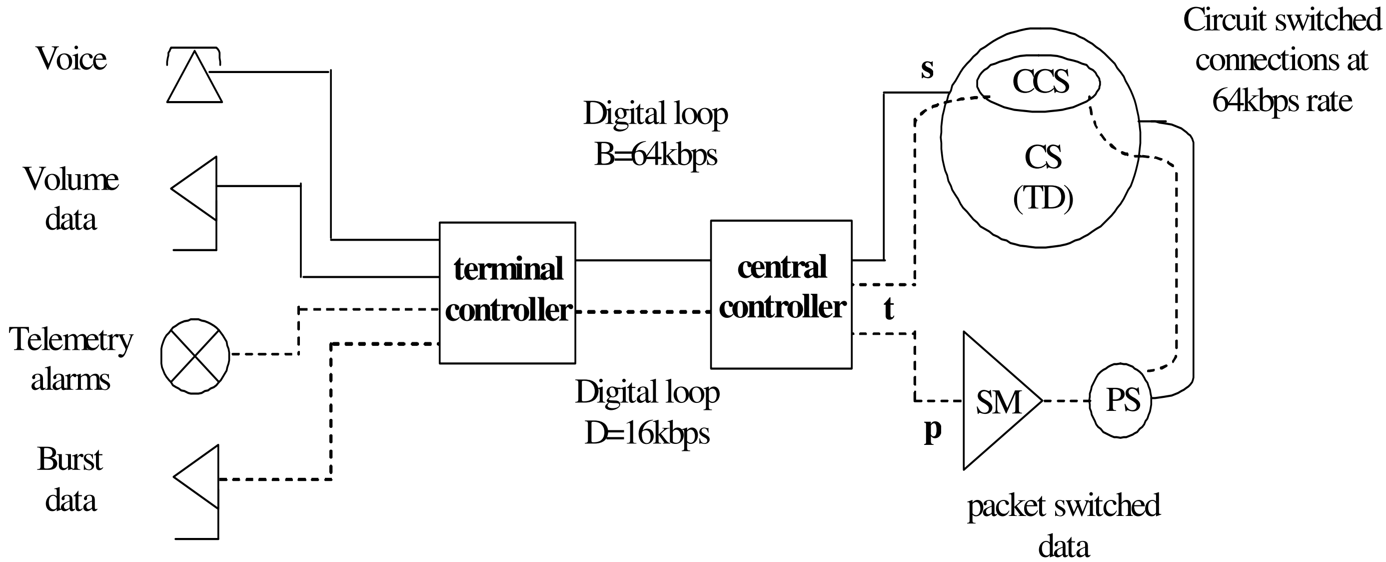
# Course 7
# Digital access techniques used in the telephone network. Narrow band ISDN

- problems related to telephone IDN:
  - circuit switching – appropriate for voice transmission and volume date, but not appropriate for burst data;
  - in general analog access of the subscribers in the network;
  - the access and transport network are designed for voice transmission;
  - coding techniques and circuit characteristics intended for voice transmissions – *non-uniform quantization, filter frequency characteristics;*
  - separate terminal equipments for voice and data transmission; separate equipments-network interfaces;

**Narrow band ISDN**

- the complete digital approach it is illustrated conceptually in fig. 1 ;




CS – circuit switching ; PS – packet switching ; SM – statistical multiplexer ; CCS – common channel signaling
CS (TD) – switching using time division

Fig. 1 Conceptual ISDN architecture

- this approach ensures a digital loop capacity for the two type of channels (effective data channels – channel B and control + data channel – channel D);
- the different information signals offered by the completely digital access are separated at the access units of the digital exchange (central controller);
- **B** channels and the associated signaling information **s** are routed to CS and CCS utilities;
- **p** information (packet switched information) is routed to PS facilities through a statistical multiplexer (SM) which concentrates the virtual circuits to PS equipment;
- **t** information (telemetry) can be manipulated either by CCS blocks or by PS blocks; in the first case is handled as a datagram while in the last case this information is transmitted on temporal or permanent virtual circuits.

**Principles of ISDN:**

- voice and data applications using a limited set of standardized facilities – defines the purpose of ISDN and the means necessary to realize it – *the use of a limited set of connection types and network interfaces with multiple utilities.*
- ensures switched applications (circuit and packet switching) and non-switched applications (dedicated lines).
- it is based on a 64kbps rate connection – basic ISDN rate chosen due to the fact that is the basic rate in digital telephony.
- intelligent network: ensures complex services besides simple circuit switching and a complex network management.
- protocols with a stratified architecture – protocols which control the subscriber link – the ISDN network protocols have a stratified structure according to the OSI model; the access of a subscriber can vary according to the required service.
- variable configurations – there are possible several physical configurations for ISDN implementation.

- Benefits of ISDN: flexibility and low prices; integrated voice and data don't require multiple transmission techniques for multiple needs.
- ISDN services (beside voice): facsimile, teletex (fast message exchange between terminals), videotex (interactive services to information access); these services are available at the rate of 64kbps (or at a lower rate).
- The user interface – the user has access to ISDN through a generic digital channel („digital pipe").
  - generic channels are available for different needs;
  - the rate between the user and the network is constant, but can be shared in different ways between different services;
    - control signals are necessary for time multiplexing of the data from different services – control signals are multiplexed on the same digital channel; the user pays according to the used capacity of the available channel.

