Answers to reviews of the paper **"FDTD Analysis of ELF Radio Wave Propagation in the Spherical Earth-ionosphere Waveguide and its Validation Based on Analytical Solutions"**, by V. Marchenko, A. Kulak, and J. Mlynarczyk

Reviewer 2

Major comments:

REVIEWER COMMENT:

Line 115-116, I don't really understand this part, what do you mean "extend the simulation time by adding the values of fields at the last time step of FDTD simulation"?

ANSWER:
Thank you for taking your time to review our manuscript.
We are sorry for being not clear in this description, and we would like to clarify this part of our analysis. Using the computer cluster we were able to run FDTD simulations up to 100 s, which gives the frequency resolution $df = 0.01$ Hz. Next we were trying to improve the frequency resolution by extending the simulation manually to 1000 s by adding the values of EM fields at the last time step of FDTD simulation (these values at $t = 100$ s are almost zero). And that what we meant by "extend the simulation time".
However, we realized that such operation is not really improving the frequency resolution in case of strong attenuation of electromagnetic waves, which is our case.
After discussing this issue in our team and following the reviewers' suggestions we have decided to remove this manual extension of TD result and keep the original (*true*) $t_{max} = 100$ sec, and $df = 0.01$ Hz.

REVIEWER COMMENT:

Line 120 – 130, please add more details for the filter used in the lightning source and add the comparison results between the original source and the filtered one.

ANSWER:
Thank you for this comment. We have added the details of filtering that we have applied. Also in Figure 1 below we present TD and FD results for filtered and not-filtered source. On that plot we show the result for probe position at $\theta = 10^{\circ}$.
Filtered and not-filtered results are similar in FD in Schumann resonance range: almost identical for the magnetic field H_p, but in case of electric field E_r for not-filtered source there are some oscillations in the spectra. Not-filtered source introduces strong artefacts in the time domain and also and in the frequency domain at frequencies out of the range of interest. Lack of filtration would also lead to energy leakage, which would influences the amplitude.

REVIEWER COMMENT:

Line 131, instead of mention "a finite speed", please give the value of the velocity used in the calculation.

