COMMISSION E: ELECTROMAGNETIC NOISE AND INTERFERE

Edited by Osamu Fujiwara

Man Made EM Noise and EMC

E.1 2004 International Symposium on EMC, Sendai

EMC'04/Sendai was organized by Prof. A. Sugiura, Tohoku University, and was held with great success at the Sendai International Center, Sendai, from June 1st to 4th, 2004. This is the fifth EMC Symposium in Japan, because they have been held every five years since 1984. More than 500 people attended from 20 countries including Japan, and about 250 technical papers were presented at the Symposium. The Risaburo Sato Award was newly established as the best paper award and granted to Prof. Osamu Fujiwara's group.

E.2 EMC measurement technology

The studies of EMI antenna and electromagnetic field probe calibration method, electromagnetic field probe using electro-optical crystal, EMI suppression effect by ferrite core, measurement method of lightning surge, evaluation method of RF absorber reflectivity in millimeter wavelength, etc, have been performed in this period. Detail descriptions are presented below.

E2-1 Antenna factor of EMI measuring antennas

Traditionally, radio disturbances emitted from electronic equipment have been measured with an EMI antenna, where the disturbance level is expressed in terms of the electrical field strength. In practical measurements, it is given by multiplying the received voltage by the antenna factor of a measuring antenna used. However, the antenna factor may vary in magnitude with the antenna height above a ground plane due to the ground reflection. Hence, to improve the measurement uncertainty, the CISPR (International Special Committee on Radio Interference) has recently decided to use the free-space value of the antenna factor for EMI measurements.

In this connection, three antenna calibration methods have newly been developed to provide the free-space antenna factor accurately:

(1) Antenna Impedance Method requires measurements of the input impedance of an antenna under calibration in the frequency range from 30 MHz up to 10 GHz. It was found that this method could yield the free-space antenna factor with an uncertainty of about 0.5 dB or less [Tsushima, et al., 2004].

(2) In addition, application of the non-linear least squares method has been investigated for the

conventional EMI antenna calibration, such as Standard Antenna Method, in the frequency range from 30 MHz to 300 MHz. This method was found to determine the free-space antenna factor with an uncertainty better thaan 0.3 dB [Fujii, et al., 2003].

(3) To produce a nearly free-space environment, the theoretical and experimental investigations were made on the use of ferrite tiles placed on the metal ground plane. It was found that the ferrite absorbers could considerably suppress the ground reflection and yield the free-space antenna factor with an error less than 0.3 dB at frequencies from 30 to 300 MHz [Matsumoto, et al., 2003].

E2-2 Calibration of electromagnetic probe

In order to calibrate an electromagnetic probe up to 18 GHz, a method using open-ended waveguides has been proposed as the standard radiators in the frequency range from 500 MHz to 18 GHz [Ishigami, et al., 2002, 2003a]. A calibration facility was established with an anechoic chamber. The uncertainty of the facility was evaluated as ±0.96 dB (500 MHz-8.2 GHz) and ±1.14 dB (above 8.2 GHz) at the confidence coefficient of 95%, respectively. A TEM cell is also used for the calibration below 500MHz. The uncertainty of the facility was evaluated as ±0.74 dB at a confidence coefficient of 95%

E2-3 Electric field probe using optical electric crystal

A magnetic and electric field probe using LiNbO3 as the optical electric crystal was presented at EMC'04 Sendai [Suzuki, et al., 2004]. The electric field probe with a 2.46 mm long dipole element could operate up to 10GHz and it was effective to measure the electric field distribution on the printed circuit board (PCB). The magnetic field probe with a square loop (4.5 mm × 4.5 mm aperture) could operate up to 5 GHz and it was effective to measure the current distribution on the PCB.

E2-4 Measurements of EMI suppression characteristics of ferrite cores

A major source of the electromagnetic interference in the frequency range below 1000 MHz is disturbance currents flowing on the cables connected to an electronic device. Hence, in order to reduce the currents, ferrite cores are usually attached to encircle the cables. However, there is no standard method for measuring the EMI suppression characteristics of the core. Hence, Prof. Sugiura's group has studied and developed a measurement method for the insertion loss and the reflection coefficients of a ferrite core [Fujii, et al., 2004].

E2-5 Compact lightning wave recorder

Malfunctions caused by lightning surges are serious problems for telecommunications equipment used for developed information technology. Lightning surge waveform observation has been carried

out to characterize the surges appearing at the telecommunication ports. However, large equipment was needed to observe the waveform. Recent developed semiconductor technology succeeds the miniaturization of waveform recorder [Honma, et al., 2004]. The size of the developed recorder is 94 mm wide, 150 mm long, and 55 mm thick, and the weight is 530 g. The dynamic range is more than 60 dB, and the recording length is 32 ms. One can operate two or more recorders simultaneously using the external trigger. It is expected to apply the study of the lightning surges inducing mechanism at AC mains and telecommunication port of the equipment.

E2-6 Evaluation of reflectivity measurement methods for millimeter wave absorber

The methods of reflectivity measurement of millimeter wave absorbers are being evaluated by round robin test with various measurement settings, to clarify preferable conditions (distance, absorber size, antenna type, etc.) and measurement procedures.

E. 3 Printed circuit board (PCB) and chip level EMC

The studies of simulation of undesired noise form PCB, EMI simulation, EMC design, EMC modeling, Design tools, etc, have been performed in this period. Detail descriptions are presented below.

E3-1 Simulation of undesired noise form PCB

In order to explain the undesired electromagnetic radiation from PCB, modeling of three-dimensional FDTD simulation and experiment are being performed in Prof. Inoue's laboratory [Kayano, et al., 2002, 2004a, 2004b, 2004c; Tanaka, et al., 2004]. It was reported that not only the common mode current dependence but also spatial radiation distribution near the tested sample should be investigated precisely. Moreover, undesired electromagnetic radiation near PCB with attached feed cable was also investigated by experiment and FDTD simulation. Structure differences of the cross section of tested PCB were found to affect the electromagnetic radiation. Comparison between 3-dimentional FDTD simulation and experiment showed good agreement. It was also reported that the special structure with guard band enables one to reduce low common mode current and EM radiation. In addition, undesired electromagnetic radiation from microstrip line on PCB with attached feed cable was studied by the experiment and FDTD simulation. It was suggested that the differential mode current should be took into account for the undesired electromagnetic radiation at higher frequencies.

E3-2 EMI Simulation and EMC design of PCB

Problems to control irelectromagnetic noise radiated from digital electronic devices have been pursued in Prof. Koga's group. A concise electromagnetic model of the power-bus in a multi-layer

PCB has been developed utilizing a cavity-mode model together with the segmentation method. Practical speed was enhanced by 400 times than traditional methods, which is useful as a powerful tool in designing PCBs in terms of turn-around time and scale of computation. Models of electric and magnetic coupling on gaped power bus structures and effects of via inductance on split power/ground planes were also investigated. A method to evaluate common-mode excitation on PCBs was demonstrated with practical PCBs having guard traces. The evaluation model is called "imbalance difference model". Accuracy of the models has been experimentally examined.

E3-3 Modeling of EMC characteristics of digital IC/LSI

The objectives of the EMC modeling of digital circuits are extended to LSIs as noise driving sources, and linear macro-models of LSIs, called LECCS models, have been developed in Prof. Koga's group. Simulation performance of a model for core logic circuits, LECCS-core, and a model for drivers, LECCS-I/O, were presented at "EMC Compo 2004" and "EMC'04/Sendai". The LECCS-core model is quite similar to the model ICEM which was proposed by French research group, and collaboration to establish an unified standard model for EMC simulation has been started.

E3-4 New design tool for PCBs

Problems to control irradiative electromagnetic noise from digital electronic devices have been pursued [Kasuga, et al., 2002, 2003a, 2003b]. A concise equivalent circuit models have been developed, which is useful as a powerful tool in designing printed circuit boards in terms of turn-around time and scale of computation. Practical speed was enhanced by 400 times than traditional methods. Accuracy of the models has been experimentally examined and objectives of the models are extended to LSI levels as well as PCB. Results will help designers of electronic devices who are always expedited in developing their products.

