COST 296 Action: **M**itigation of **I**onospheric **E**ffects on **R**adio **S**ystems (MIERS)

Draft Minutes of the 4th Management Committee Meeting
27-29 April 2006
DLR Neustrelitz, Germany
Park Hotel

1. Welcome

The participants were welcomed by Lili Cander (COST 296 Chairperson) who thanked everyone for coming and Norbert Jakowski (NJ), the local organiser, for his hospitality in hosting the meeting. Mr Holger Maass from DLR welcomed everyone and wishes us a successful meeting. Mr Andreas Grund the Major of Neustrelitz gave a very interesting presentation on the history of the area including the Market Place and the nearby lake. NJ gave some domestic announcements including inviting everyone to a special performance of 'Solar Storm' by a professional dance group. NJ also mentioned that there would be an official visit to DLR on Saturday afternoon for those interested.

2. Approval of the Agenda

The Draft Agenda for the meeting was approved without any amendments, see ANNEX I

3. Adoption of the Minutes of the first MC meeting

The minutes of the Third MC meeting held at ESA, Noordwijk 14-18 November 2005 were approved with minor typo amendments.

4. Official status of the COST 296 Action

LC proceeded to explain the current status of the signatures to the Action, pointing out that although Romania have signed the COST296 MoU there was no-one to contact regarding participation in this Action.

The application from Geomagnetic Laboratory, Natural Resources from Canada with Larisa Tritchenko as the representative is still in progress. The application from Marina Abdula from the University of Kebangsann, Malaysia, this application was accepted unanimously.

A new application was received from The Department of the Air Force, Research Laboratory, Hamscom AFB, Massachusetts, USA, contact name Dr Greg Bishop, LC read out the letter of application the MC unanimously gave approval of this as there was much support to accept this application.

5. COST296 Budget 1 July to 30 June 2006

LC reported the status of the COST 296 Budget (ANNEX III)

6. **Short Term Scientific Missions (STSMs)**

The funding for STSMs in the F/Y 1 July 2005 to 30 June 2006. At the previous MC it was decided that the maximum reimbursement for STSM would be 900 Euro per mission. Three proposals were introduced a) Turkey to UK; b) Greece to Czech Republic; c) Italy to France and accepted. So far the STSM from Turkey to UK has taken place and the applicant has been reimbursed. Also Czech Republic to National Observatory of Athens, Greece has taken place applicant still to be reimbursed. STSM from INGV Rome to University of Rennes will take place in May. A further STSM still to take place is from Poland to Spain, this mission is in place of a previously approved mission from Greece to Czech Republic that for logistical reasons could not happen. The MC gave approval for the Poland to Spain mission to take place as this was previously applied for but could not happen due to financial constraints in the previous year's budget.

7. **Collaboration between COST296 and COST724 Actions (general discussion)**

7a. IS presented further developments at the web page http://www.cbk.waw.pl/cost296/ as one of the COST274/296 joint activity.
7b. ABel reported from the latest COST 724 meetings that have taken place.
7c. BZ reported on the latest developments on the forthcoming School on Space Weather due to take place 2-19 May 2006 with four COST296 participants giving lectures and 6 young scientist from Poland, Czech Republic, Spain and Turkey attending the school.
7d. LC announced that the next Space Weather Week (SWW III) will take place from 13-17 November 2006 at the Royal Library of Belgium, Brussels, more details will follow.
7e. BZ gave an update to publication of the presentations from SWW II.

8. **COST296 activities related to the IHY**

Dr G De Franceschi: presented the latest activities relating to COST 296 for full presentation see: http://www.cost296.rl.ac.uk/

9. **The COST 296 Action Year in Review (February 2005 –April 2006)**

Lj R Cander and B Zolesi : Presented a review of the activities of the previous year February 2005-April 2006, for full presentation see: http://www.cost296.rl.ac.uk/

10. **Receipt and adoption of the progress reports of Working Group Leaders**

WG 1: Ionospheric monitoring and modelling (ANNEX IV)
WG 2: Advanced terrestrial systems (ANNEX V)
WG 3: Space based systems (ANNEX VI)

11. **COST296 website and logo**

COST 296 web site is up and running and managed at RAL http://www.cost296.rl.ac.uk/ The COST 296 logo has been decided by unanimous vote and can now be seen on the web site and the presentation of GF.

12. **Other documents for consideration**

LB presented a proposal for a letter to be sent by COST296 community to RAL to support the unfortunate closure of Chilton and Port Stanley ionosondes. MC approved this proposal to be sent by AB immediately after the MC meeting.

13. **International meetings relevant for the COST296 Action**

There are several international meetings relating to COST296 activities:

NATO/URSI – Fairbanks, USA – June 2006
IET HF Conference, London, UK – July 2006
IRI 2006 Workshop, Buenos Aires, Argentina – 16-20 October 2006
IEE – EUCAP, Nice, France - 6-10 November 2006

14. **Election of COST296 Chairperson**

Alain Bourdillon was elected as the new chairperson after the retirement of Lili Cander who was the current Chairperson.

15. **Preparation of the second COST296 Annual Report**

Material for inclusion in the 2nd COST 296 Annual Report should be sent to AB (Chairman) by 20th May at the latest.

16. **COST296 Budget from 1 July 2006 to 30 June 2007**

A new budget and work plan has been submitted to the COST, TIST and is awaiting approval.

17. **Next joint MC meeting and Workshop of the COST296 Action**

17a. Prof A Bourdillon: Second COST296 Workshop 'Radio Systems and Ionospheric Effects' and 5th MC meeting in Rennes 3-7 October 2006. More information will be posted on the COST296 web site as it becomes available.

17b. Dr J Lastovicka: COST296/IRI Workshop 2007
It is also planned to hold a joint COST296/IRI Workshop in Prague 2007 – more information to come later. IS requested that there be no parallel session scheduled.

There is no MC venue planned for the Spring 2007 to be decided at the next MC, but there is a possibility of a meeting of Working Group Leaders during the EGU in Vienna.

18. **Any other business**

AC requested reimbursement for his attendance at a recent COST284 meeting. MC decided that this matter would be considered after the 2005-06 budget final estimation at the end on June 2006.

ANNEX I

Forth Management Committee meeting of the COST 296 Action

Mitigation of Ionospheric Effects on Radio Systems (MIERS)

DLR Neustrelitz, Park hotel
27 -29 April 2006

Approved Agenda

1. Welcome
2. Approval of the Agenda
3. Adoption of the Minutes of the third MC meeting
4. Official status of the COST296 Action
5. COST296 Budget from 1 July 2005 to 30 June 2006
6. Short Term Scientific Missions (STSMs)
7. Collaboration between COST296 and COST724 actions (general discussion):
    - 7a. Prof. I. Stanislawska: European space weather related web pages
    - 7b. Dr. A. Belehaki: Report from the latest COST724 meetings
    - 7c. Prof. S. Radicela: Report on the ICTP Advanced School on Space Weather
    - 7d. Dr. Lj.R. Cander: Report on European Space weather Week III

Invited talks:

Dr. S. Hawlitschka: "Investigations of the effect of ionospheric heterogeneities on direction finding"

Dr. A. Belehaki: "DIAS: The European System for ionospheric specification and forecasting"

Mr. J. Rueffer: "On the use of ionospheric information in precise positioning and navigation"

Open Discussion

8. Dr. G. De Franceschi: COST296 activities related to the IHY
9. Lj.R. Cander and B. Zolesi: The COST296 Action Year in Review (February 2005 – April 2006)
10. Receipt and adoption of the progress reports of Working Group Leaders
    - WG 1: Ionospheric monitoring and modelling
    - WG 2: Advanced terrestrial systems
    - WG 3: Space based systems
11. COST logo and website
12. Other documents for consideration
13. International meetings relevant for the COST296 Action
14. Election of the COST296 Chairperson
15. Preparation of the second COST296 Annual Report
16. COST296 Budget from 1 July 2006 to 30 June 2007
17. Next joint MC meeting and Workshop of the COST296 Action
    - 17a. Prof. A. Bourdillon: "Second COST296 Workshop and 5th MC meeting in Rennes"
    - 17b. Dr. J. Lastovicka: "COST296/IRI Workshop 2007"
18. Any other business

ANNEX II
COST 296 Action MC meeting 27-29 April 2006
List of Attendees

B Abesser-Rastburg	(BA)	ESA, Noordwijk, Netherlands
D Altadill	(DA)	Observatory de l'Ebre, Roquetes, Spain **(NR)**
J Azevedo	(JA)	University of Madeira, Madeira, Portugal **(NR)**
L W Barclay	(LB)	Lancaster University, UK
A Belehaki	(Abe)	NOA, Athens, Greece **(NR)**
Y Beniguel	(YB)	IEEA, France **(NR)**
P Benzce	(PBE)	Hungarian Academy of Sciences, Sopron, Hungary
A Bourdillon	(AB)	University Rennes 1, France **(Co-Leader WG-2, NR)**
J Boška	(JBO)	Academy of Sciences of Czech Republic, Prague, Czech Republic **(NR)**
P A Bradley	(PB)	Consultant, UK
J Bremer	(JB)	Leibniz-Institute of Atmospheric Physics, Kühlungsborn, Germany **(NR)**
Lj R Cander	(LC)	Rutherford Appleton Laboratory, Chilton, Didcot, UK **(Chairperson, NR)**
A Casimiro	(AC)	University of Algarve, Faro, Portugal **(NR)**
Th Damboldt	(TD)	Consultant, Germany
U Foelsche	(UF)	Karl-Franzens-Universität, Graz, Austria **(NR)**
G De Franceschi	(GD)	Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy
L Ecomomou	(LE)	(Cyprus) **(NR)**
H Haralambous	(HH)	(Cyprus) **(NR)**
N Jakowski	(NJ)	DLR/DFD, Neustrelitz, Germany **(Co-Leader WG-3, NR)**
L Kersley	(LK)	University of Wales, Aberystwyth, UK
S S Kouris	(SK)	Aristotelian University of Thessaloniki, Thessaloniki, Greece **(NR)**
I Kutiev	(IK)	Bulgarian Academy of Sciences, Sofia, Bulgaria **(NR)**
J Laštovička	(JL)	Academy of Sciences of Czech Republic, Prague, Czech Republic **(Co-Leader WG-1, NR)**
J-P Luntama	(J-PL)	Finnish Meteorological Institute, Helsinki, Finland **(NR)**
V Romano	(VR)	Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy
H Rothkaehl	(HR)	Space Research Centre, Warsaw, Poland **(NR)**
I Stanislawska	(IS)	Space Research Centre, Warsaw, Poland **(Co-Leader WG-1, NR)**
S Stankov	(SS)	DLR/DFD, Neustrelitz, Germany
H Strangeways	(HR)	University of Leeds, Leeds, UK
E Tulunay	(ET)	The Middle East Technical University, Ankara, Turkey + TUBITAK-Marmara Research Center, Kocaeli, Turkey **(Co-Leader WG-2, NR)**
Y Tulunay	(YT)	Istanbul Technical University, Istanbul, Turkey **(NR)**
E Turunen	(ETU)	Sodankyla Geophysical Observatory, Finland **(NR)**
A Vernon	(AV)	Rutherford Appleton Laboratory, Chilton, Didcot, UK **(COST296 Secretary)**
M Warrington	(MW)	University of Leicester, Leicester, UK **(NR)**
B Zolesi	(BZ)	Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy **(Vice-Chairman, NR)**

NR: National Representative   IR: Institute Representative

ANNEX III

COST ACTION 296

BUDGET FOR THE PERIOD JULY 1ST 2005 TO JUNE 30TH 2006

(1)	SECRETARIAT	**7500€**
(2)	WORKSHOP and 3rd MC MEETINGS	**30000€**
(3)	4th MC MEETINGS	**20000€**
(4)	SHORT-TERM SCIENTIFIC MISSIONS	**9000€**
(5)	SEMINAR	**6000€**
TOTAL		**72500€**

PUBLICATIONS SEPARATE BUDGET

ANNEX IV

Working Group 1 – Ionospheric Monitoring and Modelling

Leaders : J. Laštovička (CZ) and I. Stanislawska (PL)

WP1.1 Near Earth space plasma monitoring
Leaders: D. Altadill (ES) and R. Stamper (UK – resigned in April 2006)

WP1.2 Data ingestion and assimilation in ionospheric models
Leaders: D. Buresova (CZ) and B. Nava (IT)

WP1.3 Near Earth space plasma modelling and forecasting
Leaders: I. Kutiev (BG) and H. Strangeways (UK)

WP1.4 Climate of the upper atmosphere
Leaders: J. Bremer (GER) and E. Turunen (FIN)

REPORT ON ACTIVITIES OVER THE PERIOD NOVEMBER 2005 – APRIL 2006 - ARRANGED ACCORDING TO THE WORKING PACKAGES AND TERMS OF REFERENCE.

