Measurements of Impulsive Noise From Specific Sources in Medium Wave Band

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***Abstract*—This letter presents the results of impulsive noise measurements in an indoor environment in the Medium Wave band. The studied channels are centered at 630, 675, 1035, 1620, 1720, and 1910 kHz. In this study, the noise generated when there is a main source of impulsive noise is measured in order to analyze different devices that originate impulses. Moreover, the appropriate parameters to characterize impulsive noise are described. As a result, reference values of impulsive noise parameters at the mentioned frequencies are given. Those measurements give answer to the request of the International Telecommunication Union, ITU, in ITU-R 214–4/3 question, which considers that it is essential to determine impulsive noise parameters and asks to obtain reference values.**

***Index Terms*—Burst, impulsive noise measurement, medium wave, noise sources, radio noise.**

I. Introduction

THE MEDIUM Wave band covers the frequency range from 300 kHz to 3 MHz. The lowest part of that frequency band has been used mainly for AM radio broadcasting. At these frequencies, broadcasting services are based on the characteristics of the ground and sky wave propagation modes. These propagation modes can reach long distances and allow a large coverage area. However, those modes are very likely to be affected by the presence of radio noise, which may also restrict the service coverage.

In the last years, some new digital audio services, such as DRM and IBOC, have been developed for broadcasting in Medium Wave band. Moreover, several facts foresee a more intensive use of this frequency band in the future. On one hand, the demand of radio spectrum is growing. The volume of data transmitted wireless has increased in the last years and will continue increasing. At the same time, more and more devices are provided with wireless sensors (Internet of Things). On the other hand, radio spectrum reallocations—such as the “digital dividend”—are changing the traditional use of some spectrum bands. Beside all, techniques such as cognitive radio will provide more dynamic spectrum access techniques. Thus, the study of noise levels in the Medium Wave band is necessary for planning these all radio and wireless services.

Impulsive noise (IN) can be considered as emissions that are present only for a certain percentage of the time, usually consisting of pulse trains of a limited, short duration and sometimes repeating at a certain rate [1]. For that reason, it is advisable to obtain not only the level of impulsive noise, but also information about the pulse distribution.

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TABLE I
IMPULSIVE NOISE MEASUREMENT

Impulsive noise source	Location	Event description
Power supply	Corridor	Off-On /On-Off
CPU	Corridor	Off-On
Fluorescent lights	Classroom	Off-On
Flickering fluorescent lights	Meeting room	Off-On

The aim of this study is to analyze the impulsive noise from specific sources in the Medium Wave band, due to the fact that a good knowledge of noise levels is required to ensure an efficient use of the spectrum. To achieve that, first it is essential to determine the appropriate parameters to describe the noise. Second, it is necessary to follow a procedure to make the measurements correctly. These measurements have been carried out when a main source of impulsive noise is present. The selected sources are common impulsive noise sources in an office and laboratory indoor environment [2], [3].

This study has been done considering the methods and parameters given in ITU-R Recommendation SM.1753 [4], but some contributions have also been added.

Section II describes the measurement campaigns and the studied sources. Impulsive noise characterization is explained in Section III. The results are presented in Section IV, and the conclusions in Section V.

II. Measurement Campaigns

The measurement campaigns have been carried out inside a four-floor office building located in an urban environment.

Six radio channels centered at 630, 675, 1035, 1620, 1720, and 1910 kHz have been studied. All of them are free of local emissions.

To study a single impulsive source, it is necessary to make the measurements when there is a main source of impulsive noise, so it is important to ensure that there are not more noise sources generating impulses. The description of the different devices that generate impulsive noise and the locations where measurements have been made are shown in Table I. Impulses are associated to changes in the operation of the device, so transitions between functioning statuses that cause impulsive noise are also described.

The first impulsive noise source that has been studied is a power supply. The measurements have been carried out in the corridor of the fourth floor. The impulses are associated to two operational statuses, those associated to plugging in and unplugging the equipment.

