The Correlation of Geomagnetic Component Disturbances and 5 GHz LOS Received Signal Daily Variation

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Abstract – **Solar activities are manifested throughout the Earth's magnetosphere characteristic changes. These effects are measurable through geomagnetic field measurements and are reflected as changes in the intensity of geomagnetic components. Performing the received signal observation of LOS radio communication at the frequency of 5 GHz, we perceived the same change pattern as measured geomagnetic vertical component daily variation. The experiment was being conducted in the continuity of five months (February – June 2012), at the area of Belgrade city, under controlled conditions.**

Keywords – **Correlation, geomagnetism, Line-of-sight propagation, Microwave propagation, Signal attenuation.**

I. Introduction

The most important radio propagation feature of electromagnetic (EM) waves spreading through the medium of certain characteristics, in terms of the communication establishment is attenuation. The EM wave power attenuation is directly proportional to the frequency and the distance to the receiver [1], [2]. During propagation process, a variety of natural and artificially generated occurrences affect the physical characteristics of EM waves. Phenomena that influence the characteristics of EM waves (amplitude, frequency, phase and polarization) are expressed through the effects of reflection, dispersion, diffraction, interference, absorption and refraction, resulting the appearance of the electromagnetic field power level reducing at the receiving site [3], [4]. Each of mentioned phenomena affects the EM wave physical characteristics. The influence domain depends on the severity of occurrence, frequency band and polarization.

Most of distraction factors come from the characteristics of propagation medium which for terrestrial wireless communications is atmosphere. The lowest layer of the atmosphere – the troposphere, which extends up to altitude of twenty kilometres, exerts a decisive influence on the propagation of terrestrial radio communication systems. For a directed microwave radio communication, in addition to the intensity of the precipitations [5], [6], refraction is the dominant phenomenon that leads to the EM wave characteristic changes. Due to the altitude increasing, the environment dielectric constant changes, consequently. In addition to that, variation of the weather conditions along the signal propagation path lead to directed radio communication EM wave front bending. The effects of the mentioned phenomenon contribute to the attenuation of the received signal at the point of reception. Slight level variations of the linearly polarized received signal may result from disruption of EM wave polarization properties which ensue from changes in direction and intensity of the electric and magnetic vector components of the EM wave at the reception site comparing to emitted signal properties. This phenomenon may result from the effects of propagation through a medium which properties are polarization influential (consisted of particles under an electric charge) or from the direct impact of natural and artificial EM radiation sources. Sun is one of the well-known natural electromagnetic radiation sources with a very wide radiation spectrum.

II. Summary of solar activities and their influence on wireless communication systems

Depending on the used frequency band for information transmission, the dominant "constraints" that originate from the solar activity effects are in the terms of the appearances listed in Table 1. The reactions that occur in the centre of the Sun release a large energy amount of very different manifestations [7]. Most of these events are detectable from the surface of the Earth. However, those that are not physically visible are manifested in the form of wide EM radiation spectrum.

Except the visible light and infrared frequency range detecting, other manifestations of EM field require more complicated equipment for their detection (radio telescopes, electromagnetic radiation sensors...). Intense physical and chemical reactions within and on the surface of the Sun produce various effects which impact the Earth electrical systems. Those effects were taken into consideration in 1849, when W.H. Barlow observed correlation between the visibility of the Aurora Borealis and galvanometer needle deflection of the operational telegraph system.

After more than a century, it has been determined a high overall impact that the effects coming directly from the universe or intermediately by geomagnetic changes have on communication systems. Those scientific facts are presented in the different studies [7], [8], [9], [10], [11], [12]. The

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aforementioned effects become more important as the technology becomes more sophisticated. The most important physical reactions on the Sun’s surface and in its centre are: solar flares, mass coronal ejections and the appearance of sunspots [13]. All of those have an impact not only on the electrical equipment, but the entire living world through the change of the Earth's magnetosphere.

