

TROPICAL LIGHTNINGS : ELECTROMAGNETIC CHARACTERIZATION
C.O.P.T. 81 EXPERIMENT (TROPICAL DEEP CONVECTION)

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Abstract :

In 1981, the National Telecommunications Research Center (C.N.E.T.) participated in the characterization of the tropical lightnings in the IVORY COAST.

In this communication, we present all the electromagnetic measurements results. Two methods were used during this campaign.

A time-domain analysis (already used in temperate country, ~~more particularly~~ in ST. PRIVAT D'ALLIER), ~~allowed to~~ characterize the radiated signals by lightnings return-strokes and these emitted by intra-cloud discharges, ~~(these are the most numerous ones in the tropics)~~. From the results obtained, we can effectively define the two types of discharges.

A ~~an-harmonic analysis was used to know~~ ^{made of} the instantaneous spectrum evolution during the different lightning phases. During this COPT campaign, we perfected the measurement method for future campaigns, as TRIP 82 (Thunderstorm Research International Program), the first results of which are presented. The data obtained allow ^{us} to understand better the physical lightning discharge process and to define the VHF-UHF environment of electronic equipment.

Introduction :

In 1981, a variety of experimental measurements were performed on the Ivory Coast (Africa), with the intent of studying thunderstorm convection in a tropical region. These experiments, collectively entitled COPT (Convection Profonde Tropicale), grouped together several different organizations from France and the Ivory Coast interested either in thunderstorm dynamic and thermodynamic

processes or their electrical properties and the characteristics of lightning. The objectives of the CNET (Centre National d'etudes des Télécommunications), working in association with the Office National d'Etudes et de Recherches Aéronautiques (France), the Laboratoire de Physique Atmosphérique (Université de Toulouse, France), and the Laboratoire de Physique de l'Atmosphère de l'Université d'Abidjan (Ivory Coast), were to characterize lightning discharges on both a phenomenological level (identify and distinguish between different stages in discharges, studies of discharge channel propagation, types and nature of leader discharge processes, comparisons with lightning properties observed in temperate regions) and a quantitative level (current amplitude as a function of time, estimates of charge transfer, location and tracking of discharge sources, and electromagnetic field measurements).

In this publication, we will discuss the ensemble of wideband (150 Hz - 20 MHz) magnetic field measurements collected during the COPT campaign. The measurement campaign has permitted a characterization of intracloud discharges, the preponderant discharge process in tropical countries. These signals from intracloud lightning are also compared with those produced during cloud-to-ground discharges.

In addition, in view of the disparity between measurements of RF radiation made by different researchers in the VHF and the poor understanding of the processes which produce these emissions, the CNET has undertaken a program of studies in this domain. The second part of this publication presents some of the

very first results of narrow band RF measurements made during the TRIP 82 (Thunderstorm Research International Program) Campaign. Measurements were made at six frequencies between 60 and 900 MHz using tuned receivers with 350 kHz bandwidths.

-I- 150 HZ - 20 MHZ ELECTROMAGNETIC
FIELD STUDIES

I.1 - DATA COLLECTION AND PROCESSING

- Experimental means

Measurements of thunderstorm discharge electromagnetic fields were made using magnetic field sensors with a 150 Hz - 20 MHz passband. These sensors were connected to two sets of recording instrumentation. Each set consisted of both a video tape recorder (VTR) (upper frequency response 3 MHz) and an oscilloscope equipped with a camera with continuously moving film which permitted the recording of fast field variations. The two chains of recording equipment had the following characteristics :

chain 1 :
oscillo. + camera :
trigger level : 45V
($1V = 10^{-9} \text{ Wb/m}^2$ or T)
maximum signal : 600V
VTR : dynamic range : 40V - 400V

chain 2 :
oscillo. + camera :
trigger level : 150V
maximum signal : 1600V
VTR : dynamic range : 40V - 1000V

The magnetic field sensors /1/ were placed horizontally in a direction perpendicular to the preferred direction of movement of thunderstorm fronts.

The different sensitivities chosen for the two chains of recording instrumentation permitted simultaneous measurements of fields from both near and distant discharges (knowing that all of our measurements would have to be made on natural lightning).

- Limits on the interpretation of results

Some of the equipment operating during these experiments, notably a field mill network, VHF interferometry and Doppler radars,

had allowed us to hope to be able to locate and track all of the discharges observed during the campaign. For our application this would have given an accurate distance to each discharge, as well as the orientation of the discharge channel with respect to the magnetic field antenna. However, the enormous task of processing the data collected by the different organizations has allowed the localization of only a few events. Knowing only rarely the distance to a discharge it has not been possible to determine lightning current amplitudes using field measurements. Also, for the oscilloscope records of magnetic fields, a delay line ought to have allowed us to record the beginning of the signal which was below trigger threshold. For some of the slower events, though, the delay time wasn't sufficient. In these cases, a readjustment of signal amplitudes was necessary.

- Processing and analysis of the data

Despite the limitations described above, it is possible to give some general results concerning the parameters which characterize an electromagnetic field impulse.

The video tape recordings were displayed on an oscilloscope and photographed, and have been used to determine the time evolution of the discharges, notably the repetitivity and duration of the events.

The film records best characterize the rapid changes in the field, notably the slopes, amplitudes, and pulse durations. Each waveform was manually digitized and the data were stored in the memory of Taktronix 4081 graphics computer. Data were subsequently transferred to a CII IRIS 80 computer for analysis.

