SIGNAL TRANSMISSION MODELING IN A LOCAL LOOP USING VARIOUS MODEM TECHNOLOGIES

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ABSTRACT

The content of this project is a description and characteristics of a digital transmission path's basic elements, as well as a description of negative environmental effects.

The goal of this project is to create the simulation program for signal transmission through metallic lines by application of various modem technologies. The output of the program is a set of numerical and graphical values. It is devoted mainly to educational purposes, to demonstrate and familiarize students about signal transmission, modem principles, etc.

The simulation program is created in MATLAB v.6.0 - technical development environment.

1 INTRODUCTION

The voice-grade telephone channel is the communication medium most widely available throughout the entire world. Its limitations, a relatively narrow bandwidth and moderate SNR figure, have challenged telecommunication researchers and engineers to develop technologies able to pass higher and higher data rates. The sophisticated combination of trellis coding and quadrature amplitude modulation increases the bandwidth utilization close to Shannon limit of 10 b/s/Hz for the 3.1 kHz bandwidth voice channel. However, the resultant data rate of about 30 kb/s does not even begin to approach the throughput needed by multimedia application.

Fortunately, twisted pair bandwidth reaches up to several megahertz, so multilevel signaling implemented as in the xDSL family of modems enables data rates of several megabits per second to be reached. Standard ADSL modems are able to deliver 8 Mb/s to a subscriber in the best case. VDSL modems can deliver 52 Mb/s, but only up to 300m, so their mass implementation will only become possible when fiber migrates into an access network closer to the user premise. Both broadband xDSL solutions approach the Shannon limit and the related spectral efficiency as well, so there is not much room left for a transmission improvement.

2 CHARACTERISTICS OF THE TRANSMISSION PATH

Transmission medium is an environment, in which components of electromagnetic waves are spread to enable the transfer of the information signal.

2.1 PARAMETERS OF THE METALLIC LINE

Typical aspects of transmission channel are delay, attenuation and phase shift. Character of these properties is deterministic. In our case the transmission channel is the metallic line.

Among basic parameters of the metallic line belong:

- primary constants of line (R [Ω/km], L [H/km], C [F/km], G[S/km])
- secondary constants of line (γ, Z)

If the line is terminated with the characteristic impedance, then the transfer function of the transmission line could be expressed as:

$$\mathcal{H}_{\text{line}}(l, f) = e^{-\gamma(f)\, l} \qquad (1)$$

where l is the length of line and f is frequency.

Resulting from a telecommunication theory, the PSD (Power Spectral Density) of the input signal is transferred by the square of the absolute value of transfer function of transmission system.

$$PSD_{OUT}(f) = |\mathcal{H}_{\text{line}}(l, f)|^2 \,.\, PSD_{IN}(f) \qquad (2)$$

where PSD_{OUT} is PSD of the signal at the end of line, PSD_{IN} is PSD of the signal at the beginning of the line.

Also the diameter of the wire, from which the line consists, has significant effect on the signal transmission, too.

2.2 SPECTRAL EFFICIENCY OF THE DIGITAL TRANSMISSION LINK

Spectral efficiency is simply measured by the ratio of a data rate R [b/s] to the bandwidth B [Hz] necessary to its delivery, η= R/B [b/s/Hz].

There are couple of main factors, that limit the spectral efficiency of a digital transmission system:

- Intersymbol Interference (ISI)
- Additive White Gaussian Noise (AWGN)
- Crosstalks (FEXT, NEXT)

2.2.1 ISI

ISI occurs when band-limited channel spreads a channel response to an input symbol beyond its duration period. Tails of previous channel responses interfere with current one, changing the amplitude of a received signal at resampling instants. If the amount of ISI added to an original sample is too high, the threshold logic in receiver will make a wrong decision.

2.2.2 AWGN

There are lot of kinds of noise in real life (e.g. thermal noise, impulse noise, inductive noise…), but they are not considered in the simulation.

2.2.3 CROSSTALKS

A crosstalk is the signal interference between pairs that may be caused by a pair picking up unwanted signals from either adjacent pairs of conductors or nearby cables. This interference can result from the magnetic field that surrounds any current-carrying conductor. There are two types of crosstalks:

- Near End Corsstalk (NEXT)
- Far End Crosstalk (FEXT)

Power spectral density (PSD) of crosstalks could be expressed as is shown in the formulas (3.) and (4.):

$$PSD_{NEXT} = PSD_{Disturber} \cdot K_N \cdot f^{\frac{3}{2}} \cdot (N/49)^{0.6} \quad 0 \le f < \infty \qquad (3)$$
$$K_N = 10^{-13}$$

$$PSD_{FEXT} = PSD_{Disturber} \,.\, K_F \,.\, f^2 \,.\, l \,.\, |\mathcal{H}_{\text{channel}}(l,f)|^2 .\, (N/49)^{0,6} \qquad (4)$$
$$K_F = 3{,}27.10^{-18}$$

where PSD $_{Disturber}$ is PSD of disturbing signal, N is the number of disturbing wires, K_N and K_F are empirical constants, H $_{\text{channel}}$(f) is transfer function of the line, l is the line length in meters and f is the frequency in hertz.