TABLE 1
SOLAR ACTIVITY EFFECTS

Freq. Range	Phenomenon	Influence	System
0-1 MHz	Micrometeorites and physical elements	Physical damage	Solar cells, the satellite elements
	The variation of the geomagnetic field components	The direct influence	Compasses, instruments for navigation and attitude control of spacecraft
		The induced electric currents in the earth	Transmission and distribution systems of electric power, long copper communication cables, pipelines
1 MHz – 1 GHz	Variation of ionosphere characteristics	Refraction, attenuation	Wireless communication systems
		Interference, scintillation (twinkling) parts of the sky	Communication satellites, instruments for geophysical research
1 GHz and above	Unexpected radio emission (bursts)	Additional radio noise	Wireless radio communications, radar systems, GPS receivers
	Particle radiation	Equipment and personnel damage in a spacecraft and aircraft	Solar cells, electronic equipment, astronauts and airline passengers
	Changes in the atmosphere	Attenuation and refraction due to changes in the dielectric properties of the transmission medium	Wireless communication systems

The first effect of the Sun's influence which is taken into consideration in wireless communications, and at the same time the most visible in practical terms is the possibility of the ionosphere to reflect the EM waves of specific properties. At the beginning of radio transmission in 1901, the first radio communication link which led to an exchange of information was established between Poldhu Station in Cornwall and St. John's in Newfoundland. The communication was possible thanks to the existence of a reflective layer in the atmosphere - the ionosphere. After that, G. Marconi (1928), who was the creator of previously mentioned wireless communication link, noted relation between the disappearance of the signal at the receiving site (fading) and the number of sunspots. Exploration of the ionosphere impact propagation effects is basically related to radio propagation in HF frequency band. Daily conditions of ionosphere, the main barrier that prevent a tremendous amount of physical and electromagnetic manifestations to affect the Earth’s surface are presented in the form of basic meteorological forecasts. As the modern radio communication solutions are moving towards higher frequency bands in order to increase communication channel capacity, the problem of transmission media influence on the quality information exchange ability in the microwave frequency range above 3 GHz arises.

Experimental measurements of communication link characteristics in the microwave band compared with the results of the meteorological phenomena measurements and other influencing factors, may contribute to universal principles illustrated in the form of models and relationships that would lead to more accurate quality calculation of directed microwave communication links.

III. EXPERIMENT DESCRIPTION

At the area of Belgrade city (44° 46’ 28’’ N and 20° 28’ 08’’ E), during the time between 1st of February until 30th of Jun 2012, we formed radio-relay link at the frequency of 5 GHz with the purpose of investigating all relevant factors which contribute to receiving signal instability (Fig. 1).

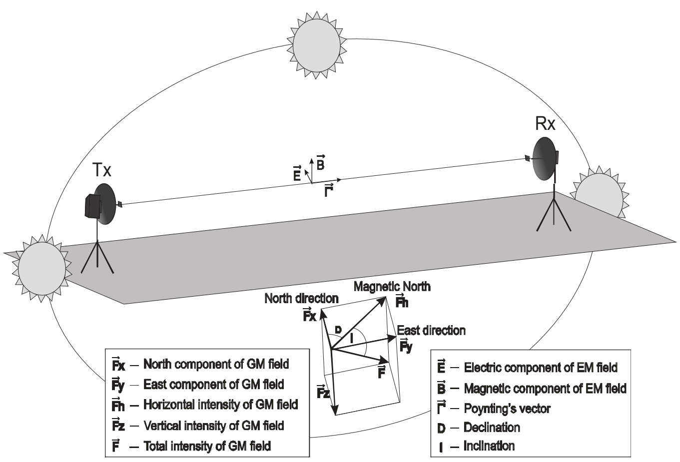

Fig. 1. Radio-relay link and components of geomagnetic field

The transmitter was emitting unmodulated carrier having the frequency stability of ± 700 Hz and radio frequency (RF) output power level of 18 dBm ± 1 dB. LOS link was established at the distance of 70 m. The signal was transmitted using the outdoor unit (ODU) and horizontally polarized parabolic antenna with 28 dBi gain. The receiving system (Rx) was formed with Tektronix SA2600 spectrum analyser that was through macro script programmed to perform 1 kHz width spectral recording into 500 points.

