GSM Fundamentals

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System Overview

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GSM History

1981 Analogue cellular introduced

Franco-German study of digital pan-European cellular system

1987 MoU signed by over 18 countries

1989 GSM was moved into the ETSI organization

GSM name changed to Global System for Mobile communications.

1990 DCS1800 (edited GSM900) specification developed

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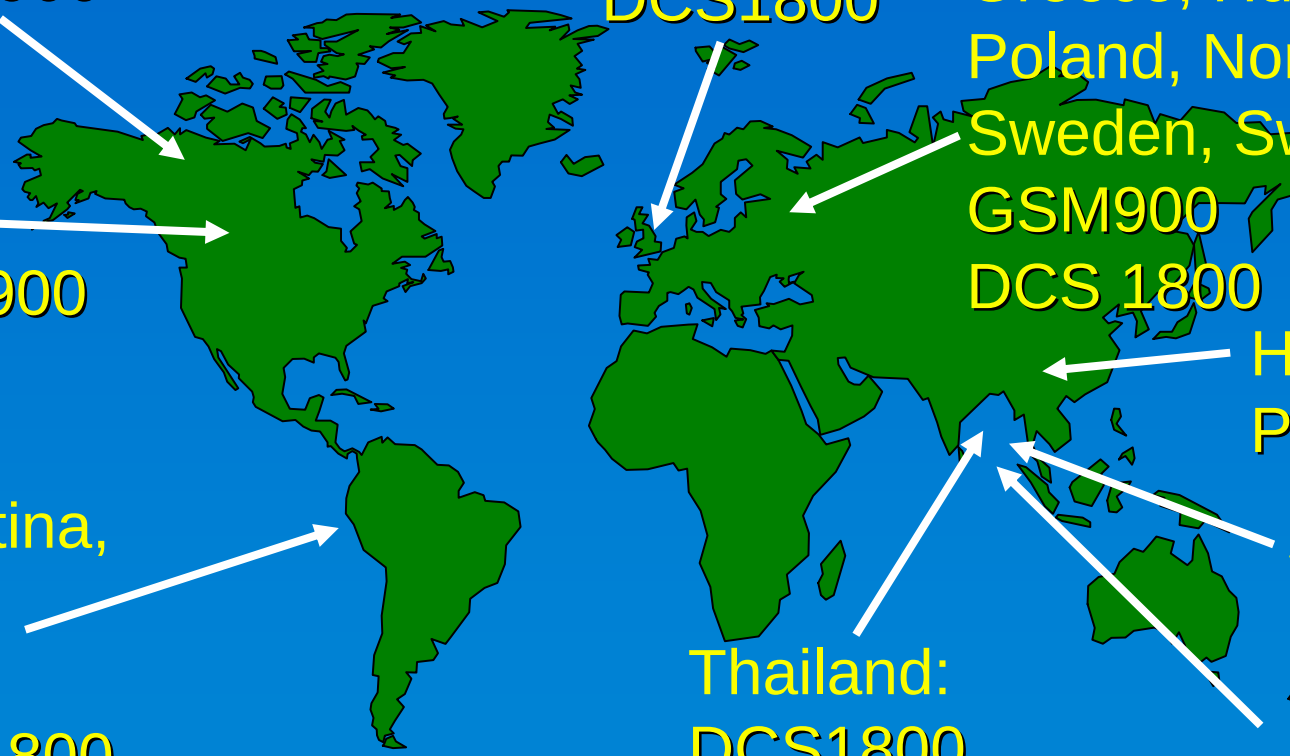
GSM Around the World



Canada:
PCS 1900

USA:
PCS1900

Argentina,
Brazil,
Chile:
DCS 1800

UK:
GSM900
DCS1800

CIS, Denmark, Finland,
France, Germany,
Greece, Hungary,
Poland, Norway,
Sweden, Switzerland:
GSM900
DCS 1800

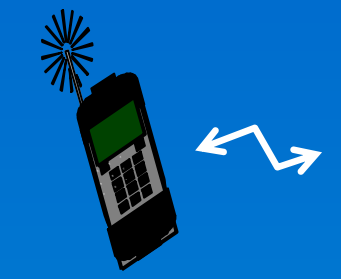
Hong Kong:
PCS 1900

Singapore
:
DCS1800

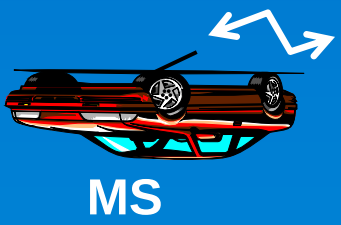
Malaysia:
DCS 1800

Thailand:
DCS1800

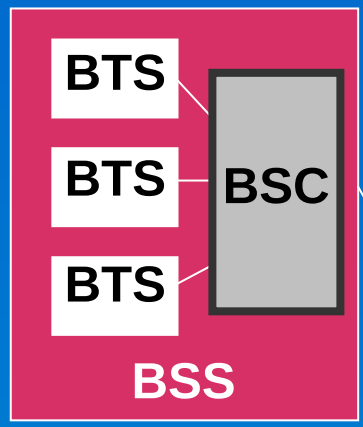
GSM Network

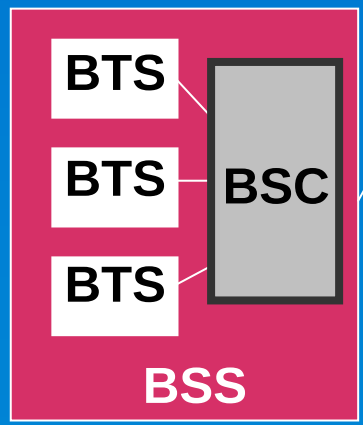


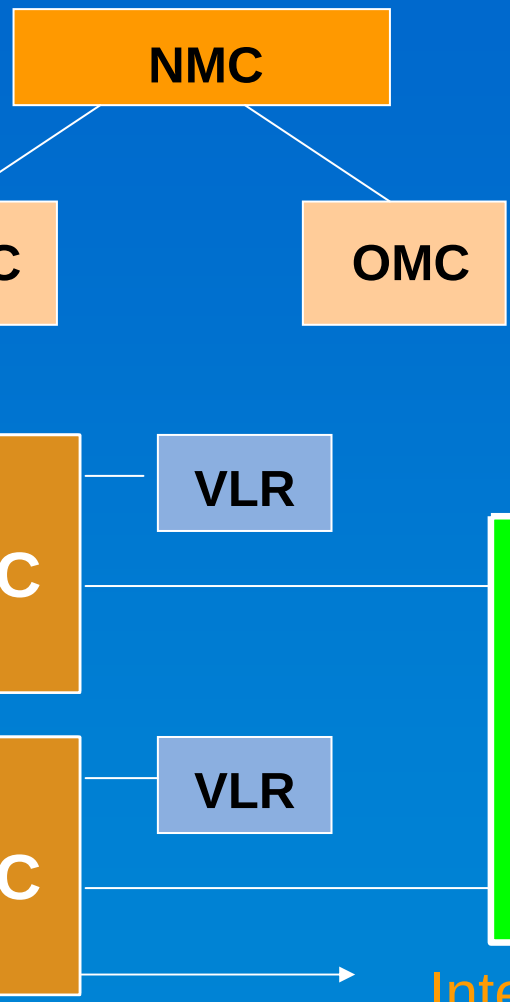
MS



MS

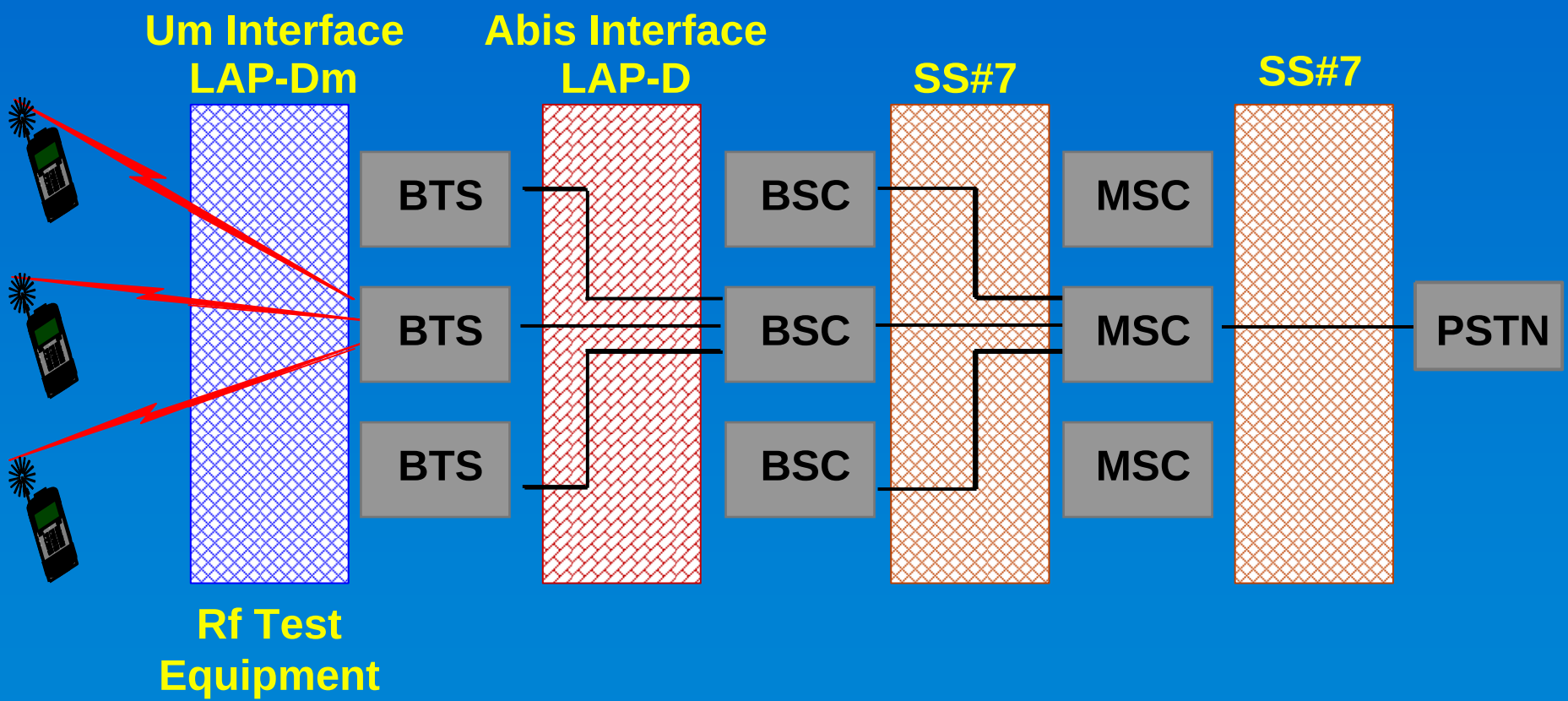






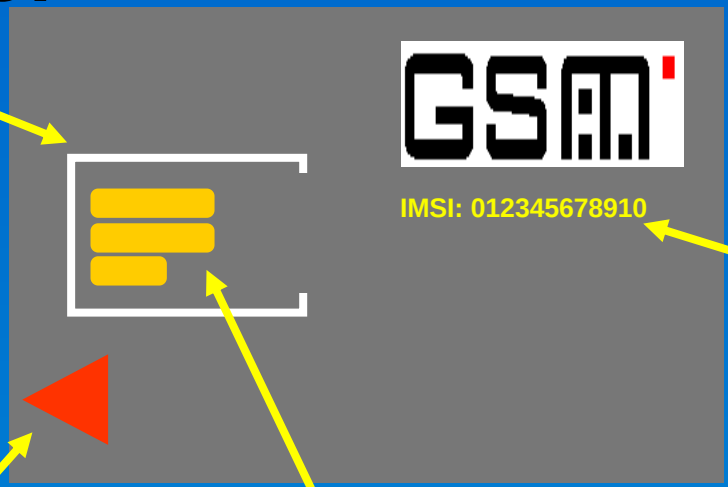
Interface to other networks

GSM Network Interfaces



SIM Card

Breakout for micro SIM



IMSI

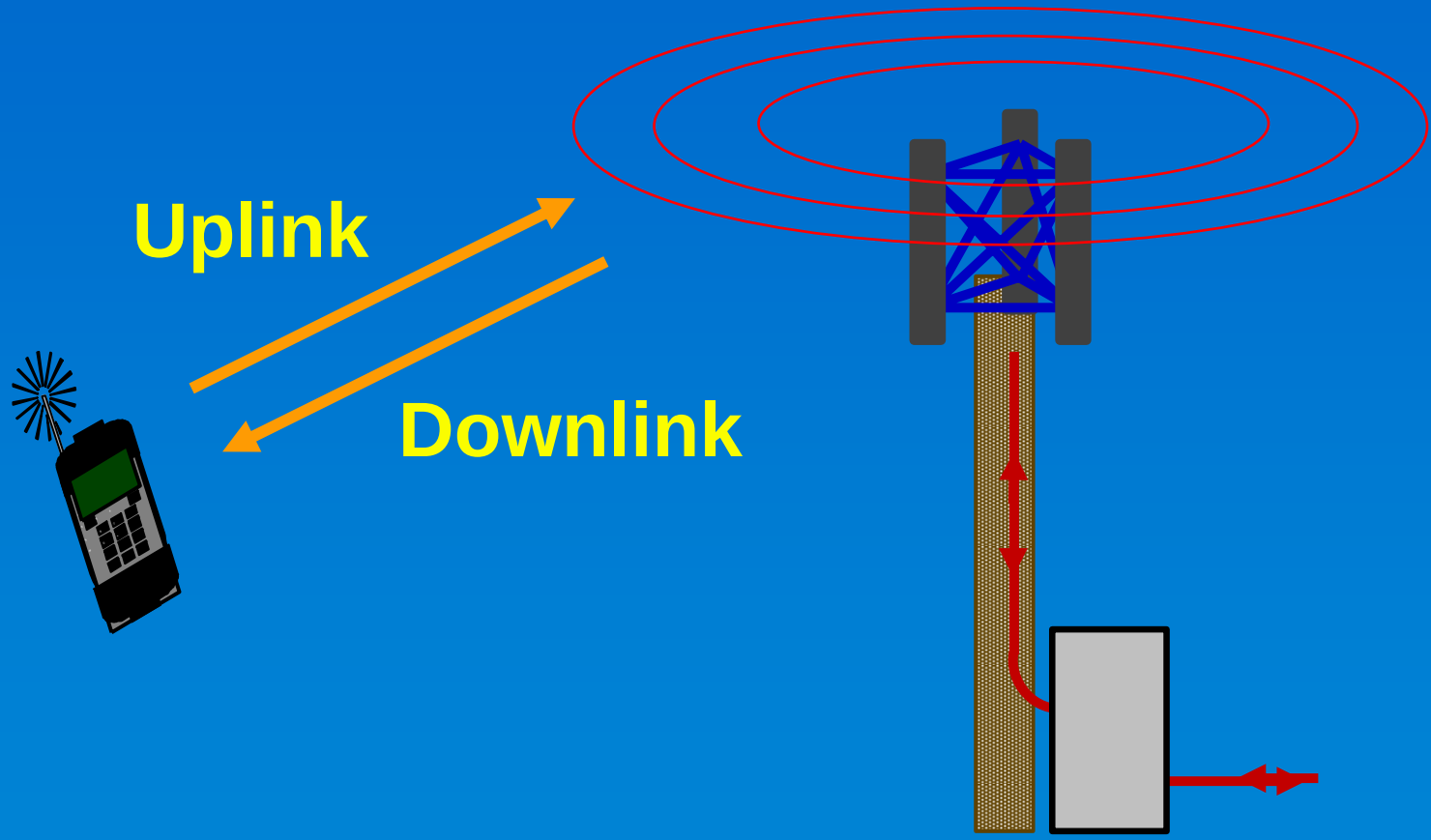
Locator for correct insertion

Active chip of smart card

SIM Card

- Plugs into Every GSM Mobile
  - Two Sizes - Standard (credit card)
    Micro (postage stamp)
- Holds All Unique Subscriber Information
  - IMSI (International Mobile Subscriber)
  - Lists of Networks Allowed For User
  - K_i - Ciphering Key
- Stores Information on Last Location
- Stores User Information
  - Speed Dial Lists, Memories, etc.

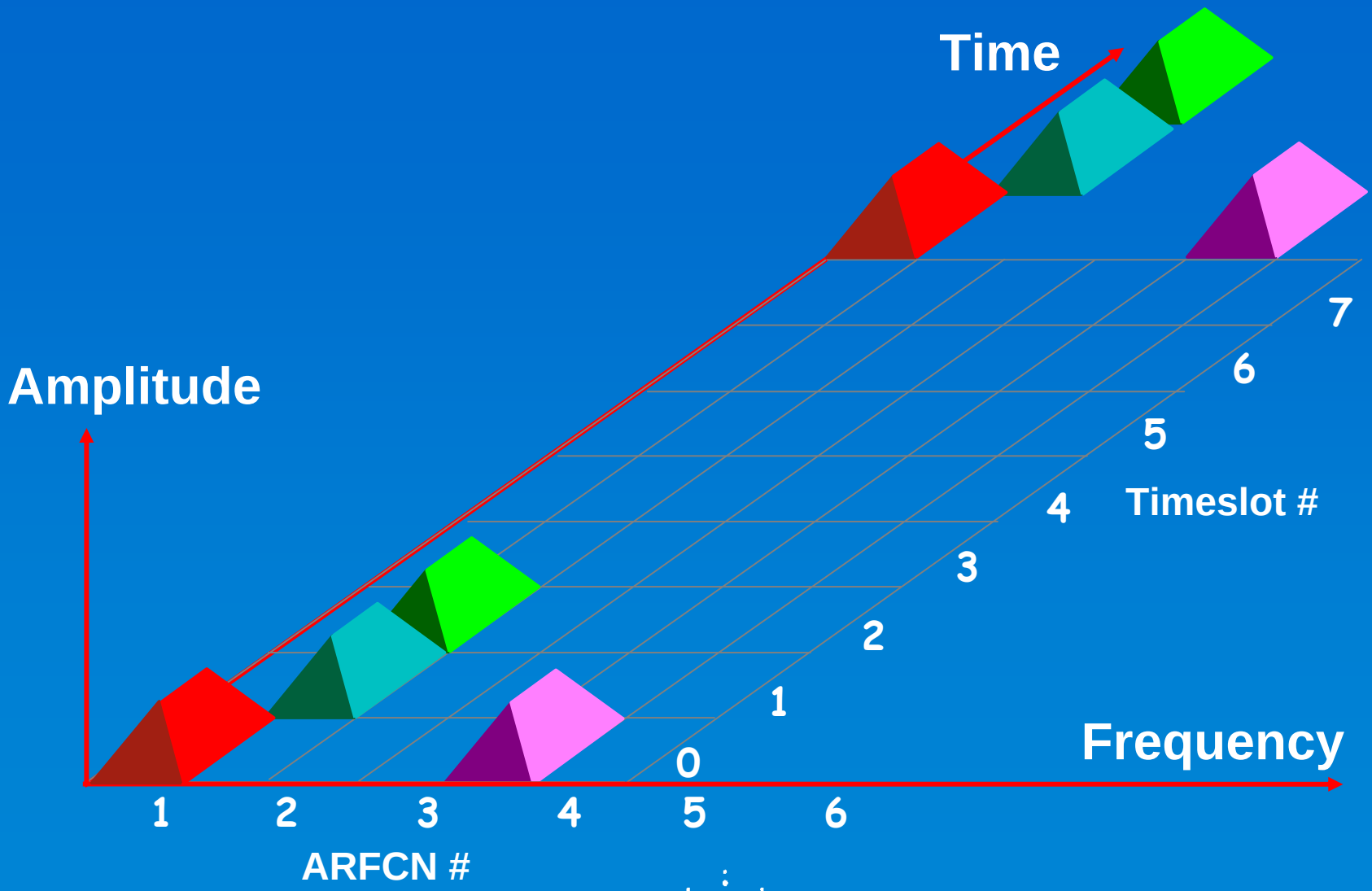
GSM Bands



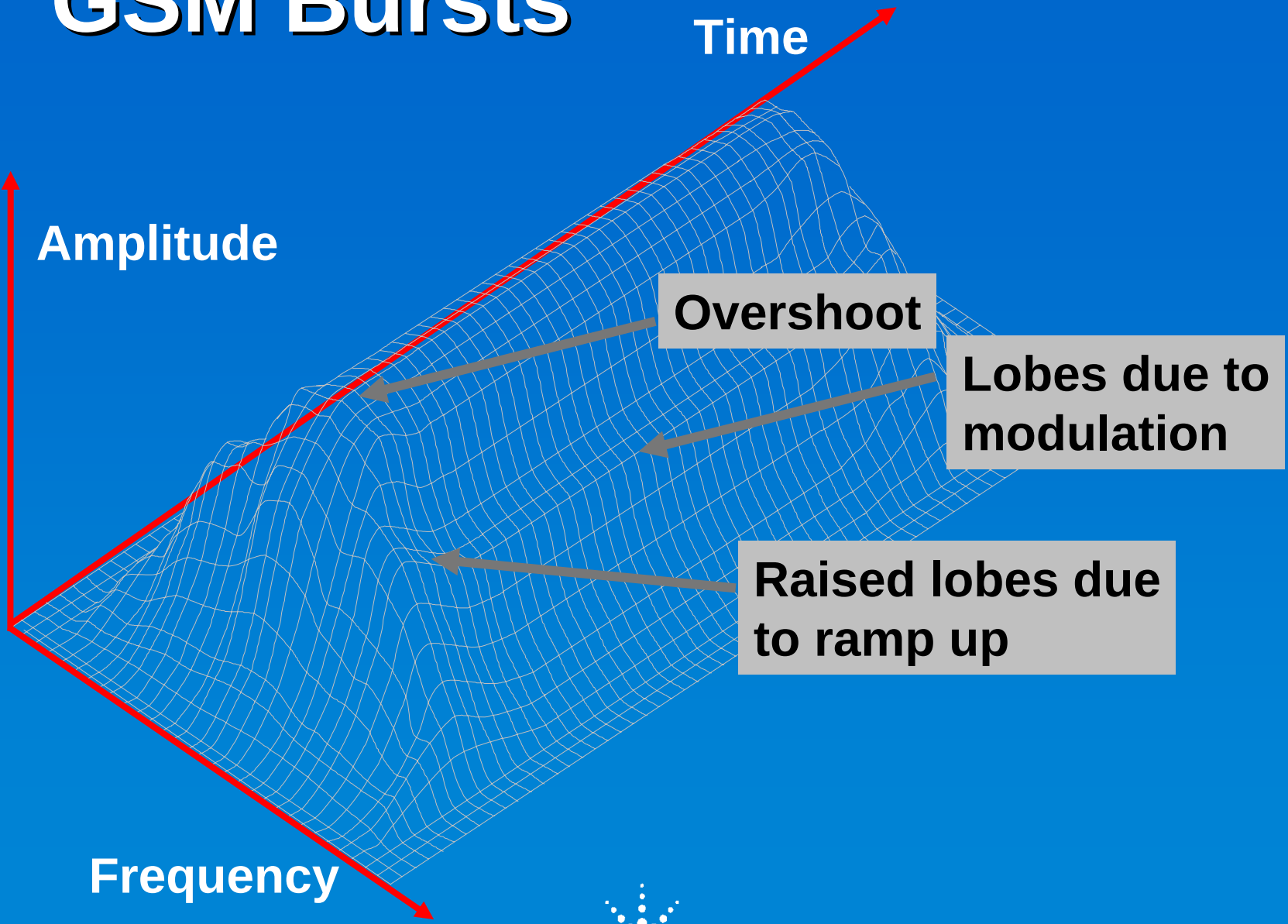
GSM Channel Plans

	Phase 1 GSM900	Phase 2 GSM900	Phase 1 DCS1800	Phase 2 DCS1800	PCS1900
Uplink Frequency Range	890 to 915MHz	880 to 915MHz	1710 to 1785MHz	1710 to 1785MHz	1850 to 1910MHz
Downlink Frequency Range	935 to 960MHz	925 to 960MHz	1805 to 1880MHz	1805 to 1880MHz	1930 to 1990MHz
ARFCN Range	1 – 124	0 – 124 and 975 – 1023	512 – 885	512 – 885	512 – 810
Tx/Rx Spacing (MHz)	45	45	95	95	80

