



Lecture no: **11**

GSM and WCDMA

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Contents

- (Brief) history of mobile "telephony"
- Global System for Mobile Communications (GSM)
- Wide-band Code-Division Multiple Access (WCDMA)



HISTORY OF MOBILE "TELEPHONY"

HISTORY

The short version



- 1959 - First automatic mobile telephony system in Stockholm. 'The Phone' weighs 40 kg and costs as much as a car.
- 1981 - NMT (Nordic Mobile Telephony) starts in the nordic countries and Saudi Arabia.
- 1989 - First GSM-system (Global System for Mobile Telephony) starts in Germany.
- 2001 - First WCDMA-system (Wide-band Code-division Multiple Access) starts in Japan.
- 2009 - First LTE (Long-term Evolution) service launched in Stockholm and Oslo.

HISTORY

Generations



1G Analog technology.
Examples are NMT in the nordic countries and AMPS in North America.

No data communication.



We focus on these here

2G Digital technology.
Examples are GSM (first in Europe) and CdmaOne in North America.

Slow data communication.
New enhancements have increased datarate to 50-100 kbit/sec.



3G Digital technology.
Examples are WCDMA (Europe) and Cdma2000 (North America).

Focus on both speech and data/multimedia.
Initially up to 2 Mbit/sec. Usually up to 10-15 Mbit/sec.



4G Digital technology.
LTE (Advanced). Early versions sometimes called 3.9 G

Focus on data and multimedia.
Initial datarates up to 100 Mbit/sec. Evolving to 1 Gbit/sec.

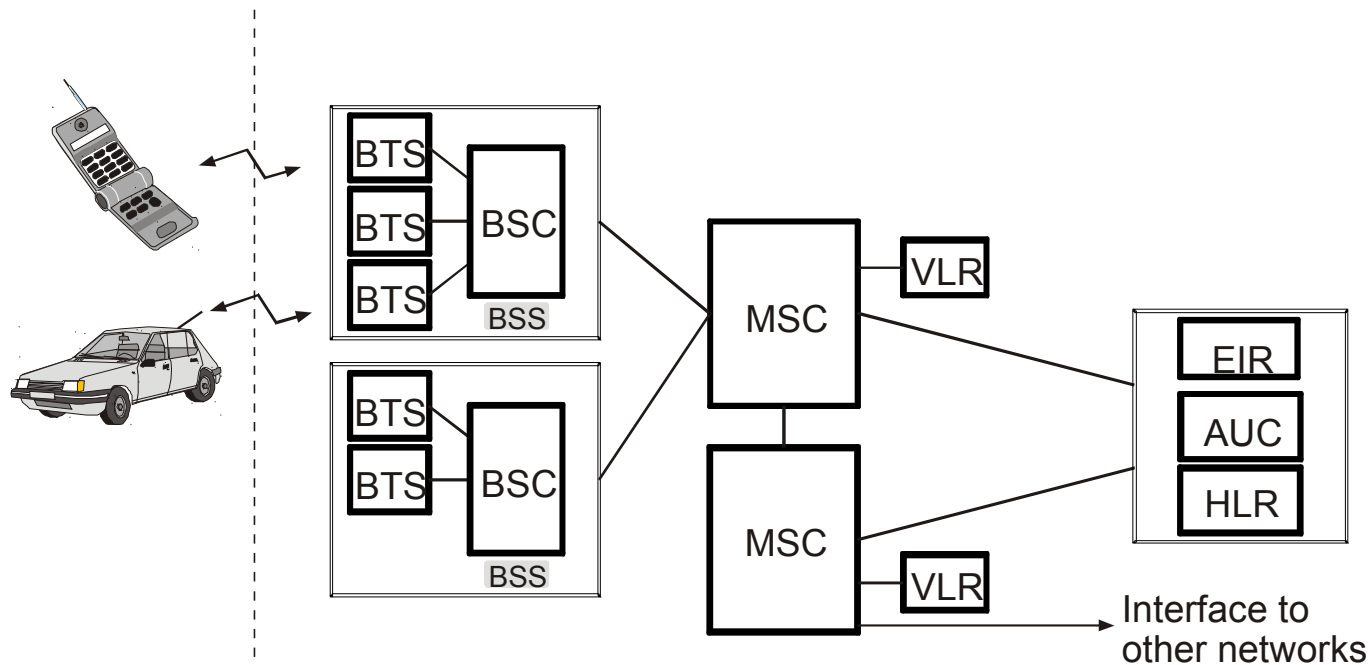




GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS (GSM)

GSM

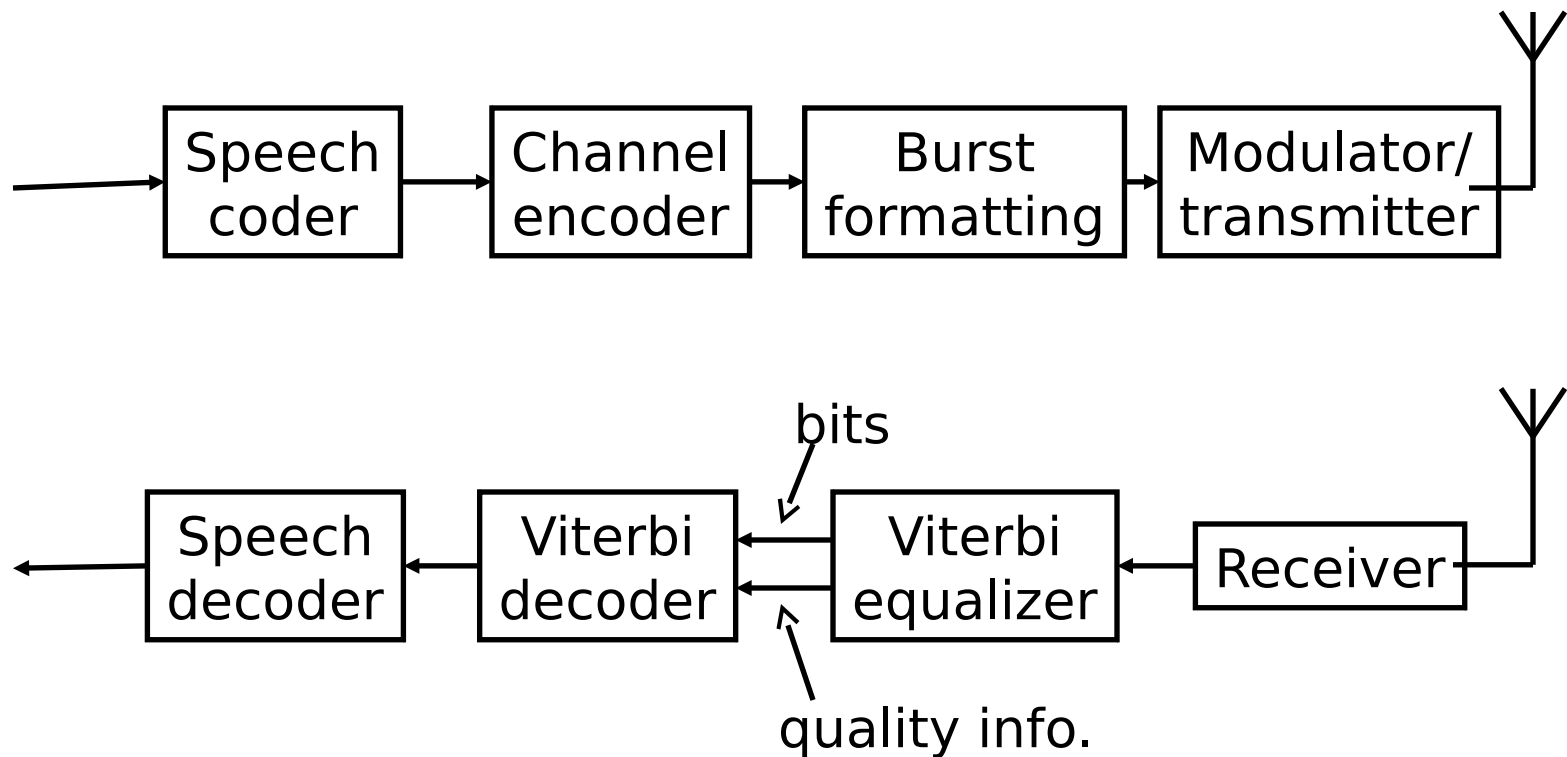
Simplified system overview



BTS	Base Transceiver Station	VLR	Visitor Location Register
BSC	Base Station Controller	EIR	Equipment Identity Register
BSS	Base Station Sub-system	AUC	Authentication Center
MSC	Mobile Switching Center	HLR	Home Location Register

