Mobile Radio Networks

- GSM Radio Interface

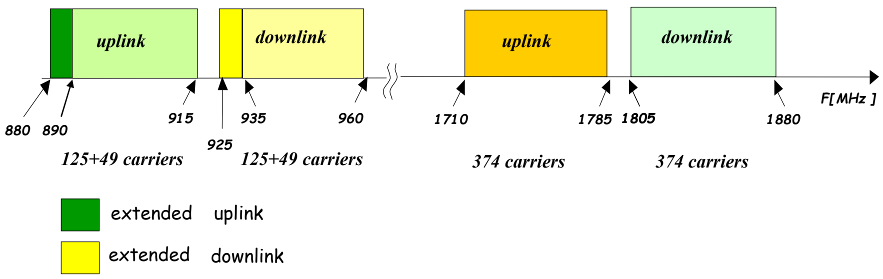
General features

- 2nd Generation (2G) digital system
- TDMA multicarrier multiple access
- fixed frequency reuse

Allocated Frequencies

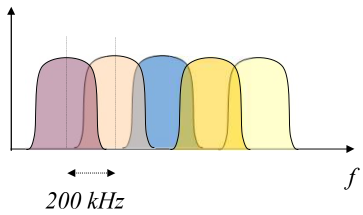
GSM /900 **DCS/1800**

- In the UK and USA bands around 1900 MHz are used instead of around 1800 MHz (1850 ÷ 1910 uplink, 1930 ÷ 1990 downlink).



Radio carriers

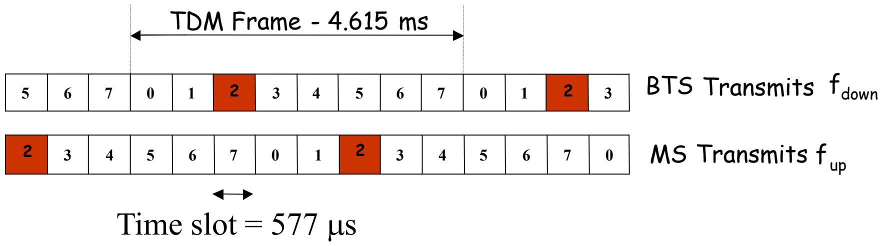
- The radio carriers are spaced 200 kHz apart



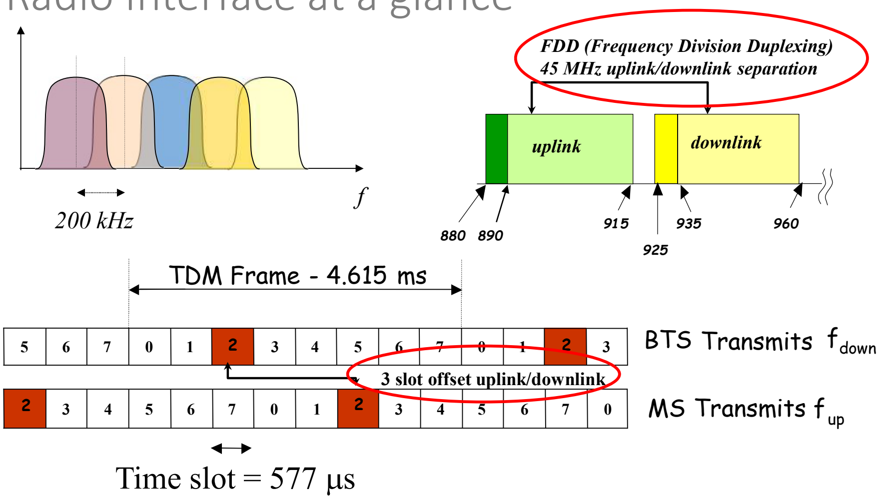
- The carriers are identified by an *ARFCN (Absolute Radio Frequency Channel Number)*
- Each pair of frequencies for uplink and downlink bi-directional channels are spaced 45 MHz in GSM 900 and 95 MHz in DCS 1800

TDMA Frame

- On each radio carrier, the TDMA structure allows the creation of up to 8 channels for the transmission of coded voice at 13 Kb/s