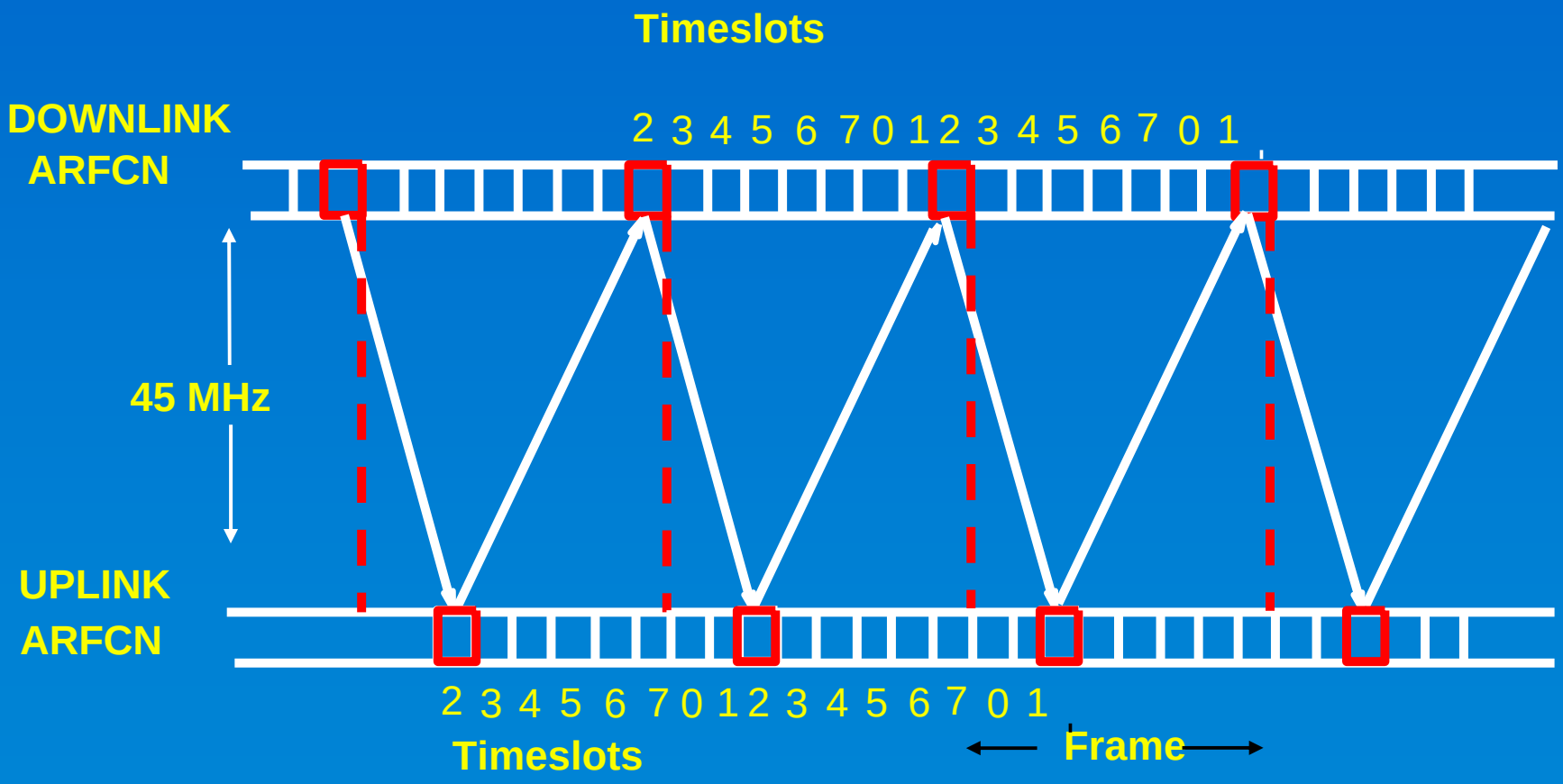
GSM FDMA and TDMA



GSM Bursts


Time
Amplitude
Overshoot
Lobes due to modulation
Raised lobes due to ramp up
Frequency

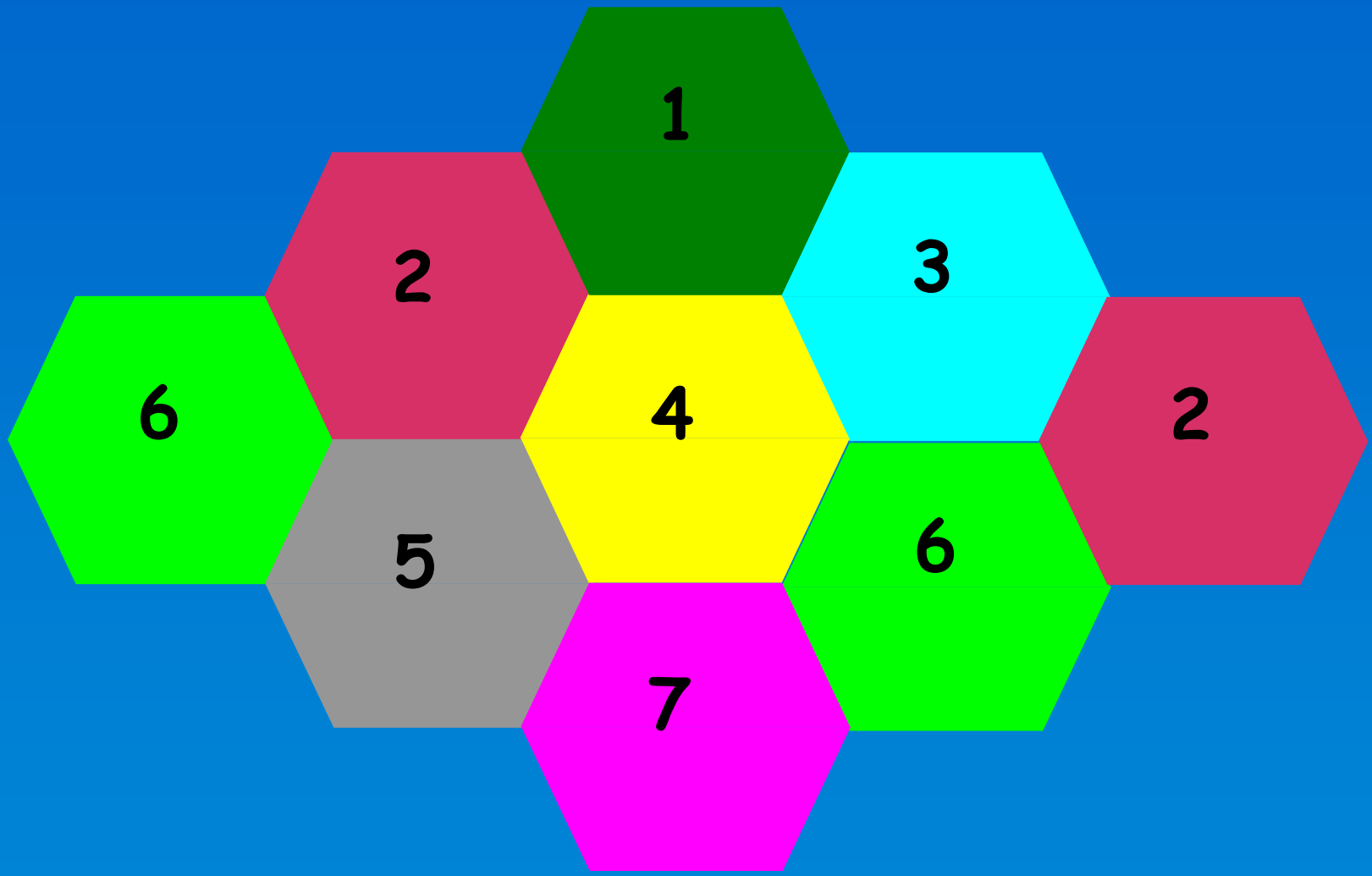
Downlink and Uplink



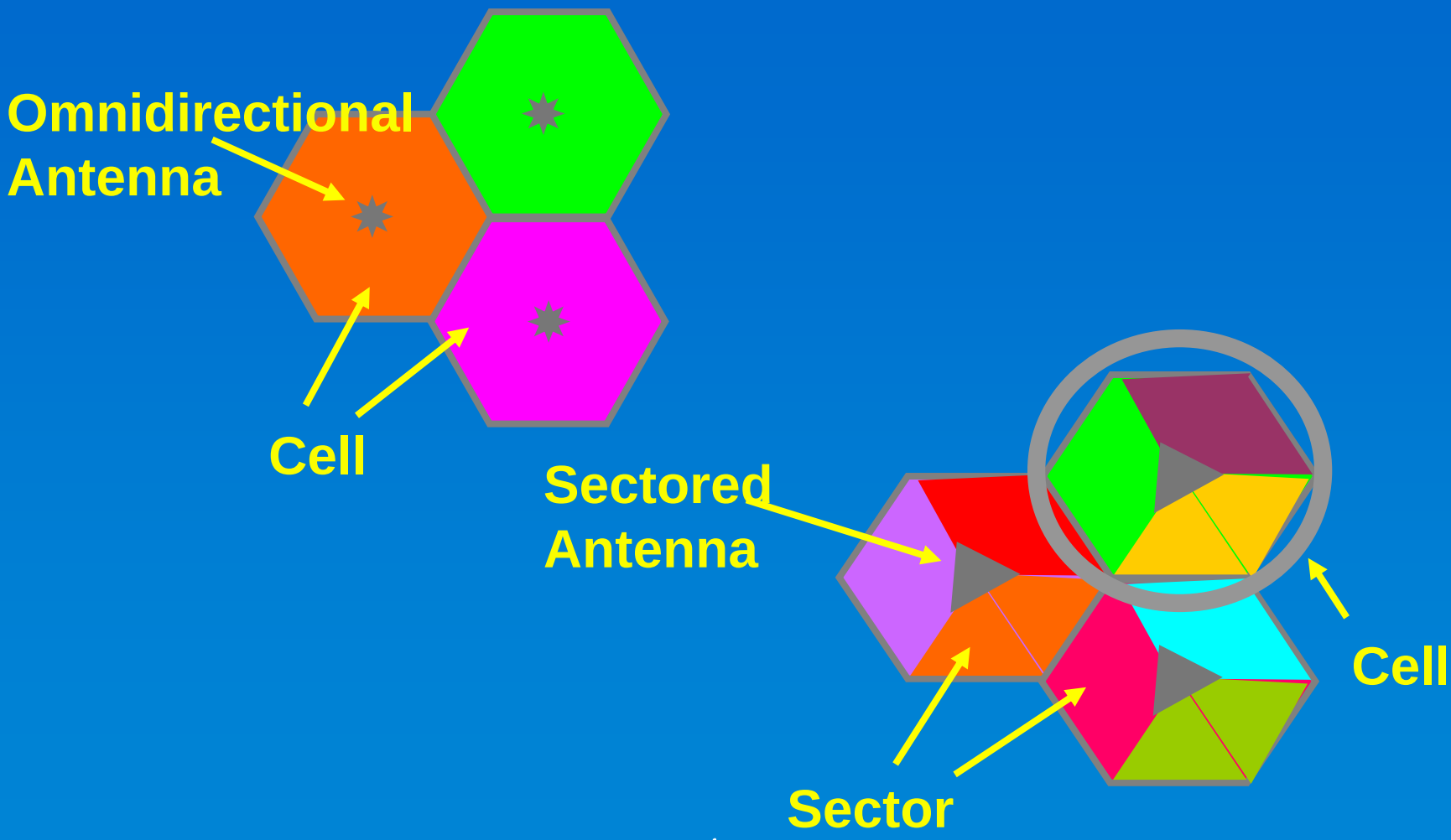
Downlink and Uplink

- Uplink Lags Downlink by 3 Timeslot periods
- Uplink and Downlink use same Timeslot Number
- Uplink and Downlink use same Channel Number (ARFCN)
- Uplink and Downlink use different bands (45MHz apart for GSM900)

