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 telefony 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.

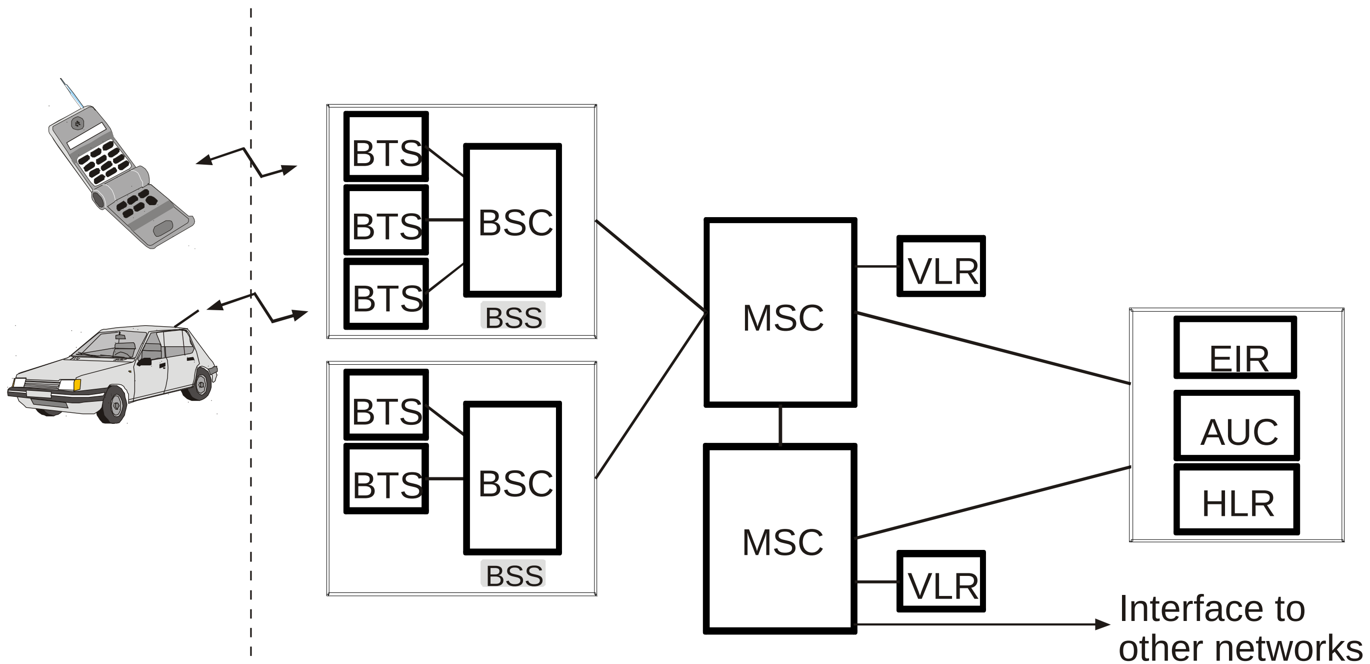
4G

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

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

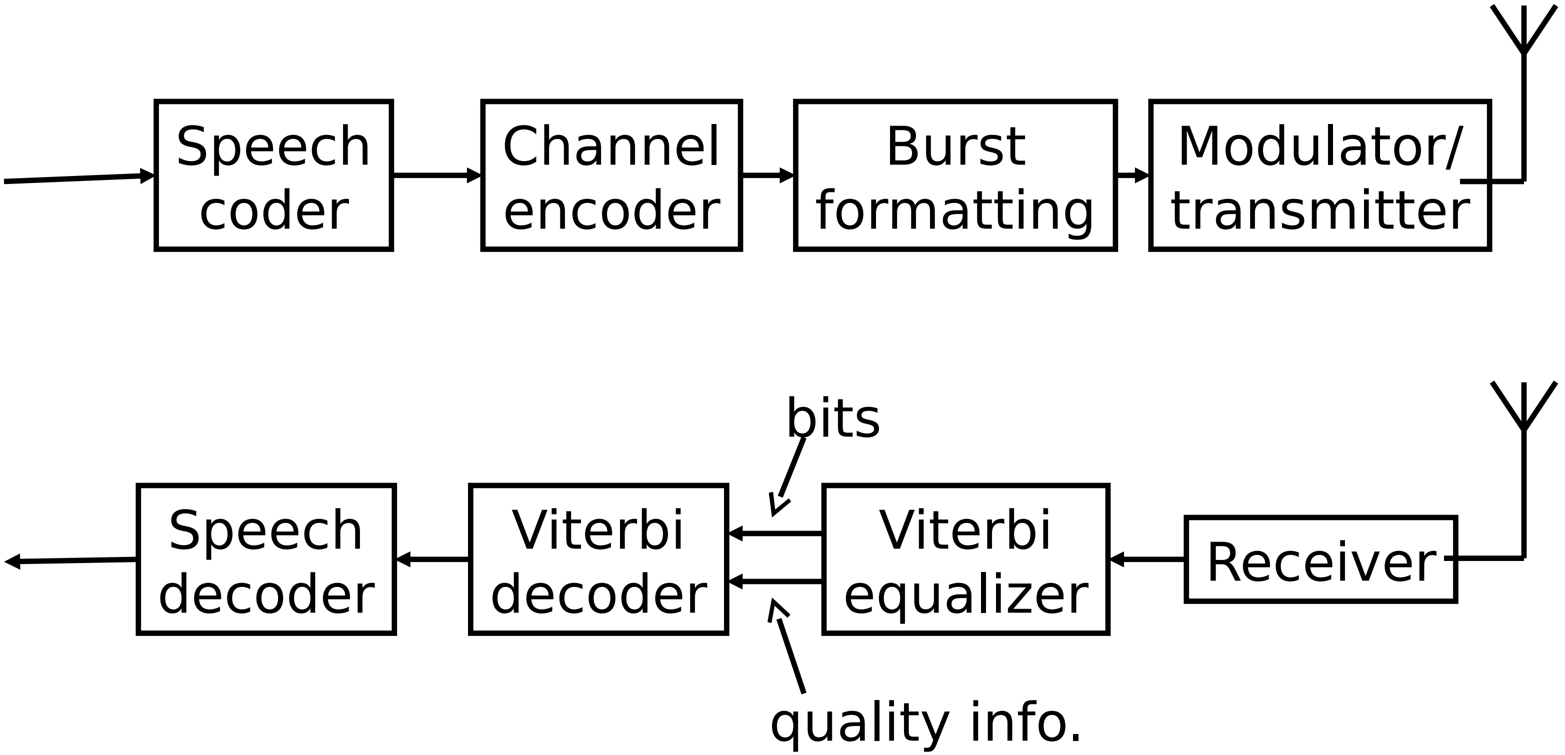
GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS (GSM)

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)

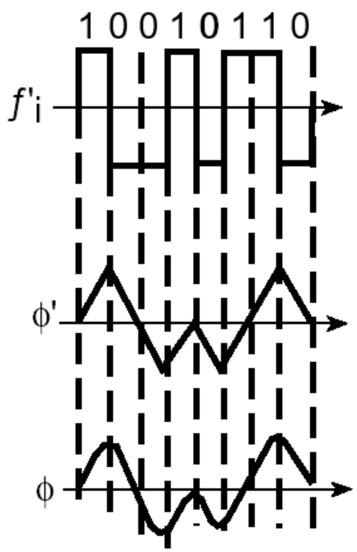
GSM
Some specification parameters

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 Exited LPC-LTP 13 kb/s
Diversity:	Channel coding
	Interleaving
	Frequency hopping
	Channel equalization

(initial specification)

