ANALYSIS OF ELECTRON TRAJECTORIES IN HARMONIC UNDULATOR WITH SCILAB'S MODEL BASED DESIGN CODES

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Paper Id- WEA2WD03, WEA2WD04 WEP2PT030

Outline

- Present work based on Scilab's Model Based design.
- Model for electron trajectory
  - Analytical method
  - Numerical method
  - From simulated/ real data of magnetic field
- Model for Undulator Magnetic field

- Scilab's Xcos model-based simulation blocks have been used to simulate the trajectories of an electron traversing through a harmonic undulator.
- The trajectory of electron along x direction has been simulated from numerical and analytical methods.
- Analysis given in the present paper is compared with the other codes.
- Parallel simulation of harmonic undulator magnetic field along with trajectories of electron is given in the present analysis.

- Model-based development (MBD) is a paradigm shift in software development.
- MBD focuses on executable models of the systems of equations. These models allow a wide range of analysis
- Scilab/ Xcos based simulation models for analytical solutions of electron trajectory equations has been presented earlier with some limitations in InPAC 2018. It has been modified in present paper.

PRESENT SIMULATION EQUATION

Undulator Magnetic field along z

$$B = [0, a_0 B_0 (sin k_u z + \Delta sin k_h z), 0]$$

Electron trajectory along x

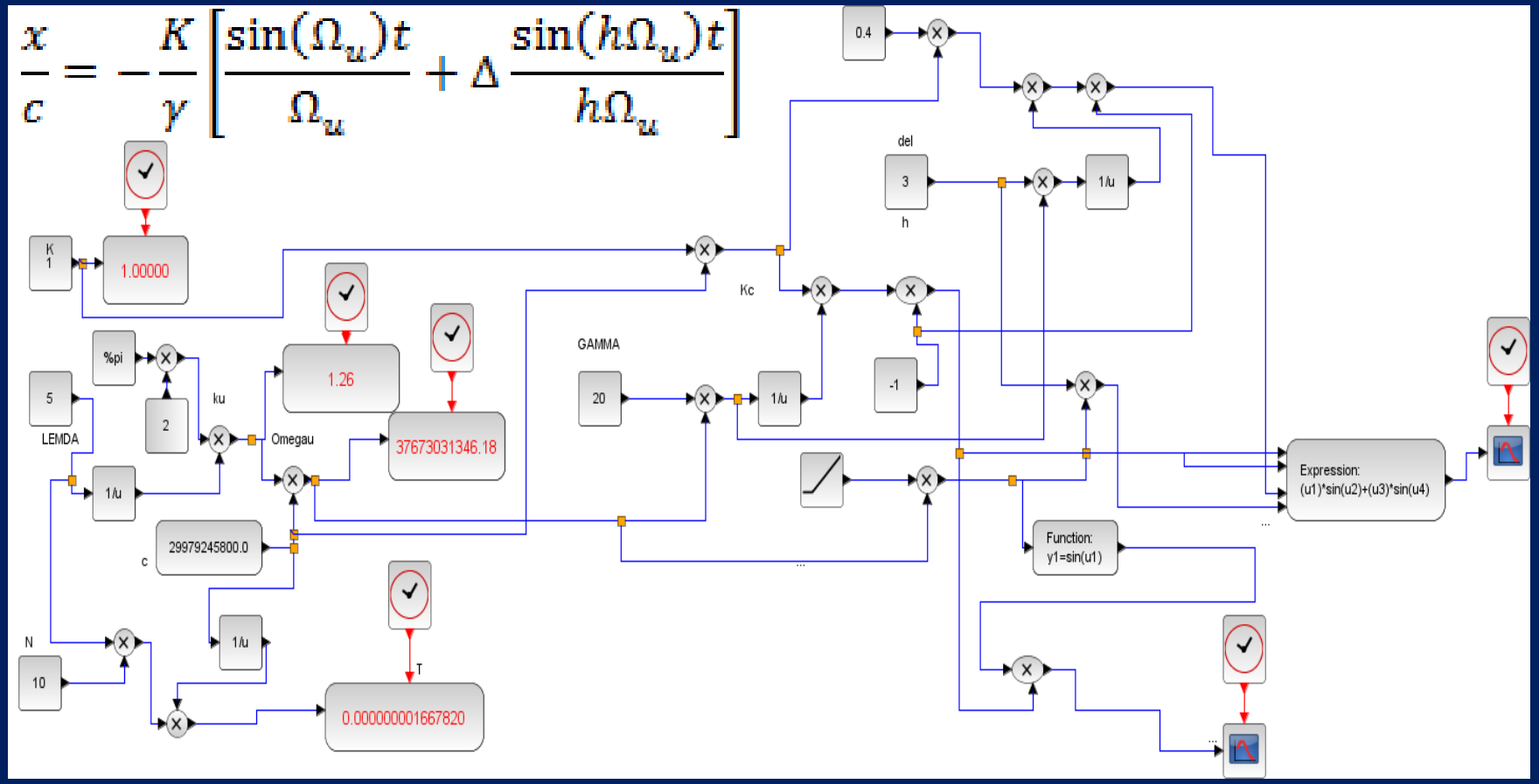
$$\frac{x}{c} = -\frac{K}{\gamma}\left[\frac{\sin(\Omega_u)t}{\Omega_u} + \Delta\frac{\sin(h\Omega_u)t}{h\Omega_u}\right]$$