E. 4 EMC problem related telecommunication system

The studies of telecommunication system using UTP cables, evaluation method of telecommunication system using APD (Amplitude Probability Density), interference caused by microwave oven, EMC evaluation method of UWB system, EMC problems caused by PLC, interference from PCs having dithered clock systems, disturbance for the radio system in LF band, etc, have been performed in this period. Detail descriptions are presented below.

E4-1 APD analysis

Two different methods, called RMS-AVG (Root Mean Square-Average) and APD, currently discussed in CISPR as a disturbance measurement method to evaluate the degradation of the digital wireless communication systems, were compared by numerical simulations [Gotoh, et al., 2005].

Repetition pulse and Gaussian noise were added as disturbances to the DQPSK (Differential Quadrature Phase Shift Keying) coded signal at the transmission path. The disturbance effects on BER (Bit Error Rate) and on each reading by the two methods were obtained quantitatively. The comparison shows that both methods account for the disturbance effect on a digital wireless communication system.

E4-2 Interference caused by microwave oven noises

Leakage of EM waves from microwave ovens may cause unwanted interference to wireless LAN systems using the 2.4-GHz band. Hence, investigations have been carried out to develop a numerical model of the oven noise in Prof. Sugiura's group. An FM-AM model was produced for the noise, and it has been employed to evaluate degradation in the transmission quality of the LAN systems interfered with the oven noises [Matsumoto, 2003]. Moreover, to investigate the impact of oven noises on the wireless systems, a useful numerical model of the oven noise was developed. Performance degradation of wireless systems (DS-SS WLAN and Bluetooth) caused by the oven noises was evaluated theoretically and experimentally. The use of adaptive filters was proposed for reducing the microwave oven interference in DS-SS WLAN systems [Nakatsuka, 2004].

E4-3 UWB (Ultra wide-Band) system

A waveform reconstruction method of the electric field emitted by UWB (ultra wideband) device by using the complex antenna factor and observed waveform with an oscilloscope was developed [Ishigami, et al., 2004a, 2005]. The waveform radiated by a transmitting antenna and an impulse generator was measured with an oscilloscope and was reconstructed by the method. The results showed that the reconstructed waveform using this method agreed well with the waveform evaluated from the output of the impulse generator. The peak power measurement using a resolution bandwidth of 50MHz specified in the document of Federal Communications Commission (FCC) part 15 was examined. If the impulse bandwidth of a spectrum analyzer has been measured, the peak power can be obtained using the conversion method described in FCC Part 15.

E4-4 Interference from PCs having dithered clock systems

Operating frequencies of the clock signals of personal computers (PCs) currently reach several GHz. Such devices radiate electromagnetic noise over a wide frequency range, which may cause interference to wireless systems. Measurements were carried out to investigate the characteristics of radiated PC noises in WLAN frequency bands (2.4 GHz and 5GHz). It was found that the harmonics of the base clock signal dominate the radiated noises from PCs, and that the harmonics were frequency modulated due to the intentional sweep (dithering) of the fundamental clock frequency. The impact of PC noises on an OFDM-based WLAN system was evaluated with numerical

simulations [Ogata, 2004].

E4-5 EMC problem related PLC system

The increase speed of power line communications may affect existing communication system. The studies were performed about the influences to the communication system and the characteristics of the indoor power line system. The EMC problems of the high-speed telecommunication system using unshielded twisted pare (UTP) cables were also studied for the emission from UTP cables and the countermeasure method. The problem related to power line communications was presented in EMC'04 Sendai in June 2004 [Shimoduma, et al., 2004]. The studies were performed about the influence to the VDSL system of the induction and the relations between the longitudinal conversion loss (LCL) of the cable and the radiated electromagnetic field.

E4-6 Transmission characteristics on AC mains line

High speed power line communication (PLC) system has been developed to use for indoor communication system. The transmission characteristics and the influences to the electromagnetic environment should be studied because PLC system uses the AC mains line system, which has not been designed to use for a high speed signal transmission. AC mains line with a ground plane was presented using four-port networks to calculate both differential and common mode impedances [Miyoshi, et al., 2005]. The radiated magnetic field was calculated from the common-mode current distribution. The results indicate that the deviation between calculated and measured value was improved to calculate the capacitances between conductors and between conductor and ground using a numerical method.

E4-7 Investigation of disturbance for LF band

40kHz and 60 kHz are used to transmit the Japan Standard Time signal. The electric field strength of the 60 kHz transmitted signal and the disturbances in the frequency range from 40kHz to 60 kHz were investigated [Nakai, et al., 2005]. The results indicated that the field strength of the transmitted signal decreases in proportion with the increase of the distance, and there are many disturbance sources in this frequency range.

E. 5 EMC test facilities

The studies of test methods using rotating electromagnetic fields, correlation between GTEM cells and anechoic chambers, evaluation methods of reverberation chamber, etc, have been performed in this period. Detail descriptions are presented below.

E5-1 Immunity/susceptibility test method

In order to clarify immunity/susceptibility characteristics against radio-frequency electromagnetic fields, a new test method of using electromagnetic fields two-dimensionally rotating at a very low rate was proposed by Prof. Kami's group, which demonstrated the characteristics depicted in visualized three-dimensional map [Murano, 2004a, 2004b, 2004c; Kami, 2004]. They also applied the method to a four-septum TEM cell [Suganuma, et al., 2004].

E5-2 GTEM Cell

A GTEM (gigahertz transverse electromagnetic) cell is used for immunity and emission tests. The correlation between the immunity-test result in a GTEM cell and that in an anechoic chamber was examined theoretically [Ishigami, et al., 2001, 2003b]. The average electric fields of the EUT surfaces in a GTEM cell and an anechoic chamber were calculated using the FD-TD method in order to evaluate a suitable installation and size of EUT in the GTEM cell. When the size of EUT was 10%, 20%, or 30% of the septum height, the difference in both the test result of the GTEM cell and the anechoic chamber was expected to be about 1dB, 2dB, or 2-3dB, respectively. Moreover, when the EUT surface approached the septum and floor conductor, the difference increased.

E5-3 Reverberation chamber

In using a reverberation chamber for radiated immunity testing, it is important to determine the number of discrete steps through which the stirrer rotates and the number of probe locations for a given test volume in the chamber. This is because they affect the uniformity and calibration of the field in the test volume. An experimental evaluation was made for the effect of the numbers of stirrers and their steps on the field uniformity, and the effect of the number of probe locations on field calibration. It was confirmed that (1) it was possible to obtain sufficient uniformity in the field by using two stirrers; (2) uniformity was not improved greatly by using more than 100 stirrer steps; and (3) the use of a small number of probe locations increased the uncertainty in the evaluation of uniformity [Harima and Yamanaka, 2001; Harima, 2004].

E.6 ESD and system level EMC

The studies of evaluation method of system level EMC, geospace environment simulator, meta -material type RF absorber, etc, have been performed in this period. Detail descriptions are presented below.

E6-1 Equivalent circuit model for human ESD

A circuit approach for calculating the discharge current through a hand-held metal piece from a charged human body has been proposed by Prof. Fujiwara's group. It has been demonstrated that the current waveforms can be predicted from the time variant

spark resistance and measured frequency characteristics of the human body impedance [Fujiwara, et al., 2001a, 2003a].

E6-2 ESD contact ad air discharge measurement

Measurement was made by Prof. Fujiwara's group for the discharge currents injected onto the Pellegrini target for the contact air discharge of a commercially available ESD-gun with respect to its approaching speed to the target. It was found that the fast approach of the ESD gun provides a sharp current with a steeper rise-time and a higher peak, while the slow approach gives a gentle current with the shorter rise-time but lower peak compared to the case for the contact discharge. It was also found that there exists a specific relationship between the rise-time and the peak current normalized to the charge voltage regardless of the approaching speed of the ESD gun [Fujiwara, et al., 2001b, Fujiwara, et al., 2004].

E6-3 FDTD simulation of contact discharge by an ESD-Gun

The electromagnetic noise caused by an electrostatic discharge (ESD) is a major source of malfunction to high-tech equipment. The ESD testing, therefore, is being specified in the IEC61000-4-2, which prescribes the current waveform from an ESD gun through a IEC recommended current detector (Pellegrini calibration target). This IEC current waveform, however, does not always correspond to the one injected onto an actual device for ESD testing. Prof. Fujiwara's group simulated a contact discharge to ground plates using our previously developed FDTD model of an ESD gun. The induced voltages through a magnetic field probe were simulated when the discharge current was injected directly to the ground plate in contact with an ESD gun, whose results were confirmed with respect to the ground plate sizes experimentally [Fujiwara, et al., 2002, 2003b].