WP1.1 Near Earth space plasma monitoring

Terms of reference:

1. **Developing monitoring techniques and parameters describing the state of the ionospheric plasma, to include ground-based and space based techniques.**

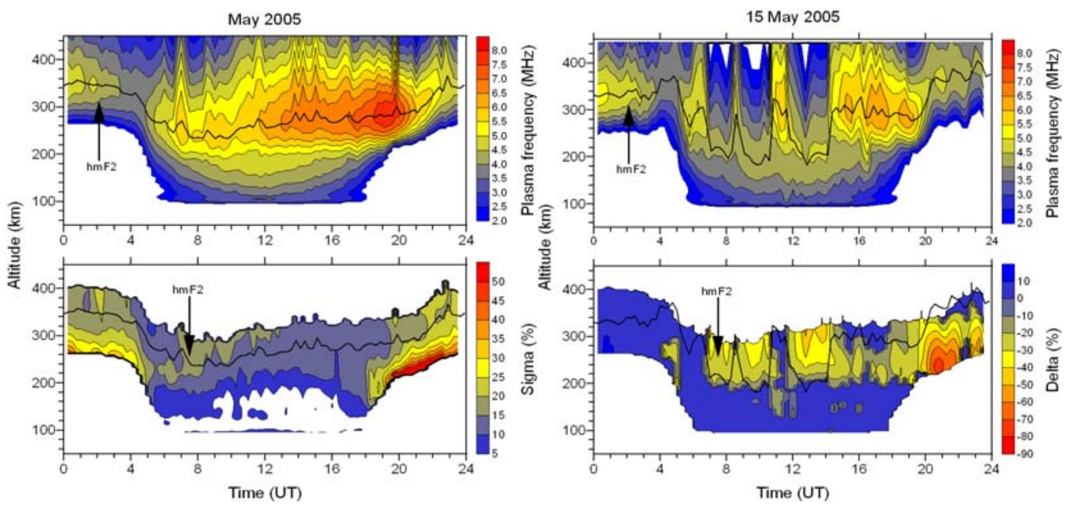
- The Ebro team, in collaboration with Czech and Argentine teams, developed a Local Climatological Model for ionospheric bottomside parameters. The model improves IRI2001 prediction of these by factor of two. Expansion of the model for larger region is under way (Submitted for publication in ASR).

- RWC Warsaw provides 24 hours ahead forecast for European, Asian and Japanese region at maps and at some ionospheric stations.

- In the DIAS project of the eContent program of the EC (Belehaki et al., 2006) an ionospheric activity index has been developed describing the ionospheric disturbance level at different European ionosonde stations. Such an index which is derived on-line from automatically scaled ionosonde observations may also be important for future work within the COST296 project for investigations of ionospheric disturbances in the European COST296 area (Bremer et al., 2005a, 2005b).

- The INGV, Roma started and carried out the eSW project. It is based on measurements performed by all the instruments installed by upper atmosphere group of INGV. The aim is the realization of a hardware-software system for a Data Base (DB) to standardize historical and real time observations for different instruments. An interactive web site supported by a well-organized DB could be a powerful tool for scientific and technological community in the field of telecommunications and Space Weather. The project will last till May 2007. In the first phase the major effort has been focused on the design of hardware and data base architecture. The first two DBs related to the ionosonde and GISTM measurements are going to be completed concerning population, tests and output procedures. The following phase will be dedicated to: all DBs completion, a web user interface realization and a system complete automation. At the end of the project, in May 2007, a dynamic web site will be opened to the community for a real time access to raw and processed data.

- The Ebro team, in collaboration with Technical University of Catalunya and French teams presented a timeline of solar events and a timeline of ionospheric effects corresponding to the geomagnetic storm which occurred on 15 May 2005 to better understand the systems coupling from the Sun to the Atmosphere. Main attention was paid on the variation of the Total Electron Content and the effects in the vertical structure of the Ionosphere. Significant effects (up to more than -20%) are observed at low altitude region (130 – 160 km).



2. Maintaining and extending the flow of real-time and historical vertical incidence and other data to databases.

- All COST296 stations contributed with real-time VI data regularly to WDC for STP, Chilton (RAL), digisondes DIDB, and selected stations to DIAS prototype data bases. Individual stations keep information on their measurements also on their Web pages. Manually revised VI data from Ebro have been regularly sent to DIDB and visible also in graphical form at http://www.obsebre.es/php/ionosfera.php (revised data) and in digital form under request.

- RWC Warsaw makes available daily review about solar, magnetic and ionospheric activity. Ionospheric data (some characteristics) are available from the past 2 months as well.

3. Validating the quality and consistency of data, particularly that collected in real time.

- The Ebro observatory promotes the availability of real-time and revised VI data for comparison validating studies. The data are visible in graphical form at http://www.obsebre.es/php /ionosfera.php, and in digital form under request.

4. Supporting and developing internet sites and protocols for disseminating data products.

- The COST296 ionosonde stations mostly maintain internet accessibility to their VI data and a few to their revised VI data.

- The COST Prompt Ionospheric Database at RAL (http://www.ukssdc.ac.uk/promptdatabase.html) continues to receive, catalogue and archive auto-scaled data on a real time basis from ionospheric sounders across Europe. The full set of contributing instruments now numbers 10 in Europe, at Athens, Chilton, Dourbes, El Arenosillo, Juliusruh, Lycksele, Pruhonice, Rome, Tortosa, and Tromsø.

5. **Organizing observation campaigns to generate more detailed data coverage, in space and/or time.**

- Several COST296 stations performed rapid VI sounding campaign on the occasion of the total Solar Eclipse in March 2006.

Presentations and publications:

Jakowski, N., S.M. Stankov, V. Wilken, D. Altadill, J. Chum, D. Buresova, J. Boska, R. Bamford, L. Cander, R. Stamper; Ionospheric behaviour over Europe during the solar eclipse of 3 October 2005 (solicited); 3rd Gen. Ass. EGU, Symp. ST5.7, Viena, 2006.
Blanch, E., I. Scholl, D. Altadill, J. Aboudarham; Solar and Earth environment observations associated to active region #10759 and its effects; 3rd Gen. Ass. EGU, Symp. ST5.2, Viena, 2006.
Bremer, J., Lj. R. Cander, J. Mielich, and R. Stamper, Derivation of ionospheric activity indices for the European region from online ionosonde observations, 2nd ESWW, ESTEC, Noordwijk, 2005.

Blanch, E., D. Altadill, J. Boska, D. Buresova, and M. Hernandez-Pajares; November 2003 event: effects on Earth ionosphere observed from ground-based ionosonde and GPS data; Ann. Geophysicae, 23, 3027-3034, 2005.
Bianchi, C. and D. Altadill; Ionospheric Doppler measurements By means of HF-Radars techniques; Annals Geophys., 48 , No. 6, 2005 (in press).
Bremer, J., Lj. R. Cander, J. Mielich, and R. Stamper, Derivation and test of ionospheric activity indices from real-time ionosonde observations in the European region, J. Atmos. Solar-Terr. Phys., 2005a (submitted).
Zolesi, B., L. R. Cander, and D. Altadill; From COST 271 to 296 EU actions on ionospheric monitoring and modelling for terrestrial and Earth-space radio systems; Adv. Space Res, 2006 (accepted).

WP1.2 Data ingestion and assimilation in ionospheric models

1. **Determine additional data products for inclusion in the COST271 Action Space Weather Database to improve support for ionospheric modelling; promote the generation of such products, to include manually corrected ionospheric parameters and N(h) profiles covering the entire European region.**

2. **Promote and coordinate the creation of a suitable set of very high quality experimental data (like TEC and ionospheric parameters) for model validation and data ingestion studies.**

- High quality ionospheric parameters and TEC data base is under development (Italy, Spain, and Czech Republic).

3. **Promote and coordinate the creation of a set of "synthetic" data (produced with a model) for assessment of retrieval techniques.**

4. **Select and validate appropriate models and data ingestion and assimilation techniques.**

5. **Improve/develop real-time or near-real-time electron density reconstruction techniques.**

- Results of the joint measurements of the Digisonde Portable Sounder (DPS-4) and new Doppler type carried out at Pruhonice ionospheric are being evaluating continuously. To compare digisonde measurements with the Doppler data during the days when Es layer is well-developed, a phase path is calculated from both Doppler and digisonde records. Sufficient discrepancies have been observed for periods with presence of a strong Es layer. The discrepancies could be related to the uncertainties of the observational inputs and to the interpretation of the digisonde data.

- The German Aerospace Center (DLR) operates a system for regularly processing space based measurement data and for reconstructing the electron density distribution in the Earth's ionosphere/plasmasphere system utilizing the ionospheric radio occultation (IRO) technique. To facilitate the topside electron density reconstruction, and to advance the knowledge of the processes in the topside ionosphere region in general, a new method of retrieving the topside ionospheric scale height based on IRO observations onboard low-earth-orbiting (LEO) satellites has been developed.

6. Identify criteria to be used to validate the data ingestion and assimilation techniques.

7. To carry out specific studies on the use of the selected data ingestion techniques in order to improve the models formulation (structure) and applicability under different degrees of disturbance of the ionosphere.

- The ionospheric scale height, being dependent on ion/electron temperatures and masses, understandably experiences large spatial and temporal variability. However, based on data accumulated from the CHAMP satellite mission, the global scale height behaviour has been well analysed and a preliminary model of the ionospheric scale height value at 425 km altitude has been developed. The standard model inputs are the local time, latitude, and season. In this way, the model can directly be implemented into iterative retrieval procedure by delivering an improved initial guess.

- The work on verifying IRI 2001 empirical model capability to reproduce main ionospheric parameters and N(h) profile under quiet and disturbed conditions is continued. Present analysis shows that IRI model calculations are in worse agreement with observations especially during daytime hours at the ionospheric heights from 200 to 400km. The IRI 2001 model has still large discrepancies for ionospheric F region bottomside parameters B0, B1 and D1, probably due to the present tabular form of these parameters. Tests are continued. The local model (LM) based on a least-square fitting to a harmonic function that simulates the diurnal, semidiurnal and seasonal variations according to different levels of solar activity has been created for Ebro station. The Monthly Averaged Representative Profile (MARP) has been used to obtain the parameters B0, B1 and D1 for quiet ionospheric conditions. The method used improves the linear coefficient of determination between the expected and IRI-predicted parameters by factor of two. The main advantage of the LM is better representation of the annual variation of the daily pattern of lower F region parameters B0, B1 and D1 for all levels of solar activity. The LM depends on a single parameter (Rz12), what yields easy to update and to extend to larger geographical region. Adaptation of LM for other stations is under development. The disagreement between IRI 2001 model calculations and measured values increases mainly under disturbed conditions. Phase prediction (positive or negative) is under development.

Publications and presentations:

Nava, B., Radicella, S. M., Leitinger, R., Coïsson, P.: A near real time model assisted ionosphere electron density retrieval method, *Radio Sci.,* (accepted), 2006.

Blanch, E., D. Arrazola, D. Altadill, D. Buresova, and M. Mosert: Improvement of IRI B0, B1 and D1 at mid-latitude using MARP, *Adv. Space Res*, 2005 (submitted).
D. Buresova, V. Krasnov, Ya., Drobzheva, J. Lastovicka, J.Chum, and F. Hruska: The method of the ionogram interpretation quality estimation using HF Doppler technique, *Ann. Geophysicae*, 2005 (submitted).
Stankov, S.M., N. Jakowski (2006): Topside ionospheric scale height analysis and modelling based on radio occultation measurements. J. Atmos. Solar-Terr. Phys., 68, No.2, 134-162, 2006.

Nava, B., Radicella, S.M., Leitinger, R., Coisson, P.: A possible way to update ITU-R maps of foF2, EGU, Vienna, 2006.
Coïsson, P., Radicella, S. M., Nava, B., Leitinger, R.: Low Latitudes topside in NeQuick, EGU, Vienna, 2006.

WP1.3 Near Earth space plasma modelling and forecasting

1. **List the available forecasting models and classify them by lead-time: warning, nowcasting and forecasting**

2. **Develop common rules for error estimates and testing procedures**

3. **Develop techniques for real-time forecasting (data adjustment)**

- The Middle East Technical University Neural Network (METU NN) model have proven the power of forecasting the parameters of a non-linear process in our previous WG Reports. In particular, we have presented the forecast TEC values and the maps based on such results [1]. Since then the METU NN and Cascade Modeling (METU-NN-C) technique based on the Hammerstein Model have been employed to forecast TEC grid values. The use of the Bezier surfaces in mapping the forecast grid values is also included. The results of the METU NN TEC Model are compared with those of the METU-NN-C results. In particular, for this task we have chosen the space weather events in November 2003. The average absolute error in "1 hour forecast" mapping of the TEC values is found to be 1.50 TEC units (TECU). When compared with the METU-NN Model this error value is about 10% smaller. In addition, there are some structural advantages in the design and operation of the METU NN-C (E. Tulunay et al.).

- Adopting the autocorrelation method in the ionospheric forecasting, we put forward a simple forecasting method — the sectional autocorrelation method, that is, for predictions of one hour to four hours ahead the autocorrelation coefficient of RDF with the "iteration" method is selected, for prediction of more than four hours ahead, the autocorrelation coefficient of *f0F2* with the "at once" method is used. The prediction precisions have been quantitatively estimated based on the data from Chongqing and Guangzhou Ionosonde Stations. The method improves much the predictions for one hour to four hours ahead. For the predictions of more than four hours ahead the prediction error reaches a saturation value, which is still lower than that of the "median" method. This new method could be applied to the short-term forecasting of other ionospheric parameters (Ruiyuan et al.).