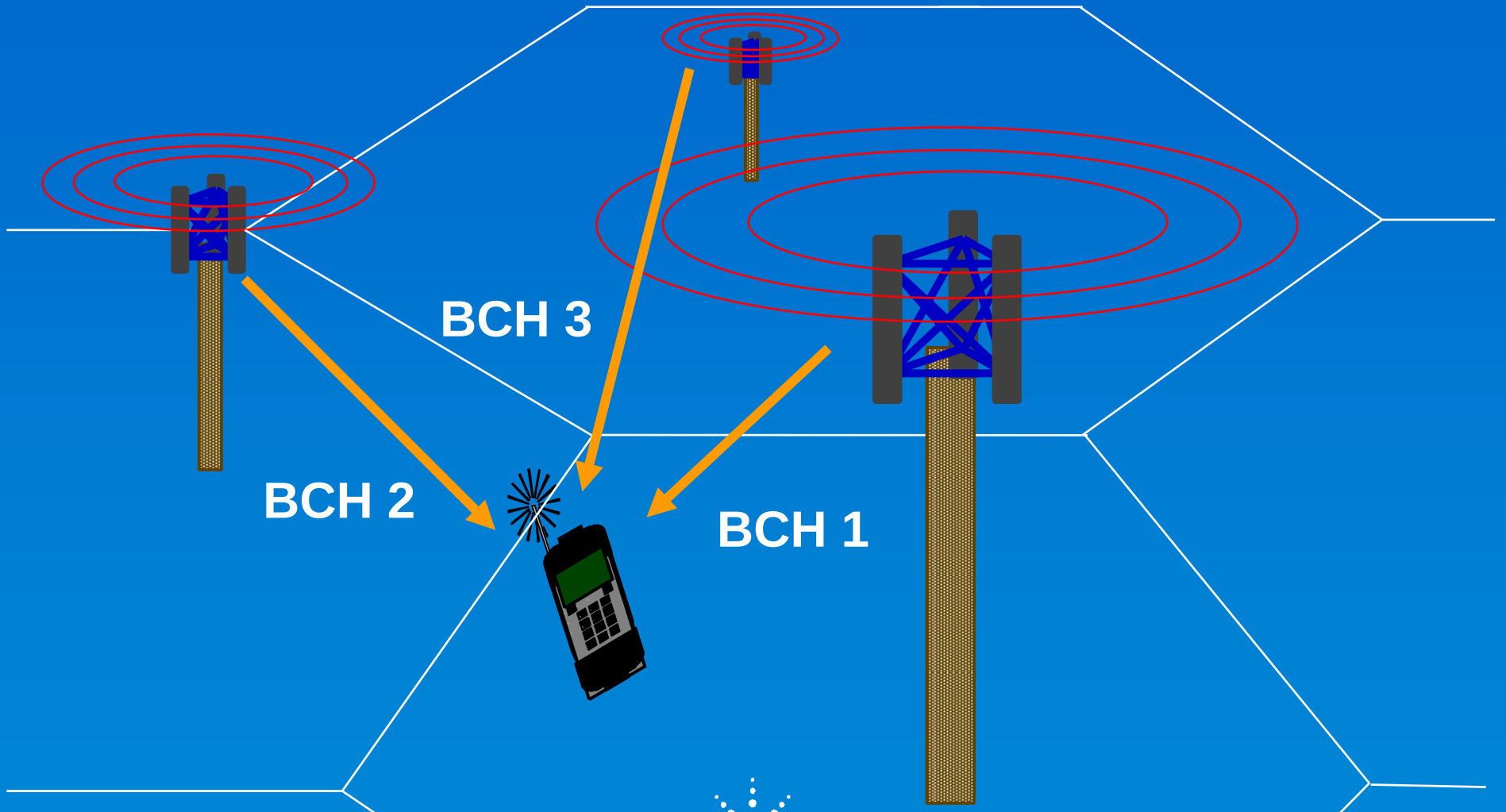
GSM Cell Plan



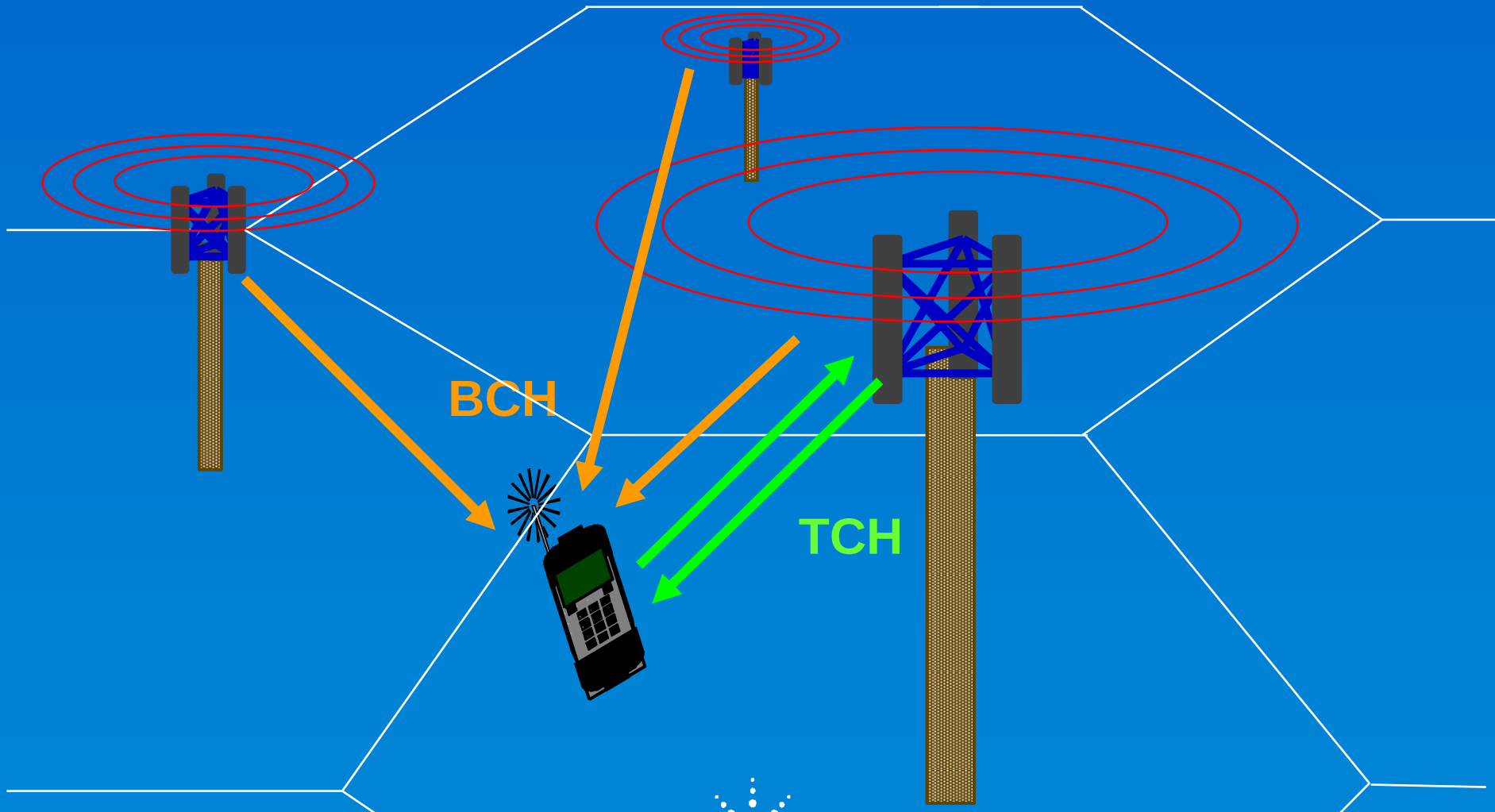
GSM Cell Types



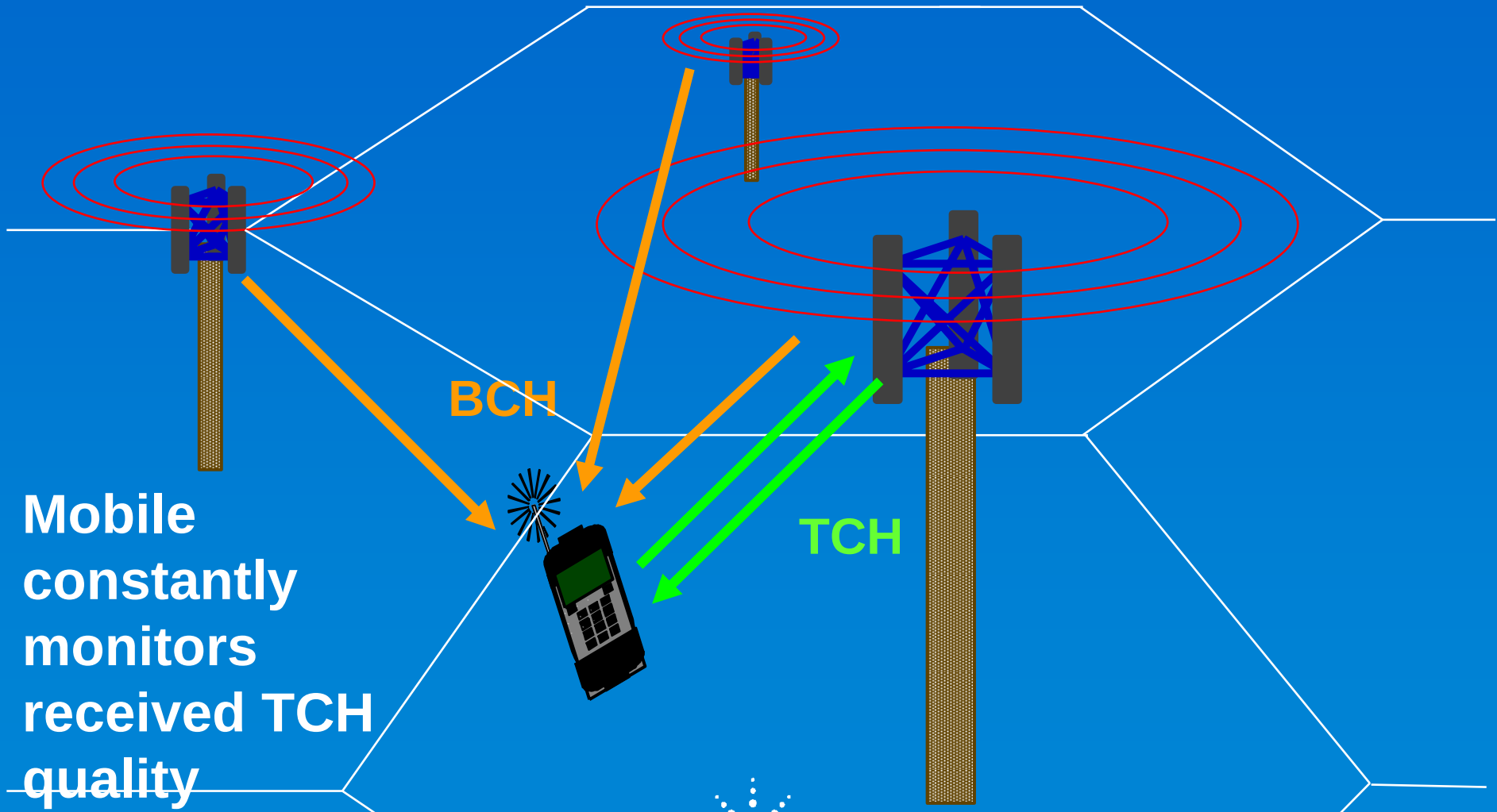
GSM Broadcast Channel



GSM Traffic Channel

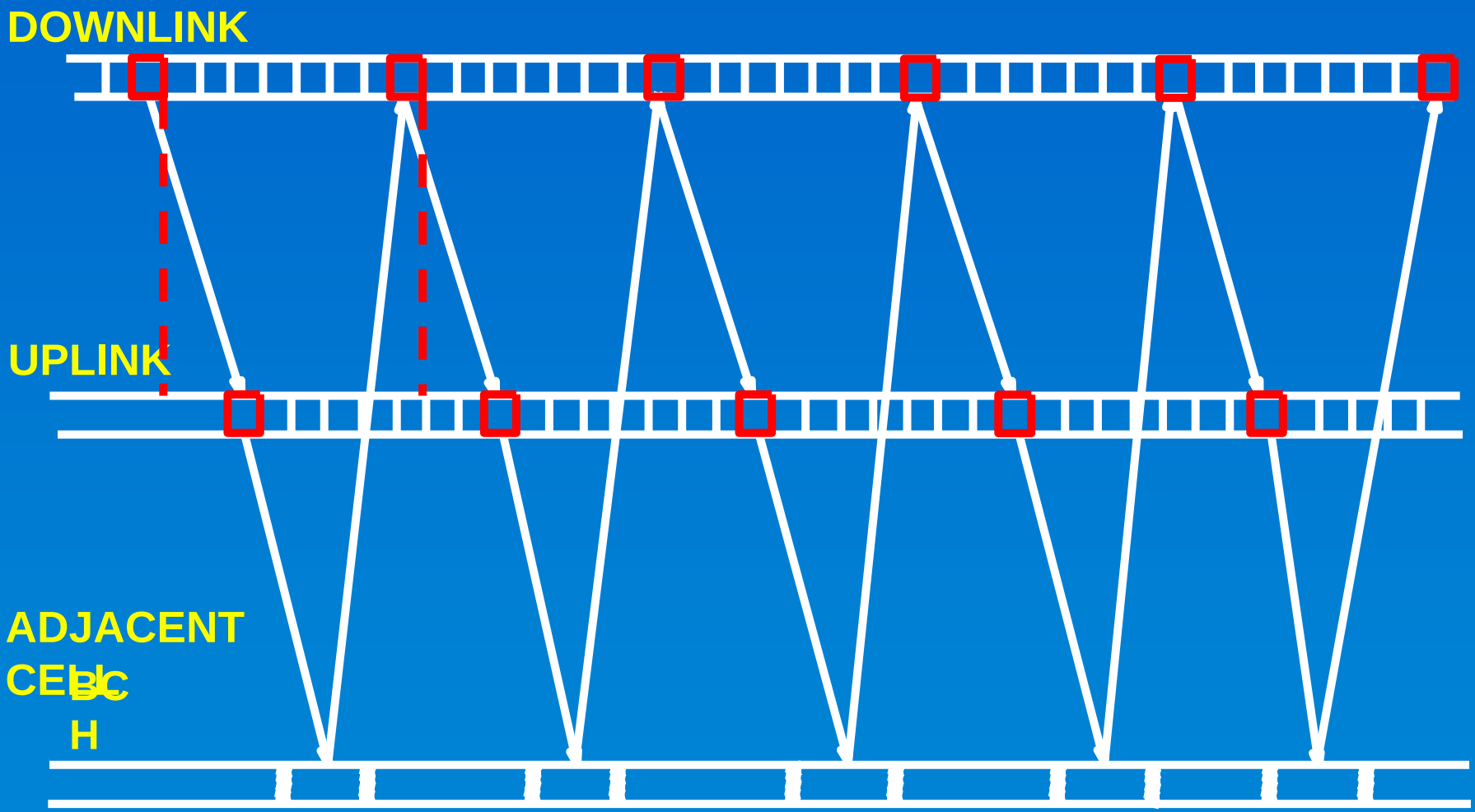


GSM Hand-Off

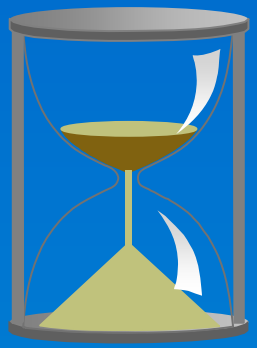


Mobile constantly monitors received TCH quality (RxQual &

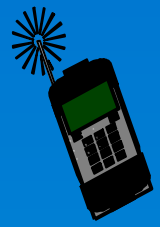
Measuring Adj BCH Power

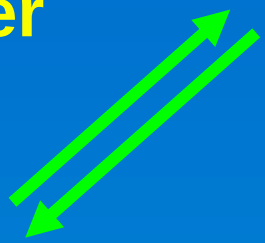


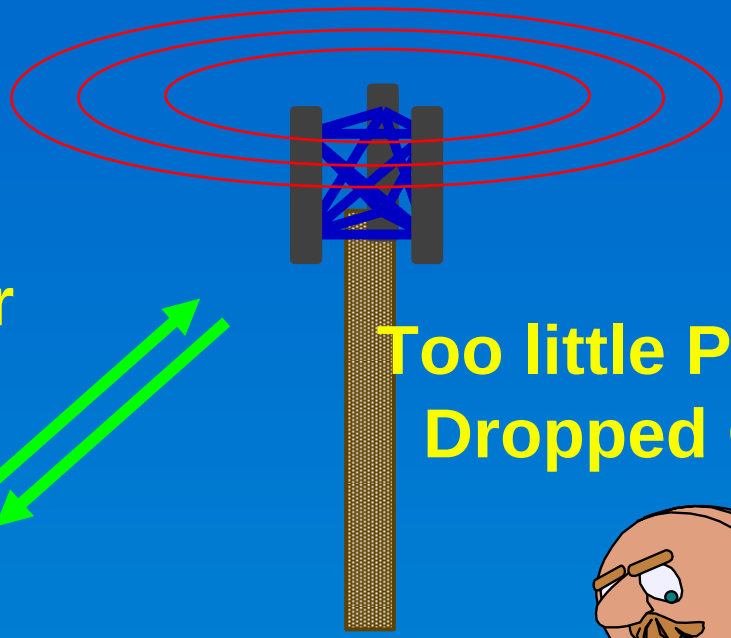
GSM Power Steps



Too much Power
Low Talk Time







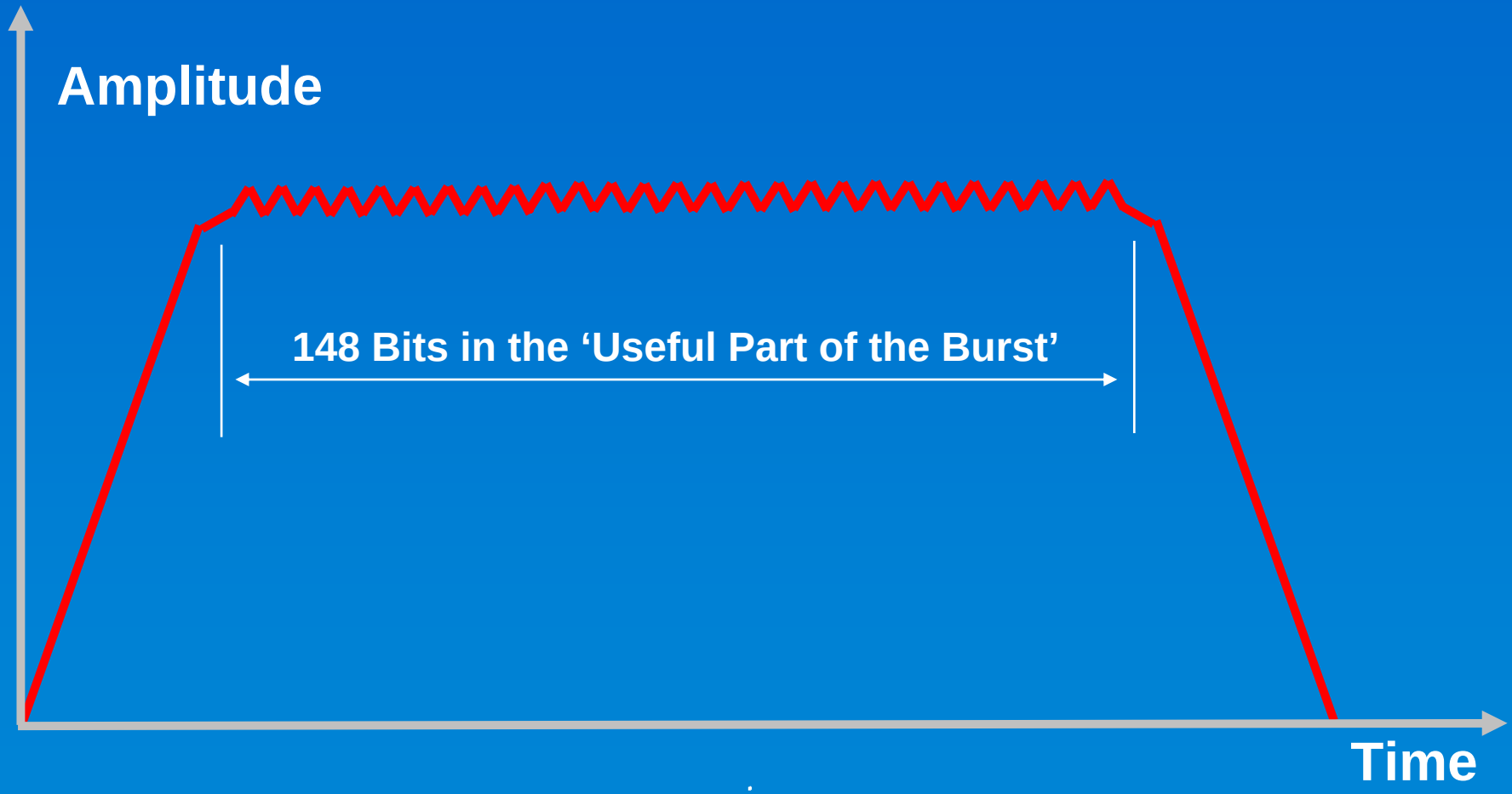
Too little Power
Dropped Calls

Mobile adjusted according to Received Signal Strength and Quality at Base Station.

Mobile Power Levels

	Phase 1 GSM900	*Phase 2 GSM900*	*Phase 1 DCS1800*	*Phase 2 DCS1800*	*PCS1900*
Mobile Max Power	20W (8W used) 43dBm/39dBm	8W / 39dBm	1W / 30dBm	4W / 36dBm	2W / 33dBm
Mobile Min Power	20mW /13dBm	3mW / 5dBm	1mW/ 0dBm	1mW / 0dBm	1mW / 0dBm
Mobile Power Control Steps	0 - 15	2 - 19	0 - 13	0 - 15	0-15 ,30,31

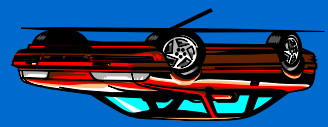
GSM Burst - TDMA

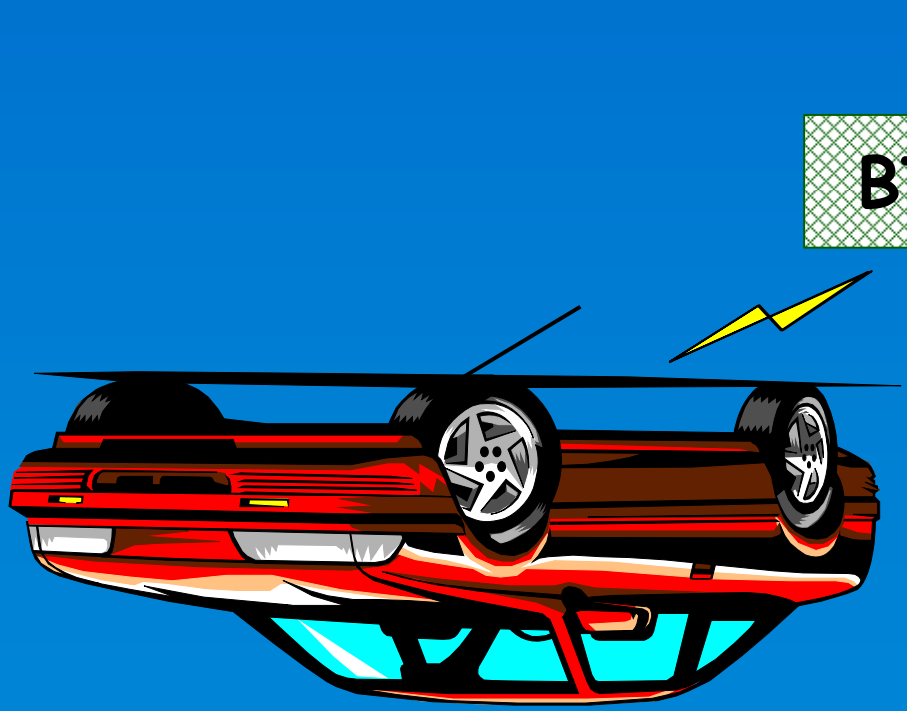


GSM Time Delay

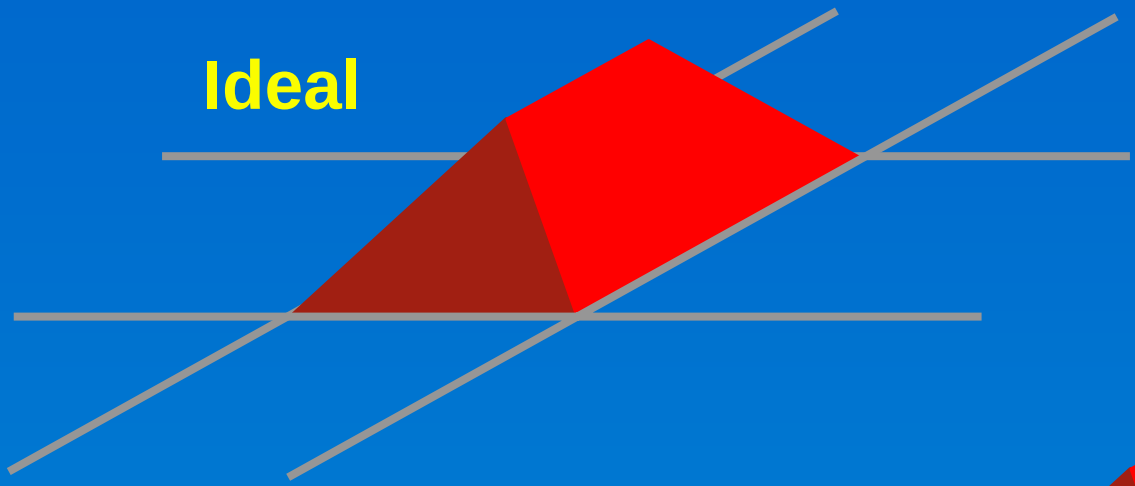
Cell radius < 35 km

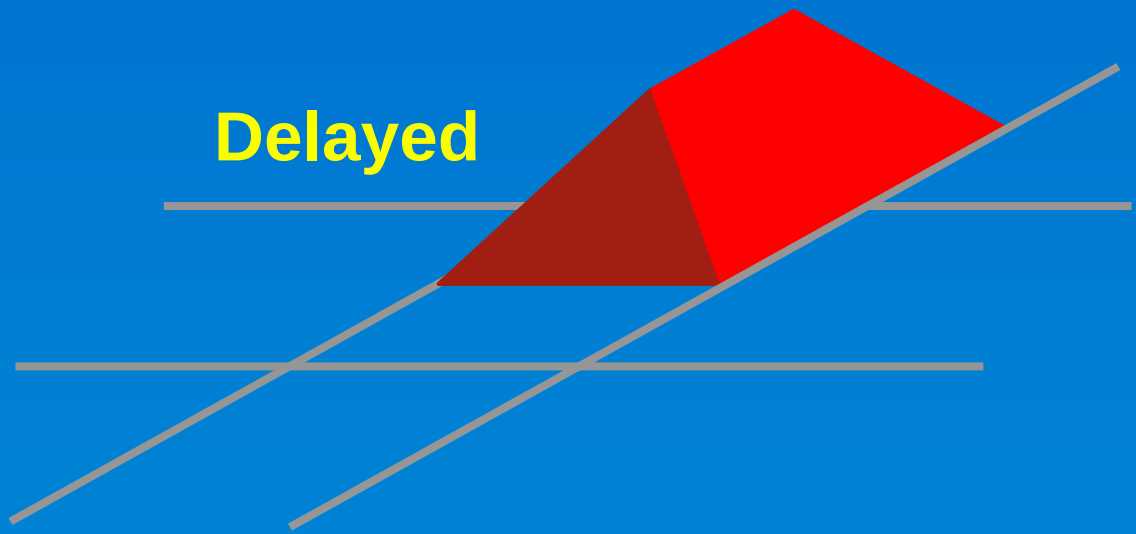
Signal travel or time 117 usec





GSM Time Delay

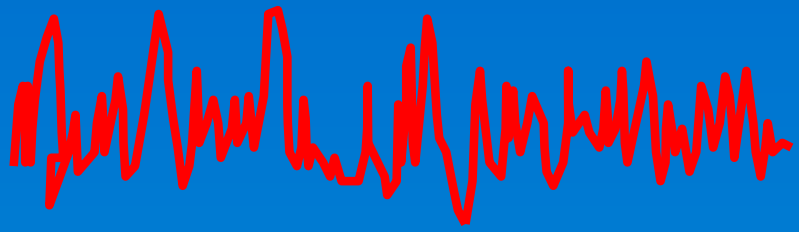




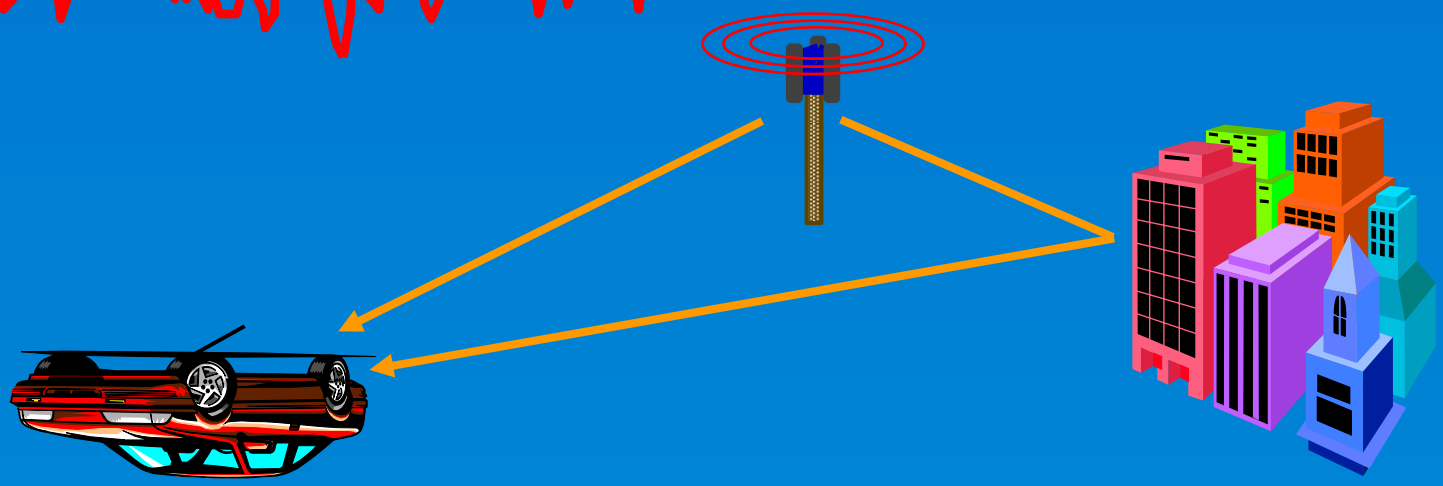
Change noted in 1/4 bit periods, but only changed if change in excess of 4/4 bit