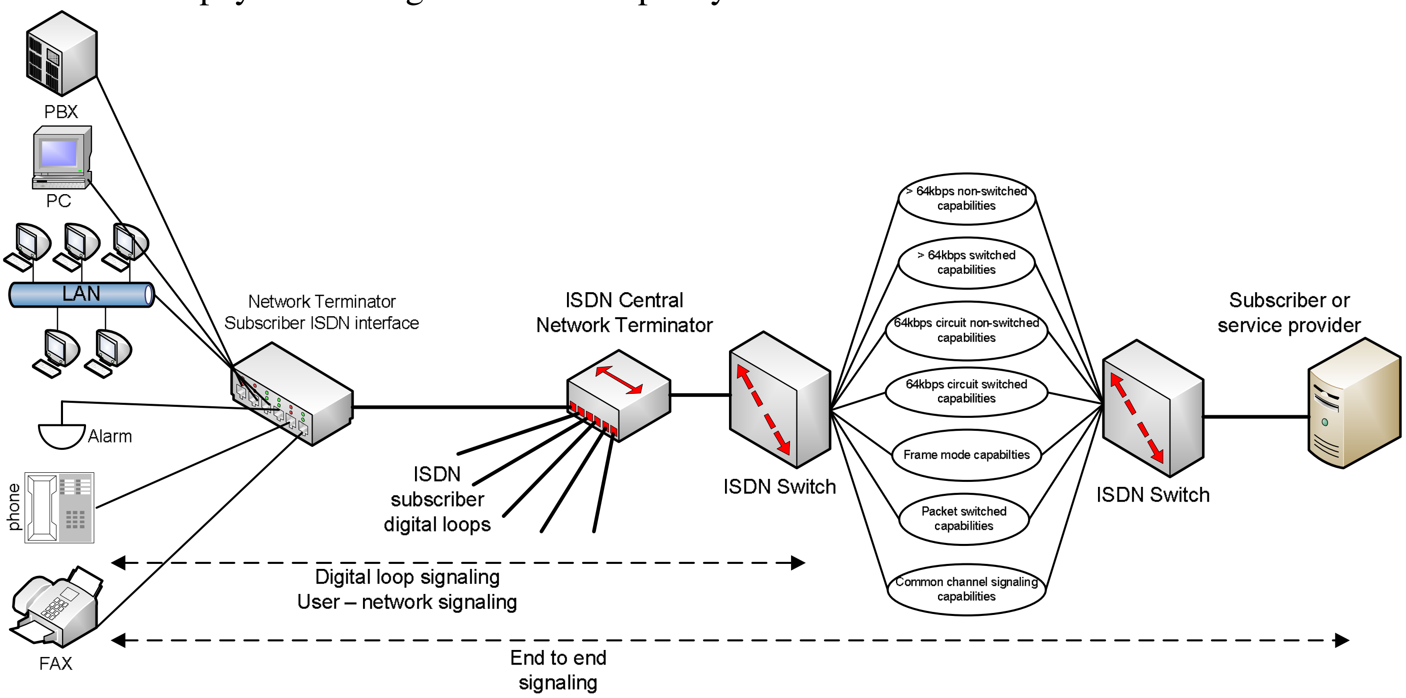



Fig. 1.1 ISDN architecture

- The structure of the transmission: the generic digital channel between the ISDN exchange and the ISDN subscriber has a number of communication channels which vary from user to user in the following way:
  - B channel: 64kbps.
    - digital data, PCM coded voice or a combination of traffic data at rates lower than 64kbps – data (file) transfer at average rate, facsimile and video with low frame rate; there are possible circuit switching type connections, packet switching type connections, non-permanent connections.
  - D channel: 16 or 64kbps.
    - control information (CCS) for the circuit switching, data in packet switching or telemetry data with low transfer rate and without signaling information.
  - H channel: 384kbps ($H_0$), 1536kbps ($H_{11}$), 1920kbps ($H_{12}$).
    - data at high transfer rates; these channels are used as high speed channel or they are divided in time in several low speed channels.
- The basic access is intended for domestic users and for small offices; the total rate (data + overhead) is 192kbps (user terminal – network terminator) and 160kbps (on the subscriber loop);
  - the primary access is intended for high capacity users, for LAN and PBX.

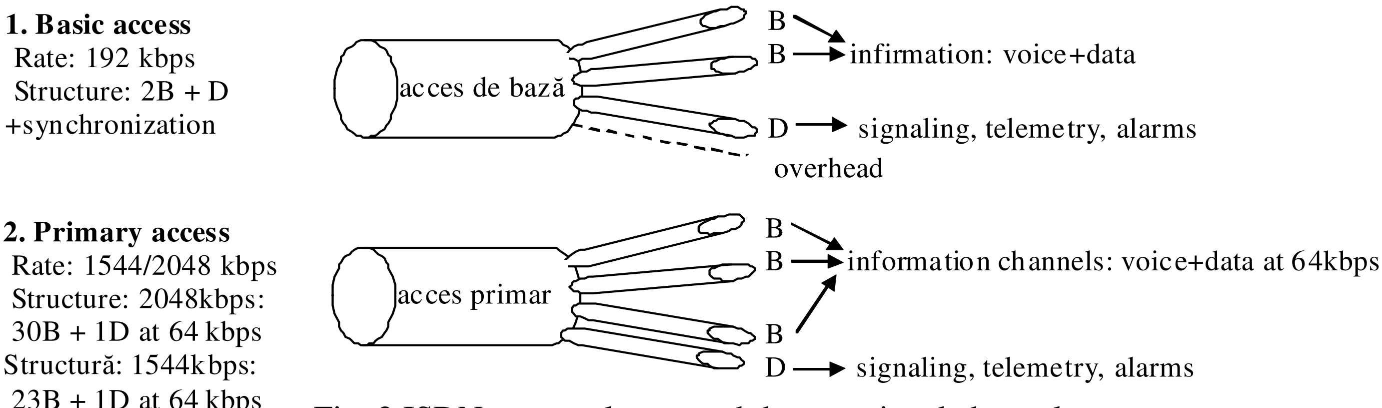


Fig. 2 ISDN access classes and the associated channels

- The user-network interface is defined by functional groups (a certain disposal (combination) of the equipments) and reference points (conceptual separation points of the functional groups (see the following fig. 3); it is defined using a structural model; the equipments must match only the interfaces.