3 COMPARATION OF VARIOUS MODEM TECHNOLOGIES

The basic information of various modem technologies are shown in the table 1.:

Year	Modem	Data rate	Modulation	Bandwidth efficiency	Application
1964	V.21	300 [b/s]	FSK	0.1 [b/s/Hz]	Data transmission
1964	V.22	2.4 [kb/s]	QPSK	0.75 [b/s/Hz]	Data transmission
1972	V.27	4.8 [kb/s]	8 PSK	1[b/s/Hz]	Data transmission
1976	V.29	9.6 [kb/s]	16 QAM	1.5 [b/s/Hz]	Data transmission
1984	V.32 (dialup)	9.6 [kb/s]	TCM	3 [b/s/Hz]	Data transmission
1998	V.34	28.8/33.6 [kb/s]	TCM	≈ 11 [b/s/Hz]	Data transmission
1998	V.90	56 [kb/s]	TCM	≈ 18 [b/s/Hz]	Internet access
1995	HDSL	2048 [kb/s]	2B1Q	2 [b/s/Hz]	E1/T1 symmetrical service, feeder plant, LAN, WAN access
2001	SDSL	768 [kb/s]	2B1Q	2 [b/s/Hz]	HDSL over single pair

1996	ADSL	Downstream 1.554-8.448 [Mb/s] upstream 16-640 [kb/s]	CAP / DMT	≈ 8 [b/s/Hz]	Internet, multimedia access, video distribution

Table 1 [3]

4 COMPARATION OF MODULATION TECHNIQUES

The basic modulation techniques are shown in the table 2:

Modulation Format	Bandwidth efficiency (C/B)	log2 (C/B)	Error free Eb/No
16 PSK	4	2	18dB
16 QAM	4	2	15dB
8PSK	3	1.585	14.5dB
4PSK	2	1	10.1dB
4QAM	2	1	10.1dB
BFSK	1	0	13dB
BPSK	1	0	10.5dB

Table. 2 [4]

The table 2 shows, that high level M-ary schemes (such as 16 PSK) are very bandwidth efficient, but more susceptible to noise in the comparison to binary schemes (BFSK or BPSK).

5 DESCRIPTION OF THE SIMULATION PROGRAM

User program for the comparison of various modem technologies in the local loop is developed in the technical simulation environment – MATLAB 6.0. A logic scheme of the simulation program is shown on the figure. 1.

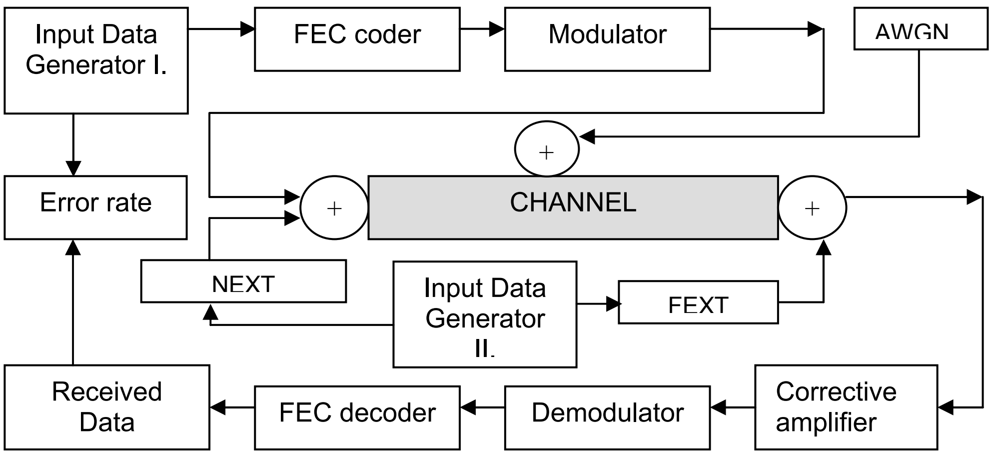

Figure 1.

Brief descriptions of particular function blocks:

Input Data Generator I. – generates a definite information sequence, which represents the input information signal, entering the simulation.

Input Data Generator II. – generates a definite information sequence, which is used for crosstalks generation.

FEC coder – codes digital signal using one of the possible coding techniques. The used code type depends on the chosen modem technology.

Modulator – modulates input signal. The type of used modulation depends on chosen modem technology.

NEXT + NOISE – adds the AWGN noise and the NEXT crosstalk to the modulated signal.

Channel – attenuates the transferred signal according to parameters specifying line (diameter of wires, length of line).

FEXT – adds the FEXT crosstalk to the modulated signal.

Corrective amplifier – amplifies transferred signal. (eliminates the attenuation caused by channel)

Demodulator – demodulates received noisy signal

FEC decoder – decodes demodulated noisy signal

Error rate – compares input and received signal and calculate the number of errors and the BER (Bit Error Rate).

6 CONCLUSION

The goal of the project was to develop and to create user program capable of visualization of various kinds of modem techniques. Program was designed in technical simulating environment MATLAB 6.0, which enables simple and effective operations with matrices and ability of creating graphical outputs.

During the development of the program I found a lot of different specifications of particular technologies, which I had to simplify because of implementation and time reasons.

Accordingly all types of modem technologies and also all kinds of functional blocks of transfer path are not implemented yet because of implementation and content complexity.

Program simulates particular technologies in different ways. While by modems from standard V.xx is the random information message generated, modulated and afterwards transferred through the channel, by the modems from xDSL family simulation consists only from transmission of the information signal through the channel because of the implementation complexity of the modulator.

One of the possible improvements of the simulation program could be realization of all the functional blocks as independent functions and so their implementation with more details.

7 REFERENCES

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