SIMULATION PARAMETER

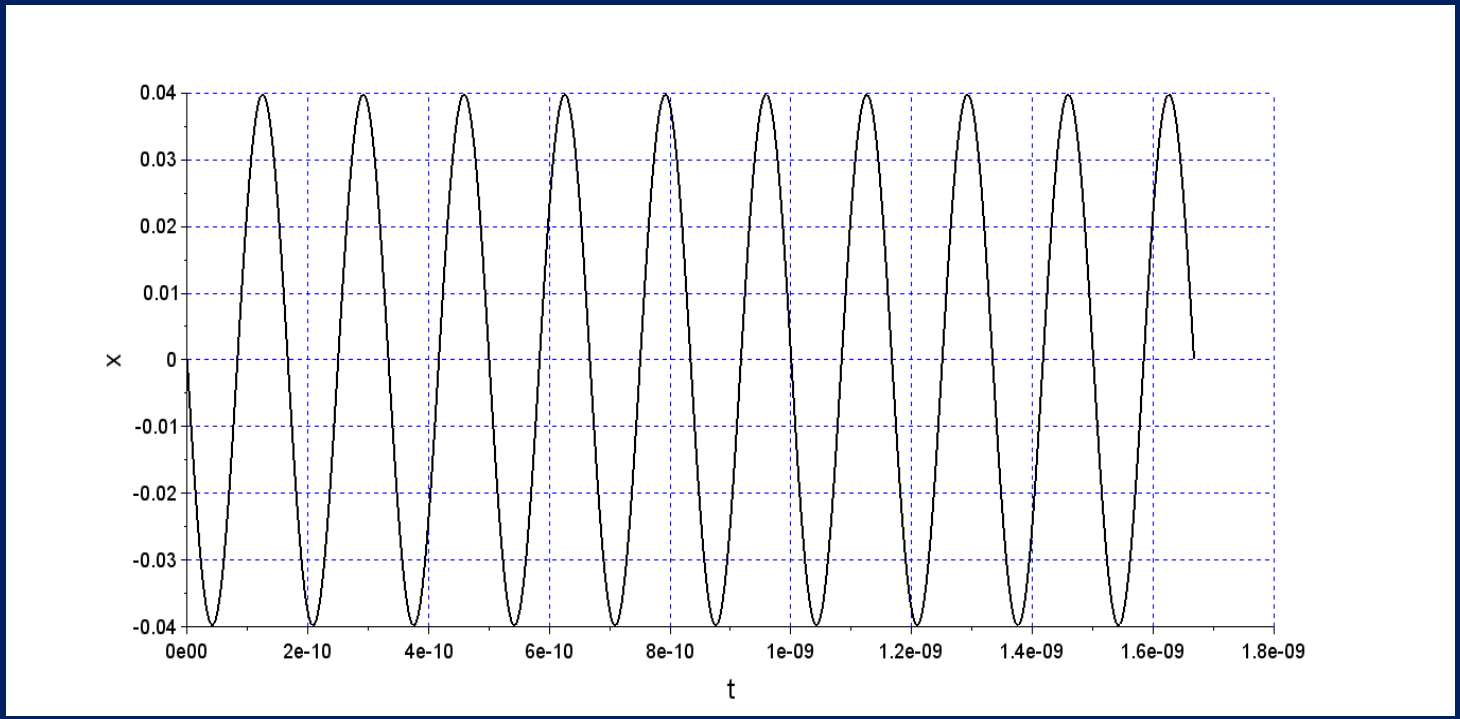
Parameter	Symbol	Values
Undulator parameter	K	1
Number of Undulator periods	N	10
Undulator wavelength	λ	5cm
Relativistic parameter	γ	20
Harmonic integer	h	3
Contribution of harmonic field	Δ	0, 0.1, 0.2, 0.4

