UMTS mobile network

Cours RE56 Printemps 2004

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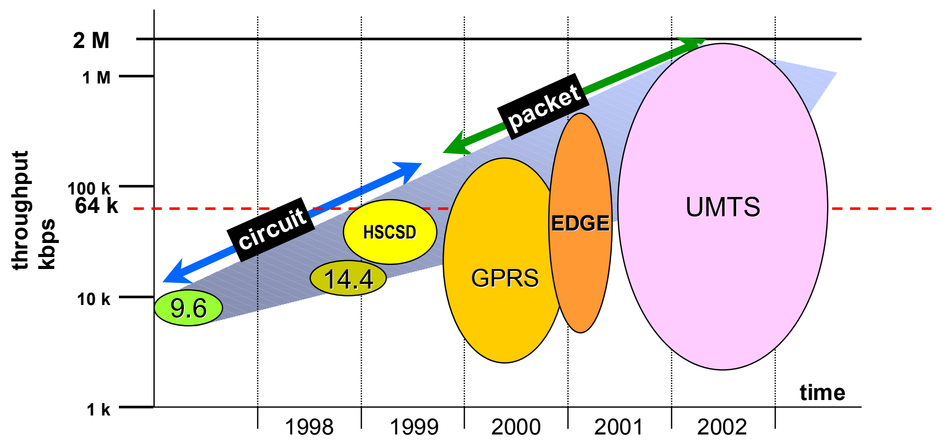
Generations from GSM to UMTS



GPRS = General Packet Radio Service
HSCSD = High Speed Circuit Switched Data
EDGE = Enhanced Data rate for GSM Evolution
UMTS = Universal Mobile Telecommunications System

Content

1. UMTS services
2. Network architecture
3. Radio interface
4. Code engineering

UMTS – Agenda of IMT2000

1990	UMTS Working Group initiated at ETSI
1992	IMT-2000 frequency bandwidths are identified at the Radio Communication World Conference
1995	Kick off of ACTS/FRAMES European project
Jan. 1998	UMTS radio interface defined by ETSI
Nov. 1999	ITU-R/TG 8-1 keeps IMT-2000 concepts with 5 modes
June 2000	3GPP organisation **approved UMTS phase1** detailed specification (**Release 99** or Release 3)
March 2002	First network in the world: Japan (really used today)
March 2003	First network in Europe: UK (commercial strategy)
Dec. 2004 ?	First network in France: Orange and SFR (commercial strategy)

UMTS – Main components

- Frequency bandwidth: **230 MHz at 2 GHz**
- UTRAN: new access network ; 2 access modes
  - FDD mode with W-CDMA
  - TDD mode with TD-CDMA
- Enhancement of spectral efficiency: nr of communications/km^2/MHz
- Manifold things as GPRS but improved
  - Circuit and packet communications
  - Asymmetric data rates DL/UL
  - Large scale of service quality: several BER, several time constraints
  - Large scale of data rates, per user: from 9,6 Kbps to 2 Mbps

UMTS – High speed non voice services

- Bearer services at several data rates
  - Indoor, few mobility: 2 Mbps
  - Outdoor, urban, few mobility: 384 Kbps
  - Outdoor, all environments, all mobility: 144 Kbps
- Needed bandwidths for multimedia services

UMTS – Services will go from 2G to 3G

- America (not only USA)
  - 2G PCS is mainly used ; high constraints for PCS compatibility
  - CDMA2000 (1X et 3X) et UWC136 (EDGE W-TDMA) are IS95 (CDMA) and IS136 (D-AMPS TDMA) evolutions
  - Mobility management based on IS41
- Europe
  - 2G GSM and 2.5G GPRS are mainly used ; UMTS asked for high data rate island networks ; HO between GSM/GPRS and UMTS
  - All spectrum used through FDD and TDD: harmonisation of TDD/TD-CDMA mode and FDD/W-CDMA mode within 3GPP
- Japan
  - Japan 2G is PDC/I-mode (NTT and Vodafone) and CDMA-One (KDDI)
  - NTT DoCoMo brought a lot of lobbying to W-CDMA development (UMTS and CDMA2000) and was the 1st worldwide company to put it on line
  - Convergence between ETSI, Japan (TTC, ARIB) and American normalisation groups to define the 3GPP and to write the system specification

