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HF NOISE MEASUREMENT IN THE WESTERN PART OF ROMANIA

Cornel BALINT, Aldo DE SABATA

Politehnica University Timişoara, Romania
cornel.balint, aldo.de-sabata@upt.ro

Abstract: *Despite the extraordinary development of mobile communications, HF radio links have several advantages that make them unique in some application areas. Knowledge of HF noise is critical for the setup of a point to point HF communication. The paper presents HF noise measurements performed using a broadband antenna and Software Defined Radio equipment for signal acquisition, followed by offline signal processing. The recording has been split into several sub-bands of small bandwidth and for each sub-band the mean power has been computed, to find the sub-band with the lowest power. It might be assumed that the frequency band having the lowest power contains only noise. An analysis of the influence of sub-band size on the noise level hasalso been made. Measurements cover a large part of HF band and a large time interval to observe the noise behaviour.The paper analyses the noise level over short and long time periods, and over a large frequency band, and reports also simultaneous noise measurements in two locations in the western part of Romania, a dense urban one and a small town one, to highlight the differences caused by man-made noise of industrial type.*

Keywords: HF, noise, Software Defined Radio

1. Introduction

Communications in the High Frequency range (3-30 MHz) take place for supporting various human activities [1] and remain important despite the widespread development of mobile wireless communications. HF electromagnetic waves propagate through the ionospheric channel, which has some characteristics that determine a particular structure of the channel noise [2]. Several noise sources overlap to form a complicated noise structure consisting of background natural atmospheric and cosmic noise, man-made noise from industrial and civil activities, radio and lightning signals travelling from very distant sources through the ionospheric channel etc. All these contribute to the usual appearance of the noise background on the displays of the measuring instruments acting as receivers, making it difficult to apply the ITU definition that “radio noise is the sum of emissions from multiple sources that do not originate from radio communication transmitters” [3].

Several attempts have been made to measure HF noise and interference in several parts of the world, but available reported data are not abundant. For example, in [4] a Bi-Kappa probability distribution of noise is proposed. Further studies indicated an important variability of noise characteristics depending on location and time [5]. It has been shown that noise is also direction-dependent [6]. The Bi-Kappa distribution has been used subsequently to model the ionospheric channel for various simulation-based studies [7]. Interference

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assessment results have been reported for the northern part of Europe in the past [8].

Noise measurement results in the HF range depend on the receiver bandwidth and on the chosen noise threshold [2,5]. Common values for the measured noise bandwidth are between 2.7-3 kHz due to current applications of HF communications, but broadband (e.g. 150 kHz) measurements are also reported [2, 5, 9]. The noise floor knowledge is crucial for spectrum occupancy measurements based on energy detection. The threshold for discriminating signal from noise has to be theoretically chosen to minimize the probability of misdetection and the probability of false alarm.

In the present paper, we discuss noise as measured with a USRP equipment from NI [10]. Data have been acquisitioned and subsequently processed digitally off-line. This approach allowed for choosing the best option for the noise receiver bandwidth and for a visual assessment of the noise threshold.

Measurements have been performed at two locations, one situated in an industrial town with heavy spectrum occupation and a remote one, with low industrial activity and quiet radio channel. As expected, the noise structure and characteristics differ in the two locations.

This work is motivated by authors' involvement in Electromagnetic Compatibility for the Automotive industry. Modern vehicles are equipped with critical security devices that are sensitive to EM radiation, including HF.

The rest of the paper is organized as follows: Section 2 describes the equipment and method used for acquiring HF signals and determining noise level. Results on noise measurements are reported in Section 3. Conclusions are drawn and future work planning is tackled in the last section.

2. Equipment and Method

Noise measurements have been performed by using an omnidirectional broadband Diamond WD 330 J antenna and Universal Software Radio Peripheral model NI USRP-2950 Dual RF Transceiver. To operate the SDR equipment in the HF range, an extension LFRX USRP Daughterboard had to be added that provided the operational frequency range DC – 30 MHz. The communication with the computer has been realized through a PCIe – MXI Express Interface Kit for USRP RIO. The system has been controlled and operated under the GNU radio environment.