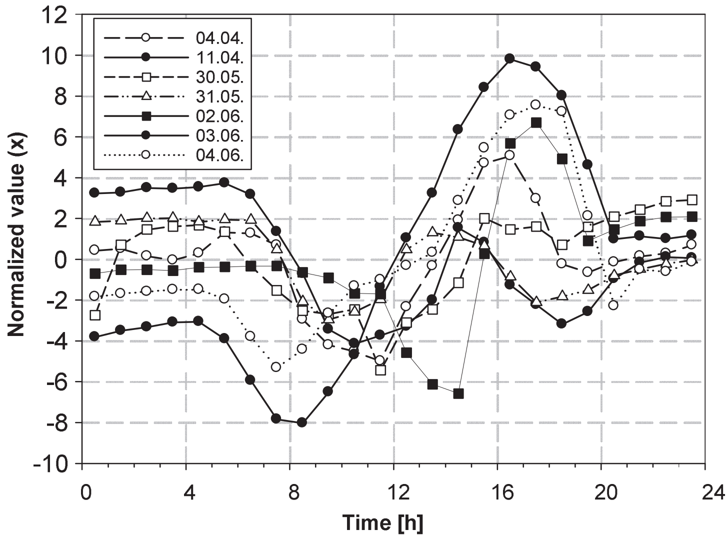

Fig. 2. Daily received signal level variations for presented seven days

In this way, the generated signal spectrum at the receiving side could be reconstructed with an accuracy of 2 Hz, which was more than enough to monitor changes in the level of the received signal through time.

The measurement was carried out so that the measuring samples of the received signal level were recorded every three minutes equidistantly during continuous operation of the radio-relay link. During the measurement period, we recorded 1692 hours of receiving signal level which made possible to reconstruct 46 days of 24-hour-measurements. Seven days that had specific received signal level variations during the daytime were noticed and analysed. Observed received signal level change starts at the time the Sun rises on the horizon and is intense during the day time, until the sunset (Fig. 2).

The values shown on Fig. 2 are obtained from Eq. (1) in order to be effectively compared and presented. Variable *i* represent measurement values of every hour.

$$x_i = 100 \cdot \frac{R_{xi} - \overline{R}_x}{\left|\overline{R}_x\right|} \tag{1}$$

Received signal level variation characteristics were compared with hourly variations of geomagnetic field components at the place of formed radio-relay link. Geomagnetic observations were conducted at Geomagnetic observatory Grocka [14]. Hourly measured values of mid-hour geomagnetic field components which include North and East, as well as vertical and total intensity were presented at parallel comparative figures which indicate the relations between hourly geomagnetic field component changes and receiving signal level at 5GHz variations (Fig. 3).

Ref. [15] shows the correlation between geomagnetic component changes during days when significant received signal level changes were occurred.

TABLE 2
PEARSON PRODUCT-MOMENT CORRELATION COEFFICIENT (PPMCC) BETWEEN MEASURED VALUES

Date (2012)	Pearson product-moment correlation coefficient			
	Received signal level vs. North component of the GM field (Fx)	Received signal level vs. East component of the GM field (Fy)	Received signal level vs. Vertical intensity of the GM field (Fz)	Received signal level vs. Total intensity of the GM field (F)
4.4.	-0.117000	0.021100	**0.710000**	0.706000
11.4.	0.343000	0.551000	**0.720000**	0.759000
30.5.	-0.155000	0.308000	**0.829000**	0.803000
31.5.	-0.503000	0.450000	**0.538000**	0.388000
2.6.	-0.513000	0.454000	**0.590000**	0.237000
3.6.	-0.562000	-0.215000	**0.654000**	-0.000576
4.6.	0.196000	-0.319000	**0.555000**	0.446000

No other considerable meteorological influences during the measuring period of time were detected. The high correlation between East geomagnetic field component and received signal level variation was noticed. The average values were 0,7344 and -0,7708, depending of the direction of transmitting antenna (east or west). The results of measurements shown at Fig. 3 are related to the specific normalized received signal level variation values, north and east geomagnetic field level values, as well as vertical and total geomagnetic field intensity values at the area of conducted measurement scenario.

Performing the correlation analysis between mentioned physical quantities, we noticed the high correlation between received signal level and vertical intensity of the geomagnetic field (Table 2).

