Communication Systems

(Lecture 4, part 2 Communicationsystems)

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Radio Propagation channel

Classical: Bandlimited + AWGN

E.g. the satellite channel

Wireless: Bandlimited + Multipath (+ AWGN)

E.g. mobile channel and small wireless devices etc.

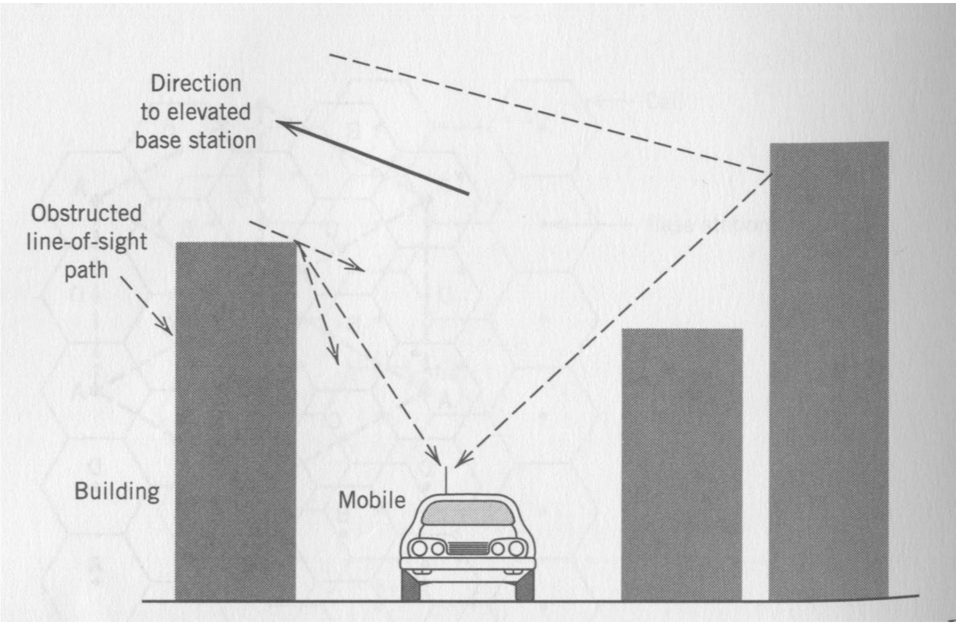
Satellite channel

- Line-of-sight radiopropagation

  E.g. links from earth to satellite and return
- Linking a transmitter and a receiver with freespace propagation
- Satellite offers global coverage but low capacity.
- Mathematical simple

Wireless channel

- Non line-of-sight condition
- Received signal is the sum (or integration) made by the antenna of the signals arriving from different directions due to reflection, scatters and diffraction.
- Mathematical complex



Satellite systems - frequency

- Frequency 1 GHz to 14 GHz
- Low attenuation due to rain (primary signal degrader)
- Insignificant sky background noise (noise from galactic, solar, terrestrial has lowest level between 1 and 10 GHz)
- Interference level a problem between 1-6 GHz =>use 10 to 14 GHz

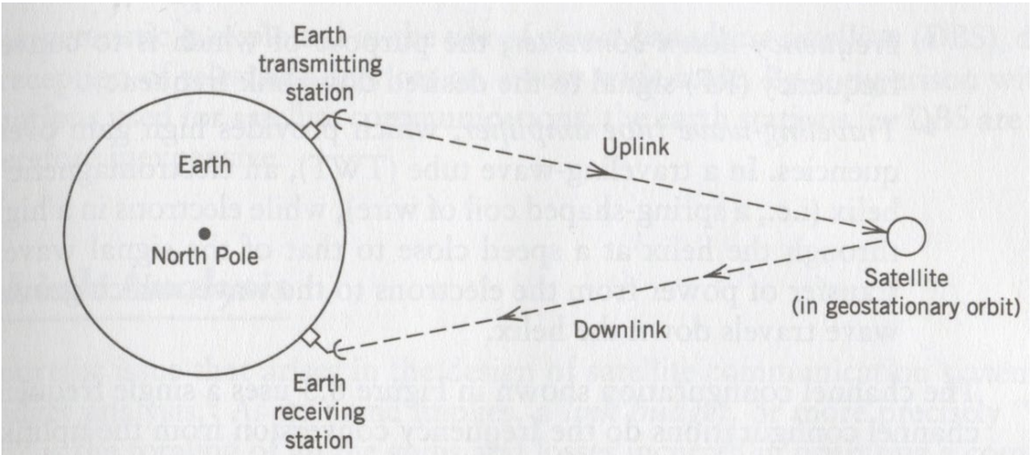
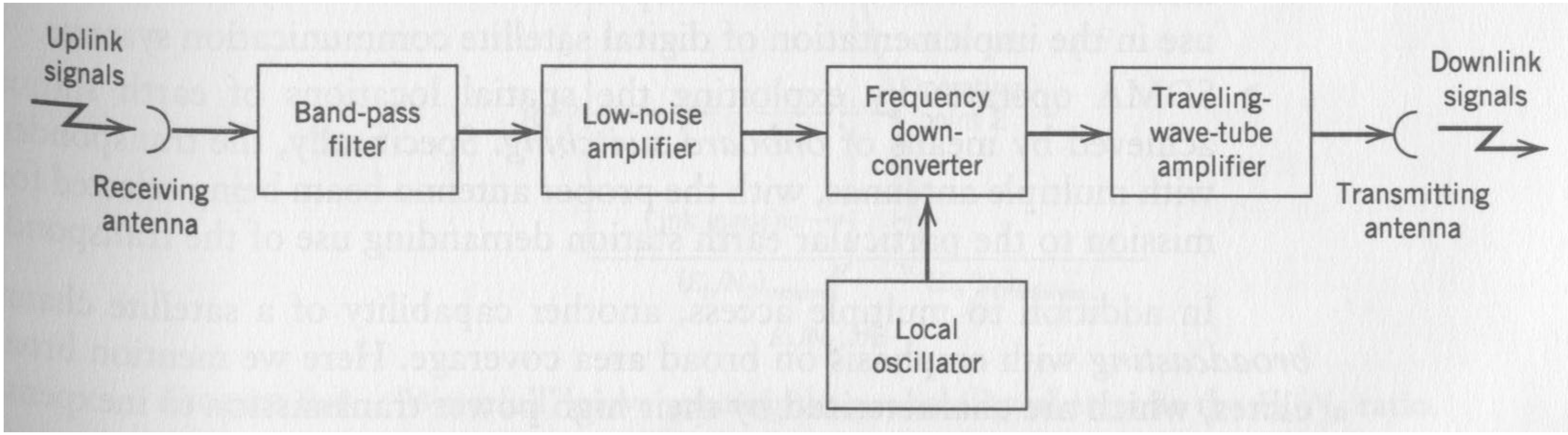


FIGURE 8.2 Satellite communications system.

Satellite system



Note that the time delay for a satellite in the geostationary orbit is very long.

Distance earth to satellite is approx 36.000 KM =>

Return delay is speed of light times distance:

$$2 \cdot d / c = 2 \cdot 36000 \cdot 10^3 / 3 \cdot 10^8 = 0.24s$$

Satellite system

- Dedicated satellite links with high antenna gain.
  - Expensive TX and RX earth stations but less expensive satellite (low power).
- Broadcast satellite with less antenna gain =>
  - Expensive TX earth station and satellites (high power) but less expensive RX earth stations.
  - Larger cover area.

Satellite systems – Link budget

Consist of:

1. Resources for TX and RX.

   Antennas, Tx-power and receiver sensitivity.

2. Propagation loss.
3. Noise sources.

Satellite systems – Link budget

Example: Link budget for a satellite link at 10 GHz to a satellite in geostationary orbit transmitting with 10 Watt to a receiver with a sensitivity of -130 dBm.

