A Model of Noise Influences in a Digital Communication Channel in Cable TV Networks

Krasen Angelov [1], Kiril Koitchev[2], Stanimir Sadinov [3]

Abstract – **In modern hybrid optical-coaxial cable networks, the cable cells support 150 to 300 subscribers. The lack of a physical separation of subscribers in a coaxial cell, leads to the accumulation of noise signals, which are of different types and are a function of time, geography, network architecture and so on. The successful localization and elimination of noise in the digital channel of a cable network requires knowledge of its spectrum profile and signature. This can be accomplished through modeling and studies using modern computer-aided methods.**

Keywords – **Model of noise influences, Bit error rate, Burst and impulse noise, Channel multipath reflections, Matlab.**

I. Introduction

Modern CATV networks tend to grow into larger structures. The rise in number of subscribers will normally cause an expansion of the area of coverage. This in turn brings forth a greater amount of disturbances and noises along the cable lines due to their extended length and also to the fact that most of these disturbances penetrate into the subscribers' part of the network.

Noises and disturbances affect in a greater extent the lower frequency area of the frequency range that is used in CATV networks, namely, the reverse channel range (from *5MHz* to *42MHz*). Noises tend to grow lower in loudness with the rise of frequency.

Several factors should be accounted for concerning the performance of the digital transmission channel:

- additive white Gaussian noise (AWGN);
- channel multipath reflections (echoes);
- burst and impulse noise;
- phase noise.

Bit Error Rate (BER) is used to estimate the fidelity of transmitted information when noises are available. BER stands for the ratio of wrongly received symbols to the total number of transmitted symbols [1].

In practice noise performance investigation is done over a definite period of time by means of a digital spectrum analyzer. Theoretical investigation of noise effects is conducted by means of state-of-the-art computer facilities, which implies preparation of relevant computer models and simulations in related software. Such models are essential since they appear to be individual ingredients of a larger model of a whole CATV network. Based on that model it is possible to develop another software or to improve the existing one for the purpose of optimum design or effective CATV networks control.

II. Explanation

Additive white Gaussian noise is a regular noise that is characterized by a high rate of prognostication.

Multiple multipath reflections in the coaxial portion of the HFC network can severely degrade the propagating analogue or digital signals before they reach the subscriber home. Multipath reflections occur when two or more propagation paths exist between the transmitter and receiver sites. The various reflections relative to the directly transmitted signal as measured at the receiver are called echoes, which are characterized off man-made or natural structures, repeaters, or the multiple transmitters. Multiple echo degradation is not seen in the digitally demodulated picture until some "threshold" level of the digital signal is reached, resulting in a loss of the receiver synchronization. Uncorrected multipath echoes introduce intersymbol interference (ISI). The effect of multiple echoes is perceived as additional noise and causes degradation to the received SNR [2].

Burst noise is generated from different man-made or natural sources and its duration is longer than that of the *(symbol rate)*$^{-1}$. Impulse noise is similar to burst noise but its duration is less than the *(symbol rate)*$^{-1}$. Burst and impulse noises are generated from various man-made sources such as electric motors and power-switching devices. Although these sources produce burst/impulse noise events in the *5 ÷ 42 MHz* upstream frequency band. Naturally occurring burst/impulse noise events include lightning, atmospherics, and electrostatic discharge, which typically extend from *2kHz* up to *100MHz*. Part of the impulses are of repetitive character and various duration. Though impulse interferences are of broadband character their power is concentrated within the range below *10MHz*.

