TRANSMIT NEWSLETTER
2012 NOVEMBER • **ISSUE 1**

TRANSMIT - Training Research and Applications Network to Support the Mitigation of Ionospheric Threats, an FP7 Marie Curie Initial Training Network. The project addresses in particular ionospheric threats to Global Navigation Satellite Systems (GNSS) and related applications, in areas such as civil aviation, marine navigation and land transportation.

INSIDE THIS ISSUE

"The GPS modernization, the restored Russian GLONASS, and the upcoming European Galileo and Chinese Compass GNSS bring forth immense benefits and challenges for ionospheric monitoring. The new civilian signals broadcast at multiple frequencies enable better ionospheric measurements through a multitude of pierce points. However, the complex structure of the new signals and the sheer number of available signals at multiple frequencies necessitate robust , but stable, receiver technology". This is the argument taken by **Marcus Andreotti** (NovAtel. Inc., Canada). TRANSMIT's Early Stage Research (ESR) fellows **Melania Susi** (ESR 2), **Shishir Priyardashi** (ESR5) and **Pavel Najman** (ESR13) tell us about their ongoing studies on ionospheric scintillation effects, models and driving external indices.

NEWS

We are pleased to announce that the **Second TRANSMIT Workshop: "A response to User Needs in the Face of the Solar Maximum"**, will take place at the Bath Spa Hotel, **Bath, UK**, from **12-13 February 2013**. This is an open event organized as part of TRANSMIT focused on the study of ionospheric phenomena and their effects on systems embedded in our daily life.

Registration: store.bath.ac.uk/browse/extra_info.asp?modid=1&prodid=0&deptid=0&compid=1&prodvarid=341&catid=69
DEADLINE: DECEMBER 1, 2012
For further enquiries please contact the local organizer: Prof. Cathryn Mitchell - cathryn.mitchell@rocketmail.com

Moreover we are pleased to announce that the **Third TRANSMIT Summer School "Ionospheric threats to Europe: impact of increased solar activity"**, will be held in **Rome, Italy, 1-5 July 2013**, local organizer **Giorgiana De Franceschi** (Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy, **giorgiana.defranceschi@ingv.it**). **THE FIRST CIRCULAR WILL COME SOON!**

www.transmit-ionosphere.net

Update Status

Marcio **Aquino**
Alan **Dodson**

The European Community has predicted an annual global market for Global Navigation Satellite Systems (GNSS) of €300bn by 2020. Europe is currently developing its own GNSS system Galileo that will become operational over the next decade. The main threat to the reliable and safe operation of GNSS is the variable propagation conditions encountered by GNSS signals as they pass through the Earth's upper atmosphere (the ionosphere). At a COST 296 workshop held in 2008, the establishment of a sophisticated Ionospheric Perturbation Detection and Monitoring (IPDM) network (http://ipdm.nottingham.ac.uk/) was proposed by European experts, and supported by the European Space Agency (ESA), as the way forward to deliver the state of the art to protect a range of essential technological systems vulnerable to Ionospheric threats. In a bid to initiate research and training of scientists in Europe for the development of the IPDM network the TRANSMIT project (www.transmit-ionopshere.net) was conceived and later funded by the European Commission through their FP7 PEOPLE Programme, in the form of a Marie Curie Initial Training Network (ITN). TRANSMIT stands for Training Research and Applications Network to Support the Mitigation of Ionospheric Threats and is a 4 year project, started in February 2011 and led by the University of Nottingham, in the UK. TRANSMIT comprises a consortium of leading universities and research centres in Europe, with associated partners from top European industry stakeholders, as well as industry and academia from as far as Brazil and Canada. Research in TRANSMIT initiated in September 2011 with the recruitment of 14 Marie Curie Fellows to take up a number of coordinated projects aiming to develop real time integrated state of the art tools to mitigate Ionospheric threats in particular to Global Navigation Satellite Systems (GNSS) and applications that rely on them. The project will fully exploit the existing specialized European science base and take advantage of insight and full commitment from European industry and end users in order to prove the IPDM network concept and setup its prototype Marie Curie ITNs aim to improve the career perspectives of researchers who are in the first five years of their research career in both public and private sectors. TRANSMIT will provide a coordinated programme of academic and industrial training in an area of immediate interest to the European society. It focuses on atmospheric phenomena that can significantly impair a wide range of systems and applications that are at the core of several activities embedded in our daily life. TRANSMIT deals with the harmful effects of the ionosphere on these systems, which will become increasingly significant as we approach the next solar maximum, predicted for 2013. The TRANSMIT newsletter will keep you posted on the latest project developments and will promote an open debate on the importance of these Ionospheric threats to modern society

