Sodankylä Geophysical Observatory

Reports

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Abstracts

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Sodankylä 2006

PROGRAMME

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Monday, 9th October 2006

Tuesday 10th October 2006

08:30 *Transportation from Hotels to SGO*

09:00 – 10:30

10:30 – 11:00 *Coffee*

11:00 – 12:00

12:00 – 13:00 *Lunch*

13:00 – 14:30

Sähkövirran magneettivaikutuksen mittaaminen ja Johan Jakob Nervanderin tangenttibussoli

Ari Sihvola

Teknillinen korkeakoulu, Sähkömagnetiikan laboratorio, Espoo, Suomi

Sähkövirta aiheuttaa ympäristöönsä kiertävän magneettikentän. Tämä ilmiö voidaan kuvata hyvin yksinkertaisesti nykyaikaisella sähköopin notaatiolla, mutta sen selvittäminen on ollut tieteen historiassa pitkä prosessi. Jatkuvaa sähkövirtaa (kvantiteettisähköä) pystyttiin kunnolla tuottamaan vasta Alessandro Voltan sähköparin keksimisen jälkeen (1800). Mutta sitten kun tanskalainen Hans Christian Örsted oli tehnyt vallankumouksellisen keksintönsä sähkövirran magneettivaikutuksesta kesällä 1820, ei kestänyt kauan, ennen kuin tieto siitä oli levinnyt Euroopan keskuksiin. Pian André-Marie Ampère selvitti matemaattiset lainmukaisuudet, joiden mukaan sähkövirran synnyttämät magneettivoimat suuntautuivat ja käyttäytyivät.

Suoran sähkövirtalangan magneettivaikutus on aika heikko. Sitä saadaan hyvin paljon vahvistettua, jos lanka käämitään moninkertaiseksi silmukaksi. Tämän periaattteen mukaisia "multiplikaattoreita" kehitettiinkin jo pian Örstedin kokeen jälkeen ja niillä pystyttiin herkästi aiheuttamaan ja havaitsemaan kelan sisälle asetetun kompassineulan liike. Johann Schweigger on saanut nimensä tieteen historiaan multiplikaattorigalvanometrin ansiosta. Leopoldo Nobili kehitti puolestaan ns. astaattisen galvanometrin, jossa Maan magneettikentän vaikutus kumoutui.

Suomalainen Johan Jakob Nervander (1805-1848) ehti lyhyen elämänsä aikana jättää nimensä historiaan monella alalla. Tässä esityksessä käsittelen hänen toimintaansa sähkömagnetismin tutkimuksen historian kannalta. Nervander oli kiinnostunut Örstedin ilmiöstä ja jo väitöskirjassaan vuodelta 1829, In doctrinam electro-magnetismi momenta, hän teki tarkkoja mittauksia sähkövirran vaikutuksesta kompassineulaan. Nervander kiersi monen vuoden ajan Eurooppaa 1830-luvulla, tapasi kuuluisimmat tiedemiehet ja kehitti ja esitteli tiedeyhteisölle uuden mittalaitteen, tangenttibussolin, jolla pystyi ennennäkemättömällä tarkkuudella määrittämään sähkövirran voimakkuuden magneettineulan kiertymästä.

Teknillisen korkeakoulun Sähkömagnetiikan laboratoriossa on käynnissä tekniikan ylioppilas Jukka Venermon diplomityö, jossa on tarkoitus rakentaa Nervanderin tangenttibussolin kopio Helsingin Yliopistomuseon Nervander-näyttelyä varten. Lisätietoja Nervanderin tangenttibussolista löytää hänen artikkelistaan "Mémoire sur un Galvanomètre à châssis cylindrique par lequel on obtient immédiatement et sans calcul la mesure de l'intensité du courant électrique qui produit la deviation de l'aiguille aimantée", jonka käännös selityksineen on julkaistu Sähkömagnetiikan laboratorion suomenkielisessä sarjassa (raportti 23, elokuu 2005).

