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Моделирование системы связи с эффектом межсимвольной интерференции (МСИ) в программном пакете Matlab Simulink.

В данной статье будет описана модель системы связи с эффектом межсимвольной интерференции. возникающего после прохождения сигналом многолучевого канала. Основное внимание будет обращено на адаптивные методы обработки сигнала, позволяющие избавиться от эффекта межсимвольной интерференции. Также будет приведена модель системы связи с обработкой сигнала после его прохождения через многолучевой канал с возникшим эффектом МСИ.

Communication systems modelling with the effect of inter-symbol interference (ISI) in the software package Matlab Simulink.

Multipath is the effect of signal transmission. In the process of this phenomenon, there are several ways of transmitted signal receiving at the one moment or with a slight delay. The multipath effect is illustrated by the figure 1.

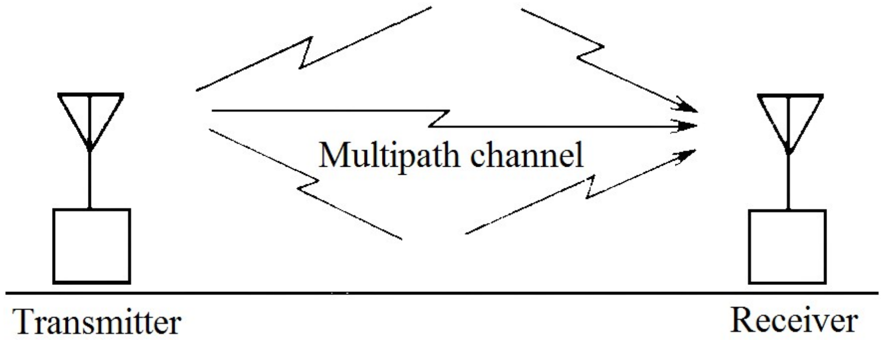

Figure 1 – Multipath signal transmission.

During the multipath signal transmission the following effects can appear:

- signal reflection;
- fading;
- inter-symbol interference.

Today conditions of signal propagation are very diverse, for example, a lot of buildings, different noises from mobile and base stations and etc. and it means that each of effects mentioned above can appear in unique way. Therefore, when one of mentioned effect appears conditions of several signal copies or several signal propagation ways appear too.

After this phenomenon studying, we can conclude that multipath signal problem is overall. Moreover, it is necessary to create such devices and methods of signal processing that echo signal or signal inter-symbol interference effects can be compensated to their minimum values or absolutely disappeared. The examples of such methods and devices are the following: adaptive filtration, channel equalizer, separate receiving, wideband signals, guard intervals between symbols. The algorithm of adaptive filtration or equalizing will be described in details further. [1]

The theoretical information about multipath is considered to present a model of a communication system with multipath channel (Figure 2).

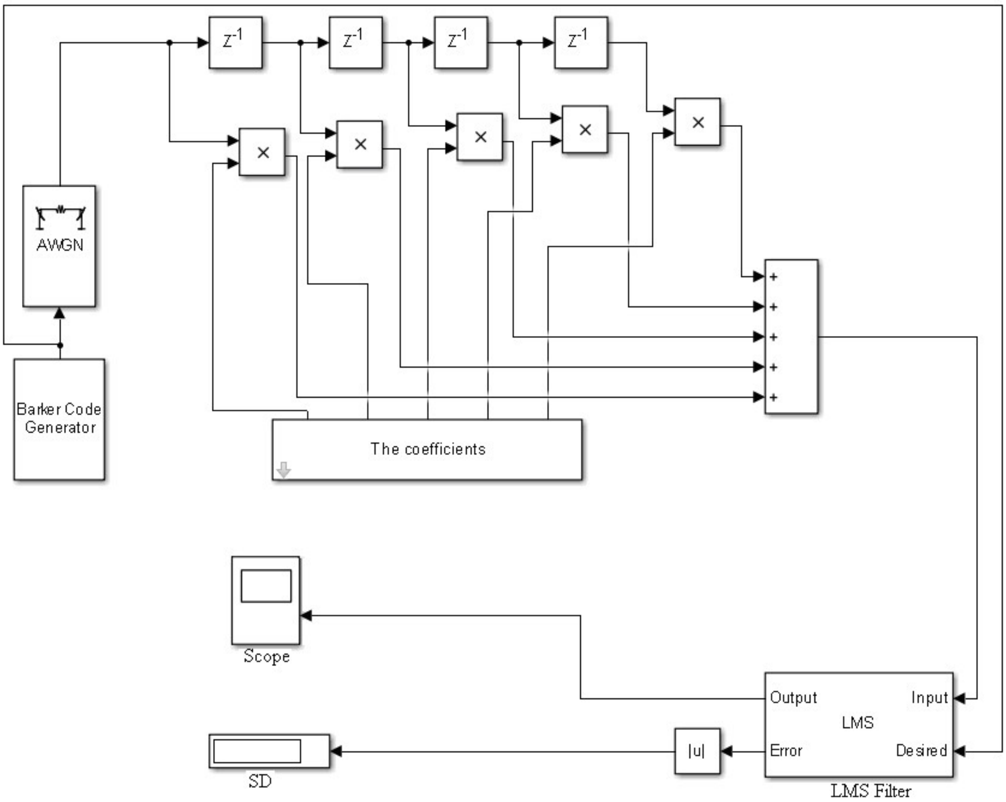

Figure 2 - A model of adaptive equalizer (SD is a standard deviation)

A model of adaptive equalizer (figure 2) consists of several blocks that allow creating the effect of the inter-symbol interference with the help of a multipath channel. Moreover, it shows cleansing of the signal from the effect of ISI using LMS Filter.

