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Role of Channel Conductance and Corona Sheath on Return Stroke Current Evolution

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Introduction

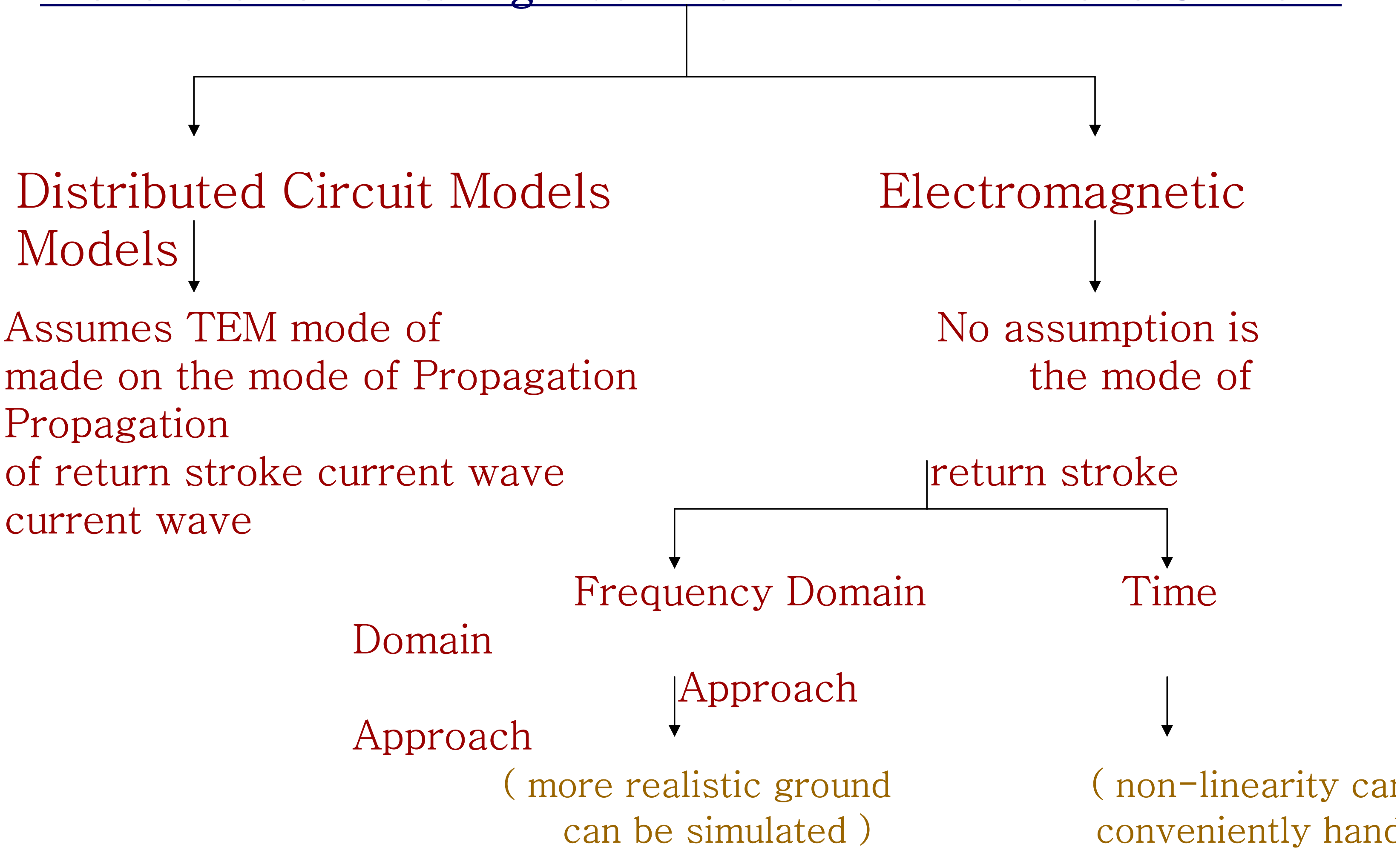
Need for Return Stroke Modeling

- better understanding of the phenomenon
- to study the interaction of lightning with tall ground based objects
- analysis and design of adequate LPS

