GSM Radio Network Engineering Fundamentals

Prerequisite: Introduction to the
Alcatel GSM Network

Contents

GSM Radio Network Engineering Fundamentals

Introduction

Contents

- Standardization
- Documentation
- Radio Network Architecture
- Mobile Phone Systems

Introduction

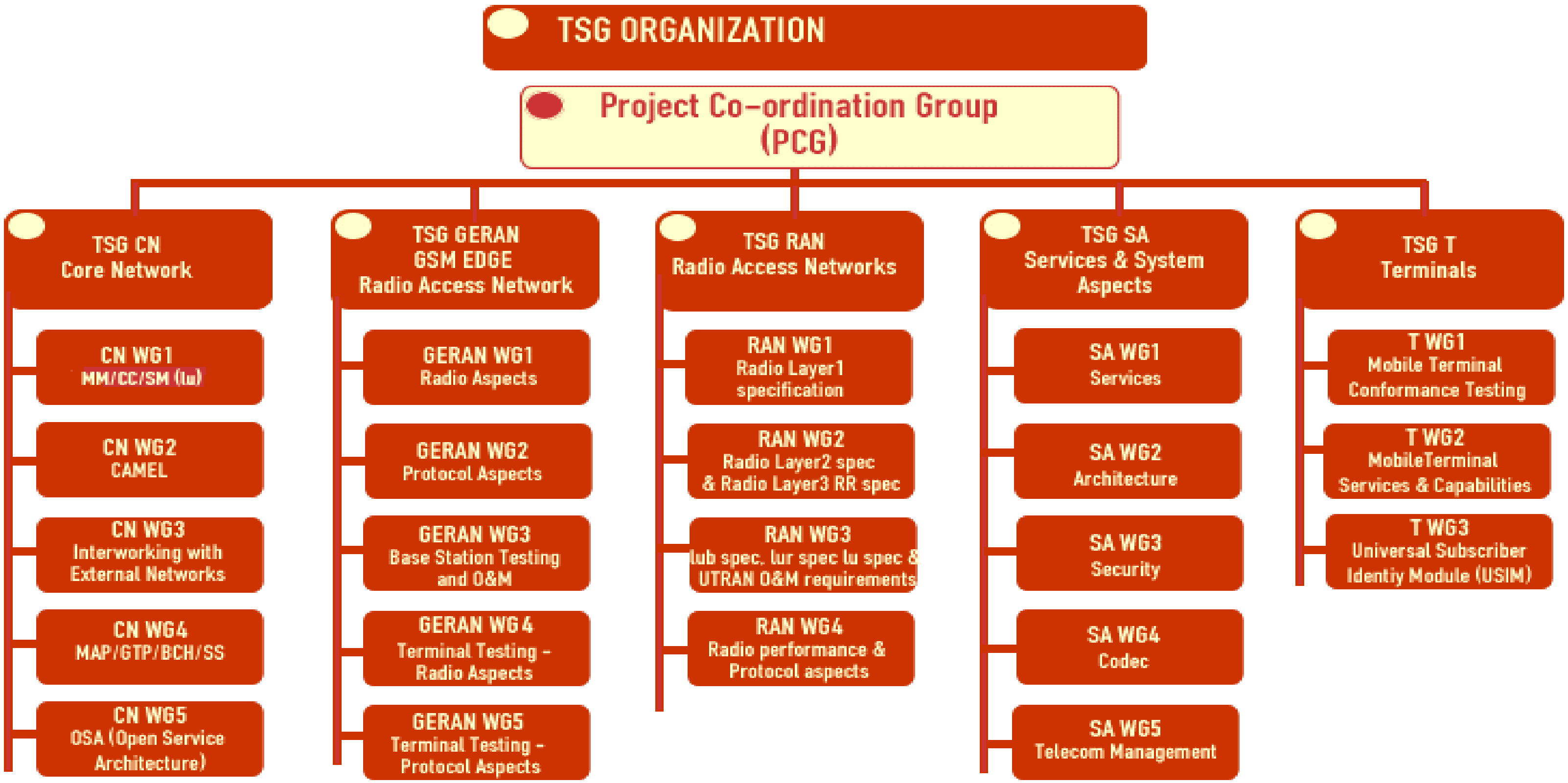
Standardization
Documentation

www.3GPP.org organizational partners

- Project supported by
  - ARIB Association of Radio Industries and Businesses (Japan)
  - CWTS China Wireless Telecommunication Standard group
  - ETSI European Telecommunications Standards Institut
  - T1 Standards Committee T1 Telecommunication (US)
  - TTA Telecommunications Technology Association (Korea)
  - TTC Telecommunication Technology Committee (Japan)

- The Organizational Partners shall determine the general policy and strategy of 3GPP and perform the following tasks:
  - Approval and maintenance of the 3GPP scope
  - Maintenance the Partnership Project Description
  - Taking decisions on the creation or cessation of Technical Specification Groups, and approving their scope and terms of reference
  - Approval of Organizational Partner funding requirements
  - Allocation of human and financial resources provided by the Organizational Partners to the Project Co-ordination Group

Technical Specification Group TSG



Specifications and Releases

- GSM/Edge Releases: http://www.3gpp.org/specs/releases.htm
  - TR 41.103 GSM Phase 2+ Release 5
    - Freeze date: March - June 2002
  - TR 41.102 GSM Phase 2+ Release 4
    - Freeze date: March 2001
  - TR 01.01 Phase 2+ Release 1999
    - Freeze date: March 2000
- For the latest specification status information please go to the 3GPP Specifications database: http://www.3gpp.org/ftp/Information/Databases/Spec_Status/
- The latest versions of specifications can be found on ftp://ftp.3gpp.org/specs/latest/

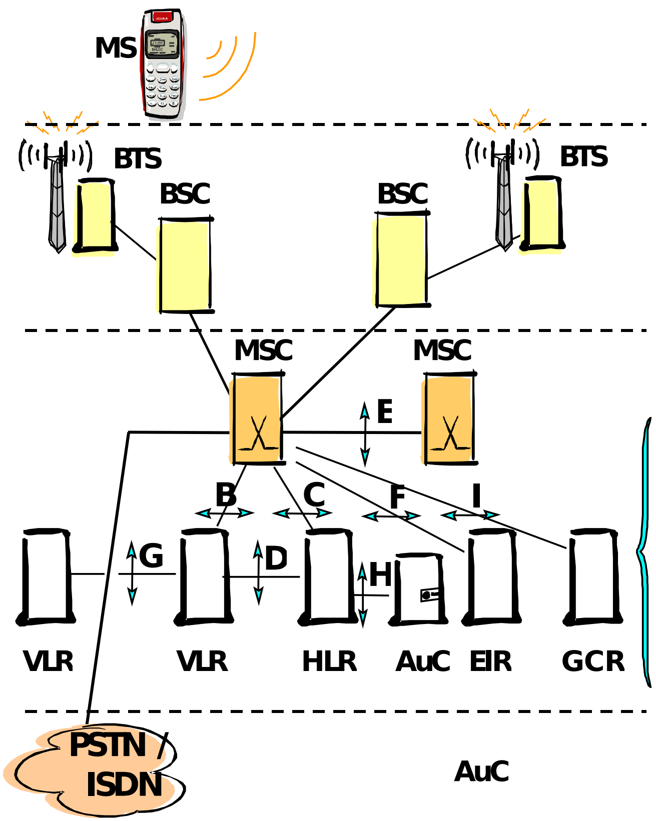
Specifications out of Release 1999

- TR 01.04 Abbreviations and acronyms
- TS 03.22 Functions related to Mobile Station (MS) in idle mode and group receive mode
- TR 03.30 Radio Network Planning Aspects
- TS 04.04 Layer 1 - General Requirements
- TS 04.06 Mobile Station - Base Stations System (MS - BSS) Interface Data Link (DL) Layer Specification
- TS 04.08 Mobile radio interface layer 3 specification
- TS 05.05 Radio Transmission and Reception
- TS 05.08 Radio Subsystem Link Control
- TS 08.06 Signalling Transport Mechanism Specification for the Base Station System - Mobile Services Switching Centre (BSS-MSC) Interface
- TS 08.08 Mobile-services Switching Centre - Base Station system (MSC-BSS) Interface Layer 3 Specification

Introduction

Radio Network Architecture
Mobile Phone Systems

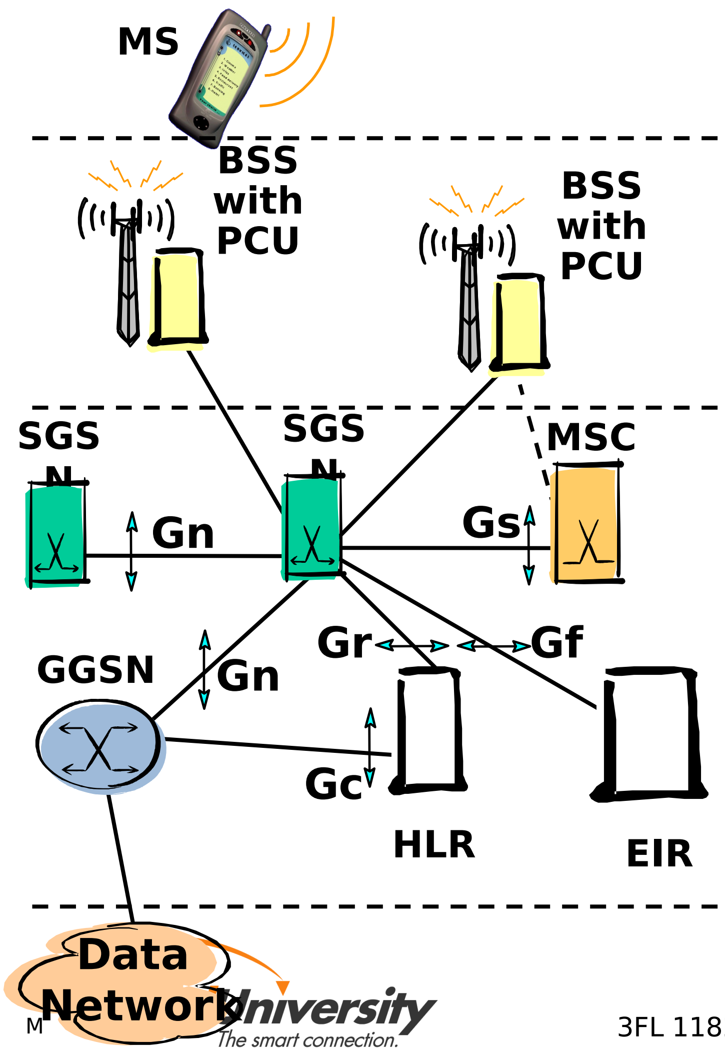
GSM Network Architecture



GSM Circuit-switching:

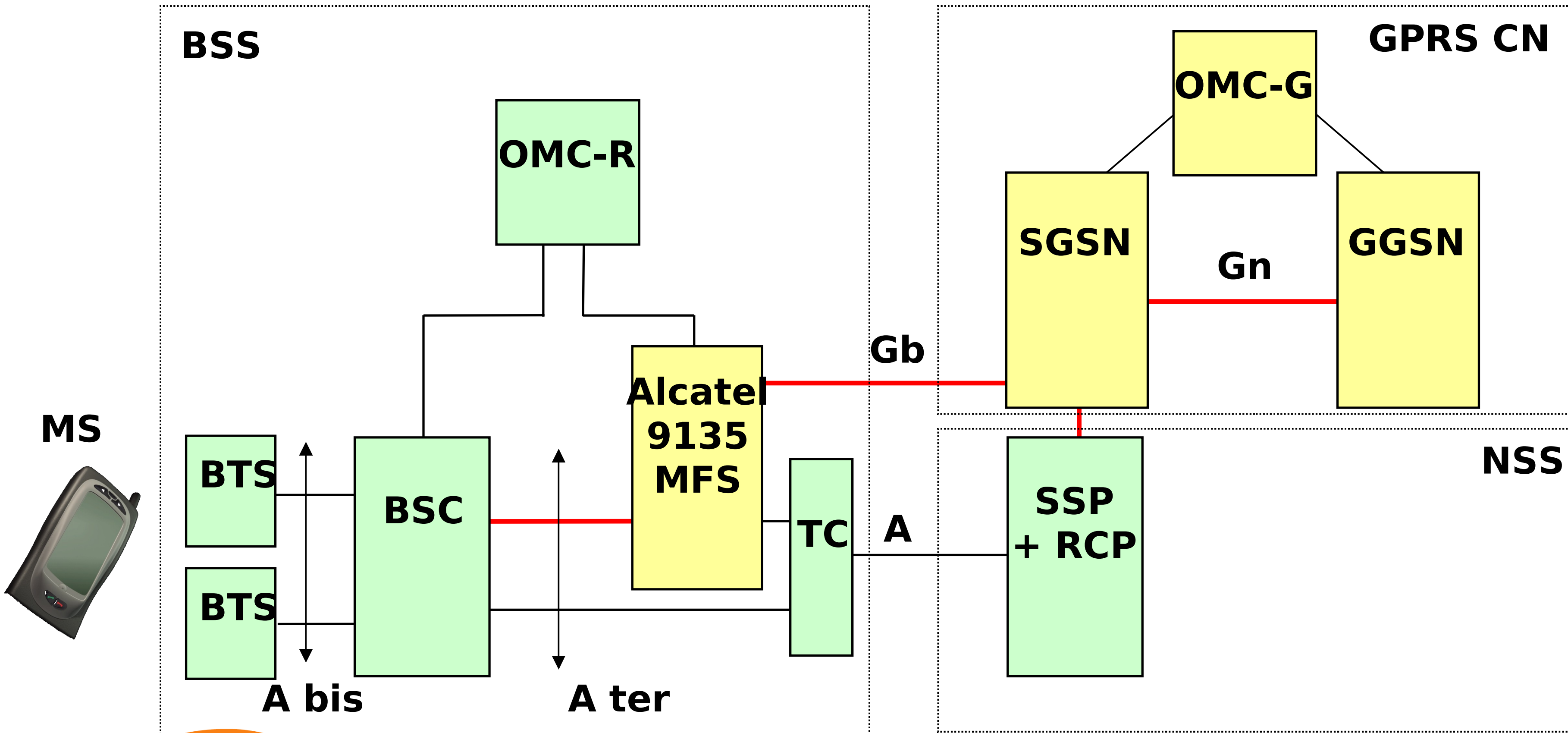
Um	MS - BTS	**LapDm** (GSM specific)
Abis	BTS - BSC	**LapD** (ISDN type)
A	BSC - MSC	**(SS7 basic) + BSSAP** (BSSAP = BSSMAP + DTAP)
B	MSC-VLR	**(SS7 basic) + MAP**
C	(SM-G)MSC-HLR	
D	HLR-VLR	
E	(SM-G)MSC-MSC	
F	MSC-EIR	
G	VLR-VLR	
H	HLR-AuC	
I	MSC-GCR	
PSTN ISDN	MSC-PSTN MSC-ISDN	**(SS7 basic) + TUP or ISUP**

GSM Packet-switching (GPRS/EDGE):



Um (Radio)	MS - BTS	LAPDm (GSM specific)
Gb	BSS - SGSN	BSSGP
Gn	SGSN-SGSN	IP
	SGSN-GGSN	IP
Gr	SGSN-HLR	SS7
Gc	GGSN-HLR	IP/SS7
Gf	SGSN-EIR	SS7
Gs	SGSN-MSC/VLR	SS7
Gi	GGSN-Data Network	IP

OMC-R


BSS
GPRS CN
OMC-G
OMC-R
SGSN
GGSN
Gn
Gb
Alcatel
9135
MFS
MS
BTS
BTS
BSC
TC
A
SSP
+ RCP
NSS
A bis
A ter

GSM Network Elements

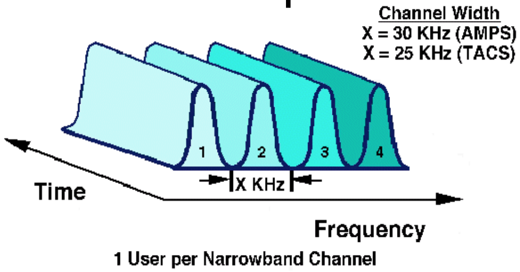
- Base Station System BSS
  - Base Transceiver Station BTS
  - Base Station Controller BSC
- Terminal Equipment
  - Mobile Station MS
- Operation and Maintenance Center-Radio OMC-R
- Network Subsystem NSS
  - Mobile Services Switching Center MSC
  - Visitor Location Register VLR
  - Home Location Register HLR
  - Authentication Center AuC
  - Equipment Identity Register EIR
- Operation and Maintenance Center OMC
- Multi-BSS Fast Packet Server (GPRS) MFS
- Serving GPRS Support Node SGSN
- Gateway GPRS Support Node GGSN

RF Spectrum

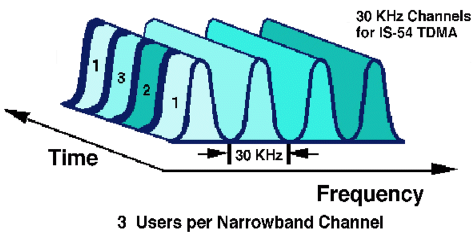
System	Total Bandwidth	Uplink frequency band /MHz	Downlink frequency band /MHz	Carrier Spacing
GSM 450	2x7.5MHz	450.4-457.6	460.4-467.6	200 kHz
GSM 480	2x7.2MHz	478.8-486	488.8-496	200 kHz
GSM 850	2x25MHz	824-849	869-894	200 kHz
GSM 900	2x25MHz	890-915	935-960	200 kHz
E-GSM	2x35MHz	880-915	925-960	200 kHz
DCS 1800 (GSM)	2x75MHz	1710-1785	1805-1880	200 kHz
PCS 1900 (GSM)	2x60MHz	1850-1910	1930-1990	200 kHz

Access Methods

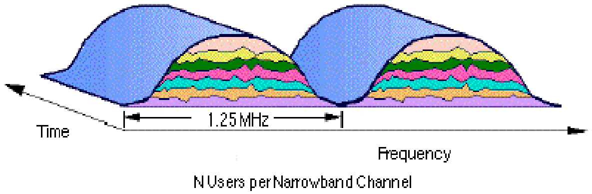
- FDMA (Frequency Division Multiple Access)



- TDMA (Time Division Multiple Access)

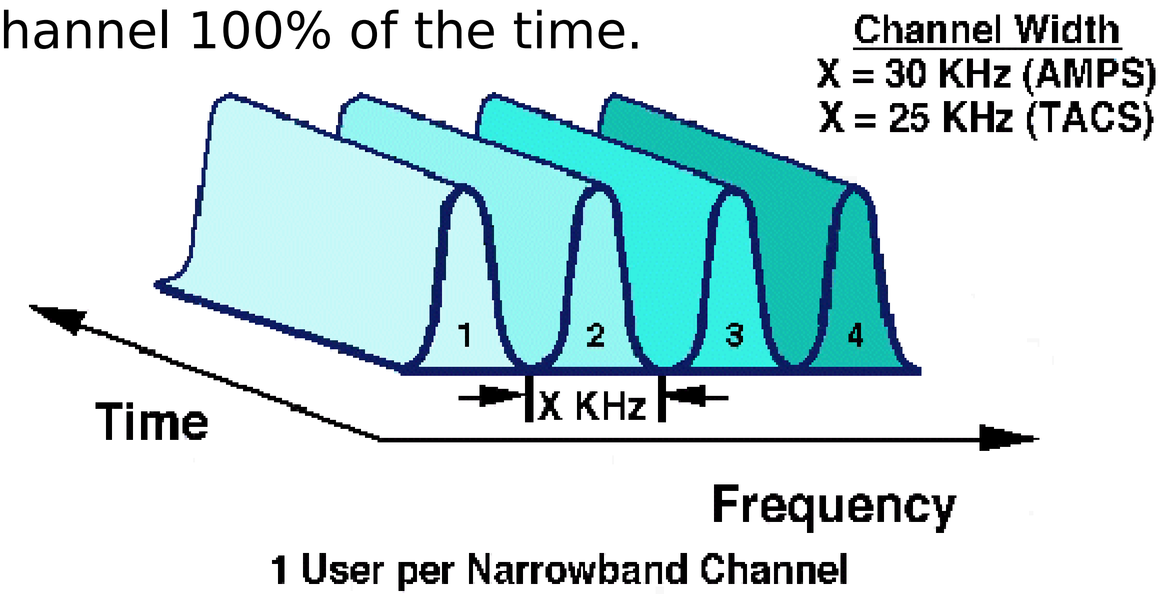


- CDMA (Code Division Multiple Access)



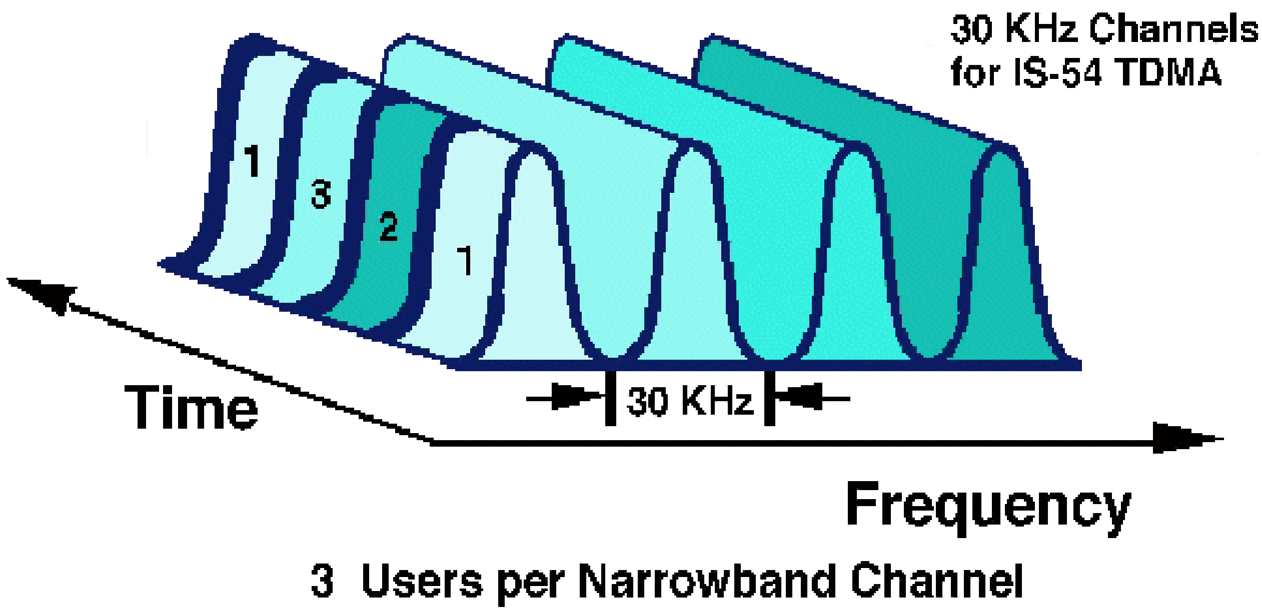
FDMA

- Used for standard analog cellular mobile systems (AMPS, TACS, NMT etc.)
- Each user is assigned a discrete slice of the RF spectrum
- Permits only one user per channel since it allows the user to use the channel 100% of the time.



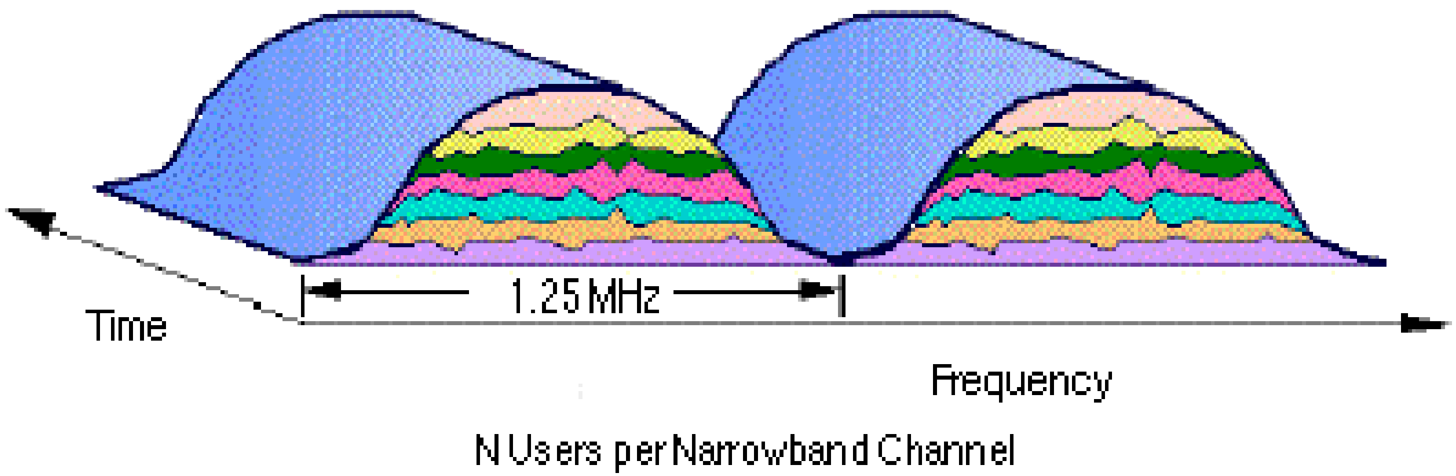
TDMA

- Multiple users share RF carrier on a time slot basis
- Carriers are sub-divided into timeslots
- Information flow is not continuous for an user, it is sent and received in "bursts"



CDMA (Code Division Multiple Access)

- Multiple access spread spectrum technique
- Each user is assigned a sequence code during a call
- No time division; all users use the entire carrier



Analogue Cellular Mobile Systems

- Analogue transmission of speech
- One TCH/Channel
- Only FDMA (Frequency Division Multiple Access)
- Different Systems
  - AMPS (Countries: USA)
  - TACS (UK, I, A, E, ...)
  - NMT (SF, S, DK, N, ...)
  - ...

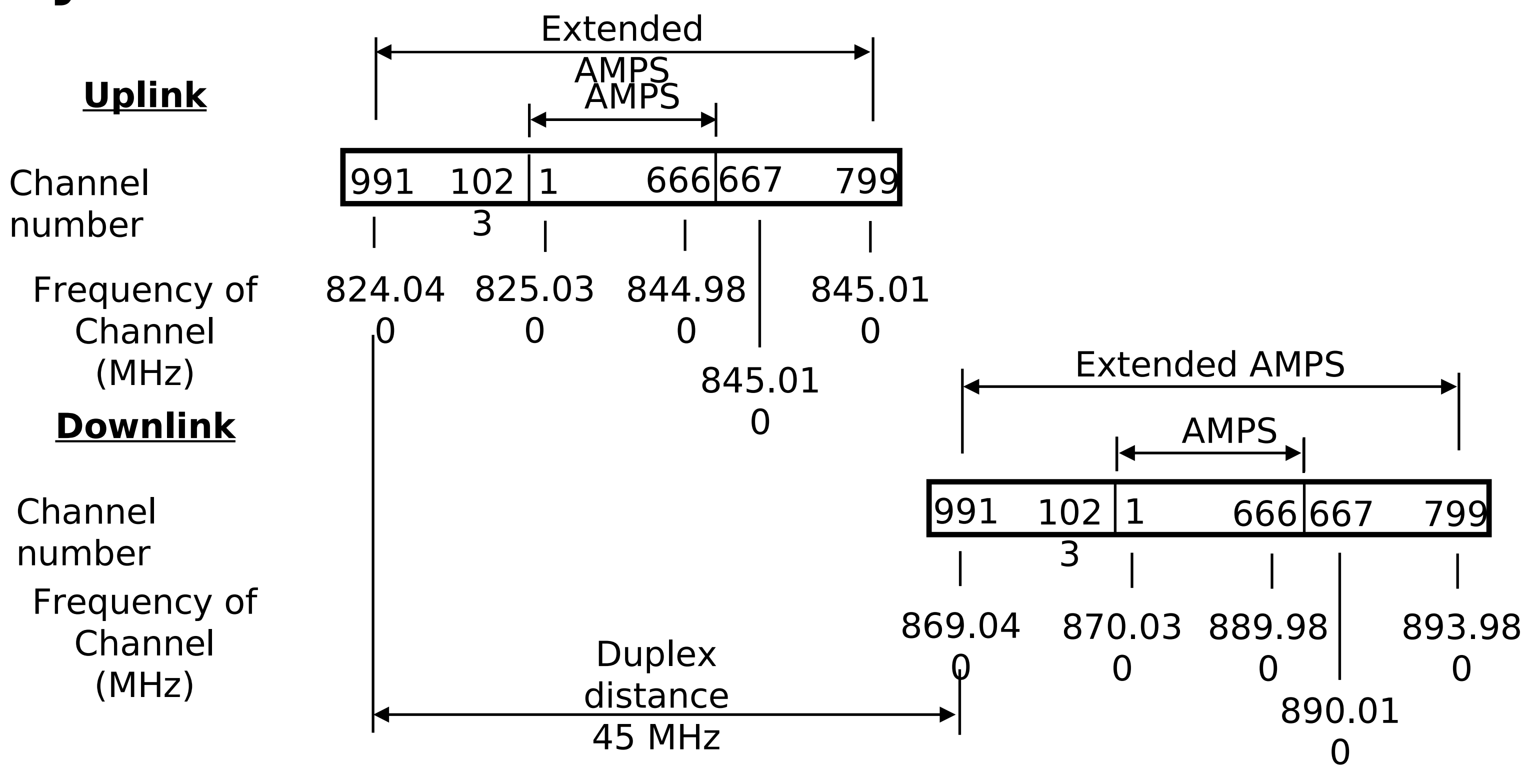
AMPS (Advanced Mobile Phone System)

- Analogue cellular mobile telephone system
- Predominant cellular system operating in the US
- Original system: 666 channels (624 voice and 42 control channels)
- EAMPS - Extended AMPS
  Current system: 832 channels (790 voice, 42 control); has replaced AMPS as the US standard
- NAMPS - Narrowband AMPS
  New system that has three times more voice channels than EAMPS with no loss of signal quality
- Backward compatible: if the infrastructure is designed properly, older phones work on the newer systems

AMPS - Technical objectives

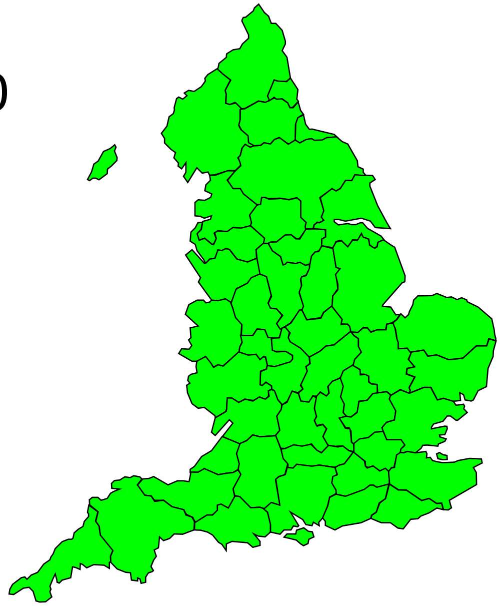
Technology	FDMA
RF frequency band	825 - 890 MHz
Channel Spacing	30 kHz
Carriers	666 (832)
Timeslots	1
Mobile Power	0.6 - 4 W
Transmission	Voice, (data)
HO	possible
Roaming	possible

AMPS Advanced Mobile Phone System



TACS Total Access Communications System

- Analogue cellular mobile telephone system
- The UK TACS system was based on the US AMPS system
- TACS - Original UK system that has either 600 or 1000 channels (558 or 958 voice channels, 42 control channels)
- RF frequency band: 890 - 960
  Uplink: 890-915 Downlink: 935-960
- Channel spacing: 25 KHz



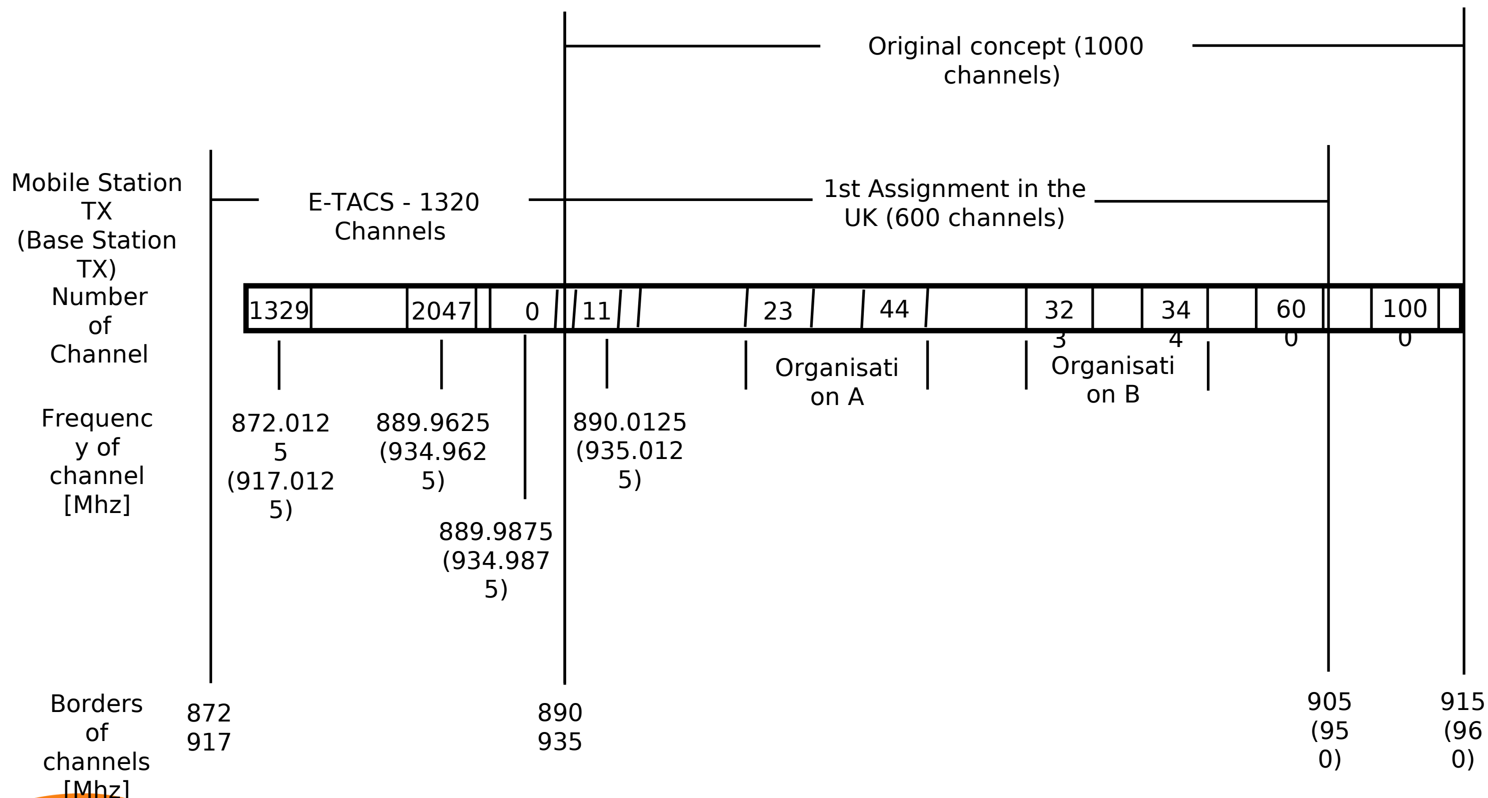
TACS - Technical objectives

Technology	FDMA
RF frequency band	890 - 960 MHz
Channel Spacing	25 kHz
Carriers	1000
Timeslots	1
Mobile Power	0.6 - 10 W
Transmission	Voice , (data)
HO	possible
Roaming	possible

Different TACS-Systems

- ETACS - Extended TACS
  - Current UK system that has 1320 channels (1278 voice, 42 control)
    and has replaced TACS as the UK standard
- ITACS and IETACS - International (E)TACS
  - Minor variation of TACS to allow operation outside of the UK by allowing flexibility in assigning the control channels
- JTACS - Japanese TACS
  - A version of TACS designed for operation in Japan
- NTACS - Narrowband TACS
  - New system that has three times as many voice channels as ETACS with no loss of signal quality

TACS (Total Access Communications System)



Why digital mobile communication ?

- Easy adaptation to digital networks
- Digital signaling serves for flexible adaptation to operational needs
- Possibility to realize a wide spectrum of non-voice services
- Digital transmission allows for high cellular implementation flexibility
- Digital signal processing gain results in high interference immunity
- Privacy of radio transmission ensured by digital voice coding and encryption
- Cost and performance trends of modern microelectronics are in favour of a digital solution

GSM - Technical objectives

Technology	TDMA/FDMA
RF frequency band	890 - 960 MHz
Channel Spacing	200 kHz
Carriers	124
Timeslots	8
Mobile Power (average/max)	2 W/ 8 W
BTS Power class	10 ... 40 W
MS sensitivity	- 102 dBm
BTS sensitivity	- 104 dBm
Transmission	Voice, data
HO	possible
Roaming	possible

DECT (Digital European Cordless Telephone)

- European Standard for Cordless Communication
- Using TDMA-System
- Traditional Applications
  - Domestic use ("Cordless telephone")
  - Cordless office applications
- Combination possible with
  - ISDN
  - GSM
- High flexibility for different applications

DECT - Technical objectives

Technology	TDMA/FDMA
RF frequency band	1880 - 1900 MHz
Channel Spacing	1.728 MHz
Carriers	10
Timeslots	12 (duplex)
Mobile Power (average/max)	10 mW/250 mW
BTS Power class	250 mW
MS sensitivity	-83 dBm
BTS sensitivity	-83 dBm
Transmission	Voice, data
HO	possible

CDMA - Technical objectives

- Spread spectrum technology
(Code Division Multiple Access)
- Several users occupy continuously one CDMA channel (bandwidth: 1.25 MHz)
The CDMA channel can be re-used in every cell
- Each user is addressed by
  - A **specific code** and
  - Selected by **correlation processing**
- Orthogonal codes provides optimum isolation between users

CDMA - Special Features

- Vocoder allows variable data rates
- Soft handover
- Open and closed loop power control
- Multiple forms of diversity
- Data, fax and short message services possible

CDMA - Technical objectives

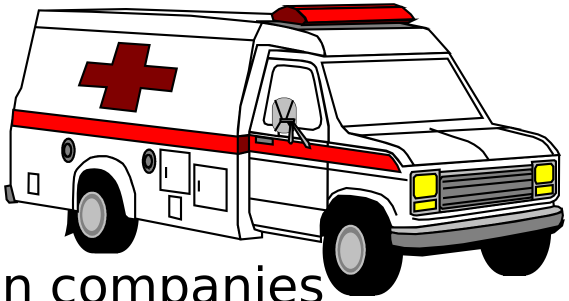
Technology	CDMA
RF frequency band	869-894 / 824-849 or 1900 MHz
Channel Spacing	1250 kHz
Channels per 1250 kHz	64
Mobile Power (average/max)	1-6.3 W / 6.3 W
Transmission	Voice, data
HO ("Soft handoff")	possible
Roaming	possible

TETRA - Features

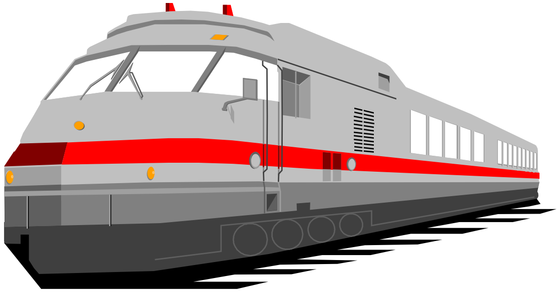
- Standard for a frequency efficient european digital trunked radio communication system (defined in 1990)
- Possibility of connections with simultaneous transmission of voice and data
- Encryption at two levels:
  - Basic level which uses the air interface encryption
  - End-to-end encryption (specifically intended for public safety users)
- Open channel operation
- "Direct Mode" possible
  - Communication between two MS without connecting via a BTS
- MS can be used as a repeater

TETRA - Typical Users

- Public safety
  - Police (State, Custom, Military, Traffic)
  - Fire brigades
  - Ambulance service
  - ...



- Railway, transport and distribution companies



TETRA - Technical objectives

Technology	TDMA/FDMA
RF frequency band	380 - 400 MHz
Channel Spacing	25 or 12.5 KHz
Carriers	not yet specified
Timeslots	4
Mobile Power (3 Classes)	1, 3, 10 W
BTS Power class	0.6 - 25 W
MS sensitivity	-103 dBm
BTS sensitivity	-106 dBm
Transmission	Voice, data, images, short message
HO	possible
Roaming	possible

UMTS (Universal Mobile Telecommunication System)

- Third generation mobile communication system
- Combining existing mobile services (GSM, CDMA etc.) and fixed telecommunications services
- More capacity and bandwidth
- More services (Speech, Video, Audio, Multimedia etc.)
- Worldwide roaming
- "High" subscriber capacity

GSM Radio Network Engineering Fundamentals

RNP Process Overview

Definition of RN Requirements

- The Request for Quotation (RfQ) from the customer prescribes the requirements mainly
- Coverage
  - Definition of coverage probability
    - Percentage of measurements above level threshold
  - Definition of covered area
- Traffic
  - Definition of Erlang per square kilometer
  - Definition of number of TRX in a cell
  - Mixture of circuit switched and packed switched traffic
- QoS
  - Call success rate
  - RxQual, voice quality, throughput rates, ping time

Preliminary Network Design

- The preliminary design lays the foundation to create the Bill of Quantity (BoQ)
  - List of needed network elements
- Geo data procurement
  - Digital Elevation Model DEM/Topographic map
  - Clutter map
- Definition of standard equipment configurations dependent on
  - clutter type
  - traffic density
- Coverage Plots
  - Expected receiving level
- Definition of roll out phases
  - Areas to be covered
  - Number of sites to be installed
  - Date, when the roll out takes place.
- Network architecture design
  - Planning of BSC and MSC locations and their links
- Frequency spectrum from license conditions

Project Setup and Management

- This phase includes all tasks to be performed before the on site part of the RNP process takes place.
- This ramp up phase includes:
  - Geo data procurement if required
  - Setting up ‘general rules’ of the project
  - Define and agree on reporting scheme to be used
    - Coordination of information exchange between the different teams which are involved in the project
  - Each department/team has to prepare its part of the project
  - Definition of required manpower and budget
  - Selection of project database (MatrixX)

Initial Radio Network Design

- Area surveys
  - As well check of correctness of geo data
- Frequency spectrum partitioning design
- RNP tool calibration
  - For the different morpho classes:
    - Performing of drive measurements
    - Calibration of correction factor and standard deviation by comparison of measurements to predicted received power values of the tool
- Definition of search areas (SAM – Search Area Map)
  - A team searches for site locations in the defined areas
  - The search team should be able to speak the national language
- Selection of number of sectors/TRX per site together with project management and customer
- Get ‘real’ design acceptance from customer based on coverage prediction and predefined design level thresholds

Site Acquisition Procedure

- Delivery of site candidates
  - Several site candidates shall be the result out of the site location search
- Find alternative sites
  - If no site candidate or no satisfactory candidate can be found in the search area
  - Definition of new SAM
  - Possibly adaptation of radio network design
- Check and correct SAR (Site Acquisition Report)
  - Location information
  - Land usage
  - Object (roof top, pylon, grassland) information
  - Site plan
- Site candidate acceptance and ranking
  - If the reported site is accepted as candidate, then it is ranked according to its quality in terms of
    - Radio transmission
      - High visibility on covered area
      - No obstacles in the near field of the antennas
      - No interference from other systems/antennas
    - Installation costs
      - Installation possibilities
      - Power supply
      - Wind and heat
    - Maintenance costs
      - Accessibility
      - Rental rates for object
      - Durability of object

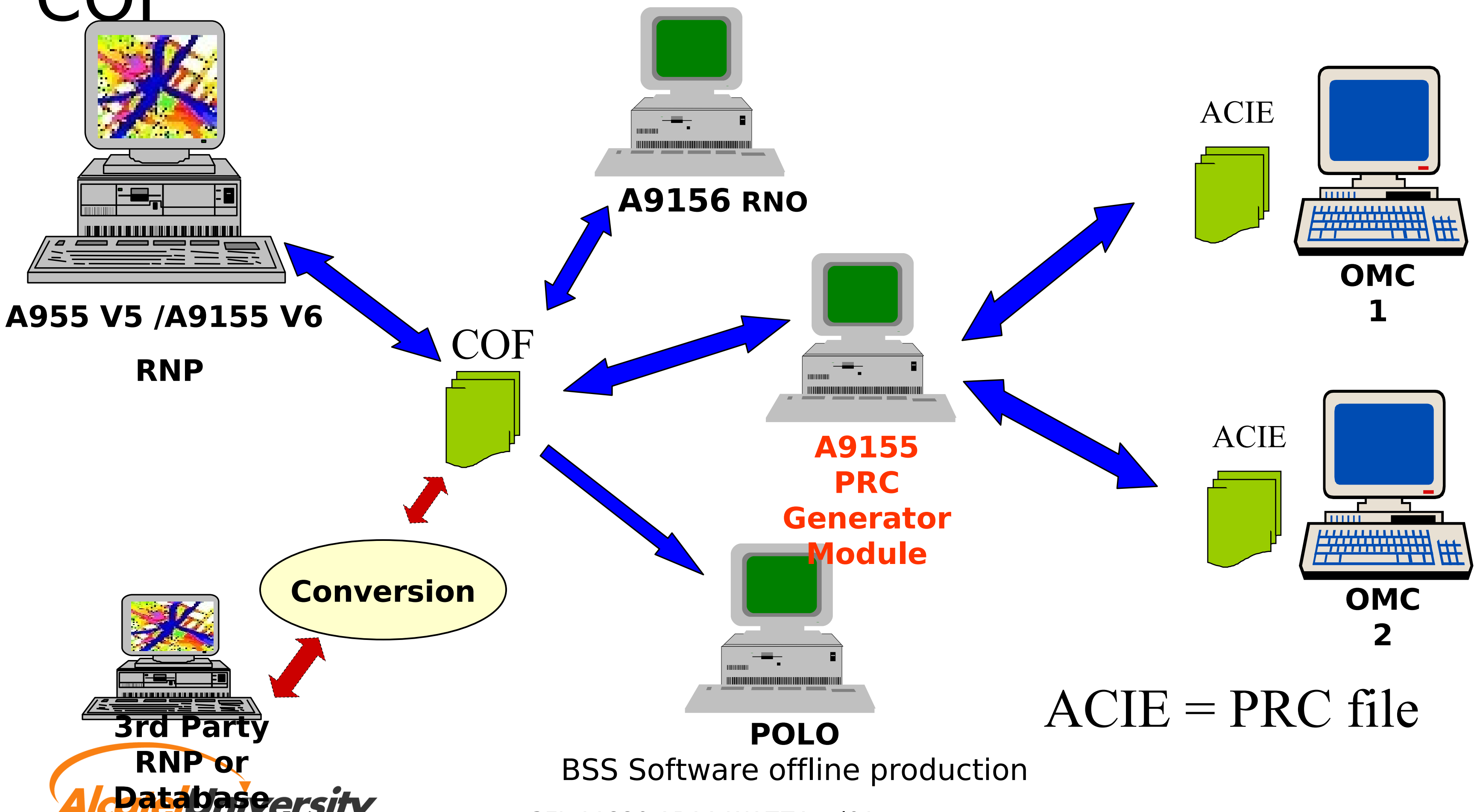
Technical Site Survey

- Agree on an equipment installation solution satisfying the needs of
  - RNE Radio Network Engineer
  - Transmission planner
  - Site engineer
  - Site owner
- The Technical Site Survey Report (TSSR) defines
  - Antenna type, position, bearing/orientation and tilt
  - Mast/pole or wall mounting position of antennas
  - EMC rules are taken into account
    - Radio network engineer and transmission planner check electro magnetic compatibility (EMC) with other installed devices
  - BTS/Node B location
  - Power and feeder cable mount
  - Transmission equipment installation
  - Final Line Of Site (LOS) confirmation for microwave link planning
    - E.g. red balloon of around half a meter diameter marks target location
- If the site is not acceptable or the owner disagrees with all suggested solutions
  - The site will be rejected
  - Site acquisition team has to organize a new date with the next site from the ranking list

Basic Parameter Definition

- After installation of equipment the basic parameter settings are used for
  - Commissioning
    - Functional test of BTS and VSWR check
  - Call tests
- RNEs define cell design data
- Operations field service generates the basic software using the cell design CAE data
- Cell design CAE data to be defined for all cells are for example:
  - CI/LAC/BSIC
  - Frequencies
  - Neighborhood/cell handover relationship
  - Transmit power
  - Cell type (macro, micro, umbrella, ...)

Cell Design CAE Data Exchange over COF



Turn On Cycle

- The network is launched step by step during the TOC
- A single step takes typically two or three weeks
  - Not to mix up with rollout phases, which take months or even years
- For each step the RNE has to define 'TOC Parameter'
  - Cells to go on air
  - Determination of frequency plan
  - Cell design CAE parameter
- Each step is finished with the 'Turn On Cycle Activation'
  - Upload PRC/ACIE files into OMC-R
  - Unlock sites

Site Verification and Drive Test

- RNE performs drive measurement to compare the real coverage with the predicted coverage of the cells.
- If coverage holes or areas of high interference are detected
  - Adjust the antenna tilt and orientation
- Verification of cell design CAE data
- To fulfill heavy acceptance test requirements, it is absolutely essential to perform such a drive measurement.
- Basic site and area optimization reduces the probability to have unforeseen mysterious network behavior afterwards.

HW / SW Problem Detection

- Problems can be detected due to drive tests or equipment monitoring
  - Defective equipment
    - will trigger replacement by operation field service
  - Software bugs
  - Incorrect parameter settings
    - are corrected by using the OMC or in the next TOC
  - Faulty antenna installation
    - Wrong coverage footprints of the site will trigger antenna re-alignments
- If the problem is serious
  - Lock BTS
  - Detailed error detection
  - Get rid of the fault
  - Eventually adjusting antenna tilt and orientation

Basic Network Optimization

- Network wide drive measurements
  - It is highly recommended to perform network wide drive tests before doing the commercial opening of the network
  - Key performance indicators (KPI) are determined
  - The results out of the drive tests are used for basic optimization of the network
- Basic optimization
  - All optimization tasks are still site related
  - Alignment of antenna system
  - Adding new sites in case of too large coverage holes
  - Parameter optimization
    - No traffic yet -> not all parameters can be optimized
- Basic optimization during commercial service
  - If only a small number of new sites are going on air the basic optimization will be included in the site verification procedure

Network Acceptance

- Acceptance drive test
- Calculation of KPI according to acceptance requirements in contract
- Presentation of KPI to the customer
- Comparison of key performance indicators with the acceptance targets in the contract
- The customer accepts
  - the whole network
  - only parts of it step by step
- Now the network is ready for commercial launch

Further Optimization

- Network is in commercial operation
- Network optimization can be performed
- Significant traffic allows to use OMC based statistics by using A9156 RNO and A9185 NPA
- End of optimization depends on contract and mutual agreement between Alcatel and customer
  - Usually, Alcatel is only involved during the first optimization activities directly after opening the network commercially

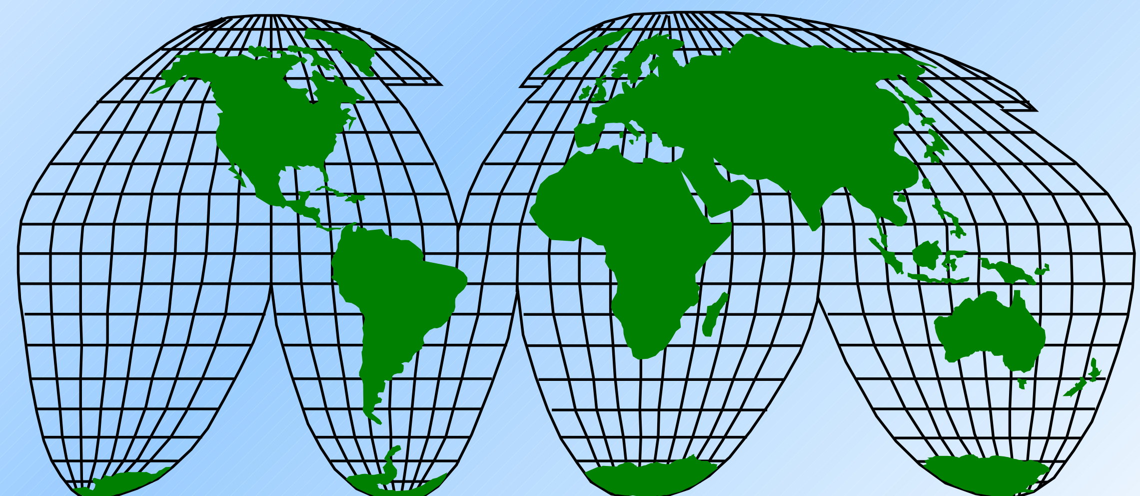
GSM Radio Network Engineering Fundamentals

Coverage Planning

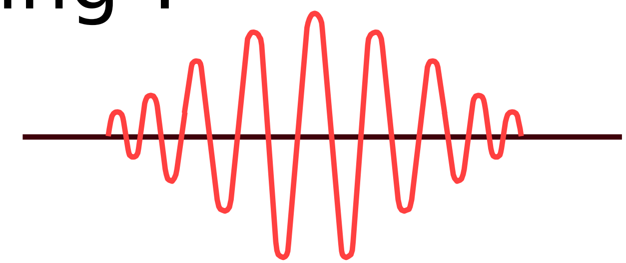
Contents

Coverage Planning

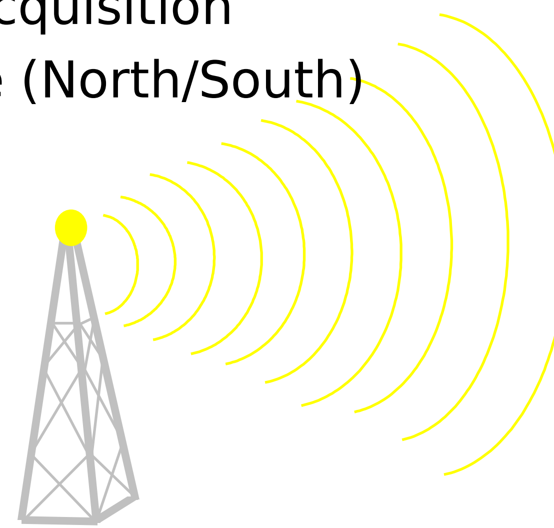
Geo Databases



Why are geographical data needed for Radio Network Planning ?