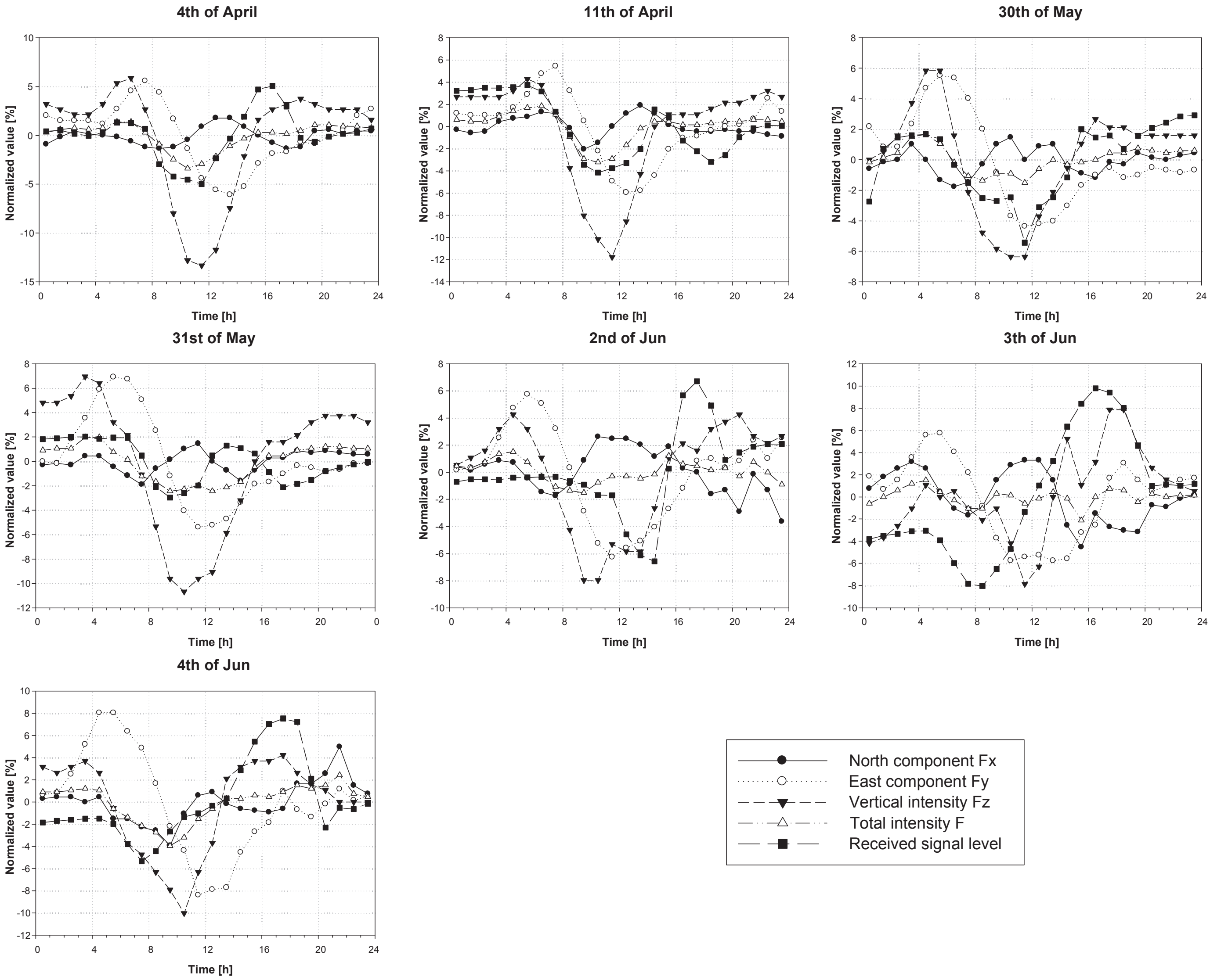

Fig. 3. Hourly variations of received signal level and geomagnetic field components

TABLE 3
VERTICAL GM FIELD VALUES AND RECEIVED SIGNAL LEVEL DOMAINS

Date (2012)	**Vertical intensity of the GM field (Fz) [nT]**			**Received signal level domain [dB]**
	MIN	**MAX**	**Δ**	
4.4.	41911	41949	38	6.36
11.4.	41911	41942	31	4.97
30.5.	41928	41955	27	3.45
31.5.	41915	41950	35	2.12
2.6.	41925	41950	25	5.74
3.6.	41938	41971	33	7.26
4.6.	41926	41957	31	5.07

IV. CONCLUSION

The vertical GM component amplitude which direction vector assorts with magnetic component vector of horizontally polarised emitted electromagnetic wave was changing during the measurement time within the values from 41,911 up to 41,957 μT. The variation was in the scale from 25 to 38 nT, depending on the day during which the measurement was conducted (Table 3). On the basis of presented results, we observed the high correlation between vertical GM field intensity variation and 5 GHz directed EM wave receiving signal level alteration. The average correlation coefficient was 0,656.