E6-4 Safety evaluation for stochastically varying electromagnetic fields

The cumulative amplitude probability distributions (APD) of leaked electric fields in fusion experimental facilities were measured and an approach to derive their time-average from the measured APD was proposed [Wang, et.al., 2004]. The statistically averaged electric field showed fair agreement with the time-averaged electric field during 6 minutes being specified in the safety guidelines. This finding suggested the usefulness of the APD measurement in lieu of the field measurement during a 6-minute period because the APD can be obtained for a time period much less than 6 minutes.

E6-5 Geospace environment simulator

In order to make quantitative evaluation of electromagnetic environment around spacecraft, three

dimensional electromagnetic particle simulations are being performed using 125 nodes (2 TB Memory) of the Earth Simulator System, reporting various physical processes induced by emission of heavy ions in electric propulsion.

E6-6 Application of meta-material to EM wave absorber and shielding material

Meta-material is the material which can control the dielectric constant and the magnetic permeability. At the special condition, the real part of the dielectric constant and the magnetic permeability are negative. This phenomenon makes the flexibility of a design for EM-absorber and shielding material [Hatakeyama, et al., 2004].

Natural EM Noise

E.7 Lightning

Study in Prof. Kawasaki's group

Thunderstorms observed by TRMM/PR and LIS have been investigated, and Lightning Research Group of Osaka University (LRGOU) has unveiled several interesting features.

Correlation between lightning activities and the snow depth of convective clouds may follow the power-five law. The power five law means that the flash density is a function of the snow-depth to power five. The definition of snow depth is the height of detectable cloud tops by TRMM/PR from the climatological freezing level, and it may be equivalent to the length of the portion where the solid phase precipitation particles exist. This is given by examining more than one million convective clouds, and we conclude that the power five law should be universal from the aspect of the statistic.

Three thunderstorm active areas are well known as "Three World Chimneys", and those are the Central Africa, Amazon of the South America, and South East Asia. Thunderstorm activities in these areas are expected to contribute to the distribution of thermal energy around the equator to middle latitude regions. Moreover thunderstorm activity in the tropical region is believed to be related with the average temperature of our planet earth. That is why long term monitoring of lightning activity is required. After launching TRMM we have accumulated seven-year LIS observations, and statistics for three world chimneys are obtained. We have recognized the additional lightning active area, and that is around the Maracaibo lake in Venezuera. We conclude that this is because of geographical features of the Maracaibo lake and the continuous easterly trade wind.

Lightning Activity during El Nino period is another interesting subject. LRGOU studies thunderstorm occurrences over west Indonesia and south China, and investigates the influence of El Nino on lightning . We compare the statistics between El Nino and non El Nino periods. We learn that the lightning activity during El Nino period is higher than non El Nino period instead of less precipitation on the ground during El Nino period. Since we expect the strong correlation between

precipitation and lightning activity, the results seem to be against the conventional common sense. However analyzed results for these two areas show no contradictions, or we can say that the results are exactly same from the aspect of statistics. The meteorological comprehension is still remained.

Lightning Research Group of Osaka University (LRGOU) has been working for a novel technique of VHF Broadband Digital Interferometer (BDITF) to monitor thunderstorm activity and to image lightning channels for these ten years. The VHF BDITF has been improved to be a quasi operating system, and LRGOU has equipped the BDITF in Korea, in Australia and at four sites near central Japan. LRGOU controls these BDITFs through internet, and conducts remote and continuous monitoring of lightning activity.

The BDITF antenna is capacitive, which bandwidth is from 25 to 100 MHz including amplifier, and its shape is circular with about 30 cm diameter. The BDITF consists of three antennas, and these antennas are deployed at three apexes of an isosceles right triangle. The length of two sides around the right angle is between 5 to 10 meters, because the antenna spacing is not necessary to be fixed to some required length. These two sides are normally set up to direct to north-to-south and east-to-west. Once we have a lightning flash, a few thousands of VHF impulses are emitted, and the BDITF can detect VHF impulses within about 50 km. The scheme to estimate source location of VHF impulses is based on the Fourier analysis. Received VHF impulses are decomposed into Fourier components by FFT (Fast Fourier Transform). Phase differences for all Fourier components between two antennas output are calculated to estimate the incident angles against the base line of two antennas. Since one unit of BDITF consists of three antennas, two dimensional source locations, azimuth and elevation, can be observed. If we install two sets of BDITF with proper spacing, we are able to have 3-D image of lightning channels.

BDITF observations during winter thunderstorm seasons have been carried out around Mikuni and Kanazawa. Three dimensional images of lightning progressions are observed around Mikuni. The propagation velocity of the negative breakdown is estimated, and it is in the order of ten to power five meters per second. This value is nearly the same of the velocity formally observed by the optical streak camera. The lightning channels with branching are captured, and we learn the excellent capability of BDITF. Possible positively charged region is visualized by detecting negative breakdown during continuing current. The observations around Kanazawa for winter thunderstorms are still ongoing.

An electric filed change and VHF/UHF radiation associated with positive cloud-to-ground (CG) flashes during winter in Japan has been observed, and it can be noticed that the intensity of VHF/UHF radiation increases immediately after a return stroke occurrence. It is well known that VHF/UHF radiation intensity by a negative CG decreases during and after a return stroke, and the strong VHF/UHF emission after the return stroke is believed be peculiar to the positive CG. VHF/UHF radiation due to negative CG flashes is emitted from a tip of leader progression, and a

lightning channel imaging is available by VHF/UHF interferometer observations. In case of a positive CG, channel imaging of a VHF/UHF interferometer is not available. To interpret the discrepancy of VHF/UHF source mapping between negative and positive CGs, a theory of "Bi-directional Leader Concept" is introduced. That means VHF/UHF radiation associated with a negative breakdown can be observed for both positive and negative CG, and for a negative CG that is the leader progression tip, and for positive CG that is possible positive charge regions. From this aspect, the location of VHF/UHF radiation source for positive CG mapped by interferometers may be equivalent to the location of positive charge distribution inside thunderclouds. In other words we are able to see the charge distribution by the interferometer. The 3D mapping for positive CG obtained during winter thunderstorm in Japan by means of VHF/UHF interferometer frequently gives a very large volume of source distribution, and its horizontal extension occasionally exceeds ten kilometers. The most possible altitude of the distribution of VHF/UHF source location is equivalent to or slightly lower than the altitude of -10 degree Celsius. The sources are superimposed on the radar cross section, and it is noticed that sources are rather located in a stratified region instead of a convective region. Though it has been believed that the thundercloud during winter in Japan might be small size because of weak convection, our observations by VHF/UHF interferometer are against the conventional understanding. We have occasionally experienced the MCS like thunderclouds even in winter. The total amount of charge is estimated to be a few hundred Coulombs, and it is supposed that thunderclouds, which cause positive CG during winter in Japan, should be a possible parent thundercloud.

Study in Prof. Hayakawa's group:

The fractal dynamics of intracloud microdischarges responsible for the formation of a so-called drainage system of electric charge transport inside a cloud volume has been discussed. Mesospheric optical emissions (sprites) for the winter lightning were successfully observed in the Hokuriku area, and the associated phenomena (ionospheric perturbations (Trimpis), ELF sferics) were also discussed. The Schumann resonance observation was started again in 1996 at Moshiri, Hokkaido in order to monitor the global warning. The Schumann resonance data there have been used in order to study the correlation of Schumann resonance intensity and ground temperature.

