Name of discipline:

Transmission systems of access networks (TSAN)

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Lecture 3

CODING TECHNOLOGIES OF LINEAR SIGNALS IN THE XDSL

Requirements for the linear code

In the subscriber line (SL) at frequencies up to 25 kHz influence of impulsive noise is significant, and a range up to 50 kHz –volatility affects of the wave impedance (Z_w). This causes the limitation of digital spectrum from the bottom where an analog voice signal is transmitted.

The simplest method of organizing DTS-SL (digital transmission system for subscriber line) is the transfer of the data signal spectrum to the HF(high frequency) domain using a radio signal, but attenuation increases sharply at HF.

Therefore, the linear range of the signal should be limited to the top, otherwise installing repeaters won’t be avoided, that is undesirable.

The following requirements should be taken into account when choosing a method of line encoding DTS-SL:

- Limitation of the signal above and below;
- The possibility of extraction of linear synchronization signal;
- Monitoring and correction of errors without interruption;

- Provision of equipment for reverse polarity circuit veins of SL;
- Simple (cheap) construction of the equipment, minimizing the current RPS (remote power supply) and dimensions of RT (remote terminal) and COT (central office terminal).

To perform these requirements special linear signals (codes) can be designed. DTS-SL signal passed along the chain composed of series connected different types cables with different conductors diameters.

The use of linear codes such as AMI, HDB-3 (RZ signal) leads to the formation of multiple reflections and interference types associated flow.

The implementation of xDSL technology is possible with the using of new line-level signals that can transmit data signal in a narrow band in comparison with the codes plesiochronous DTS.

These types of modulation should also provide the common transmission of an analog signal to VB (voice band) and they shouldn’t contain passive pause for reducing the impact of associated flow.

The following types of linear modulation signals in xDSL - BPS, 2B1Q; CAP; DMT and TC-PAM:

- RBPS - relative bi-pulse signal;
- 2B1Q - 2 Binary, 1 Quartenary (2 bits of information, level 4);
- CAP - Carrierless Amplitud and Phase Modulation (AFM - amplitude and phase modulation without a carrier);
- QAM - Quadrature Amplitude Modulation;
- DMT - Discret Multi-Tone (discrete multi-frequency modulation);
- TC-PAM - Trellis Coded Pulse Amplitude Modulation (pulse amplitude and phase modulation with Trellis coding).

RBPS - relative bi-pulse signal

The first digital signal SL applied double-pulse signal wherein for each transmission symbol of binary data (0, 1), for each clock interval two pulses of different polarity with the duration T/2 were generated , Fig. 3.1.

Relative double-pulse signal is chosen for reasons of:

a) The balance of the DC (direct current);

b) The independence of the transmission quality polarity wires in chain connected to the hardware. Algorithm RDPS binary "1" is transmitted by the AMI law, and a binary "0" is transmitted by double-pulse signal (Fig. 3.2a, b).