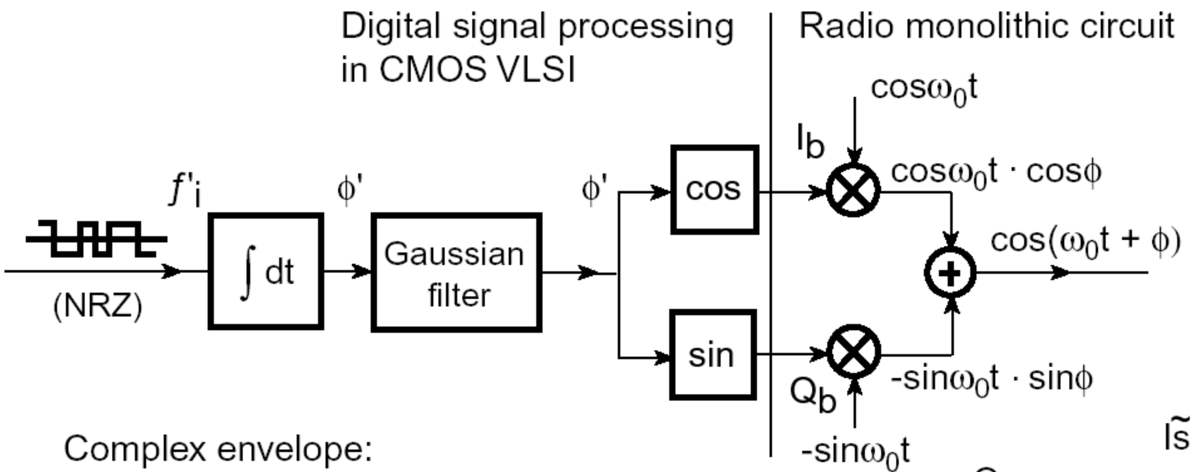
GSM
GMSK modulation

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



ϕ' corresponds to MSK

ϕ corresponds to GMSK



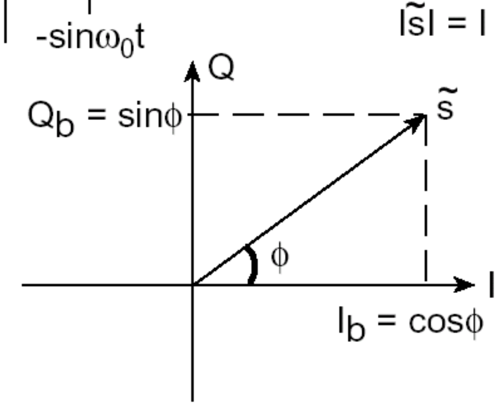
Complex envelope:

$\tilde{s} = I_b + jQ_b = \cos\phi + j\sin\phi = e^{j\phi}$

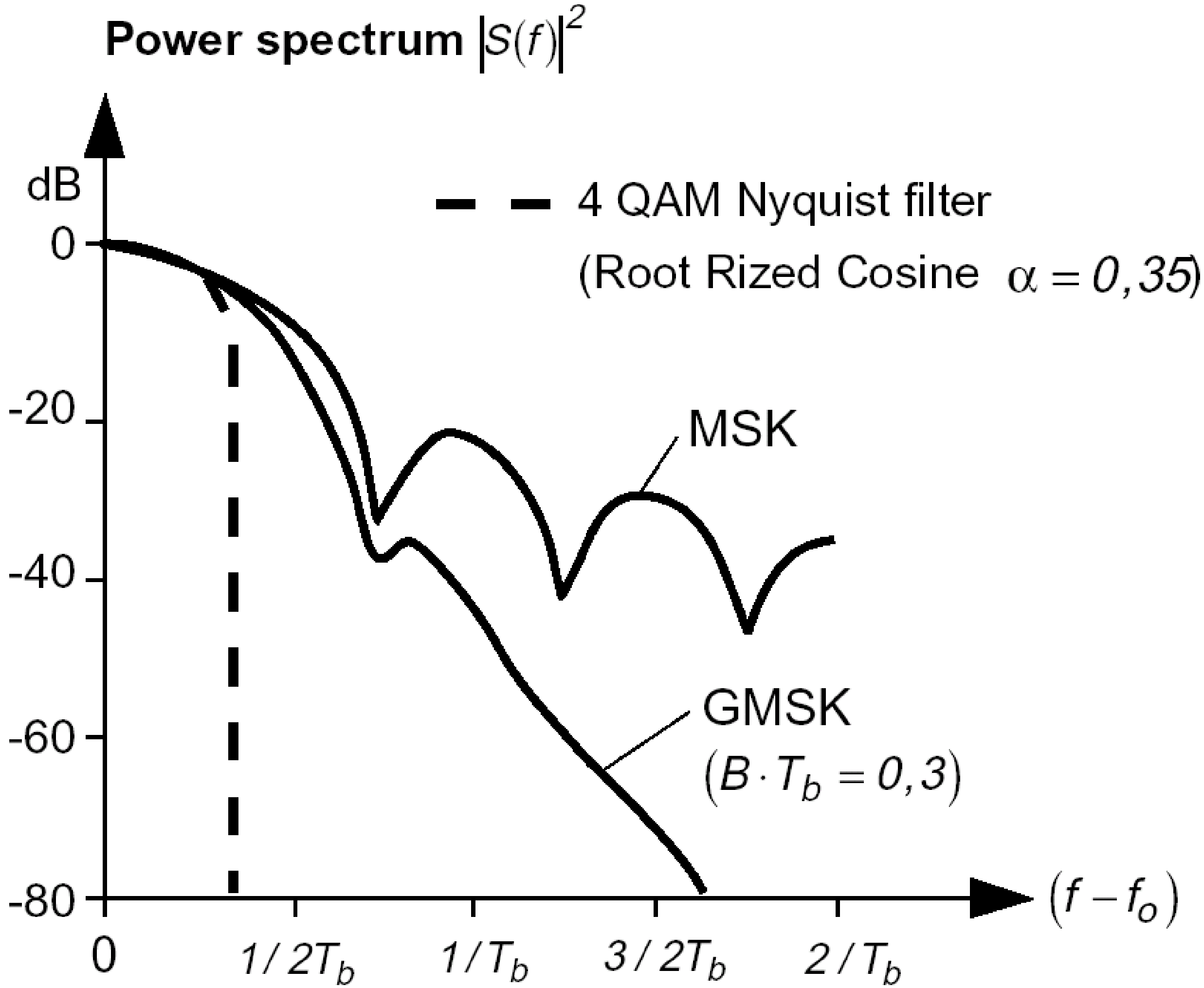
Complex signal: $\tilde{s}e^{j\omega_0 t} = e^{j(\omega_0 t+\phi)}$

Physical signal: $\mathrm{Re}[\tilde{s}e^{j\omega_0 t}] = \cos(\omega_0 t+\phi)$
(Normalize $|\tilde{s}| = 1$)

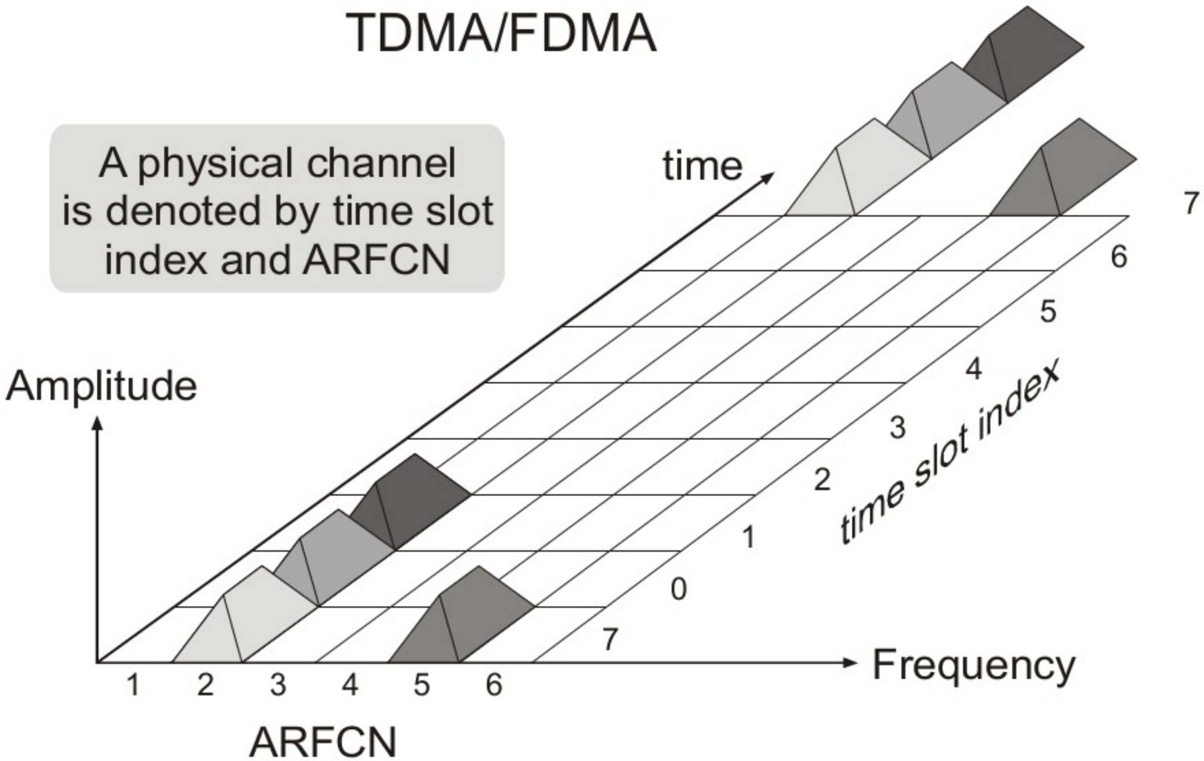
$(\cos\omega_0 t\cos\phi - \sin\omega_0 t\sin\phi = \cos(\omega_0 t + \phi))$



