**Experimental and theoretical study of the bi-leader process**
**Part I : Experimental study**

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## 1. Introduction

It has been shown from experimental results that the aircraft striking process is initiated by the bi-directional propagation of two leaders of opposite polarities [1][2]. In order to obtain data on this phenomenon different experiments have been realized, using both laboratory and triggered lightning techniques, with various optical and electrical measurements. First, a detailed study of the physical processes involved in the bi-leader development has been performed in laboratory experiments conducted in the Electricité de France High Voltage Laboratory. Second, the analysis of the bi-leader phase has been performed on lightning flashes artificially triggered in altitude (which reproduces most of the conditions of the flash initiated by the presence of an aicraft).

## 2. Laboratory simulation of the bi-leader process

In this experiment, an electrically floating object was suspended by insulating wires in the middle of a plane-plane gap of about 10m length, the upper plane being submitted to a negative H.V. pulse. The central conductor shape was designed (using the results of previous experiments [3]) to ensure the development of both leaders, before their connection with the planes. Figure 1 presents the test arrangement, with indication of the current and field sensors in the floating object.

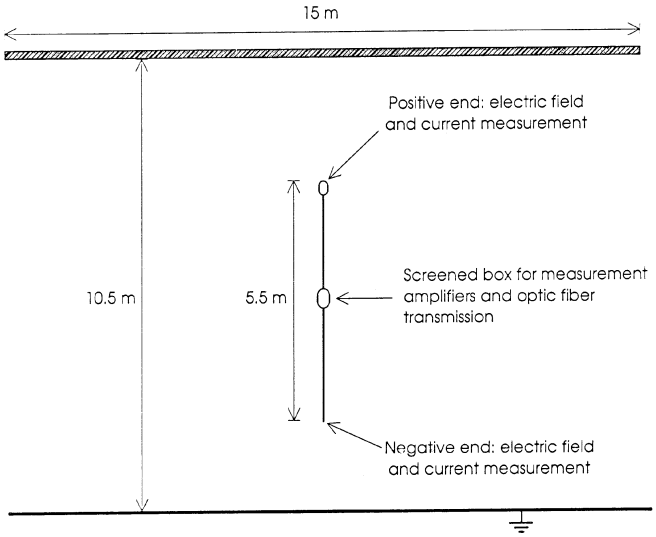


Fig. 1 - Electrodes configuration

Streak photographs and electrical measurements show the space-time development of positive discharge in the upper gap, and negative stepped-leader in the lower gap (see fig. 2 and 3). It is shown that both discharges evolve through the different phases typically observed in laboratory positive and negative long sparks. However, the inception and development times of each discharge are associated to changes in the propagation conditions of the opposite discharge (accelerations, reilluminations, current increases). The coupling effect between the

two parts of the bi-leader have been studied through the analysis of the floating potential of the central conductor [4].

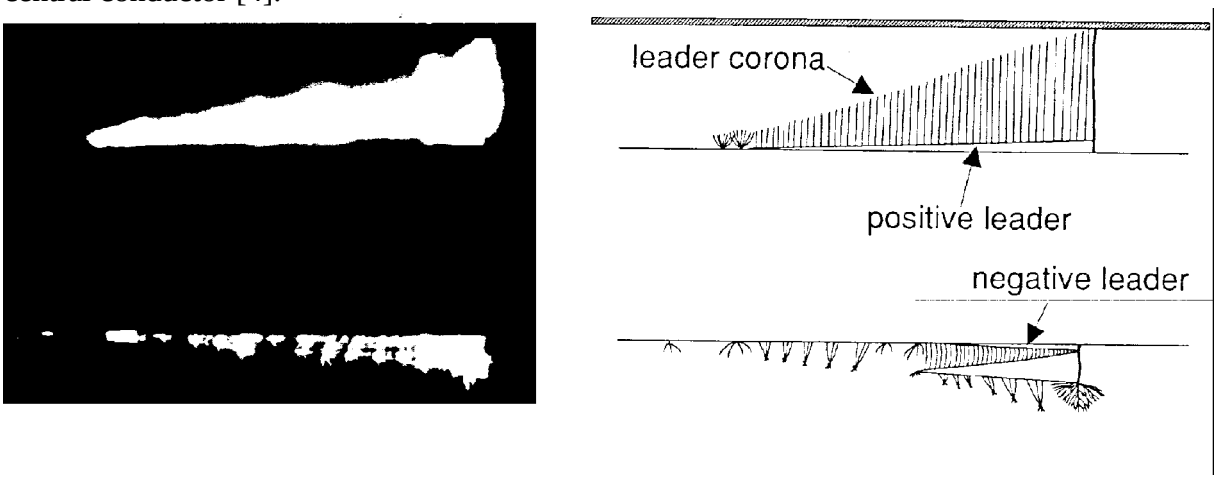


Fig. 2 -Streak photograph of the bi-leader with schematic diagram of the phenomenon