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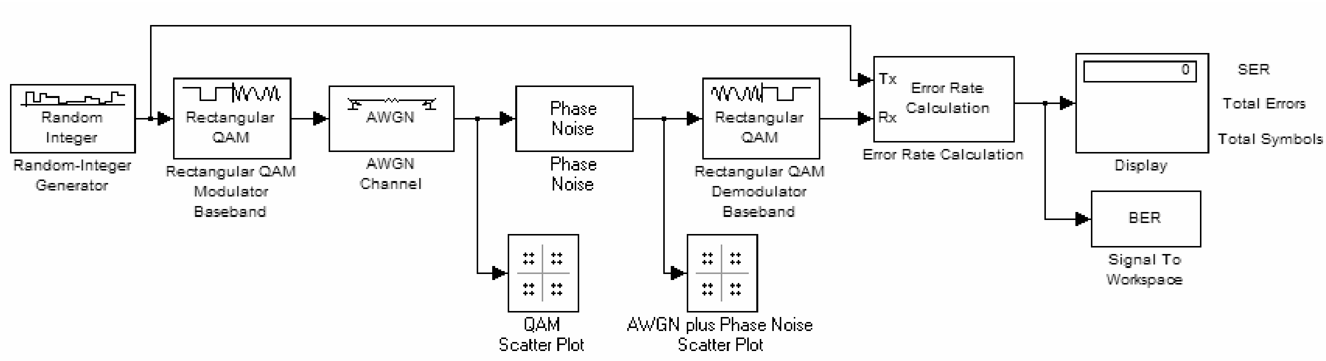

Fig. 2. Modeling the effect of additive white Gaussian noise and phase noise

The burst and impulse noise and the narrowband short-wave signals make up the so called ingress noise that is the most important and dominant noise source. In most cases narrowband short-wave signals are generated from short-wave radio transmitters whose signal penetrates the network through different poorly screened network elements. Other potential sources are short-wave radio broadcast stations and short-wave amateur stations, both of which operate within the range of *27MHz* (CB – Citizens Band) and pagers [3].

The observed increase in the ingress noise levels as the number of homes passed is increased in due to the so-called noise funneling effect. This effect is based on the assumption that the unwanted noise signals are located at the subscriber's location with time-dependent amplitude [2].

With the increase of phase noise the lowest necessary signal-to-noise ratio for effective transferring of information is shifted upwards, in other words, in order to keep the same level of the bit error rate it is necessary to reduce the noise level within the channel.

To investigate the effect of various types of noise we can use the following block schematic (Fig. 1):

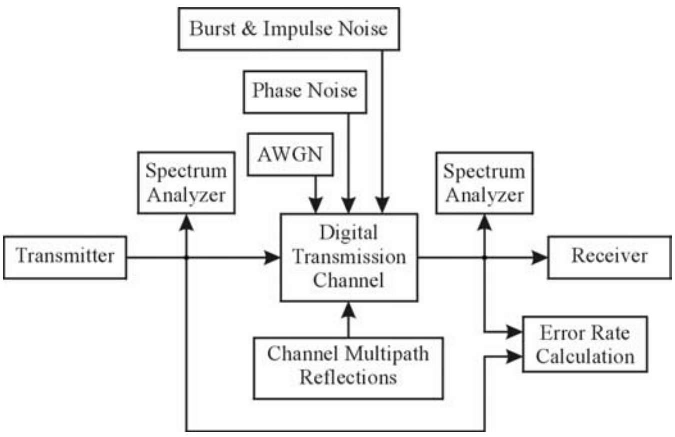

Fig. 1. Simplified block diagram for modeling of noise effect

The Maltab software includes ready functional blocks, which facilitate the implementation of simulation models that are made up according to the above block schematic. Additional functional possibilities are featured by the mechanisms for input and output of data arrays inside and outside the model. These allow to easy modify the parameters of the model and simulation as well as to facilitate the use of output data for further processing [4].

The model for simulation of the effect of additive white Gaussian noise and phase noise is relatively simple to implement (Fig. 2) [4].

Here, by using Maltab Command Window, it is possible to assign the automatic start of a series of simulations for a preset change in the signal-to-noise ratio which should result in the graphic dependence of the bit error rate on the average bit energy density relative to that of the noise – $BER = f(E_b/N_0)$. Fig. 3 shows the dependence $BER = f(E_b/N_0)$ when additive Gaussian noise is available. This dependence is obtained after four consecutive simulations corresponding to the four basic modulation formats used in CATV networks. The simulation was made with no presence of phase noise, i.e. without the use of Phase Noise block from Fig. 2.