- Propagation models depend on geographical data
- Geographical information for site acquisition
  - Latitude (East/West) / Longitude (North/South)
  - Rectangular coordinates
    (e.g. UTM coordinates)

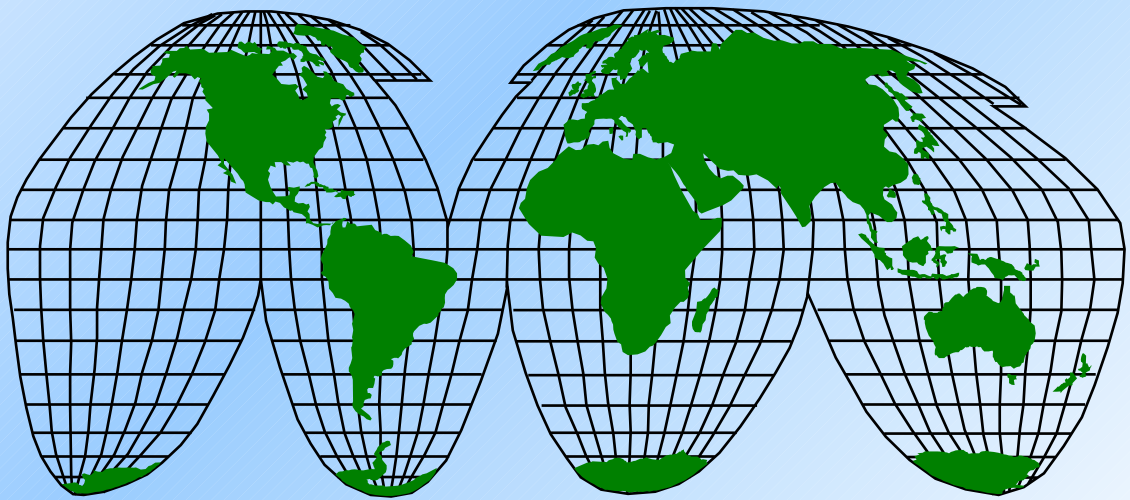


Contents

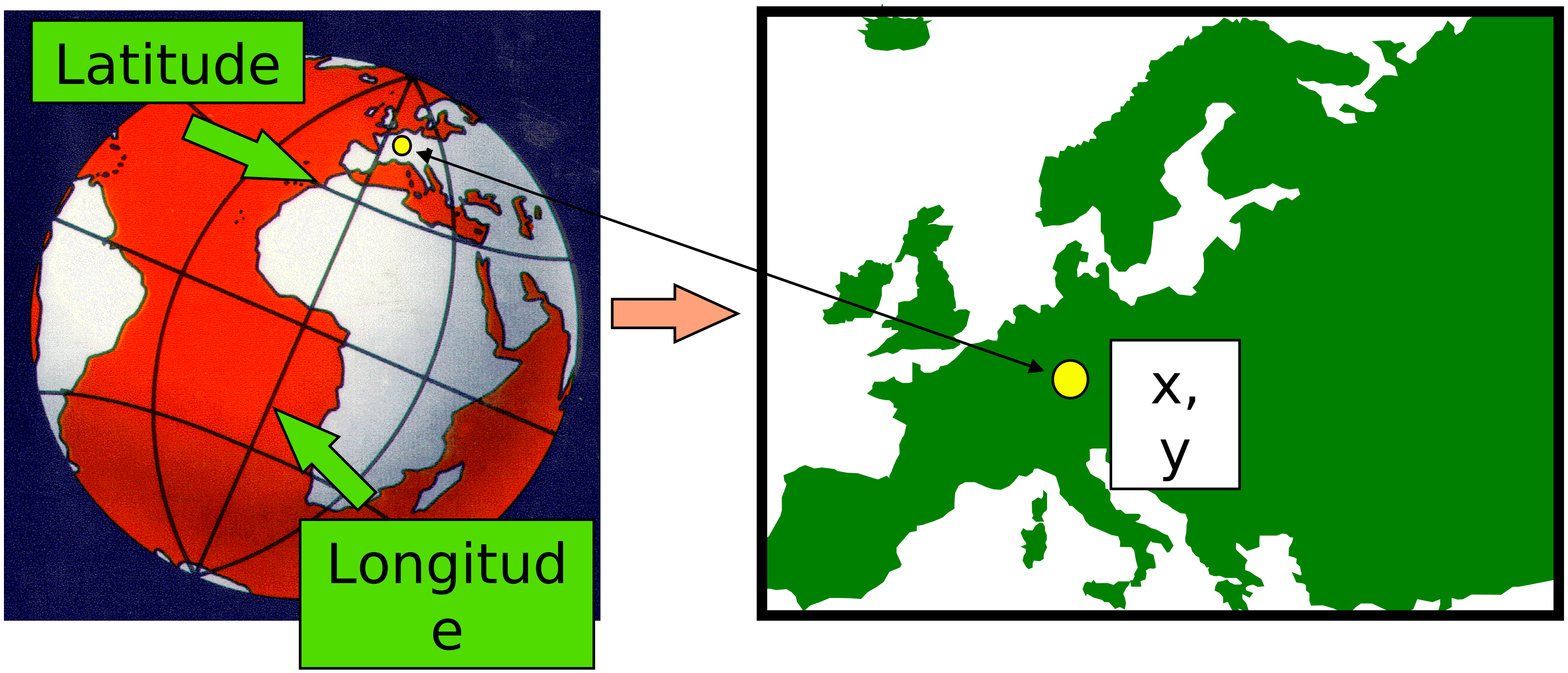
- Map Projection
  - Different Map Projections: conical, cylindrical, planar/ azimuthal
  - Geodetic Datum: e.g. WGS 84
  - Transverse Mercator Projection: e.g. UTM
- Types of Geospatial Data
  - Creation of geospatial databases
  - Raster data: DEM /Topography, Morphostructure/ Clutter, Buildings
  - Vector data: airport, coastline, border line, buildings, etc.
- Geocoordinate Transformation
  - Practical Applications
    - Converting one single point
    - Compare to different geodetic datums
    - Converting a list of points

Geo Databases

Map Projection

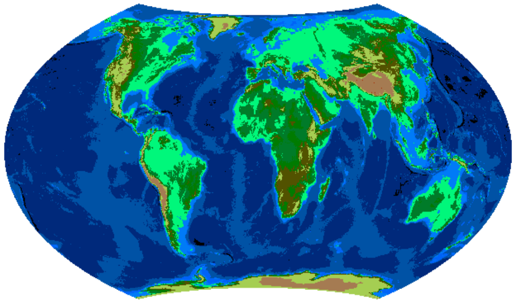


Maps are flat



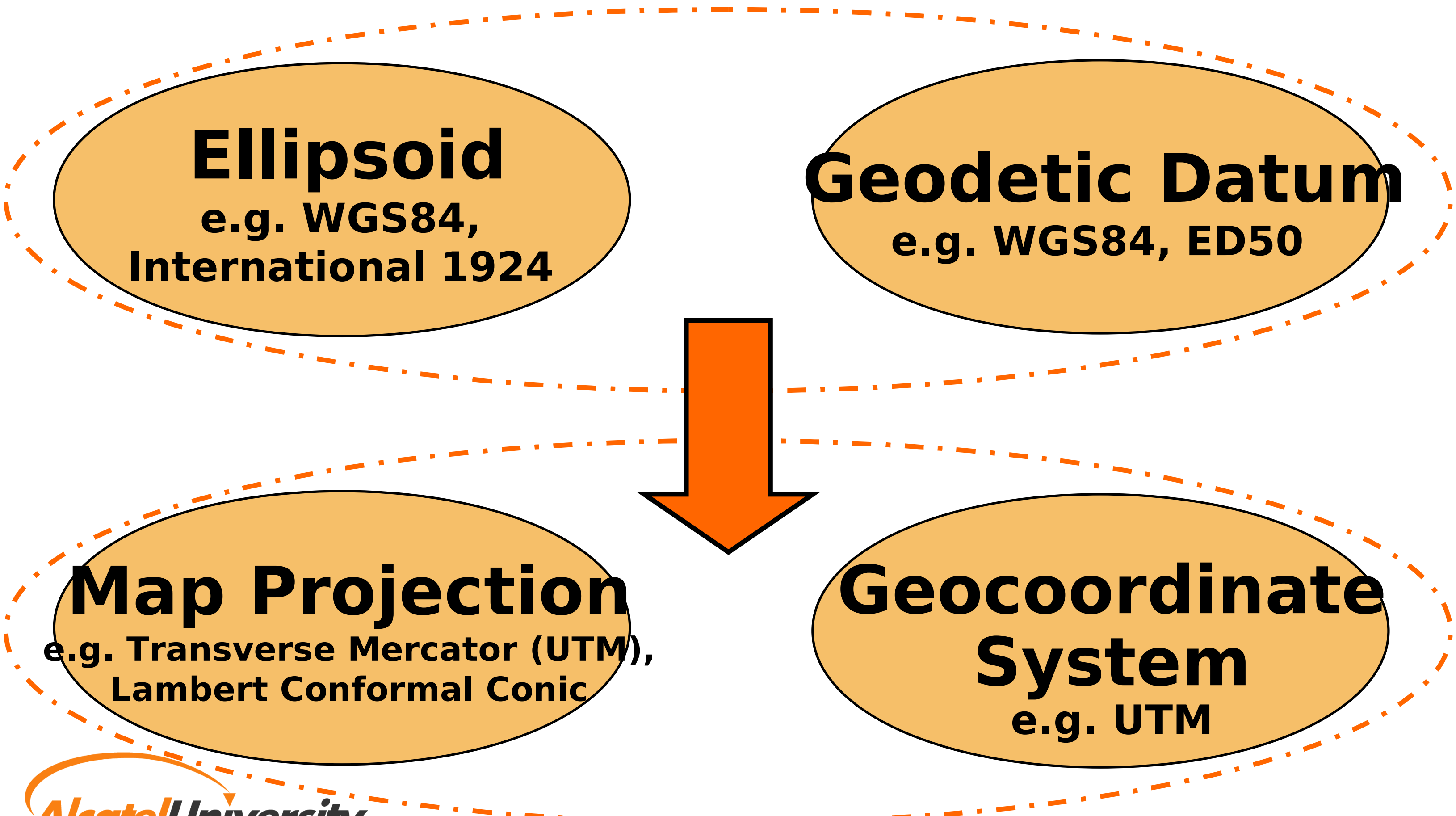
Problem: Earth is 3D, the maps are 2D

Mapping the earth



- The Earth is a very complex shape
- To map the geography of the earth,
  a ***reference model (-> Geodetic Datum)*** is needed
- The model needs to be simple so that it is easy to use
- It needs to include a ***Coordinate system*** which allows the positions of objects to be uniquely identified
- It needs to be readily associated with the physical world so that its use is intuitive

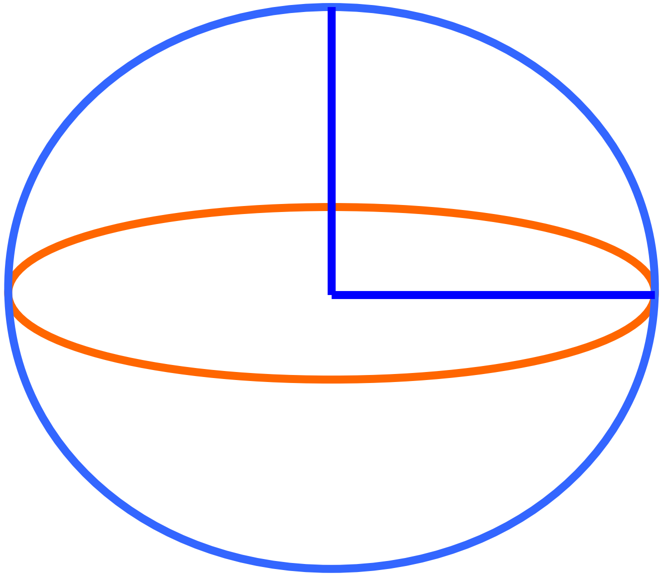
Map Projection



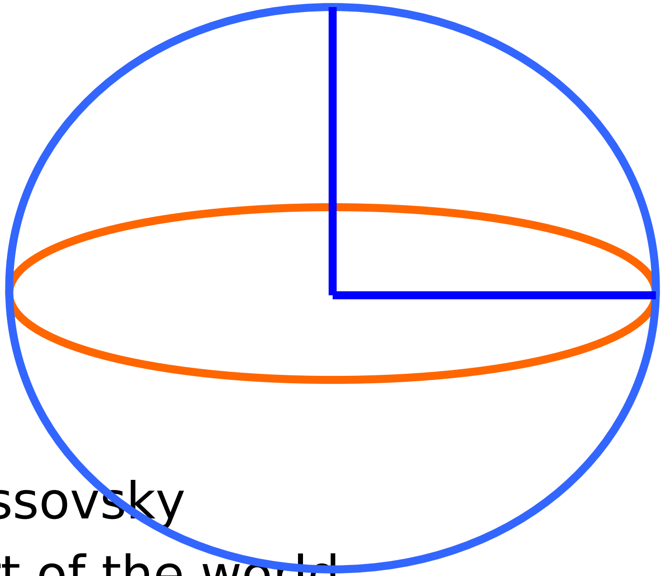
Geodetic Ellipsoid

Definition:
A mathematical surface (an ellipse rotated around the earth's polar axis) which provides a convenient **model** of the size and shape **of the earth**. The ellipsoid is chosen to best meet the needs of a particular map datum system design.

Reference ellipsoids are usually defined by semi-major (equatorial radius) and flattening (the relationship between equatorial and polar radii).



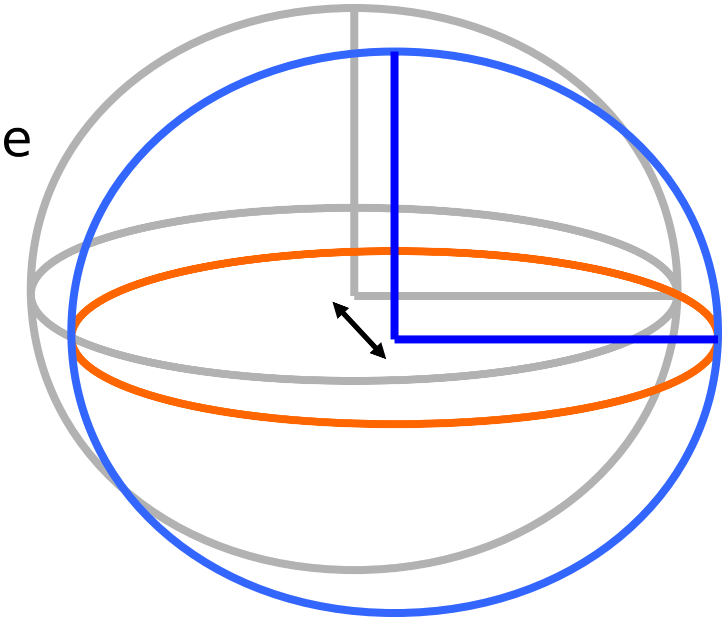
Global & Regional Ellipsoids



- **Global ellipsoids**
  e.g. WGS84, GRS80
  - Center of ellipsoid is "Center of gravity"
  - Worldwide consistence of all maps around the world
- **Regional ellipsoids**
  e.g. Bessel, Clarke, Hayford, Krassovsky
  - Best fitting ellipsoid for a part of the world ("local optimized")
  - Less local deviation

Geodetic Datum

- A Geodetic Datum is a Reference System which includes:
  - A local or global **Ellipsoid**
  - One **“Fixpoint”**

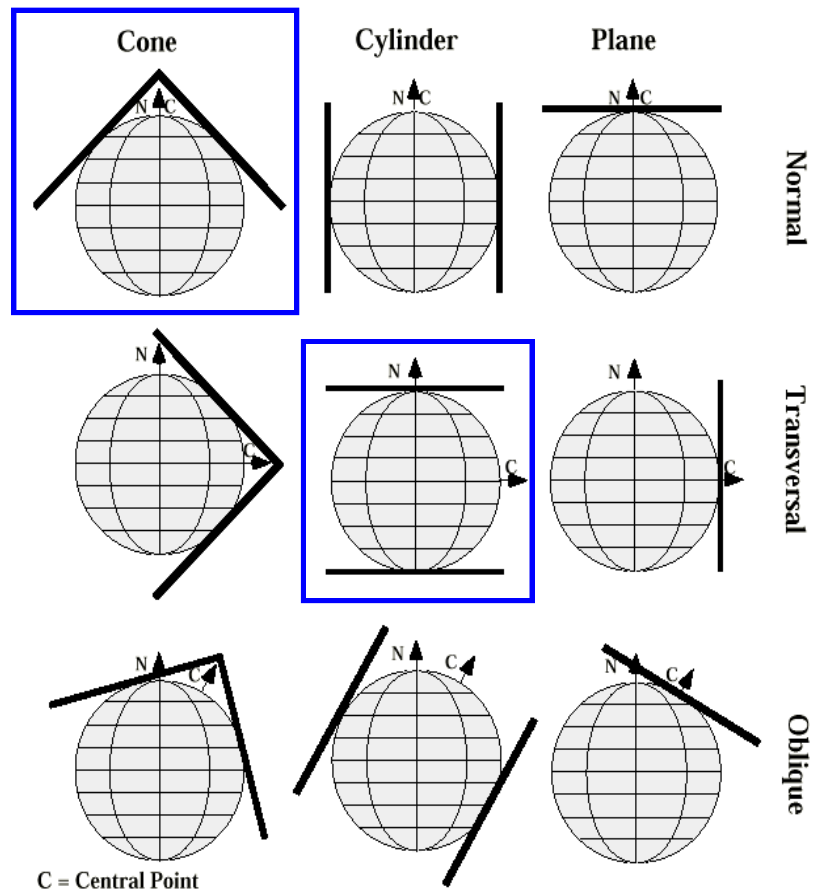


Attention: Referencing geodetic coordinates to the wrong map datum can result in position **errors of hundreds of meters**

Info:
In most cases the shift, rotation and scale factor of a Map Datum is relative to the “satellite map datum” WGS84.

Map Projection

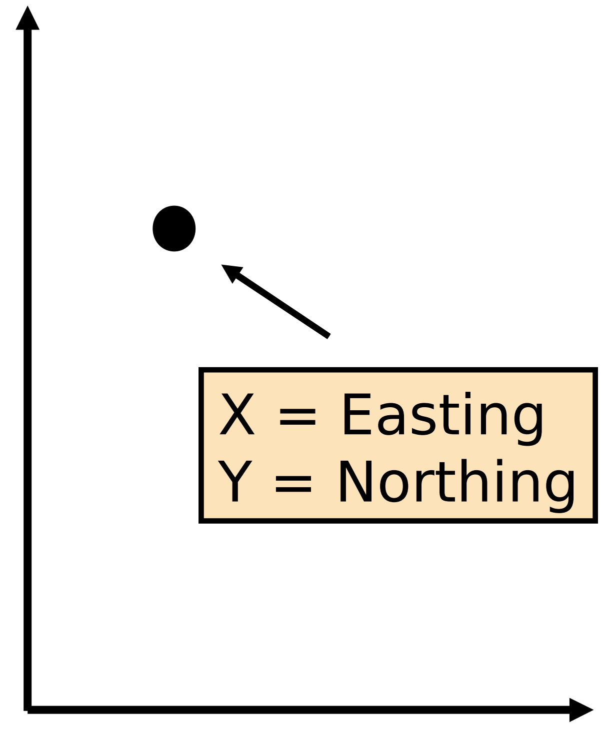
- Cylindrical
  - e.g. UTM, Gauss-Krueger
- Conical
  - e.g.Lambert Conformal Conic
- Planar/Azimuthal



Info: In 90% of the cases we will have a cylindrical projection in 10% of the cases a conical projection

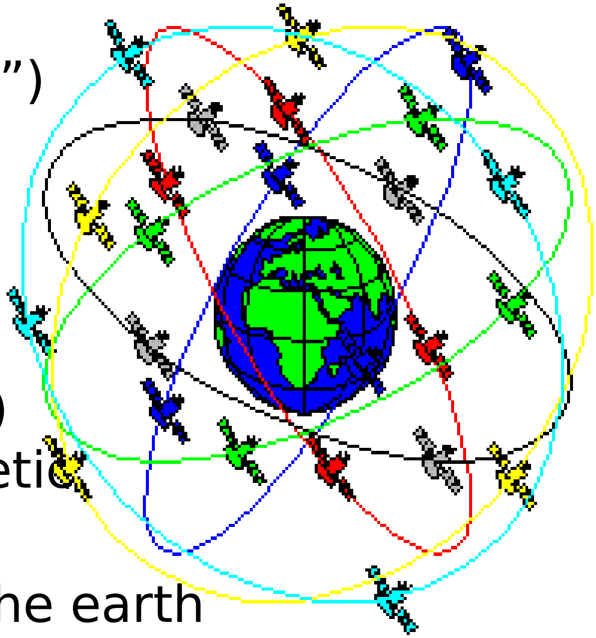
Geo-Coordinate System

- To simplify the use of maps a **Cartesian Coordinates** is used
- To avoid negative values a
  - **False Easting** value *and a*
  - **False Northing** value is added
- Also a **scaling factor** is used to minimize the "projection error" over the whole area



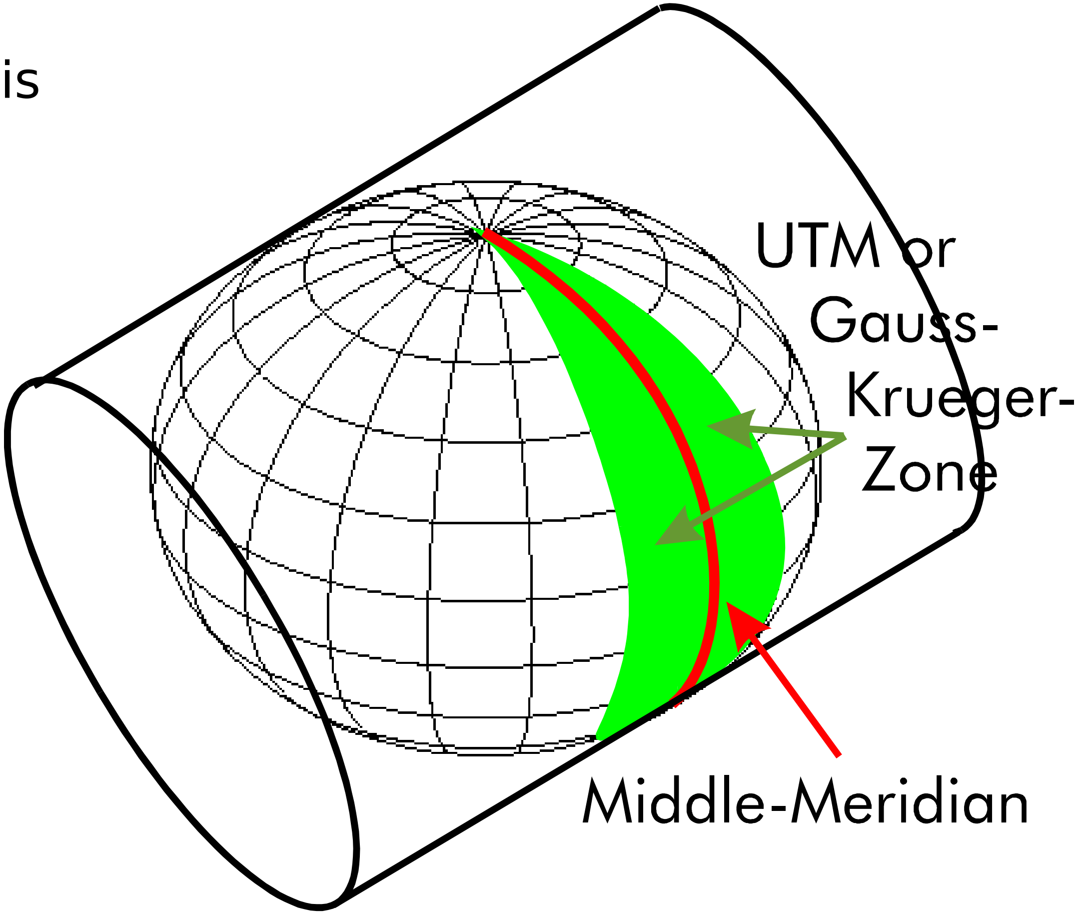
WGS 84 (World Geodetic System 1984)

- Most needed **Geodetic Datum** in the world today (“Satellite Datum”)
- It is the reference frame used by the U.S. Department of Defense is defined by the National Imagery and Mapping Agency (NIMA)
- The Global Positioning System (GPS) system is based on the World Geodetic System 1984 (WGS-84).
- Optimal adaption to the surface of the earth

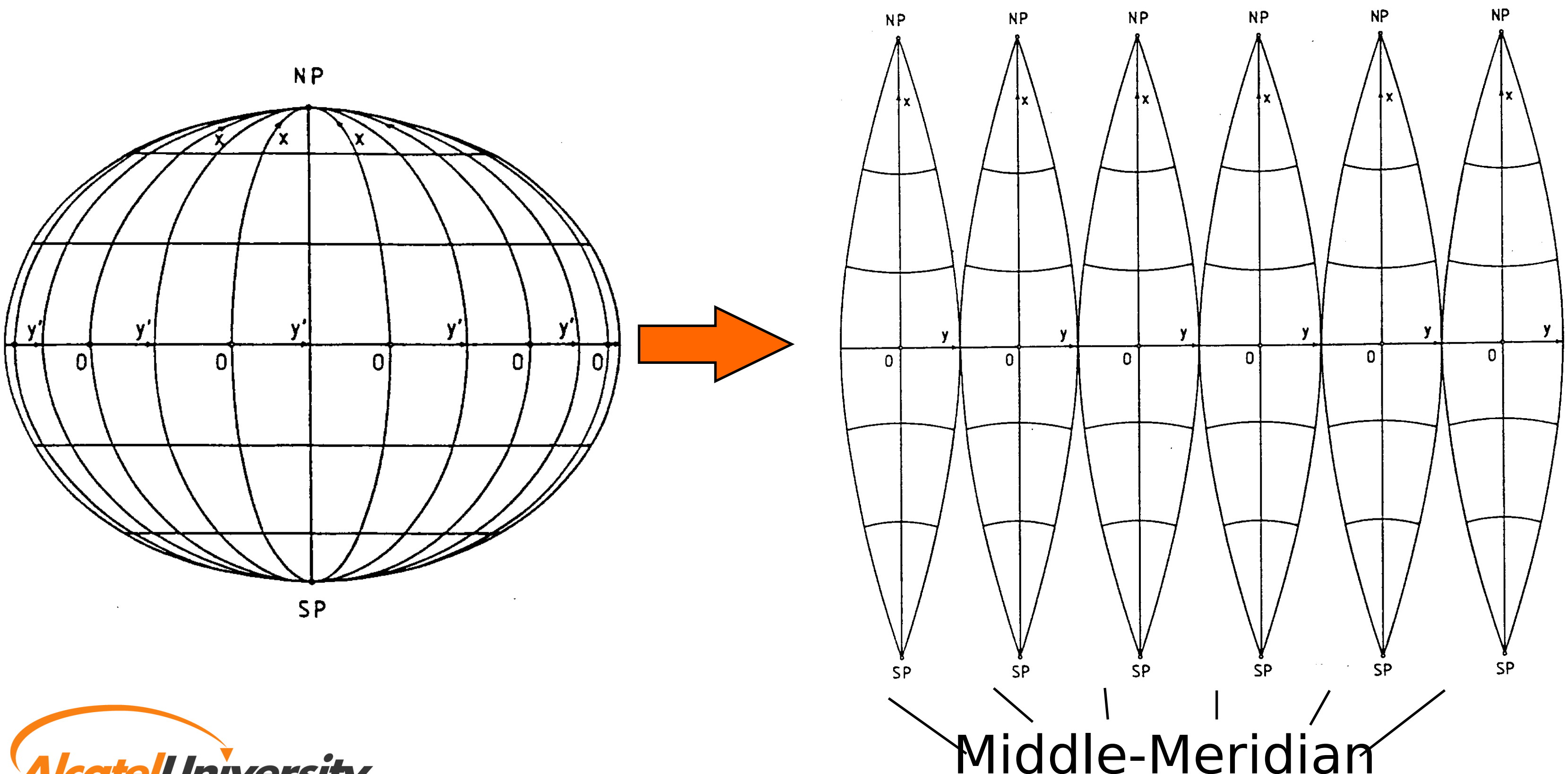


Transverse Mercator Projection

- Projection cylinder is rotated 90 degrees from the polar axis (“transverse”)
- Geometric basis for the UTM and the Gauss-Krueger Map Projection
- Conformal Map projection



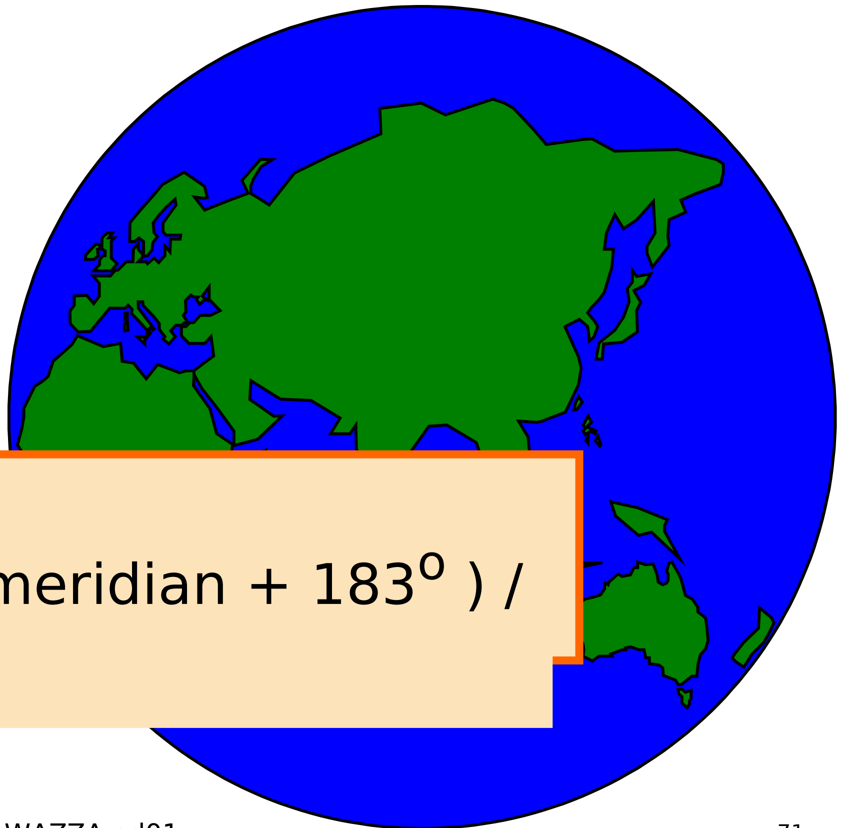
Transverse Mercator Projection (e.g. UTM)



UTM-System

(Universal Transverse Mercator System)

- 60 zones, each 6^o ($60 \cdot 6^o = 360^o$)
- $\pm 3^o$ around each center meridian
- Beginning at 180^o longitude (measured eastward from Greenwich)



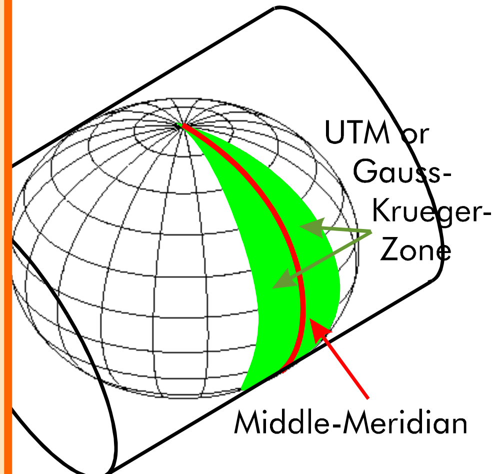
Zone number = (center meridian + 183^o) / 6^o

UTM - Definitions

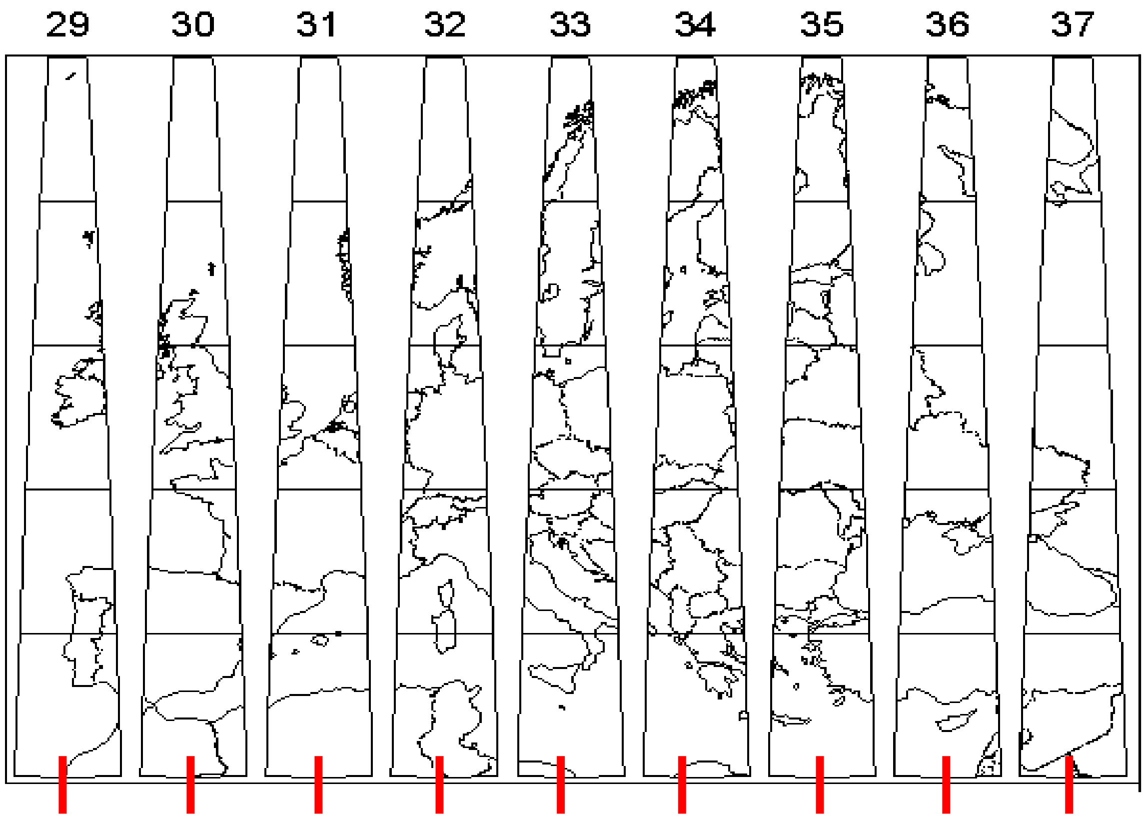
False Easting: 500 000 m
(Middle-meridian x = 500 000 m)

False Northing:
Northern Hemisphere: 0 m
Southern Hemisphere: 10 000 000 m

Scaling Factor: 0,9996
(used to minimize the "projection error" over the whole area)

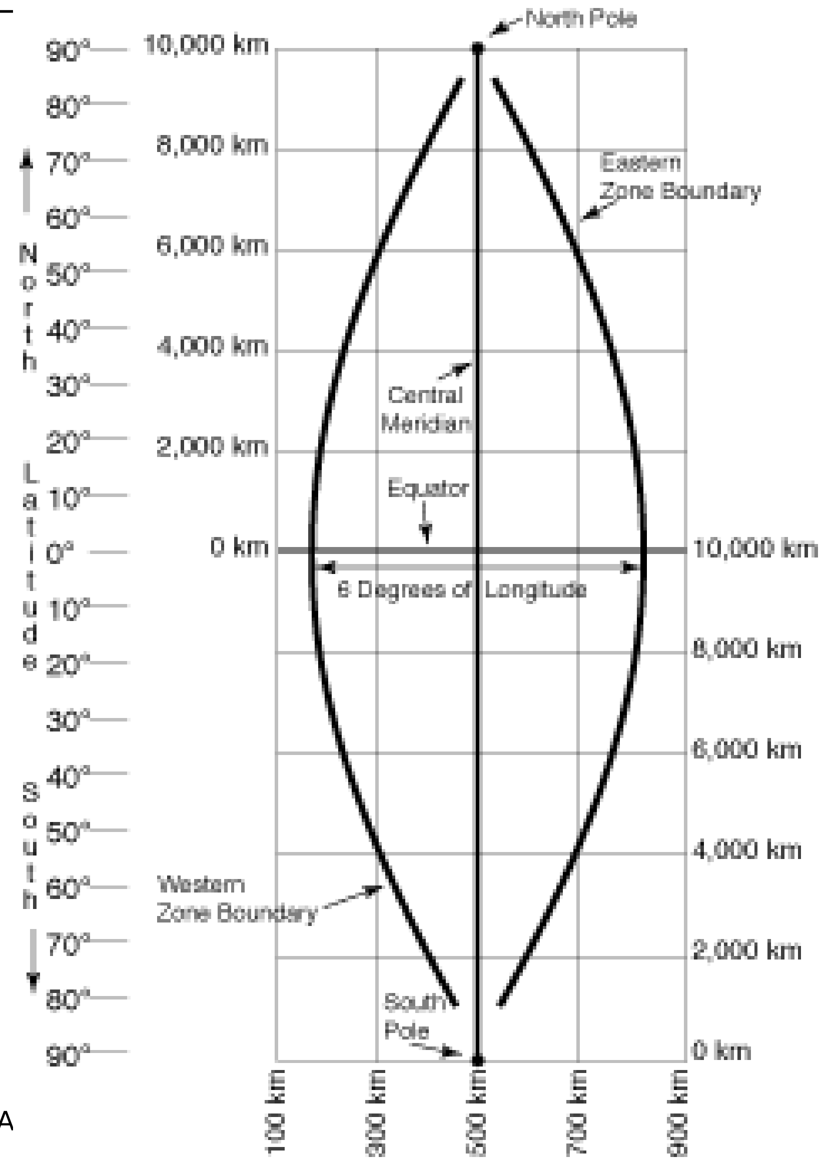


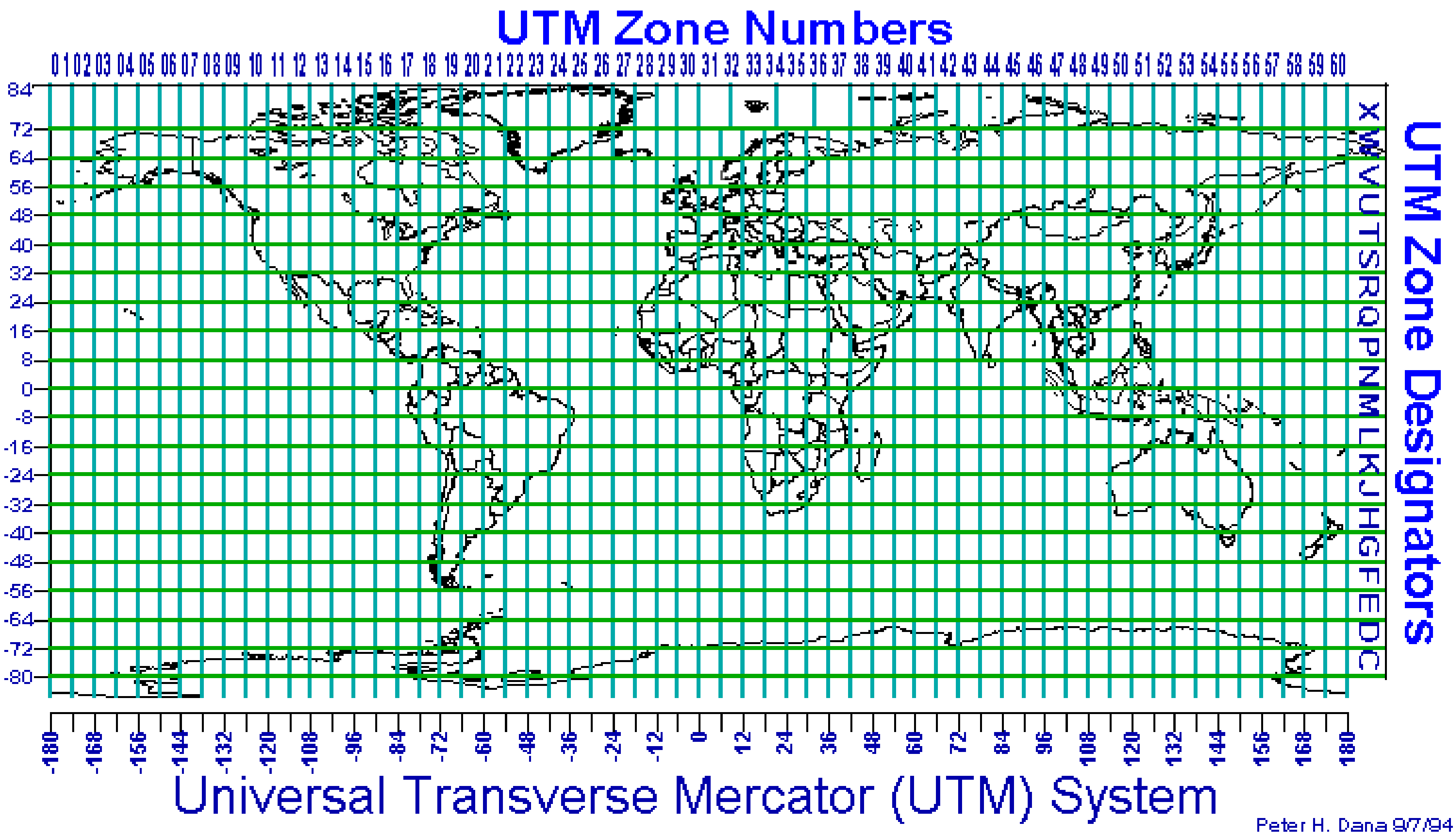
UTM Zones (e.g. Europe)



UTM-System (2)

- False origin on the central meridian of the zone has an easting of 500,000 meters.
- All eastings have a positive values for the zone
- Eastings range from 100,000 to 900,000 meters
- The 6 Degree zone ranges from 166,667 to 833,333 m, leaving about a 0.5° overlap at each end of the zone
(valid only at the equator)
- This allows for overlaps and matching between zones




UTM Zone Numbers
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
84 72 64 56 48 40 32 24 16 8 0 -8 -16 -24 -32 -40 -48 -56 -64 -72 -80
X W V U T S R Q P N M L K J H G F E D C
UTM Zone Designators
-180 -168 -156 -144 -132 -120 -108 -96 -84 -72 -60 -48 -36 -24 -12 0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180
Universal Transverse Mercator (UTM) System
Peter H. Dana 9/7/94

UTM-System: Example "Stuttgart"

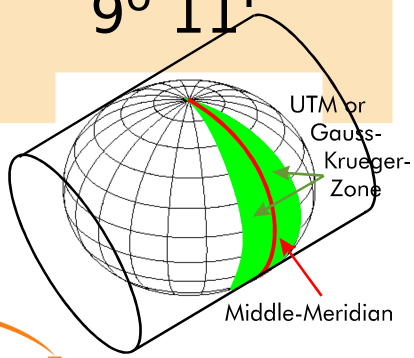
Transformation: latitude / longitude → UTM system

North 48° 45' 13.5''

East 9° 11' 7.5''

y = 5 400 099 m

x = 513 629 m



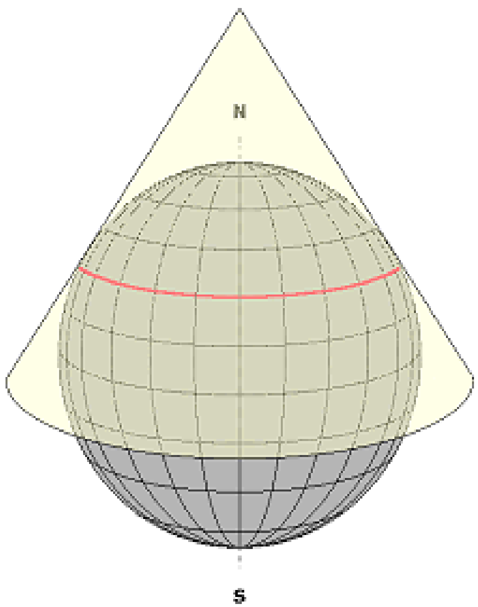
UTM-Zone: 32

Middle meridian: 9°

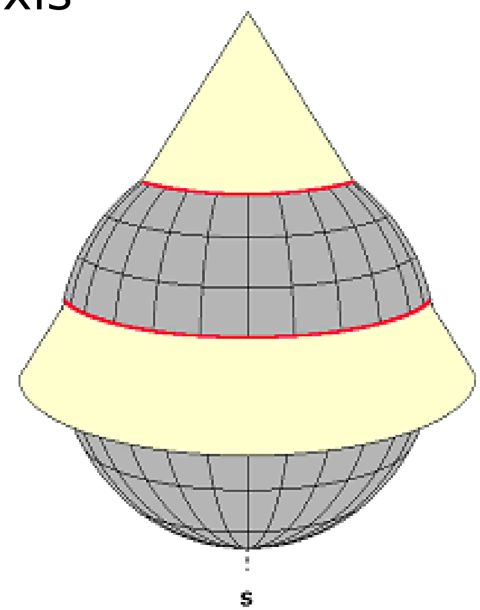
(9° ≙ **500 000** m "False Easting")

Lambert Conformal Conic Projection

- Maps an ellipsoid onto a cone whose central axis coincides with the polar axis



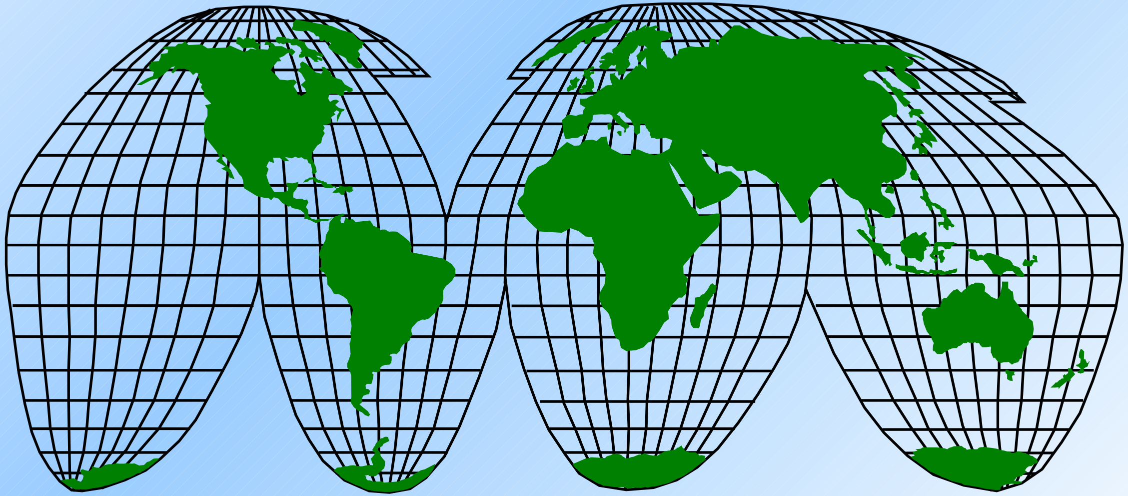
Cone touches the ellipsoid
=> One standard parallel (1SP)
(e.g. NTF-System in France)



Cutting edges of cone and ellipsoid
=> Two standard parallels (2SP)
(e.g. Lambert-Projection in Austria)

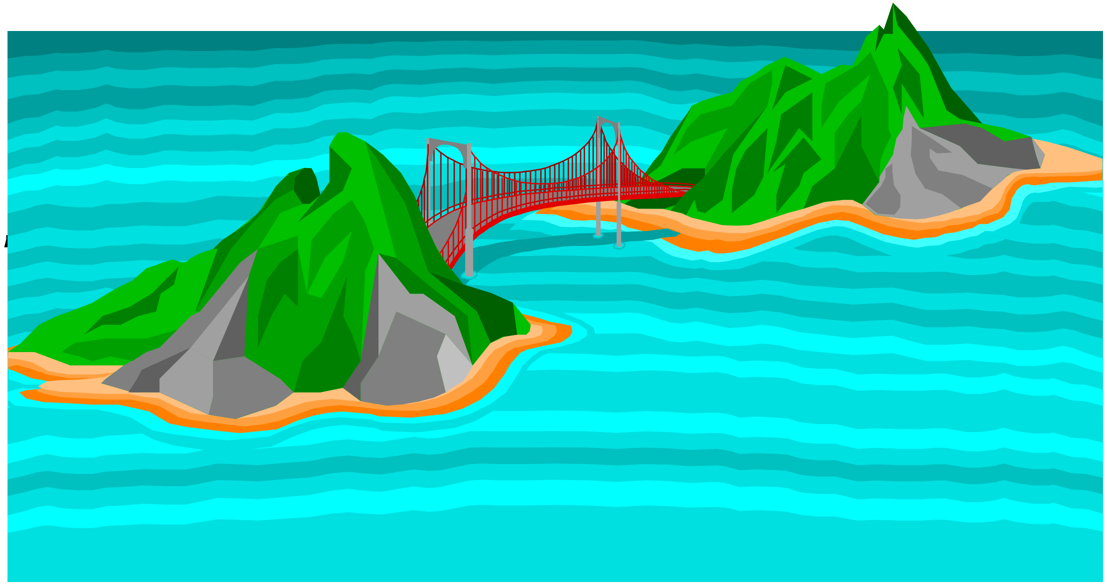
Geo Databases

Types of Geospatial Data

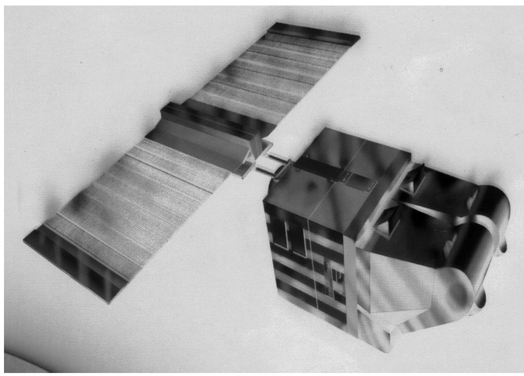


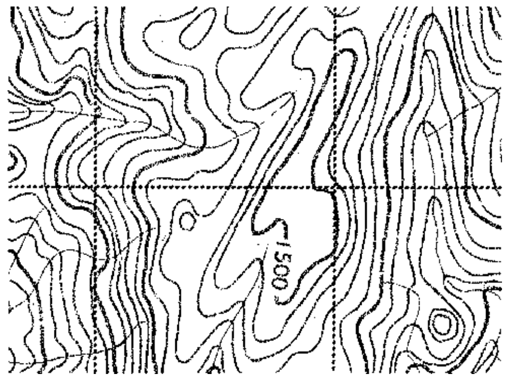
Geospatial data for Network Planning

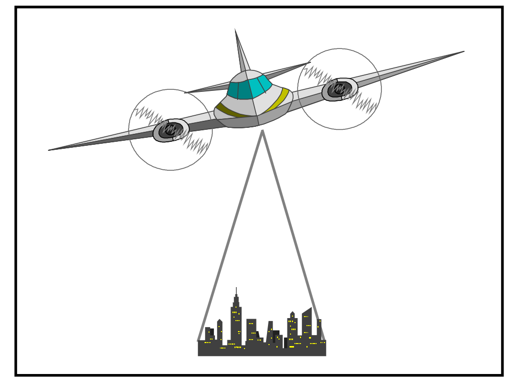
- DEM (Digital Elevation Model)/ Topography
- Morphostructure / Land usage / Clutter
- Satellite Photos / Orthoimages
- Scanned Maps
- Background data (streets, borders, coastlines, etc.)
- Buildings
- Traffic data



Creation of geospatial databases







Satellite imagery

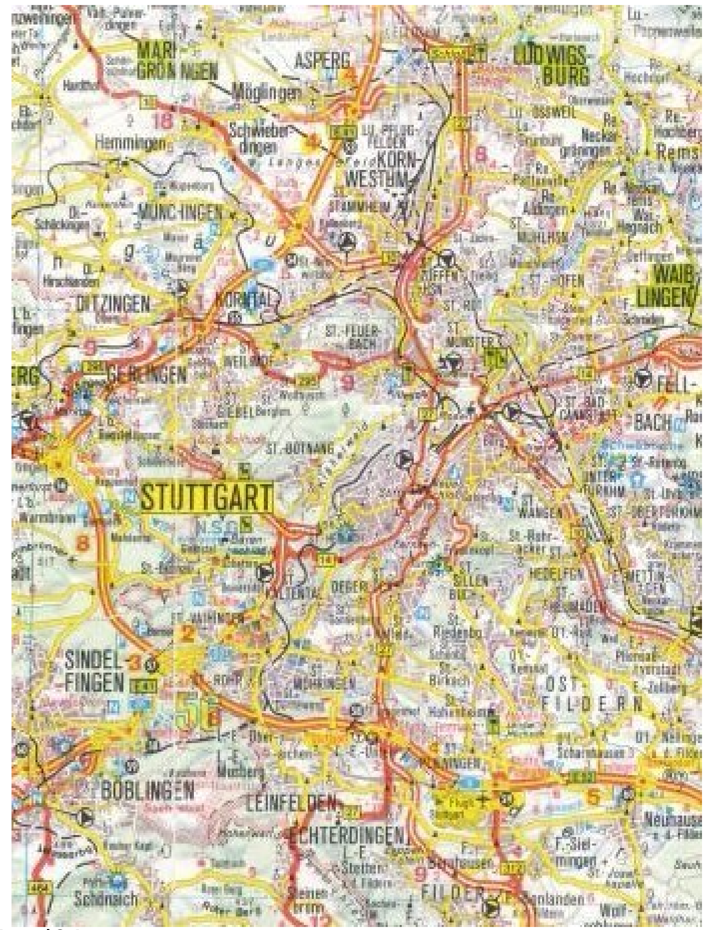
Digitizing maps

Aerial photography

Geospatial data

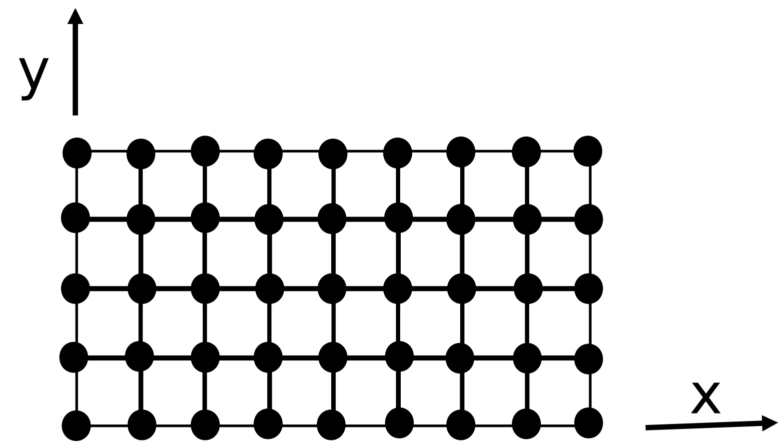
Parameters of a Map

- Coordinate system
- Map Projection
  (incl. Geodetic Datum)
- Location of the map (Area ...)
- Scale:
  - macrocell planning
    1:50000 - 1:100000
  - microcell planning
    1:500 -1:5000
- Thematic
- Source
- Date of Production

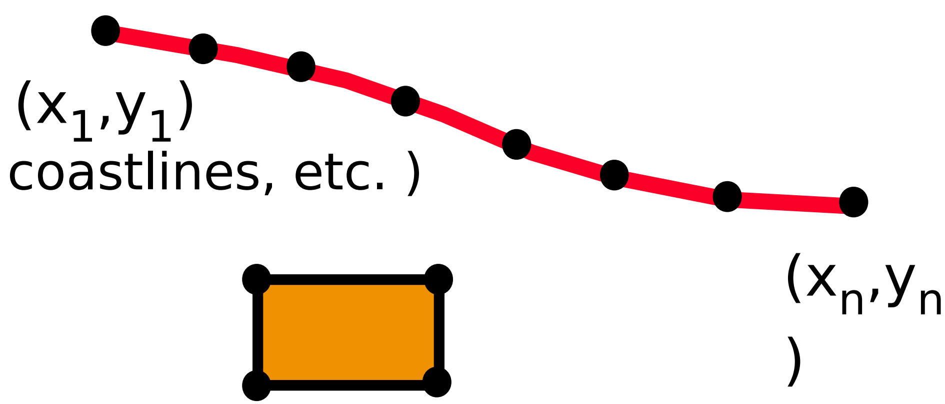


Raster- and Vectordata

- Raster data
  - DEM /Topography
  - Morphostructure / Land usage / Clutter
  - Traffic density