1. Propagation loss=

$$\left[\frac{\lambda}{4\pi d}\right]^2 = \left[\frac{c/f}{4\pi d}\right]^2 = \left[\frac{3\cdot 10^8/10^{10}}{4\pi\cdot 36\cdot 10^6}\right]^2 \approx 4.4\cdot 10^{-21} \approx -203dB$$

2. $P_{\text{received Isotropic}}$ = 40 dBm-203dB= -163 dBm

Satellite system – Link budget Example

3. Minimum antenna gain needed -130dBm-(-163dBm)= 33dBi

Can a 0.5 meter disc do the job?

Max Gain for a disc-antenna of 0.5 meter in diameter?

Satellite system – Link budget Example

3. Minimum antenna gain needed -130dBm-(-163dBm)= 33dBi

Can a 0.5 meter disc do the job?

Max Gain for a disc-antenna of 0.5 meter in diameter? => use the maximum efficient area

$$A_{em} = \frac{\lambda^2}{4\pi} \cdot G_0 = \frac{(c/f)^2}{4\pi} \cdot G = \frac{0.03^2}{4\pi} 2000 = 0.1432 m^2$$

$$A_{physical} = \pi \cdot r^2 = 0.196 m^2$$

Communication Systems channel (or mobile channel)

Due to the nature of the signal its characterisation need:

1. Practical measurements
2. Statistical analysis

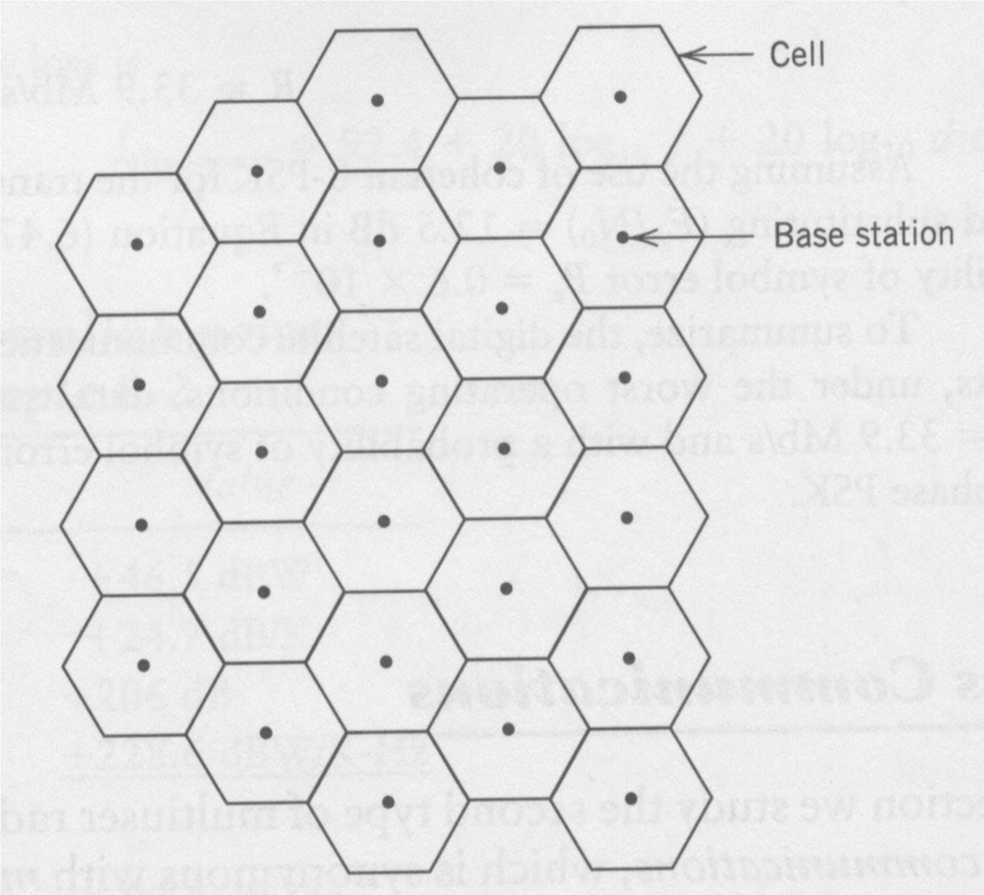
To find e.g.

1. Mean signal strength
2. Signal variability

Cellular radio

Compared to fixed systems additional we need:

1. Radio resource management.
2. Mobility management.

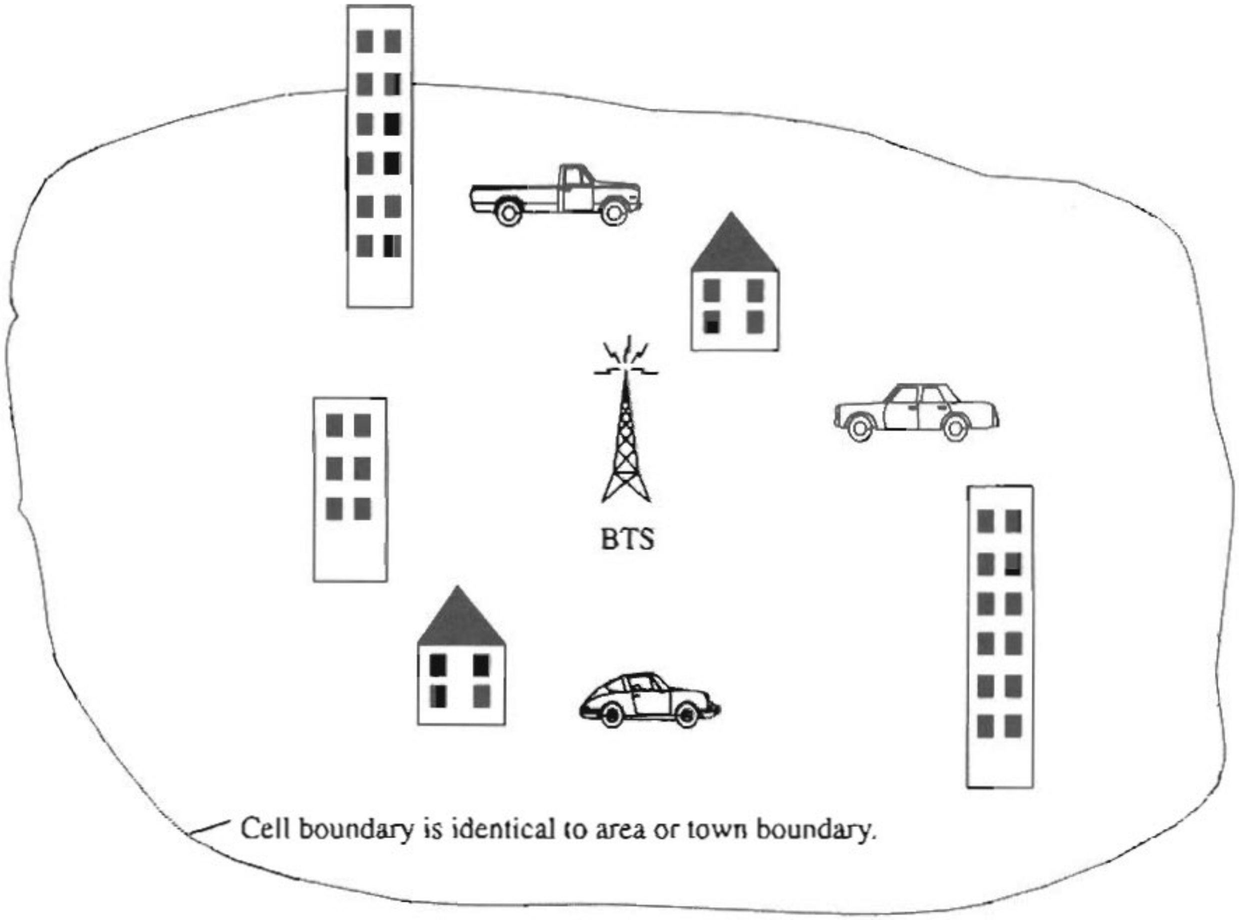


Cell size?

