European COST Action P18

Second International Symposium on

Lightning Physics and Effects

Discussion on the influence of the time derivative of the current and the charge acceleration on the radiation fields from lightning channels

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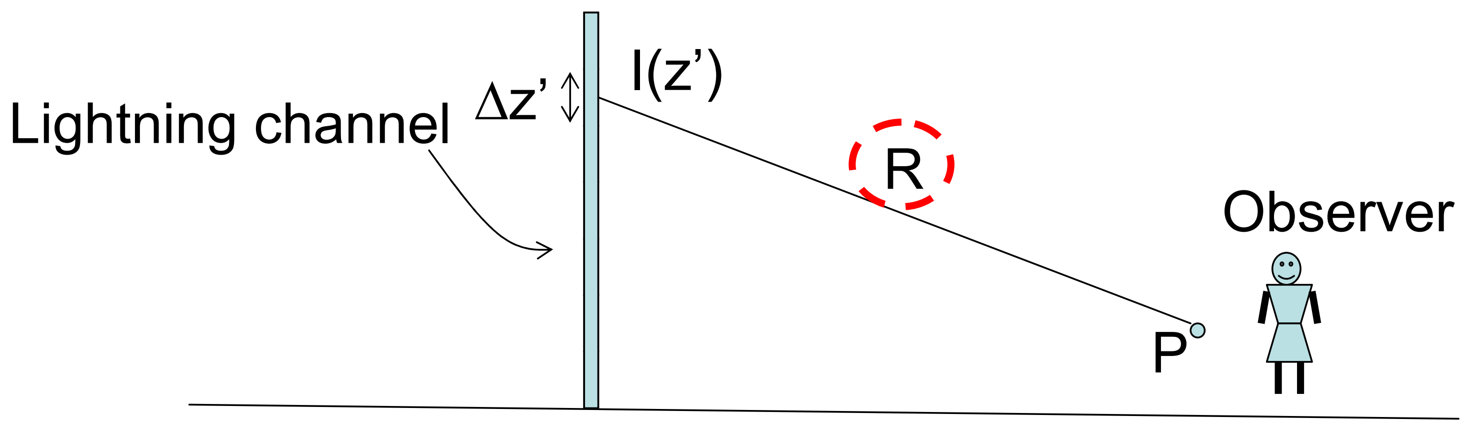
Outline

- Illustrate the way in which the radiation fields from return strokes are calculated
- Does di/dt $\neq 0$ imply radiation?
- Implications for field calculations

Calculation of the Return Stroke Fields

1. Find the current along the channel
2. Divide channel into differential elements
3. Find field from each element
4. Add the contributions of all elements



Fields from infinitesimal dipole in the time domain (including the image)

$$d\vec{E} = \frac{dz'}{4\pi\varepsilon_o}\left\{\cos\theta\left[\frac{2}{R^3}\int_0^t i(z',\tau - R/c)\,d\tau + \frac{2}{cR^2}\,i(z',\tau - R/c)\right]\vec{a}_R\right.$$

$$\left. + \sin\theta\left[\frac{1}{R^3}\int_0^t i(z',\tau - R/c)\,d\tau + \frac{1}{cR^2}\,i(z',\tau - R/c) + \frac{1}{c^2R}\frac{\partial i(z',\tau - R/c)}{\partial t}\right]\vec{a}_\theta\right\}$$

Derived by Uman et al. in 1975

Only this term produces a non-zero energy flow away from the channel

$$\sin\theta \frac{dz'}{c^2 R} \frac{\partial i(z', \tau - R/c)}{\partial t} \vec{a}_\theta$$

Thottappillil and Rakov (2001) have shown that the 1/R distance dependence is not sufficient to identify the radiation term