Simulation model of Electron Trajectory in Planar and Harmonic Undulator

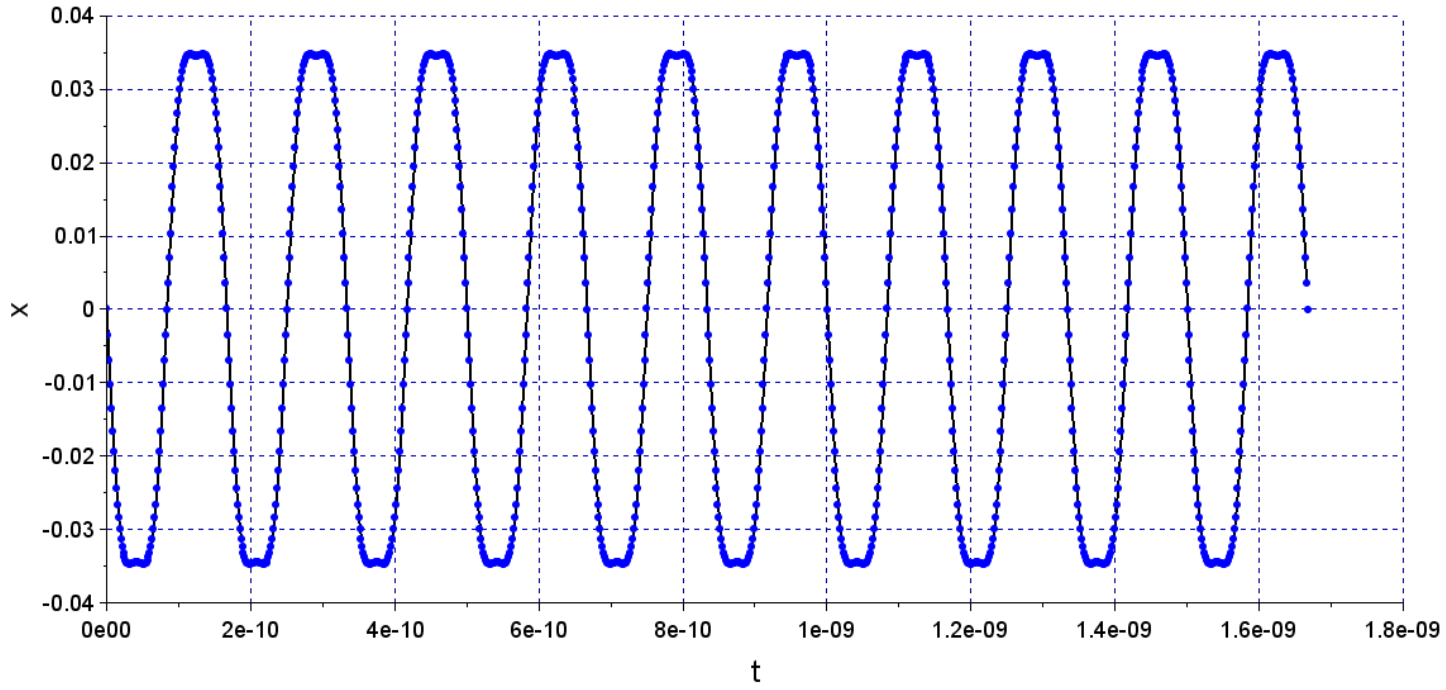
$$\frac{x}{c} = -\frac{K}{\gamma}\left[\frac{\sin(\Omega_u)t}{\Omega_u} + \Delta\frac{\sin(h\Omega_u)t}{h\Omega_u}\right]$$



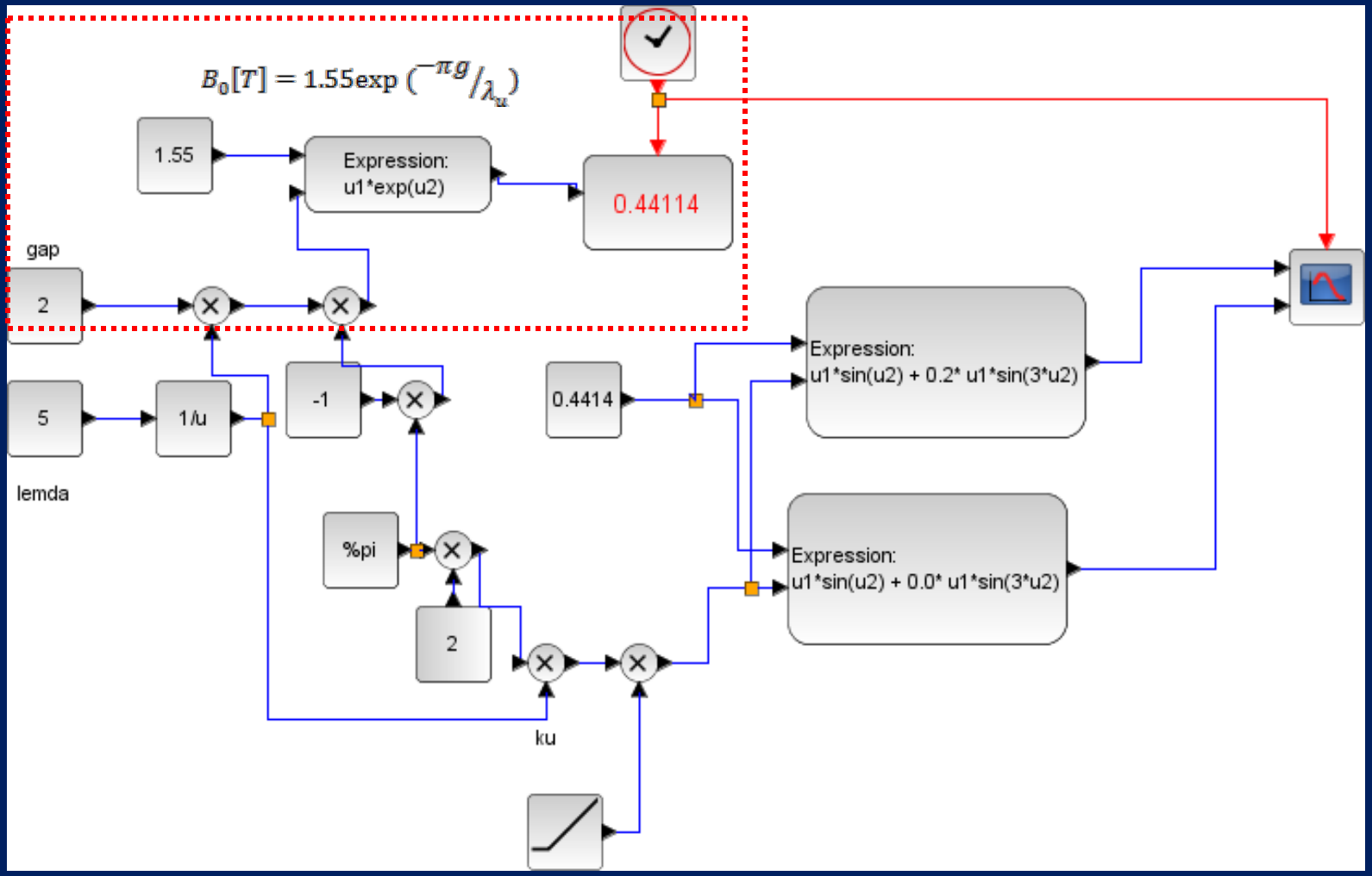
Trajectory of electron along ‘x’ in cm v/s time in seconds in Planar undulator