I.2 - RESULTS OBTAINED

- Classification of intracloud
and cloud-to-ground discharges

A field mill network, operated by the ONERA (Office National d'Etudes et de Recherches Aérospatiales (ONERA) permitted the simultaneous measurement, at 10 locations, of electrostatic field variations at the ground. These data allowed us to identify whether a field change appeared to involve charge neutralization of only one polarity, or both positive and negative charge, descriptions which are often used to model cloud-to-ground

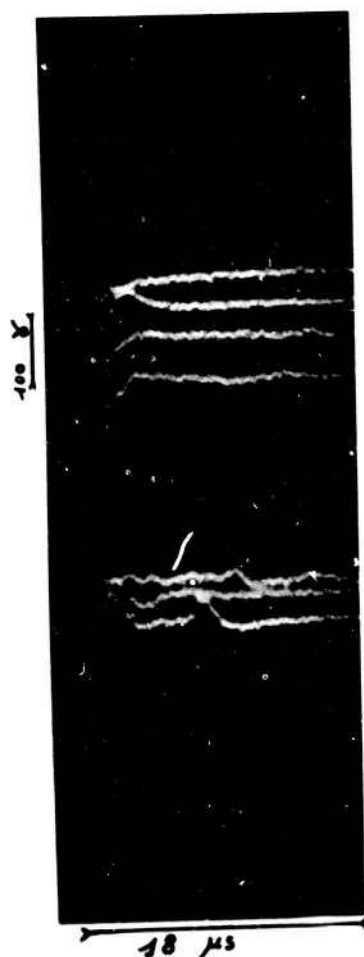
and intracloud discharges, respectively. Also, sequences of impulses of mixed polarities are more likely to be produced by intracloud discharges, because the large amplitude signals radiated by return strokes during a cloud-to-ground discharge are ordinarily all of the same sign. (see photos 1 and 2).

- Characteristics of tropical lightning intracloud discharges

We have studied the following parameters :

1. Maximum amplitude
2. Slope during fast field transitions
3. Pulse width (between $t = c$ and the half peak amplitude point following the peak)
4. Sequences of impulses within a discharge

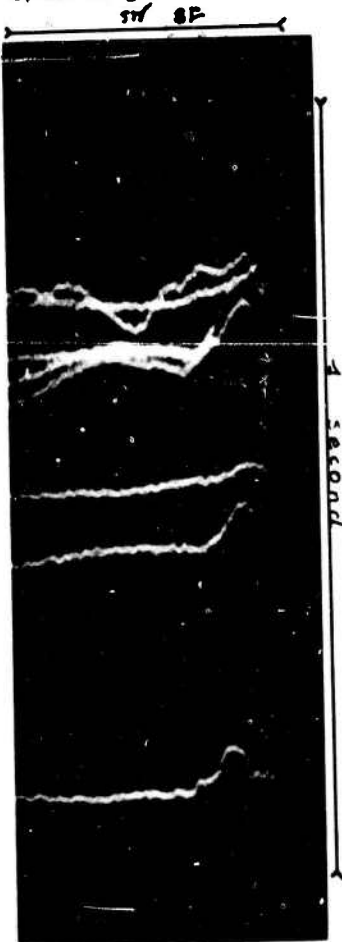
Intra-cloud



4 h 56' 24''

22 June 1981

Cloud-to-ground



4 h 55' 28''

1) Because of the limitations discussed earlier (I.1), it is difficult to present conclusion results regarding intracloud and cloud-to-ground discharge field amplitudes. Nonetheless the table below gives peak amplitudes and the number of events recorded (N) (see reservations in section I.1) :

- Intracloud : $N = 109$;
mean peak amplitude : 96 Y ; $\sigma = 49 \text{ Y}$
- Cloud-to-ground : $N = 33$;
mean peak amplitude : 120 Y ; $\sigma = 64 \text{ Y}$

For some of the intracloud discharges ($N = 35$), the location of high reflectivity zones in the storm clouds by radar has given an estimate of distances ($2 < D < 20 \text{ km}$) between the field measurement station and the discharges. For these discharges, the mean peak amplitude is 70 Y . If we apply theory developed for return stroke discharges [3,4/

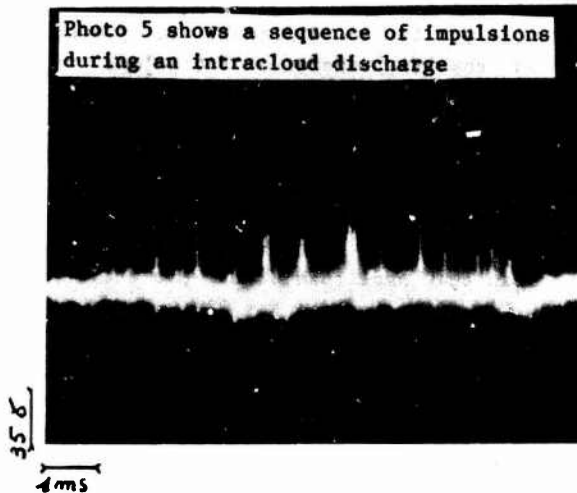
Photos 1 and 2

Streak camera records of successive oscilloscope triggers produced by magnetic field impulses :

film transport speed 5 cm/s
trigger level : 45 Y
inhibition time between successive triggers : 5 ms

- Detailed study of one discharge

22 June 81 - 4 h 53' 08''



This event is one of the most complicated to analyse because of the large number of impulsions recorded. Figure 4 shows the time evolution of this discharge, as inferred from the video tape recording. A large amplitude pulse is present near the center of this record which, in contrast with the other impulsions which were produced by intracloud processes, was radiated by a return stroke. This discharge was located (5km away from the measurement station) by the VHF interferometer being operated by the ONERA. The amplitude of the magnetic field exceeded 1000 γ during one 80 μ s period (the VTR record was saturated), which, we note implies a peak current of about 60 kA, much larger than the mean peak return stroke current observed in temperate regions (Berger /2/ gives a mean peak current value of 12 kA).