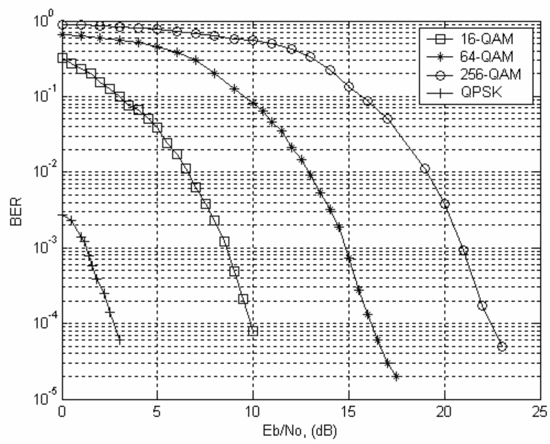

Fig. 3. $BER = f(E_b/N_0)$ for QPSK, 16-, 64- and 256-QAM modulation in presence of additive white Gaussian noise

Phase noise presence can be investigated in the same manner (by adding the Phase Noise block as shown at Fig. 2). Figs. 4 and 5 show exemplary results for 16- and 64-QAM modulation for the two different values of phase noise: *–66dBc/Hz* and *–80dBc/Hz*.

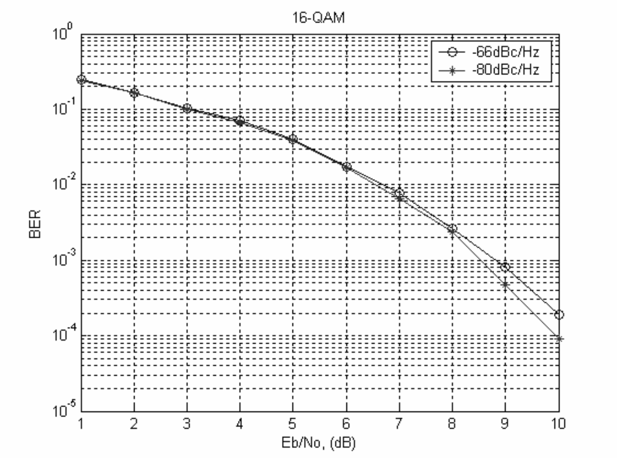

Fig. 4. $BER = f(E_b/N_0)$ for 16-QAM modulation with two different values of phase noise

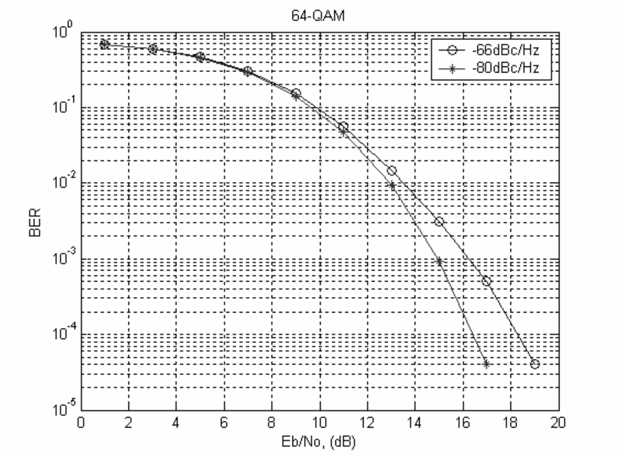

Fig. 5. $BER = f(E_b/N_0)$ for 64-QAM modulation with two different values of phase noise

Impulse noise can be best described as an infinite series of interfering impulses with high level and short duration [3, 5]. For the purpose of modeling the effect of burst and impulse noise we use a model in which impulses occur periodically at a predetermined repetition rate. The three parameters in this model are the burst/impulse duration, the burst amplitude, and the repetition frequency [6]. This model can be further simplified resulting in impulses of pseudo-random character.

Modeling the effect of burst and impulse noise in a digital transmission channel is possible to obtain by means of the exemplary model shown in Fig. 6. In this model the impulse noise is entered by way of generating errors vector in which the presence of “0” means no errors whereas “1” means available error. The location and sequence of “1”s (the errors) in the errors vector can be predefined, but for the purpose of simplifying the model (the operations needed) we use errors vector each of whose entries independently takes the value zero with probability 1/2.