Realization of impedance boundary in terms of wave-guiding medium

Ismo Lindell and Ari Sihvola

TKK, Espoo, Finland

Impedance boundary is generally considered as an approximate model for material interfaces. Considering an electromagnetic field in a certain wave-guiding anisotropic material it is shown that a slab of such a material backed by a PEC plane can be exactly represented by impedance-boundary conditions. As a result of the analysis, a novel explicit relation is derived between the surface admittance dyadic of the impedance boundary and the material and geometric parameters of the anisotropic slab which can be used to realize a given admittance dyadic. The relation is verified with results known for the perfect electromagnetic (PEMC) boundary and bi-axial material, considered as special cases of the theory.

Polarizability of a hemisphere

Henrik Kettunen

Sähkömagnetiikan Laboratorio / TKK, Espoo, Finland

The polarizability of a homogeneous hemisphere is examined. The polarizability is determined as the ratio of the dipole moment of the polarized object and the external electric field. In case of a hemisphere, the polarizability is dependent on the direction of the electric field. Two special directions are considered: the axial case and the transversal case.

To solve the polarized dipole moment, a solution for the potential is required. The electrostatic potential function must satisfy the Laplace equation, the solution of which is sought as a series expansion. However, the unorthogonality of the Legendre functions on a hemispherical surface leads to a situation where the terms of the series expansion are not orthogonal. The coefficients of the expansion for the potential can however be solved from a set of linear equations, which can be written as a matrix equation and solved by a matrix inversion.

The polarizability of the hemisphere is presented as a function of relative permittivity. To verify the results, the problem is also solved numerically.

Also negative values for permittivity are considered. It is observed that the corners of the hemisphere cause several so called static resonances with relative permittivity values between -3 and -1/3, meaning that between these values the potential has several singularities and the series expansion does not converge. It is also observed that when the permittivity of the object is exactly the opposite number of the permittivity of the surrounding medium, the potential can be singular even on smooth, planar surfaces.

Forest height estimation with interferometric polarimetric synthetic aperture radar, the FINSAR experiment.

Jaan Praks[1], Florian Kugler[2] and Martti Hallikainen[1]

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Synthetic aperture radar (SAR) has been used for remote sensing applications already for several decades. However, instruments and imaging techniques still develop constantly. Latest newcomer in synthetic aperture radar remote sensing is technique called polarimetric interferometry. Polarimetric interferometry allows to estimate height of the certain type of scattering centers using several SAR images.

Helsinki University of Technology, Laboratory of Space Technology and German space agency DLR arranged in autumn 2003 a polarimetric interferometric measurement experiment, called FINSAR, where German airborne radar E-SAR and Finnish helicopter borne microwave scatterometer HUTSCAT were operated together over a forested area near Helsinki. The objective of the project was to evaluate the performance of polarimetric interferometric tree height estimation algorithm for boreal forest.

In our presentation we give an overview of the campaign, the instruments and the methods used to detect the forest height from polarimetric interferometric L-band SAR images and HUTSCAT scatterometer measurement profiles and discuss the results.

Arbitrarily modulated radar transmission codes that minimize measurement error of static target

Juha Vierinen and Markku Lehtinen

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A framework for finding arbitrarily modulated radar transmission codes that minimize measurement errors of a stationary target is presented. A random local improvement algorithm is then presented and used to find codes that satisfy given constraints on total power and amplitude ranges of the transmission code, and at the same time give minimal measurement errors when estimating a target. Results show that nearly perfect codes, with performance similar to a delta spike pulse of similar power can be found using moderate requirements for modern transmission equiptement. Also, finding these codes is not computationally expensive and such codes can be found for nearly all code lengths.

Multi-pattern receiving antenna systems in ionospheric sounding

Riika Autio, Tauno Turunen and Aarne Ranta

Sodankylä Geophysical Observatory, University of Oulu, Sodankylä, Finland

Sodankylä Geophysical Observatory's new ionosonde "Alpha-Wolf" started its ionospheric measurements in November 2005. Ionosonde's simple basic mode with few receiving antenna and fixed gain will be soon replaced with a multi-pattern receiving system currently under construction. New system differs from other receiving antenna systems commonly used in ionosonde stations around the world. At the same time are designed and examined more different antenna systems to be possibly used later on by "Alpha-Wolf". Intention is to find more effective patterns to define angles of arrival of echoes.