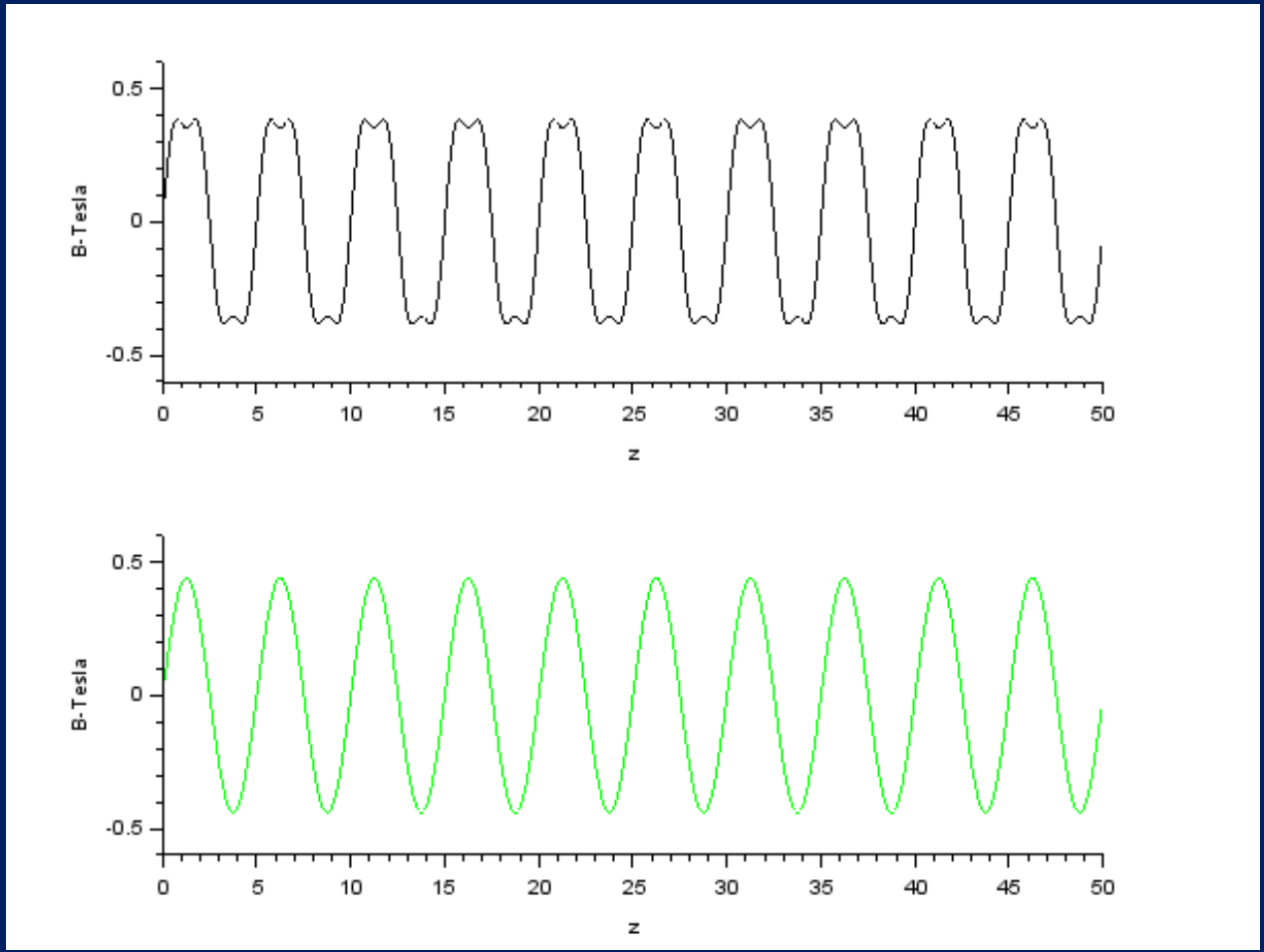
Trajectory of electron along ‘x’ in cm v/s time in seconds in Harmonic undulator