E.8 Seismo electromagnetics

(1) The presence of ULF electromagnetic emissions before large earthquakes has been noticed by means of different signal analysis methods (including polarization, fractal methods, and principal component analysis etc.). Another important method for short-term earthquake prediction is the use of subionospheric VLF/LF propagation. A case study for the Tokachi-oki earthquake and statistical study on the correlation of the VLF anomaly with different geophysical parameters (geomagnetic activity, particle precipitation) and seismic effect have been performed. The full-wave computation

has been made for explaining the shift in the terminator time due to the presence of seismo-ionospheric perturbations .
(2)The French micro satellite for seismo-electromagnetics "DEMETER" has been launched on June 29, 2004. DEMETER is a project of low altitude microsatellite that mainly aim the study of electromagnetic signals generated by seismic or volcanic events. The data around Japan are registered in the special mode, therefore new findings for physical mechanisms on seismo-electromagnetics are expected in simultaneous measurements on the ground and onboard.
(3) The prediction of earthquake with ELF electromagnetic waves has been developed. New method for detect of precursory phenomena using Schumann resonance on “Kii” peninsula earthquakes and on “Chuetsu” earthquakes in Niigata is being analyzed.
(4) The study on the earthquake prediction using the VAN method and ULF geomagnetic, and geopotential measurement at Izu, Iwate, Matsusiro, and Taiwan have been conducted. The main attention was paid to new signal analysis.
(5) Broadband spectral observations have been conducted in the VHF band regularly in Chiba, Japan to investigate any natural radiation and/or anomaly of propagation of broadcasting waves. It has been found that distant oversea TV broadcasting waves can sometimes propagate to the observatory. The propagation of these TV waves has been classified and those mechanisms have been investigated. A possibility of natural radiations associated with earthquakes by receiving broadband white noise has been presented.
(6) A network of seismogenic ULF emissions in the Kanto area, and a nation-wide network of VLF/LF subionospheric wave have been established in order to find the seismic effect onto the ionosphere for short-term earthquake prediction.
(7) The precursors of the earthquake related to ELF electromagnetic wave below 50Hz has been investigated. Schumann resonance was observed at Nakatsugawa, and VLF transmitters (NWC, 19.8kHz and JG2AS, 40kHz) wave observed at Kasugai.

References

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Fujii, K., S. Harada, T. Umeda, Y. Matsumoto, and A. Sugiura [2003], "Estimation of the Free-Space Antenna Factors Using a Nonlinear Least-Squares Method," Proc. of the In-ternational Conference on Electromagnetics in Advanced Applications (ICEAA'03), pp. 259-262, Sep. 8-12, Torino, Italy.

Fujii, K., Y. Dowaki, Y. Jito, Y. Matsumoto, and A. Sugiura [2004], "Insertion Loss Measure-ment of EMI Suppression Ferrite Cores," International Symposium on EMC, Jun. 1-4, Sendai, Japan, 3C3-2, pp. 641-644.

Fujiwara, O., and T. Ikawa [2001a], “Numerical calculation of human-body capacitance by surface charge method (in Japanese),” Trans. IEICE, vol.J84-B, no.10, pp.1841-1847.

Fujiwara, O., M. Funato, H. Seko [2001b], “Level estimation of magnetic far-field generated by spark discharge between charged metal spheres (in Japanese),” Trans. IEE of Japan, vol.121-C, no.12, pp.1813-1818.

Fujiwara, O., H. Seko, Y. Yamanaka [2002], “FDTD computation of electromagnetic fields due to electrostatic discharge using a spark resistance formula (in Japanese),” Trans. IEICE, Vol.J85-B, No.9, pp.1644-1651.

Fujiwara, O., H. Tanaka, Y. Yamanaka [2003a], “An equivalent circuit modeling of discharge current injected in contact with an ESD-gun (in Japanese),” Trans. IEE of Japan, vol.123-A, no.8, pp.784-789.

Fujiwara, O., X. Zhang, Y. Yamanaka [2003b], “FDTD simulation of electrostatic discharge current by ESD testing (in Japanese),” Trans. IEICE, Vol.J86-B, No.11, pp.2390-2396.

Fujiwara. O., I. Mori, S. Ishigami and Y. Yamanaka [2004], "Calculation of magnetic near-field generated by the contact discharge of an ESD-gun", IEEJ Trans. FM, Vol. 124, No.9, pp. 763-768.

Gotoh, K., Y. Matsumoto, T. Shinozuka, and Y. Yamanaka [2005], “Comparison of the disturbance measurements between APD method and RMS-AVG method”, 2005 General Conference of IEICE, B-4-83 (In Japanese).

Harima, K. and Y. Yamanaka [2001], “Evaluation of electric-field uniformity in a reverberation chamber for radiated immunity testing”, IEICE Transactions on Communications, Vol.E84-B, No.9, pp. 2618-2621.

Harima, K. [2004], “Statistical Characteristics of Maximum E-Field Distribution in a Reverberation Chamber,” 2004 IEEE International Symposium on Electromagnetic Compatibility, pp. 724-727, Santa Clara, USA.

Hatakeyama, K., T. Tsutaoka, and K. Fujimoto [2004], “Application of meta-material to EM wave absorbing/shielding materials, ” 2004 IEICE society conference, BS-1-4, Tokushima, (In Japanese).

Honma, Y., S. Chikai, S. Kuramoto, and Y. Tada [2004], “Development of compact and high-resolution lightning wave recorder, ” 2004 IEICE society conference, B-4-63, Tokushima, (In Japanese).

Ishigami, S., K. Harima, and Y. Yamanaka [2001], “TEM-mode E-field uniformity in a GTEM cell”, IEICE Transactions on Communications, Vol.E84-B, No.9, pp. 2610-2617.

Ishigami., S., H. Masuzawa, I. Nishiyama, T. Shinozuka, and Y. Yamanaka [2002], “EM probe calibration by using open-ended waveguides, Part.1”, Technical Report of IEICE, EMCJ2002-50, pp.49-54 (In Japanese).

Ishigami, S., H. Masuzawa, I. Nishiyama, T. Shinozuka, and Y. Yamanaka [2003a], “EM probe calibration by using open-ended waveguides, Part.2”, 2003 General Conference of IEICE, SB-2-7 (In Japanese)

Ishigami, S., K. Harima, and Y. Yamanaka [2003b], “Theoretical evaluation of condition of EUT installation on a GTEM cell on immunity testing”, IEICE Transactions on Communications, Vol.J86-B, No.7, pp. 1183-1190 (In Japanese).

Ishigami, S., and Y. Yamanaka [2004a], “Reconstruction of electric-field waveform radiated from UWB device by using the complex antenna factor”, 2004 International Symposium on Electromagnetic Compatibility, Sendai (EMC'04 SENDAI), 2C4-5, pp.41-44.

Ishigami, S., and Y. Yamanaka [2004b], “Time-domain measurement of electric field emitted from UWB device within an arbitrary bandwidth by using the complex antenna factor”, EUROEM 2004 (Euro Electromagnetics), UWB11-3, pp.166-167.

Ishigami, S., K. Gotoh, Y. Matsumoto, and Y. Yamanaka [2004c], “Time-domain measurement of UWB radiation power by using the complex antenna factor”, Technical Report of IEICE, EMCJ2004-68, pp.75-80 (In Japanese).

Ishigami, S., K. Gotoh, and Y. Matsumoto [2005], “Influence of pulse-repetition frequency in peak power measurement of UWB signals”, 2005 General Conference of IEICE, A-5-22, p.138 (In Japanese).

Kami, Y., F. Xiao, K. Murano, and M. Tayarani [2004], “Radiated immunity/susceptibility test method using slowly rotating electromagnetic wave,” Proc. International Symposium on EMC, Sendai.

Kasuga, T., M. Tanaka and H. Inoue [2002], “Estimation on magnetic near field noise from PCB by FDTD implemented non-linear switching transistor”, Proc. of IEEE 2002 EMC Sympo., Minneapolis, pp.727-732.

Kasuga, T., and H. Inoue [2003a],“Estimation for wideband electromagnetic field distribution from printed circuit board with switching transistor”, IEICE Trans. Electron., Vol.E86-C, No.6, pp.995-1001.

Kasuga, T., M. Tanaka, and H. Inoue [2003b],“Estimation of spatial distribution of wideband electromagnetic noise around printed circuit board”, IEICE Trans. Commun., Vol.E86-B, No.7, pp.2154-2161.

Kayano, Y., M. Tanaka, J.L. Drewniak and H. Inoue [2002], ”Common-mode current due to a trace on a PCB with a guard-band –experiment and FDTD modeling-”, International Conference on Electronics Packaging (ICEP).

Kayano, Y., M. Tanaka, J.L.Drewniak and H. Inoue [2004a], “Common-mode current due to a trace near a PCB edge and its suppression by a guard band”, IEEE Trans. on Electromagnetic Compatibility, Vol.46, No.1, pp.46-53.