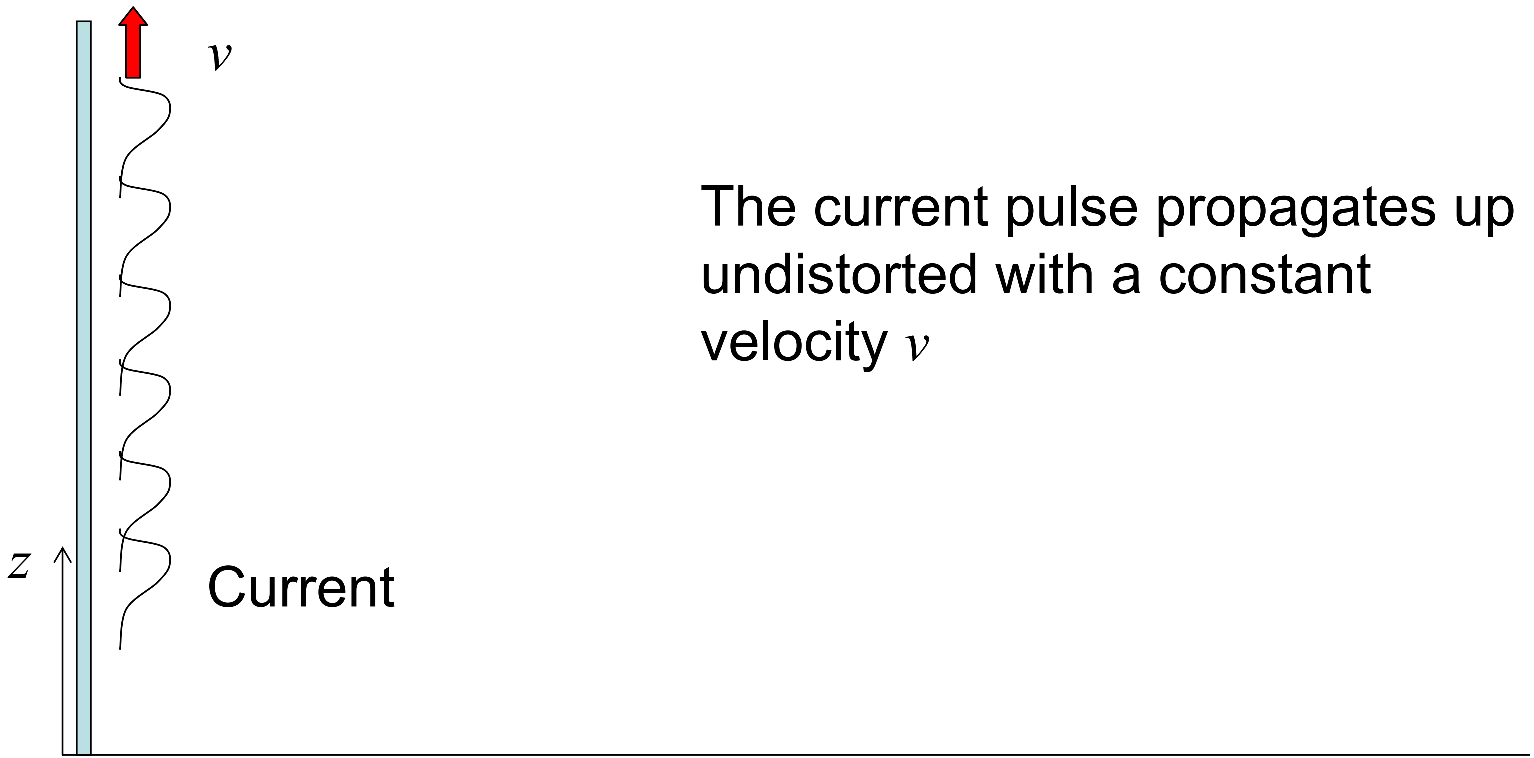
$$\sin\theta \frac{dz'}{c^2 R} \frac{\partial i(z', \tau - R/c)}{\partial t} \vec{a}_\theta$$

But the radiation term always contains the time derivative of the current

The question is:

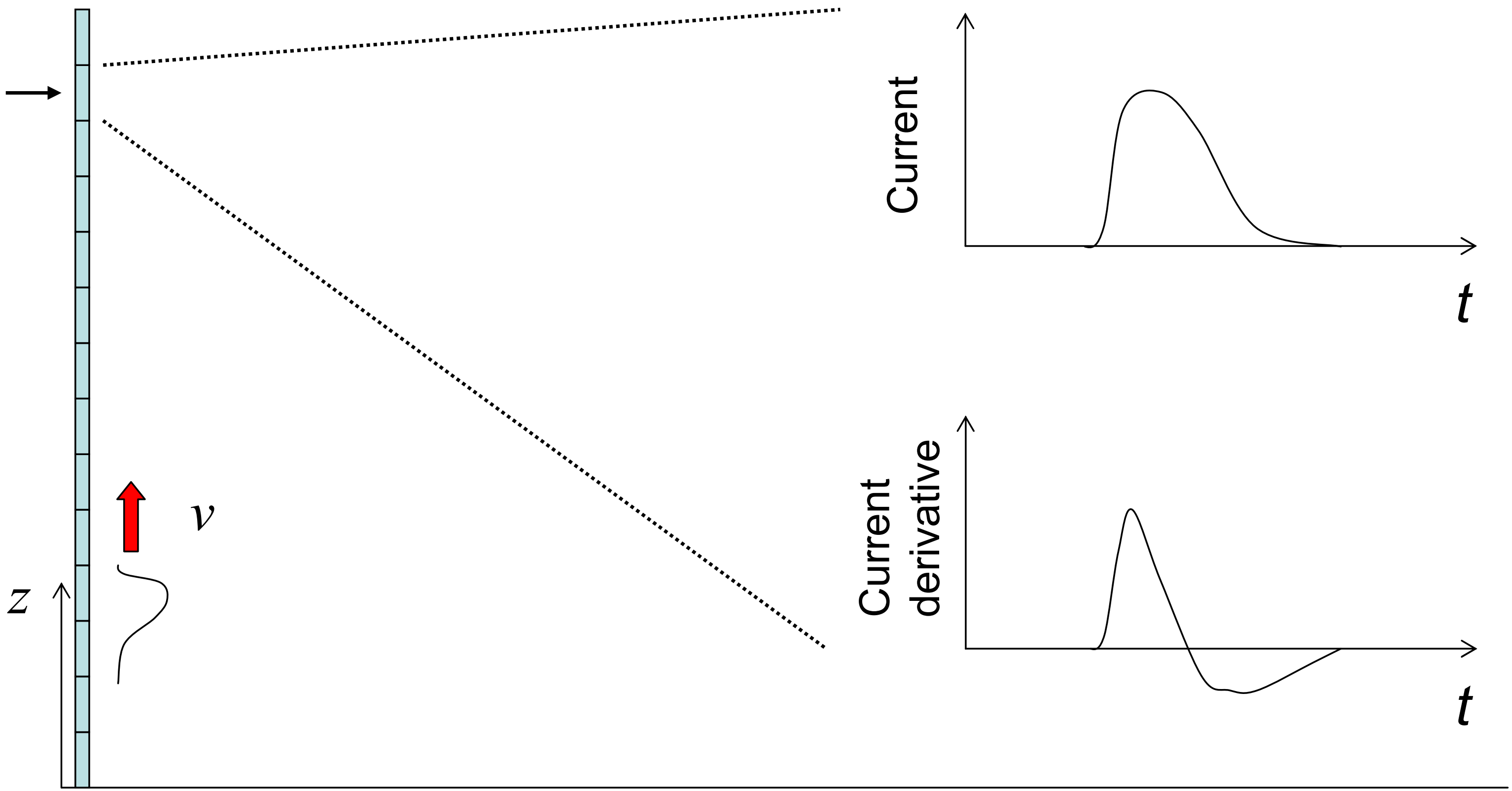
If a current varies with time,
does it radiate?