UMTS – Migration from GSM/GPRS to UMTS R99

- UMTS Release 99 = extension of GSM/GPRS developed in Dec. 1999 at 3GPP and approved in Europe in June 2000

- Objectives
  - Migration of existing GSM/GPRS services: voice, SMS, MMS, data...
  - UMTS core network built on GSM/GPRS core network
  - Compatibility of IS and Data Bases of subscribers: HLR, VLR…
  - Same MSISDN number

- Reduction of the release R99
  - Limitation on data rates
    - Data rate < 64 kbps on circuit mode
    - Data rate < 384 kbps on packet mode
  - Real time services are not really available with high QoS…

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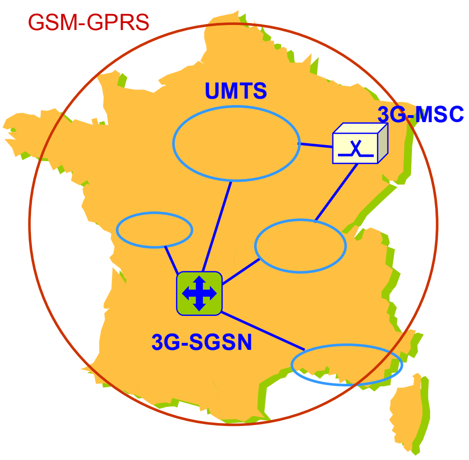
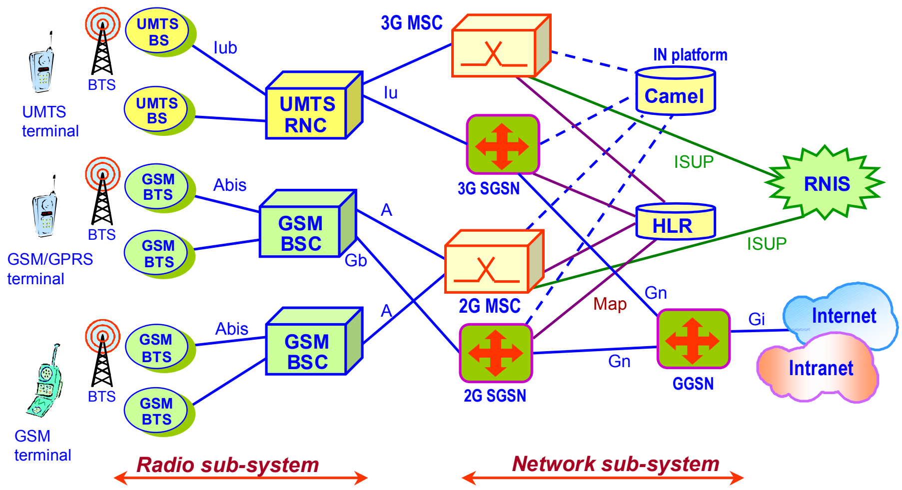
UMTS – Phase 1 (R99) from GSM/GPRS



- UMTS starts with small and independent covered areas
  - Priority to high rate area with multimedia traffic
  - Reuse of GSM/GPRS sites (1x1)
  - Addition of new radio Equipment
- Service continuity between zones with GSM/GPRS and UMTS
  - Bi-mode terminals
  - HO and selection/reselection between cells of 2 layers
  - Dynamic service negotiation depending on zones