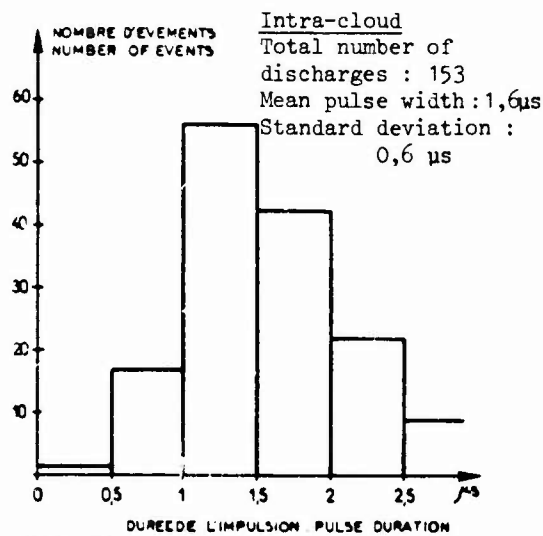


Fig. 2

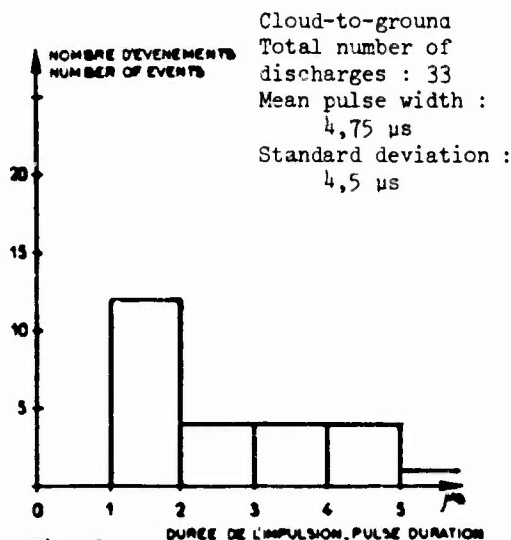


Fig. 3

For the intracloud impulses produced during this discharge, which were also located by the VHF interferometer, we have observed both large numbers of isolated impulsions, with durations which range from a few tens to a few hundreds of microseconds, as well as sequences of very narrow impulsions (pulse widths of a few microseconds). The duration of these pulse sequences was typically 50-60 ms.

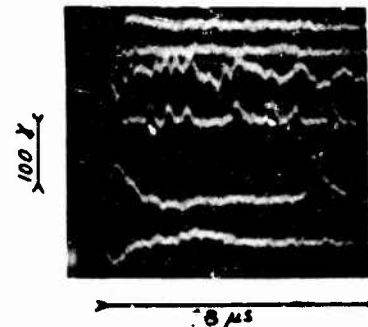


Photo 6

In photo 6, we can see some examples of sequences of very narrow impulsions, with pulse widths and interval times of the same order, 1 or 2 microseconds. These sequences are one characteristic particular to intracloud discharges and have been observed to occur during different discharges.

The peak amplitudes of the intracloud impulsions during this discharge ranged from a few tens of γ to 300 γ .

to these discharges, the value of the peak current, taking into account the distance, is between 2 and 20 kA.

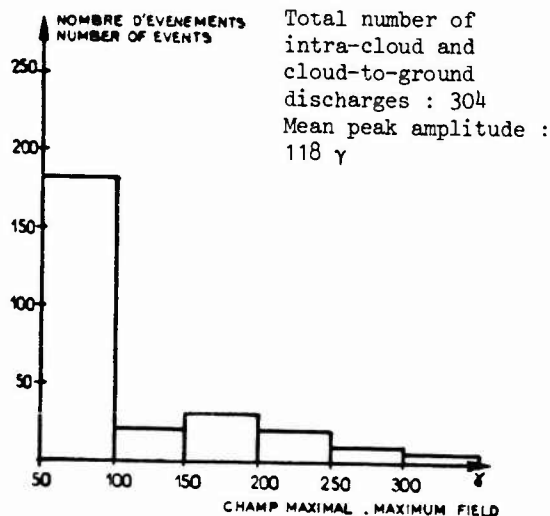


Fig. 1

Figure 1 gives a histogram of peak magnetic field amplitudes, intracloud and cloud-to-ground discharges combined, observed during the course of the COPT campaign.

2) The slope between 10 and 90 percent of peak during rapid field transitions has been calculated for all digitized waveform data using the method of least squares. The values obtained for intracloud and cloud-to-ground discharges are comparable.

