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A1. Time and Frequency Standards and Time Transfer Technique

In Japan, the researches and developments on Time and Frequency (T&F) Standards and Time Transfer Technique are mainly carried out in the National Institute of Information and Communications Technology (NICT) and National Metrology Institute of Japan (NMIJ).

NICT headquarters has been keeping UTC(NICT) and Japan Standard Time (JST). A maximum of eighteen Cs atomic clocks and four hydrogen masers are used for making the timescale. A new JST generation system including various upgrades was completed after four years for development and started operation in February 2006 [Nakagawa et al. 2005, Hanado et al. 2006, 2007]. The timescale algorithm of UTC(NICT) has been investigated by NICT staffs [Hosokawa et al. 2005], and some improvements have been added to suppress the undesirable effects of anomalous clocks.

As for dissemination, two LF radio stations continuously transmit 40kHz and 60kHz respectively of JST time signal and the standard frequency signal. The field strength of LF signals during transmission was theoretically modeled. [Wakai et al. 2005]. To verify this model, two observation cruises on the Southeast Asian line and the North Pacific line using container ships were carried out in 2007. Results of the observation will be submitted to ITU-R WP7A in 2008. Public dial up time service via telephone lines has satisfied a large number of accesses.

NICT has started the accuracy evaluations of TAI unit by the Cs atomic fountain primary frequency standard NICT-CsF1 [Kumagai et al., 2005, 2006a, b, 2007]. Frequency uncertainty of NICT-CsF1 was estimated as 1.9×10^{-15} [CIRCULAR T 221].

NICT has developed an engineering model of space-borne hydrogen maser atomic clock. The weight of the physical part is reduced from 36.5 kg (breadboard model) to 27 kg. [Ito et al. 2007a].

NICT newly developed a Network Time Protocol (NTP) server with high-performance and started a public time service from 2007. The number of access is about <u>fifteen million per day</u> [Toriyama et al. 2007]. A new protocol for high-speed network time transfer has been investigated by using this server [Iwama et al. 2006, 2007].

On-site calibration system for frequency standards at NICT was equipped with a new system and approved by a peer review in 2006. Accordingly measurement uncertainty was improved from 10^{-13} to 5×10^{-14}. NICT has also started a remote calibration system since 2005[Saito et al. 2006].

NICT is regularly performing Two Way Satellite Time and Frequency Transfer (TWSTFT) between Germany (PTB) and Asian T&F institutes (KRISS, TL, NTSC, SPRING, and NMIJ), and calibrated their station delays for TL, KRISS and NMIJ. Obtained data by TWSTFT and GPS are reported to BIPM. The TWSTFT data for NICT/PTB link has been adopted for TAI link since April 2007 in place of GPS data [CIRCULAR T 231]. Researches about GPS carrier phase method and TWSTFT for a long baseline are in progress. NICT is developing a new TWSTFT method using dual Pseudo Random Noises (PRN). NICT and USNO plan to install a new TWSTFT relay station in Hawaii for their link.

To distribute precise frequency by optical fiber, basic experiment using delay control has been started in a lab and a field.

NICT achieved pico-second order precision for two-way time and frequency comparison between the ground clock and the on-board atomic clock on ETS-8 satellite, which has been launched on December 2006. Both code phase and carrier phase showed consistent result and capability to monitor on-board atomic clock.

The time transfer subsystem (TTS) of the engineering model (EM) of the Quasi-Zenith Satellite System (QZSS) passed the environmental test, and the development of its proto-flight model (PFM) has been started. Its ground system is also been developing. The first QZS will be launched in 2010.

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In NMIJ, following researches have been conducted.

Primary Frequency Standards; NMIJ has made the calibration of the International Atomic Time

(TAI) with the Cs atomic fountain frequency standard, NMIJ-F1, a few times per year with a combined uncertainty of 3.9×10^{-15} since September 2005. This uncertainty is larger than that in the preliminary evaluations [Kurosu et al. 2004, Yanagimachi et al. 2005] and is limited by the evaluation uncertainty of a collision shift. We have changed the trapping scheme of atoms from MOT to optical molasses, in order to improve the long term stability. Laser systems, optics, and microwave systems have been upgraded for a better operationality [Yanagimachi et al. 2006]. NMIJ-F1 will be used as a reference oscillator for the evaluation of the optical lattice clocks in NMIJ, the development of our second fountain (NMIJ-F2), as well as used for the TAI contribution. Recently, we have started the construction of NMIJ-F2 to reduce the uncertainty.

Ultra-stable microwave oscillator; NMIJ has developed two cryogenic sapphire oscillators (CSOs) for local oscillator of a Cs atomic fountain and reference signal of a femtosecond mode-locked laser. The CSOs employ a loop oscillator configuration, which is servo controlled by a Pound-type frequency stabilization scheme and a power control servo. These oscillators exhibited a fractional frequency stability of 1.1×10^{-15} at an averaging time of 1 s [Watabe et al. 2006]. For averaging times between 2 s and 640 s the measured oscillator fractional frequency instability was below 10^{-15} with a minimum of 5.5×10^{-16} at an averaging time of 20 s. Also, we have implemented optical frequency synthesis from a CSO using a fiber-based frequency comb. The synthesized optical frequency exhibited an Allan deviation of $\sim 6 \times 10^{-14} \tau^{-1/2}$ for averaging times between 1 s and 100 s and a minimum frequency instability of 3.0×10^{-15} at averaging times of 1280 s by comparing a rubidium two-photon stabilized laser. The short-term frequency stability was limited by the rubidium two-photon stabilized laser [Watabe et al. 2007].

Time Keeping; Four cesium atomic clocks with high-performance beam tubes (Agilent 5071A) and three active hydrogen maser frequency standards are operated for time keeping in NMIJ. One of the hydrogen maser frequency standards has been used for the generation of UTC(NMIJ) since March 2006 to improve the short term stability of UTC(NMIJ).

Time and Frequency Transfer; In NMIJ, dual frequency GPS receiver is one of the main international time and frequency transfer tools. In addition, the Two Way Satellite Time and Frequency Transfer (TWSTFT) have been conducted between NICT and several East Asia institutes using JCSAT-1B and the multi-channel modem. Starting from September 2007, TWSTFT between NMIJ and PTB has been constructed using IS-4 satellite.

