ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2008. No. 5(85)
ELEKTRONIKA IR ELEKTROTECHNIKA

TELECOMMUNICATIONS ENGINEERING
T180
TELEKOMUNIKACIJŲ INŽINERIJA

Some Fading-related Problems at Shortwave Propagation Path in the Baltics

E. Lossmann, U. Madar, A. Raja, M. A. Meister
Dept. of Radio and Communications Engineering, Tallinn University of Technology,
Ehitajate str. 5, 19086 Tallinn, Estonia, phone: +372 620 2360, e-mail: eriklos@lr.ttu.ee

Introduction

The ionospheric propagation of shortwave frequencies is by nature an extremely complicated process, involving multiple different influences. The negative side-effect of this complex process is the fading, which reveals itself thru stochastic fluctuations in received signal, being affected by different factors of propagation environment. Due to fading effect, the shortwave radio transmissions are characterized by unstable signal quality and high bit error rate (BER).

The interferential nature of fading is characterized by so-called multi-path transmission. The split components of a shortwave transmission will be mixed together after reflection from different layers of ionosphere. Consequently the radio waves reach the receiving antenna by various trajectories and after different number of refractions in ionosphere. The quality of received signal depends on difference of phase and amplitude of diverse signal components. As the size of shortwave wavelength is insignificant in scale of ionosphere, the fluctuation there can cause two signals with approximately equal levels arrive the receiver in 180 degree phase shift. It's enough to have a minor fluctuation of the reflecting layer – in tens of meters, to produce this type of fading.

Due to the movement of gases, zones with concentration of electrons, differing (higher or lower) from the layers mean concentration can develop. These zones can measure up to hundreds of meters and they can move rapidly (up to 100 m/s). If a temporary reflecting layer is developing at the height of layer E, then layer F2 is no more a part of a propagation process. This phenomenon is called *a sporadic E- reflection* (E_s) [1].

Every trajectory, passed by radio signals, depending on elevation angle and critical frequency of the ionosphere, will have a certain value of MUF. With the variations in the status of ionosphere, the MUF value for different directions varies significantly. Generally, the MUF value is highest for the signal path, that is against the Sun i.e. east in the morning, south at noon and west in the evening [2].

Also the magnetic field of Earth takes part in creation of layers in ionosphere. Ionospheric disturbances and magnetic storms can disrupt the layer F2 in a fashion, that it loses the ability to reflect radio waves. This occurrence is characteristic to higher geomagnetic latitudes. Earth's magnetic field can influence the propagation of radio waves directly, breaking the "beam" onto two components: O-ray (*ordinary wave*) and X-ray (*extraordinary wave*). This can cause multi-beam propagation over only one hop of transmission. Usually the O-ray is more stable and it's critical refraction frequency is lower.

Behavior of the ionosphere appears as a function of geophysical factors in ways that are not entirely defined and may change rapidly. For instance, sporadic E formations and spread-F effects vary in unpredictable ways, and F-layer densities differ significantly with storm-time [3].

Several ITU-R (i.e., International Telecommunication Union, Radio Sector) recommendations are relevant to the evaluation of the ionospheric propagation prediction and observation problems. These documents should be taken into consideration as a background [4, 5, 6].

Objectives of the study

We analyze field strength measurement data for two medium-range (path length 250-500 km) communication channels in the Baltic in this paper. Propagation and system performance calculations were carried out for shortwave at frequency of 6120 kHz for a given time and path. Radio signal under study originated from broadcast station in Pori, Finland (Yleisradio) with transmitter's ERP about 50 kW. Monitoring has been conducted in November 16 and 17, 2006 from 0700 to 2300 EET, in the northern Estonia (propagation path length 280 km) and November 29 until 30, 2006 from 0700 to 2300 EET, in the northern Latvia (propagation path length 450 km). Graphical results of field strength measurements are presented on Figs. 2 and 5 respectively. It should be emphasized that average received signal level depends significantly on the ratio of land and sea surface on the propagation path. Share of the Baltic Sea surface is 30 % of the propagation path between Tallinn and Pori but only 10 % of the path between Pori and Northern Latvia.

R&S Propagation Wizard was used to prediction S/N ratio and field strength at the receiver site (see example in

Fig. 1). Atmospheric, galactic and man-made noises at the site of reception are taken into account in accordance with the pertinent CCIR recommendations.

It is noticeable that MUF decreases towards the nighttime.