The Transmission Line Model (TL)

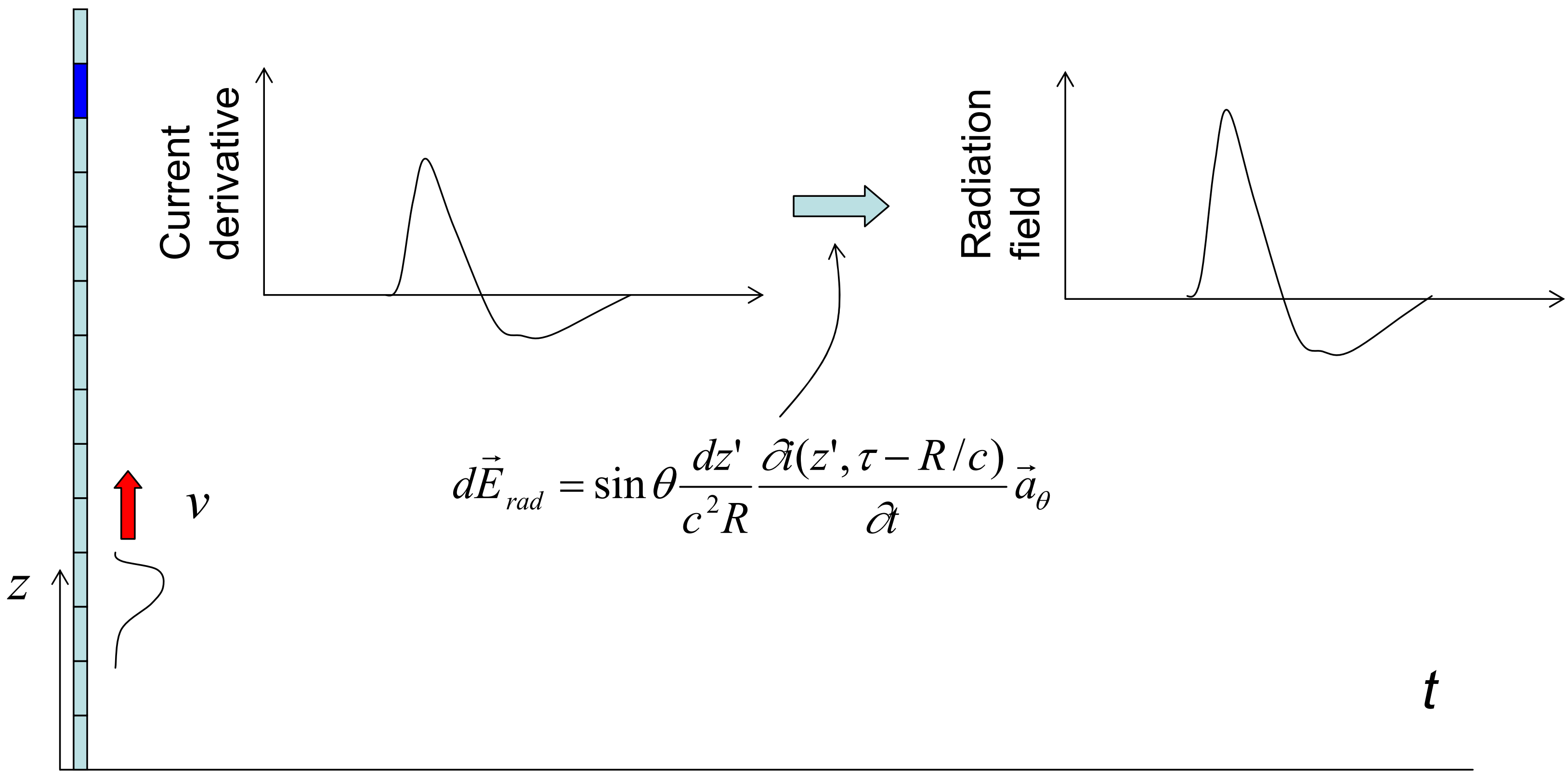


The current pulse propagates up undistorted with a constant velocity v

One Differential Element in the TL model

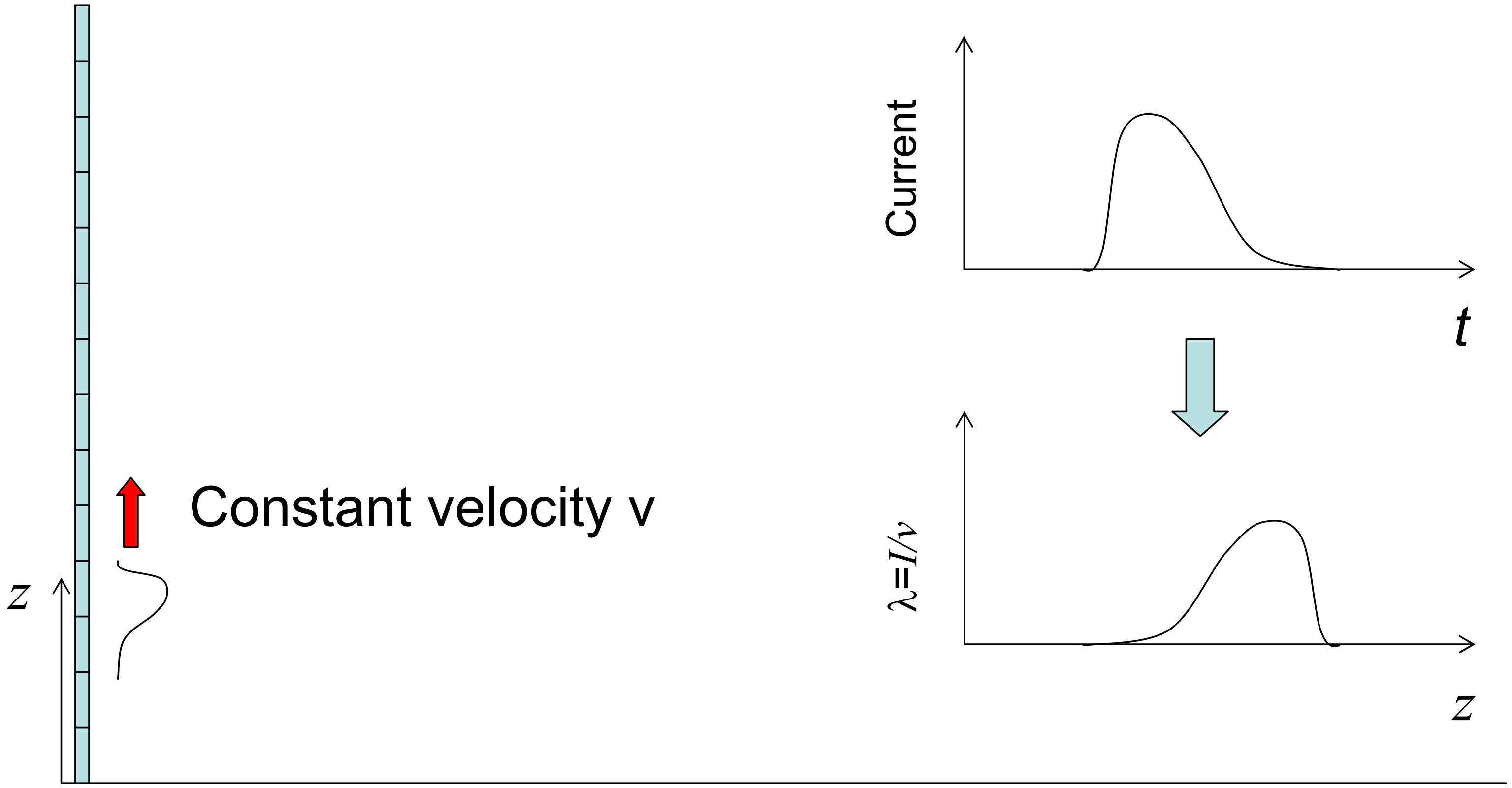