- Intracloud : N = 153 ;
mean slope : 71 γ / μs σ = 40 γ / μs
- Cloud-to-ground : N = 33 ;
mean slope : 76 γ / μs σ = 53 γ / μs

3) The most notable difference between the impulses radiated during intracloud and cloud-to-ground discharges is in the pulse widths, here, the time between $t = 0$ and the half amplitude point following the peak. This difference is obvious in photos 1 and 2. Figures 2 and 3 present histograms of measured pulse widths. Mean values are summarized below

- Intracloud : N = 153 ;
Mean pulse width 1,6 μs ;
σ = 0,6 μs
- Cloud-to-ground : N = 33 ;
Mean pulse width 4,75 μs ;
σ = 4,54 μs

The intracloud discharge pulses are much narrower than those radiated during cloud-to-ground discharges.

4) With the video tape records we have been able to observe that during an intracloud discharge, impulses often occur very quickly in sequence, that is with interval times ranging from a few microseconds to a few tens of microseconds (see, for example, photos 3 and 4).

Repetition frequencies of this order, which have been observed in different intracloud discharges, are much higher than are found during a cloud-to-ground flash. Berger /2/, for example, gives a mean interval time between return strokes of 33 ms.

Intra-cloud

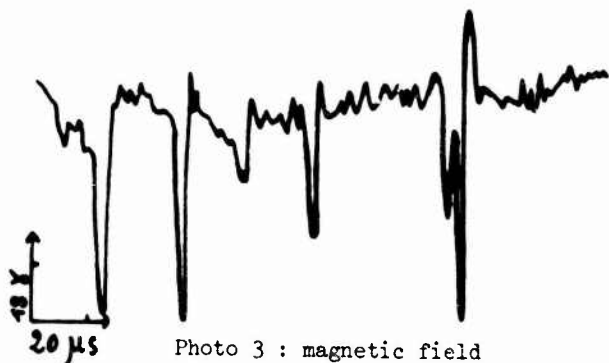


Photo 3 : magnetic field
22 juin 4 h 56' 24'' 20 μs/division
18 γ/division

Intra-cloud

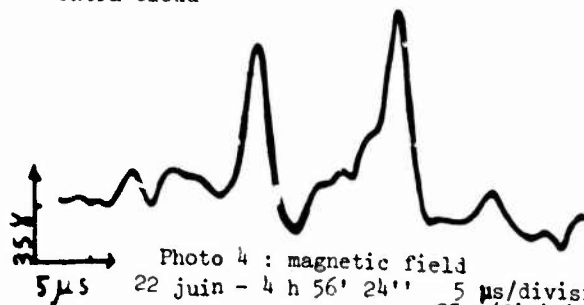


Photo 4 : magnetic field
22 juin - 4 h 56' 24'' 5 μs/division
35 γ/division

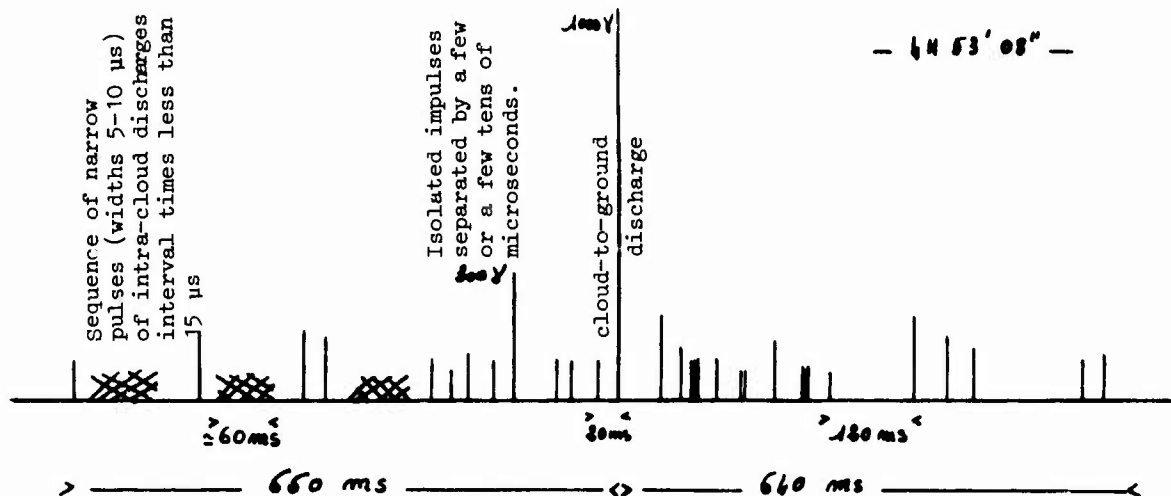


Fig. 4 : Chronology for the discharge of 22 Jun 81 - 4 h 53' 08''

1.3 - DISCUSSIONS AND CONCLUSION

Up until the present day, most experimental studies of thunderstorm discharges have been confined to cloud-to-ground flash /2, 5, 6, 7/. As a result, we have in hand a considerable amount of data characterizing the different aspects of that process. By comparison, when one considers the intracloud discharge process, there is a very real shortage of data. The intracloud discharge is also very complex /8/. Electromagnetic field measurements, with which it is possible to compare our results from the COPT campaign, have been made in Florida by /9, 10/. Those authors have also observed isolated large amplitude impulses, during intracloud discharges, with durations which range from 10 to about 200 μ s, as well as trains of narrow pulses (widths of 2-3 μ s). They note also that the risetime of the fast pulses is comparable (ie, less than a microsecond) to that found in return stroke fields.