4. **Improve the existing and develop new space plasma models**

- The DLR established an operational space-plasma and space-weather monitoring service within the comprehensive project SWACI - Space Weather Applications Center Ionosphere (http://www.kn.nz.dlr.de/swaci). Within this project, several nowcast and forecast products are being developed: Total Electron Content (TEC) maps, spatial and temporal TEC gradient maps, etc. A recent development is the 3-dimensional reconstruction of the electron density distribution in the Earth's ionosphere/plasmasphere system. The reconstruction is based on ionospheric radio occultation data from the low-earth orbiting (LEO) satellite CHAMP. In addition to being used for space weather monitoring, such global reconstruction can serve also as a valuable verification tool helping the near earth plasma modeling efforts.

5. Unify geomagnetic drivers for forecasting models (Dst, Kp, Ap)

6. Prediction of geomagnetic indices

7. Forecasting of foF2 and TEC

- A prediction procedure of the hourly values of the critical frequency of the F2 ionospheric layer, foF2, based on the utilisation of a geomagnetic index, is presented. There is used a time-weighted accumulation magnetic index *ap(τ)* based on recent past history of the geomagnetic planetary index *a*p.

- An empirical relationship between the ratio *log(NmF2(t)/ NmF2M)*, where *NmF2(t)* is the hourly maximum electron density at the F2 peak layer and *NmF2M* is its 'quiet' value, and *ap(τ)* is applied. Geomagnetic storms with a maximum of $ap \geq 132$, classified as strong events, are selected between 1996 to 2001. The prediction of foF2 is calculated during periods of severe magnetic activity in 2001 in Rome (41.9° N; 12.5° E) observatory. The results are satisfactory obtaining r.m.s values, for the cases analysed, between 0.74-2.14. Where r.m.s. values are calculated considering the foF2 forecasted and the foF2 observed values. (Perrone et al.)

- Method for TEC map construction useful particularly for day/night transition, trough and substorms is under development (Swiatek et al.).

- Construction of the spatial interpolation method of ionospheric Ne in order to obtain 3-dimensional maps is continuously improved. Further tests at different heights and for different ionospheric characteristics (hmF2) are provided (Stanislawska et al.).

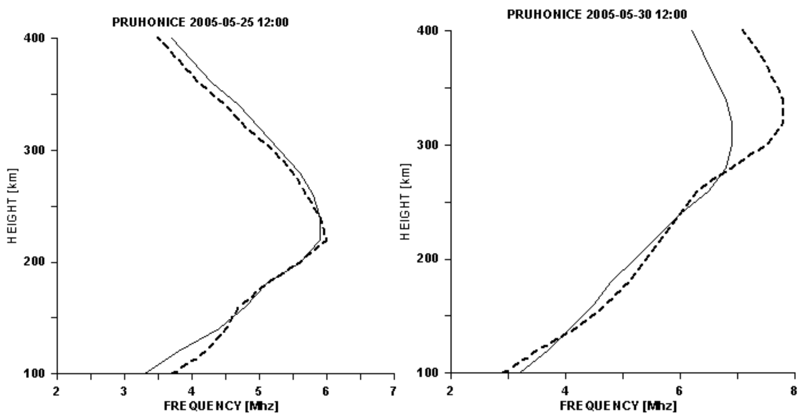
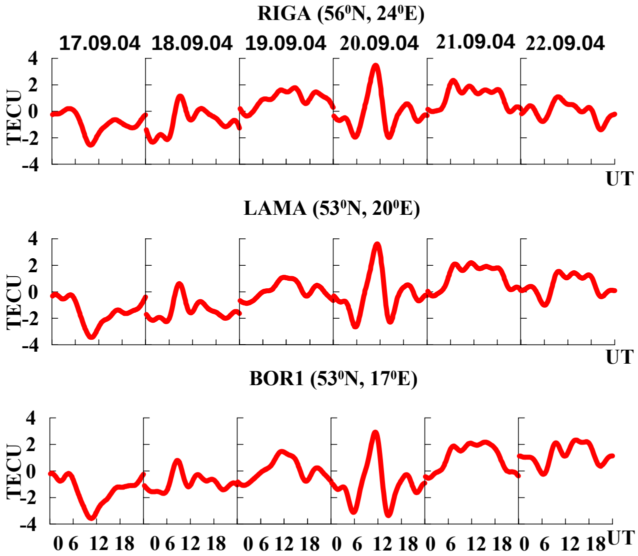


Figure - comparison of measurements (full line) and modeled values (dotted line) for Pruhonice station for 12 UT for two days: quiet 25.05.2005 and disturbed 30.05.2005.

8. Modelling and predicting different scale ionospheric perturbations

- GPS data from the IGS network were used to study the development of TEC fluctuations at high-latitude ionosphere. GPS observations covering the auroral and polar ionosphere were made to investigate the occurrence of TEC fluctuations dependent upon geomagnetic activity (Krankowski et al.).

Figure: Left - ΔTEC over RIGA, LAMA and BOR1 stations from 17th to 22nd September 2004.



- Deep TEC fluctuations associated with polar patches are regularly detected in phase measurements along individual GPS satellite passes at Antarctic stations. The intensity of patch structures increased during geomagnetic disturbances and TEC fluctuations during the storm reached 10-40 TECU (Krankowski et al.).

9. Tomographic imaging for model validation

- The Radio and Space Physics group of the University of Wales Aberystwyth are studying the large-scale density enhancements of the high-latitude region on horizontal scales of tens to hundreds of kilometres, and the associated steep gradients that may develop at their edges. Of particular recent interest is the tongue-of-ionisation (TOI) that comprises a ridge of dayside plasma drawn antisunward into the polar region by the convection driven by the solar wind. Runs of the Sheffield University Coupled Thermosphere Ionosphere Plasmasphere model predict that in winter the feature is most prominent when Europe is in the night-side sector, with ionisation being transported from the dayside, through the polar region and into the auroral oval. Experimental evidence for night-side plasma arising from the TOI has been obtained from the UWA radio tomography experiment in northern Scandinavia, supported by observations by the EISCAT Svalbard Radar and the SuperDARN radar facilities. Case studies demonstrated that polar enhancements were reconfigured on flowing into the auroral region, becoming latitudinally-confined, but longitudinally-extended features at the equatorward edge of the evening auroral oval, confirming earlier modelling work on a possible origin of the boundary blob surmounting the poleward wall of the trough. (Pryse et al.)

10. Channel modeling by neurofuzzy and other novel techniques

- The final purpose of our research project is to design and implement an HF communication system. But we are attacking the problem from the very beginning. First of all, we want to model the ionospheric channel in order to get an efficient forecast system that allows optimisation of the HF communication channel. With this objective, we are involved in modelling and short-term prediction of the F2-region ionospheric parameters foF2 and hmF2. We are applying neurofuzzy techniques and this is the main novelty of our study. The natural capability that neurofuzzy systems have to model highly non-linear systems, like the ionosphere, is well known and thus we hope to obtain good results. The method has been tested under quiet and moderate geomagnetic conditions providing foF2 forecasts (1-24 hours in advance) with relative mean deviation between 5-11%. The final purpose will be to check the efficiency of neurofuzzy modelling during disturbed geomagnetic periods in order to develop a foF2 prediction tool that could be applied to ionospheric communications. (Mélida et al.)

11. Modelling of irregularities for propagation predictions and from inversion of propagation data

- The pattern of the changes in TEC during the Baltic Sea earthquake was analysed using GPS permanent observations from the EUREF permanent GPS network. The seismo-ionospheric perturbations were detected one day before the earthquake. The anomaly had a positive sign with TEC enhancement of about 4 TECU (it is 20-25% relative to a normal non-perturbed state of the ionosphere). The duration, size and local character of this anomaly can be associated with the seismo-ionosheric precursor.
- The evolution of diurnal variations of TEC over different European stations displays anomalous behavior of diurnal TEC variations on 20 September 2004 over all observed stations. This anomaly took place about 11 UT with TEC enhancement. Such site-specific behavior of TEC was not observed 10 days before and 10 days after the earthquake (Krankowski et al.).

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WP1.4 Climate of the upper atmosphere

1. Derivation of long-term trends in different ionospheric/atmospheric parameters and different height regions to get hints about their origin (greenhouse effect, geomagnetic influence, or other sources)

- A first scenario of global change in the upper atmosphere at heights above 50 km, i.e. in the mesosphere, thermosphere and ionosphere, has been constructed. The known potential drivers of upper atmospheric long-term global change include increasing concentrations of greenhouse gases (CO2, CH4 and others), anthropogenic changes of the ozone layer, and natural long-term variations of geomagnetic activity, which increased throughout the 20th century. For most (if not all) parameters, the dominant driver of long-term change in the last 3-4 decades is, directly or indirectly, increasing greenhouse forcing. The observed temperature decline in the mesosphere and lower thermosphere, and the positive electron density trends in the lower ionosphere are qualitatively consistent with thermal contraction of the mesosphere. Trends in the ionospheric E and F1 region parameters, in ion temperature near 350 km and average F-region temperature, and in thermospheric densities between 200 and 800 km, are also qualitatively consistent with the expected effect of greenhouse cooling and contraction of the upper atmosphere. The predominant trends in the observed F2 region peak parameters are also qualitatively consistent with the greenhouse effect, but they may also be explained by changes in geomagnetic activity. Data collected during the next several years should help resolve these two sources, which are no longer acting in the same direction (Laštovička et al., 2006b).

- The investigation of trends in the lower ionosphere/mesosphere has been continued using LF-phase height observations at Central Europe between 1959 and 2005. Here some indications of a connection with trends in the total ozone content at mid-latitudes have been found. More detailed results will be presented at the next COST296 workshop.

2. **Detection of signatures of different atmospheric waves (e.g. gravity, planetary and infrasonic), the investigation of their propagation through the atmosphere/ionosphere, and the search for possible predictability of their effects on the ionosphere.**

- Wavy phenomena during the solar eclipses of 11 August 1999 (Šauli et al., 2006a) and of 3 October 2005 were analyzed (Jakowski et al., 2006).

- Investigations of ionospheric effects of infrasound continued – a solicited paper was presented at the EGU Assembly, Vienna, April 2006 (Chum et al., 2006).

- A new method of separation of ionospheric drifts measured by digisonde in the E and F regions was introduced and first results were presented at the EGU Assembly, Vienna, April 2006 (Boška et al., 2006).

3. **Investigation of ionospheric variability at middle as well as high latitudes (influence of precipitating high energy particles on the ionised and neutral part of the atmosphere).**

- F2-layer disturbances (global morphology and physical mechanisms) which are not related to geomagnetic activity (Q-disturbances) but have their origin presumably in the lower atmosphere have been investigated by Mikhailov et al. (a morphological study using all available foF2 observations over 26 Northern Hemisphere ionosonde stations). The most important results are as follows:
(a) Analysis has revealed both positive and negative Q-disturbances, their amplitude being comparable to moderate F2-layer storm effects resulted from increased geomagnetic activity.
(b) Positive disturbances are more numerous than negative ones at all latitudes and at any level of solar activity. Both types of Q-disturbances are more numerous (twice) during solar minimum. The percentage of long duration Q-disturbances increases with latitude.
(c) Both types of disturbances are most frequent in the evening and night-early-morning LT sectors and they are rare during daytime.
(d) Winter season (Nov-Jan) is the most preferable for negative Q-disturbances. The occurrence probability is small for other seasons. The seasonal variation pattern for positive Q-disturbance is less systematic.
(e) Spatial variation pattern is different for positive and negative Q-disturbances. The amplitude of positive disturbance increases with latitude while it is almost latitudinal independent for negative perturbations. Longitudinal variation looks like a planetary wave with the minimal deviations in the American and the maximal deviations in the European sectors. Large longitudinal gradients in NmF2 are related with the front of such waves.

- The derivation of climatology of disturbances in the ionosphere and plasmasphere is in progress by the group of S. Kouris.

- The Ebro team evaluated the daily, seasonal and long-term patterns of the standard deviation $\sigma(h)$ of the electron density profiles N(h) recorded above Ebro station. The percentage of $\sigma(h)$ vs. typical profile under quiet conditions shows that the larger variability occurs during night-time, as expected, but there being much better expressed at the base of the *F*-region, the latter having clear local time dependence. Typical values of percentage of variability at altitudes of the electron density maximum are 10–20%, whereas they can be as large as 50% during night-time at the base of the *F*-region. The systematic daily, seasonal and long-term behaviors of $\sigma(h)$

are discussed in terms of potential modeling purposes. This would be of interest for model users who, in addition to know the typical behavior of the ionosphere (ionospheric models), they also needs the expected deviations from it (variability models).

4. Incoherent radar observations and model calculations for investigations of the coupling between the ionized and neutral part of the atmosphere for quiet and disturbed conditions.

- Coupling of ionised and neutral atmosphere during high ionisation events was studied during selected solar proton events using the coupled ion-neutral chemistry model SIC (Sodankyla Ion Chemistry model). Model approach was validated and compared with experimental data from EISCAT incoherent scatter radar, VLF propagation experiments and satellite observations of the neutral minor constituents by the GOMOS instrument.

- Quantifications of production of odd nitrogen and odd hydrogen, as well as consequent reduction of ozone were presented.

5. Space weather impacts on the midlatitude ionosphere.

- Investigation of various special phenomena, like pre-storm enhancements, is progressing in the IAP Prague.

- The global time varying picture of the ionospheric trough was constructed on the base of the sequence of HF waves spectra registered in the top-side ionosphere(description of physical processes) as well as TEC (general environmental information) and VI measurements (time evolution) (Rothkaehl et al.).