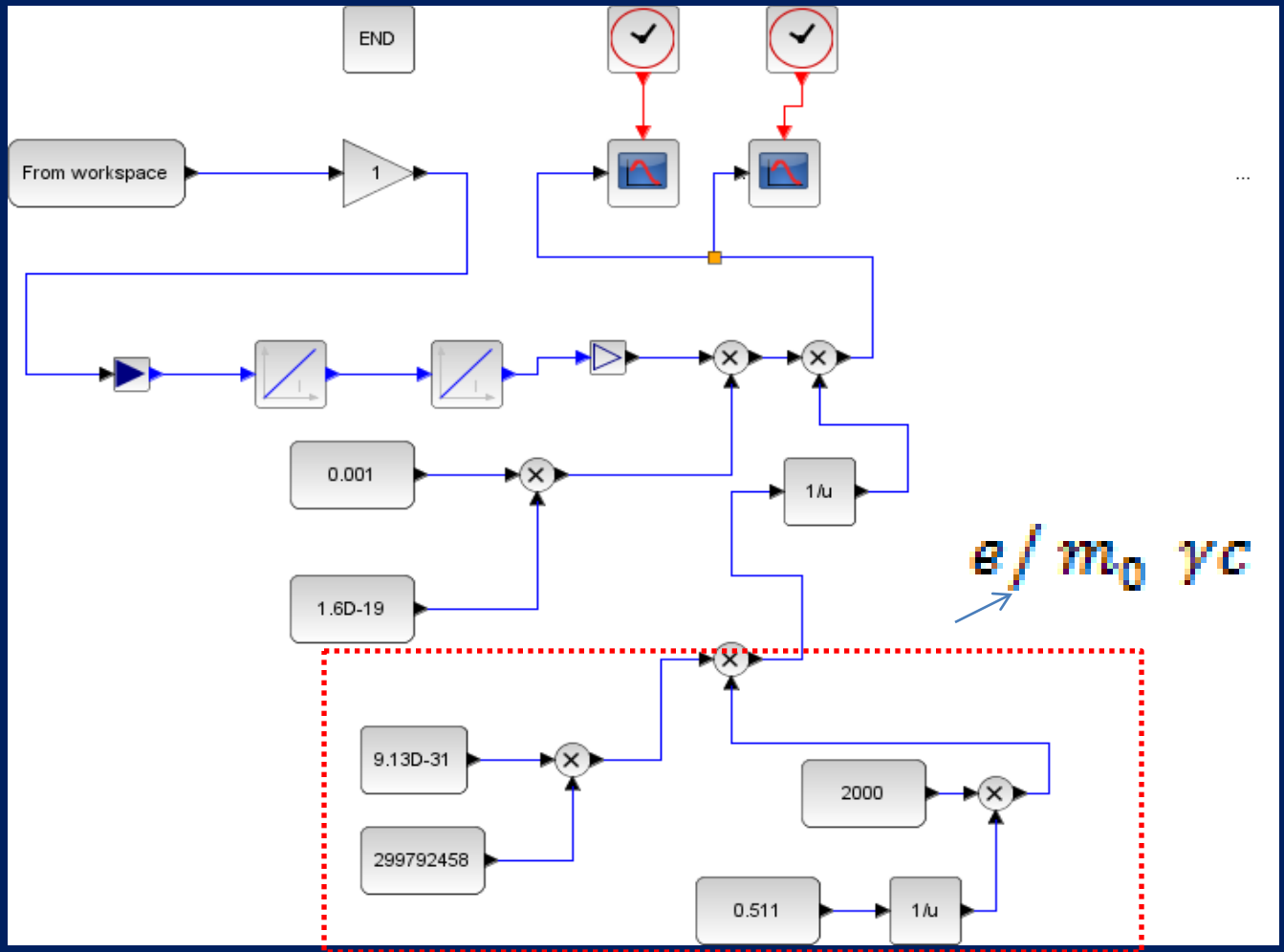
Simulation model for Planar and Harmonic Undulator Field in Xcos