Some universally used receiving systems are compared to the system in SGO and some new ideas will be presented with the radiation pattern examples.

Measurement system for adaptive antennas

Marko Sonkki[1], Antti Rissanen[1], Veli-Matti Holappa[2], Mikko Alatossava[2], Erkki Salonen[1], Juha Ylitalo[2] and Pekka Lilja[2]

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Adaptive antennas are becoming more and more important for mobile communication applications. Antenna arrays can be used for interference rejection and for optimizing some characteristics of the received signal. Direction finding algorithms can be applied for data received by the antenna array to find the direction of arrival (DOA) and to separate the signal(s) of interest.
The system has eight transmitting antennas, which all can be controlled separately. 2-12 receiving branches are able to choose to combine the received signals, respectively. Total amount of receiving branches can be extended up to 16 or even more, depending on measured antenna array and used power combiner.
The key features are how A/D conversion can be done effectively, and how economically computing can be performed. This needs DSP-processing or very efficient LabView™ and Matlab™ programming in post processing. Also synchronization of the transmitter and receiver plays great role in the system.
The system uses time-division multiplexing to combine the signals after measured antenna array. Multiplexing is implemented by using electronically controlled power combiner.
Time-division multiplexing is tested in anechoic chamber at University of Oulu by using PropSound™ multi-dimensional channel sounder. The device, made by Elektrobit Group, is generally used for MIMO channel characterization. Eight element uniform circular array (UCA) is used as a receiving antenna when two antennas are used as a transmitting antennas. UCA is rotated on a turntable, 0.60 m away from the centre, by using three measurements setups. Spacing of the transmitting antennas in those setups are 0.5, 1.0 and 1.5 meters.
The results done by PropSound™ are promising but more detailed post processing is still needed. Measurement of 360° in azimuth plane, steps done by 1°, takes 90 seconds, and the measurements are done continuously. Results can be seen after post processing by using DOA and beamforming algorithms. Calibration matrix used in DOA algorithm is created from the measured data. The coding used in the measurements was 63 chips long DS-code. The disadvantage of the time-division multiplexing is the complexity of the post processing.
A time-division multiplexing measurement method is demonstrated. It gives good characteristics to improve the system as being physically not so complicated; only one receiver chain is needed when power combiner is used for switching the received signals.

Fields of magnetic current line source in wire medium

Ari Viitanen, Igor Nefedov and Sergei Tretyakov

Helsinki University of Technology, Espoo, Finland

Wire medium is a medium formed by a lattice of ideally conducting parallel thin wires. Wires in lattice can be in one, two or three directions. Such a medium is sometimes called artificial plasma because of plasma like behaviour at certain frequency range. The plasma frequency in wire medium depends on the geometry of the wire structure. Effectively wire medium is uniaxial material whose permittivity components depend on the plasma number and on the wave vector component parallel to wires. For this reason, wire medium is strongly spatially dispersive material, unlike normal plasma. Spatial dispersive materials have recently received attention because of interesting electromagnetic phenomena and possible new applications. For example, the presence of spatial dispersion causes existence of additional waves and a necessity to use additional boundary conditions for solution of boundary-value problem for such media. For the same reason the standard expressions for fields, excited by sources in unbounded anisotropic media are not applicable for media with spatial dispersion.

In this study we have developed field expressions caused by a magnetic current line source inside a single wire medium. This expression contains three parts, describing excitation of the TEM field, the TM field, and a contribution caused by their interaction. The developed approach can be used for more complicated problems for sources in plane-stratified media. One application of wire medium is to affect the radiation properties of the source and make more effective antennas. An other example is to make artificially solid materials whose permittivity can be very low or negative.

