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Lightning observations by the satellite and the characteristics of the electromagnetic waveforms

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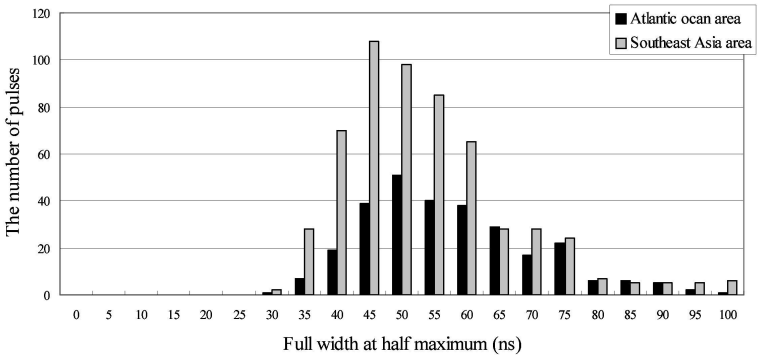
The well-developed thundercloud causes local downpours and tornadoes accompanied with the lightning discharge. These climatic phenomena in a short period of time are difficult to monitor in real time with an existing system. The monitoring of the thunderstorm activities is useful to prevent the weather disasters. The present study aims to monitor the thunderstorm activities from space. In our research group, the Broadband Digital Interferometer (DITF) has been already used to observe the lightning activities above ground. The DITF is a system to locate the sources of impulsive VHF radiation based on the digital interferometric technique. In other words, the DITF is a equipment to visualize lightning channel by VHF radio observations. The remarkable feature of the DITF is its bandwidth (from 25 MHz to 100 MHz) and implicit redundancy for the direction-of-arrival (DOA) estimation. The fairly high resolution and the compactness of the system are great advantage to be the spaceborne system. The goal of this study is to realize the spaceborne DITF and to monitor constantly the thunderstorm activities with the satellites. The Maido-1 observed the lightning discharges from February to October 2009. We indicated the recorded data with the Maido-1 above Southeast Asia area and the Atlantic Ocean area. The pulse width and the number of the pulses are thought to be highly affected by the propagation length through the ionosphere and the lightning activity level, respectively.

We calculated the change of the pulse width with the electromagnetic wave propagation in the ionosphere. The pulse width grows wider in the medium because the short duration VHF pulse with lightning activity has the wide band frequency characteristic. We conducted the propagation simulation in order to understand the change of the waveform. The ionospheric model was developed to calculate the change of the pulse width in the ionosphere. It was divided into the multi-layered media to consider the altitude distribution of the electron density. The model assumes that the ionosphere and the earth are the spherical shape with their origin at the center of the earth. The each layer has the thickness at 10 km. The values of the electron density are used the international reference ionosphere 2007 (IRI-2007) model. In the each layer, the value of the electron density and the refractive index stay constant. The full width at half maximum (FWHM) changed about the tens of nanoseconds. Next we compared to the pulse width of the received pulses by the Maido-1 satellite at the two observation areas. The results in the Atlantic Ocean area had the greater FWHM than those in the Southeast Asia area. The deference of the FWHM was about 5ns. The results had a similar finding for the ground-based observations.

Then we discussed the relationship between the number of the received pulses and the lightning activity. The relationship was calculated by using the observation results of the Maido-1 and the WWLLN. As the first step, the lightning activity factor is defined as the lightning detected number of the WWLLN. The lightning detected number indicates the number which the WWLLN detected the lighting activity in the satellite observation range and in five minutes around the time of the satellite observation. Second, the received pulse number by the Maido-1 was counted using the fitted pulses with the LogisticCum function. Then, we compared the detected number by the WWLLN with the received pulse number by the Maido-1. This result indicated the clear link between the number of the received pulses by the Maido-1 and the detected number by the WWLLN.

We concluded that the pulse width and the received pulse number with the VHF lightning satellite observation indicated the probability of the reference indexes for monitoring the lightning activities.



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