Another device that has been analyzed is a computer CPU, which has been studied in the same location as the power supply. Impulsive noise has been detected when turning on the computer.

Fluorescent lights are also sources of impulsive noise. Measurements have been made in two different places. In the classroom, the noise caused when turning on eight fluorescent tubes at the same time has been studied. In the meeting room, there are seven tubes, but these flicker for a few seconds before turning on completely.

The measurement system consists of an antenna, a test receiver, and a computer. The computer runs a program that sends commands to the receiver in order to set the appropriate configuration parameters. This software also controls the receiver and allows saving the results while the measurement is running.

A rod antenna has been used. It is a passive broadband electric field monopole antenna, which has a frequency range of 1 kHz to 30 MHz.

The receiver used is EMI ESPI3 of Rohde & Schwarz. The measurements were carried out in the time domain using a sample detector, collecting 8001 samples per second, which is the maximum sample rate allowed by this receiver.

III. Characterization of Impulsive Noise

The characterization of impulsive noise has been made following ITU-R Recommendation SM.1753 [4] and making some contributions to it. This recommendation provides guidelines on measurement and analysis of radio noise, but there is a lack of information about how to proceed when a specific source is measured. Several studies of impulsive noise have been done following that recommendation [6], [7], but they do not analyze a specific source, so results and methodology are not suitable for comparison.

The appropriate parameters to describe impulsive noise when there is a principal source of noise are listed as follows:

— number of bursts;
— burst level or amplitude;
— burst length or burst duration;
— burst separation.

A burst is a single event that integrates the peaks of a pulse train as defined in the above-mentioned recommendation ITU-R SM.1753 [4].

These parameters cannot be measured directly. It is necessary to determine them later, when data processing. Once the measurements have been made, the following steps should be applied to the obtained raw data.

The first step is to determine the level of radio noise for each location and each frequency band. For this purpose, a measurement is made when the specific impulsive source is not working. Then, the root mean square (R.M.S.) value of the measured samples must be calculated. In this way, the White Gaussian noise (WGN) is characterized.

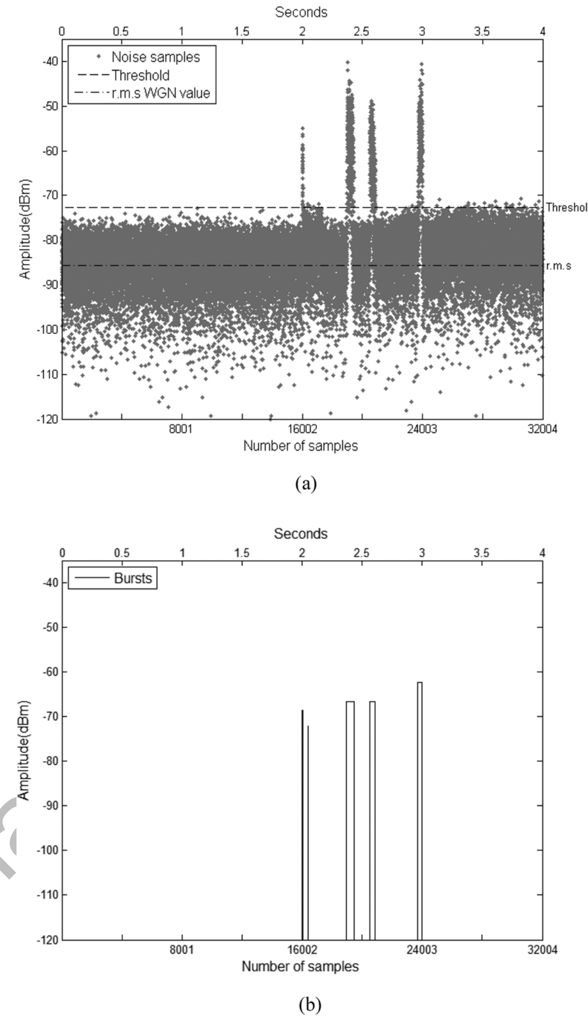

Fig. 1. Results of a measurement: (a) before data processing; impulsive measurement, (b) after data processing; result presentation.