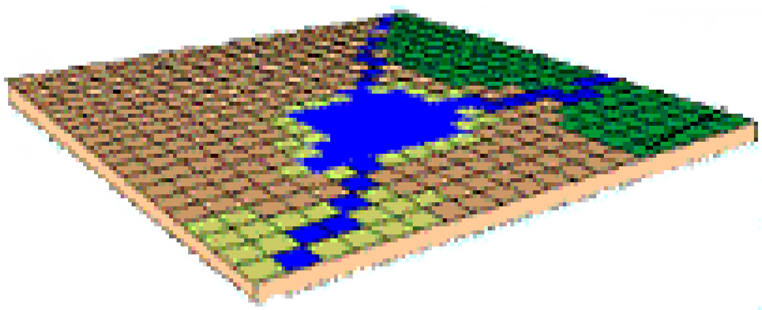


- Vector data
  - Background data (streets, borders, coastlines, etc.)
  - Buildings



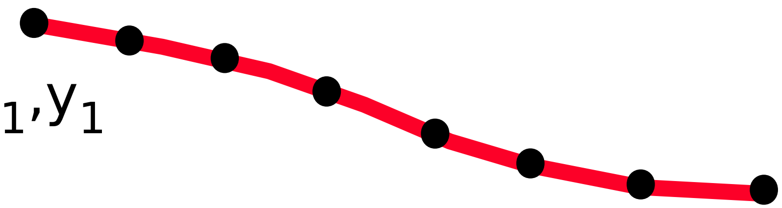
Rasterdata / Grid data

- Pixel-oriented data
- Stored as row and column
- Each Pixel stored in one or two byte
- Each Pixel contents information (e.g. morphoclass, colour of a scanned map, elevation of a DEM)



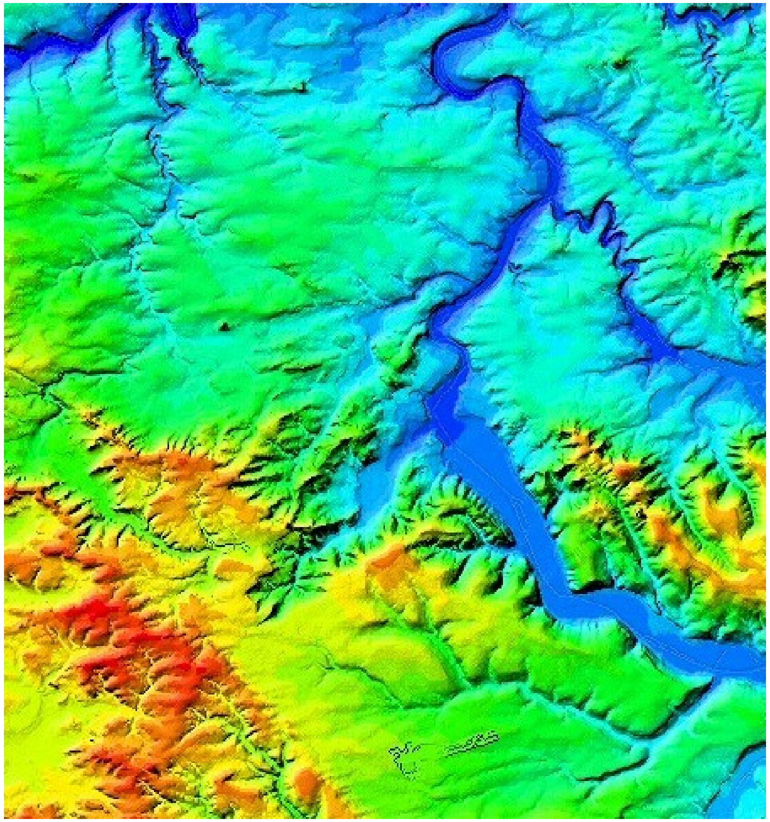
Vectordata

- Vector mainly used are: airport, coastline, highway, main roads, secondary roads, railway, rivers/lakes
- Each vector contents
  - Info about kind of vector (e.g. street, coastline)
  - A series of several points
    Each point has a corresponded x / y -value
    (e.g. in UTM System or as Long/Lat)
  - Info about *Map projection* and used *Geodetic Datum*



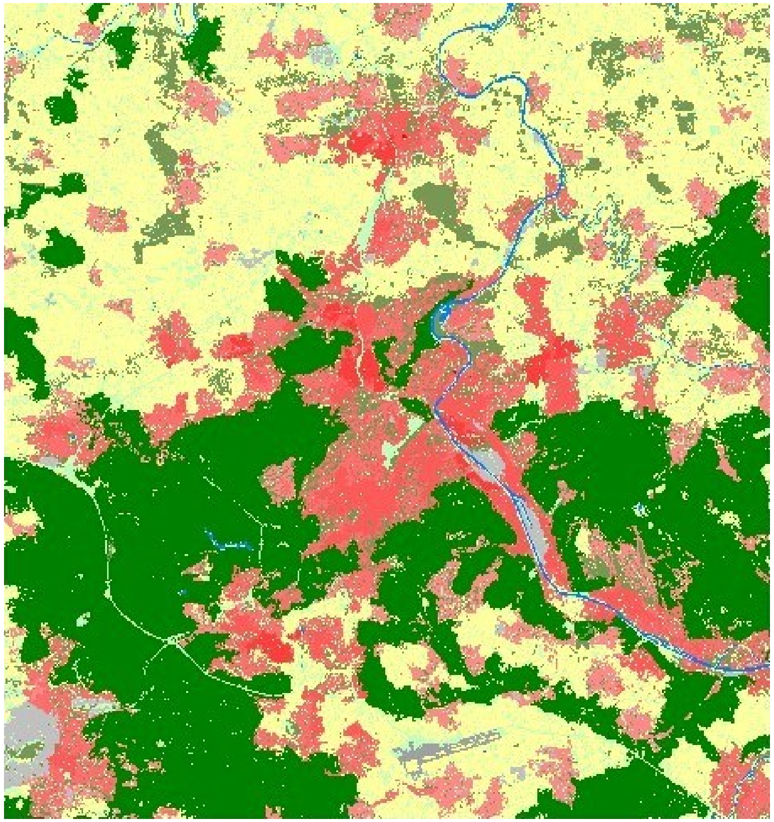
Digital Elevation Model (DEM)

- Raster dataset that shows terrain features such as hills and valleys
- Each element (or pixel) in the DEM image represents the terrain elevation at that location
- Resolution in most cases:
  20 m for urban areas
  50-100 m for other areas
- DEM are typically generated from topographic maps, stereo satellite images, or stereo aerial photographs



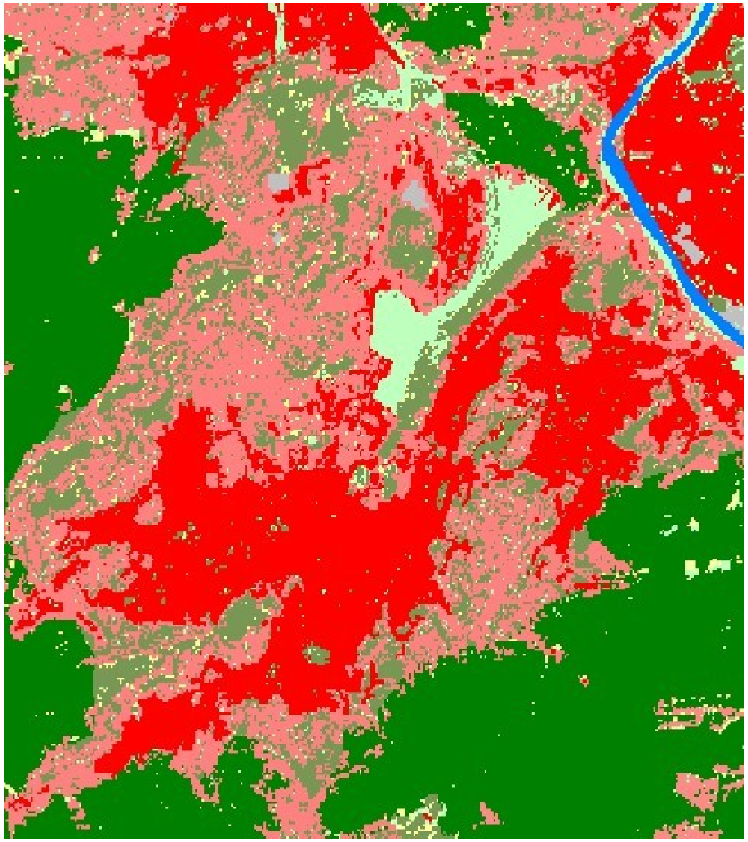
Morphostructure / Land usage / Clutter (1)

- Land usage classification according to the impact on wave propagation
- In most cases:
  7...14 morpho classes
- Resolution in most cases:
  20 m for cities
  50...100m other areas
  for radio network planning

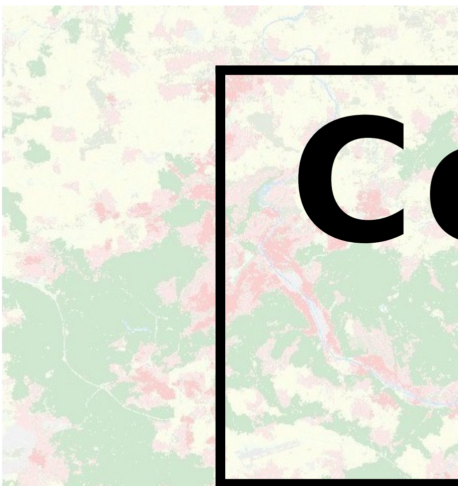


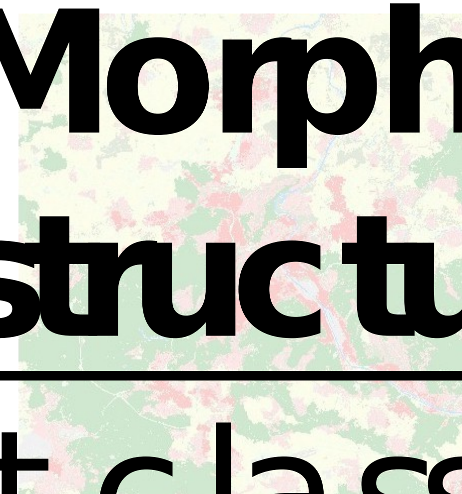
Morphostructure (2)

- Besides the topo database the basic input for radio network planning
- Each propagation area has different obstacles like buildings, forest etc. Obstacles which have similar effects on propagation conditions are classified in *morphoclasses*
- Each morphoclass has a corresponding value for the correction gain
- The resolution of the morpho databases should be adapted to the propagation model
- Morpho correction factor for predictions:
  0 dB (”skyscapers") … 30 dB (”water")



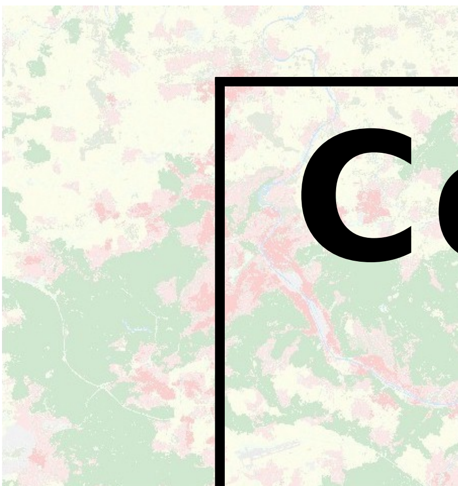
Morphoclasses

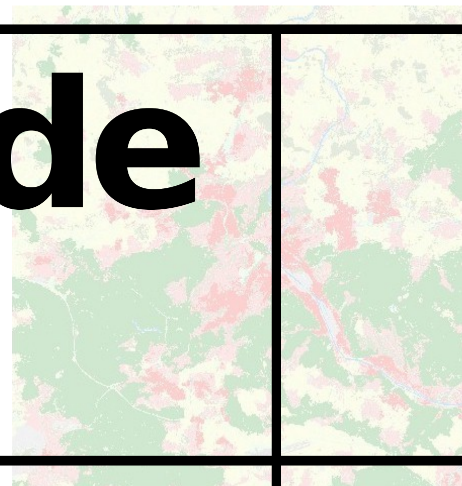


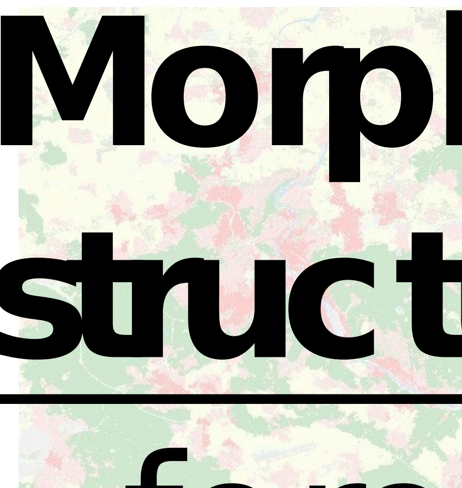


Code	Morpho- structure
0	not classifi

Morphoclasses



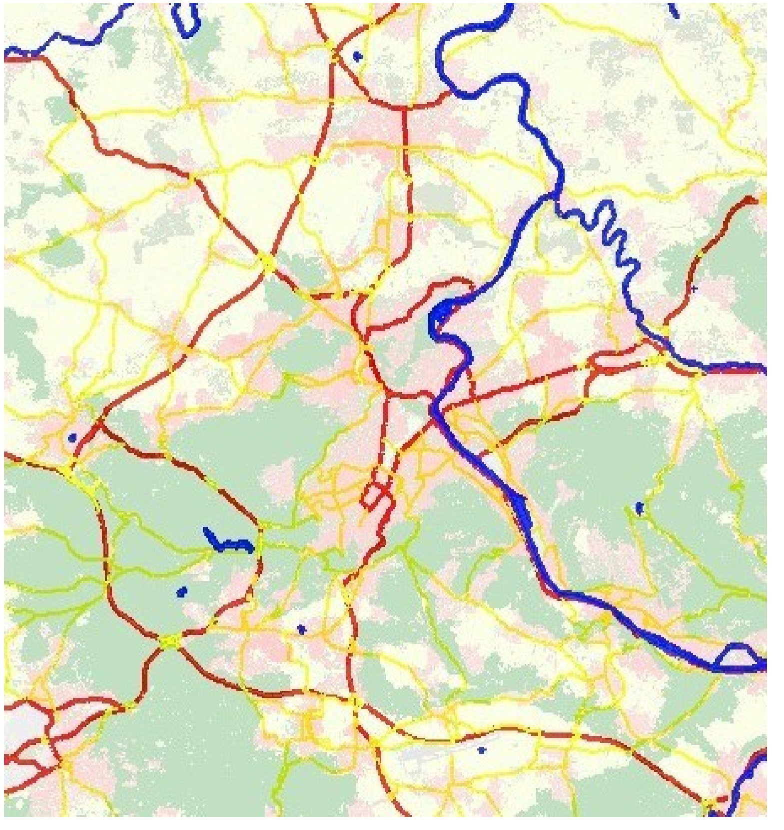




Code	Morpho structur
7	forest

Background data (streets, borders etc.)

- All kinds of information data like streets, borders, coastlines etc.
- Necessary for orientation in plots of calculation results
- The background data are *not needed* for the calculation of the fieldstrength, power etc.

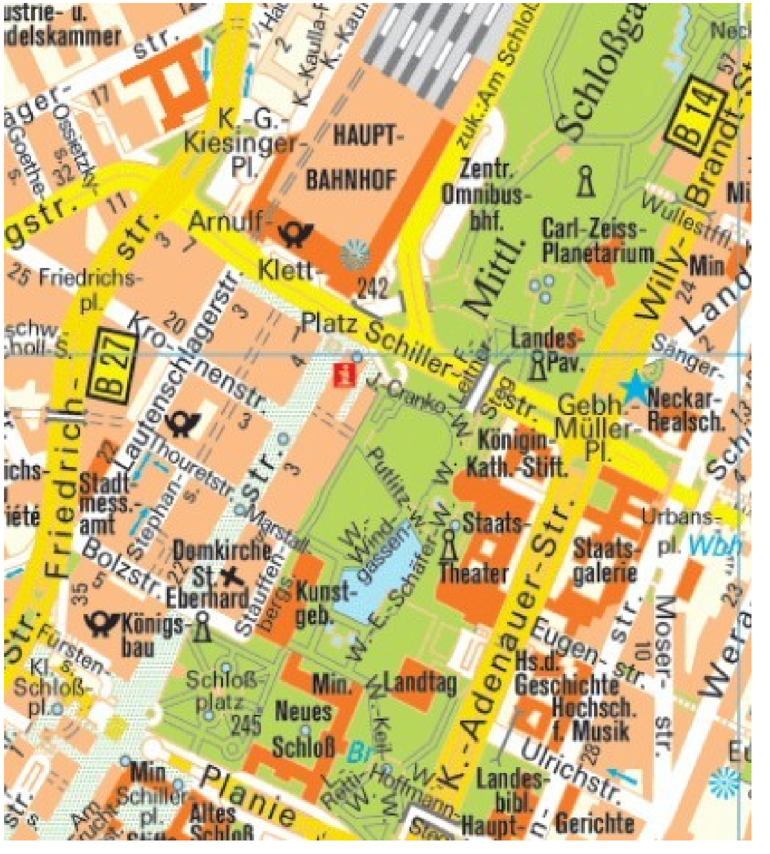


Orthophoto

- Georeferenced Satellite Image
- Resolution:
  most 10 or 20 m
- Satellite: e.g. SPOT, Landsat

Scanned Maps

- Mainly used as background data
- Not used for calculation but for localisation
- Has to be geocoded to put it into a GIS (Geographic Information System) e.g. a Radio Network Planning Tool

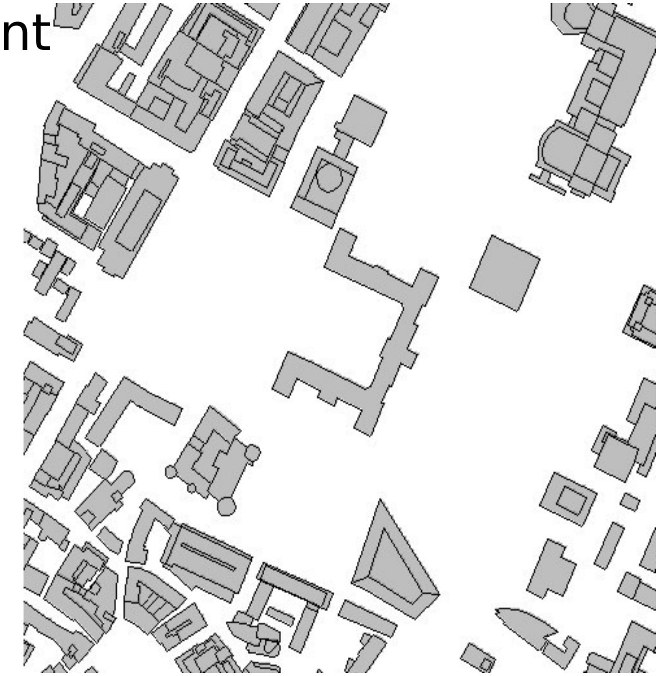


Buildings

- Vectordata
  - Outlines of
    - single buildings
    - building blocks
  - Building heights
  - Material code
    - not: roof shape

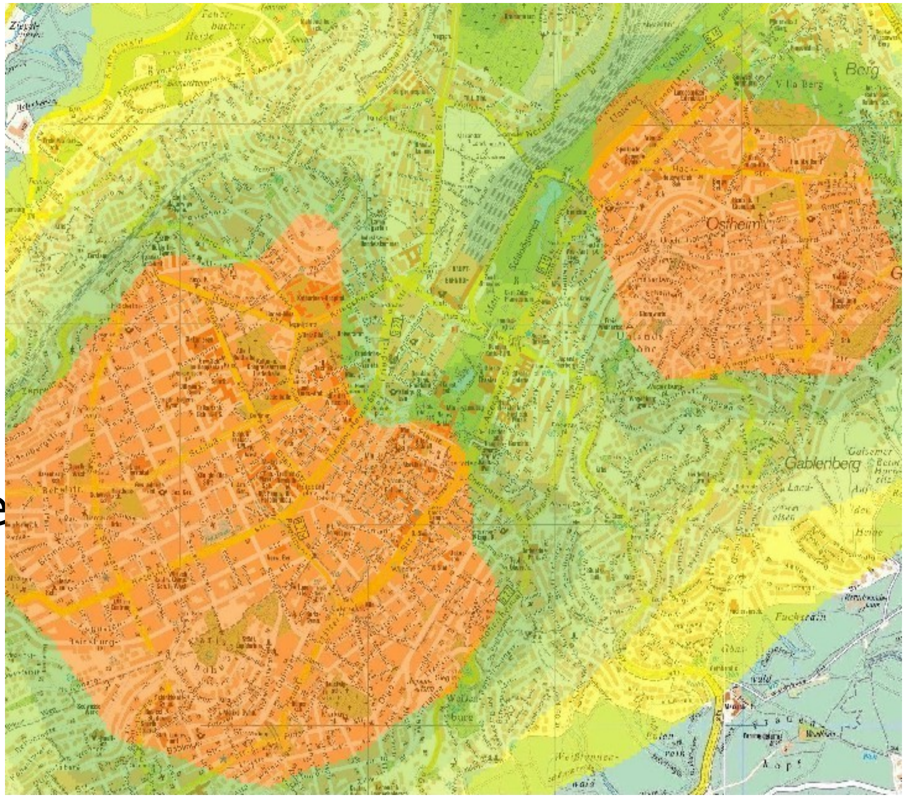
Buildings (2)

- Microcell radio network planning is mainly used in urban environment
- The prediction of mircowave propagation is calculated with a ray-tracing/launching model
- A lot of calculation steps are needed
- ➡ Optimum building database required (data reduction) to minimize the pre-calculation time



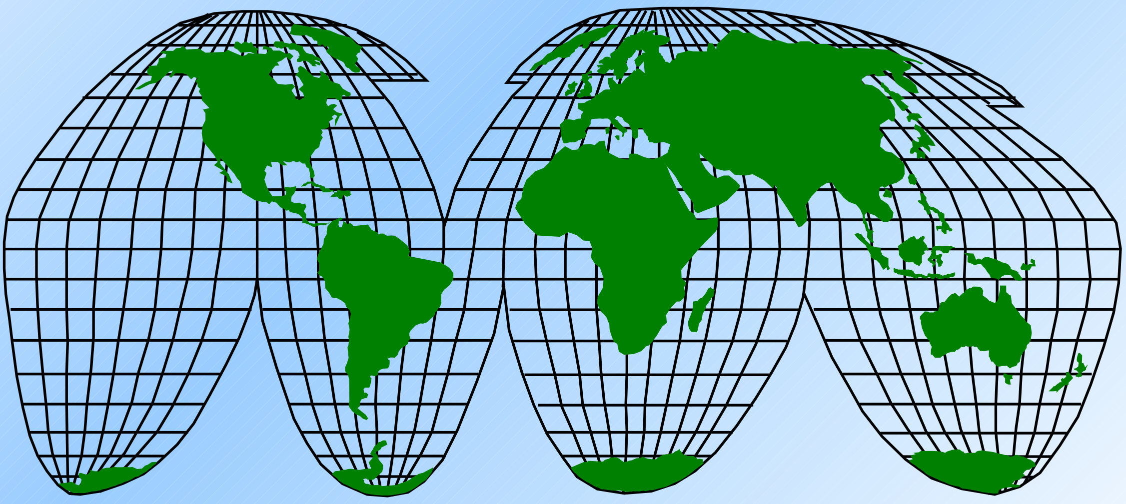
Traffic density

- Advantageous in the interference calculation, thus for frequency assignment and in the calculation of average figures in network analysis
- Raster database of traffic density values (in Erlangs) of the whole planning area
- Resolution: 20...100 m



Geo Databases

Geocoordinate transformation



Converting one single point (1a)

Example “Stuttgart” (Example 1)

Long/Lat (WGS84) => UTM (WGS84)

Exercise: Convert following example with the program “Geotrans”:

Input:
Longitude: 9 deg 11 min 7.5 sec
Latitude: 48 deg 45 min 13.5 sec
Datum “WGE: World Geodetic System 1984”; Projection: “Geodetic”

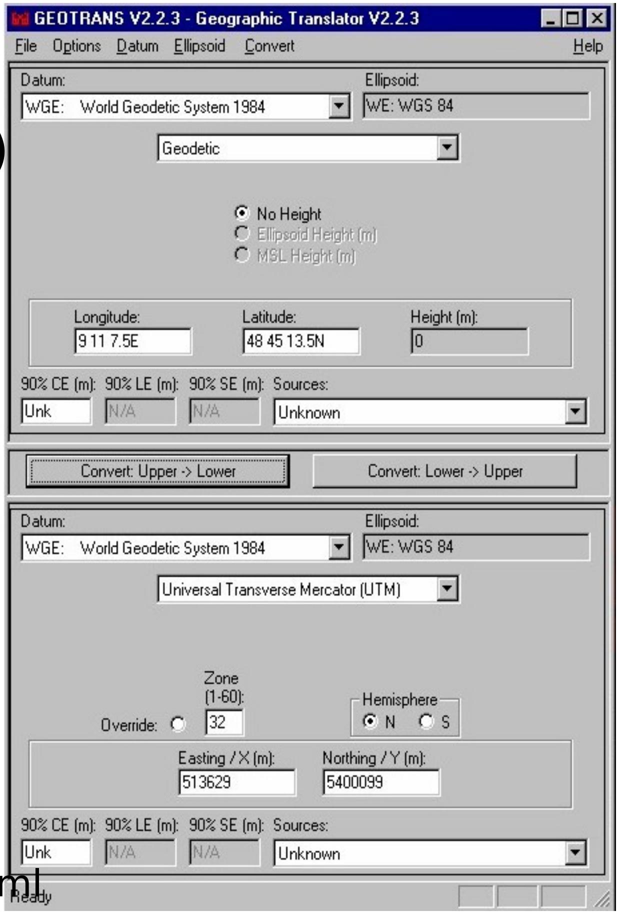
Output:
Easting: 513629 m
Northing: 5400099 m
Datum “WGE: World Geodetic System 1984”
Projection: “Universersal Transverse Mercator (UTM)”
Zone: 32 ; Hemisphere: N (North)

} Values, which will calculated by program (Easting, Northing)

} Preset of this values necessary (Datum, Projection, Zone, Hemisphere)

Converting one single point (1b)

Example “Stuttgart” (Example 1)
Long/Lat (WGS84) => UTM (WGS84)



GEOTRANS (Geographic Translator) is an application program which allows you to convert geographic coordinates easily among a wide variety of coordinate systems, map projections, and datums.

Source: http://164.214.2.59/GandG/geotrans/geotrans.html

Converting one single point (2a)

Example “Stuttgart” (Example 2)

Long/Lat (WGS84) => UTM (ED50)

(ED50 = EUR-A = European Datum 1950)

Exercise: Convert following example with the program “Geotrans”:

Input:
Longitude: 9 deg 11 min 7.5 sec
Latitude: 48 deg 45 min 13.5 sec
Datum “WGE: World Geodetic System 1984”; Projection: “Geodetic”

Output:
Easting: 513549 m
Northing: 5403685 m
Datum “EUR-A: EUROPEAN 1950, Western Europe”
Projection: “Universersal Transverse Mercator (UTM)”
Zone: 32 ; Hemisphere: N (North)

} Values, which will calculated by program (Easting, Northing)

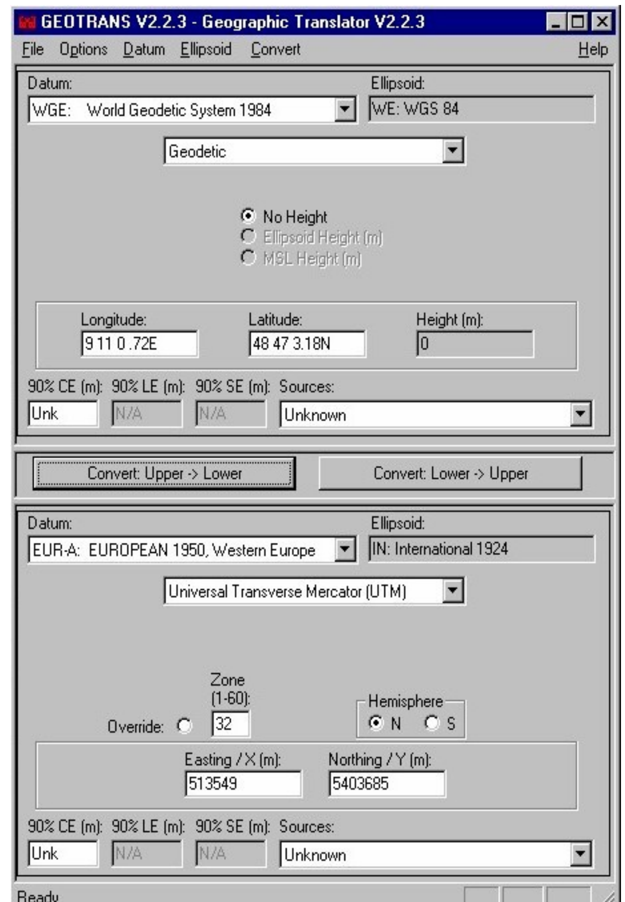
} Preset of this values necessary (Datum, Projection, Zone, Hemisphere)

Converting one single point (2b)

Example “Stuttgart” (Example 2)
Long/Lat (WGS84) => UTM (ED50)
(ED50 = EUR-A = European Datum 1950)

Diff. X (Ex.2 - Ex.1): 69 m
Diff. Y (Ex.2 - Ex.1): 200 m
Difference because of different Geodetic Datums

Attention:
For flat coordinates (e.g. UTM) as well as for geographic coordinates (Long/Lat) a reference called “Geodetic Datum” is necessary.



Converting a list of points (3a)

Example “Stuttgart” (Example 3)
Long/Lat (WGS84) => UTM (WGS84)

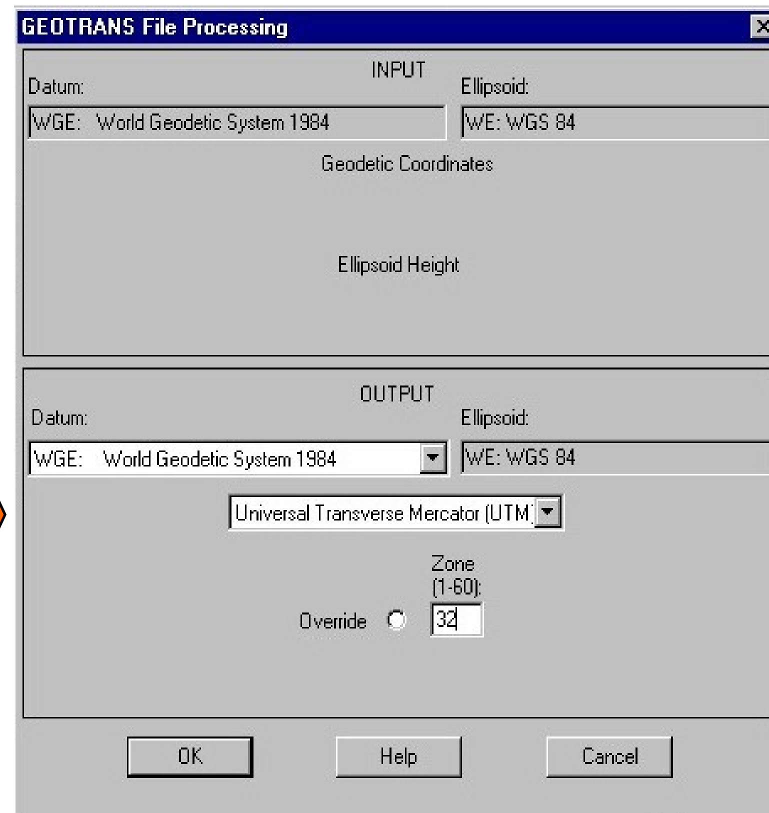
Input:
text-file with the values (list) of the longitude and latitude of different points
(How to create the *inputfile* see on page 3c)

Output:
Datum: “WGE: World Geodetic System 1984”
Projection: “Universal Transverse Mercator (UTM)”
Zone: 32

Preset of this values necessary

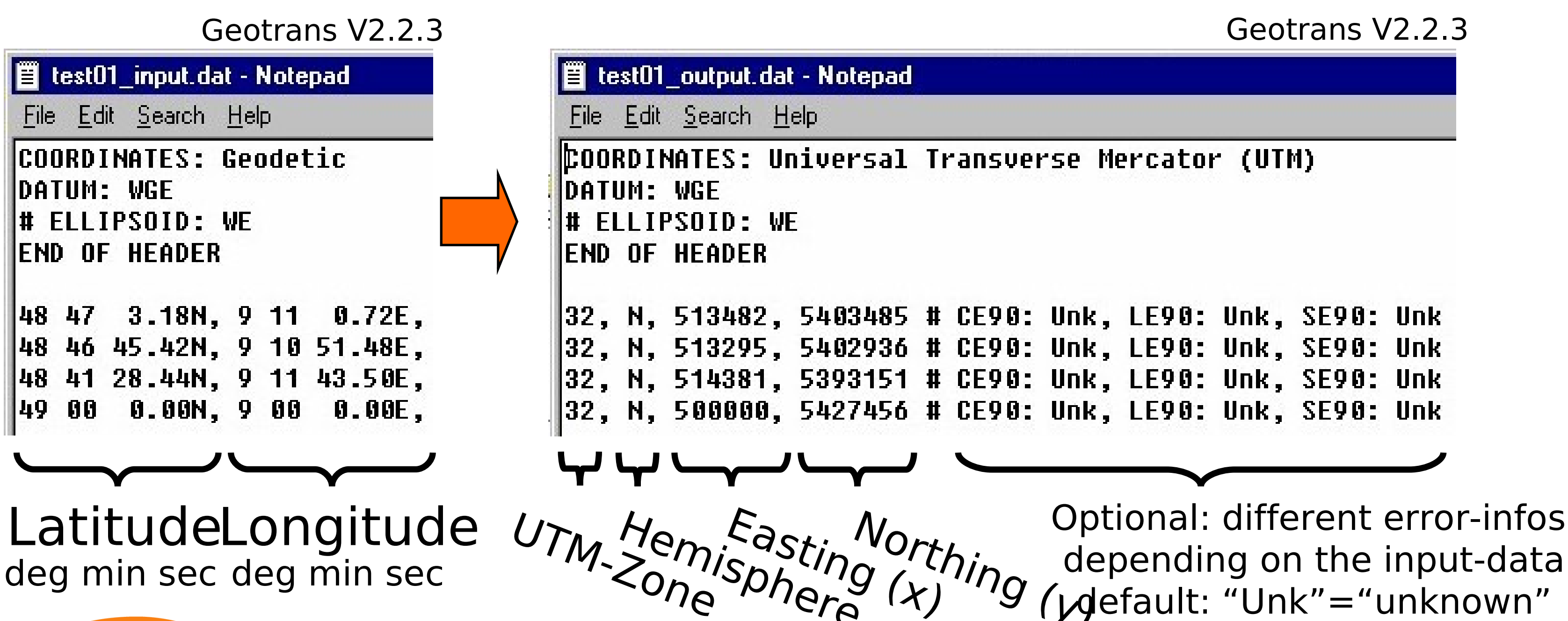
Converting a list of points (3b)

Example “Stuttgart” (Example 3)
Long/Lat (WGS84)
=> UTM (WGS84)



Converting a list of points (3c)

- Example “Stuttgart” (Example 3)
  Long/Lat (WGS84)=> UTM (WGS84)



test01_input.dat - Notepad

```
COORDINATES: Geodetic
DATUM: WGE
# ELLIPSOID: WE
END OF HEADER

48 47  3.18N, 9 11  0.72E,
48 46 45.42N, 9 10 51.48E,
48 41 28.44N, 9 11 43.50E,
49 00  0.00N, 9 00  0.00E,
```

test01_output.dat - Notepad

```
COORDINATES: Universal Transverse Mercator (UTM)
DATUM: WGE
# ELLIPSOID: WE
END OF HEADER

32, N, 513482, 5403485 # CE90: Unk, LE90: Unk, SE90: Unk
32, N, 513295, 5402936 # CE90: Unk, LE90: Unk, SE90: Unk
32, N, 514381, 5393151 # CE90: Unk, LE90: Unk, SE90: Unk
32, N, 500000, 5427456 # CE90: Unk, LE90: Unk, SE90: Unk
```

Provider for Geospatial data

Geodatasupplier	**Internet**
BKS	www.bks.co.uk
ComputaMaps	www.computamaps.com
Geoimage	www.geoimage.fr
Infoterra	www.infoterra-global.com
Istar	www.istar.fr
RMSI	www.rmsi.com

Links for more detailed infos

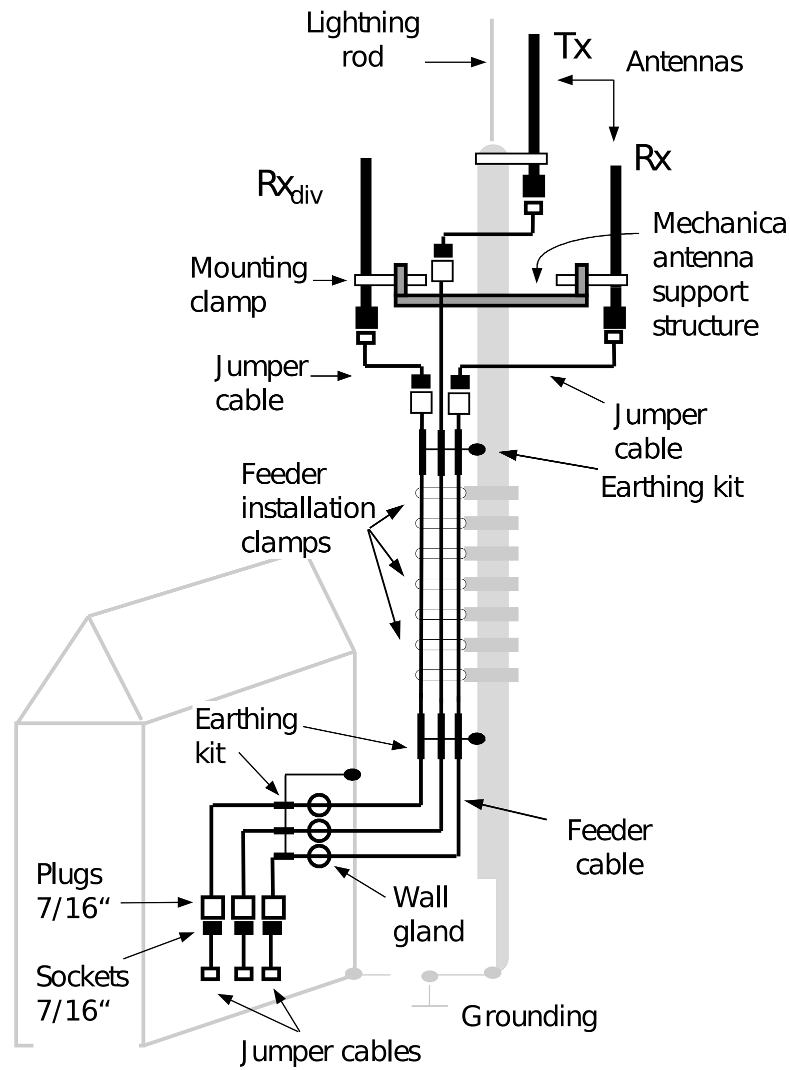
- Maps Projection Overview
  http://www.colorado.edu/geography/gcraft/notes/mapproj/mapproj.html
  http://www.ecu.edu/geog/faculty/mulcahy/mp/
  http://www.wikipedia.org/wiki/Map_projection
- Coordinate Transformation (online)
  http://jeeep.com/details/coord/
  http://www.cellspark.com/UTM.html
- Map Collection
  http://www.lib.utexas.edu/maps/index.html
- Finding out Latitude/Longitude of cities etc.
  http://www.maporama.com

Coverage Planning

Antennas and Cables

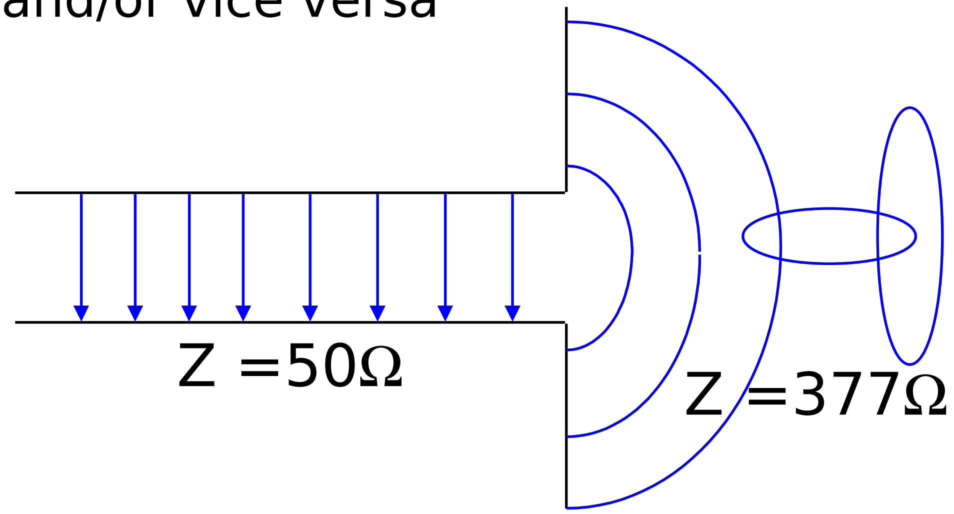
Antenna Systems

- Antennas
- Power divider
- Cables (jumper)
- Feeder cables
- Connectors
- Clamps
- Lightning protection
- Wall glands
- Planning



Antenna Theory

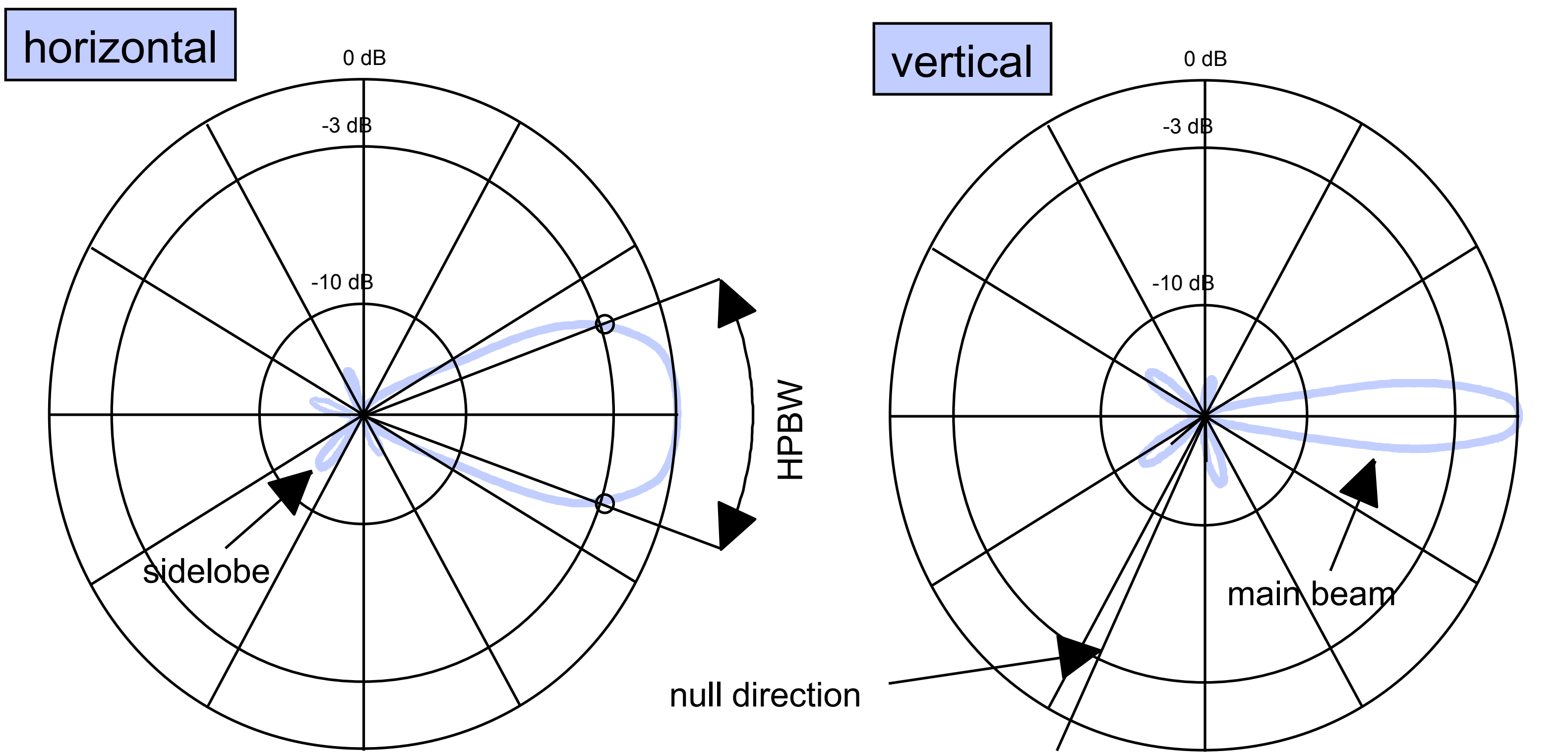
- 50Ω is the impedance of the cable
- 377Ω is the impedance of the air
- Antennas adapt the different impedances
- They convert guided waves, into free-space waves (Hertzian waves) and/or vice versa



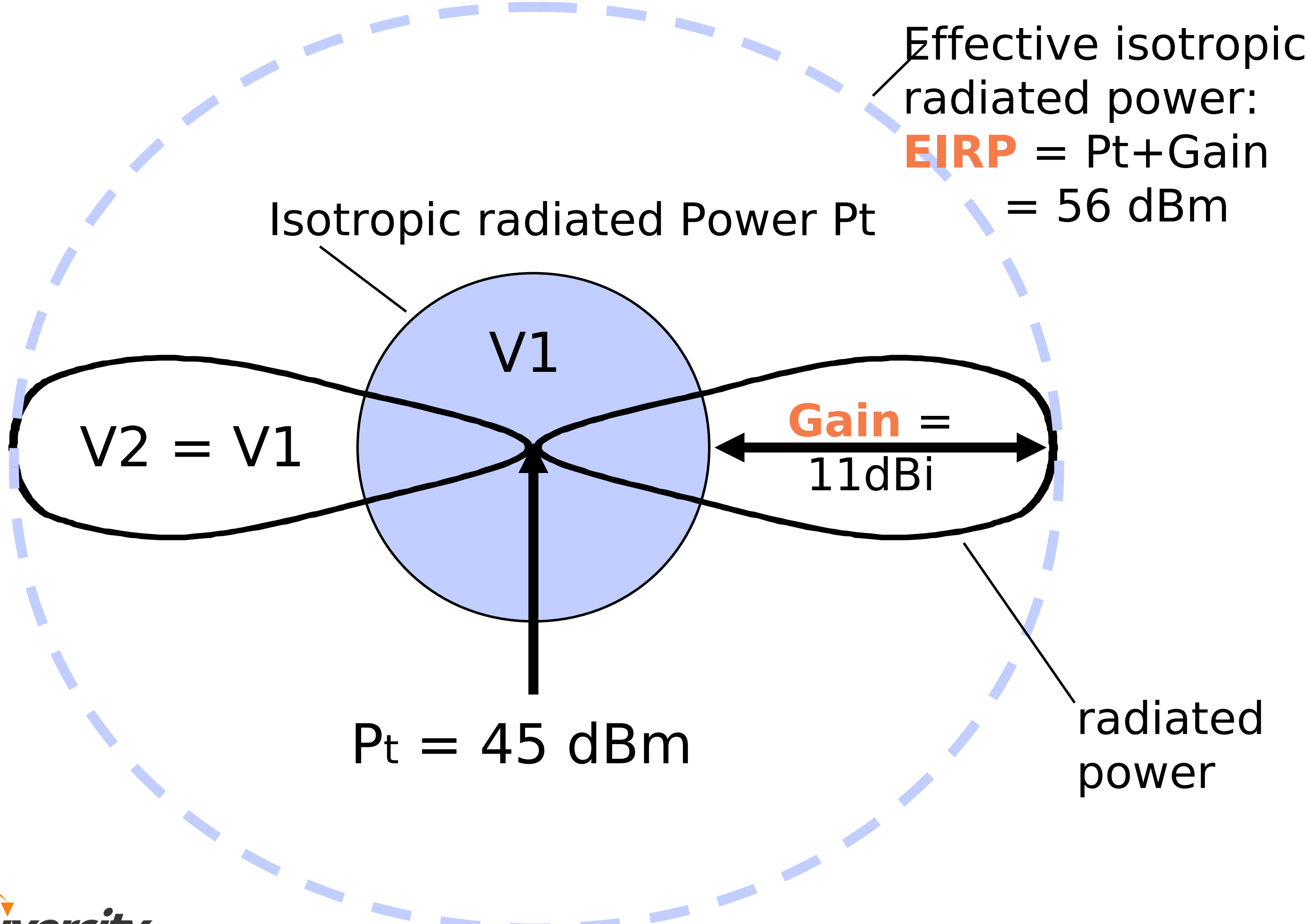
Antenna Data

- Polarization
  - Specification due to certain wave polarization (linear/elliptic, cross-polarization)
- Half power beam width (HPBW)
  - Related to polarization of electrical field
  - Vertical and Horizontal HPBW
- Antenna pattern
  - Yields the spatial radiation characteristics of the antenna
- Front-to-back ratio
  - Important for interference considerations

Antenna Pattern and HPBW

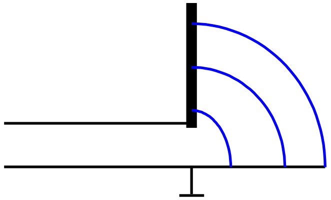


EIRP

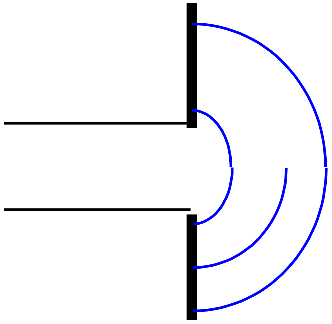

Effective isotropic
radiated power:
EIRP = Pt+Gain
= 56 dBm
Isotropic radiated Power Pt
V1
V2 = V1
Gain =
11dBi
Pt = 45 dBm
radiated
power

Linear Antennas: Monopole and Dipole

- For the link between base station and mobile station, mostly linear antennas are used:
  - Monopole antennas
    - MS antennas, car roof antennas

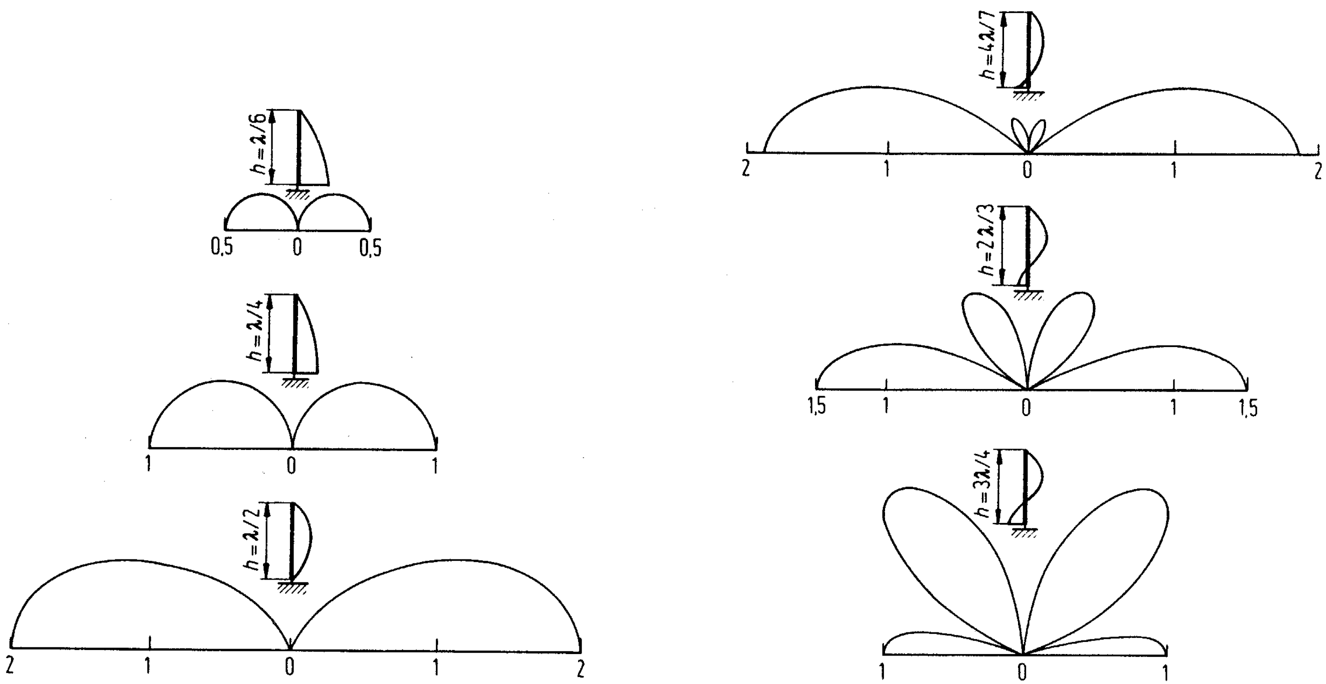


  - Dipole antennas
    - Used for array antennas at base stations for increasing the directivity of RX and TX antennas



Monopole Antenna Pattern

- Influence of antenna length on the antenna pattern

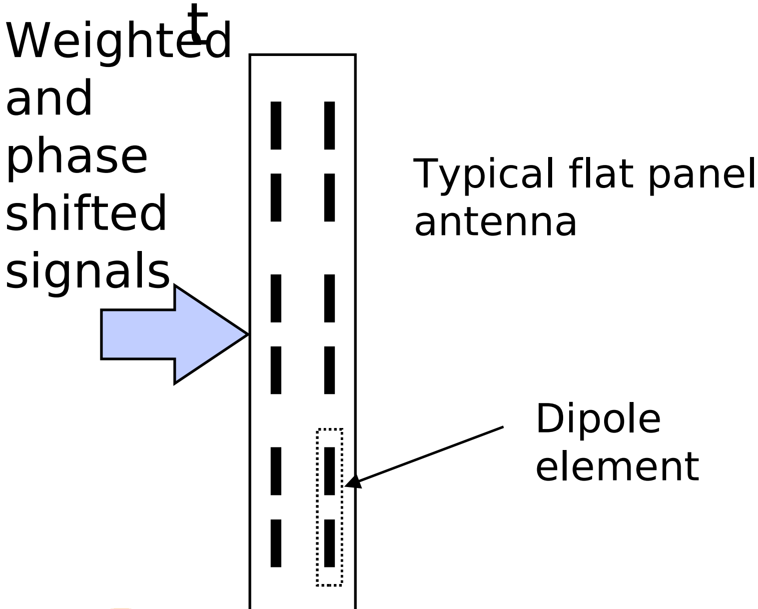


Panel Antenna with Dipole Array

- Many dipoles are arranged in a grid layout
- Nearly arbitrary antenna patterns may be designed
  - Feeding of the dipoles with weighted and phase-shifted signals
  - Coupling of all dipole elements