GPS data analysis software named GCAST for short base line, such as 50 km, was developed at NMIJ. Its main purpose is the data analysis for the time and frequency transfer between NMIJ in Tsukuba and the University of Tokyo in Tokyo to use for the frequency evaluation of the Sr optical lattice clock developed by the University of Tokyo. GCAST uses the broadcast navigation data and it can provide frequency uncertainty of $1\text{-}2 \times 10^{-15}$ at averaging time of 1 day for 50 km baseline [Fujii et al. 2006, Imae et al. 2007].

An optical fiber bidirectional frequency transfer system using Wavelength Division Multiplexing technology is also studied in NMIJ as future precise time and frequency comparison technique [Amemiya et al. 2006b].

Frequency Calibration Service; NMIJ and related organizations have been conducting to construct remote calibration systems for several metrology areas since 2001. Time and frequency division of NMIJ has been developing a frequency calibration system using GPS common-view method and Internet. NMIJ's remote frequency calibration service has been started since 2006 to the calibration laboratories. NMIJ has also started to develop the user equipment for the end users of the remote frequency calibration service [Imae et al. 2006]. A simple and cost effective frequency dissemination method also has been developed in NMIJ. In this method, optical fiber network service (INS-1500) is used for generating 10 MHz reference signal. Stability test results showed a good performance with an uncertainty of less than 1×10^{-12} at an averaging time of one day [Amemiya et al. 2006a].

Other activities related to Time and Frequency standards; One of other groups in AIST has been focusing its efforts on the development of a remote synchronization system for an onboard crystal oscillator (RESSOX) of the Japanese Quasi-Zenith Satellite System (QZSS). This system can synchronize ground time standard and the onboard crystal oscillator within 10 ns using signal delay models and pseudo-ranges of QZSS positioning signals [Tappero et al., 2006]. Through hardware simulation, AIST has demonstrated that synchronization within a few nanoseconds can be realized [Iwata et al., 2006, 2007].

A2. Laser Stabilization and Frequency Measurement

The researches and developments in Japan on the stabilization of lasers and the optical frequency measurement are also mainly carried out in the National Institute of Information and Communications Technology (NICT) and National Metrology Institute of Japan (NMIJ), together with some very active Universities.

NICT is developing a single Ca+ ion trap optical frequency standard. Matsubara et al. have measured the absolute frequency of the 4s2S1/2 - 3d2D5/2 forbidden transition with the measurement error of +-1.4kHz [Matsubara et al., 2007b]. To observe the a narrow linewidth laser is being developed. Its linewidth is 66 Hz and the floor of the Allan variance is 8.3×10^{-14} at an averaging time of 32 s. The long term frequency drift was 0.5 Hz / s [Li et al., 2007b].

To measure the laser frequency, NICT is developing two optical frequency comb based on commercially available Ti:sapphire laser [Ito et al., 2006, Nagano et al., 2006]. They measure the relative frequency stability between two combs and estimate the stability as 2×10^{-14} and 1×10^{-15} at averaging time of 1 s and 100 s respectively [Ito et al., 2007].

Various time and frequency standards related researches have been conducted in NICT and some Unversities, such as on atomic and molecular physics [Fukuda et al. 2005a, b, 2006, 2004 a, b, Kajita 2005a, b, c, d, 2006a, b, c, d, e, f, Matsubara et al. 2005c, 2006a, b, 2007a, b] and laser frequency stabilization [Li et al. 2005a, b, 2006a, b, 2007a, Matsubara et al. 2005a, b]. Dr. Kajita has proposed an infrared frequency standard based on trapped NH molecule. He estimate the uncertainty of the clock transition can potentially be reduced to lower than 1E-17 [Kajita, 2006].

NMIJ and Katori Group in Tokyou University have obtained the following results.

Activities in optical frequency region; In the optical lattice clock scheme, a collision-shift-free atomic clock was proposed and realized by using a one-dimensional lattice clock with a spin-polarized fermionic isotope [Takamoto et al., 2006]. Katori group and NMIJ have measured the transition frequency for the Sr lattice clock with an uncertainty of 9.8×10^{-15} using an optical frequency comb referenced to the SI second [Takamoto et al., 2006]. In October 2006, the International Committee of Weights and Measures (CIPM) decided to adopt the Sr lattice clock as one of “the secondary representations of the second”.

NMIJ has conducted the following researches on the optical measurements and standards; One is the development of an Yb optical lattice clock [Yasuda et al., 2007]. Vacuum system and laser systems have been prepared. Magneto-optical trapping of cold Yb atoms was realized using an intercombination transition ($^1S_0$ - $^3P_1$; 556 nm). The experiment is under way toward trapping ultracold atoms in the optical lattice. A probe laser to drive the $^1S_0$ - $^3P_0$ transition in Yb atoms, which is stabilized to a high finesse Fabry-Perot etalon, is also being developed. A long-term measurement of optical frequencies has been demonstrated by using a fiber-based frequency comb [Inaba et al., 2006a]. Doppler-free spectroscopy using optical frequency synthesizer has been demonstrated by using a mode-locked Ti:sapphire laser and a continuous-wave optical parametric oscillator [Inaba et al., 2006b].

Prof. Takahashi et al. (Kyoto University) have obseved a Bose-Einstein condensate in a bosonic isotope of ytterbium 170Yb [Fukuhara et al., 2007]. Generation of a BEC in an even isotope of Yb is helpful in optical lattice clock using even isotopes of alkaline-earth-metal-like atoms.

Suzuki et al.(Tohoku University) have developed a ultralow noise and narrow linewidth DFB Er-doped fiber laser. A linwidth of the fiber laser was estimated as 6kHz [Suzuki et al., 2007].

A3. Realization of Electrical Units (DC & LF)

Research works and developments on dc and low frequency electrical standards, that is, standards for dc voltage, dc resistance, ac resistance, capacitance, inductance, ac/dc transfer and so on, are implemented in Electricity and Magnetism division of National Metrology Institute of Japan (NMIJ) and Nanoelectronics Research Institute of Advanced Industrial Science and Technology (AIST). Most of these standards are realized based on Josephson arrays, or Quantum Hall Effect (QHE).

Concerning the research on Josephson arrays, fabrication of 5 V programmable Josephson arrays operated at 10 K has been finished. By connecting two 5 V samples in series, 10 V programmable Josephson voltage standard has been completed. [Shoji, A. et al., 2006-2007].