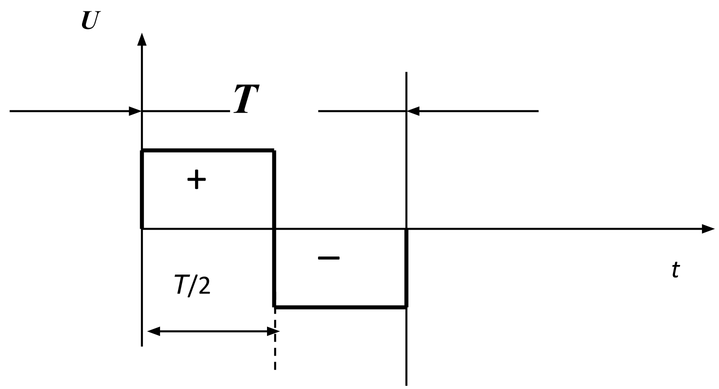

Figure 3.1

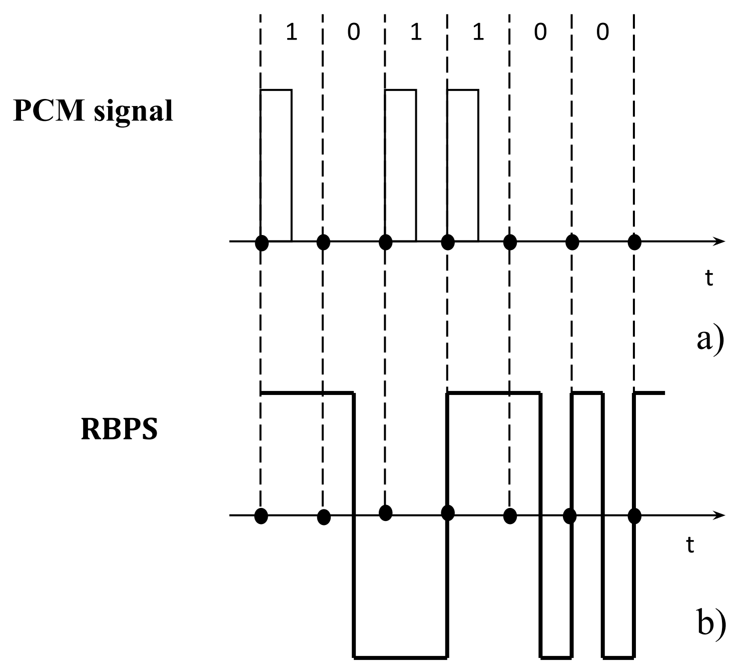

Figure 3.2

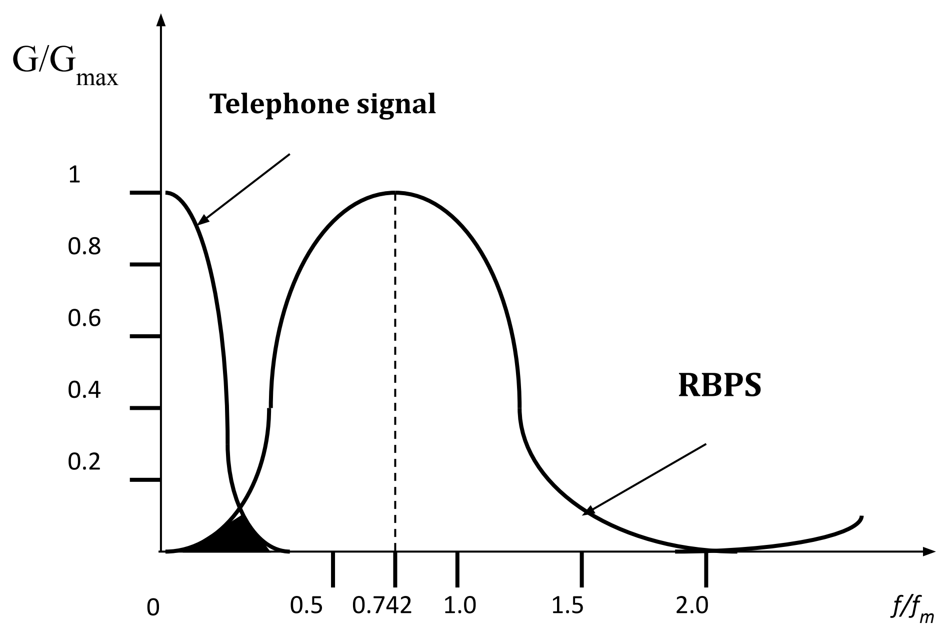

Figure 3.3

Even in a perfectly balanced code RBPS low power spectral components are significant in the range of VB channels (Figure 3.3), ie this code does not provide a joint transmission without interference of digital and analog signals over a single pair of SL.

This problem is solved in the code 3B2T- RBPS, so for rates of 192 kbit/s the bandwidth of: 5...140 kHz is occupied.

Linear signal 2B1Q

2B1Q modulation (4-level PAM) is standardized for networks ISDN, where the digital stream is transmitted at a rate of 144 kbit / s. Later it began to be used for transmission over high-speed streams in the HDSL technology.

The code is modulated by a signal having a level 4, i.e. at each time two bits of information are transmitted, Fig. 3.4 . Clock interval duration will be increased, and the clock frequency - halved.