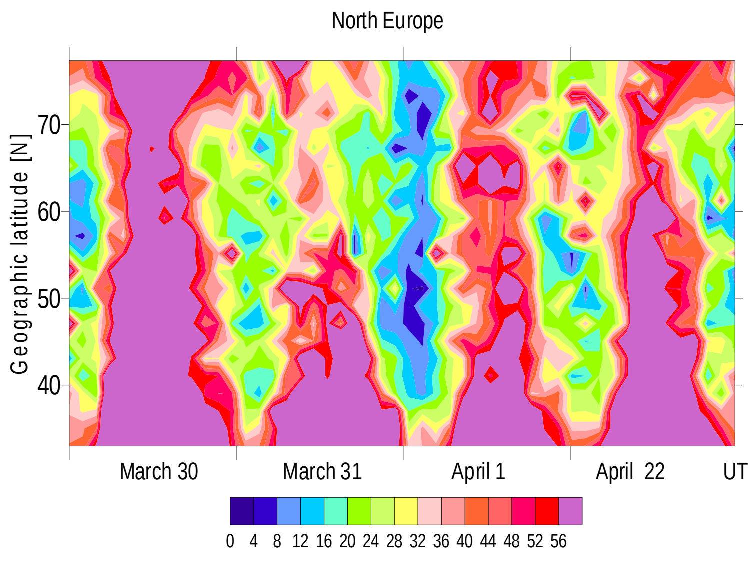

Figure - latitudinal variations of TEC for March 30 – April 2, 2001 at longitude of ~20ºE.

- In Europe the presence of both phases of ionospheric storm is rather common, more frequent in winter and at lower latitudes. Only negative phase is more frequent in summer. Only positive storm phase appears rarely, more at lower latitudes.

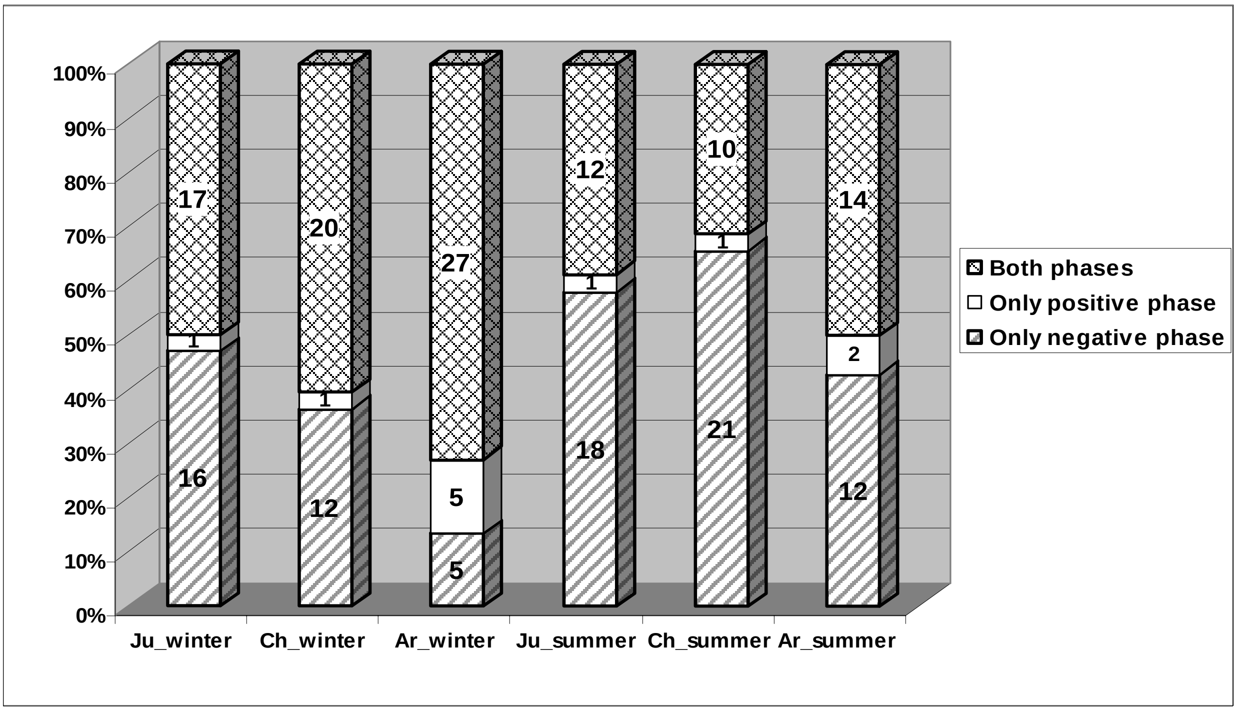

Figure - occurrence of negative and positive phases during geomagnetic storm main phase above three European stations Juliusruh, Chilton and El Arenosillo for winter and summer half of the year for the period 1995-2005, 65 strong-to-severe geomagnetic storms.

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PROGRESS REPORT
Presented at the 4th MCM, Neustrelitz

Working Group 2 - Advanced terrestrial systems
Leaders: Prof A. Bourdillon and Prof E. Tulunay

WP2.1 - Radar and radiolocation
Leaders: Dr C. Bianchi and Dr E.M. Warrington

1. ***Hot clutter modelling for surface wave radar: existing hot clutter models will be evaluated and a new model may be proposed. Models will be validated with the measurements from a basic surface wave set-up. Experimental set-up will be designed and implemented***

2. ***Frequency management of ground-wave and sky-wave radars***

3. ***Angle of arrival measurements for sky-wave signals***

Measurements campaigns have been carried out during the 2005 year. While the use of a heterogeneous antenna array is tied to the antennas responses, we are investigating some solutions to verify or to correct these responses. Whereas an electromagnetic calibration is difficult to achieve, a passive method to estimate some discrepancies between models and measurements is applied to our different arrays. Beforehand, estimated angles of arrival, in the particular case of an incoming carrier of an AM broadcast transmitter, allow comparing the amplitudes and phases of received signals to those expected by the theoretical responses. The aim of this kind of calibration is to identify within a receiving array: inhomogeneous ground effects, antenna misalignments. Correcting errors both in homogeneous or heterogeneous arrays can be provided with a direction of arrival dependence.

L. Bertel, G. Le Bouter, D. Lemur, F. Marie and M. Oger

4. ***Propagation effects that influence radar and radiolocation systems***

4.1 In recent years, considerable progress made in modelling the propagation mechanisms resulting in off-great circle propagation over northerly paths (such mechanisms often result in deviations of up to 100° from the great circle direction). Further work has commenced directed towards:

(a) Making additional measurements along the trough to investigate differences in the propagation characteristics between solar maximum and solar minimum. A new DF receiver will be installed at the Leicester field site in May 2006 and measurements will then be made for at least a year over paths from Uppsala and St Petersburg to Leicester.

(b) Further development of ionospheric ray-tracing techniques for the northerly ionosphere, in particular to include methods for the prediction of the channel scattering function (delay and Doppler dispersions).

The northerly ionosphere is a dynamic propagation medium that causes HF signals reflected from this region to exhibit delay and Doppler shifts and spreads which significantly exceed those observed over mid-latitude paths. Since the ionosphere is not perfectly horizontally stratified, the signals associated with each propagation mode may arrive at the receiver over a range of angles in both azimuth and elevation. Such large directional spreads may have severe impact on radio systems employing multi-element antenna arrays and associated signal processing techniques since the signal environment is not comprised of a small number of specular components often assumed by the processing algorithms. In order to better understand the directional characteristics of HF signals reflected from the northerly ionosphere, prolonged measurements have recently been made over two paths: (a) from Svalbard to Kiruna, Sweden, and (b) from Kirkenes, Norway to Kiruna. An analysis of these data has been undertaken and the directional characteristics summarised. Consideration has been given to modelling the propagation effects in the form of a channel simulator suitable for the testing of new equipment and processing algorithms. This work has now been reported in *Radio Science* [Warrington *et al*, 2006].

E.M. Warrington, A.J. Stocker, D.R. Siddle and N.Y. Zaalov

4.2 Real time HF raytracing through a tilted ionosphere

High frequency (HF) direction finding (DF) systems measure the angles of arrival of signals at selected frequencies. With this information, raytracing can accurately determine the location of the HF transmitters if the 3-D electron density (Ne) distribution between the DF site and the transmitters is known. The usual approach is to use an ionospheric model like the International Reference Ionosphere (IRI) as a proxy for the density distribution. We describe a more realistic approach developed in cooperation with Codem Systems in Merrimack, NH. A collocated digisonde at the DF site measures the vertical electron density profile and the local ionospheric tilt providing, in real time, the inputs for the construction of the 3-D Ne distribution. The vertical profile is automatically obtained from the ARTIST-scaled ionogram, and the local tilt from the skymaps recorded after each ionogram. The characteristics of each layer, e.g., critical frequencies and peak heights, are expressed as a function of latitude l and longitude y. In the neighborhood of the DF site each characteristic, e.g., foF2, is given as:

$$foF2(l, Y) = foF2m(1+C_7 Dl+C_8 DY)\,(1+C_l Dl+C_Y DY)$$

The coefficients C_7 and C_8 for any given azimuth direction are determined with the use of the URSI/CCIR coefficients (that are also used in IRI), and the calculation of C_l and C_y makes use of the measured ionospheric tilt data; *foF2m* is the local, measured foF2 value. When the measured density profile and tilt data are available, the derived 3-D density distribution represents the instantaneous ionosphere structure near the site. The numerical raytracing includes the effects of the magnetic field and properly treats the spitze effect making the raytracing program especially useful for small distances. Raytracing through simulated tilts shows that the differences in ground distances for one hop high frequency (HF) propagation vary from about 1 km to 100 km depending on the assumed tilts and distances. Operational tests for distances up to approximately 100 km have demonstrated good results in determining the transmitter location in real time, and have illustrated the importance of using the actual ionospheric profiles and tilts in the raytracing.

Xueqin Huang and Bodo W. Reinisch

4.3 Performing inversion of HF radar backscatter ionograms

Ph. D. Student: Eulalia Benito (ONERA)
Thesis advisor: Alain Bourdillon (Université de Rennes 1)
Supervisor: Stéphane Saillant (ONERA)

A backscatter radar system is an oblique HF radar where the transmitted wave is reflected from the ionosphere, scattered from the ground and returned via the ionosphere to the receiver.

These radars need a real time acknowledgement of the ionospheric characteristics in order to fit the frequencies on the focus area and to localize the targets accurately. In fact, the distance covered by the wave is a function of the ionospheric characteristics, the emission frequency and the elevation angle.

Our purpose is to determinate the ionospheric characteristics from radar backscatter ionograms with an inversion technique.

A backscatter ionogram is the result of one elevation-scan backscatter sounding. The backscatter ionograms displays the propagation time (T_g, or group path, the path is equivalent to the propagation time) as a function of elevation angle (E). The ionogram also indicates the relative signal level received back. So the ionogram is a three-dimensional figure representing propagation delay, elevation angle and signal level (see Figure 1).

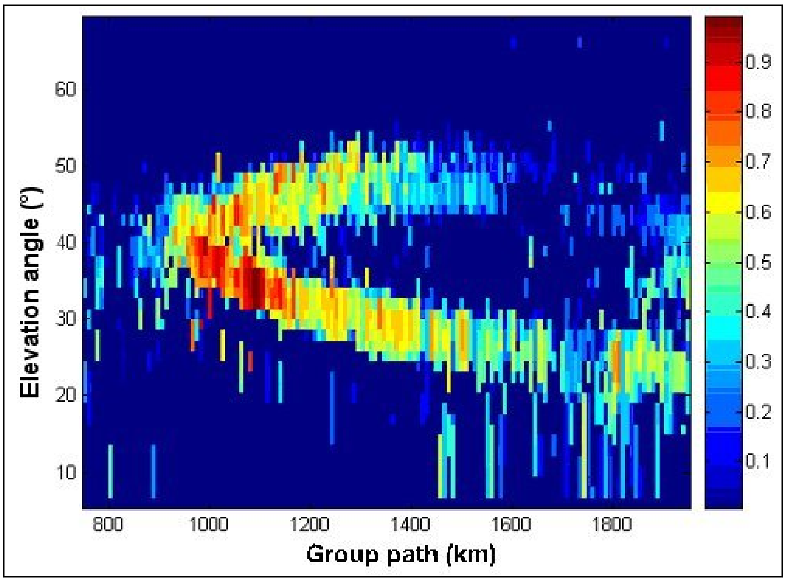

Figure 1 : Elevation-scan backscatter ionogram.

We will use the elevation-scan backscatter soundings to estimate the ionospheric characteristics because they are feasible with the HF radar NOSTRADAMUS at ONERA and because it can cover 360° in azimuth.

The ionospheric characteristics are three parameters for each layer of the ionosphere. They are:

- f_c: critical frequency of the layer
- h_m: value of h (distance from the surface of earth) at which the electron density is maximum.
- y_m: semi thickness of the layer

The model of the ionosphere used for the inversion method is the Multi Quasi-parabolic layer model. This model has been used because it allows a simple analytical solution for the propagation equations (see figure 2).