UMTS – New Equipment on phase 1



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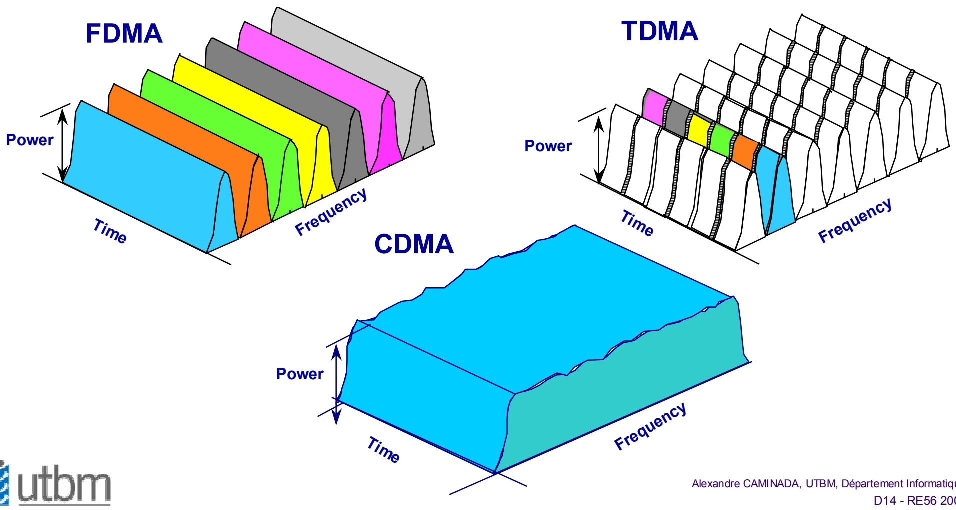
3. **Radio interface**
4. Code engineering

UMTS – UTRAN parameters

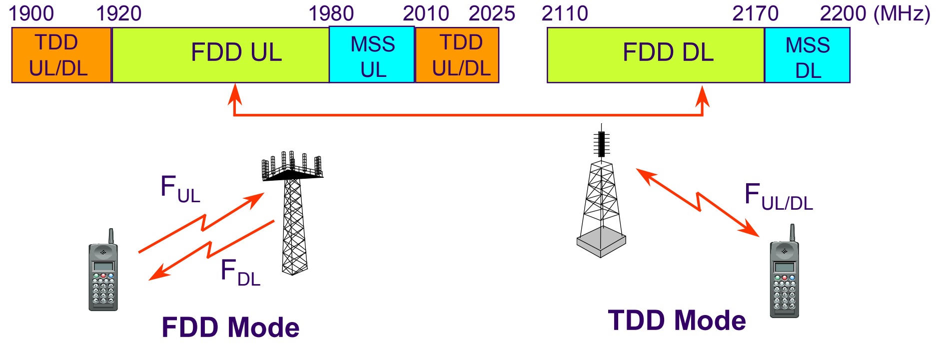
Mode	FDD	TDD
Access	DS-CDMA	TD-CDMA
Chip rate	3,84 Mc/s	
Carrier	4,4 à 5 MHz with 200 kHz raster	
Frame duration	10 microseconds	
Frame structure		15 slots (0,666 ms) per frame
Modulation	QPSK	
Spreading factor	4 to 512 DL 4 to 256 UL	1 to 16

UMTS – Access technologies

– Multiplexing: combination of several separate communication circuits in a single transmission channel



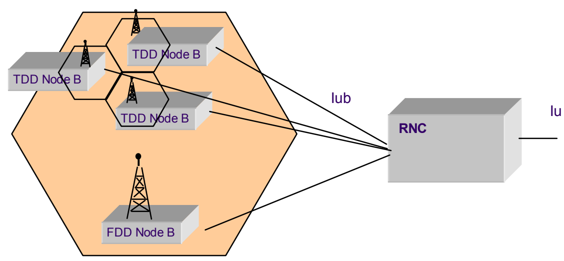
UMTS – Duplex modes



1. FDD mode (Frequency Domain Duplex) on paired bands (2x60 MHz)
2. TDD mode (Time Domain Duplex) on unpaired bands (35MHz)
3. TDD mode will be added to FDD mode in huge traffic areas