Kayano, Y., M. Tanaka and H. Inoue [2004b], “A study on common-mode current on a feed cable attached to a PCB with different cross sectional structures”, Proc. International Symposium on Electromagnetic Compatibility, EMC2004/Sendai, Vol.1, pp.1-4.

Kayano, Y., M. Tanaka and H. Inoue [2004c], “Identifying the frequency response of common-mode current on a cable attached to a PCB”, IEICE Trans. Electronics, Vol.E87-C, No.8, pp.1268-1276.

Matsumoto, Y., T. Umeda, A. Nishikata, K. Fujii, Y Yamanaka, and A. Sugiura [2003], "EMI Antenna Calibration on an Absorber-Lined Ground Plane to Determine Free-Space An-tenna Factor," IEEE Trans. on EMC, vol.45, no,4, pp656-660, 2003.

Matsumoto, Y., M. Takeuchi, K. Fujii, A. Sugiura, and Y. Yamanaka [2004], "A Time-Domain

Microwave Oven Noise Model for the 2.4 GHz Band," IEEE Trans. on EMC, vol.45, no.3, pp561-566, 2003.

Miyoshi, K., N. Kuwabara, Y. Akiyama, and H. Yamane [2005], “Calculation of radiated magnetic field from indoor AC mains cable using four-port network,” IEICE technical report, EMCJ2004-123, pp.37-42, (In Japanese).

Murano, K., T. Sanpei, F. Xiao, C.Wang, Y. Kami, and J. L. Drewniak [2004a], “Susceptibility characteristics of a cavity with an aperture by using slowly rotating EM fields: FDTD analysis and measurement,” IEEE Trans. Electromagnetic Compatibility, vol. 46, no. 2, pp.169-177.

Murano, K., F. Xiao, Y. Kami [2004b], “An immunity/susceptibility test method using electromagnetic wave of rotating polarization,” IEEE Trans. Instrumentation and Measurement, vol. 53, no. 4, pp.1184-1191.

Murano, K., F. Xiao, M. Tayarani and Y. Kami [2004c], “3D-susceptibility evaluation of actual housings of electronic equipment using rotating EM fields,” Proc. 2004 IEEE International Symposium on EMC, Santa Clara.

Nakai, R., Y. Shimoshio, H. Abe, K. Someya, A. Mikami, M. Higashi, and Y. Yamashita [2005], “Characteristics of low frequency signals, which are emitted from home electric appliance measured by a small loop antenna for radio wave clocks,” IEICE technical report, EMCJ2004-121, pp.25-30, (In Japanese).

Nakatsuka, M., Y. Matsumoto, K. Fujii, and A. Sugiura [2004], "Reduction Microwave Oven Interference in DS-SS WLAN Systems Using Adaptive Filters," International Sympo-sium on EMC, D02, vol. 1, pp. 229-233, Sep. 6-10, Eindhoven, The Netherlands.

Ogata, A., Y. Matsumoto, K. Fujii, and A. Sugiura [2004], "Measurement of Disturbances Radiated from Personal Computers in the WLAN Frequency Band," 2004 Asia-Pacific Radio Science Conference(AP-RASC'04), S2-07, pp. 508-509, Aug. 24-27, Qingdao.

Shimoduma, Y., A. K. M. Mahbub Ar Rashid, N. Kuwabara, Y. Akiyama, and H. Yamane [2004], “A study of PLC signal influence on VDSL system by induction between indoor power line and telecommunication line,”, IEMC’04 Sendai, 4C3-1, pp. 837-840, Sendai.

Suganuma, Y., F. Xiao, K. Murano, M. Tayarani, and Y. Kami [2004], “Four-septum TEM cell for immunity/susceptibility test rotating EM field,” Proc. International Symposium on EMC, Sendai.

Suzuki, E., S. Arakawa, H. Ota, K. Arai, and R. Sato [2004], “Double-loaded EO magnetic field probe working above 10 GHz,”, Proc. EMC’04 Sendai, IC4-3, pp. 153-156, Sendai.

Tanaka, M., Y. Kayano, J.L. Drewniak and H. Inoue [2004],“Common-mode current due to trace and slit in ground plane and effect of guard band”, Proc. International Symposium on Electromagnetic Compatibility, EMC2004/Sendai, Vol.1, pp.221-224.

Tsushima, S., K. Fujii, A. Sugiura, Y. Matsumoto, and Y. Yamanaka [2004], "Determination of the Antenna Factor of Microwave Antennas Using the Antenna Impedance Measure-ment," 2004 Asia-Pacific Radio Science Conference(AP-RASC'04), S2-06, pp. 506-507, Aug. 24-27, Qingdao.

Wang, J., O. Fujiwara and T. Uda [2004], “Statistical measurement of radio-frequency electromagnetic fields in a fusion experimental facility,” Prof. Int. Symp. on Electrom. Compat., Sendai, pp. 593-596.

Natural EM Noise

Dakkak, M., A. Hirata, R. Muhida, and Z-I. Kawasaki [2003], “Operation strategy of residential centralized photovoltaic system in remote areas”, Renewable Energy, Vol.28, pp.997-1012.

Hamid, E.Y., and Z-I. Kawasaki [2001a], “Wavelet packet transform for RMS values and power measurements”, IEEE Power Engineering Review. Vol.21, pp.49-52.

Hamid, E.Y., Z-I. Kawasaki, H. Yoshida, and H. Doi [2001b], “Wavelet and wavelet packet data compression of power system disturbances”, IEE J. Trans-.B, Vol.121-B, pp.1221-1227.

Hamid, E.Y., Z-I. Kawasaki, H. Yoshida, and H. Doi [2002a], “Wavelet analysis of voltage disturbances for power quality applications”, IEE J. Trans-.B, pp.323-330.

Hamid, E.Y., R. Mardiana, and Z-I. Kawasaki [2002b], “Method for RMS and power measurements based on the wavelet packet transform”, IEE Proceedings-Science, Measurement & Technology, Vol.149, pp.60-66.

Hamid, E.Y., Z-I. Kawasaki [2002c], “Instrument for the quality analysis of power systems based on the wavelet packet transform”, IEEE Power Engineering Review, Vol.22, pp.52-54.

Hamid E.Y., and Z-I. Kawasaki [2002d], “Wavelet-based data compression of power system disturbances using the minimum description length criterion”, IEEE Transactions on Power Delivery, Vol.17, pp.460-466.

Hamid, E.Y., N. Yokoyama, and Z-I. Kawasaki [2002e], “RMS and power measurements: a wavelet packet transform approach”, IEE J. Trans-.B, Vol.122-B, pp.599-606.

Hirata, A., T. Morimoto, and Z-I. Kawasaki [2003], “DOA estimation of ultra-wideband EM waves with MUSIC and interferometry”, IEEE Antennas and Wireless Propagation Letters, Vol.2, pp.190-193.

Kawasaki, Z.-I., S. Yoshihashi, and L.-J. Ho [2002], “Verification of bi-directional leader concept by interferometer observations”, Journal of Atmospheric Electricity, Vol.22, pp.55-79.

Mardiana, R., T. Morimoto, and Z-I. Kawasaki [2001], “Imaging lightning progression using VHF broadband radio interferometery”, IEICE Transactions on Electronics, Vol.E84-C, pp.1892-1899.

Mardiana, R., T. Morimoto and Z-I. Kawasaki [2002], “Three-dimensional lightning observations of cloud-to-ground flashes using broadband interferometers”, Journal of Atmospheric and Solar-Terrestrial Physics, Vol. 64, pp.91-103.

Morimoto, T., A. Hirata, Z-I. Kawasaki, and T Shiozawa [2003], “Direction-of-arrival estimation for ultra-wideband EM pulses with an interferometer”, Microwave and Optical Technology Letters, Vol.37, pp.17-18.

Morimoto, T., A. Hirata, Z-I. Kawasaki, T. Ushio, A. Matsumoto, and J.-H. Lee [2004], “An operational VHF broadband interferometer for lightning monitoring”, IEEJ Transactions on Fundamentals and Materials, Vol. 124, pp. 1232-1238.

Torii, T., T. Nishijima, Z-I. Kawasaki, and T. Sugita [2004], “Downward emission of runnaway electrons and bremsstrahlung photons in thunderstorm electric fields”, Geophysical Research Letters, Vol. 31, L05113, L19067.