Radio Interface at a glance

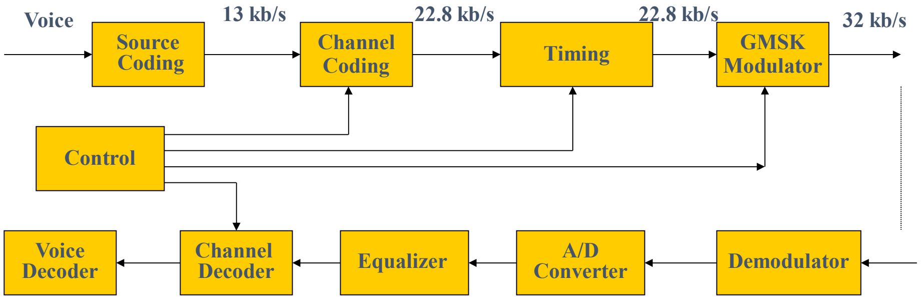


Radio Interface

- Modulation:
  - MGSK (Minimum Gaussian Shift Keying)
    - Phase continuous modulation with Gaussian pulse (intersymbol interference)
- Channel coding:
  - Convolutional
    - with differentiated rates for different service types
- Equalization:
  - Known bit sequences transmitted in each physical burst
  - In reception, the known sequence is used to estimate the channel and synthesize the equalization filter
- Voice coding:
  - 13 kbit/s (RPE codec - *full rate*)
  - 12.2 kbit/s (CELP codec - *enhanced full rate*)

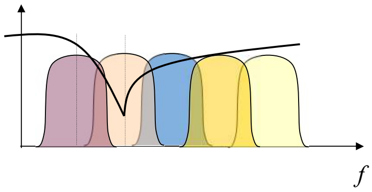
Trasmission and Reception

- From 13 Kbit/s of the codec we get to 32 Kbit/s on the radio channel



Frequency Hopping

- The effect of multipath fading also depends on the frequency of the signal
- There can be carriers with low attenuation and carriers with high attenuation



- Since the transmission is protected by FEC codes, it is better that the errors due to some strongly attenuated carriers are distributed over several information flows
- It adopts a frequency hopping mechanism that changes the frequency each slot in a fixed sequence

Power Control

- The emission power of the MS is controlled by the BTS
- The BTS sends power control commands which require the MS to raise or lower the transmission power
- The increase/decrease step is 2 dB
- The objective of the control is to bring the power received from the BTS to a pre-set level
- Power control reduces the average interference in the system by reducing the power of MSs with small channel attenuation (close to BTS)
- The power control also reduces MS power consumption

Synchronization in GSM

- Carrier synchronization
  - each MS must accurately retrieve the radio carrier frequency
- Slot synchronization
  - Each MS must have information about the current slot
- Frame synchronization
  - Each MS must know the current Frame Number
- Base Station synchronization (opzional)
  - Base stations have synchronous clocks
  - The base stations have the same frame number

Carrier synchronization

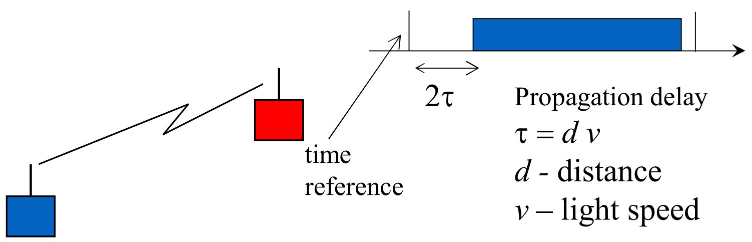
- The radio carrier frequency is retrieved from the MS by listening to the common broadcast channel transmitted by the BTS
- On this channel, at regular intervals, a special slot with fixed bits is transmitted which are used to accurately retrieve information on the carrier frequency and thus adjust the frequency of the local oscillator

Slot and Frame synchronization

- Many channels in GSM follow a multi-frame structure (for example: the broadcast channel is transmitted every x frames)
- The frequency hopping sequence depends on the multi-frame
- Each MS must therefore know the current frame number to correctly interpret the information
- The BTS base station transmits information on the broadcast channel which allows the MS to reconstruct the slot time scan and the Frame Number