Rural: 5 to 30 Km

Indoor microcell: 25 to 100m

Cellular radio – physical cell



Cellular concept

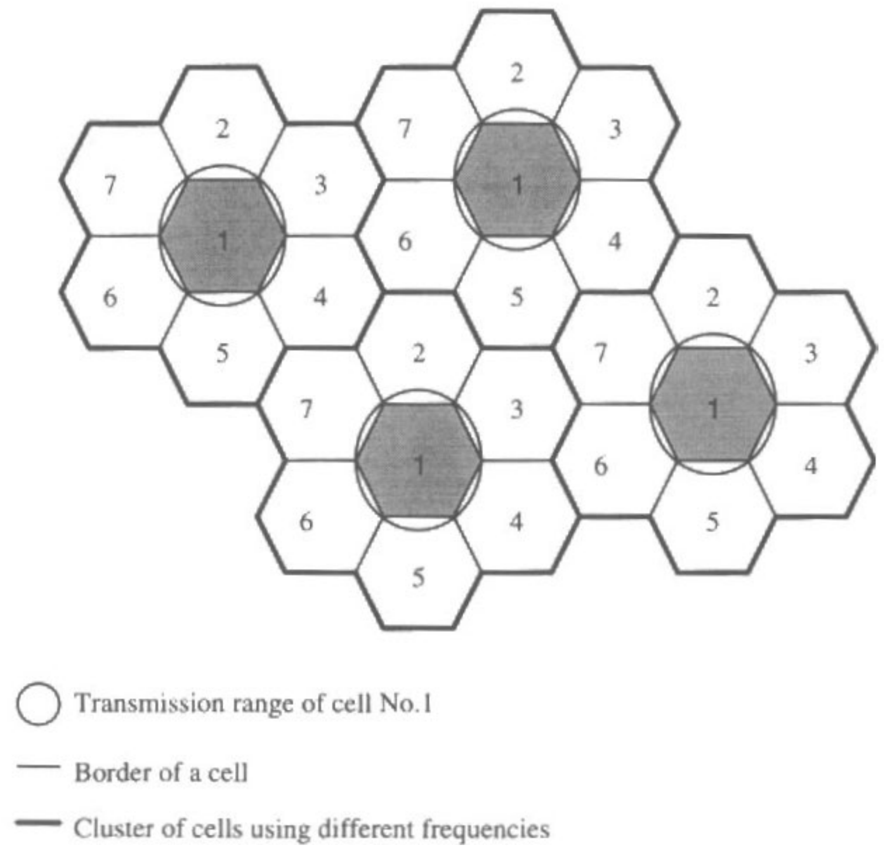
Frequency reuse:

One high power and high elevated BS =>

1. Low capacity
2. Large area with interference

Larger reuse factor => less interference but low capacity.

Frequency is expensive! e.g. 5G auction!

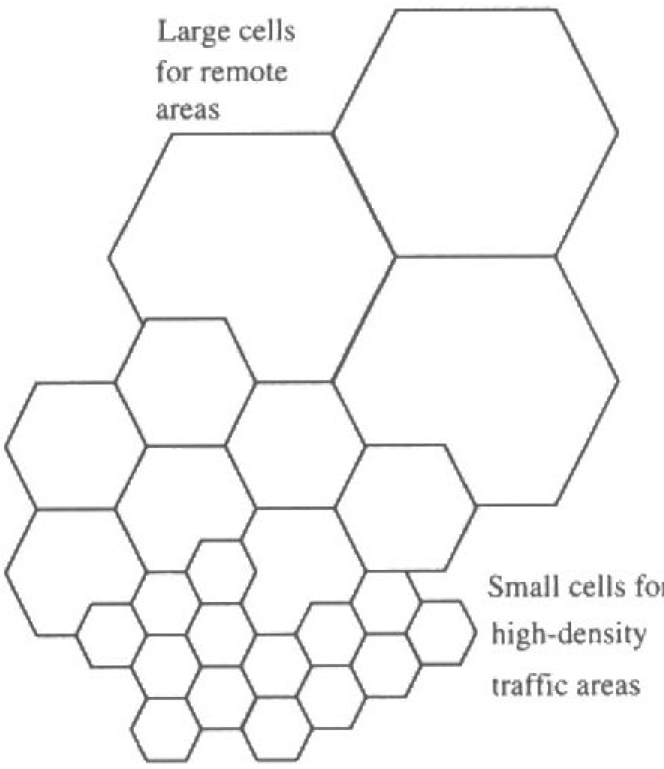


Cellular concept

Cell splitting:

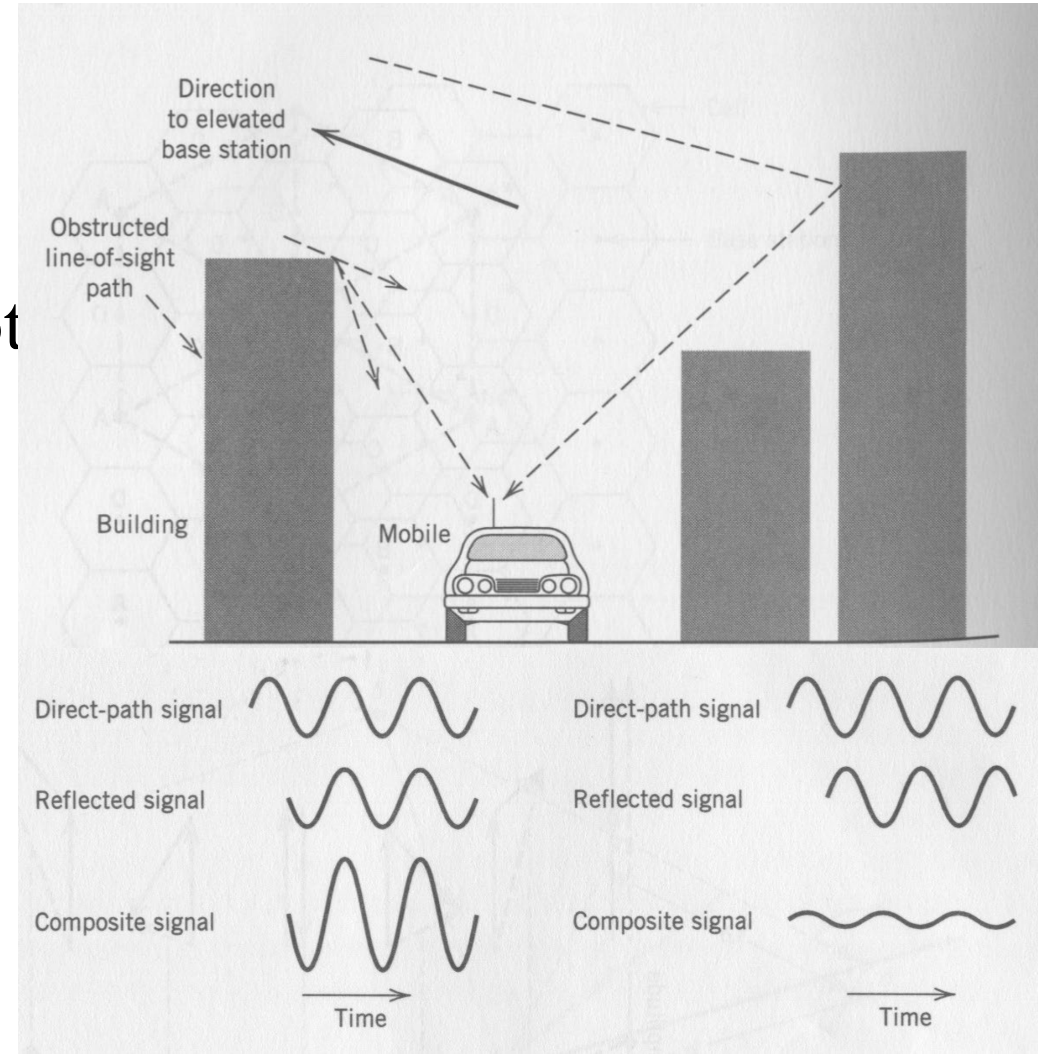
Create flexibility – first coverage then capacity *and only* where needed.