Tungakanawanich A., and Z-I. Kawasaki [2001], “Analysis of VHF-wideband impulsive electromagnetic noises from power distribution lines” Transactions of IEE Japan, Vol.120-B, pp.1538-1544.

Ushio, T., S. J. Heckman, D. J. Boccippio, H. Christian, and Z-I. Kawasaki [2001], “A survey of thunderstorm flash rates compared to cloud op height using TRMM satellite data”, Journal of Geophysical Research, Vol.106, pp.24089-24095.

Ushio, T., S. Heckman, K. Driscoll, D. Boccippio, H. Christian, and Z-I. Kawasaki [2002], “Cross-sensor comparison of the lightning imaging sensor (LIS)”, International Journal of Remote Sensing, Vol.23, pp.2703-2712.

Ushio, T., S. J. Hackman, H. J. Christian, and Z-I. Kawasaki [2003], “Vertical development of lightning activity observed by the LDAR system: Lightning Bubble”, Journal of Applied Meteorology, Vol.42, pp.165-174.

Yamamoto, K., Z-I. Kawasaki, T. Ushio, and S. Sekioka [2003], “On the direct lightning strike to distribution power line–shielding effect of reinforced concrete building”, Journal of Atmospheric Electricity, Vol.23, No.1, pp.1-8.

Alperovich, L. S., V. Zheludev, and M. Hayakawa [2002], “Wavelet study of long - period geomagnetic variations associated with the 1989 M = 7 Loma Prieta and two 1997 M = 6 Japanese earthquakes”, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.55-60, Tokyo.

Alperovich, L., V. Zheludev and M. Hayakawa [2003], “Use of wavelet analysis for detection of seismogenic ULF emissions”, Radio Sci., Vol.38, No. 6, pp.1093, doi:10.1029/2002RS002687.

Ando, Y., M. Hayakawa, and O. A. Molchanov [2002], “Theoretical analysis on the penteration of power line harmonic radiation into the ionosphere”, Radio Sci., vol.37, No. 6, pp.1093, doi: 10.1029/2001RS002486.

Ando, A. and M. Hayakawa [2004], “2-D finite difference analyses of Schumann resonance and identification of lightning distribution”, IEEJ Trans. Fundamentals and Materials, vol. 124, No. 12,

pp.1225-1231.

Biagi, P. F. and M. Hayakawa [2002], “Possible premonitory behaviour of LF radiowaves on the occasion of the Slovenia earthquakes (M = 5.2-6.0-5.1) occurred on March - May 1998”, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.249-253, Tokyo.

Biagi, P. F., R. Piccolo, L. Castellana, A. Ermini, S. Martellucci, C. Bellecci, V. Capozzi, G. Perna, O. Molchanov and M. Hayakawa [2004a], “Variations in a LF radio signal on the occasion of the recent seismic and volcanic activity in Southern Italy”, *Phys. Chem. Earth*, Vol.29, pp.551-557.

Biagi, P.F., R. Piccolo, L. Castellana, T. Maggipinto, A. Ermini, S. Martellucci, C. Bellecci, G. Perna, V. Capozzi, O. A. Molchanov, M. Hayakawa, and Ohta [2004b], “VLF-LF radio signals collected at Bari (South Italy): a preliminary analysis on signal anomalies associated with earthquakes”, Natural Hazards and Earth System Sci., 4, pp.685-689.

Fukumoto, Y., M. Hayakawa, and H. Yasuda [2002], “Reception of over-horizon FM signals associated with earthquakes”, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.263-266, Tokyo.

Gladychev, V., L. Baransky, A. Schekotov, E. Fedorov, O. Pokhotelov, S. Andreevsky, A. Rozhnoi, Y. Khabazin, G. Belyaev, A. Gorbatikov, E. Gordeev, V. Chebrov, V. Sinitsin, A. Lutikov, S. Yunga, G. Kosarev, V. Surkov, O. Molchanov, M. Hayakawa, S. Uyeda, T. Nagao, K. Hattori, and Y. Noda [2002], “Some preliminary results of seismo-electromagnetc research at Complex Geophysical observatory, Kamchatka”, in ‘Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.421-432.

Gorbatikov, A. V., O. A. Molchanov, M. Hayakawa, S. Uyeda, K. Hattori, T. Nagao, H. Tanaka, A. V. Nikolaev, and P. Maltsev [2002], “Acoustic emission possibly related to earthquakes, observed at Matsushiro”, Japan and its implications, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.1-10, Tokyo.

Gotoh, K., Y. Akinaga, M. Hayakawa, and K. Hattori [2002], “Principal component analysis of ULF geomagnetic data for Izu islands earthquakes in July 2000”, J. Atmos. Electr., Vol. 22, No. 1., pp.1-12.

Gotoh, K. M. Hayakawa and N. Smirnova [2003], “Fractal analysis of the gromagnetic data obtained at Izu Peninsula, Japan in relation to the nearby earthquake swarm of June-August 2000”, Natural Hazards Earth System Sci., Vol.3, pp.229-236.

Gotoh, K., M. Hayakawa, N. A. Smirnova, and K. Hattori [2004], “Fractal analysis of seismogenic ULF emissions”, *Phys. Chem. Earth*, Vol.29, pp.419-242.

Grimalsky, V. V., M. Hayakawa, S. V. Koshevaya, G. N. Burlak, and J. Sanchez-Mondragon [2002], “Mexico City as seismic resonator”, in “Seismo Electromagnetics (Lithosphere - Atomosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.87-89, Tokyo.

Hattori, K., Y. Akinaga, M. Hayakawa, K. Yumoto, T. Nagao, and S. Uyeda [2002], “ULF magnetic anomaly preceding the 1997 Kagoshima Earthquakes, in “Seismo Electromagnetics (Lithosophere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.19-28, Tokyo.

Hattori, K., A. Serita, K. Gotoh, C. Yoshino, M. Harada, N. Isezaki and M. Hayakawa [2004a], “ULF geomagnetic anomaly associated with 2000 Izu Islands earthquake swarm, Japan”, *Phys. Chem. Earth*, Vol.29, pp.425-435.

Hattori, K., I. Takahashi, C. Yoshino, N. Isezaki, H. Iwasaki, M. Harada, K. Kawabata, E. Kopytenko, Y. Kopytenko, P. Maltsev, V. Korepanov, O. Molchanov, M. Hayakawa Y. Noda, T. Nagao, and S. Uyeda [2004b], “ULF geomagnetic field measurements in Japan and some recent results associated with Iwateken Nairiku Hokubu earthquake in 1998”, *Phys. Chem. Earth*, Vol.29, pp.481-494.

Hayakawa, M. and A. P. Nickolaenko [2001], “Lightning effects in mesosphere and associated ELF radio signals”, Proc. Indian Nat'l Science Academy, Vol.67, A, No.4 & 5, pp.509-529.

Hayakawa, M., O. A. Molchanov, N. Shima, A. V. Shvets, and N. Yamamoto [2002a], “Wavelet analysis of disturbances in subionospheric VLF propagation correlated with earthquakes”, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakwa and O. A. Molchanov, TERRAPUB, pp.223-228, Tokyo.

Hayakawa, M., O. A. Molchanov, and A. P. Nickolaenko [2002b], “Model variation in atmospheric radio noise caused by pre-seismic modifications of tropospheric conductivity profile”, in “Seismo

Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)", Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.349-352.

Hayakawa, M. and T. Otsuyama [2002c], "FDTD analysis of ELF wave propagation in inhomogencous subionospheric waveguide models", Appl. Computational Electromagnetics Soc. J., Vol.17, No.3, pp.239-244.

Hayakawa, M. and K. Ohta [2003], "The importance of direction finding technique in general VLF studies, in "Very Low Frequency (VLF) Phenomena", Ed. by A.R.W. Hughes, C. Ferencz and A.K. Gwal", pp. 22-35, Narosa Pub. House, New Delhi.

Hayakawa, M., O. A. Molchanov [2004a], "NASDA/UEC team, Summary report of NASDA's earthquake remote sensing frontier project", *Phys. Chem. Earth*, Vol.29, pp.617-625.

Hayakawa, M., T. Nakamura, Y. Hobara and E. Williams [2004b], "Observation of sprites over the Sea of Japan and conditions for lightning-induced sprites in winter", J. Geophys. Res., Vol. 109A01312, doi:10.1029/2003JA009905.

