WIDEBAND IMPULSIVE NOISE MEASUREMENTS

IN DVB-T AND UMTS RADIO CHANNELS

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ABSTRACT

This paper presents the results of a study covering measurement of the wide band impulsive noise present in DVB-T and UMTS radio channels. The measurements have been taken in an urban environment in the frequency band corresponding to channel 69 for DVB-T and the lower channel in the UMTS band. To analyse the impulsive noise it has been modelled as a pulse train where the pulse amplitude, pulse duration and elapsed time between pulses are considered random variables. Results show that noise pulses appear in noise bursts. The pulse amplitudes can be very high compared to the thermal noise and even compared to the signal levels specified for both systems. However, pulse duration is small compared to the system symbol interval.

INTRODUCTION

A radio communication system may experiment several kinds of noise. In most of the cases, e.g. thermal, atmospheric or galactic noise, a Gaussian model can represent it. However, man-made noise which appears in urban environments cannot be assumed to be Gaussian. As it presents a shot nature, it has to be represented by an impulsive model.

Gaussian and impulsive noise models present some differences. The Gaussian model defines a Gaussian probability density function and a constant power spectral density. The power spectral density of the Gaussian noise is affected by linear filtering, while its probability density function is not. Therefore, after filtering, both in-phase and quadrature components are still independent Gaussian noises. Gaussian noise degrades slowly the objective quality of a digital communication system as its power level relative to the signal level increases. The main parameter of the Gaussian model is the noise power.

Conversely, impulsive noise is modelled as a random train [1] of pulses with a very wide band power spectral density. The probability density function of the impulsive noise changes by the filtering process. The resulting in-phase and quadrature components are uncorrelated but dependent [2,3]. This kind of noise may jam the system, even in case of high signal to noise ratios. Although its effect over the BER could be negligible, the subjective degradation of the signal may be important.

MEASUREMENT SYSTEM AND ENVIRONMENT

Two measurement systems were built, one for DVB-T and another for UMTS. The design of both systems is similar. The radio signal is received through an antenna, filtered, amplified, and fed to a mixer. Two linearly polarised antennas were used: a vertical monopole with 1 dBi gain and 50 Ω output impedance for the UMTS measurements and a horizontal polarised omni directional antenna made of two orthogonal folded dipoles with 5 dBi gain and 75 Ω output impedance for the DVB-T measurements.

The specific channel in the band is selected at IF by varying the frequency of the local oscillator (LO_1). Then, the signal is band limited to 8 MHz for DVB-T measurements and 5 MHz for UMTS. The IF signal is demodulated and the base band in-phase and quadrature components are sampled, at 20 Msamples per second each, by means of an A/D card in a computer where the data is stored. The time resolution is 50 ns, and the maximum recording length 4096 samples per channel, equivalent to 204 µs.

The A/D card trigger was set just above the thermal noise level, so that only the scans with at least one noise pulse were recorded. A low level would trigger off the card with high background noise peaks, whereas a high trigger level will truncate the statistical distribution of the impulsive noise amplitude, as the low impulsive noise peaks would be lost. A conservative point of view was taken when setting the level in order to avoid truncating the statistics of the impulsive noise. However, on doing this, some records may have contained only thermal noise. These "empty" records were suppressed during the statistical analysis.

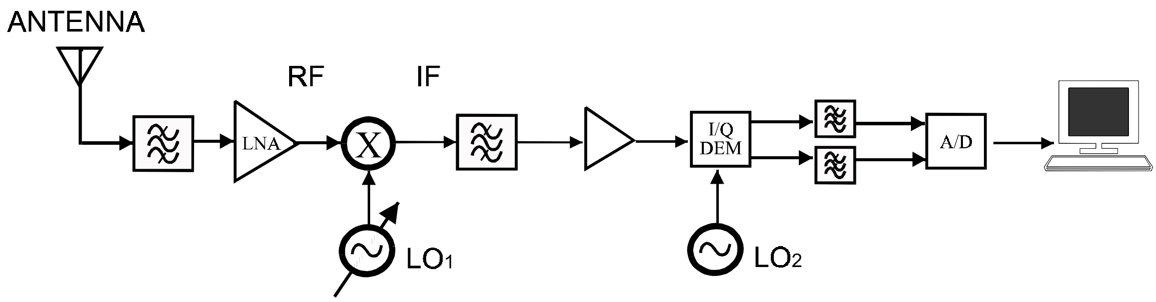

Fig.1. Measurement system setup

The measurement system must be previously characterized to identify its transfer function. A calibration was conducted to relate the recorded voltage levels to the received noise voltage level at the output of the receive antenna.

The outdoor environment considered is an urban micro cell near a round about. The antennas were placed outdoors at a height of four meters.

Fig.2. Measurement environment

The selected channel for DVB-T was channel 69, while the UMTS measurement band was set between 1852.5 MHz and 1857.5 MHz.

STATISTICAL MODEL

Mathematical model

The impulsive noise envelope, n(t), can be represented [1] as the summation of pulses with random amplitudes, a_i, random duration, w_i, and random arrival time t_i, as shown in (1).

$$n(t) = \sum_i a_i \prod\nolimits_{wi} (t - t_i) \quad (1)$$

According to this model, three random variables have to be measured to identify the impulsive noise envelope behaviour: the amplitude of the pulses, the duration of the pulses and the elapsed time between pulses.

