Sensing fundamentals

Applied Electromagnetic Research Institute

Director General　Kazumasa Taira

In order to create new value for humans through the use of ICT, we must obtain information by observing various phenomena and situations in our environment. The mission of the Applied Electromagnetic Research Institute in NICT is to fulfill this requirement through the use of electromagnetic waves. We aim to realize more accurate electromagnetic-based measurements in order to protect the activity of society and deliver new scientific value by observing what has previously been impossible to see. Such efforts may result in novel applications of electromagnetic waves, particularly by collaborating with industry and academia.

Specifically, we are conducting research and development using electromagnetic waves in four main areas: Remote sensing technology and Space environment measurement technology for the acquisition, collection, and visualization of diverse information from diverse objects that surround us, Space-time standards technology that forms the basis for the generation, dissemination, and utilization of high-quality time and frequency signals, and Electromagnetic environment technology that provides a platform for ensuring the electromagnetic compatibility of equipment and systems in order to maintain a safe and secure electromagnetic environment for future diversification in the usage of electromagnetic waves. Some of our research and development themes are introduced below.

The world's first practical multi-parameter phased array weather radar (MP-PAWR)

As part of a Cross-ministerial Strategic Innovation Promotion Program (SIP) for the research and development of resilient technology to prevent and mitigate disasters and predict localized heavy rainfall (cloudbursts) and tornadoes, we have developed a Multi-Parameter Phased Array Weather Radar (MP-PAWR) that combines a phased array weather radar capable of performing high-speed three-dimensional observations of clouds over time scales ranging from 30 seconds to one minute, and a multiparameter (dual phase) radar that can measure rainfall with high accuracy and predict torrential rainfall up to 30 minutes in advance. The installation of this radar at Saitama University was completed in November 2017, and in March 2018 we acquired a radio station license and began evaluating the radar performance. (Fig.1)

R&D for the numerical prediction of solar flares that have a large impact on society

In collaboration with the Advanced Speech Translation Research and Development Promotion Center, we have developed a solar flare prediction model that uses deep learning to predict the occurrence of large solar flares that can have a large effect on our satellites and communication/broadcasting infrastructure. This work has now reached the stage of putting this model into actual operation.

When a large solar flare was detected in September 2017, the NICT issued a press release and held a press conference to warn of its possible effects on society, resulting in widespread media coverage (271 newspaper articles, 60 television programs, and 779 Web news items) (Fig.2). The NICT Space Weather Forecast website received 1.8 million hits in two days.

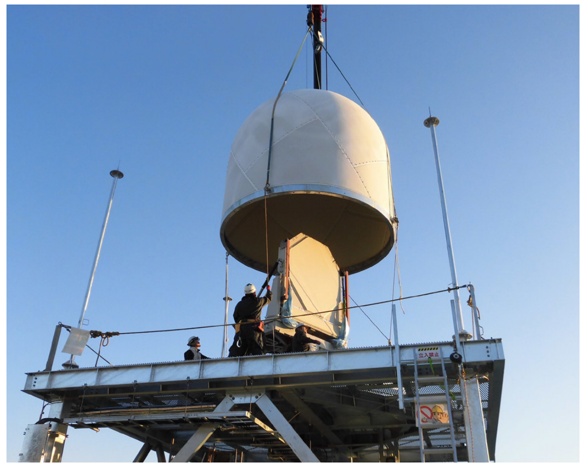

Fig.1 : Multi-Parameter Phased Array Weather Radar installed at Saitama University

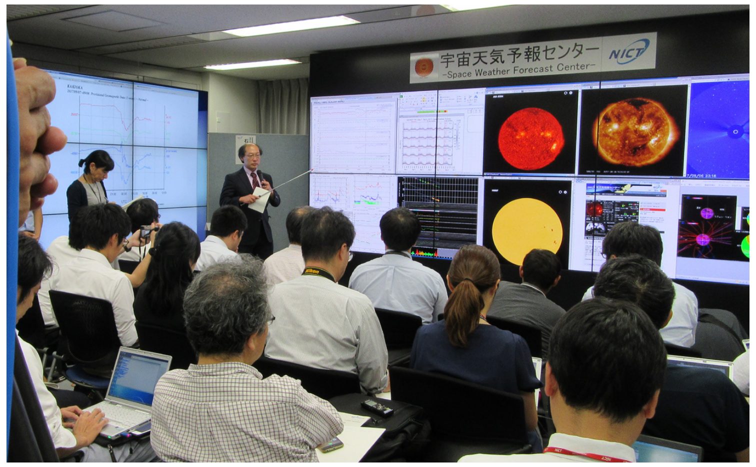

Fig.2 : Solar flare press conference

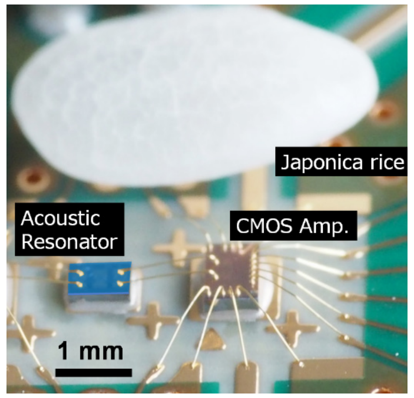

Fig.3 : 3.4 GHz FBAR oscillator for use in chip-scale atomic clocks

R&D of ultra-precise atomic clocks

The transition frequencies of the strontium optical lattice clock and the indium ion clock were accurately measured in NICT, leading to the adoption of these technologies in the Consultative Committee for Time and Frequency at the International Committee for Weights and Measures. The committee was held in June 2016, and we made a large contribution to the revision of recommended frequencies.