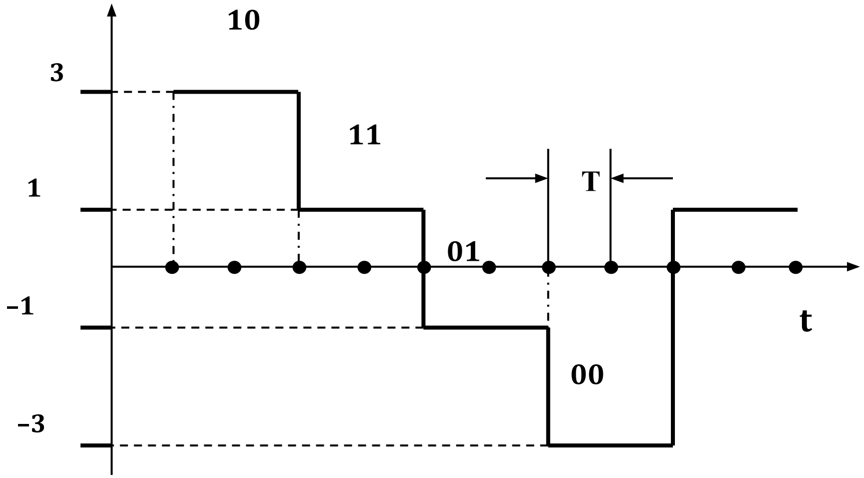

Figure 3.4

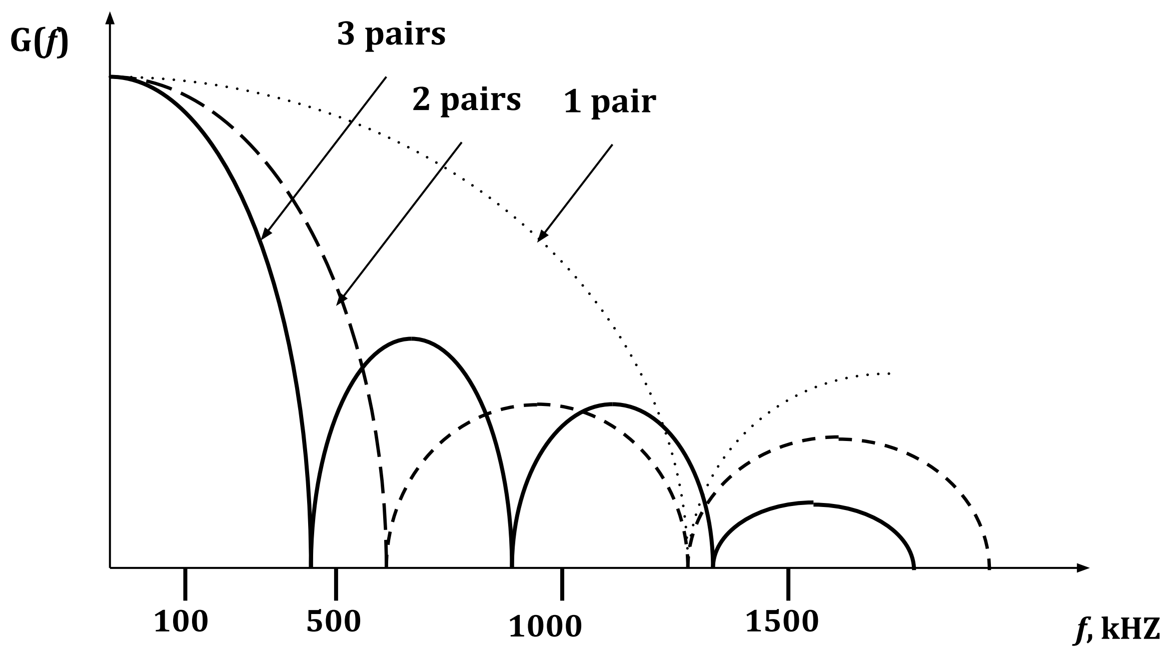

Figure 3.5

In the 2B1Q code the E1 stream transmission is possible (in parts) for one, two or three pairs. For HDSL technology transmission rate for three pairs of 784 kbit/s, 2 pairs - 1168 kbit/s for 1 pair - 2320 kbit/s.

The energy spectrum is characterized by a constant , low and high frequency components (Fig. 3.5). The latter fact reduces the maximum signal transmission distance with the required quality. Joint transmission of analog voice signal is not possible.

Technology 2B1Q is sensitive to low-frequency distortion and noise, and an acceptable quality of transmission is achieved by using modern methods of correction.

Despite the fact that one pair of transmission does not satisfy the basic requirements for transmission range 2B1Q technology is widely used due to its cheapness .

In addition , you should consider the fact that foreign (Western) SL are shorter and have better quality.

QAM – Quadrature Amplitude Modulation

According to this algorithm the coding is done by simultaneous changing in-phase ($\cos 2\pi f_c t$) and quadrature ($\sin 2\pi f_c t$) components of carrier harmonic signal with frequency $\omega_c = 2\pi f_c$, that have phase difference on 90° ($\pi/2$).

A resultant QAM signal $s(t)$ is equal to sum of components:

$$s(t) = a_к \cos 2\pi f_c t + b_к \sin 2\pi f_c t,$$

sinphase component quadrature component

where a_k i b_k – means of symbols, that transmit on k-th clock interval.

QAM signal represented as vector diagram (Fig.3.6). Vector of a signal $s(t)$ has appropriate module and phase: $|s| = \sqrt{a_k^2 + b_k^2}$, $\phi_к = \text{arctg}(b_к / a_к)$.

