Magnetic Field due to the Radiation of High Altitude Lightning

Meenu Singh, Vijay Kumar, Sidhartha Gupta, P. P. Pathak

***Abstract:** High altitude optical discharges generated by extreme cloud-to-ground lightning strokes, which occur in the middle region of the atmosphere known as sprites. Streamer formation in sprites has been well stated to be existing by several previous workers. These streamers are not only responsible for the initiation of sprites but also they are composed of these streamers. It causes the production of electromagnetic radiation upto or below the ELF (very low frequency) region which have been reported earlier through various research theories. Thus, we are reporting out for the formulation of the model by using an earlier model used to estimate higher frequency radiation from cloud and ground lightning discharges through these positive corona streamers. Taking it into account, other terms like radiation magnetic field has been evaluated with the studied observations.*

***Keywords:** Altitude, ELF, magnetic, Streamer.*

I. INTRODUCTION

Luminous electrical discharges occurring at stratospheric and mesospheric levels are known as TLEs (Transient Luminous Events) or sprites (stratospheric/mesospheric perturbations resulting from intense thunderstorm electrification). Most of the sprite events are associated with huge positive cloud to ground lightning phenomenon [Mishin, 2008] giving rise to a various visual shapes.

Singh et al.[2017] coated other authors that the electromagnetic radiation]phenomenon takes place, due to strong CG lightning discharges, in the radio frequency range. Farges et al.[2011] and some other authors coated in his report to illustrate that sprites are well correlated electromagnetic field radiation in the ELF band. Along with that, Qin et al.[2013] modelled for sprite streamer mechanism modelled for sprite streamer mechanism which illustrate the relations of sprites and sprite streamers. The electric and magnetic field generation due to return stroke-lateral corona streamers (RS-LC) system and red sprites in time and frequency domain has been well described by Paras et al.[2011]. The first experimental evidence of ELF radiation produced by the electrical currents flowing in the body of sprites given by Cummer et al.[1998].

II. THEORETICAL MODEL

It has been proved that the sprites are the cause of filamentary discharges in the form of streamers which height up to 40 to 90 km. Few authors have observed the electrical parameters of sprites occurs due to streamers discharges. The important observation is the exponential growth of streamers with time [Kosar, 2012]. The streamer formation and propagation can be taken in conical shape. The conical shaped tip has positive charge Q within a small width ‘a’ and negative charge –Q distributed uniformly throughout rest of the cone as shown in fig. 1. We have used the formulation used by Pathak [Pathak, 1994] for the high frequency radiation.

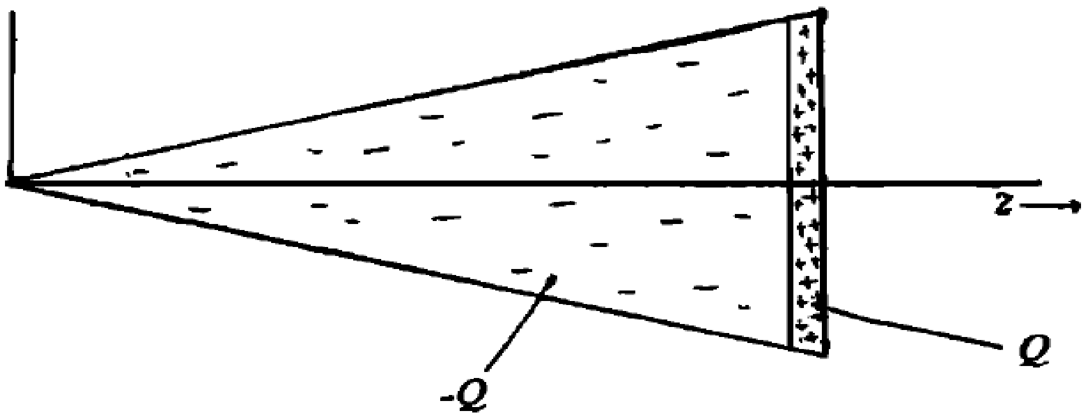

Fig. (1): Assumed charge distribution in the streamer cone

A dipole is created due to this system of positive and negative charges. So the dipole moment of that system become as

$\mathbf{p} = r\int\rho(r,t)dv$ (1)

given in the above mentioned paper, one gets

$\mathbf{p} \approx (Q/4)\, z\, \hat{k}$ (2)

where,

$Q=Q_0\exp(t/\tau)$ (3)

The formulation of radiation power has been done in the above mentioned paper. For

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Meenu Singh (Corresponding Author)**,** Department of Physics, Gurukula Kangri Vishwavidyalaya, Haridwar, Uttrakhand, India. E-mail: minsmeenu7@gmail.com

Vijay Kumar, Professor, Department of Physics, Graphic Era Hill University, Dehradun, Uttrakhand, India.