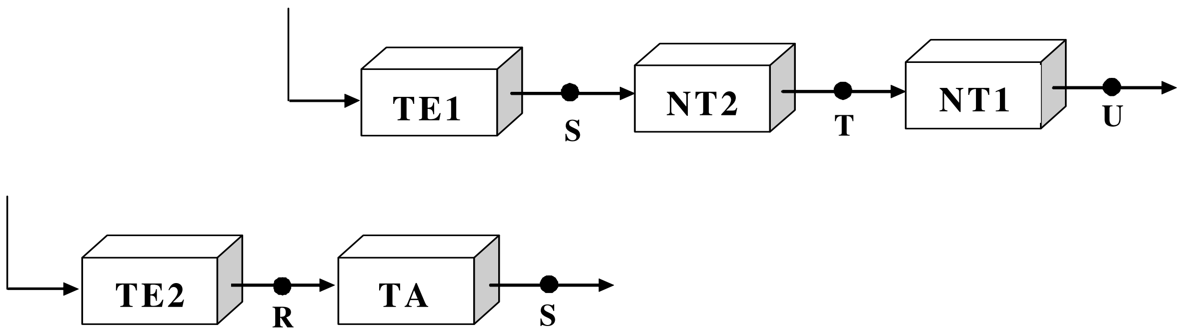


Fig. 3 ISDN functional groups and reference points

- The roles and the characteristics of the functional blocks and of the reference points are the following:
  - NT1 – effective connection to the digital loop, multiplexing of the logical channels (for ex. 2B+D) using TDM; NT2 has switching functions; can be a digital PBX, a terminal controller or a LAN;
  - TE1 – equipment with standard ISDN interfaces (for ex. digital phone, voice/data integrated terminal, digital fax);
  - TE2 – non-ISDN equipment (ex. RS-232 interface, X.25 interface);
  - T reference point – ISDN terminator at the user side; separates the network equipments from the subscriber equipments;
  - S reference point – interface of the individual ISDN terminal; separates the user terminal from the communication functions of the network;
  - R reference point – ensures a non-ISDN interface between a non-ISDN user equipment and an equipment adaptor;
  - U reference point – describes the full-duplex data signal on the digital subscriber line.
  - Possible access configurations are presented in fig. 4
    - **maximum 8 TE1 terminals for passive bus**
    - **cable length 250-1000m for 1 TE1 and 150m for 8 TE1**

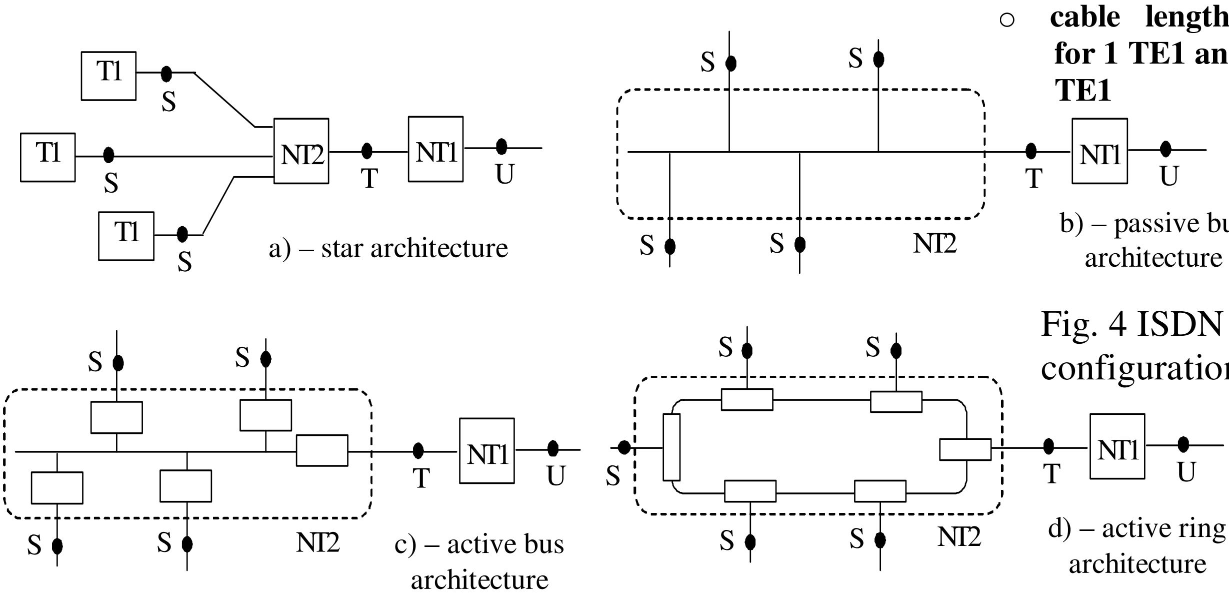



Fig. 4 ISDN access configurations

- The basic user-network interface (the primary access)
  - The functions of the physical layer in points S and T:
    - coding of the digital signals;
    - full-duplex transmission on channels B and D;
    - multiplexing of the channels for the construction of the basic access;
    - activation-deactivation of the physical circuit;
    - power supply of the terminal equipment from the NT module, terminal identification;
    - faults isolation, multipoint access- management of channel D for access;
      - B channels are allocated to one user at a given time in an ordered mode;
      - D channel controls the access on B channels; several terminals can try to access these channel in the same time; special protocol is necessary to solve the access conflicts;