Slot synchronization

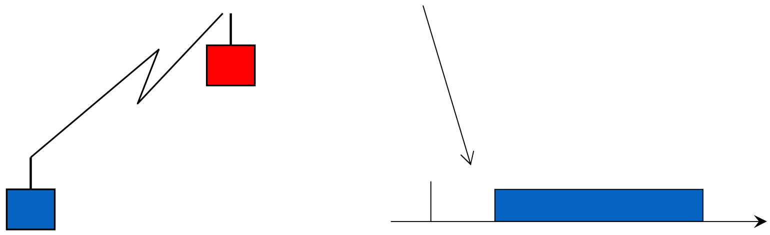
- Up/down link transmissions suffer propagation delays depending on the position of the MSs
- Need to have a part of non-significant bits in each slot to ensure a certain margin on error



Slot synchronization

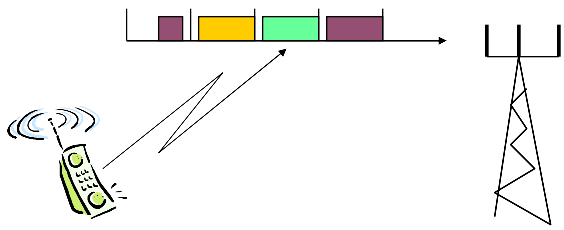
- Generally, a conservative choice is made for where the guard time is:

$$T_g = \max_i(2\tau_i)$$



Slot synchronization

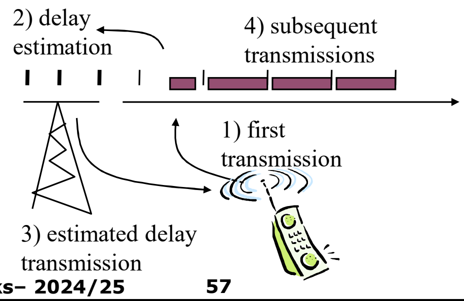
- The GSM network is designed to have cells with R_{max}=35 Km
- In the worst situation (at the edges) we have a guard time of 2τ = 2 x 35 / 3 x 10^8 = 233 μs
- Which corresponds to 68,25 bit at the 270.8 kb/s rate



Slot synchronization : Timing Advance

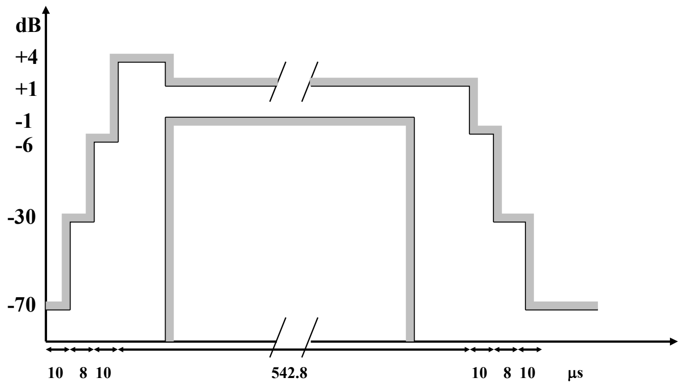
To reduce the guard time:

- the BTS estimates the delay and sends the information to the MS which can then compensate by anticipating the transmission
- used in GSM: the transmission is anticipated when moving away from the base (timing advance, reduces the guard time to about 9 bits, equal to 33.3μsec)



Physical block (Burst)

- The burst is the physical layer PDU transmitted in a time slot
- Due to TDMA scheme each burst is an autonomous transmission with its own power profile



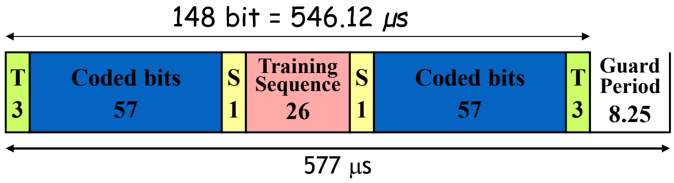
Burst classification

- Normal Burst
  - Used for data transmission in traffic channels
- Access Burst
  - Used for the first access on the Random Access Channel (RACH)
  - It has a long guard time since the timing advance mechanism is still not active