GSM Midamble Equalisation

Reference Color Code (Midamble)



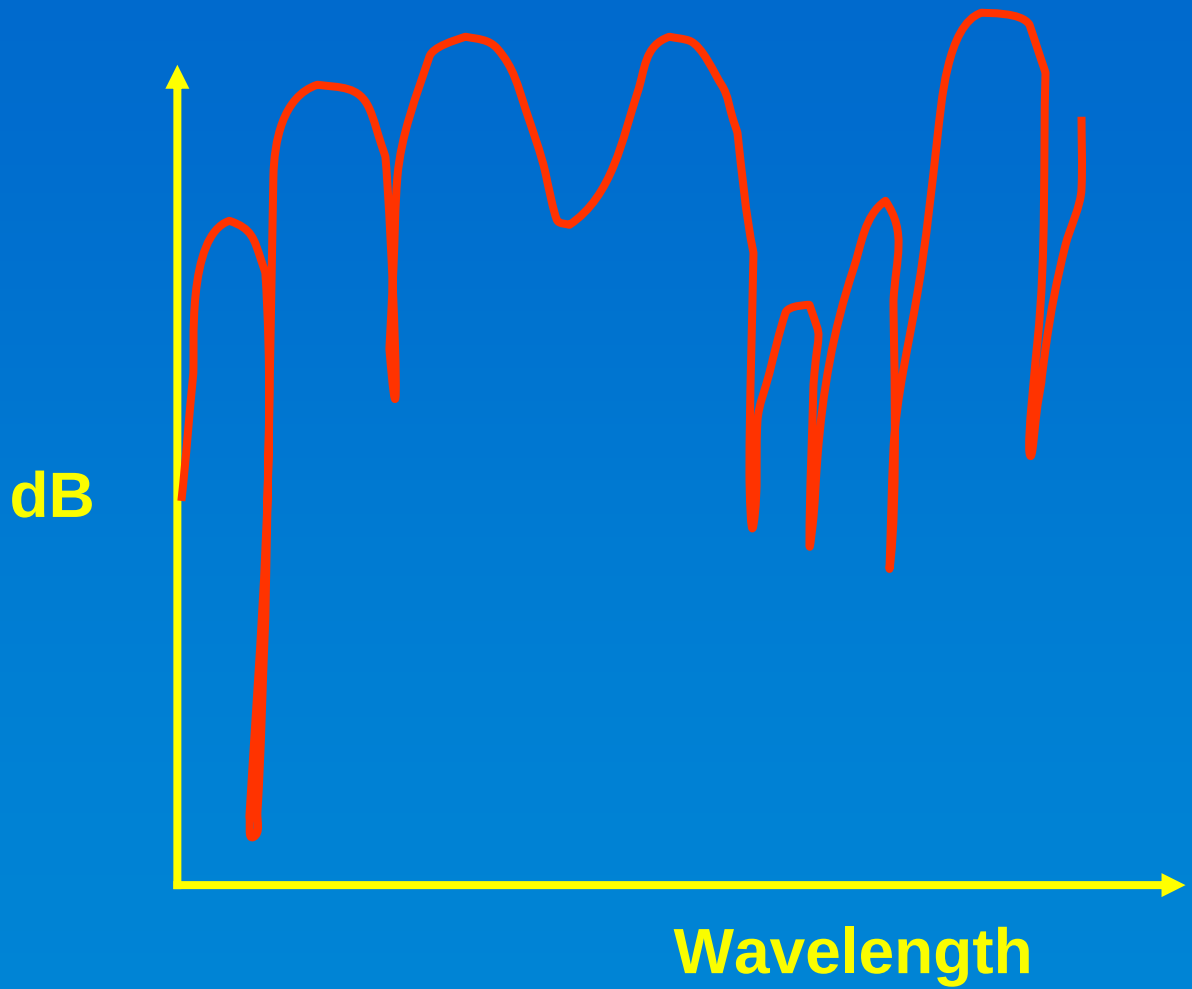
Actual Received Signal



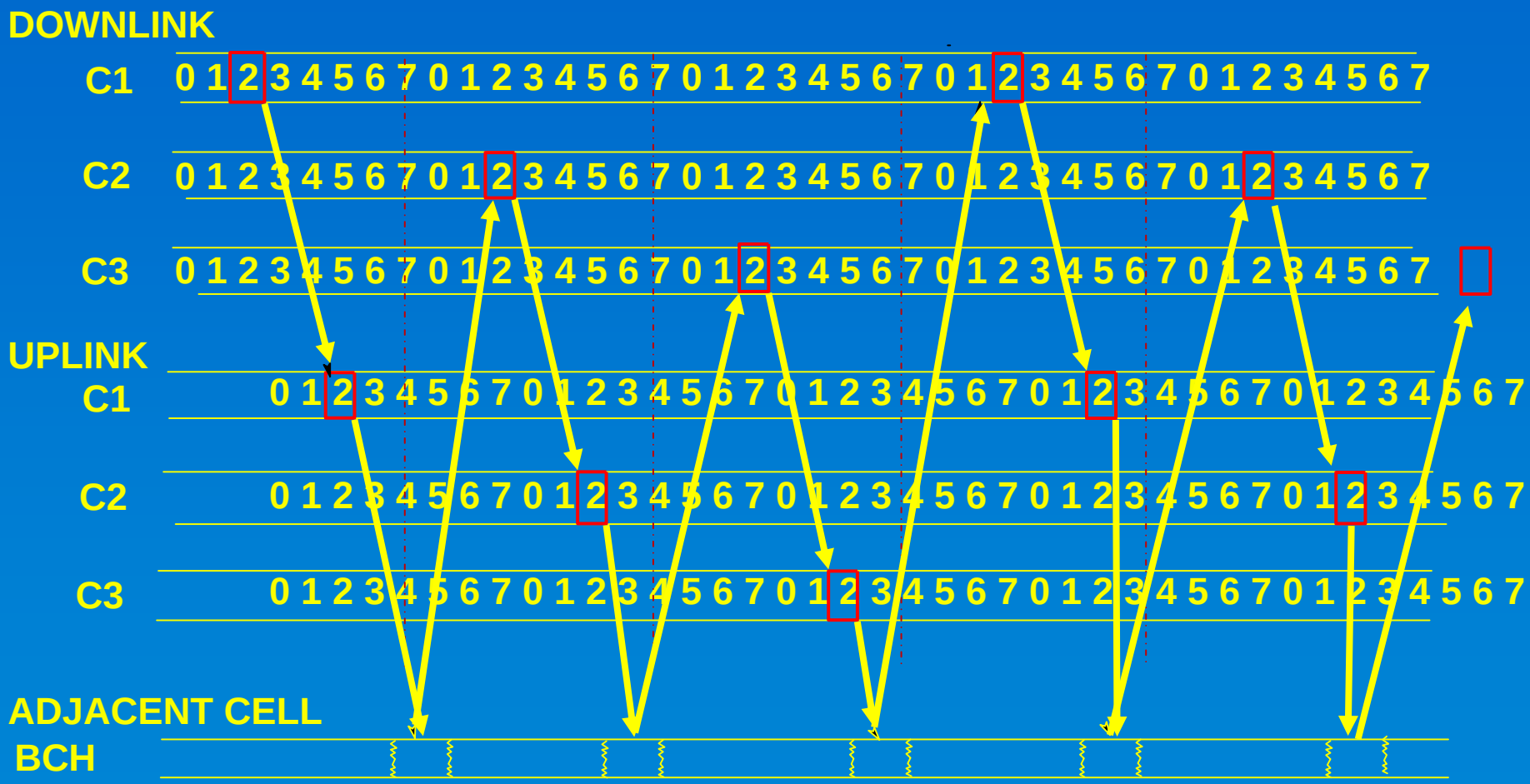
Midamble or Training Bits

- 8 Midamble Patterns (Colour Codes) of 26 bits
- Equalizer Estimates Channel Impulse Response From Midamble
- Mathematically Construct Inverse Filter
- Uses Inverse to Decode Data Bits

Frequency Diversity



Hopping Sequences



Hopping Sequences

- Control Channels NEVER hop
- Can employ cyclic or pseudo-random hopping sequences
- Different mobiles in a cell have different MAIO's (Mobile Allocation Index Offset)

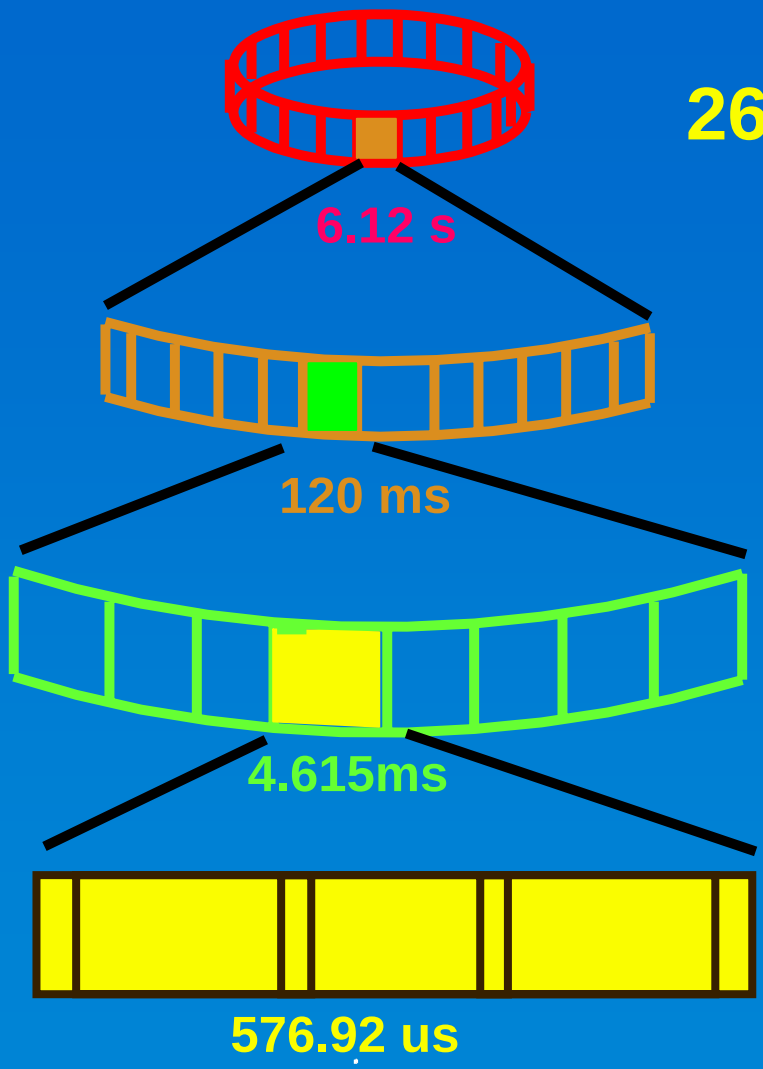
GSM BCH Frames

Agilent Technologies

BCH - Frames

Super-frame

26 Multiframes



Multi-frame

51 Frames

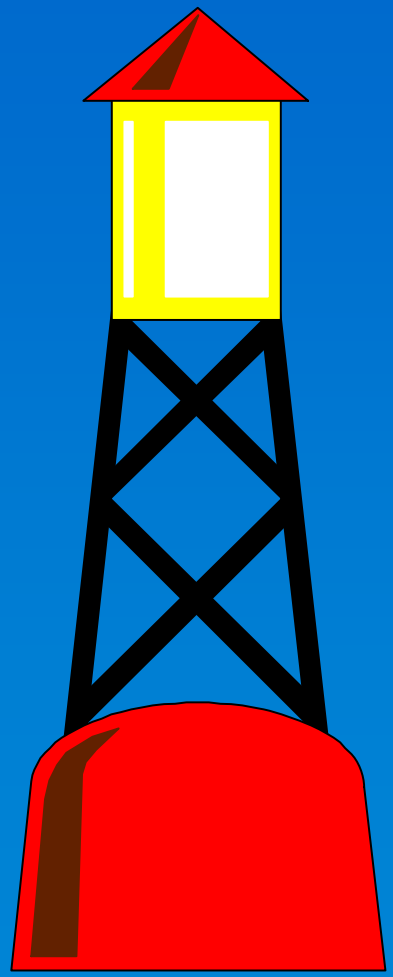
Frame

8 Timeslots

Timeslot (normal burst)