Since the time derivative of the current is $\neq$ 0, the element radiates

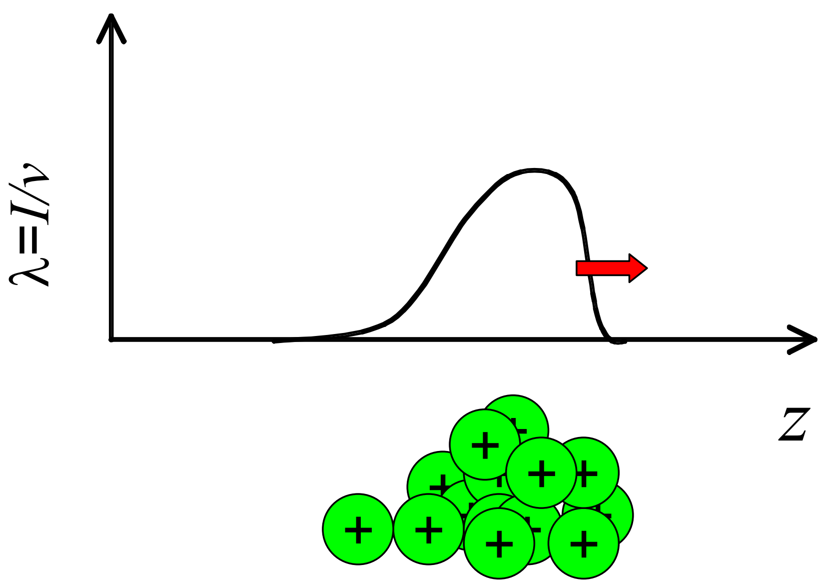


$$d\vec{E}_{rad} = \sin\theta \frac{dz'}{c^2 R} \frac{\partial i(z', \tau - R/c)}{\partial t} \vec{a}_\theta$$