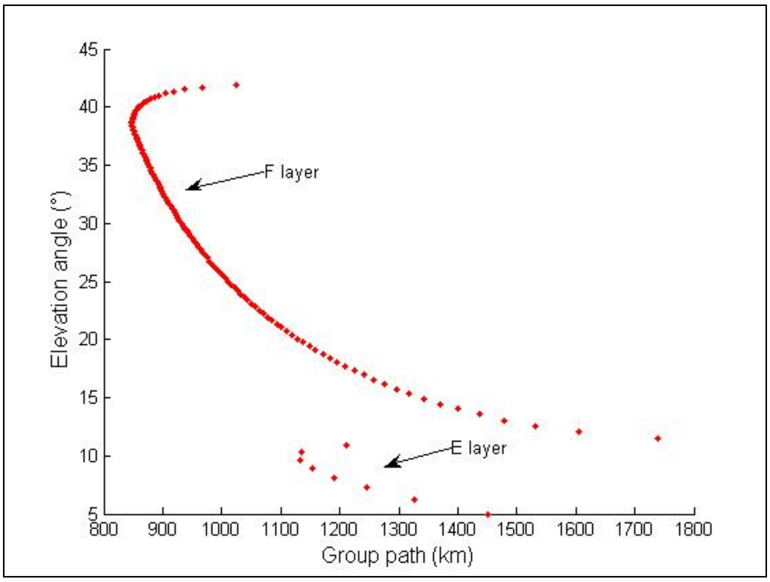

Figure 2 : Elevation-scan backscatter ionogram simulated.

The problem is that the ionogram don't show the echoes corresponding to the lowest layers of the ionosphere (E layer) due to the antenna beamwidth. So we will estimate the ionospheric characteristics (f_c, h_m, y_m) of the upper layers (F layer) and we will use the ionospheric forecasts to complete the model.

Inversion technique

The purpose is to recover the initial model parameters (f_c, h_m, y_m) from three points of the ionogram. The algorithm used to invert the data consists of the following steps:

1. The first step is to record the coordinates of three points in the elevation-group path plane (T_{exp1}, T_{exp2}, T_{exp3}) at three fixed elevation angles (E_{ref1}, E_{ref2}, E_{ref3}).
2. The second step is to simulate the elevation-group path curve (see Figure 2) using a parametric model of the ionosphere, in order to obtain the coordinates of the three group paths (T_{ref1}, T_{ref2}, T_{ref3}) corresponding to the three fixed elevation angles, as functions of the parameters of the electron density profile f_c, h_m and y_m.
3. The third step is to compute the *a posteriori* probability density σ_p over a grid of points sampling the parameter space (f_c, h_m, y_m), for three given pairs of experimental values, using equation:

$$\sigma_p(f_c,h_m,y_m)=\exp\left[-\frac{1}{2}\left(\frac{T_{\exp 1}-T_{ref1}(f_c,h_m,y_m)}{\delta T_{\exp 1}}\right)^2\right]\cdot\exp\left[-\frac{1}{2}\left(\frac{T_{\exp 2}-T_{ref2}(f_c,h_m,y_m)}{\delta T_{\exp 2}}\right)^2\right]\cdot$$
$$\cdot\exp\left[-\frac{1}{2}\left(\frac{T_{\exp 3}-T_{ref3}(f_c,h_m,y_m)}{\delta T_{\exp 3}}\right)^2\right]$$

where δT_{exp1}, δT_{exp2}, et δT_{exp3} represent the variances of the measurement errors over T_{exp1}, T_{exp1} and T_{exp1}, which are presumed to be Gaussian and independent.

4. The last step is to identify the maximum value of σ_p and record it as the solution of the inverse problem.

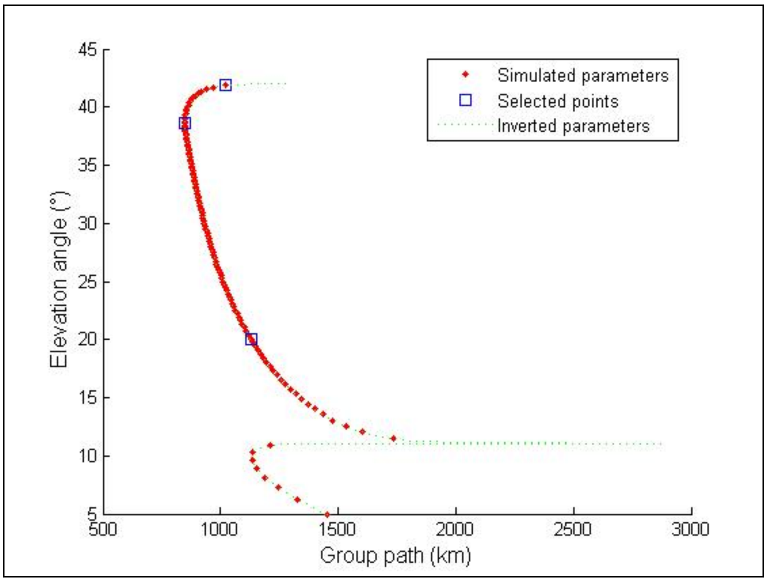

Figure 3 : Group path-elevation angle curve simulated with the true parameters and the inverted parameters.

5. The effects of environmental noise on HF radar systems

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Work Package 2.2 - HF/MF communications
Leaders: Prof. Dr. J. M. Andujar and Dr P. Lassudrie-Duchesne

The main contributions fitted within the terms of reference of this work package, as well as the list of published and submitted papers and presented ones at meetings, are listed as follows:

1. ***Digital radio systems – predictions, methods of estimating reliability: experimental studies concerning channel reliability by using existing experimental set-up complied with ITU standards will be conducted in cooperation with University of Leicester, UK.***

   As it was agreed during the previous COST 296 MCM, a technical campaign will be conducted between UK and Turkey with the objective of studying the High Frequency (HF) Channel Characterization between UK and Turkey during the total solar eclipse of 29 March 2006. Thus a contribution will be made to HF operators in real life applications.

   A formal short-term scientific mission planned between UK and Turkey will be provided as soon as possible with the following details:

   Road Map:

   1. Mr. Murat Özgür Sarı (MOS) will visit Prof. Mike Warringhton and his Group in order to facilitate the followings
      1.1. Parameters suitable for channel characterization will be specified
      1.2. Transmitter and receiver will be programmed in accordance with 1.1.
   2. Mid-inospheric station under the total eclipse part will be specified and contact will start in establishing the relavant data and information
   3. Preliminary experiments will start before March 2006 between Leicester and Istanbul in collabiration with TUBITAK MRC and METU.
   4. The actual total eclipse experiment will be realised during the week of 29 March 2006.

   STSM Hosts: Prof. Dr. M. Warrington, Leicester University, UK, and Prof. Dr. Lj. Cander, RAL, Didcot, UK

   Budget Request: Round trip travel between Ankara and Leicester and subsistance for 10 days: 1300 € (amount for travel: 500€ ; amount for subsistence: 800€).

2. ***Wideband propagation modelling and development of a hardware simulator***

   The Dr. Angling's contribution (Centre for RF Propagation and Atmospheric Research, Marvern, UK) concerning this term of reference can be resumed as follows:

   XIPPT
   An IDL GUI (XIPPT) has been developed to demonstrate the use of EDAM predictions. XIPPT provides an interface to QinetiQ's Integrated Propagation Prediction Tool (IPPT) and allows a user to access IPPT's propagation models (Figure 1). Furthermore XIPPT embodies a scheduler that will download EDAM output from an FTP server at set times and call IPPT to perform

propagation predictions. IPPT itself has been modified to detect and use the EDAM output if it is present in the IPPT working directory. The aim of this software is to be sufficiently flexible that it can provide a realistic test of the EDAM output, and to be reasonably close to how an operational tool may look, whilst remaining simple enough to demonstrate and place with potential users without extensive training.

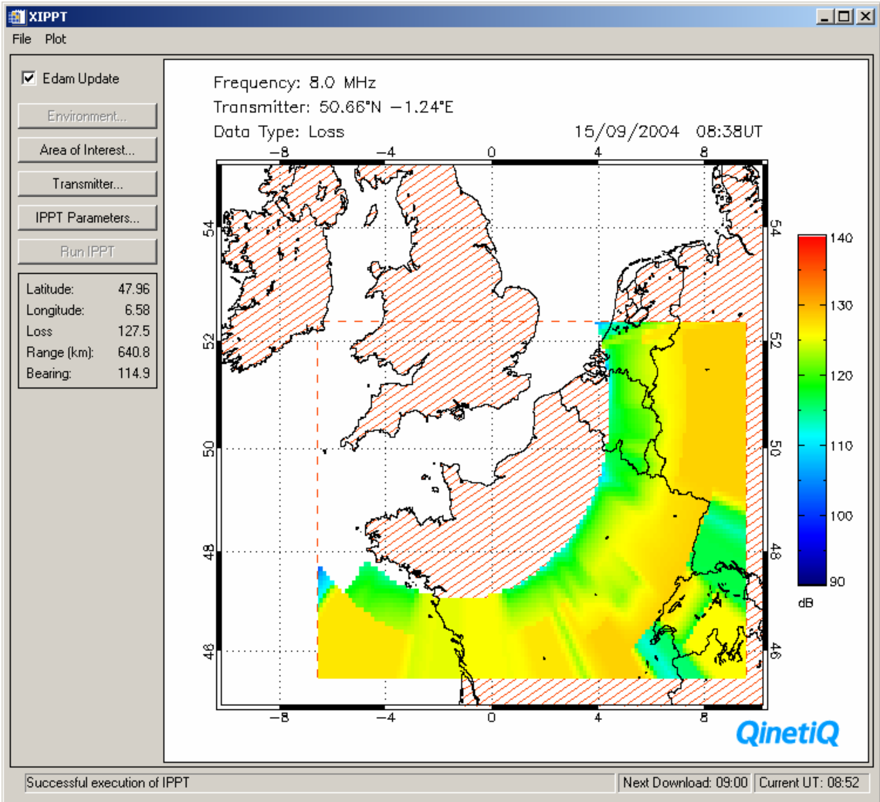

Figure 1: Screengrab of XIPPT showing an HF loss prediction using EDAM output.

TEMPLAR

The Tactical Enhanced Muf Prediction for the Local ARea (TEMPLAR) has also been developed. The tool is based on EDAM and exploits a single GPS receiver to provide a local area (up to 700 km) now-cast of the maximum usable frequency for HF communications operators (Figure 2). Results indicate that the TEMPLAR MUF estimates are susceptible to bias caused by variations in the ionospheric slab thickness (Figure 3). Whilst this can be mitigated by modifying the background model to account for seasonal effects, it is likely that vertical structure information will be required to provide the highest accuracy results.

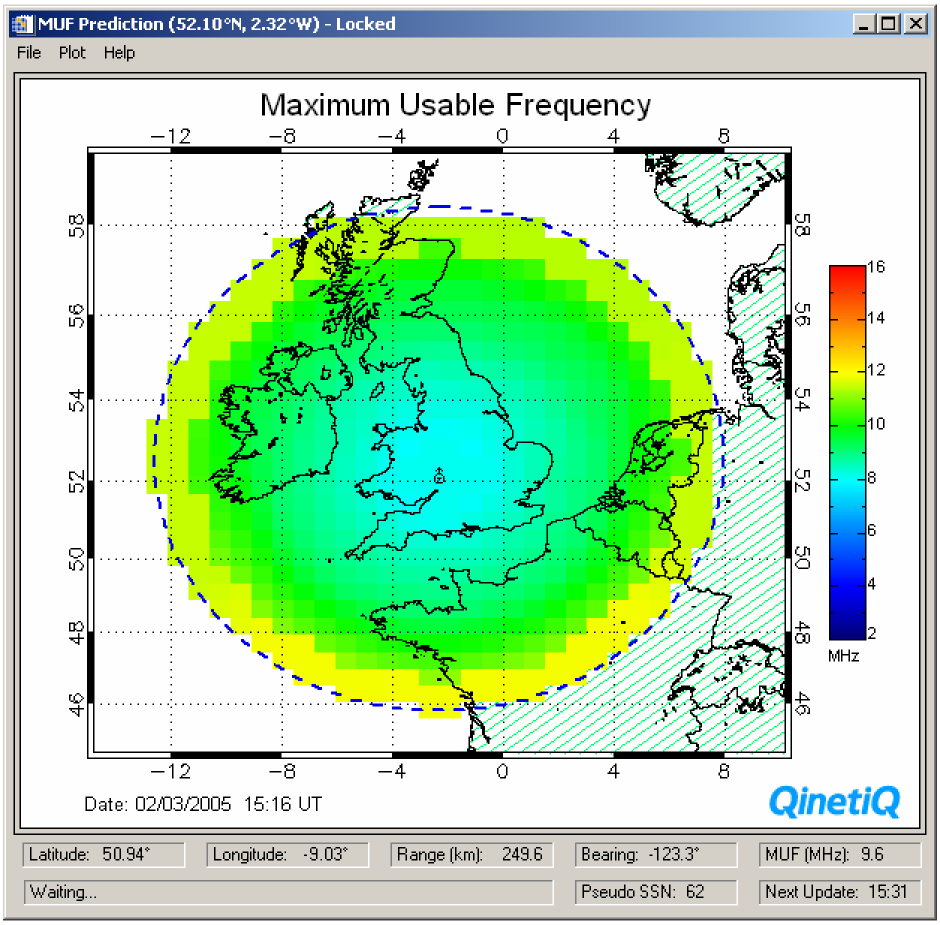

Figure 2: Example TEMPLAR output showing colour coded MUF from a station in Malvern.