GSM

Simplified block diagram



(Encryption not included in figure)

GSM

Some specification parameters



Frequency band:	890 - 915 MHz (uplink)
(frequency duplex)	935 - 960 MHz (downlink)
Channel spacing:	200 kHz
Modulation:	GMSK
System data rate:	271 kb/s
TDMA Frame:	4.6 ms
Time slots:	8 x 0.58 ms
Data rate (full-rate traffic channel):	22 kb/s
Speech coder:	Regular Pulse Excited LPC-LTP 13 kb/s
Diversity:	Channel coding Interleaving Frequency hopping Channel equalization

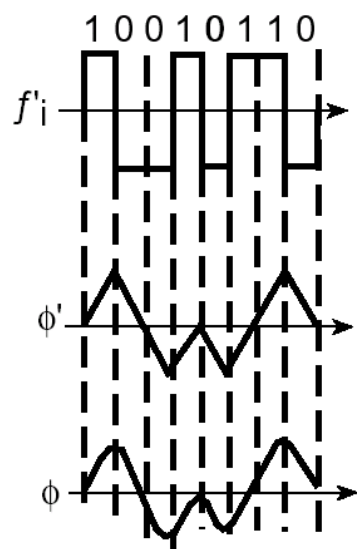
(initial specification)

GSM

GMSK modulation

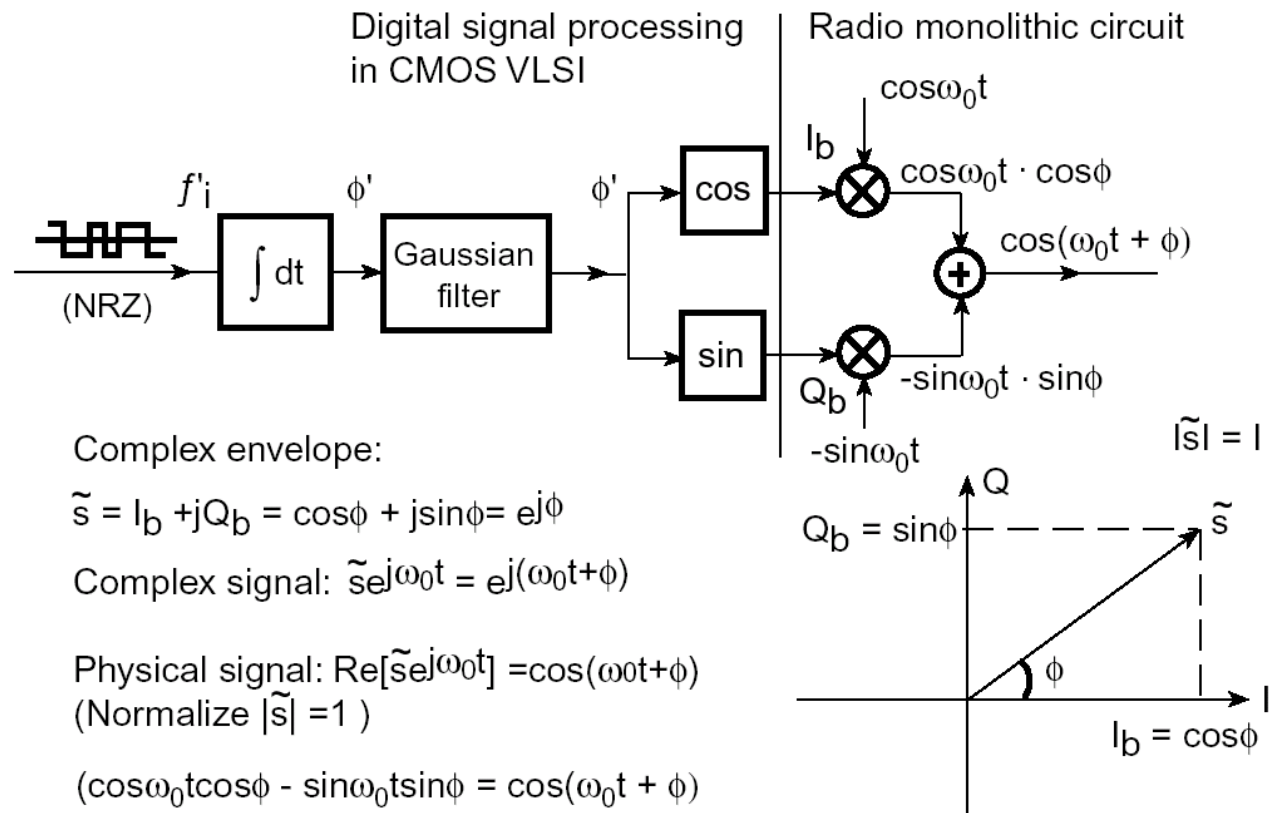


GMSK modulator (GMSK = Gaussian-filtered Minimum Shift Keying)
MSK interpreted as QAM (Complex signal representation)



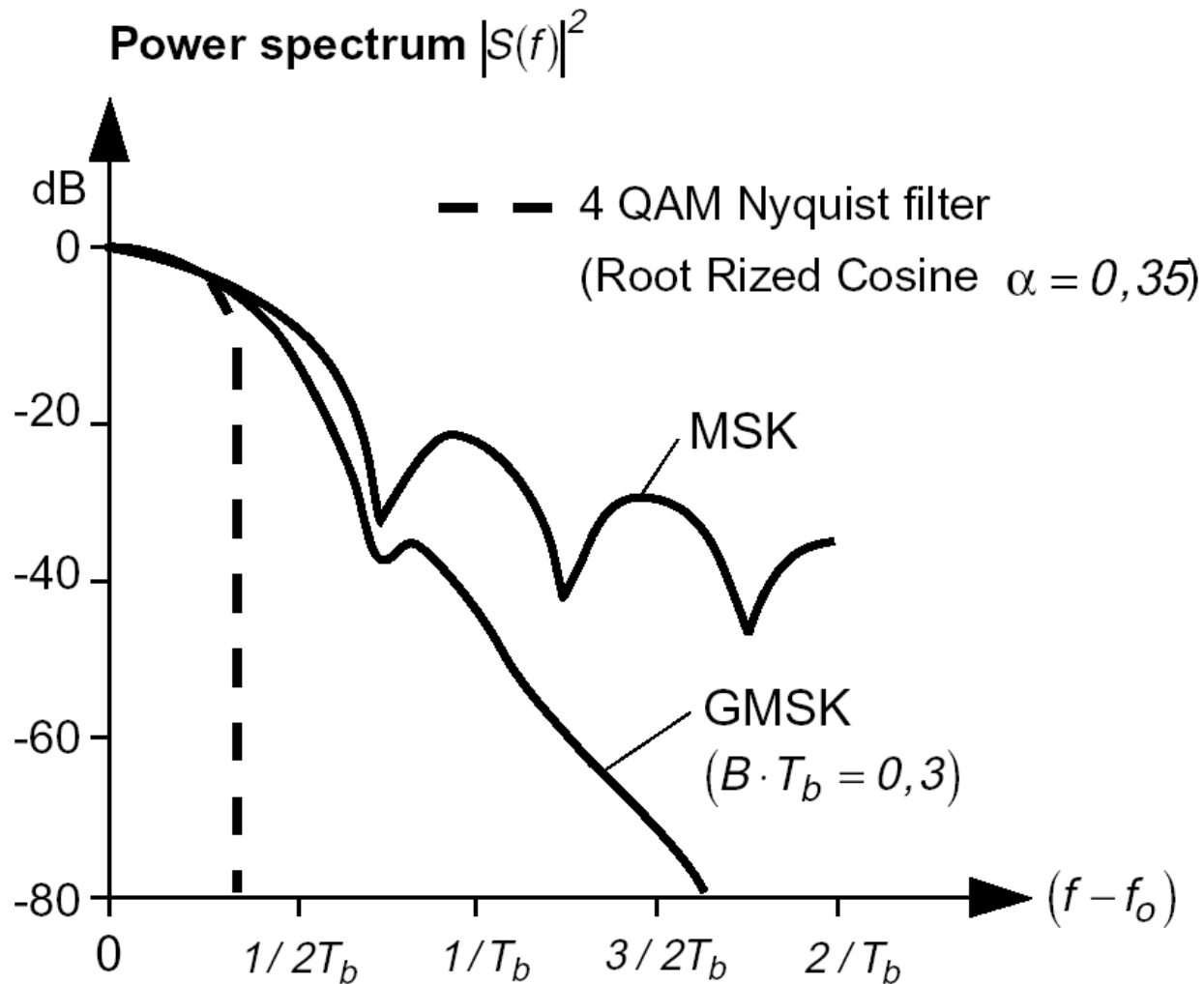
ϕ' corresponds to MSK

ϕ corresponds to GMSK

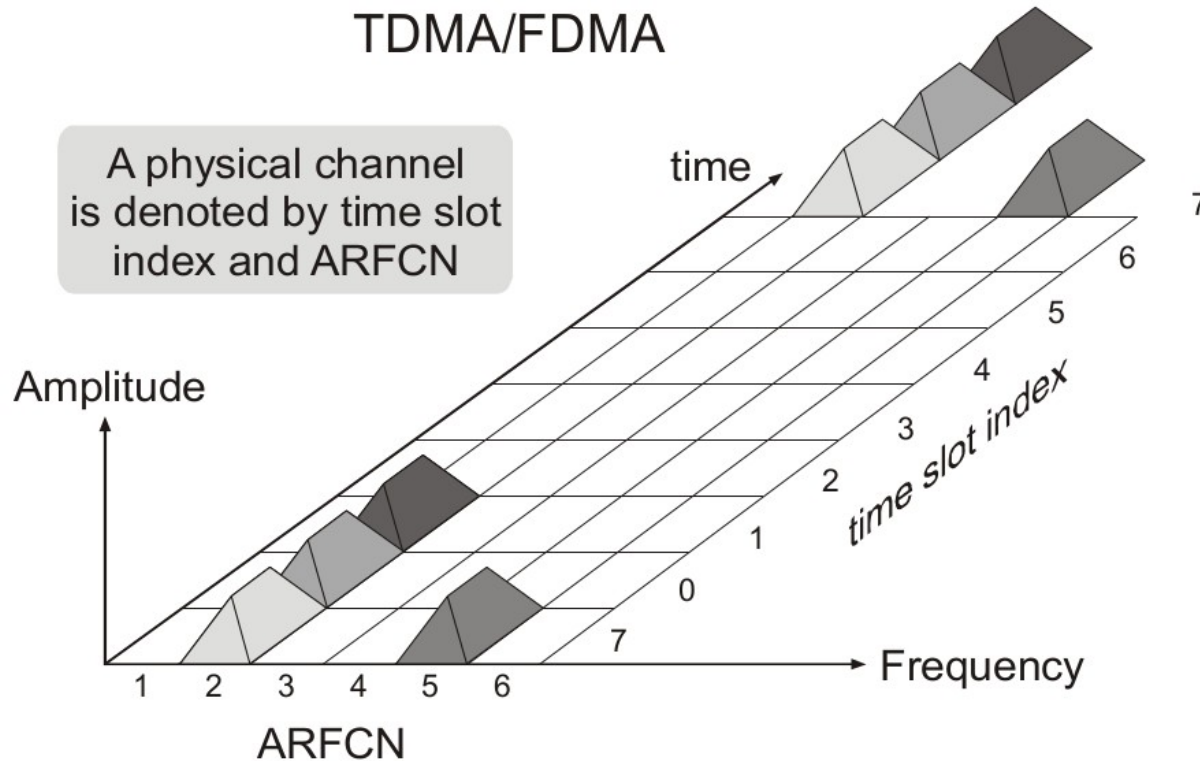


GSM

Power spectrum

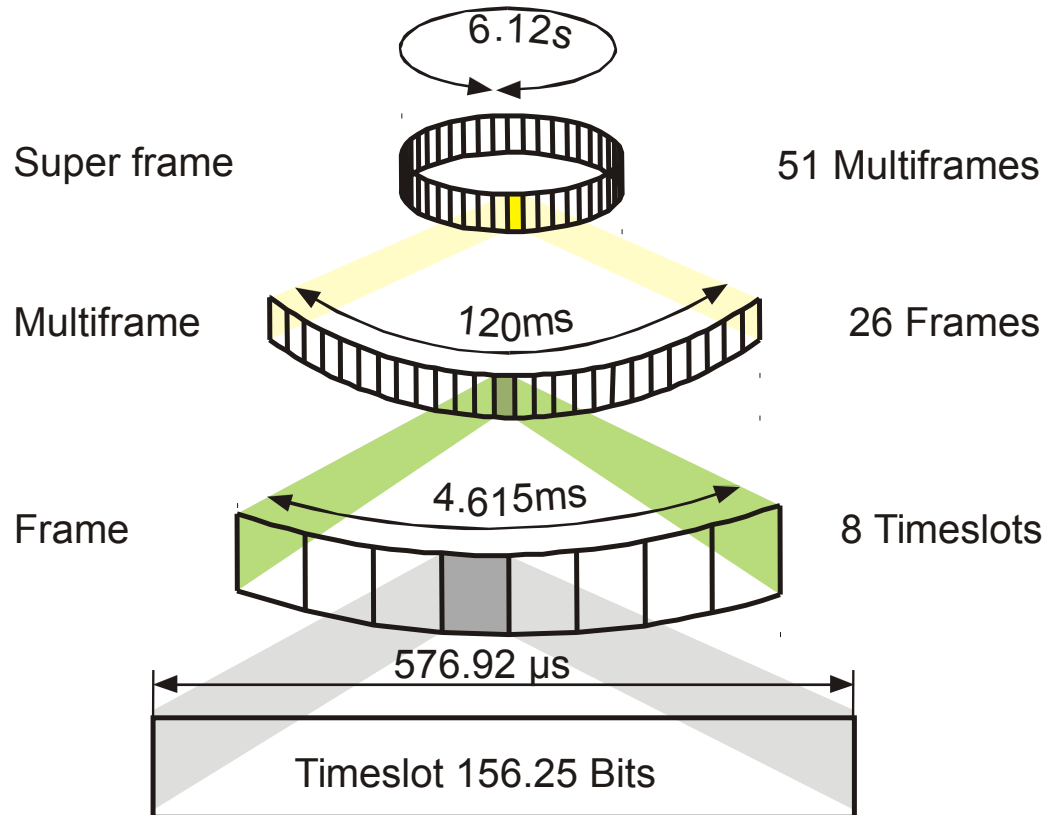


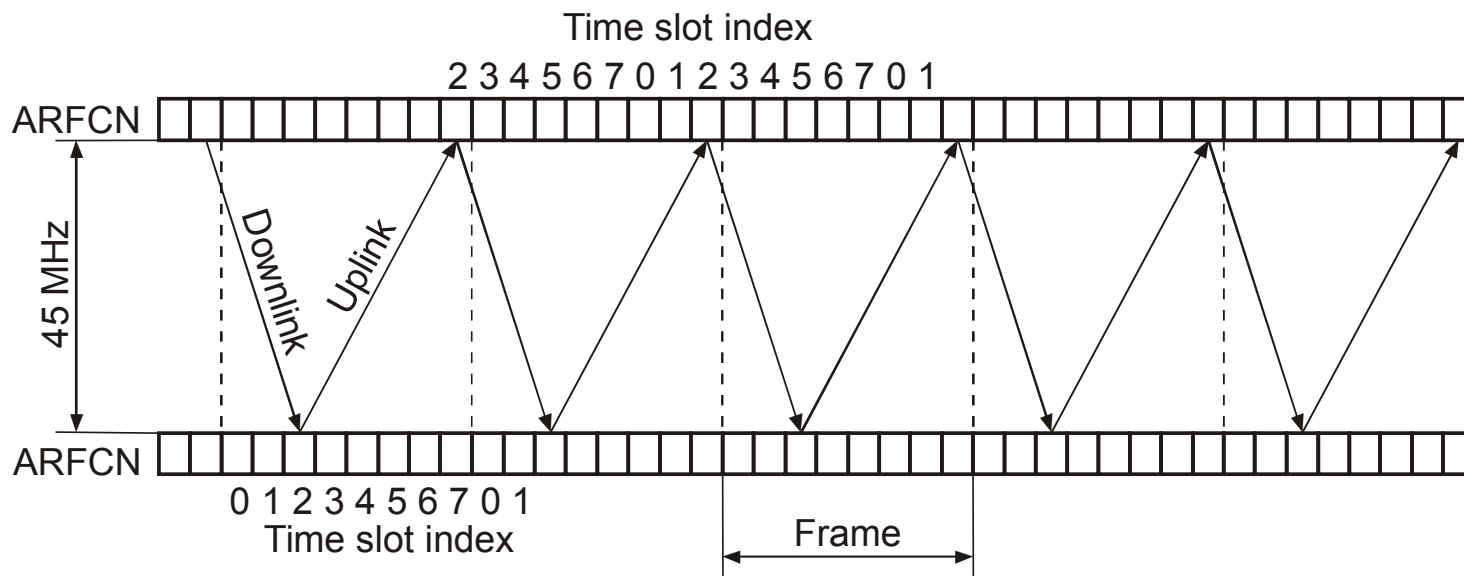
GSM TDMA/FDMA structure



ARFCN

Absolute Radio Frequency Channel Number





The MS transmits to the BS three time-slots after it receives a transmission from the BS.

Using this strategy, the duplex scheme is a combination of TDD and FDD, and the MS avoids simultaneous transmission and reception.



Normal

3 start bits	58 data bits (encrypted)	26 training bits	58 data bits (encrypted)	3 stop bits	8.25 bits guard period
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FCCH burst

3 start bits	142 zeros	3 stop bits	8.25 bits guard period
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SCH burst

3 start bits	39 data bits (encrypted)	64 training bits	39 data bits (encrypted)	3 stop bits	8.25 bits guard period
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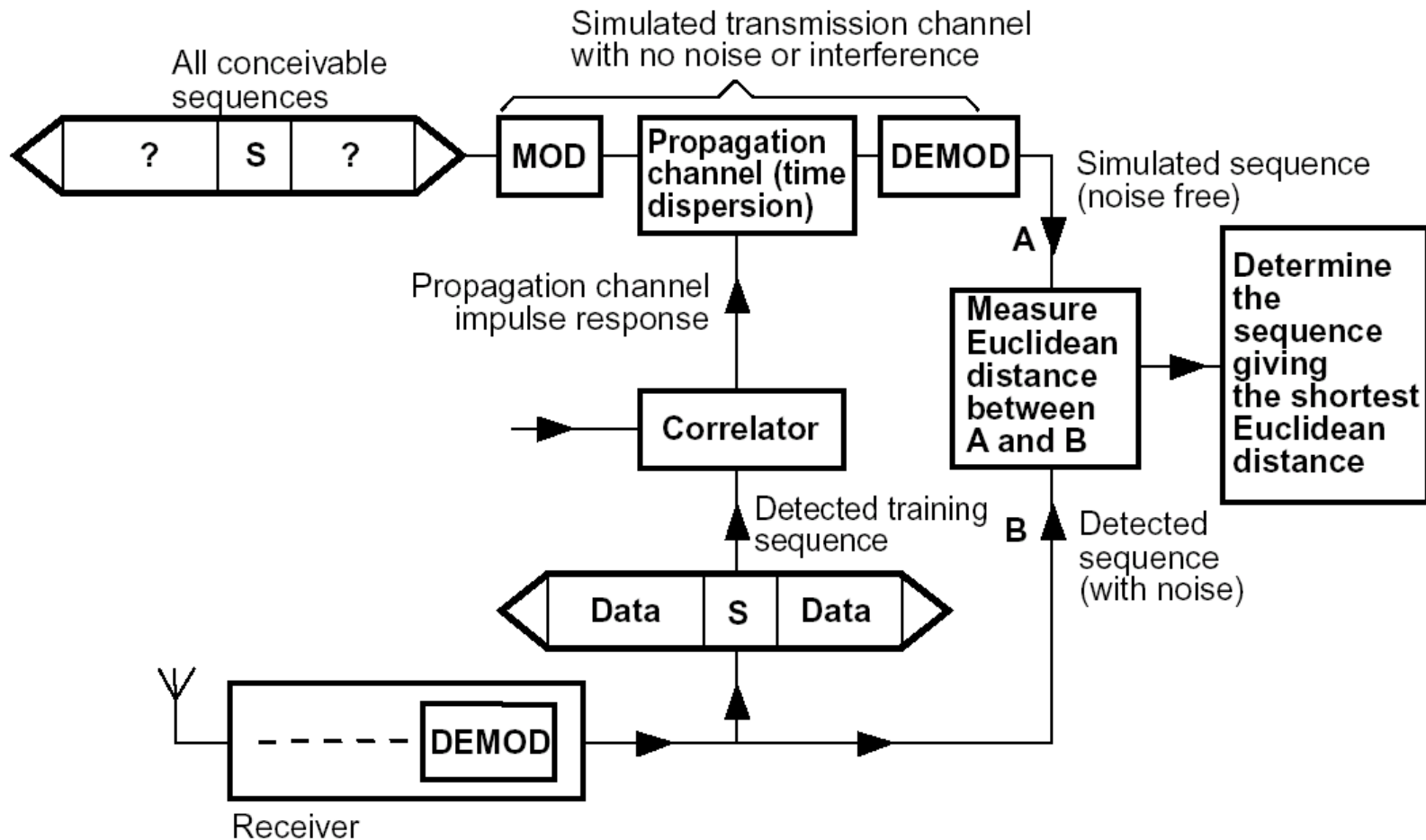
RACH burst

8 start bits	41 synchronization bits	36 data bits (encrypted)	3 stop bits	68.25 bits extended guard period
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FCCH Frequency Correction CHannel
SCH Synchronization CHannel
RACH Random Access CHannel

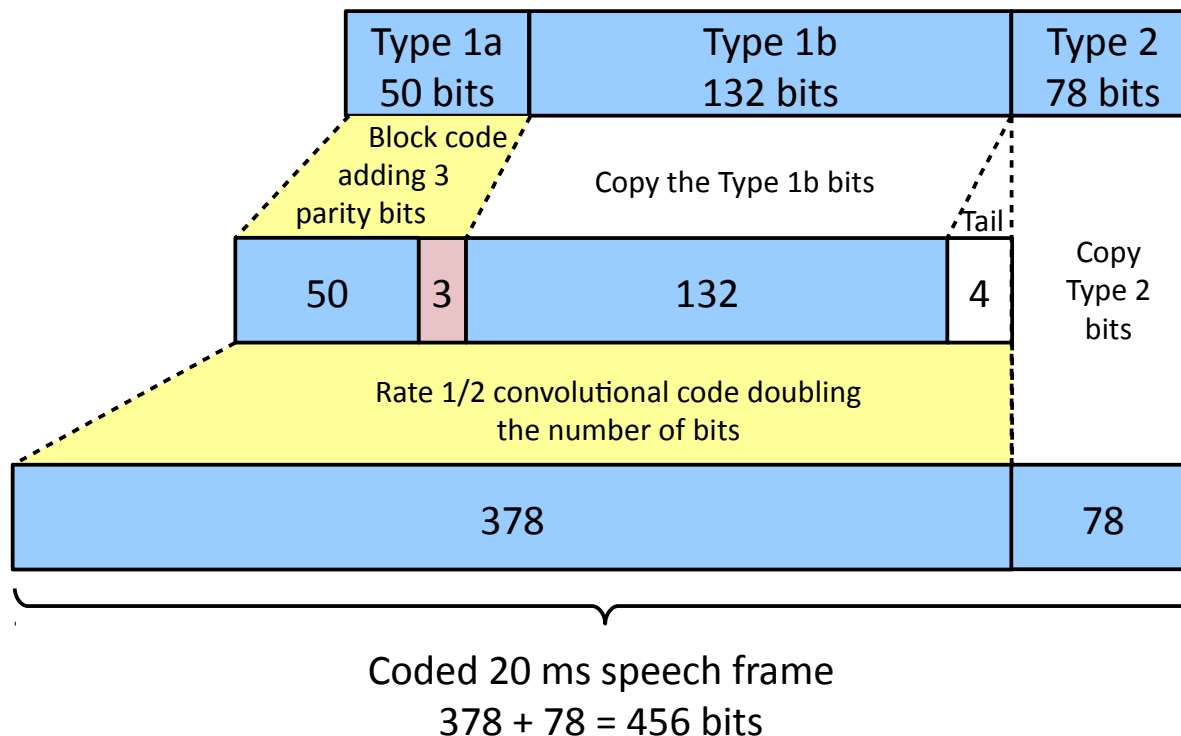
GSM

Viterbi equalizer





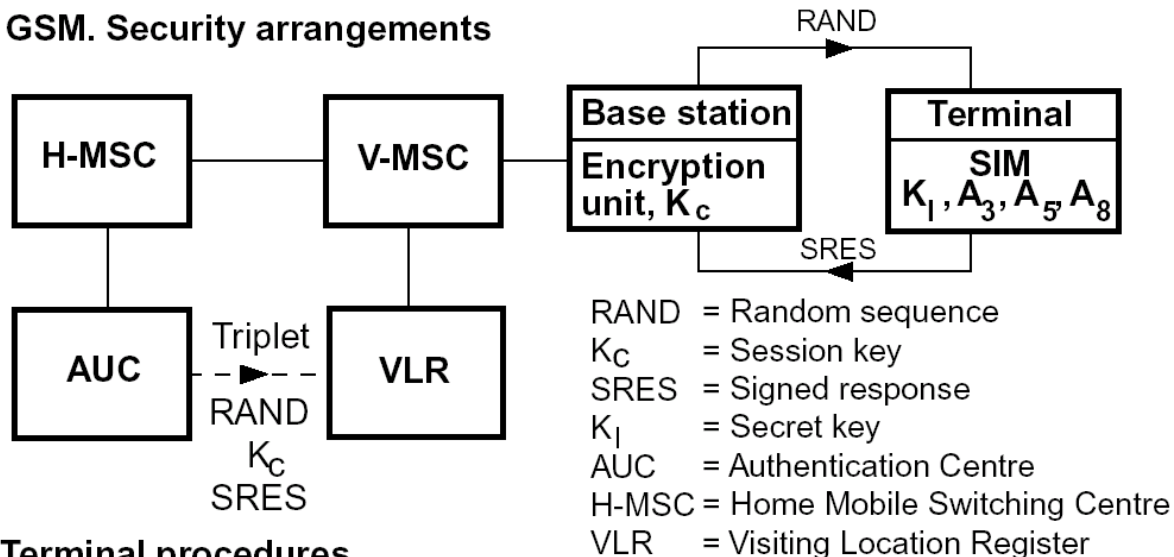
The speech code bits are in three categories, with different levels of protection against channel errors.



GSM Encryption

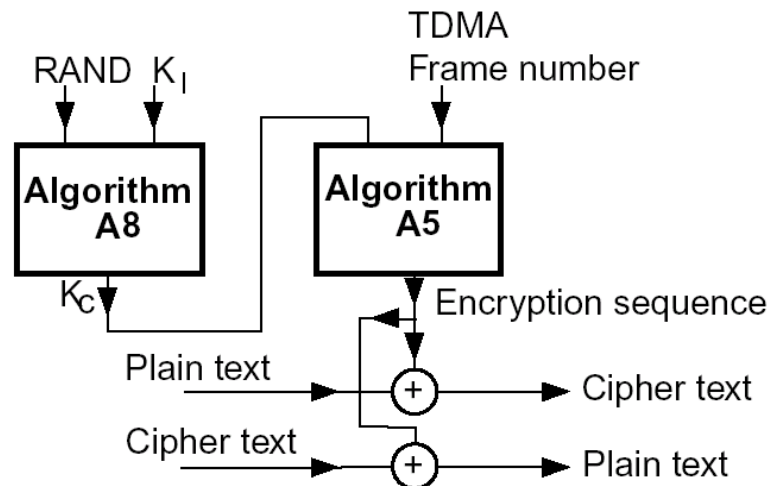
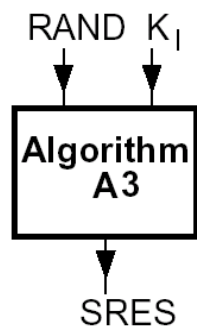


GSM. Security arrangements



Terminal procedures

Authentication



GSM GPRS and EDGE



GSM has evolved into a high-speed packet radio system in two steps

GPRS

General Packet Radio Services

where empty time slots can be used to transmit data packets.

Four new coding schemes are used (CS-1, ..., CS-4) with different levels of protection.

Up to 115 kbit/sec

EDGE

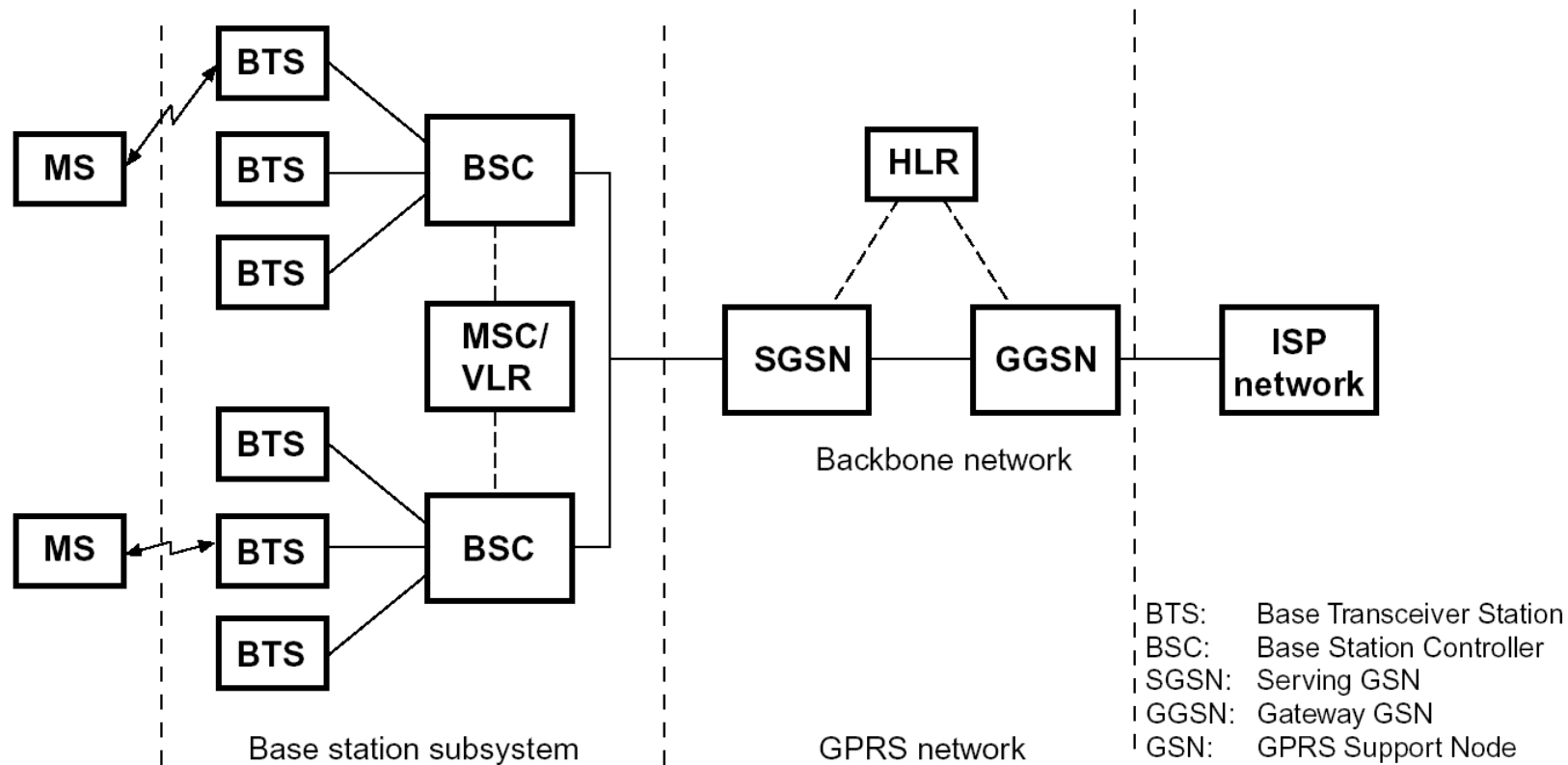
Enhanced Data-rate for GSM Evolution

where, in addition to GPRS, a new 8PSK modulation is introduced.

Eight new modulation and coding schemes are used (MCS-1, ..., MCS-8) with different levels of protection.

Up to 384 kbit/sec

GSM GPRS network



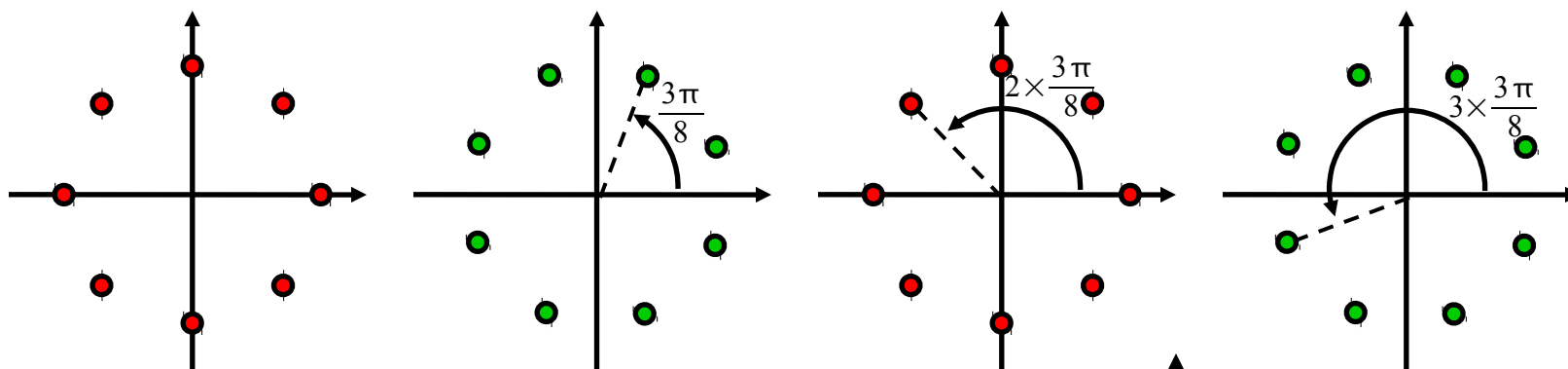
SGSN Serving GPRS Support Node
 GGSN Gateway GPRS Support Node
 ISP Internet Service Provider

GSM

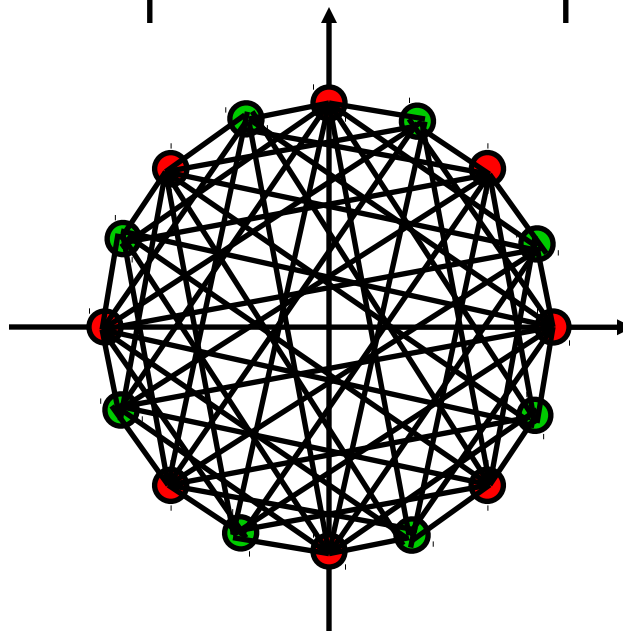
EDGE 8PSK modulation



Linear 8-PSK ... but with rotation of signal constellation for each symbol



We avoid transitions close to origin, thus getting a lower amplitude variation!





WIDE-BAND CODE-DIVISION MULTIPLE ACCESS (WCDMA)

WCDMA

Some parameters



Carrier spacing	5 MHz
Chip rate	3.84 Mchips/sec
Uplink spreading factor	4 to 256
Downlink spreading factor	4 to 512

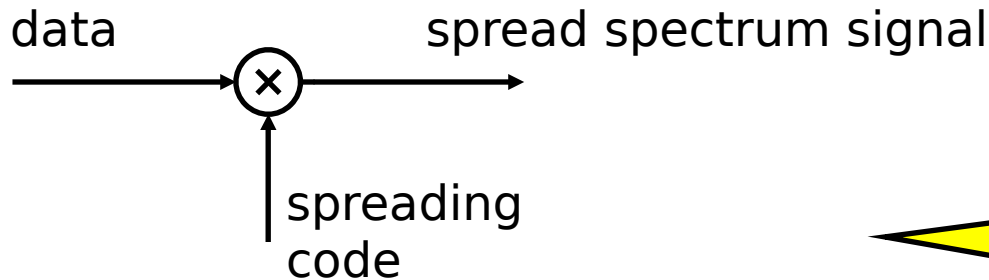
Like we discussed during Lecture 9, all cells use the same frequency band!

WCDMA

Direct-Sequence CDMA

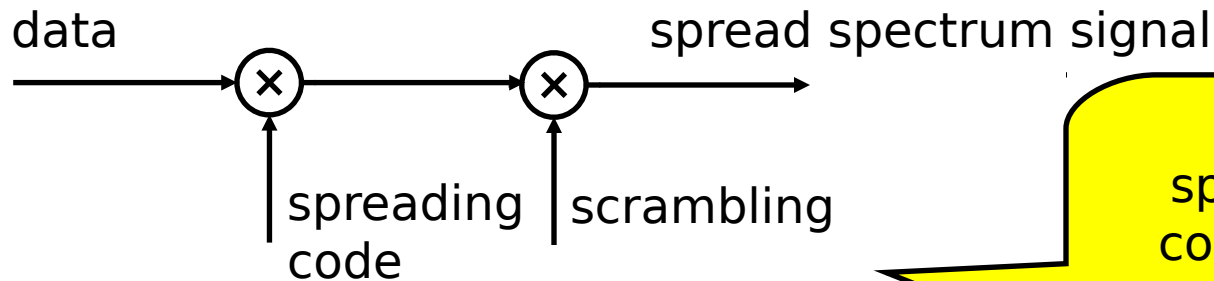


What we learned during Lecture 9:

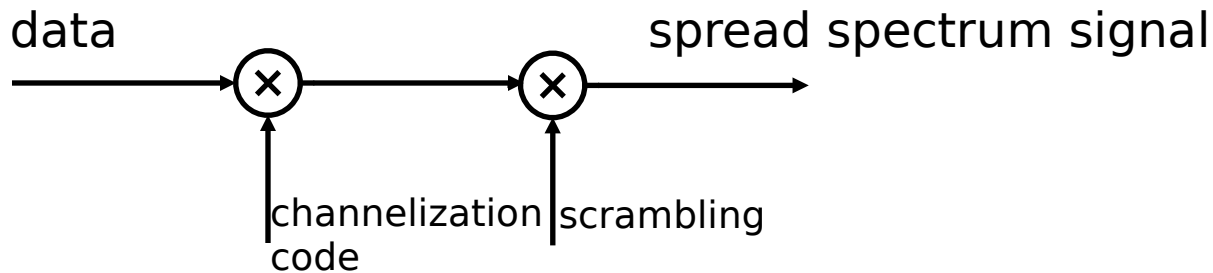


Users/channels are separated by different codes.

In WCDMA we do this a bit different:



The total spreading is a combination of spreading and scrambling.



The different channelization/spreading codes are orthogonal and have different spreading factors between 4 and 512.

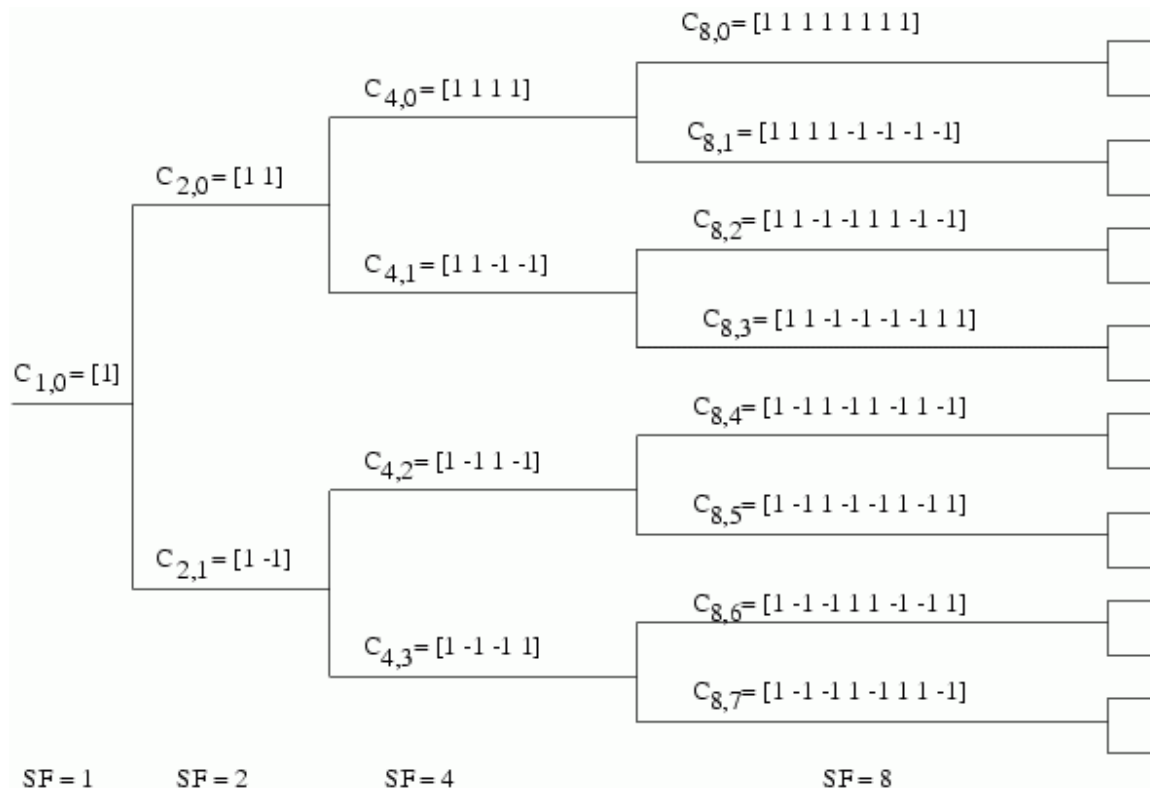
Scrambling makes the total spreading (spreading + scrambling) unique between different sources.



WCDMA

Orthogonal Variable Spreading Factor

The OVSF codes used for variable rate spreading can be viewed as a code tree.



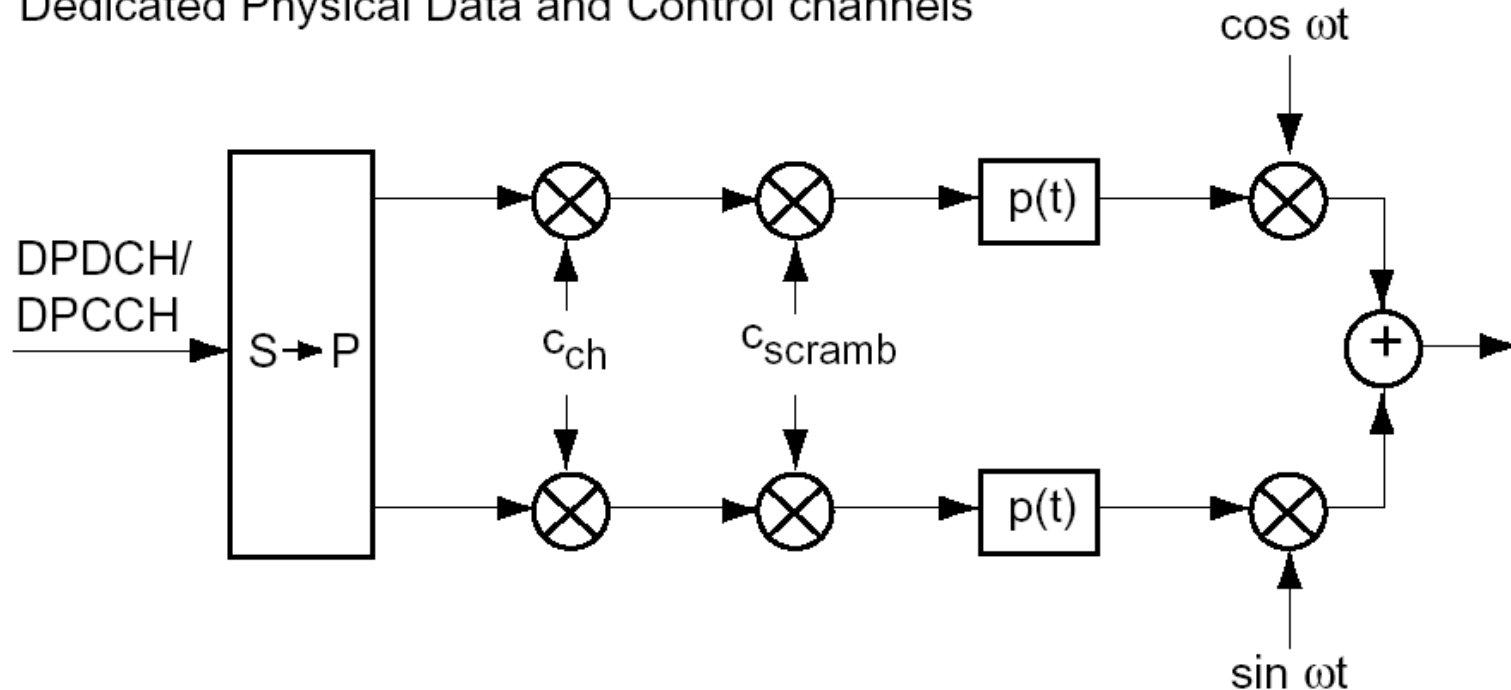
We can create several orthogonal channels by picking spreading codes from different branches of the tree.

WCDMA Downlink



Downlink Spreading and Modulation

Dedicated Physical Data and Control channels

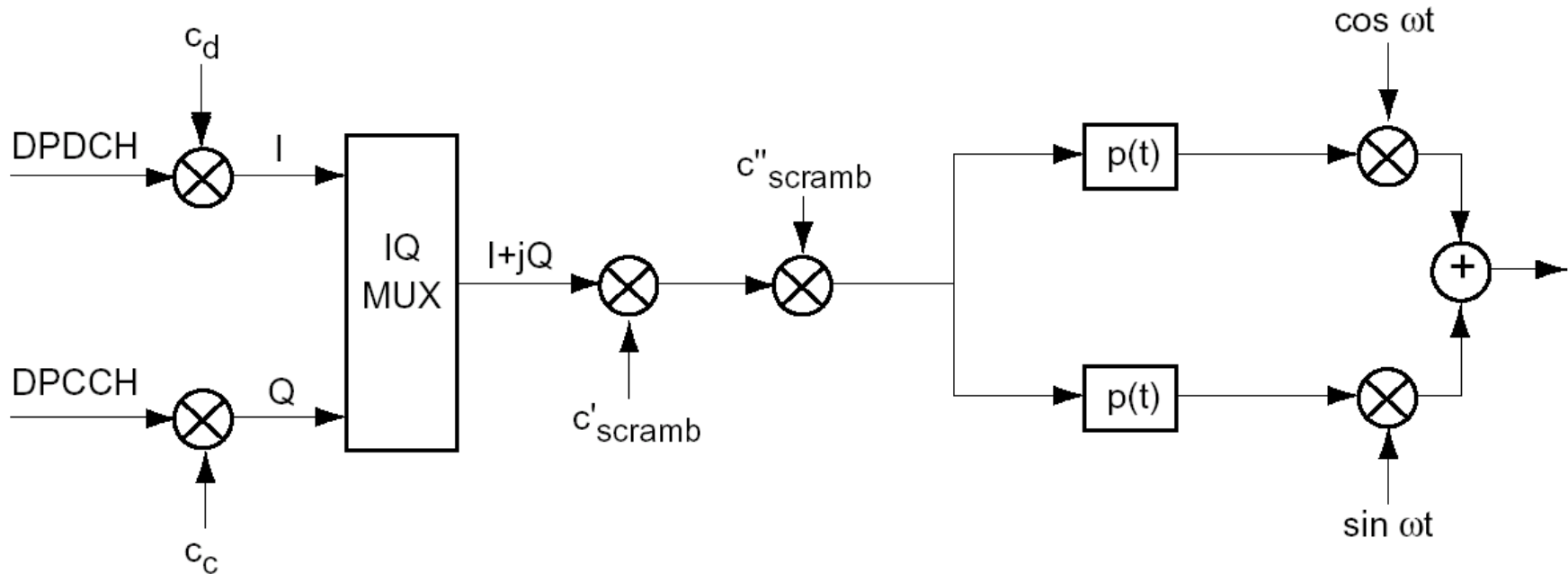


- c_{ch} Channelization code (OVSF)
- c_{scramb} Scrambling code (10 ms) $2^{18}-1$ Gold code (40 960 chips)
- $p(t)$ Root-raised cosine pulse shaping roll off 0.22
- OVSF: Orthogonal Variable Spreading Factor