On Ionospheric Scintillation Monitor Technology based on GNSS signals

Marcus **Andreotti** | NovAtel Inc. Canada

Unmodeled ionospheric delay is the largest and most variable cause of error in single-frequency GNSS receivers. Unlike the troposphere, the ionosphere is a dispersive medium that is predominant with electrically charged atoms and molecules (ions) and free electrons formed primarily due to ionization by solar radiation. The ionosphere exhibits both diurnal and seasonal effects originating from solar activity. The Sun enters a period of increased activity approximately every eleven years called the solar maximum, which influences the amount of irradiance received from the Sun on earth. Solar maximum is associated with increased solar flares (of powerful X types) and coronal mass ejection that causes intense disturbances of Earth's magnetosphere temporarily. The impending solar maximum is expected in 2013.

GNSS systems broadcast signals on more than one frequency so that a correction of the delay through the ionosphere can be determined, as it is proportional to the signal frequency. For instance, dual-frequency GPS receivers track L1 and L2 signals to form ionosphere-free pseudorange and carrier phase observables. This ionosphere free combination is effective in mitigating the propagation error due to the first order ionospheric effect. This methodology is, however, useful only when the ionosphere is not disturbed by irregular activity.

Single-frequency GNSS receivers use broadcast correction data based on ionospheric models, such as the Klobuchar model used by GPS and NeQuick model that is adopted in the upcoming Galileo system. Unfortunately, the ionospheric corrections from these models are limited during high ionospheric activity. Improved ionospheric corrections can be attained using the broadcast data from satellite based augmentation systems (SBAS) such as the US WAAS, the European EGNOS, the Japanese MSAS, and the future Indian GAGAN. These SBAS systems provide ionospheric delay corrections along with integrity/accuracy data on those corrections known as the Grid Ionospheric Vertical Error (GIVE). GIVE characterizes the residual error in the ionospheric corrections for the estimated ionospheric delays over several strategically located ionospheric grid points (IGP). Nonetheless, during ionospheric events, the augmentation systems are unable to provide accurate vertical guidance, leaving safety critical users with horizontal guidance alone. Besides, augmentation systems are themselves vulnerable in equatorial regions.

GNSS and Ionosphere Monitoring

GNSS signals despite being vulnerable to ionosphere effects provide an excellent means for ionospheric monitoring on a global basis in a continuous fashion. With multiple satellites and multiple signals available, the ionospheric effect can be measured through many pierce points simultaneously. Ionospheric effects are typically characterized by measuring their impact on amplitude and phase of the received GNSS signal. The most widely considered measures are the scintillation indices (i.e. amplitude and phase), and the Total Electron Content (TEC). The amplitude scintillation index, or the S4 index, measures the standard deviation of the normalized signal intensity, typically over a 60 second period. The phase scintillation index (Ð) is the standard deviation of the received signal phase over a defined period of time that is typically a 60 seconds period (Ð60). Both amplitude and phase scintillation measurements should be detrended to extract the contribution from scintillation alone, while attempting to reject the effects of sources such as the signal dynamics and multipath.

Ionospheric Scintillation Monitor Technology

Single- or dual-frequency GNSS receivers with configurable carrier tracking loop bandwidth have been traditionally used as Ionospheric Scintillation Monitors (ISM). Until recently, most ISM receivers relied on GPS semi-codeless L2 P(Y) tracking techniques to derive the dual frequency observables, because of the encryption of the GPS L2 P(Y) signal. The semi-codeless techniques incur squaring loss that is a function of L2 C/N0. Even the best semi-codeless tracking incurs a squaring a loss of about 19 dB at a C/N0 level of 30 dB-Hz. Secondly, the semi-codeless techniques are heavily aided with the C/A code tracking to achieve a very narrowband code and carrier tracking loops to minimize the inherent squaring loss. Therefore, given the typical 25-Hz spectral bandwidth of scintillation, good quality scintillation parameters are greatly limited due to the very use of the narrowband tracking loops.

