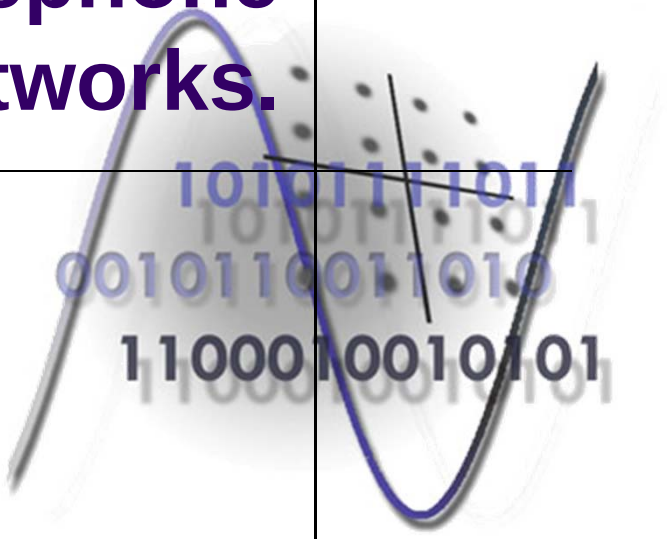
Course 2
Access and signaling techniques used in classical telephone networks.



Zsolt Polgar

Communications Department
Faculty of Electronics and Telecommunications,
Technical University of Cluj-Napoca

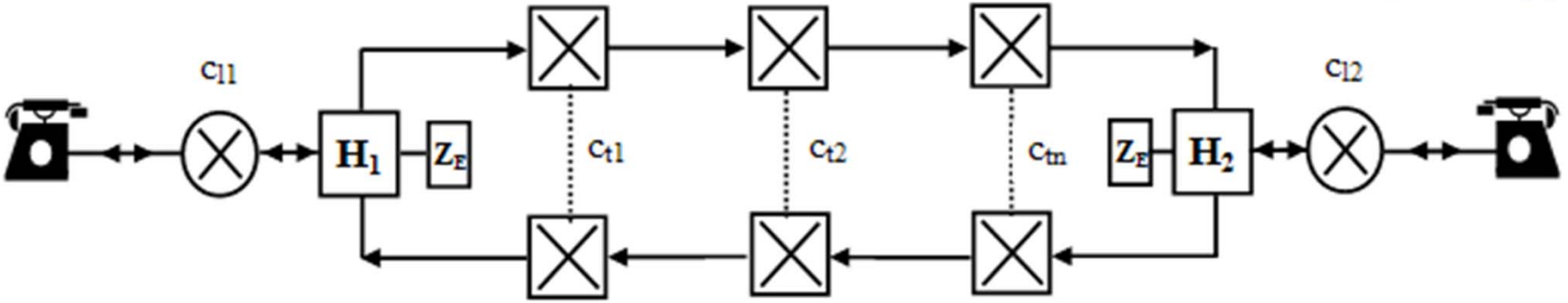
Content of the course

- The analogue access. Basic characteristics;
- Classification of the signaling techniques;
- Access signaling;
  - “loop start” and “ground start” signaling;
  - FX (FXS/FXO) signaling;
- Trunk signaling;
  - Basic signaling diagram;
  - E&M signaling;
  - MFC-R2 signaling;

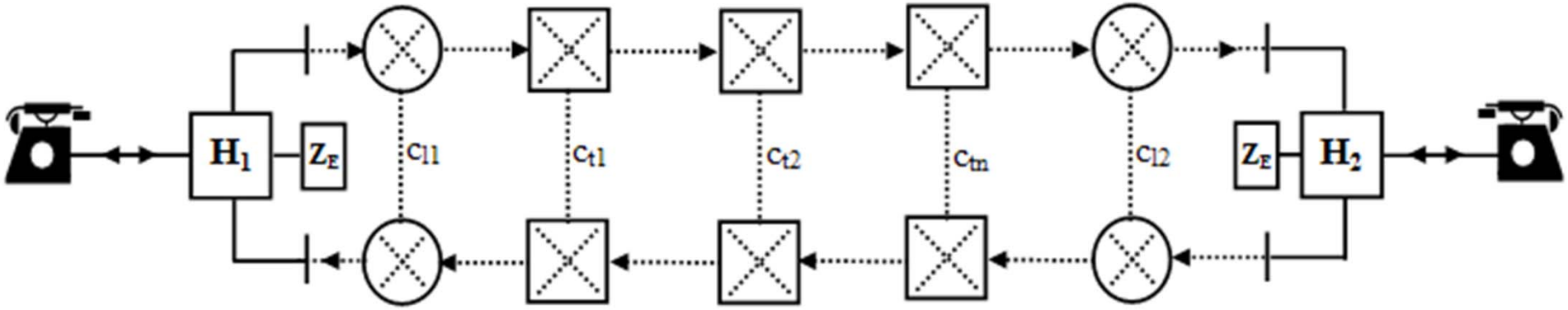
The analogue access

- The simplest access method in the telephone network;
  - it is characteristic to classical telephone networks POTS (Plain Old Telephone Service);
  - is used due to its simplicity in IDN network;
- Main characteristics of the analogue access:
  - frequency band: 300Hz – 3400Hz;
    - extended to 4kHz in digital networks;
  - two wire access and remote power supply from the exchange at -48V DC;
    - the telephone device works on four wire but the transmission to the exchange takes place on two wires;
      - the notion of four wires refers to two channels with opposite directions implemented on different physical channels (wires for example);
    - the local analogue switching takes place on two wires while the digital switching and long distance transmission (both analogue and digital) takes place on four wires.