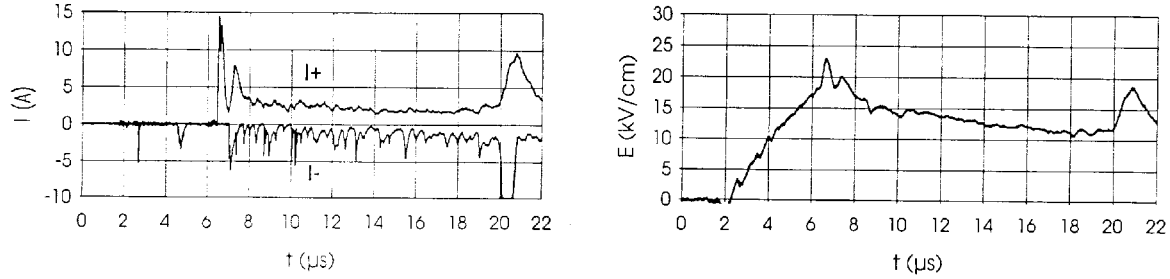


Fig. 3 -Current measured at the two ends of the floating conductor and electric field recorded at the upper end

3. Study of the bi-leader phase in lightning flashes triggered in altitude

This experiment consists in launching of a small rocket trailing out a wire with a lower insulating part (about 400m length) and an upper conductive part. In the reported experiment, the discharge process begins when the conductive part of the wire extends from 400m to 650m of altitude [5].

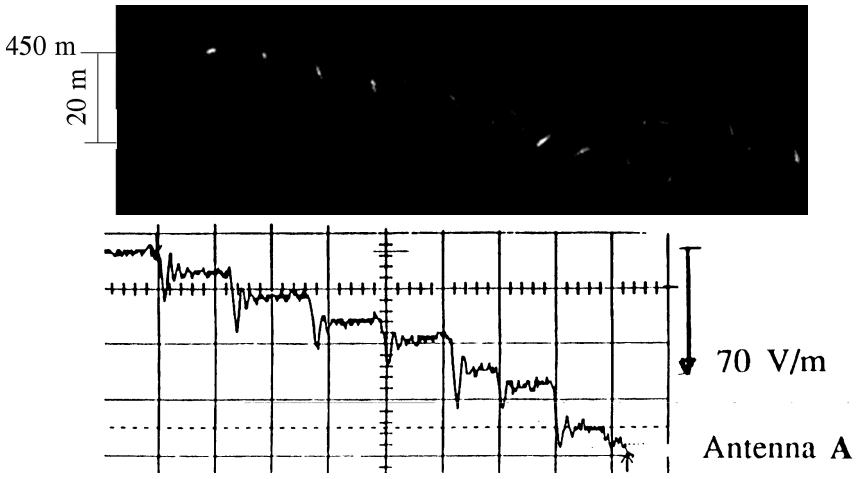


Fig. 4 -Onset of the negative downward leader in altitude triggered flash : near UV streak picture and E field signal from a capacitive antenna

Electric field measurements at ground with fast capacitive antennas indicate that an upward propagating positive leader develops during a few milliseconds before the negative leader onset. This time delay is of the same order than that observed during the bi-leader phase in aircraft striking flashes. The negative downward stepped-leader propagation has been analyzed through optical and E-field measurements which provide the mean step length and charge, and time period (fig. 4).

## 4. Conclusion

These experimental investigations have provided valuable information on the bi-leader phenomenon, and on the scale effects between the laboratory spark and the triggered flash. Measurements of discharge current, charge, characteristic lengths and stepping period will be used to validate theoretical modelling of the bi-leader described in part II of the present paper.

## References

[1]V. Mazur "A physical model of lightning initiation on aircraft in thunderstrorms", JGR Vol.94, n°D3, March 1989.

[2] J. L. Boulay, "Comparaison des mesures obtenues sur avion en vol lors du foudroiement", ONERA Report n°1/6777PY, April 1992.

[3] G. Labaune, F. Issac, J.P.Moreau, A. Bondiou, J.C.Alliot, B.Hutzler, F. Morillon "Simulation en laboratoire de l'attachement d'un leader à une structure flottante" Revue de Physique Appliquée, **25** (1990), pp.131-137.

[4] A. Castellani, A. Bondiou-Clergerie, A. Bonamy, P. Lalande, I. Gallimberti "Laboratory simulation of the bi-leader process on an electrially floating conductor" to be published in IEE

[5]P; Laroche, V. Idoine, A. Eybert-Berard, L. Barret "Observations of bi-directional leader development in a triggered lightning flash" Int. Conf. on Lightning and Static Electricity, April 1991, Coco Beach USA.