Our success in generating a time scale using a strontium lattice clock was published not only in an original paper but also in a press release (Research Highlight p.44).

For chip-scale atomic clocks that we hope will be installed in mobile phones or IoT devices, we have developed a 3.4 GHz oscillator using a film bulk acoustic resonator (FBAR) (Fig.3), resulting in an atomic clock with better short-term frequency stability than commercial products.

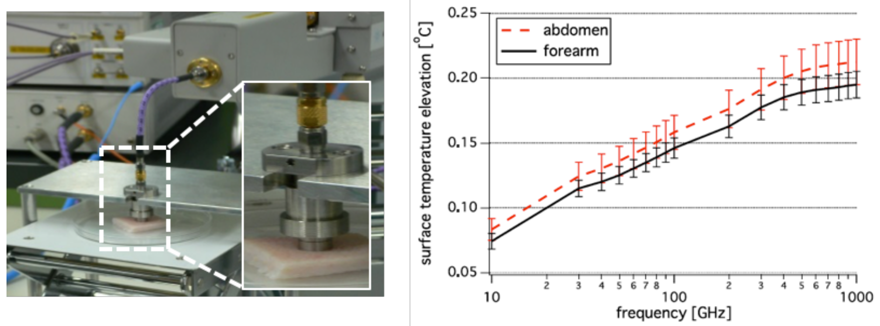

Fig.4 : Measurements of the dielectric constants of biological tissues in the millimeter-wave frequency band (left), and the results of a numerical analysis of the increase in temperature at the surface of the body due to exposure to electromagnetic waves up to the terahertz band (right)

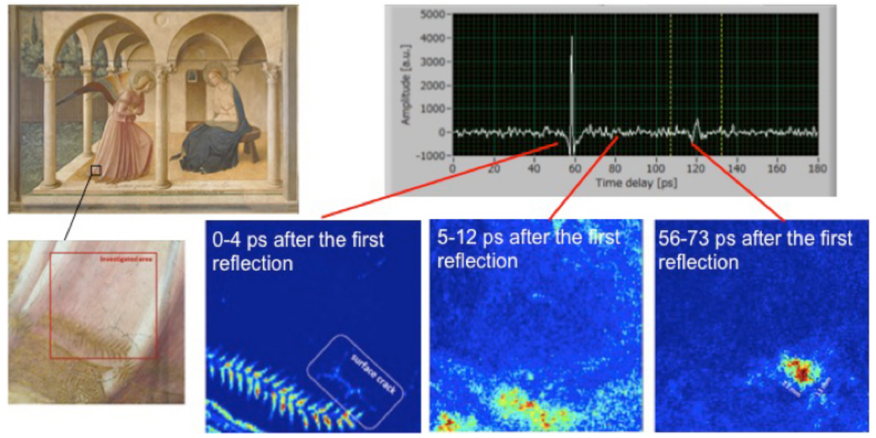

Fig.5: Analysis of the mortar condition beneath The Annunciation — a typical renaissance-era fresco, painted by Fra Angelico

R&D of electromagnetic compatibility (EMC)

Regarding calibration techniques for high-frequency power measuring instruments up to the terahertz band, we have developed a calorimeter for the 220-330 GHz band in collaboration with the National Institute of Advanced Industrial Science and Technology. By establishing the traceability to the national standard and assessing the uncertainty of the results, we started a calibration service from FY2018.

The results of a study that accurately evaluated human exposure based on measurements of the dielectric constants of biological tissues up to the terahertz band was published by the UK Institute of Physics in the journal Physics in Medicine and Biology (Fig.4), and was adopted as the basis of the next revision to the international guidelines on RF safety that the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the IEEE have been developing and will publish in the near future.

Various social advances in electromagnetic wave technology

We are actively involved in various efforts to utilize electromagnetic wave in real society. For example, we are collaborating with a general conductor to develop short-distance positioning technology for the use in construction sites. It is based on wireless two-way time comparison (WiWi) technique. We are also contributing at an international level by working with foreign museums on the use of electromagnetic waves in non-destructive sensing technology for the study of social infrastructure and cultural properties (Fig.5). Furthermore, our wavefront printing technique is expected to be used in various applications such as automotive or in-vehicle display devices, because it enables the fabrication of very complex optical components on a lightweight holographic film.