TOTAL ELECTRIC FIELD DUE TO AN ELECTRON AVALANCHE AND ITS COUPLING TO TRANSMISSION LINE CONDUCTORS

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INTRODUCTION

Air is used extensively as an insulating medium in transmission, distribution and electrical substations

At surface irregularities partial breakdown of air can take place → produces violet glow, hissing noise ozone gas

Corona Discharge

- Power loss, Audible Noise
- Interference with Radio, TV broadcasting and communication

Extensive work has been carried out → Mostly Experimental resulting in Empirical relationship between measured corona current and RIV

It is necessary to relate the electromagnetic field to the physical phenomenon

TOTAL ELECTRIC FIELD DUE TO AN ELECTRON AVALANCHE

A single electron moving in the direction of the applied electric field results in $e^{\int_0^z \bar{\alpha} dz}$ electrons on travelling a distance z

The total electric field for an electron avalanche is derived for the first time

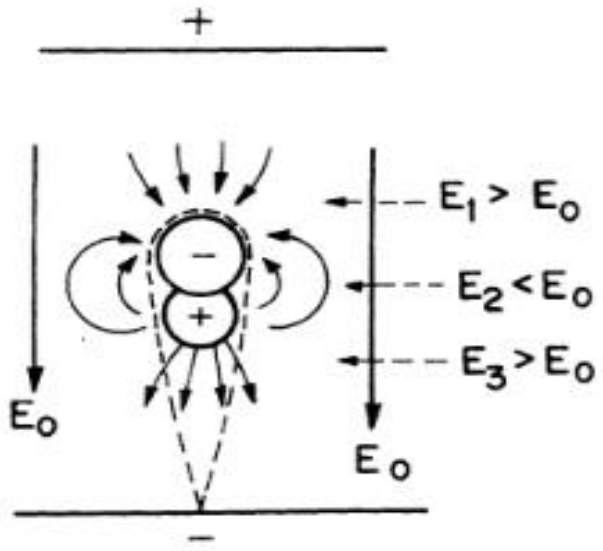


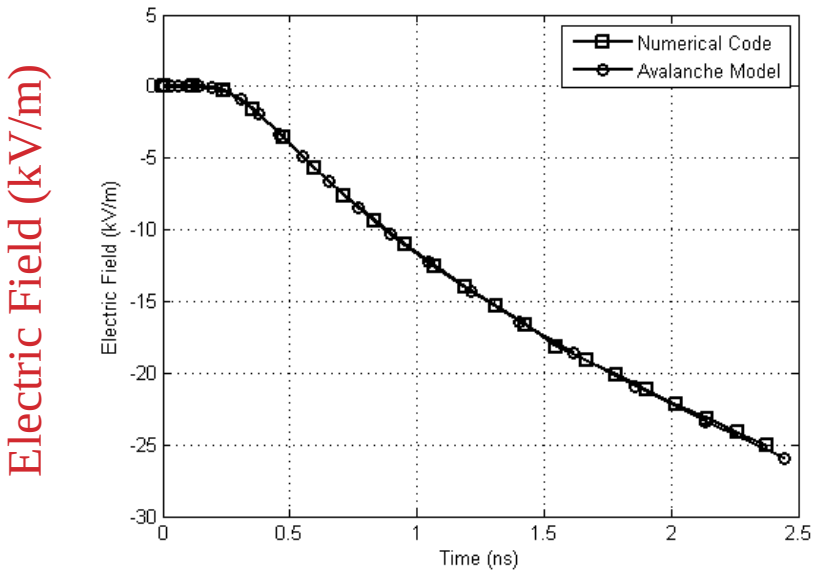
Fig.1. Townsend Model for Electron Avalanche

$$\vec{E}(\vec{r},t) = \frac{[\![q]\!]}{4\pi\varepsilon_0[\![\mathcal{K}^3]\!]}\left[\!\!\left[\frac{1}{r^2}\left(\hat{r}-\frac{\vec{v}}{c}\right)\left(1-\frac{v^2}{c^2}\right)+\frac{1}{cr}\left(\hat{r}\times\left(\hat{r}-\frac{\vec{v}}{c}\right)\times\frac{\vec{a}}{c}\right)\right]\!\!\right]$$