Second, the measurements are taken when the impulsive source is working. Impulsive noise (IN) samples need to be separated from Gaussian noise. A threshold is set to 13 dB above the R.M.S. value previously calculated. All measurement samples above the threshold are treated as impulses [4].

The next step is to combine impulses to bursts. The requirements for including a sample in a burst are explained in ITU-R SM.1753. However, this recommendation does not explain how to obtain Burst amplitude. In this study, burst amplitude has been calculated as the linear average of samples belonging to the burst.

Finally, the values of mentioned parameters must be determined.

Fig. 1 shows an impulsive noise measurement in the time domain and the result presentation after data processing. The duration of this measurement is 4 s, which corresponds to 32 004 samples.

IV. Measurement Results

In this section, the measurement results are presented. For each source and frequency, the number of bursts that appear during each event is given. Moreover, the average and standard deviation of all impulsive noise parameters are determined.

TABLE II
BURST AMPLITUDE—POWER SUPPLY TURNING ON EVENT

Frequency (kHz)	Average Amplitude (dBm)		Standard Deviation (dBm)	
	12V	1.5V	12V	1.5V
1035	-59.13	-59.71	3.24	1.04
1620	-65.72	-58.81	1.05	3.85
1720	-55.78	-58.56	1.46	3.24
1910	-64.20	-65.85	1.19	4.17

TABLE III
BURST AMPLITUDE—POWER SUPPLY TURNING OFF EVENT

Frequency (kHz)	Average Amplitude (dBm)		Standard Deviation (dBm)	
	12V	1.5V	12V	1.5V
1035	-52.13	-51.51	5.84	3.19
1620	-55.82	-55.11	4.95	4.98
1720	-58.05	-53.56	3.02	2.47
1910	-55.53	-55.06	3.43	3.59

TABLE IV
BURST DURATION—POWER SUPPLY TURNING ON EVENT

Frequency (kHz)	Average Burst Duration (ms)		Standard Deviation (ms)	
	12V	1.5V	12V	1.5V
1035	0.50	0.37	0.25	0.10
1620	0.37	0.54	0.10	0.40
1720	0.56	0.25	0.26	0.10
1910	0.37	0.51	0.10	0.27

TABLE V
BURST DURATION—POWER SUPPLY TURNING OFF EVENT

Frequency (kHz)	Average Burst Duration (ms)		Standard Deviation (ms)	
	12V	1.5V	12V	1.5V
1035	1.15	0.97	0.74	0.10
1620	0.94	0.80	0.23	0.47
1720	1.06	1.15	0.22	0.16
1910	1.45	1.45	0.47	0.46

TABLE VI
BURST AMPLITUDE—CPU TURNING ON EVENT

Frequency (kHz)	Average Amplitude (dBm)	Standard Deviation (dBm)
630	-50.63	1.14
675	-53.04	4.44
1035	-54.86	2.34
1620	-63.58	1.81
1720	-61.94	2.73
1910	-66.04	1.61

TABLE VII
BURST DURATION—CPU TURNING ON EVENT

Frequency (kHz)	Average Burst Duration (ms)	Standard Deviation (ms)
630	0.39	0.16
675	0.56	0.19
1035	0.70	0.24
1620	0.44	0.15
1720	0.52	0.14
1910	0.57	0.47

TABLE VIII
BURST SEPARATION—CPU TURNING ON EVENT

Frequency (kHz)	Burst Separation (ms)	Standard Deviation (ms)
630	1.25	0.10
675	0.87	0.27
1035	1.00	0.18
1620	0.49	0.09
1720	0.69	0.09
1910	0.87	0.12

When more than one burst appear, the weighted average amplitude is obtained considering the duration of each burst.