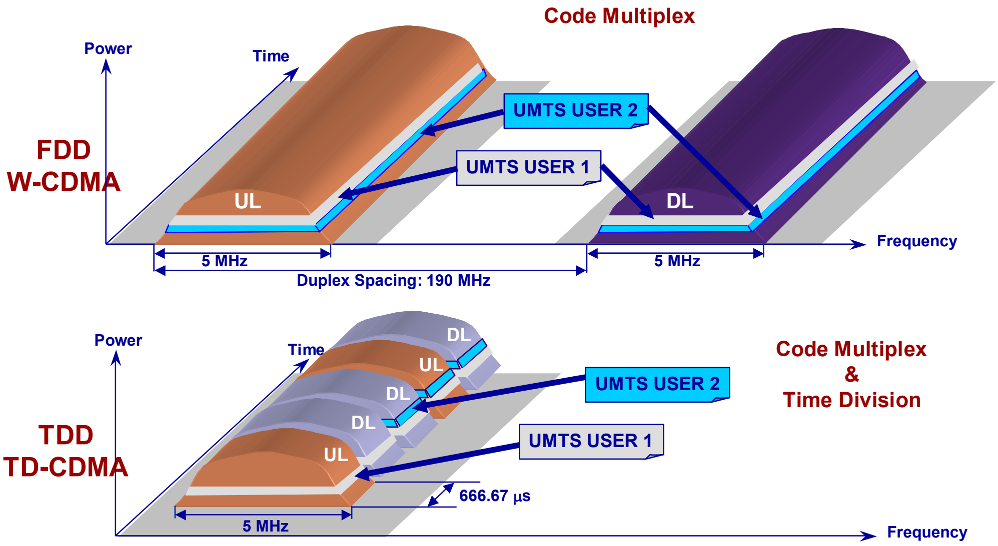
UMTS – Duplex modes

– TDD will complete FDD in hot spots areas such as airports, commercial zones, industrial zones… with good features for asymmetric traffic



- Physical layer and network procedures are harmonized with FDD
- Use of another frequency which does not modified FDD planning
- Common FDD and TDD RRM inside the RNC

UMTS – Access technologies



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UMTS – Wideband versus narrowband systems

- NB
  - The total spectrum is carved up into radio channels (carrier frequency)
  - The entire transmission must be confined within the correlation bandwidth
  - High requirements on transmitter/receiver filters (expensive radio)
  - If a fade occurs, the entire narrowband transmission is affected
  - If blocking rate is too high, more channels have to be added to cells
  - Typically employed by TDMA systems
- WB
  - Basis of spread spectrum system ; negation of channelization assumption
  - The entire channel is available to every user at the same time
  - Overhead of information (bits expended) allows signal and noise coexistence
  - Multipath induced fade does not affect the entire signal
  - No hard limit on user number, the noise level gradually increase
  - Typically employed by CDMA systems

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UMTS – Spread spectrum on TDMA multiplex

- Frequency-Hopping Spread Spectrum (TDMA)
  - A code is used to generate a unique sequence of frequency hops to allow the information signal to spread the spectrum inside several narrow channels
  - Achieved hops, for a specified percentage of the communication time, the carrier frequency is not jammed ; trying to keep good quality transmission (BER < 10e-2)
  - SFH on GSM ; FFH needs to transmit few bits at a time (military)
- Interference effects
  - The total power of noise is spread over the entire band (every single frequency)
  - Multipath fades only occur from time to time on some frequency (not on every frequency), so small percentage of hops
  - Interference level gradually rises with the number of communications (soft blocking instead of hard blocking)

UMTS – Spread spectrum on CDMA multiplex

- Direct-Sequence (Direct Coding) Spread Spectrum (CDMA)
  - A code is used to generate a randomized noise-like high bit rate signal mixed with the information signal to spread the spectrum
  - Kind of "noise modulation": add together 2 digital signals, information signal at e.g. 10 kb/s, and a stream of random bits at 100 Mb/s
  - At the receiver, a generator is producing the same random stream to remove
  - High bit rate involves transmission expansion (100 MHz for 100 Mb/s), that is spread spectrum function
- Interference effects
  - Voice signal is transmitted with a much stronger noise-like signal, of which characteristics are precisely known by receiver (test in 1950 with C/I = -35 dB!)
  - Assignment of different random sequences distinguishes different users and many DS/SS transmitters can operate on the same channel (as with FH/SS)
  - Users share the same spectrum and occupy it entirely at the same time