-II- NARROW-BAND RF MEASUREMENTS 60-900 MHz

II.1 - BIBLIOGRAPHIC ASPECT

A considerable amount of work has been done with the intent of quantifying the energy radiated by the electrical processes of a lightning discharge. A review and synthesis of results has been published by /11/ and more recently by /12/. Among the outstanding points considered were the following.

- Form of the spectrum

Two types of representation of the radiation as a function of frequency are used.

- The first consists of expressing the spectral amplitude density of the radiation beginning with continuous recordings of signals from a battery of tuned narrow-bandwidth receivers. Integration of these data, the exact form of which depends on the shape of the impulses recorded, is then necessary. This method has been employed by /13/. The mean spectral amplitude density from several discharges and normalized to a distance, $d = 10$ km, is proportional to f^{-1} in the range 10 KHz to 100 MHz.

- The other method adopted by /11/ gives directly the mean peak amplitude, an average of observations from several flashes, as a function of the receiver frequency and bandwidth. Disparate measurements are normalized to a distance, $d = 10$ km from the flash and to a bandwidth of 1 KHz. If for frequencies from 10 KHz to 10 MHz there appears to be concordance among the results published by different authors, for a $1/f$ decrease in the spectrum with increasing frequency, outside of that interval there is a large dispersion in the data, which is all the more difficult to interpret because of its limited number. One can only remark that there is a tendency for the amplitude to vary more slowly with frequency. Results published by /14/ show an increase of amplitudes beginning at and continuing above 300 MHz and suggest that this turning point in the spectrum appears to be due

to the intervention of a different discharge process. More recently /15/ have observed a similar phenomenon beginning at 50 MHz, with the RF emissions showing a maximum around 100 MHz.

- Temporal structure

While strong RF emissions associated with intracloud discharges and the stepped leader, dart leader, and K change phases of a cloud-to-ground discharge have been observed, the time evolution of the radiation produced during a return stroke is still a subject of controversy. For example, /16/ as well as /17/, have mentioned a delay of a few tens of microseconds between the VHF radiation and the abrupt fast electric field change associated with the beginning of a return stroke. The explanation given for this delay is that the return stroke current which propagates from the ground towards the cloud does not radiate at VHF frequencies, but that these radiations are due to the branches of the return stroke channel and due to junction processes once the current wave has entered the cloud /16, 17/. This explanation, which leaves the impression that VHF radiation does not accompany the creation of the return stroke current wave, seems to be contradicted by observations made at 3 MHz by /18/. Here, in 90 % (54 of 61) of the records examined, a large impulse (in 25 of the 54, the largest) was observed at the beginning (time synchronization accuracy 1 μ s) of the first return stroke. A large impulse (the peak in the RF emissions in 99 % of more than 100 observations) was observed to occur at the beginning of subsequent strokes also.

II.2 - EXPERIMENTAL MEANS

Six receivers with 350 kHz bandwidths and central frequencies of 60, 100, 175, 300, 500 and 900 MHz have been used during the experimental campaigns COPT 81 and TRIP 82. Each receiver was equipped with a logarithmic amplifier which gave an 80 dB dynamic range.

The front end of each receiver was connected to a vertically polarized half wave dipole antenna, the ensemble of which were mounted on a mast in a fashion that would minimize mutual coupling between antennas.

The signals thus obtained were recorded with a 400 kHz bandwidth magnetic tape recorder

operating in the FM mode.

Signals from a capacitive electric field antenna (BW 400 Hz - 2 MHz) were recorded simultaneously to permit precise temporal location of the different phases of a discharge, most notably the return stroke. To achieve the maximum possible bandwidth, the recorder was operated at peak tape transport speed, which, with 14 inch tape reels, allowed about 15 minutes of continuous recording.

The campaign COPT 81 at Korhogo, on the Ivory Coast, permitted us to test the functioning of the bank of receptors and to put the system into an improved configuration during the TRIP 82 campaign. These data are presently in the process of being digitized. The use of digitized data will permit an investigation more detailed than the preliminary approach to be presented here. For these initial studies, the analog tape data were played back using an optical (UV) chart recorder, permitting a reconstitution of the time evolution of the signals with a bandwidth of 128 kHz. The fastest time scale achievable was 156 μ s/cm.

It should be noted that time displacements between channels due to misaligned magnetic recorder heads as well as time scale changes due to capstan jitter and stretching of the tape, allow us to resynchronize the signals with an accuracy of the order of 10 μ s. After digitization, the use of time synchronization signals which were superposed on all data channels on a second magnetic tape recorder, will permit synchronization of better than 1 μ s.

II.3 - TRIP 82 RESULTS

During the course of the TRIP 82 Campaign, which was conducted at Socorro, New Mexico, about ten triggered discharges and a large number of natural flashes have been studied ; a total of about 1 hour of thunderstorm activity was recorded.

During the remainder of this publication we intend to describe in detail, observations based on two discharges - one triggered and one natural discharge.