Burst classification

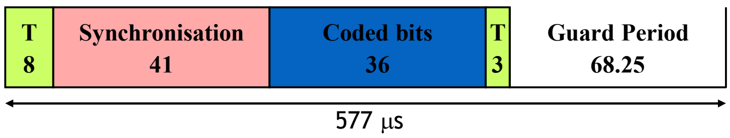
- Frequency Correction Burst
  - Used on the synchronization channel (Frequency Correction Channel - FCCH)
  - 142 bits set to “1”
- Synchronisation Burst
  - Used to transmit information for synchronization of slot and frame
- Dummy Burst
  - Does not contain information but only stuffing bit
  - Used in the slots of the system main frequency when there are no active traffic channels to keep the power level up

Normal Burst



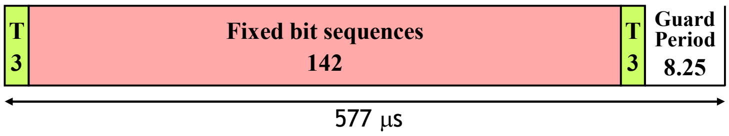
- T-bits: always set to 0, used as guard times and for demodulator initialization
- S-bits: (stealing bits) signal if the burst contains user or signaling data
- Coded Data: user bits (voice, data, etc.), 114 bits after channel encoding, which corresponds to 13 kbit/s net for voice, 9.6 kbit/s or less for data (plus redundant channel encoding)
- Training Sequence: Control bits used for equalization and for locking transmitters
- GP: guard period to allow the transmitters to be switched on and off

Access Burst



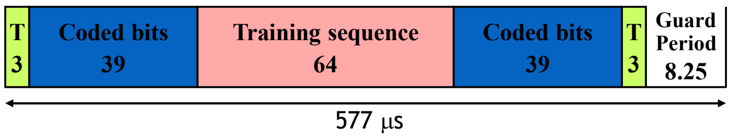
- It is used by the MS on the random access channel in the first transmission to the BTS before being registered
- It is therefore used asynchronously without timing advance control
- Contains 156.25 bits
  - 8 tailing bits
  - 41 synchronization sequences
  - 36 coded bits
  - 3 tailing bits
  - 68.25 bits as guard period

Frequency Correction Burst



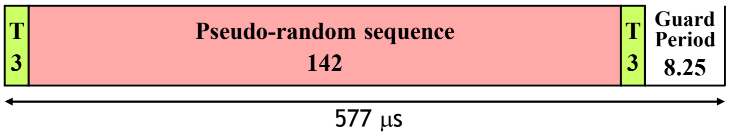
- Includes 148 + 8.25 bits
  - 2 x 3 tail control bits
  - 142 fixed-bit sequences
    - they are all 0
    - they represent a constant frequency reference in a fixed ratio with that of the carrier
  - 8.25 guard bits

Synchronisation Burst



- Includes 148 + 8.25 bits
  - 2 x 3 tail control bits
  - 2 x 39 coded bits
    - 25 bits of information
    - encoded become 78 bits
    - split into two 39-bit chunks
  - 64-bit training sequence
  - 8.25 bit guard period