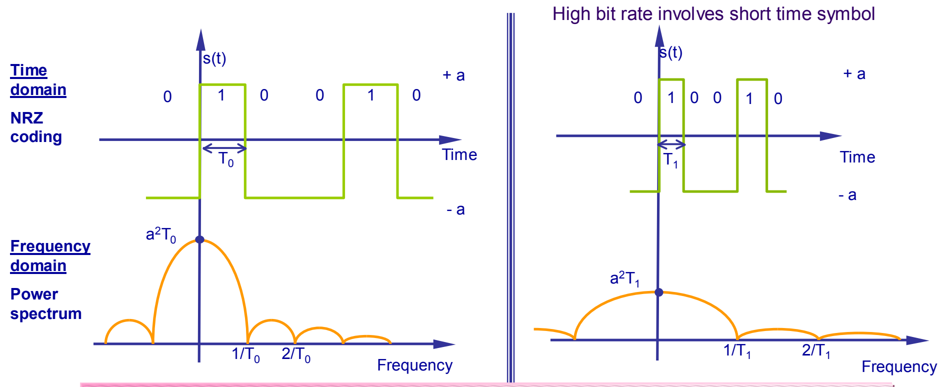
UMTS – Spread spectrum principle

- Bandwidth is much wider than in a conventional channelization radio system
- Each communicator follows an orthogonal random sequence of
  - Frequency hops with FH-TDMA
  - Noise-like bits stream with DS-CDMA
- Random sequences are share by transmitter and receiver
- Different sequence distinguish different users
- As more and more users transmit over the (wide) channel, interference is gradually rises