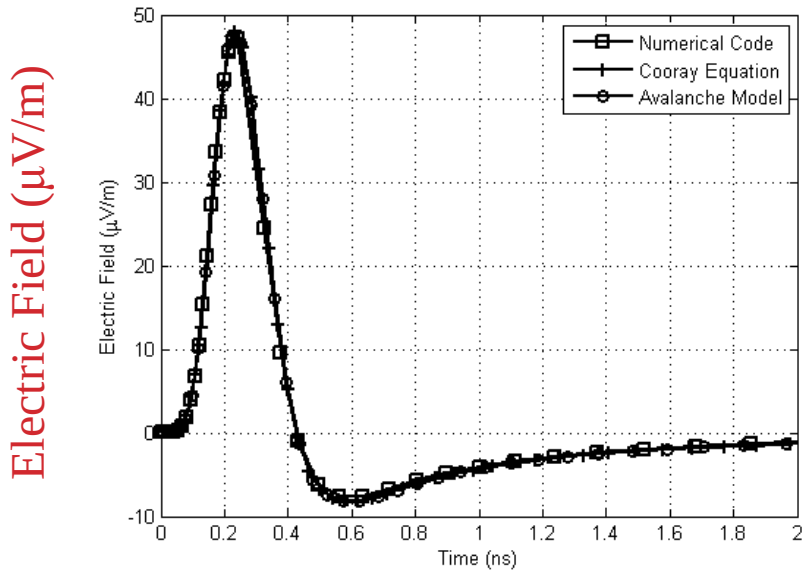
$$+\frac{1}{4\pi\varepsilon_0}\left[\!\!\left[\frac{\partial q}{\partial t}\left(\frac{\hat{r}}{c^2\mathcal{K}^2 r}\,\hat{r}.\overrightarrow{v}-\frac{1}{c^2\mathcal{K}^2}\left(\frac{\vec{v}}{r}\right)\right)\right]\!\!\right]+\frac{1}{4\pi\varepsilon_0}\int_0^{[\![R_r]\!]}\frac{\hat{r}}{r^2}\lambda\,\partial l$$

VALIDATION

By representing avalanche as a thin structure with current due to moving electrons as a line current, fields are computed using EFIE



Time (ns)
(a)



Time (ns)
(b)

Fig.2. Total electric field at (a) 1.7mm along z-axis and (b) (10m, 0, 17.32m)

Validated for various distances and even relativistic avalanches

INDUCED CURRENT FOR NEGATIVE AVALANCHE AWAY FROM THE CONDUCTOR

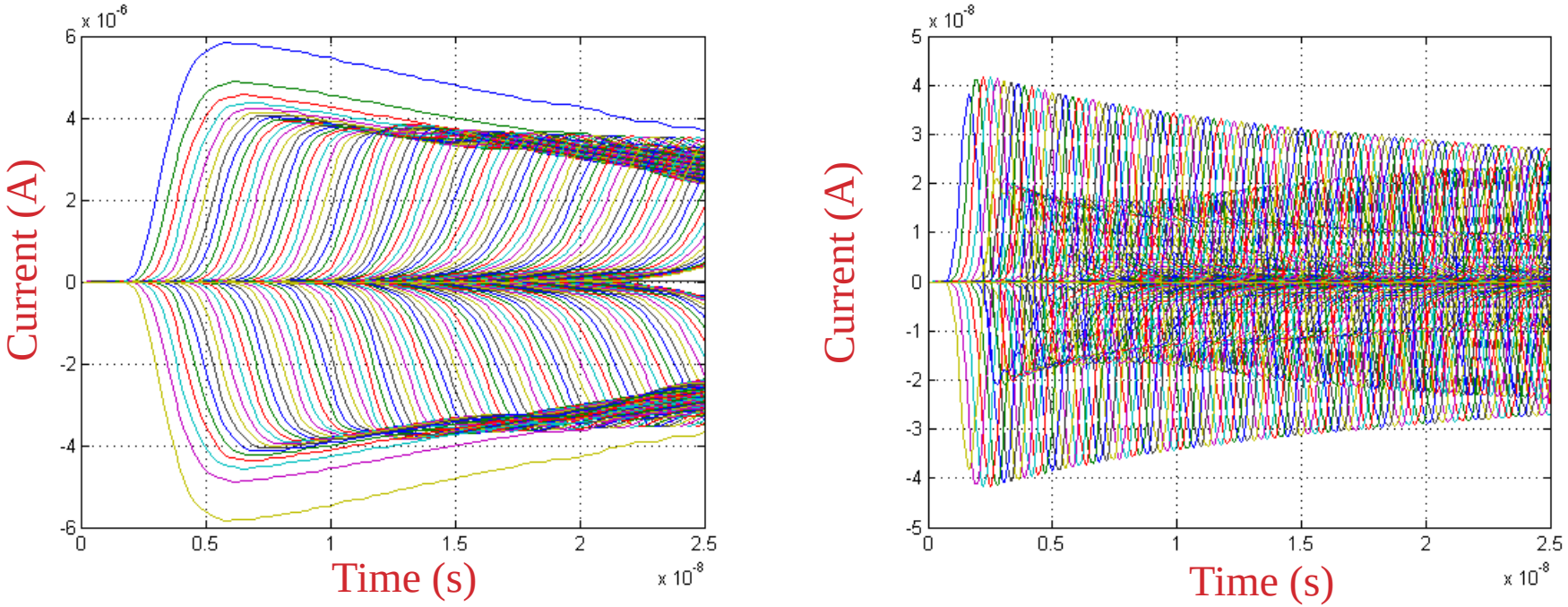


Fig.3. Induced Current due to Near Field and Far Field component of the Total Electric Field