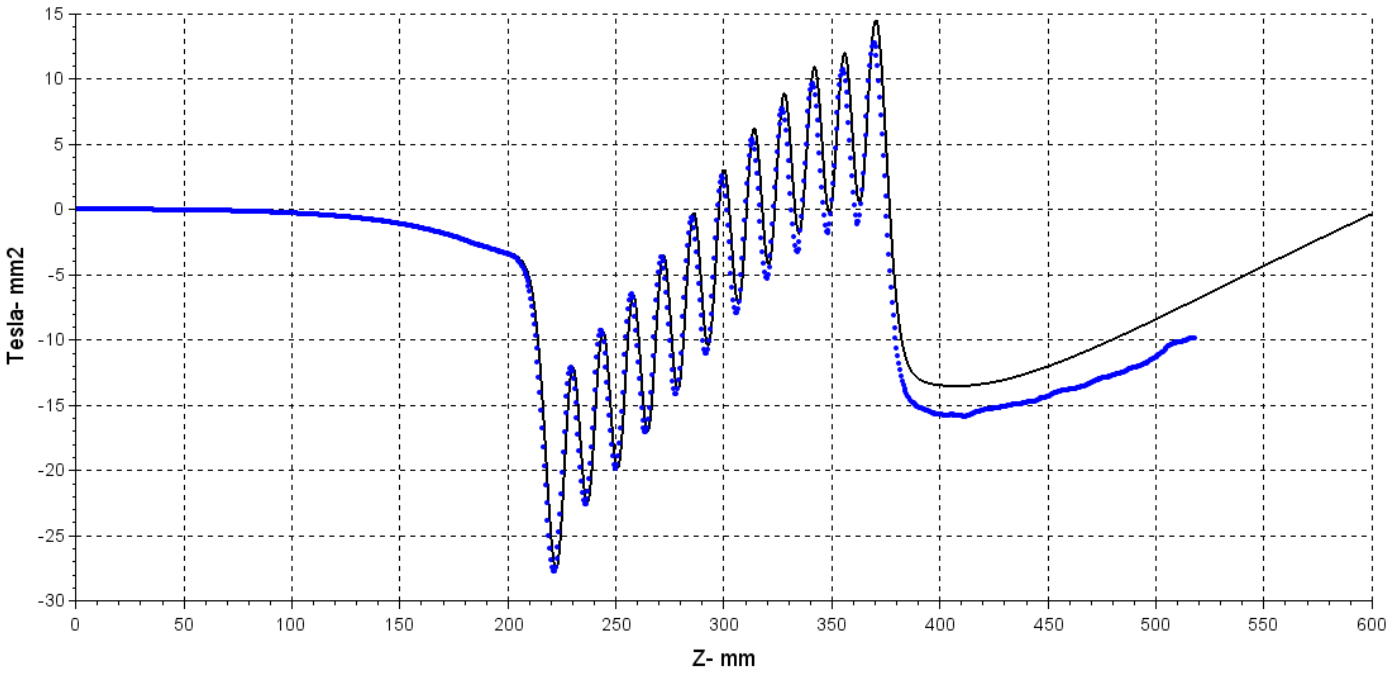
On axis Planar undulator magnetic field with and without harmonic content.