Changes to the network are only made locally (in the particular cell where more capacity is needed)



Wireless propagation

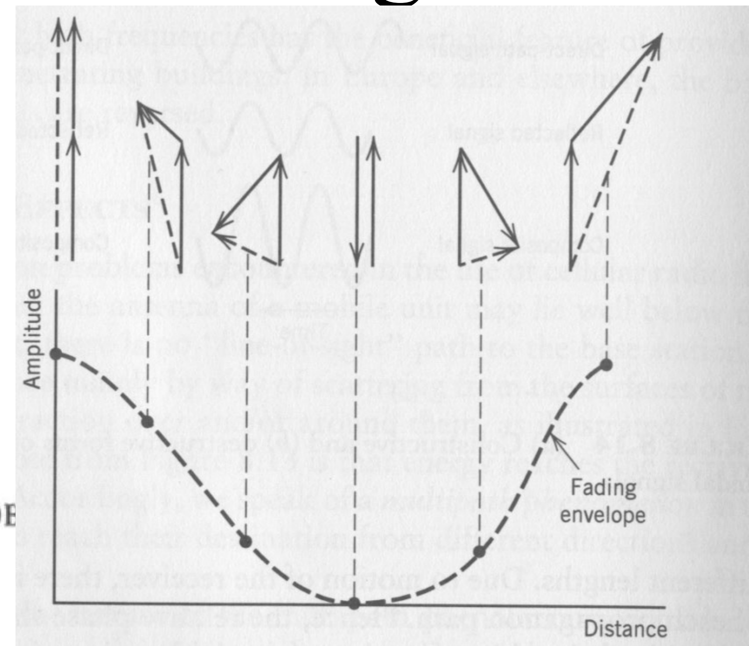
The antenna is moving and the static description used for the 2-ray model can not be used directly.

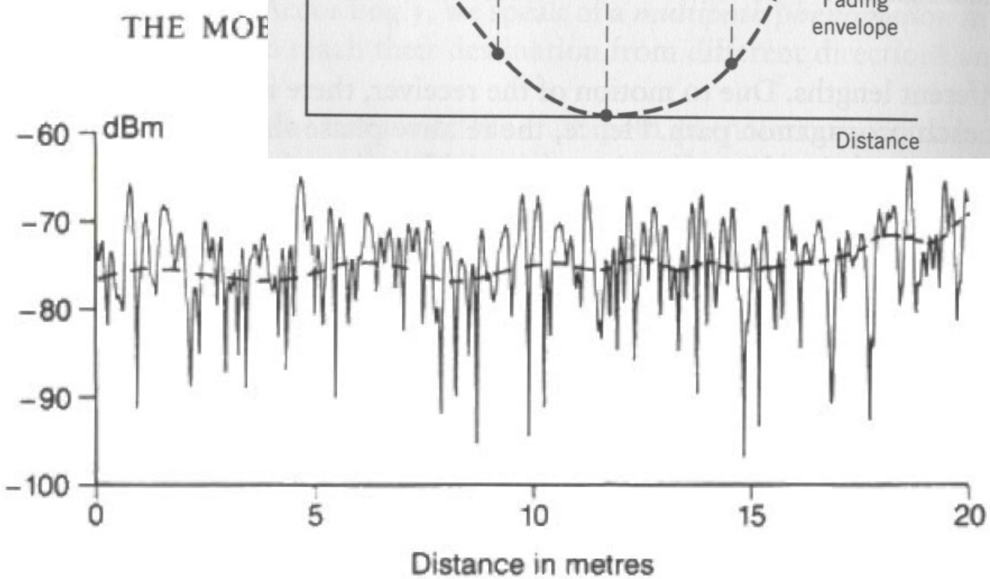


The signal is timevarying!

Wireless propagation - fading

The sum of all incoming waves are integrated by the antenna => the signal strength changes easy a 100 times for a movement of half a wavelength!





The signal is also space varying!

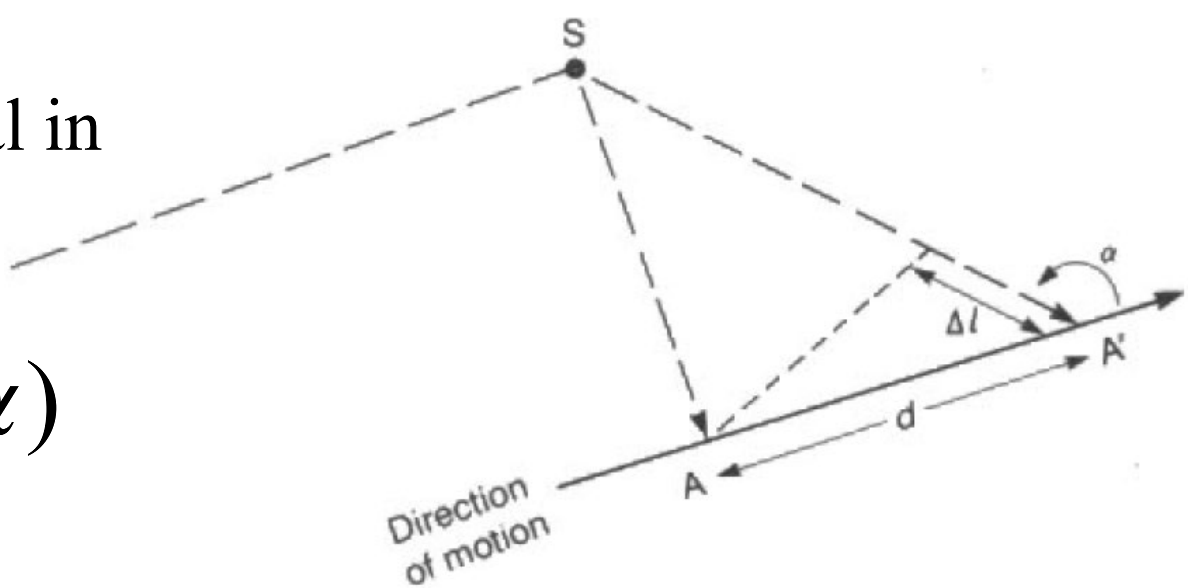
Doppler shift

The frequency changes slightly when moving with high speed towards the transmitter (frequency increases), or in general in any direction as:

$$\upsilon = \frac{v}{\lambda}\cos(\alpha)$$

Ex.: GSM1800, V=250 km/h

$$\upsilon = \frac{v}{\lambda}\cos(\alpha) = \frac{250*1000/3600}{c/1.8\cdot 10^9} \leq \pm 417\,Hz$$

