7 Terahertz-Wave Remote Sensing

7-1 Introduction to Terahertz-Wave Remote Sensing

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There have been only a few technique with THz technology for atmospheric remote sensing observations. The development of the observation technique is quite difficult in this frequency region, because THz region is technically the boundary area between the electronics and the opt-photonics. However, recently, THz technology has made tremendous progress. In NICT, we are developing the THz remote sensing on the powerful collaboration with device development research center.

Keywords
Terahertz, Atmospheric radiative transfer, Remote sensing, Humidity, Green house gas, Polluted gas, Ice cloud

Terahertz observation is performed in the frequency range between the frequencies used for microwave and infrared observations. This area of the spectrum remains a “gap” in the overall range of earth-observation frequencies; as a result, continuous observation has never been performed over all of these frequency ranges. Efforts at bridging the gap from the microwave side have been ongoing for the past twenty years. A number of satellite endeavors are included among these efforts: the Odin/SMR satellite of Sweden launched in 2002, for example, and the Japanese Experiment Module/Superconducting Submillimeter-Wave Limb Emission Sounder (JEM/SMILES) to be launched in 2009 for the International Space Station. These satellite projects share a common goal in establishing observations via submillimeter waves, in the sub-terahertz range. The Microwave Limb Emission Sounder (MLS/AURA), launched by NASA in the United States in July 2004, is equipped with OH observation equipment in the 2.5-THz range[2]. Meanwhile, others have approached the terahertz gap from the infrared side. For example, NASA’s Langley Research Center recently succeeded in simultaneous balloon observation of water vapor and clouds in the terahertz range using FIRST equipment aboard the craft[1].

The terahertz range covers over 50 % of Earth’s long-wavelength radiation, and has also long been pointed out as a critical frequency range in the understanding of global warming (Fig. 1). As terahertz waves are located in the boundary range between radio waves and light, they display the combined characteristics of both. Most notably, these waves combine the transmittance of radio waves and the directionality of light (i.e., high spatial resolution). When observing ice clouds, for example — a key element of global warming mechanisms (as currently discussed in the Intergovernmental Panel on Climate Change, or IPCC), the characteristics of terahertz waves are particularly advantageous.

It is difficult to observe the microphysical processes of ice clouds with radio waves or light due to the thinness, size, and scattering characteristics of the ice-cloud components. We cannot observe the interior of the cloud using light (whether infrared, visible, or ultraviolet), as the cloud is reflective to all such light. On the other hand, radio waves penetrate the cloud and propagate at larger wavelengths than the component elements of the ice cloud, which renders observation difficult. However, terahertz waves make it possible both to penetrate and to observe these clouds. Our studies have clarified that the range of terahertz wavelengths most suitable for observing objects the size of ice-cloud particles is on a scale of several hundred μm. We are also beginning to recognize that this frequency range is most suitable for observing the water vapor present in Earth's atmosphere. For example, the use of terahertz waves may make it possible to provide local forecasts for torrential rain in urban areas, taking advantage of the flexibility and sensitivity of terahertz-based water vapor observation.

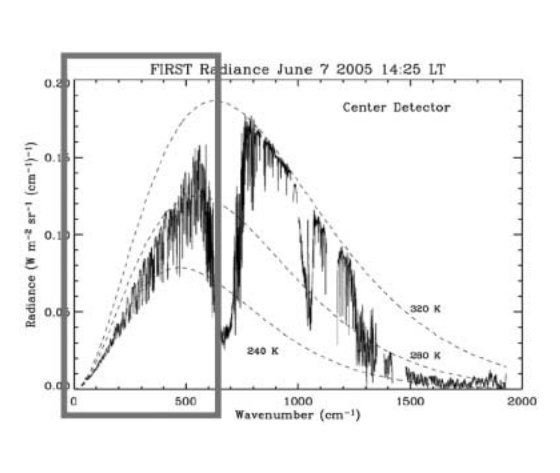

Fig. 1 *Relationship between terahertz frequency range (enclosed in frame) and Earth radiation*

Radiance is cited from an infrared spectrum recorded by FIRST, Martin G. Mlynczak et al. GRL, 33, GL025114, (2006)[1].

These advantages notwithstanding, the field of terahertz-wave remote sensing observation is exceptionally immature and still developing through recent scientific projects. NICT, the worldwide leader in the associated technologies, is continuing to explore possibilities by trial and error. Chapter 6 describes some of the terahertz-wave remote-sensing techniques we are currently developing (Fig. 2).

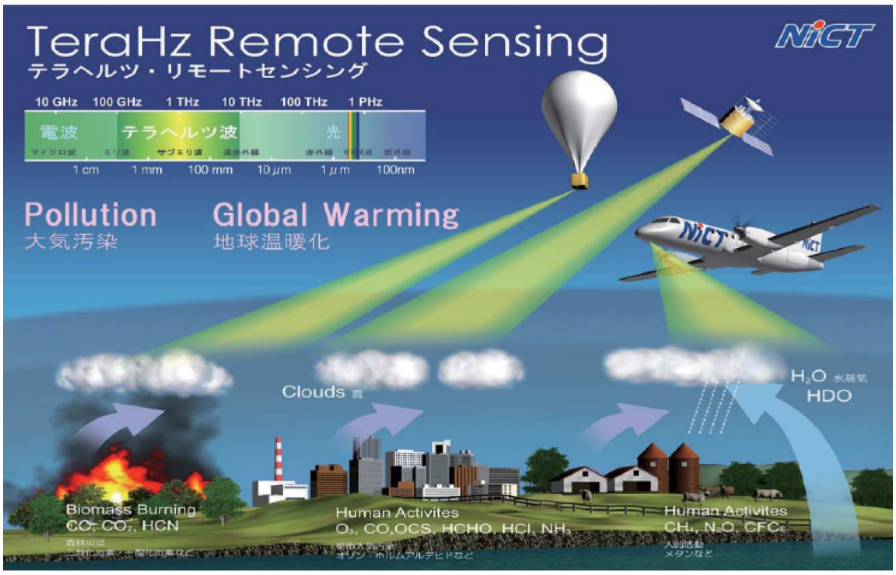

Fig. 2 *NICT's terahertz-wave remote-sensing techniques*

References

1 Martin G. Mlynczak. et al, "First light from the Far-Infrared Spectroscopy of the Troposphere (FIRST) instrument", GRL, 33, GL025114, 2006.

2 Waters, J. W. et al. "The Earth Observing System Microwave Limb Sounder (EOS MLS) on the Aura satellite", IEEE Trans. Geosci. Remote Sensing 44, No.5, 2006.

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