Measurements data are stored in files and processed offline in Matlab.

A USRP linearity check across the HF range was performed using a quality signal generator (Agilent N5182A) and a spectrum analyzer (Agilent N9320B). The detected nonuniformity was below 0.1dB and no correction of the results was required.

The acquisitioned signal (records) had a duration t_r (e.g. t_r =5 seconds) and a bandwidth B_r (e.g. B_r =1 MHz) centred on a frequency f_c from the HF band. The central frequencies have been chosen to cover the HF band. The power spectrum of each sub-record has been numerically calculated, based on the Discrete Fourier Transform properties and the Parseval theorem.

Noise measurements require the setting of a threshold to distinguish between natural HF noise and intentionally transmitted signals. The measurement method we used replaced this threshold with a search in the frequency-domain as follows. Each record has been split into several sub-bands of bandwidth B (e.g. B= 3 kHz) and the remaining frequencies at the edges have been discarded. For each sub-band the mean power has been computed to find the sub-band with the lowest power. It might be assumed that this frequency band having the lowest power contains only noise. The computed spectrum and the smallest power sub-band for a signal around a 10 MHz central frequency are plotted in Figure 1.

3. Experimental results on noise measurements

According to the previously described procedure, many signals around different central frequencies covering the HF band and different time periods has been acquired and processed.

To highlight the minor influence of the measurement bandwidth on the noise measurement results, we have considered different values for measurement bandwidth. Figure 2 plots the measured noise level for a measurement bandwidth between 3 and 50 kHz.

A variation less than 0.2 dB was observed for measurement bandwidth between 3 and 5 kHz, and for 5 and 50 kHz the deviation is about 0.1 dB. This assumption may be not valid for a signal having a high grade of spectrum occupancy and narrow sub-bands containing only noise.

Figure 3 plots the noise level for short time (5 min). As expected, small variations in short-term noise level were observed.

The difference between maximum and minimum noise level for short time is about 2.8 dB and the standard deviation is of 0.2234. Similar behaviour was observed for different central frequencies.