The use of wide carrier loop noise bandwidths can help maintain phase tracking during periods of ionospheric phase scintillation by tracking rapidly changing phase. On the other hand, narrow carrier loop noise bandwidth is desirable to tolerate amplitude scintillation with the ability to track at lower C/N0 conditions, or to "fly-wheel" through the deep fades.

The phase noise of the reference oscillator is of crucial importance as it can easily dominate the overall phase measurement limiting the ability to measure the phase scintillation variations. ISM receivers such as the NovAtel GSV4004X series, and the more recent NovAtel GPStation-6 GISTM (GNSS Ionospheric Scintillation and TEC Monitor) receiver have a built-in ultra-stable low phase-noise OCXO as frequency reference. The use of ultra-low noise OCXO ensures that the oscillator phase noise does not obscure the effects of low level phase scintillation.

Multipath, if not mitigated, has a large impact on the amplitude scintillation measurement as it causes fading of the received signal due to constructive and destructive combination of the direct and delayed signals. The GPStation-6 receiver uses the proprietary pulse aperture correlator (PACTM) multipath mitigation technology that effectively limits the magnitude of multipath error to within 5 meters. More importantly, it reduces the fading that can be interpreted as amplitude scintillation. Therefore, the power measurements used for the amplitude scintillation indices are taken closer to the signal code-correlation peak.

Conclusions

The GPS modernization, the restored Russian GLONASS, and the upcoming European Galileo and Chinese Compass GNSS bring forth immense benefits and challenges for ionospheric monitoring. The new civilian signals broadcast at multiple frequencies enable better ionospheric measurements through a multitude of pierce points. However, the complex structure of the new signals and the sheer number of available signals at multiple frequencies necessitate robust , but stable, receiver technology

Scintillation Effects on GPS Receivers

Melania **Susi** | ESR2

Ionospheric scintillations are fast and random fluctuations of Radio Frequency (RF) signal amplitude and phase caused by small scale irregularities inside the ionosphere. This phenomenon can impact on the performance of a GPS receiver carrier tracking loop inducing bit errors, cycle slips and also a complete loss of carrier lock. Indeed, phase scintillation produces a Doppler shift in the GPS signal that, if larger than the phase lock loop bandwidth, could lead to cycle slips or a total loss of lock. Moreover, deep signal fading can force the signal level to drop down below the minimum receiver threshold allowed for the signal tracking.

When this phenomenon involves several satellite-receiver links simultaneously, outages in the GPS receiver operation can occur. Even if the scintillation is not severe enough to prevent the signal tracking, the accuracy and the reliability of the final solution could be degraded. Such effects can be of concern especially for GPS users requiring high reliability and continuity of navigation service or for precise positioning users relying on carrier phase measurements, notably more precise than code measurements but also more sensitive to the stress dynamics produced by this type of event.

Due to its random nature, scintillation occurrence is hard to predict. Consequently, to mitigate the effects of scintillation events the robustness of GPS receiver to this phenomenon should be increased. With the approach of the next solar maximum, foreseen for 2013, and the consequent exacerbation of scintillation occurrence, receiver manufacturers are especially interested in enhancing the robustness of GPS receivers.

Addressing this concern, the sub-project of the TRASMIT project "Improved receiver tracking models and GNSS scintillation simulation tool" has the purpose to investigate scintillation related issues at the receiver tracking level and to propose novel tracking schemes robust under scintillation. The design of tracking schemes robust under scintillation requires a deep understanding of the main issues arising from scintillation at the tracking loop level. For this purpose, a first stage of the project has been dedicated to the assessment of a commercial receiver performance under simulated scintillation. To create RF signals affected by scintillation a hardware signal generator, the GS8000 Spirent simulator, has been used in conjunction with a physics based model, the SPLN (St. Petersburg-Leeds-Newcastle) model (Gherm et al., 2005). The latter requires as input different parameters, including the ionosphere background profile, and allows modelling of any type of scenario, including high latitude and strong scintillations that cannot be recreated by using the Cornell model (Humphreys et al., 2010) already implemented into the Spirent simulator.