The analogue access



- Analogue switching;



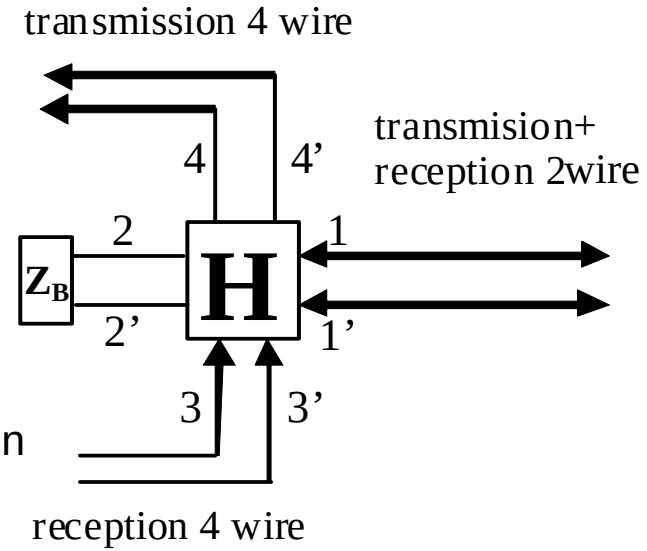
- Digital switching;
- There are necessary two 2 wire – 4 wire transition points ensured by a differential system called hybrid transformer (H);

The analogue access

- The roles of the hybrid transformers:
  - transfers the signals generated by the terminal on the unidirectional transmission path of the 4 wire circuit;
  - transfers the signals from the transmission paths of the 4 wire circuit on the 2 wire subscriber loops;
  - attenuate the signals passing from the reception path on the transmission path of the 4 wire circuit;
    - the differential system (or hybrid transformer) represents a bridge whose balance is ensured by the relation: $Z_l = Z_b$ (or Z_E) (1), where Z_l is the line (subscriber loop) impedance, and Z_b (Z_E) is the balance impedance;
    - condition (1) cannot be fulfilled in the whole frequency band and for all subscriber loop lengths;
      - it is not ensured a perfect balance and impedance mismatch appears;
      - a fraction of the signal received from the reception path of the 4 wire loop is sent back on the transmission path of the 4 wire loop as an echo signal.

The analogue access

- Characteristics of the hybrid transformer;
  - It is called also differential system;
  - It is characteristic also to systems/equipments where is necessary a separation of the transmission and the reception paths:
    - for ex. a radio equipment using the same antenna for transmissions and reception requires a differential system to separate the output of the transmitter amplifier from the input of the receiver amplifier;
  - Represents a 4 port circuit having the following ports:
    - bidirectional port (1 – 1'):
      - ensures the connection of the 2 wire line;
    - balancing port (2 – 2'):
      - connects the balance impedance;
    - unidirectional reception port (3 – 3');
    - unidirectional transmission port (4 – 4')
      - two unidirectional ports ensuring the connection of the 4 wire line (loop).