WCDMA Uplink

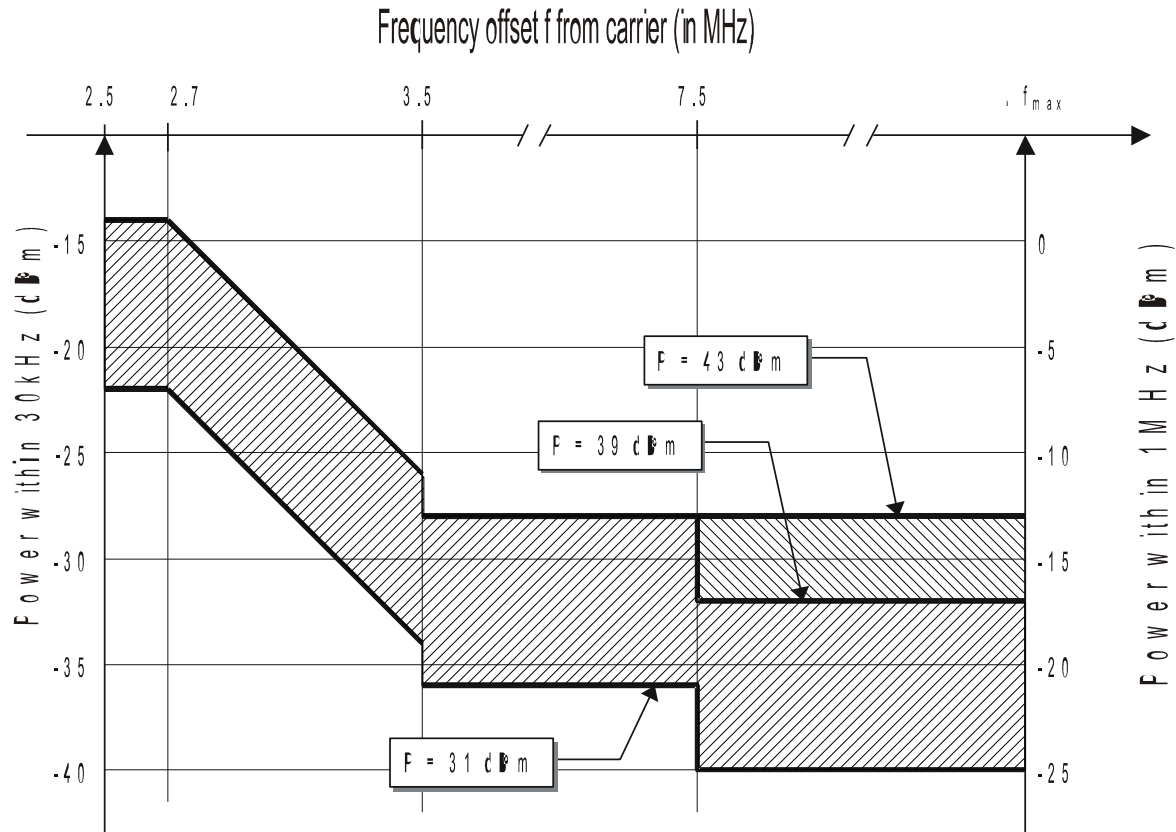


Spreading/modulation for uplink dedicated physical channels



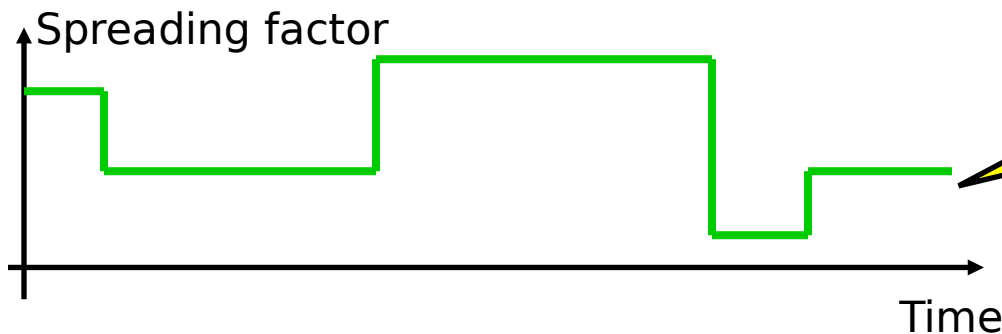
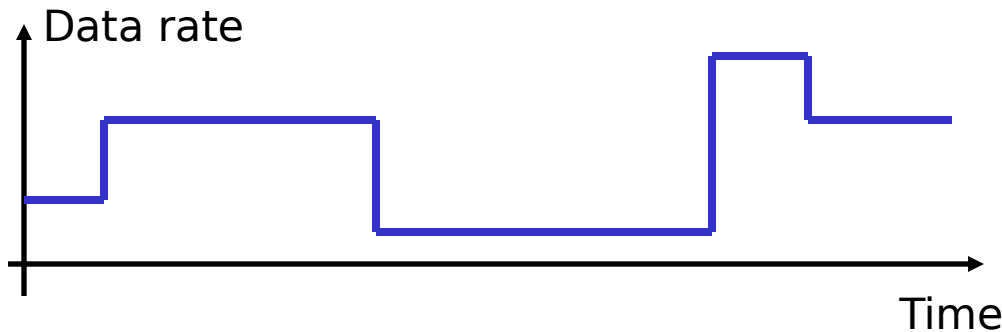
- c_c, c_d Channelization codes (OVSF)
- c'_scramb Primary scrambling code (256 chips) VL-KASAMI code (2 codes)
- c''_scramb Secondary scrambling code (10 ms optional) $2^{41}-1$ Gold code (40 960 chips)
- $p(t)$ Root-raised cosine pulse shaping, roll-off 0.22

WCDMA Spectrum mask

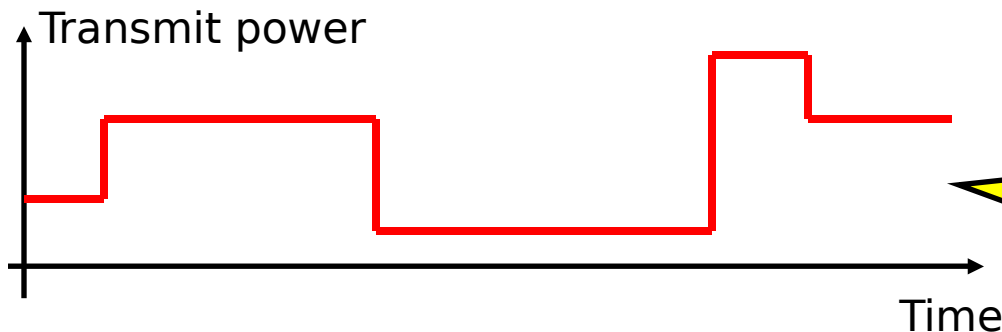


WCDMA

Data rate and spreading factor



We always spread to the full bandwidth.



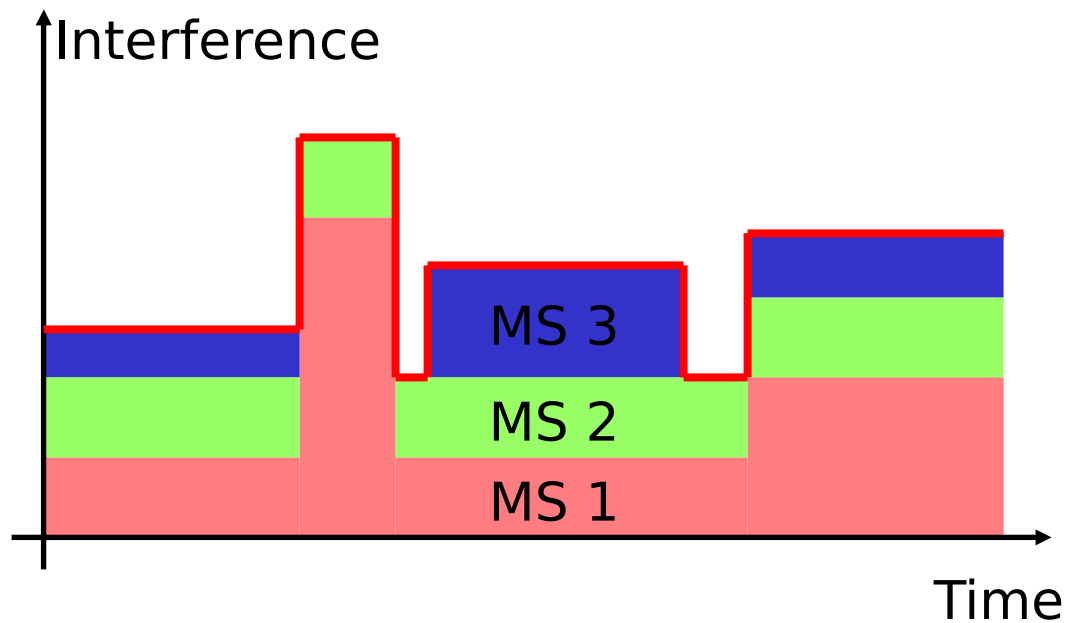
Transmit power and generated interference to others vary accordingly.

WCDMA

Data rate and interference



In simple words, with a limited interference allowed, we can have many low data-rate channels or a few high data-rate channels.



The interference level also varies with propagation loss, which makes power control important!

WCDMA

Soft handover



Since all base stations used the same frequency band, a terminal close to the cell boundary can receive “the same” signal from more than one base station and increase the quality of the received signal.