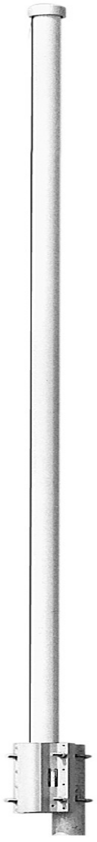
Dipole Arrangement

- Dipole arrangement

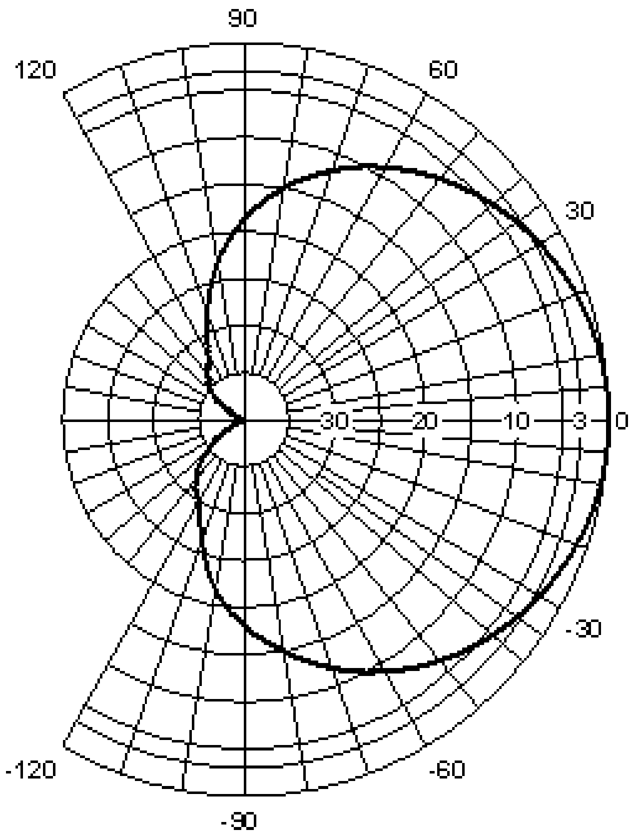


Omni Antenna

- Antenna with vertical HPBW for omni sites
  - Large area coverage
- Advantages
  - Continuous coverage around the site
  - Simple antenna mounting
  - Ideal for homogeneous terrain
- Drawbacks
  - No mechanical tilt possible
  - Clearance of antenna required



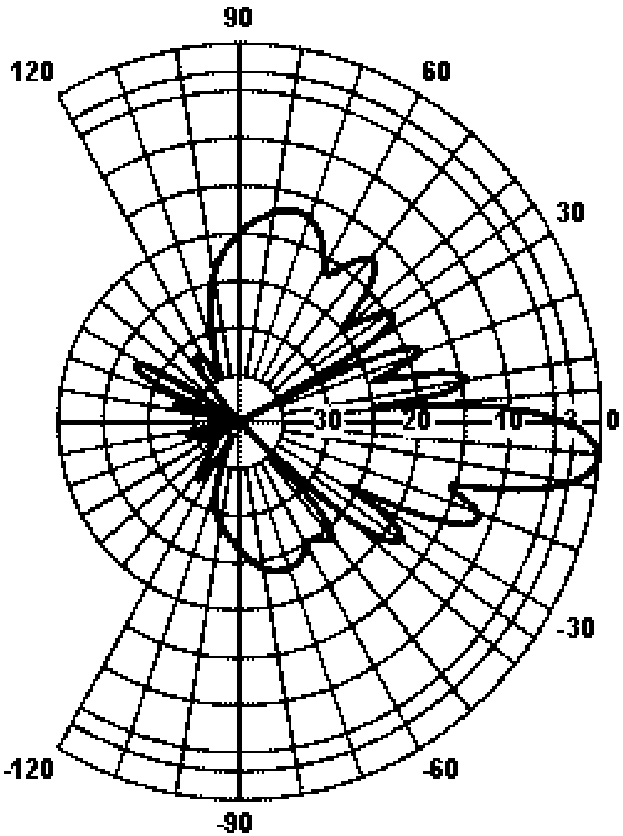
X 65° T6 900MHz 2.5m



Horizontal Pattern

- Rural road coverage with mechanical uptilt
- Antenna
  - RFS Panel Dual Polarized Antenna 872-960 MHz
  - APX906516-T6 Series
- Electrical specification
  - Gain in dBi: 17.1
  - Polarization: +/-45°
  - HBW: 65°
  - VBW: 6.5°
  - Electrical downtilt: 6°
- Mechanical specification
  - Dimensions HxWxD in mm: 2475 x 306 x 120
  - Weight in kg: 16.6

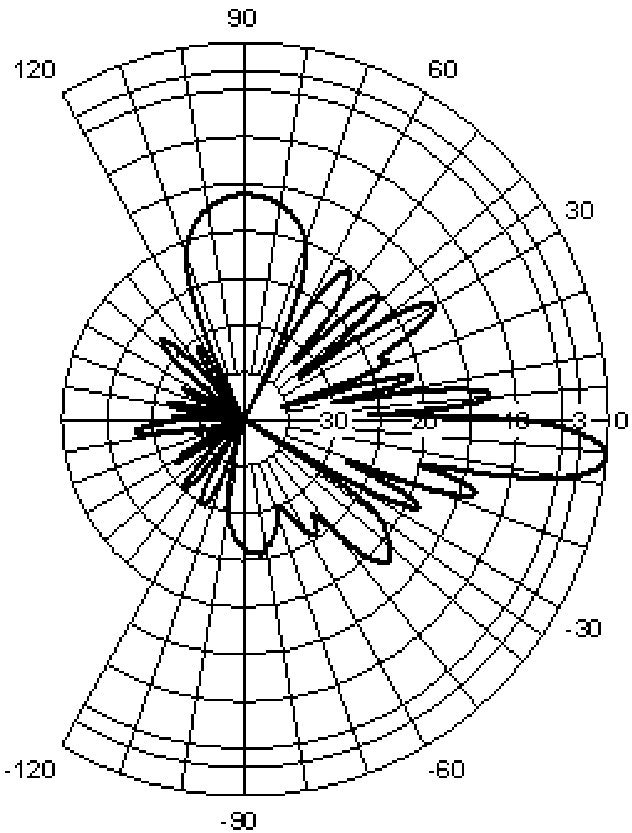
X 65° T6 900MHz 1.9m



Vertical Pattern

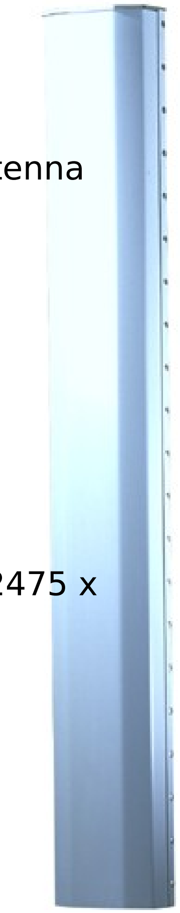
- Dense urban area
- Antenna
  - RFS Panel Dual Polarized Antenna 872-960 MHz
  - APX906515-T6 Series
- Electrical specification
  - Gain in dBi: 16.5
  - Polarization: +/-45°
  - HBW: 65°
  - VBW: 9°
  - Electrical downtilt: 6°
- Mechanical specification
  - Dimensions HxWxD in mm: 1890 x 306 x 120
  - Weight in kg: 16.6

X 90° T2 900MHz 2.5m

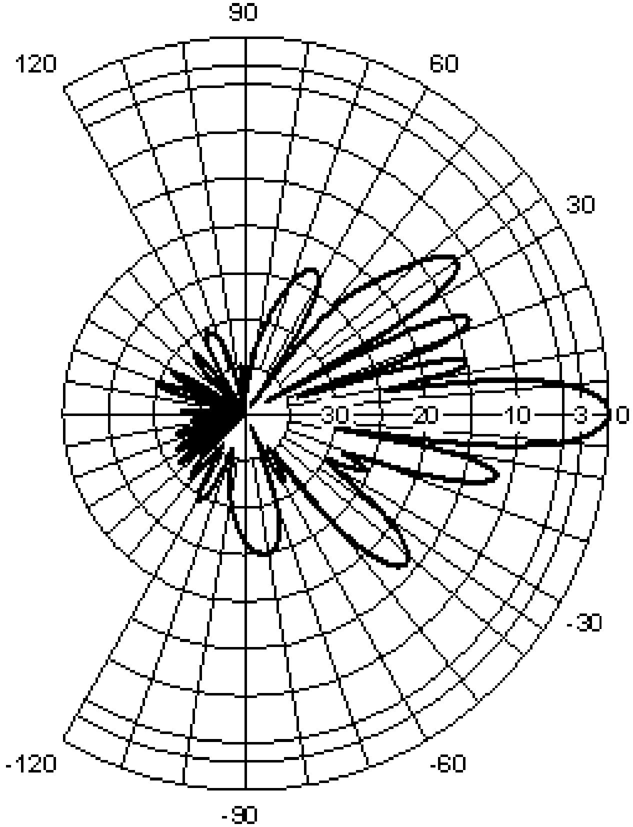


Vertical Pattern

- Rural area with mechanical uptilt
- Antenna
  - RFS Panel Dual Polarized Antenna 872-960 MHz
  - APX909014-T6 Series
- Electrical specification
  - Gain in dBi: 15.9
  - Polarization: +/-45°
  - HPBW: 90°
  - VBW: 7°
  - Electrical downtilt: 6°
- Mechanical specification
  - Dimensions HxWxD in mm: 2475 x 306 x 120
  - Weight in kg: 15.5



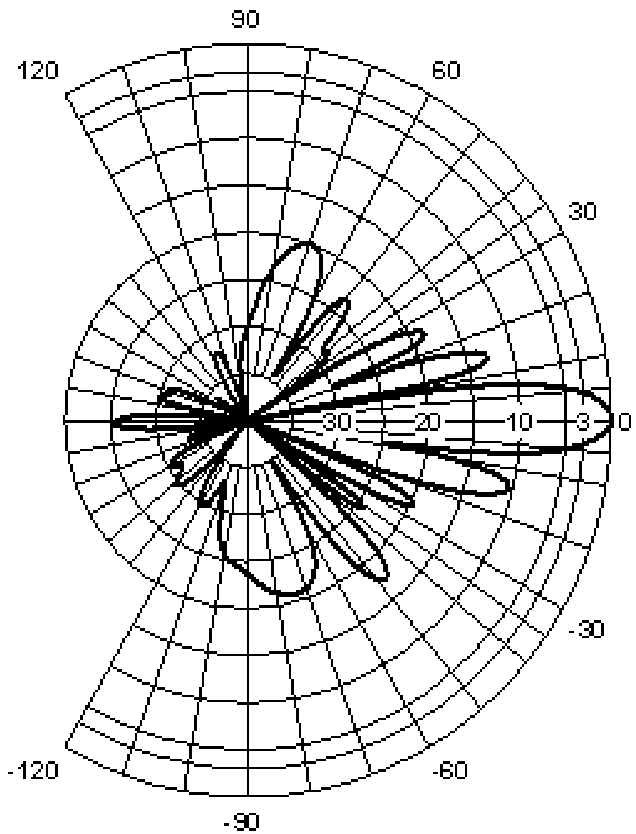
V 65° T0 900MHz 2.0m



Vertical Pattern

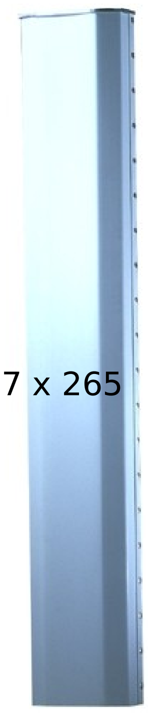
- Highway
- Antenna
  - RFS CELLite® Panel Vertical Polarized Antenna 872-960 MHz
  - AP906516-T0 Series
- Electrical specification
  - Gain in dBi: 17.5
  - Polarization: Vertical
  - HBW: 65°
  - VBW: 8.5°
  - Electrical downtilt: 0°
- Mechanical specification
  - Dimensions HxWxD in mm: 1977 x 265 x 130
  - Weight in kg: 10.9

V 90° T0 900MHz 2.0m

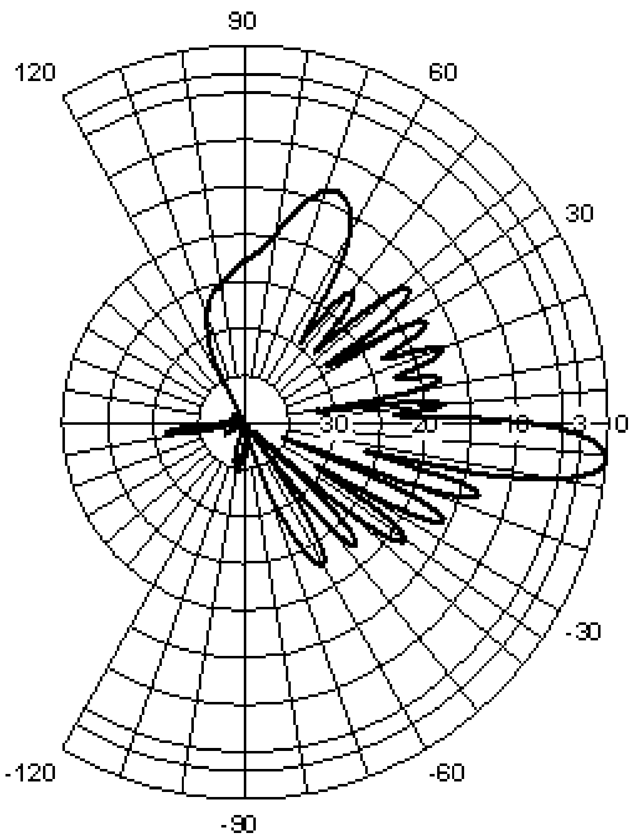


Vertical Pattern

- Rural Area
- Antenna
  - RFS CELLite® Panel Vertical Polarized Antenna 872-960 MHz
  - AP909014-T0 Series
- Electrical specification
  - Gain in dBi: 16.0
  - Polarization: Vertical
  - HBW: 65°
  - VBW: 8.5°
  - Electrical downtilt: 0°
- Mechanical specification
  - Dimensions HxWxD in mm: 1977 x 265 x 130
  - Weight in kg: 9.5



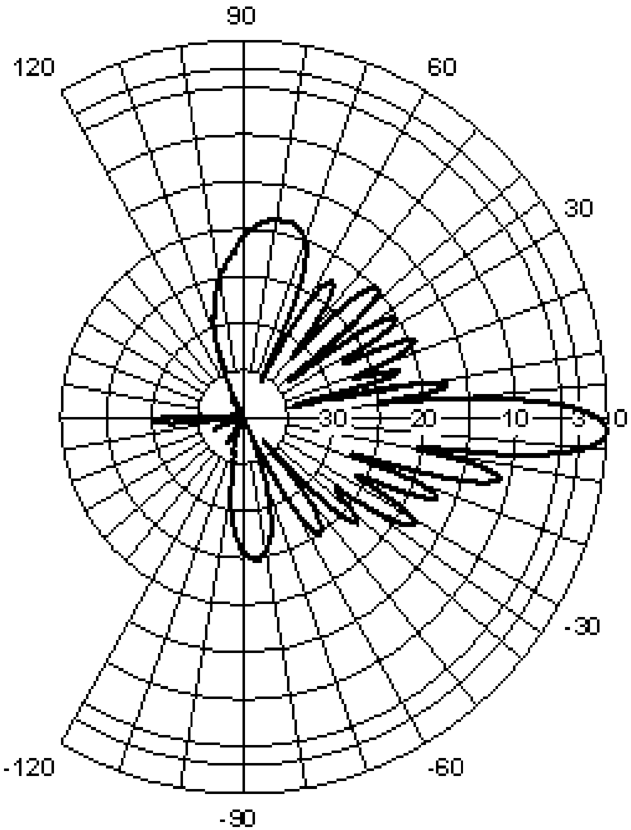
X 65° T6 1800MHz 1.3m



Vertical Pattern

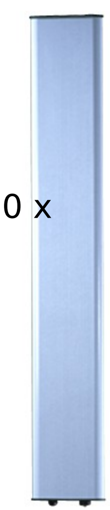
- Dense urban area
- Antenna
  - RFS Panel Dual Polarized Antenna 1710-1880 MHz
  - APX186515-T6 Series
- Electrical specification
  - Gain in dBi: 17.5
  - Polarization: +/-45°
  - HBW: 65°
  - VBW: 7°
  - Electrical downtilt: 6°
- Mechanical specification
  - Dimensions HxWxD in mm: 1310 x 198 x 50
  - Weight in kg: 5.6

X 65° T2 1800MHz 1.3m

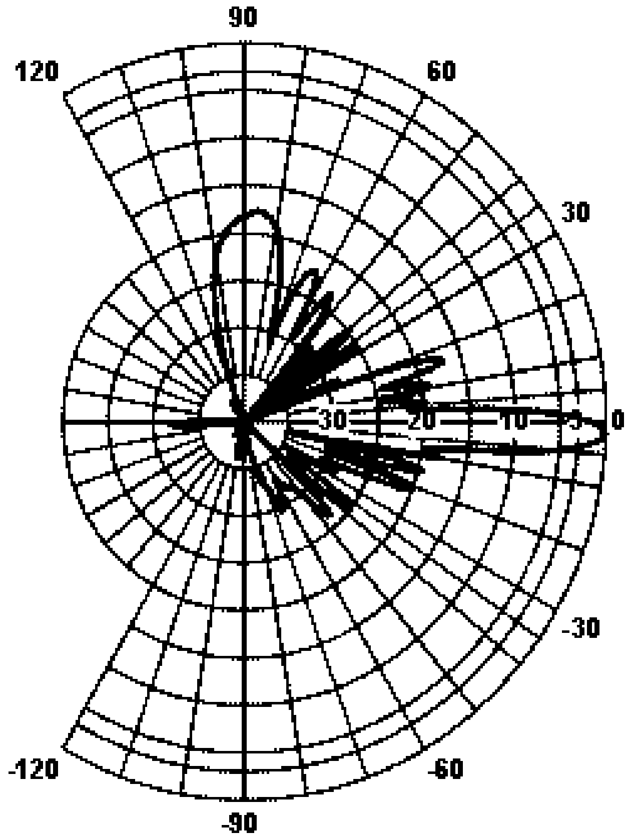


Vertical Pattern

- Dense urban area
- Antenna
  - RFS Panel Dual Polarized Antenna 1710-1880 MHz
  - APX186515-T2 Series
- Electrical specification
  - Gain in dBi: 17.5
  - Polarization: +/-45°
  - HBW: 65°
  - VBW: 7°
  - Electrical downtilt: 2°
- Mechanical specification
  - Dimensions HxWxD in mm: 1310 x 198 x 50
  - Weight in kg: 5.6



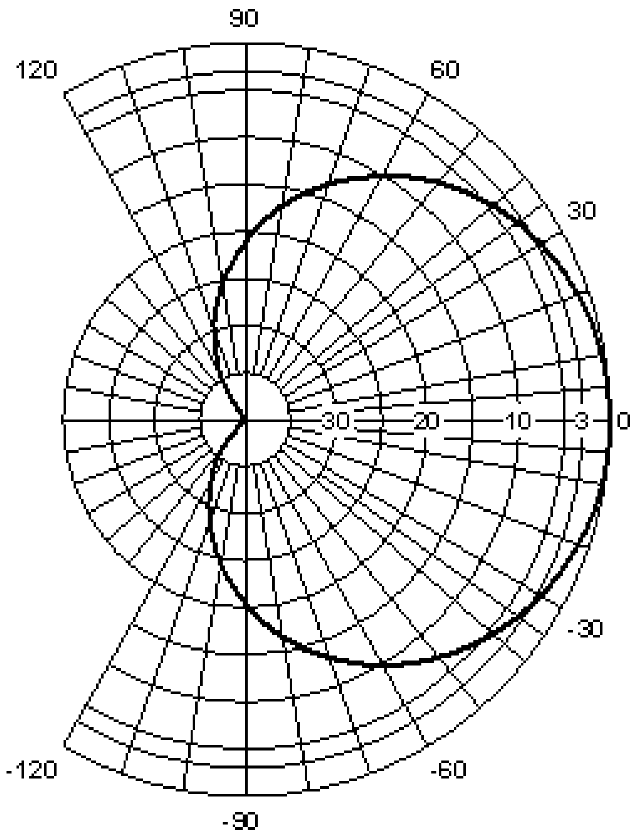
X 65° T2 1800MHz 1.9m



Vertical Pattern

- Highway
- Antenna
  - RFS Panel Dual Polarized Antenna 1710-1880 MHz
  - APX186516-T2 Series
- Electrical specification
  - Gain in dBi: 18.3
  - Polarization: +/-45°
  - HBW: 65°
  - VBW: 4.5°
  - Electrical downtilt: 2°
- Mechanical specification
  - Dimensions HxWxD in mm: 1855 x 198 x 50
  - Weight in kg: 8.6

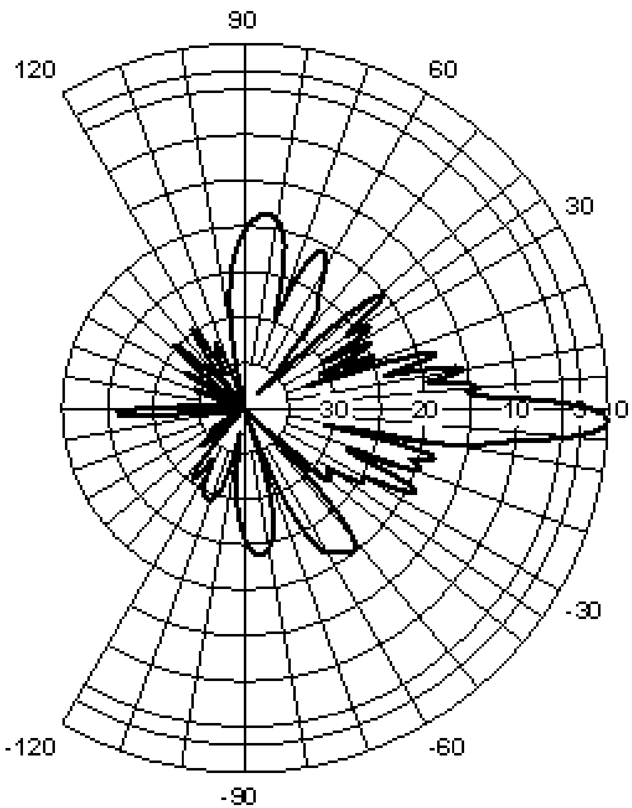
V 65° T2 1800MHz 1.3m



Horizontal Pattern

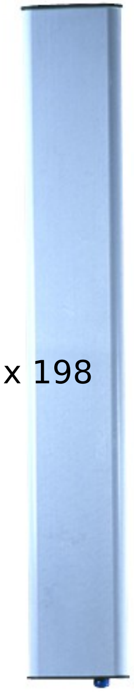
- Highway
- Antenna
  - RFS CELLite® Panel Vertical Polarized Antenna 1710-1880 MHz
  - AP186516-T2 Series
- Electrical specification
  - Gain in dBi: 17.0
  - Polarization: Vertical
  - HBW: 65°
  - VBW: 7.5°
  - Electrical downtilt: 2°
- Mechanical specification
  - Dimensions HxWxD in mm: 1310 x 198 x 50
  - Weight in kg: 4.7

V 90° T2 1800MHz 1.9m



Vertical Pattern

- Highway
- Antenna
  - RFS CELLite® Panel Vertical Polarized Antenna 1710-1880 MHz
  - AP189016-T2 Series
- Electrical specification
  - Gain in dBi: 17.0
  - Polarization: Vertical
  - HBW: 90°
  - VBW: 5.5°
  - Electrical downtilt: 2°
- Mechanical specification
  - Dimensions HxWxD in mm: 1855 x 198 x 50
  - Weight in kg: 6.0



7/8" CELLFLEX® Low-Loss Coaxial Cable

- Feeder Cable
  - 7/8" CELLFLEX® Low-Loss Foam-Dielectric Coaxial Cable
  - LCF78-50J Standard
  - LCF78-50JFN Flame Retardant
    - Installation temperature >-25°C
- Electrical specification 900MHz
  - Attenuation: 3.87dB/100m
  - Average power in kW: 2.65
- Electrical specification 1800MHz
  - Attenuation: 5.73dB/100m
  - Average power in kW: 1.79
- Mechanical specification
  - Cable weight kg\m: 0.53
  - Minimum bending radius
    - Single bend in mm: 120
    - Repeated bends in mm: 250
  - Bending moment in Nm: 13.0
  - Recommended clamp spacing: 0.8m

1-1/4" CELLFLEX® Coaxial Cable

- Feeder Cable
  - 1-1/4" CELLFLEX® Low-Loss Foam-Dielectric Coaxial Cable
  - LCF114-50J Standard
  - LCF114-50JFN Flame Retardant
    - Installation temperature >-25°C
- Electrical specification 900MHz
  - Attenuation: 3.06dB/100m
  - Average power in kW: 3.56
- Electrical specification 1800MHz
  - Attenuation: 4.61dB/100m
  - Average power in kW: 2.36

- Mechanical specification
  - Cable weight kg\m: 0.86
  - Minimum bending radius
    - Single bend in mm: 200
    - Repeated bends in mm: 380
  - Bending moment in Nm: 38.0
  - Recommended clamp spacing: 1.0m

1-5/8" CELLFLEX® Coaxial Cable

- Feeder Cable
  - 1-5/8" CELLFLEX® Low-Loss Foam-Dielectric Coaxial Cable
  - LCF158-50J Standard
  - LCF158-50JFN Flame Retardant
    - Installation temperature >-25°C
- Electrical specification 900MHz
  - Attenuation: 2.34dB/100m
  - Average power in kW: 4.97
- Electrical specification 1800MHz
  - Attenuation: 3.57dB/100m
  - Average power in kW: 3.26

- Mechanical specification
  - Cable weight kg\m: 1.26
  - Minimum bending radius
    - Single bend in mm: 200
    - Repeated bends in mm: 508
  - Bending moment in Nm: 46.0
  - Recommended clamp spacing: 1.2m

1/2" CELLFLEX® Jumper Cable

- CELLFLEX® LCF12-50J Jumpers
  - Feeder Cable
    - LCF12-50J CELLFLEX® Low-Loss Foam-Dielectric Coaxial Cable
  - Connectors
    - 7/16” DIN male/female
    - N male/female
    - Right angle
  - Molded version available in 1m, 2m, 3m
- Mechanical specification
  - Minimum bending radius
    - Repeated bends in mm: 125
- Electrical specification 900MHz
  - Attenuation: 0.068db/m
  - Total losses with connectors are 0.108dB, 0.176dB and 0.244dB
- Electrical specification 1800MHz
  - Attenuation: 0.099dB/m
  - Total losses with connectors are 0.139dB, 0.238dB and 0.337dB

Coverage Planning

Radio Propagation and Path Loss Prediction

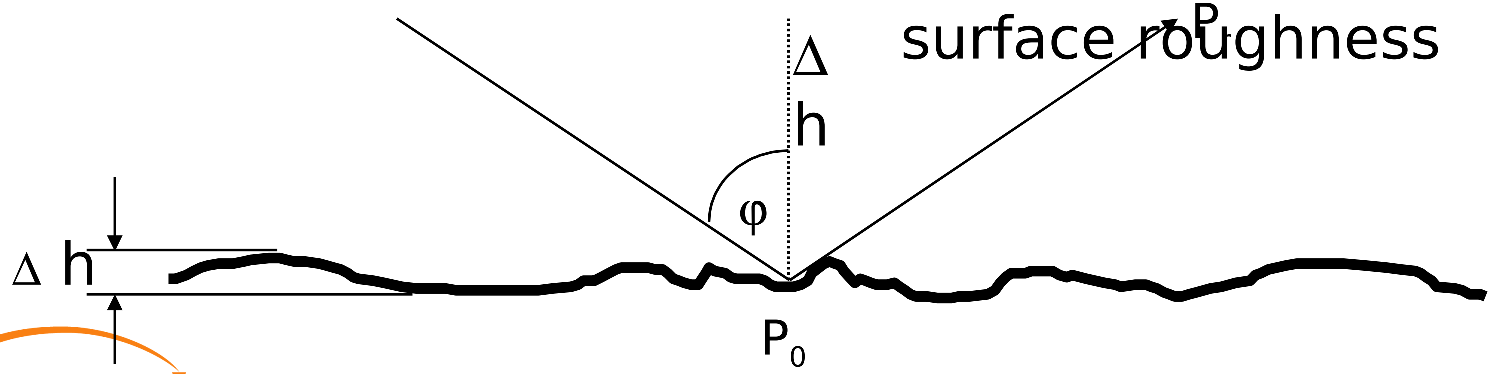
Propagation effects

- Free space loss
- Fresnel ellipsoid
- Reflection, Refraction, Scattering
  - in the atmosphere
  - at a boundary to another material
- Diffraction
  - at small obstacles
  - over round earth
- Attenuation
  - Rain attenuation
  - Gas absorption
- Fading

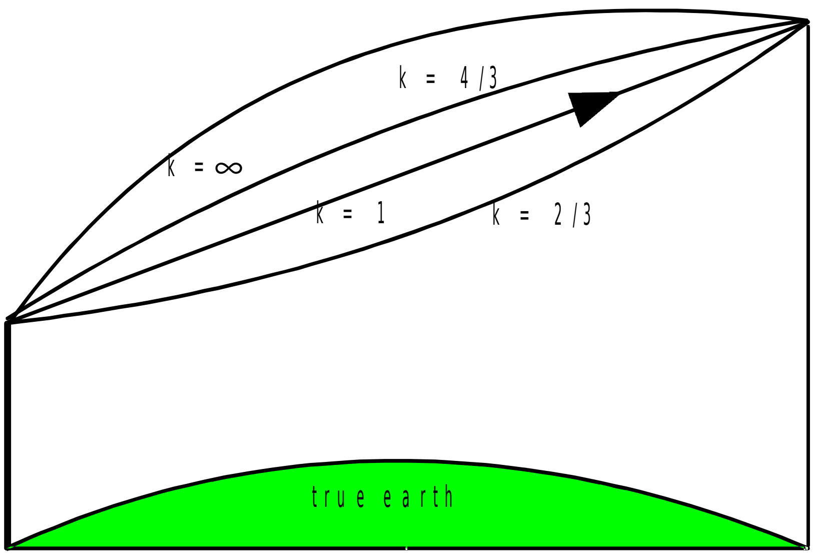
Reflection

- $P_r = R_{h/v} \cdot P_0$
- $R_{h/v} = f(\varphi, \varepsilon, \sigma, \Delta h)$

R_h	horizontal reflection factor
R_v	vertical reflection factor
φ	angle of incidence
ε	permittivity
σ	conductivity
Δh	surface roughness

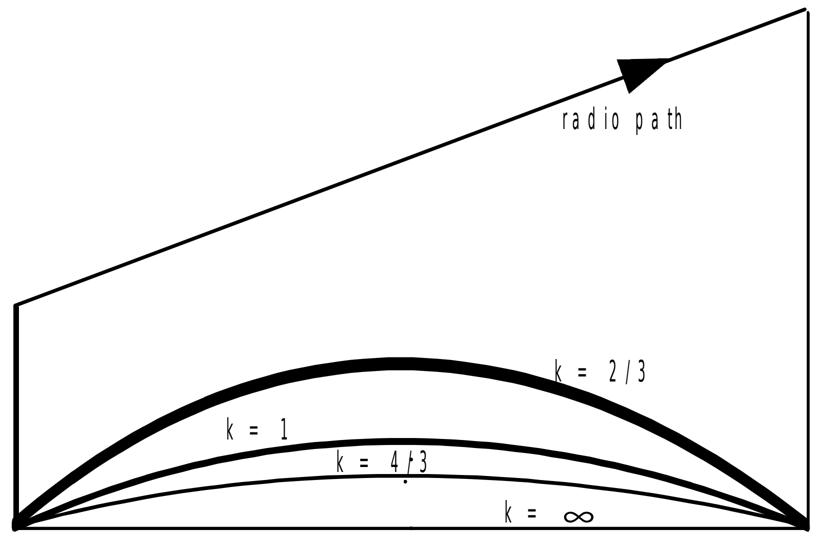


Refraction



Ray paths with different k over true

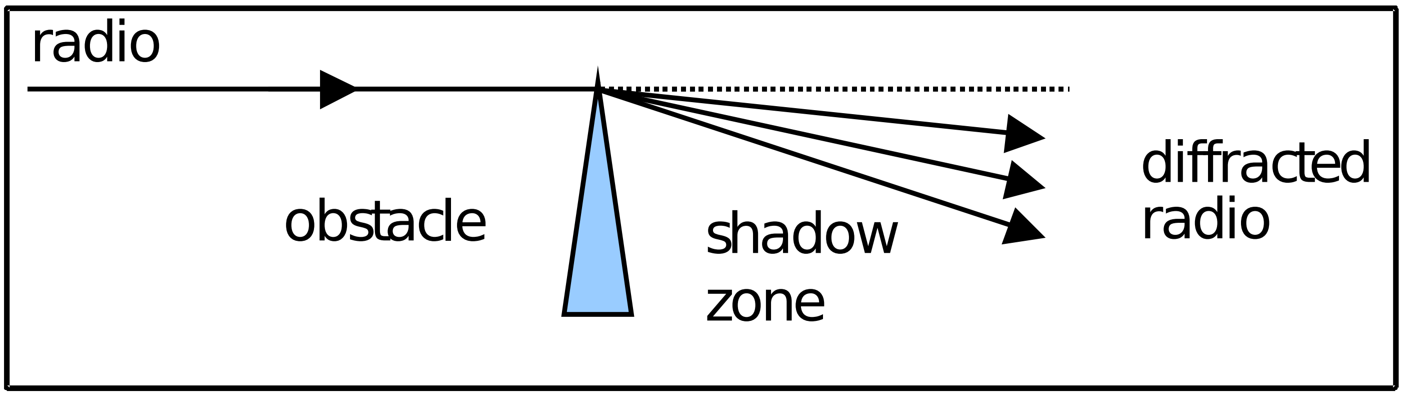
- Considered via an effective earth radius factor k



Radio path plotted as a straight line by changing the earth's radius

Diffraction

- Occurs at objects which sizes are in the order of the wavelength λ
- Radio waves are 'bent' or 'curved' around objects
  - Bending angle increases if object thickness is smaller compared to λ
  - Influence of the object causes an attenuation: diffraction loss



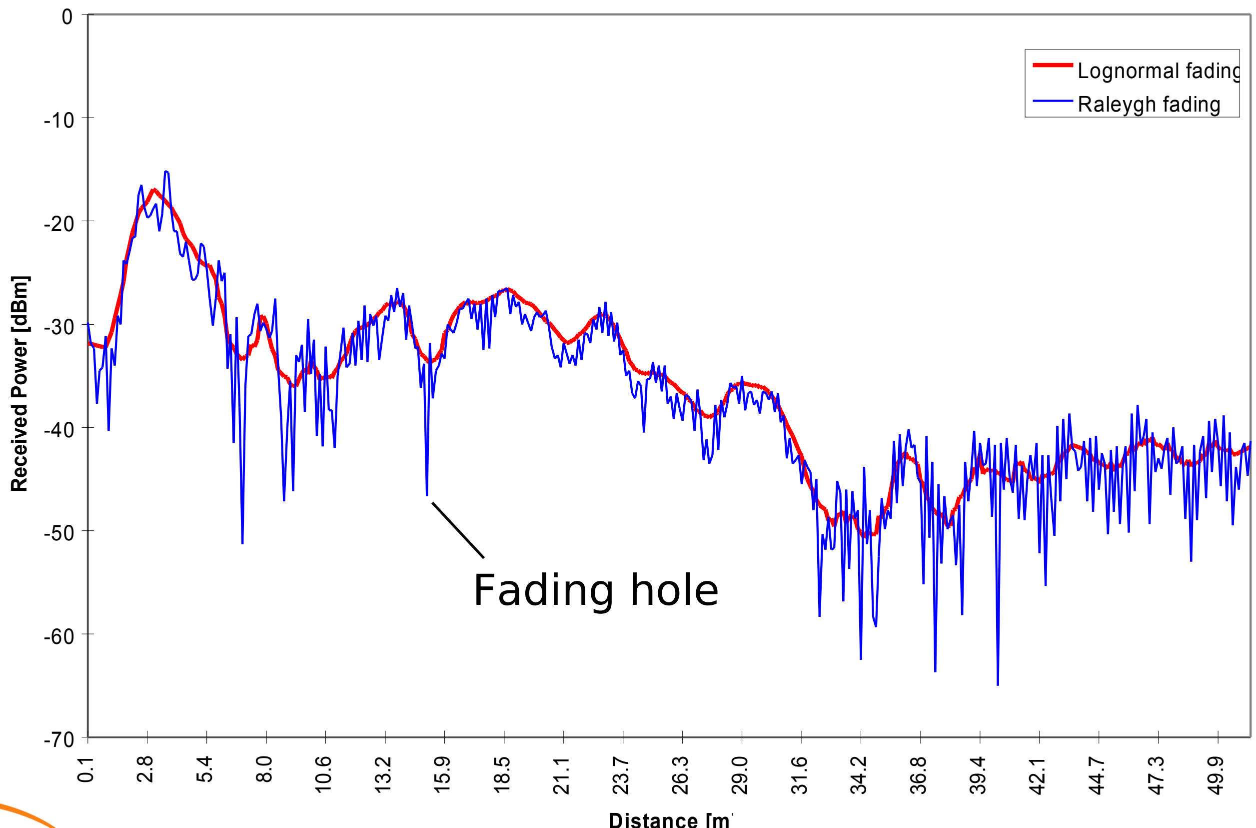
Fading

- Caused by delay spread of original signal
  - Multi path propagation
  - Time-dependent variations in heterogeneity of environment
  - Movement of receiver
- Short-term fading, fast fading
  - This fading is characterised by phase summation and cancellation of signal components, which travel on multiple paths. The variation is in the order of the considered wavelength.
  - Their statistical behaviour is described by the Rayleigh distribution (for non-LOS signals) and the Rice distribution (for LOS signals), respectively.
  - In GSM, it is already considered by the sensitivity values, which take the error correction capability into account.

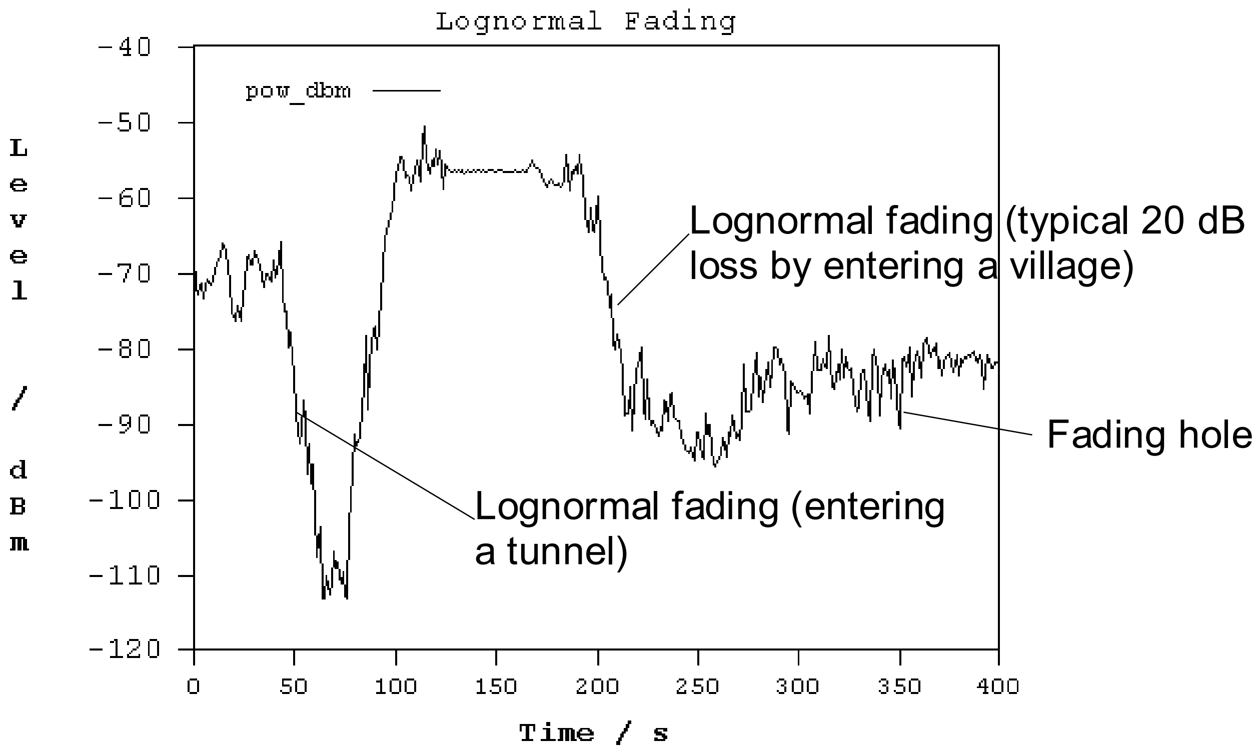
Fading types

- Mid-term fading, lognormal fading
  - Mid-term field strength variations caused by objects in the size of 10...100m (cars, trees, buildings). These variations are lognormal distributed.
- Long-term fading, slow fading
  - Long-term variations caused by large objects like large buildings, forests, hills, earth curvature (> 100m). Like the mid-term field strength variations, these variations are lognormal distributed.

Signal Variation due to Fading



Lognormal Fading



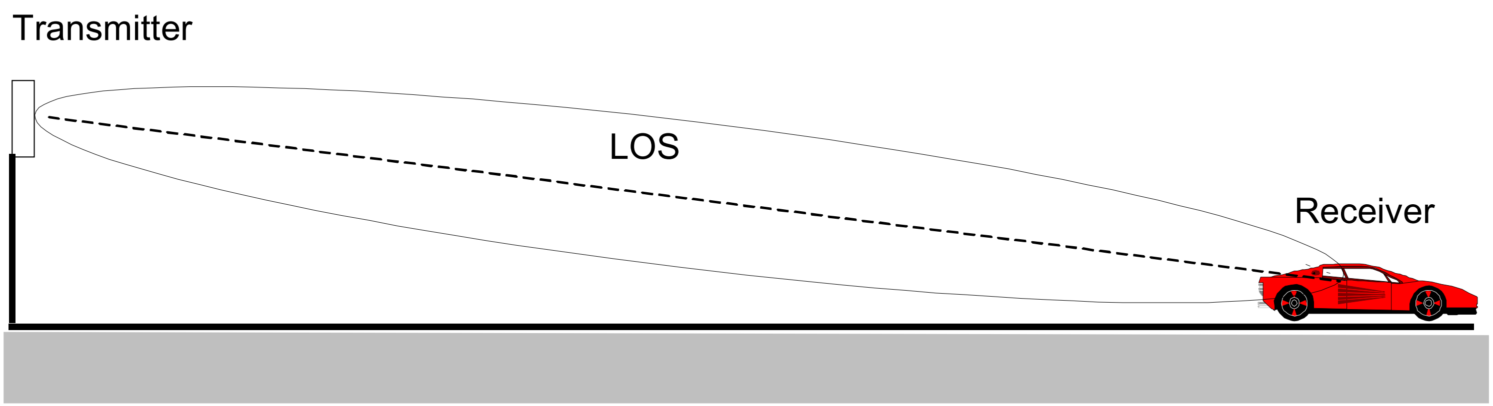
Free Space Loss

- The simplest form of wave propagation is the free-space propagation
- The according path loss can be calculated with the following formula
- Path Loss in Free Space Propagation
  - L free space loss
  - d distance between transmitter and receiver antenna
  - f operating frequency

$$L_{freespace} = 32.4 + 20 \cdot \log \frac{d}{km} + 20 \cdot \log \frac{f}{MHz}$$

Fresnel Ellipsoid

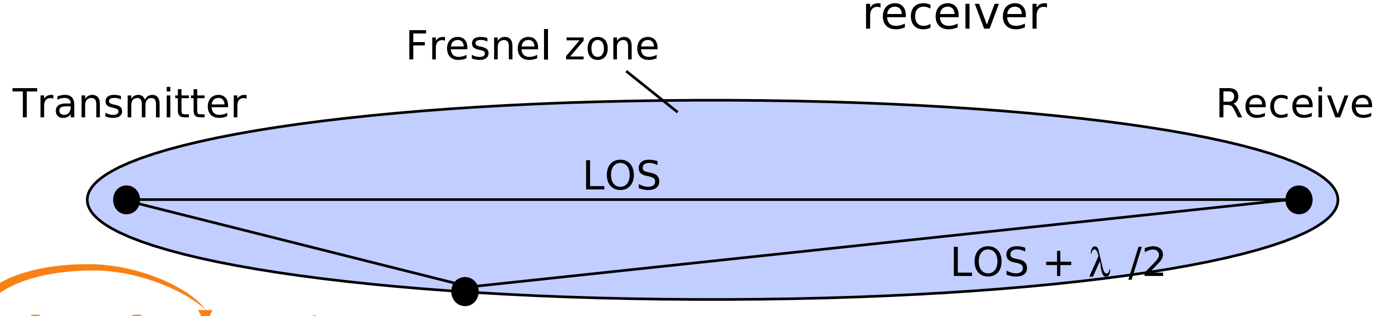
- The free space loss formula can only be applied if the direct line-of-sight (LOS) between transmitter and receiver is not obstructed
- This is the case, if a specific region around the LOS is cleared from any obstacles
- The region is called Fresnel ellipsoid



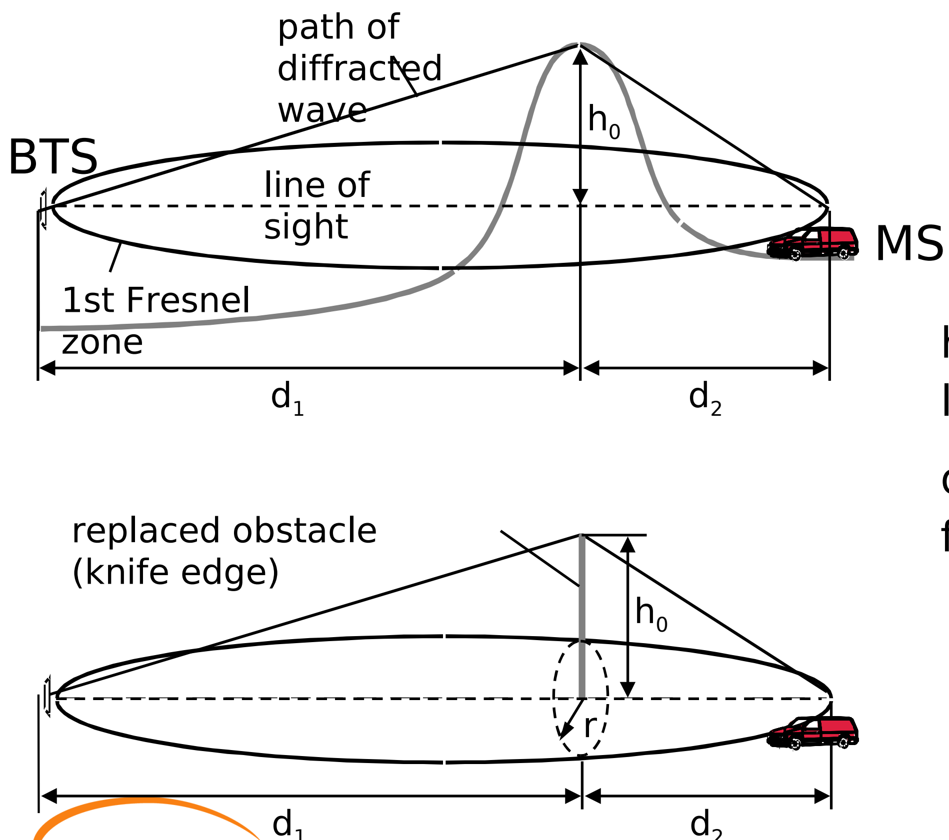
Fresnel Ellipsoid

$$r = \sqrt{\frac{d_1 \cdot d_2 \cdot \lambda}{d_1 + d_2}}$$

- The Fresnel ellipsoid is the set of all points around the LOS where the total length of the connecting lines to the transmitter and the receiver is longer than the LOS length by exactly half a wavelength
- It can be shown that this region is carrying the main power flow from transmitter to receiver



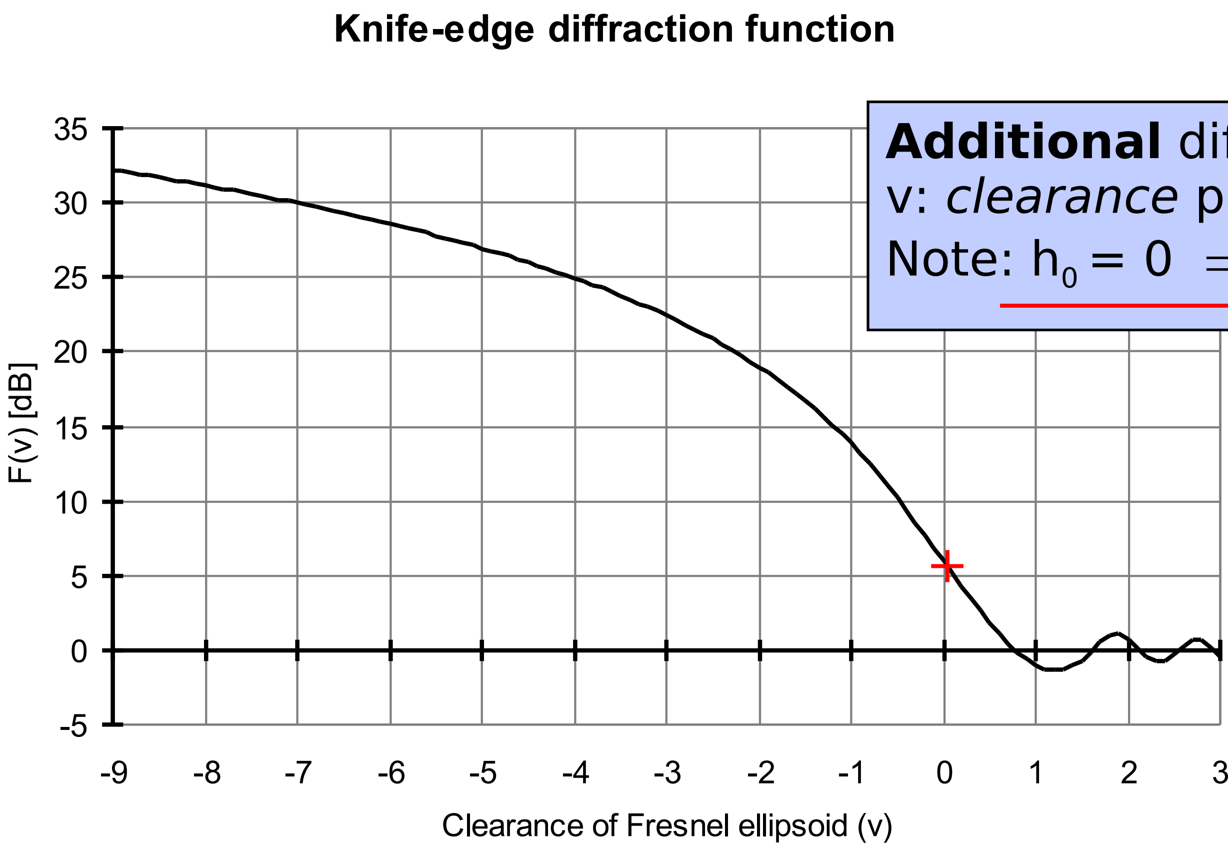
Knife Edge Diffraction



h_0 = height of obstacle over line of sight

d_1, d_2 = distance of obstacle from BTS and MS

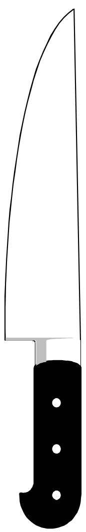
Knife Edge Diffraction Function



Additional diffraction loss F(v)

v: *clearance* parameter, $v = -h_0/r$

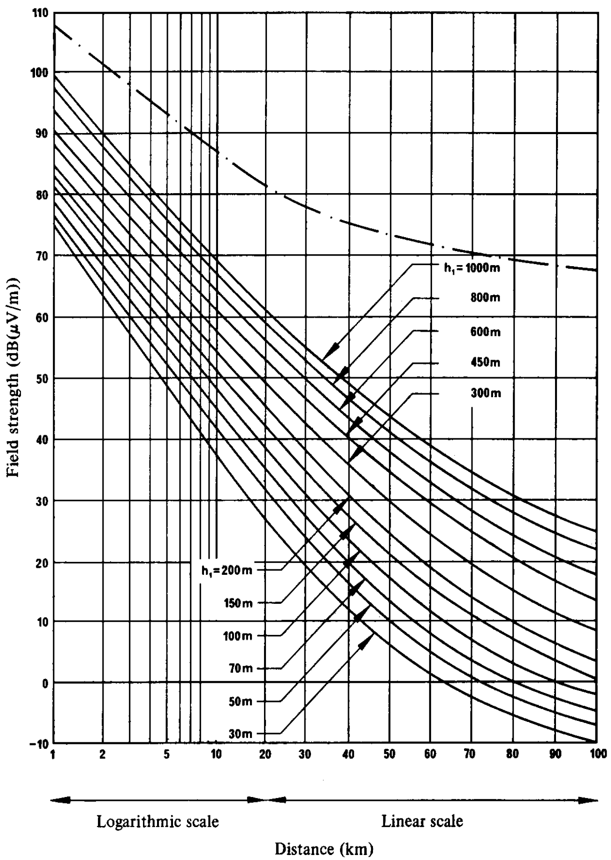
Note: $h_0 = 0 \Rightarrow v = 0 \Rightarrow L = 6$ dB



Computers: the "Final Solution" for Wave Propagation Calculations?