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Position and guidance service for visually disabled people in a wireless network environment

Jyri Rajamäki and Petri Viinikainen

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The aim of this this working life project is innovative service solutions that will improve the quality of life of visually disabled people. For example a shopping center can be so large that these customers do not always find the services or shops they want to. Therefore new service solutions that exploit the technical features of WLAN positioning systems in an innovative way are being developed.

The service idea is to combine wordmap databases and existing Wireless Local Area Network (WLAN) location techniques such as Ekahau Positioning Engine (EPE), Skype or Voice over Internet Protocol (VoIP). This project needs an application that can combine both indoor and outdoor positioning.

A shopping center is a challenging environment because the location service needs to be developed both indoors and outdoors and also between different floors in the building. In the experiment a new system that exploits for example Ekahau Positioning Engine (EPE) WLAN positioning systems is being developed. Global Positioning System (GPS) positioning system is not able to work inside and it cannot recognise different floors in a building.

In Laurea Univeristy of Applied Sciences several student projects have begun in autumn 2006. These projects' purpose is to investigate how to create an application that can connect to the EPE interface and how the application can be used for forming wordmaps.

The following items are developed in the service:

1) real-time location of a person inside a building

2) giving people computer generated voice advice that helps them to move around

3) production of wordmaps.

The service will increase the feeling of freedom of this customer group because after launching the service they no longer need an assisting person when they want to go shopping or for example to the bank.

The largest market area in the future is that the same service can be exploited also as positioning service system in mobile phones that support WLAN features. Later the service will be developed to also assist eldrely people in different situations. The technique also makes it possible to develop many other supplementary services, for example location of children in a shopping center.

UWB coexistence measurements

Ari Isola, Matti Hämäläinen and Jari Iinatti

Centre for Wireless Communications, Oulu, Finland

This paper presents results from the ultra-wideband (UWB) coexistence measurements with IEEE 802.11a wireless local area network (WLAN). The measurements were carried out in the different conditions, where setups vary from theoretical laboratory setups to real-life scenarios. All measurements were done with a real WLAN link interfered by a radiated UWB transmission.

Due to the wide spectrum nature of the UWB transmission, overlapping with other existing narrowband and wideband radio systems cannot be avoided. And thus, the study of the UWB coexistence plays important role in a field of UWB technology.

In the measurements, direct sequence (DS) spread spectrum technique based singleband UWB devices were used to cause interfering signal. The interference level that decrease the WLAN performance were studied as a function of UWB activity factor (AF), pulse repetition frequency (PRF), interference distance and number of active devices.

WLAN coexistence measurements were carried out with two different kinds of hardware setups; commercial WLAN cards and laboratory instruments. In the WLAN card measurements, the radio link was created between two laptops. User datagram protocol (UDP) mode with full IEEE 802.11a bitrate, i.e. 54 Mbits/s, was used. Monitored results were throughput and signal level at the receiver.

The hardware setup with the laboratory instruments consists of Agilent ESG (signal generator), Agilent PSA (spectrum analyzer), amplifiers and Agilent Infiniium DSO (oscilloscope). In these measurements, the WLAN signal was created and eventually recorded with EEsof Advanced Design System (ADS) software. The latter system setup in coexistence measurements is a novel approach in this context. In both cases, the final data analysis was done with Matlab.

Both WLAN measurements were carried out in the anechoic chamber, where unintentional interference could be eliminated. Using the commercial WLAN cards, measurements in the regular classroom were also carried out.

Final paper discusses the result in more details.

The impact of co-existing systems on MB-OFDM and DS-UWB system performances in AWGN and multipath channels

Harri Viittala, Matti Hämäläinen and Jari Iinatti

Centre for Wireless Communications, Oulu, Finland

Multiband orthogonal frequency division multiplexing (MB-OFDM) and direct sequence ultra wideband (DS-UWB) systems are studied in interfered additive white Gaussian noise (AWGN) and modified Saleh-Valenzuela (SV) channels. Co-existing systems, i.e., interference, are assumed to be based on the IEEE 802.11a and the forthcoming 4G. From the published studies, it becomes evident that the comparison between these systems in interfering environment is unsubstantial.