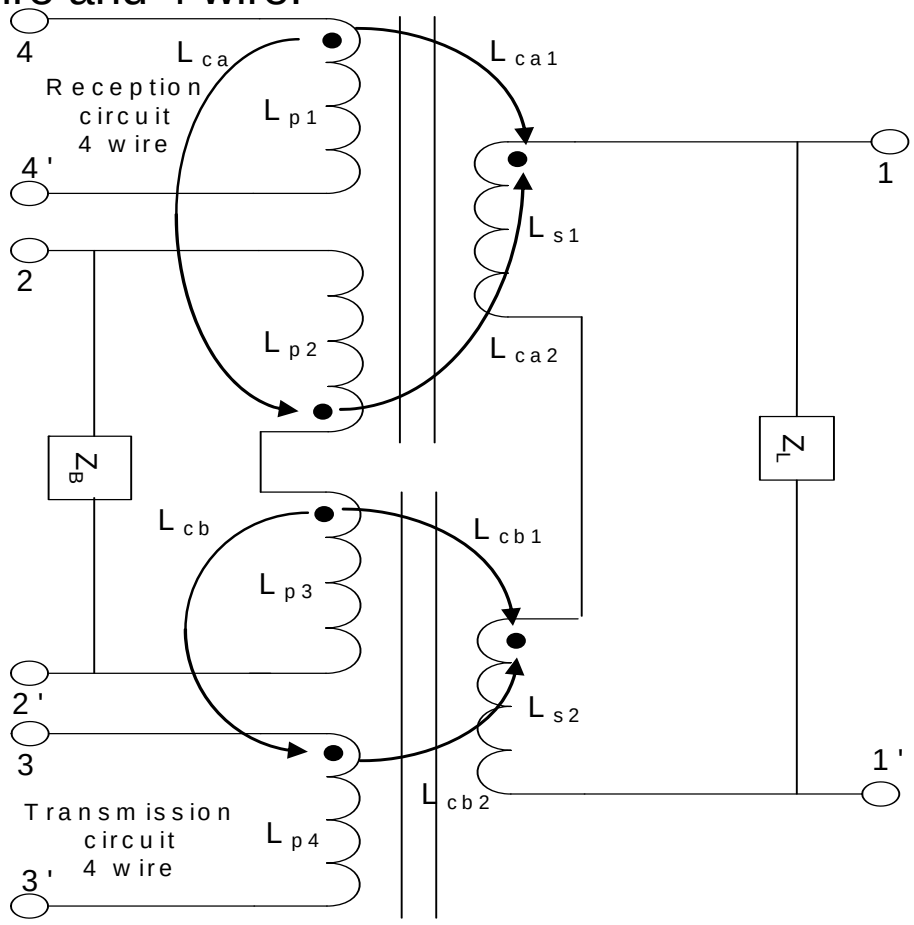


The analogue access

- Parameters of the hybrid transformer:
  - Attenuation between ports (3 – 3') - (4 – 4'):
    - attenuation between the reception and transmission path of the 4 wire circuit;
      - this attenuation has to be as large as possible;
      - ideally it is an infinite attenuation and in real circuits has a value of 15 - 20dB – it is about the return loss of the hybrid transformer;
      - by reciprocity the same attenuation has to be ensured between ports (1 – 1') - (2 – 2'), but this attenuation is not very important.
  - Attenuation between ports (1 – 1') - (4 – 4') and (3 – 3') - (1 – 1'):
    - attenuation between the reception path of the 4 wire circuit and the 2 wire circuit and the attenuation between the 2 wire circuit and the transmission path of the 4 wire circuit;
      - these attenuations have to be as small as possible;
      - usually they are 3dB in the case of transformers with symmetrical structure, due to equal splitting of received/transmitted power by a port to the adjacent ports;
      - by reciprocity the attenuation between ports (2 – 2') - (4 – 4') is equal with attenuation between ports (1 – 1') - (4 – 4') and the attenuation between ports (3 – 3') - (2 – 2') is equal with attenuation between ports (3 – 3') - (1 – 1').

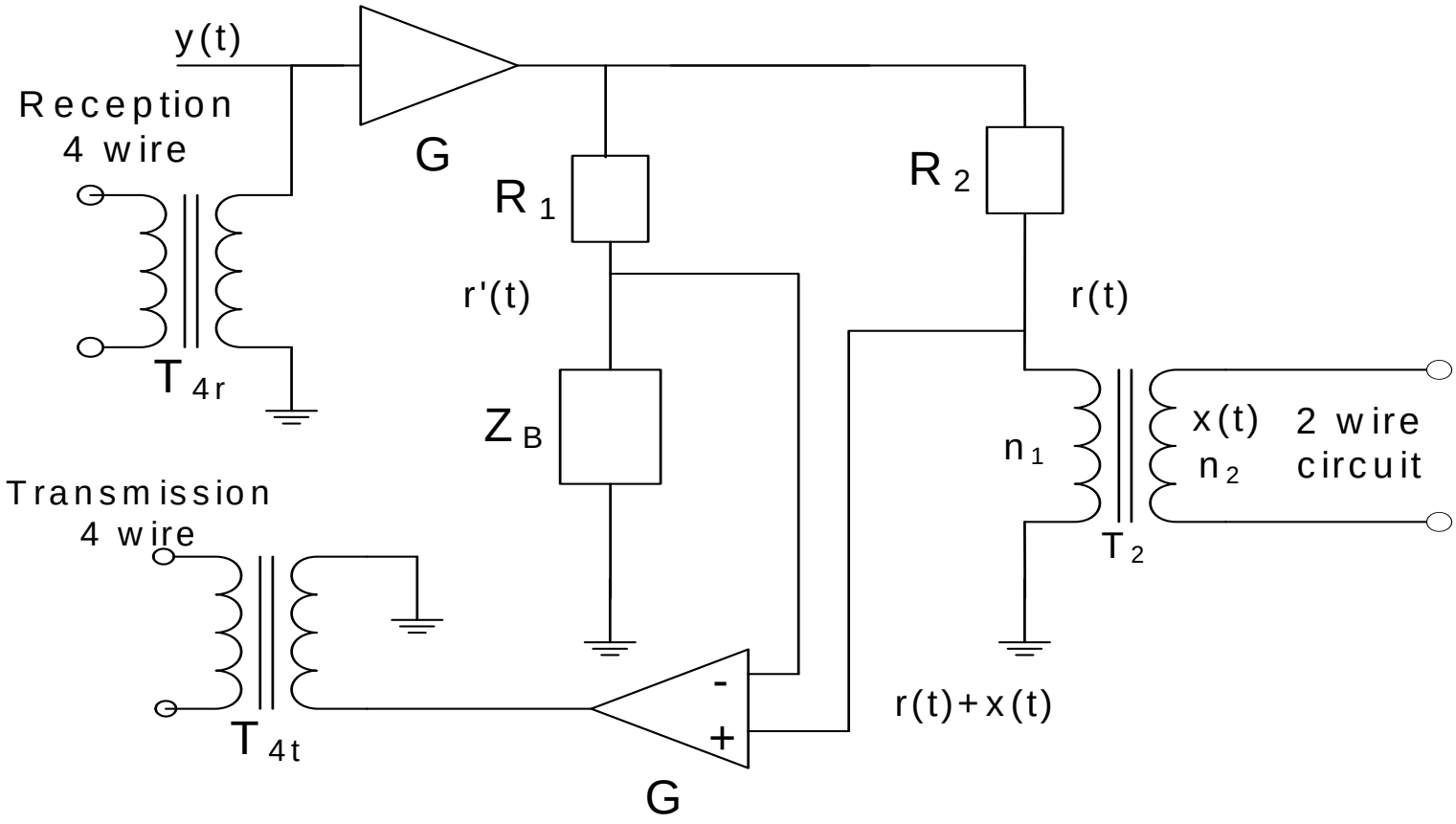
The analogue access

- Input / output impedances at ports (1 - 1'), (3 – 3'), (4 – 4'):
  - important from the point of view the impedance matching between the hybrid transformer and the circuits on 2 wire and 4 wire.
- Hybrid transformers from the subscriber interfaces:
  - Passive transformer with galvanic separation of circuits;
  - It is composed of two transformer with center taps.
  - It is symmetrical:
    - the symmetry depends on the symmetry of the component transformers.