It is Observed that the Induced current is completely dominated by the Near Field component of the Total Electric Field

INDUCED CURRENT FOR NEGATIVE AVALANCHE AWAY FROM THE CONDUCTOR

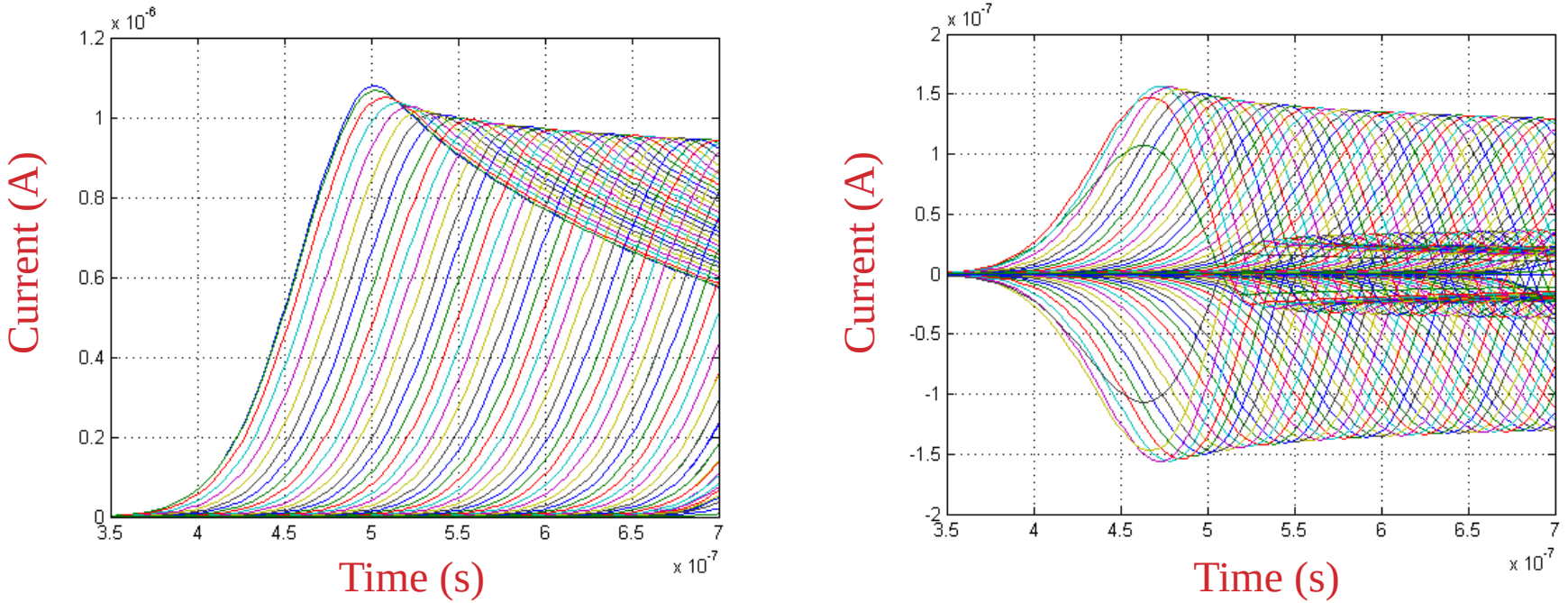
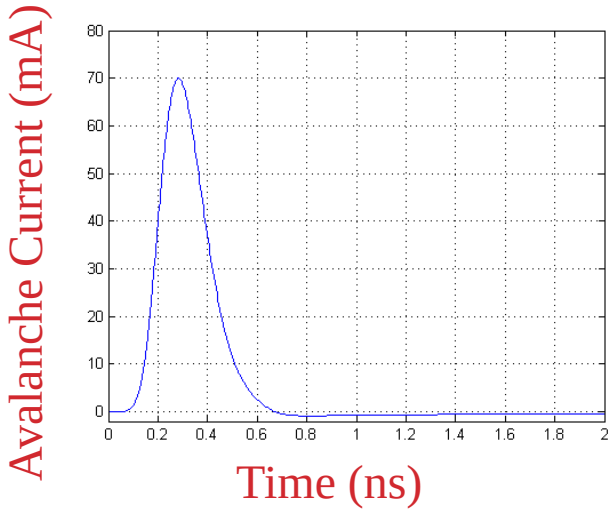