In order to realize just 10 kohm resistance standard based on the QHE, Quantum Hall Resistance

(QHR) arrays are being developed. Using the series and parallel combination of QHE bars, various values of resistance are expected to be realized. Fabrication of single QHE bars used for QHR arrays has been finished. [Kaneko, N. et al., 2006-2007].

In the development of new device for ac/dc transfer staandard, planner multi-junction thermal converters (PMJTC) are being developed for the use of calibration of ac/dc current differences up to 1 A. A prototype of the PMJTC has been developed. [Fujiki, H., 2006-2007].

Calibration range for both ac resistance standards and inductive voltage dividers has been expanded from 10 ohm to 100 kohm at 1 kHz and 10 kHz [Domae, A. et al., 2005-2007], and the ratios of 0.01 to 1.0 at 200 Hz, 400 Hz, 1 kHz and 10 kHz [Sakamoto, N. et al., 2005-2007], respectively. Standards for loss angle of capacitors have been developed for 10 pF to 10 microF. [Nakamura, Y. et al., 2005-2006].

NMIJ has designated Japan Electric Meters Inspection Corporation (JEMIC) as an institute to be responsible for national standards of power and energy at 45 - 65 Hz. [Nakamura, Y. et al., 2007].

A4. EM field, Power density and antenna Measurement

In the field of precision measurements for EM field, a dipole antenna is a simple linear antenna and it is often used as a reference antenna. Since most of the electromagnetic compatibility/electromagnetic interference (EMC/EMI) measurements are carried out on an open-area test site, the antennas used in the measurement should be calibrated above the ground plane. Several calibration methods for the antenna factor (AF) have been proposed and widely applied by the metrology institutes. However, although a critical quantity sated in their certificate to trace the calibration chain is uncertainty, detailed uncertainty analysis associated their calibration has not been published. Uncertainty analysis strictly following the *GUM* for the three-antenna method and the reference antenna method was published [Morioka, et al. 2006]. The final uncertainty after these two methods is reported 0.7 dB (k=2) in the frequency range from 30 to 1000 MHz. Some EMC procedures require the measurements above 1 GHz. Measurements in an anechoic chamber get common in this frequency range. Since the measurement environment is quasi-free space, the free space AF of the antenna should be calibrated. The three-antenna method is applied and the calibration capability has been achieved to 0.4 dB (k=2) in the frequency range from 1 to 2 GHz.

A continuous antenna factor in a wide frequency range is convenient to be used and such a broad-band antenna as a log-periodic antenna was evaluated for a metrology standard. A new method was proposed for evaluating a free-space antenna factor continuously through a wide frequency band. The method is based on a technique of a time-domain analysis and a pulse-compression technology for reducing the influence by the reflected waves from surrounding obstacles. The method was examined for calculating the free-space antenna factor of a log-periodic antenna widely used for EMI measurement [Kurokawa et al. 2005, 2006].

The developments of calibration techniques for loop antennas were carrying out by AIST and NICT. AIST started to develop the calibration method since 2002. Basically they calibrate the standard loop antenna by the “3-Antenna Method [Ishii et al. 2005]” and the customer’s loop antennas by the “Reference Antenna Method [Ishii et al. 2007a]”. In order to simply calibrate the standard loop antenna, they also studied another new calibration method “Measuring Impedance Method [Ishii et al. 2007b]”. AIST also started a calibration service for small loop antennas whose diameters are about 10 cm and 60 cm in the frequency range from 9 kHz to 30 MHz.

On the other hand, NICT and Tohoku University are developing the loop antenna calibration system. Basically, their method depends on the “Standard Field Method”. It is a novel method, because the system does not need a vacuum thermocouple to measure the current on the antenna element [Nakajima et al. 2005].

A novel optical system was proposed to measure S-parameters in one-path 2-port calibration [Hirose et al 2007a]. This system can completely replace coaxial cables by optical fibers in RF measurements using a vector network analyzer that require many kinds of calibration techniques for the accurate measurements. Using this system, antenna measurements were done blow 2 GHz and proved that the system realizes the dynamic range of 45 dB and the difference within 0.03 at a reflection coefficient compared to the coaxial cable system. This system is especially promising in antenna measurements because it realizes measurements without metallic cables.

A novel method was proposed in antenna measurements [Hirose et al. 2007b]. The method realizes antenna measurements in full 2-port calibration that requires only open-short-load calibration at each port without through calibration because of using the unknown thru algorithm. The residual systematic errors are completely equivalent to the conventional unknown thru method. No need to do through calibration is especially important in antenna measurements because we are released from the hard labor to mate cable connectors directly or to other cable connectors.

A method and a simple equation for determining the magnetic complex antenna factor (M-CAF) of a shielded loop antenna are presented. The investigated shielded loop antenna has two output ports of which outputs are differentially combined in time domain. The low-directivity of this loop antenna is useful for mapping magnetic fields. The proposed method is based on an equivalent circuit of the antenna system. The derived equation makes it possible to determine the M-CAF from the calculated effective length of the loop element and the measured reflection coefficient at an output port. The proposed method is confirmed by comparison between the waveform reconstruction using the M-CAF and the theoretical calculation for an electromagnetic pulse radiated from a monopole antenna on a ground plane. [Kohmura, 2006]

A method and configuration for generating a calculable electromagnetic pulse is proposed in which the electromagnetic pulse is radiated from a small monopole antenna placed near the edge of a semi-infinite ground plane. The monopole antenna is excited by an impulse train. The radiated electric field at a distance from the edge is calculated by the waveform of the excited impulse with the assistance of the Uniform Theory of Diffraction (UTD) to include the effect of diffraction from the edge of the ground plane. The electric field is also reconstructed by signal processing using the complex antenna factor (CAF) of a receiving wide-band antenna. The estimated systematic effects and the agreement of the calculated and reconstructed waveforms show that the generated electromagnetic pulse has a possibility to be used as a reference wave for electromagnetic pulse measurements. [Iwasaki, 2006]

A5. Power, Attenuation and Impedance Measurement

A direct comparison calibration system for WR-15 waveguide RF power sensors (60 GHz) was developed in NMIJ in 2004 to carry out the calibration system of millimeter wave power in addition to a calorie meter system for microwave power. After that, an international peer review and an ISO/IEC 17025 assessment of the quality management system for 2.9 mm coaxial RF power meter calibration in NMIJ were performed, and the quality management system was accredited by an accreditation body(National Institute of Technology and Evaluation) in February 2005. The report of CCEM.RF-S1.CL international comparison of RF power measurement with 2.4 mm connectors, in which NMIJ had participated in, in April 2004, was approved by BIPM in October 2005[2005]. Further, a direct comparison calibration system for 2.4 mm coaxial waveguide RF power sensors (full band) was developed in NMIJ in 2005 in addition to a caloriemeter system to extend the frequency range of calibration service. Besides, the frequency range of the NMIJ WR-15 waveguide calibration system was extended from only a point frequency of 60GHz to full band (from 50 GHz to 75 GHz) in 2006. In addition, a direct comparison calibration system for WR-10 waveguide RF power sensors (W band) was developed in NMIJ in 2006.