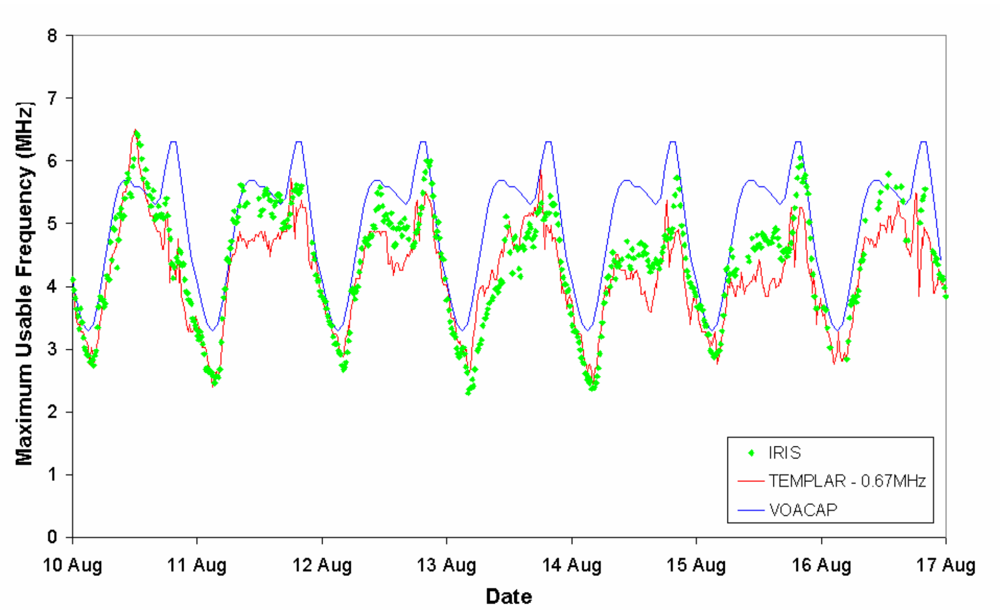

Figure 3: Measured (IRIS) and estimated (TEMPLAR) maximum usable frequency between Inskip and Malvern. VOACAP predicted frequencies are also shown.

3. High data transfer rate system of radio communications through the ionospheric channel

3.1 Latest results about the "TRILION" project, University of Rennes (France):

A digital transmission have been established through the ionospheric channel, operating between Rennes (France) and El Arenosillo (south of Spain), a radio link with a 1300 km range [1].

The waveform was a QAM16 modulation with a symbol rate of 7500 bauds (30 kbits/s data rate) and a maximum power of 700 W. The transmitting system was located in Monterfil (near Rennes).

The heterogeneous array used at the receiving system had to be set up in Spain, at the INTA (Instituto Nacional de Técnica Aeroespacial). The array was composed of crossed loop and monopole antennas, using the space and antenna diversity.

As an application, still compressed images were transmitted with a robust joint source and channel coding. The corresponding multi channel processing integrates a spatio temporal equalization which balances the distortion of the received signal in an extended bandwidth of 9 kHz. The multi channel processing associates the following functions:

- a blind spatio temporal equalization resorting to the combination between the CMA (constant modulus algorithm) and the LMS (Least Mean Square) algorithm
- a carrier recovery, separated from the equalization, containing a second order loop filter
- a symbol timing recovery based on a Gardner detector

Many results show the efficiency of the array processing: the combination CMA->LMS for equalization is able to converge when fading effect or frequency selectivity occur, and in some cases, the algorithm keeps tracking when jammers disrupt the transmission. Finally, the restored images appear to be good in terms of visual quality.

Finally, a real time demonstrator [2] has been set up using a DSP board. The first results are encouraging and the bit rate reached 20 kbits/s within 6 kHz bandwidth (between Rennes and El Arenosillo) for a limited evaluation version.

References

[1] *"1300km HF Radio Link With A 30 kbits/s Data Transfer Rate",* C. Perrine, Y. Erhel, D. Lemur, A. Bourdillon, N. Melida Garrido, IEE IRST 2006 London, 18-21 juillet 2006. Accepted for publication.

[2] "*Modem vectoriel HF à haut debit*", C. Perrine, PhD, University of Rennes 1, Decembre 2005.

3.2 HF MIMO

Mike Warrington and Sana Salous have been successful in an application for funding to undertake an experimental investigation into the feasibility of MIMO techniques within the HF band (see http://gow.epsrc.ac.uk/ViewGrant.aspx?Grant=EP/D037034/1 and http://gow.epsrc.ac.uk/ViewGrant.aspx?Grant=EP/D036666/1). They will be appointing two research assistants in the next two or three months and will then be in a position to start work on the technical aspects.

E.M. Warrington and S. Salous

3.3 Comparison of observations and predictions for HF propagation over northerly paths

Observations of the direction of arrival and signal strength have been compared with VOACAP predictions for four paths, two roughly tangential to the mid-latitude trough, one trans-auroral, and one located within the polar cap. The presence of off great-circle propagation was a common feature of the propagation on all of these paths, although the exact behaviour was different for each path. The principal findings are given below

3.4 Paths affected by the mid-latitude Trough:

1. During the day, the propagation tends to arrive close to the great circle direction (the median azimuth deviation from the great circle is less than about 4°), and the VOACAP predictions of signal strength and time of flight are reasonably close to the observations – although the effect

of the D-region absorption on the signal strength appears to be underestimated for higher frequencies (e.g. 11.1 MHz) and overestimated for lower ones (e.g. 5.1 MHz).

2. At night: the signal often arrives strongly deviated from the great circle direction. For example, the median deviation can be as high as 40°, while the upper-decile can exceed 80°.
3. The azimuth deviations are strongly dependent on season – being generally much lower in the summer months than at other times of year.
4. There is a difference in behaviour between the observations made at sunspot maximum than at sunspot minimum. The azimuth deviations at sunspot minimum are larger than those at sunspot maximum, although these may be explained by the differences in path length and geometry. Furthermore, at sunspot minimum, significant upper-decile deviations of up to 40° are still found in the summer months (albeit smaller than those found in the winter) while propagation from off-great circle occurs on 20–40% of nights compared to under 20% for sunspot maximum.
5. At night when off-GC modes are present, VOACAP can underestimate the signal strength by up to 10dB.

3.5 Trans auroral path

1. Upper-decile deviations in the azimuth from the great circle direction of up to 90° have been observed.
2. The deviations decrease with decreasing sunspot number and tend to be smaller in the summer than the winter.
3. For most frequencies the deviations are a nighttime phenomenon, however, frequencies that have a reflection in or close to the auroral oval can also arrive from off great circle during the day.
4. Similarly to the paths affected by the trough, VOACAP can underestimate the signal strength in the presence of off great circle propagation

3.6 Polar cap path

1. Deviations in azimuth from the great circle of up to 70° have been found at night, while the daytime values do not exceed 20°.
2. The deviations depend on season (summer values are smaller), but not on sunspot number (although observations are only available for a limited range of, comparatively low, sunspot numbers).
3. Deviations are higher for frequencies closer to the MUF.
4. The number of observations is reasonably well correlated with the signal strength predicted by VOACAP. However, occasionally VOACAP predicts a 2E mode that obscures the 1F modes otherwise found which leads to a fall in the expected signal strength that is not observed.

The statistical observations presented in this paper have quantified the azimuth deviations that might be expected in operating HF systems in the polar cap, auroral, and sub-auroral regions and also indicated the potential increase in signal strength that might be expected over the VOACAP predictions when off great circle propagation occurs.

A.J. Stocker, E.M. Warrington and D.R. Siddle

- Summary of report from the University of Leister (UK):

Dr. Sana Salous and Dr. E.M. Warrington have been successful in an application for funding to undertake an experimental investigation into the feasibility of MIMO techniques within the HF band. Two research assistants will be appointed in the next two or three months and the team will then be in a position to start work on the technical aspects. Technical progress will be reported in future.

4. *Gravity and planetary wave and infrasound effects on propagation.*

Czech Group (J. Lastovicka, P. Sauli, J. Boska, D. Buresova, T. Sinderalova and D. Kouba) working on this term of reference points out phenomena which could deteriorate HF communications. Specifically, with the Doppler type system, they observed S-shaped phenomena and rapid linear shape changes, both on Doppler shift spectrograms at time scales of tens of seconds (spectral range of infrasound).

Submitted to publication:

J. Chum, F. Hruška, D. Burešová, J. Laštovička, J Baše, J Maděra, V. Krasnov: Short time phenomena in HF Doppler records; first results of continuous Doppler sounding in the Czech Republic. Ann. Geophysicae.

5. *Extension of existing wideband HF simulators to the MF band*

The team at the University of St. Petersburg, Russia, N. Zernov and V. Gherm, have been working on further development of the general techniques to account for the effects of strong fluctuations of the field amplitude in the problem of HF propagation in the fluctuating ionospheric reflection channel. Their main results can be found in the following papers:

Published Papers:

V.E.Gherm, N.N.Zernov, H. J. Strangeways. HF Propagation in a Wideband Ionospheric Fluctuating Reflection Channel: Physically Based Software Simulator of the Channel, Radio Science, 40(1), RS1001, doi:10.1029/2004RS003093, 2005.

A.A.Bitjukov, V.E.Gherm, N.N.Zernov, Two-frequency, two-position coherence function of the random field: separation of variables in the parabolic equation (in Russian), Radiotekhnika i Elektronika (Russian Academy of Sciences), 50, №5, 2005.

A.A.Bitjukov, V.E.Gherm, N.N.Zernov, Two-frequency, two-position coherence function of the random field: model problems (in Russian), Radiotekhnika i Elektronika (Russian Academy of Sciences), 50, №5, 2005.

Presented at meetings:

Results have been also presented at All-Russia Conference on Radio Wave Propagation, held in Joshkar-Ola, Russia in May of 2005:

V.E.Gherm, N.N.Zernov, H.J.Strangeways, Modelling of the Wideband HF Ionospheric Channels of Propagation (in Russian), Proceedings of the 21-st All-Russia Conference on Radio Wave Propagation, v. 2, pp. 316-320. Joshkar-Ola, Russia. May, 25-27, 2005.

6. HF experiments during the 29 March 2006 solar eclipse (NEW)

Teams from ODTU, TUBITAK, ASELSAN and the Univ. of Leicester report that HF propagation measurements have been performed during the 29 March total solar eclipse in Africa.

WP2.3 - Spectrum management
Leaders: Prof L.W. Barclay and Prof A. M. Casimiro

1. Use of GPS to improve HF communications management

2. Adaptive waveform management

3. Occupancy determination of HF band for the East Mediterranean conducted using calibrated HF spectrum measurements and HF receiver array

Prof. Lefteris Economou, Prof. Charalambous and their team from Cyprus have the work focused on the occupancy of the HF Spectrum over Northern Europe in cooperation with the Victoria University of Manchester (UMIST). They are also making the development of an online occupancy prediction and plotting software, and made publications of their work.

Prof. Yurdanur, Prof. Ersin and their team continue the studies of the occupancy determination of HF band for the East Mediterraneam. The principal focus was in the total eclipse event and they now report on this measurements campaign.

Measurements During the *29 March 2006 Total Eclipse* Week

Ersin Tulunay[1,2], E. Mike Warrington[3], Yurdanur Tulunay[4], Yıldırım Bahadırlar[2], Ahmet Serdar Türk[2], Reha Çaputçu[2], Tolga Yapıcı[4], Erdem Türker Şenalp[1], Hakkı Nazlı[2], Emre Altuntaş[4], Özgür Sarı[1,5], Olcay Büyükpapuşcu[1,5]

[1] ODTÜ, Middle East Technical Univ., Dept. Of Electrical and Electronics Eng., Ankara
[2] TÜBİTAK, MRC, BTE, Gebze, Kocaeli, [3]University of Leicester, Leicester,
[4] ODTÜ, Middle East Technical Univ., Dept. Of Aerospace Eng., Ankara, [5] ASELSAN, Ankara

The total solar eclipse experience was the channel occupancy and Atmospheric Noise Measurements over the HF band during the 29 March 2006 total solar eclipse in Antalya (36° N, 30° E) Turkey.