- transmission and line coding at S and T interfaces: full-duplex transmission on 4 wire; pseudo-ternary (modified AMI: 1 no voltage, 0 negative or positive impulse – alternatively), rate 192kbps=2*64kbps+16kbps+overhead.
- the schematic of the connection between equipments TE and NT is presented in the fig. 5; it can be noticed the distant power supply of the terminal equipment (TE) from the NT equipment; there is also possible the supply of the terminal equipment from NT on a separate circuits or inversely the supply of NT from TE on a separate circuit.

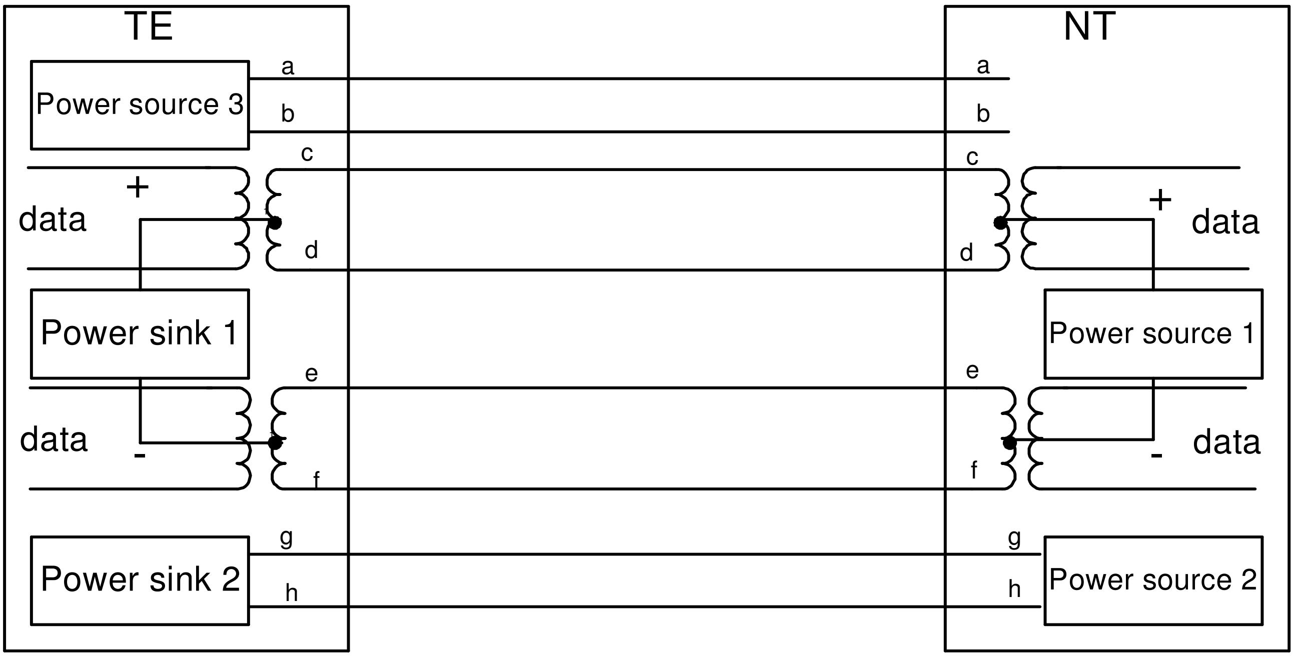



Fig. 5 Schematic of the TE – NT link

- the multiplexing of the basic channels (2B+D – fig. 6) and the composition of the basic frames: multiplexing of a 144kbps rate on a 192kbps rate channel - the spare capacity is used for frame synchronization and D channel access control;
  - 48 bits frame with 250µs duration;
  - the frame from TE to NT is delayed with 2 bits;
  - the F-L bits synchronize the frame at the receiver end;
  - bit $F_A$ is used as auxiliary synchronization bit, N balance bit for $F_A$;
  - bit A activates or deactivates TE; bit M is used for the composition of multiframes;
  - S is reserved for subsequent standardizations;
  - F is always +0, first zero bit after L inserts a violation of the pseudo-ternary coding rule (F and L are alternant);
  - bit L has role in dc balancing; bit E ensures the control of the access of several terminals to channel D.