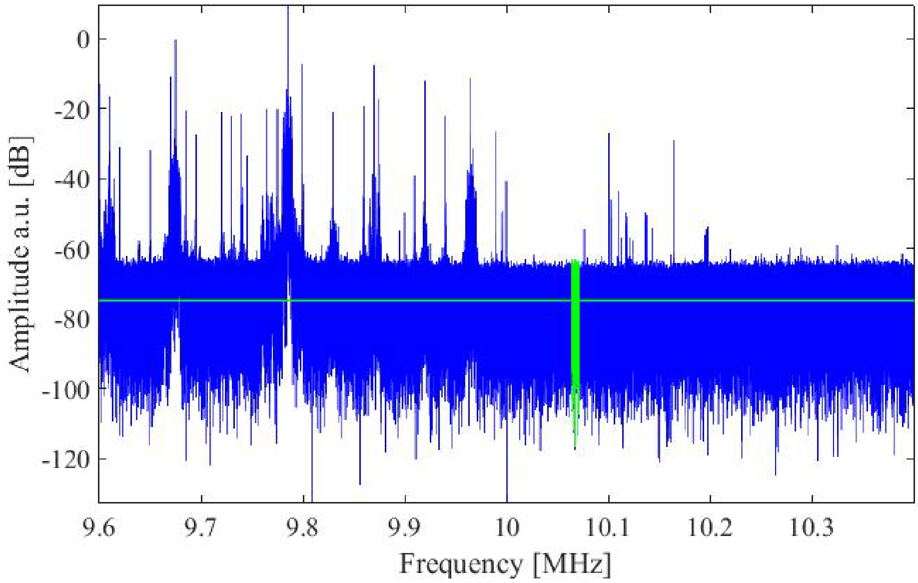

Figure 1: Signal spectrum, noise sub-band and average noise level

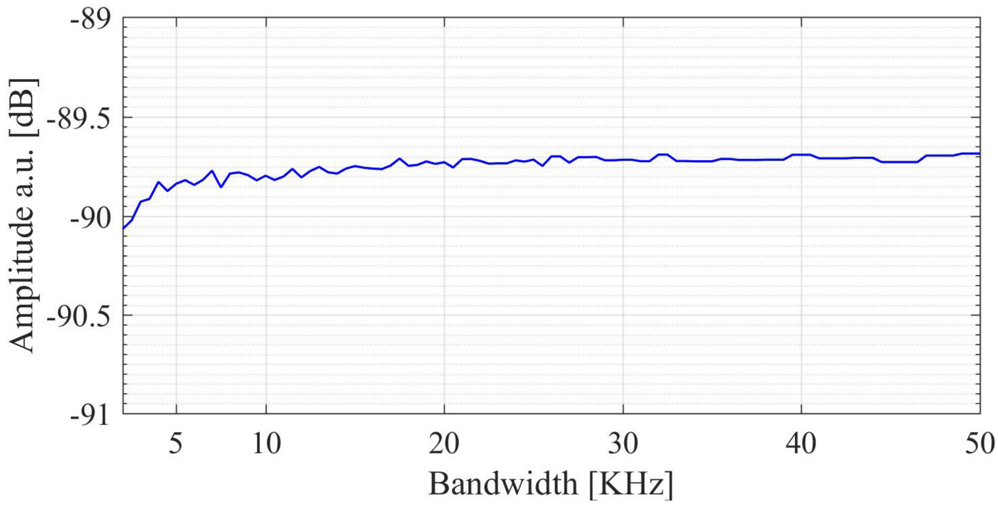

Figure 2: Noise level function vs measurement bandwidth

Noise level variation during a time interval of 24 hours is plotted in Figure 4. Noise values in Figure 4 was computed every 15min.For this higher time interval, as expected, a larger noise level variation compared to the short time variation was observed. The difference between maximum and minimum values is about 2.8 dB for the considered central frequency and time instant. Many measurements at different frequencies and time moments showa difference no larger than 4 dB for a 24-hour interval.

Measurements over a wide range of frequencies show significant differences of noise level at diverse frequencies in the HF band. Figure 5 plots the noise level for a range between 3 MHz and 25 MHz. The noise level is very high (about –85 ÷ –90 dB)at lower frequencies, compared to –95 ÷ –97 dB at frequencies higher than 10 MHz. The reason can be a very intensive wideband noise supposed to be of industrial origin, frequently observed in the measurement area. A sample of signal affected by this noise in a time-frequency plot is shown in Figure 6.

The maximum usable frequency (MUF) might also have an impact on the decrease of the noise level at higher frequencies in the considered range.

Simultaneous noise measurements have been performed at two locations, one situated in an industrial town with heavy spectrum occupation (Timisoara, RO) and a remote one, with low industrial activity and quiet radio channel (Lipova, about 50 km N-E from Timisoara). As expected, the noise characteristics plotted in Figure 7, are different at the two locations. Figure 7 shows that the noise in the quiet area is about 3 – 7 dB lower at the considered frequencies.