156.25 Bits

GSM BCH



Broadcast Channel

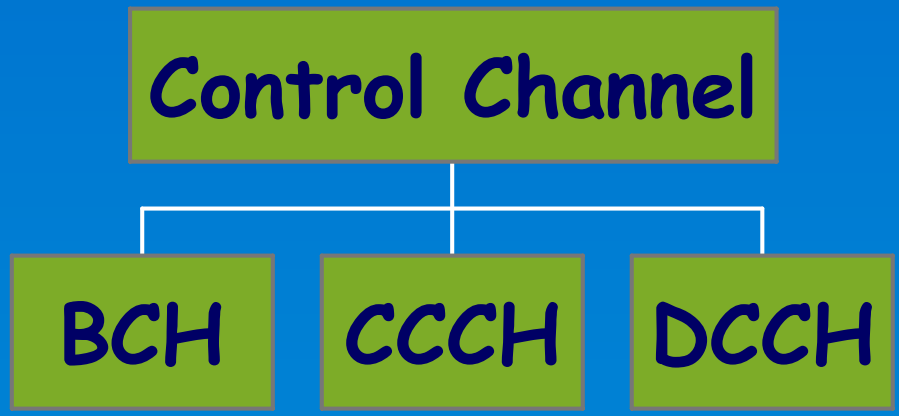
One BCH on all the time, in every cell

BCH Information carried in Timeslot 0

Identifies Network Carries, Paging and other Control Information

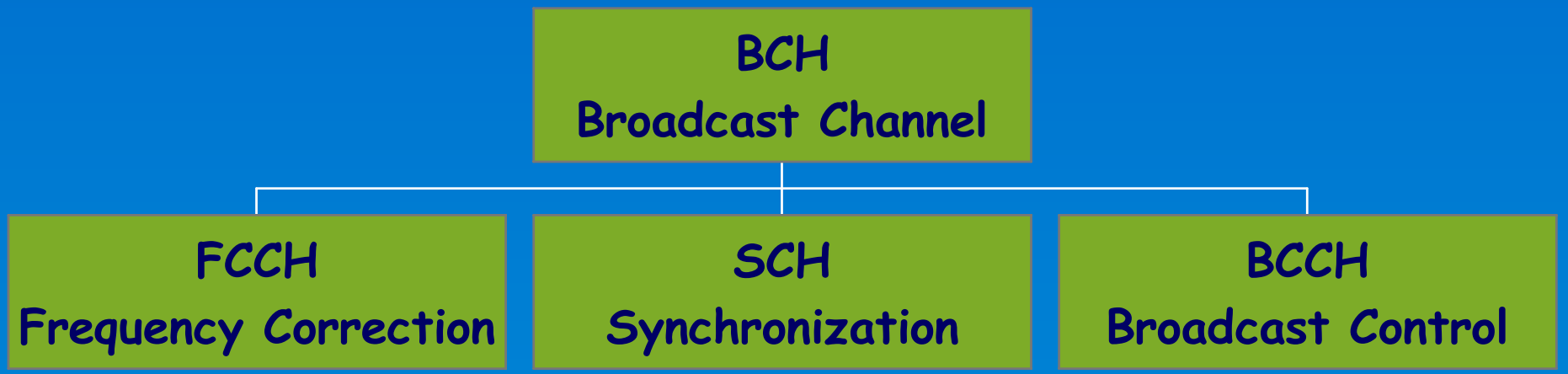
Broadcast Channel

Control Channel Organization

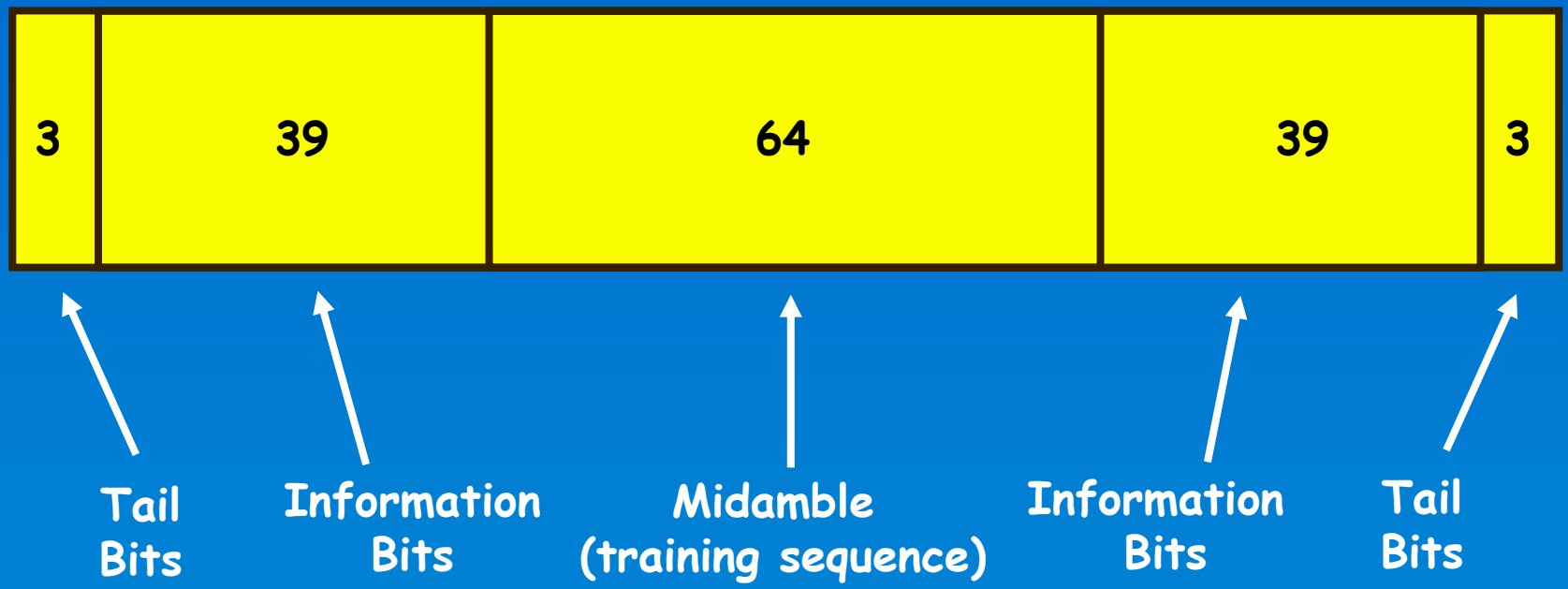


BCH - Subchannels

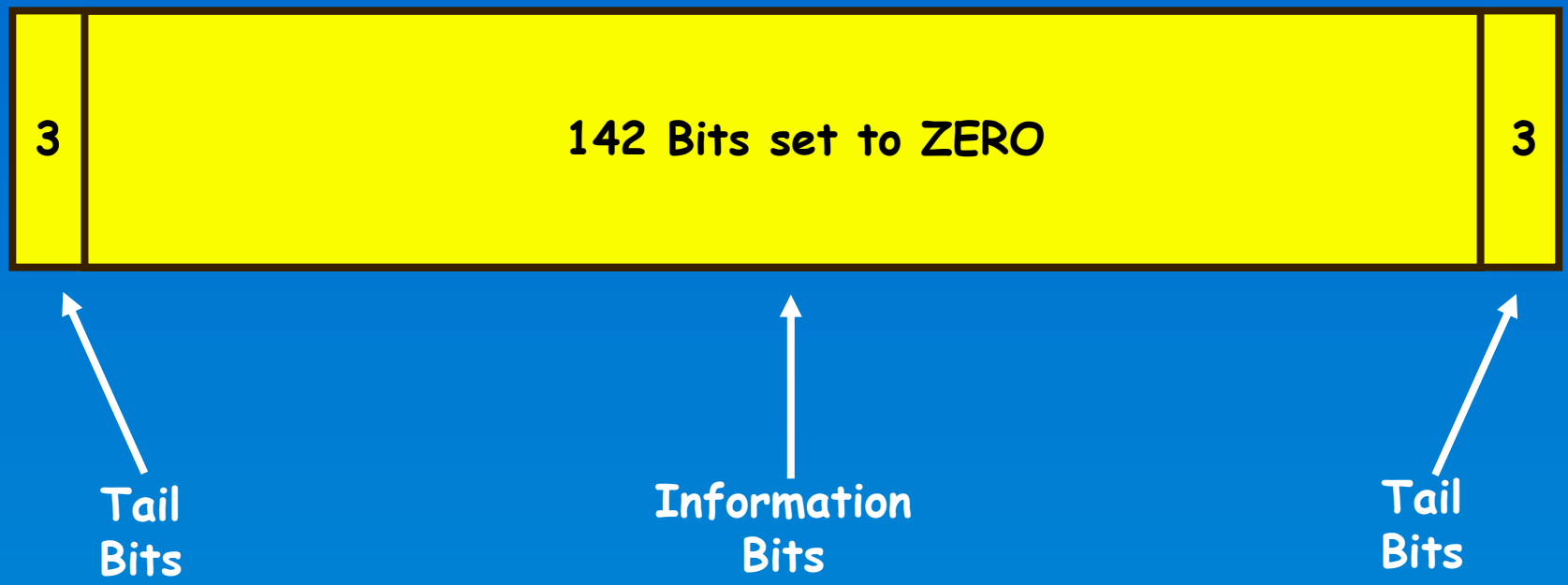
Broadcast Channel Organization



SCH - The ‘S’ Burst

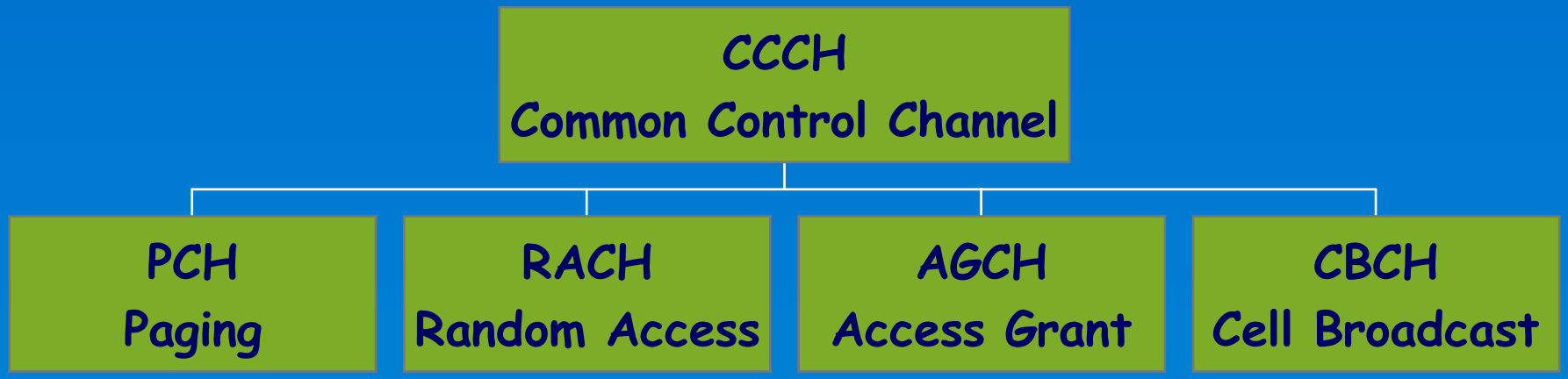


FCCH - The ‘F’ Burst

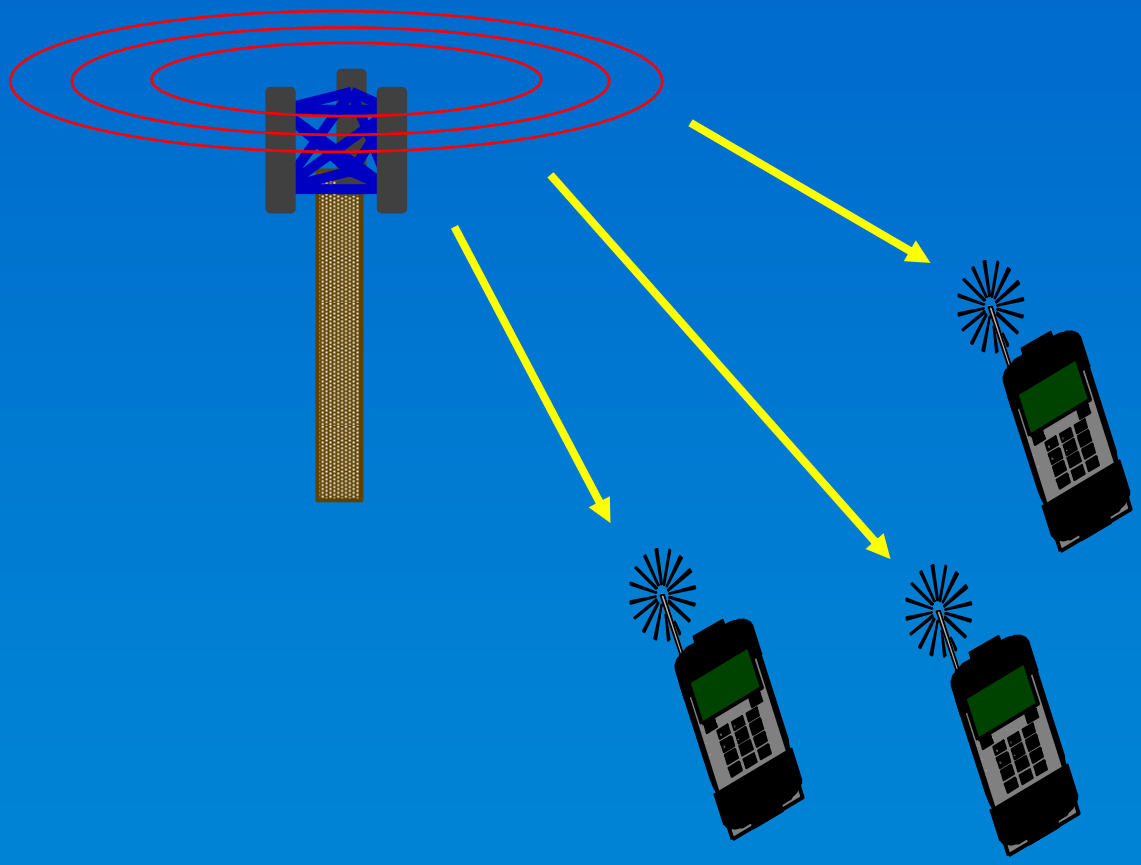


CCCH - subchannels

Common Control Channel Organization



SMS Cell Broadcast

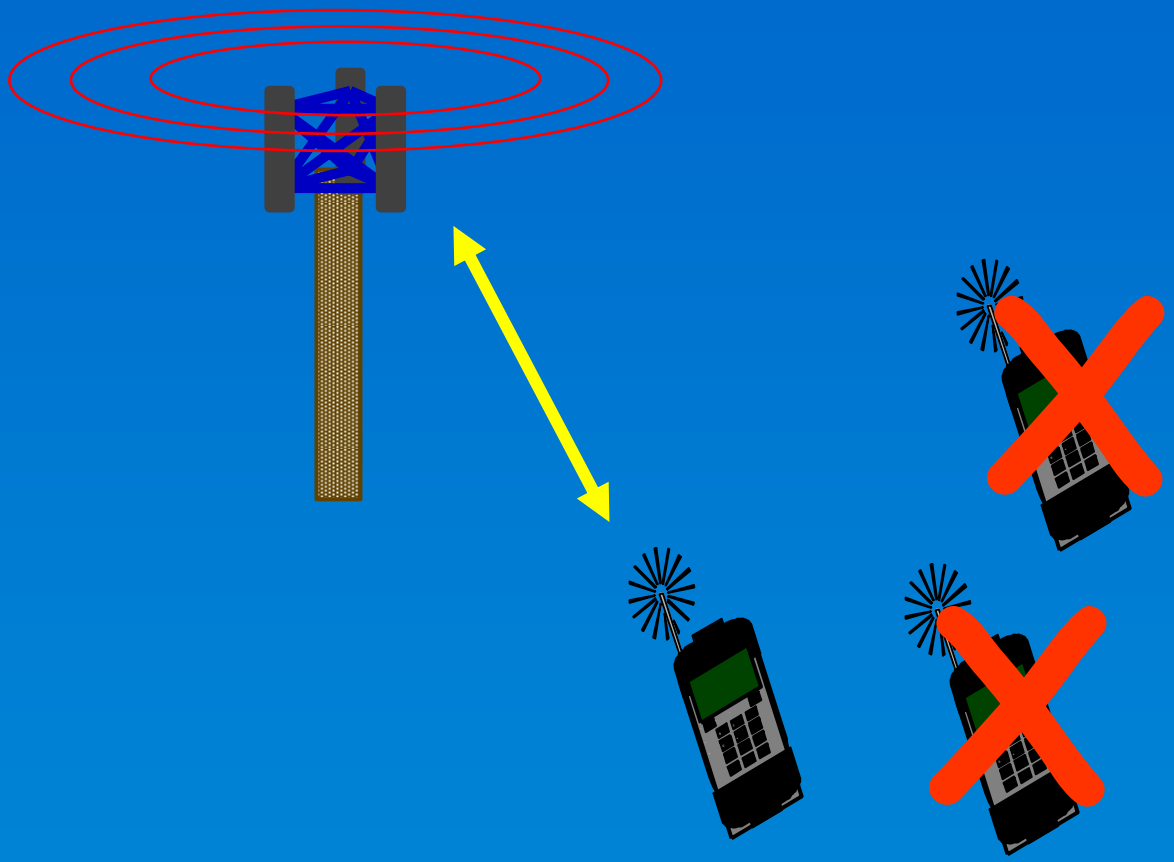


All mobiles in a cell receive the same message from the base station

CBCH

- Mobiles can receive SMS messages in IDLE and DEDICATED modes:
- Cell Broadcast Channels (CBCH's) are part of CCCH so IDLE state mobiles can receive SMS.
- FACCH sets up SMS send and acknowledge. SACCH carries data for mobiles in DEDICATED mode.

SMS Point to Point

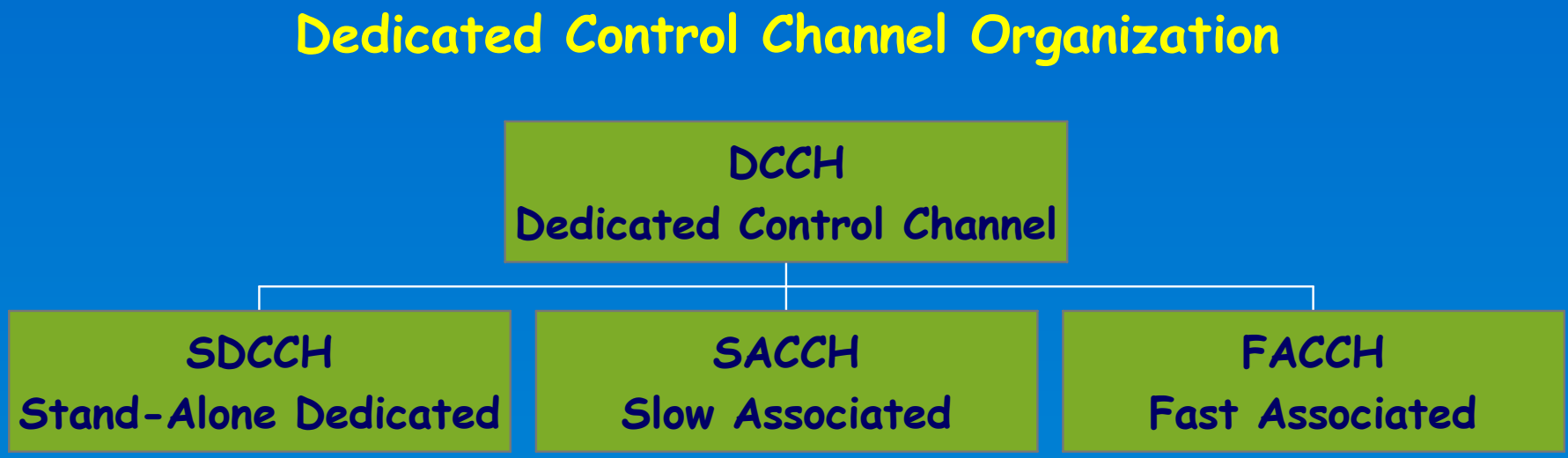


Only a single mobile in a cell receives the message from the service center

SMS Point to Point

- This is a message that comes to a particular user, from a service center, or to the service center from the user.
- Sent and Received as data on the TCH as a call.
- Send and Receive transparent to the user.

DCCH - subchannels



GSM SDCCH

Stand Alone Dedicated Control Channel

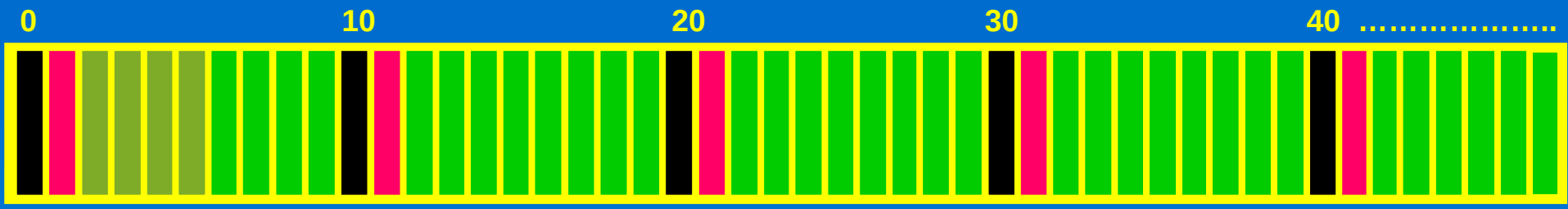
Used during Call Setup

Stepping Stone between BCH and TCH

Used for Authentication

BCH Organization

Timeslot



FCCH

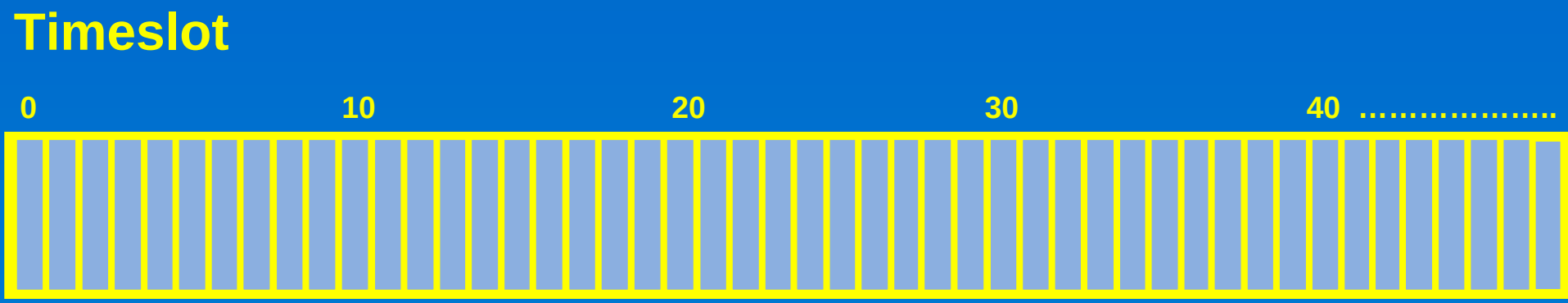
SCH

BCCH

CCCH

DOWNLINK

BCH Organization



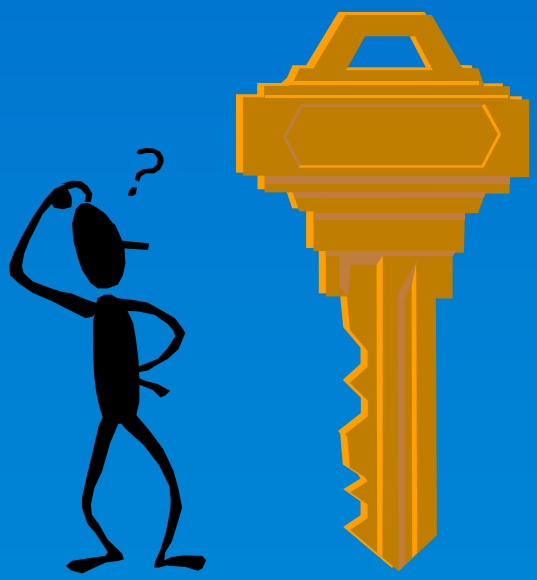
RACCH

UPLINK

GSM RACH

Random Access Channel

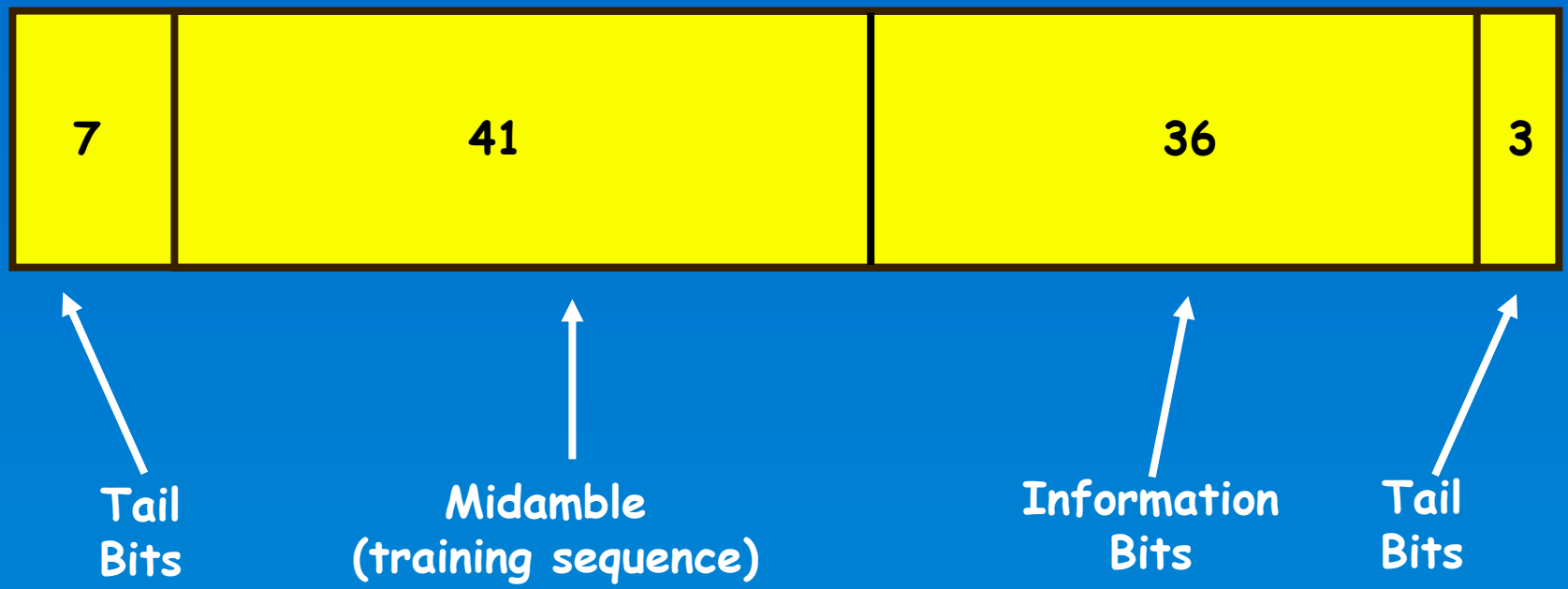
Used by the mobile to get attention



SHORT BURST

Mobile sends normal burst after getting Timing Advance

Frame Format - RACH



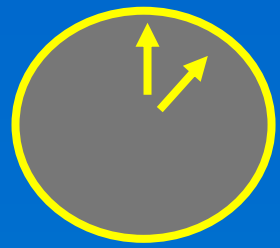
DRX

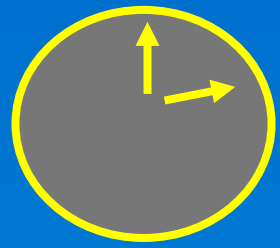
ZZZzzzzzz

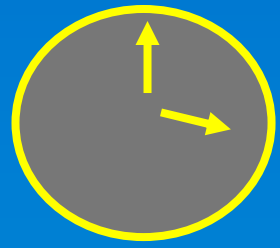
ZZZzzzzzz

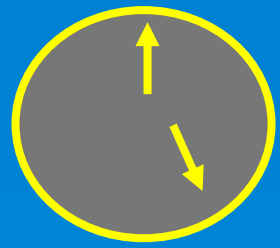
ZZZzzzzzz

Look for Pages









DRX

- Only looks for pages during its assigned ‘Paging Group’
- Paging Group is a function of the mobile IMSI
- Reduces power consumption as receiver can ‘sleep’ between pages