Trajectory along the undulator with real data of magnetic fields

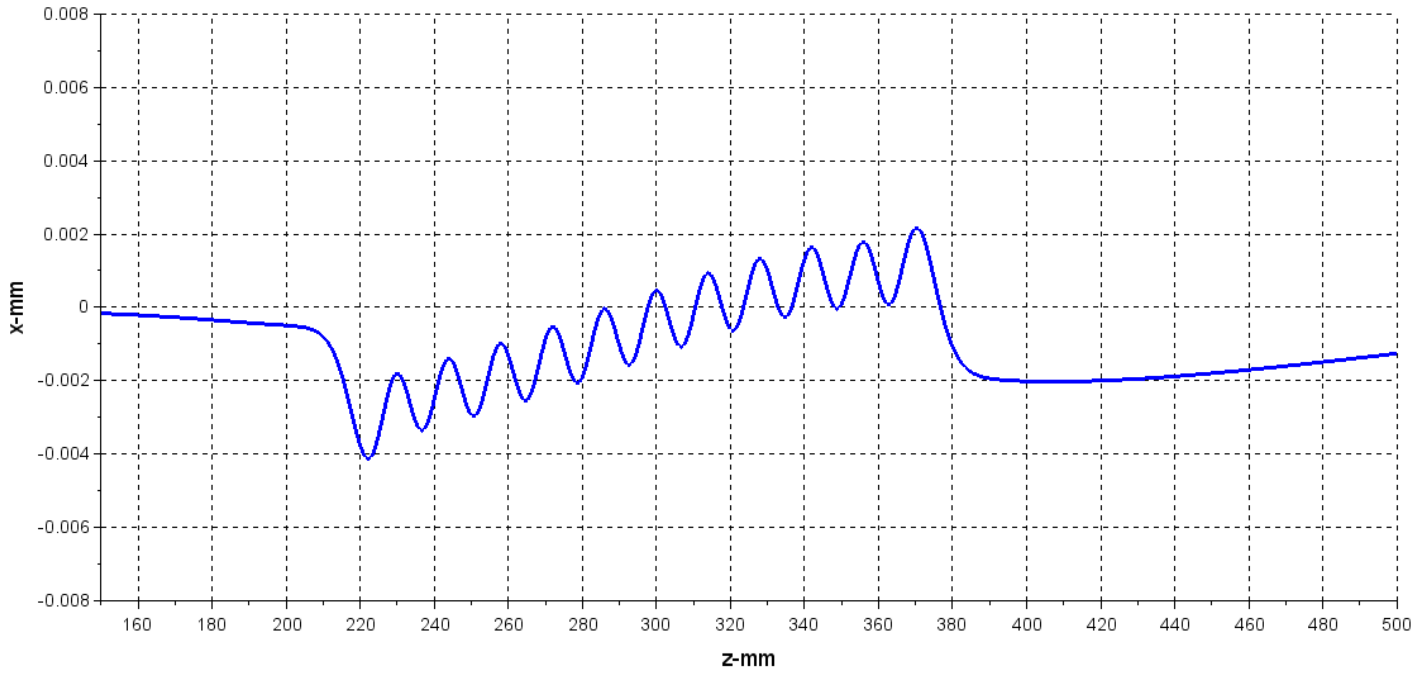


Double integration with present model and in the same figure, the data for double integration from Mathematica code



G Mishra et al J Synchrotron radiation 2017 Mar 1;24(Pt 2):422-428. doi: 10.1107/S16005-77517001540. Epub 2017 Feb 16

Trajectory along ‘x’ direction simulated in the same model.



Trajectory model by numerical method

$$\frac{dv}{dt} = -\frac{e}{\gamma mc}\left(\vec{v} \times \vec{B}\right)$$

$$\ddot{x} = -v_z B_0 sin\,(k_u z)$$

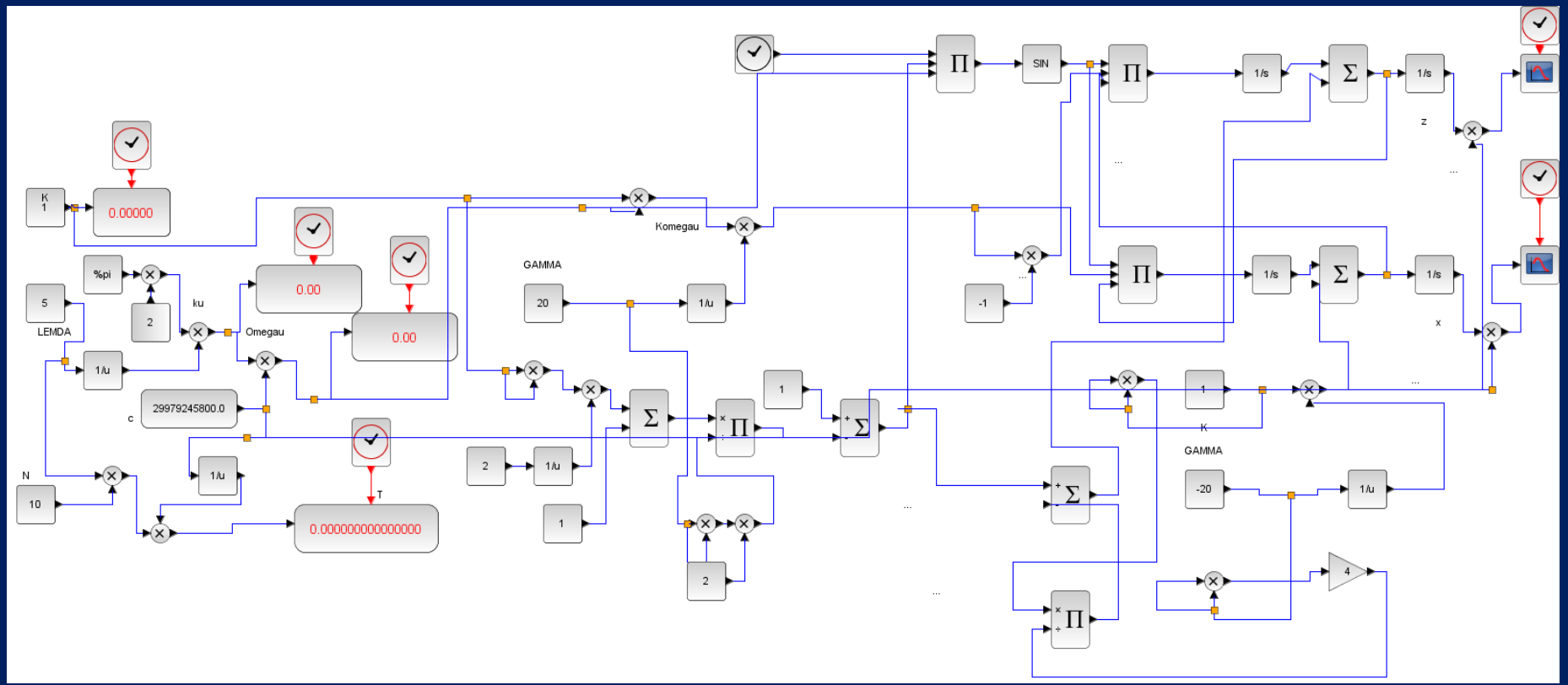
$$\frac{x}{c} = \frac{K}{\gamma\widetilde{\Omega_u}} sin\,(2\widetilde{\Omega_u} t)$$

