Open Innovation

Terahertz Technology Research Center

Director General Iwao Hosako

The terahertz band refers to electromagnetic waves at frequencies ranging from roughly 100 GHz to 10 THz (3 mm to 30 μm in wavelength), which lies between so-called radio waves and light waves. Electromagnetic waves in this region have so far been difficult to generate and detect. As a result, the terahertz band remained unused and unexplored. However, due to trends such as the recent growth in demand for high capacity communication between wireless terminals, coupled with the increasing competition for microwave frequency resources that are already in use, there is a rapidly growing need for technology that can exploit new frequencies in the terahertz band. This situation has led to a rapid acceleration in the research and development of devices capable of operating in the terahertz band, as well as advances in basic measurement technology. Researchers are now starting to consider how this frequency band can be used for "active services" involving the generation of terahertz signals. To accelerate this trend, the Terahertz Technology Research Center has leveraged NICT's diverse capabilities in R&D ranging from materials to systemization, and has driven forward with the research and development of cutting edge measurement technology to support the realization of terahertz wireless communication systems with a capacity of the order of 100 Gbit/s. In addition, by working with organizations such as the Terahertz Systems Consortium, we will promote joint studies with industry and academia and take part in discussions about standardization aimed at improving the environment so that the terahertz band can be used effectively (Fig.1).

Core technology for terahertz radio test bed

In FY2007, we examined a method for generating optical frequency comb signals with low phase noise and high purity with the aim of generating terahertz signals with high spectral efficiency. Figure 2 shows an outline of an optoelectronic oscillator incorporating an optical frequency comb oscillator built using this method. By using a highly pure microwave signal produced by self-excitation of an optoelectronic resonator structure to directly generate an optical frequency comb, we have successfully generated an optical frequency comb signal with high frequency stability and a 300 GHz bandwidth.