Direct conjunction between solar activities and electromagnetic wave propagation characteristics in the microwave frequency band is very difficult to determine considering the fact that is quite hard to simultaneously monitor all the factors which affect the EM during its propagation. This paper presents the correlation values between measured directed horizontally polarised 5 GHz received signal level and geomagnetic field component values. The GM field variations may not be direct factor that affect the received signal level in terms of its time change. However, those variations are influenced by the activities that evince microwave communication parameters, as well.

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REFERENCES

[1] Calculation of free-space attenuation, Rec. ITU-R P.525-2, August, 1994.

[2] A. O. Michael, "Standardization of attenuation formula for radio waves propagation through free space (LOS) communication links," *Sc. Journal of Physics*, vol. 2012, Article ID sjp-281, pp. 1-7, 2012.

[3] J. S. Seybold, *Introduction to RF Propagation, Wiley-interscience*, John Wiley & Sons, INC. New Jersey, U.S.A, 2005.

[4] H. R. Anderson, *Fixed broadband wireless system design, Wiley-interscience*, John Wiley & Sons, INC. West Sussex, Country: England, 2003.

[5] J. B. Bajčetić, M. S. Andrić and B. M. Todorović, "Measuring of snowfall impact on 5 GHz radio wave propagation," *ETRAN 2012*, Zlatibor, Serbia, June 2012.

[6] O. Shoewu, F. O. Edeko, "Microwave signal attenuation at 7.2 GHz in Rain and Harmattan Weather," *American Journal of Scientific Research*, vol. 2, no. 3, pp. 332-345, 2011.

[7] D. E. Gary, C. U. Keller, *Solar and space weather radiophysics*, Kluwer Academic Publishers, Astrophysics and space science library, Tucson, AZ, U.S.A, 2004.

[8] C. Ho, S. Slobin, A. Kantak and S. Asmar, "Solar Brightness Temperature and Corresponding Antenna Noise Temperature at Microwave Frequencies," *The Interplanetary Network Progress Report,* Pasadena, U.S.A, vol. 42-175, pp. 1-11, 2008.

[9] S. Jin, O. F. Luo and P. Park, "GPS observations of the ionospheric F2-layer behavior during the 20th November 2003 geomagnetic storm over South Korea," J. Geod, vol. 82, no. 12, pp. 883-892, Dec. 2008.

[10] E. S. Babayev, "Influence of the solar and geomagnetic activity on trans-ionospheric radio waves scintillation," *Solar Researches in the South-Eastern European Countries: Present and Perspectives*, Bucharest, Romania, 24-28 April, 2001.

[11] V. V. Bochkarev, I. R. Petrova and V. Yu. Teplov, "Effects of the Geomagnetic Storm on October 29–31, 2003, on Mid-Latitude Short-Wave Radio Paths (the Data of Doppler Measurements)," *Cos.Res*, vol. 42, no. 6, pp. 614-618, 2004.

[12] S. J. Mihajlović, M. Rašić, Lj. R. Cander and P. Palangio, "Geomagnetic, geoelctricity and ionospheric disturbance on October 2003," *ETRAN 2004*, Čačak, Serbia, vol. 3, pp. 237-240, June 2004.

[13] N. Gopalswamy, R. Mewaldt and J. Torsti (Eds.), *Solar Eruptions and Energetic Particles, Geophys*. Monogr. Ser., vol. 165, pp. 385, AGU, Washington, D. C, 2006.

[14] Geomagnetic Institute of Serbia, "Geomagnetic bulletin No.1 (2012)", Geomagnetic Observatory Grocka (GCK), Serbia, 2012.

[15] J. B. Bajčetić, M. S. Andrić and B. M. Todorović, "Correlation of 5 GHz LOS received signal level and geomagnetic field intensity," *Frequenz*, under review, 2013.