ABSTRACT: Electrostatic field measurements under storms have been widely measured in several aims, for current investigation, basically, corona and other phenomena [Lance et al. 1991]. On the other hand the application of the electrostatic field measurement results attractive for lightning hazard warning system. But several phenomena perturb and cause not a full representation of the storm electrification. For this reason, signal processing is necessary and joined with other variables in a point of view as a lightning hazard warning system [Montaña et al., 2002]. This work presents a digital processing of electrostatic field signal, in particular, it presents the homomorphic deconvolution of the electrostatic field in different situations.

INTRODUCTION

Natural electric field reaches typical average values around 100 to 200 V/m maintained by the global electric circuit. In presence of an electrified cloud the electric field can reach values up to 10 kV/m. In several works the electric field at ground level has been measured in storm conditions and concluded that is not full representative of the cloud electrification by several phenomena.

As the cloud becomes electrified, an inversion of the fine weather polarity is done, then the initial electrification is being developing. The initial electrification stage duration is in order of few tens of minutes and it's ended when the first lightning discharge appears. At this moment, the active stage is beginning with duration from few minutes to an hour or more. During this stage each lightning produces a sudden change and usually also polarity reversals. Sign reversal denotes the presence of corona charge, usually positive, above the measurement point. This corona charge acts as a shelter limiting the maximum values of the electric field at ground level, so corona charge resides at relative low level from the ground surface [Livingston et al., 1978]. Precipitation and downdrafts make field excursions over the other effects. Finally, in the dissipation stage the End of Storm Oscillation indicates the field recovery.

The whole processes make that the field measurement at ground, in order to characterise the electrification level and its evolution are not easy. Other phenomena as charge generators (power systems), point effect (if the measurement is made over a structure) have to be taken into account.

Since the electric field signal during a storm is similar to a voice signal, we take advantage of the signal processing techniques developed for speech characterisation. In this work we present an homomorphic deconvolution based on cepstrum determination. Homomorphic deconvolution is widely applicable to characterise linear systems, for example: the behaviour of different parts that take place in the speech process [Rabiner et al., 1978]. With the deconvolution, is possible to identify different parts of a system such as excitations and transfer functions. We have applied this method to the electrostatic field during a storm and interesting results have been obtained.

The electric field was measured by an electrostatic field mill, also rain and other weather variables were registered. Besides, magnetic field and electric field antennas were used to verify lightning discharges.

THE HOMOMORPHIC DECONVOLUTION

An output of a discrete system is composed by the convolution of the excitation and the transfer function. In this study the electric field is treated as an output of a complex system, figure 1.

\[
\begin{align*}
\text{x}(n) & \xrightarrow{H[\cdot]} \text{E}(n) \\
\end{align*}
\]

Figure 1. Linear system representation

Where \(x(n)\) is the input that can be composed by several convoluted excitations:

\[
\begin{align*}
x(n) = x_1(n) * x_2(n) * ... * x_t(n) \\
\end{align*}
\] (1)
And the output is represented by:

\[ E(n) \otimes H^e(n) \]  \hspace{1cm} (2)

Developing the transfer function \( H[] \) results:

\[ H(n) = h_1(n) \ast h_2(n) \ast \ldots \ast h_j(n) \]  \hspace{1cm} (3)

Where \( h_j \) is the \( j \)-th impulsive response of the system. To simplify, in (4) the output will be considerate as the convolution of the excitations \( x(n) \) with the impulsive response \( H(n) \).

\[ E(n) = H(n) \ast x(n) \]  \hspace{1cm} (4)

A hypothesis is the assumption of the electric field behaviour as an output of a time variant system with relatively slowly properties variation. Then, if short segments are considered, each element can be modelled as a time invariant system whose input is composed by a train of impulses and noise. The temporal response of invariant time system and the excitation are in convolution to produce an output, that in this case, is the electrostatic field. If these components are in frequency separable, these can be identified by means of the homomorphic deconvolution.

The \( z \)-transform of (4) results:

\[ E(z) = H(z) \cdot X(z) \]  \hspace{1cm} (5)

where in \( z \) space the convolution is the product and then, taking logarithms the product becomes an addition:

\[ \ln E(z) + \ln H(z) + \ln X(z) \]  \hspace{1cm} (6)

and inverting (6) with the inverse \( z \)-transformation, the cempstrum is obtained:

\[ C_e(n) = C_x(n) \otimes C_h(n) \]  \hspace{1cm} (7)

If the cepstral components are identified in \( C_e \) before being windowed, these will be separated with the inverse transformation and the estimated components of \( x(n) \) and \( h(n) \) will be obtained, figure 2.

![Figure 2. Homomorphic deconvolution block diagram](image)

Cepstrum computation is obtained by the discrete fourier transform instead the \( z \)-transform. A particular situation is done when the excitation of a system is an impulse train. Then, the complex cepstrum will be non zero at multiples integer so it will be easy to identify systems with this excitation characteristic.

RESULTS

By the application of the discrete fourier transform and aliasing minimization the signal is taken in a 512 points segments. In real time applications the segments can be superimposed, in this work only the results of the deconvolution are treated.

Figure 3 shows the cepstrum, \( C_e \) result over a fine weather segment. By the application of a central window, we can view this central region of \( C_e \) is empty or not having anything standing out.
Figure 3. Cepstrum, $C_e$, of a fine weather segment

Figure 4 shows an example of a segment with several lightning discharges. In this case it is possible to see several peaks at the centre of the cepstrum, $C_e$, corresponding to the excitation of the “system” which its output is the electric field.

Figure 4. Cepstrum, $C_e$, of a segment with several lightning discharges

As well as speech, the central part of the cepstrum belongs to the excitation, while both laterals regions belong to the impulsion response. Also, the excitation shape is similar as speech where the excitation is composed by an impulse train. In our situation the train of impulses is related to the lightning activity.

According to the block diagram showed in figure 2, once the cepstrum $C_e$ is calculated, by windowing both, central and laterals regions, the approximated cepstrums $\hat{C}_c(n)$ and $\hat{C}_h(n)$ are given. Then, the inverse operation of the cepstrum determination is done and the approximated excitation and impulse response are determinate. If this algorithm is applied to the cepstrum obtained in figure 4, corresponding a lightning period, the excitation $\hat{x}(n)$ is showed in figure 5.

Figure 5. Excitation estimation, $\hat{x}(n)$, corresponding to the lightning segment of figure 3

And the impulsion response resulting from the lateral windowing figure 3 is showed in figure 6.

Figure 6. Impulsional response estimation, $\hat{h}(n)$, corresponding to the lightning segment of figure 3
Figure 7 shows other example of a close lightning discharge.

![Figure 7](image)

Figure 7. Segment with a nearby lightning, cepstrum $C_0$, excitation $\hat{x}(n)$ and impulse response $\hat{h}(n)$

During raining periods without lightning discharges, as figure 8, the cepstrum also does not show anything standing out in its central region.

![Figure 8](image)

Figure 8. Raining segment and its cepstrum

CONCLUSIONS

The application of the homomorphyc deconvolution on the electric field in several situations has been presented. This application gives another curious point of view of the storm and it comes to be useful as an input in decision algorithms such as neural networks where the variability of the signal in its several stages (fine weather, rain and lightning) are very different. Also the results are interesting for pattern determination of behaviours in different measurement points.

Further work would be to correlate between estimated excitations (time and magnitude) with the data given by the national lightning detection network.

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