GSM
Power spectrum

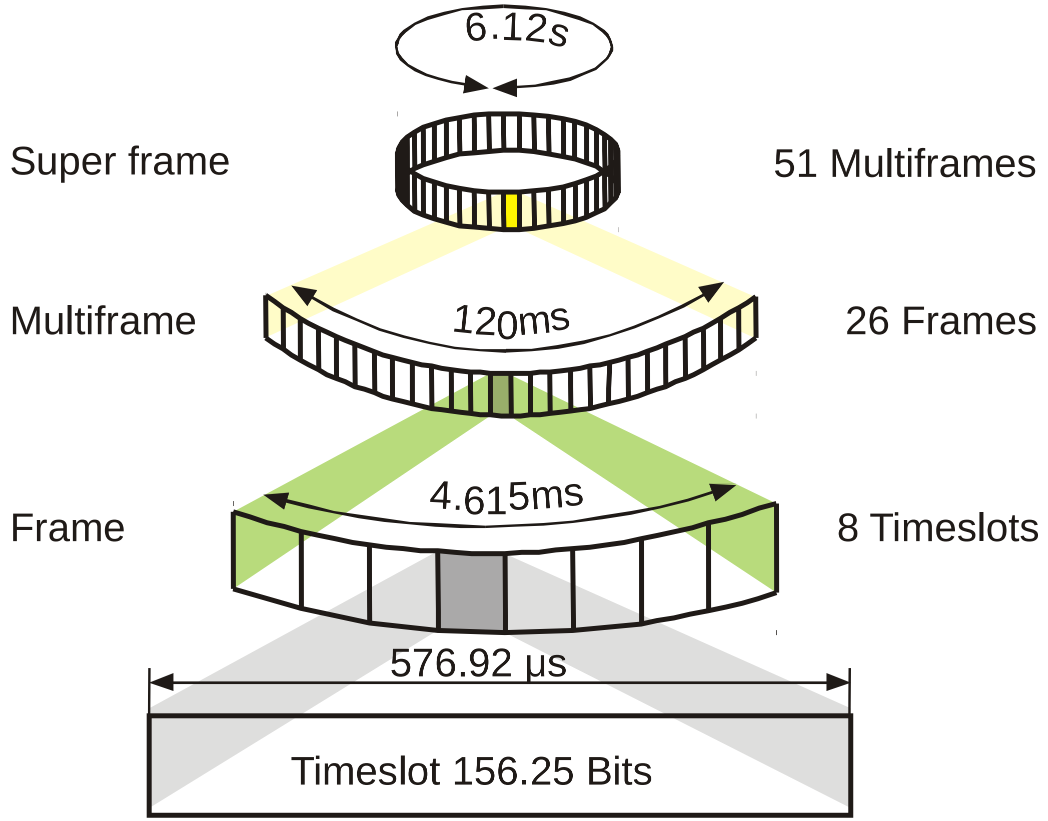


GSM
TDMA/FDMA structure

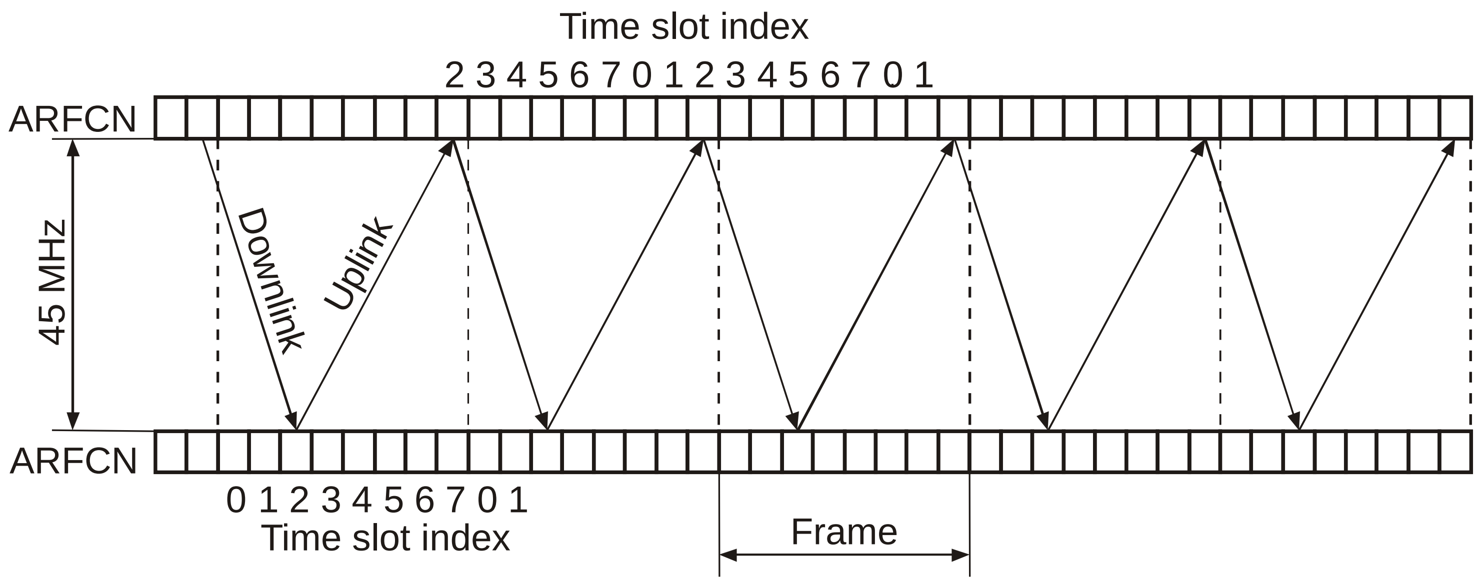


ARFCN Absolute Radio Frequency Channel Number

GSM
Frames and multiframes



GSM
Up/down-link time slots



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.