- Exact field solution requires too much computer resources!
  - Too much details required for input
  - Exact calculation too time-consuming
  - ➨ Field strength *prediction* rather than *calculation*
- Requirements for field strength prediction models
  - Reasonable amount of input data
  - ***Fast*** (it is very important to see the impact of changes in the network layout immediately)
  - ***Accurate*** (results influence the hardware cost directly)
  - ➨ Tradeoff required (accurate results within a suitable time)
  - ➨ Parameter tuning according to real measurements should be possible

CCIR Recommendation



- The CCIR Recommendations provide various propagation curves
  - Based on Okumura (1968)
  - Example (CCIR Report 567-3):

    Median field strength in urban area

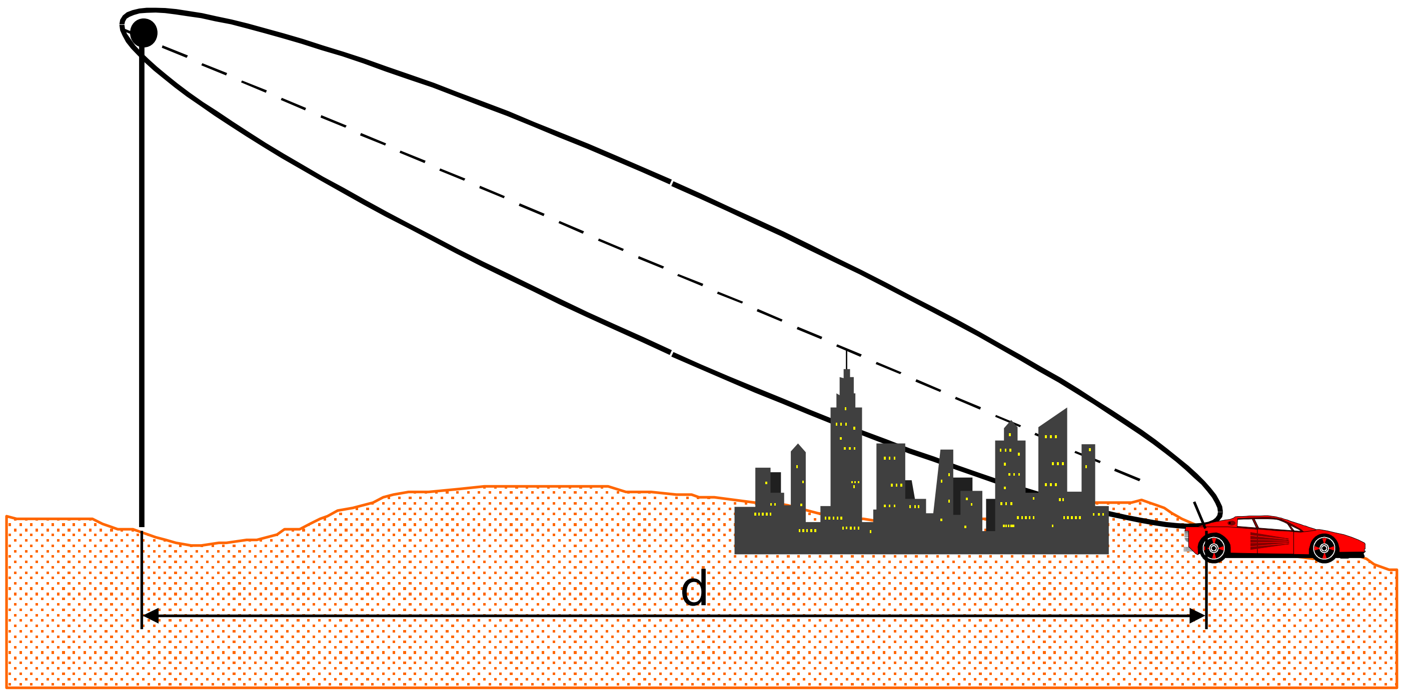
    Frequency = 900 MHz

    h_{MS} = 1.5 m

    Dashed line: free space
- How to use this experience in field strength prediction models?
  - Model which fits the curves in certain ranges → ***Hata's model***

    was modified later by the European Cooperation in Science and Technology (COST): COST 231 Hata/Okumura

Mobile Radio Propagation



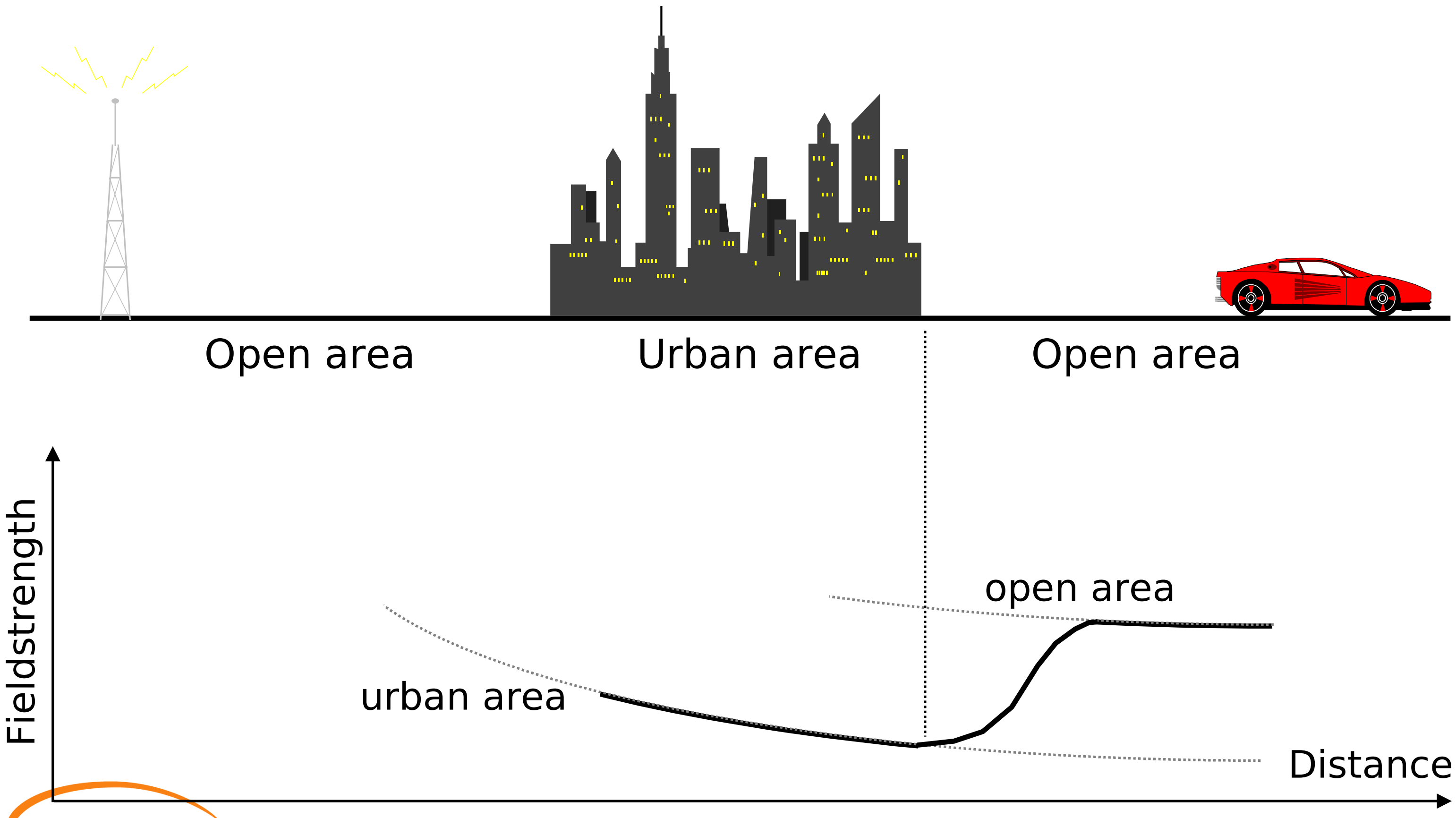
Free-space propagation (Fresnel zone not obstructed) $\rightarrow$ L ~ d^2

Fresnel zone heavily obstructed **near** the mobile station $\rightarrow$ L ~ d^{37}

Terrain Modeling

- Topography
  - Effective antenna height
  - Knife edge diffraction
    - single obstacles
    - multiple obstacles
- Surface shape/Morpho-structure
  - Correction factors for Hata-Okumura formula

Effect of Morphostructure on Propagation Loss



Hata-Okumura for GSM 900

- Path loss (Lu) is calculated (in dB) as follows:

$$Lu = A_1 + A_2 \log(f) + A_3 \log(h_{BTS}) + (B1 + B2\log(h_{BTS})) \log d$$

- The parameters A1, A2, A3, B1 and B2 can be user-defined. Default values are proposed in the table below:

Parameters	Okumura-Hata $f \leq 1500$ MHz	Cost-Hata F>1500 MHz
A_1	69.55	46.30
A_2	26.16	33.90
A_3	-13.82	-13.82
B_1	44.90	44.90
B_2	-6.55	-6.55

CORRECTIONS TO THE HATA FORMULA

- As described above, the Hata formula is valid for urban environment and a receiver antenna height of 1.5m. For other environments and mobile antenna heights, corrective formulas must be applied.

$L_{model1} = Lu - a(h_{MS})$ for large city and urban environments

$L_{model1} = Lu - a(h_{MS}) - 2\log^2(f/28) - 5.4$ for suburban area

$L_{model1} = Lu - a(h_{MS}) - 4.78\log^2(f) + 18.33\log(f) - 40.94$ for rural area

$a(h_{MS})$ is a correction factor to take into account a receiver antenna height different from 1.5m.

Environments	$A(h_{MS})$
Rural/Small city	$(1.1\log(f) - 0.7)h_{MS} - (1.56\log(f) - 0.8)$
Large city	$3.2\log^2(11.75h_{MS}) - 4.97$

te: When receiver antenna height equals 1.5m, $a(h_{MS})$ is close to 0 dB regardless of freque

COST 231 Hata-Okumura for GSM 900

$$Loss_{Hata} = 69.55 + 26.16 \log (f) - 13.82 \log (h_{BTS}) - a(h_{MS}) + (44.9 - 6.55 \log (h_{BTS})) \log (d) - L_{morpho}$$

$$a(h_{MS}) = (1.1 \log (f) - 0.7)\, h_{MS} - (1.56 \log (f) - 0.8)$$

- Formula valid for frequency range: 150...1000 MHz

L_{morpho} [dB]	Morpho/surface shape-Correction factor 0 dB: 'Skyscrapers'->27 dB: 'open area'
f [MHz]	Frequency (150 - 1000 MHz)
h_{BTS} [m]	Height of BTS (30 - 200 m)
h_{MS} [m]	Height of Mobile (1 - 10m)
d [km]	Distance between BTS and MS (1 - 20 km)
	Power law exponent shown colored

COST 231 Hata-Okumura GSM 1800

$$Loss_{Hata} = 46.3 + 33.9 \log(f) - 13.82 \log(h_{BTS}) - a(h_{MS}) + (44.9 - 6.55 \log(h_{BTS})) \log(d) - L_{morpho}$$

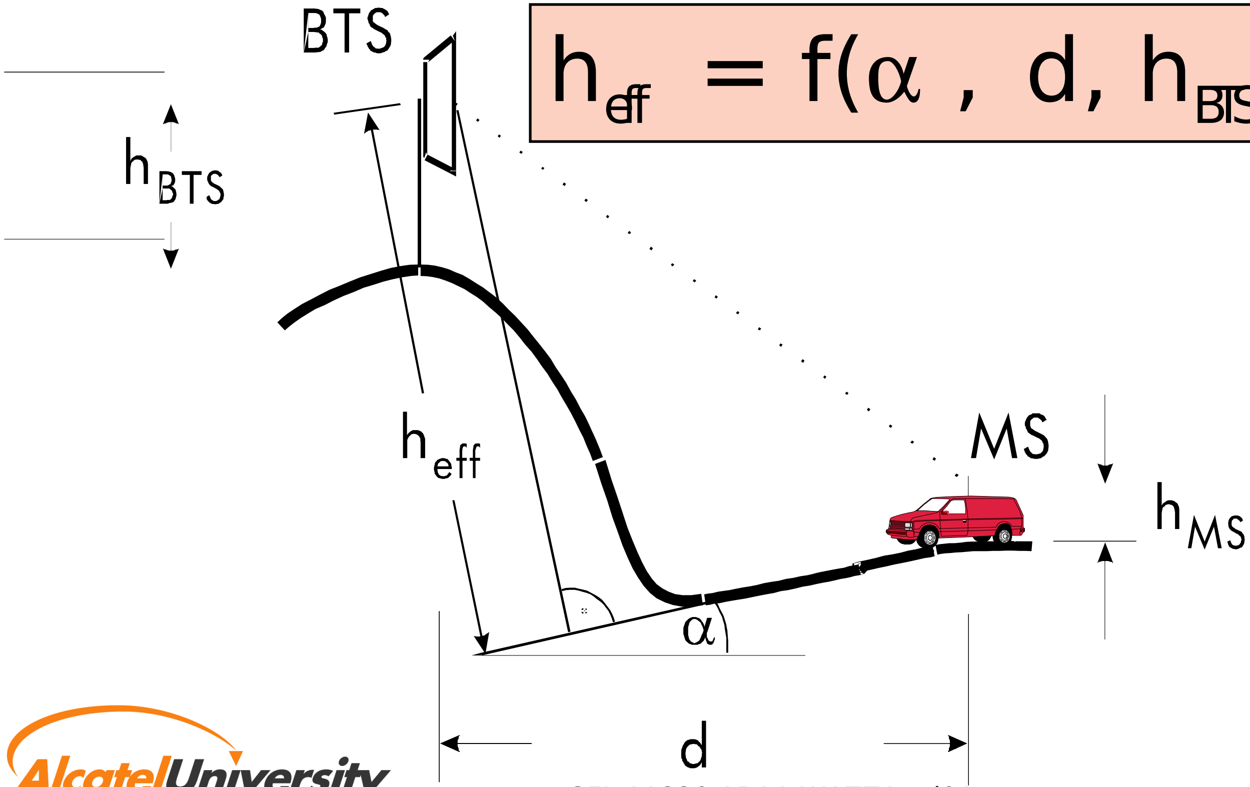
$$a(h_{MS}) = (1.1 \log(f) - 0.7)\, h_{MS} - (1.56 \log(f) - 0.8)$$

- Formula is valid for frequency range: 1500...2000 MHz
- Hata's model is extended for GSM 1800
  - Modification of original formula to the new frequency range
- For cells with small ranges the COST 231 Walfish-Ikegami model is more precisely

Alcatel Propagation Model

- Using of effective antenna height in the Hata-Okumura formula:

$$h_{eff} = f(\alpha\ ,\ d, h_{BTS}\ ,\ h_{MS}\ )$$



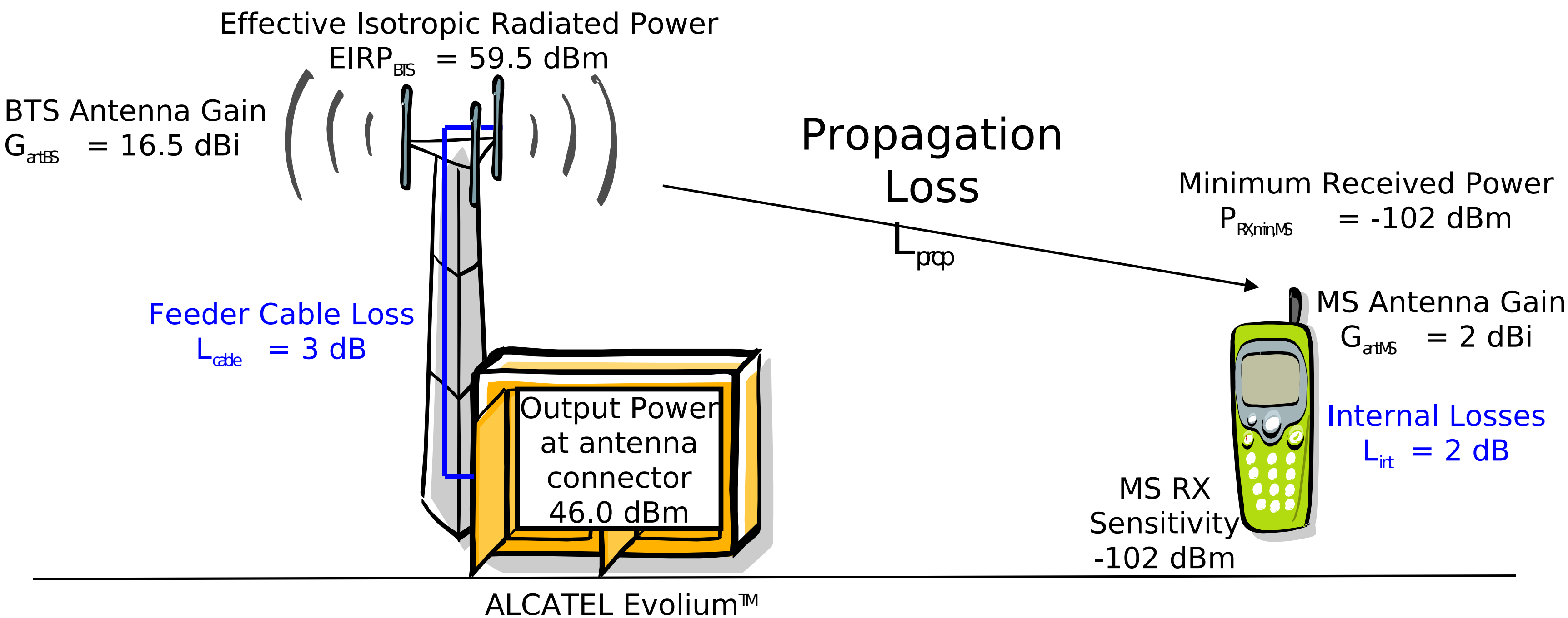
Exercise ‘Path Loss’

- Scenario
  - Height BTS = 40m
  - Height MS = 1.5m
  - D (BTS to MS) = 2000m
- 1. Calculate free space loss for
  - A.) f=900MHz
  - B.) f=1800MHz
- 2. Calculate the path loss for f = 900MHz
  - A.) Morpho class ‘skyscraper’
  - B.) Morpho class ‘open area’
- 3. Calculate the path loss for f = 1800MHz
  - A.) Morpho class ‘skyscraper’
  - B.) Morpho class ‘open area’

Coverage Planning

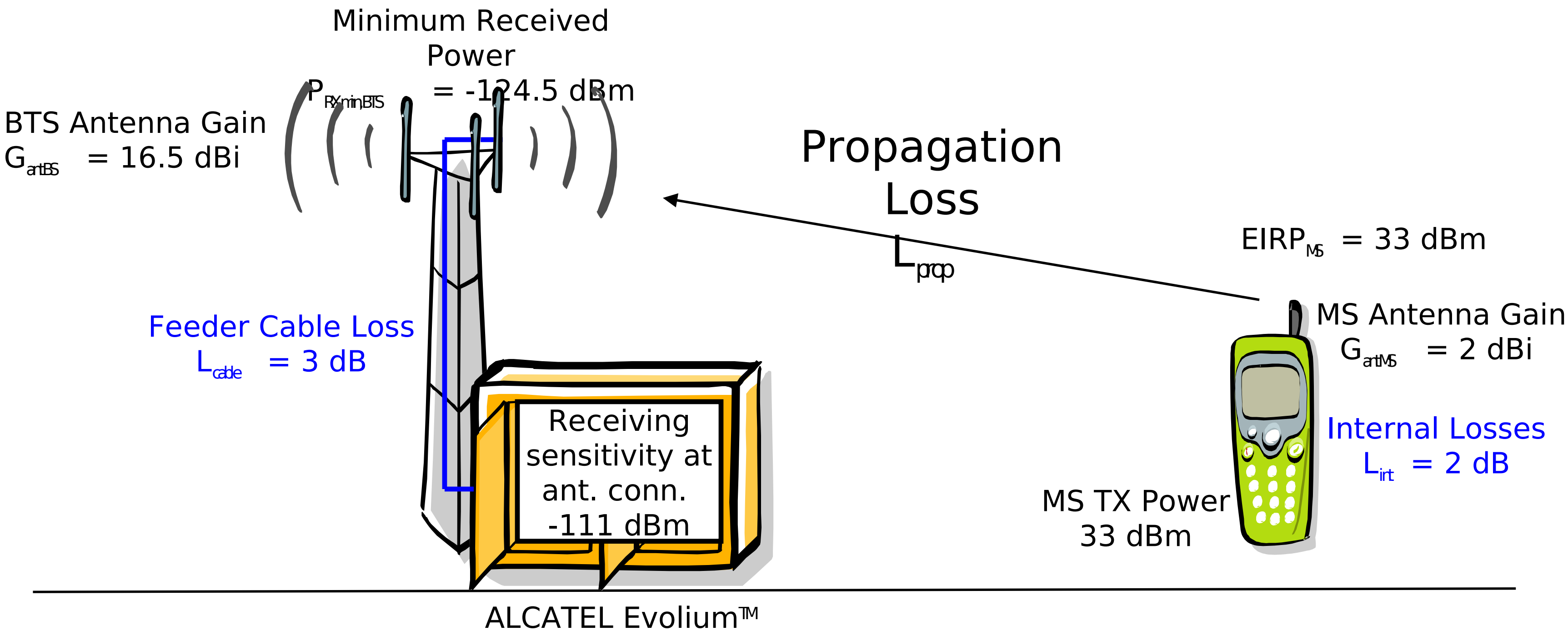
Link Budget Calculation
Coverage Probability
Cell Range

Maximum Propagation Loss (Downlink)



Maximum allowed downlink propagation loss: $L_{prop,max} = EIRP_{BTS} - P_{RX,min,MS} = 161.5$ dB

Maximum Propagation Loss (Uplink)



Max. allowed uplink propagation loss: $L_{prop,max} = EIRP_{MS} - P_{RX,min,BTS} = 157.5$ dB

With antenna diversity gain of 3dB: $L_{prop,max,AD} = EIRP_{MS} - P_{RX,min,BTS} + G_{AD} = 160.5$ dB

With TMA compensating cable loss: $L_{prop,max,AD,TMA} = EIRP_{MS} - P_{RX,min,BTS} + G_{AD} + G_{TMA} = 163.5$ dB

Link Budget (1)

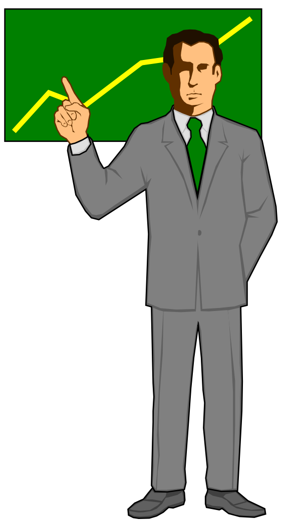
GSM900 Macro Evolium Evolution A9100 BTS

	MS to BS		*BS to MS*	
TX	**Uplink**		**Downlink**	
Internal Power	33,0	dBm	41,0	dBm
Comb+Filter Loss, Tol.	0,0	dB	3,0	dB
Output Power	33,0	dBm	38,0	dBm
Cable,Connectors Loss	2,0	dB	3,0	dB
Body/Indoor Loss	4,0	dB		
Antenna Gain	2,0	dBi	11,0	dBi
EIRP	29,0	dBm	46,0	dBm

RX	**Uplink**		**Downlink**	
Rec. Sensitivity	-104,0	dBm	-102,0	dBm
Body/Indoor Loss			4,0	dB
Cables, Connectors Loss	3,0	dB	2,0	dB
Antenna Gain	11,0	dBi	2,0	dBi
Diversity Gain	3,0	dB		
Interferer Margin	3,0	dB	3,0	dB
Lognormal Margin 50%→ 90,9%	8,0	dB	8,0	dB
Degradation (no FH)	0,0	dB	0,0	dB
Antenna Pre-Ampl.	0,0	dB		
Isotr. Rec. Power:	-104,0	dBm	-87,0	dBm

Max. Pathloss	133,0	dB	133,0	dB

GSM1800 Link Budget



LB_1800_1

GSM 1800, Dense urban, 95 % coverage probability

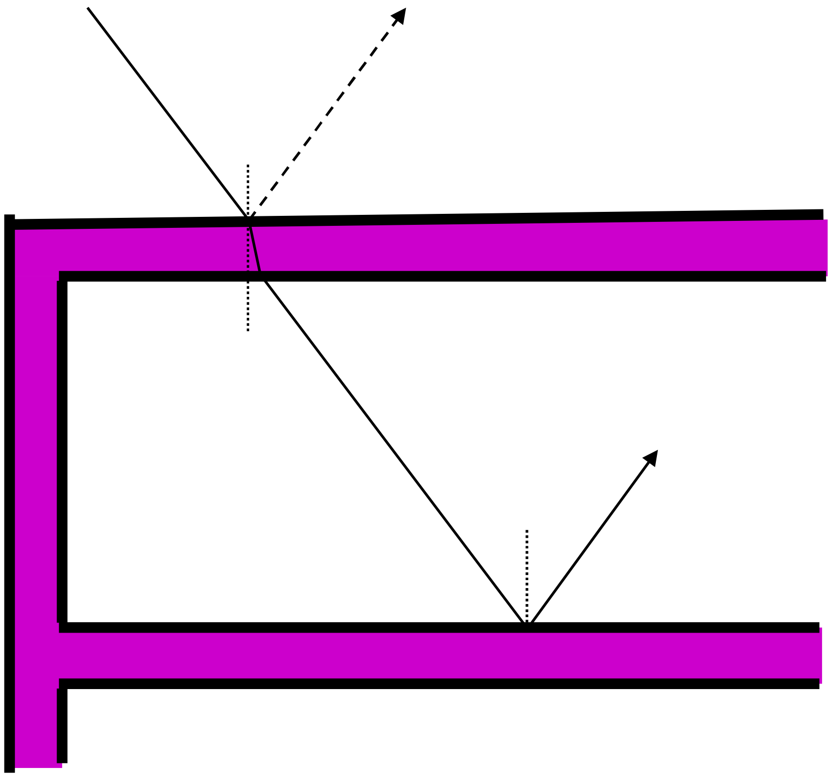
	Uplink	Downlink	
RX Parameter			
RX Sensitivity	-111.0	-102.0	dBm
Antenna Diversity Gain	6.0		dB
Feeder Loss (26m LCF 7/8")	1.4	0.0	dB
Jumper and Connector Loss	0.7		dB
TMA Contribution	0.0		dB
RX Antenna Gain	17.5	0.0	dBi
Loss of External Devices	0.0		dB
Isotropic Power	-132.4	-102.0	dBm
TX Parameter			
TX Output Power	30.0	44.4	dBm
Feeder Loss (26m LCF 7/8")	0.0	1.4	dB
Jumper and Connector Loss		0.7	dB
TMA Insertion Loss		0.0	dB
TX Antenna Gain	0.0	17.5	dB
Slant Polarization Loss		0.0	dB
Loss of External Devices		0.0	dB
EIRP	30.0	59.8	dBm
Margins			
Slow Fading Margin (sigma=7.6)	8.1	8.1	dB
Interference Margin	3.0	3.0	dB
Body Loss	3.0	3.0	dB
Penetration Margin	16.0	16.0	dB
Other Margins	10.0	10.0	dB
Total Margins	40.1	40.1	dB
Results			
Path Loss per Link	122.2	121.6	dB
Maximum Allowable Pathloss	121.6		dB
Design Level	-71.9		dBm
Acceptance Level	-80.0		dBm
Propagation			
BTS Antenna Height	30		m
MS Antenna Height	1.5		m
Area Coverage Probability	95		%
Propagation model	Hata-Okumura		
Cell Range	0.47		km

Additional Losses Overview

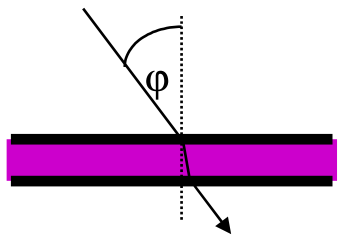
Loss type	Reason	Value
Indoor loss	Electrical properties of wall material	20dB (3...30dB)
Incar loss	Brass influencing radio waves	7dB (4...10dB)
Body loss	Absorption of radio waves by the human body	3dB (0...8dB)
Interferer margin	Both signal-to-noise ratio and C/I lo	3 dB
Lognormal margin	Receiving the minimum field strength with a higher probability	According to probability

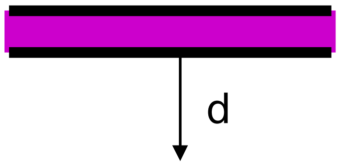
Indoor propagation aspects

- Penetration Loss
- Multiple Refraction
- Multiple Reflection
- Exact modeling of indoor environment not possible
- Practical solution: empirical model!

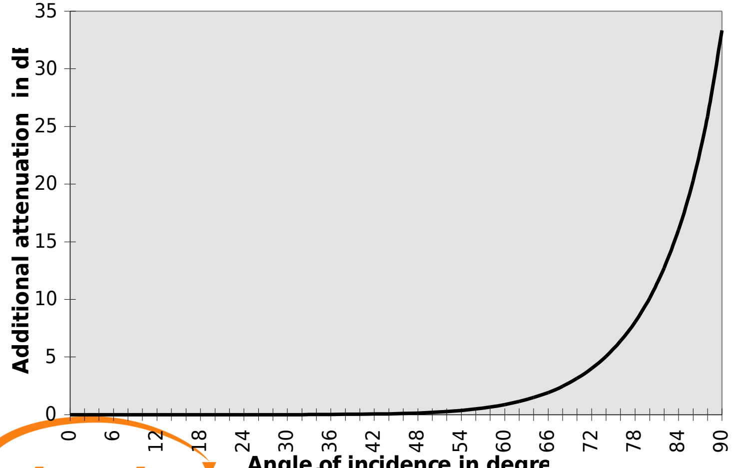


Indoor propagation: empirical model

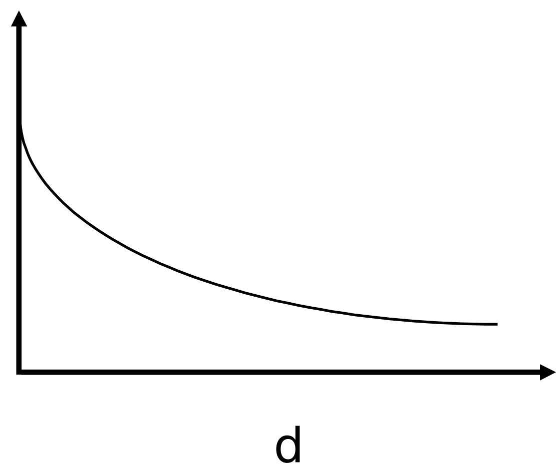




Additional Loss in [dB] relative to loss at vertical incidence

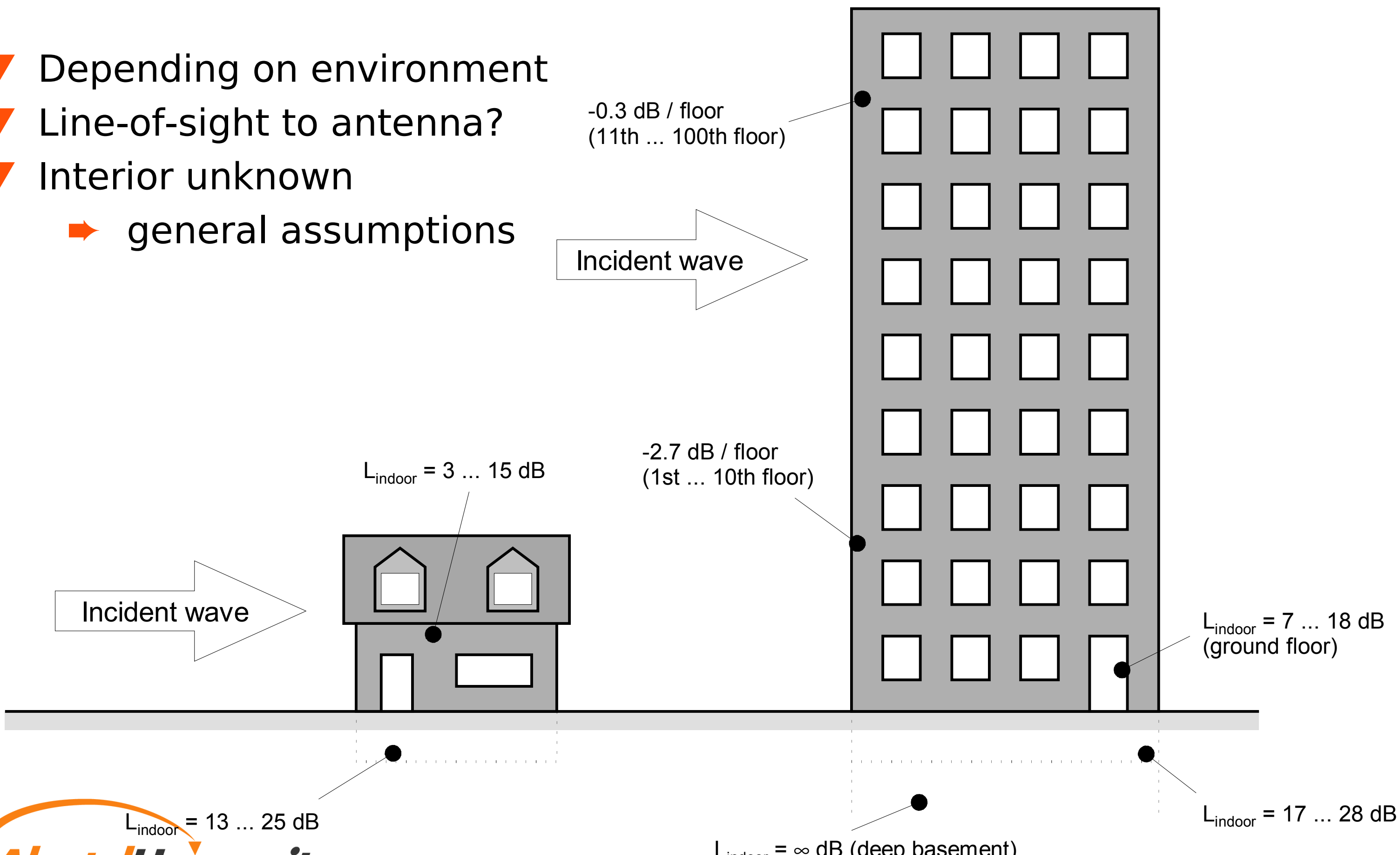


Power relative to power at d=0



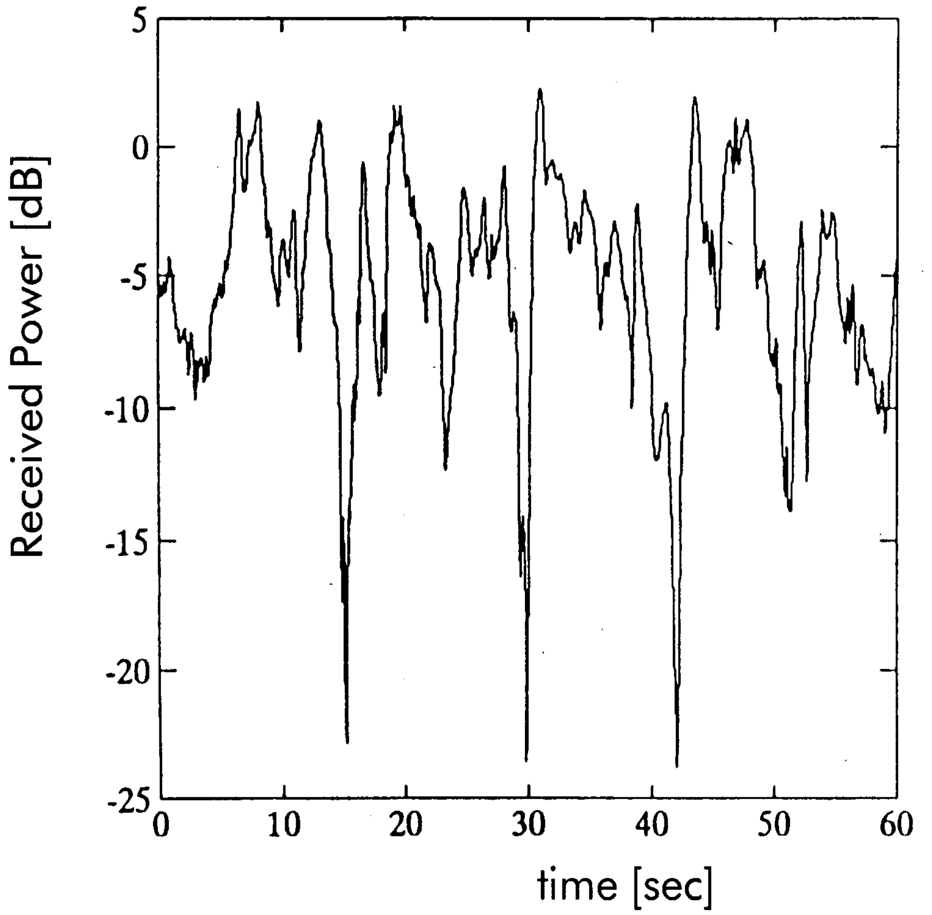
Indoor Penetration

- Depending on environment
- Line-of-sight to antenna?
- Interior unknown
  - ➨ general assumptions

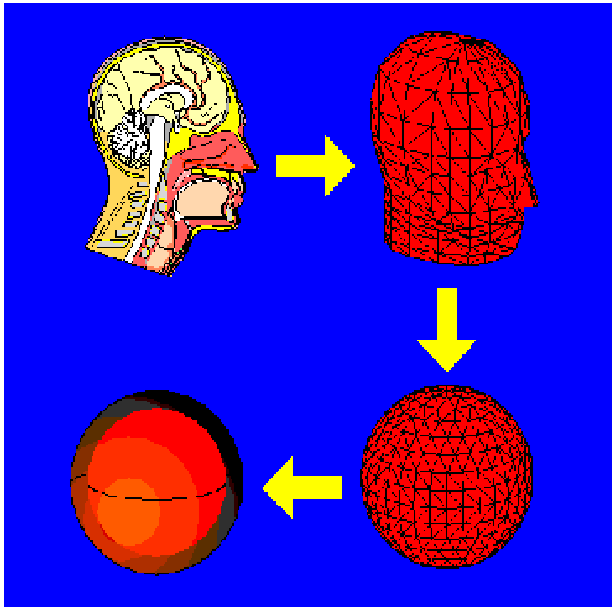


Body Loss (1)

Measured attenuation versus time for a test person walking around in an anechoic chamber

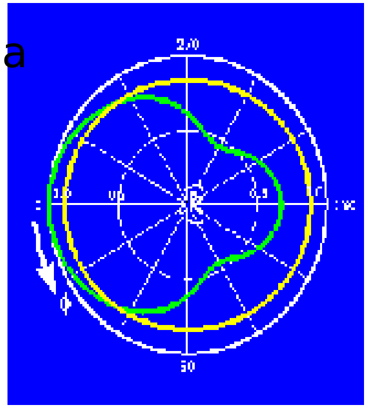


Body Loss (2)

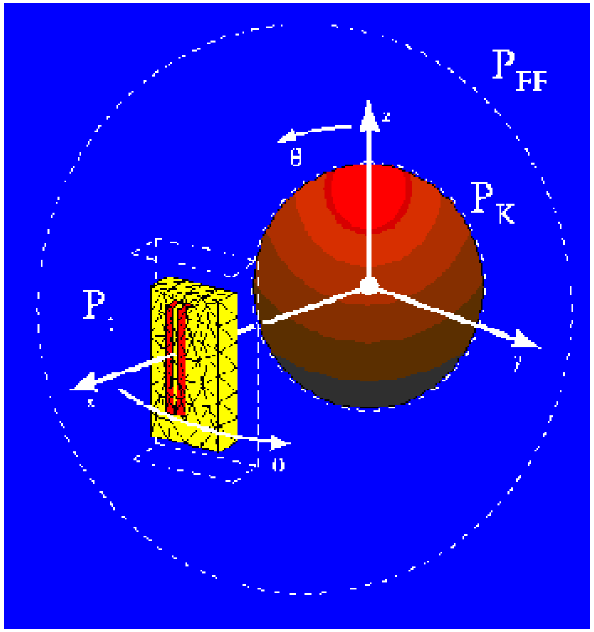


Head modeled as sphere

Near field of MS antenna
- without head
- with head

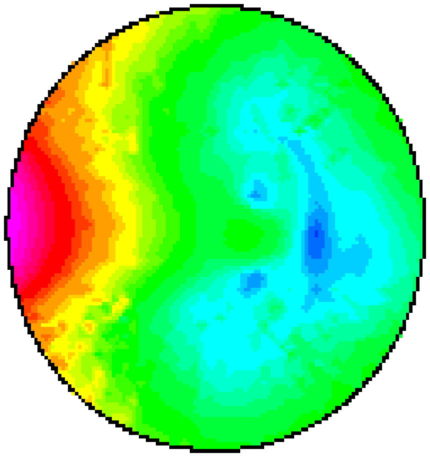


Calculation model



Body Loss (3)

Test equipment for indirect field strength measurements



Indirect measured field strength penetrated into the head (horizontal cut)

Interference Margin

- In GSM, the defined minimum carrier-to-interferer ration (C/I) threshold of 9 dB is only valid if the received server signal is not too weak.
- In the case that e.g. the defined system threshold for the BTS of -111dBm is approached, a higher value of C/I is required in order to maintain the speech quality.
- According to GSM, this is done by taking into account a correction of 3 dB.

Degradation (no FH)

- GSM uses a frame correction system, which works with checksum coding and convolutional codes.
- Under defined conditions, this frame correction works successfully and copes even with fast fading types as Rayleigh or Rician fading.
- For lower mobile speed or stationary use, the fading has a bigger influence on the bit error rate and hence the speech quality is reduced.
- In such a case, a degradation margin must be applied. The margin depends on the mobile speed and the usage of slow frequency hopping, which can improve the situation for slow mobiles again.

Diversity Gain

- This designates the optional usage of a second receiver antenna.
- The second antenna is placed in a way, which provides some decorrelation of the received signals.
- In a suitable combiner, the signals are processed in order to achieve a sum signal with a smaller fading variation range.
- Depending on the receiver type, the signal correlation, and the antenna orientation, a diversity gain from 2…6 dB is possible.

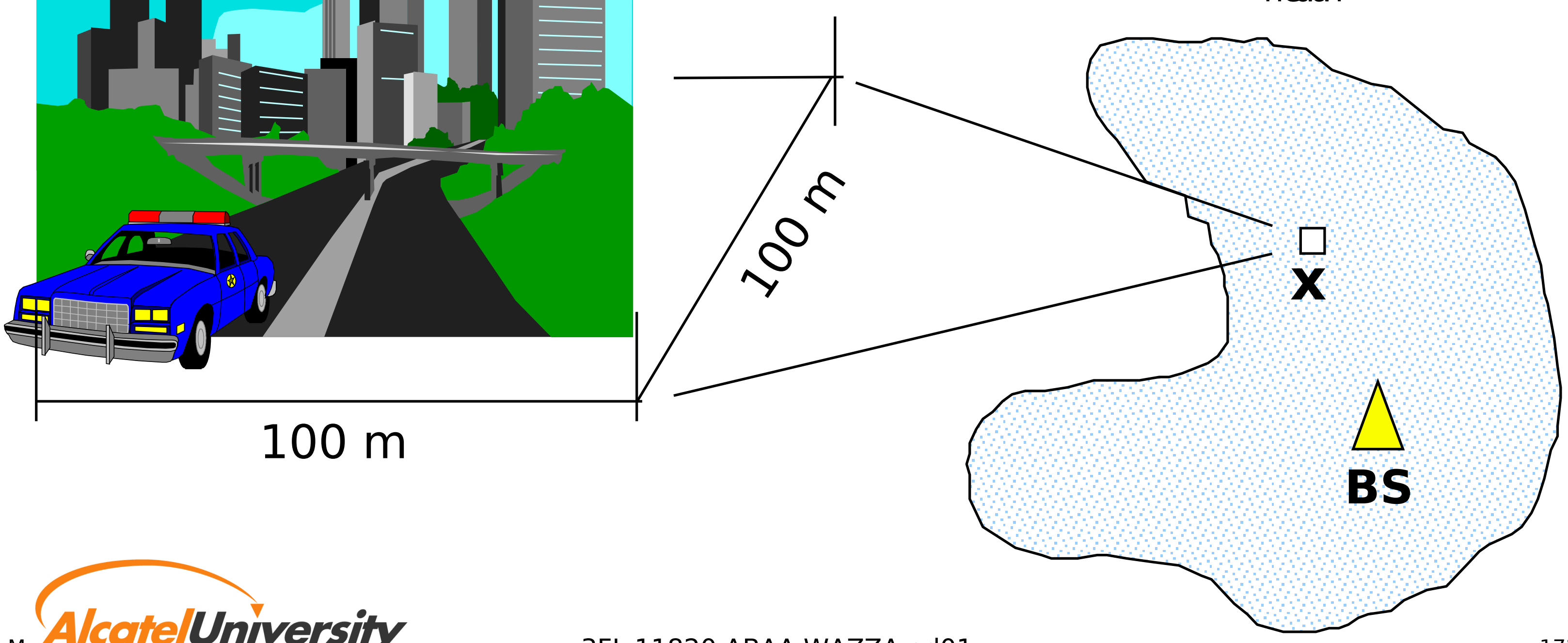
Lognormal margin

- Lognormal margin is also called fading margin
- Due to fading effects, the minimum isotropic power is only received with a certain probability
  - Signal statistics, lognormal distribution with median power value F_{med} and standard deviation σ (sigma)
- Without any margin, the probability is 50%, which is not a sufficient value in order to provide a good call success rate.
- A typical design goal should be a coverage probability of 90...95%. The following normalised table can be applied to find fading margins for different values of σ . The fading margin is calculated by multiplying the value of k (in the table) with the standard deviation:
- **Lognormal/Fading Margin = kσ** .

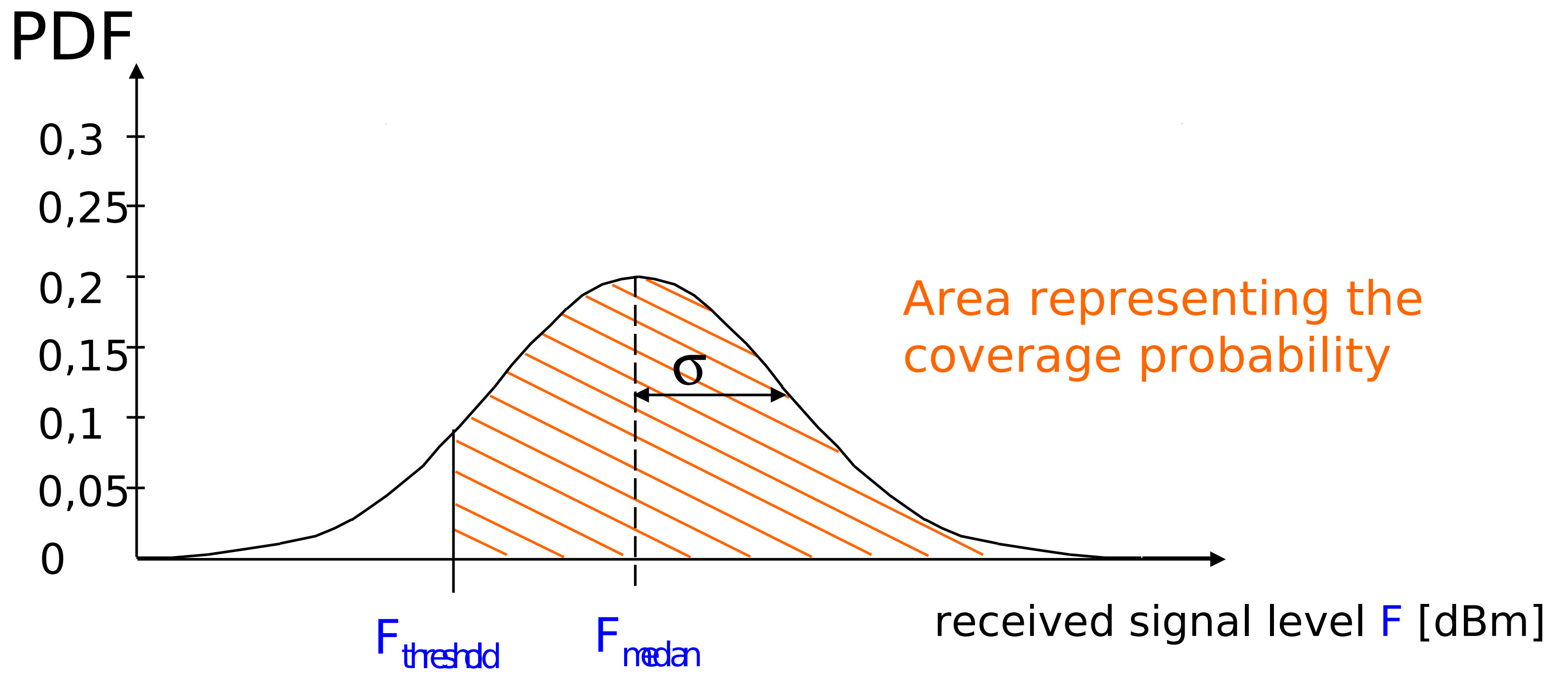
k	-∞	-0.5	0	1	1.3	1.65	2	2.33	+∞
Coverage Probability	0%	30%	50%	84%	90%	95%	97.7 %	99%	100 %

Consideration of Signal Statistics (1)

Field strength at location x lognormally distributed arround F_{median}



Consideration of Signal Statistics (2)



Local coverage probability: $P_{cov} = P[\, F > F_{threshold} \,]$

Calculation of Coverage Radius R

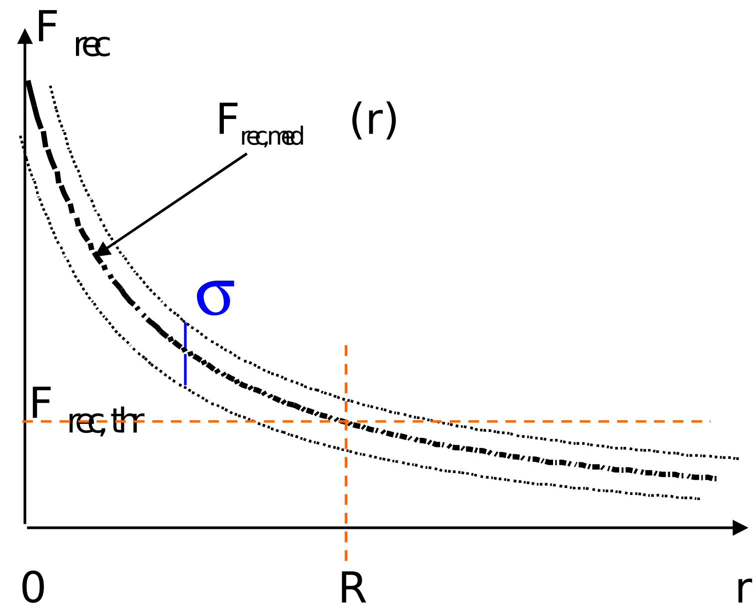
For what Radius R is the <u>average</u> coverage probability in the cell area 95% ?

$$F_{rec,med}(r) = EIRP - Loss_{Hata}(r)$$

$$Loss_{Hata} = f(h_{BS}, h_{MS}, f, r) + K_{mor}$$

$$P_{cov}(r) = P(F_{rec}(r) > F_{rec,thr})$$

$$\langle P_{cov}(R) \rangle = \frac{2\pi \int_0^R P_{cov}(r)\, dr!}{\pi R^2} = 0.95$$



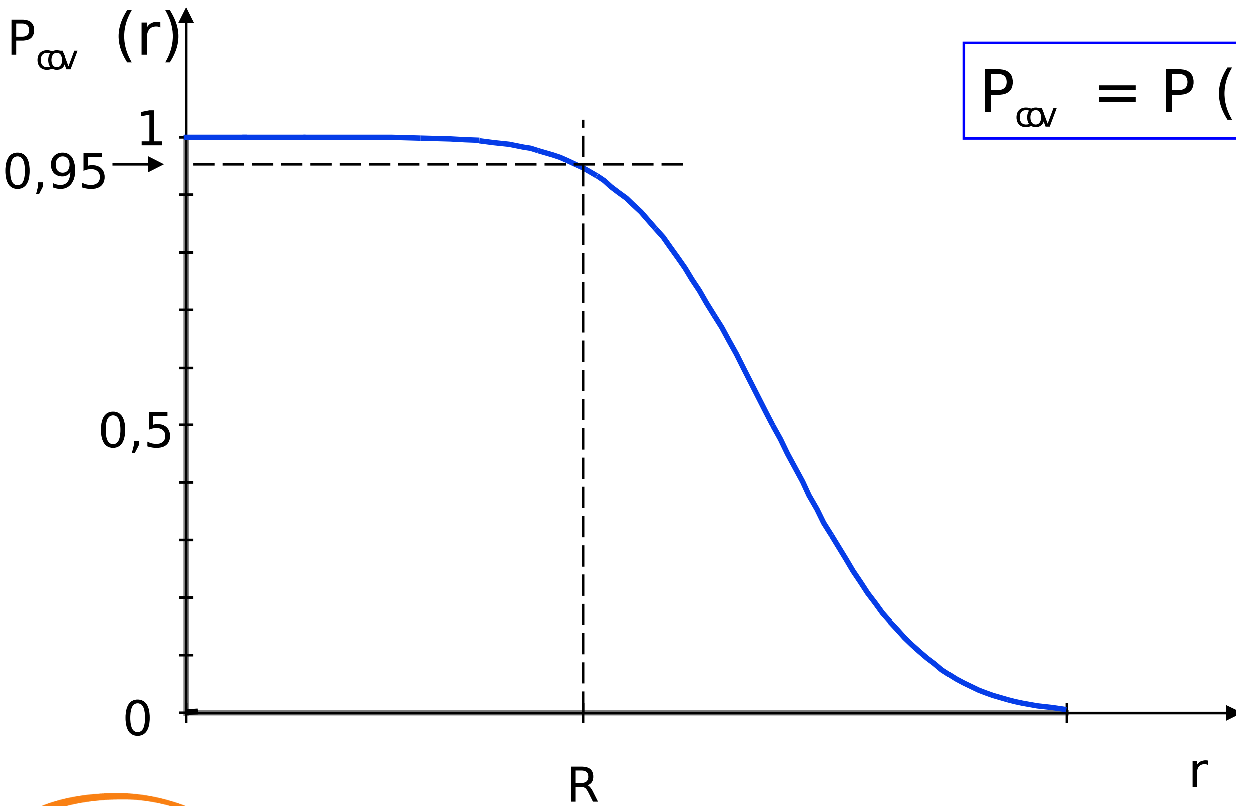
$$R = f(h_{BS}, h_{MS}, f, K_{mor}, EIRP, F_{rec,thr})$$

r = distance between BTS and MS

F_{rec} = received power

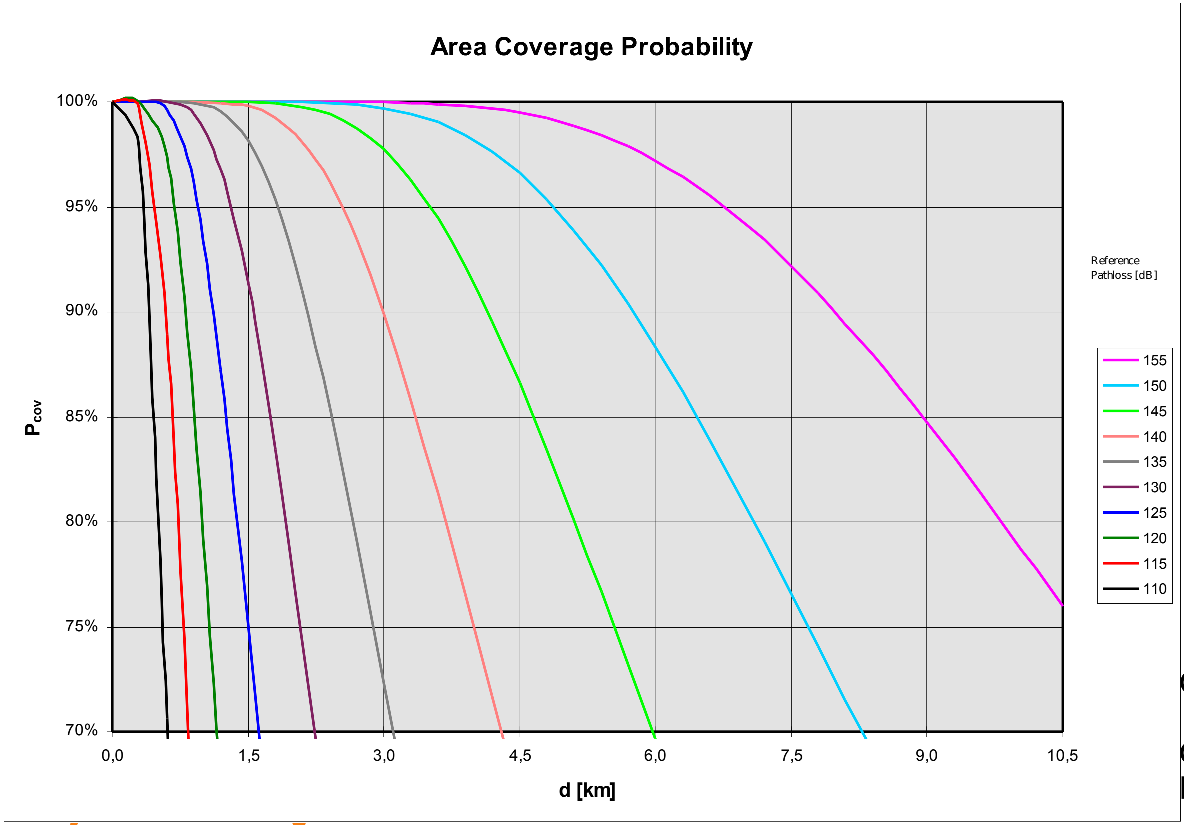
σ = Standard deviation

Coverage Probability



$$P_{cov} = P\,(\,F_{rec} > F_{rec,thr}\,)$$

Coverage Ranges and Hata Correction Factors

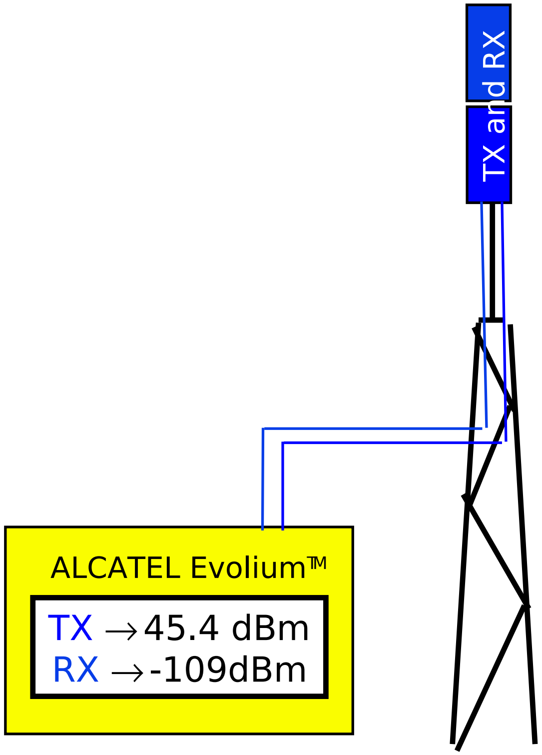


Clutter type	Cor [dB]	σ [dB]
Skyscrapers	0	6
Dense urban	2	6
Medium urban	4	7
Lower urban	6	7
Residential	8	6
Industrial zone	10	10
Forest	8	8
Agricultural	20	6
Low tree density	15	8
Water	27	5
Open area	27	6