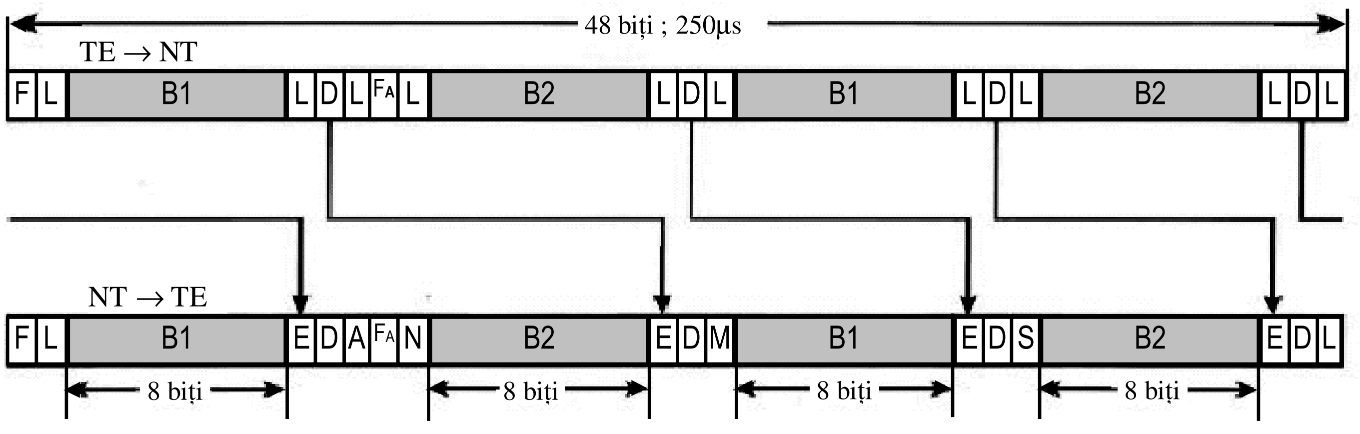



Fig. 6 Structure of the multiplex data frame at S and T interfaces

- The U interface composes frames of 240 bits and duration 1.5ms, the transfer rate being 160kbps;
  - the structure of the frame is the following: synchronization word on 18 bits, 12 groups of 18 bits with B and D channel data, a channel M of 4kbps for management and other purposes (see the fig. 7)

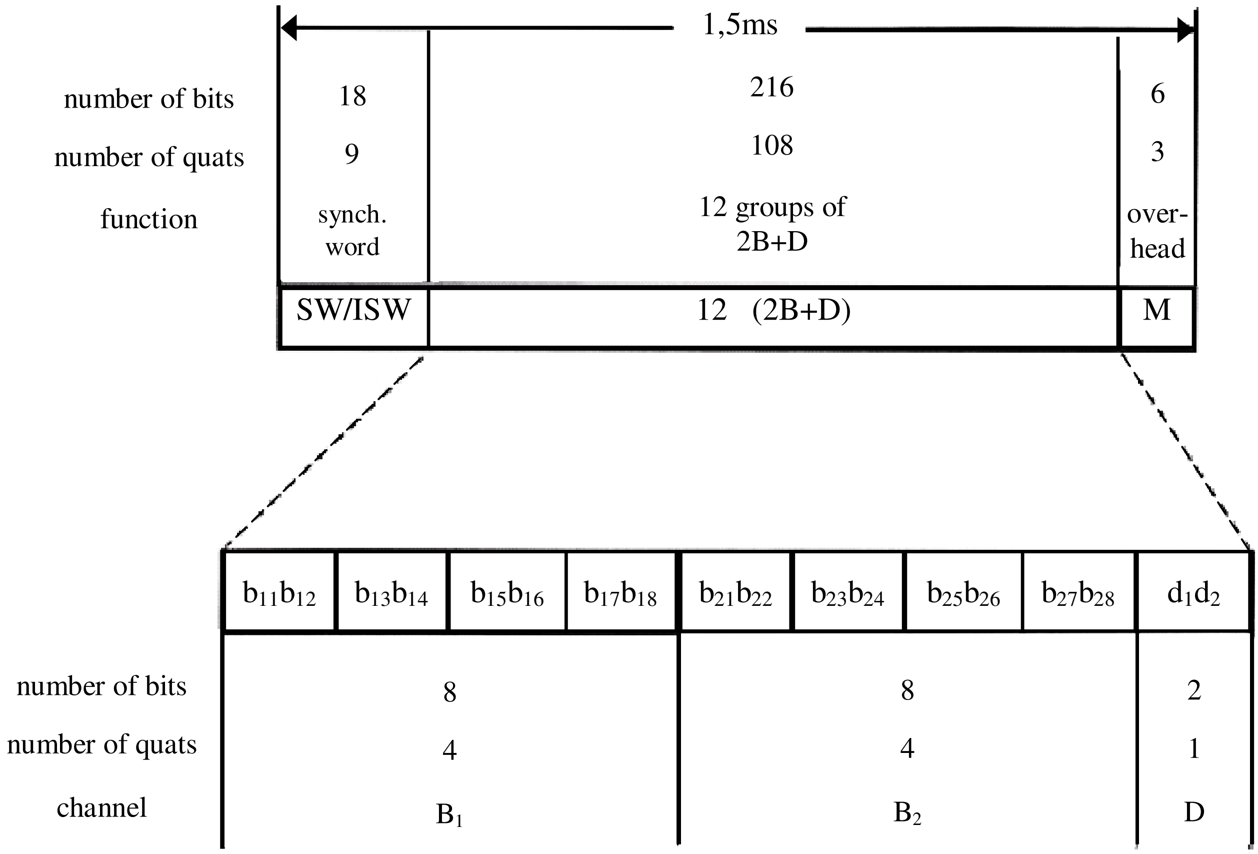



Fig. 7 Structure of the multiplex data frame at U interface

- Line coding using 2B1Q code; 4 level high spectral efficient line code; for the coding rule see the following figure;

| Bit 1 | Bit 2 | Simbol quat | Nivel tensiune |
|---|---|---|---|
| 1 | 0 | +3 | 2.5 V |
| 1 | 1 | +1 | 0.833 V |
| 0 | 1 | -1 | -0.833 V |
| 0 | 0 | -3 | -2.5 V |