UMTS – Spread spectrum principle

1 - Time - Frequency Duality

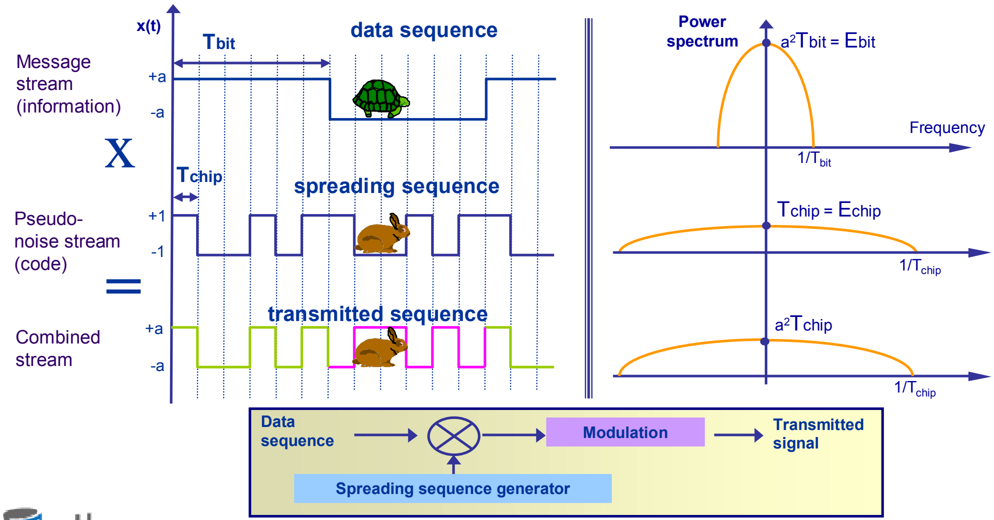
Binary data to transmit 0 1 0 0 1 0



The faster the bit rate, the more the energy is spread on the spectrum

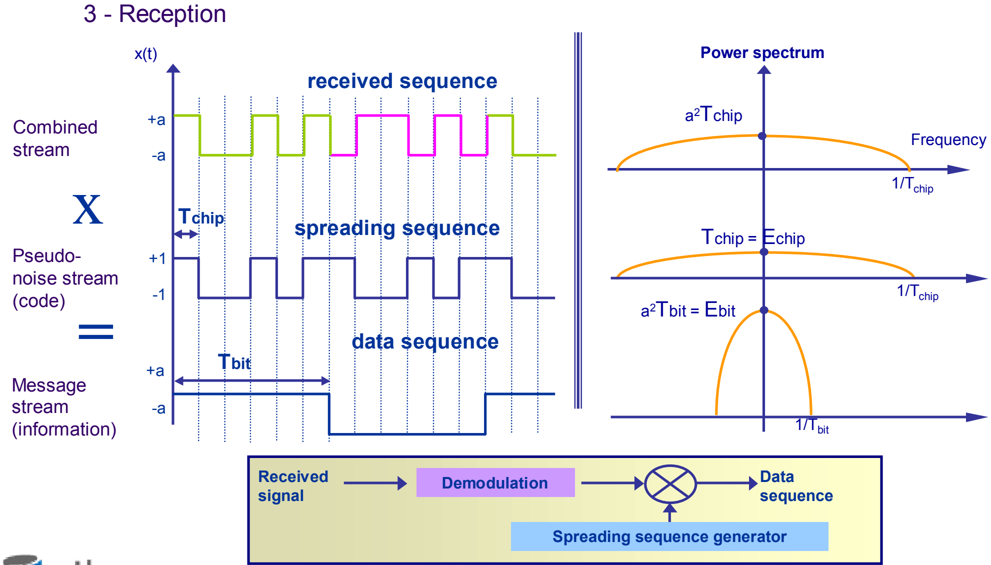
UMTS – Spread spectrum principle

2 - Transmission



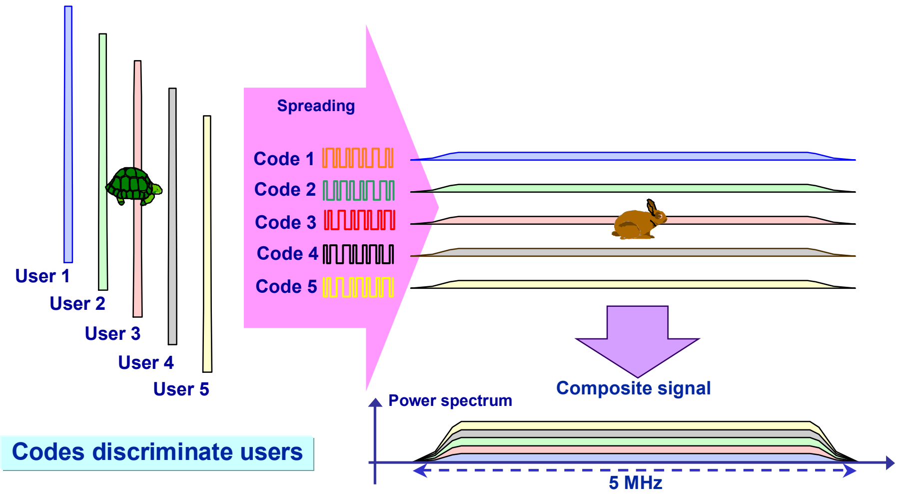
UMTS – Spread spectrum principle

3 - Reception



UMTS – Spread spectrum principle

4 - Code multiplexing

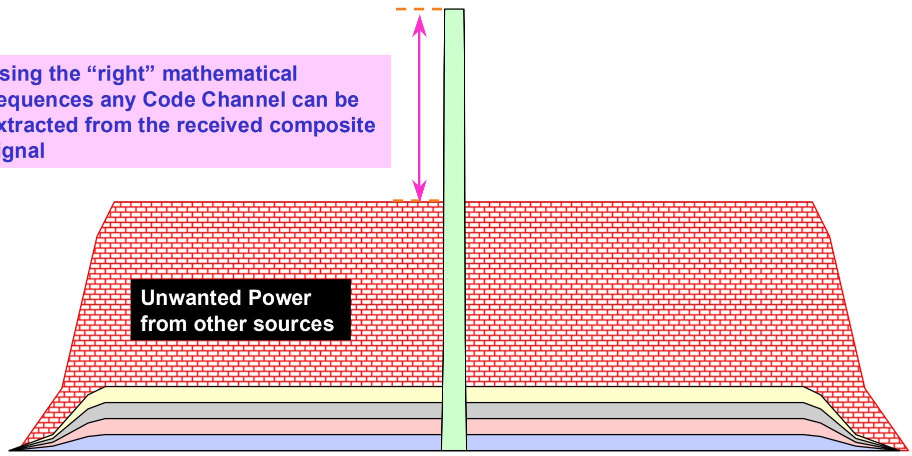


Codes discriminate users

UMTS – Spread spectrum principle

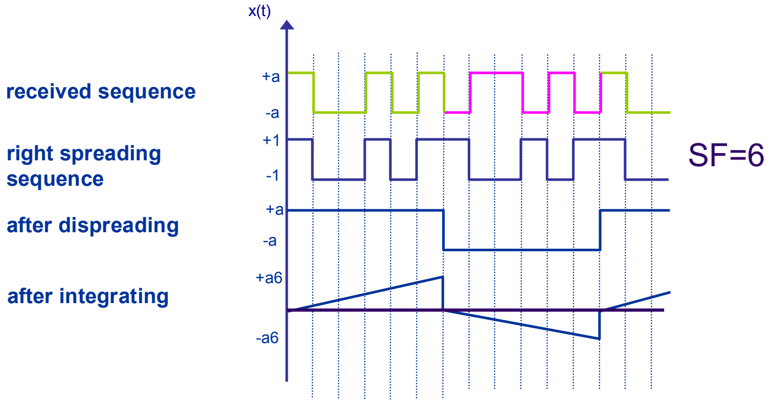
5 - Extraction

Using the "right" mathematical sequences any Code Channel can be extracted from the received composite signal



UMTS – Spread spectrum principle

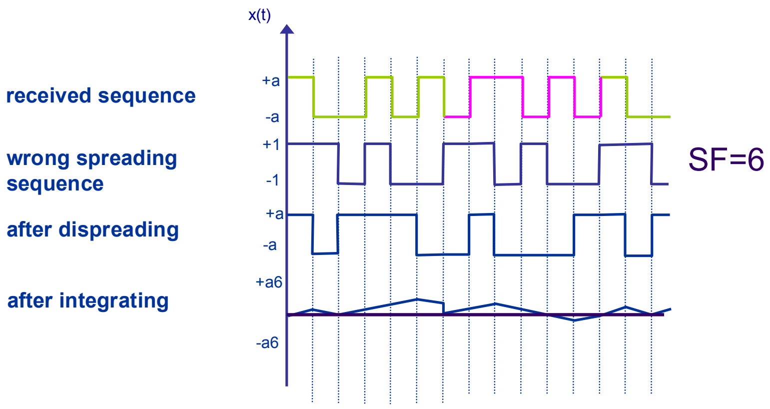
5 - Extraction



The receiver integrates (sums) the dispread bits at each symbol time
Signal amplitude is amplified by the spreading factor => "processing gain"

UMTS – Spread spectrum principle

5 - Extraction



Signal * wrong spreading sequence, then receiver integration doesn't allow the signal to be extracted from power spectrum

UMTS – Gain in spread spectrum

- Processing gain or spread factor (theory)
  - SF (dB) = 10log (channel bandwidth / information bandwidth)