The LMS Filter block can implement an adaptive FIR filter using five different algorithms. The block estimates the filter weights, or coefficients, needed to minimize the error, e(n), between the output signal y(n) and the desired signal, d(n). When you select LMS for the Algorithm parameter, the block calculates the filter weights using the least mean-square (LMS) algorithm. This algorithm is defined by the following equations.

$$y(n) = w^T(n-1)\,u(n) \tag{1}$$

$$e(n) = d(n) - y(n) \tag{2}$$

$$w(n) = \alpha w(n\text{-}1) + f\,(u(n),e(n),\mu) \qquad (3)$$

where n is a current time index; u(n) is a vector of buffered input samples at step n; w(n) is a vector of filter weight estimates at step n; y(n) is a filtered output at step n; e(n) is a estimation error at step n; d(n) is a desired response at step n; μ is a adaptation step size; α is a leakage factor ($0 < \alpha \le 1$).

The various LMS adaptive filter algorithms available in this block are defined as:

- Standard LMS

$$f\,(u(n),e(n),\mu) = \mu e(n)u^*(n) \qquad (4)$$

where u*(n) is a complex conjugate of the vector of buffered input samples at step n.

- Normalized LMS

$$f\,(u(n),e(n),\mu) = \mu \cdot e(n) \cdot \frac{u^*(n)}{\varepsilon + u^H(n) \cdot u(n)} \qquad (5)$$

- Sign-Error LMS

$$f\,(u(n),e(n),\mu) = \mu sign(e(n))\; u^*(n) \qquad (6)$$

- Sign-Data LMS

$$f\,(u(n),e(n),\mu) = \mu e(n) sign(u(n)) \qquad (7)$$

where u(n) is real.

- Sign- Sign LMS

$$f\,(u(n),e(n),\mu) = \mu sign(e(n)) sign(u(n)) \qquad (8)$$

where u(n) is real.[2]

Now we consider a few various of LMS adaptive filter algorithms and examine simulation results (figure 3). The simulation was performed for the Barker code of length 13, for three different LMS adaptive filter algorithms and for the similar amplitudes of the multipath component [0,05 0,04 0,03 0,02 0,01].

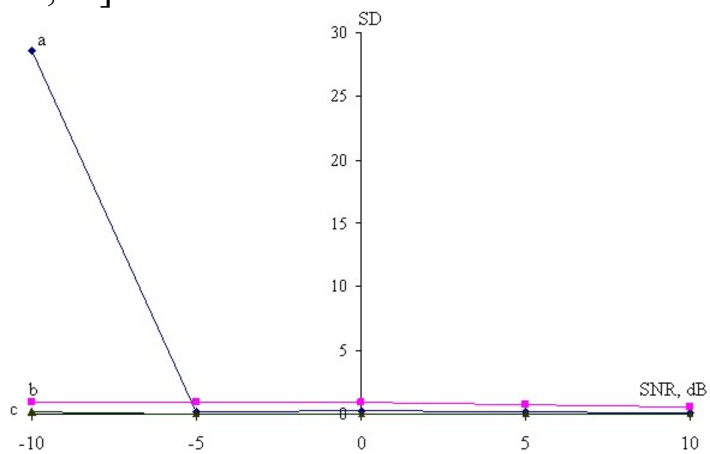

Figure 3 – Standard deviation from signal-to-noise ratio
(a – LMS; b – NLMS; c - Sign-Error LMS)

Experiment conclusions.

As the result of my own experiment with the model of figure 2 for the Barker code of length 13 we can see that three of LMS adaptive filter algorithms converge in the right sequence according to the theory. This experiment starts from standard LMS adaptive filter algorithm that has the worst convergent ability and finishes with LMS adaptive filter algorithm with better convergent mistake between all previous LMS adaptive filter algorithms. This result exists because of Barker code of length 13 best noise immunity and each of further LMS adaptive filter algorithms has better convergent ability.

Moreover, we can see figure 2 adaptive filter output signal oscillation waveform shown at the figure 4 that was found during the work where Barker code of length 13, normalized LMS adaptive filter algorithm and -5 dB SNR were taken as oscillation waveforms examples.

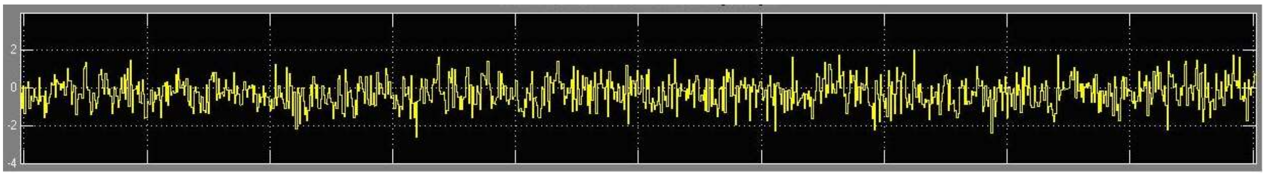

Figure 4 - The output signal of the adaptive filter

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