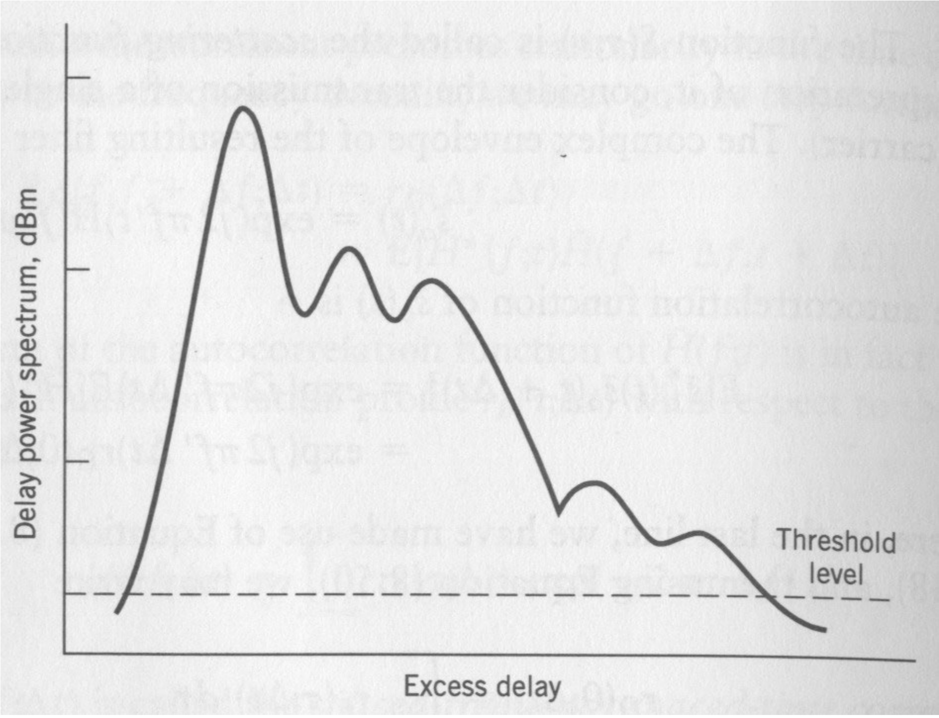


Delay spread (or echoes)

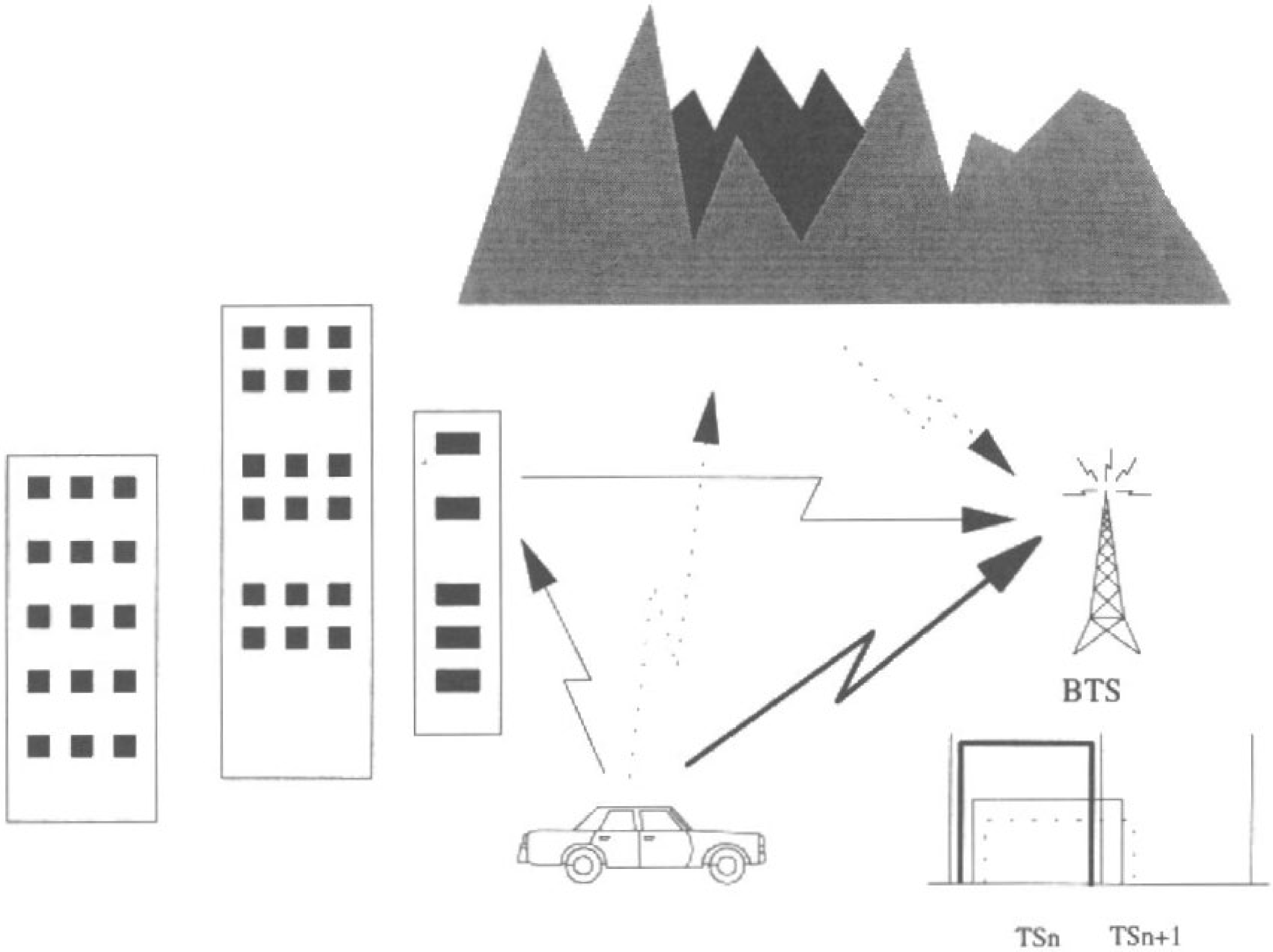
Due to the different path lengths for the different multipaths some waves arrive later than others which results in time spreading of the signal!

If the echoes arrive so late that the next symbol is started on the earlier paths => troubles!

Equalizer is needed!



Delay spread (or echoes)

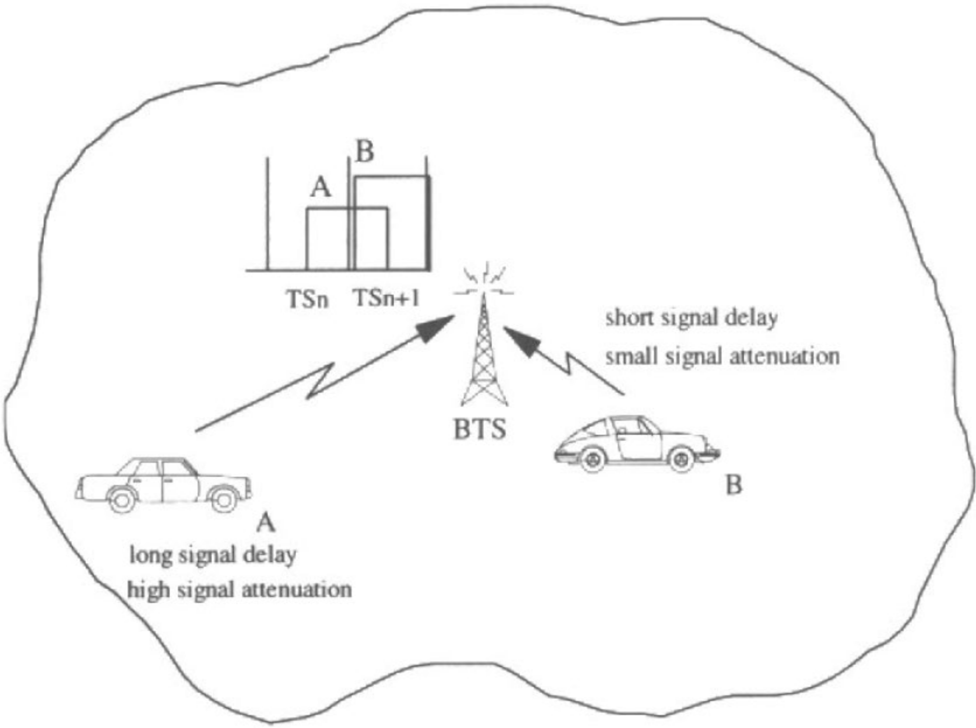


Timing of mobile stations

Due to the different distance between the mobiles and the basestation, each mobile need to know the distance in time to the basestation. Otherwise interference is introduced!