Once realistic scintillation scenarios have been reproduced the next step is to design robust tracking schemes. To deal with the scintillation fading, a narrow carrier phase tracking bandwidth should be selected in order to reduce the noise. However, fast phase variations, as are associated with scintillation, require a high bandwidth to enable tracking these fast dynamics. With the aim to select the optimum bandwidth for the specific case an adaptive bandwidth Phase Locked Loop (PLL) can be exploited. Indeed, this tracking scheme is based on the adjustment of the tracking bandwidth according to the signal dynamics and the signal to noise ratios. The reconfigurability of a software receiver can be employed to implement this adaptive tracking scheme. First results seem to confirm the validity of this model in the case of moderate scintillation, in agreement with the results reported in (Mao et al., 2010). The next step will be to assess the above tracking schemes using both simulated, e.g. produced by implementing the SPLN model, and real data. Furthermore, alternative tracking schemes will be also investigated and their performance compared to the adaptive tracking scheme. Once the optimum tracking scheme is selected, which is able to minimize the output phase error under strong scintillation scenarios, the tracking error estimated for each channel could be used also to calculate weights and aid the computation of the final solution, for instance by applying the method suggested in Aquino et al. (2009)

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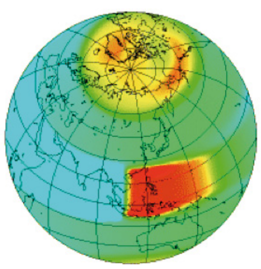

Review of Existing Scintillation Models

Shishir **Priyardashi** | ESR5

Trans-ionospheric communication of radio waves from transmitter to user is affected by high variability in time and spatial scales of the dynamic ionosphere. Ionospheric scintillation is the term given to irregular amplitude and phase fluctuations of the transmitted signals and related to the electron density irregularities in the ionosphere. Key sources of ionospheric irregularities are plasma instabilities. Scintillation depends on local time, season, solar and magnetic activity but there is no unique relationship between the strength and /or occurrence of scintillation and any particular parameter. Various models of scintillation have been developed to mitigate this problem.

The first empirical model of scintillation was proposed by Fremouw and Rino in 1973. This model could estimate the scintillaion index S4 on VHF/UHF, under weak scatter conditions. A weak scatter condition is often exceeded near the equatorial anomaly and auroral regions. This model led to the foundation of a more advanced model "WBMOD". Aarons developed an analytic model in 1985 using 15-min peak to peak scintillation indices (not S4) taken over 5 years at Huancayo, Peru using LES 6 satellite transmitted at 254 MHz. Later came the India model by Iyer and his group in 2006. They used a cubic-B spline technique to develop an empirical model of magnetic quiet time scintillation occurrence at Indian equatorial and low latitudes. A 250 MHz signal from FLEETSAT satellite was measured for 2 years at Trivandrum, near the magnetic equator, and at Rajkot at the crest of equatorial anomaly. To describe the structure and extent of the radio scintillation generated by turbulence around and within the equatorial plumes a physical model has been developed by J. M. Retterer (2010).

The first climatological model WBMOD was developed by Northwest Research Associates, Inc. in which the user can specify his operating scenario. As output the model returns: the phase scintillation spectral index p, the spectral strength parameter T, S4, and rms phase ĐĐ. Another, GISM, has been described by Beniguel and Buonomo in 1999. The model consists of two parts; the NeQuick model and the scintillation model based on a multiple phase screen algorithm and a second part which needs statistical information about irregularities as input. The algorithm is used to calculate the scintillation index at the receiver.