Tabel 1. 2B1Q coding rule

- The super frame is composed from 8 frames with 48 M bits, which include a 12 bit CRC (see table 2)

| | | Framing | 2B+D | Overhead bits ($M_1 – M_6$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Quad positions<br>Bit positions | | 1-9<br>1-18 | 10-117<br>19-234 | 118<br>235 | 118<br>236 | 119<br>237 | 119<br>238 | 120<br>239 | 120<br>240 |
| Superframe | Basic frame | Synch. word | 2B+D | $M_1$ | $M_2$ | $M_3$ | $M_4$ | $M_5$ | $M_6$ |
| A | 1 | ISW | 2B+D | eoc | eoc | eoc | act | 1 | 1 |
| A | 2 | SW | 2B+D | eoc | eoc | eoc | dea | 1 | 1 |
| A | 3 | SW | 2B+D | eoc | eoc | eoc | 1 | crc | crc |
| A | 4 | SW | 2B+D | eoc | eoc | eoc | 1 | crc | crc |
| A | 5 | SW | 2B+D | eoc | eoc | eoc | 1 | crc | crc |
| A | 6 | SW | 2B+D | eoc | eoc | eoc | 1 | crc | crc |
| A | 7 | SW | 2B+D | eoc | eoc | eoc | 1 | crc | crc |
| A | 8 | SW | 2B+D | eoc | eoc | eoc | 1 | crc | crc |
| B, C, D | - | - | - | - | - | - | - | - | - |

act: activation bit; dea: deactivation bit; eoc: embedded operations channel; crc: cyclic redundancy check

Tabel 2 Structure of the data multiframe at interface U

- A comparison between the spectral characteristics of different line codes is presented in fig. 8, fig. 9 and fig. 10; the code 4B3T is a ternary code with a complicated coding rule.

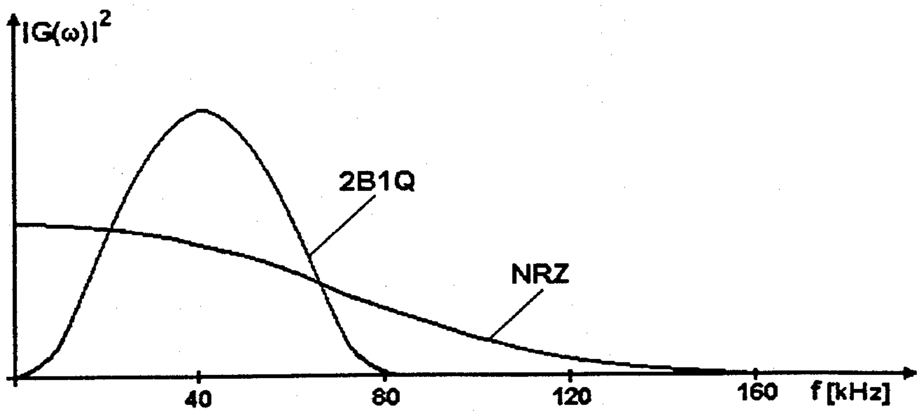



Fig. 8 Power spectral distribution of NRZ and 2B1Q coded signal for a 160kbps bit rate

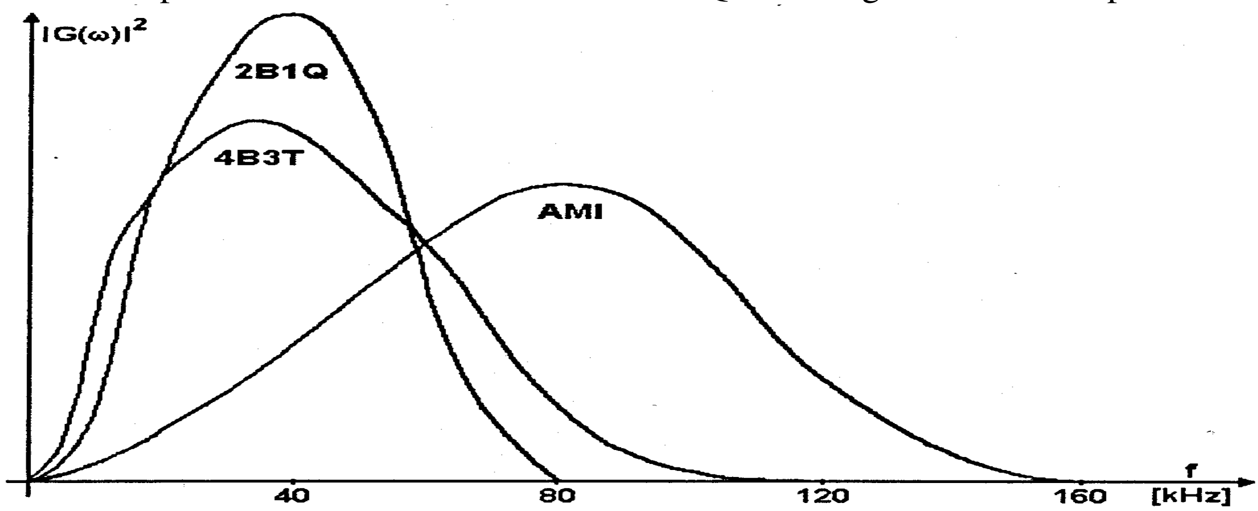



Fig. 9 Power spectral distribution of 2B1Q, 4B3T and AMI coded signal for a 160kbps bit rate