Ex: R=30Km => time difference = R/c=100µs

In GSM each timeslot is 577µs and max cell radius 36 km.



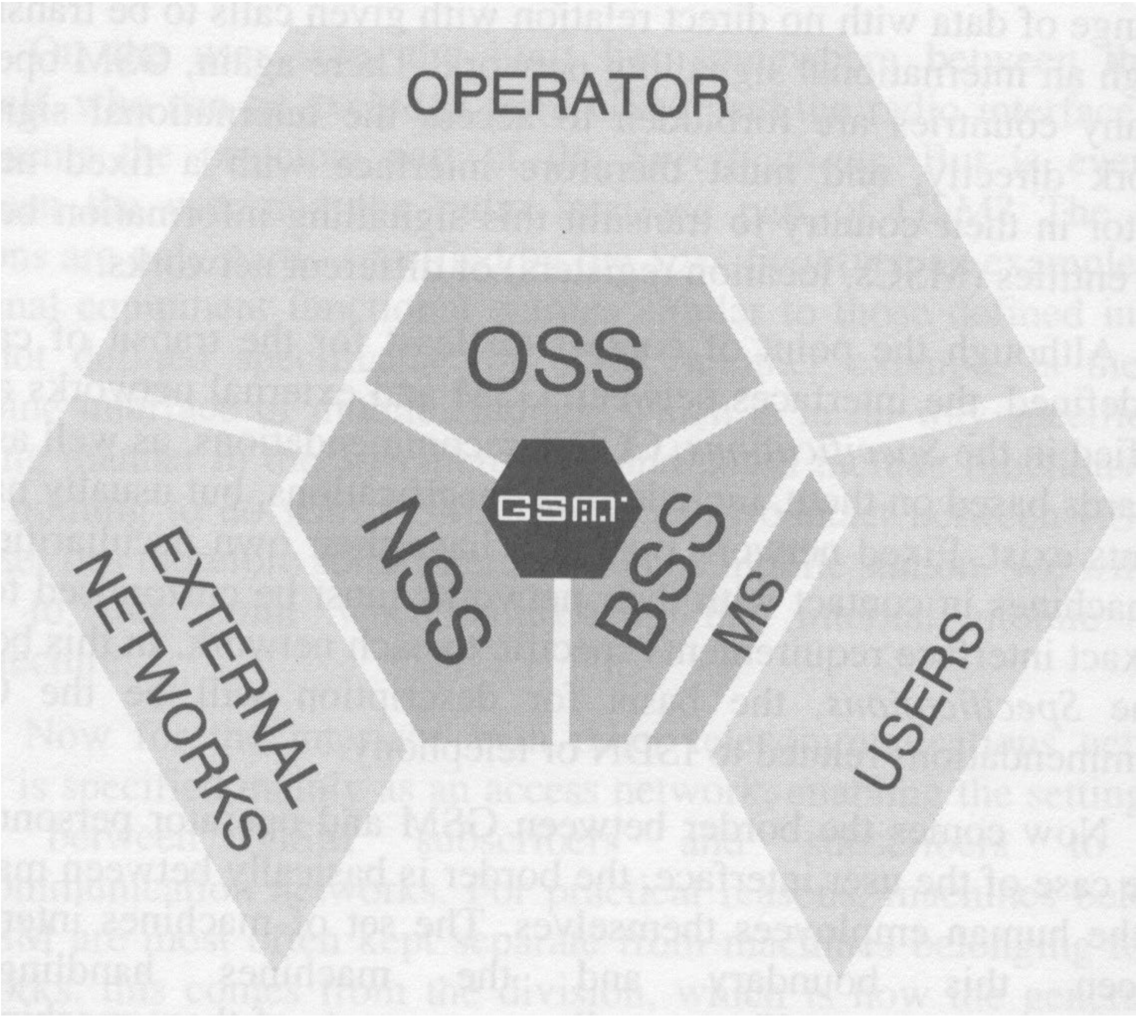
Mobile system need to take care of

- Radio resource management
- Mobility management
- Fading – and fast time varying channel
- Frequency changes due to velocity – Doppler
- Echoes due to multipaths
- Timing – due to different distances to the base