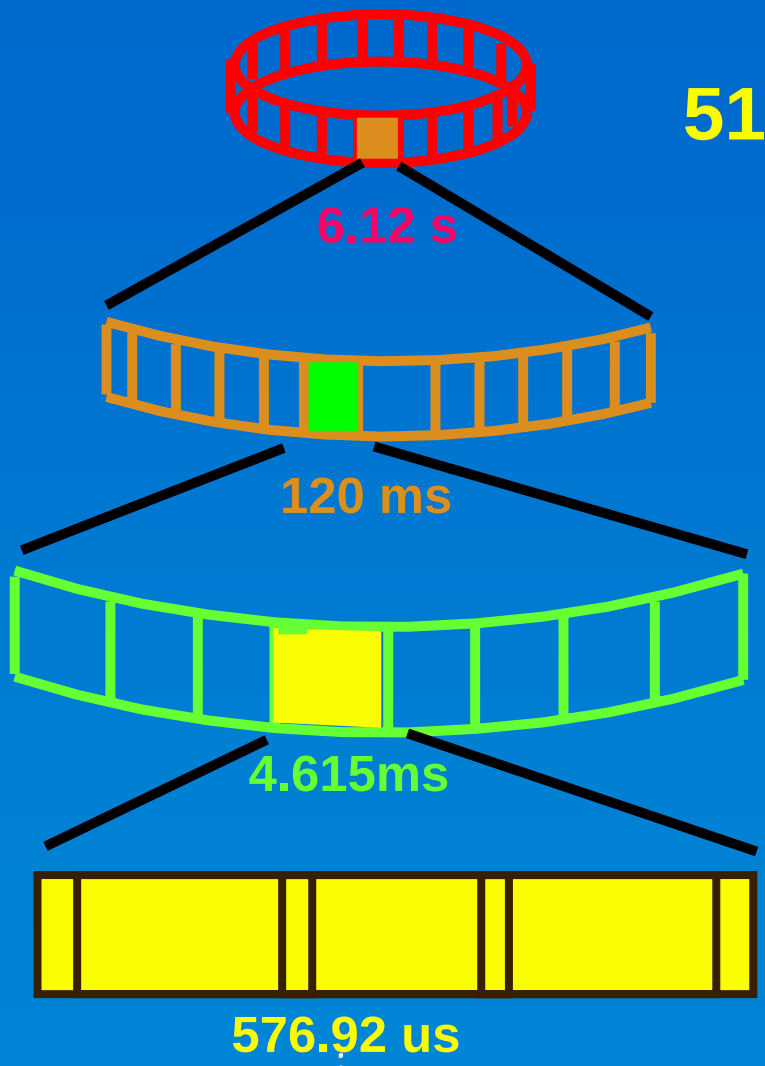
GSM TCH Frames

Agilent Technologies

TCH - Frames

Super-frame

51 Multiframes



Multi-frame

26 Frames

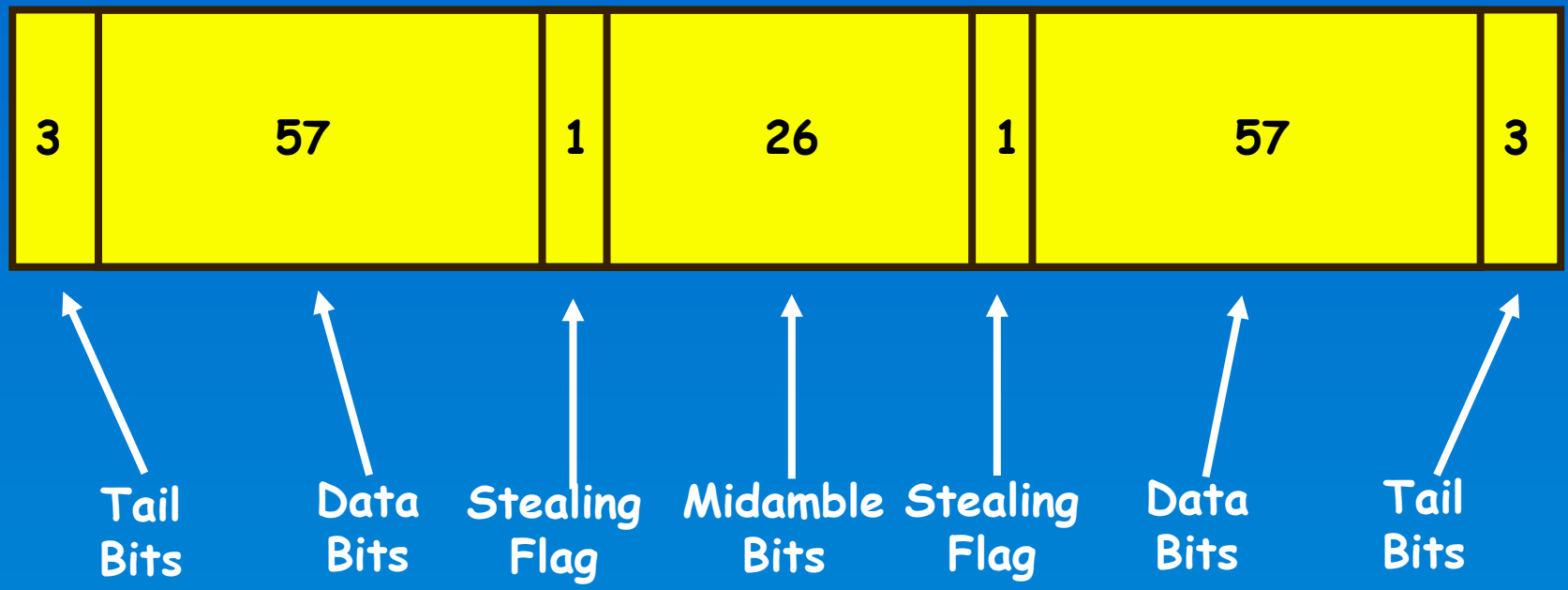
Frame

8 Timeslots

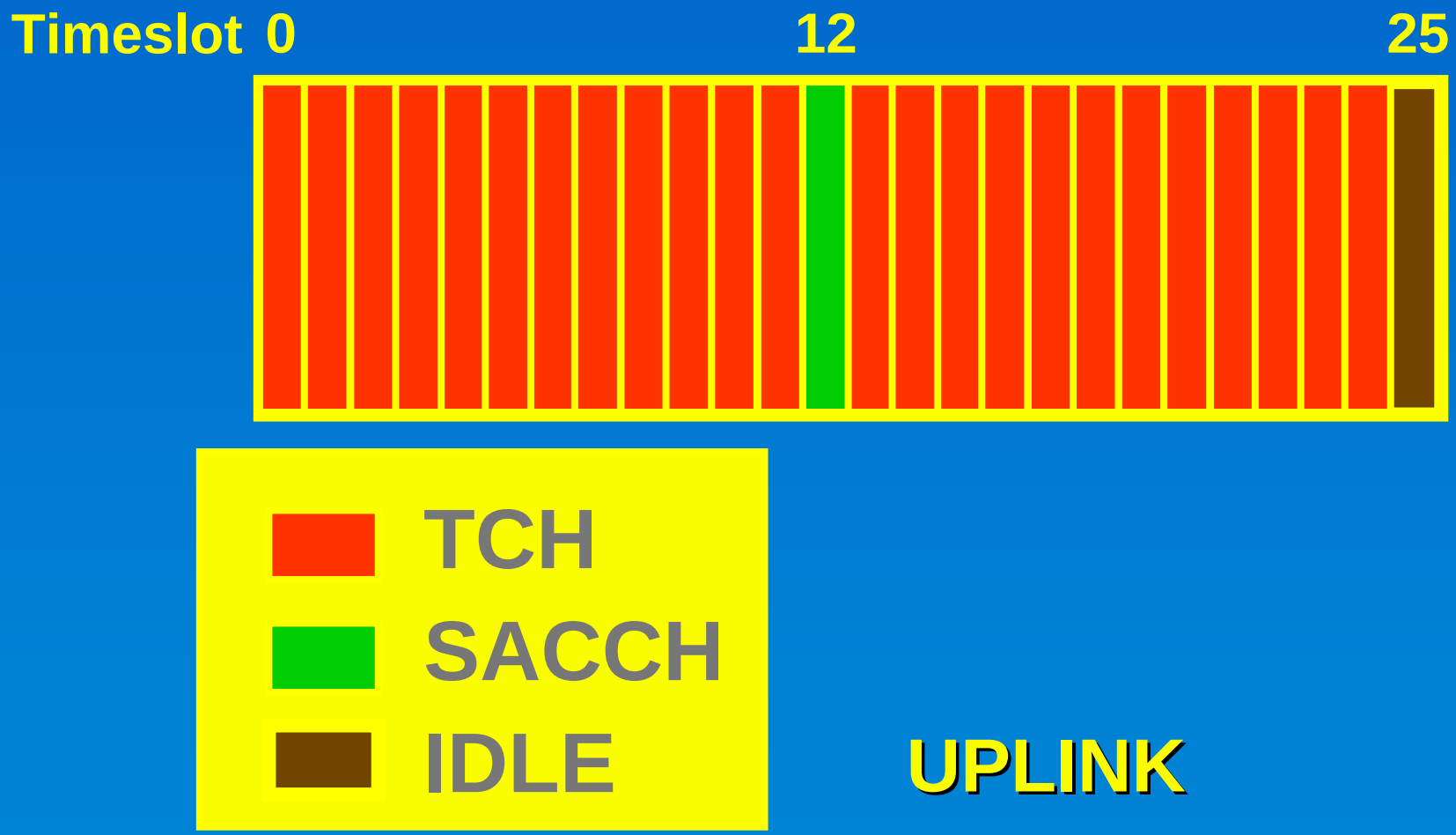
Timeslot (normal burst)

156.25 Bits

Frames format - TCH

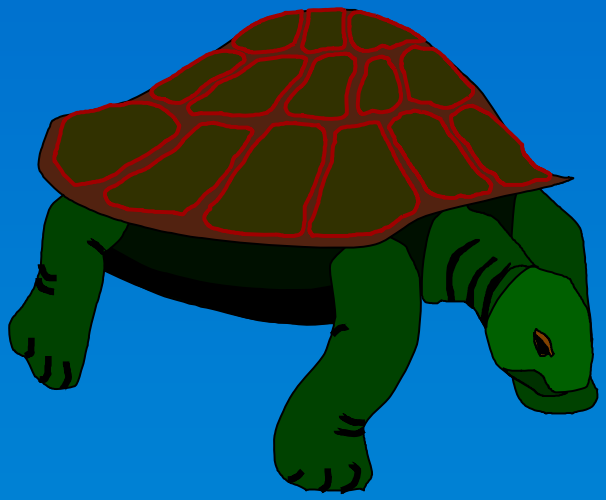


TCH Organization



GSM SACCH

Slow Associated Control Channel



DOWNLINK

- Mobile Tx Power Commands
- Mobile Timing Advance
- Cell's Channel Configuration

UPLINK

- RXQual report
- RXLev report

GSM SACCH Timeout

Slow Associated Control Channel

SACCH delivers RxQual and RxLev, which starts Radio_Link_Timeout counter. If no reports within this timeout period, then the call is dropped.

SACCH

DOWNLINK	*UPLINK*
* Timing	* Adjacent BCH
* Power Ctrl.	* Channel Power
* Call configuration	* Rx Level
* Hopping frequency	* Rx Qual.

GSM FACCH

Fast Associated Control Channel

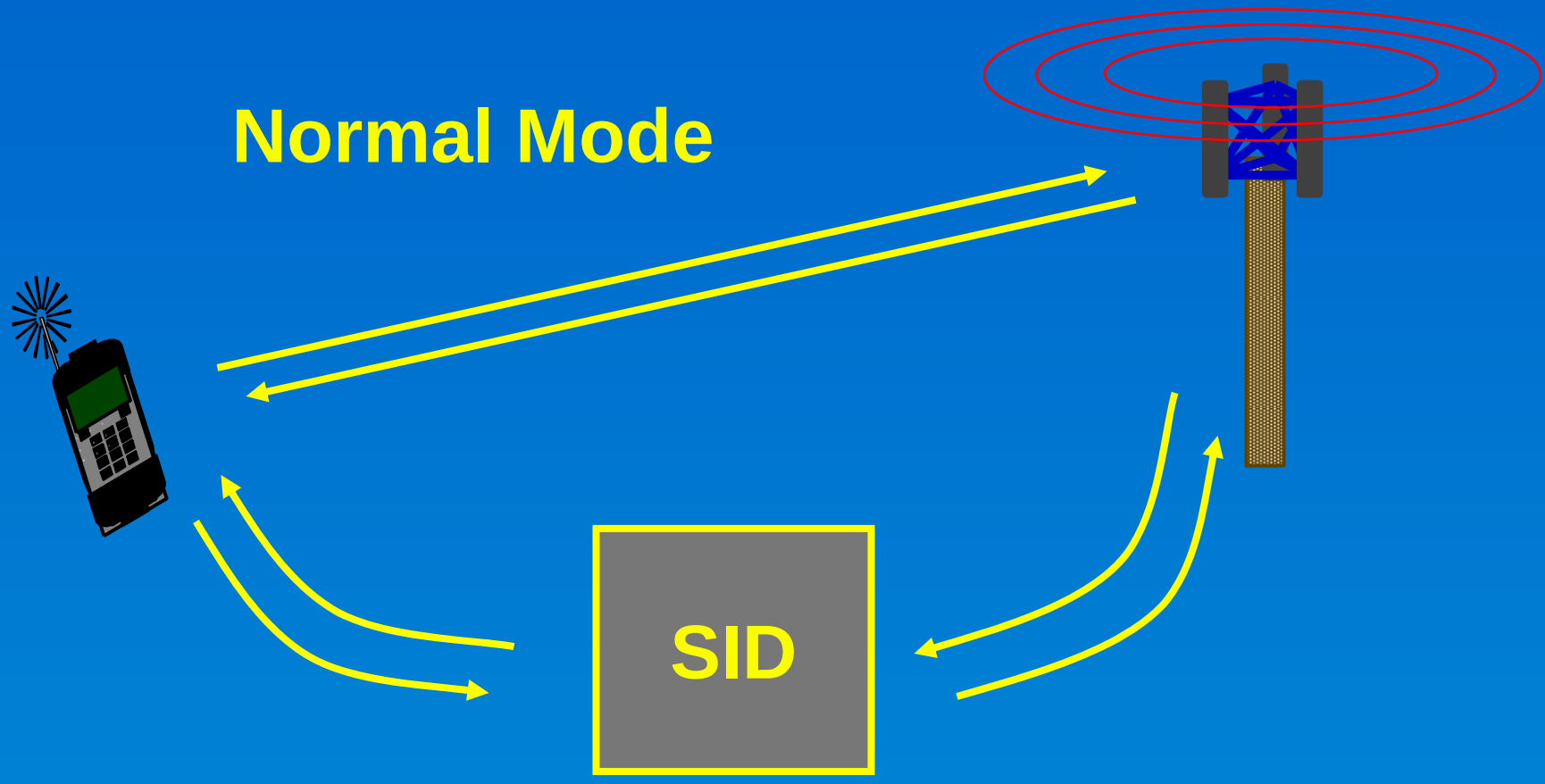
Used by BS and MS to send large amounts of data FAST

Hand-offs

Set Stealing Flags

DTX

Normal Mode



Discontinuous Mode

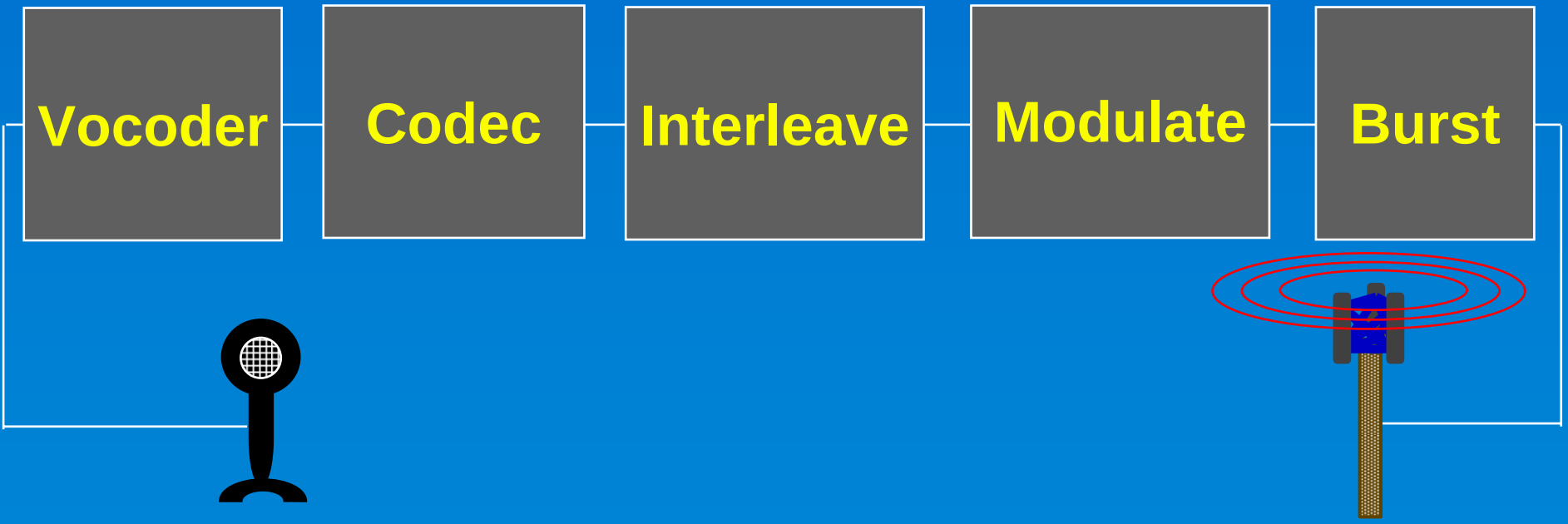
DTX

- Instead of transmitting useless background noise, the mobile sends Silence Descriptor Frames (SIDs)
- Reduces the power consumption by the mobile
- Reduces the noise in the Spectrum for other users