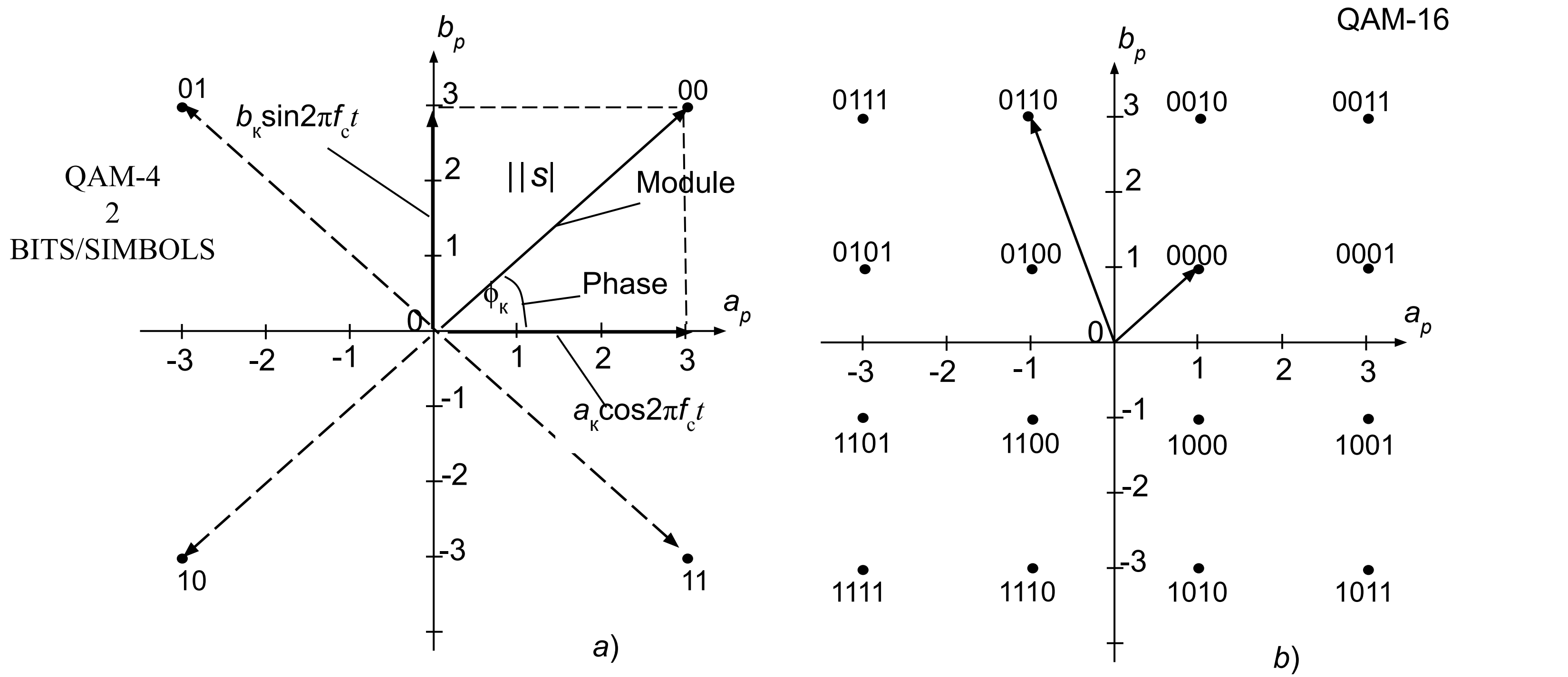

Fig 3.6 − Signal constellation QAM-4 (*a*) i QAM-16 (*b*)

Carriers $\cos\omega_c t$ i $\sin\omega_c t$ are consider as orthogonal coordinate axes, and transmitted on times slot signals a_p i b_p determine coordinates of signal points on a phase plane in this coordinate system. Quantity information bits, that transmitted per one clock interval , is a whole numbe of $n = 1, 2, 3,\ldots, n_{max}$ (usually, n_{max} not exceed than 15). Quantity of signal points on two-dimensional coordinate system is equal $M = 2^n$.

A complex of signaling points on the plane named as **signal constellation**. On a Fig. 3.6,*a* is represented signal constellation for an easiest kind of modulation QAM-4 (a radius-vector can to take up $M = 2^2 = 4$ positions on a phase plane, each of them is correspond to some combination of two bits – 00, 01, 10, 11). For the QAM-16 (Fig. 3.6,*b*) a radius-vector can to take up 16 positions ($n = 4$, $M = 2^4 = 16$) on the phase plane, each of them is correspond to some combination of four bits.

Advantages of QAM:

- narrow line spectrum, its location on frequency axis is depend on choice of carrier;
- easy realization of FDC when multichannel (parallel) transmission or when frequency division of specters, that are trasmitted in the opposite direction by one pair of signals in an asymmetrical DSL;
- simplicity of implementation, low price.