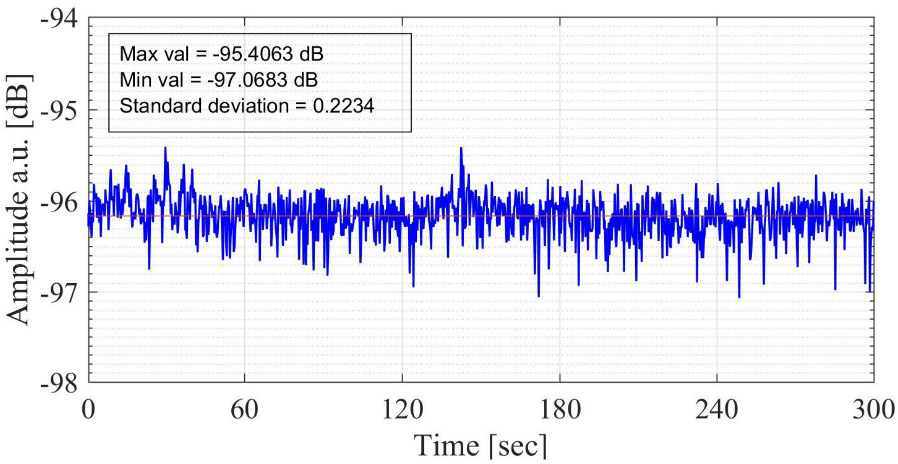

Figure 3: Short time noise measurement at 10 MHz

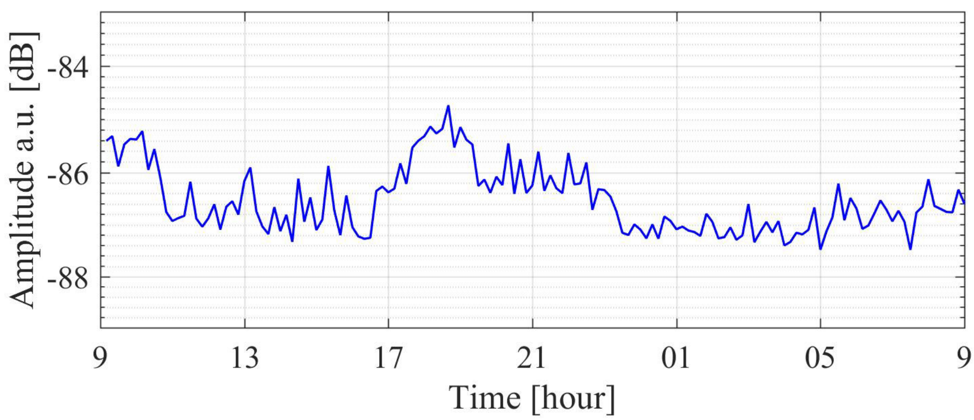

Figure 4: 24 hours noise measurement at 7MHz. Time count start at 09 am, Feb. 6th, 2019