II.3.1 - Shape of the spectrum

Figure 5 presents the peak signal

levels observed during each of the two flashes at the different frequencies and normalized to the Pierce curve [11], that is normalized to a

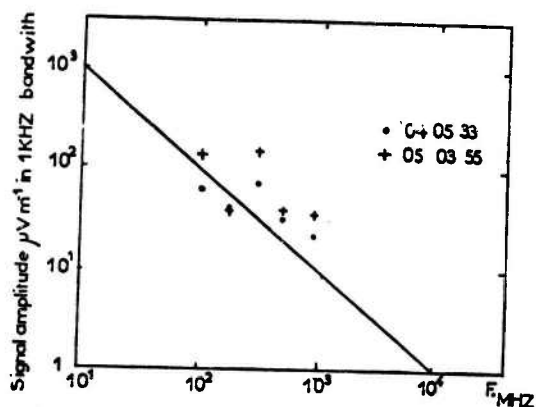


Fig 5: Peak received amplitude at 10 Km

1 kHz bandwidth and a distance of 10 km. We can remark that there is reasonable accord between the observed peak amplitudes and the Pierce curve.

II.3.2 - Radiation macrostructure

Figures 6 and 7 reproduce, totally, the signals recorded during the triggered event 04-05-33 and the natural discharge 05-03-55, respectively. In these two figures one can see clearly the simultaneous evolution of the VHF radiations at the six frequencies studied, and the signal from the capacitive antenna.

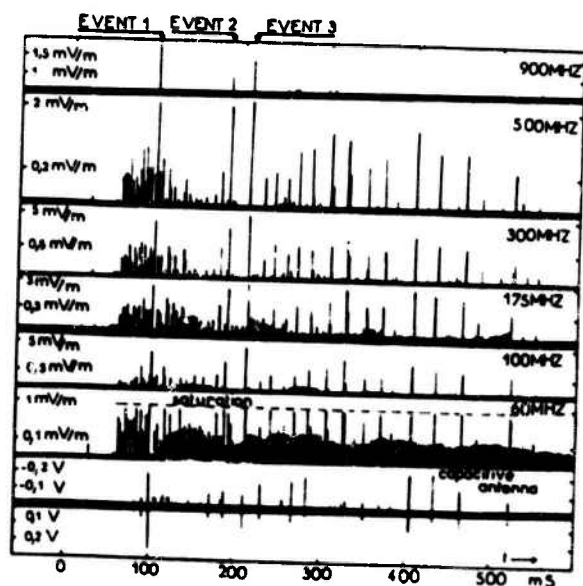


Fig 6: Signal amplitudes in 128 kHz bandwidth - Lightning 04-05-33

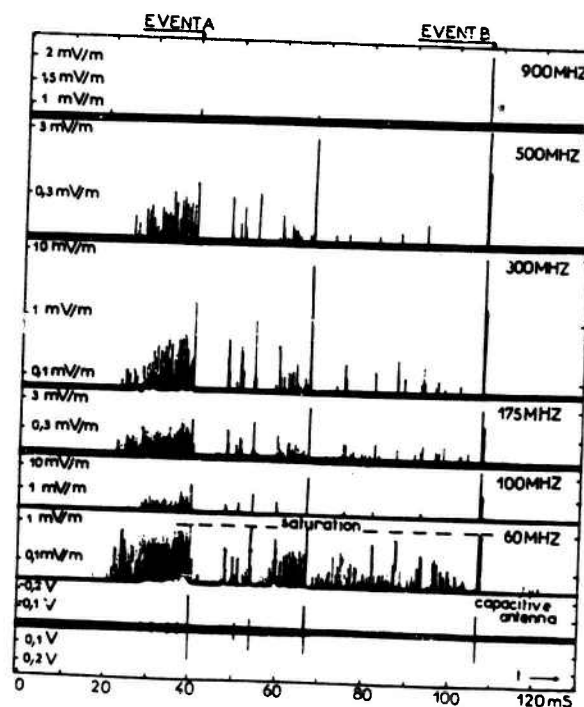


Fig 7: Signal amplitudes in 128 kHz bandwidth - Lightning 05-03-55

One can observe that in both cases, the beginning of the discharge is indicated by continuous VHF activity, which persists for a few tens of milliseconds and ends with a brutal increase of radiation associated with a change on the capacitive antenna signal. This initial radiation corresponds with preliminary breakdown processes within the cloud, as well as the development of a stepped leader which initiates the first stroke in a cloud-to-ground discharge.

If for the natural discharge 05-03-55 this phase has a very regular evolution, corresponding to the creation of a stepped leader which continues to develop up until the return stroke, for the triggered discharge 04-05-33 the appearance is much more disturbed. We see here an abrupt beginning of a stepped leader which stops 20 μs later and is followed, during the next 30 μs, by perhaps ten intracloud events visible at the different frequencies. It is only after a second stepped leader of very short duration (1.7 μs) that the return stroke is initiated. The short duration of this leader can be explained perhaps by the existence of a non-radiating, continuously moving upward discharge initiated by the wire pulled upward from the ground by the rocket.

The stepped leader doesn't intervene until after the end of the triggering phase of the discharge.

During the following phases of the two discharges, the VHF radiation appears as abrupt impulses with durations of less than 1 ms and mean interval times on the order of 10 ms.

For the event 04-05-53, the capacitive antenna record shows roughly a dozen large amplitude impulses indicating significant currents flowing within the cloud or between the cloud and ground. There are roughly 20 large impulses visible on the VHF records, however, which leads us to conclude that the VHF radiation isn't associated exclusively with the cloud-to-ground discharges, nor with K change processes within the cloud.

These emission sequences last for about 500 ms in the case of discharge 04-05-33 and for about 100 ms for event 05-03-55. There is no radiation afterwards and for the several seconds preceding the next discharge.