Disadvantages – high level of carrier power (relative to the low levels of side bands) on the QAM spectrum results to energy transition on the neighbor pears. It’s complicate a parallel work of several DSL by one cable.

CAP linear signal (APM without a carrier)

On a SL of relatively large length CAP modulation is applicable. This is the narrow-band coding technology, insensitive to most of the interference and enables collaboration and digital transmission of telephone signals.

CAP technology is one of the latest advancements modulation technology and microelectronics. CAP signal diagram is similar to the QAM signal diagram.

The carrier frequency is modulated by both amplitude and phase, creating a code space with 64 or 128-th code states.

On the transfer of the carrier frequency, which does not contain the information, but has a maximum power, "cut out" and is restored at a reception microprocessor.

At CAP-64 6 bits of information are transmitted at each time, that is 6 times higher than the code 2B1Q. At CAP-128 7 bits of information per clock cycle are passed. This greatly reduces the signal range that eliminates the sections of the spectrum subject to distortions and interferences.

The spectral density of the CAP signal is concentrated in the frequency range from 40 ... 260 kHz.

CAP spectral diagram in comparison with the diagrams 2B1Q and HDB-3 at Fig. 3.7.

CAP signaling can be carried in the frequency band of 40 ... 260 kHz at 2320 kbit / s over a single pair, and 1168 kbit / s - in two pairs.

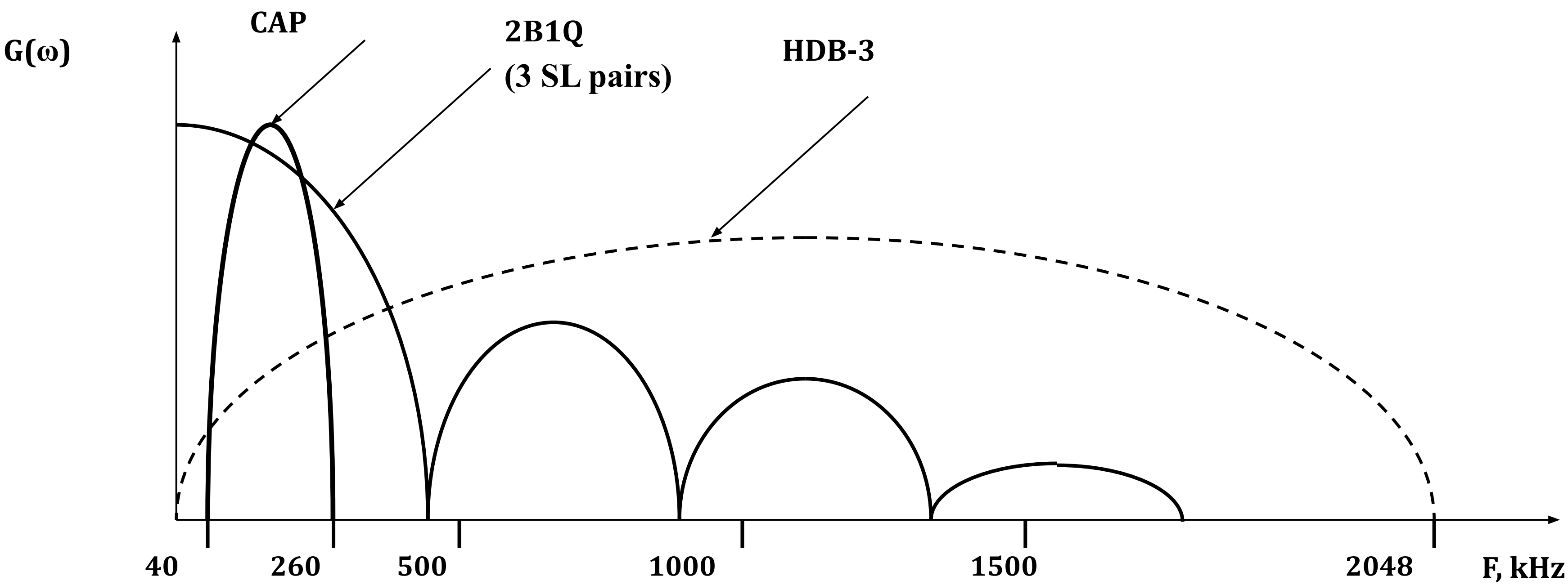

Figure 3.7

Advantages of CAP.