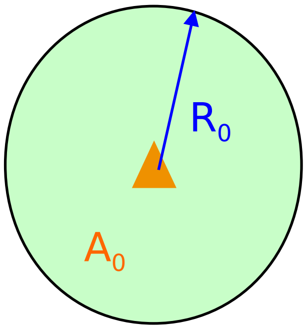
Calculation conditions:

Correction = 3; Sigma = 7
h_{BS} = 30 m; h_{MS} = 1.7m; f = 900 Mhz

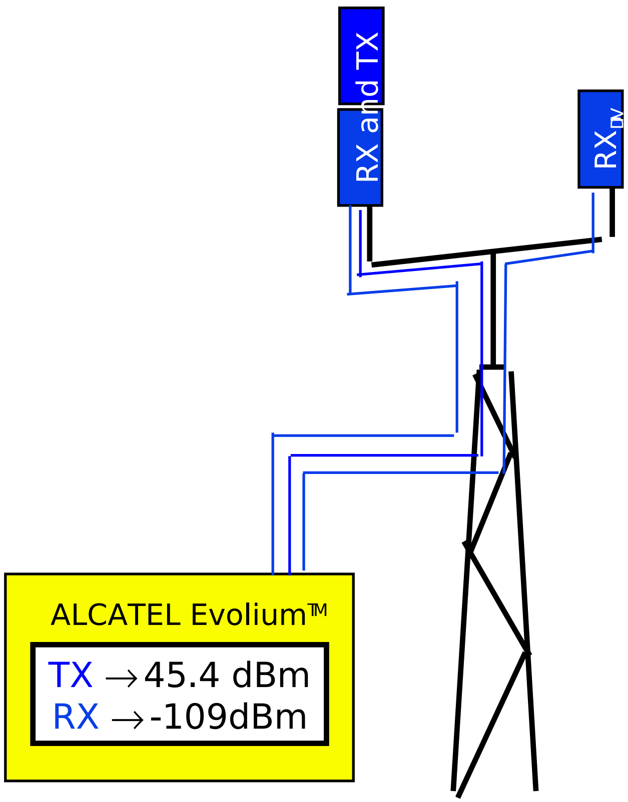
Conventional BTS Configuration



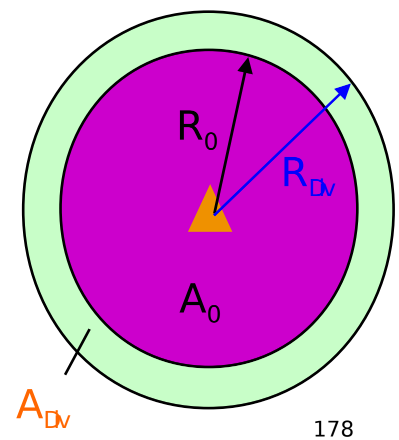
- 1 BTS
- Omnidirectional antenna for both TX and RX
  - Coverage Range R_0
  - Coverage Area A_0



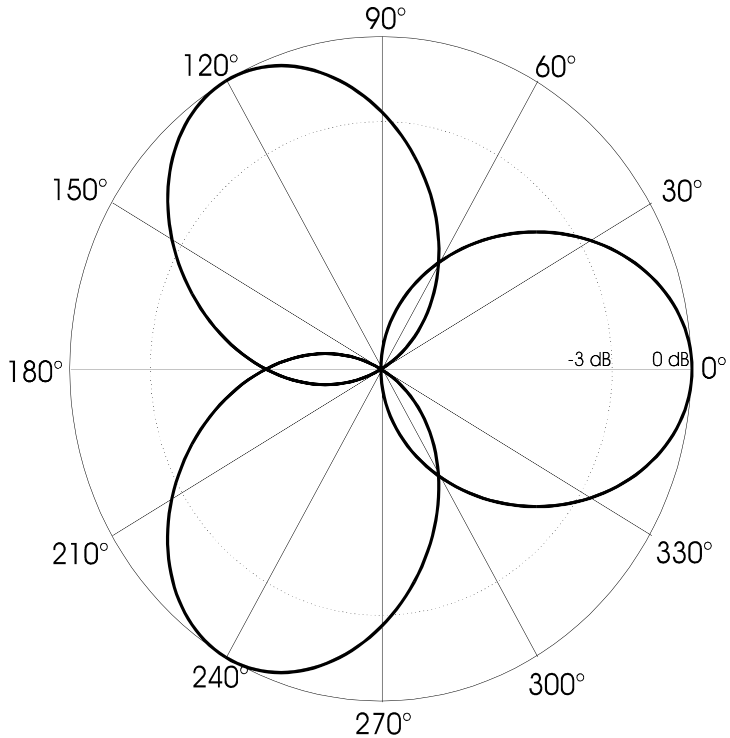
Coverage Improvement by Antenna Diversity

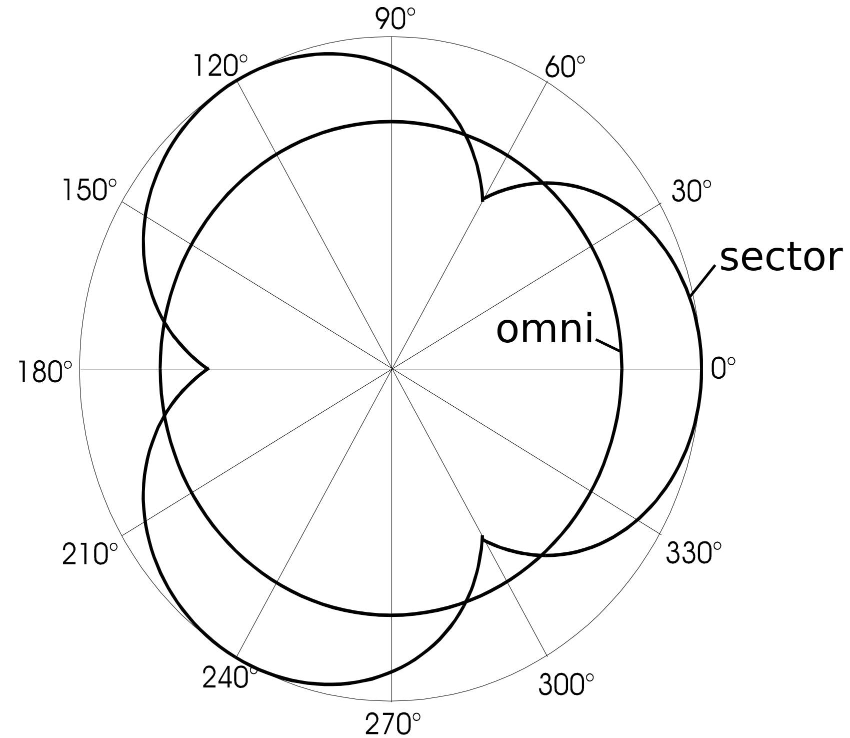


- 1 BTS
- Omnidirectional antennas
  - one for both RX and TX
  - one for RX_{DIV}
- Antenna diversity gain (2...6 dB)
  - Example: 3 dB
- Coverage range
  $R_{Div} = 1.23 \cdot R_0$
- Coverage area
  $A_{Div} = 1.5 \cdot A_0$



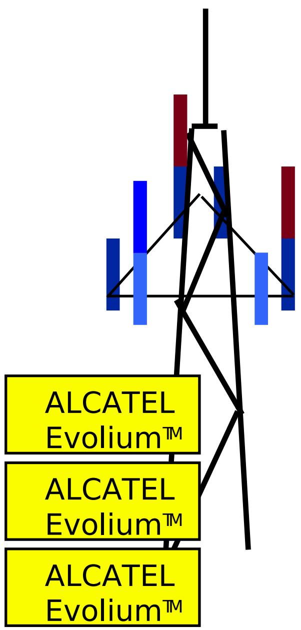
Radiation Patterns and Range



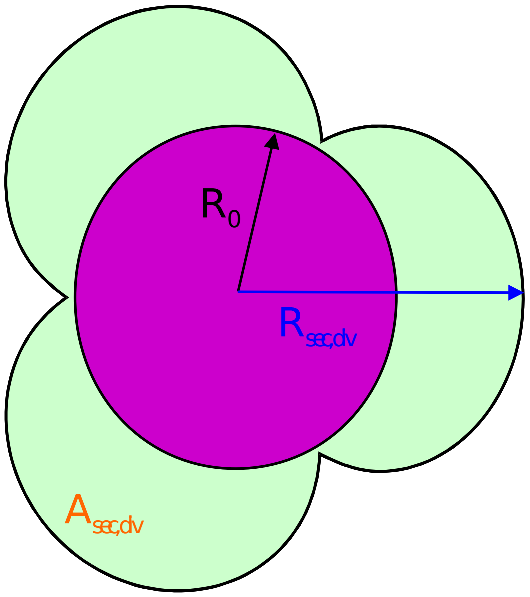


3 antennas at sector site,
Gain: 18 dBi, HPBW: 65° → Resulting antenna footprint ("cloverleaf") compared to an 11 dBi omni antenna

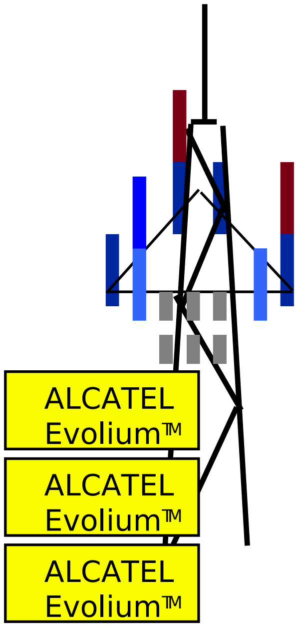
Improvement by Antenna Diversity and Sectorization



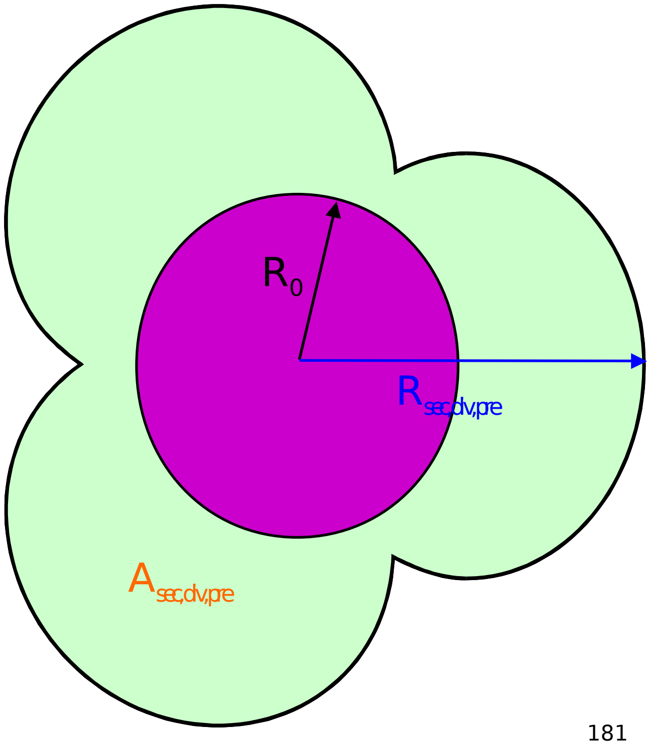
- 3 BTS
- Directional antennas (18 dBi)
- Antenna diversity (3 dB)
- ➡ Max. coverage range
  $R_{sec,div} = 1.95 \cdot R_0$
- ➡ Coverage area
  $A_{sec,div} = 3 \cdot A_0$



Improvement by Antenna Preamplifier



- 3 BTS
- Directional antennas (18 dBi)
- Antenna diversity (3 dB)
- Antenna preamplifier (3dB)
- Max. coverage range
  $R_{sec,dv,pre} = 2.22 \cdot R_0$
- Coverage area
  $A_{sec,dv,pre} = 3.9 \cdot A_0$
- General:
  $A_{sec} = g \cdot A_0$
  g: Area gain factor

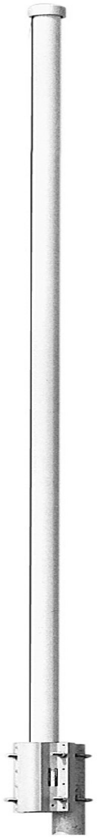


Coverage Planning

Antenna Engineering

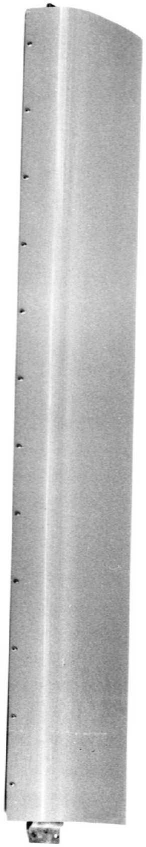
Omni Antennas

- Application
  - Large area coverage
  - Umbrella cell for micro cell layer
- Advantages
  - Continuous coverage around the site
  - Simple antenna mounting
  - Ideal for homogeneous terrain
- Drawbacks
  - No mechanical tilt possible
  - Clearance of antenna required
  - Densification of network difficult



Sector Antenna

- Antenna with horizontal HPBW of e.g. 90° or 65°
- Advantages
  - Coverage can be focussed on special areas
  - Low coverage of areas of no interest (e.g. forest)
  - Allows high traffic load
  - Additional mechanical downtilt possible
  - Wall mounting possible
- Drawbacks
  - More frequencies needed per site compared to omni sites
  - More hardware needed
  - Lower coverage area per sector



Typical Applications

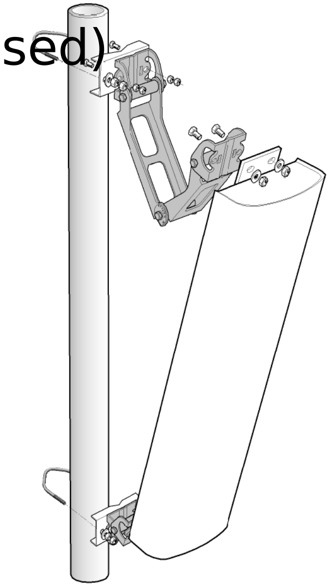
- Wide horizontal beam width (e.g. 90°)
  - For areas with few reflecting and scattering objects (rural area)
  - Area coverage for 3-sector sites
  - Sufficient cell overlap to allow successful handovers
- Small horizontal beam width (e.g. 65°)
  - For areas with high scattering (city areas)
  - Coverage between sectors by scattering and by adjacent sites (mostly site densification in urban areas)

Antenna Tilt

- Downtilting of the Antenna main beam related to the horizontal line
- Goals:
  - Reduction of overshoot
  - Removal of insular coverage
  - Lowering the interference
  - Coverage improvement of the near area (indoor coverage)
  - Adjustment of cell borders (handover zones)
- Mechanical / Electrical or Combined downtilt

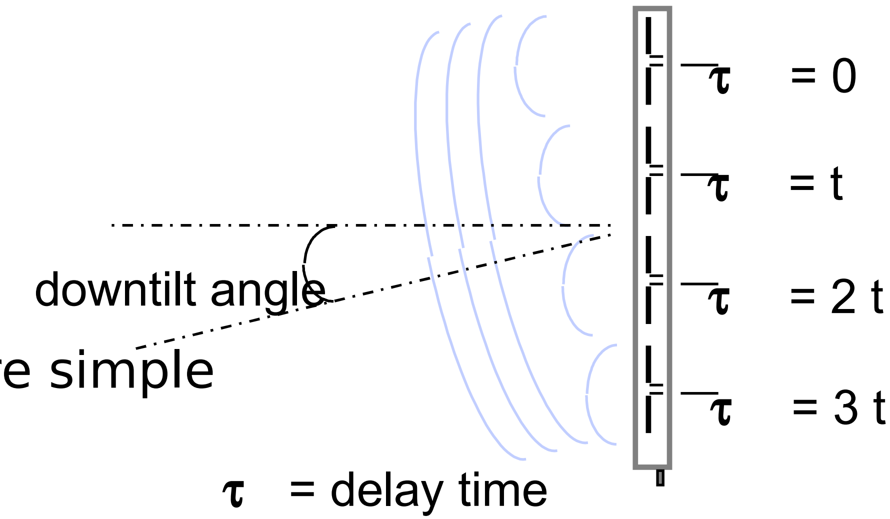
Mechanical Downtilt

- Advantages
  - Later adjustment of vertical tilt possible
  - Antenna diagram is not changed, i.e. nulls and side lobes remain in their position relative to the main beam
  - Cost effective (single antenna type may be used)
  - Fast adjustments possible



- Drawbacks
  - Side lobes are less tilted
  - Accurate adjustment is difficult
  - Problems for sites with difficult access

Electrical Downtilt



- Advantages
  - Same tilt for **both** main and side lobes
  - Antenna mounting is more simple
    $\rightarrow$ no adjustment errors
- Drawbacks
  - Introduction of additional antenna types necessary
  - New antenna installation at the site if downtilting is introduced
  - Long antenna optimization phase
  - Adjustment of electrical tilt mostly not possible

Combined Downtilt

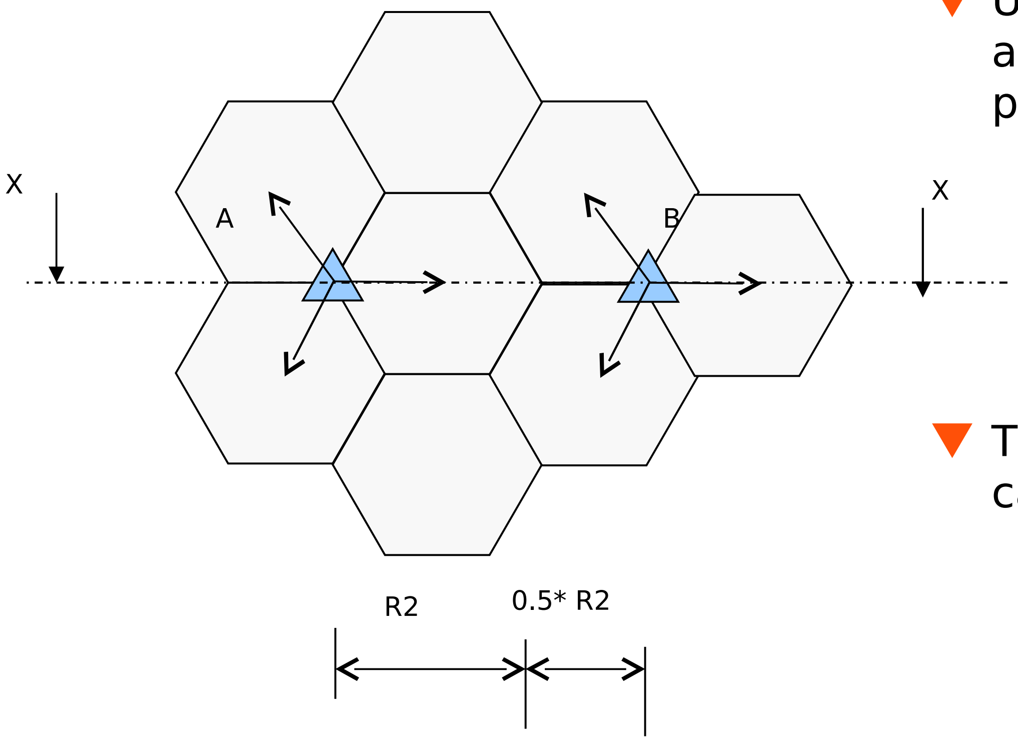
- Combination of both mechanical and electrical downtilt
  - High electrical downtilt: Distinct range reduction in sidelobe direction (interference reduction)
  - Less mechanical uptilt in main beam direction

- Choose sector antennas with high electrical downtilt (6°...8°) and apply mechanical uptilt installation for optimum coverage range in main beam direction

Assessment of Required Tilts

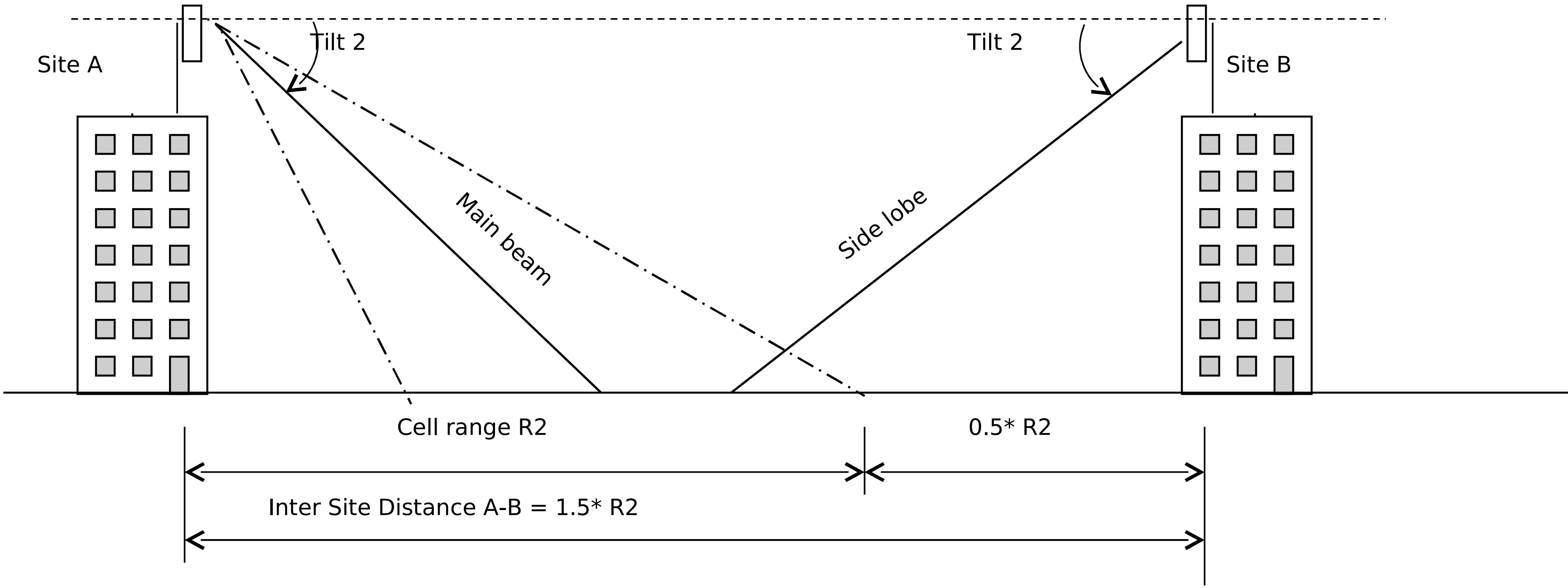
- Required tilt is estimated using *Geometrical Optics*
- Consideration of
  - Vertical HPBW of the antenna
  - Antenna height above ground
  - Height difference antenna/location to be covered
  - Morpho-structure in the vicinity of the antenna
  - Topography between transmitter and receiver location
- Tilt must be applied for both TX and RX antennas!

Inter Site Distance in Urban Area



- Using sectorized sites with antennas of 65° horizontal half power beam width
  - The sidelobe is approximately reduced by 10dB.
  - This is a reduction of cell range to 50%.
- The inter site distance calculation factor depends on
  - Type of antenna
  - Type of morpho class
    - Multi path propagation
    - Scattering
    - Sigma (fading variations)

Downtilt in Urban Area

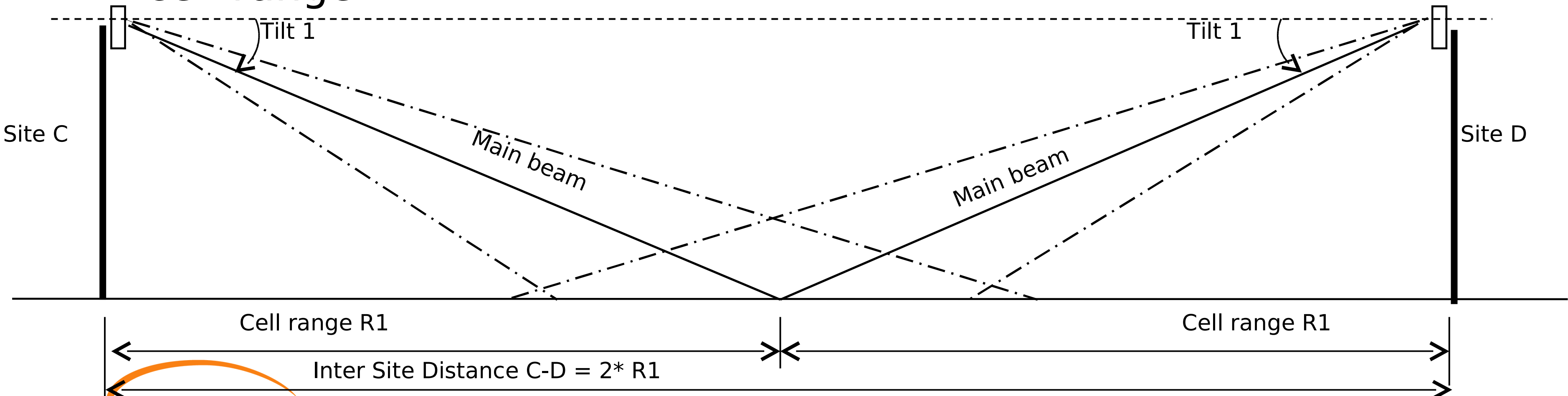


Downtilt in Urban Area

- The upper limit of the vertical half power beam width is directed towards the ground at maximum cell range
  - Upper –3dB point of the vertical antenna pattern
- To be used in areas with
  - Multi path propagation condition
  - Good scattering of the beam
- Aim
  - Reduction of interference
- Optimization
  - Coverage Optimization in isolated cases using less downtilt
  - Interference Reduction in isolated cases using more downtilt

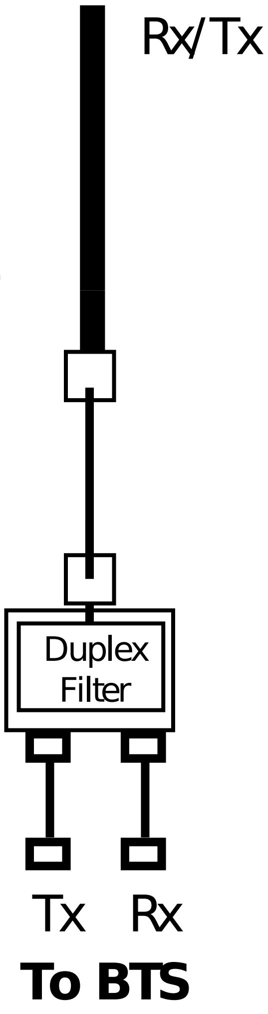
Downtilt in Suburban and Rural Area

- Downtilt planning for
  - Suburban
  - Rural
  - Highway Coverage
- The main beam is directed towards the ground at maximum cell range

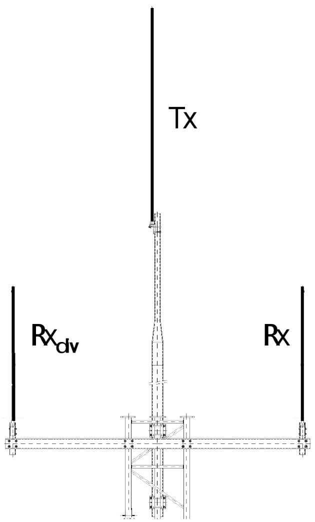


Antenna configurations

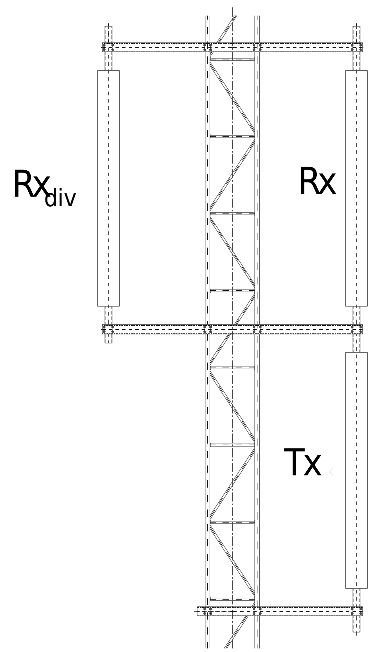
- Application of Duplexer
  - Consists of a TX/RX Filter and a combiner
  - ➡ one antenna can be saved
- Tower Mounted Amplifier (TMA)
  - Increase Uplink Sensitivity
  - TMA needs to have TX bypass
    => in case of duplexer usage
- Diversity
  - Space diversity
  - Polarization diversity



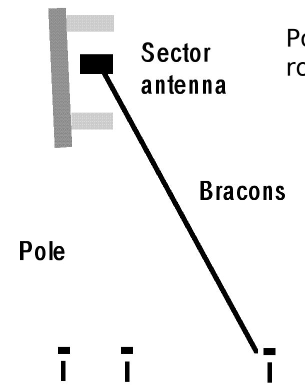
Antenna Configurations for Omni and Sector Sites



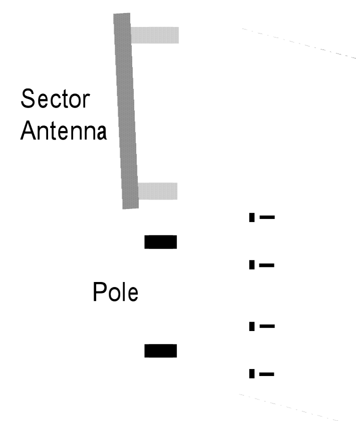
Tower mounting for omni antennas



Tower mounting for directional antennas

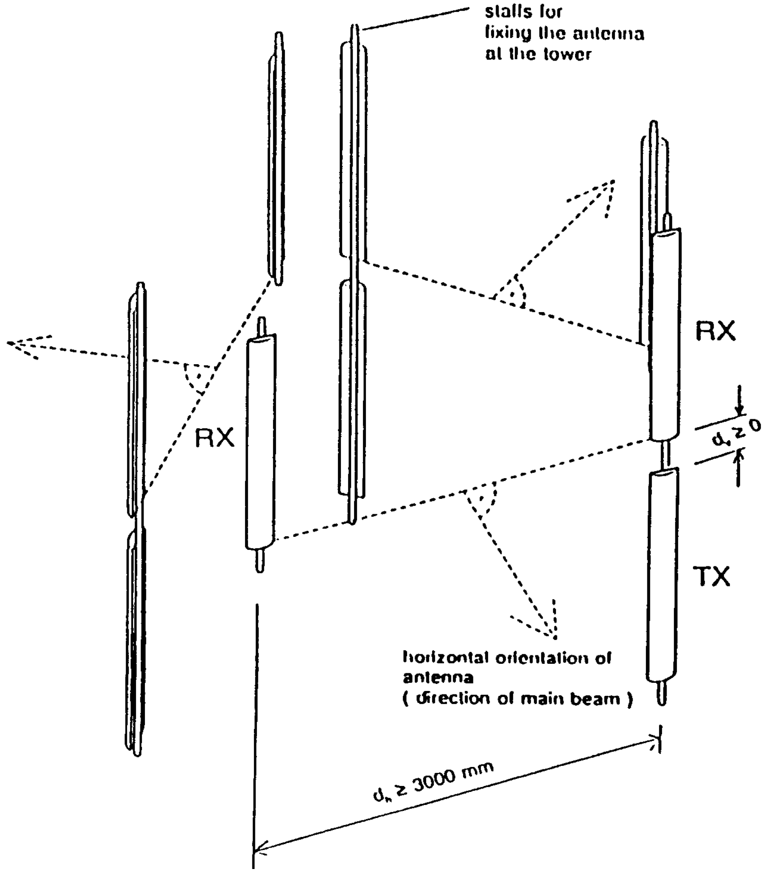


Pole mounting for roof-top mounting



Pole mounting for wall or parapet mounting

Three Sector Antenna Configuration with AD



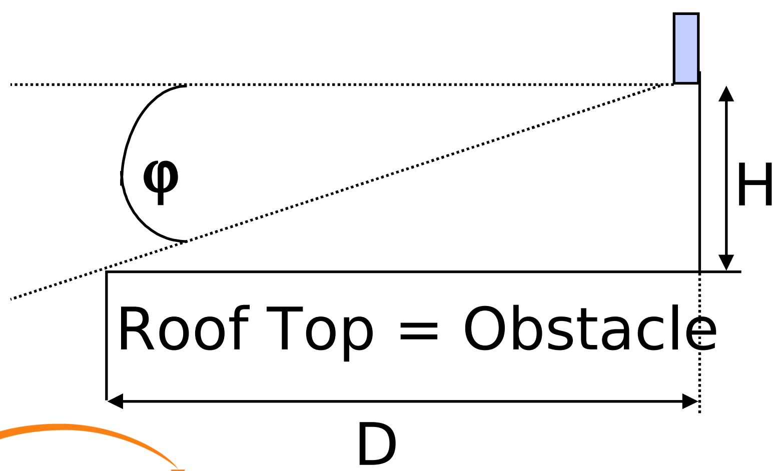
Antenna Engineering Rules

- Distortion of antenna pattern: No obstacles within
  - Antenna near field range
  - HPBW Rule plus security margin of 20°
  - First fresnel ellipsoid range (additional losses!)
- TX-RX Decoupling to avoid blocking and intermodulation
  - Required minimum separation of TX - RX antennas dependent on antenna configuration (e.g. duplexer or not)
- Diversity gain
  - Required antenna separation for space diversity

Distortion of antenna pattern

- Antenna Near Field Range: Rmin = $2D^2/\lambda$
  - D = Aperture of antenna (e.g. 3m)
  - => R_{min} = 60 / 120m for GSM / DCS

- HPBW Rule with securtiy margin of 20° and tilt α



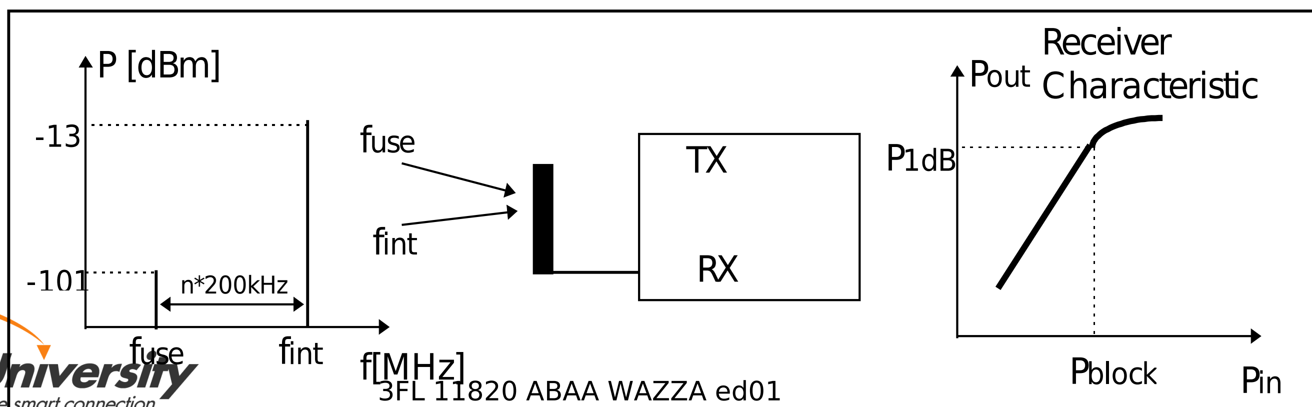
$\varphi = HPBW/2 + 20° + \alpha$

D[m]	1	5	10
H[m]	0.5	2.5	5

HPBW = 8°, α = 2°

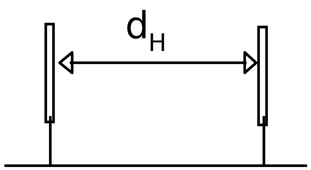
Tx-Rx Decoupling (1)

- Out of Band Blocking Requirement (GSM Rec. 11.21)
  - GSM 900 = +8 dBm
  - GSM 1800 = 0 dBm
- Required Decoupling (n = number of transmitters)
  - TX-TX = 20 dB
  - TX-RX GSM = 30 + 10 log (n) dB
  - TX-RX DCS = 40 + 10 log (n) dB

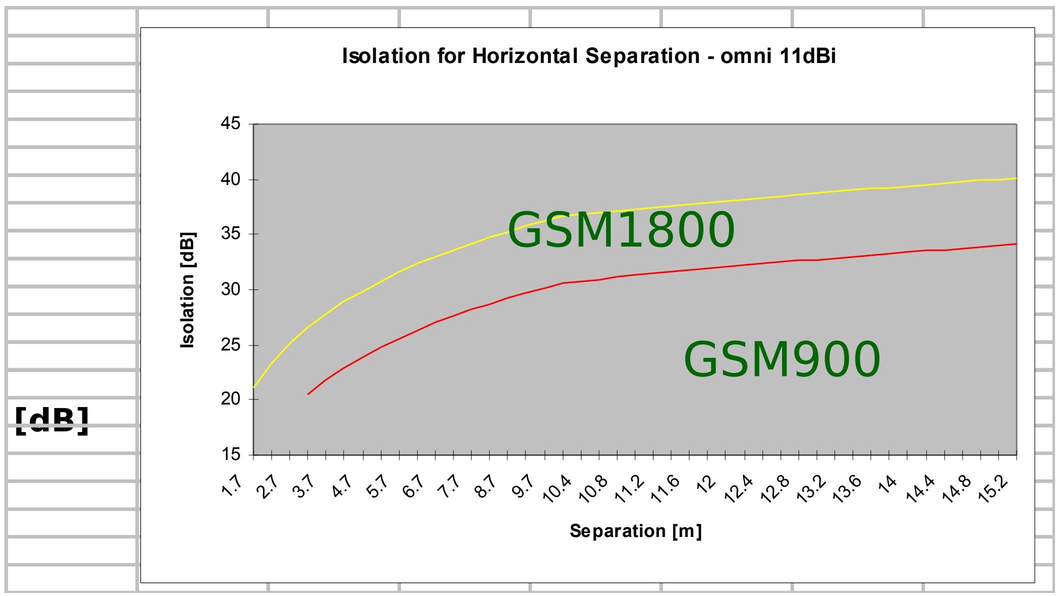


TX-RX Decoupling (2)

- Horizontal separation (Approximation)

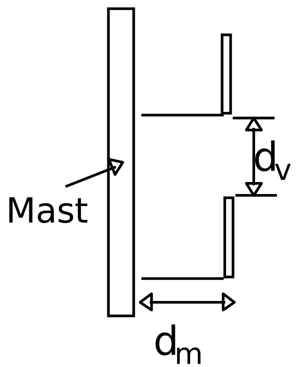


$$I_H = 22 + 20\log(d_H/\lambda) - (G_T + G_R)\ [dB]$$

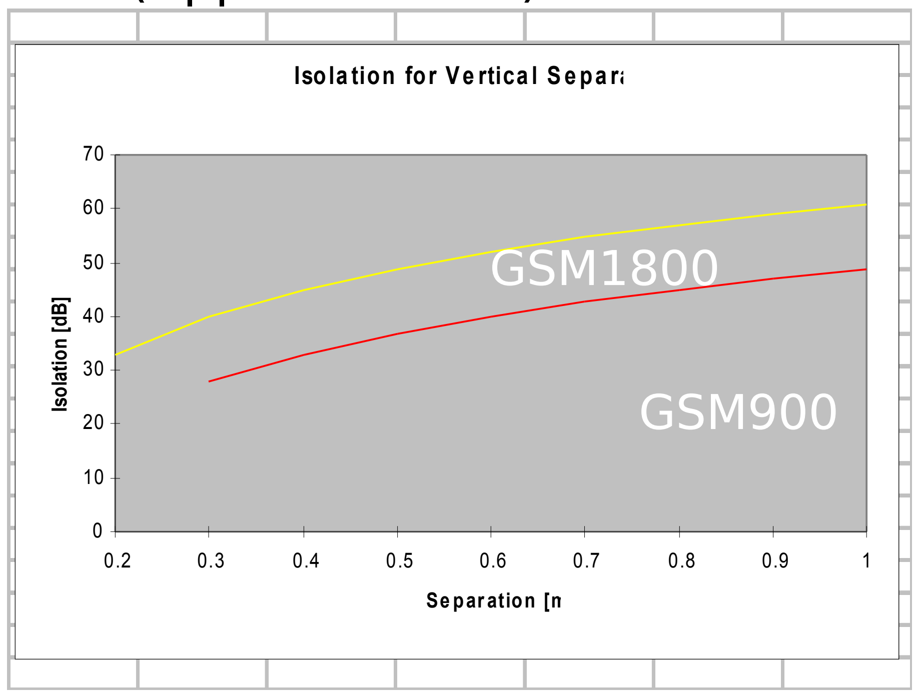


TX-RX Decoupling (3)

- Vertical separation (Approximation)

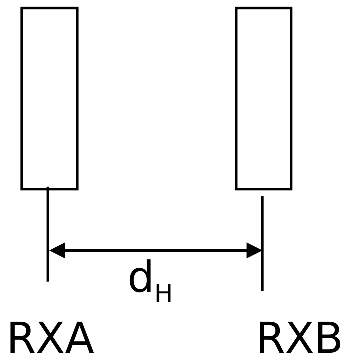


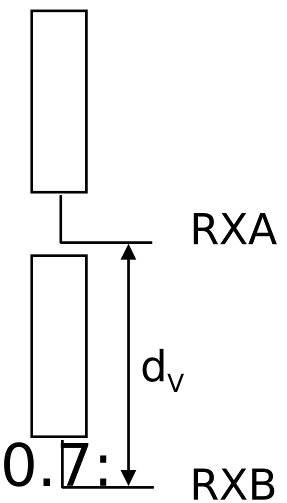
$I_v = 28 + 40\log(d_v/\lambda)$ [dB]



Space Diversity

- Required separation for max. diversity gain = F(λ)





For a sufficient low correlation coefficient ρ < 0.7:

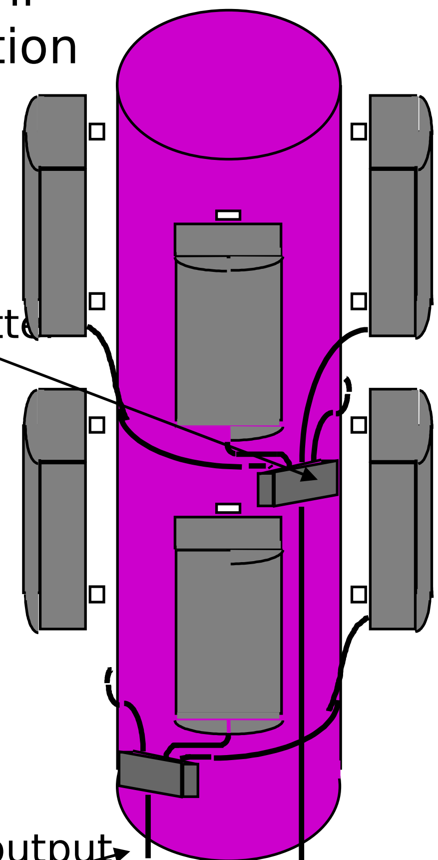
$d_H = 20\lambda$ => GSM 900: 6m / GSM1800: 3m

$d_V = 15\lambda$ => GSM 900: 4.5m / GSM1800: 2.25m

Power Divider

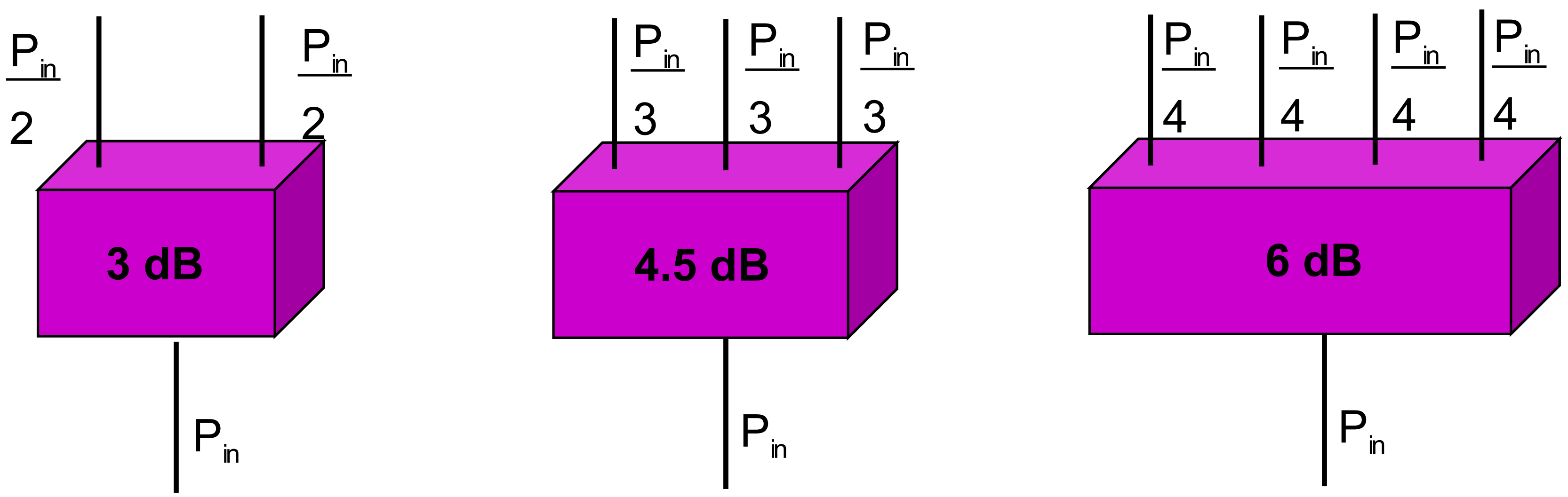
- Power dividers connect several antennas to one feeder cable

- For combination of individual antenna patterns for a requested configuration
  - Quasi-omni configuration
  - Bidirectional configuration (road coverage)



Power divider

- Also called "power splitter" or "junction box"
- Passive device (works in both (transmit and receive) direction)



Example: Power Splitter

Low-Loss Power Splitter
790 – 960 MHz

KATHREIN
Antennen · Electronic

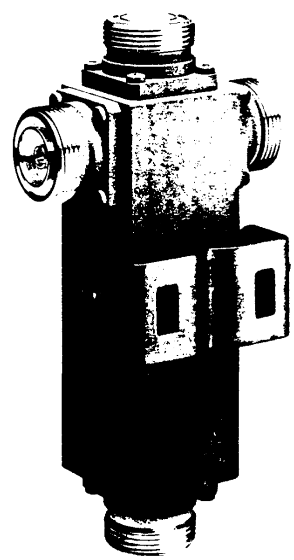
For outdoor and indoor use.

2-Splitter 900
3-Splitter 900
4-Splitter 900

Type No.	K 63 20 62 1	K 63 20 62 7	K 63 20 63 1	K 63 20 63 7	K 63 20 64 1	K 63 20 64 7
Connector (female)	N	7-16	N	7-16	N	7-16
Max. power at 50 °C ambient temperature	500 W	1000 W	500 W	1000 W	500 W	1000 W
For connecting ... antennas	2		3		4	
Frequency range	790 – 960 MHz					
VSWR	< 1.1					
Impedance	50 Ω					
Insertion loss	< 0.05 dB					
Max. size	210 mm/80 mm/80 mm					

Material: – Case: Aluminum.
Inner conductor: Brass.

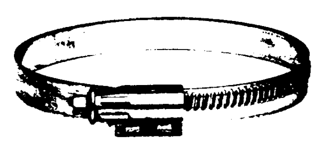
Mounting: – Bracket included for wall mounting.
For tubular mast mounting use clamps listed below (order separately).