A measuring system of the reflection coefficient of reference power source of RF power meters was developed, and the technology was presented in CPEM 2006 in Turin, Italy [Shimaoka et al. 2006a].The result of CCEM.RF-S1.CL international comparison of RF power measurement with 2.4 mm connectors was presented in CPEM 2006 in Turin, Italy [Crowley et al. 2006b]. A new study of an atomic RF power standard started in 2007. This new technology is based on the observation of the Rabi oscillation of the double resonance spectrum of Cs vapor. The absolute RF power in WR-90 waveguide in a frequency of 9.2 GHz is determined by converting the frequency of the Rabi oscillation to the field strength in the waveguide. As a result of a basic experiment, a linear response of the Rabi oscillation frequency to input RF power was observed in 2007. Now, NMIJ is a pilot laboratory of APMP.RF-K8.CL RMO key comparison of RF power measurement with Type N connector. This RMO key comparison is now in preparation.

As for the noise standard, National Meteorology Institute of Japan (NMIJ) has extended a microwave radiometer system for the measurement of noise sources with WR42 waveguide output flanges in the frequency range from 18 GHz to 26.5 GHz. An uncertainty analysis for the thermal noise measurement is applied to the total power radiometer system which is represented by a radiometer equation [Shimada 2006]. NMIJ has been also developing the original cryogenic standard noise source with WR90 waveguide flange by using the sliding short method which is cooled by liquid nitrogen. The estimated value of the noise temperature of the original noise source is good agreement with the noise temperature which is measured by the calibrated radiometer. Uncertainties of the original noise source are being evaluated in detail now.

The development of a new broadband RF attenuation measurement system was begun in 2000 at the NMIJ, to meet the increasingly growing demands for accurate, traceable, and broad-band standards which have a high attenuation range. The system was planned to cover the frequency range of 10 MHz to110 GHz and the attenuation range of greater than 60 dB. The intermediate frequency (IF) substitution method using the inductive voltage divider (IVD) operated at several kHz as a reference standard was selected for the advantageous broadband characteristics. The IVD was adopted for the high accuracy and direct traceability to the national standard for a low-frequency voltage ratio. An attenuation system using the dual channel type of the IF substitution method with the IVD operated at 1 kHz was successfully produced for the frequency range of 10 MHz to 18 GHz. The system is used as a national standard and provides the attenuation calibration to several service systems including Japan Calibration Service System (JCSS). Improvement to the system was carried out to cover the frequency range of 18 GHz to 40 GHz. Higher accuracy as well as the system at the low frequency range was obtained by raising the IF to 10 kHz and employing two seven-decade IVDs in cascade arrangement [Widarta et al, 2007a]. A 10-kHz voltage-ratio standard was also constructed for uncertainty evaluation of the 10-kHz IF section/receiver of the system [Kawakami et al, 2006]. In order to increase the degree of automation in the measurement process, an automated receiver was constructed using a commercial programmable IVD and an originally designed attenuation constant IF phase shifter [Widarta et al, 2007b]. Comparison results on attenuation measurements between the automated and the manual receivers show good agreements. A study on simplifying structure of the system, particularly on the RF circuit which might be built in hollow waveguides, was carried out for implementation to the frequency range of higher than 40 GHz. A single channel type IF substitution method with the IF phase-locked loop was experimentally constructed and examined at 10 GHz [Iida et al, 2006a]. Satisfied enough IF signals for operating the IVD reference standard were obtained, even applying RF signals under the severe conditions. Good performances of the system in the V-band (50 GHz to 75 GHz) were also ensured [Iida et al, 2006b]. Some improvements and uncertainties evaluations to this system are being proceeded now.

In recent years, the development and dissemination of the microwave impedance standards, that are indispensable for the uncertainty evaluations of the power and attenuation standards in the microwave frequency region, is strongly required because of a traceability demand of the vector network analyzer and the input impedance of various test instruments, i.e. EMI receiver, on the basis of various regulations.

In the year 2004, NMIJ has started to develop the evaluation infrastructure for the microwave impedance standards on the basis of air dielectric coaxial standard lines, so-call ‘air line’ [Horibe, 2005a]. For next two years, the evaluation systems of the air lines have been established for the various types of connectors [Horibe et al., 2004, 2005b]. The calibration services of the complex voltage reflection coefficients, in the frequency range of 30 kHz to 18 GHz, have been started for PC7 connector in 2005, and for Type-N50 connector in 2006 [Horibe et al., 2006c, d, 2007a]. These calibration cervices are based on use of the air line as the original impedance standards in the range of 0.5 GHz to 18 GHz, however, the impedance standards are traced to foreign NMI in other frequency regions. Uncertainty less than 0.0059 for PC7 connector and 0.0069 for Type-N50 connectors were achieved by using the air lines. Furthermore, the calibration services of the characteristic impedance derived from the dimensional measurements were started for the air line with PC7 connector in order to meet the industry’s needs in the traceability issue on the vector network analyzer and impedance analyzers [Horibe et al., 2005c]. In the year 2006, the three coordinate measuring machine (CMM) was additionally installed and evaluated for the accurate measurement of the air line’s length as the phase standards [Horibe et al., 2006a, 2007b]. These activities made enhancing the NMIJ’s evaluation capability of the air line with various connector types, i.e. PC14, PC7, Type-N50, Type-N75, PC3.5, PC2.92, PC2.4, PC1.85 and PC1.0 (up to 110 GHz). In 2006, the calibration services of the complex voltage reflection coefficients for PC3.5 connector, in the frequency range of 30 kHz to 33 GHz, have been started in 2006. Subsequently, in 2007, the scattering parameter (S-parameter) standards have been established for PC3.5 connectors in the frequency range of 0.1 GHz to 33 GHz [Horibe et al., 2007a].