  - In DS/SS, SF is equivalent to 10log(channel bit rate / information symbol rate)
  - In FH/SS, SF is equivalent to 10log(total channel width / width of frequency)

Mode	FDD	TDD
Access	DS-CDMA	TD-CDMA
Chip rate (channel bit rate)	3,84 Mc/s	
Spreading factor (times)	4 to 512 DL 4 to 256 UL	1 to 16

- The processing gain is added directly to S in Signal-Noise-Ratio
  - Interference Margin = SF – (required SNR + system losses) (dB)
  - Large SF involves better circuit quality in noisy background
  - From 6 dB (4 times) to 27 dB (512 times)
  - System losses is typically 4-6 dB

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UMTS – Gain in spread spectrum

- With GSM, voice communication requires C/I = 9 dB
- With WCDMA, voice communication at 12,2 kbps requires C/I = -20 dB
  - SF = $10\log_{10}$ (3,84e6/12,2e3) = 25 dB
  - If Eb, is the energy or power density per bit, and No, is the power density of noise and interference, then Eb/No is the expected power density ratio between the signal after dispreading and the interference
  - Eb/No expected for voice is 5 dB
- Another gain: RAYLEIGH fades tend to be frequency selective, SS brings frequency diversity
  - Fades experienced by FH/SS systems is equivalent to 2-3 dB instead of 20-30 dB without SS

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UMTS – Problem in high symbol rates

