distance using a novel expression different from previous works (Hepburn F., "Analysis of smooth type atmospheric waveforms", *Jornal of Atmospheric and Terrestrial Physics*, vol. 19, 1960, pp. 37-53 and Ozaki M., Yagitani S., Miyazaki K., Nagano I., "An Improved Distance Finding Technique for Single-Site Lightning Location System Using Reflection Characteristics of the Anisotropic Ionosphere", *General Assembly and Scientific Symposium, 2011 at Istanbul, URSI*).

The novelty of our work is a new formulated technique that may be easier to implement in an automatic system. That kind of system should be used to monitor the far lightning activity in meteorological studies.

In our present work, we consider the earth and the ionosphere as a waveguide with height h. From image theory, a waveguide mode is formed by a set of rays that are finite in practice because of losses. From simple considerations (the earth is a perfect E-plane and the ionosphere is a perfect H-plane) and using the impulse response of a waveguide, it can be shown that each half-wave of the signal corresponds to a received ray N. It's now easy to separate each of them and extract their time duration T. Then for each ray the distance ρ is estimated by:

$$\rho = 2hN\sqrt{\left(\frac{2h}{Tc}\right)^2 - 1} \tag{1}$$

where c the speed of light. Then a convergence of estimated distance is obtained for each T values at the correct N values of each received ray. For a very distant lightning (ρ>2000 km) N should start by 2 or 3 since the first ray is carrying a too high frequency to be supported by the earth-ionosphere waveguide at day time (D region absorption). Another reason for this may be found in the lightning (return stroke part) radiated spectrum.

A wideband receiving system (100 Hz-100 kHz) with an untuned ferrite rod antenna and a low noise transimpedance amplifier is used to receive the signals. Finally a comparison with the lightning maps activity given by the World Wide Lightning Location Network (WWLLN) shows a good correlation between the estimated distance and the distance of African stormy area from our station located in Paris.