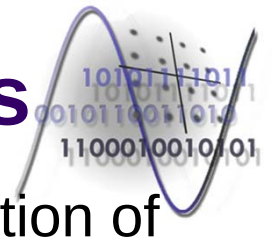


The analogue access

- The electronic hybrid transformer;
  - The schematic of the electronic hybrid:



The analogue access



- Transformers T_{4r}, T_{4t} and T_2 ensure the galvanic separation of the hybrid from the 4 wire and 2 wire circuits;
  - ensure a symmetrical/differential character relatively to the connected circuits;
- The effective balancing bridge is composed of resistances R_1, R_2, impedance Z_b and impedance $Z_{r\text{-}l}$;
  - $Z_{r\text{-}l}$ is the impedance of the subscriber loop reflected in the primary winding of the transformer T_2, and is given by: $$Z_{r-l} = \left(\frac{n_1}{n_2}\right)^2 \cdot Z_l$$
    - Z_l is the impedance of the 2 wire subscriber loop;
  - balance condition of the bridge: $$\frac{R_1}{R_1 + Z_b} = \frac{R_2}{R_2 + Z_{r-l}}$$

Signaling. General aspects

- The signaling in telephony refers to:
  - Call control signals;
  - Transmission techniques for control signals;
  - Call management algorithms;
- Purpose of the signaling:
  - Control of the set up, deployment and interruption of a telephone connection;
- There are several possible classifications:
  - According to the type of the controlled channel:
    - subscriber signaling;
      - used between the subscriber terminal and the local exchange.
    - trunk signaling;
      - used on the trunk lines between the exchanges of the public networks, between PBX and local exchanges and between PBX exchanges.

Signaling. General aspects

- According to the way the signaling is transmitted:
  - in-band signaling;
    - the signaling is transmitted in the same frequency band as the speech signal.
  - out-band signaling;
    - the signaling is transmitted outside the frequency band of the speech signal.
  - channel associated signaling;
    - each voice (data) channel has assigned a separate signaling channel.
  - common channel signaling;
    - the signaling assigned to all voice (data) channels or to a group of channels is realized on a common channel used specially for this operation.
- According to role performed:
  - network management signaling:
    - characteristic only to trunk signaling;
      - for example management of congestions in switches.

Signaling. General aspects

- alerting signaling;
  - refers usually to sending to the called terminal (telephone or trunk equipment) of a ringing signal;
  - this signal is applied to a line or a trunk.
- address signaling;
  - refers to the transmission of the information related to the called number on subscriber lines or on trunks;
  - performed by the terminal or by a switching equipment;
  - can be accomplished by sending impulses or DTMF tones or special data packets in digital networks (ISDN);
  - this information have to be sent in a public network across several links up to the final completion of the connection;
  - the address signaling on trunks is realized usually (in classical telephone networks) by using a MF (Multi-Frequency) type technique:
    - different to the DTMF technique used on the subscriber line (code 2 of 6);
    - this signaling has the format: KP + number +ST;
    - KP (Key Pulse) represents the beginning of the telephone number transmission;
    - ST (Start) represents the end of this transmission and the beginning of the call processing – see the following table.

Signaling. General aspects

- MF coding of the characters (digits) used in trunk address signaling:
  - the frequencies are expressed in Hz;

Digit/symbol	Frequency 1	Frequency 2
KP	1100	1700
KP2	1300	1700
1	700	900
2	700	1100
3	900	1100
4	700	1300
5	900	1300
6	1100	1300
7	700	1500
8	900	1500
9	1100	1500
0	1300	1500
ST	1500	1700

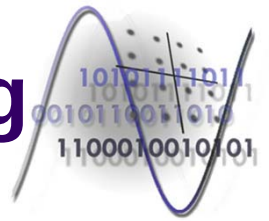
Signaling. General aspects

- call supervision (supervisory) signaling;
  - detects the state or changes the condition of a line or trunk;
    - there are two possible supervised conditions: ON-HOOK (idle state) and OFF-HOOK (active state);
    - when a line/trunk goes OFF-HOOK, it is interpreted as a seizure by the system and the operating state of the considered line goes from idle to active;
    - brief changes in the on-hook/off-hook status of a line or a trunk (transition called *wink* or *hook flash*) are also part of the supervision signaling.
  - out-band signaling is used usually;
    - an important part of supervisory signaling is represented by the (subscriber) access signaling and station loop signaling of the exchange.
      - the access signaling refers to detection of the off-hook state of the calling (subscriber) terminal or equipment (ex. PBX);
      - the station loop signaling refers to the answer of the local exchange (or PBX), signaling related the acceptance or non-acceptance of the access in the network;
        - access accepted/granted: the dial tone is transmitted;
        - unaccepted/rejected access: the busy ton is transmitted.

Signaling. General aspects

- another important component of the supervisory signaling is the answer and disconnect supervision;
  - it is important for billing.
- call progress indicator signals are tightly related to supervisory signaling;
  - these signals refer to audible tones that indicate to the calling side the progress of the telephone call;
  - these tones are characterized by frequency (or groups of frequencies) and timing (cadence);
  - these tones are the following:
    - dial tone – the CO/PBX is ready to accept the digits of the number from the subscriber;
    - busy tone – the called terminal is busy;
    - reorder tone – the same as the busy tone, but the call is rejected due to congestion of local/transit exchanges or to unavailability of trunk circuits;
    - special information tones – faulty line or non existent number, a.s.o.;
    - ring-back tone – indicates to the calling terminal the establishment of the connection and the alerting of the called terminal.