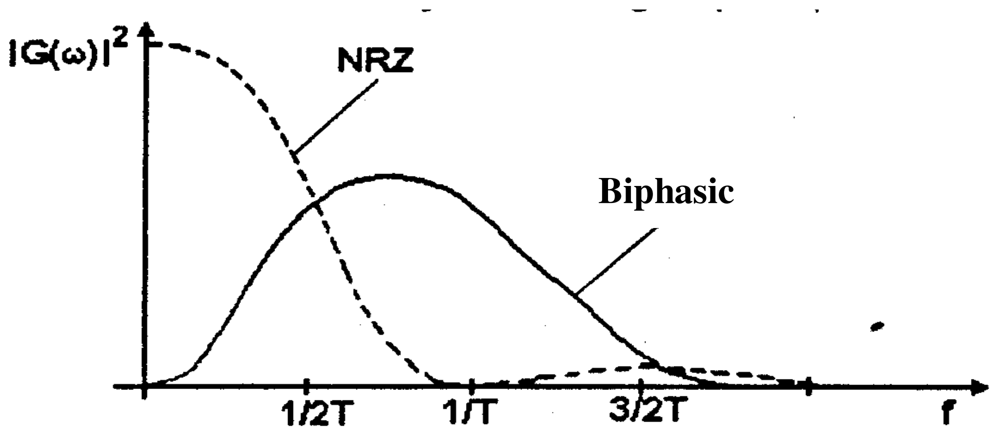


Fig. 10 Power spectral distribution of NRZ and Biphasic code

- Problems related to the power spectral distribution, decoding complexity, synchronization capability of the line codes must be considered when a code is chosen.
- Problems related to the multiple access on channel D must be also considered – non-differential line code is necessary for the TE – NT communication.
- The NT terminal must ensure the conversion from 2 wire to 4 wire and inversely; there are two basic techniques namely:
  - o TCM (Time Compression Multiplexing) – multiplexing with compression in time, transmission in burst mode or in ping-pong mode;
    - it is achieved by dividing the bit sequence in each transmission direction in frames (burst) of de n bits;
    - the duration of the burst is $\Delta = n/D$, where D is the user data speed;
    - each burst is transmitted with a speed $D_0$ at least twice the user speed D;
    - the relation between $D_0$ and D depends on the duration of the burst $\Delta$, the transit time $\delta$ on a line with maximum length $l_L$ and the guard time, $\tau$, between the bursts;
    - a possible block schematics and the description of this access mode is presented in fig. 11.
    - the timing of the transmitted signals is presented in fig. 12; the relation between D and $D_0$ bit rates is given by:

$$\frac{D_0}{2D} = \frac{1}{1 - \frac{2}{\Delta}\cdot(\tau + \delta)} \qquad (1)$$

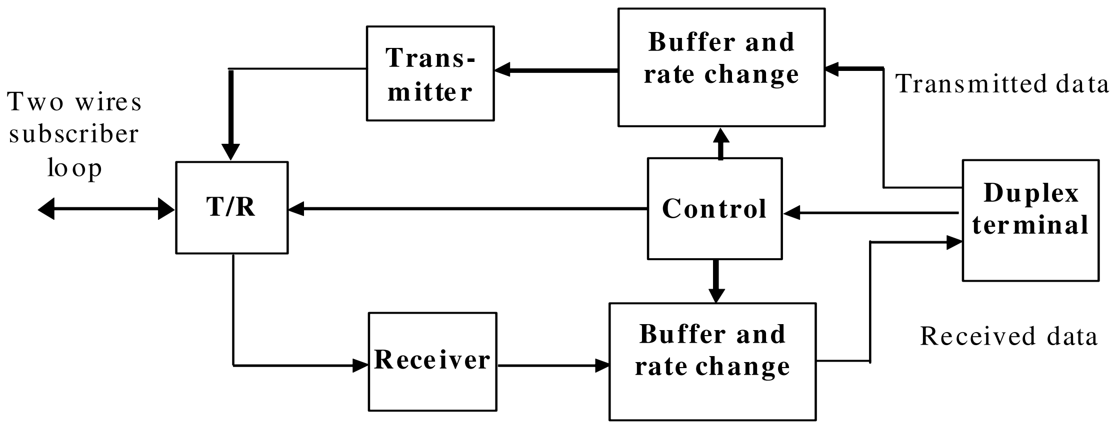


Fig. 11 Block schematic of the transmission equipment used in conjunction with the TCM method of transmission path separation