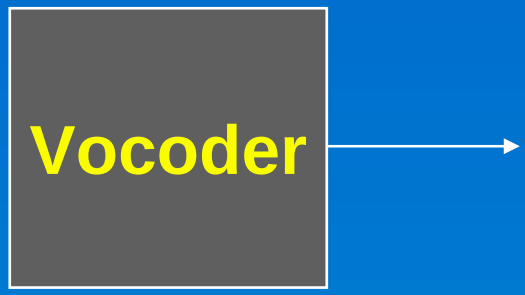
GSM Signal Path

Agilent Technologies

GSM Voice Path



GSM Vocoder



20ms Speech makes 260 Bits

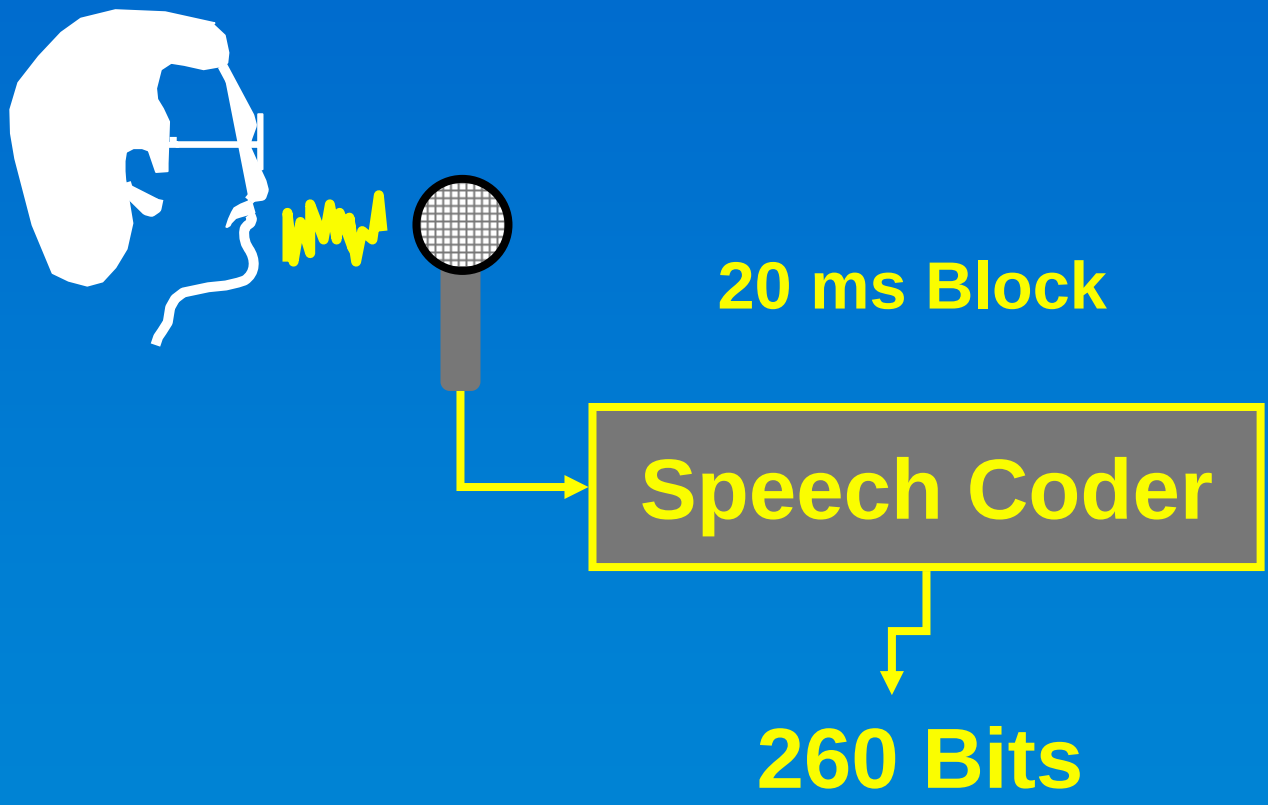
Output 13 kbit/s

3 Classes of bits output

RELP - Residually Excited Linear Predictive

LTP - Long Term Predictive

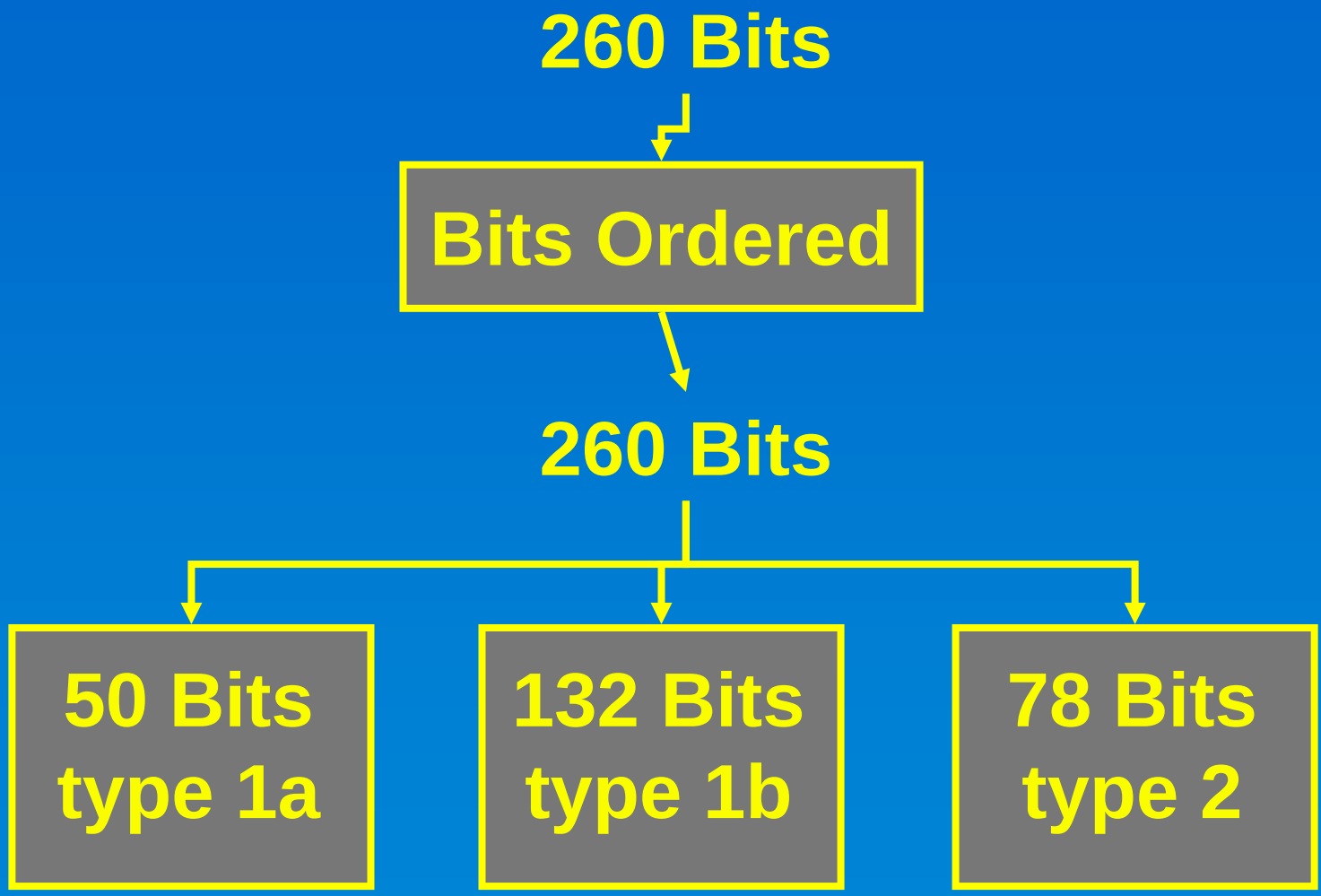
Speech Coder



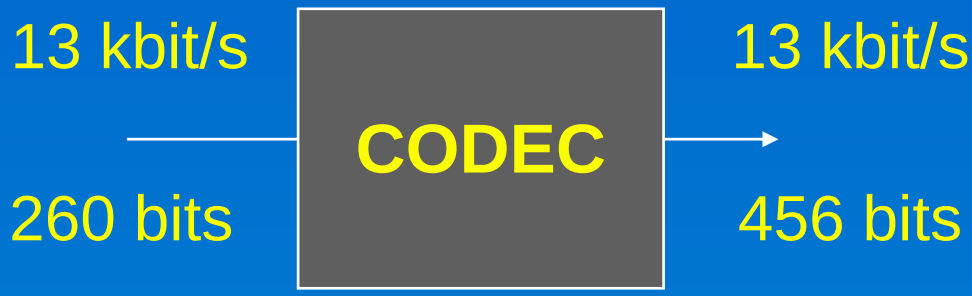
Speech Coder

- LongTerm Prediction
- Linear Predictive Coding
- ADPCM - Adaptive PCM
- MOS - Mean Opinion Scoring

Speech Coder



GSM Codec



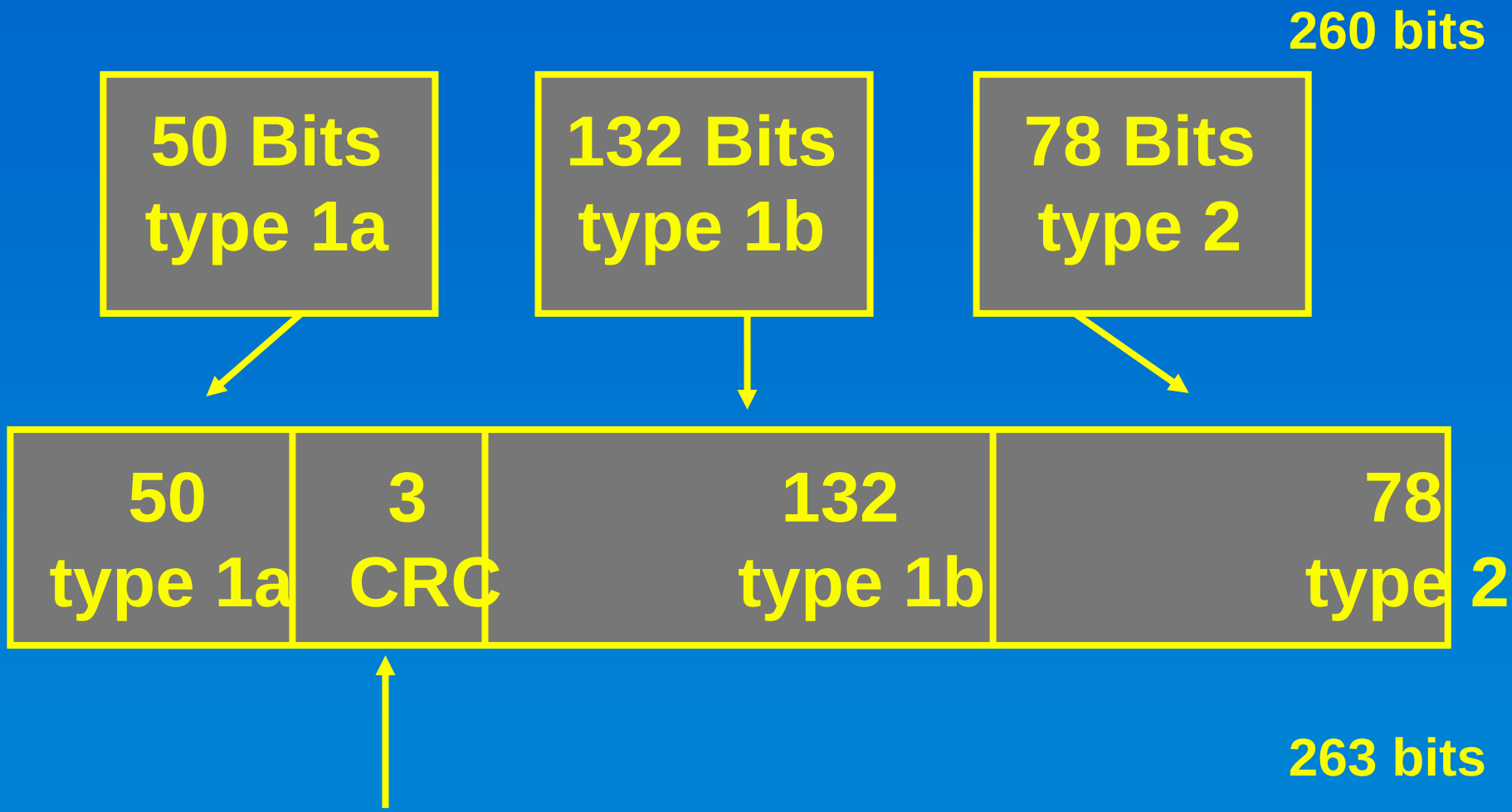
3 classes of error correction

Class 1a bits: Error Correction and CRC bits

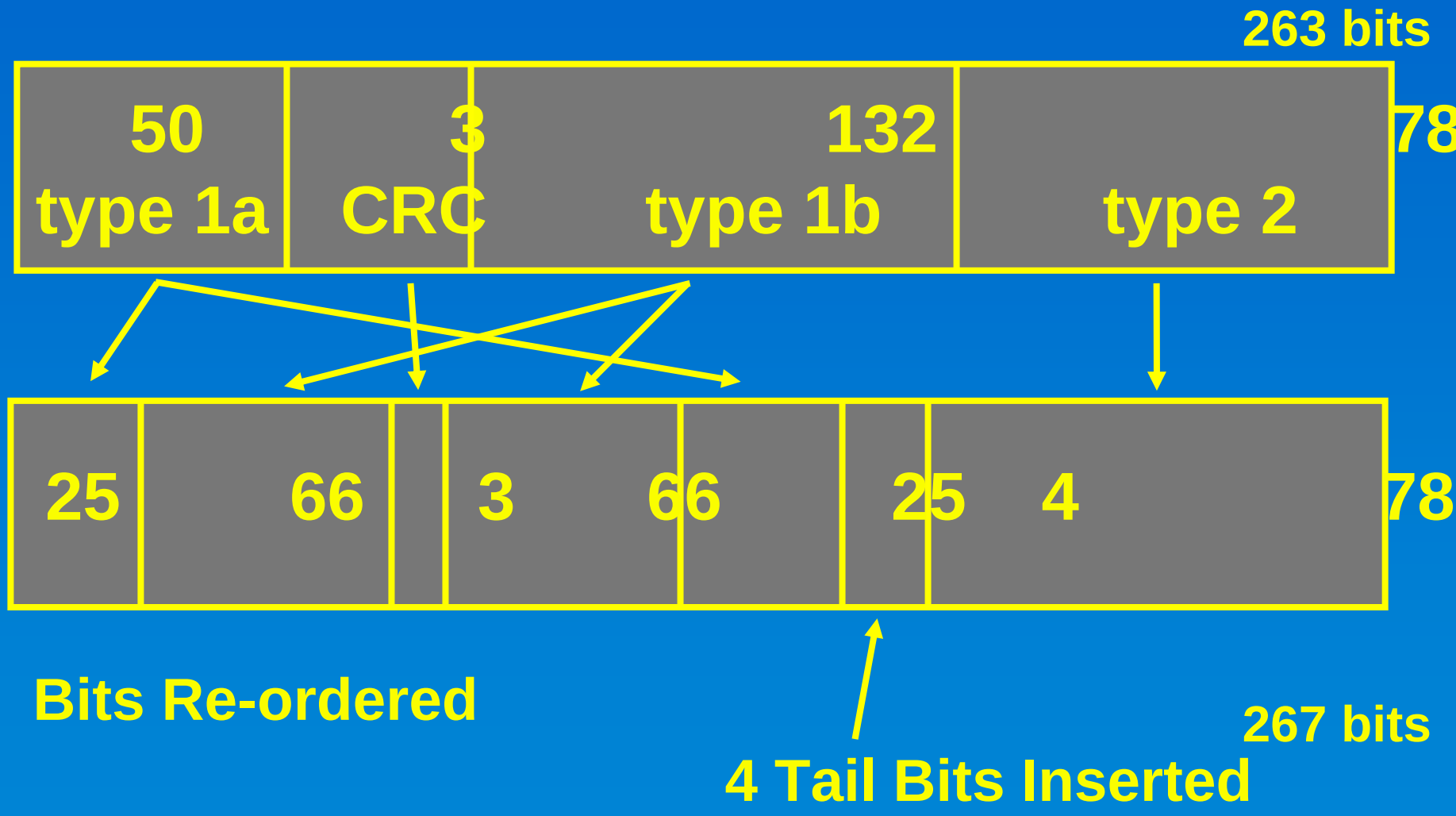
Class 1b bits: Error Correction only

Class II bits: No Error Correction

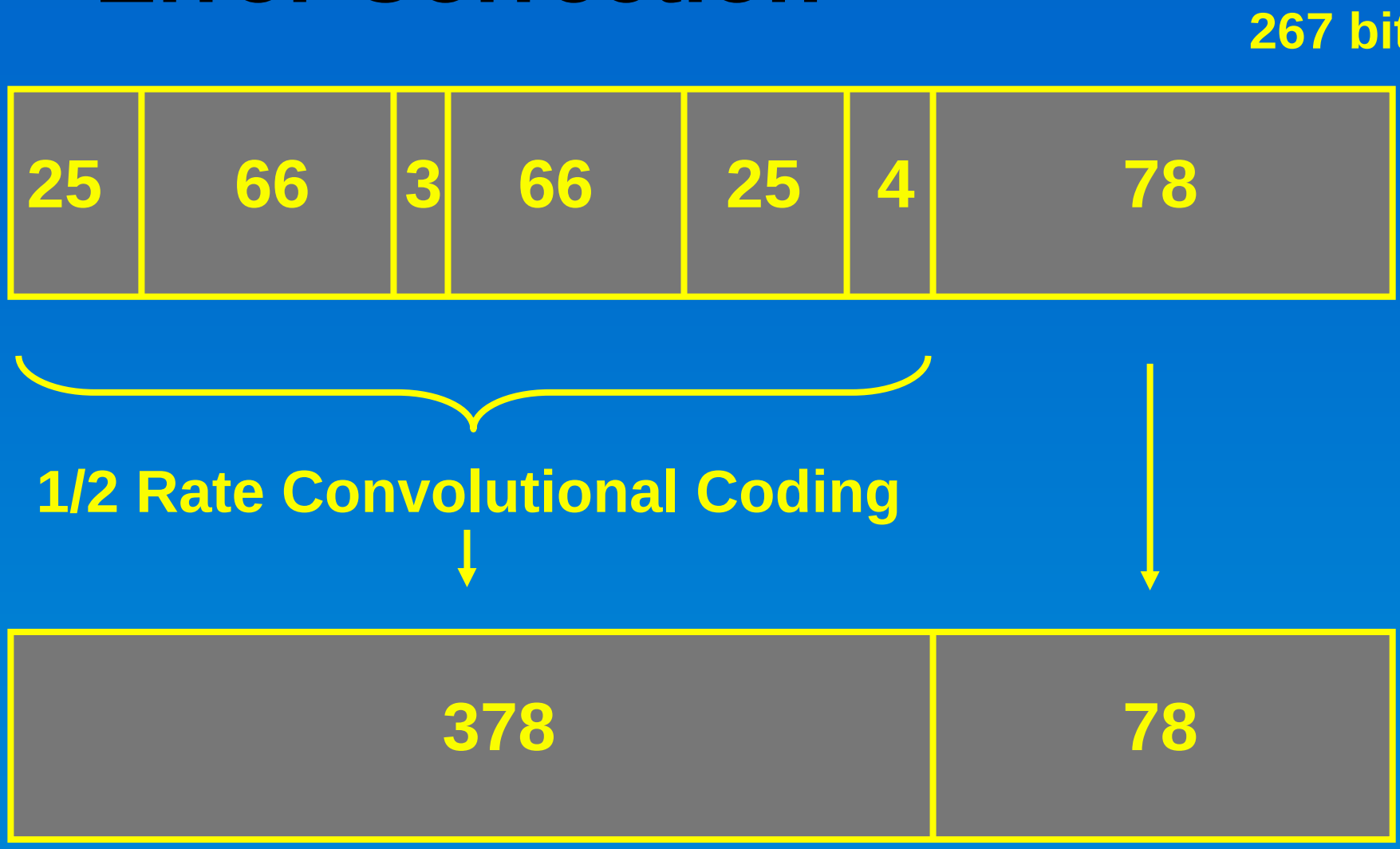
Error Correction



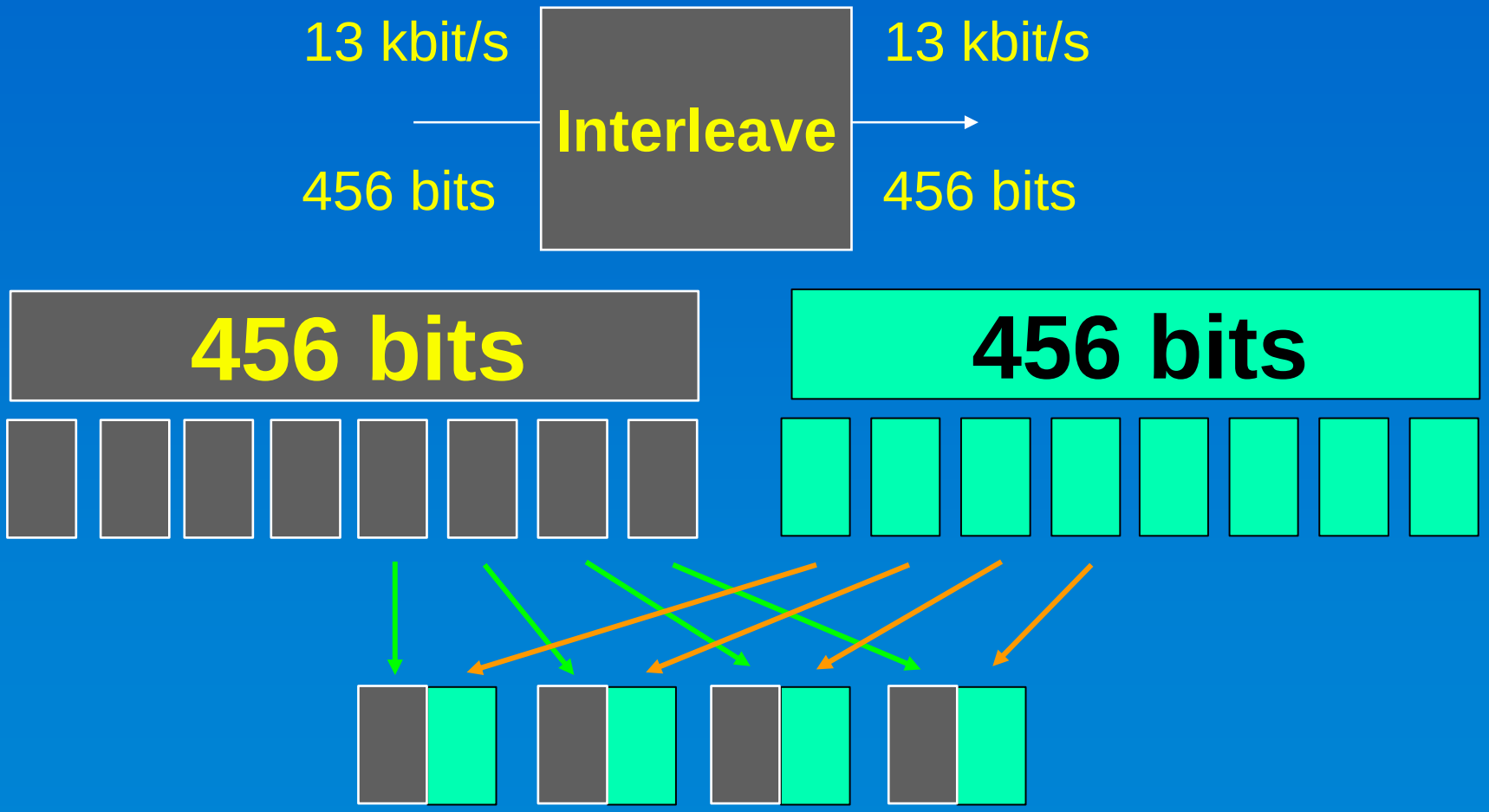
Error Correction



Error Correction



GSM Interleave



Diagonal Interleaving

- TCH Bursts carry two 57 bit blocks
- 120ms of speech = 456 x 6 = 2736 bits
- 2736 / 114 = 24 bursts needed to transmit
- TCH Multiframe is 26 frames and 120ms

- Now have 2 spare bursts:
- Use one for the SACCH

CRC

- Capable of correcting single errors

× Not able to correct multiple bit errors

Coding: Channel Types

TCH/F *different classes & coding*

260 in, 456 out Parity (3 bits)

Convolution 1/2

TCH/F9.6 (data)

240 in, 456 out Convolution 1/2

punctured 1/15 bit

Coding: Channel Types

TCH/F4,8 (data) + 32 null bits

120 in, 456 out Convolution 1/3

TCH/F2.4 (data)