Access signaling



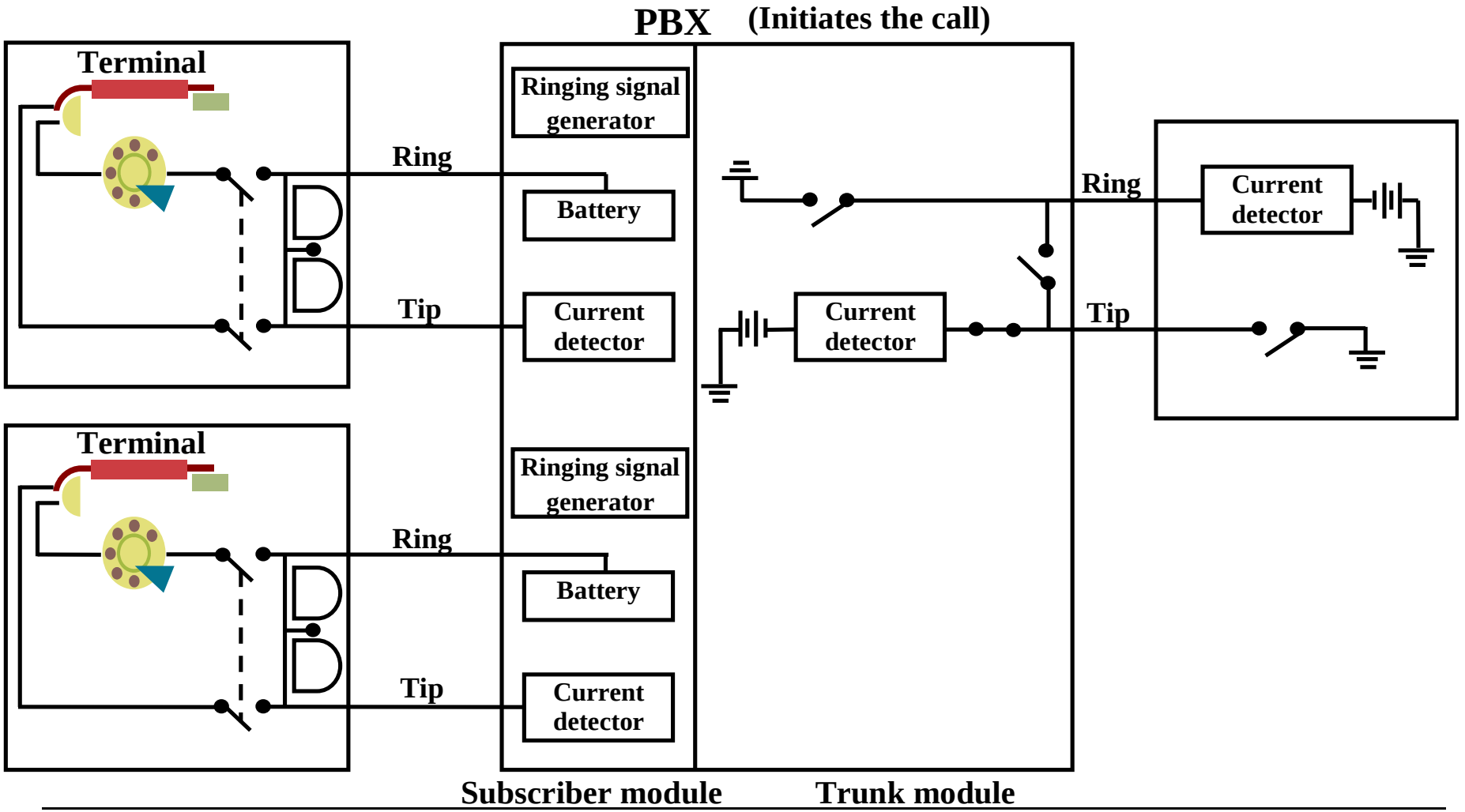
- The access signaling;
  - Determines (announces) when a line is off-hook or on-hook;
    - there are two basic variants of this signaling, namely:
      - „loop start” type signaling;
      - „ground start” type signaling.
    - „loop start” signaling is characteristic to PSTN networks (“Public Switched Telephone Network”);
      - when the phone is active a current loop is closed, loop composed of the phone, wires and the battery located in the exchange;
      - the current is detected by a current sensing circuit and the exchange responds with the dial tone;
      - the incoming call to the phone is signaled by a ringing signal repeated according to a given on/off pattern;
      - problems related to this type of signaling:
        - automatic answer machines could be blocked in off-hook state;
        - the exchange is not capable to interrupt the connection;
        - the line/trunk can be seized in the same time from both directions;
          - the dialing starts in the moment when a call is received;

Access signaling

- the „ground start” type signaling is used especially on the analogue trunk connections (PBX - CO);
  - when an equipment tries to access the network (to initiate a call) it connects the RING lead to the ground;
  - the exchange (accessed) detects the current through this lead and if it can accept the call connects the TIP lead to the ground;
  - the call initiating equipment senses the current through the TIP lead and starts the call;
  - the interruption of the connection can be realized by both parts involved in communication;
  - a dial tone can be provided to the calling part, but it is optional.