- Mobile environment produces delay spread (multipath transmission)
  - A transmitted pulse (< microsecond) is detected by the receiver as greater duration event (several microsecond)
  - Delay spread is fixed for a couple (frequency, environment)
- If the transmission delay spread is large relative to average symbol time, there is inter-symbol interference
  - Individual symbols begin to overlap one another
  - Between 0.5 and 5 microseconds in urban environment at 900 MHz
- Symbol duration is given by symbol rate ; at 200Kb/s bit rate
  - With BPSK (1 bit/symbol), one symbol is 1/200 000 sec = 5 microsecond
  - With QPSK (2 bits/symbol), one symbol is 10 microsecond ; the effect of delay spread is less
- High symbol rate brings problems ; intensive equalization are required

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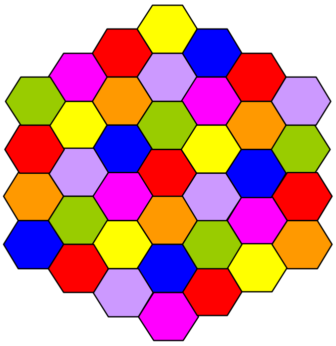
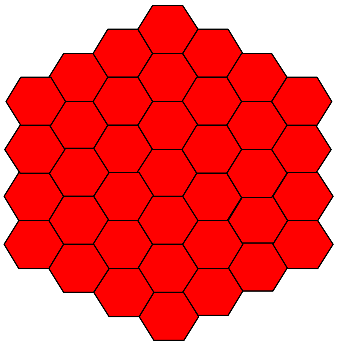
UMTS – Code planning

– TDMA: Frequency reuse planning in GSM



– CDMA: the processing gain allows a universal reuse
– Additional frequency may be used to add capacity



UMTS – Different codes

– Several codes are used by the system to different functions
  - Synchronisation codes
    – To enable terminals to locate and synchronise to cells main control channel
  - Scrambling codes
    – DL: separation of sectors
    – UL: separation of terminals
    – These codes do not change the bandwidth
  - Channelization codes
    – DL: to separate connection to different terminals in a same cell
    – UL: to separate physical data (DPDCH) and control data (DPCCH) from the same terminal
    – These codes define the SF

– Some codes have to be assigned by the planner, other are given by the system
– Code assignment must be done satisfying hard constraints (fixed or forbidden codes) and soft constraints (interference between cells)

UMTS – Code features

- DL scrambling code
  - One scrambling code per cell: they distinguish the cells between each other
  - 512 available codes: high constraint on network planning
- UL scrambling code
  - One scrambling code per mobile: they distinguish the mobiles between each other
  - 2^{24} available codes: few constraint on network planning
- Primary Synchronisation Code (PSC)
  - Synchronisation of the MS with the network
  - One code for all cells of one network
- Secondary Synchronisation Code (SSC)
  - Two neighbour cells have different SSC
  - 64 available codes: high constraint on network planning
  - SSC and Scrambling Code are linked: $SC = SSC*8 + k$, with $0 \leq k \leq 7$

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UMTS – Channelization code features

- Channelization code are orthogonal codes called OVSF (Orthogonal Variable Spreading Factor Code)
- OVSF is a Walsh-Hadamard code ; the code $c_{n,i}$ has the following features
  - The 1st component of $c_{n,i}$ is always +1 whatever n
  - $c_{n,i}$ has the same number of +1 and –1 excepted $c_{n,1}$
  - 2 codes of same sizes satisfy the inter-correlation function

$$R_{c_n, c_m}(0) = \sum_{i=0}^{M-1} c_n(i) * c_m(i) = 0, \forall n \neq m$$

  - n indicates the number of codes and the spread factor size SF
- Two methods to generate the OVSF codes

Recursive Hadamard matrix, each line is a code

$$H_1 = [1]$$

$$H_{2M} = \begin{pmatrix} H_M & H_M \\ H_M & -H_M \end{pmatrix}, \text{ avec } M \geq 1$$

Generator tree with $C_{1,1} = (1)$

$C_{n,i} = (X)$ → $C_{n+1, 2i-1} = (X, X)$, $C_{n+1, 2i} = (X, -X)$

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UMTS – Channelization code features

After application of the channelization code on the data, the data rate is extended

Then the scrambling code is applied but it conserves the data rate

$SF_{UL} \in \{4, 8, 16, 32, 64, 128, 256\}$; $SF_{DL} \in SF_{UL} \cup \{512\}$