K 63 20 64 7

Clamps

Type No.	Description	Remarks
736 801	1 Clamp	30 – 55 mm diameter
736 802	1 Clamp	55 – 75 mm diameter
736 803	1 Clamp	75 – 95 mm diameter
736 804	1 Clamp	95 – 115 mm diameter
736 805	1 Clamp	115 – 135 mm diameter

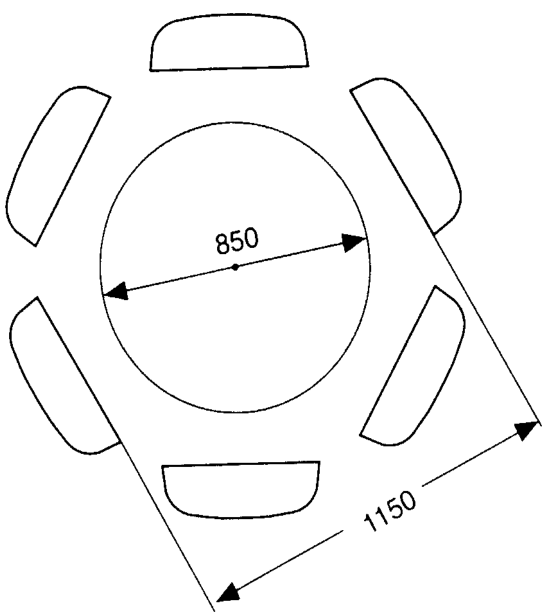


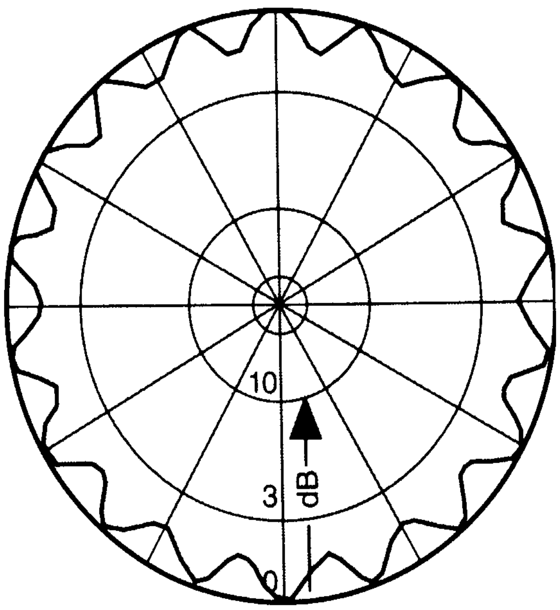
736 805

Panel Configurations (1)

- Radial Arrangement

  of 6 Panel Antennas with horizontal beamwidth = 105 °
  gain = 16.5 dBi, mast radius = 0.425 m, mounting radius = 0.575 m

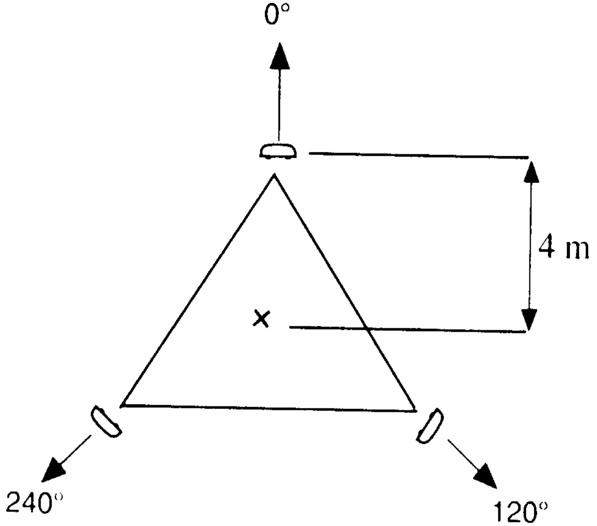


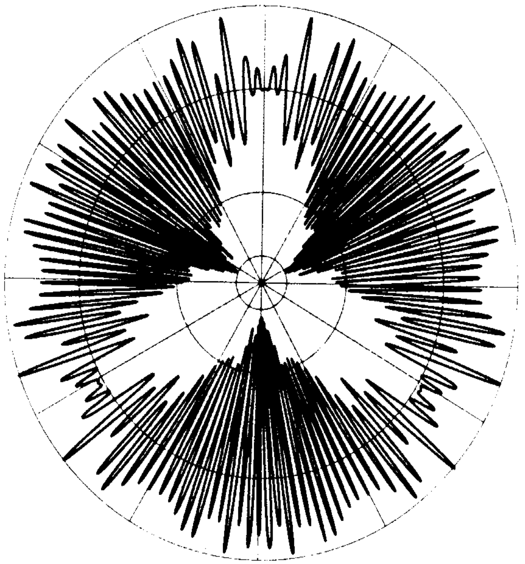


Panel Configurations (2)

- Example 2: Quasi Omni Arrangement

  of 3 antennas with horizontal beamwidth = 105 °, gain =13.5 dBi,
  mounting radius = 4 m

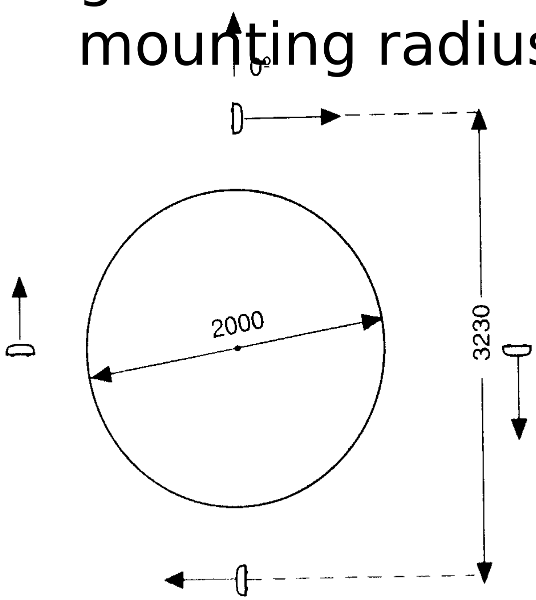


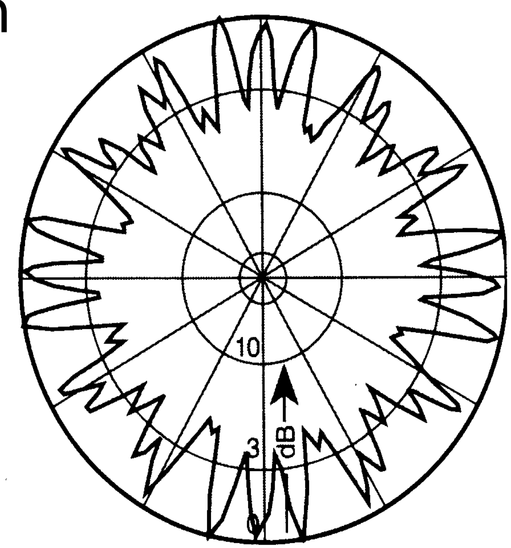


Panel Configurations (3)

- Example 3: Skrew Arrangement

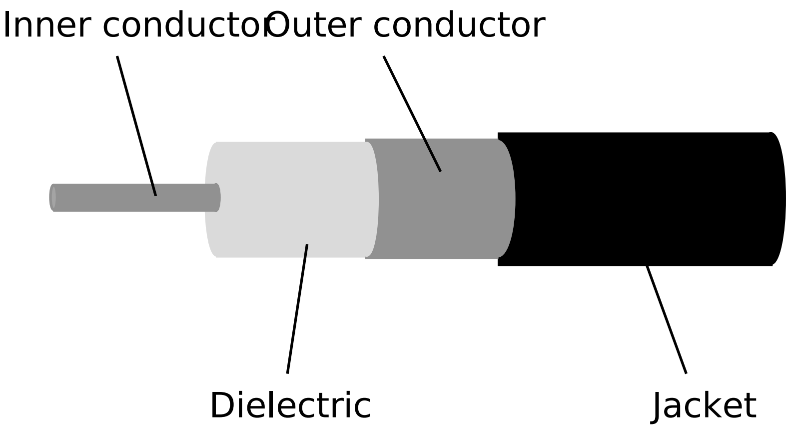
  of 4 Panel Antennas with horizontal beamwidth = 65 °,
  gain = 12.5 dBi, mast radius = 1 m,
  mounting radius = 1.615 m



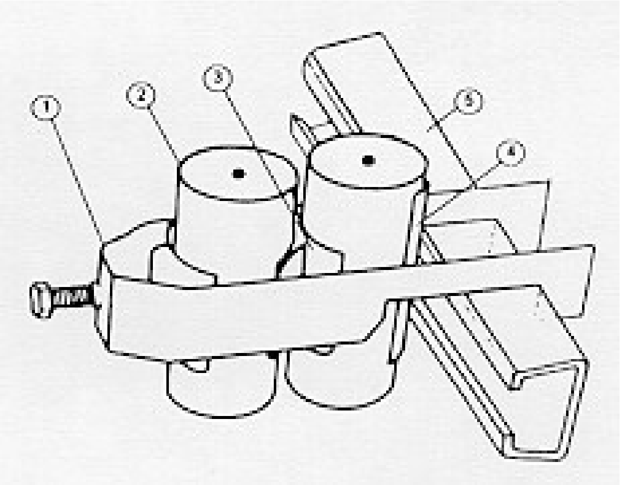


Feeders

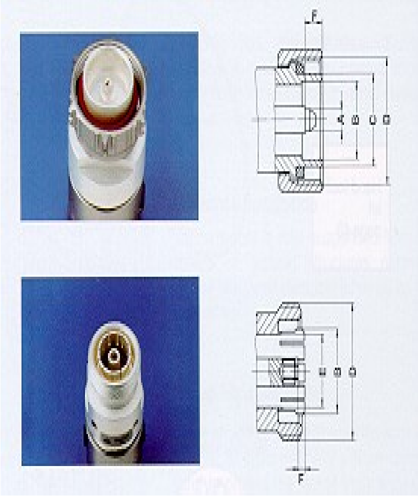
- Technical summary
- Inner conductor: Copper wire
- Dielectric: Low density foam PE
- Outer conductor: Corrugated copper tube
- Jacket: Polyethylene (PE) black



Feeder Installation Set and Connectors



1 Cable Clamps
2 Antenna Cable
3 Double Bearing
4 Counterpart
5 Anchor tape



7/16 Connector:
- Coaxial Connector
- Robust
- Good RF-Performance

Feeder Parameters

Type	Minimum bending radius		Jacket (outer diameter)	Weight (m)	Recommended clamp spacing
	Single bending	Repeated bending			
LCF 1/2''	70 mm	210 mm	16 mm	0.35 kg	0.6 m
LCF 7/8''	120 mm	360 mm	28 mm	0.62 kg	0.8 m
LCF 1 5/8''	300 mm	900 mm	49.7 mm	1.5 kg	1.2 m

	GSM 900		**GSM 1800**		**GSM 1900**	
Type	Attenuation /100 m [dB]	Recommended max length [m]	Attenuation /100 m [dB]	Recommended max length [m]	Attenuation /100 m [dB]	Recommended max length [m]
LCF 1/2“	6.6	45	10.3	30	10.6	28
LCF 7/8“	4.0	75	6.0	50	6.3	47
LCF 1_5/8“	2.6	115	4.0	75	4.2	71

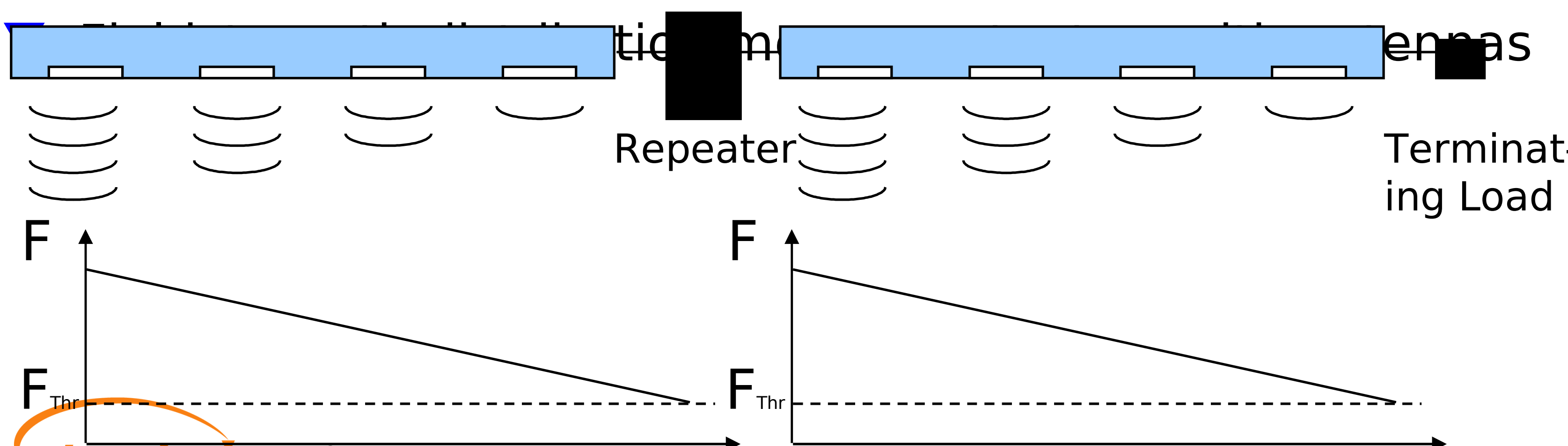
These values are based on feeder types with an impedance of 50 ohms

Feeder attenuation (1)

- Main contribution is given by feeder loss
  - Feeder Cable 4dB/100m => length 50m   Loss =2.0dB
  - Jumper Cable 0.066dB/1m => 5m   Loss =0.33dB
  - Insertion Loss of connector and power splitter < 0.1dB
  - Total Loss 2.0dB+2x0.33dB+5x0.1dB+0.1dB=3.26dB
- Cable type is trade off between
  - Handling flexibility
  - Cost
  - Attenuation

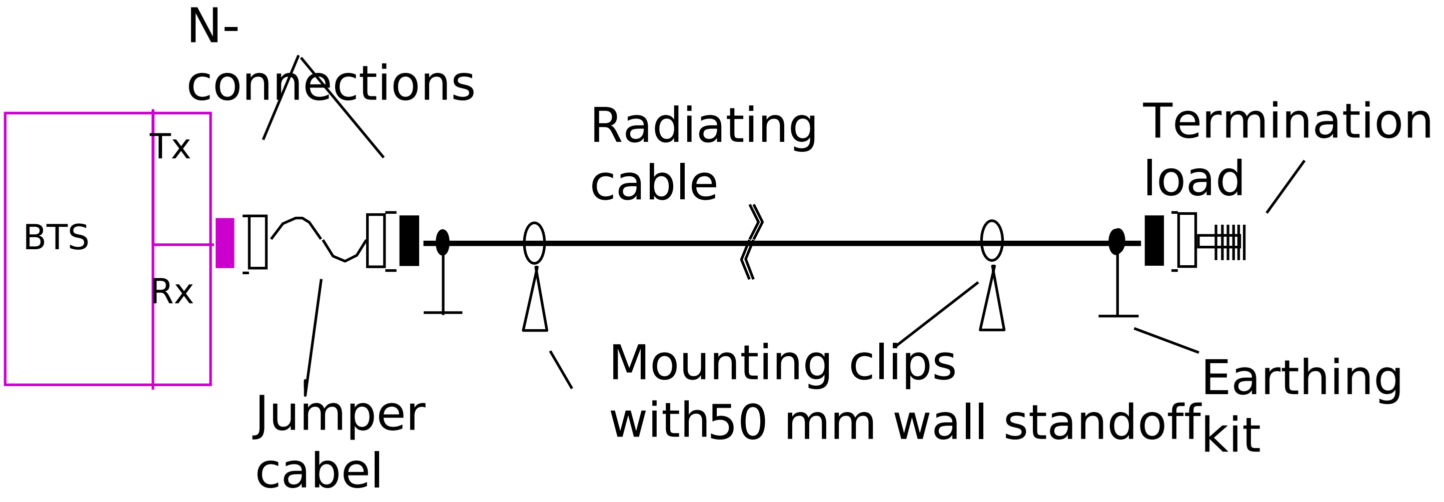
Radiating Cables

- Provide coverage in Tunnels, buildings, along side tracks or lines
- Principle: Radiate a weak but constant electromagnetic wave
- Suitable for coverage over longer distances (Repeater)



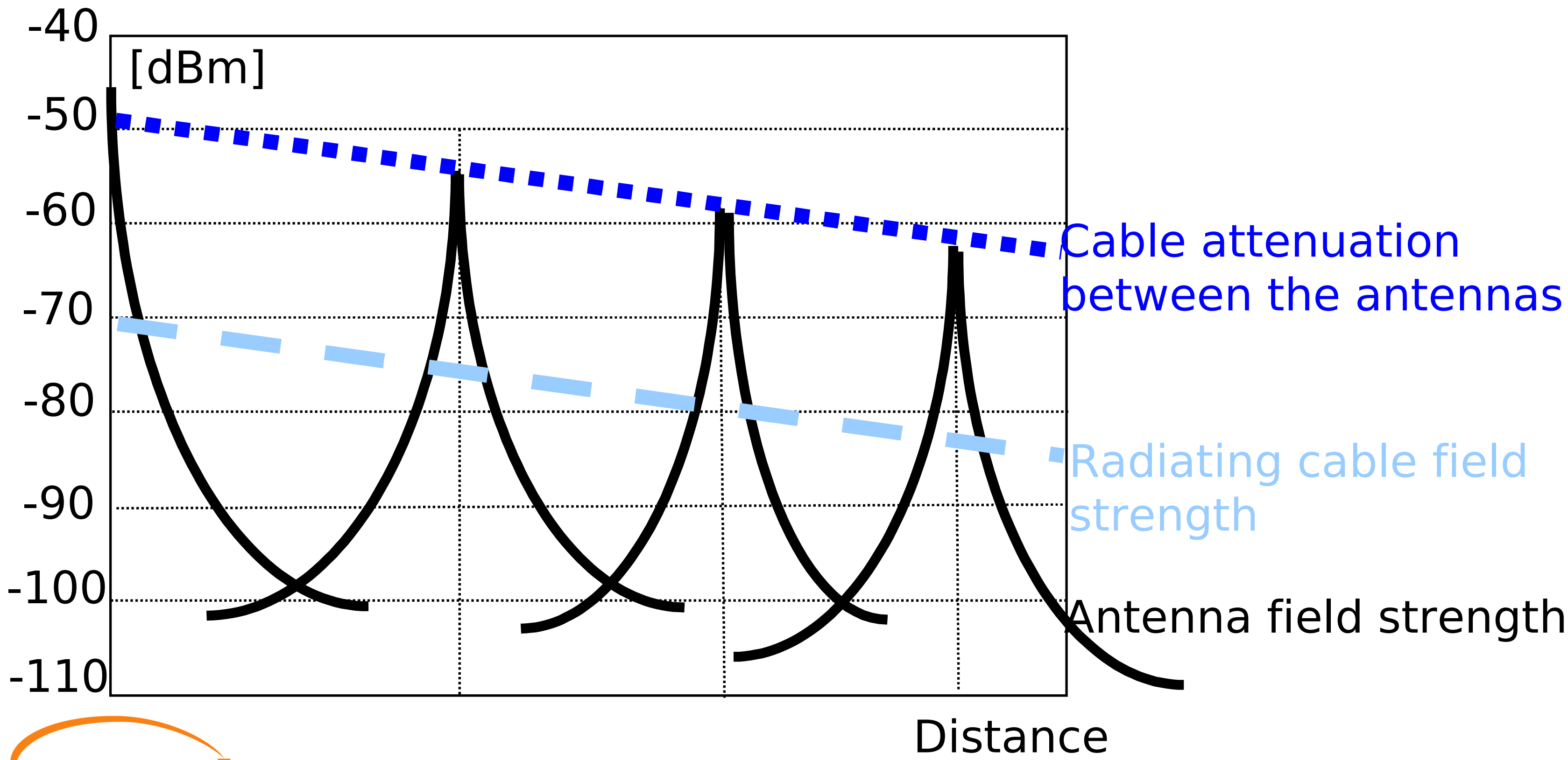
Components of a radiating cable system

- Components are shown with black lines

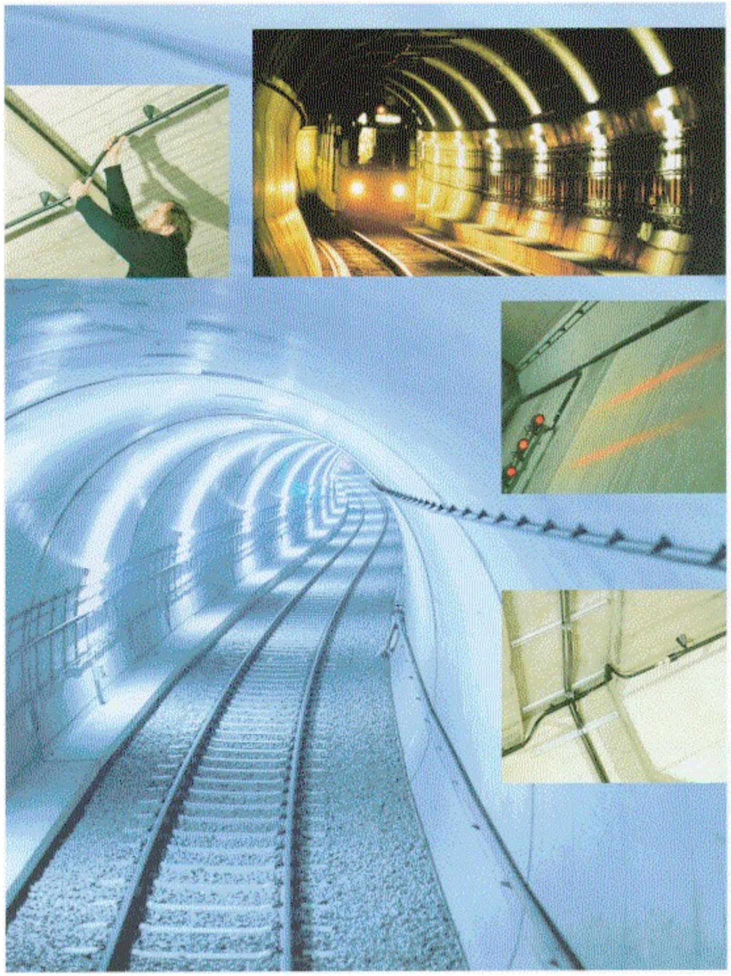


1-leg radiating cable system

Comparison of field strength: Radiating cable and standard antenna



- **Example of a radiating cable in a tunnel**



Microwave antennas, feeders and accessories

- Microwave point to point systems use highly directional antennas
- Gain

$$G = 10\ \lg \frac{4\pi A e}{\lambda^2}$$

with G = gain over isotropic, in dBi

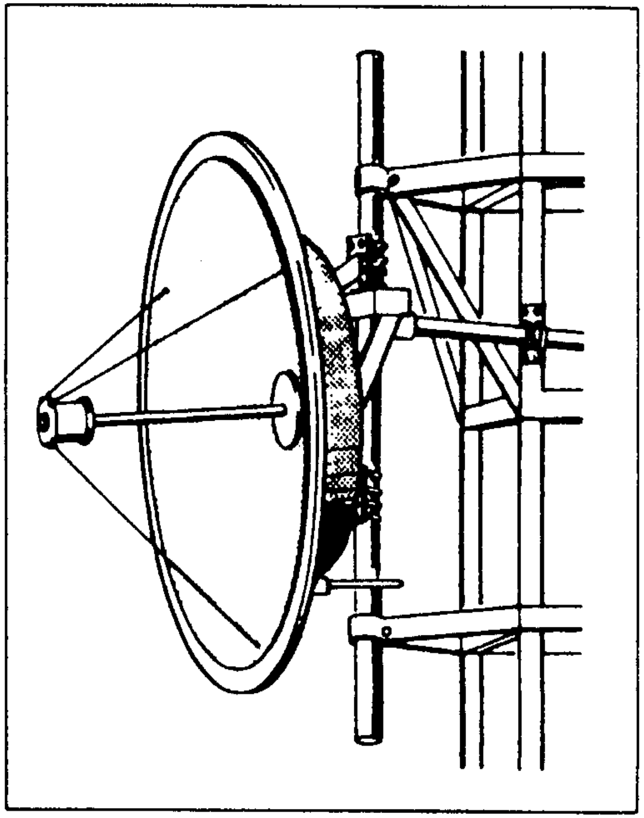
A = area of antenna aperture

e = antenna efficiency

- Used antenna types
  - parabolic antenna
  - high performance antenna
  - horn lens antenna
  - horn antenna

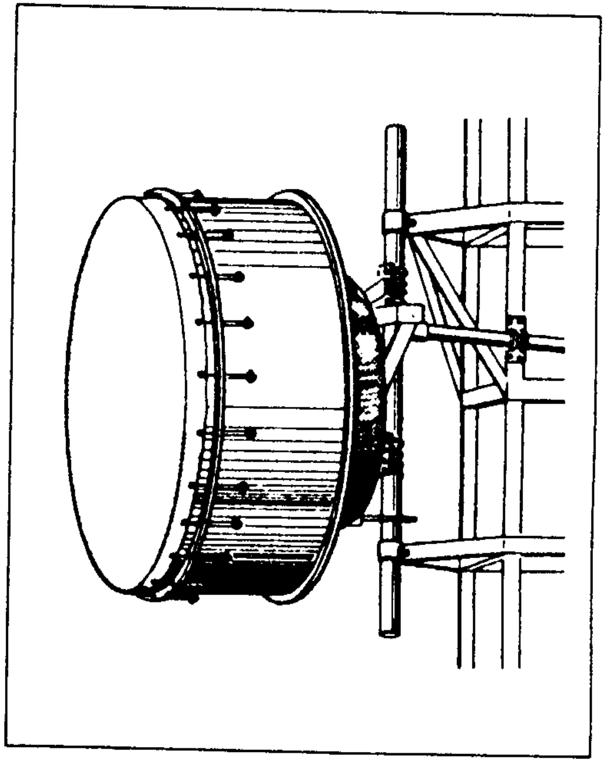
Parabolic antenna

- Parabolic dish, illuminated by a feed horn at its focus
- Available sizes: 1’ (0.3 m) up to 16’ (4.8 m)
- Sizes over 4’ seldom used due to installation restrictions
- Single plane polarized feed vertical (V) or horizontal (H)
- Also: dual polarized feeder (DP), with separate V and H connections (lower gain)
- Front-to-back ratios of 45 dB not high enough for back-to-back configuration on the same frequency
- Antenna patterns are absolutely necessary for interference calculations



High performance antenna

- Similar to common parabolic antenna, except for attached cylindrical shield
- Improvement of front-to-back ratio and wide angle radiation discrimination
- Available in same sizes as parabolic, single or dual polarized
- Substantially bigger, heavier, and more expensive than parabolic antennas
- Allow back-to-back transmission at the same frequency in both directions (refer to interference calculation)



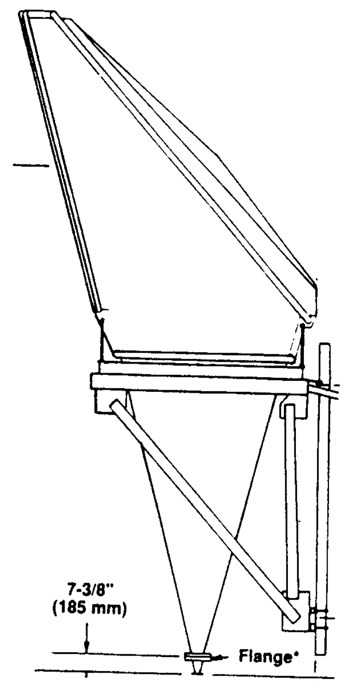
Horn antennas

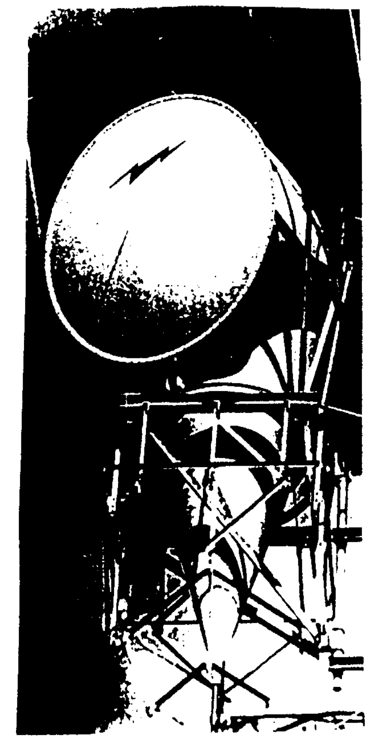
Horn lens antenna

- For very high frequencies > 25 GHz
- Replacement for small parabolic antennas (1’)
- Same electrical data, but easier to install due to size and weight

Horn reflector antenna

- Large parabola, energy from the feed horn is reflected at right angle (90°)
- Gain like 10’ parabolic antenna (60 dBi), but higher front-to-back ratios > 70 dB





- Big and heavy, requires a complex installation procedure
- Only used on high capacity microwave backbones (e.g. MSC-MSC interconnections)

Specific Microwave Antenna Parameters (1)

- Cross polarization discrimination (XPD)
  - highest level of cross polarisation radiation relative to the main beam; should be > 30 dB for parabolic antennas
- Inter-port isolation
  - isolation between the two ports of dual polarised antennas; typical value: better than 35 dB
- Return loss (VSWR)
  - Quality value for the adaption of antenna impedance to the impedance of the connection cable
  - Return loss is the ratio of the reflected power to the power fed at the antenna input (typical> 20 dB)

Specific Microwave Antenna Parameters (2)

- Radiation pattern envelope (RPE)
  - Tolerance specification for antenna pattern (specification of antenna pattern itself not suitable due to manufacturing problems)
  - Usually available from manufacturer in vertical and horizontal polarisation (worst values of several measurements)
- Weight
- Wind load

Data sheet 15 GHz

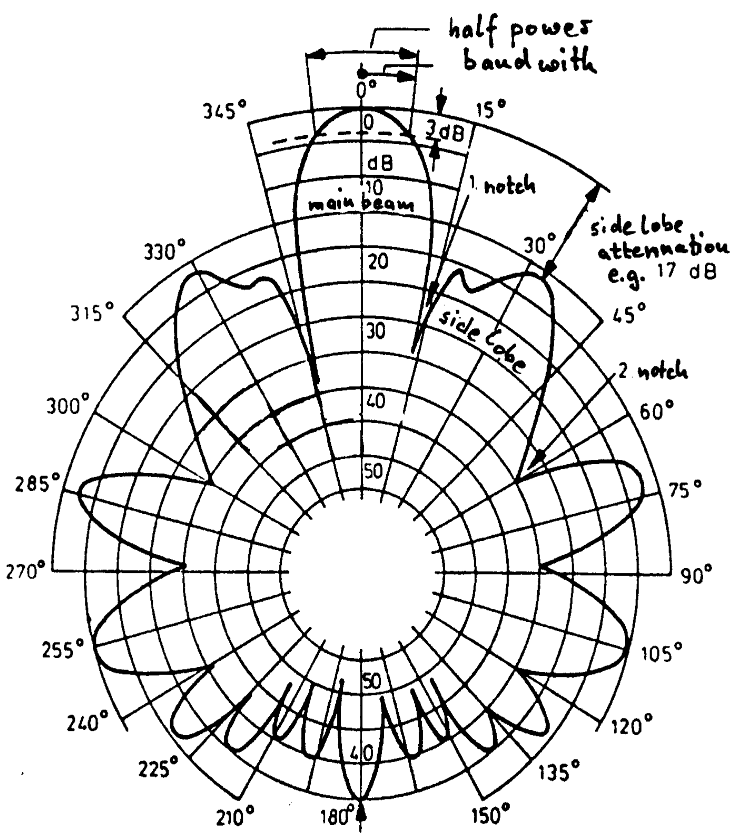
Bandwidth	(GHz)	14.4 - 15.35	14.4 - 15.35	14.4 - 15.35
Model number		PA 2 - 144	PA 4 - 144	PA 6 - 144
Nominal diameter	(m)	0.6	1.2	1.8
	(ft)	2	4	6
Half-power beamwidth	(deg)	2.3	1.2	0.8
Gain low band	(dBi)	36.2	42.3	45.8
Gain mid band	(dBi)	36.5	42.5	46.0
Gain high band	(dBi)	36.7	42.8	46.3
Front-to-back ratio	(dB)	42	48	52
Cross polar discrimination	(dB)	28	30	30
Return loss	(dB)	26	26	28
Weight	(kg)	19	43	73
Windload				
Elevation adjustment	(deg)	+/- 5	+/- 5	+/- 5

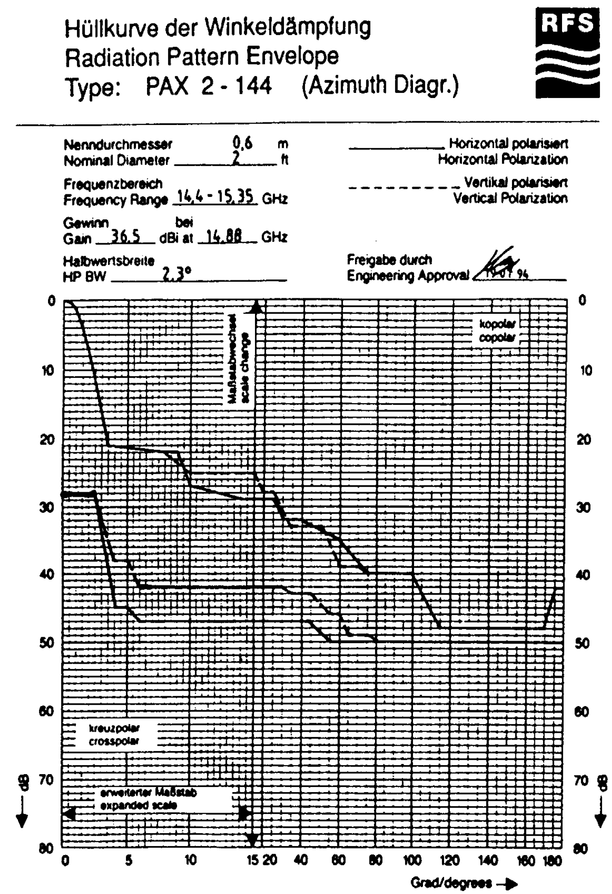
Bandwidth	(GHz)	14.4 - 15.35	14.4 - 15.35	14.4 - 15.35
Model number		DA 2 - 144	DA 4 - 144	DA 6 - 144
Nominal diameter	(m)	0.6	1.2	1.8
	(ft)	2	4	6
Half-power beamwidth	(deg)	2.3	1.2	0.8
Gain low band	(dBi)	36.2	42.3	45.8
Gain mid band	(dBi)	36.5	42.5	46.0
Gain high band	(dBi)	36.7	42.8	46.3
Front-to-back ratio	(dB)	65	68	68
Cross polar discrimination	(dB)	28	30	30
Return loss	(dB)	26	26	26
Weight	(kg)	28	55	130
Windload				
Elevation adjustment	(deg)	+/- 12	+/- 12	+/- 12

Parabolic antenna 15 GHz

High performance antenna 15 GHz

Radiation pattern envelope





Feeders (1)

- Coaxial cables or waveguides (according to frequency)
- Most important characteristic: loss and return loss
- Coaxial cables
  - Used between 10 MHz and 3 GHz
  - Dielectric material: foam or air
  - Parameters of common coaxial cables:

type	dielectric	diameter (mm)	loss (dB/100m)	power rating (kW)	bending radius (mm)
LCF 1/2’ CU2Y	foam	16.0	10,9 / 2 GHz	0.47	200
			13.8 / 3 GHz		
LCF 7/8’ CU2Y	foam	28.0	6.5 / 2 GHz	0.95	360
			8.5 / 3 GHz		
LCF 1 5/8’ CU2Y	foam	49.7	4.4 / 2 GHz	1.7	380
			5.6 / 3 GHz		

Feeders (2)

- Waveguides
  - Used for frequency bands above 2.7 GHz
  - Three basic types available: circular, elliptical and rectangular
- Rigid circular waveguide
  - Very low loss
  - Supports two orthogonal polarisations
  - Capable to carry more than one frequency band
  - Usually, short components of this type are used
  - Disadvantages: cost, handling and moding problems

Feeders (3)

- Elliptical semiflexible waveguides
  - Acceptable loss, good VSWR performance
  - Low cost and easy to install
  - Various types optimised for many frequency bands up to 23 GHz
  - Used for longer distances (easy and flexible installation)
  - Can be installed as a "single run" (no intermediate flanges)

type	loss / 100 m	Frequency
EW 34	2.0	4 GHz
EW 52	4.0	6GHz
EW 77	5.8	8GHz
EW 90	10.0	11 GHz
EW 220	28.0	23 GHz

Feeders (4)

- Solid and flexible rectangular waveguides
- Solid rectangular waveguides
  - Combination of low VSWR and low loss
  - High cost and difficult to install
  - Used for realising couplers, combiners, filters

type	loss / 100 m	Frequency
WR 229	2.8	4 GHz
WR159	4.5	6GHz
WR112	8.5	8GHz
WR 90	11.7	11 GHz
WR 75	15.0	13 GHz

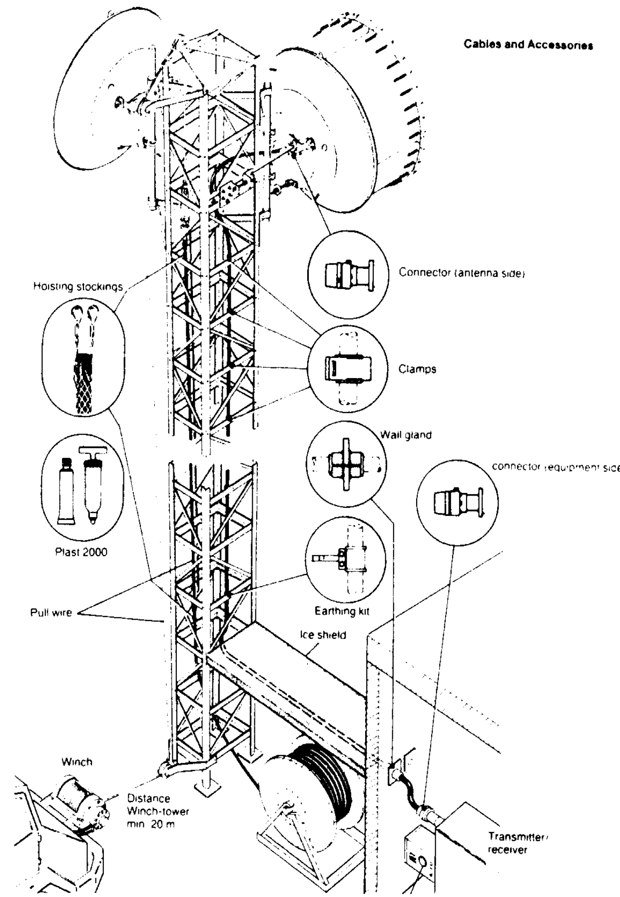
Feeders (5)

- Flexible rectangular waveguides
  - Worse VSWR and losses than for solid waveguides
  - Often used in short lengths (<1 m), where position between connection points depends on actual installation place
  - Common applications: connection of microwave system to antenna (close together on rooftops or towers) for frequencies >13 Ghz

type	loss / m	Frequency
PDR140	0.5	15GHz
PDR180	1	18 GHz
PDR220	2	23 GHz

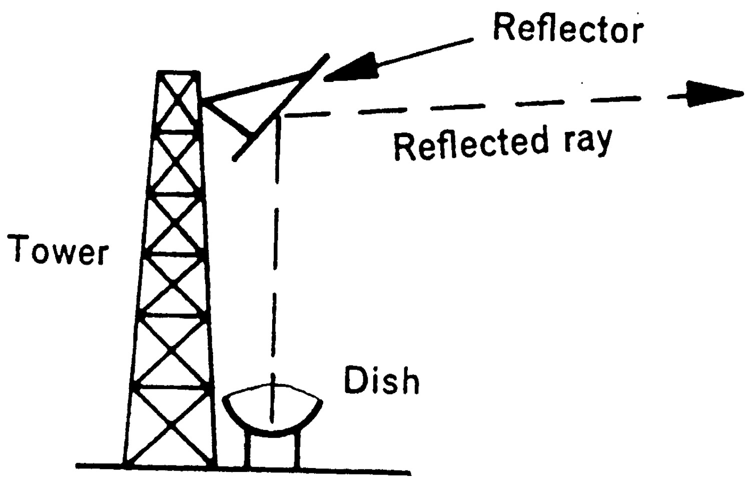
Antenna feeder systems (1)

- Direct radiating system
  - Most commonly used for frequencies up to 13 Ghz
  - Depending on accepted feeder loss/length, higher frequencies may be possible
  - Excessive attenuation and costs in long runs of wave guide
  - Occurence of echo distortion due to mismatch in long runs of waveguide possible



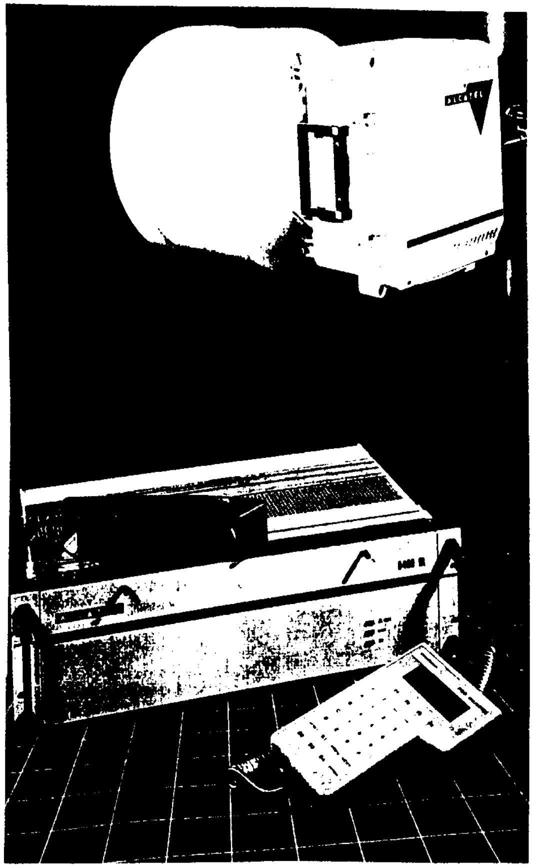
Antenna feeder systems (2)

- Periscope antenna system
  - Used for
    - considerable antenna heights
    - waveguide installation problems
  - Negligible wave guide cost and easy installation
  - System gain is a function of antenna and reflector size, distance and frequency
  - Used above 4 GHz , because reflector size is prohibitive for lower frequencies

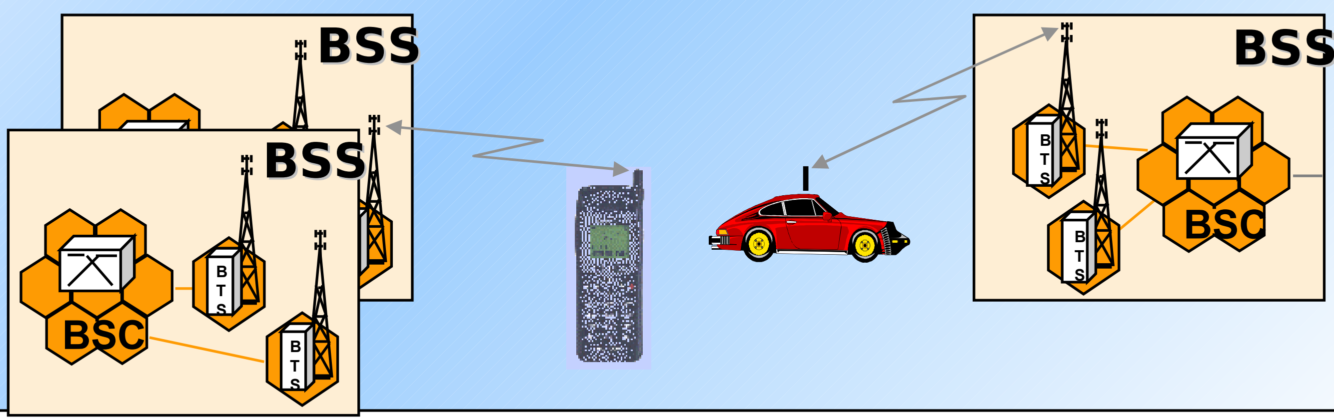


Antenna feeder systems (3)

- Combined antenna with transceiver
  - Antenna and transceiver are combined as a single unit to cut out wave guide loss (higher frequencies)
  - Units are mounted on top of a mast and connected to multiplex equipment via cable

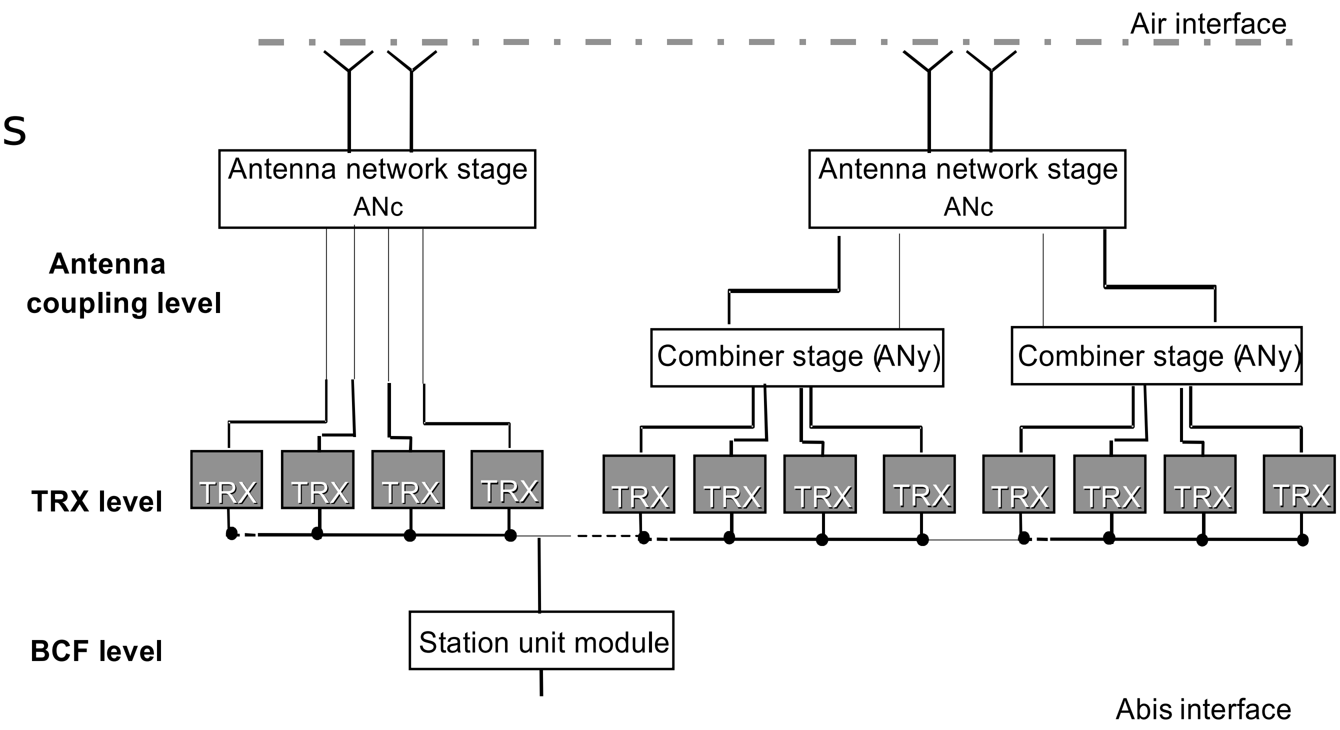


Alcatel BSS (Examples)



Architecture of BTS - Evolium Evolution A9100

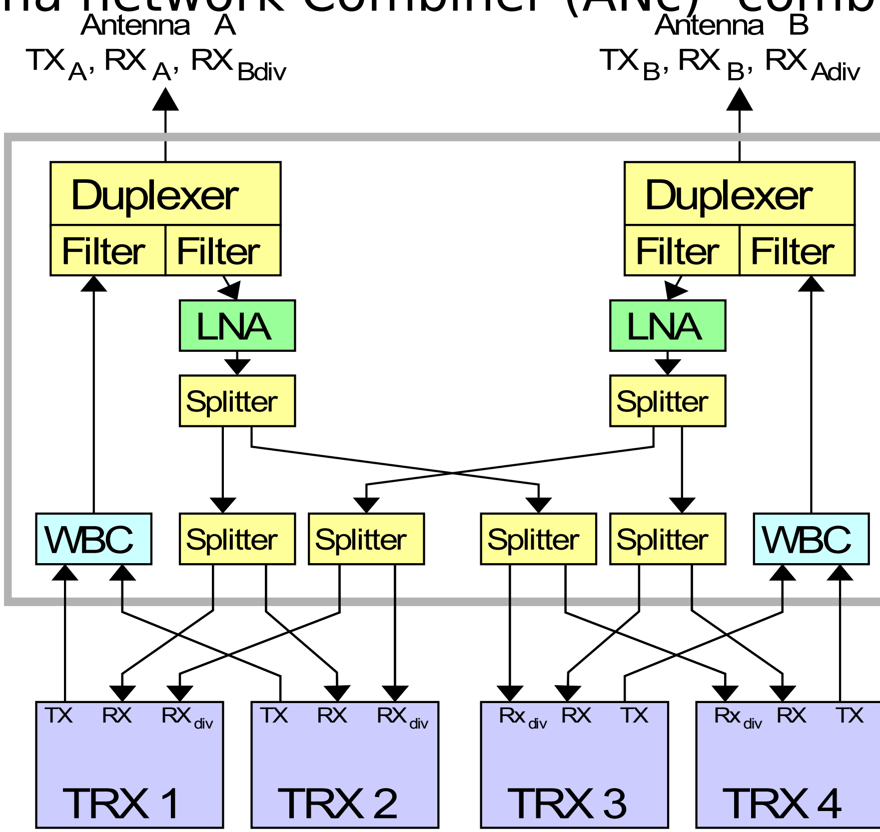
- 3 levels



Abbreviations
BCF Base station Control Function
TRX Transceiver

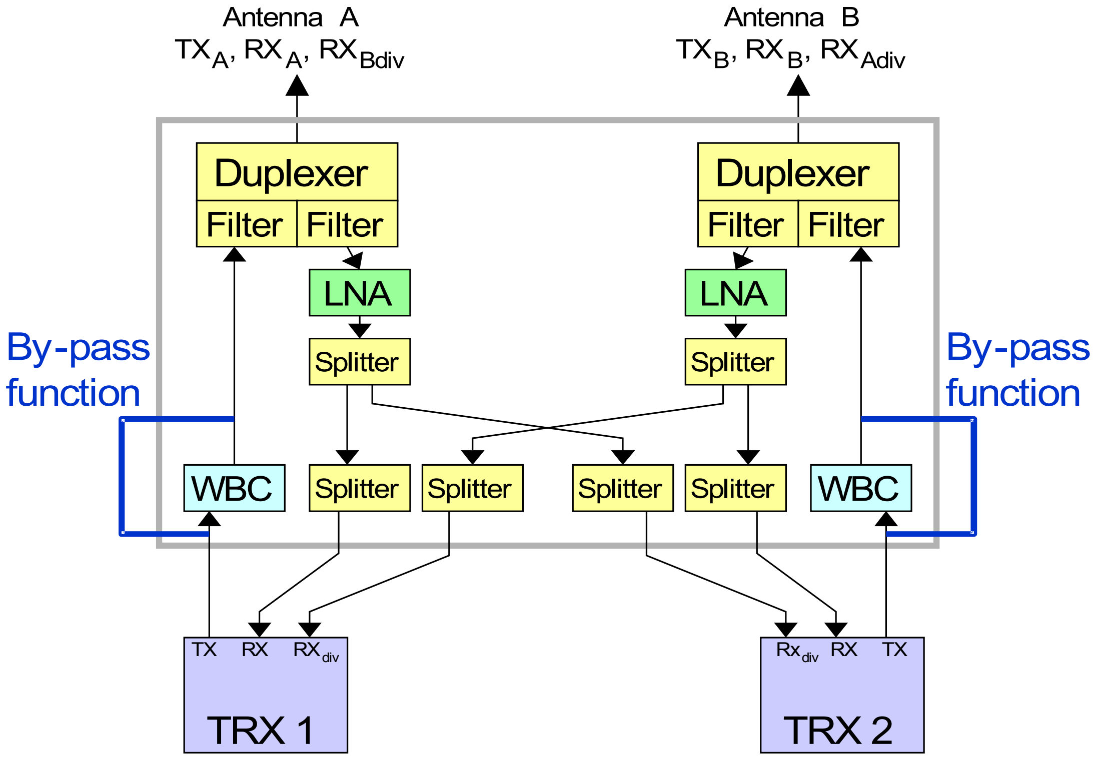
EVOLIUM™ A9100 Base Station (1)

- The Antenna network Combiner (ANc)- combining mode



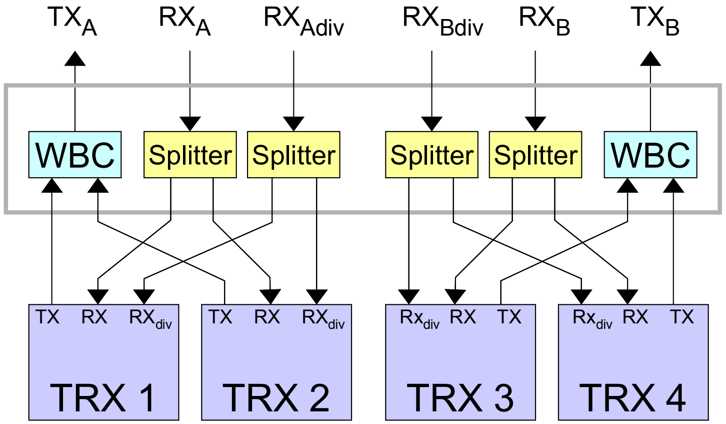
EVOLIUM™ A9100 Base Station (2)

- The Antenna network Combiner (ANc)- bypass mode



EVOLIUM™ A9100 Base Station (3)

ANy: Twin Wide Band Combiner Stage



2 types of Any

For GSM 900 and GSM 1800, two versions each are available:

Band	Variant	Function
GSM 900	3BK 07237 **AA**xx	Up to four standard TRX, up to two high-power TRX
	3BK 07237 **AB**xx	Up to four standard TRX, up to four high-power TRX
GSM 1800	3BK 07245 **AA**xx	Up to four standard TRX, up to two high-power TRX
	3BK 07245 **AB**xx	Up to four standard TRX, up to four high-power TRX

EVOLIUM™ BTS Features (1)

- **Standard Features according to GSM**
  - DR (Dual Rate), EFR (Enhanced Full Rate coder), AMR (Adaptive Multi Rate) requires that the BSS software release and the other network elements also support these codecs
  - HW supports GSM 850, E-GSM, GSM 900, GSM 1800 and GSM 1900 bands
  - Multi Band Capabilities (supporting of 850/1800 TRX, 850/1900TRX, and, 900 /1800 can be located in the same cabinet)
  - All known A5 algorithms to be supported; HW provisions done
- **Standard Features due to new Architecture and new SW Releases**
  - SUS (Station Unit Sharing)
    Only one central control unit (SUM) for all BTS per cabinet
  - Multiband BTS (GSM 900/1800) in one cabinet
  - Static (Release 4) and statistical (Release 6) submultiplexing on Abis
    - Better use of Abis-interface capacity: More BTS/TRX to be supported in a multidrop loop
  - Introduction of GPRS and HSCSD without HW changes
  - EDGE compatible TRX

EVOLIUM™ BTS Features (2)

- **Features specific to Radio Performance**
  - TX Output Power

Frequency band	TX output power, **GMSK**	TX output power, **8-PSK (EDGE)**
GSM 850	45 W = 46.5 dBm –0.5/+1 dB	15 W = 41.8 dBm –0.5/+1 dB (4.7dB backoff included)
GSM 900 MP	45 W = 46.5 dBm –0.5/+1 dB	15 W = 41.8 dBm –0.5/+1 dB (4.7dB backoff included)
GSM 900 HP	60 W = 47.8 dBm –0.5/+1 dB	25 W = 44.0 dBm –0.5/+1 dB (3.8dB backoff included)
GSM 1800 MP	35 W = 45.4 dBm –0.5/+1 dB	12 W = 40.8 dBm –0.5/+1 dB (4.7dB backoff included)
GSM 1800 HP	60 W = 47.8 dBm –0.5/+1 dB	25 W = 44.0 dBm –0.5/+1 dB (3.8dB backoff included)
GSM 1900	45 W = 46.5 dBm –0.5/+1 dB	25 W = 44.0 dBm –0.5/+1 dB (2.5dB backoff included)

  - RX Se
    (GS.
  - Synthesized Frequency Hopping as general solution
    - Standard RF hopping mode
    - Pseudo baseband RF hopping mode
  - Antenna Diversity in general
    - Two antennas per sector
    - One cross-polarized antenna
  - Duplexer (TX and RX on one antenna) as general solution

Generic Configurations for A9100 G4 BTS

- The configurations for indoor (MBI) and outdoor (MBO) cabinet are presented in the next slides
- larger configurations with more than one cabinet can be derived from the tables
- configurations are valid for EDGE capable TRX (Evolution step 2)
- availability of multiband configurations other than GSM 900 / GSM 1800 must be checked with product management (authorization required)
- Notation:
  - BBU - Battery Backup Unit
  - BATS - Small Battery Backup
  - LBBU - Large Battery Backup Unit

Generic configurations for cabinets MBI (1)

RACK	CONFIGURATION TYPE	DC	AC w/o BBU	AC with BATS	AC with LBBU	GSM 850	GSM 900	GSM 1800	GSM 1900
Standard configurations									
MBI3	1x1...4		X	X		(2)	X	X	X
MBI3	1x1...8	X				(2)	X	X	(1)
MBI3	2x1...2		X	X		(2)	X	X	X
MBI3	2x1...4	X				(2)	X	X	(1)
MBI3	3x1		X	X		(2)	X	X	X
MBI3	3x1...2	X				(2)	X	X	X
MBI5	1x1...8	X	X	X	X	X	X	X	X
MBI5	1x9...12	X	X	X		(2)	X	X	(1)
MBI5	2x1...4				X	(2)	X	X	X
MBI5	2x1...6	X	X	X		X	X	X	(1)
MBI5	1x1...8+1x1...4	X	X	X		(2)	X	X	
MBI5	3x1...2				X	(2)	X	X	X
MBI5	3x1...4	X	X	X		X	X	X	(1)
MBI5	4x1. . 3	X				X	X	X	(1)
MBI5	2x4 + 2x2	X				X	X	X	(1)

(1) Restrictions for GSM 1900:

(1) Up to +45°C ambient temperature possible if maximum 6 TREs in MBI3, 10 TREs in MBI5

(2) Limitation to +40°C otherwise (+45°C possible if power is reduced to 28W (P_{max} –2 dB))

(2) Not in generic list, but possible (check with SD or product management before use)

Generic configurations for cabinets MBI (2)

RACK	CONFIGURATION TYPE	DC	AC w/o BBU	AC with BATS	AC with LBBU	GSM 850	GSM 900	GSM 1800	GSM 1900
Low Losses configurations									
MBI3	1x3...4	X	X	X		(2)	X	X	X
MBI5	1x3...8	X	X	X	X	(2)	X	X	X
MBI5	1x9...12	X	X	X		(2)	X	X	(1)
MBI5	2x3...6	X				(2)	X	X	(1)
High Power configurations									
MBI3	2x1	X	X	X			X	X	
MBI5	1x1...4	X	X	X			X	X	
MBI5	2x1...4	X	X	X			X	X	
MBI5	3x1...3	X	X	X			X	X	
Extended Cells configurations									
MBI5	1x1...4LL/1x1...4	X	X	X	X		X		
MBI5	1x1...4/1x1...4 with TMA	X	X	X	X		X		

(1) Restrictions for GSM 1900:
- (1) Up to +45ºC ambient temperature possible if maximum 6 TREs in MBI3, 10 TREs in MBI5
- (2) Limitation to +40ºC otherwise (+45ºC possible if power is reduced to 28W (P_{max} –2 dB))

(2) Not in generic list, but possible (check with SD or product management before use)

Generic configurations for cabinets MBO (1)

RACK	CONFIGURATION TYPE	DC	AC w/o BBU	AC with BBU	GSM 850	GSM 900	GSM 1800	GSM 1900
Standard configurations								
CBO	1x1…2			X	(1)	X	(2)	(1)
CBO	2x1			X	(1)	X	(2)	(1)
MBO1	1x1...6			X				X
MBO1	1x1...8			X	X	X	X	
MBO1	2x1...3			X				X
MBO1	2x1...4			X	X	X	X	
MBO1	3x1...2			X	X	X	X	X
MBO2	1x9...12			X	X	X	X	X
MBO2	2x1...6			X	X	X	X	X
MBO2	1x1...8+1x1...4			X	X	X	X	X
MBO2	3x1...4			X	X	X	X	X
MBO2	4x1…3			X	X	X	X	X
MBO2	2x4 + 2x2			X	X	X	X	X

(1) CBO for GSM 850 and GSM 1900 are planned for 2004. For availability, check with SD or the product management (authorization required).
(2) CBO for GSM 1800 planned for Q4 2003 (check with SD)

Generic configurations for cabinets MBO (2)

RACK	CONFIGURATION TYPE	DC	AC w/o BBU	AC with BBU	GSM 850	GSM 900	GSM 1800	GSM 1900
Low Losses configurations								
MBO1	1x5...6			X				X
MBO1	1x5...8			X	X	X	X	
MBO2	2x3...6			X	X	X	X	X
MBO2	3x3...4			X	X	X	X	X
High Power configurations								
CBO	1x1…2			X		X	(2)	
CBO	2x1			X		X	(2)	
MBO1	1x1...4			X		X	X	
MBO1	2x1...2			X		X	X	
MBO1	3x1...2			X		X	X	
MBO2	2x1…4			X		X	X	
MBO2	3x1…4			X		X	X	

(1) CBO for GSM 850 and GSM 1900 are planned for 2004. For availability, check with SD or the product management (authorization required).

