Experimental set-up for the evaluation of clipping noise statistical behaviour of CATV optical transmission system

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Abstract - In a hybrid CATV analog/digital multichannel optical transmission system, the clipping-induced impulsive noise is a potential major impairment spread out over a wide spectrum. Consequently, its statistical behaviour knowledge is very important. For that purpose, we have developed an original set-up based on a high speed digitising oscilloscope coupled to proprietary software process. The software allows to select pulses present in a specific channel bandwidth and therefore may help CATV operators to chose the best channel spectral allocation when installing a new modem link in the upstream path.

INTRODUCTION

In directly modulated system, clipping occurs when the subcarrier multiplex (SCM) modulating current occasionally falls below the laser threshold current. It has been pointed out in scientific literature that distortions generated by this clipping phenomenon have an impulsive nature and significantly degrade the performance of the digital channels [1, 2].
Clipping noise is a subject of interest in many studies on subcarrier multiplexed (SCM) lightwave systems. Many experimental studies in previous published papers analyse the downstream clipping-induced impulsive noise. But to the best of our knowledge, none of them presents the statistical properties of clipping-induced impulse noise according to a specific channel bandwidth.
For that purpose, a novel broadband clipping-induced impulsive noise measurement system has been developed. This original measurement system based on a high speed digitising oscilloscope coupled with a proprietary software process is presented in this paper. Based on it, for the first time, experimental results of clipping noise statistical behaviour in terms of bandwidth are shown. Finally, an analysis's example of its statistical behaviour is realised.

MEASUREMENT SET-UP

The measurement set-up is depicted in fig. 1. The main pieces consist in a clipping noise generator, an oscilloscope and a personal computer.
The clipping noise generator is also detailed on fig. 1. In this figure, the laser diode is directly modulated by eight return path carriers provided by a multi-carrier generator. A variable electrical attenuator is used to calibrate the Optical Modulation Index OMI (8,1%). The fiber attenuation is simulated by a variable optical attenuator. At the output of the optical receiver, the electrical signal is composed by the carriers and the distortions generated by the laser clipping as presented in fig. 2. These distortions are spread over a wide spectrum but have a low intensity compared to carriers. To select only the distortion generated by the clipping, it is mandatory to filter and to amplify before the acquisition

process by the oscilloscope. This operation is performed in the 5 to 31MHz bandwidth where the signal is only composed by distortions.

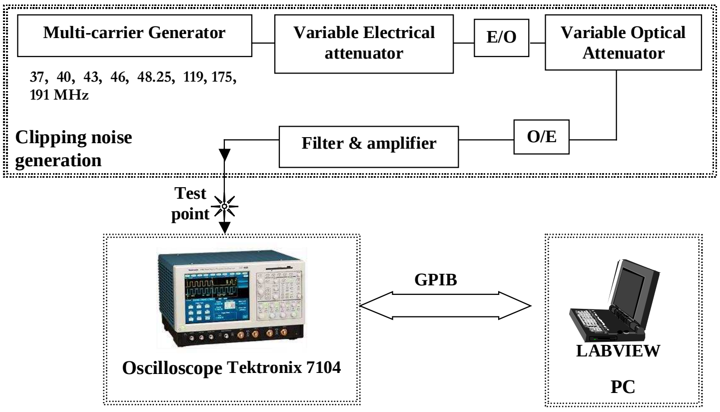

Fig. 1 – Measurement set-up

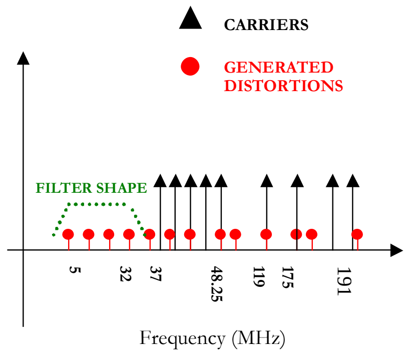

Fig. 2 – Spectrum of signal at the output of the receiver

Generally speaking, if the signal consists mainly of spikes, bursts, impulses and other transient phenomena, it is important to measure it with a special triggering operation as it will be described shortly [3]. Note that the clipping noise belongs to this category of signal because it is constituted by impulses whose inter-arrival time depend on the SCM frequency [1].