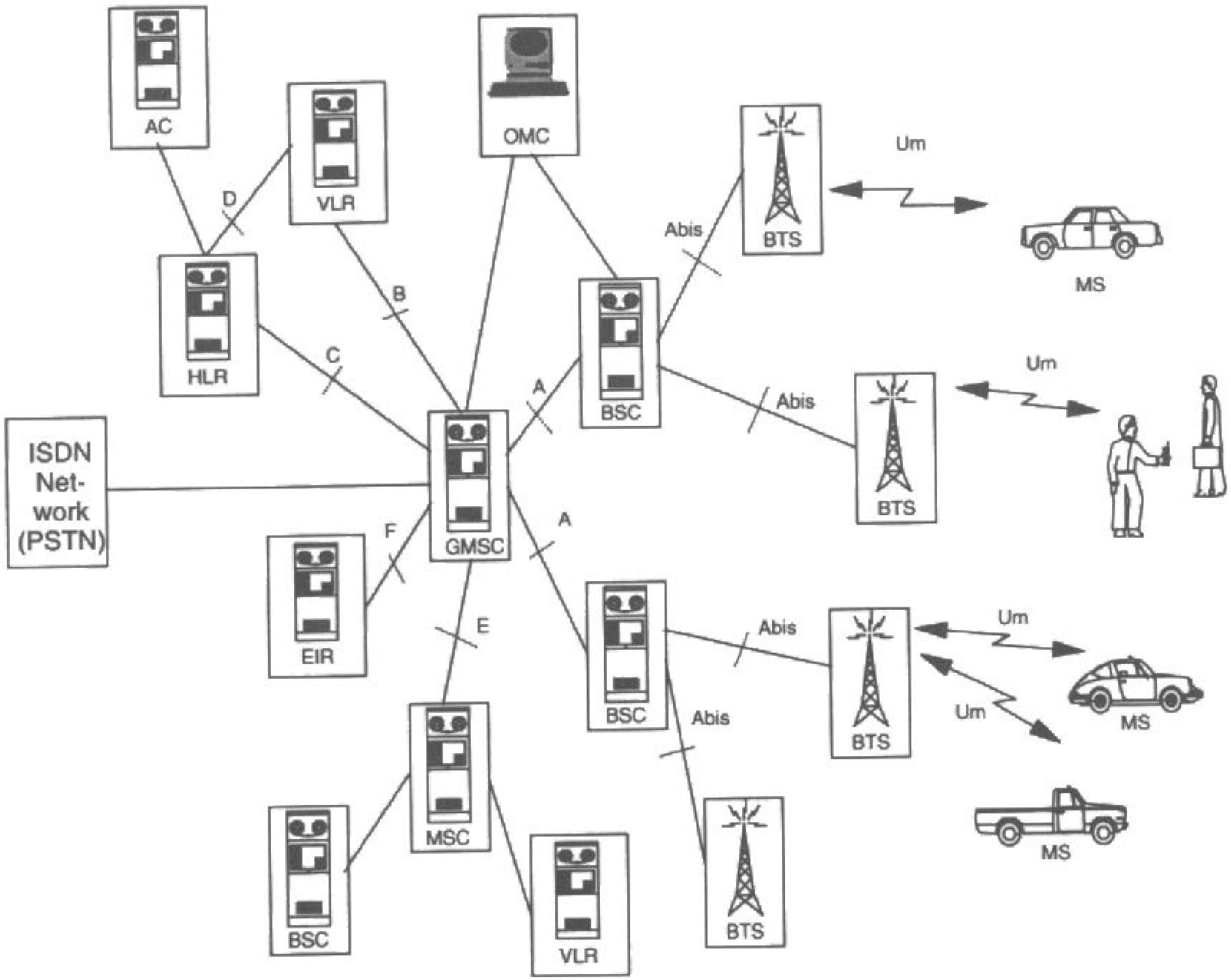
Mobile system example

GSM

GSM system



GSM system



AC
VLR
OMC
D
HLR
B
C
BTS
Um
Abis
MS
BSC
A
Um
Abis
ISDN Net- work (PSTN)
GMSC
A
F
EIR
E
Abis
Um
MS
Um
BSC
Abis
BTS
MSC
MS
BSC
VLR
BTS

GSM system – RF spec.

Frequency:GSM400, 850, 900, 1800, 1900 (MHz)

GSM900:

Uplink 890 – 925 MHz

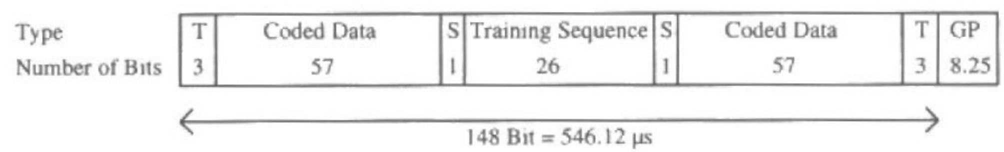
Downlink 935 – 960MHz

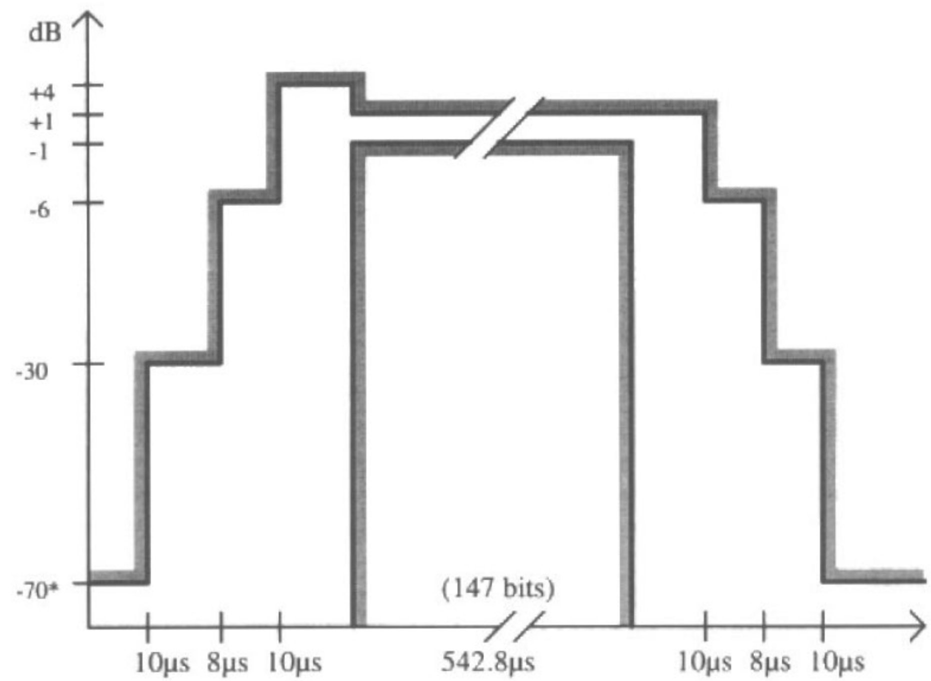
Frequency spacing 200kHz =>

124 Ch (374 for 1800)

MS Tx power, class 5, 2Watt peak power (1 Watt for 1800).

Receiver sensitivity -102 dBm





GSM system

How does GSM take care of the 6 listed issues?, viz:

1. Radio resource management.
2. Mobility management.
3. Fading – and fast time varying channel.
4. Frequency changes due to velocity – Doppler.
5. Echoes due to multipaths.
6. Timing – due to different distances to the base.

GSM system

Radio Resource management

1. Each MS measure signalstrength and signal quality from neighbour cells (using the broadcast channel). This information is reported to the BS (each approx. 0.5s).
2. Each MS can regulate the transmit power in steps of 2 dB in a 20 dB range and are instructed by the BS.
3. Each MS can Tx and Rx on all channels and more frequency bands (e.g. GSM900, GSM1900) controlled by the BS

GSM system

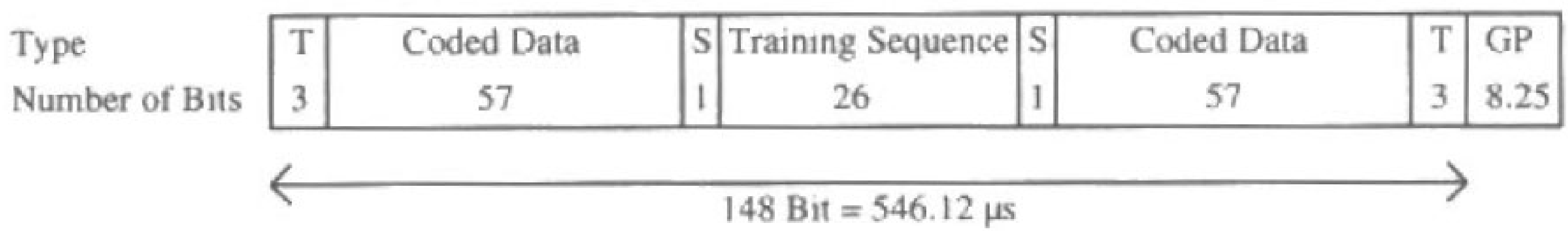
Mobility management

1. Each MS listen to the broadcast channel on the BS with the best propagation condition and decodes the ID and the area code of the BS. If the MS finds that it enters a new area it request an update in the HLR (Home Location Register) or VLR (Visitor Location Register).
2. Each MS can report when it is turned “off” and “on”.

GSM system

Fading – and fast time varying channel

1. Each burst (of 577µs) contains a centre part for estimating the mobile channel. Knowing the channel is like a filter and can be "unconvolved" by signal processing.



2. Using frequency hopping (change frequency channel each burst). Helps slow moving users out of a fade.

GSM system

Fading – and fast time varying channel

3. Using interleaving and channel coding.

Type	T	Coded Data	S	Training Sequence	S	Coded Data	T	GP
Number of Bits	3	57	1	26	1	57	3	8.25

148 Bit = 546.12 μs

4. Using diversity – utilise that there are more paths between BS and MS – e.g. in time or more antennas (antenna diversity).

GSM system

Doppler and Delayspread.