Dummy Burst

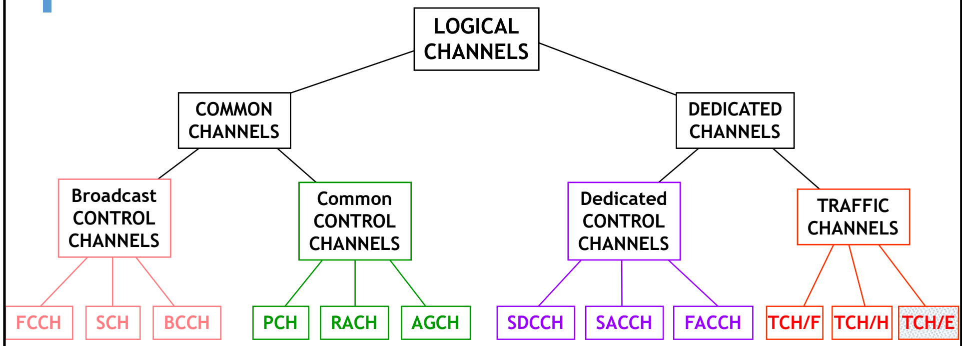


- It is used on the common control channel carrier when there is no other information or traffic channel to transmit to ensure that the measured average power level is sufficient to allow fast MS lockup
- Contains 148 + 8.25 bits
  - 2 x 3 tail control bits
  - 142 pseudo-random sequences
  - 8.25 bits of guard period

Logical channels

- “Logical channels” in GSM identify different types of information transmitted over the air interface:
  - Signaling
  - Traffic data
- They are divided into:
  - Traffic channels and Control channels
  - Common channels and Dedicated channels

Logical channels

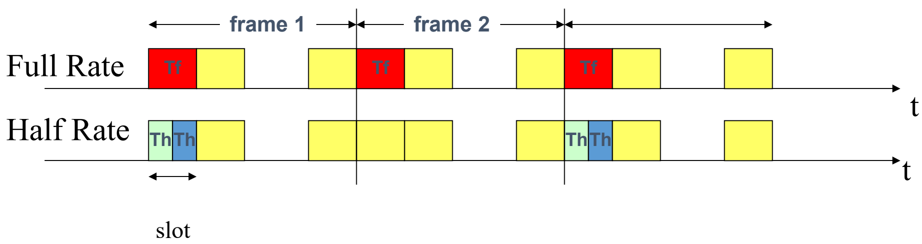


FCCH=Frequency Correction CHannel
SCH=Synchronisation Channel
BCCH=Broadcast Control CHannel
PCH=Paging CHannel
RACH=Random Access CHannel
AGCH=Access Grant CHannel

SDCCH=Stand-alone Dedicated Control CHannel
SACCH=Slow Associated Control CHannel
FACCH=Fast Associated Control CHannel
TCH/F=Traffic CHannel Full rate
TCH/H=Traffic CHannel Half rate
TCH/E=Traffic CHannel Enhanced Full rate

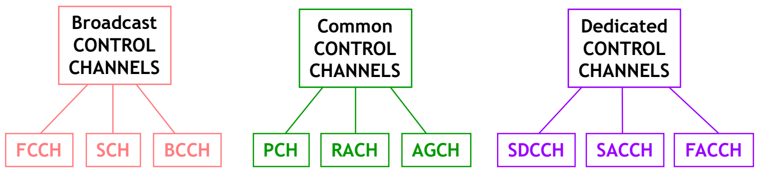
Traffic Channels (TCH)

- Channels transporting user data (voice or data)
- They can be:
  - Full Rate channels: 22,8 Kb/sec
  - Half Rate channels: 11,4 Kb/s



Control Channels (CCH)

- Used for transporting signaling of different types (14 types of control channels!!)
- Tre categorie of CCHs
  - Broadcast Channels (BCH): system information transmitted in the downlink
  - Common Control Channels (CCCH): shared channels for connection initialization (shared among more connections)
  - Dedicated Control Channels (DCCH): signaling channels dedicated to specific traffic connections



Broadcast CONTROL CHANNELS

Broadcast Channels (BCH)

- FCCH (Frequency Correction Channel): Channel for frequency synchronization (frequency correction bursts containing only the carrier synchronization sequence)
- SCH (Synchronization Channel): it includes BTS id (BSIC) frame number (FN)
- BCCH (Broadcast Control Channel): General system information.