Sidhartha Gupta, A. P., Department of Computer Science & Engineering, Graphic Era Deemed to be University, Dehradun, Uttrakhand, India.

P. P. Pathak, Professor, Department of Physics, Gurukula Kangri Vishwavidyalaya, Haridwar, Uttarakhand, India.

clarity some of the steps are repeated here.

$P(t)=(1/4\pi\varepsilon_o)\,(2/3)\,(|p|^2)/c^3$

$= P_o(2+t/\tau)^2 \exp(2t/\tau) + P_1 t^2$ (4)

Where, ε_o and c are the permittivity of free space and speed of light in vaccum respectively. Also,

$P_o = (q_o v^2/\tau^2)/96\pi\varepsilon_o c^3)$ and $P_1 = (3Q_o v^6/8\pi c^3 z_o^4)$ (5)

Further the Fourier transformation is used to convert the radiated power formula into the frequency domain, which is follows as:

$[P(\omega)]^2=[\int_0^t P(t)\cos\omega t\, dt]^2+[\int_o^T P(t)\sin\omega t\, dt]^2$ (6)

Now, we are taking the case when $T(=2\pi/\omega = 1/f)>t_0$; then the integration will be broken into two parts. Therefore, equation (4) has two termsin which first part will be integrated between limits 0 and t_0 and the second term would be integrated between t_0 and T. Thus equation (5) would be further expanded into real and imaginary parts as follows:

$[P(\omega)]^2 = [P(\omega)_R)]^2 + [P(\omega)_I]^2$ (7)

(real) (imaginary)

Consequently the expression for $T>t_0$ will be theoretically formulated as

$P(\omega)_R = 4P_0 I_{1t} + (4/\tau) I_{2t} + (1/\tau)^2 I_{3t} + P_1 I_{4t}$ (8)

$P(\omega)_I = 4P_0 I_{1t}' + (4/\tau) I_{2t}' + (1/\tau)^2 I_{3t}' + P_1 I_{4t}'$ (9)

The details of expressions are given by Pathak[1994].

By theoretical observations of sprites, the speed of streamers can be taken as

$v=10^5$ m/s.

Using a electrodynamics relation between radiated power and electric field which is as follows:

$P = E^2/120\pi$ (10)

Where $c= 3\times10^8$m/s is the speed of light.

Therefore, the expression for the electric field is

$P = c^2B^2/120\pi$

So, $B = \frac{\sqrt{120\pi P}}{c}$ (11)

Moreover using above formula, we have calculated the magnetic field produced by streamer discharges.

We have plotted a graph between magnetic field and time domain shown in fig. (2).

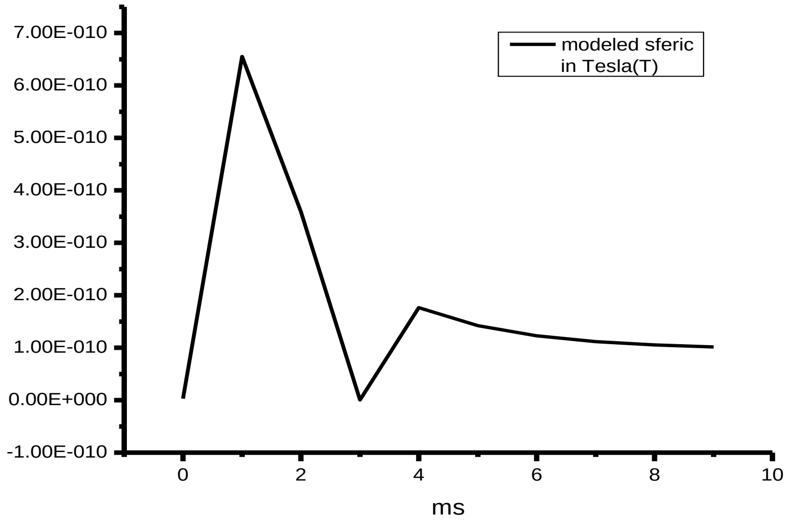

Fig. (2): Calculated magnetic field sferic in Tesla plotted with the time domain.

III. CONCLUSION

Numerical calculations illustrate that as the time grows on, the speed of streamer containing sprites grows on with the radiated powerwith the values containing $\tau=3.22246\times10^{-8}$ s and taking $Q_o=10^{-19}$C. The peak goes high i.e. the higher radiation goes upto $P(t)= 1.83372\times10^{-9}$ Wm^2Hz^{-1} at t= 3s and that symptomized to extremely low frequency electromagnetic radiation.

Fig. (2) described that the magnetic sferic due to streamers of sprites peaks valued on $2.95474\times10^{-12}$and 7.39788×10^{-13} at1 ms and 4 msrespectively. Afterwards the magnetic field due to radiation goes on decreases. Therefore our modelling sferic results are experimentally verified by the Cummer[1998]

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