RELATIONSHIP BETWEEN THE SCINTILLATION AND IONOSPHERIC IRREGULARITIES OVER KOTOTABANG (0.2°S, 100.3°E)

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ABSTRAK

Sintilasi adalah fenomena gangguan yang terjadi pada penerimaan sinyal satelit karena ketidakstabilan dan ketidakaturan plasma di lapisan ionosfer. Sintilasi dapat terjadi karena berbagai sebab. Oleh karena itu, penelitian ini dilakukan untuk mengetahui sebab atau sumber terjadinya sintilasi, dengan studi kasus beberapa kejadian sintilasi pada waktu tertentu. Gangguan penerimaan sinyal satelit tersebut akan meningkat seiring dengan meningkatnya aktivitas matahari 11 tahunan. Pada penelitian ini, sintilasi diukur menggunakan alat GPS Ionospheric Scintillation and TEC Monitor (GISTM) Pontianak untuk studi kasus kejadian FAI (Field Aligned Irregularities) tanggal 1 Maret dan 8 Maret 2011, dengan asumsi bahwa antara Kototabang dan Pontianak berada pada lintang geomagnet yang berdekatan dan plasma bubble terjadi sepanjang lintang tersebut (di wilayah lintang rendah dan ekuator). Data Field Aligned Irregularities (FAI) diperoleh dari data radar atmosfer ekuator (EAR). Kemudian untuk mengkonfirmasi peristiwa sintilasi, ditambahkan analisis Large Scale Wave Structure (LSWS) yang diperoleh dari data GNU Radio beacon Satellite Receiver (GRBR). Hasil analisis data menunjukkan adanya kaitan yang kuat antara kejadian sintilasi dengan FAI. Analisis lebih lanjut dilakukan dengan menggunakan data ionosonda CADI Pontianak dan ionosonda IPS 71 Tanjungsari, untuk melihat kejadian spread F saat data radar EAR menunjukkan terjadinya FAI. Indeks sintilasi juga menunjukkan nilai yang tinggi pada waktu yang bersesuaian. Hasil tersebut dikuatkan oleh hipotesa yang menyatakan bahwa sintilasi berkaitan kuat dengan ketidakaturan di lapisan ionosfer.

Kata Kunci : *Sintilasi, GISTM, Radar Atmosfer Equator, GRBR, Ketidakteraturan Lapisan Ionosfer.*

ABSTRACT

Scintillation is a satellite signal reception interference phenomena due to plasma instabilities and plasma irregularities in the ionosphere layer. Scintillation can be caused by many sources. Therefore, this study was conducted to confirm the source of interference in the case study scintillation events at any given time. The interference will increase as the 11-year cycle of solar activity. In this research, scintillation was analyzed using GISTM (GPS Ionospheric Scintillation and TEC Monitor) Pontianak data output for the Field Aligned Irregularities occurrences on March 1 and March 8, 2011. Assume that Pontianak and Kototabang located at adjacent geomagnetic latitude and plasma bubble occurred along the region (low latitude and equator region). Field Aligned Irregularities (FAI) obtained from Equatorial Atmosphere Radar (EAR) data and the results of GRBR data analysis for LSWS was used for confirming scintillation events. The results indicate a strong association between the occurrence of scintillation with FAI. Further analysis using ionosonde data for spread F occurrences from CADI Pontianak and IPS 71 Tanjungsari showed that spread F occurrence on March 1 and March 8, 2011 confirmed by improvement of signal from the EAR radar. Scintillation index also showed strong value at the appropriate time. These results

confirmed the hypothesis that the scintillation occurrences due to irregularities of ionosphere layer.

Keywords : Scintillation, GPS Ionospheric Scintillation and TEC Monitor, Equatorial Atmosphere Radar, GNU Radio Beacon Receiver, Field Aligned Irregularities

INTRODUCTION

Upper atmosphere and ionosphere are dynamic layers where in signal of radiowaves fluctuated because of refractive index difference. The random fluctuations of the refractive index which distort the original wave front, giving rise to a random phase modulation of a wave known as scintillation. Scintillations are known to occur on frequencies below 3 GHz and are a concern to many sectors, both civilian and military. The generation of these irregularities is one of the most spectacular manifestations of space weather in the Earth's ionosphere. In the scintillation cases, the temporal variations of amplitude and phase are occurred and recorded on the ground if the satellite and/or the ionosphere move relative to the receiver. The fluctuations in the refractive index are due to the irregularities in the ionosphere.