Predicted propagation characteristics of the communication channel composed by Propagation Wizard agree with the empirical results.

Monitoring receiver in use was Rohde & Schwarz ESMB with active monopole (rod) antenna and laptop computer equipped with monitoring software ARGUS. Measurement results analyzed using software package MATLAB.

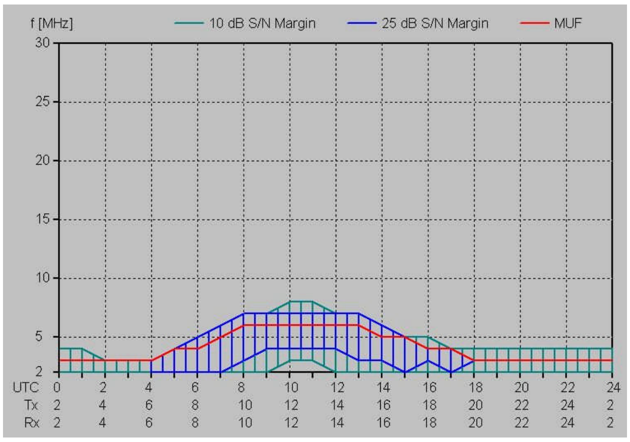

Fig. 1. Daily changes in field strength (R&S Propagation Wizard)

The trial environment

Transmission lines are in both cases, by their ground characteristics, so called inhomogeneous paths. For the receiving site in Tallinn 2/3 of the propagation path lies over the land. The last third of the path where the waves travel across the sea surface does not influence the electromagnetic field significantly. The low salinity of the Baltic Sea has also taken into account. The observations have shown, that radio signal is more stable, if the sea surface environment lies in the beginning of transmission route [7, 8].

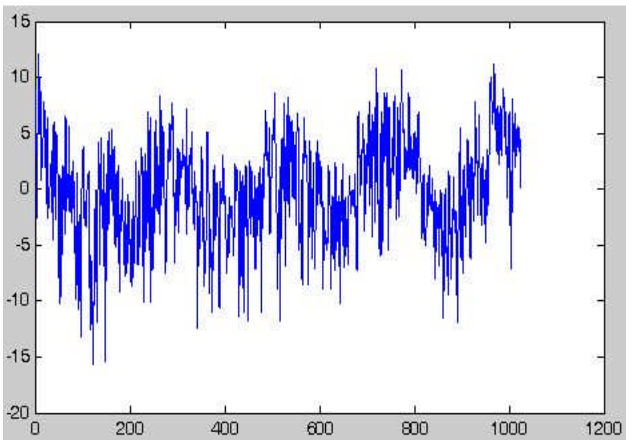

Fig. 2. Example of fading in received signal. This plot shows the field strength measurement results (Tallinn, Nov. 16th, 1310 – 1440 EET). Average difference of field strength is 7 dB for the maximum and minimum of a fading cycle

The dominant propagation mechanism of first communication path is ground-wave. Evaluated fading parameters are average fading period and average fading intensity. Observed data designates that fades on this channel can last 25 minutes. It is relatively slow fading channel. Slow fading has its advantages and disadvantages as well. First, the slower fading is easier to follow. On the other hand, when the radio signal fades below the noise level, it can stay there for a longer time, what will cause extended group of errors [9].

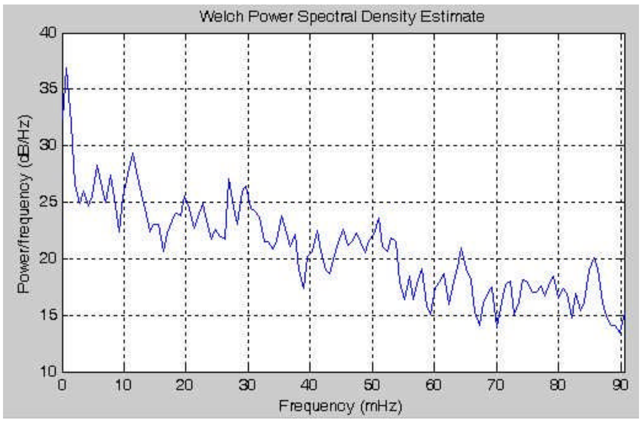

Fig. 3. The plot illustrates the frequency content of the above-displayed data (Tallinn, Nov. 16th, 1310 – 1440 EET)

