High Power Short Duration Discharges
Located by the NMIMT LMA During STEPS 2000

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Abstract: During STEPS there were several examples of high powered, short duration RF sources that were located by NMIMT's LMA. One storm on June 23, 2000 produced several of the these energetic events, including an event that had a source power of 52 MW in the 60-66 MHz passband. Several energetic events were produced within an hour during the storm. Most of these events occurred at high altitudes, +11 km, and were isolated in time and space from other lightning discharges. A comparison with radar shows that they were occurring away from the high reflectivity cores, where a majority of the lightning activity was. Some of these high powered events were located by the Los Alamos National Laboratory Sferic array, and classified as narrow bi-polar's. Using a simple electrostatic model, the total energy of these high powered discharges can estimated to be about 1 MJ.

Introduction
In support of the Severe Thunderstorm Electrification and Precipitation Study (STEPS 2000), New Mexico Tech’s Lightning Mapping Array (LMA) was dispersed over an 80 km wide area of eastern Colorado and western Kansas from early May to mid August of 2000. Operating 13 stations, with real time communications, enabled us to locate and record all lightning activity within 200 km. Radar coverage during the campaign was provided by CSU-CHILL, S-POL, and KSG. Lightning locations overlaid on the data from the radar give important physical information about the storm. Other measurements that were taken include ground based electric field data. On June 22-23 a line of convective storms passed over the LMA network, with one cell producing several energetic events during the lifetime of the storm.

Figure 1a, a time color coded plot of the discharge that produced a 52 MW event, figure 1b.

Observations
As well as locating lightning radiation sources, the LMA also records the power of the received signal at each station. By assuming a isotropic point source we are able to estimate the source power of each event. The majority (99%) of located sources have powers between 1W (0dBW) and 10 kW (40dBW) in our 60-66 MHz passband [Thomas et al., 2001]. The higher power, energetic sources are rare, but they are an important part of the total lightning picture. In a New Mexico storm in 1999, several energetic sources were identified as the initial point in an intra-cloud discharge [Rison et al., 1999]. During STEPS there were some storms that produced these high power sources. The storm on June 22-23 produced over 100 such events within an hour. These events occurred at a high altitude in the storm, +11 km, and
were isolated from most of the other lightning activity. One of these energetic discharges was the highest powered source yet located by the LMA at a peak source power of 52 MW (figure 1b). This was one of the few events that coincided with an intra-cloud discharge (figure 1a). The source altitude was 18 km, but the fit to the data was poor, due to saturation of the receivers, thus giving a high chi squared.

The CSU-CHILL radar was collecting ppi volume scans during this storm. One scan centered at 00:24:00 is displayed in figure 2 with four minutes of energetic lightning sources overlaid. During this time there were about 25 events that had a source power of 100 kW or greater. The two reflectivity ppi images are at constant elevation at 3 km and 11 km. The rhi is a north/south slice through the storm at -35 km, with the overlaid events limited to +/- 5 km of the plane. These plots show that the high power points are located away from the high reflectivity cores indicative of hail.

![Diagram](image)

**Figure 2.** CSU-CHILL volume scan with energetic points overlaid.

During STEPS the Los Alamos Sferic Array (LASA) located and identified several positive bi-polar’s which corresponded to some of the high power events located by the LMA. These bi-polar event are of interest to LANL because they have been observed from space using the FORTE satellite Smith et al., 1999. For the storm on June 23 the LASA located 48 positive bi-polar events within the LMA network over an one hour time range. The event that the LMA located with a source power of 52 MW was identified as a positive bi-polar with a difference of location of about 5 km (Figure 3).
Figure 3. Sferic from LASA for the 52 MW event.

Figure 4. Total energy for E vs d.

One simple way of looking at these high power points is to estimate the amount of energy radiated and to relate that to the strength and size of the electric field needed to produce that much energy. The average power of the energetic events is about 1 MW in our 60-66 MHz passband. The average duration of the RF radiation of bi-polar events is 3 microseconds Smith et al., 1999. This gives a fraction of the total energy to be 3 J. By using the energy in an electrostatic field,

\[ W = \frac{1}{2} \varepsilon_0 E^2 V \] (1)

Figure 4, shows how E and V are related for different values of total energy, assuming that V is a cube with sides of length, d. Assuming a field strength of $10^5 \text{ V}$ and a 500 meter length Smith et al, 1999 the total energy of a bi-polar event is about 3 MJ. Now this is a simple calculation assuming a constant field over a fixed volume, and there are better models that can be used. However the issue remains, where is the energy for these events coming from.

Summary

The existence of high power events within storms is an important issue when addressing the initiation of lightning. It has been shown that some of these events initiate flashes, some are embedded with flashes, and some are totally isolated. They are very short duration, and are often at a high altitude in the storm away from the high reflectivity regions. What ever mechanism that is responsible for this type of discharge has to be highly unstable to have such a wide variety of results. If there is enough charge in a region to produce a mega-watt transmitter, then why is there no other lightning activity in the area? Why do some of these events occur and then stop, while others continue to produce an intra-cloud discharge? These are some of the questions that need to be answered by any model of lightning initiation.

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References