1) **The range of the signal components of the CAP does not exceed 260 kHz, and therefore can be transmitted over greater distances than with a signal code 2B1Q or HDB-3.** Despreading leads to gain on the transmission distance compared to systems 2B1Q (two pairs) to 15 ... 20%, and for systems operating one pair of - 30 ... 40%. Gain compared with a DTS PCM-30 is 350 ... 400% on a site without a regenerator for conductors with a diameter of 0.4-0.5 mm.

2) **High noise immunity and insensitivity to the group delay .** Since there are no components in the spectrum below 40 kHz and above 260 kHz , the technology is insensitive to ATS HF crosstalk (crosstalk radio interference) and the impulse noise as well as low distortion and crosstalk (start powerful electric cars , electric). Since the spectral width is less than 200 kHz, the effect does not occur due to the group delay time.

3) **The minimum level of interference, and interference in the band VB channels.** CAP signal does not cause mutual influences and interference in the spectrum of the phone signal , due to the absence in the spectrum of the components below 4.0 kHz. This fact removes the restrictions on the sharing of adjacent pairs of cables for analog subscriber or interoffice connections.

4) **Compatible with hardware compression , running at adjacent pairs**. Systems with CAP may cause interferences in its operating range , but the other channels are not affected . Consequently, the possibility of parallel work on the same cable equipment CAP and ATS. System with the same code 2B1Q cause interferences on all channels ATS workers to neighboring pairs.

5) **CAP modulation is not sensitive to the quality of the SL .**

Modulation of DMT (Discrete Multi-Frequency Modulation)

DMT - is a modulation using a plurality of subcarriers in the range 26 kHz ... 1,104 MHz (for ASDL-technology). This range is divided into 256 subchannels. Each sub-channel has a width of 4 kHz , Fig. 3.8. Each carrier is modulated with the information signal on the basis of QAM - quadrature amplitude modulation.

The number of bits of data transmitted in each sub-channel depends on the link quality and signal/noise ratio (S/N) in his band.