The study is more focused on MB-OFDM system, whereas DS-UWB is used as a point of comparison. Simulation parameter configurations are based on the same spectral allocation and data rate. Hence, MB-OFDM utilizes the six lowest subbands, occupying spectrum from 3.1 GHz to 6.3 GHz. The 5th, 6th and 7th derivatives of the Gaussian monocycle are the applied pulse waveforms for DS-UWB. Having a pulse length of 0.5 ns, these pulse waveforms adapt approximately the same spectrum as MB-OFDM does. When DS-UWB applies the processing gain of 16 dB, which is based on repetition coding, and the pulse length of 0.5 ns, data rate is 50 Mbps that is close to the lowest data rate supported by MB-OFDM. In the case of MB-OFDM, quaternary phase shift keying (QPSK) and dual carrier modulation (DCM) are used as data modulations where DS-UWB utilizes binary amplitude modulation (BPAM). In SV channels, the systems' performances decrease from the AWGN performance dramatically. Therefore, MB-OFDM applies error correction coding and DS-UWB utilizes 8 finger rake receiver.

Interference is modeled as colored Gaussian noise (CGN). For 4G, the center frequency and the bandwidth are assumed to be 4.5 GHz and 100 MHz, respectively. IEEE 802.11a is locating at 5.25 GHz and has 20 MHz bandwidth.

The systems' bit error rate (BER) performance is examined as a function of signal-to-noise power ratio, interference-to-signal power ratio (ISR), the center frequency of the interference and the bandwidth of the interference. The results point out that DS-UWB performs better with low ISR values in all studied channels. At the same time, MB-OFDM turned out to be better choice when ISR increases. The center frequency of interference has not major influence to the system's performances. The increasing bandwidth of interference affects to MB-OFDM system performance more than DS-UWB.

Can ionospheric D region opacity for cosmic radio waves be modulated by artificial HF heating?

Antti Kero, Carl-Fredrik Enell, Thomas Ulich and Esa Turunen

Sodankylä Geophysical Observatory, Sodankylä, Finland

The effect of artificial D-region heating on cosmic radio noise absorption has been theoretically estimated but not yet quantitatively observed. In this study a 3-dimensional modelling of the effect produced by EISCAT Heater Facility and observed by the IRIS imaging riometer (Kilpisjärvi, Finland) is presented. In addition, a statistical analysis is done for data from the IRIS imaging riometer (Kilpisjärvi, Finland) corresponding to a selected set of EISCAT heating experiments carried out 1994–2004.

A small but statistically significant median offset signature is seen in IRIS beam number 9, which overlaps the EISCAT heater beam at D-region altitudes around 90 km. The found median absorption difference between heated and unheated ionosphere is approximately 0.003 dB, which is roughly one order of magnitude less than the model predicts.

Monitoring ionospheric total electron content in the Fennoscandian sector

Juha-Pekka Luntama and Kirsti Kauristie

Finnish Meteorological Institute, Helsinki, Finland

The GNSS (Global Navigation Satellite System) applications use the measurements of the range between the transmitters and the receiver to solve the location of the receiver. The range measurements are based on the phase of the code modulated on the satellite carrier signal and on the phase of the carrier signal itself. Both the code and the carrier phase suffer distortions when the signal passes through the ionosphere and the plasmasphere surrounding the Earth. Without correction the ionospheric error in the navigation solution can be up to 30 m, and the error is proportional to the total electron content (TEC) integrated along the signal propagation path. In the case of two-frequency receivers the ionospheric distortion can be eliminated almost totally and the necessary correction can be used to estimate the spatial distribution of TEC. Several research institutes today publish near real-time TEC maps based on the data of dense GNSS receiver networks.

With the support of TEKES (Finnish Funding Agency for Technology and Innovation) the Finnish Meteorological Institute has conducted a pilot project to investigate the opportunities to use GNSS receivers in the Fennoscandian sector (e.g. from IGS, EUREF, national geodetic and commercial networks) for the production of high spatial resolution TEC-maps. Such maps would be valuable input for ionospheric models in scientific work and essential information in the mitigation of ionospheric errors in single-frequency GNSS applications. In the presentation we will outline main lessons learnt in the pilot project and discuss the opportunities to use TEC-information together with other Fennoscandian ionospheric observations in solar-terrestrial research.