Common
CONTROL
CHANNELS

Common Control Channels (CCCH)

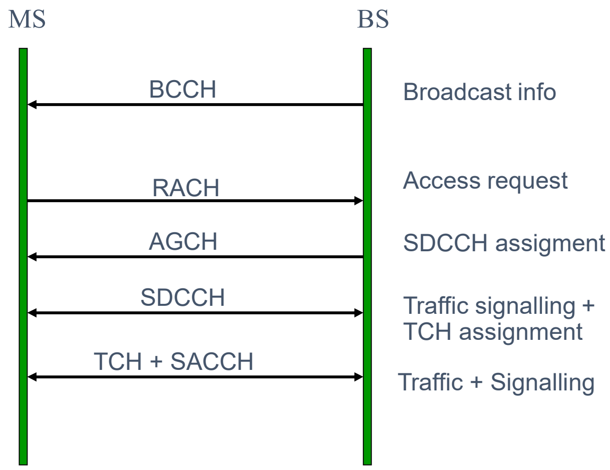
- PCH (Paging Channel): downlink used by the BTS to inform MSs of incoming calls, broadcasted over the LA
- RACH (Random Access Channel): uplink used by MSs for accessing the network (new calls, location update, etc.). It is contention based (slotted Aloha)
- AGCH (Access Grant Channel): downlink, used for replies to RACH requests

Dedicated
CONTROL
CHANNELS

Dedicated Control Channels (DCCH)

- SACCH (Slow Associated Control Channel):
  exchange of measurements during connection between MS and BTS (signal strengths, quality, ….). Multiplexed with the traffic channel (184 bits every 20 ms of measurements)
- FACCH (Fast Associated Control Channel):
  used for signaling during handover. It partially replaces traffic channel in the TDMA structure.
- SDCCH (Stand-alone Dedicated Channel):
  Signaling channel assigned in the first phase of call setup after the RACH/AGCH message exchange (identification, authentication, call set-up, …)

Example of channel use: Connection setup

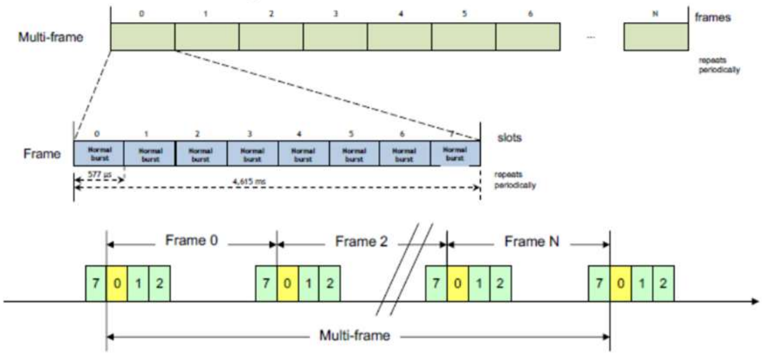


Multiple Access on RACH

- Multiple access to RACH channel is random (uncoordinated with other mobile stations)
- Thus, transmission collisions may occur
- Successful reception of the access message is acknowledged by the response of the BS on the AGCH channel
- A temporary identifier (pseudo-random sequence) is inserted in the message on the RACH which is then reported in the message on the AGCH channel
- The RACH management mechanism is in fact of the Slotted-ALOHA type

Mapping of logical channel into physical channels

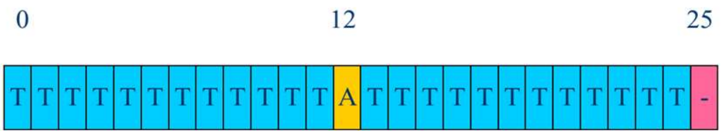
- Signaling requires a lower transmission bit rate than user information (It would be a waste of resources to assign 1 SLOT per frame to signaling)
- The effective transmission speed can be reduced with the multiframe mechanism
- IDEA: the slots assume an identity, and can be assigned over a period of multiple plots, precisely the multi-frame



Mapping of logical channel into physical channels: TCH+SACCH

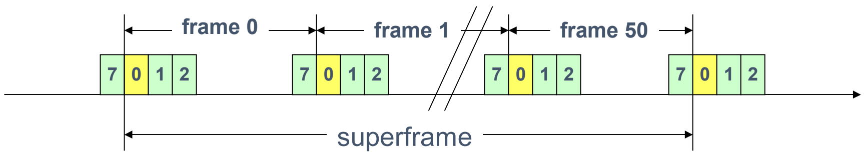
- Example: TCH + SACCH
  - A normal burst has 114 bits of data
  - Using one slot per frame we have 114 [bits]/4.6 [ms] = 24.7 Kb/s
  - The rate of coded voice is however 22,8 Kb/s
  - We have additional 1,9 Kb/s equivalent to 1 SLOT every 13 frames
  - SACCH: 1 SLOT every 26 frames for a speed of 950 bits/sec.