Need For Theoretical Model

- Field Experimentation – extremely difficult
- Laboratory Experimentation – highly impractical

Models for Simulating Evolution of Return Stroke Current



Distributed Circuit Models
Models

Assumes TEM mode of
made on the mode of Propagation
Propagation
of return stroke current wave
current wave

Electromagnetic

No assumption is
the mode of
return stroke

Frequency Domain
Domain
Approach
Approach
(more realistic ground
can be simulated)

Time

(non-linearity ca
conveniently hanc

Essential Aspects of Return Stroke Evolution

- Electric field due to charges deposited on the channel forms the excitation
- Transient enhancement of conductance by several orders at the bridging zone initiates return stroke
- Non-linear variation of channel conductance is responsible for the evolution of return stroke current
- The proper accounting of associated dynamic electro-magnetic field

❖ Such a modeling has been recently proposed in ICLP – 2008 & OAASJ (2008, vol. 2, 261-270)

Assumptions

- Only axi-symmetric geometry is considered
- Only stroke to ground is considered
- Lightning channel without any branches
- Cloud dynamics is neglected
- Explicit reference to dynamically varying channel radius,
  temperature and the air density is not made
- Earth is considered to be perfectly conducting

Parameter Values used in the Model

1) Streamer gradient (E_{str}) = 400 kV/m
2) Leader gradient (E_{leader}) = 6 kV/m

3) Steady –state arc gradient (E_{∞}) = 200 V / m
4) Arc time constant for rising current ($\boldsymbol{\theta}_r$) = 50 µs
5) Arc time constant for falling current ($\boldsymbol{\theta}_f$) = 500 µs

6) Leader Section Conductance

min. value = 0.0167 S/m, max. value = 0.75 S/m

7) Streamer Section Conductance

min. value (g_{ms}) = 0.25 mS/m

8) Conductivity of corona sheath ($\boldsymbol{\sigma}$) = 40 µS/m

9) segment length = 5 m. time step = 16.67

Effect of Channel Conductance

- Without switching to non-linear change in conductance – current builds up
  simultaneously everywhere

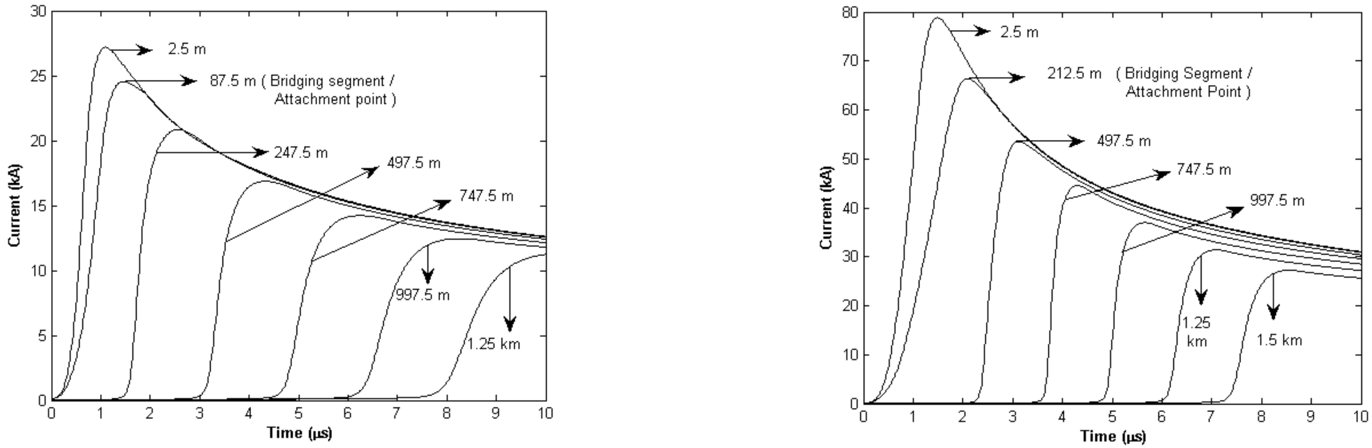
- Fixed value of conductance does not lead to reduction in velocity but current decay to some extent