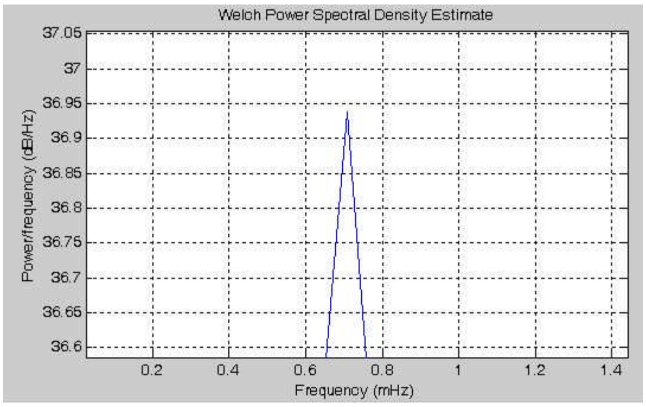

Fig. 4. Recurrence of field strength varies. Clearly expressed periodicity, spectrum with dominant frequency 0.7 mHz, i.e., fading with period about 25 min.

Channel statistical characteristics indicate 7 dB average fading intensity and 0.7 mHz fading rate for receiving path in northern Estonia with period about 23 min (Fig. 4). Surface wave is the dominating propagation mechanism for the given path.

The second receiving site was chosen in the northern Latvia where we presume that radio signal propagation is mainly affected by ionosphere. In this case the dominating propagation mechanism is skywave propagation. At this site a clearly expressed periodicity of fading with the period of 13 min. can be observed from the spectra (Figs. 6 and 7). Intensity of fading is approx. 15 dB. A conclusion can be made that skywave propagation features more intense fading with shorter period than ground-wave propagation.

Dispersion, characteristic for skywave transmissions, is mainly caused by multi-path propagation. However, the means to describe ionospheric pattern are pretty limited, also the characteristics of propagation paths and reflecting ionospheric layers are physically not measurable. These factors increase the significance of empirical studies.

The movement of Earth causes seasonal variations which means that the zenith angle of the sun changes and the amount of suns radiation that hits the upper layers of atmosphere changes with it. The ionization density of E-layer is higher during summer, as it depends on the Sun's zenith angle – it is highest at summer and lowest at winter. The ionization of F1-layer (which exists only during daytime) and its critical frequency vary with changing seasons. As sunshine-less time is much longer during autumn-winter period in Baltic region, the ionization levels drop notably. Also, the critical frequencies are very low. F1 and F2 layers are frequently conjoined at that period.

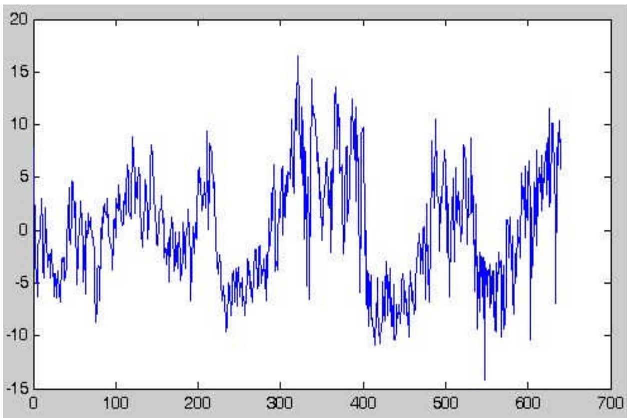

Fig. 5. Example of fading in received signal in northern Latvia. This plot shows the field strength measurement results Nov. 29th, 1445 – 1545 EET

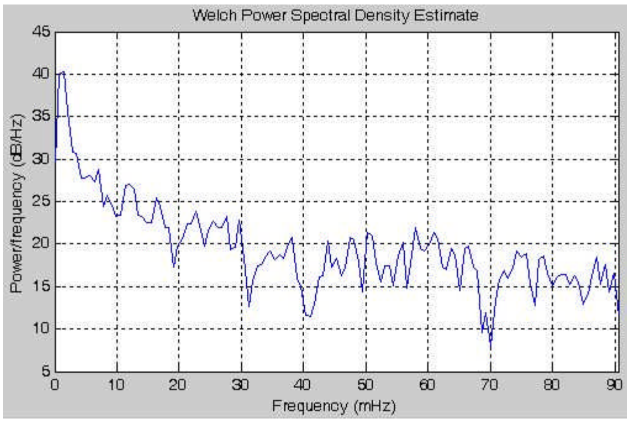

Fig. 6. The plot illustrates the frequency content of the above-displayed data (northern Latvia, Nov. 29th, 1445 – 1545 EET)

At the same time, the closer the transmission frequency is to MUF, the less the multi-path phenomenon is distorting the signal. Because of this, the temporal dispersion is stronger on lower frequencies. If the skywave has temporal dispersion, it almost always suffers also from frequency dispersion or Doppler spread as well. This is caused by ionospheric drift.