The data acquisition, running on LABVIEW, is a continuous loop process. A high speed digitizing oscilloscope is set up to trigger the signal acquisition only when a transient event has occurred. It is therefore considered that a transient event occurred when the signal is above a defined trigger threshold. This trigger threshold must be adequately chosen according to the clipping noise level : it must be high enough to avoid measurements of background noise but also low enough to capture all the weakest impulses events. This triggering action allows to acquire only data with interesting information and consequently to facilitate the data storage.

All gathered data are transferred from the main memory of the oscilloscope to the personal computer via the General Purpose Interface bus – GPIB for the signal processing.

A special selection of impulse event must be performed on the captured data. For that, elementary definition of an impulse event is : an impulse begins when the signal passes above a given threshold Uth, and ends when this signal stays below another threshold Uth' during a specified period of time tD (fig. 3 gives an illustration).

Thanks to that definition, four temporal parameters of impulse noise induced by clipping are defined : - the impulse voltage defined as the total voltage of an impulse, - the maximum voltage defined as the maximum voltage of an impulse, - the impulse duration defined as the time elapsed between the beginning and the end of an impulse, - the impulse inter-arrival time is the time between the beginning of the two consecutives impulses. A fifth parameter is spectrally defined to describe impulse noise : the power spectral density (PSD) of the impulse event. All these parameters are statically considered.

To analyse the behaviour of clipping-induced impulse noise in a particular bandwidth, an optional filtering operation based on FFT/IFFT can be performed before selecting the impulses events. By the way of this filtering process, all the parameters of the clipping noise can be obtained in different bandwidths and be accurately compared.

Moreover, the spectrogram (the mean PSD of the selected impulses events according to a defined time slot) as well as the number of selected impulses (versus the central frequency of fixed bandwidth and during a time slot) are also used to present our results. This representations allow therefore to easily allocate an efficient bandwidth when choosing a new return path carrier.

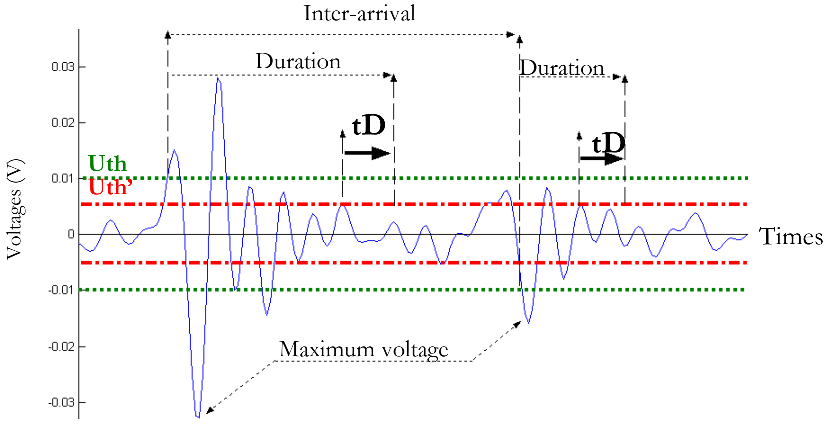

Fig. 3 - Impulse noise temporal parameters

STATISTICAL PARMETERS ANALYSIS

In this section, some properties of the studied clipping noise are given and their analysis are performed. In fact the spectrogram is examined according the number of selected impulses events.

Fig. 5 presented the spectrogram of selected impulses. To obtain this figure, the PSD of all impulse selected during an interval of 100µs are computed and displayed. As it appears, the highest values of PSD are located around 27 MHz. It seems is more disturbed. But, to conclude that firmly, it is important to know well the number of selected impulses whose give these values. This number is depicted in fig. 4 in terms of bandwidth and time. This figure represents the number of selected impulses during 100µs for different 2 MHz bandwidth. It emerges clearly that a great number of impulses occurs in the 26-28 MHz bandwidth, which then involves a small inter-arrival time. Consequently, the bandwidth around 27 MHz is more hostile for spectral allocation. Note that, this conclusion results of the joint analysis the two figures. To fully complete the analysis, the Probability Density Function (PDF) of respectively impulse inter-arrival time and duration in the bandwidth of 26 to 28 MHz are presented in fig. 6 and fig. 7. The impulse inter-arrival time is characterized by a main value of 4µs which derives directly from the content of the SCM signal as shown in [1] and the mean impulse duration is 0.56µs.