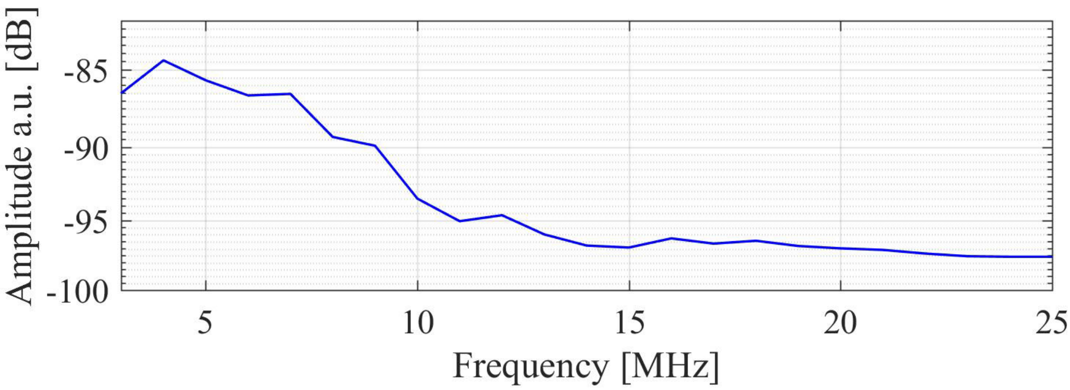

Figure 5: Short time noise measurement

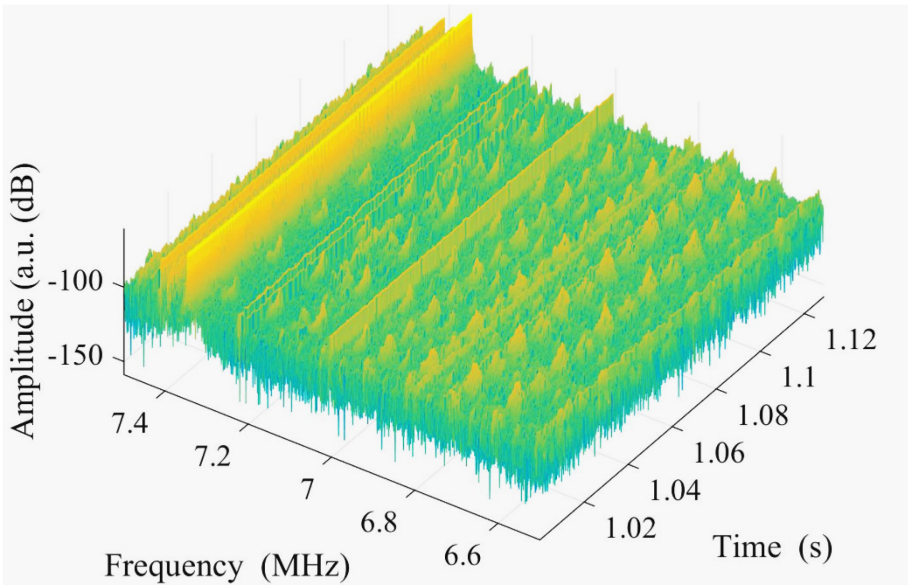

Figure 6: High level periodic noise detected in measurement area

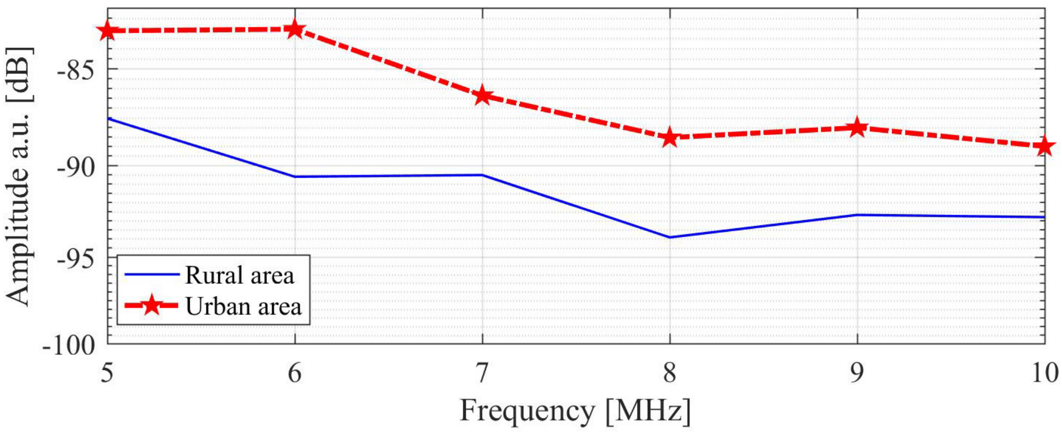

Figure 5: Short time noise measurement at two locations

4. Conclusions

The paper presents the results on the noise level measurements in the HF band. Signals have been acquired using a broadband antenna and SDR equipment. The power spectrum of recorded signal has been computed, then split into several sub-bands and the sub-band with the lowest power was identified. It might be assumed that the frequency band having the lowest power contains only noise. The paper analyses the noise level over short and long time, and over a large frequency band and reports also simultaneous noise measurements in two locations in western part of Romania, one dense urban and one small town, to highlight the differences caused by man-made noise of industrial type.

As future work, we are considering the characterization of the HF noise distribution and the measurements using a calibrated antenna to obtain absolute values of noise level in V/m.

Acknowledgements

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