- Traffic CHannels (T) and Slow Associated Control Channel(SACCH) (A) are multiplexed together in a single slot of a frame using a multi-frame of 26 frames (120 ms)



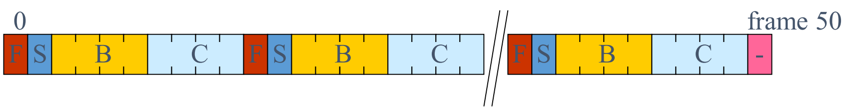
Mapping of logical channel into physical channels: Common control channels

- A particular slot (slot 0) on a particular carrier (frequency 0) is used to derive one or more super-frame mode channels from 51 frames (235.38 ms)

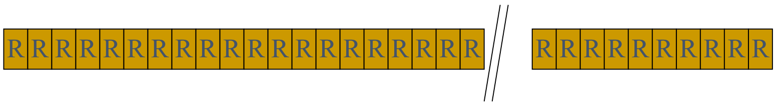


Mapping of logical channel into physical channels: Common control channels

- In downlink:
  - Frequency synchronization (FCH)
  - Bit synchronization (SCH)
  - Broadcast Control Channel (BCCH)
  - Common Control Channel

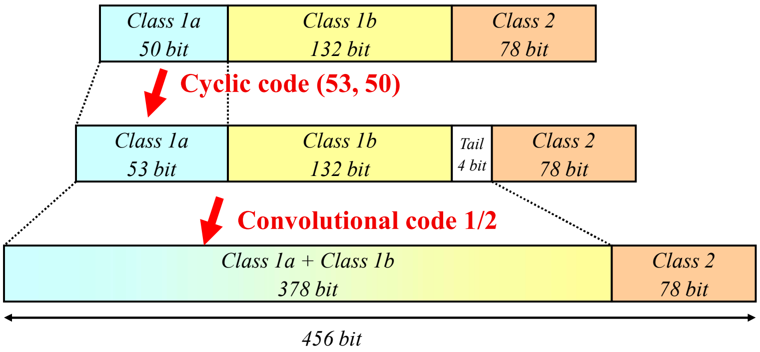


- **in uplink: Random Access Channel (RACH)**



Channel coding: voice channel 13 Kb/s

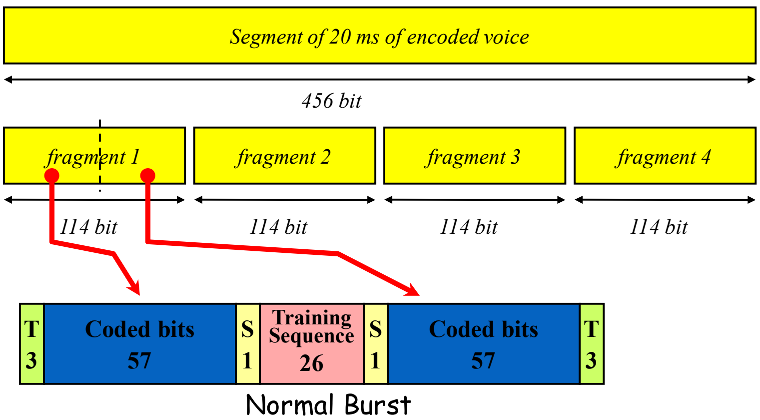
- The 13 Kb/s encoder considers 20 ms speech segments
- Every 20 ms the encoder procures 260 bits which are divided into 3 groups (class 1a - 50 bits, class 1b - 132 bits, class 2 - 78 bits) to which different encodings are applied