Figs. 7 and 8 show the signal spectrum with absence and presence of impulse noise in the transmission channel at 64-QAM modulation.

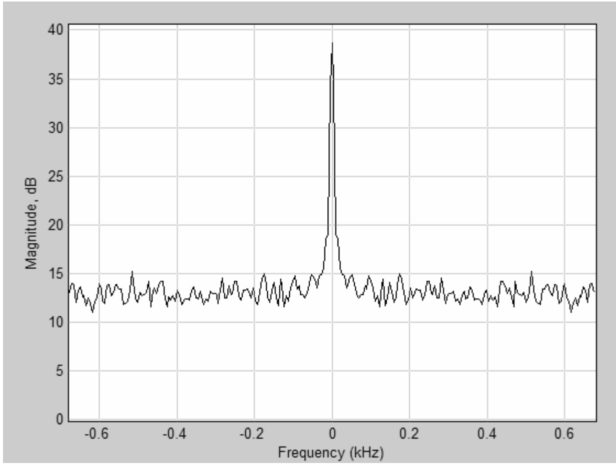

Fig. 7. Signal spectrum diagram with absence of impulse noise for 64-QAM modulation

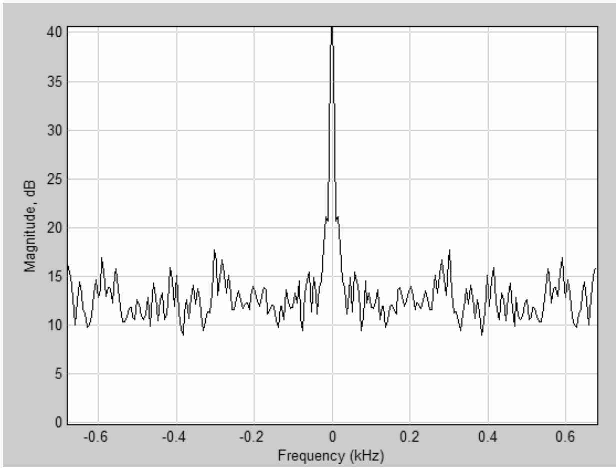

Fig. 8. Signal spectrum diagram with presence of impulse noise for 64-QAM modulation

As stated before, most disturbances penetrate through the subscribers’ portion of the cable network. Noise sources appear to be TVs and the outputs of splitters, which are not connected to matched load. Another possible reason for noise interference is the poor matching of subscribers’ receivers with the network, which result in the occurrence of strong channel multipath reflections in some sectors. The basic model for multipath reflections is to use a discrete channel model with 3 echoes – each consecutive echo being of a delay *T*, *2T*, *3T* respectively where *T* is a period of the symbol, and has attenuation *10dB*, *20dB*, *30dB* respectively below the main signal path. An illustration of the model of the effect of the channel mulltipath reflections in digital cable channel is shown on Fig. 9 where using the three blocks of Integer Delay it is possible to simulate the presence of echo inside the channel.

For 64-QAM modulation with input signal whose spectrum is shown in Fig. 7 we get at the model output a signal which is shown in Fig. 10 and which is the result of the impact of channel multipath reflections.