A. Power Supply

The impulsive noise generated by a power supply has been measured. The power supply outputs can be adjustable at 12 and 1.5 V. When plugging in or unplugging the supply, there is always a unique burst. Impulsive noise is more significant when turning off the power supply than when turning on. Tables II and III show the burst amplitudes for different events. Burst durations are reported in Tables IV and V. Each measurement has been taken during 5 or 6 s.

In this case, impulsive noise has not appeared at 630 and 675 kHz.

B. Computer CPU

The impulsive noise is generated when turning on the CPU. In this case, between one and three bursts are detected, so burst separation is also given. Impulsive noise is present at the six studied frequencies. Table VI shows the burst amplitudes. Burst durations are reported in Table VII, and burst separations in Table VIII. The measurement duration is 7 or 8 s.

C. Fluorescent Lights

The following tables show impulsive noise parameters generated by turning on eight fluorescent tubes simultaneously. In

TABLE IX
BURST AMPLITUDE—FLUORESCENT LIGHTS TURNING ON EVENT

Frequency (kHz)	Average Amplitude (dBm)	Standard Deviation (dBm)
630	-58.37	5.93
675	-59.57	0.73
1035	-59.93	1.37
1620	-68.20	1.84
1720	-69.86	1.08
1910	-70.19	0.58

TABLE X
BURST DURATION—FLUORESCENT LIGHTS TURNING ON EVENT

Frequency (kHz)	Average Burst Duration (ms)	Standard Deviation (ms)
630	29.26	13.48
675	25.29	5.21
1035	43.62	10.65
1620	37.66	2.18
1720	48.80	19.22
1910	48.95	31.82

TABLE XI
BURST AMPLITUDE—FLICKERING LIGHTS TURNING ON EVENT

Frequency (kHz)	Average Amplitude (dBm)	Standard Deviation (dBm)
1035	-60.59	0.96
1620	-63.72	0.59
1720	-65.58	1.41
1910	-65.76	0.76

some cases, more than one burst appeared; anyway, there is always a burst much longer. Results have been obtained considering only this main burst. The measurement duration is between 3 and 5 s.

Burst amplitudes are shown in Table IX, and burst durations in Table X.

D. Flickering Fluorescent Lights

In the room with seven fluorescent tubes that flickered for a few seconds before turning on completely, several bursts, between 27 and 34, have appeared. These bursts are very similar in amplitude and duration. Burst separations are quite large compared to bursts obtained from other sources. Table XI shows the burst amplitudes. Burst durations are reported in Table XII, and burst separations in Table XIII. The measurement duration is between 5 and 6 s.

Impulsive noise has not been detected at 630 and 675 kHz.

TABLE XII
BURST DURATION—FLICKERING LIGHTS TURNING ON EVENT

Frequency (kHz)	Average Burst Duration (ms)	Standard Deviation (ms)
1035	0.50	0.06
1620	0.48	0.08
1720	0.52	0.03
1910	0.64	0.08

TABLE XIII
BURST SEPARATION—FLICKERING LIGHTS TURNING ON EVENT

Frequency (kHz)	Burst Separation (ms)	Standard Deviation (ms)
1035	146.31	62.17
1620	118.26	22.55
1720	109.46	40.61
1910	104.60	10.15

V. CONCLUSION

This letter presents an analysis of impulsive noise generated by specific sources in the Medium Wave band. The appropriate parameters to characterize impulsive noise are specified. In addition, reference values of these parameters are given.

This work provides a significant contribution to the study of impulsive noise. Apart from making measurements, data processing has also been made according to the latest recommendation given by the ITU-R [4]. This letter also provides a procedure for measuring and characterizing impulsive noise from specific sources, as there is a lack of information about it. Previous studies have analyzed that noise component in several ways, but not following the same methodology [3], [8].

Moreover, this study gives answer to the request of the International Telecommunication Union, ITU, in ITU-R 214–4/3 question [5], which asks to study impulsive noise parameters.

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