NASA TECH BRIEF
John F. Kennedy Space Center

Determining Distance to Lightning Strokes from a Single Station

The problem:

Lightning, a well known threat to buildings and man, also causes extensive forest fires as well as breakdown in electronic equipment. The methods for rapid detection of the distance to a lightning strike, however, have been less than adequate. Under the present circumstances, one approach requires two observers at separate fixed locations. Each observer has to spot the same strike; then both have to communicate with each other to determine the exact spot by triangulation. Clearly this method is subject to a large human error. In another approach, two automatic cameras at two locations photograph each lightning strike. The distance is determined later by triangulation. This method is slow and useful only for a future study.

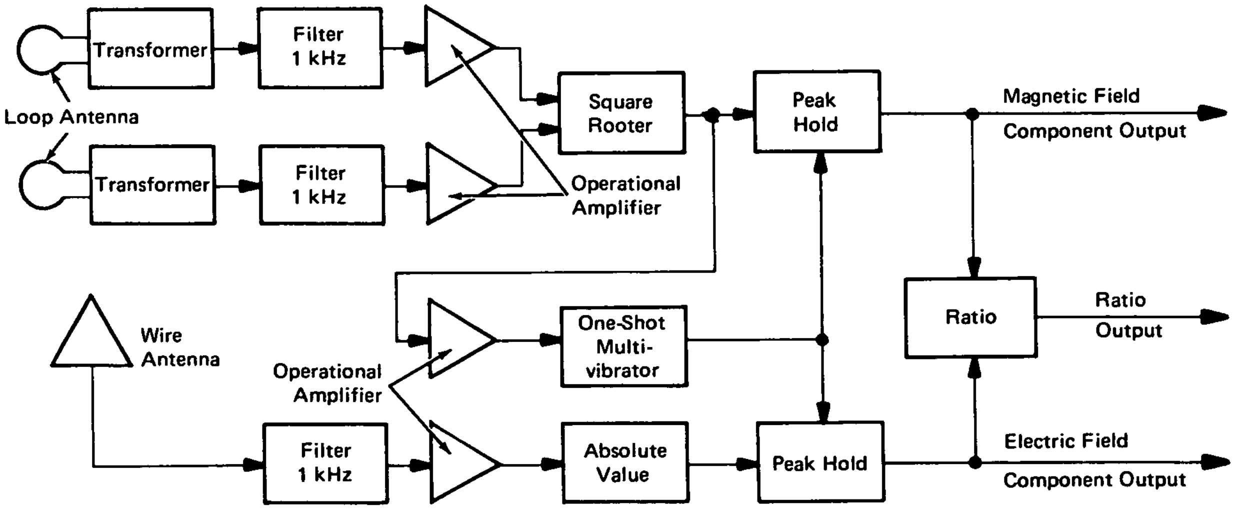
The solution:

An electronic system was developed which can rapidly determine the location of lightning strikes occurring within a 3- to 30-km range. Longer distances are also determined, but with a reduced accuracy.

How it's done:

The distance to lightning is determined from the ratio of the magnetic to electric field. Studies have shown that a lightning bolt emits an electromagnetic wavefront whose magnetic field decreases with the square of the distance, while the electric field decreases with the cube of the distance. Both the magnetic and electric fields received at 1 kHz can be processed to form distinct ratios over the range of 3 to 30 km. It is from this ratio that the system determines the distance to the lightning strike.

The block diagram of the system is shown in the illustration. In this configuration, the electric field is sensed by a horizontal wire antenna, approximately 10 m long and 2 m above ground. The antenna is connected to ground through a 10-kilohm resistor in order to be properly matched to a passive filter. The filter has a center frequency of 1 kHz, attenuation which drops 2 dB at ± 3 percent off the center frequency, and slopes of 40 dB/octave on both sides of the center frequency.



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The output of the 1-kHz filter produces peak amplitudes of 1 volt for a very close lightning strike and 10 μV for a strike about 160 km (100 miles) away. Peak voltage detectors as well as strip chart recorders do not usually handle such a large range accurately enough. The signal, therefore, is amplified before the peak voltage detector using an operational amplifier with a three-position control to vary the gain, by orders of 10, from 10 to 1000.

After amplification, the signal is fed into an absolute-value circuit. The information on strike polarity, which is lost by this procedure, is already obscured by the sharp filter and is not needed in this method of determining distance to the strike.

The output of the absolute-value circuit is fed to a peak-hold module. The output of this module is a positive pulse one second long whose amplitude is proportional to the magnitude of the electric field at 1 kHz. This output voltage appears at an output terminal on the front of an electric-field processing instrument and can be fed to a strip chart recorder.

The magnetic field, on the other hand, is sensed by two loop antennas. Each loop produces a voltage U_m, which depends on the angle θ of the loop planes to the signal source, the frequency of observation ω, the loop area F and the number of turns n

$$U_m = \mu \cdot H \cdot \omega \cdot F \cdot n \cdot \cos\theta$$

This voltage usually appears as a very low impedance source because of technical difficulties in constructing high loop inductances. The source inductance L (henry) is approximately given by

$$L = 2.6 \cdot 10^{-6} \cdot n^2 \cdot \sqrt{F}$$

For the prototype model, each loop antenna consists of 50 turns and a loop area of 4 m^2. The measured inductance is 12.4 mH. Both loop antennas are followed by identical transformers with a turn ratio of 1:18. These transformers match the loop impedance to the 1-kHz filter. The loop antenna produces a voltage equivalent to an electrical antenna of an effective height of 4 mm. This makes it necessary to eliminate electrostatic pickup, which otherwise will interfere with the magnetic pickup. Therefore, the center tap of the primary winding of the transformer is grounded, and the two-conductor cables and the loop antennas are shielded.

The filters, amplifiers, and peak voltage detector are identical to the electric-field branch. A rectifier module is used as a "square-rooter" to add the signals from both loop antennas such that the directional characteristic of the loop antennas is eliminated.

The trigger signal for the peak detector is produced by a conventional one-shot multivibrator using an operational amplifier with an R-C network to produce 10-V, one-second pulses. This multivibrator is fed by pulses from the output of the "square-rooter" after a 100-fold amplification.

Note:

Requests for further information may be directed to:
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Patent status:

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning non-exclusive or exclusive license for its commercial development should be addressed to:
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