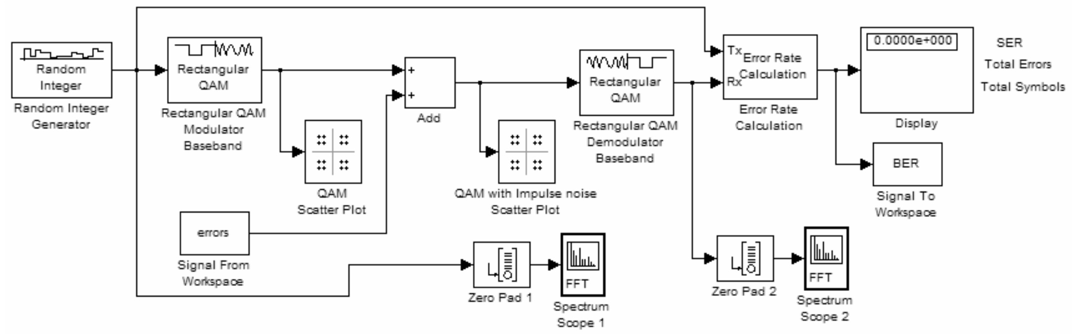

Fig. 6. Modeling the impact of burst and impulse noise

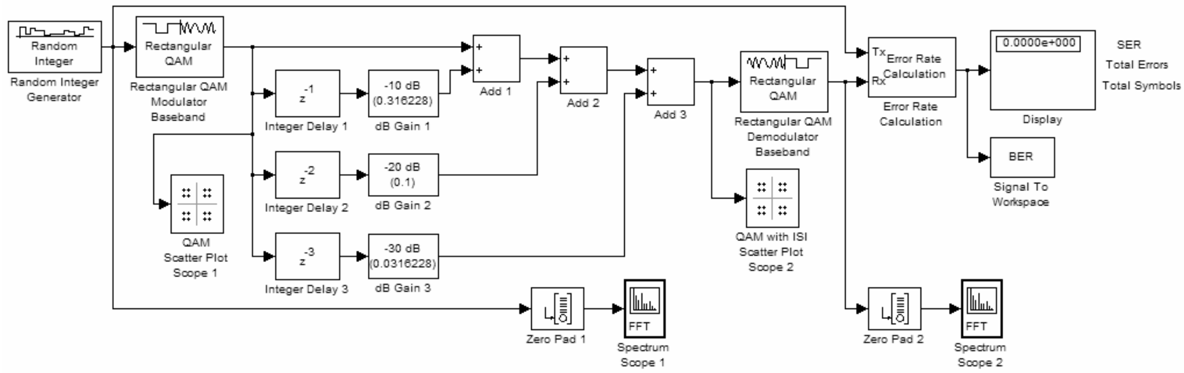

Fig. 9. Modeling the impact of channel multipath reflections

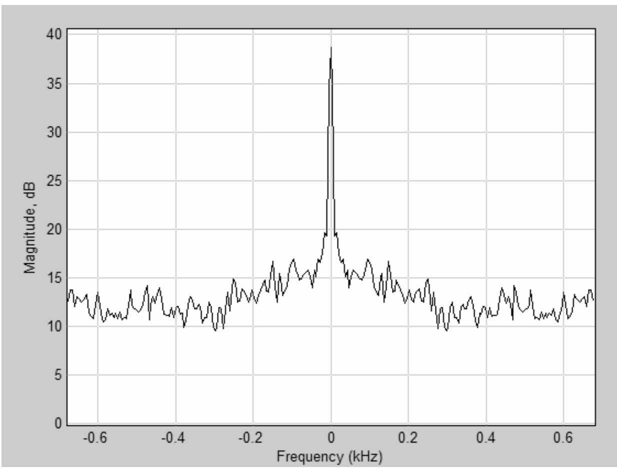

Fig. 10. Signal spectrum diagram in presence of channel multipath reflections for 64-QAM modulation

III. Conclusion

The effect of impulse noise can be very high and can certainly lead to communication errors. Applying appropriate error correcting techniques can reduce the effect of impulse noise. Since the peak power of impulse noise can be very high, increasing the power of transmitted signals will only slightly reduce the effect of impulse noise. On the other side, if it is accurately known how impulse noise disturbs the original signal, error correction can be used.

In the presence of Gaussian noise, the spectrum of the 64-QAM signal is essentially flat across most of the symbol rate bandwidth. If, however, multipath reflections are present, constructive and destructive interference of the reflected paths with the direct path will cause ripples in the otherwise flat spectrum. Even without the presence of multipath echoes, the use of various filters in the coaxial amplifiers typically generates group delay variation because of their nonflat frequency response. Note that placing the echo power at the maximum of the delay range produces the largest group delay variation, but not necessarily the worst effect of the transmitted signal. Breaking the echo power into multiple echoes within the time-delay range lowers the group delay variation, but actually has a worse effect on the transmitted signal due to higher peak-to-rms ratio for combining multiple echoes compared with a single echo.

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