- 456 bit in 20 ms correspond to 22.8 Kb/s

Channel coding: voice channel 13 Kb/s

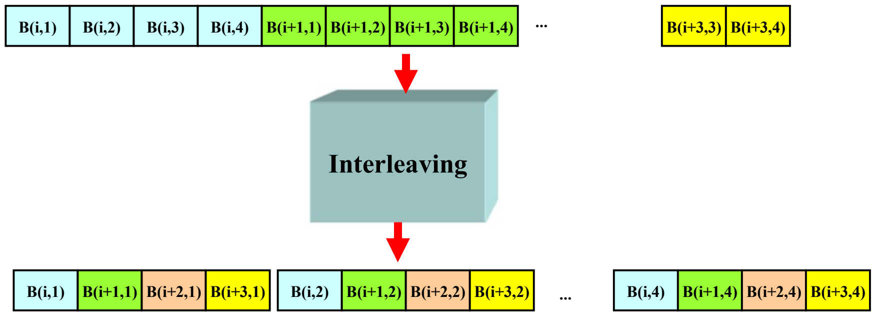
- 4 Normal Bursts transmitted in 4 frames or in 4.6*4 = 18.4 ms
- but one slot every 13 is signaling and therefore on average 18.4*13/12=20 ms



Channel coding: voice channel 13 Kb/s

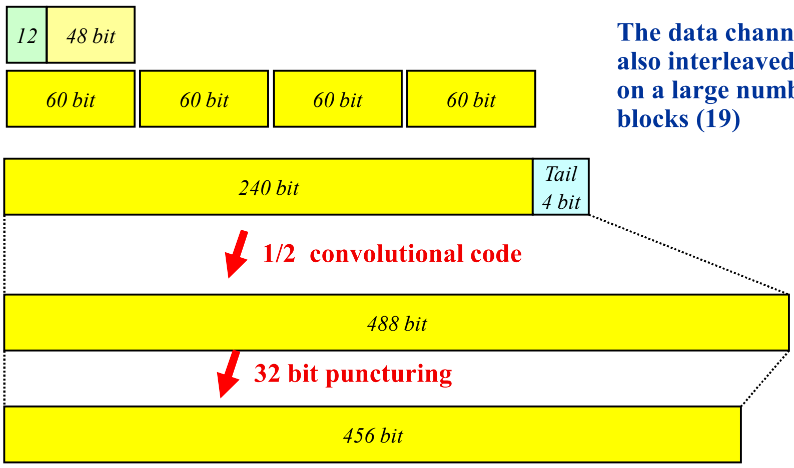
Interleaving

- In reality, the bits of the 4 physical 114-bit blocks are not contiguous sequences of output bits from the coding process
- The bits are mixed:



Channel coding: data channel at 9.6 Kb/s

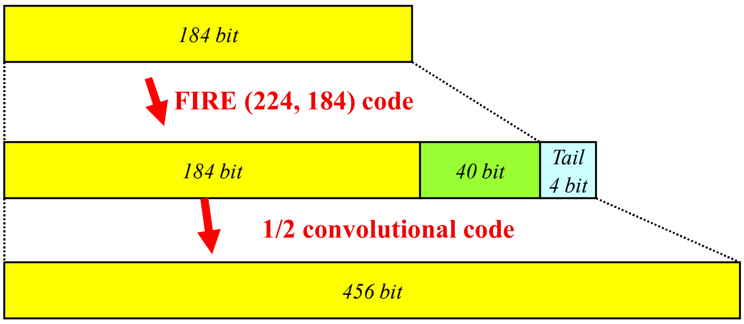
- Every 5 ms a 48-bit block is generated to which 12 bits of line protocol overhead are added for a total of 60 bits



The data channel is also interleaved and on a large number of blocks (19)

Channel coding: signalling channel SDCCH, BCCH, PCH, AGCH

- The channels generate information blocks of 184 bits every 20 ms



Mobile Radio Networks

- GSM Procedures

Main GSM procedures

- Security Procedures
- Network Access
- Mobility
- Originated Call (Call Set Up)
- Handovers
- Terminated Call (Paging)