Basu and his group used in situ satellite data in scintillation modeling for the first time in 1976. They assumed a 3D power law irregularity spectrum with a constant spectral index of 4. They prepared another high latitude scintillation model (1988) using Atmospheric Explorer D data. Due to limited availability of data the model was only suitable for northern winter under sunspot minimum condition.
Wernik et al. (2007) used the Dynamics Explorer B data to estimate the irregularity spectral index and turbulence strength parameter, the factors that are required to calculate the scintillation index (Rino, 1979). Their approach has been extended by Liu et al. (2012) by introducing the finite outer scale ⋮

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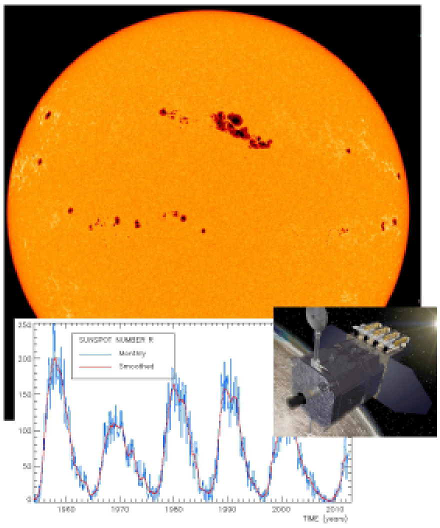
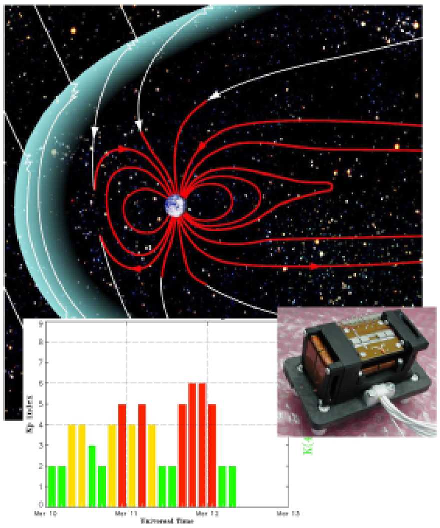
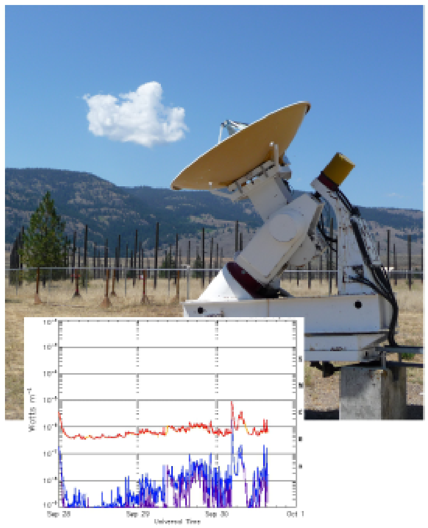
Sunspots



Kp - index



Solar Flux



Which Solar Index is the Best?

Pavel **Najman** | ESR13

All Global Navigation Satellite Systems (GNSS) use a similar principle of operation. Every GNSS receiver measures times of travel of radio signals travelling from satellites to the receiver. According to these times of travel, a receiver computes its distance from each satellite, and thereby its position. However, there are several factors which change the speed and trajectory of radio signals and can result in error in the estimation of the position. One of the most extensive errors is caused when the signal travels through the ionized part of the atmosphere, the ionosphere.
One way to correct the ionospheric error is by using a model of the ionosphere. Such a model will estimate the present condition of the ionosphere enabling the receiver to estimate the ionospheric error However, the ionosphere is not constant all the time. Firstly, the condition of the ionosphere, as well as the resulting error, depends on location. The ionospheric error in Italy and in Norway for example at the exact same time can be very different. Secondly, the conditions also changes according to the day of year, time of day and current solar activity. For this reason, every model has to adjust the estimation of the ionosphere according to the actual conditions of the "space weather". There are several indices which indicate if the radiation of the sun is low (so called quite periods) or high (solar maximum or solar events). The most widely used indices are: Sunspot number, Geomagnetic index Kp (or Ap) and value of Solar Flux. The sunspot number is derived from the number of dark spots which can be observed on the surface of the Sun. The Kp index indicates variations in the Earth's magnetic field which also changes according to solar activity. The Solar Flux values are measurements of radiation from outer space observed on the surface of the Earth. It can be said that even though each index is related to the different phenomena, still, all of them are used to describe processes in the space between the Sun and the Earth. Usually most ionospheric models use just one of these indices. Previous studies showed that all of them behave in a very similar way and, therefore, they can be more or less interchangeable. However, a recent study by Clette and Lefèvre (2012) shows that the behaviour of the indices is not as similar as it was 5 years ago. So the questions arise: "Which index is the best one?", "Which index describes the effects of the Sun most accurately?" and "Is one index enough to effectively describe Sun - Earth processes in a model?"
In the future research, we will try to find answers for these questions. The next step of our research will be to study the behaviour of the ionosphere under high solar activity. Furthermore, we will investigate choosing the best indicators of "space weather" processes and to finding out which is the best way to describe changing solar conditions in an ionospheric model ⋮