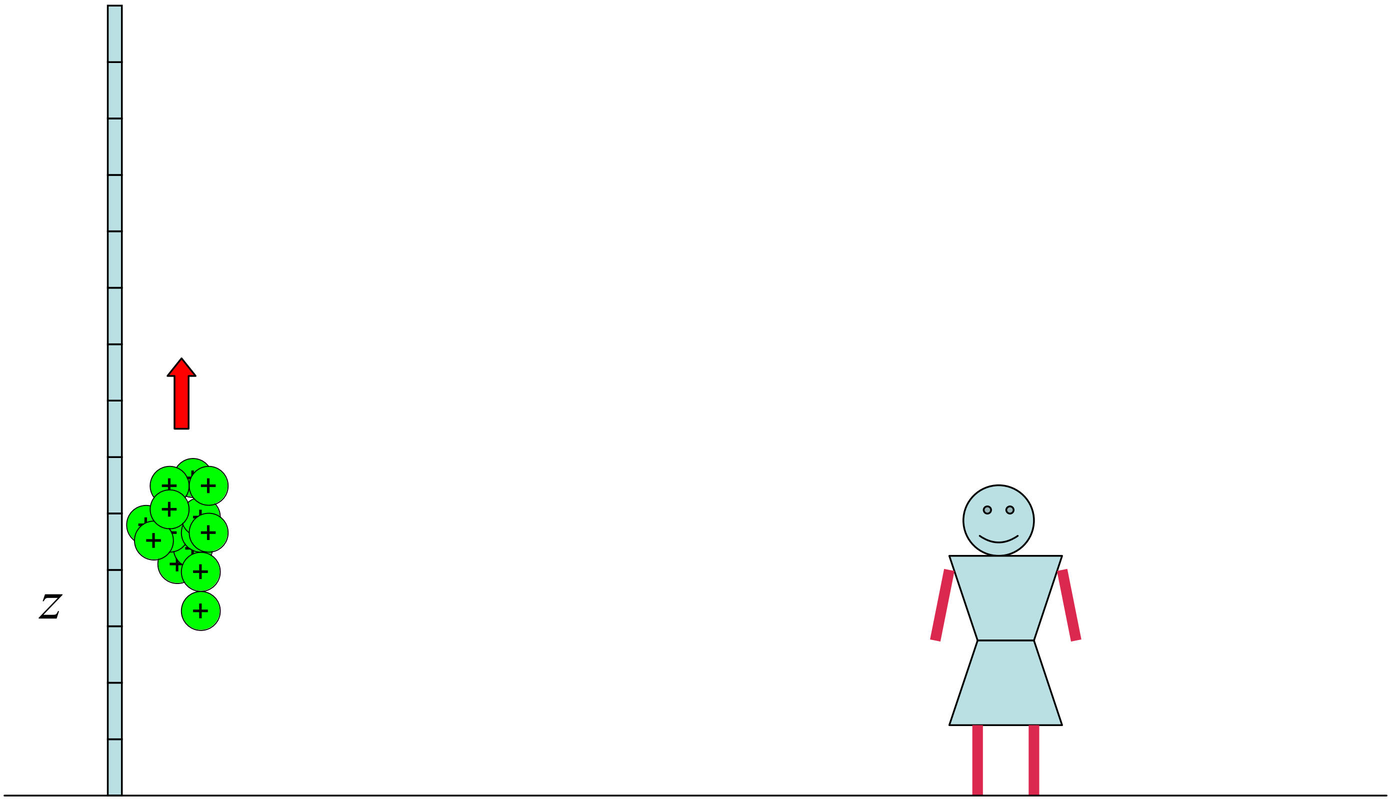
The charge density in the pulse at any given time is given by $\lambda(z)=I(t-z/v)/v$