Hayakawa, M., O. A. Molchanov, A. Y. Schekotov, and E. Fedorov [2004c], "Observation of ionospheric Alfven resonance at a middle latitude station", Adv. Polar Upp. Atmos. Res., No. 18, pp.65-76.

Hobara, Y., N. Iwasaki, T. Hayashida, M. Hayakawa, K. Ohta, and H. Fukunishi [2001], "Interrelation between ELF transients and ionospheric disturbances in association with sprites and elves", Geophys. Res. Lett., Vol.28, No. 5, pp.935-938.

Hobara, Y., H. C. Koons, J. L. Roeder, H. Yamaguchi, and M. Hayakawa [2002], "New ULF/ELF observation in Seikoshi, Izu, Japan and the precursory signal in relation with large seismic events at Izu Islands in 2000", in "Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)", Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.41-44.

Hobara, Y., M. Hayakawa, K. Ohta and H. Fukunishi [2003], "Lightning discharges in association with mesospheric optical phenomena in Japan and their effect on the lower ionosphere", Adv. Polar Upper Atmos. Res., no. 17, pp. 30-47.

Ismaguilov, V. S., Yu. Kopytenko, K. Hattori, and M. Hayakawa [2003], "Variations of phase

velocity and gradient values of ULF geomagnetic disturbances connected with the Izu strong earthquakes", Natural Hazard Earth System Sci., Vol.3, pp.211-215.

Iudin, D. I., N. V. Korovkin, O. A. Molchanov, V. V. Surkov, and M. Hayakawa [2002], "Model of earthquake triggering due to gas-fluid "bubble" upward migration I. Physical rationale", in "Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)", Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.177-185, Tokyo.

Koons, H. C., J. L. Roeder, Y. Hobara, M. Hayakawa, and A. C. Fraser-Smith [2002], "Statistical analysis of the data from the ULF sensors at Seikoshi Station", in "Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)", Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.29-39, Tokyo.

Korovkin, N. V., D. I. Iudin, O. A. Molchanov, M. Hayakawa, and V. V. Surkov [2002], "Model of earthquake triggering due to gas-fluid "bubble" upward migration II. Finite-automaton model", in "Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)", Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.187-194, Tokyo.

Korepanov, V., O. Molchanov, M. Hayakawa, and G. Lizunov [2002], "Coordinated registration of seismogenic effects in the ionosphere by means of remote ground-based and local satellite measurements", in "Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)", Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.397-403.

Kopytenko, Yu. A., V. S. Ismaguilov, K. Hattori, P. M. Voronov, M. Hayakawa, O. A. Molchanov, E. A. Kopytenko, and D. B. Zaitev [2002a], "Monitoring of the ULF electromagnetic disturbances at the station network before EQ in seismic zones of Izu and Chiba peninsulas(Japan)", in "Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)", Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.11-18, Tokyo.

Kopytenko, Y. A., V. S. Ismaguilov, O. A. Molchanov, E. A. Kopytenko, P. M. Voronov, K. Hattori, M. Hayakawa, and D. B. Zaitzev [2002b], "Investigation of ULF magnetic disturbances in Japan during seismic active period", J. Atmos. Electr., Vol.22, pp.207-215.

Kulchitsky, A. V., Y. Ando and M. Hayakawa [2004], "Numerical analysis on the propagation of ULF/ELF signals in the lithosphere with highly conductive layers", *Phys. Chem. Earth*, Vol.29, pp.495-500.

Lin, Y., Q. Li, M. Hayakawa, and X. Zeng [2002], “Wavelet analysis and seismo - magnetc effect”, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.61-68, Tokyo.

Miyaki, K., M. Hayakawa, and O. A. Molchanov [2002], “The role of gravity waves in the lithosphere - ionosphere coupling, as revealed from the subionospheric LF propagation data”, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, TERRAPUB, pp.229-232, Tokyo.

Molchanov, O. A., M. Hayakawa, and K. Miyaki [2001], “VLF/LF sounding of the lower ionosphere to study the role of atmospheric oscillations in the lithosphere-ionosphere coupling”, Adv. Polar Upper Atmos. Res., 15, pp.146-158.

Molchanov, O., A. Kulchitsky, and M. Hayakawa [2002a], “ULF emission due to inductive seismo-electromagnetic effect”, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.153-162, Tokyo.

Molchanov, O. A., M. Hayakawa, V. V. Afonin, O. A. Akentieva, and E. A. Mareev [2002b], “Possible influence of seismicity by gravity waves on ionospheric equatrial anomaly from data of IK-24 satellite 1. Search for idea of seismo-ionosphere coupling”, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakwa and O. A. Molchanov, TERRAPUB, pp.275-285.

Molchanov, O. A., M. Hayakawa, V. V. Afonin, O. A. Akentieva, E. A. Mareev, and V. Yu. Trakhtengerts [2002c], “Possible influence of seismicity by gavity waves on ionospheric equatrial anomaly from data of IK-24 satellite 2. Equatorial anomaly and small-scale ionospheric turbulence”, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.287-296, Tokyo.

Molchanov, O. A., A. Yu. Schekotov, E. Fedorov, G. G. Belyaev, M. S. Solobiea and M. Hayakawa [2004a], “Preseismic ULF effect and possible interpretation”, Ann. Geophys. (Italy), Vol. 47, N.1, pp.119-132.

Molchanov, O., E. Fedorov, A. Schekotov, E. Gordeev, V. Chebrov, V. Surkov, A. Rozhnoi, S.

Andreevsky, D. Iudin, S. Yunga, A. Lutikov, M. Hayakawa, and P. F. Biaigi [2004b], “Lithosphere – atmosphere – ionosphere coupling as govering mechanism for preseismic short-term events in atmosphere and ionosphere”, Natural Hazards Earth System Sci., Vol.4, pp.757-767.

Naman, Sh., L. S. Alperovich, Sh., Wdowinski, M. Hayakawa, and E. Calais [2002], “Comparison of simultaneous variations of the ionospheric total electron content and geomagnetic field associated with strong earthquakes”, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.303-308.

Nagao, T., Y. Enomoto, Y. Fujinawa, M. Hata, M. Hayakawa, Q. Huang, J. Izutsu, Y. Kushida, K. Maeda, K. Oike, S. Uyeda and T. Yoshino [2002], “Electromagnetic anomalies associated with 1995 Kobe earthquake”, J. Geodynamics, Vol.33, pp.477-487.

Nickolaenko, A. P., L. M. Rabinowicz, and M. Hayakawa [2004a], “Time domain presentation for ELF pulses with accelerated convergence”, Geophys. Res. Lett., Vol. 31, L05808, doi: 10.1029/2003GL018700.

Nickolaenko, A. P., L. M. Rabinowicz, and M. Hayakawa [2004b], “Natural ELF pulses in the time Domain : Series with accelerated convergence”, IEEJ Trans. Fundamentals and Materials, vol. 124, No. 12, pp.1210-1215.

Nickolaenko, A. P., S. O. Nikolayenko, Yu. Schekotov, and M. Hayakawa [2004c], “Alternative interpretation of ionospheric Alfven resonance”, J. Atmos. Electr., Vol.24, pp.17-30.

Ohta, K., K. Umeda, N. Watanabe, and M. Hayakawa [2002a], “Relationship between ELF magnetic fields and Taiwan earthquake”, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.233-237, Tokyo.

Ohta, K., K.Umeno, N.Watanabe, M.Hayakawa [2002b], “ELF magnetic fields at Nakatsugawa in Japan on Taiwan earthquakes”, Int. Wroclaw Symposium on EMC, pp.717-721, Wroclaw, Poland.

Ohta, K., S.Hanai, S.Hara, M.Hayakawa [2003], “Observation of subionospheric JG2AS signal as precursor of the earthquakes”, Journal of Atmospheric Electricity, 23, 2, pp.85-95.

Ohta, K., S.Hara, M.Hayakawa [2004a], “Improvement in detection of earthquake precursory by

means of Terminal time method in subionospheric VLF propagation", Journal of Atmospheric Electricity, 24, 1, pp.31-38, 2004.

Ohta, K., S.Hara, N.Watanabe M.Hayakawa [2004b], "Anomalous behavior of Schumann resonance, possibly with Taiwan earthquakes", Int. Symposium on EMC, pp.753-756, Sendai, Japan, 2004

Ohta, K., N.Watanabe, M.Hayakawa [2004c], "Electromagnetic fields and Schumann resonance on Taiwan earthquakes", Int. Wroclaw Symposium on EMC, pp.575-578, Wroclaw, Poland.