Access signaling

- „loop start” and „ground start” type access signaling;

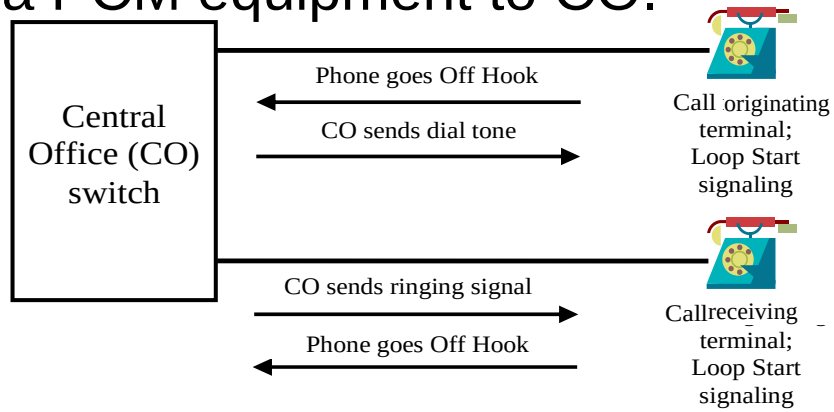


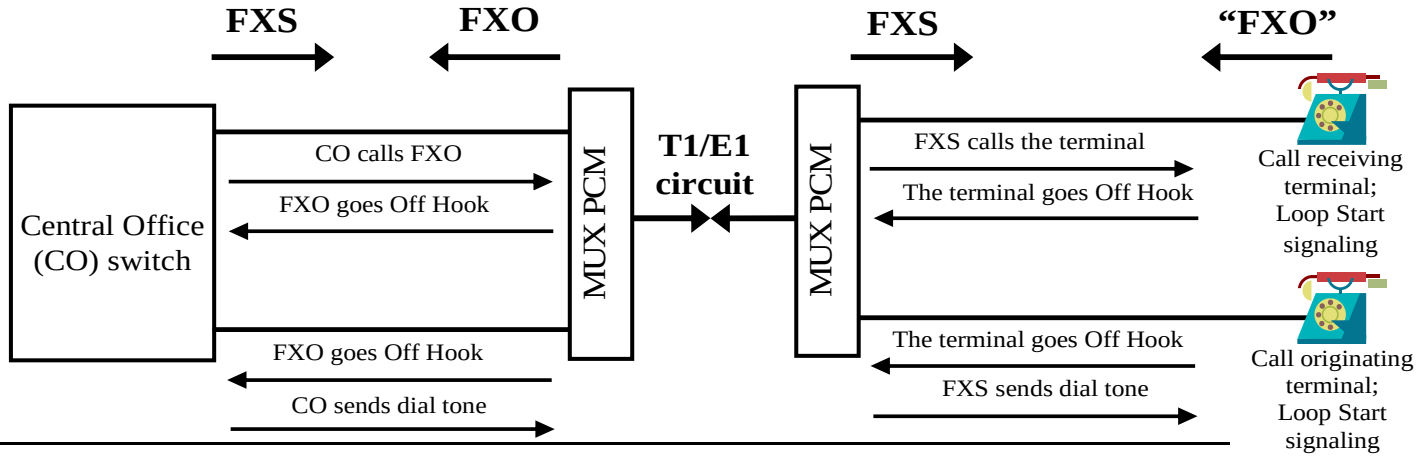
Access signaling

- **F**oreign e**X**change (FX) signaling;
  - called also FXS/FXO signaling – Foreign eXchange Station (FXS) / Foreign eXchange Office (FXO);
  - it was developed for connecting PBX exchanges to local exchanges (Central Office);
  - an FXS type interface is also used for connecting a multiplexer to the CO;
  - the interface between the phone device and the CO is similar with the FX interface;
  - the FXS interface located in the CO ensures:
    - the supply voltage;
    - ringing signal generation;
    - off-hook detection;
    - call progress indicator signals.
  - the FXO interface located in PBX (or phone) ensures:
    - detection of dial tone;
    - ringing signal detection;
    - call progress signal detection.

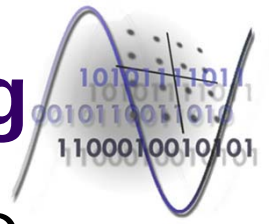
Access signaling

- The principle of FXS/FXO signaling;
  - Connecting a phone to CO;
  - Connecting a PCM equipment to CO.