We studied also the distribution of measured field strength values to find out if the field strength variations can be described by some known probability distribution. Figs. 8 and 9 illustrate the histograms according to the field strength measurement results in Tallinn and Northern Latvia. The histograms feature significant asymmetry. These histograms follow approximately Rayleigh' and Rayleigh'-Rice distribution. This conclusion agrees with earlier results discussed by several authors, e.g. [1, 10].

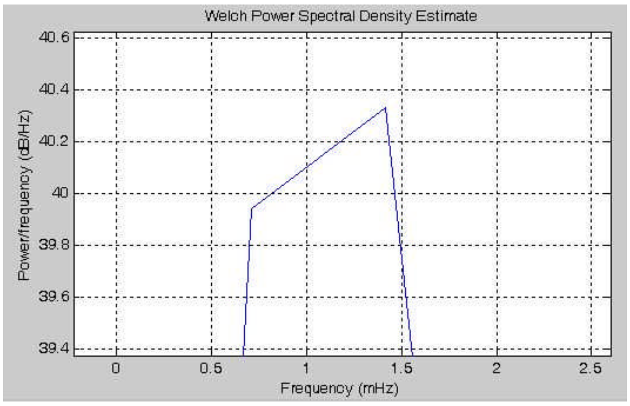

Fig. 7. Recurrence of field strength varies. Clearly expressed periodicity, spectrum with dominant frequency 1.3 mHz, fading with period about 13 min

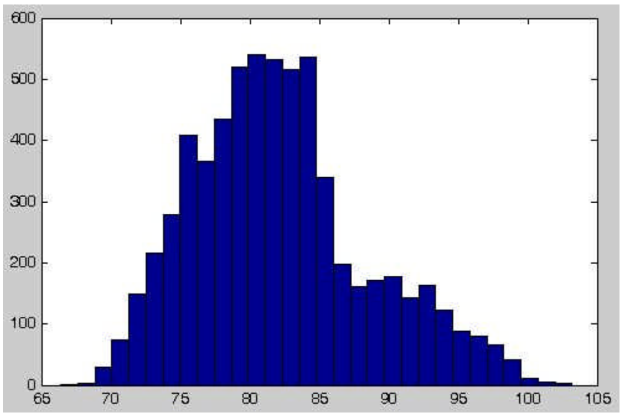

Fig. 8. Example of field strength histogram of a fading signal received in Tallinn

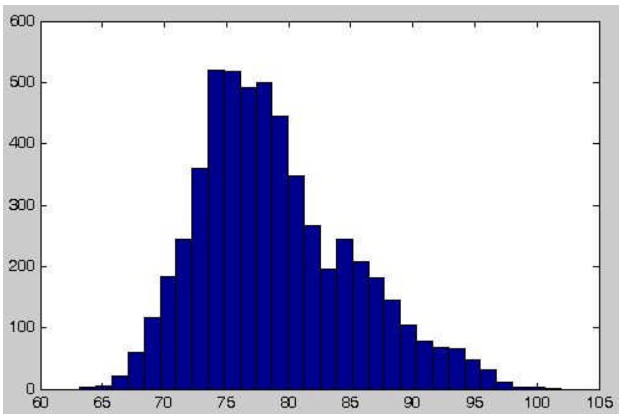

Fig. 9. Example of field strength histogram of a fading signal received in Northern Latvia

The results of fitting the measured field strength histograms to various distributions using MATLAB suggest the log-normal distribution as the best match. More reliable conclusions can be made using larger sets of field strength measurement results. Our future research plans include also such types of studies.

Conclusions

We made an attempt to characterize quantitatively the fading of shortwave broadcast transmitter signals at two receiving sites at mid-range distances of several hundred kilometers from transmitter. Fading-related features of these two shortwave communications channels were quantitatively characterized by depth of fading and fading period. Longer path from Pori, Finland to Northern Latvia features mostly skywave propagation with deeper and faster fading than fading observed in association with ground-wave propagation between Pori and Tallinn. Field strength values follow approximately lognormal distribution.