Path of the Eclipse Through Asia

Total Solar Eclipse of 2006 Mar 29

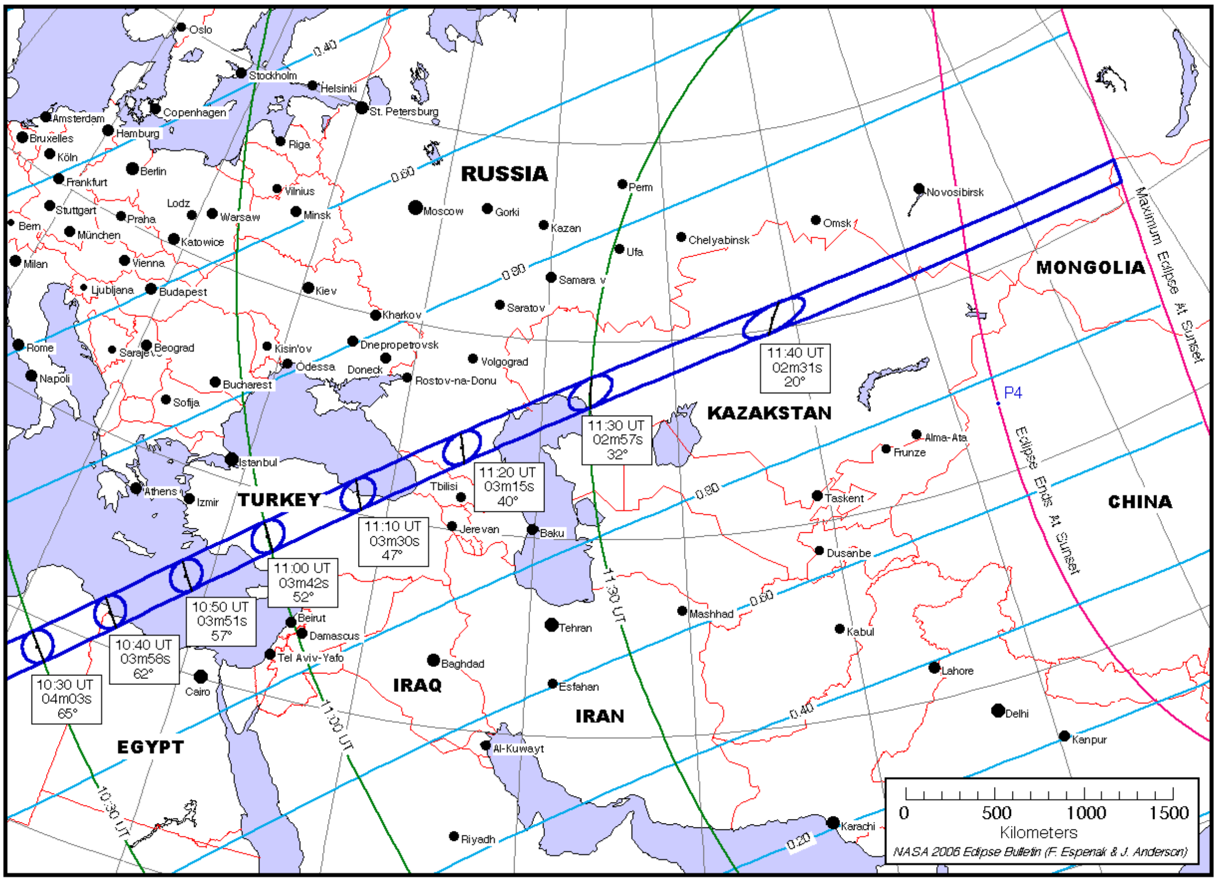

Figure 4. The Total Eclipse Path over part of Africa, Turkey and Asia

The whole HF band ranging from 1 to 30 MHz has been swept using 10 kHz peak and 200 Hz average detectors of a certified EMI receiver (HP-8542E) equipped with a calibrated active monopole antenna (HE-011). The block diagram of the experimental setup is shown in Figure 2. The geographic coordinate site is 36° 51’ 49.4’’ N, 30° 43’ 35.0’’ E.

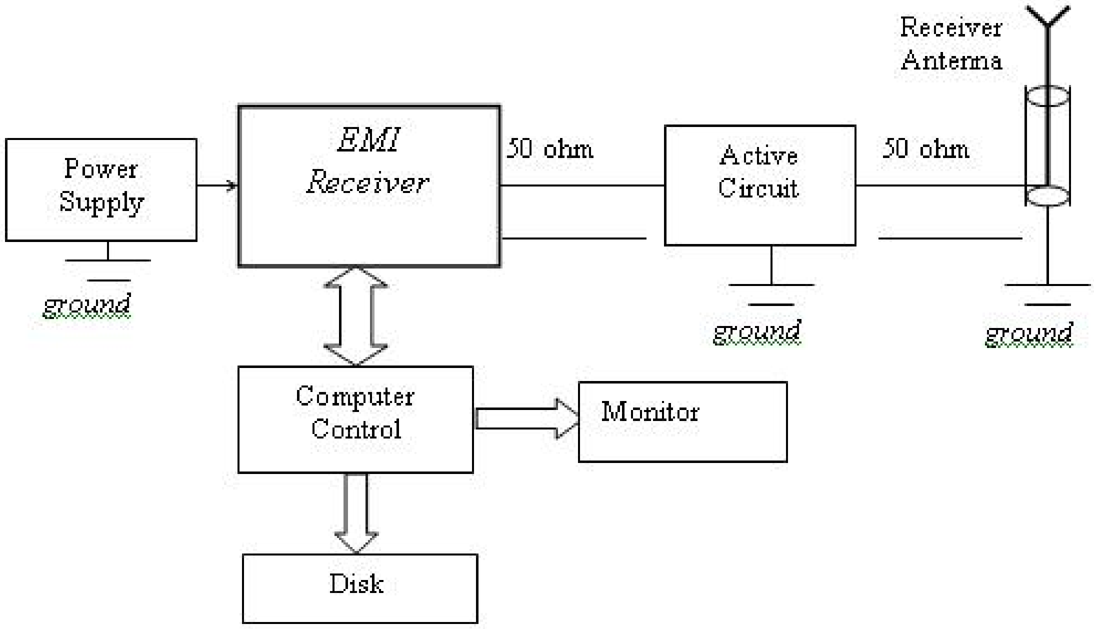

Figure 5. Block Diagram of the Experimental Setup

Figure 3 is the average atmospheric noise level in dB microvolt versus frequencies in MHz. The area under this curve indicates the associated power on the 28 March 2006, the day before the total eclipse at 0 LT and 12 LT hours. These two representative curves illustrate the behavior between midnight and midday.

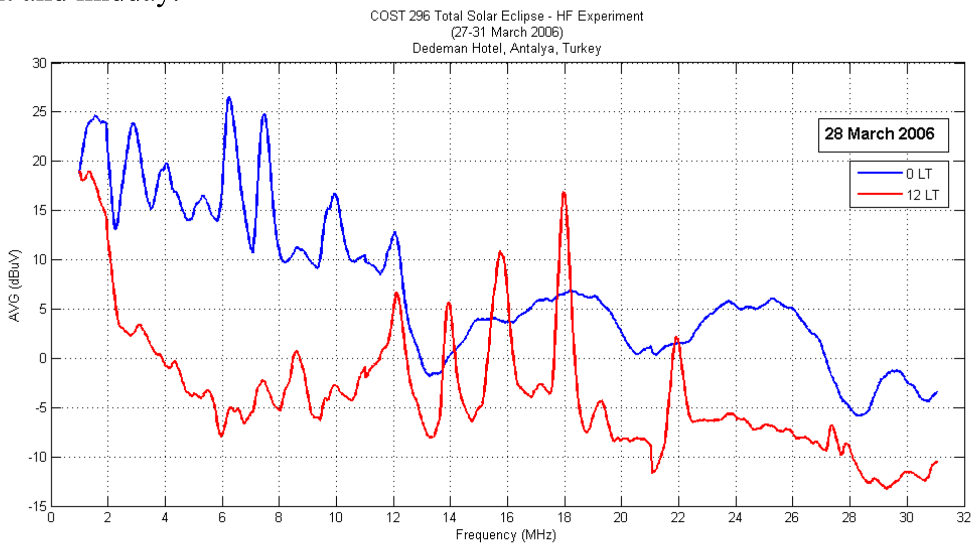

Figure 6. Average atmospheric noise level versus frequency

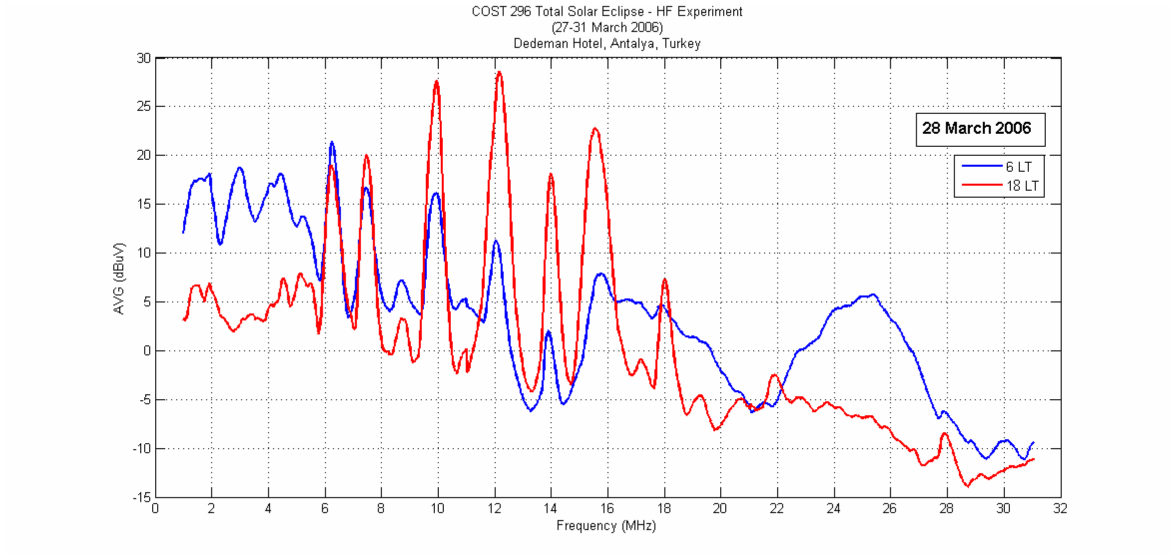

Figure 7. The associated power on the same day at 6 LT and 18 LT hours

Figure 4 illustrates the associated power on the same day at 6 LT and 18 LT hours. Unlike the curves of Figure 3, these two curves are similar to each other.

Figure 5 illustrates the average environmental noise in dB microvolt versus frequencies on the total eclipse day, 29 March 2006, covering all the local times before the eclipse.

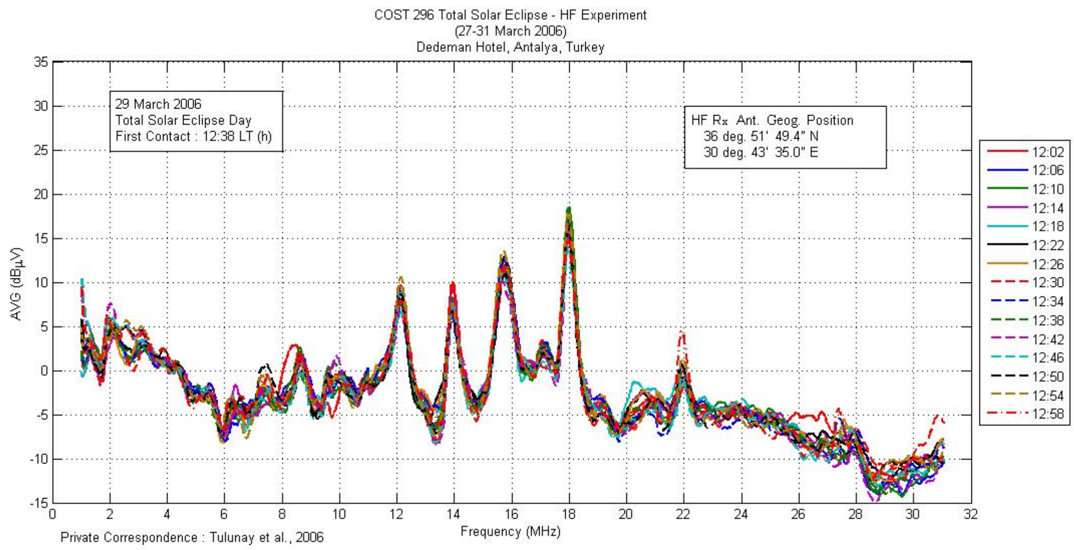

Figure 8. The average environmental noise in dB microvolt versus frequencies on the total eclipse day, 29 March 2006.

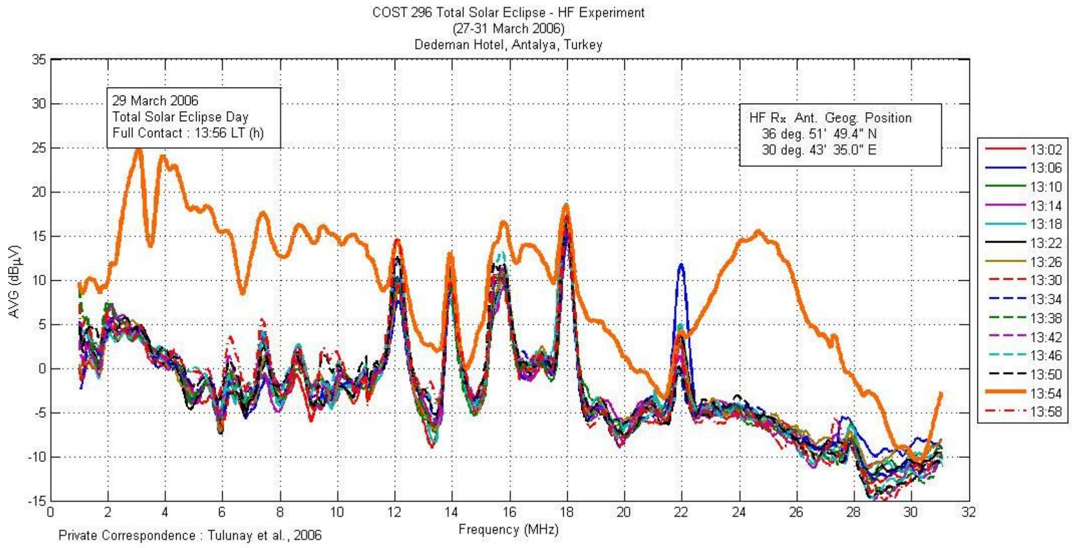

Figure 9. The atmospheric noise level on the time of the total eclipse

Figure 6 shows the atmospheric noise variation almost at the time the total solar eclipse. The results indicate that during the total eclipse the noise level exhibited different pattern. Qualitatively, "the eclipse" values are somehow representing the characteristic behaviour of the night-time as observed in Figure 3.