References

CIRCULAR T 207 ISSN 1143-1393 2005

CIRCULAR T 208 ISSN 1143-1393 2005

CIRCULAR T 218 ISSN 1143-1393 2006

CIRCULAR T 221 ISSN 1143-1393 2006

CIRCULAR T 236 ISSN 1143-1393 2007

Amemiya M., M. Imae, Y. Fujii, T. Suzuyama, S. Ohshima, S. Aoyagi, Y. Takigawa, and M. Kihara [2006b], "Time and frequency transfer and dissemination methods using optical fiber network", IEEJ Trans. FM, Vol.126, No.6, pp.458-463.

Amemiya M., M. Imae, Y. Fujii, T. Suzuyama, S. Ohshima, and M. Susumu [2006a], "Simple time and frequency dissemination method using optical fiber network" ATF (Asia-Pacific Workshop on Time and Frequency) 2006,New Delhi, pp. 98-105.

Crowley, T. P., Miall J., de Vreede J. P. M., Furrer J., Michaud A., Dressler E., Zhang T., Shimaoka K. Kim J. H., Metrologia[2005], “CCEM.RF-S1.CL (GTRF/02-03): RF power measurements with 2.4 mm connectors,” 2006, 43, Tech. Suppl., 01007.

Crowley, T. P., Miall J., de Vreede J. P. M., Furrer J., Michaud A., Dressler E., Zhang T., Shimaoka K. Kim J. H [2006b], “Supplementary comparison of RF power measurements using 2.4 mm connectors, CCEM.RF-S1.CL,” Conference digest CPEM 2006, pp. 194-195.

Fujii Y., M. Imae [2006], "Development of the Precise Time Transfer Software Analyzing GPS Carrier Phase with Common-View Method", ATF (Asia-Pacific Workshop on Time and Frequency) 2006.

Fujiki, H., “Extention of AC-DC transfer standards from 1 V dowen to 10 mV at NMIJ”, Conference on Precision Electromagnetic Measurements Digest, pp. 206-207, 2006.

Fujiki, H., “New thin-film multijunction thermal converter design for improved high-frequency performance”, IEEE SENSORS JOURNAL, vol. 7, no. 9 & 10, pp. 1243-1247, 2007.

Fukuda, K., H. Toriyama, A. Ch. Izmailov, M. Tachikawa, [2005a], "Dark resonance of Cs atoms velocity-selected in a thin cell," Applied Physics B-Lasers and Optics, vol.80, no.4-5, pp.503-509.

Fukuda, K., A. Toriyama, A.Ch. Izmailov, M. Tachikawa, [2005b] "EIT Resonance of Cs Atoms in a Thin Cell," ICOLS05.

Fukuda, K., A.Ch. Izmailov, M. Tachikawa, [2006] "Dark resonance of Cs atoms in a thin cell," Workshop on Chip Scale Atomic Clock: status and potentiality NICT,IEEJ.

Fukuhara, T., S. Sugawa and Y. Takahashi, [2007], "Bose-Einstein condensation of an ytterbium isotope", Phys. Rev. A 76, 051604(R)

Hirose, M., S. Kurokawa, K. Komiyama [2007a], “Antenna Measurements by One-path Two-port Calibration Using Radio-on-fiber Extended Port Without Power Supply”, IEEE Trans. Instrum. Meas., vol. 56, no. 2, pp.397-400.

Hirose,. M., and K. Komiyama [2007b], “Novel Method for Antenna Measurements Using SOL Without T Calibration”, IEEE APS. Int. Sympo. Digest, pp. 605-608.

Horibe,Masahiro., Masaaki Shida, and Koji Komiyama, [2004], Development of RF & microwave impedance standards - Low loss measurements for transmission lines -, Papers of Technical Meeting on Instrumentation and Measurement, IEE Japan, vol. IM-04, No. 56-62, pp.1-5 (in Japanese)

Horibe,Masahiro., [2005a], A survey of RF & microwave impedance standards, AIST Bulletin of Metrology, vol.3, no.4, pp.625-632 (in Japanese)

Horibe,Masahiro., Masaaki Shida, and Koji Komiyama, [2005b], Development of Metrological Impedance Standards of Coaxial Lines in the Frequency Range of RF and Microwave : Development and Evaluation of PC-7 Airline Standards, The Institute of Electronics, Information and Communication Engineers, MW2005-34, vol.105, No.151, pp. 9-14 (in Japanese)

Horibe,Masahiro., Masaaki Shida, and Koji Komiyama, [2005c], Calibration Services of Metrological High-Frequency Impedance Standards and Evaluation of Residual Error in Vector Network Analyzer, The Institute of Electronics, Information and Communication Engineers, MW2005-90, vol.105, No.368, pp. 25-30 (in Japanese)

Horibe,Masahiro., Masaaki Shida, and Koji Komiyama, [2006a], Development of Metrological Impedance Standards with PC3.5 connectors in the Frequency Range of RF and Microwave, Papers of Technical Meeting on Instrumentation and Measurement, IEE Japan, vol.IM-06, No.67-70, pp.13-18 (in Japanese)

Horibe,Masahiro., Masaaki Shida, and Koji Komiyama, [2006b], Dissemination of National Metrology Standard of Scattering parameter with PC3.5 connectors, Papers of Technical Meeting on Instrumentation and Measurement, IEE Japan, vol.IM-07, No.22-28, pp.21-26 (in Japanese)

Horibe,Masahiro., Masaaki Shida, and Koji Komiyama, [2006c], Assessing the Repeatability of RF and Microwave Connectors in High-Frequency Precision Measurements, ICEC2006 Digests, pp.203-208

Horibe,Masahiro., Masaaki Shida, and Koji Komiyama, [2006d], S-PARAMETES OF STANDARD AIRLINES WHOSE CONNECTOR IS TIGHTENED WITH SPECIFIED TORQUE, CPEM2006 Digests,pp.280-281

Horibe,Masahiro., Masaaki Shida, and Koji Komiyama, [2007a], S-PARAMETES OF STANDARD AIRLINES WHOSE CONNECTOR IS TIGHTENED WITH SPECIFIED TORQUE,IEEE Trans on Instru. and Meas., 56-2, pp.401-405, 2007/04

Horibe,Masahiro.,[2007b], Research and Development to Promote the Creation and Utilization of an Intellectual Infrastructure. Research and Development of the impedance standards in the frequency range of microwave and milliwave (FY2006) Final Report, New Energy and Industrial Technology Development Organization (in Japanese)

Iida, H., A. Widarta, T. Kawakami and K. Komiyama [2006a], “An accurate microwave attenuation measurement system using an inductive voltage divider based on a single-channel IF substitution method,” Meas. Sci. Technol., vol.17, pp.1947-1949

Iida, H., A. Widarta, T. Kawakami and K. Komiyama [2006b] “Attenuation measurement system using inductive voltage divider in the frequency range of 50 GHz to 75 GHz,” 2006 CPEM Digest, Tha3_7, pp.668-669

Imae M., Y. Fujii, T. Suzuyama, and M. Amemiya [2006], "Development of a frequency traceability system using GPS common-view method for general users", ATF (Asia-Pacific Workshop on Time and Frequency) 2006.