72 in, 456 out Convolution 1/6

Coding: Channel Types

SCH (control) Parity 10 bits

25 in, 78 out Convolution 1/2

RACH (control) Parity 6

8 in, 36 out Convolution 1/2

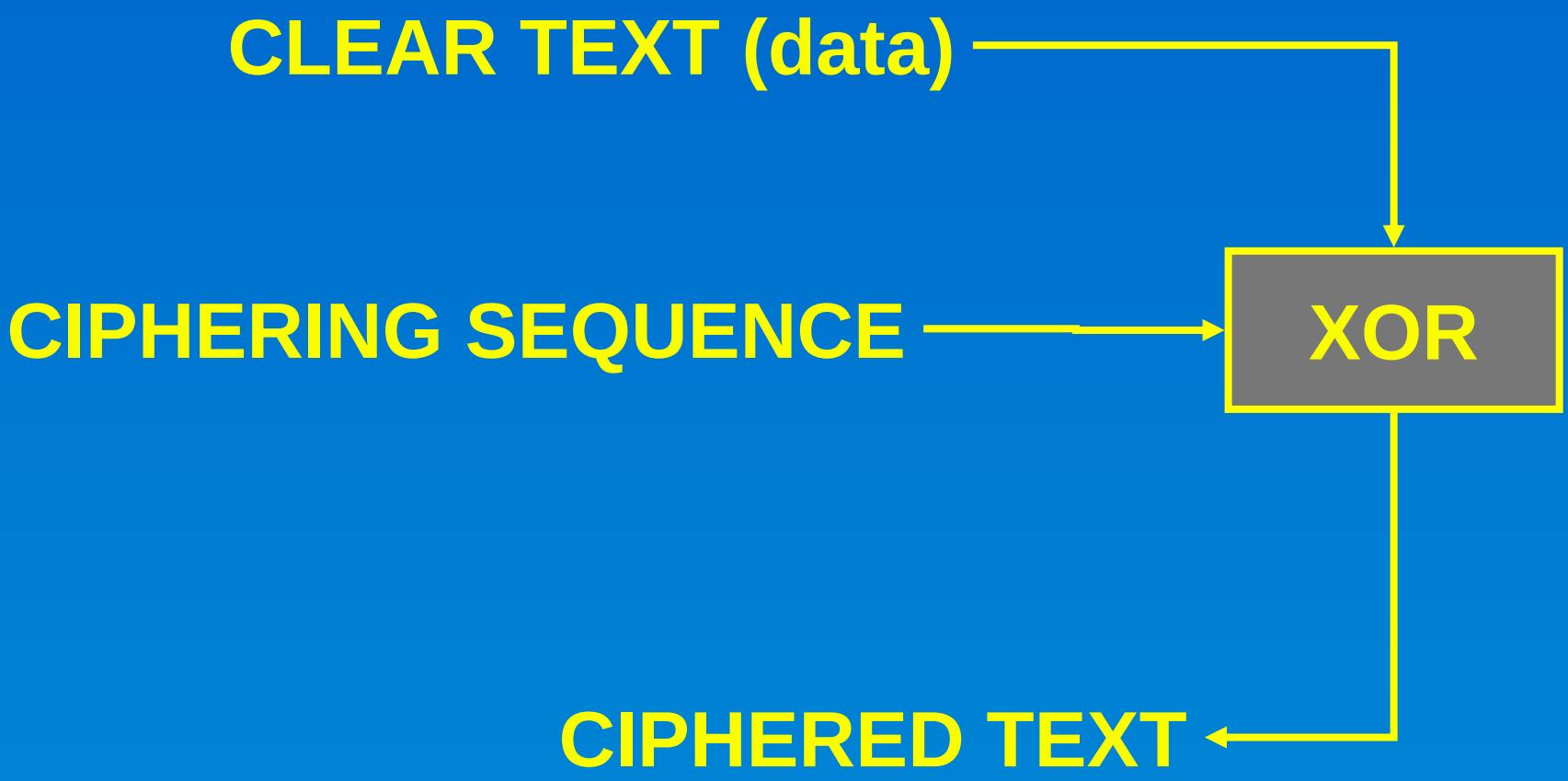
FACCH (control) Firecode 224/184

184 in, 456 out Convolution

Interleaving: Channel Types

TCH/F	8 half-bursts
TCH/F9.6 portions	22 unequal
TCH/F4.8 portions	22 unequal
TCH/F2.4	8 half-bursts
SCH (control)	1 S burst
RACH (control)	1 Access burst
FACCH (control)	8 half-bursts

Ciphering



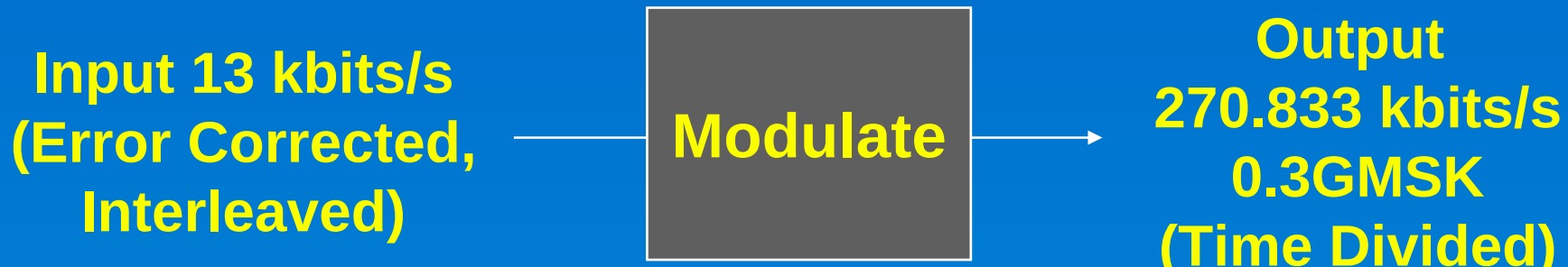
Ciphering

Clear Text	**0 1 0 0 1 0 1 1 1 0 0 1 . . .**
Cipher Sequence	**0 0 1 0 1 1 0 0 1 1 1 0 . . .**
XOR	
Ciphered Text	**0 1 1 0 0 1 1 1 0 1 1 1 . . .**

Ciphering

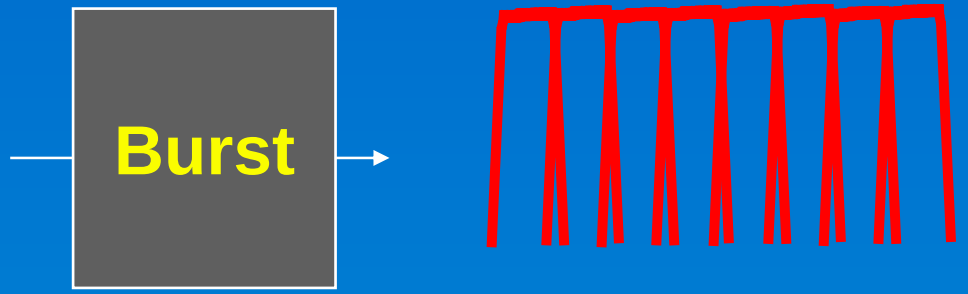
- BS Controls if active or not
- After Interleaving, before Burst Building
- Very tightly controlled algorithms
- Requires K_i Cyphering Key from HLR
- Similar to techniques used by DOD

GSM Modulate



GSM Burst

Input
270.833 kbits/s
0.3GMSK
(Time Divided)



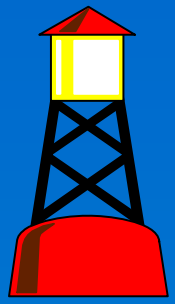
270.833 kbits/s
Output 0.3GMSK
(bursted)

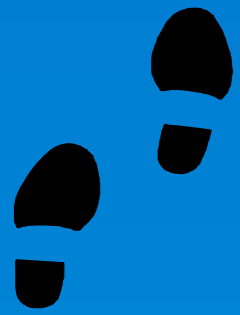
GSM Protocols

Agilent Technologies

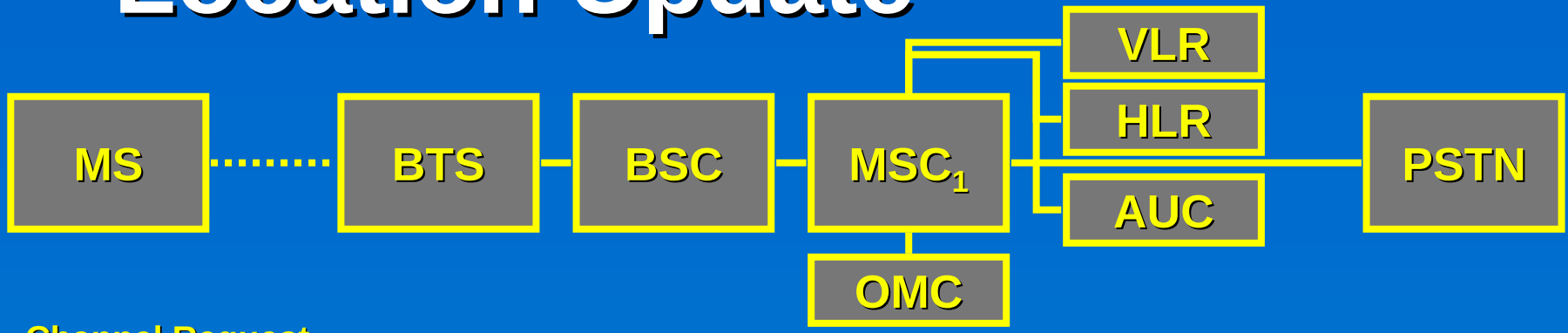
Mobile Turn-On

- Mobile Searches for Broadcast Channels (BCH)
- Synchronizes Frequency and Timing
- Decodes BCH sub-channels (BCCH)
- Checks if Network Allowed by SIM
- Location Update
- Authentication





Location Update



Channel Request

Immediate Assignment

Location Update Request

Location Updating Request

Authentication Request

Authentication Response

Cipher Mode Command

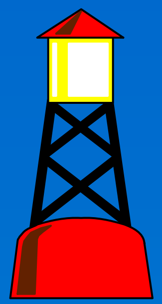
Cipher Mode Complete

Location Updating Accept

IMSI Attach

- Forced Location Update on Power On
- Only if LAC on SIM is different
- Forced Location Update on Power Off

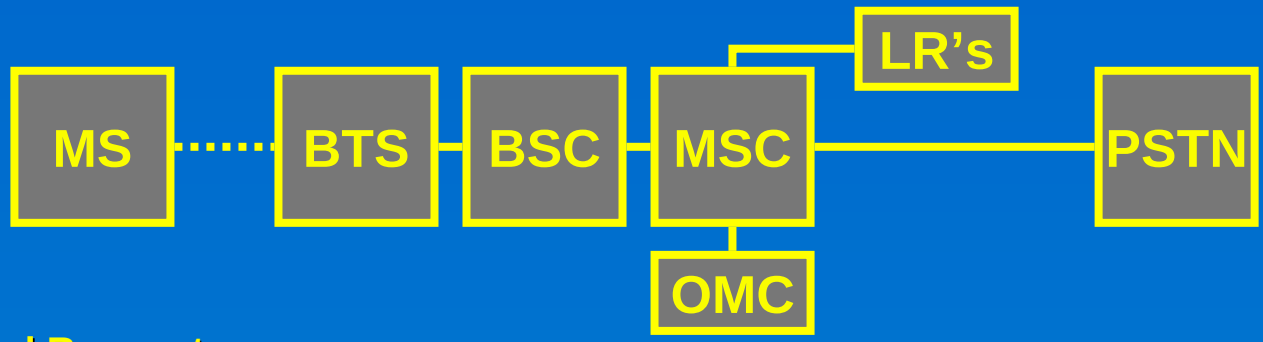
Mobile Originated Call



- Mobile Sends RACH
- Channel Assignment Posted on BCH (AGCH)
- Mobile and Base Station communicate on SDCCH

- Authentication
- Mobile Assigned to Traffic Channel (TCH)
- Speech Data sent and received

Mobile Originated Call (1)



Channel Request

Immediate Assign to DCCH

Asynchronous Mode

Unnumbered Acknowledge

Set-up Indication

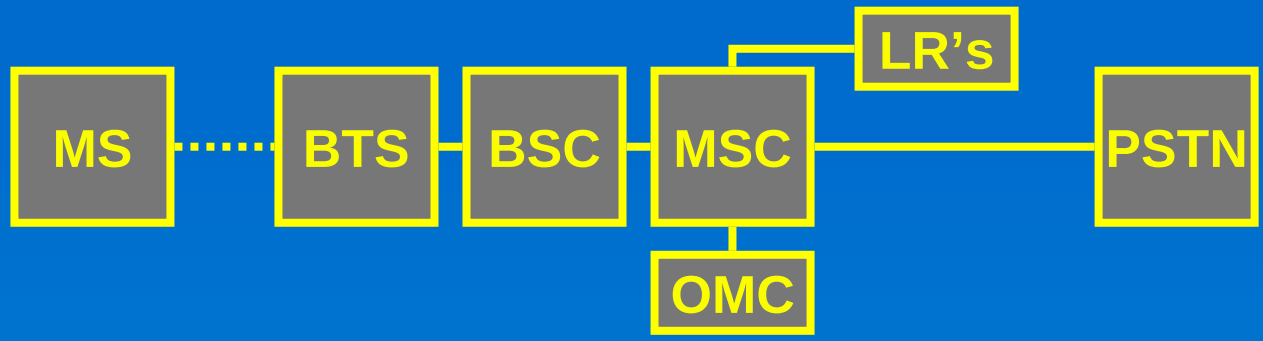
Authentication Request

Authentication Response

Cipher Mode

Cipher Mode Complete

Mobile Originated Call (2)



Call Set Up

Assign Command

Assign Complete

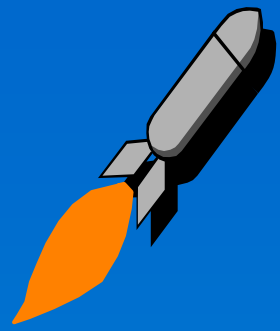
Alert (Ringing)

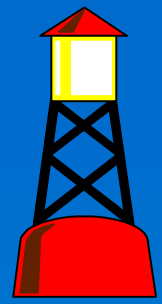
Call Connect

Speech

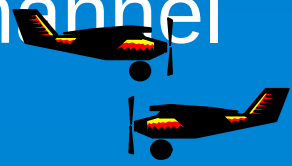
Speech

Mobile Terminated Call

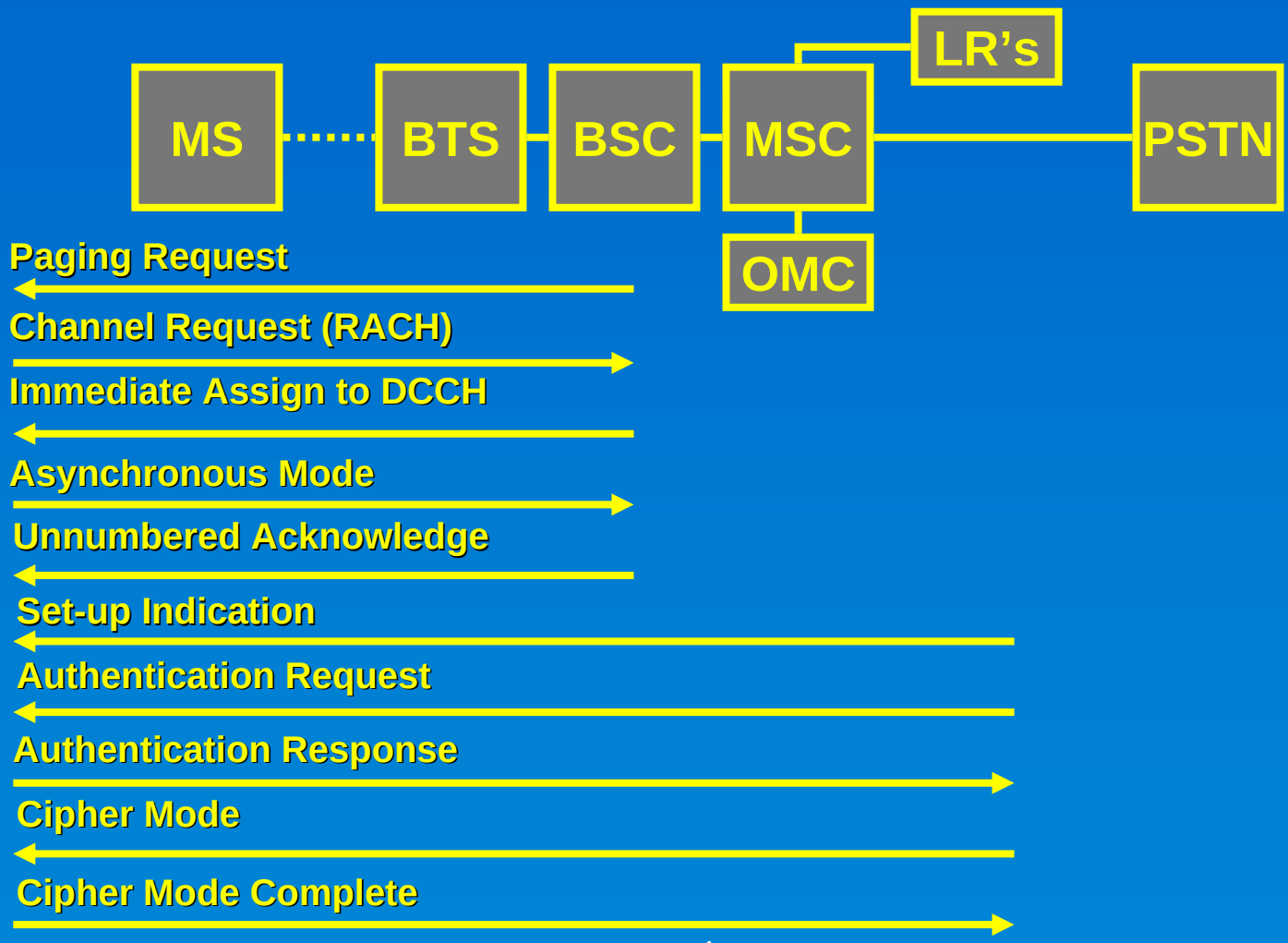




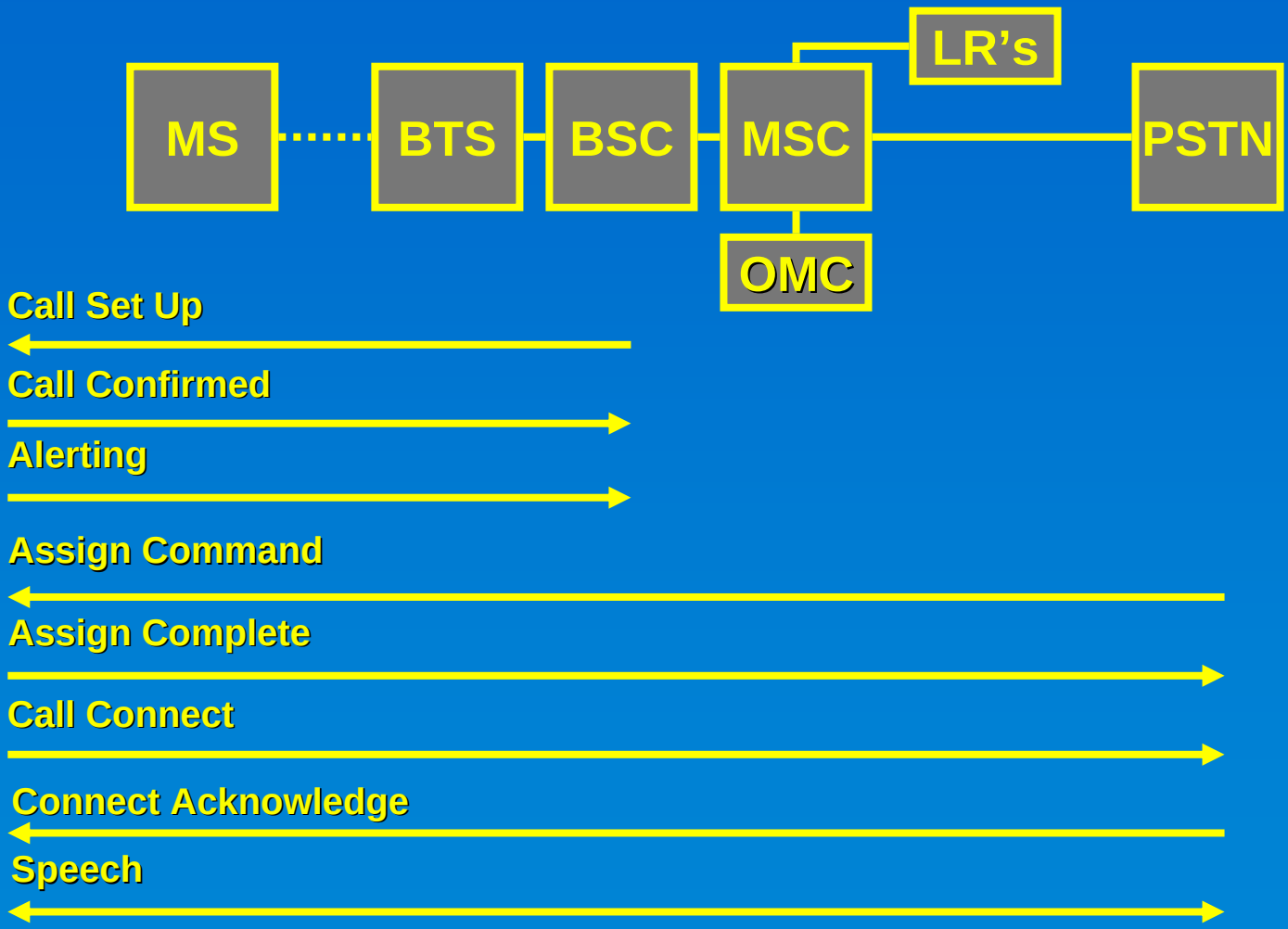
- Mobile Sees Page
- Mobile Sends RACH
- Channel Assignment Posted on BCH (AGCH)
- Mobile and Base Station communicate on SDCCH
- Authentication
- Mobile Assigned to Traffic Channel (TCH)



Mobile Terminated Call (1)



Mobile Terminated Call (2)



Mobile Handoff

Hand-over required

Start of path establishment

End of path establish and hand over command to MS

Allocation and activation of radio channel

Hand-over command to MS

MS has accessed cell B

Release of Path