ELF-VLF measurements at SGO

Jyrki Manninen, Tauno Turunen and Thomas Ulich

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Sodankylä Geophysical Observatory has carried out ELF-VLF recordings since 1970s. The equipment has been developed and built at SGO. At the moment there are three different generations of wideband ELF-VLF receivers for measurement campaigns in addition to another receiver belonging to the British Antarctic Survey for continuous recordings. Furhtermore one receiver monitors VLF signals from 6 transmitters around the world, while another receiver is part of the World Wide Lightning Location Network.

Most of the recordings have been made during special campaigns, which were related to EISCAT and auroral measurements. In many cases the data has shown totally novel events and all the time new findings are made.

The analysis software has also been made at SGO. Some examples will be shown.

A Woollen Aardvark in Sodankylä

Thomas Ulich[1], Craig Rodger[2], Mark Clilverd[3], Tero Raita[1] and Jyrki Manninen[1]

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[3] British Antarctic Survey, Cambridge, UK

For some years, we are running a six-channel, narrow-band VLF receiver in collaboration with the British Antarctic Survey. The instrument was first deployed in Perunkajärvi, near Rovaniemi, and today it is situated at Pittiövaara Station near Sodankylä. The so-called OmniPAL (Omnifarious Phase and Amplitude Logger) system monitors typically six naval VLF transmitters in the northern hemisphere and allows to monitor the Earth-Ionosphere waveguide over large areas along the great-circle paths between transmitters and the receiver. There are several equivalent systems deployed around the world and collaborating through Aard(d)vark, i.e. the "Antarctic-Arctic Radiation Belt (Dynamic) Deposition - VLF Atmospheric Research Konsortia."

Since August 2005 however, Sodankylä has become a woollen aardvark! SGO has joined the World-Wide Lightning Location Network (WWLLN, pronounced "woollen") and a dedicated VLF receiver for real-time lightning detection has been installed at Pittiövaara. It monitors strong lightning at distances of greater than 500 km and relays the recorded VLF signatures in real-time to the central processing computer in Seattle, USA, where signatures from many receivers are combined and lightning locations are computed based on the time delays of the recordings. The entire network is synchronised by GPS timing. Every 10 minutes, maps of global lightning occurrence are published on the woollen web server at http://webflash.ess.washington.edu/.

Alpha Wolf – the new ionosonde of Sodankylä Geophysical Observatory

Tauno Turunen and Aarne Ranta

Sodankylä Geophysical Observatory

Ionosonde is a vertical HF radar working typically from about 1 MHz to 16-30 MHz depending on geographic latitude. The measurement result is called ionogram and describes the reflection range of ionospheric echoes as a function of frequency. Sodankylä Geophysical Observatory started ionospheric HF soundings in 1957 using a ionosonde, which observatory got from MPI für Aeronomy in Lindau, Germany. In 1978 this first ionosonde, was replaced by IS-14 sounder, which at that time was quite a modern device having even a lot of digital signal processing, but it still used the classical photographic recording. IS-14 was designed and constructed in Finland in a large co-operative project. These two ionosondes were pulsed radars. In November 16th 2005 the IS-14 sounder was replaced by Alpha Wolf, which is a chirped continuous wave sounder and it is fully designed and produced in SGO. Alpha Wolf uses GPS based timing, and it synthesizes the continuous wave chirped waveform from 0.5 to 16 MHz at 0.5 MHz chirp rate using 10 MHz frequency reference from GPS. Direct digital synthesis (DDS) has 200 MHz processing clock frequency. The receiver antenna is a phased array of active loop antennae. Complex quadrature detection is done without any intermediate frequency stages. Dynamic range has been arranged by 24 bit AD conversions. Signal processing includes polarization separation. Ionograms are available within couple of minutes to the users around the world. The basic solutions in Alpha Wolf are described, measurement examples are show and some planned future developments are mentioned.

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