Imae M., Y. Fujiia, F. L. Hong, M. Takamotob, R. Higashi, and H. Katori [2007], " Precise time and frequency transfer link used for the uncertainty evaluation of Sr. optical lattice clock", Proc. SPIE Vol. 6673, 66730G-1-G-10.

Inaba H., T. Ikegami, F. L. Hong, Y. Bitou, A. Onae, T. R. Schibli, K. Minoshima, and H. Matsumoto [2006], "Doppler-free spectroscopy using a continuous-wave optical frequency synthesizer," Applied Optics, vol. 45, pp. 4910-4915.

Inaba H., Y. Daimon, F. L. Hong, A. Onae, K. Minoshima, T. R. Schibli, H. Matsumoto, M. Hirano, T. Okuno, M. Onishi, and M. Nakazawa [2006], "Long-term measurement of optical frequencies using a simple, robust and low-noise fiber based frequency comb," Optics Express, vol. 14, pp. 5223-5231.

Ishii, M., M. Hirose, K. Komiyama [2005], “Measurement of magnetic antenna factor of shielded loop antenna by 3-antenna method”, Proc. ISAP2005, Seoul, pp. 281-284.

Ishii, M., and Y. Shimada [2007a], “A Reference Antenna Method for Small Circular Loop Antennas in Low Frequency Band”, Proc. the Society Conference of IEICE, B-4-38.

Ishii, M., and K. Komiyama [2007b], “Impedance Method for a Shielded Standard Loop Antenna”, IEEE Trans. Instrum. and Meas., vol. 56, no. 2, pp. 422-425.

Ito, H., S. Nagano, Y. Li, K. Matsubara, M. Hosokawa, [2006], "Development of optical frequency standards in NICT," 11th European Conference on Networks & Optical Communications, pp.314-321.

Ito, H., S.Nagano, Y.Li and M.Hosokawa, [2007b], "Development of optical frequency combs at NICT", Asia-Pacific Metrology Programme (APMP) Meetings, 2007

Ito, H., T. Morikawa, S. Hama, M. Takizawa, Y. Numata, S. Mattori, [2007a], "Development and performance evaluation of spaceborne hydrogen maser atomic clock in NICT," ION NTM 2007, pp.1-3.

Iwasaki, T., H. Nakata, L. Hamada, "Generation Method of a Calculable Electromagnetic Pulse and its Evaluation," IEEJ, Transaction on Fundamentals and Materials, Vol. 126, No. 6, pp. 420-425, (2006.6)

Iwata T., M. Imae, T. Suzuyama, H. Murakami, Y. Kawasaki, N. Takasaki, A. Iwasaki, F. Tappero and A. Dempster [2006], "Simulation and Ground Experiments of Remote Synchronization System for Onboard Crystal Oscillator of Quasi-Zenith Satellite," Navigation, Vol. 53, No. 4, pp. 231-235.

Iwata T., Y. Kawasaki, M. Imae, T. Suzuyama, T. Matsuzawa, S. Fukushima, Y. Hashibe, N. Takasaki, K. Kokubu, A. Iwasaki, F. Tappero and A. Dempster [2007], "Remote Synchronization System of Quasi-Zenith Satellites Using Multiple Positioning Signals for Feedback Control," Navigation, Vol. 54, No. 2, pp. 99-108.

Kajita, M. A.V. Avdeenkov, [2006f], "Manipulations of collisions of cold polar molecules," ICAP2006.

Kajita, M., A.V. Avdeenkov, [2005d], "Ultracold collisions of polar molecules: thresholds effects," CLEO 2005, no.EF4-3-WED.

Kajita, M., A.V. Avdeenkov, [2006c], "Collisions between linear polar molecules trapped in a microwave field," Euro. Phys. J. D, vol.41, pp.499-504.

Kajita, M., A.V. Avdeenkov, [2006e], "Collisions between trapped polar molecules," International Seminar on Progress and Excitement in AMO Physics.

Kajita, M., Y. Li, K. Matsubara, K. Hayasaka, M. Hosokawa, [2005a], "Optical frequency standard with 43Ca+ ion," URSI.

Kajita, M., Y. Li, K. Matsubara, K. Hayasaka, M. Hosokawa, [2005b], "Prospect of optical frequency standard based on a 43Ca+ ion," Phys. Rev. A, vol.72, no.43404, pp.1-7.

Kajita, M., Y. Li, K. Matsubara, K. Hayasaka, M. Hosokawa, [2006d], "Shift estimation of the 43Ca+ S-D transition frequency," EFTF2006, pp308-310.

Kajita, M., Y. Li, K. Matsubara, M. Hosokawa, K. Hayasaka, [2005c], "Analysis aiming the optical frequency standard with 43Ca+ ion," CLEO 2005, no.EE-2-TUE.

Kajita, M., [2006a], "Collision between magnetically trapped NH molecules in the (N=0,J=1) state," Phys. Rev. A, vol.74, no.032710, pp.1-9.

Kajita, M., [2006b], "Loss estimation of electrostatically trapped ND3 molecules," Euro. Phys. J. D, vol.38, pp.315-322.

Kaneko, N., Urano, C., Itatani, T., Kiryu, S., " DEVELOPMENT OF A 10 k ohm QUANTUM HALL ARRAY RESISTANCE STANDARD", Conference on Precision Electromagnetic Measurements Digest, 2006.

Kaneko, N., " DEVELOPMENT OF A VOLTAGE DIVIDER BASED ON QUANTIZED HALL RESISTANCE ARRAYS FOR A HIGH DC VOLTAGE STANDARD", Conference on Precision Electromagnetic Measurements Digest, 2006.