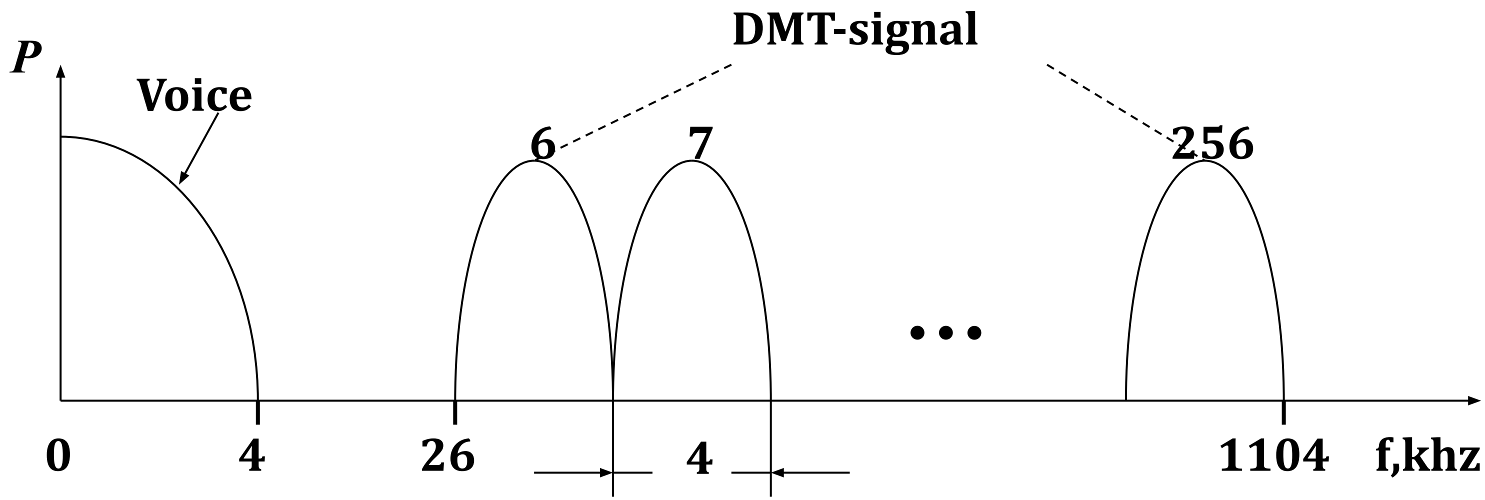

Figure 3.8

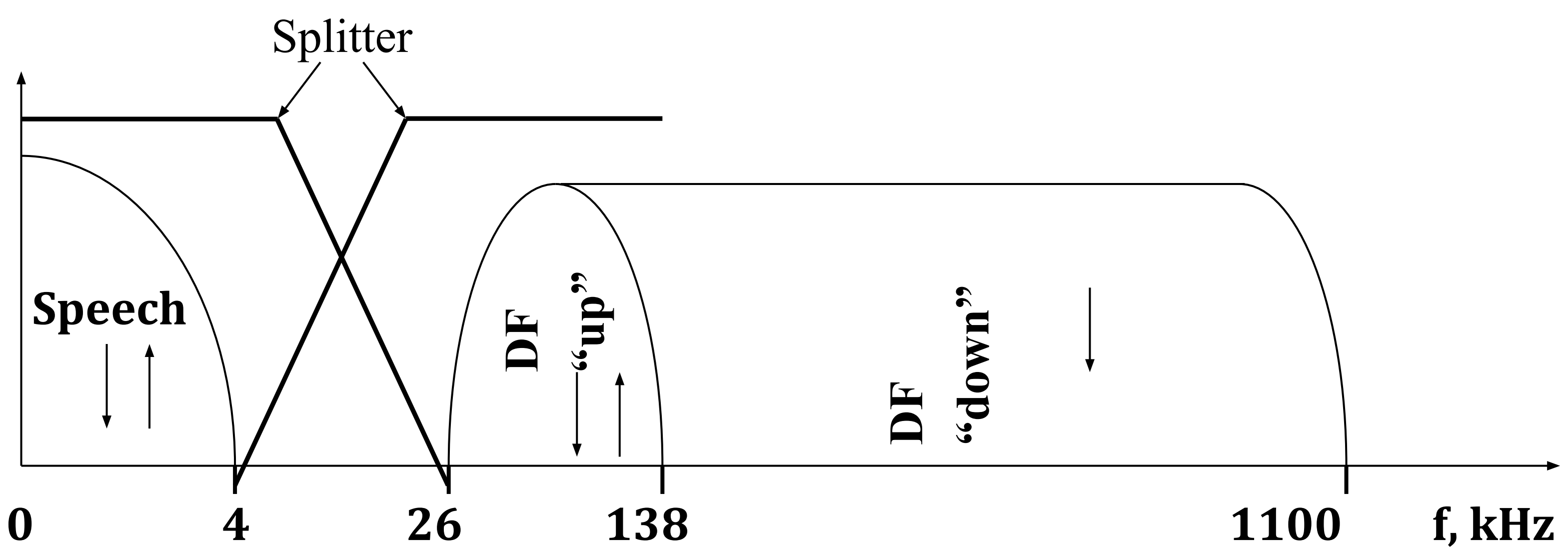

Figure 3.9

In each DMT subchannel there is an individual choice of transmission rate as much as possible for a given S/N. The values of the level of transmission of information transmitted to the receiver are also selected. Thus , DMT uses the principle of multi-frequency division , but , moreover, allows to exclude the transfer of highly noisy subchannels or frequency band . Thus , DMT is adaptive modulation. This method also solves the problem of separating the speech and data signals , but is more complex to implement than the CAP. DMT standardized code in technology ADSL and VDSL.

In DMT technology three streams of information are actually passed (Fig.3.9): voice in the VBC, bi-directional data stream "up" (from the subscriber to the network) and simplex data stream "down" (from the network to the subscriber.)

The transfer is carried out over a two-wire line. Separation of analog and digital signals is made with a splitter (frequency splitter).

Separation of opposing streams of data is done by the echo compensation method in the band 26 ... 138 kHz or by the frequency method.

TC-PAM - Trellis Coded Pulse Amplitude Modulation

The recommendations ANSI, ETSI, ITU chosen for simmetrical DSL- making new technology TC-PAM (HDSL- 2 standard , G.SHDSL).

Benefits of TC- PAM technology are like 2B1Q its simplicity and CAP modulation its effectiveness. TC- PAM has the best performance for electromagnetic compatibility (EMC). The essence of the encoding method is to increase the number of code levels or distances from 4 to 16 and the application of a special error correction mechanism.

Coding technologies TC- PAM (for example, PAM -16) transmits one symbol of 3 bits of useful information and fourth additional bit for error protection coding.

TC- PAM technology is not anything new, it's PAM technology , as well as coding 2B1Q. But the use of lattice or trellis codes has reduced due to the redundancy introduced into the transmitted data , the probability of error when winning a 5 dB immunity. To decode the TC - PAM modulation the Vitterbi algorithm is used . TC- PAM technology is accepted by ITU as a single Symmetrical DSL-standard for all developers (GSHDSL).

Relative spectra of TC-PAM and 2B1Q for speed 784 kbit / s are shown at Fig.3.10.