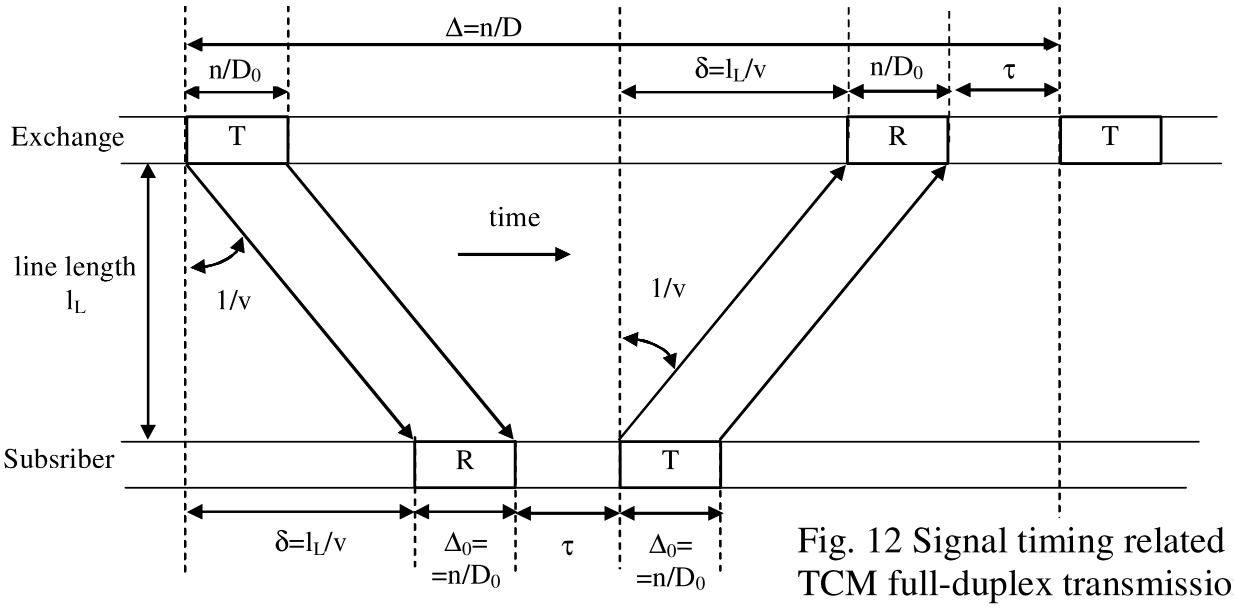



Fig. 12 Signal timing related to the TCM full-duplex transmission

- the balancing method using hybrid transformer and echo canceller;
  - the method ensures the transfer of data in both directions at the user speed;
  - the hybrid ensures the directional separation and the echo cancellation improves the separation of the channels;
  - comparatively with the TCM method it is ensured a decrease of the required bandwidth and are ensured non-accumulative delays in long access loops;
  - it is a more complex method (see fig. 13 for a possible block schematic).

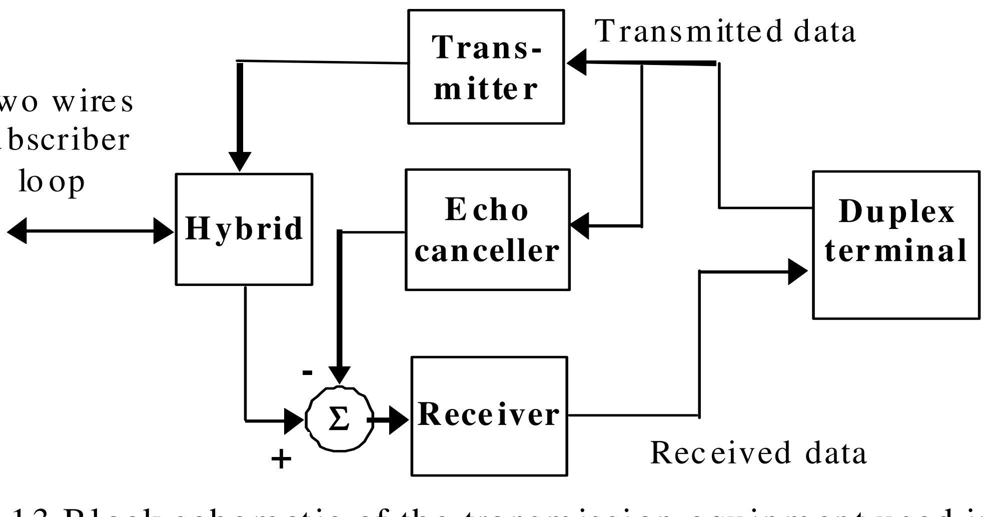



Fig. 13 Block schematic of the transmission equipment used in conjunction with the balancing method of transmission path separation

| Stări codor Grup biți | $S_1$ | $S_2$ | $S_3$ | $S_4$ |
|---|---|---|---|---|
| 0001 | 0 - + (1) | 0 - + (2) | 0 - + (3) | 0 - + (4) |
| 0111 | - 0 + (1) | - 0 + (2) | - 0 + (3) | - 0 + (4) |
| 0100 | - + 0 (1) | - + 0 (2) | - + 0 (3) | - + 0 (4) |
| 0010 | + - 0 (1) | + - 0 (2) | + - 0 (3) | + - 0 (4) |
| 1011 | + 0 – (1) | + 0 – (2) | + 0 – (3) | + 0 – (4) |
| 1110 | 0 + - (1) | 0 + - (2) | 0 + - (3) | 0 + - (4) |
| 1001 | + - + (2) | + - + (3) | + - + (4) | - - - (1) |
| 0011 | 0 0 + (2) | 0 0 + (3) | 0 0 + (4) | - - 0 (2) |
| 1101 | 0 + 0 (2) | 0 + 0 (3) | 0 + 0 (4) | - 0 0 (2) |
| 1000 | + 0 0 (2) | + 0 0 (3) | + 0 0 (4) | 0 - - (2) |
| 0110 | - + + (2) | - + + (3) | - - + (2) | - - + (3) |
| 1010 | + + - (2) | + + - (3) | + - - (2) | + - - (3) |
| 1111 | + + 0 (3) | 0 0 – (1) | 0 0 – (2) | 0 0 – (3) |
| 0000 | + 0 + (3) | 0 - 0 (1) | 0 - 0 (2) | 0 - 0 (3) |
| 0101 | 0 + + (3) | - 0 0 (1) | - 0 0 (2) | - 0 0 (3) |
| 1100 | + + +(4) | - + - (1) | - + - (2) | - + - (3) |

Tabel 3 Regula de codare 4B3T