Access signaling



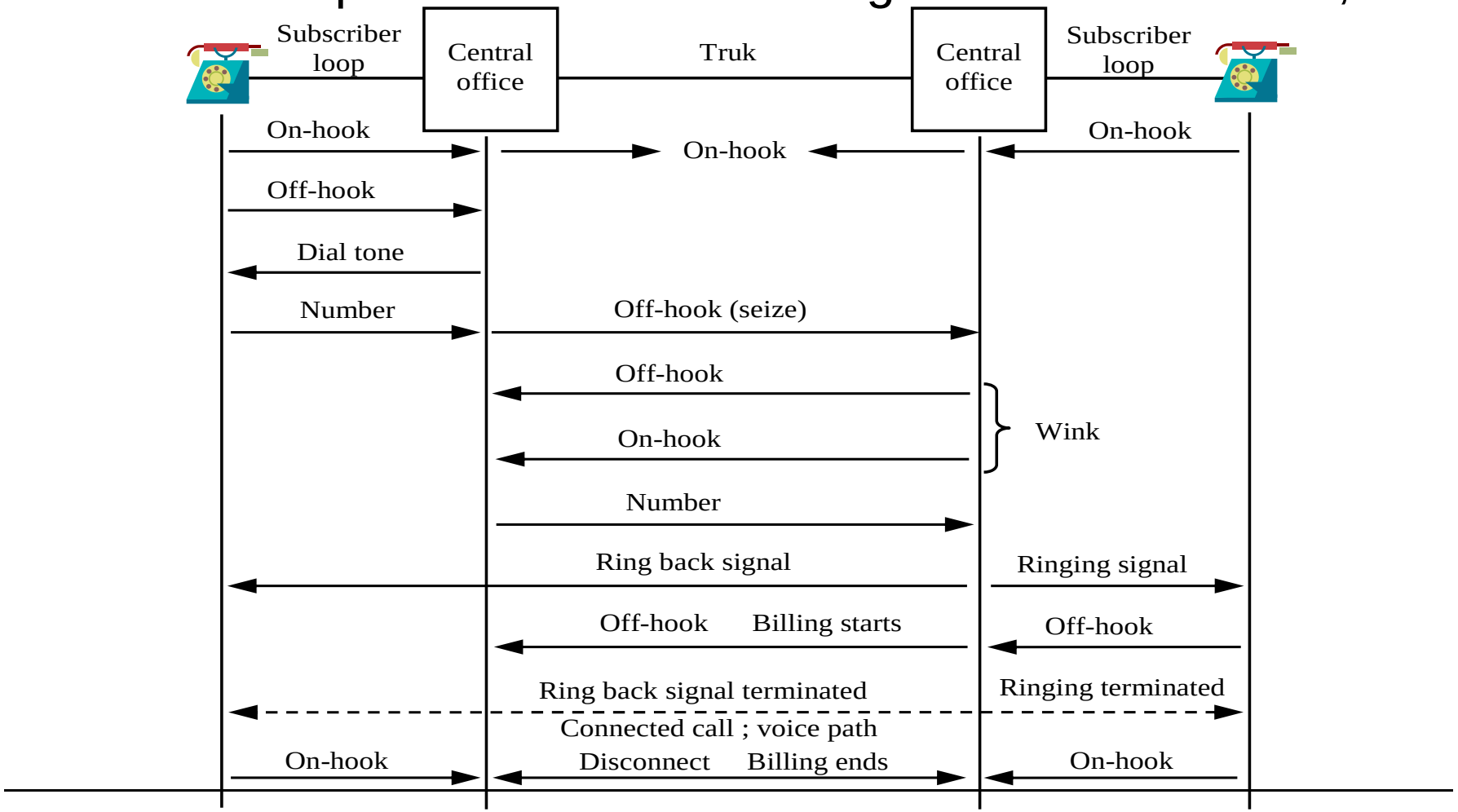
- Allocation of AB bits to signals associated to FXS/FXO signaling:

Signal / direction	Forward (to FXO)	Backward (to FXS)
IDLE / ON HOOK	AB = 0 1	AB = 0 1
OFF HOOK		AB = 1 1
RINGING	AB = 0 0	
RING GROUND		AB = 0 0 (only GS)
TIP CLOSED	AB = 0 1 (only GS)	
FORWARD DISCONNECT	AB = 1 1 (only GS)	

- GS: Ground Start;

Trunk signaling

- Signaling sequence associated to a telephone call in a classical telephone network involving a trunk connection;

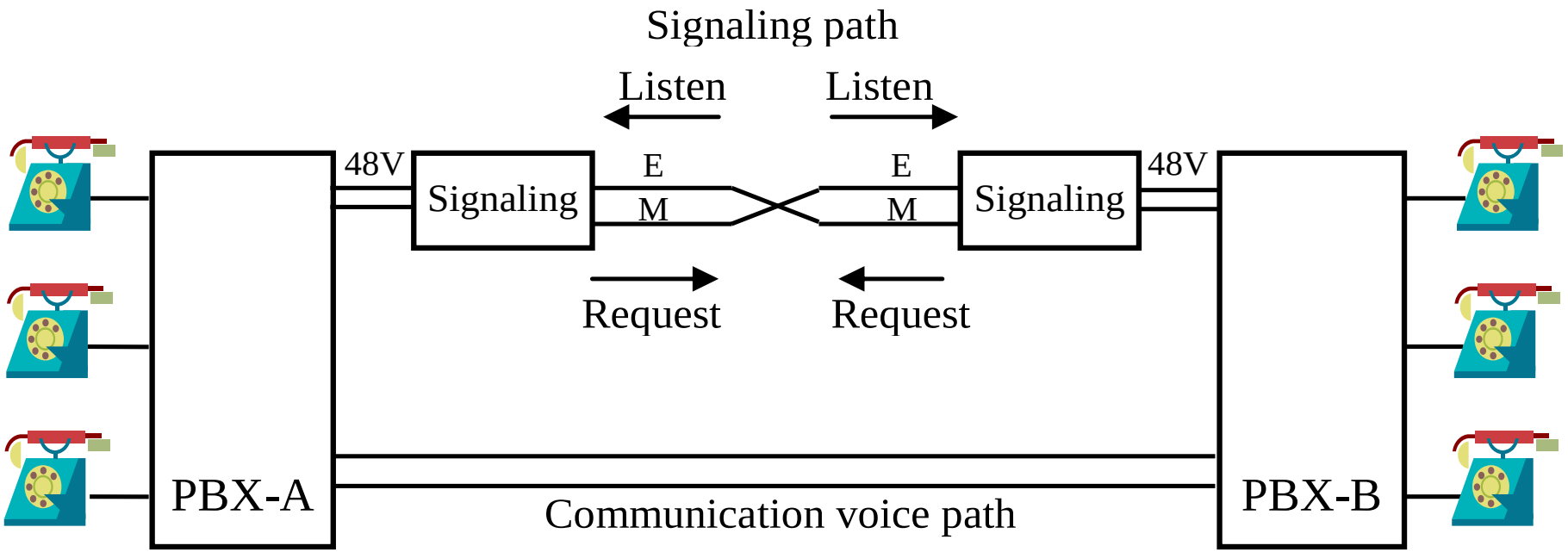


Trunk signaling

- E&M (“**E**ar and **M**outh” sau “rec**E**ive and trans**M**it”) signaling;
  - signaling technique developed for trunk signaling between PBX and PSTN exchanges;
  - there were developed different signaling variants (types I - V);
  - this signaling technique is based on two signals, called M and E;
    - the M signal is generated by the trunk call initiating exchange;
    - the E signal is a response sent by the exchange located at the opposite end of the trunk;
    - the E&M signaling channel is separated from the voice channel of the trunk;
    - using these two signals are coded the states of the equipments located at the two ends of the trunk connection:
      - equipments which can be in the IDLE / ON HOOK state or in the BUSY (SEIZED) / OFF HOOK state;
      - using some impulses (activation – deactivation : „wink”) other information can be transmitted on these lines as well.

