EGU21-3973, updated on 18 May 2021
https://doi.org/10.5194/egusphere-egu21-3973
EGU General Assembly 2021

Modeling ELF waves in the non-uniform Earth-ionosphere cavity

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Below 100 Hz, in the lowest part of the extremely low frequency (ELF, 3 Hz - 3 kHz) band lightning-radiated electromagnetic waves propagate with extremely low attenuation (roughly below 1 dB/Mm) within the Earth-ionosphere waveguide which makes possible the formation of global electromagnetic resonances, known as Schumann resonances (SRs). The most commonly used description of this resonance field assumes a uniform Earth-ionosphere cavity, i.e. that the propagation conditions for ELF waves are practically the same on the dayside and nightside hemispheres, which is the most vulnerable simplification of these models.

In this work we present two different forward models for SRs that take into consideration the day-night asymmetry of the Earth-ionosphere cavity and are based on the analytical and numerical solutions of the two-dimensional telegraph equation (TDTE). We present numerical tests showing that the two models produce practically the same output, i.e. the relative difference between them is less than 0.4%. The conspicuous conformity between the outputs establishes not only the correctness of the formalisms but the correctness of the implementations (the coding) as well. To the best of the authors' knowledge this is the first work that verifies this conformity between the two independent solutions.

We also compare our stationary models with time-dependent solutions of the TDTE as the stationarity of the resonance field may represent the next most vulnerable simplification that needs to be dismissed to approach a more realistic theoretical description of SRs. All these steps in model development serve our aim to infer global lightning activity based on multi-station ELF measurements by applying a sophisticated inversion algorithm.