Loading (Ω/m)	Decay rate of current at 2.25 km / 1 km (%)	Velocity (m/s)
0	6	c *
0.1	11	c
0.2	16	c
0.35	21	c
0.5	25.6	c
1.174	51.5	c
2	61.5	c

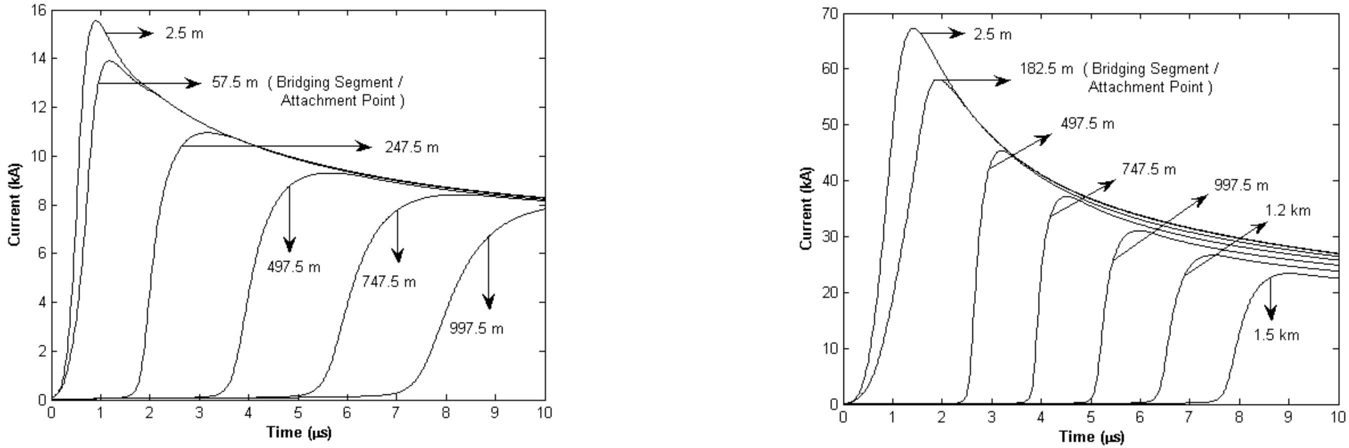
* c = velocity of light in vacuum

Role of Non-Linear Channel Conductance (without Corona Sheath)

(Field due to the initial charge distribution is the source)



(a) Cloud Base Potential = 50 MV **channel length = 2.5 km** **(b) Cloud Base Potential = 100 MV**



(a) Cloud Base Potential = 50 MV **channel length = 4.5 km** **(b) Cloud Base Potential = 100 MV**

Observations :

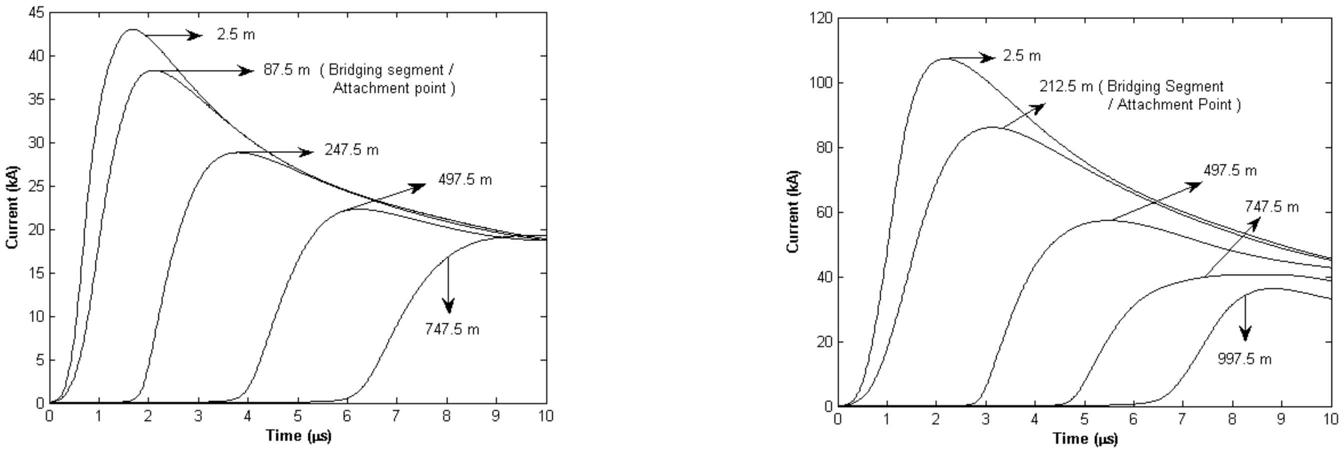
- Current evolution could be seen
- Wave shape is satisfactory

Channel Length (km)	Cloud Base Potential (MV)	Peak current magnitude at 1 km from ground (kA)	Velocity *
2.5	50	12.46 (49.3 %)	0.52c
	100	36.99 (44.2 %)	0.6c
4.5	50	8.01 (42.4 %)	0.45c
	100	31.08 (46.5%)	0.59c

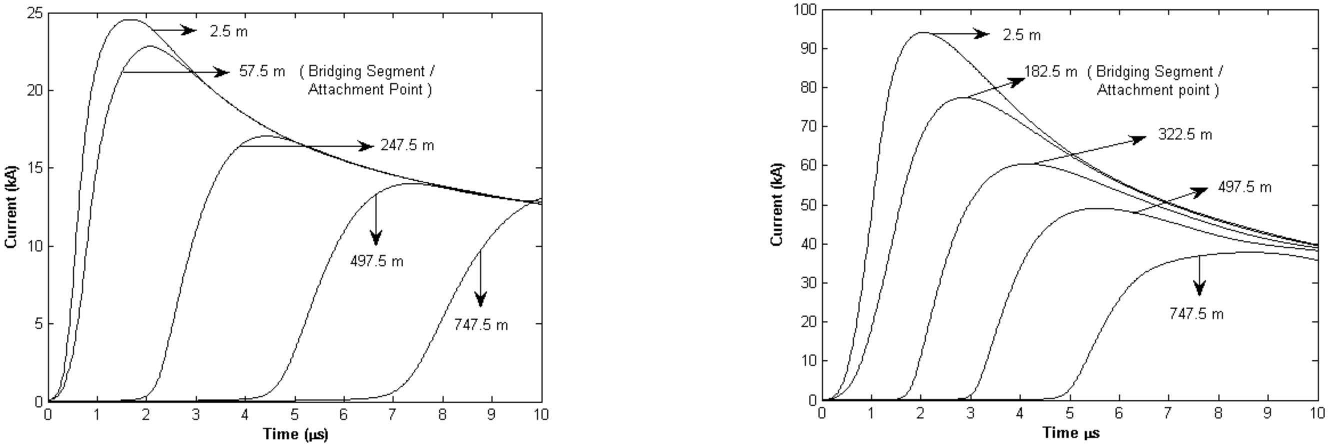
- Velocity & current decay rate is calculated using Bridging segment as reference segment

Role of Corona Sheath and Conductance

(Field due to the initial charge distribution is the source)



(a) Cloud Base Potential = 50 MV **channel length = 2.5 km** **(b) Cloud Base Potential = 100 MV**



(a) Cloud Base Potential = 50 MV **channel length = 4.5 km** **(b) Cloud Base Potential = 100 MV**

Observations :

- ➢ Peak magnitude of current has increased
- ➢ Velocity of current wave has decreased
- ➢ Rise time of Current (10 – 90 %) has increased

Channel Length (km)	Cloud Base Potential (MV)	Peak current magnitude at 750 m from ground (kA)	Velocity
2.5	50	19.25 (49.7 %)	0.39c
	100	40.62 (52.8 %)	0.44c
4.5	50	13.07 (42.8 %)	0.34c
	100	37.79 (51.2 %)	0.43c

Summary

- The role of channel conductance and diffusion of charge to corona sheath on return stroke current evolution has been investigated using a new class of electromagnetic model

- The non-linearly varying channel conductance is shown to be mainly responsible for the spatio-temporal building of current

- The charge diffusion to corona sheath leads to slowing down of the current wave but produces an increase

Thank You

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