Figure 7 illustrate that after the eclipse, the atmospheric noise level returned back to their pre-eclipse pattern both in magnitude and configuration.

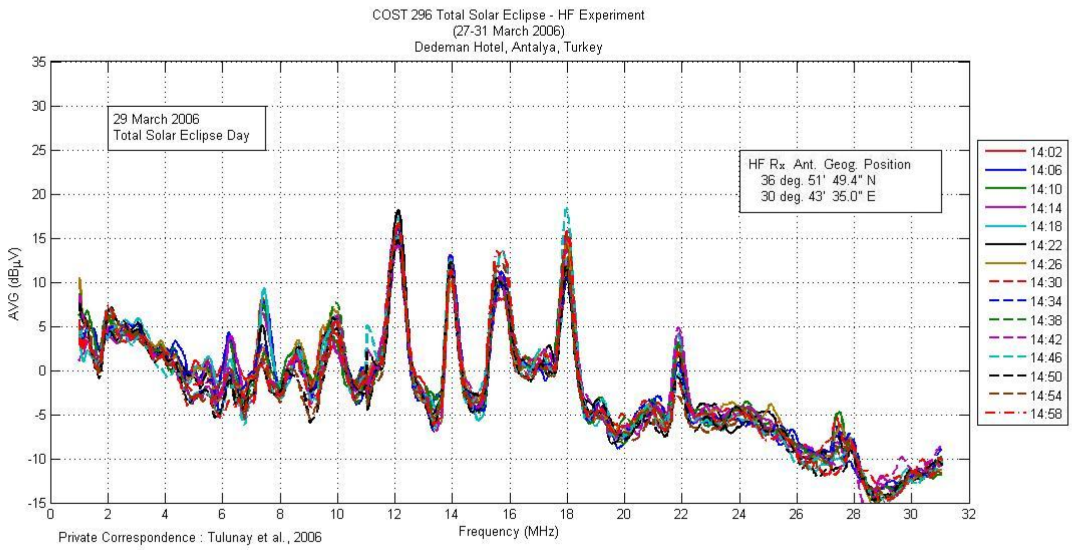

Figure 10. The atmospheric noise level returned back to their pre-eclipse pattern both in magnitude and configuration.

4. Supporting research and application in antenna systems to increase their efficiency and mitigate the propagation errors

Prof. Azevedo, Prof. Casimiro and our teams go on the research work in the antenna systems and it was made publications.

5. Developing new techniques to analyse the radiation path in the propagation channel

It was also made research work in developing new techniques to analyse the radiation path in propagation channel, and it was made publications.

ANNEX VI
WG 3 Space based systems
WP 3.1 Space plasma effects

Space plasma effects have been investigated according to the terms of reference by several groups in Europe which have reported their activity at the EGU General Assembly 2006 in Vienna.
The German Aerospace Center (DLR) established an operational space-plasma and space-weather monitoring service within the comprehensive project SWACI - Space Weather Applications Center Ionosphere (http://www.kn.nz.dlr.de/swaci) (Jakowski et al., 2005). One of the key issues to be addressed in this project is the GNSS reference Network Model Integrity (NMI) under perturbed ionosphere/space weather conditions. The work in this direction was first focused on the assessment of the space weather impact on GNSS-based positioning and NMI in particular (Stankov et al., 2005). The next step will be to properly index the space weather impact (Jakowski et al., 2005) with the aim of eventually predict the network integrity.
Interesting changes of the ionospheric drifts were observed at Průhonice observatory during several periods of a suddenly enhanced solar and geomagnetic activity (2004 – 2005 year). The analyse of the ionospheric drifts, measured during disturbed conditions, shows , that vertical drift velocity reaches, from typicalvalue 50 m/s for quiet conditions, up to - 60 m/s and –250 m/s during disturbed cinditions.The variations in horizontal components are a result of increasing of TID activity during storm. Investigations of ionospheric effects of infrasound continued – a solicited paper was presented at the EGU Assembly, Vienna, April 2006.

WP 3.2 Mitigation techniques

1) Basic mitigation techniques which are based on:

a) separate models

b) operational measurements for real-time corrections

At the end of September 2005 DLR has established the new ionosphere data service SWACI funded by the state government Mecklenburg-Vorpommern which substitutes the ESA co-funded Space weather pilot project SWIPPA. The service provides near-real-time ionospheric information derived from ground and space based GPS measurements: near real time vertical TEC and TEC gradient (temporal and spatial) maps with an update rate of 5 minutes suitable for error mitigation. Research work is focused on improving temporal and spatial resolution of the TEC maps and on developing forecast tools (DLR, N. Jakowski)

2) Mitigation techniques for specific GNSS applications

a) GNSS radio occultation

Development of special mitigation techniques in the frame of GNSS radio occultation experiments (figure 1) aiming at retrieving neutral atmosphere parameters. In the frame of such applications, it is particularly important to be able to separate ionosphere and neutral atmosphere effects on the signals. In April 2006, six satellites of the Taiwan/US COSMIC constellation have been successfully launched. The ESA satellite MetOp will follow end of June. All these satellites are equipped with high quality radio occultation receivers. These measurements will form a rich basis for error studies with focus on the influence of higher-order ionospheric errors and the development of mitigation techniques (University of Graz, U. Foelsche).

b) GNSS reference networks

Assessment of the feasibility to use existing ionosphere models or near real time TEC maps in order to mitigate the ionosphere error in mobile GNSS applications. On the one hand, the models used in this study are IRI2001, NeQuick and Klobuchar. On the other hand, up to now, IGS and EUREF data were processed to produce real-time corrections. (Finnish Meteorological Institute, Juha-Pekka Luntama)

c) triple frequency methods (Galileo, modernized GPS)

Study aiming at using the third frequency which will be available with Galileo and with modernized GPS for a better mitigation of ionospheric effects on precise positioning, in particular, for a more efficient ambiguity resolution using TCAR method. Different combinations of the 3 frequencies (based on simulated data) are being tested in order to be able to solve ambiguities in real-time using undifferenced observations i.e. only one station is used (Royal Observatory of Belgium, R. Warnant).

3) Higher order ionospheric influences in dual frequency systems with emphasis on long-term applications.

Research work is being performed at DLR in order to estimate higher order refraction effects in GNSS systems (DLR, N. Jakowski)

4) Capabilities and remaining weakness of mitigation techniques for GNSS under quiet and perturbed ionospheric conditions

Studies in order to assess the effects of disturbed ionospheric conditions (geomagnetic and ionospheric storms, scintillations, Travelling Ionospheric Disturbances) on the accuracy of GNSS applications:-

- assessment of the effect of TID's on high accuracy real time positioning techniques like the so-called Real Time Kinematic technique : origin of TID's and of their impact in terms of local TEC variability; their effects in the different steps of the data processing algorithms, in particular on ambiguity resolution. It has been demonstrated that strong TIDs can affect ambiguity resolution even on distances as short as 4 km (Royal Observatory of Belgium, R. Warnant and the Geophysical Institute of the Bulgarian Academy of Science, I Kutiev).
- assessment of the effects of scintillations on high accuracy positioning : data quality (data losses), ambiguity resolution, correlation between scintillation index, data quality and positioning error in order to develop new mitigation techniques. In particular, during the last few months, the impact of scintillations on ambiguity resolution on short baselines has been investigated (IESSG Nottingham, M. Aquino, Royal Observatory of Belgium, R. Warnant).

WP 3.3 Scintillation Monitoring and Modelling

Work has been made at different topics according to the terms of reference. Topics are highlighted in the following:

1. **Climatology of irregularities and scintillations under different helio-geophysical conditions from scintillation modelling** (A. Wernik, L. Alfonsi, M. Materassi)
After the formulation of a scintillation model based on in situ plasma density data from the DE-2 satellite, some properties of irregularities and scintillation under different helio-geophysical conditions have been investigated. Simulations performed for all the DE-2 passes between 1981 and 1983 that allow covering large area of the globe with scintillation 'measurements' have been used to produce maps of scintillation parameters. Such maps have been sorted in dependence on season, magnetic local time, Kp magnetic index and according to two different latitudinal sectors (invariant latitude between 50° and 70° and invariant latitude greater than 70°). All these information will be crucial for a later use in the prediction of scintillation activity at a given satellite-receiver link. First (preliminary) tests on GPS scintillations data are in progress.
2. **GPS scintillation monitoring in the frame of ISACCO (Ionospheric Scintillation Arctic Coordinated Campaign Observations) project** (V. Romano, G. De Franceschi, L. Alfonsi)
In the frame of the GPS scintillation and TEC monitoring, efforts have been addressed on maintaining the polar station where two GISTM (GPS Ionospheric Scintillation and TEC Monitor) receivers are located at Ny Alesund (79.9N, 11.9E, Svalbard, Norway) under ISACCO (Ionospheric Scintillation Arctic Coordinated Campaign Observations) project managed by INGV. Remote access facility to both data and instruments has been developed and construction of data base is in progress. Last January another GISTM receiver has been installed at the Italian Antarctic Station "Mario Zucchelli" at Terra Nova Bay.
3. **Monitoring of scintillations as solar disturbances and magnetic storms signatures on the ionosphere** (G. De Franceschi, L. Alfonsi, V. Romano, M. Aquino, A. Wernik)
After a first analysis of the GISTM data acquired at Ny Alesund to investigate the scintillations as signatures of solar disturbances and magnetic storm during the 30th October 2003 event, a deeper study has been performed to follow the ionospheric plasma movement over Europe. In particular, using the observations from a network of GPS receivers deployed by the Bath University (UK) and by IESSG University of Nottingham (UK), similar to the INGV receiver, the investigations has revealed a pattern of irregularity movement coherent with tomographic reconstruction (MIDAS), polar cap ionospheric potential simulation (Weimer model) and SuperDARN observations.
4. **Wavelet analysis of ionospheric scintillation** (M. Materassi, L. Alfonsi, G. De Franceschi, V. Romano, A. Wernik)
Since radio scintillation induced by ionospheric irregularities is typically a non-stationary phenomenon, often characterized by sudden impulsive events localized in time, involving several time scales, a study of it based on wavelet analysis has been started. It has been shown that the observation of wavelet energy plots of the scintillating radio signals is a powerful way of localising the most intense events and of resolving their short time structure. A characterisation of the wavelet coefficient statistics of time intervals before, during and after a scintillation event has been initiated, so to draw a relationship between the imminence of burst events

and the wavelet statistics of the time interval right before. Last but not least, comparisons are under study between the scalogram of scintillation on a satellite-to-ground radio link and the same plot for the ionization density measured in situ of a region compatible with the radio link.

5. **Scintillation monitoring over China** (Zhen Weimin)
   GPS network is running to monitor ionospheric scintillation under the support of NSFC (National natural Science Foundation of China) in low-latitude region of China, which operates at UHF and L bands. A databank has been set up for scintillation data and TEC data management at CRIRP
   In the past half year, most of the ionospheric scintillation monitor in the network at Chinese low latitude area has been connected to the internet. ionospheric scintillation data can be transferred to the centre in realtime by internet empirical model for nowcast and forecast methods are being tested by the realtime data. Three ISMs has been set in Haikou to receive data of UHF band. Data can also be used to analyze the velocity of ionospheric irregularities.
6. **Italy-China scientific and technological co-operation project** (W. Zhen, V. Romano, B. Zolesi, G. De Franceschi, L. Alfonsi)
   Within the framework of the Agreement on Scientific and Technological Co-operation between the People's Republic of China and the Italian Republic, the Ministry of Science and Technology (MOST) of China and the Ministry of Foreign Affairs of Italy in January 2006 approved the project: "**Warning and forecasting methodology in ionospheric scintillation for communication systems**". The activity will take place during three years (2006-2008). For details on the project items an goals contact: romano@ingv.it
7. **DLR activities regarding the investigation of ionospheric scintillations**
   At present DLR operates two 50Hz JAVAD receiver for the investigation of ionospheric scintillation effects on GNSS in the auroral and equatorial regions. The receivers are located at: Kiruna; Sweden (20.41°E, 67.84°N), Bandung; Indonesia (107.6°E, -6.9°N). DLR has developed and implemented a processor to automatically analyze the 50Hz JAVAD data from these receivers and to retrieve a geo-referenced database of: S4, σ-Phase, dTEC/sec. Since November 2005 the data are processed on a continuous base with a delay of 1 day. The routinely processing of Bandung data are currently at an experimental stage, but data from December 2005 to February 2006 are available at DLR and are currently analyzed. One of the major current aims is, to identify unambiguous scintillation events that can be used i.e. for spectral and amplitude- and phase-scintillation correlation analysis. Software routines for automatic near real-time spectral analysis are currently under development.

   Prediction of Ionospheric Scintillations – ESA project (DLR, IETR, ENSTB, GMV, CLS, IEAA) In the frame of an ESA project it is intended to perform studies and measurements campaigns. The aims are: to produce scintillations data base, to derive scintillations parameters and to improve GISM model. This project started in January and will last two years.

Recent Publications and talks related to WG3 activities

Publications:

M. Aquino, A. Dodson, J. Souter and T. Moore: Ionospheric Scintillation Effects on GPS Carrier Phase Positioning Accuracy at Auroral and Sub-auroral Latitudes, accepted by Springer.

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