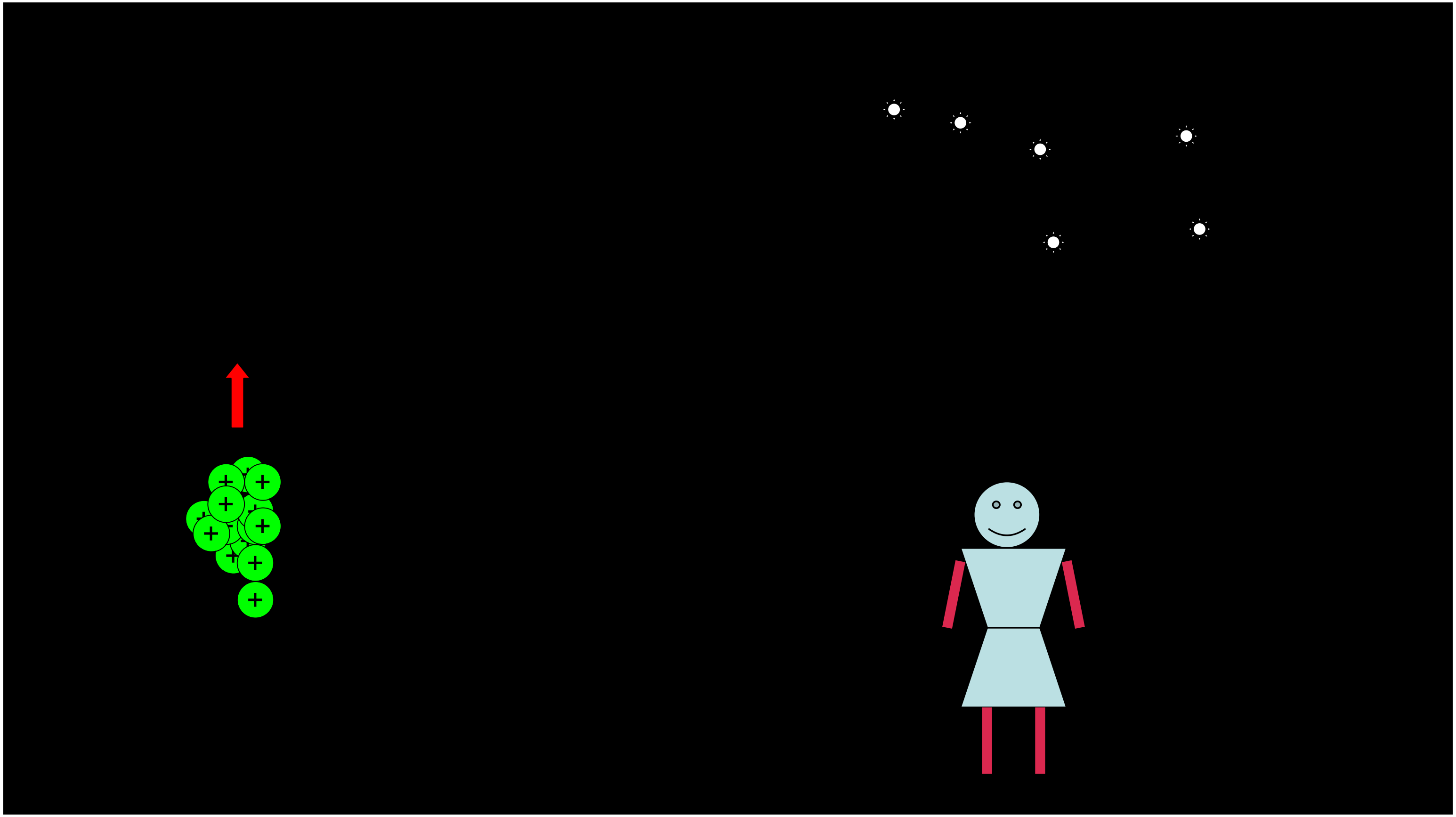
We will represent the charge graphically as follows



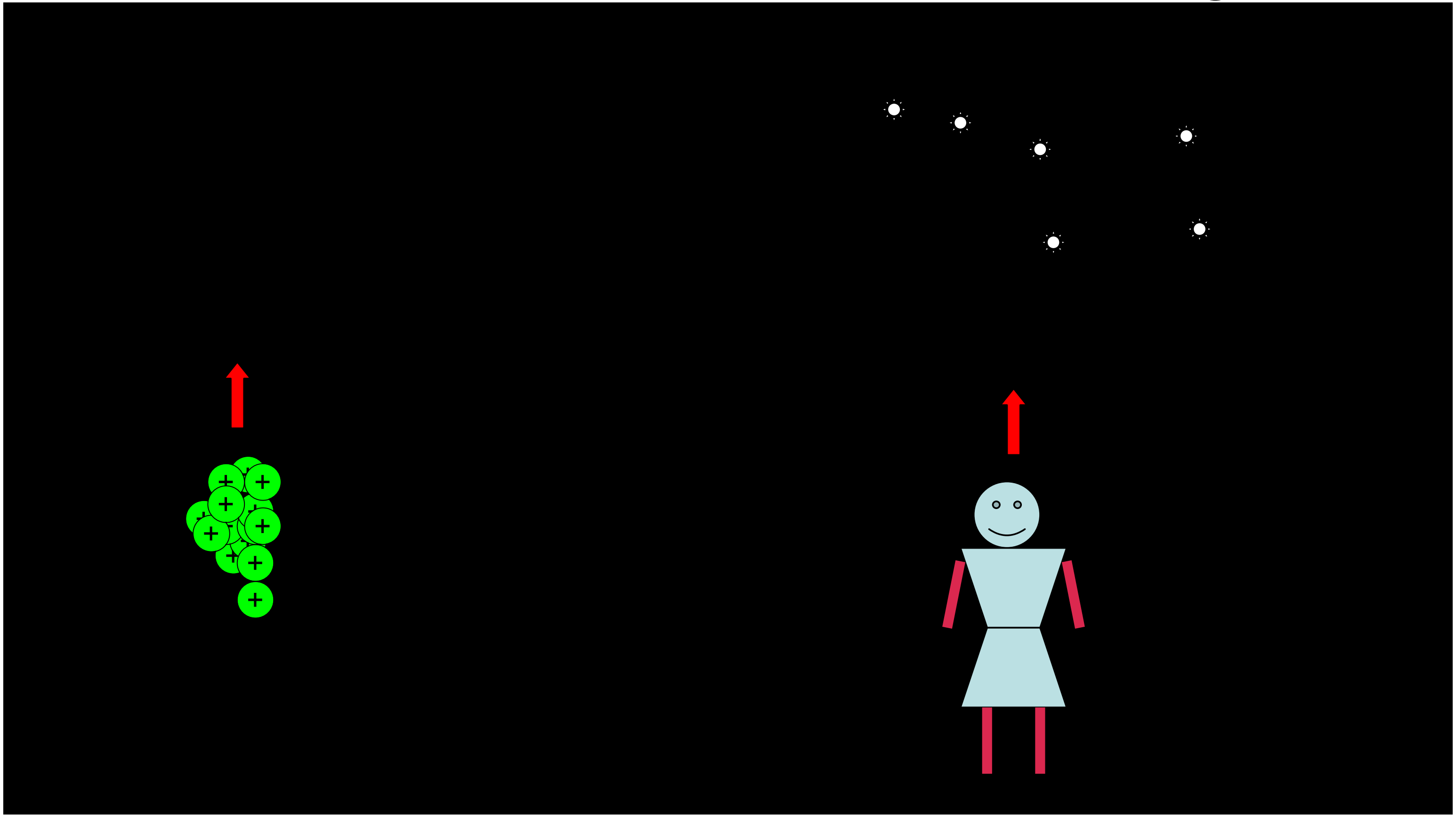
Observer on the ground measures radiated field from TL channel