References

1. **Doluhanov M. P.** Распространение радиоволн. – Связь: Москва, 1972.
2. **Straw R. D.** The ARRL Antenna Book // The national association for Amateur Radio. – Newington CT. – 2007. – P. 23–38.
3. **Goodman J. M.** Operational communication systems and relationships to the ionosphere and space weather // Space Weather and Telecommunications. Advances in Space Research. – 2005. – Vol.36, No. 12. – P. 2241–2252.
4. **ITU-R rec. P.533-9.** HF propagation prediction method. – International Telecommunications Union, 2007.
5. **ITU-R rec. P.1148-1**. Standardized procedure for comparing predicted and observed HF sky-wave signal intensities and the presentation of such comparisons. – International Telecommunications Union, 1997.
6. **ITU-R rec. P.1239-1.** Reference Ionospheric Characteristics. – International Telecommunications Union, 2007.
7. **ITU-R rec. P.368-7.** Ground-wave Propagation Curves for Frequencies between 10kHz and 30 MHz. – International Telecommunications Union, 1992.
8. **An J.** Empirical Analyses on Maritime Radio // IEEE 59th Vehicular Technology Conference. – 2004. – Vol. 1. – P. 176–180.
9. **Nieto J. W.** Does Modem Performance Really Matter of HF Channels? An Investigation of Serial-tone and Parallel-tone waveforms // Proceedings of the Nordic Shortwave Conference HF 01. – Nordic Radio Society. – August 2001.
10. **Freeman R. R.** Telecommunications Transmission Handbook. – Wiley, 1998.

Submitted for publication 2008 02 15

E. Lossmann, U. Madar, A. Raja, M. A. Meister. Some Fading-related Problems at Shortwave Propagation Path in the Baltics // Electronics and Electrical Engineering. – Kaunas: Technologija, 2008. – P. 57–60.

The ionospheric propagation of shortwave frequencies is characterized by stochastic fluctuations, known as fading. Due to fading effects, the level of radio signal can vary (tens to hundreds of times), but in addition, the same phenomenon can cause a randomly variable temporal dropouts – from tenths of a second to tens of seconds. Within this paper, the fading characteristics of the broadcast transmitter signal from Pori (Finnish Broadcast Company, YLE) over two medium-range propagation paths in northern Estonia and northern Latvia are examined. Comparisons are drawn for both groundwave and ionospheric propagation data. Observed fading phenomenon is described with reference temporal and frequency aspects. The research data is statistically analyzed in MATLAB environment and the graphical results are presented. Ill. 9, bibl. 10 (in English; summaries in English, Russian and Lithuanian).

Е. Лоссман, У. Мадар, А. Рая, М. А. Меистер. Проблемы распространения коротких волн на пространстве стран Балтии // Электроника и электротехника. – Каунас: Технология, 2008. – No. 5(85). – P. 57–60.

Исследуются способы распространения сигналов на территории Латвии и Эстонии финского передатчика „Pori“. Ослабление сигнала описывается с учетом времени суток и частотного спектра. Полученные результаты оценены с использованием программы MATLAB. Результаты представлены в виде графиков. Ил. 9, библ. 10 (на английском языке; рефераты на английском, русском и литовском яз.).

E. Lossmann, U. Madar, A. Raja, M. A. Kai kurios trumpųjų bangų sklidimo Baltijos valstybių teritorijoje problemos // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2008. – No. 5(85). – P. 57–60.

Trumpųjų bangų sklidimą jonosferoje apibūdina stochastinės fliuktuacijos, kitaip vadinamos slopinimu. Dėl slopinimo poveikio radijo signalo lygis gali kisti nuo dešimčių iki šimtų kartų. Be to, tas pats reiškinys gali sukelti atsitiktinius kintamos trukmės signalo trūkius, kurių trukmė kinta nuo dešimtųjų sekundės dalių iki dešimčių sekundžių. Nagrinėjamos suomių kompanijos „Pori“ siųstuvo transliuojamo signalo charakteristikos Estijos ir Latvijos teritorijoje. Lyginamas antžeminių ir jonosferoje esančių bangų sklidimo pobūdis. Pasireiškiantis slopinimas aprašomas atsižvelgiant į laiko ir dažnio aspektus. Duomenys statistiškai analizuojami MATLAB programoje. Rezultatai pateikiami grafiškai. Il. 9, bibl. 10 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).