Figure 1. Illustration of Scintillation Event
([http : //roma2.rm.ingv. It/en/themes/11/ ionosphericscintillation](http://roma2.rm.ingv.it/en/themes/11/ionosphericscintillation))

The ionosphere of Earth often shows the occurrence of highly irregular plasma density and velocity fluctuations with a large range of scale sizes and amplitudes at almost all altitudes throughout the latitude and longitude sectors. The most of plasma irregularities at F region of ionosphere dominated by a nighttime phenomenon. The F region of ionosphere is also very interesting because of the complex dynamical phenomena and instability occurrence in this region. The horizontal geomagnetic field lines at the magnetic equator perpendicular to gravity, and also prevailing natural wind and background electric field, compose unique phenomena to develop the plasma irregularities in the equatorial region.

The Equatorial Spread F (ESF) are post sunset plasma irregularities that generally magnetic field aligned. The phenomena have zonal widths of typically a few tens of km and extend along the magnetic field lines for hundreds to thousands of km depending on the peak altitude of the irregularity (bubble) development (*Sobral et al.*, 2002), while their vertical heights range from a few tens of km to several hundred km (*Labelle et al.*, 1997). The FAI (Field Aligned Irregularities) data analysis obtained from Equatorial Atmosphere Radar as a proxy of plasma irregularities also shown occurrence of coupling process

between E and F region of ionosphere (*Martiningrum*, 2012). Understanding the day-to-day variability of the plasma irregularities of ionosphere has become a highly active area of research and important to space weather information services.

In this work has been studied the relationship between the scintillation and ionospheric irregularities over Kototabang site from analysis of *GPS Ionospheric Scintillation and TEC Monitor* (GISTM), Equatorial Atmosphere Radar (EAR), GNU Radio Beacon Receiver (GRBR) data and confirmed by ionosonde data. This study also have been done to understand variability of plasma irregularities of ionosphere therefore it give general pattern of the relationship between scintillation and plasma irregularities of ionospheric layer.

DATA AND METHODS

By using GISTM Pontianak (0.02°S, 109.3°E, dip lat 8.9°S) and Bandung (6.9°S, 107.6°E, dip lat 17.5°S) data, Field Aligned Irregularities obtained from Equatorial Atmosphere Radar and structure of Large Scale Wave Structure (LSWS) from GRBR of Bac Lieu (9.3°N, 105.7°E) were analyzed relationship between scintillation and ionospheric irregularities. Furthermore the result confirmed by ionosonde data from Tanjungsari dan Pontianak.

The GISTM Pontianak and Bandung data provide distribution of scintillation occurrence map and its strength. The Field Aligned Irregularities data obtained from RTI plot of Equatorial Atmosphere Radar. The important factor of the upper atmosphere dynamic is waves which in this study derived from GRBR data in term LSWS. The ionogram is trace of radiowave that propagate through ionosphere layer as confirmation data of plasma irregularities (ESF) occurrence. Those some kind of instruments and methods could show ionospheric irregularities both of latitudinally and longitudinally and also mainly for Kototabang site.

RESULTS AND ANALYSIS

RTI (range-time-intensity) plot of EAR data provide FAI occurrence during the observation. Analysis of FAI was shown ionospheric irregularities over Kototabang in the certain time. Furthermore, dynamic of upper atmosphere and ionosphere layer investigated by using GRBR data obtained from GRBR's site Bac Lieu (9.3°N, 105.7°E), Vietnam where close to Kototabang. By choosing three places of the instruments (Kototabang, Pontianak and Bac Lieu) could obtained variabilities of plasma irregularities latitudinally and longitudinally.

A. Case March 1, 2011. FAI from EAR and LSWS from GRBR.

Figure 2. Plot of FAI and LSWS event of March 1, 2011

The left panel in Figure 2 show RTI plot for March 1, 2011. EPB or ESF occurred at pos sunset time around 20:00 to 23:00 LT. LSWS derived from GRBR data for the appropriate time of FAI occurrence also show fluctuation of received satellite signal started at 11:23 UT (18:23 LT) to 13:06 UT (20:06 LT) (right panel). Scintillation from GISTM Pontianak (blue) and Bandung (black) was showed in figure 3 below :

Figure 3. Satellite track and Scintillation index (S_4) of March 1, 2011

The Figure 3 (left panel) also show satellite track of Pontianak (blue) and Bandung (black). Strength of scintillation indicated by scintillation index (S_4) categorized according three type strong, moderate, and weak (right panel). The strong scintillation index (S_4) was identified when those reach more than 0.5. The strong scintillation index (S_4) was found at around the time when EPB/ESF occurred. Furthermore, ionogram of Pontianak confirmed ESF occurrences at the same time.