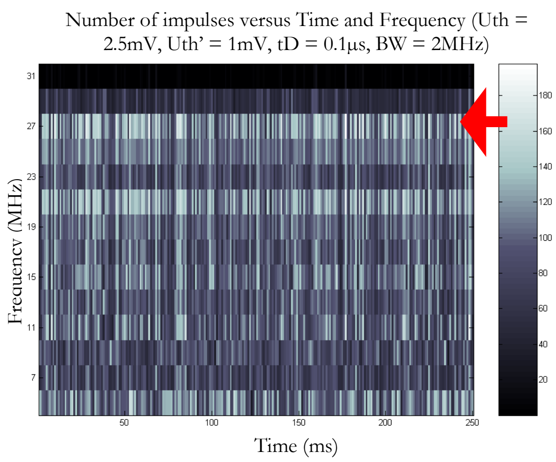

Fig. 4 - Number of impulses

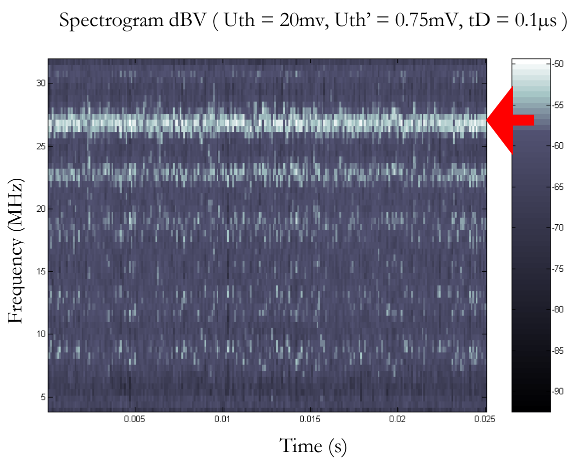

Fig. 5 - Spectrogram of clipping noise

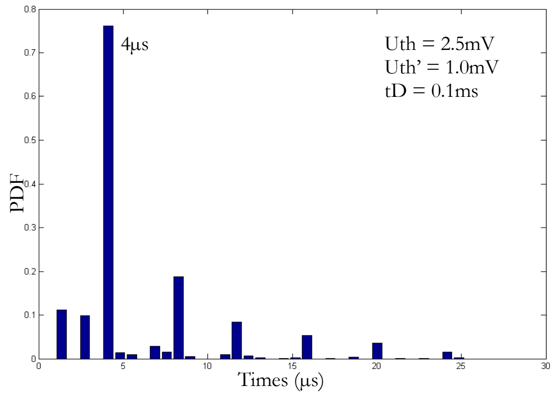

Fig. 6 – PDF of Inter-arrival Time (BP = 26-28MHz)

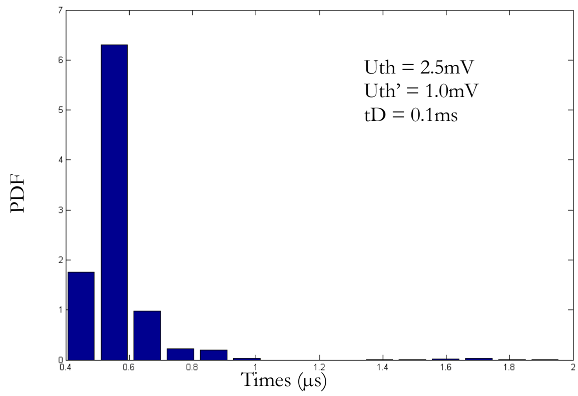

Fig. 7 – PDF of Duration (BP = 26-28MHz)

CONCLUSION

In this paper, clipping noise is studied as impulse noise. A simple definition of impulse events is given and all the parameters of clipping- induced impulse noise events are defined.

A novel clipping-induced impulse noise measurement system has been presented. This system is based on a particular data acquisition and signal processing. It allows to precisely determine in the bandwidth of typical modulation, the statistical behaviour of distortions due to clipping particularly in return path of optical CATV transmission.

Some useful results for transmissions systems are exposed. An analysis tool is provided which allows the optimisation of the channel allocation of carriers.

Furthermore, thanks to the impulsive nature of clipping distortions, the developed bench can be used to analyse the impulse noise performance of other transmission systems.

ACKNOWLEGDMENTS

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