Trunk signaling

- E&M signaling basic schematics;
  - Sending of the called number on the trunk connection is realized using a MF type (coding) transmission on the voice path;
    - it is ensured a larger speed of the address signaling;

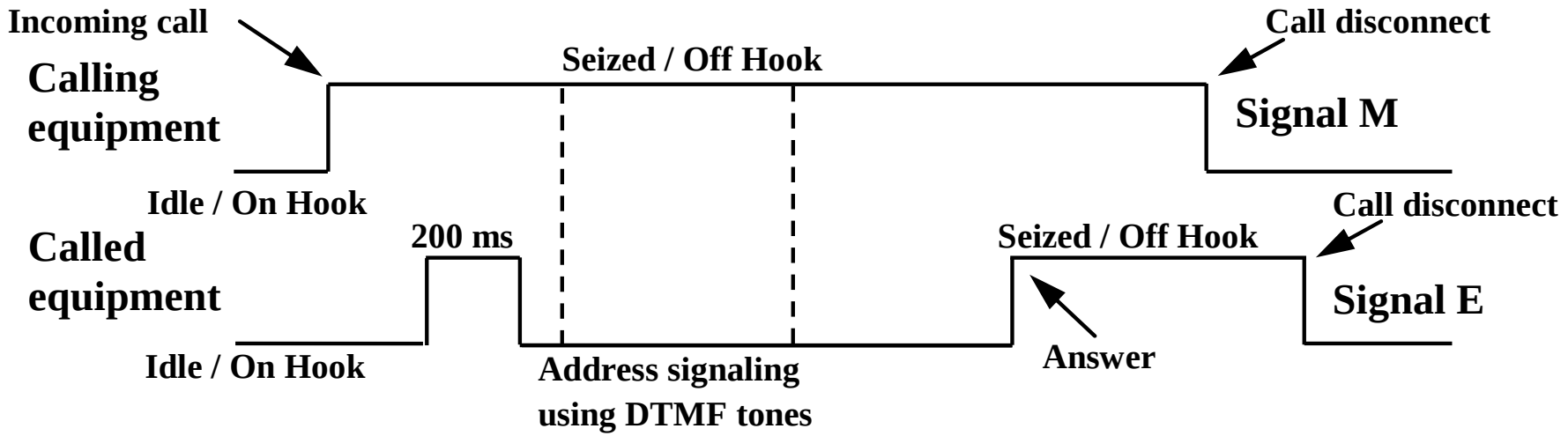


Trunk signaling

- Types of E&M signaling:
  - **E&M immediate:**
    - the trunk call initiating equipment goes OFF HOOK and transmits immediately the called number;
    - after the reception of the number the trunk equipment on the opposite end goes OFF-HOOK during the entire duration of the call;
    - both equipments can terminate the call by going in the ON-HOOK state;
    - there is the possibility that the called trunk equipment is not ready to receive the number;
  - **E&M wink:**
    - the terminal equipment responds to an OFF-HOOK state of the calling equipment with a short OFF-HOOK impulse („wink”) in the moment when is ready to receive the called number;
    - the opening of the voice path and the starting of the billing process is achieved after the E signal goes OFF-HOOK.

Trunk signaling

- Signaling sequence corresponding to E&M wink:



- **E&M wink-wink:**
  - the terminal equipment responds to an OFF-HOOK state of the calling equipment with a short impulse on signal E;
  - the call originating equipment sends the number in MF code on the voice path;
  - the receiving equipment sends another short impulse on signal E, signaling that it received all the digits.

Trunk signaling

- Allocation of AB(CD) bits to physical signals characteristic to E&M signaling:

Direction	State	A	B	C	D
Transmission	Idle/On-Hook	0	0	0	0
Transmission	Seized/Off-Hook	1	1	1	1
Reception	Idle/On-Hook	0	0	0	0
Reception	Seized/Off-Hook	1	1	1	1

  - MFC-R2 signaling – „Multifrequency Compelled R2 Signaling System”, called also R2 signaling;
    - the R2 term refers to the region 2, considered to be Europe (USA was considered region 1);
    - it is called also inter-register signaling;
      - register – signaling equipment used to control the switching process – is the part dedicated to address signaling, switching control and (partially) control of the connection – for ex. billing control);

Trunk signaling

- it is dedicated especially to E1 type connections;
  - it is characterized by the fact that each command has an appropriate acknowledgement signal;
  - it is somewhat similar (as principle) with E&M signaling ;
    - call supervisory signaling is realized based on digital signals transmitted with A B C D bits;
    - the address signaling is accomplished also by MF technique;
    - some of the control signals are also transmitted by MF technique;
- two distinct parts can be identified in the case of this signaling technique:
  - line signaling, used to seize or to release the trunk at both ends
    - it is accomplished based on A B C D digital signals;
  - inter-register signaling;
    - accomplished by the use of MF signals.
  - the allocation of the A B C D bits:
    - the A B bits are used for basic operations; codes the line (trunk) states;
    - the C D bits can be used for signaling associated to supplementary services such as call forwarding.