II.3.3 - Radiation microstructure

(a) First return stroke

The fine structure of events (1), (2) and (3) of discharge 04-05-33 as well as that of events (A) and (B) of discharge 05-03-55 are presented in figures 8, 9 and 10.

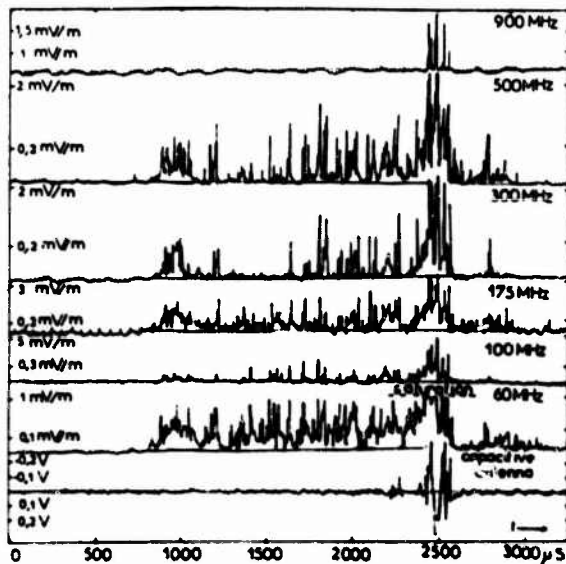


Fig 8: Signal amplitudes in 128KHz bandwidth-Lightning 04-05-33-Event 1

Figure 8 and figure 10 (a) show the radiation associated with the propagation of the stepped leader and the initiation of the first return stroke for the two discharges.

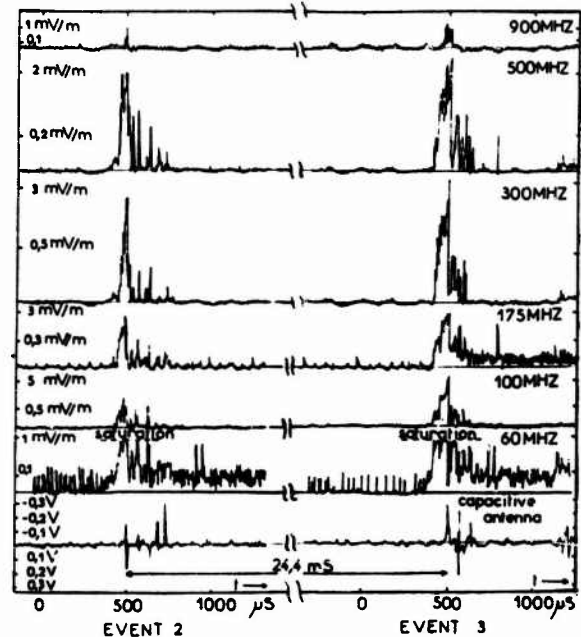


Fig 9: Signal amplitudes in 128KHz bandwidth-Lightning 04-05-33-Events 2, 3

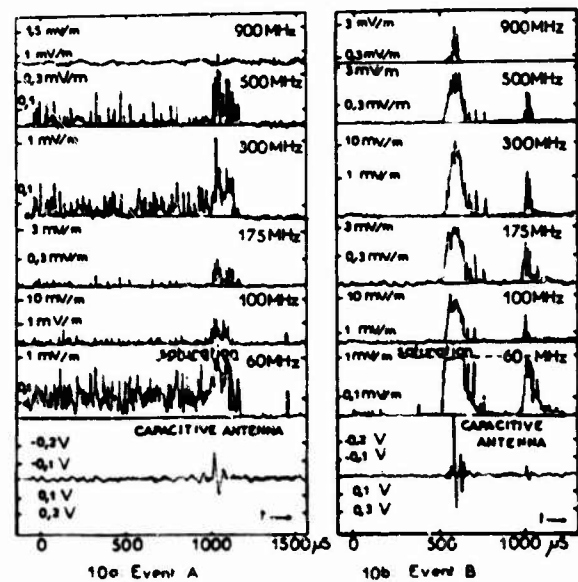


Fig 10: Signal amplitudes in 128KHz bandwidth-Lightning 05-03-55

While figure 10 (a) represents only the final part of the leader associated with event (A), figure 8 shows all of the radiation from the leader of event (1). We note that the

beginning of this leader is indicated by a burst of radiation which lasts for about 200 μ s. In both cases one can observe that the radiation consists of a large number of impulses with pulse widths and interval times less than the 3 μ s time constant of the receiver producing more slowly varying features. Despite this effect, the largest impulses have mean interval times of a few tens of microseconds and could correspond with steps of the leader process.

The end of the leader phase occurs in conjunction with an abrupt transition on the capacitive antenna record and is characterized by a sharp increase in the level of RF radiation at all frequencies. These emissions persist for a few hundreds of microseconds and are followed by a quiet period of a few milliseconds duration.

(b) Subsequent events

Figures 9 and 10 (b) show the fine structure of events (2) and (3) of discharge 04-05-33 and of event (B) of discharge 05-03-55.

These events occur simultaneously with abrupt changes of level on the capacitive antenna record. They are not preceded by VHF emissions, except at 60 MHz, where the radiation might be due to corona discharge off the end of the antenna. It should be noted that none of the subsequent events in these 2 flashes is preceded by VHF radiation which could be identified with a leader, thus it seems to us that this process might not radiate at the frequencies studied.