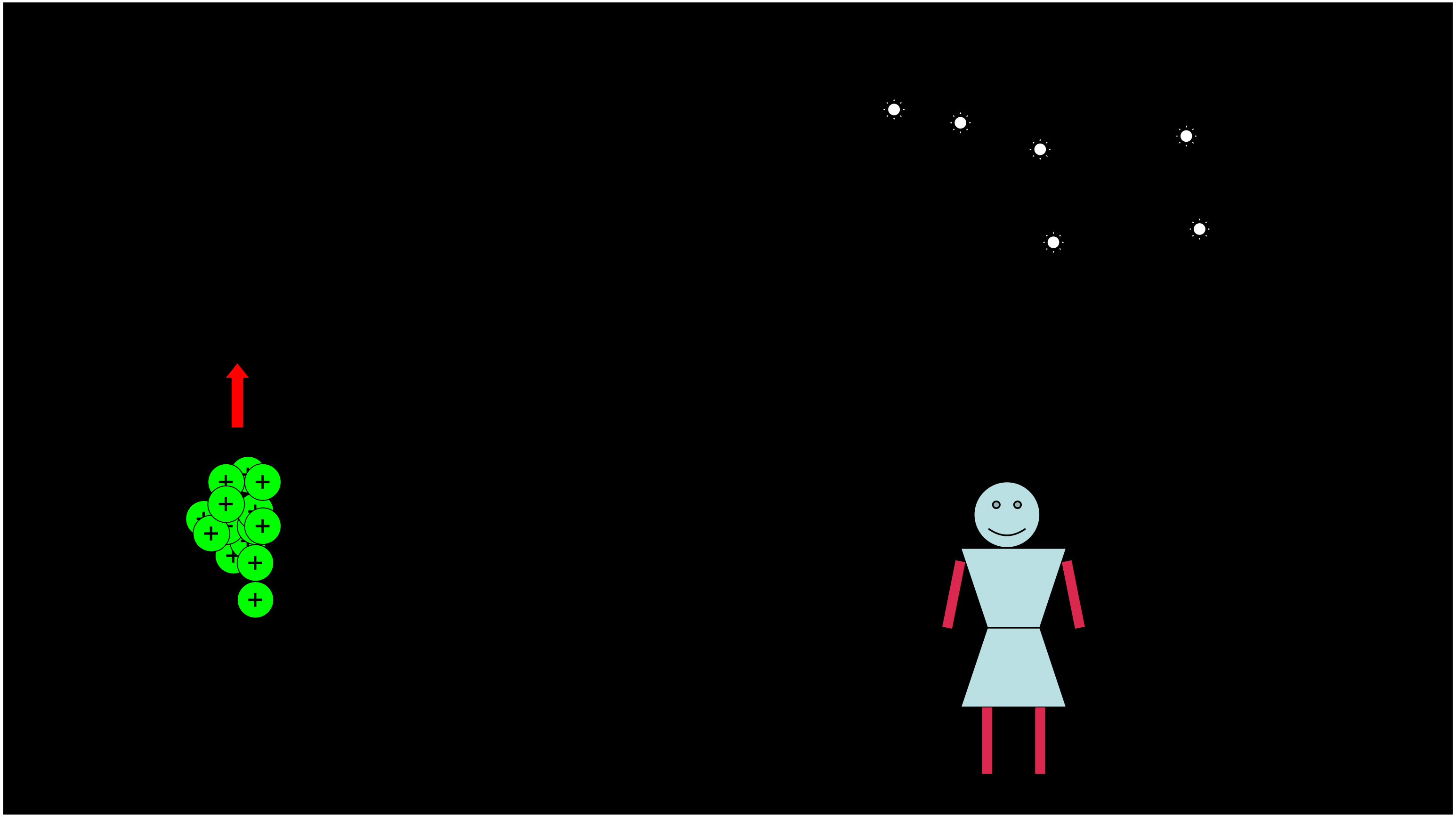
Does an observer in empty space see radiation?