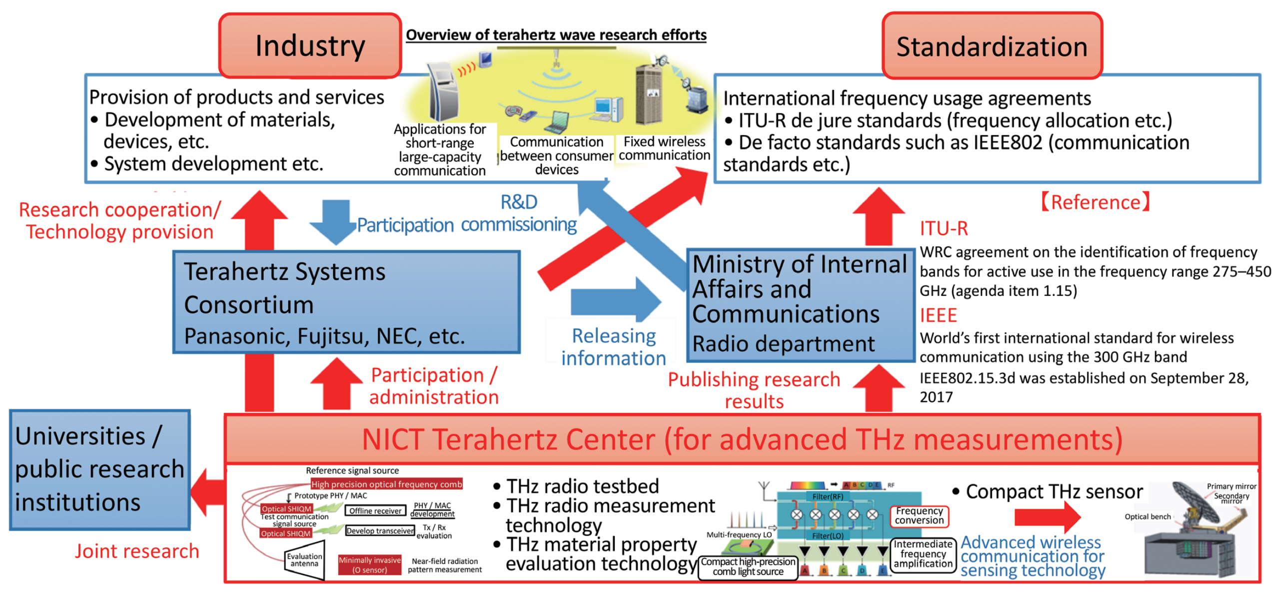

Fig.1 : Overview of the Terahertz Center

Fundamental technologies for terahertz spectrum measurements

In FY2007, we designed, prototyped and evaluated a 400 GHz band mixer that can input frequency bands equally divided by a filter bank and simultaneously downconvert them to an intermediate frequency (IF). By making this mixer's IF band as wide as possible, we were able to reduce the number of filter banks needed to cover the measurement frequency band. By reducing the number of mixers, we ended up with a simpler system. In a conventional mixer, an isolator is used to eliminate the impedance mismatch with the IF amplifier connected to the mixer, but this restricts the IF band. In our study, as shown in Fig.3(a), we integrated a 3–21 GHz band IF amplifier into a 400 GHz band mixer block, and we coupled the mixer chip and a monolithic microwave integrated circuit (MMIC) with a wideband matching circuit. Figure 3 (b) shows the results of measuring how the mixer's noise temperature and gain vary across the IF band, together with the simulated results obtained from an equivalent circuit model. We successfully achieved a bandwidth much broader than the 4–12 GHz band caused by the limitations of conventional isolators, and the device performance also matched the simulated behavior very closely.

International standardization

In WP5A (Land mobile service) and WP5C (Fixed wireless systems), two new reports have been completed on technical operation characteristics and spectrum requirements of LMS and FS systems operating at 275–450 GHz, and these reports have been published as Report ITU-R M.2417-0 and Report ITU-R F.2416-0. In WP3K (Point-to-area propagation), a revision of Recommendation P.1238 has been proposed regarding terrestrial mobile input to 300 GHz band terrestrial mobile application systems. Meanwhile, at an APT preparatory meeting for WRC-19 (APG19-3), an NICT official was put in charge of the DG (drafting group) for agenda item 1.15, and compiled an APT draft provisional opinion on this item.

Furthermore, the IEEE (Institute of Electrical and Electronic Engineers) standardization task group 802.15.3d has been studying the standardization of 300 GHz band short-range WPAN (Wireless Personal Area Network) systems, and Director General Iwao Hosako of the Terahertz Technology Research Center has taken part as vice chairperson of the working group. Due to the strong leadership of the standardization study, the study of this group is way ahead of schedule, and on September 28, 2017, its system specifications received final approval and were published as IEEE std 802.15.3d-2017.

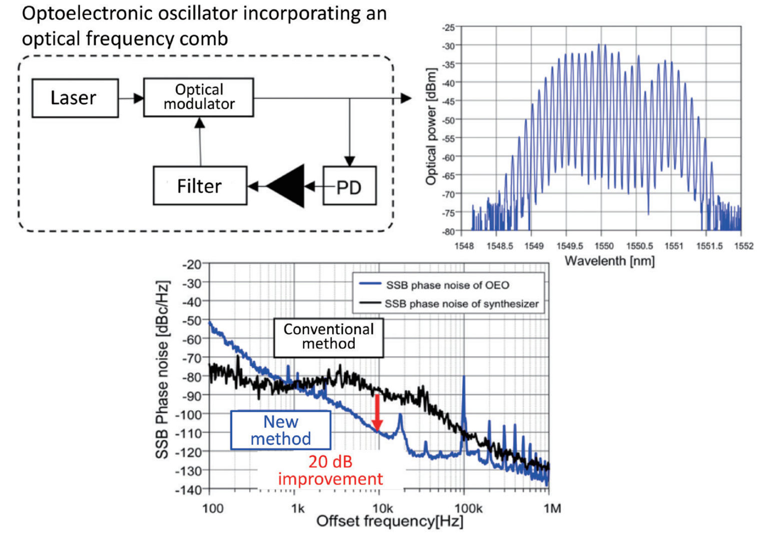

Fig.2 : Improvement of oscillation and phase noise characteristics of an optoelectronic oscillator incorporating an optical frequency comb oscillator

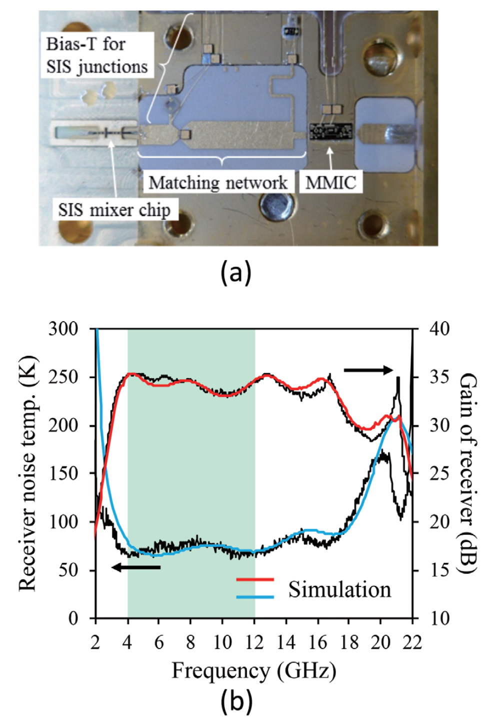

Fig.3 : (a) Photograph of the integrated parts of the mixer chip and IF amplifier, (b) Comparison of simulated and measured noise / gain characteristics