In the case of the event in figure 9, the initial envelope of radiation seems to provoke a persistent radiation indicated by the offsets visible at 60 MHz for event (2) and at 60 and 175 MHz for event (3). This radiation might be produced by micro-discharges which follow an abrupt field change produced by an intracloud discharge. This phenomenon does not appear in the case of event (B) in figure (6) which seems to be a subsequent stroke.

The envelopes of VHF radiation are composed of a multitude of impulses which occur more frequently and have larger amplitudes than found during the leader phase. One can frequently distinguish between successive groups of impulses which are separated by a few tens of microseconds, such as seen in figures 8, 9 and 10. The suggestion

made by /16/ and /17/ is that this radiation is produced by the branches in the first return stroke channel as well as junction processes within the cloud. To support this hypothesis it is interesting to note the compact appearance of event (B) in keeping with an absence of branches and a minimum of micro discharges associated with subsequent strokes.

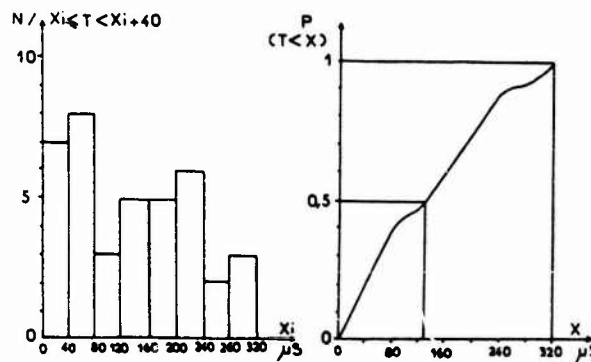


Fig 11: Distribution of the widths of envelopes of impulses, T

Figure 11 gives the distribution of the widths, T, of the envelopes of impulses based on about 40 events from the two flashes. The mean width obtained, "T mean", is 132 μ s.

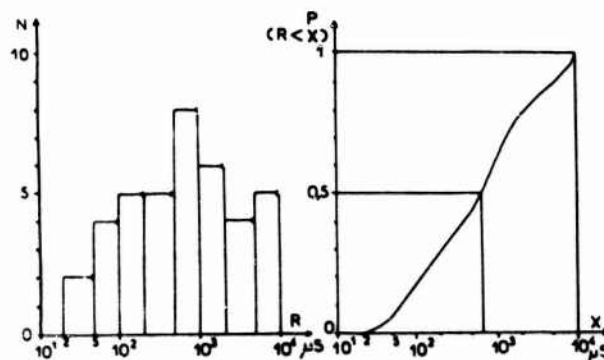


Fig 12: Distribution of the delay R between two successive envelopes of impulses

For each of the events presented in figures 8, 9 and 10 we observe a second narrow envelope of impulses which appears a few hundreds of microseconds after the principal packet of impulses. For the event (B) this second burst of radiation is itself accompanied by an appreciable capacitive antenna change. The phenomenon has also frequently been observed to occur without a capacitive antenna change. Figure 12 presents the distribution of separation times between two successive impulse groups based on about 40 measurements. In 50 % of the cases the separation time is less than 680 μ s.

The second burst of radiation which we have observed could be generated by the current flowing from a charge induced in the cloud following a return stroke or a K change process.

II.4 - CONCLUSION

Continued reduction and analysis of data from the TRIP 82 campaign will permit us to verify and explore in more detail the considerations given here which were based on two discharges, and will allow a better characterization of the radiation from different phases of a discharge. With the digitized data and sufficiently precise synchronization between channels, we will be able to reconstruct the temporal evolution of the spectrum and the capacitive antenna record on a microsecond time scale. Like /19/, we can already say that the forms of the signals recorded at different frequencies are not identical. This puts into evidence the existence of numerous different discharge processes during a lightning flash.

Additional narrow-band RF measurements will be made 3 km from a discharge triggering point during the campaign to be held June-September, 1983, at the experimental station at St-Privat-d'Allier, France. Based on these early studies, it appears necessary to increase the sensitivity of the 900 MHz receiver, which was insufficient for detailed study except during very energetic phases of a discharge. The saturation of the 60 MHz receiver must be attributed to an incorrect choice of the terminating resistance, the receiver doesn't require any modification. During the course of the next campaign, to remove any ambiguity concerning the type of radiating process, a wideband magnetic field sensor (150 Hz - 20 MHz), as well as an optical sensor which will point a couple of hundred meters above the rocket launching point, will be recorded in addition to the signal from the capacitive antenna.

Finally, in order to begin studies of lightning emissions at microwave frequencies, a 4,6 GHz signal from a microwave horn antenna, pointing at the triggering site, will be recorded alongside the six RF frequencies already studied.

COMMENTARY

The results presented in this communication treat two particular aspects of thunderstorm electromagnetic emissions - the radiation produced by intracloud discharges and the radiation in the VHF-UHF band.

Despite the fact that these data can have important consequences for the development of telecommunications systems whether situated in a high risk area (tropical region) or because they involve new techniques (numerically encoded radio wave transmission for example), very few studies of this kind are found in the literature.

From this initial work we can say :

- that, based on the amplitudes measured at the ground and the frequency of occurrence, the influence of electromagnetic field impulses produced by intracloud discharges in a tropical region on a telecommunication network, particularly a digital system, cannot be neglected.

- that our understanding of the physical processes and the possible consequences that lightning radiation in the VHF-UHF band may have on new radio wave transmission systems (digital systems, for example) is still too limited.

ACKNOWLEDGEMENTS

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