Propagation of preliminary breakdown pulses preceding cloud-to-ground lightning discharges

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A sequence of electromagnetic pulses lasting from a few milliseconds to several tens of milliseconds is usually observed prior to the first return stroke of a cloud-to-ground lightning flash. The sequence is composed of three parts. It begins with a group of relatively large bipolar pulses which are believed to be connected with preliminary breakdown processes. They are usually followed by a relatively low and irregular pulse activity. The sequence ends with a train of smaller and faster pulses attributed to the stepped leader.

We study 11 groups of preliminary breakdown pulses measured by two different types of instruments at different distances during one thunderstorm. The magnetic-field waveforms are measured close to the thunderstorm ($\sim 12-44$ km) using a broad-band analyzer with a sampling period of 12.5 ns. The electric-field waveforms are measured at three distances (~ 300 km, ~ 400 km, ~ 600 km) using identical analyzers with a sampling period of 80 ns.

We compare the waveform patterns of pulse groups belonging to the same flash as they are simultaneously observed at different distances. We study variations of the amplitudes of individual electric-field pulses with the observation distance. We use these data to estimate the attenuation of the pulses during their propagation over land. We compare the attenuation of the pulses with the attenuation of the corresponding return strokes.

We use the short range (20 km) magnetic field waveform to obtain a reasonable estimate of the source current waveform. We compute simulated waveform using the estimated source current and the FDTD (Finite-Difference Time-Domain) simulation with and without ionospheric reflection. We compare the measured waveforms with the simulated ones in order to see the role of ionospheric reflections.