$$\beta^* = 1 - \frac{1}{2\gamma^2}\left[1 + \frac{K^2}{2}\right]$$

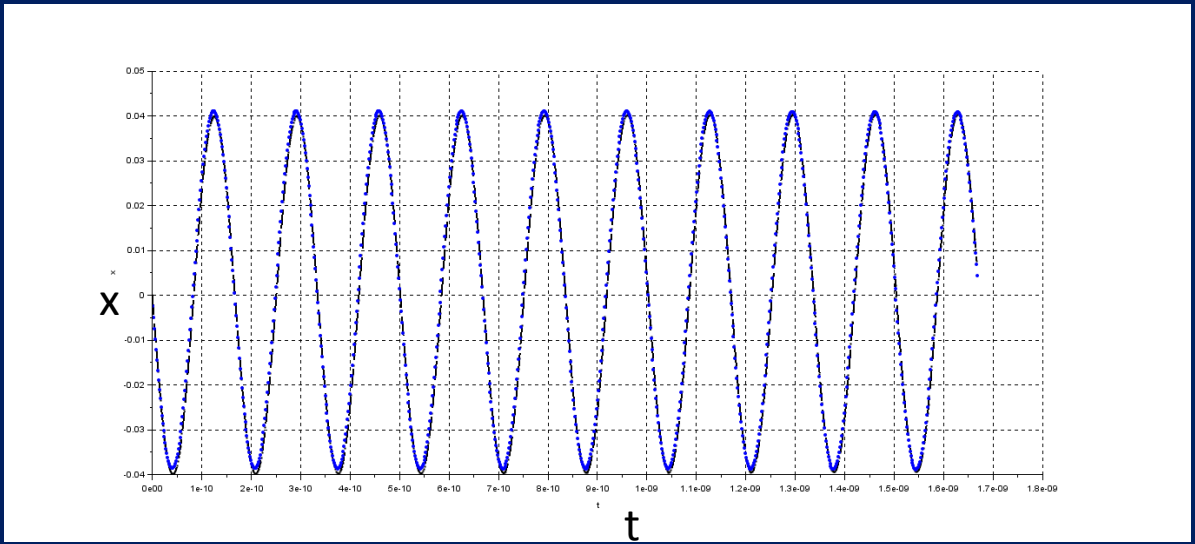
$$\ddot{z} = -v_x B_0 sin\,(k_u z)$$

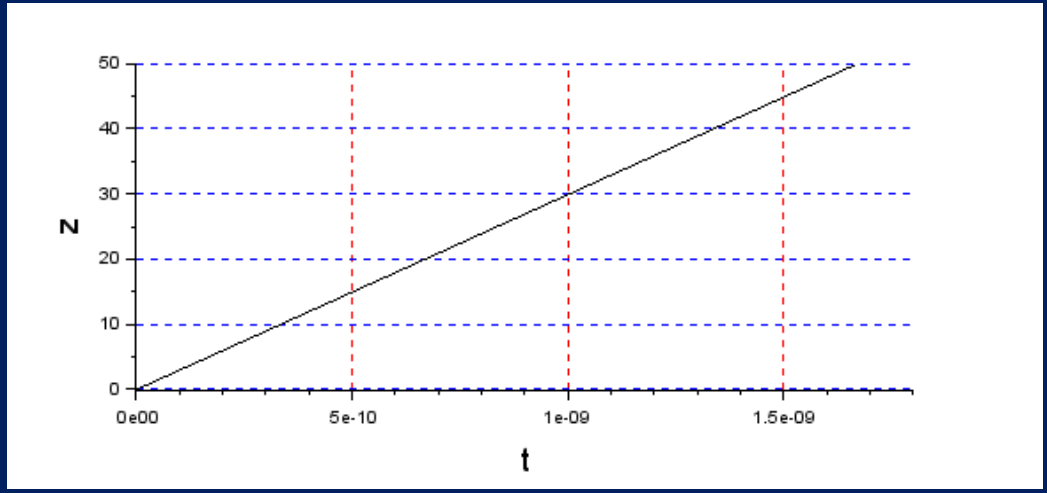
$$\frac{z}{c} = \beta^* t - \frac{K^2}{8\gamma^2\widetilde{\Omega_u}} \sin\left(2\widetilde{\Omega_u} t\right)$$

$$\widetilde{\Omega_u} = k_u\,\beta^* c$$



Trajectory along ‘x’ and ‘z’ direction by numerical method





Conclusion

- In the present paper Scilab Xcos based model has been used for electron trajectories and magnetic field.
- Electron trajectory along 'x' direction and variation of magnetic field along 'z' direction has been modelled and simulated for Planar and Harmonic undulator.
- These models does not require a separate plotter tool. In our analysis.
- We have also presented the model for determination of trajectory in real system or in simulation model given by other codes considering the factors of possible errors in planar undulator magnetic field.
- The above work can be extended as a model for trajectory in 'x' and 'y' direction, along with the intensity of spontaneous radiation. The GUI interface for present model is also a future scope of the work