Kawakami, T., A. Widarta, H. Iida and K. Komiyama [2006], "Voltage ratio system constructed for RF attenuation standard -Working standard for control of attenuation calibrator-," AIST Bulletin of Metrology, vol. 5, no.2, pp.111-123

Kohmura, A and T. Iwasaki "Determination of Magnetic Complex Antenna Factor of Double-Output Shielded Loop Antenna Using an Equivalent Circuit," IEEJ, Transaction on Fundamentals and Materials, Vol. 126, No. 6, pp. 414-419, (2006.6)

Kumagai, M., H. Ito, M. Kajita, M. Hosokawa, [2005] "New CesiumAtomic Fountain Frequency Standard at NICT," EFTF 2005.

Kumagai, M., H. Ito, M. Kajita, M. Hosokawa, [2006a] "NICT's operational atomic fountain NICT-CsF1," ATF2006, pp.77-83.

Kumagai, M., H. Ito, M. Kajita, M. Hosokawa, [2006b], "Evaluation of atomic fountain NICT-CsF1," CPEM-2006, no.Th_P46.

Kumagai, M., H. Ito, M. Kajita, M. Hosokawa, [2007], "Recent Results of NICT Caesium Atomic Fountains," IEEE-FCS 2007, pp.602-606.

Kurokawa, S., M. Hirose, K. Komiyama [2005], “Experimental study of self-calibration method for Log-periodic antenna”, Proceedings of ISAP2005, pp.285-288.

Kurokawa, S., M. Hirose, K. Komiyama,[2006], “Time-domain Three Antenna Method for Evaluation of Antenna factors of Log-periodic Antenna”, Proceedings of the 37th EuMC, pp.94-97.

Kurosu T., Y.Fukuyama, Y.Koga, and K.Abe [2004], "Preliminary evaluation of the Cs atomic fountain frequency standard at NMIJ/AIST," IEEE Trans. Instrum. Meas. 53, pp. 466-471.

Li, Y., H. Ito, K. Matsubara, K. Fukuda, M. Kajita, M. Hosokawa, [2005a], "Frequency stable and tunable diode laser system for the S-D transition of Ca+ ion, " CPT2005, Vol.08, no.P-33, pp.145-146.

Li, Y., H. Ito, K. Matsubara, M. Kajita, K. Fukuda, M. Hosokawa, [2005b], "Development of clock laser for the S-D Transition of Ca+ Ion, " CLEO 2005, no.EE-6-TUE.

Li, Y., H. Ito, K. Matsubara, M. Kajita, K. Fukuda, M. Hosokawa, [2006b], "A Clock Laser for the Optical frequency Standard of Ca+ ion, " ICAP2006.

Li, Y., H. Ito, K. Matsubara, M. Kajita, S. Nagano, M. Hosokawa, [2007a], "Development of a clock laser system of Ca+ ions for the optical frequency standards in NICT," CPT2007 pp.81-82.

Li, Y., K. Matsubara, H. Ito, S. Nagano, M. Kajita, K. Fukuda, M. Hosokawa, [2006a], "Development of a single calcium ion optical frequency standard in NICT," ATF2006, pp.1-8.

Li, Y., S. Nagano, H. Ito, K. Matsubara, M. Kajita, M. Hosokawa, [2007b], "Development of a Clock Laser of Ca+ Ion for the Optical Frequency Standards," CLEO/QELS/ 2007.

Matsubara, K., S. Hama, K. Imamura, Y. Koyama, H. Toriyama, and M. Hosokawa, [2007b], "Update of Research Activities on Time and Frequency at the National Institute of Information and Communications Technology (NICT)," 38th PTTI, pp.17-24.

Matsubara, K., S. Uetake, H. Ito, Y. Li, K. Hayasaka, M. Hosokawa, [2005a], "Frequency stabilization of diode lasers by scanning transfer cavities for laser cooling of Ca+ ions," CPT2005, vol.08, no.P-32, pp.143-144.

Matsubara, K., S. Uetake, H. Ito, Y. Li, K. Hayasaka, M. Hosokawa, [2005b], "Precise Frequency-Drift Measurement of Extended-Cavity Diode Laser Stabilized with Scanning Transfer Cavity," Jpn. J. Appl. Phys. vol.44, no.1A, pp.229-230.

Matsubara, K., T. Ido, M. Hosokawa, [2006a], "Recent Progress in Optical Frequency Standards," MAPAN, vol.21, no.4, pp.201-211.

Matsubara, K., Y. Li, K. Fukuda, H. Ito, S. Nagano, M. Kajita, K. Hayasaka, S. Urabe, M. Hosokawa, [2006b], "Quadrapole Transition Spectrum Measurement of Single Ca+ Ions Toward Optical Frequency Standards," 38th PTTI, pp.123-135.

Matsubara, K., Y. Li, K. Fukuda, S. Nagano, K. Hayasaka, M. Hosokawa, [2007a], "Quadrupole Transition Spectrum of Single Ca+ Ions for Optical Frequency Standards," CPT2007, pp.111-112.

Matsubara, K., Y. Li, M. Kajita, K. Hayasaka, S. Urabe, M. Hosokawa, [2005c], "Single Ca+ ion trapping toward precise frequency measurement of the 4 2S1/2 - 3 2D5/2 Transition," The joint conference between the Frequency Control Symposium and the Precise Time and Time Interval Systems Applications Meeting, pp.616-622.

Morioka, T., and K. Komiyama [2006], “Uncertainty analysis of dipole antenna calibration above a ground plane," IEEE Trans. Electromagn. Comat., vol. 48, no. 4, pp.781-791.

Murayama, Y., Urano, C., Iwasa, A., Yamamori, H., Shoji, A., Ishizaki, M., "Comparison between a 1-V NbN-based Programmable and a Conventional SIS Josephson Array", Jpn. J. Appl. Phys., vol. 46, no. 12, pp. 7912-7915, 2007.

Nagano, S., H. Ito, Y. Li, K. Matsubara, M. Hosokawa, [2006], "Development of femtosecond optical frequency combs for optical frequency standards in NICT," SPIE Optcs East 2006, vol.6389, no.63890J, pp.1-12.

Nakajima, Y., K. Fujii, A. Sugiura, Y. Matsumoto, Y. Yamanaka [2005], "Experimental Tests of Calculable Loop Antennas for Loop Antenna Calibration", Proc. the Society Conference of IEICE, B-4-68.