Figure 4. Ionogram of March 1, 2011 at Pontianak

Trace of ionogram taken every 15 minutes detected ESF occurrences on March 1, 2011 started at 18:00 LT to 21:30 LT. Those time are appropriate to FAI and scintillation occurrences. The result describe the relationship between the scintillation and ionospheric irregularities. Other similar result need to confirm relationship between ionospheric irregularities, scintillation, and equatorial spread F.

B. Case March 8, 2011. FAI from EAR and LSWS from GRBR.

Figure 5. Plot of FAI and LSWS event of March 8, 2011

The other case related to FAI, scintillation, and ESF occurrence also found on March 8, 2011. The Figure 5 shows RTI plot for March 8, 2011. Similar to the previous case EPB or ESF occurred at pos sunset time around 20:30 to 23:30 LT. LSWS derived from GRBR data for the appropriate time of FAI occurrence also show fluctuation of received satellite signal started at 18:18 LT to 24:06 LT (right panel). Figure 6 shows scintillation occurrences from GISTM Pontianak (blue) and Bandung (black).

Figure 6. Satellite track and Scintillation index (S_4) of March 8, 2011

The Figure 6 (left panel) show satellite track of Pontianak (blue) and Bandung (black). Strength of scintillation indicated by scintillation index (S_4) categorized according three type strong, moderate, and weak (right panel). Similar result also obtained from scintillation index (S_4) data. The strong scintillation index (S_4) occurred at around the time when EPB/ESF occurred. The ionogram of Tanjungsari (near Bandung) confirmed ESF occurrences (Figure 7).

Figure 7. Ionogram of March 8, 2011 at Tanjungsari (Bandung)

Trace of ionogram taken every 15 minutes also detected ESF occurrences on March 8, 2011 started at 21:45 LT to 23:30 LT. Those time are appropriate to FAI and scintillation occurrences. The result confirm the relationship between the scintillation and ionospheric irregularities as detected from the previous case.

Ionospheric irregularities as proxy of Equatorial Plasma Bubble (EPB) or Equatorial Spread F (ESF) are forced by Large Scale Wave Structure in seeding mechanism. Scintillation occurred as impact of ionospheric irregularities. The several-generation mechanisms of the ESF have been reported, which often include a complex process and mechanisms of plasma, electrostatic turbulence, convection, chemical and neutral atmospheric effects, and particle precipitation.

The physical mechanism for the generation of ESF mostly triggered by Rayleigh-Taylor instability (RTI) that can be develop when heavier plasma is supported by the lighter plasma (Dungey, 1956). The conditions required for the RTI are generally met around post-sunset at the magnetic equator where the bottomside of the F-layer has recombined and the entire F-layer itself has been raised considerably by the pre-reversal enhancement in the

eastward electric field. This creates a very sharp vertical density gradient that is unstable to vertical perturbations in the ionosphere. The exact source of the perturbation is still the cause of much debate, and several mechanisms, including gravity waves (McClure *et al.*, 1998; Abdu *et al.*, 2011) have been suggested.

The resultant release of gravitational energy stored in the height of the ionosphere leads to the growth of an equatorial plasma bubble (EPB). Internal to this depleted region are intense, small-scale perturbations in the electric field and electron density. These perturbations cause the widespread effects of ESF, which sometimes reach more than 20° latitude from the generation region at the magnetic equator (Kelley *et al.*, 2002; Makela and Kelley, 2003). This is due to the large conductivity along the magnetic field lines, allowing the perturbed electric fields to efficiently map poleward where they can affect the local ionosphere.

CONCLUSION

Ionospheric irregularities indicated by FAI from EAR have impact on satellite signal reception interference showed as scintillation. This study found 2 cases show that phenomena, March 1, 2011 and March 8, 2011. Those result confirmed by Equatorial Spread F occurrences from ionosonde data at the simultaneous time. LSWS data from GRBR indicate that ionospheric irregularities prefer by LSWS in term seeding mechanism. This result prove that scintillation related to ionospheric irregularities. There are 3 major sector of scintillation activity. Those are the equatorial region, the north polar region, and south polar region. The further observation and study suggested to include those regions for further understanding sources of scintillation.

ACKNOWLEDGEMENT

Author (Dyah R Martiningrum) grateful to RISH, Kyoto University for giving opportunity to visit Radar Atmospheric Science Laboratory. Part of data (EAR data) taken from IUGONET project. Author wish to acknowledge the encouragement given by LAPAN mainly for supporting ionosonde data from Bank Data Ionosfer Regional Indonesia working group, Division Ionospheric and Telecommunication.

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