Ondoh, T. and M. Hayakawa [2002], "Seismo discharge model of anomalous sporadic *E* ionization before great earthquakes", in "Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)", Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.385-390.

Otsuyama, T. and M. Hayakawa [2002], "FDTD simulation and experimental result on VLF scattering by ionospheric perturbations in Earth-ionosphere waveguide, Trans. IEE of Japan, Vol. 122-A, No. 1, pp.59-64.

Otsuyama. T., T. Kariya and M. Hayakawa [2003a], "VLF signatures of ionospheric perturbation in the Hokuriku area of Japan", Adv. Polar Upper Atmos. Res., no. 17, pp. 109-119.

Otsuyama, T., D. Sakuma and M. Hayakawa [2003b], "FTDT analysis of ELF wave propagation and Schumann resonanace for a subionopheric waveguide model", Radio Sci., Vol.38, No.6, pp.1103, doi:10.1029/2002RS002752.

Otsuyama, T., J. Manaba, M. Hayakawa, and M. Nishimura [2004a], "Characteristics of subionospheric VLF perturbation associated with winter lightning around Japan", Geophys. Res. Lett., Vol. 31, L04117, doi:10.1029/2003GL019064.

Otsuyama, T., J. Manabe and M. Hayakawa [2004b], "Characteristics of subionospheric VLF perturbations associated with winter lightning around Japan", Adv. Polar Upp. Atmos. Res., No. 18, pp.77-86.

Otsuyama, T. and M. Hayakawa [2004c], "FDTD analysis of ELF wave propagation for realistic subionospheric waveguide", IEEJ Trans. Fundamentals and Materials, vol. 124, No. 12, pp.1203-1209.

Rapoport, Y., V. Grimalsky, M. Hayakawa, V. Ivchenko, D. Juarez-R, S. Koshevaya and O. Gotynyan [2004], “Change of ionospheric plasma parameters under the influence of electric field which has lithospheric origin and due to radon emanation”, *Phys. Chem. Earth*, Vol.29, pp.579-587.

Rozhnoi, R., M. S. Solovieva, O. A. Molchanov and M. Hayakawa [2004], “Middle latitude LF (40 kHz) phase variations associated with earthquakes for quiet and disturbed geomagnetic conditions”, *Phys. Chem. Earth*, Vol.29, pp.589-598.

Shvets, A. V., M. Hayakawa and O. A. Molchanov [2002], “Subionospheric VLF monitoring for earthquake-related ionospheric perturbations”, J. Atmos. Electr., Vol.22, pp.87-99.

Shvets, A. V., M. Hayakawa, O. A. Molchanov, and Y. Ando [2004a], “A study of ionospheric response to regional seismic activity by VLF radio sounding”, *Phys. Chem. Earth*, Vol.29, pp.267-237.

Shvets, A. V., M. Hayakawa, and S. Maekawa [2004b], “Results of subionospheric radio LF monitoring prior to the Tokachi (m=8, Hokkaido, 25 September 2003) earthquake”, Natural Hazards Earth System Sci., Vol.4, pp.647-653.

Singh, B. and M. Hayakawa [2001], Propagation modes of low- and very-low-latitude whistlers, J. Atmos. Solar-terr. Phys., Vol.63, pp.1133-1147.

Singh, B. and M. Hayakawa [2003], “Propagation modes of low and very low latitude whistlers, “Very Low Frequency (VLF) Phenomena”, Ed. by A.R.W. Hughes, C. Ferencz and A.K. Gwal”, pp.174-199, Narosa Pub. House, New Delhi.

Singh, R. P., B. Singh, P. K. Mishra and M. Hayakawa [2003a], “On the lithosphere -atmosphere coupling of seismo-electromagnetic signals”, Radio Sci. Vol.38, No.4, pp.1065, doi:10.1029/2002RS002683.

Singh, B., M. Hayakawa, P. K. Mishra, R. P. Singh and D. R. Laskshmi [2003b], “VLF electromagnrtic noise bursts observed in a borehole and their relation with low-latitude hiss”, J. Atmos. Solar-terr. Phys., Vol.65, No.269-276.

Singh, V., B. Singh, M. Hayakawa, M. Kumar, V. Kushwah, and O. P. Singh [2004], “Nighttime amplitude decrease in 19.8kHz NWC signals observed at Agra possibly caused by moderate seismic

activities along the propagation path", J. Atmos. Electr., Vol.24, pp.1-15.

Smirnova, N., M. Hayakawa, and K. Gotoh [2004], "Precursory behavior of fractal characteristics of the ULF electromagnetic fields in seismic active zones before strong earthquakes", *Phys. Chem. Earth*, Vol.29, pp.445-451.

Soloviev, O. V. and M. Hayakawa [2002], "Three-dimensional subionospheric VLF field diffraction by a truncated highly conducting cylinder and its application to the Trimpi effect problem", Radio Sci., Vol. 37, No. 5, 1079, doi:10.1029/2001RS002499.

Soloviev, O. V. and M. Hayakawa [2004], "3D modeling method of VLF subionospheric radio wave propagation allowing for a localized ionospheric perturbation", IEEJ Trans. Fundamentals and Materials, vol. 124, No. 12, 1216-1224.

Sorokin, V. M., E. N. Federov, A. Yu. Schekotov, O. A. Molchanov and M. Hayakawa [2004], "Depression of the ULF geomagnetic pulsation related to ionospheric irregularities", Ann. Geophys. (Italy), Vol. 47, N. 1, pp.191-198.

Surkov, V. V., D. I. Iudin, O. A. Molchanov, N. V. Korovkin, and M. Hayakawa [2002a], "Thermofluctuational mechanism of cracks migration as a model of earthquake preparation", in "Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)", Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.195-201, Tokyo.

Surkov, V. V., S. Uyeda, H. Tanaka and M. Hayakawa [2002b], "Fractal properties of medium and seismoelectric phenomena", J. Geodynamics, Vol.33, pp.519-534.

Surkov, V. V., O. A. Molchanov and M. Hayakawa [2003], "Pre-earthquake ULF electromagnetic perturbation as a result of inductive seismomagnetic phenomena during microfracturing", J. Atmos. Solar-terr. Phys., Vol.65, pp.31-46.

Tronin, A. A., M. Hayakawa and O. A. Molchanov [2002], "Thermal IR satellite data application for earthquake research in Japan and China", J. Geodynamics, Vol.33, pp.519-534.

Troyan, V. N. and M. Hayakawa [2002], "Methods for geophysical data processing in seismc active zones", in "Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)", Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.215-221, Tokyo.

Uyeda, S., T. Nagao, K. Hattori, Y. Noda, M. Hayakawa, K. Miyaki, O. Molchanov, V. Gladychev, L. Baransky, A. Schekotov, G. Belyaev, E. Fedorov, O. Pokhotelov, S. Andreevsky, A. Rozhnoi, Y. Khabazin, A. Gorbatikov, E. Gordeev, V. Chebrov, A. Lutikov, S. Yunga, G. Kosarev, and V. Surkov [2002a], “Russian-Japanese complex geophysical observatory in Kamchatka for monitoring of phenomena connected with seismic activity”, in “Sesmo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.413-419.

Uyeda, S., M. Hayakawa, T. Nagao, O. A. Molchanov, K. Hattori, Y. Orihara, K. Gotoh, Y. Akinaga and H. Tanaka [2002b], “Electric and magnetic phenomena observed before the volcano-seismo activity in 2000 in the Izu Island Region”, Japan, Proc. US National Academy of Sci. (PNAS), Vol.99, pp.7352-7355.

Yunga, S., A. Lutikov, O. Molchanov, and M. Hayakawa [2002], “Upward migration of earthquakes as a hint on origin of foreshock activity and other related phenomena”, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.167-172, Tokyo.

Zeng, X., M. Hayakawa, Y. F. Lin, and C. R. Xu [2002], “Infrastructural analysis of geomagnetic field and earthquake prediction”, in “Seismo Electromagnetics (Lithosphere - Atmosphere - Ionosphere Coupling)”, Ed. by M. Hayakawa and O. A. Molchanov, TERRAPUB, pp.463-468.