Nakamura, Y., Yonenaga, A., Sakamoto, N., Shimoyama, A., "Remote Calibration of Standard Inductors", IEEJ Trans. FM, vol. 126, no. 11, pp. 1183-1186, 2006.

Shimada, Y [2006], "Uncertainty analysis of radio-frequency noise standard", AIST Bulletin of Metrology, vol.5, no.2, pp.105-110

Shimaoka, K., M. Shida, K. Komiyama[2006a], "Source Reflection Coefficient Measurements of the power reference of power meters," Conference digest CPEM 2006, pp. 664-665.

Suzuki, A., Y. Takahashi., M. Yoshida. M. Nakazawa, [2007], "An Ultralow Noise and Narrow Linewidth lambda/4-Shifted DFB Er-Doped Fiber Laser With a Ring Cavity Configuration", Photonics Tech. Lett. IEEE, Vol. 19, Issue: 19, pp. 1463-1465

Takamoto M., F.-L. Hong, R. Higashi, Y. Fujii, M. Imae and H. Katori[2006], "Improved Frequency Measurement of a One-Dimensional Optical Lattice Clock with a Spin-Polarized Fermionic ^87Sr Isotope," J. Phys. Soc. Jpn 75, 104302.

Takamoto, M., F.-L. Hong, R. Higashi, Y. Fujii, M. Imae and H. Katori, [2006], "Improved Frequency Measurement of a One-Dimensional Optical Lattice Clock with a Spin-Polarized Fermionic ^87Sr Isotope", J. Phys. Soc. Japan Vol. 75 No. 10, 2006, pp. 104302-104312

Tappero F., A. Dempster, T. Iwata, M. Imae, T. Ikegami, Y. Fukuyama, K. Hagimoto and A. Iwasaki [2006], "Proposal for a Novel Remote Synchronization System for the On-Board Crystal Oscillator of the Quasi-Zenith Satellite System," Navigation, Vol. 53, No. 4, pp. 219-229.

Urano, C., Murayama, Y., Iwasa, A., Shoji, A., Yamamori, H., Ishizaki, M., "A Precise Evaluation of NbN-Based 1-V Programmable Josephson Voltage Standard Arrays", IEEE Trans. Instrum. and Meas., vol. 54, no. 2, pp. 645-648, 2005.

Urano,N., Kaneko, N., Maezawa, M., Saito, K., Itatani, T., Gorwadkar, S., Maeda, J., Kiryu, S., "PROGRESS ON THE DEVELOPMENT OF ABITRARY WAVEFORM SYNTHESIZER AT AIST", Conference on Precision Electromagnetic Measurements Digest, pp. 390-391, 2006.

Urano,N., Kaneko, N., Maezawa, M., Saito, K., Itatani, T., Gorwadkar, S., Maeda, J., Kiryu, S., " OBSERVATION OF QUANTIZED VOLTAGE STEPS USING A JOSEPHSON JUNCTIONARRAY DRIVEN BY OPTOELECTRONICALLY GENERATED PULSES ", IEEE Trans. Instrum. and Meas., vol. 56, no. 2, pp. 614-616, 2007.

Urano,N., Kaneko, Oe, T., N., Maezawa, M., Saito, K., Itatani, T., Gorwadkar, S., Maeda, J., Kiryu, S., " Operation of Josephson Junctions with Current Pulses Generated by Triggering A Cold Photo Detector with An Optical Comb ", IEEE Transaction on Applied Superconductivity, vol. 17, no. 2, pp.

870-873, 2007.

Urano,N.,Kaneko, Oe, T., N., Maezawa, M., Saito, K., Itatani, T., Gorwadkar, S., Maeda, J., Kiryu, S., “Generation of constant voltage steps by a Josephson array driven by optoelectronically generated pulses”, Physica C, vol. 463-465 , pp. 1123-1126, 2007.

Watabe K., H. Inaba, K. Okumura, F.-L. Hong, J. G. Hartnett, C. R. Locke, G. Santarelli, S. Yanagimachi, K. Minoshima, T. Ikegami, A. Onae, S. Ohshima, and H. Matsumoto [2007], "Optical frequency synthesis from a cryogenic sapphire oscillator using a fiber-based frequency comb," IEEE Trans. Instrum. Meas., vol. 56, no. 2, pp. 632-636.

Watabe K., J. G. Hartnett, C. R. Locke, G. Santarelli, S. Yanagimachi, T. Shimazaki, T. Ikegami, and S. Ohshima [2006], "Short term frequency stability tests of two cryogenic sapphire oscillators," Jpn. J. Appl. Phys., vol. 45, no. 12, pp. 9234-9237.

Yamada, T., Sakamoto, N., Nakamura, Y., “DEVELOPMENT OF 100 V/ 50 HZ INDUCTIVE VOLTAGE DIVIDERS FOR AC POWER STANDARD AT NMIJ”, Conference on Precision Electromagnetic Measurements Digest, pp. 80-81, 2006.

Yanagimachi S., K. Watabe, K. Hagimoto, A. Kubota, T. Ikegami, and S. Ohshima [2006], "Recent Status of an atomic fountain frequency standard NMIJ-F1", CPEM2006 Digest, pp. 588-589

Yanagimachi S., Y.Fukuyama, T.Ikegami, and T.Kurosu [2006], "Numerical Simulation of Distributed Cavity Phase Shift in an Atomic Fountain Frequency Standard", Jpn.J. Appl.Phys. 44, pp. 1468-1475.

Yasuda, M., F. -L. Hong, T. Kohno, H. Inaba, K. Hosaka, C. Willis, T. Kurosu, A. Onae, S. Ohshima [2007], "Present status of the development of an Yb optical lattice clock at NMIJ/AIST", in Time and Frequency Metrology, edited by R. Jason Jones, Proceedings of SPIE, Vol. 6673(SPIE, Bellingham, WA, 2007) 6673-12.

Yonenaga, A., Nakamura, Y., “Inductance Scaling System Using an LCR Meter and Two Inductive Voltage Dividers ”, Conference on Precision Electromagnetic Measurements Digest, pp. 526-527, 2006.

Widarta, A., H. Iida and T. Kawakami [2007a], “Attenuation-measurement system in the frequency range of 18-40 GHz,” IEEE Trans. on IM, vol.56, no.2, pp.641-645

Widarta, A., H. Iida and T. Kawakami [2007b], “An automated 1-kHz null-balance receiver for precision RF and microwave attenuation measurements and standards,” 69th ARFTG Conference Digest