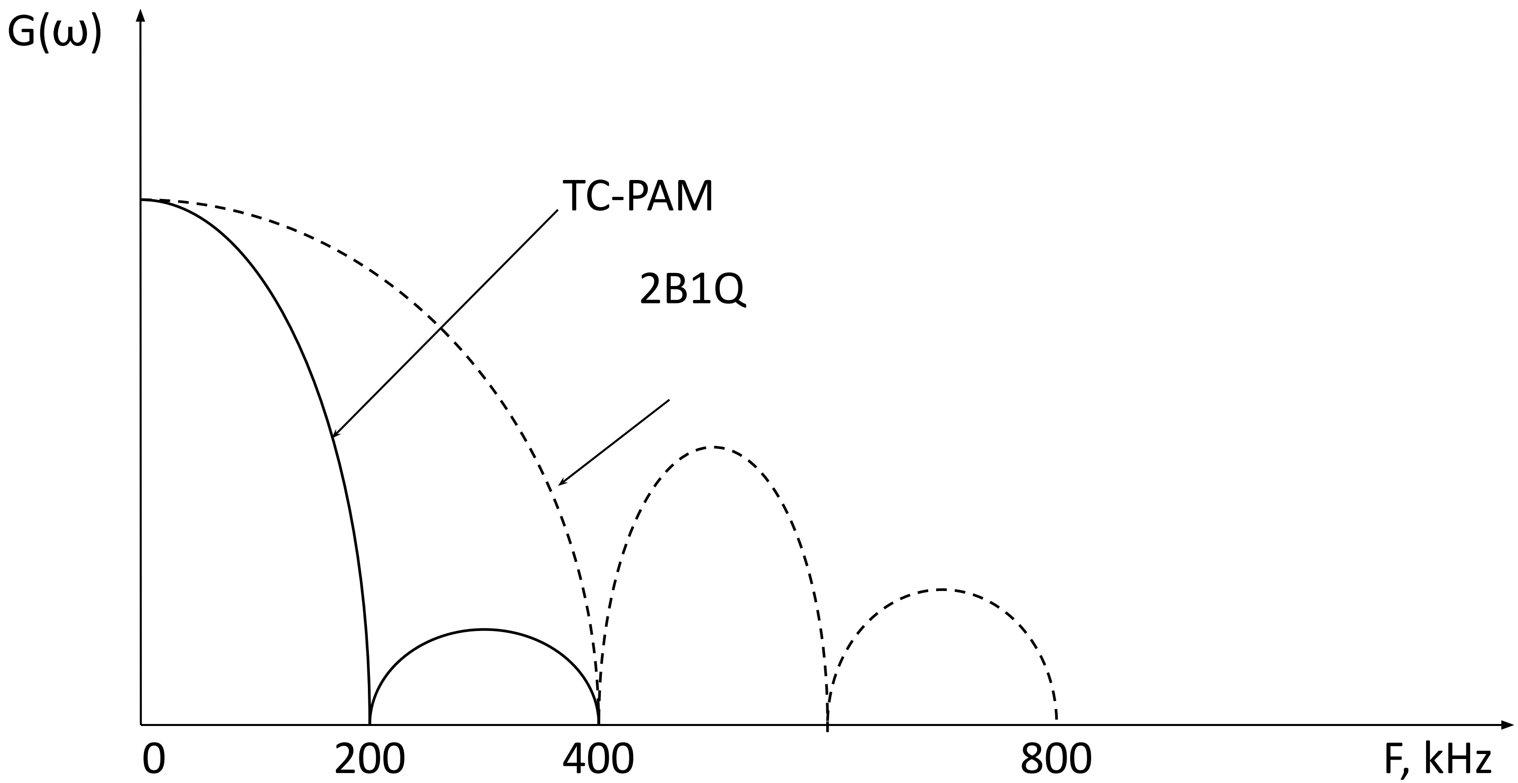

Figure 3.10.

Comparison of the energy spectra shows that in parallel operation xDSL systems crosstalk caused technology TC- PAM will be less interference coding 2B1Q, ie at a downstream ADSL crosstalk is absent, and at upward is negligible.

For CAP technology, the presence of c connection of high power signal is transmitted in the frequency bands of 10 to 40 kHz and 150 - 200 kHz and large electromagnetic effects , parallel use of other xDSL- technologies is almost impossible.

Experimentally confirmed that a linear encoding provides TC- PAM compared to technology 2B1Q greater by 30 - 45% of the data rate on the lines of equal length and at most 15 - 20% range with the same transmission speed.

Thus , data is transferred at high speed duplex on the 1st pair of wires at a significant level of interference.

Control test. 1-st attestation

Name and surname of student

____

Task: **M** is equal to the last digit of the test book.

M = _____

The transmission rate of information flow

B= 1000+(M+1)*300 kbit/s

Draw a linear signal spectral diagram if 2B1Q code is used.

Solution: