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Noise Level Estimation in the Shortwave Frequency Range

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Introduction

The presence of noise is the fundamental principle of wireless communication which must be taken into account always when setting the parameters of radio system such as sensitivity, modulation type and coding, but also choosing location of the receiving site etc. Generally, electromagnetic noise is classified according to its source – atmospheric or man-made noise. It is common to apply the recommendation ITU-R P.372-9 for estimating the environmental character of background noise. The recommendation defines five typical environments in the context of RF (*Radio Frequency*) reception.

At lower frequencies of short-wave band, the atmospheric noise predominates. The main causes of atmospheric noise are thunderstorms, occurring mostly in the tropical regions of the Earth. Electromagnetic noise, developed by these storms, uses much the same propagation mechanisms as the skywave. Temporal grouping of noises depends on daily changes in the ionosphere, time of the year, and solar activity. Total atmospheric noise level at a receiving site is in tight correlation with local weather conditions. For example the local thunderstorm may increase the noise levels by about 10 dB, compared to a silent period [1].

Level of a man-made noise is less dependent on the number of people, living in a certain area, than the technical sophistication of local infrastructure and lifestyle. Power supplies of some lighting equipment, starting systems for electrical motors, generators, different impulse power supplies and big computer farms contribute to the level of local noise environment. Because of this, the background noise levels in peak hours can raise substantially over the top level set by the standards [2].

As the infrastructure in Estonia has changed greatly within the last decade and the level of technological sophistication has increased significantly also in rural areas, it is appropriate to explore how those 5 different noise environments described in the recommendation ITU-R P.372-9 can be empirically identified and which particular sources of noise they mainly depend on. The monitoring was carried out to evaluate short-wave radio communication sites with respect to the quality of reception and to get an overview of spectral occupancy within the frequency range from 1.5 to 15 MHz.

Measurements

Since short-wave range is not in the focus of commercial interest, there is a lack of comprehensive data about spectrum usage and electromagnetic noise level in Estonia. In order to determine the character of background noise in the prospective shortwave reception sites and to gather data about spectral occupancy in general the current survey was initiated by the Estonian Defense Forces.

We present several samples of the measured data and give an outline of monitoring equipment in this paper, but the more detailed description of the research procedure has been proposed by the authors in [3].

Right choice of the antenna is critical to the measuring of interferences, because the directivity, polarization and gain characteristics affect significantly the results of the measurement [4]. Also the stability of power supply has crucial importance. We conducted comparative measurements, using power from the battery to check the noise level induced by the local mains power. The monitoring receiver in use was Rohde & Schwarz ESMB with the active monopole (rod) antenna and the laptop computer equipped with the monitoring application ARGUS (Fig. 1).

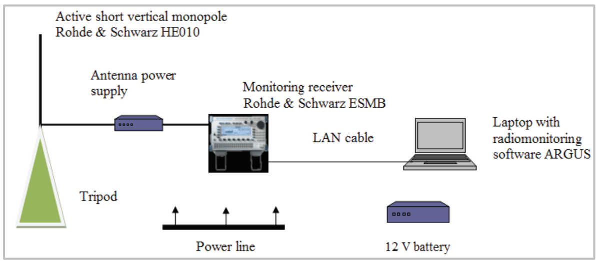

Fig. 1. Layout of the monitoring system

The RF band was scanned using 5 kHz frequency step and with receiver bandwidth 4 kHz (Fig. 2). Measurement results were analyzed using software package MATLAB.

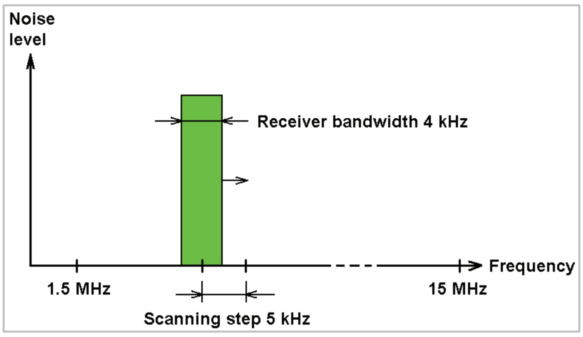

Fig. 2. Parameters related to the measurements

Recommendation ITU-R P.372-9

External noise is among the most important factors determining the noise floor when estimating the signal-to-noise ratio in short-wave range. Certainly it is most advantageous to operate on short-wave channel with no interference at the distant end receiver in the optimum operating frequency, yet this is not commonly feasible. The useful radio signal has to compete with the disturbances in the radio channel at every given moment, considering theoretically unlimited number of noise and interference sources. In addition to the local sources of background noise and interference one also needs to take into account noises, originating thousands of kilometers away, as ionosphere is equally well providing propagation of signal, noise and diverse interferences.

ITU-R P.372-9 gives the common methodology for specification of noise electromagnetic pattern in four environmental categories plus galactic noise. While predicting the expected noise levels, the characteristic trends with frequency, time of day, season, and the geographical location are taken into account explicitly. There are other variations that could be considered only statistically. The Recommendation gives the prediction methodology for approximated calculations of background noise level on the assumption that interferences due to surplus co-channel transmissions and other sources of impulse noise in close range are not present [5, 6].

The external noise figure F_a which is defined by ITU-R P.372-9 in logarithmic notation for the frequency f applies to a short vertical antenna over a perfectly conducting ground plane. This parameter is related to *rms* noise field strength E_n along the antenna by

$$E_n = F_a + 20\log f + B - 95.5\,, \qquad (1)$$

where E_n is in dB (above 1 μV/m), frequency f is expressed in MHz, and the receiver bandwidth B – in dB (where B is in dB-Hz).

In a real communication environment the character of external noise power is highly impulsive and non-Gaussian, hence fitting of probabilistic distribution of the received random noise waveform is required. Nevertheless, for the long-term predictions it is more convenient to use the median level of man-made noise. For estimation of median values of man-made noise power for different environments and frequencies the following expression is given by:

$$F_{am} = c - d\log f\,, \quad [dB]\,, \qquad (2)$$

where frequency f is expressed in MHz and environmental constants c and d are listed in the Table 1.

Table 1. Values of environmental constants ***c*** and ***d***

Environmental category	*c*	*d*
Business (curve A)	76.8	27.7
Residential (curve B)	72.5	27.7
Rural (curve C)	67.2	27.7
Quiet rural (curve D)	53.6	28.6
Galactic noise (curve E)	52.0	23.0

The curves illustrating the expected levels of background noise are shown on Fig. 3.

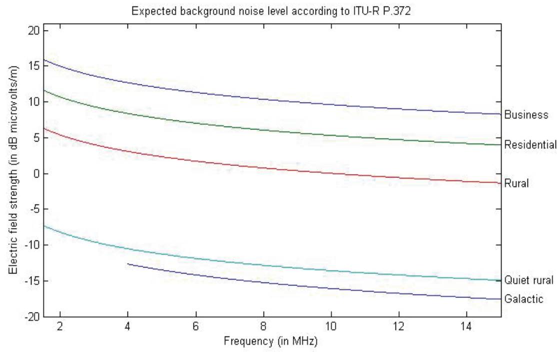

Fig. 3. Curves of the expected background noise level for the frequency range from 1.5 to 15 MHz

These curves are idealized. The recommendation also gives table for *decile* values of average man-made noise power expressed in dB above or below the median. These values were measured in the 1970s and may change considerably with day-to-day, in order to the activities which may generate man-made noise. It shows that short-term behaviour of the noise level can vary rather largely.

Comparison of the empirical data to the Recommendation

In real communication environment the value of F_a changes stochastically, as both the development of thunderstorms and propagation conditions are changing randomly. Usually domestic appliances and their power supplies can cause the noise on low frequencies. The atmospheric noise predominates at frequencies below 10 MHz, but simultaneously we can find the man-made noise and interference pattern as well. This is the case illustrated on Fig. 4. Measurements were carried out on 28th October 2009 during daytime between 12 and 13 UTC.

Fig. 5 and Fig. 6 are examples of background noise pattern at two rural sites and the associated contours plot were recorded on the 21st and 25th of October 2009.

Fig. 6 reveals broadband disturbances below 5 MHz originated from the combination of an engine-generator and bad grounding of the communication equipment.

Fig. 7 and Fig. 8 present plots of the noise pattern in two residential areas. Spectrum was scanned on 21st of October and 10th of November 2009 between 1400 and

1500 UTC. The daily sunspot number varied from 11 to 23 during the monitoring.

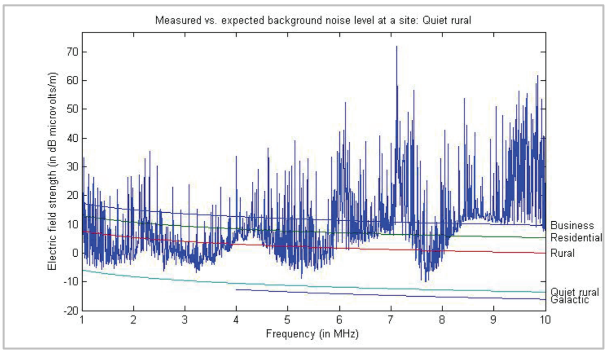

Fig. 4. Measured background noise at a quiet rural site

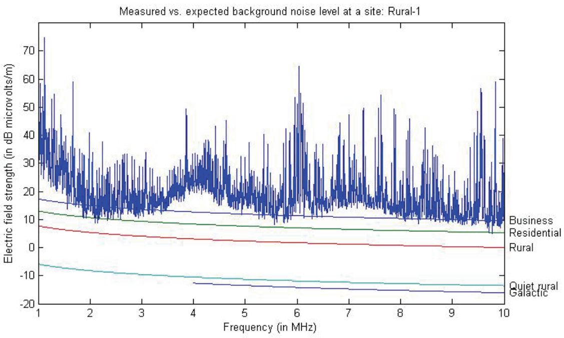

Fig. 5. Measured background noise at a rural site 1

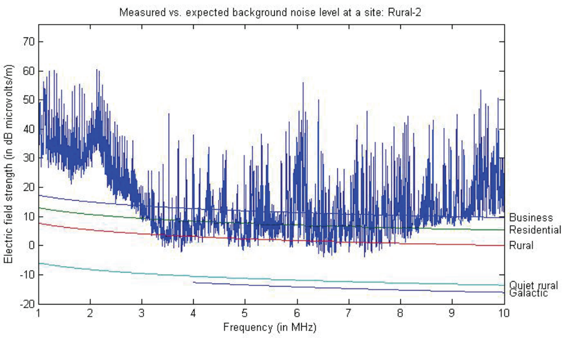

Fig. 6. Measured background noise at a rural site 2

We refer to it as the quiet period of solar activity. These plots are shown to illustrate strong interferences and man-made noise regarding the location, the time-of-day and propagation conditions. The comparisons between theoretical level of predicted data and those measured in practice reveal considerable disparities [6]. Although the noise dissemination may use either sky wave or ground wave methods the primary sources of noise are local ones.

Fig. 9 shows measurement results performed in an office at the University of Technology equipped with large PC farms. Yet the ITU-R P.372-9 does not cover the indoor noise levels. This example is present to view as a reference to get the idea of the EMC scenario. The PC emission dominates over the spectrum in question as it was expected. Similar measurements were made by Weinmann and Dostert [7].

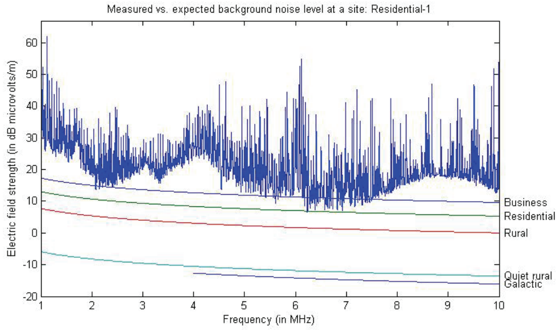

Fig. 7. Measured background noise at a residential site 1

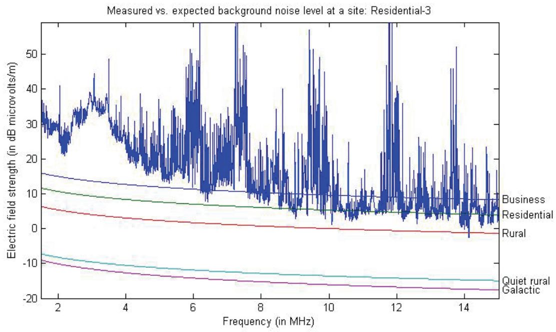

Fig. 8. Measured background noise at a residential site 2

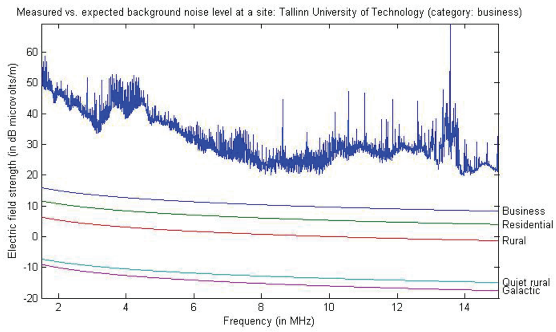

Fig. 9. Measured background noise at a business site inside the building

Conclusions

The lower end of shortwave band is a very complicated communications environment with respect to noise and interference. There exist significant deviations from the expected background noise level, especially at lower frequencies from 1.5 to 4 MHz since the amplitude of man-made noise decreases with increasing frequency. The noise originates mainly from electric motors and ignition systems located in the close range of receiving antenna. The good grounding is also very important for shortwave communication. However, business sites with a number of interference sources such as computer farms and various communication systems produce equally very high levels of background noise within the whole shortwave spectrum.

Altogether the noise level on short waves could be characterized relatively well by using the data provided in ITU-R P.372-9.

There is a need for more detailed knowledge about the variations of interference levels. It is of crucial importance to monitor shortwave band over a longer period of time with averaging over multiple scans, to observe seasonal changes, solar activity etc for long-term channel assignment.

Acknowledgements

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References

1. **Freeman R.** Telecommunications Transmission Handbook. – USA: Wiley, 1998. – 1232 p.
2. **Berdnikova J., Ruuben T., Müürsepp I., Lossmann E.** Resolution and Doppler Tolerance of Cognitive System Waveforms // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 7(103). – P. 101–104.
3. **Meister M.–A., Lossmann E., Madar U.,** Results of the Practical Research for HF Communications in Estonia // Nordic Shortwave Conference Proceedings. – Arkitektkopia AB, Växjö, Sweden, 2010. – P. 4.2.1.–4.2.10.
4. **Straw R.D** The ARRL Antenna Book. – USA: The National Association for Amateur Radio, Newington, CT, 2007. – P. 23–29 (chapter 23).
5. **Goodman J. M.** Operational communication systems and relationships to the ionosphere and space weather // Advances in Space Research, 2005. – Vol. 36. – Iss. 12. – P. 2241–2252.
6. **Bradley P. A., Damboldt T., Suessmann P.**, Propagation models for HF radio service planning // HF Radio Systems and Techniques, 2000. – Eighth International Conference on (IEE Conf. Proc. No. 474). – P.175–179.
7. **Weinmann F., Dostert K.,** Verification of background noise in the short wave frequency range according to recommendation ITU–R P.372 // AEU – International Journal of Electronics and Communications, Volume 60, Issue 3, 1 March 2006. – P. 208–216.

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Noise is a composite signal by nature, changing widely over time, and some of its components can be controlled while the others cannot. Although the signal-to-noise ratio (SNR) is the main factor determining the signal quality at the receiving end, it is quite complicated to define the characteristics of the local noise, especially in the shortwave bands. This paper provides an overview of the background noise measurements to evaluate the problematic shortwave communications sites in Estonia and to assess their suitability as radio receiving sites. Extensive statistical data was collected during the study, the sources of interference were identified and their spatiotemporal influence was analyzed. Monitoring results were compared to methods and models, presented in recommendation ITU-R P.372-9. Ill. 9, bibl. 7, tabl. 1 (in English; abstracts in English and Lithuanian).

E. Lossmann, M. A. Meister, U. Madar. Triukšmo lygio įvertinimas trumpadažnių bangų diapazone // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 6(112). – P. 85–88.

Kai kurias triukšmo signalo dedamąsias galima kontroliuoti, kitų negalima. Signalo kokybę lemia signalo ir triukšmo santykis. Estijoje analizuojamas trumpadažnių bangų diapazonas ir šiame dažnyje atlikti triukšmų tyrimai. Surinkti statistiniai duomenys. Nustatyti triukšmų šaltiniai, pateikta įtakos analizė. Gauti rezultatai palyginti su ITU-R P.372-9 rekomendacijoje aprašytais metodais ir modeliais. Il. 9, bibl. 7, lent. 1 (anglų kalba; santraukos anglų ir lietuvių k.).