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FORTHCOMING EVENTS

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EVENT	WEB SITE	DATE	LOCATION	DEADLINE
2012				
Navitec 2012 and European Workshop on GNSS Signals and Signal Processing	www.congrexprojects.com/12c13/introduction	December 5-7, 2012	ESTEC, Noordwijk, NL	CLOSED
2013				
First CNES-ONERA Workshop on Earth-Space Propagation	www.isi-initiative.org/index.php?option=com_docman&task=cat_view&gid=186&Itemid=16	January 21-23, 2013	Toulouse FRANCE	CLOSED
ION International Technical Meeting	www.ion.org/meetings/	January 28-30, 2013	San Diego CALIFORNIA	CLOSED
TRANSMIT WORKSHOP: A response to User Needs in the Face of the Solar Maximum	www.transmit-ionosphere.net Contact: cathryn.mitchell@rocketmail.com	February 12,13	Bath UK	December 1, 2012
European Navigation Conference (ENC)	www.enc2013.org/	April 23-25, 2013	Wien AUSTRIA	December 17, 2012
Pacific PNT 2013	www.ion.org/meetings/	April 22-25, 2013	Hawaii USA	TBD
International Conference on Localisation and GNSS	www.icl-gnss.org/	June 25-27, 2013	Turin ITALY	February 15, 2012
Third TRANSMIT Summer School "Ionospheric threats to Europe: impact of increased solar activity"	www.transmit-ionosphere.net Contact: giorgian.defranceschi@ingv.it	July 1-5, 2013	Rome ITALY	TBD
2013 Beacon Satellite Symposium	www.bc.edu/research/isr/ibss.html Contact: cathryn.mitchell@googlemail.com	July 8-12, 2013	Bath UK	December 15, 2012
IGNSS International Global Navigation Satellite Systems	www.ignss.org/	July 16-18, 2013	Queensland AUSTRALIA	February 4, 2013
ISRSSP 2013 (3rd International Symposium on Radio Systems and Space Plama)	www.isrssp.org/index.htm	August 28-30,2013	Sofia BULGARIA	March 11, 2013
ION GNSS 2013	www.ion.org/meetings/	September 16-20, 2013	Nashville TENNESSEE	March, 2013
IEEE/ION PLANS 2014	www.ion.org	May 5-8, 2014	Monterey CALIFORNIA	TBD
2014				
European Navigation Conference (ENC)	www.enc-gnss2014.com/	April 14-17, 2014	Rotterdam NL	TBD

ABOUT US

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TRANSMIT Project FELLOWS

TRANSMIT Project PARTNERS

TRANSMIT counts on an exceptional set of partners, encompassing both academic excellence and top end users, including the aerospace and satellite communications sectors, as well as GNSS system designers and service providers, major user operators and receiver manufacturers. There is currently no assistance against ionospheric threats in Europe and TRANSMIT will promote step-change research that will enable Europe to minimise disruption and consequential societal costs associated with them. It will promote European competitiveness by ensuring the contribution of top centres of excellence in the field and by adopting a global approach to the problem. There are two types of partners in TRANSMIT, namely level 1 and level 2 partners.

The University of Nottingham — UNITED KINGDOM · CHINA · MALAYSIA — TRANSMIT Coordinator