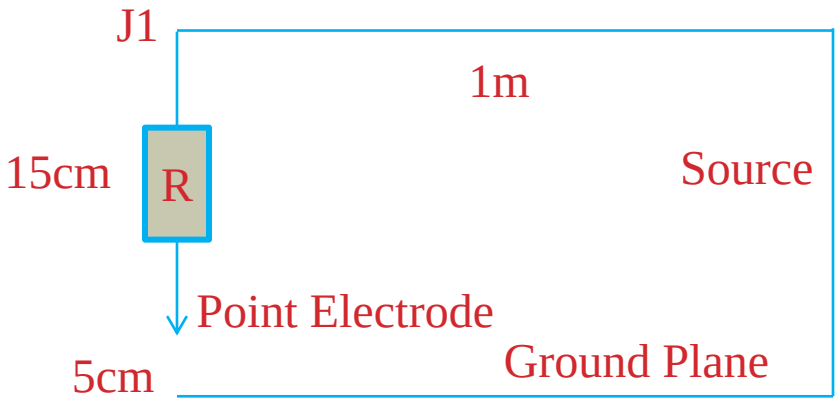
Fig.3. Injected Current Models (series current sources) used in literature versus Actual polarity of the Induced current due to Electron Avalanche away from the conductor

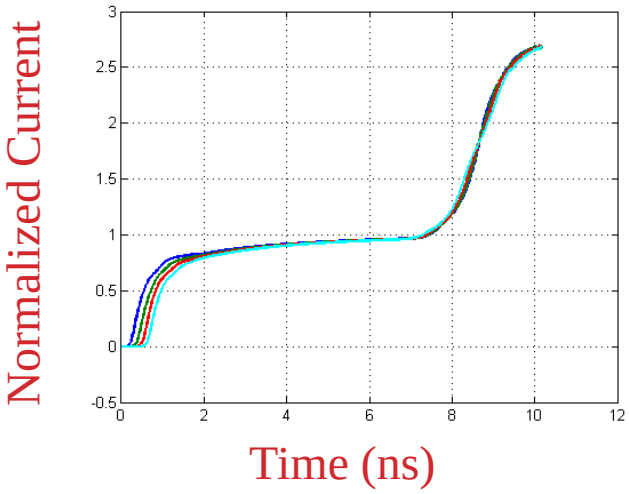
- The Induced Current due to Electron Avalanche is observed to be Bipolar in Nature

- In Literature, injected currents are assumed in the form of series connected current sources, thus resulting in unipolar current

INDUCED CURRENT FOR NEGATIVE AVALANCHE – POINT PLANE GEOMETRY







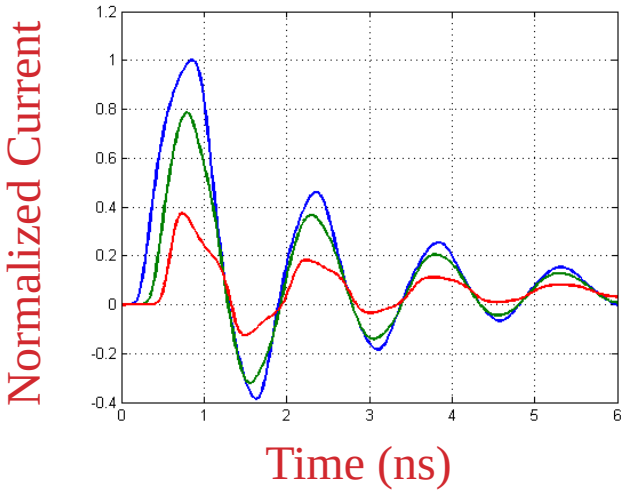


Fig.4. Normalized Current with zero resistance and 10kΩ inserted at J1

INDUCED CURRENT FOR NEGATIVE AVALANCHE – POINT PLANE GEOMETRY

- Near Field component of the total electric field dominates in governing the induced current
- Circuit locus and the circuit components (resistance) affects the measurement
- Fundamental difference exists between the Avalanche current and the current measured in the setup

SUMMARY AND CONCLUSION

- Analytical expression for the total electromagnetic field produced by an isolated electron avalanche has been derived for the first time
- Validated using the EFIE based modeling
- The current induced in the conductors is practically determined by the near field component of the total electric field
- It is shown that it is impossible to measure the actual current in the electron avalanche