GSM
Some of the time slots

Normal

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

FCCH burst

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

SCH burst

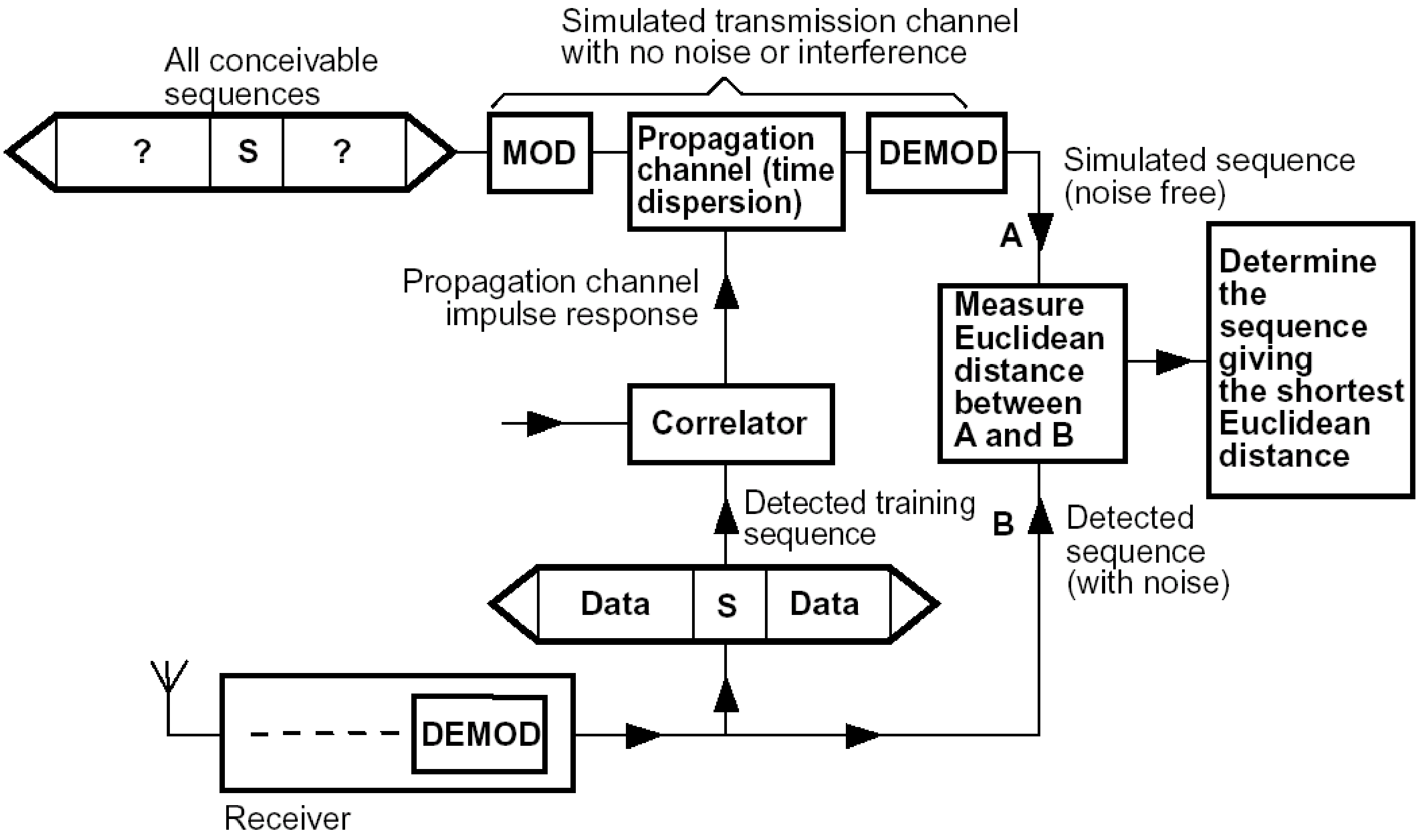
3 start bits	39 data bits (encrypted)	64 training bits	39 data bits (encrypted)	3 stop bits	8.25 bits guard period

RACH burst

8 start bits	41 synchronization bits	36 data bits (encrypted)	3 stop bits	68.25 bits extended guard period

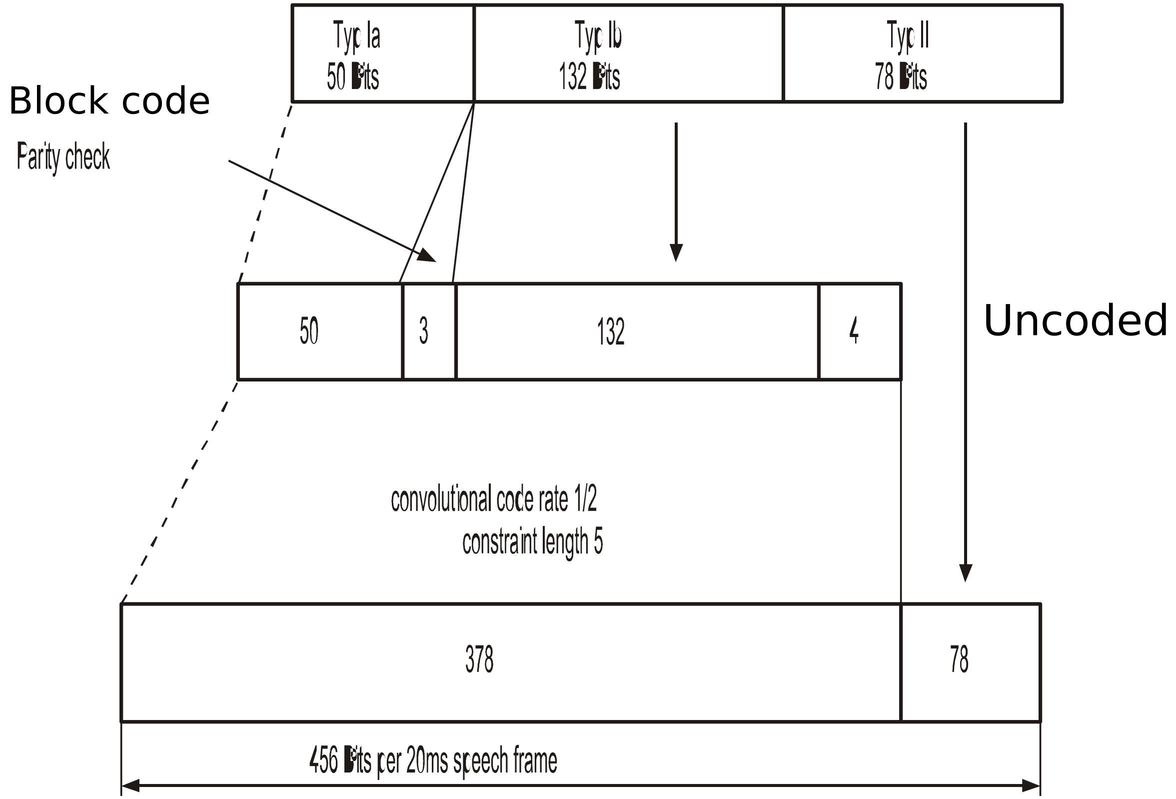
FCCH	Frequency Correction CHannel
SCH	Synchronization CHannel
RACH	Random Access CHannel

GSM
Viterbi equalizer

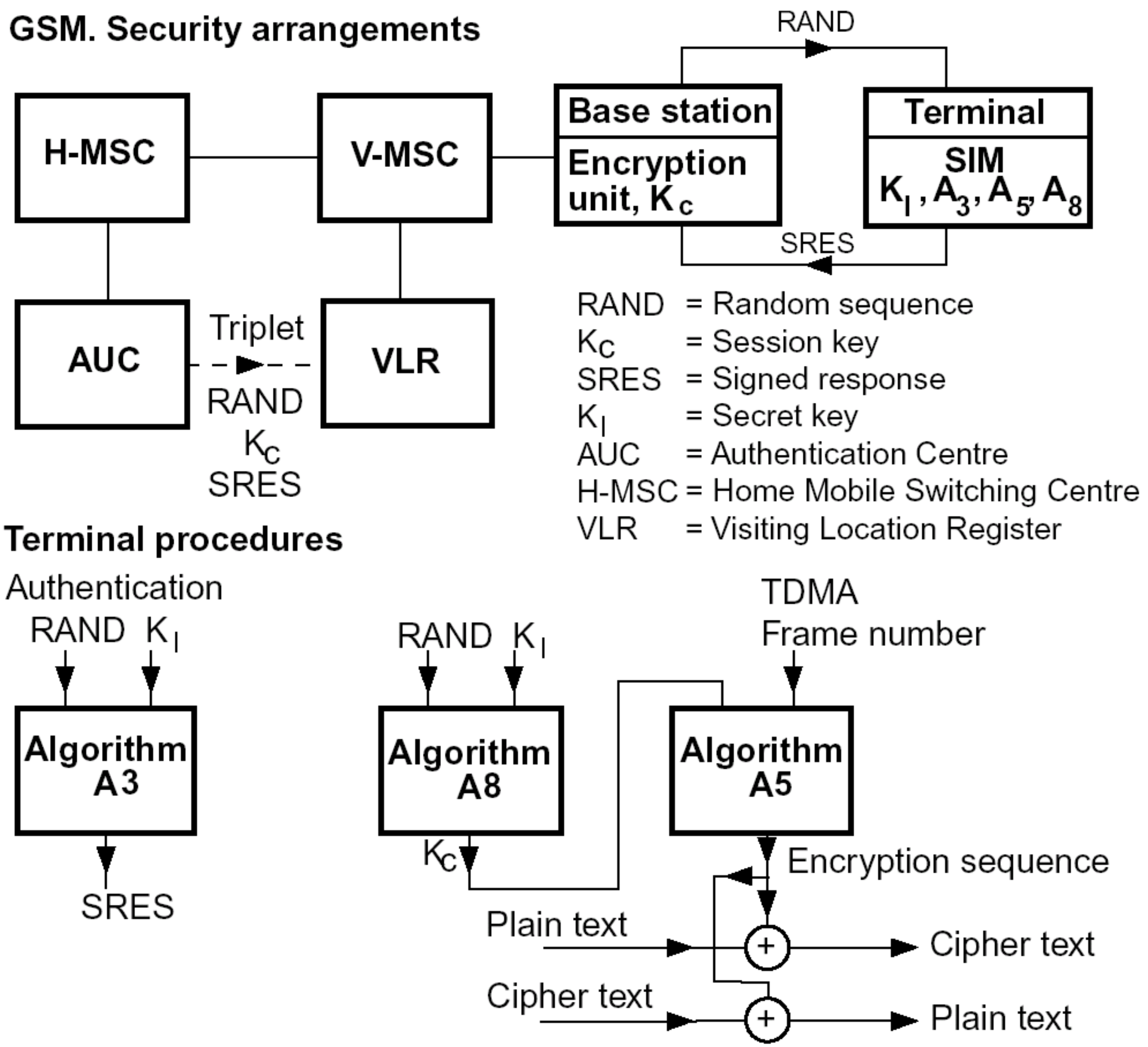


GSM
Channel coding of speech

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



GSM Encryption



GSM
GPRS and EDGE

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

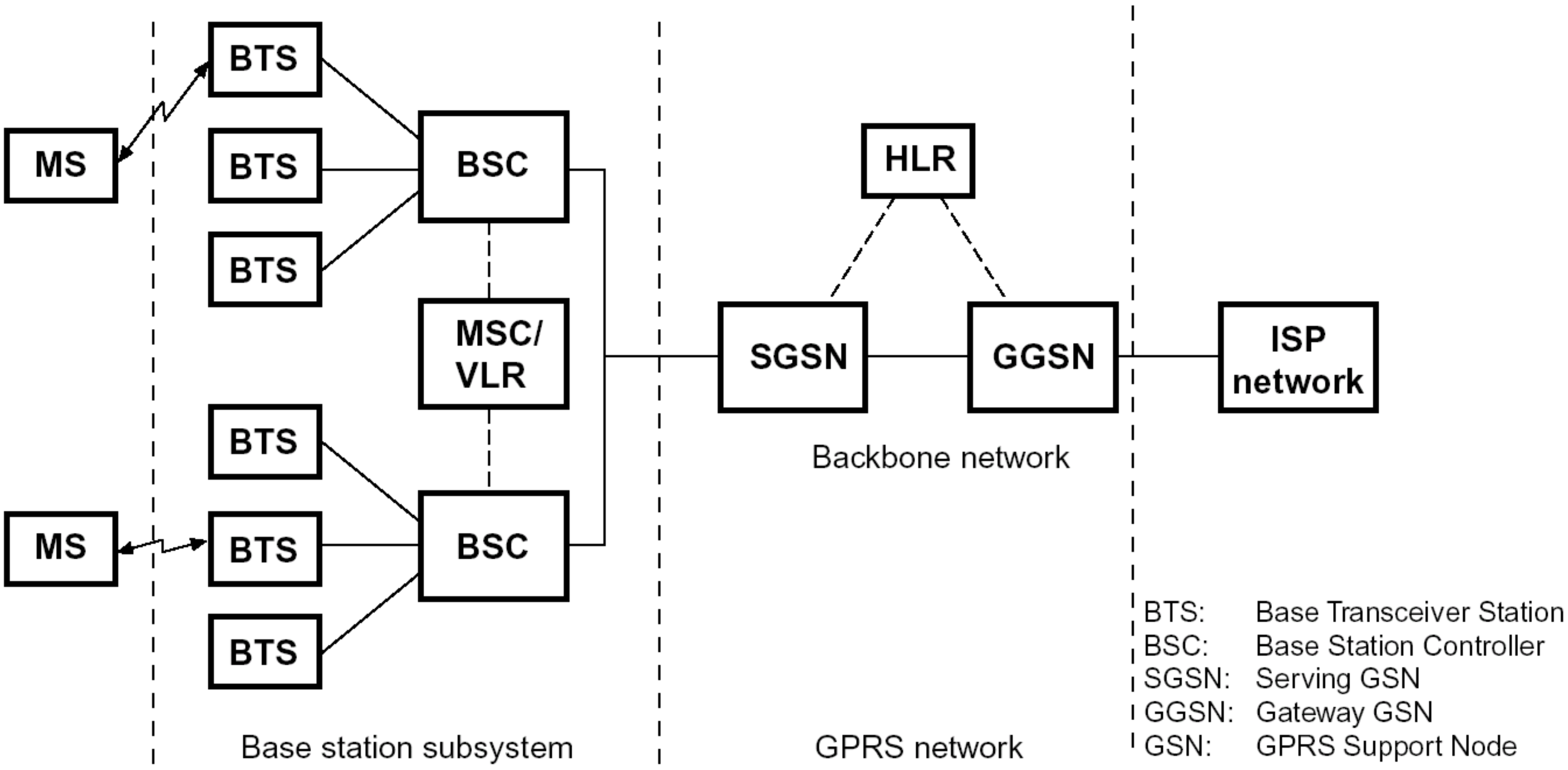
GPRS **General Packet Radio Services**
where empty time slots can be used to transmit data packets.
Four new coding schemes are used (CS-1, ..., CS-4) with different levels of protection.

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

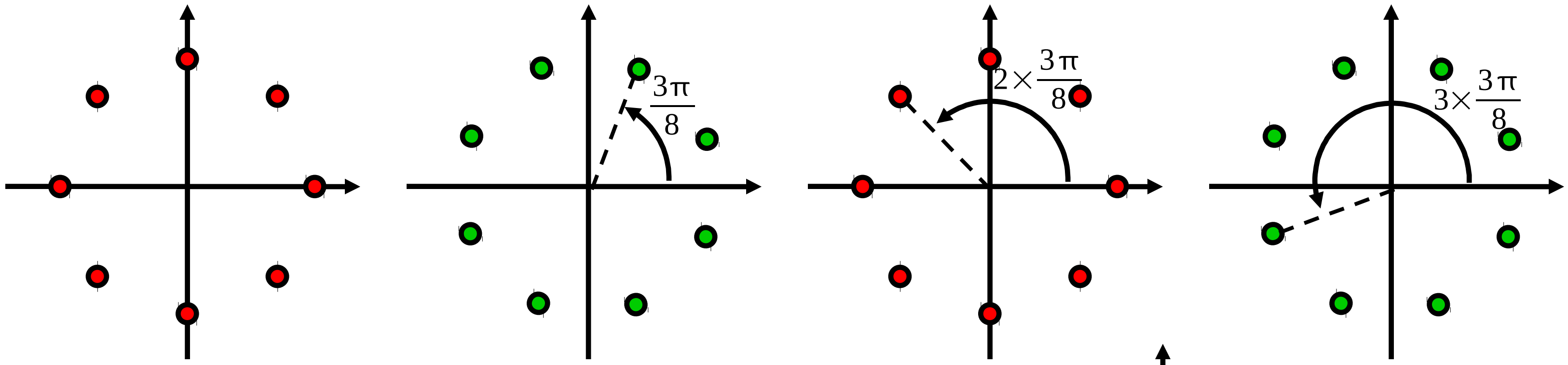
GSM
GPRS network



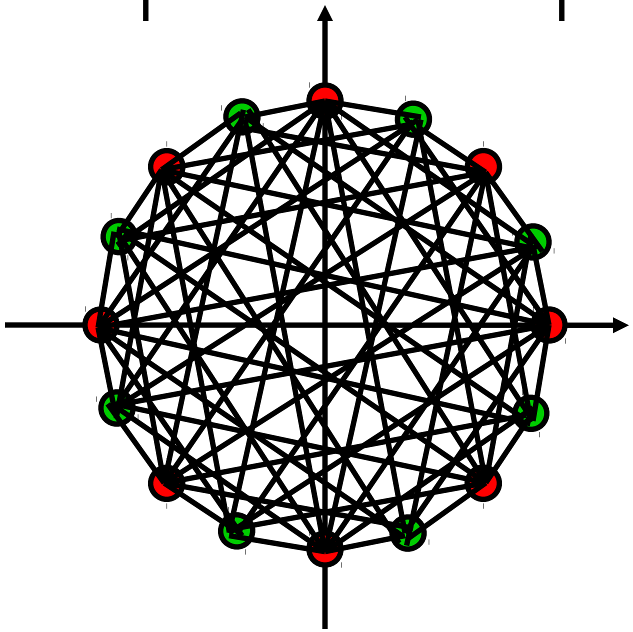
SGSN Serving GPRS Support Node
GGSN Gateway GPRS Support Node
ISP Internet Service Provider

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)

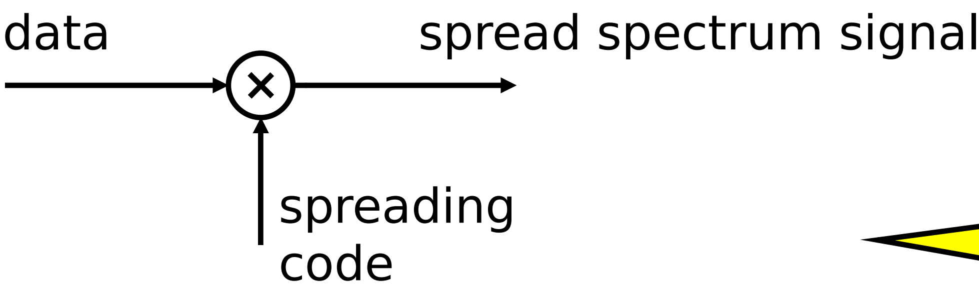
WCDMA
Some parameters

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!

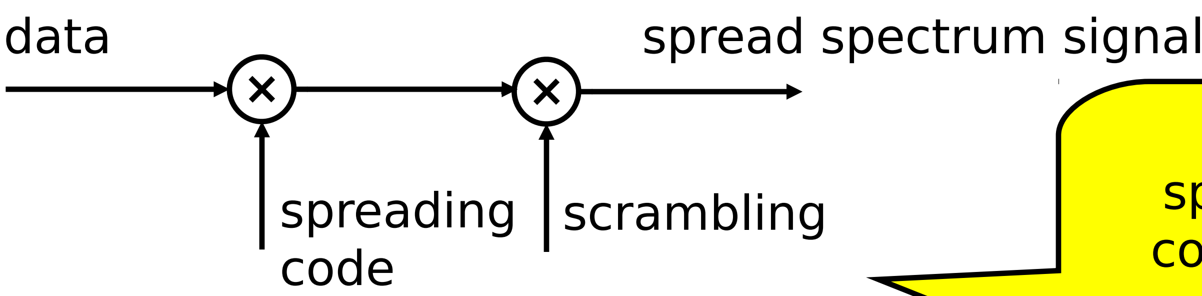
WCDMA
Direct-Sequence CDMA

What we learned during Lecture 9:



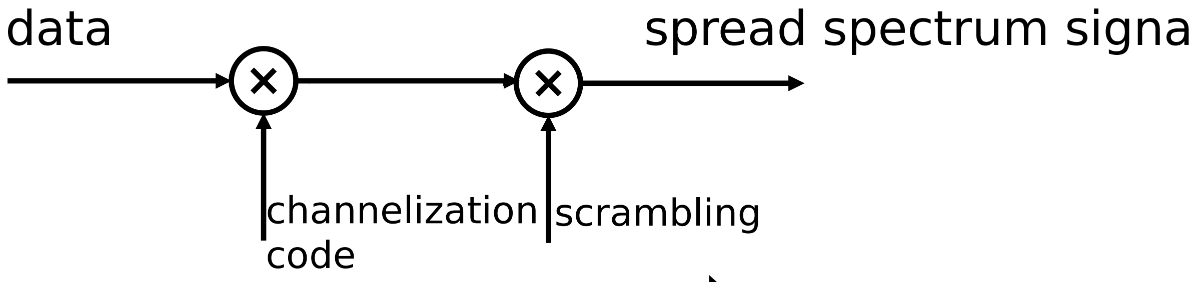
Users/channels are separated by different codes.

In WCDMA we do this a bit different:



The total spreading is a combination of spreading and scrambling.

WCDMA
Channelization and scrambling

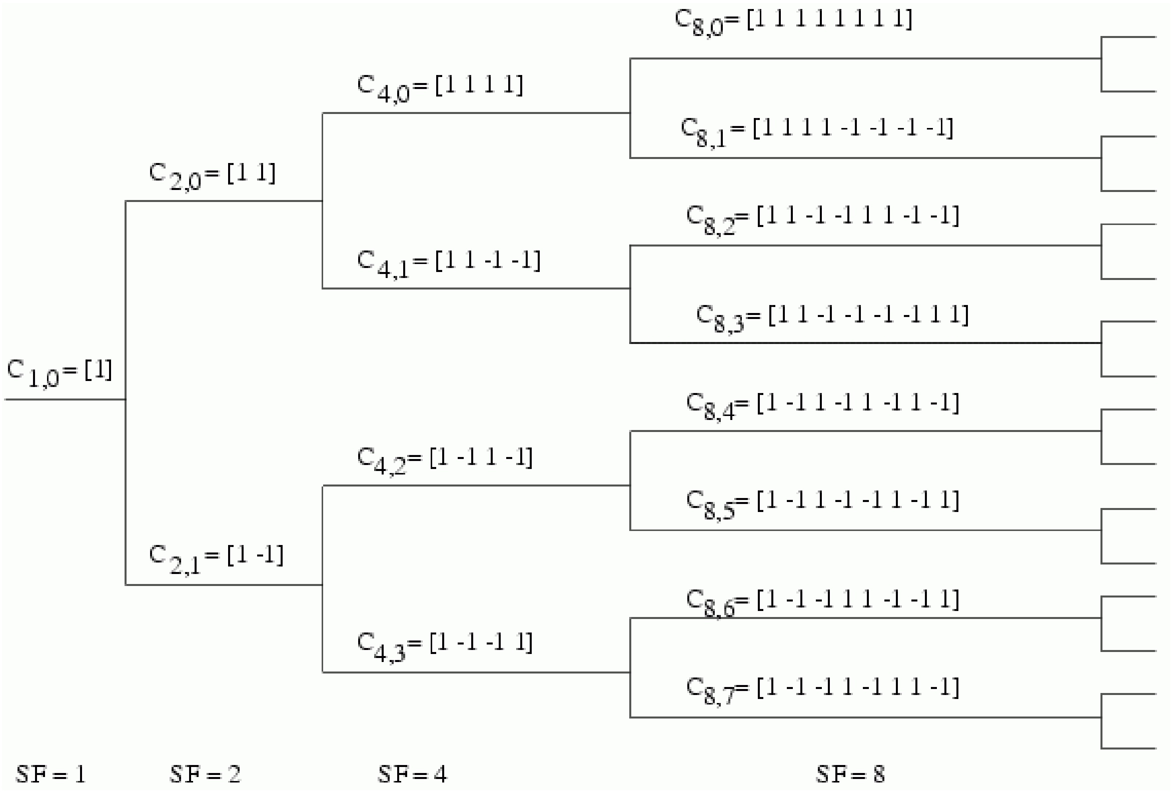


The different channelization/spreading codes are orthogonal and have different spreading factors between 4 and 512.

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.

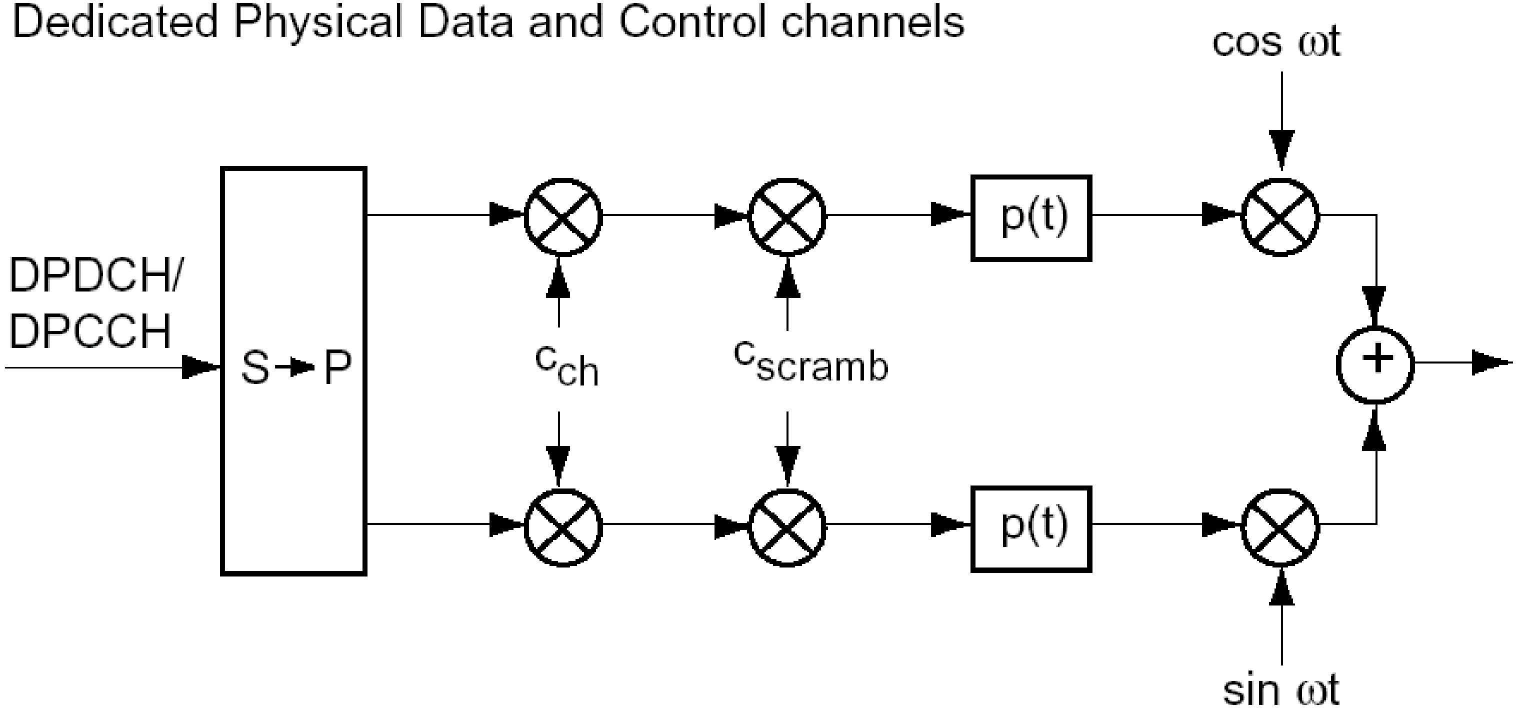


We can create several orthogonal channels by picking spreading codes from different branches of the tree.

WCDMA Downlink

Downlink Spreading and Modulation

Dedicated Physical Data and Control channels



c_{ch} Channelization code (OVSF)

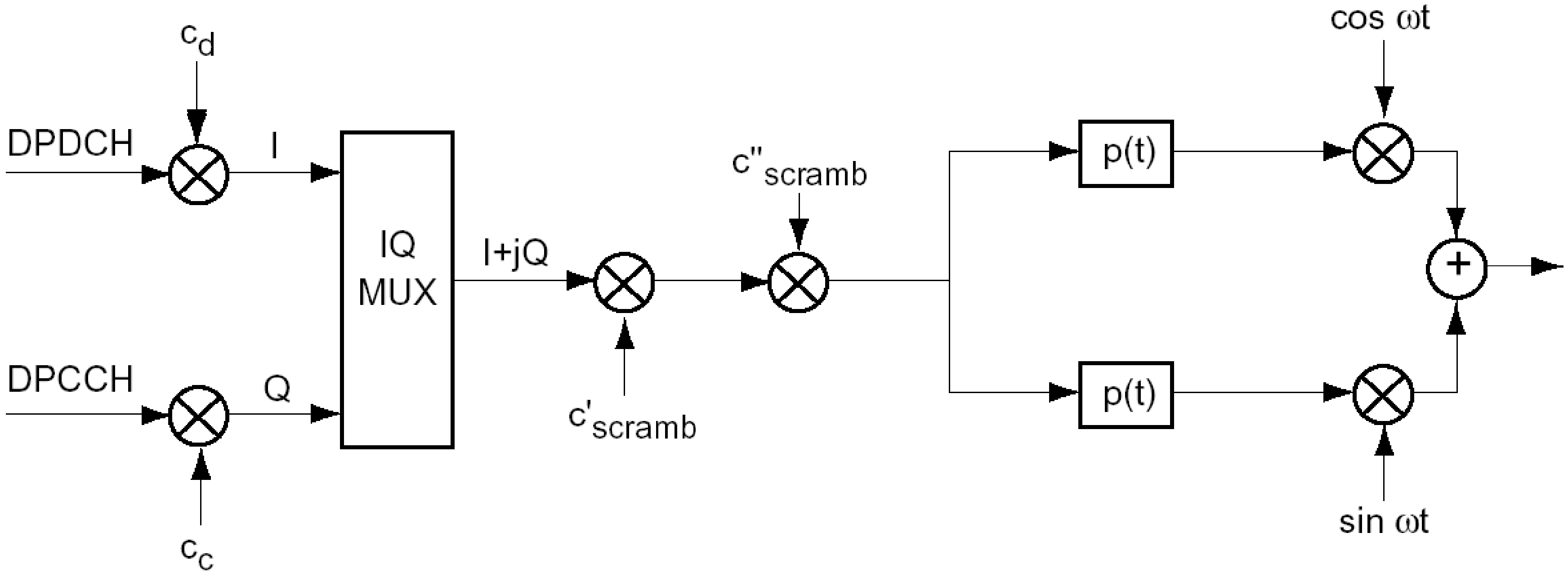
c_{scramb} Scrambling code (10 ms) 2^{18}-1 Gold code (40 960 chips)

p(t) Root-raised cosine pulse shaping roll off 0.22

OVSF: Orthogonal Variable Spreading Factor

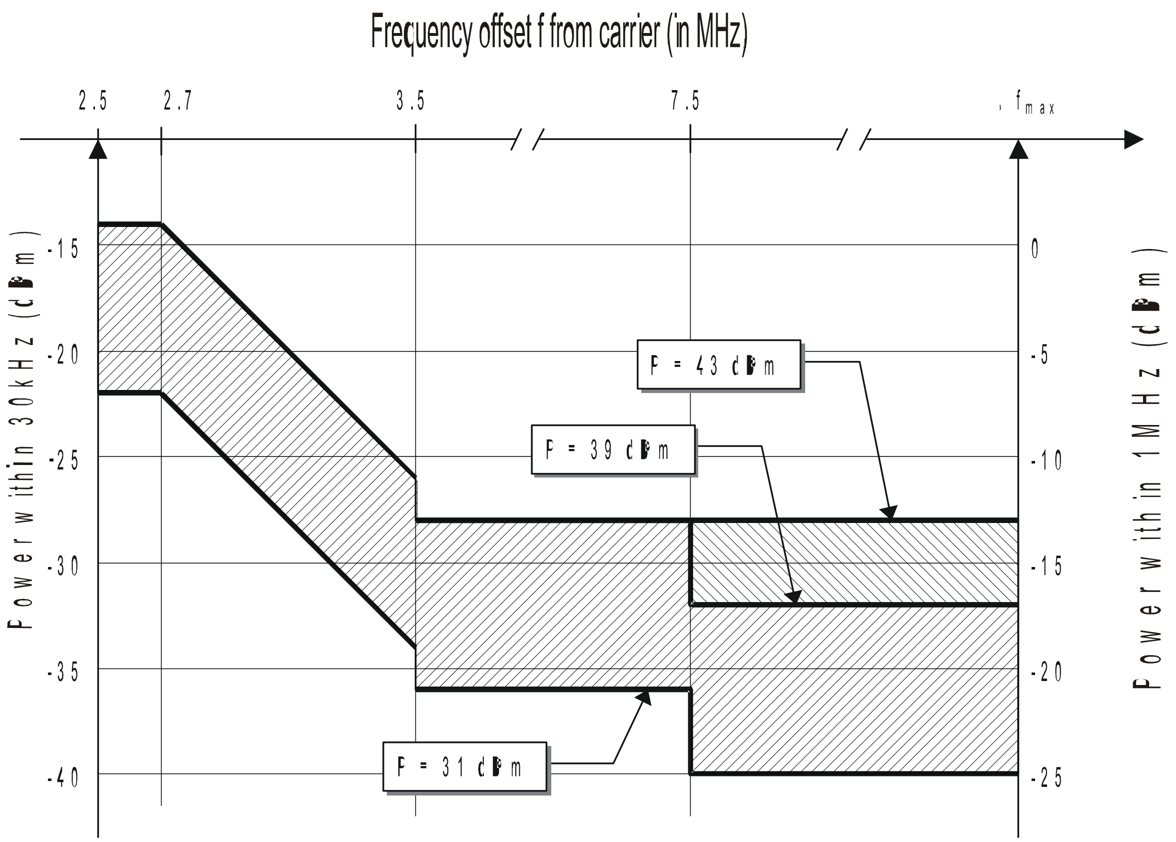
WCDMA Uplink

Spreading/modulation for uplink dedicated physical channels

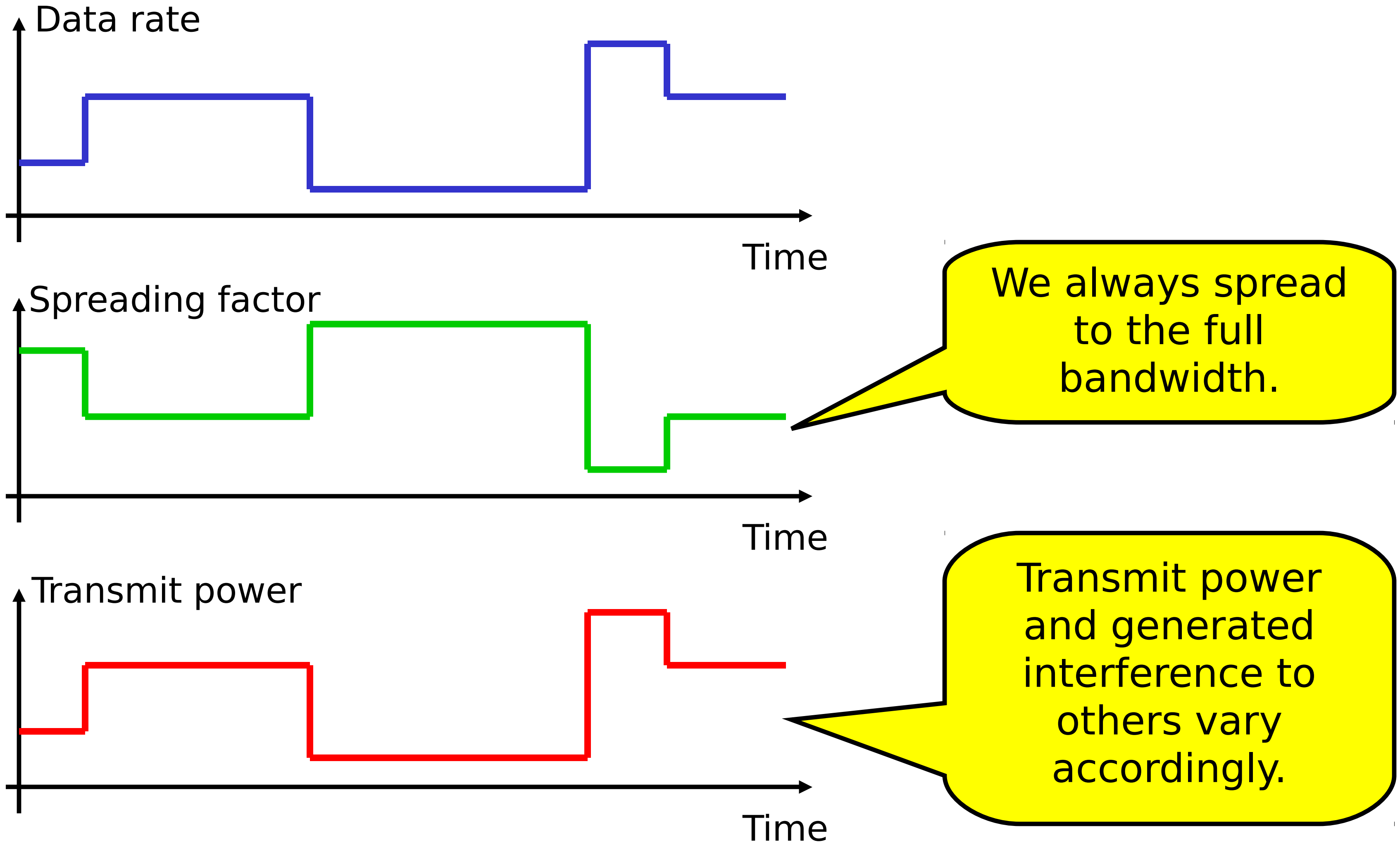


c_c, c_d	Channelization codes (OVSF)
c'_{scramb}	Primary scrambling code (256 chips) VL-KASAMI code (2 codes)
c''_{scramb}	Secondary scrambling code (10 ms optional) 2^{41}-1 Gold code (40 960 chips)
p(t)	Root-raised cosine pulse shaping, roll-off 0.22

WCDMA
Spectrum mask

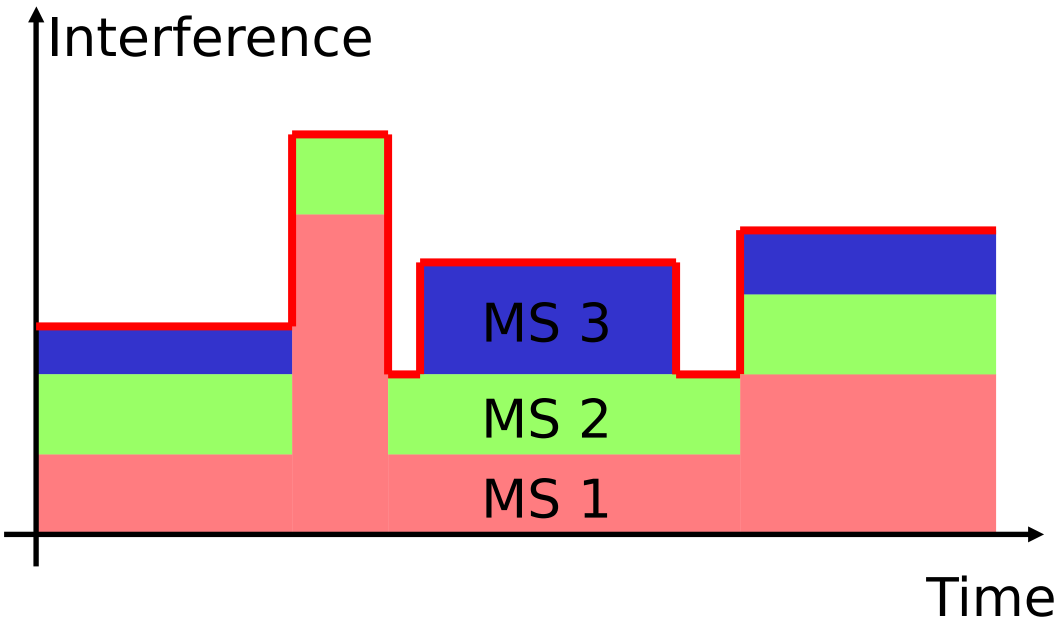


WCDMA
Data rate and spreading factor



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.