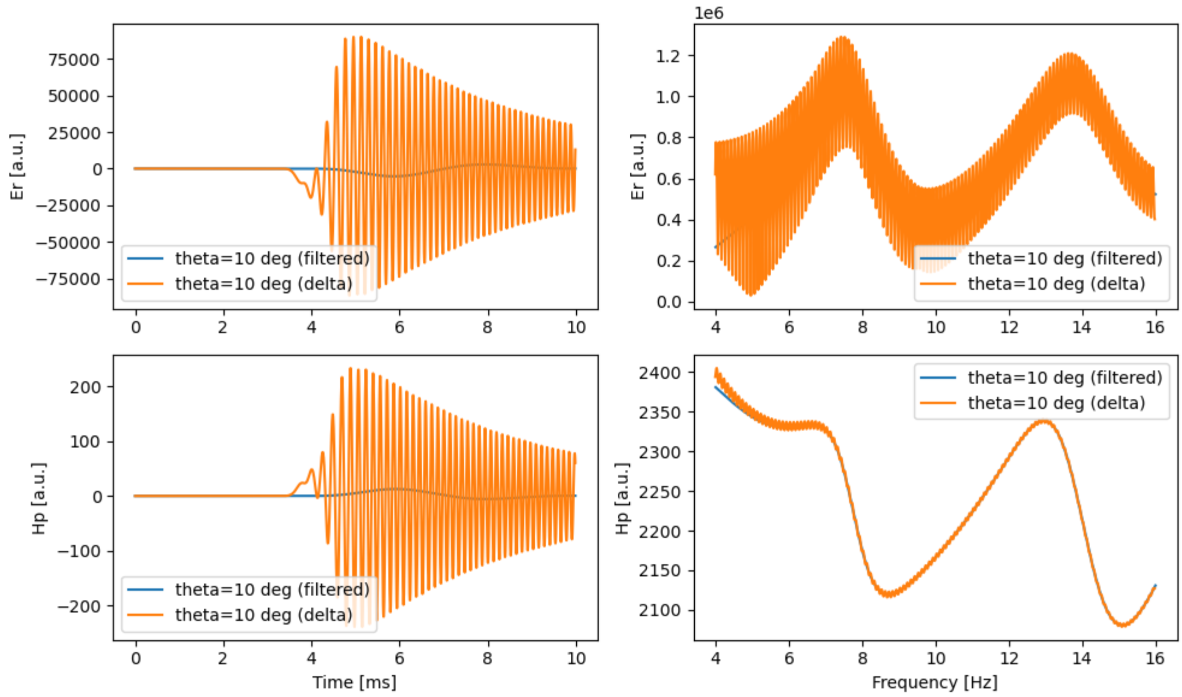

Figure 1: The comparison of TD and FD results for filtered and not-filtered source.

ANSWER:
Thank you for this comment. We have added the value of the velocity, that we took from Rakov (2007), namely $v = 10^8\ m/s$.

REVIEWER COMMENT:

> The Schumann resonance spectrum figures corresponding to the table 1-3 are suggested to present in the paper.

ANSWER:
Thank you for this suggestions. We have added the correspondent spectra to all models of conductivity profiles that we have used.

REVIEWER COMMENT:

> In section 3.3, I don't really understand why the authors used the "two-layered" waveguide since there are different exponential profiles which are capable to describe the features. For example, the traditional Wait and Spies' exponential profile gives a reasonable approximation for the electron density profile below 90-km altitude compared to the IRI model. How did you deal with the conductivity located at the boundary between the different two layers?

ANSWER:
We have used two-layered conductivity profile in order to be able to validate the FDTD simulations, because for two-layered profile we can calculate the results analytically using our analytical model, and then compare it with FDTD.
As a continuation of our FDTD simulations using more realistic conductivity profile we decided to use recently published profile from Kudintseva et al. (2016). Since this profile is defined up to 100 km, the electromagnetic waves were not attenuated enough, causing artefacts. Therefore we have decided to extend the conductivity profile from Kudintseva et al. (2016) with some realistic continuation to higher values of conductivity, and as such natural continuation we have used the corresponding IRI profile for middle altitudes which smoothly extends the profile from Kudintseva et al. (2016).

REVIEWER COMMENT:

> In section 4, I am also confused, instead of the entire IRI model, why did the authors use the partial profile proposed in Kudintseva et al, 2016] and partial IRI model? Please add more comments for this part.

ANSWER:
We needed a realistic model from the Earth's surface up to about 500 km. Since IRI model is defined for $h > 80$ km we combined it with a recently published conductivity profile in Kudintseva et al. (2016) for the altitudes $h < 100$ km.

Minor comments:

REVIEWER COMMENT:

> Line 25, add the reference:
> Marshall, R. A. (2012), An improved model of the lightning electromagnetic field interaction with the D-region ionosphere, J. Geophys. Res., 117, A03316, doi:10.1029/2011JA017408

ANSWER:
We have added this reference.

REVIEWER COMMENT:

> Line 42, the full-wave method (FWM) based on finite element approach need to mention in the introduction part:
> Lehtinen, N. G., and U. S. Inan (2008), Radiation of ELF/VLF waves by harmonically varying currents into a stratified ionosphere with application to radiation by a modulated electrojet, J. Geophys. Res., 113, A06301, doi:10.1029/2007JA012911
> Lehtinen, N. G., and U. S. Inan (2009), Full-wave modeling of transionospheric propagation of VLF waves, Geophys. Res. Lett., 36, L03104, doi:10.1029/2008GL036535

ANSWER:
We have added these studies to the introduction.

REVIEWER COMMENT:

> Line 44, if I understand here correctly, the authors want to mention the "Q bursts" in the Schumann resonance:
> Ogawa, T., Y. Tanaka, M. Yasuhara, A. C. Fraser-Smith, and R. Gendrin. "Worldwide simultaneity of occurrence of a Q-type ELF burst in the Schumann resonance frequency range." Journal of geomagnetism and geoelectricity 19, no. 4 (1967): 377-384.

ANSWER:
We have added this reference.

REVIEWER COMMENT:

> Line 142, please explain the parameters in the equation there.

ANSWER:
Thank you for this comment. We have added the explanation of these parameters.