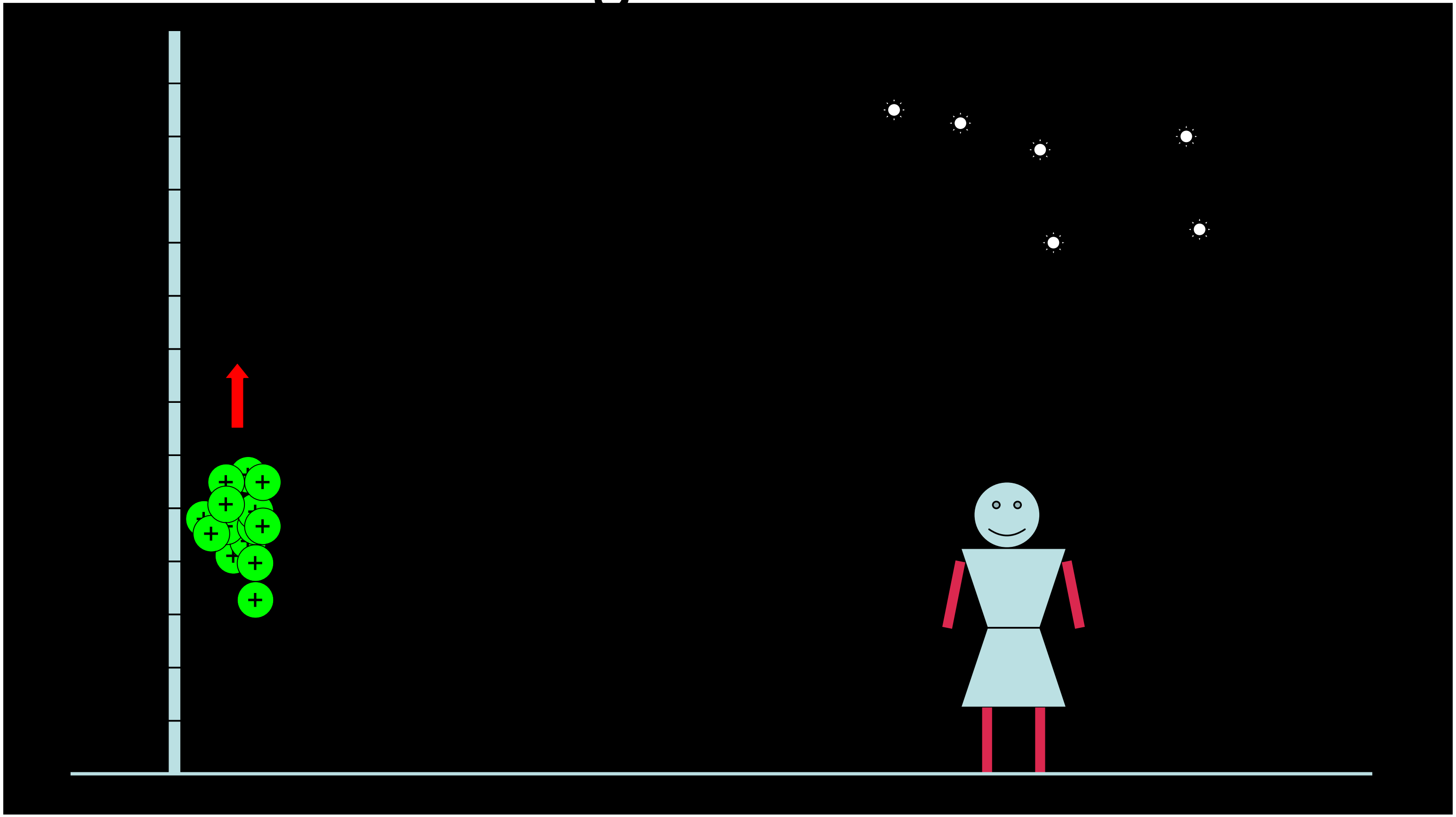
If the observer moves at the same constant speed, he or she sees a static charge



Back to the case of a static observer. There can be no radiation either!



The difference is the ground where charge is being accelerated



There is no radiation from static charges!

- A non-zero time derivative of the current is not a sufficient condition to have radiation
- Charge needs to be accelerated for radiation to exist
- If constant speed charge radiated, it would lose energy and it would have to decelerate

Larmor's formula for the radiation from a moving point charge

$$RadiatedPower = \frac{q^2 a^2}{6\pi\varepsilon_o c^3}$$

J. Larmor, "On a dynamical theory of the electric and luminiferous medium", *Philosophical Transactions of the Royal Society* **190**, (1897) pp.205-300 *(Third and last in a series of papers with the same name).*

Calculation of the radiation fields

- For the TL model, no need to calculate the fields from each one of the segments. Fields from the ground attachment point suffice
- For TL model with tortuousity, only a small discrete number of points radiate
- If the fraction of the charge that is not accelerated can be calculated, it can be left out of the radiation calculation

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Thank you for your attention!