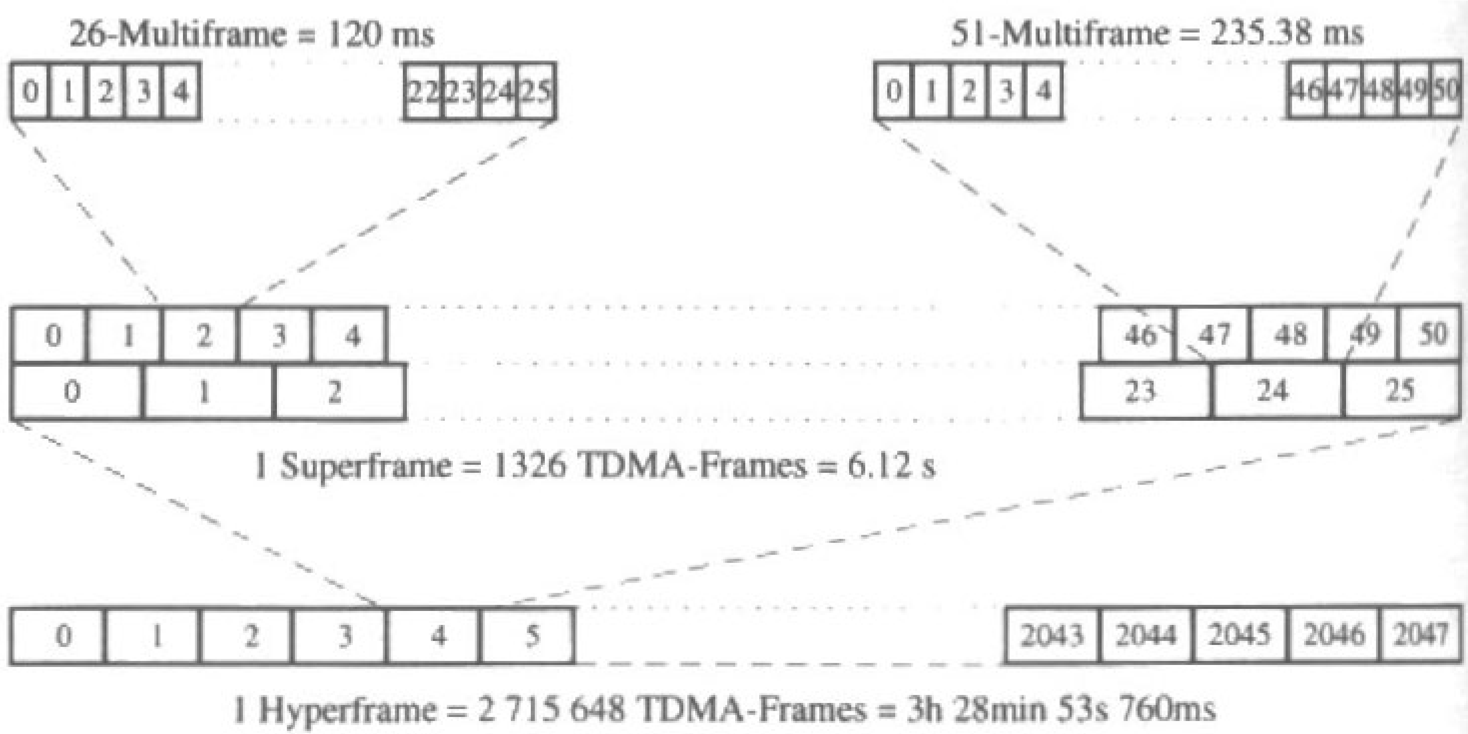
1. Max Doppler is in the range of 0.5 to 1 kHz and the frequency channel spacing is 200 KHz. A small guard frequency band can take care of this.

2. Late Echoes are in the range of 16μs in mountain areas and the symboltime is 3.7μs. Therefore channel equalisation is needed and the information is known from the channel estimation made in each received burst.

GSM system

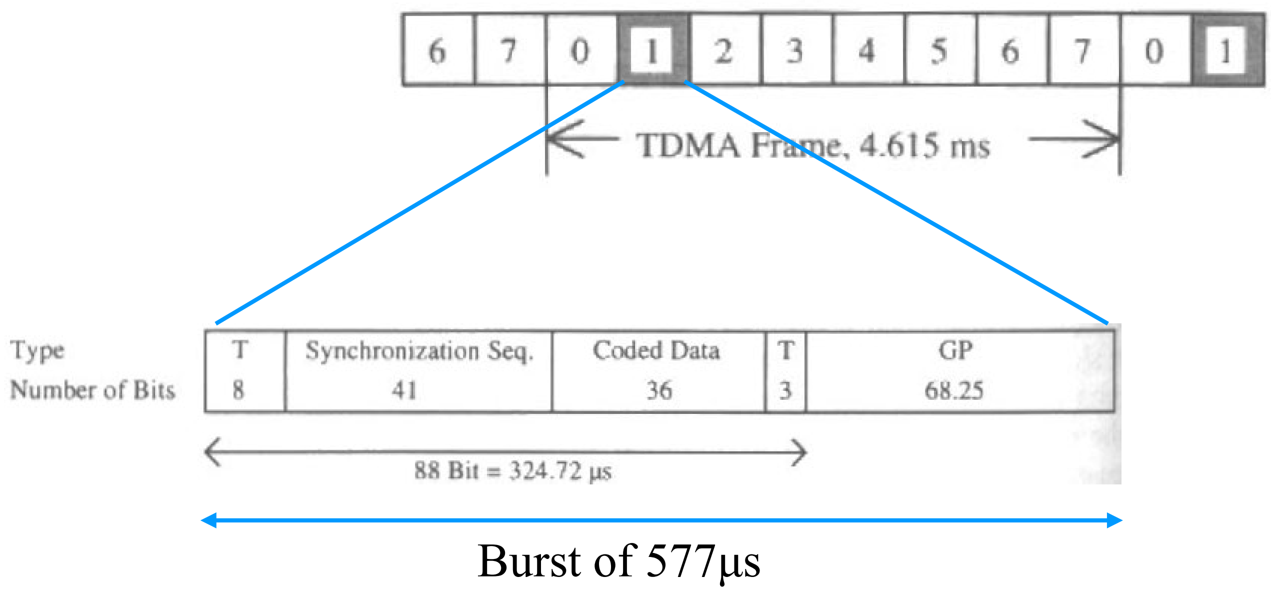
Timing – due to different distances to the base.

Each MS need absolute timing (to know the timeslot no).



GSM system – Timing/Synchronisation

Each MS need synchronisation which is obtained by receiving and decoding a synchronisation burst from the broadcast channel. The MS is instructed to set its "Time-advancement" when addressing the BS (up to 64bit time)



GSM – ca

log. Channel	Mobile Station Base Station	
PCH	←	Paging of the mobile station
RACH	→	Channel request
AGCH	←	Channel assignment
SDCCH	→	Answer to the paging from the network This is already transmitted on the assigned channel
SDCCH	←	Authentication request from the network
SDCCH	→	Authentication response from the mobile station
SDCCH	←	Request to transmit in the ciphered mode
SDCCH	→	Acknowledgment of the ciphered mode
SDCCH	←	Setup message for the incoming call
SDCCH	→	Confirmation
SDCCH	←	Assignment of a traffic channel
FACCH	→	Acknowledgment of the traffic channel
FACCH	→	Alerting (now the caller gets the ringing sound)
FACCH	→	Connect message when the mobile is off-hook
FACCH	←	Acceptance of the connect message
TCH	↔	Exchange of user data (speech)

GSM – Where is decision taken

MS	BTS	BSC	(G)MSC	VLR	HLR	Action
→	→					Channel Request
	←					Channel activation command
	→					Channel activation acknowledge
←	←					Channel Assignment
→	→	→				Location Update Request
←	←	←				Authentication Request
→	→	→				Authentication Response
			↔			Comparison of the Authentication parameters
←	←	←				Assignment of the new area and the temporary identity (TMSI)
→	→	→				Acknowledgment of the new area and the temporary identity (TMSI)
			↔ ↔			Entry of the new area and identity into the VLR and HLR
←	←					Channel Release