The noise phase is assumed to be a random variable uniformly distributed in [0,2π].

Measurement processing

All the registers stored in the computer correspond to voltage at the input of the A/D card. The first processing step is to convert the recorded voltage signal to the electric field strength at the position of the antenna, using the calibration curves. The envelope of the impulsive noise is calculated as the square root of the sum of the in-phase and quadrature components squared.

The impulsive noise in the register is mixed with background noise. The second step in the measurement processing is to set a decision level to extract the noise pulse from the background noise. This decision level is calculated using the algorithm described in [4].

Once the decision level is fixed, the pulse start and end points are determined as the points where the measured signal crosses the decision level with positive and negative slope, respectively. The pulse duration is taken as the time elapsed between the starting and the ending points. The value is rounded because of the finite time resolution of the measurement system. The pulse amplitude is characterized by the peak power the pulse reaches between the starting and ending points. If more than one pulse is present in the register, the elapsed time between pulses is measured as the time between the starting points of both pulses. These data are used in the subsequent statistical analysis of the three variables considered in the study.

RESULTS

The same number of noise registers was obtained for each band (2000), however the number of noise pulses in the DVB-T channel (25650) is higher than the number of pulses in the UMTS channel (11792). This means that the noise pulses are more frequent in the DVB-T channel than in the UMTS channel. Due to the burst nature of the impulsive noise there is, in average, more than one noise pulse per noise register. The elapsed time between pulses can only be measured if there are two or more noise pulses per register. If there is only one noise pulse in the register, the elapsed time can not be calculated, but it can be concluded that it is larger than 204 µs.

The measurements show that, as expected, the in-phase and quadrature components are uncorrelated but dependent, and that the noise phase is uniformly distributed in the [0,2π] interval.

As can be seen in Fig.3, the peak amplitude cumulative distribution function of the received field shows that the noise pulse peak amplitudes are larger in the DVB-T channel than in the UMTS channel. Anyway, some noise pulses occur with very high peak amplitudes in both bands. According to [5], the minimum median field strength in UHF band V is +70 dBµV/m. Some measured noise peak amplitudes are higher than this level. However, the pulse noise durations are much shorter that the system symbol interval. The maximum pulse duration in the DVB-T channel is below 1.5 µs, while the symbol interval is always higher than 224 µs, as can be seen in Fig.4.

The elapsed time between pulses is shorter for the DVB-T measurements. This confirms that the noise pulses are more frequent in the DVB-T channel than in the UMTS channel. Due to the burst nature of the impulsive noise, several noise pulses may occur during a symbol interval [6].

SUMMARY AND CONCLUSIONS

Impulsive noise has been measured and characterized in DVB-T and UMTS channels. It has been shown that noise pulses are more frequent and have larger peak amplitudes in the DVB-T channel than in the UMTS channel. It has also been shown that the pulses have a shorter duration in the DVB-T channel.

In DVB-T channel, noise peak amplitudes are high compared to the minimum signal level required for the receiver to operate, noise pulse durations are much shorter that the symbol interval, but the elapsed time between pulses can be shorter. This means several pulses may occur in one symbol interval.

Further work has to be conducted to asses the effect of the impulsive noise on the system behaviour. However, due to the high power and the high repetition rate of the pulses, it can be expected a DVB-T receiver could fail under impulsive noise conditions, and that an UMTS system will have the capacity of the system reduced.

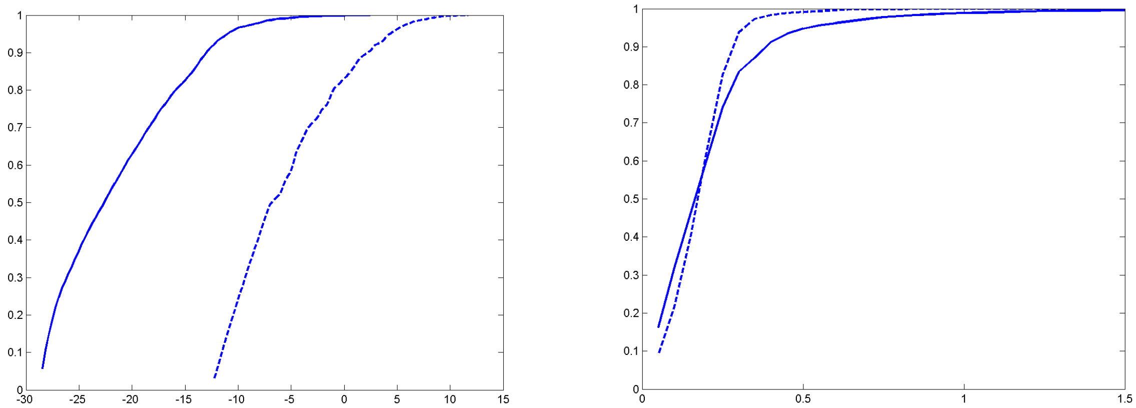

Fig. 3: (a) Noise peak amplitude cumulative distribution functions. (b) Pulse duration cumulative distribution. Urban enviroment (solid line) and industrial environment (dashed line).

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