(2) CBO for GSM 1800 planned for Q4 2003 (check with SD)

TRX Types

- This slide is referring only to Evolium macro BTS A9100
- Overview on TRX types of A9100 Evolium Evolution BTS (G4)

Module name		Output power			
		GMSK		8PSK	
Evolution Step 1					
TRGM	GSM 900	35 Watts	45.44 dBm		
TRDM	GSM 1800	35 Watts	45.44 dBm		
TRDH	GSM 1800	60 Watts	47.78 dBm		
Evolution Step 2					
TRAL	GSM 850	45 Watts	46.53 dBm	15 Watts	41.76 dBm
TRAG	GSM 900	45 Watts	46.53 dBm	15 Watts	41.76 dBm
TAGH	GSM 900	60 Watts	47.78 dBm	25 Watts	43.98 dBm
TRAD	GSM 1800	35 Watts	45.44 dBm	12 Watts	40.79 dBm
TADH	GSM 1800	60 Watts	47.78 dBm	25 Watts	43.98 dBm
TRAP	GSM 1900	45 Watts	46.53 dBm	25 Watts	43.98 dBm

BTS Output Power

- What is monitored during validation is the BTS output power at antenna connector
- The individual losses for duplexer, combiner and internal cabling are not systematically measured
- for detailed info consult the BTS product description

Feature Power Balancing

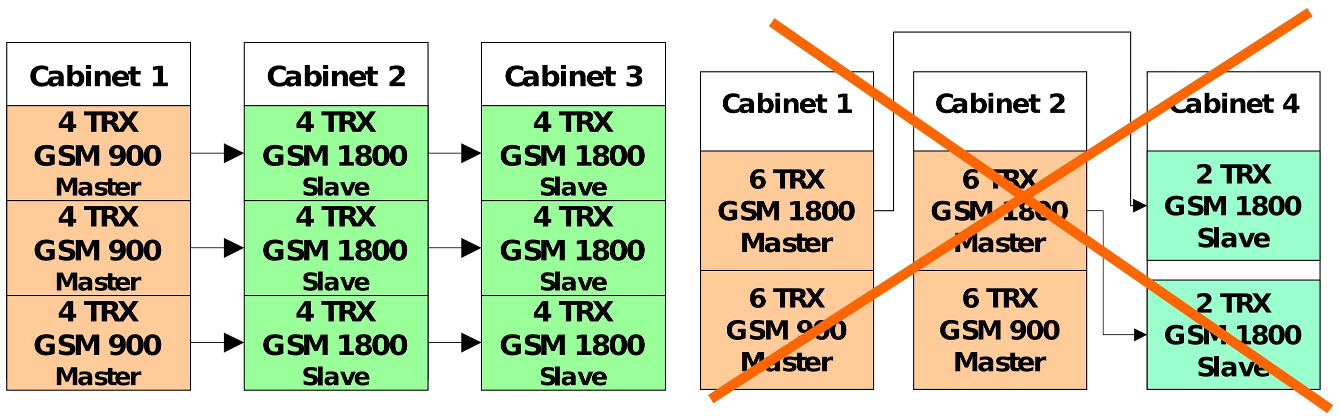
- G4 BTS it is allowed to use TRXs of different power within the same sector, or to use of different combining path for TRX belonging to the same sector.
- Reason: the G4 BTS is able to detect unbalanced losses/powers within a sector and automatically compensate it for GMSK modulation.
- Consequence: All TRX connected to one ANc are automatically adjusted to the GMSK output power of the weakest TRX (required for BCCH recovery)

Cell Split Feature

- Principle
  - Cell Split allows to provide one logical cell with one common BCCH over several BTS cabinets. The cabinets must be synchronized
- Benefits
  - Same number of TRX in fewer racks
  - No need to touch/modify the configuration of existing BTS (cabling)
  - Take full benefit of 12 TRX per cabinet
- Drawback: more complex antenna system
- Applications
  - Multi-band cells
  - Configuration extension of sites by adding TRX
  - Large configurations
- Condition: BTS must be synchronized

Influence of Cell Split feature on BTS configurations

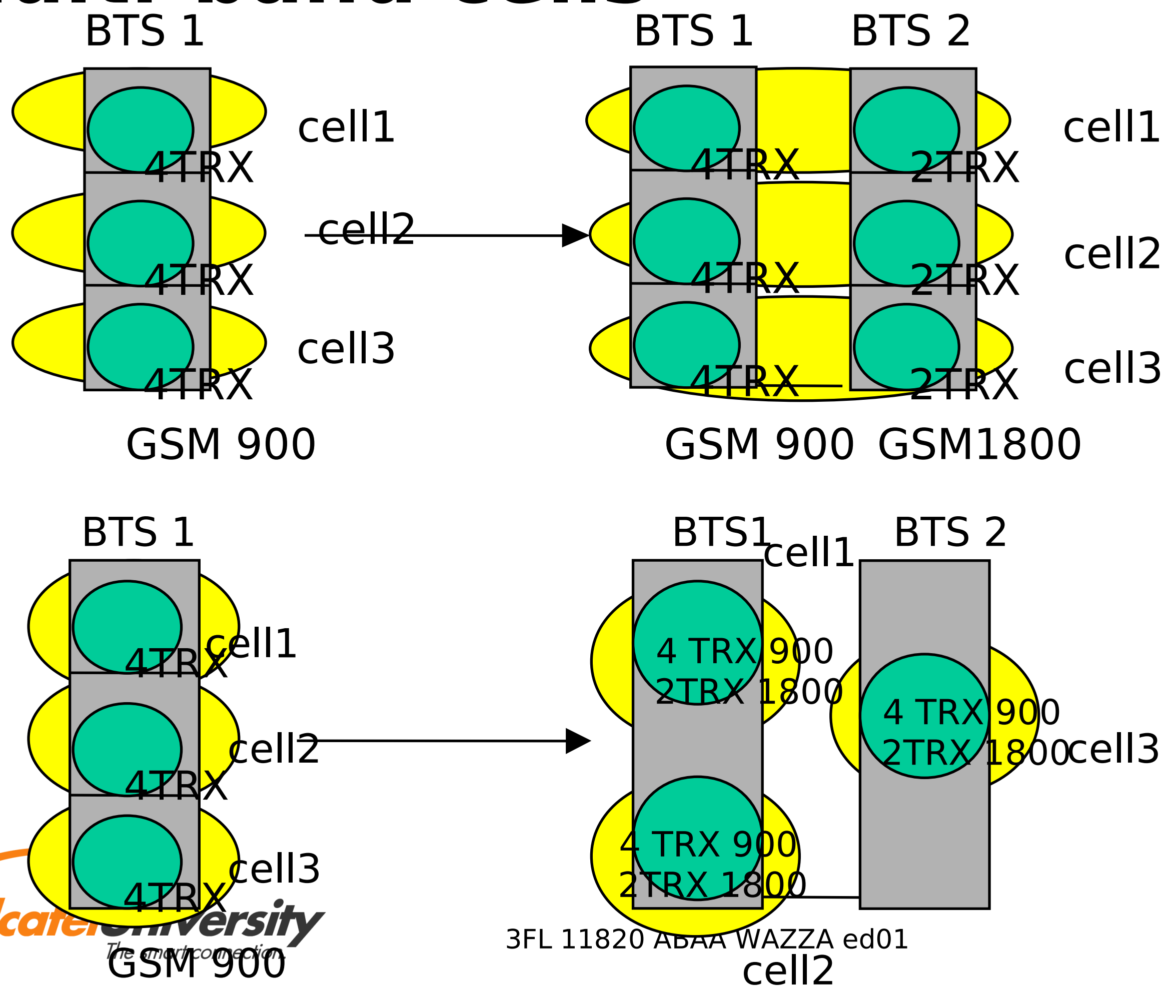
- One slave cabinet can only have one master
- One master can control three slave cabinets



Possible cell split configuration

Not allowed cell split configuration

Cell Split Example: Deployment of multi-band cells

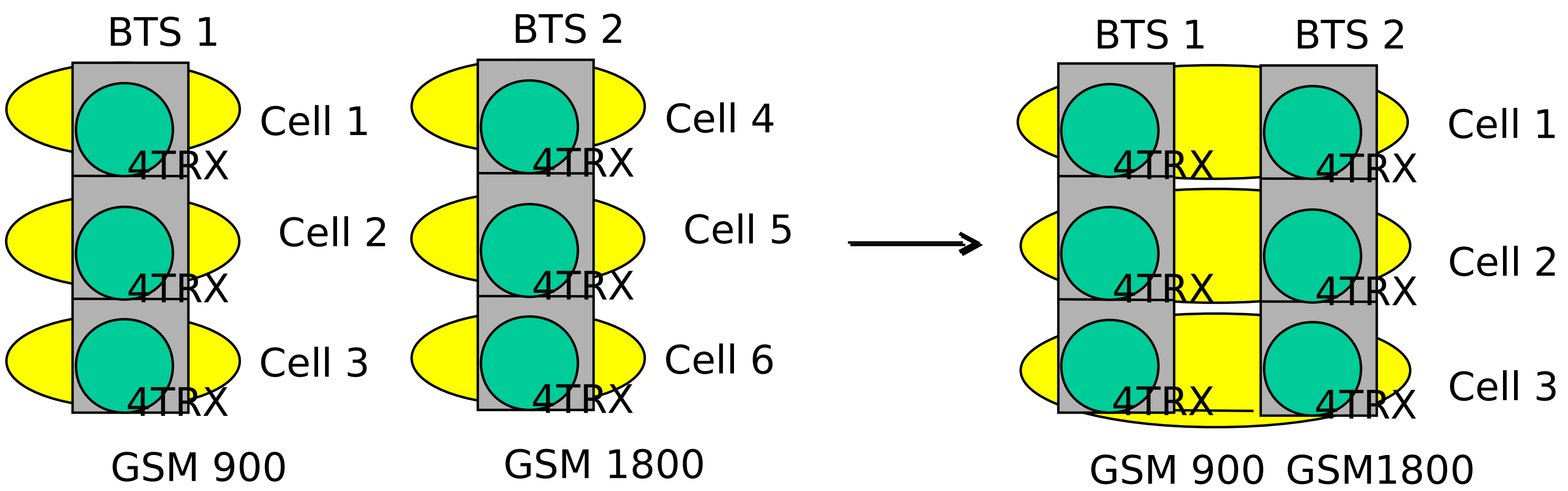


With cell split:
- No antenna re-cabling
- No TRX moving
- Connection to the first BTS while the BTS is working
- Short service interruption during radio conf. change

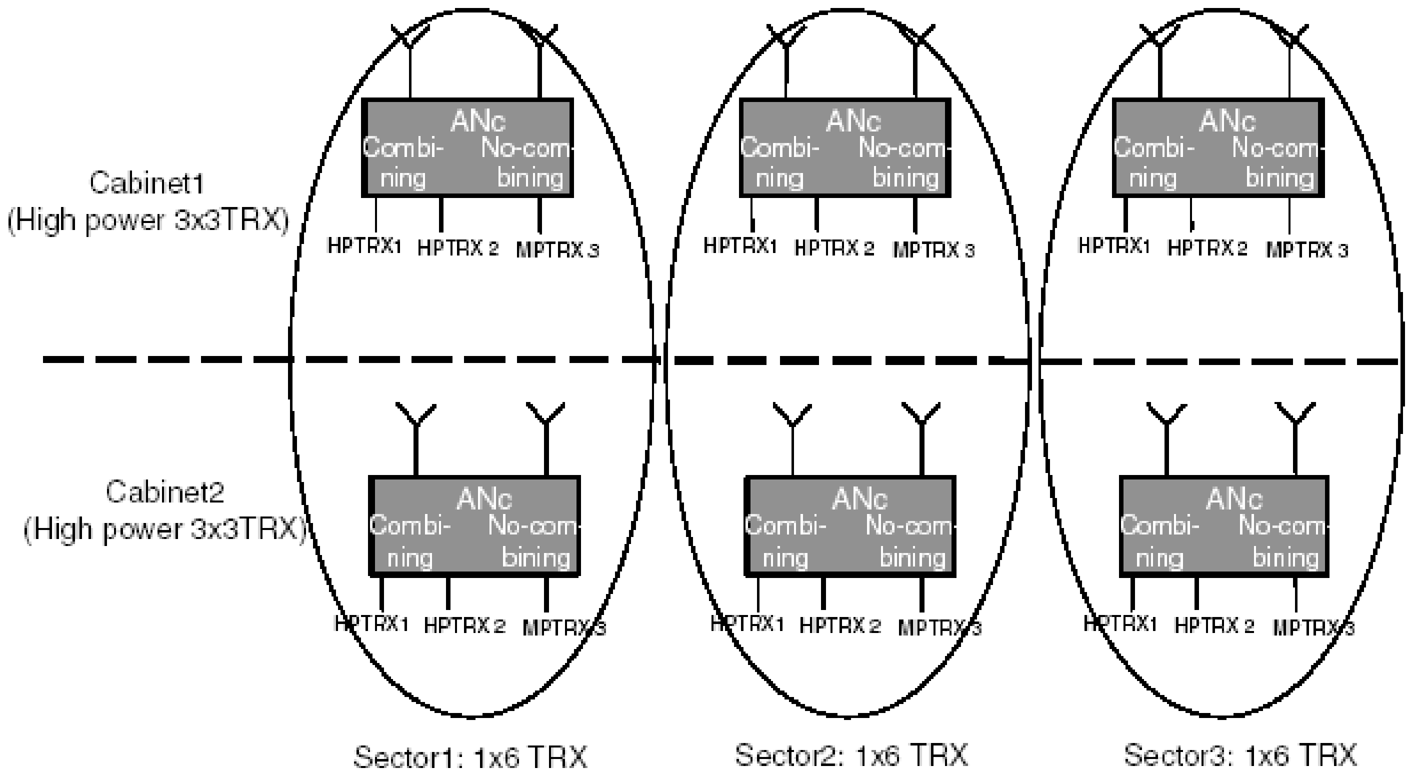
Without cell split:
- Complete re-configuration

Cell Split Example: Migration to multiband cells

- Example: Migration from multiband BSS (single BCCH) to multiband cells (dual BCCH)
- No more limitation to have the 900 and the 1800 TRX's installed inside the same cabinet

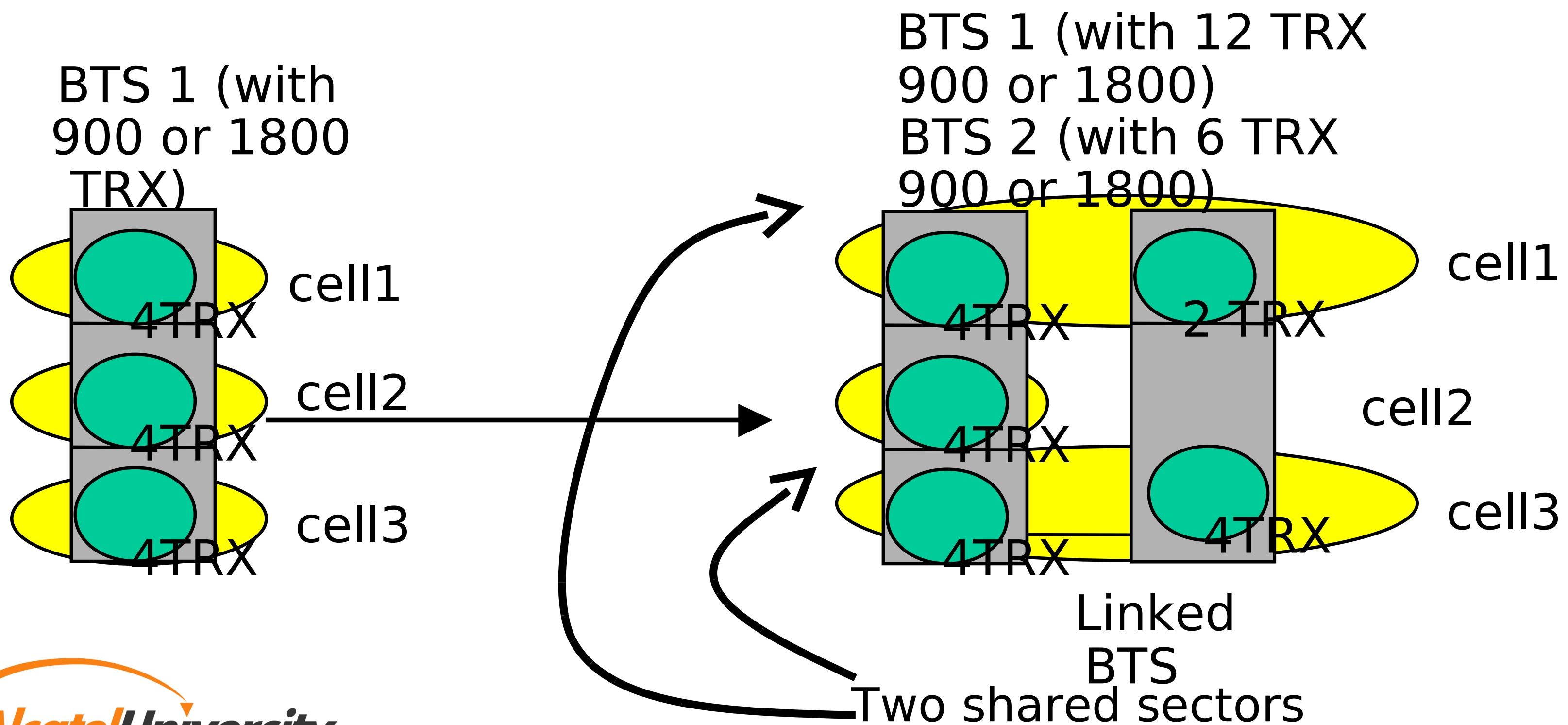


Cell Split Example: High Power Configuration



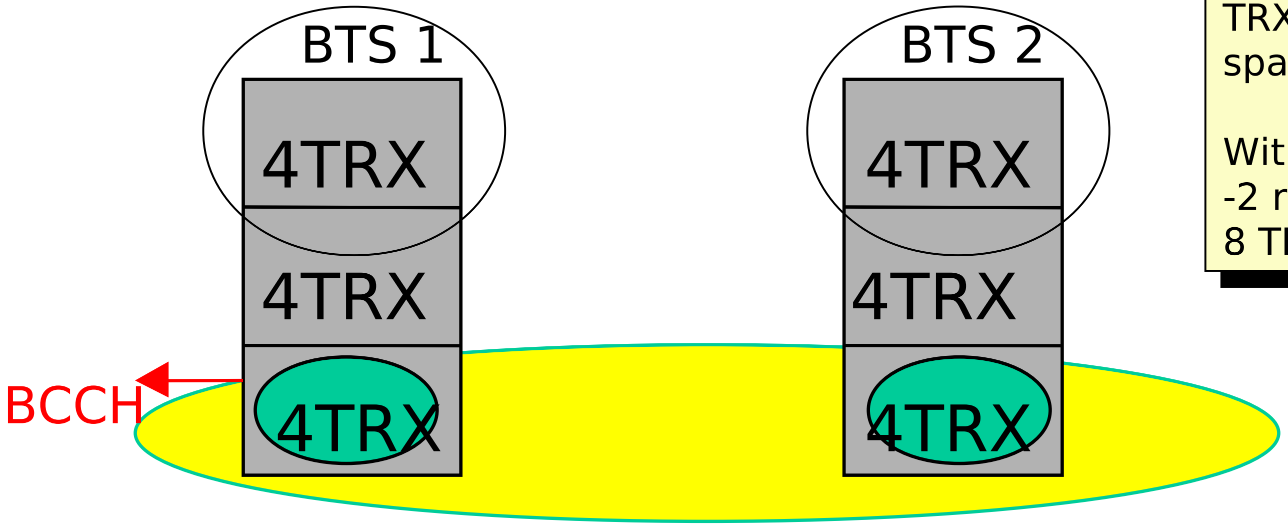
Cell Split Example: Configuration extension

- 3x4 sector cells extended to cell 1(6 TRX), cell 2 (4 TRX), cell 3 (8 TRX)



Cell Split Example: Large configurations

- 3x8 TRX with 2 racks:



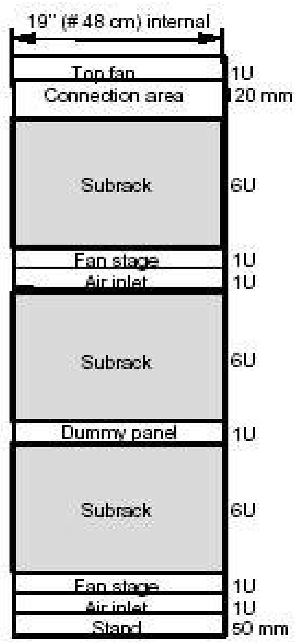
Without cell split:
-3 racks with 8 TRX/sector, empty space

With cell split:
-2 racks with 12 TRX, 8 TRX per sector

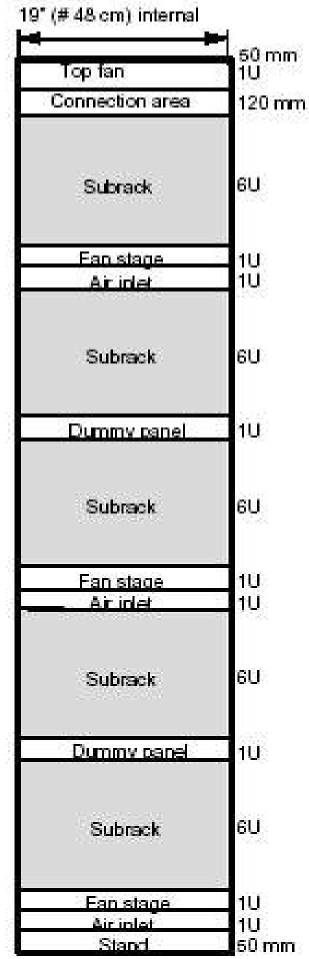
- 16 TRX's per cell

Indoor BTS Rack Layo

External dimensions	MBI3 BTS	MBI5 BTS
Depth	45 cm	45 cm
Height	130 cm	194 cm
Width	60 cm	60 cm
Max. TRX capacity	8 TRX	12 TRX



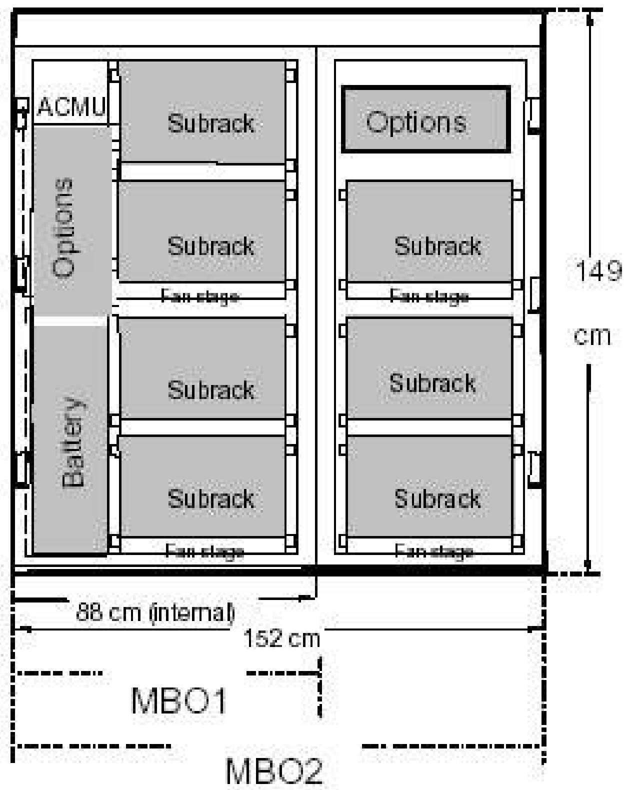
MBI3 BTS
(3 subracks)



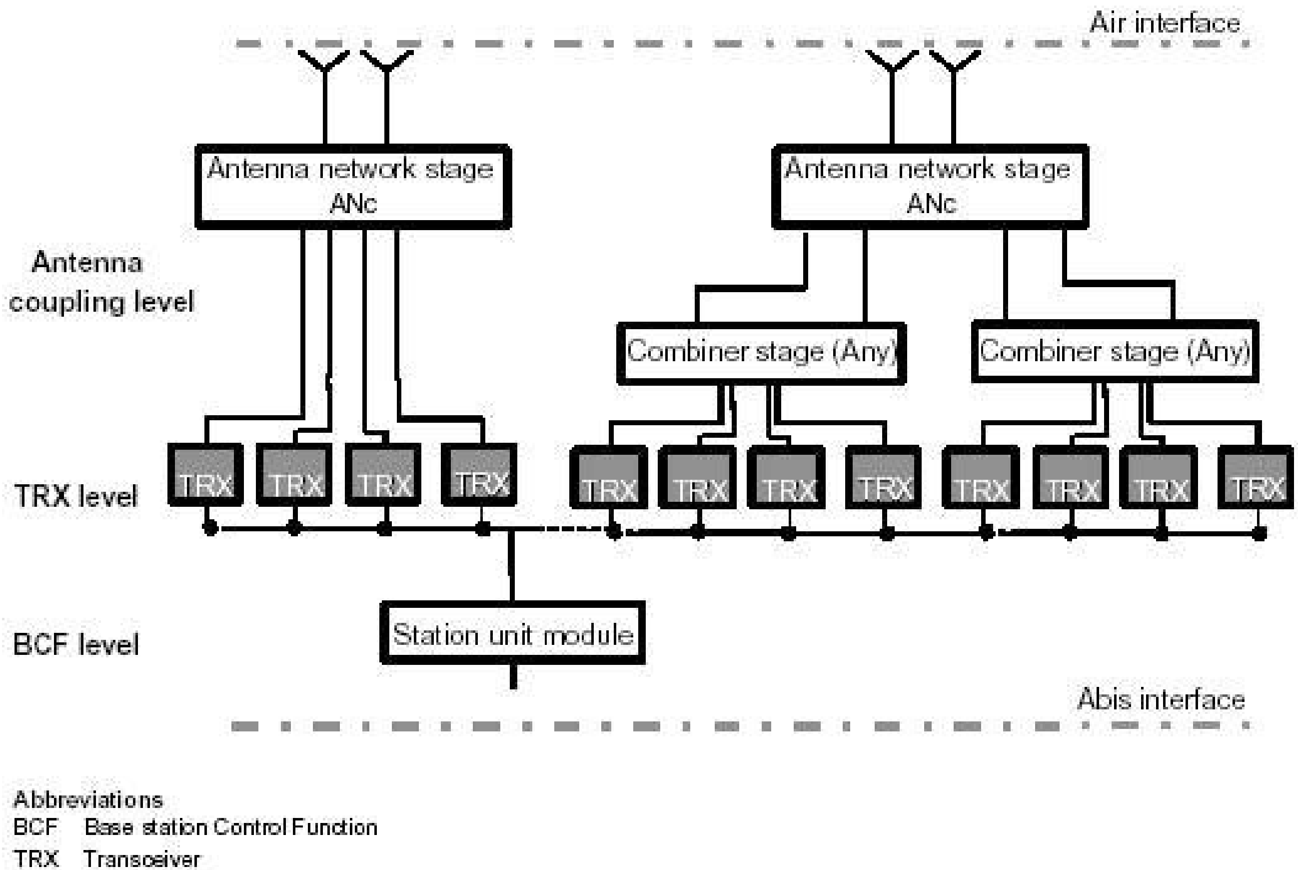
MBI5 BTS
(5 subracks)

Outdoor BTS Rack Layout

External dimensions	MBO1 BTS	MBO2 BTS
Depth	74 cm	74 cm
Height	149 cm	149 cm
Width	90 cm	152 cm
Max TRX capacity	8 TRX	12 TRX



3 Level Architecture



Micro BTS types

- EVOLIUM A910 Micro Base Station (internal reference M4M)
  - still operational in a large number
  - is being out phased
  - up to 6 TRX-es
- M5M EVOLIUM A9110 Micro-BTS (M5M)
  - Introduced in Q3 2003
  - up to 12 TRX-es
  - site configurations can mix older A910 with newer A9110-E
  - support for GPRS and EDGE (release dependent)

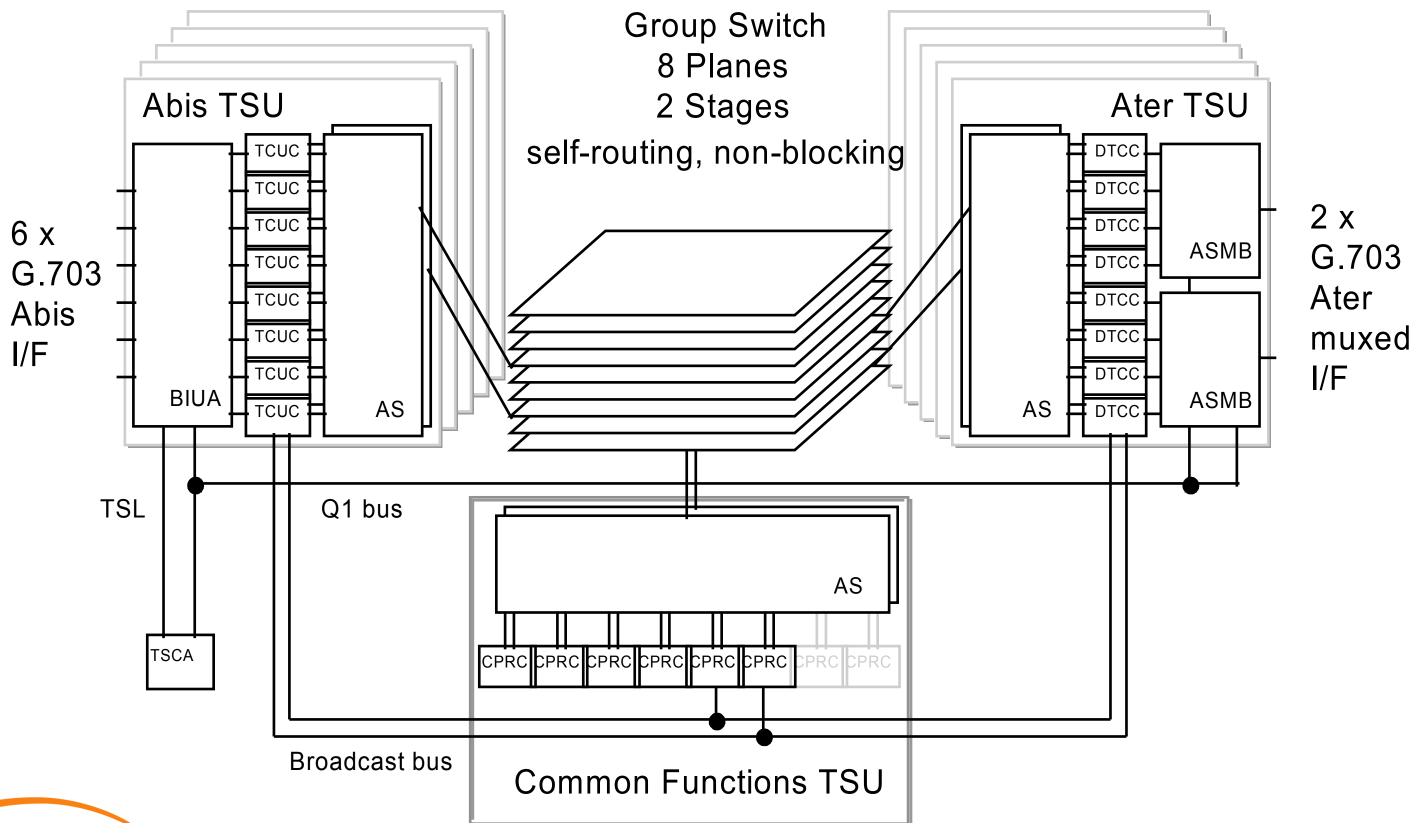
Technical Data

	A910 (2 TRX)	A9110 (2 TRX)
Frequency band	GSM 850, E-GSM, GSM900, GSM 1800, GSM 1900	GSM 850, E-GSM, GSM900, GSM 1800, GSM 1900
Tx output power (at antenna connector)	Up to 4.5 W	7 W
Rx sensitivity	-107 dBm	-110 dBm
Radio FH	Yes	yes
Temperature range (max.)	55 °C	55 °C
Max. power consumption	130 W	145 W
Size (volume)	54 litres	54 litres
Weight	39.6 kg (incl. connection box)	32.5

Evolium™ BSC Characteristics

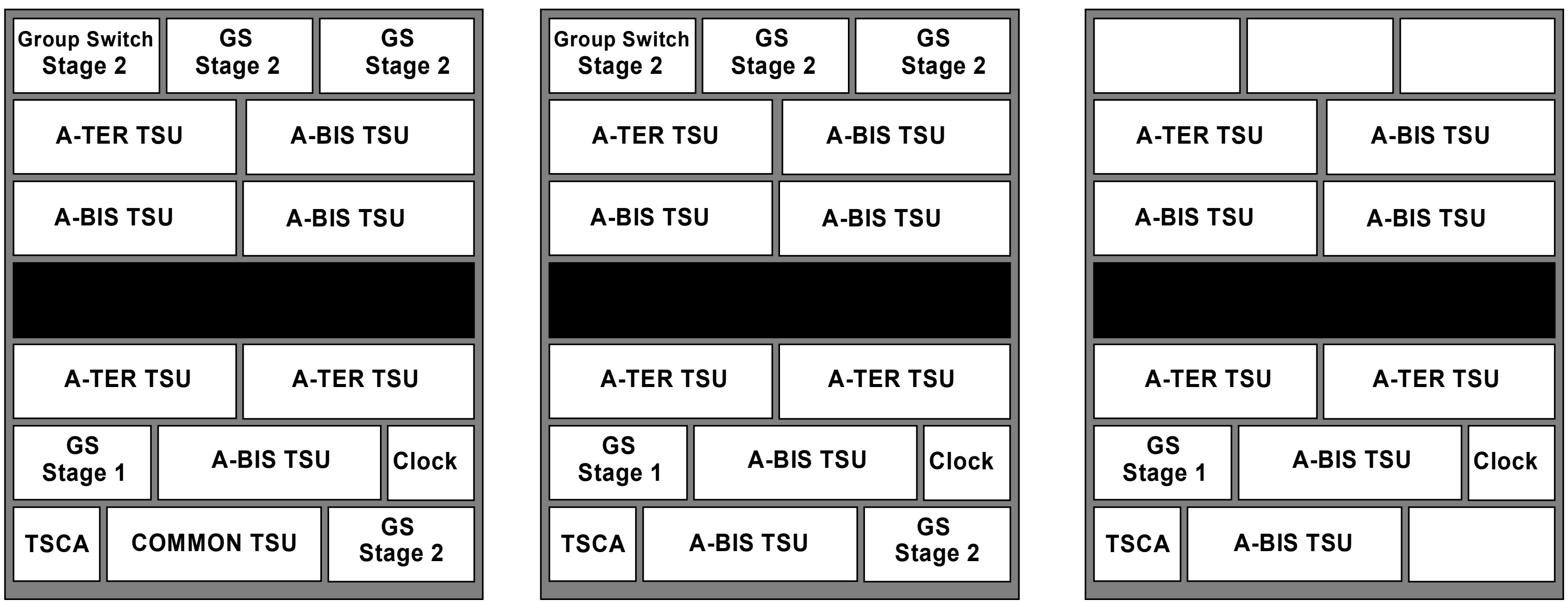
- Capacity
  - Maximum physical capacity: 352 FR TRX or 176 DR TRX in 255 BTS
  - Traffic and signalling capacity: up to 1500 erlang->∅13,5 erl/BTS traffic capacity
- Flexibility
  - 6 Abis interfaces per SM module with integrated cross connect function
  - Integrated in BSC subracks (no cabling), 100% Alcatel
  - No BSC internal recabling for network extensions/modifications
- Compactness
  - Maximum BSC configuration in three standard Alcatel 1000 S12 cabinets (90 cm width, 52 cm depth)
- Technology
  - Two stage Alcatel 1000 S12 switching technology
  - Distributed processing in trunk control units and processing resources
  - Same application SW running on both BSC generations

BSC Architecture



BSC Rack Layouts

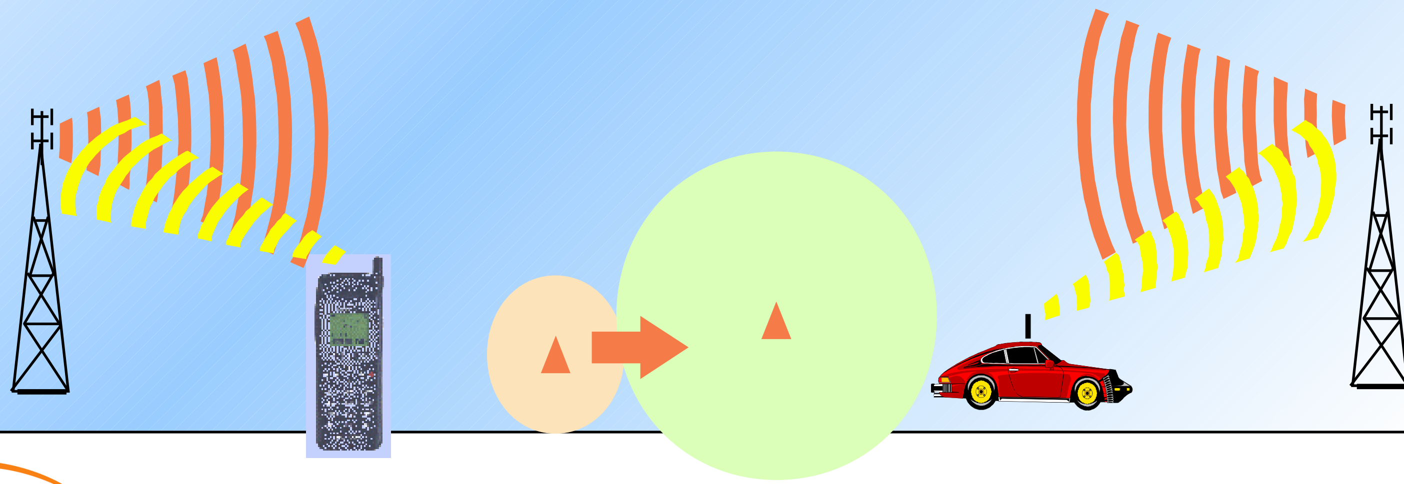
- 6 Configurations possible



Cabinet #1 Cabinet #2 Cabinet #3

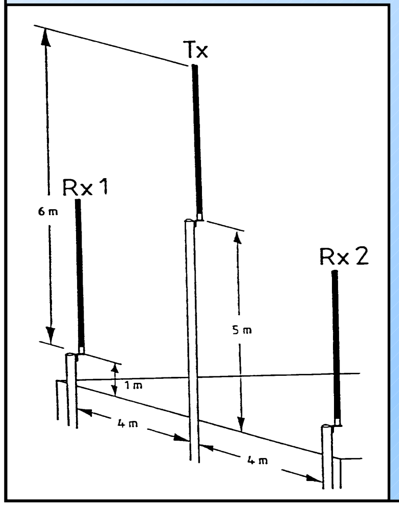
Coverage Planning

Coverage Improvement



Coverage Improvement

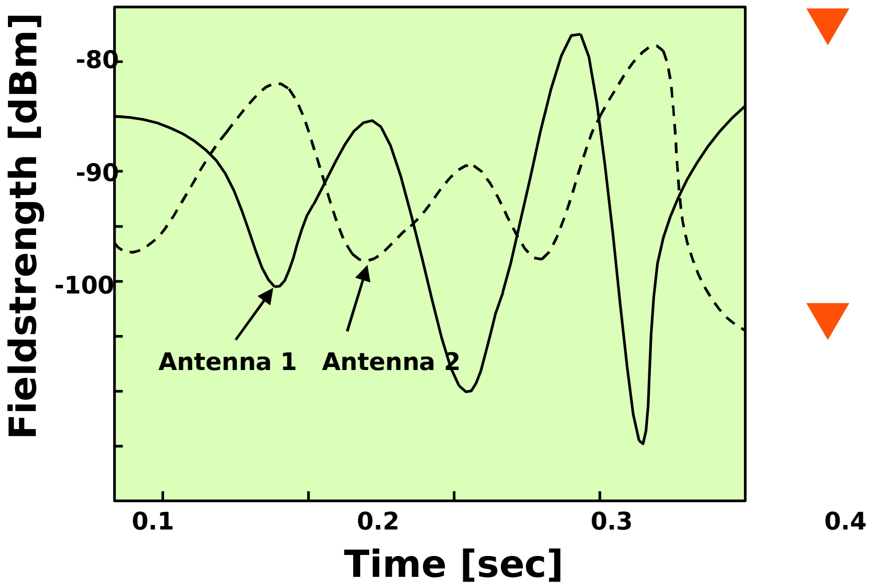
Antenna Diversity



Diversity

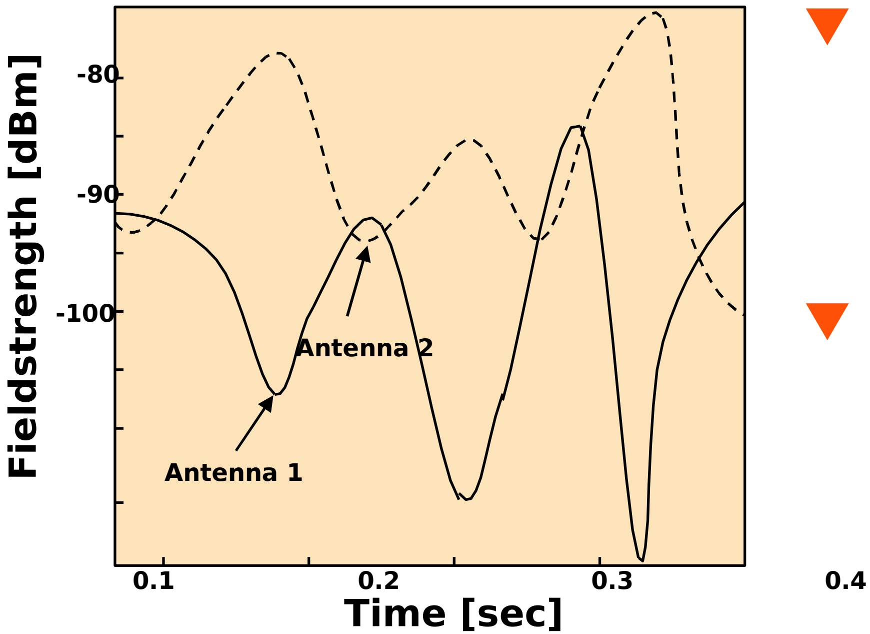
- Purpose
  - Improvement in fading probability statistics
  - leads to a better total signal level or better total S/N ratio
- Principle
  - Combining signals with same information from different signal branches
- Demands
  - correlation between different signal branches should be low
- Combining methods
  - Selection Diversity
  - Maximum Ratio Combining
  - Equal Gain Combining

Selection Diversity (1)



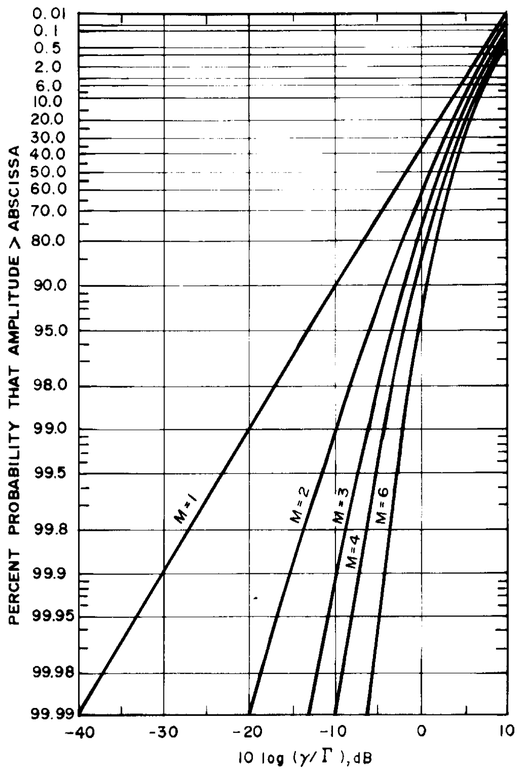
- Principle
  - selection of the highest baseband signal-to-noise ratio (S/N) or of the strongest signal (S+N)
- Correlation of signal levels
  - a lower correlation between signal levels of different branches improves the total signal level
- Correlation of signal levels should be low

Selection Diversity (2)



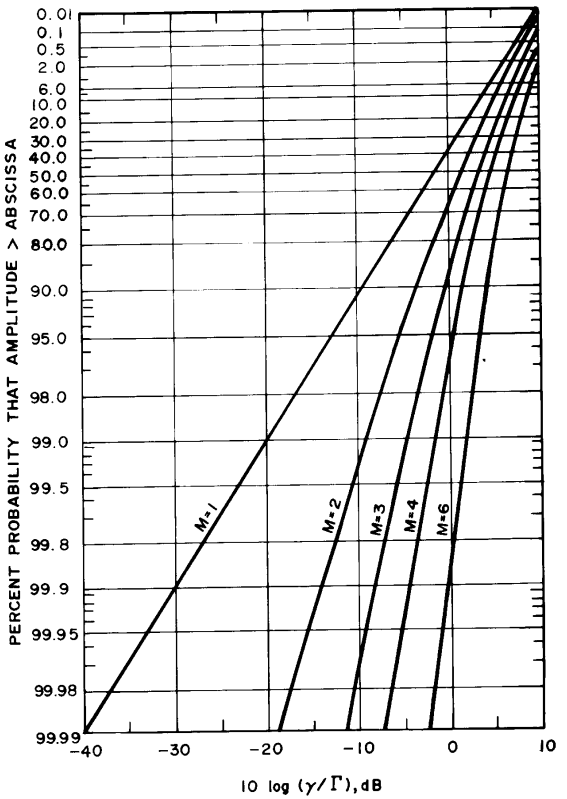
- Difference in signal level
  - a high difference in signal levels of two branches doesn’t improve the total signal level
- Difference in signal levels should be low

Selection Diversity (3)



- Theoretical diversity gain
  - 10dB for two-branch diversity at the 99% reliability level
  - 16dB for four branches at the 99% reliability level
- The theoretical diversity gain doesn’t improve linear with the number of branches

Equal Gain Combining (1)

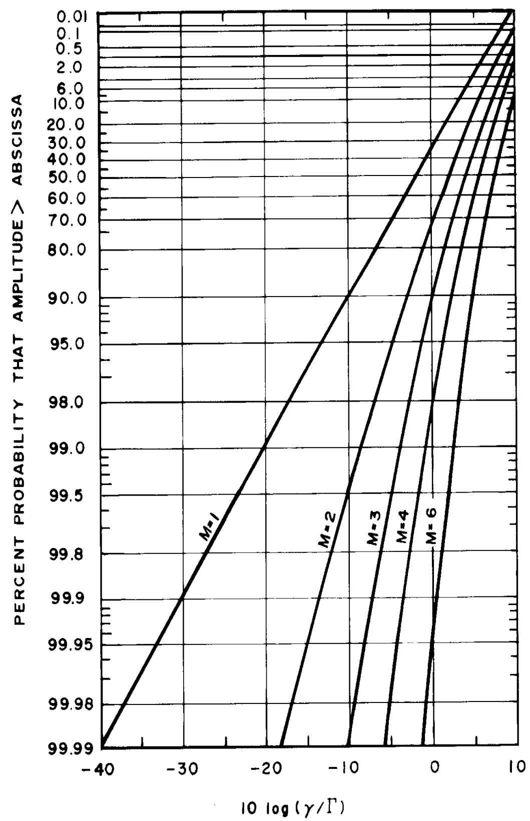


- Principle
  - cophase signal branches
  - sum up signals
- Coherent addition of signals and incoherent addition of noises
- Theoretical diversity gain
  - 11dB for two-branch diversity at the 99% reliability level

Equal Gain Combining (2)

- Correlation of signal levels
  - a lower correlation between signal levels of different branches improves the total S/N ratio
- Correlation of signal levels should be low
- Difference in signal level
  - Assuming equal noise in the branches, the higher the difference in signal levels is, the higher is the loss of S/N ratio of the better signal branch after summation
- Difference in signal levels should be low

Maximum Ratio Combining (1)



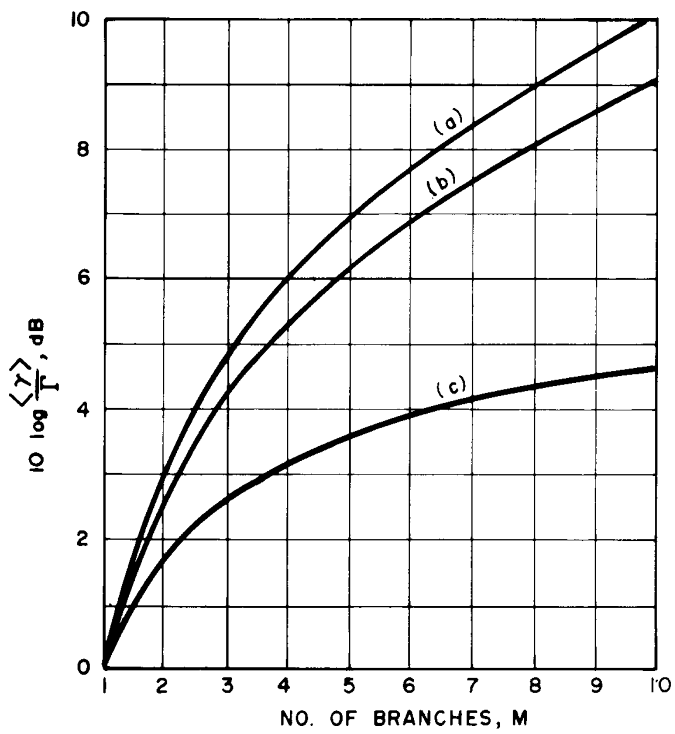
- Principle
  - weight signals proportionally to their S/N ratios
  - cophase signal branches
  - sum up the weighted signals
- Coherent addition of signals and incoherent addition of noises
- Improved S/N

Maximum Ratio Combining (2)

- Correlation of signal levels
  - a lower correlation between signal levels of different branches improves the total S/N ratio
- Correlation of signal levels should be low

- Difference in signal level
  - Assuming equal noise in the branches, the higher the difference in signal levels is, the higher is the loss of S/N ratio of the better signal branch after summation
  - comparing to equal ratio combining, this combining reduces influence of worse signal branches
- Difference in signal levels should be low

Comparison of combining methods



- Improvement of average SNR from a diversity combiner compared to one branch
  - (a) Maximum Ratio Combining
  - (b) Equal Gain Combining
  - (c) Selection Diversity
- The maximum ratio combining, which is used in the ALCATEL BTS, gives the best statistical reduction of any known linear diversity combiner.

Enhanced Diversity Combining (1)

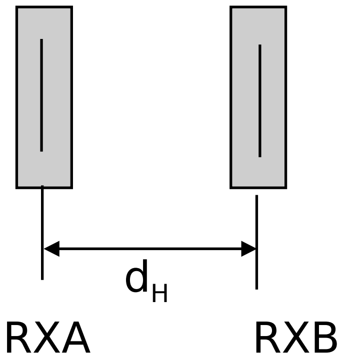
- Principle:
  - 2 algorithms
    - Beam forming algorithm (available also for MRC)
    - Interference reduction algorithm (new)
  - best efficiency when the useful signal and the interfering signals come from different directions.
- Requirements to benefit from this feature:
  - Hardware: G4 TRE (Edge capable TRX) installed in Evolium Evolution BTS step1 resp. step 2 (internal name: G3 resp. G4)
  - Software release: from B6.2 onwards
  - For a maximum gain: antenna engineering rules respected
    - Correct antenna choice for the considered environment
    - Correct antenna spacings and orientations (in case of space diversity)

Enhanced Diversity Combining (2)

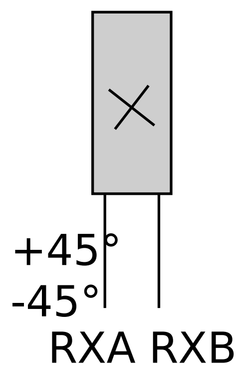
Antenna diversity gain recommendation for link budget		
Environment	Evolution step 1, Evolution step 2 up to B5	Evolution step2 since B6.2
Urban, dense urban	5 dB	6 dB
Residential, suburban	3.5 dB	5 dB
Rural (horizontal space diversity)	3 dB	3.5 dB

- The values in the right column are due to the feature Enhanced Diversity Combining, Selective Beam-forming Combining

Diversity systems in Mobile Radio Networks



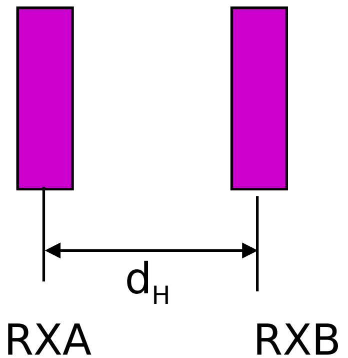
- Two diversity systems are used in Mobile Radio Networks :
  - Space Diversity
    - horizontal
    - vertical
  - Polarization Diversity



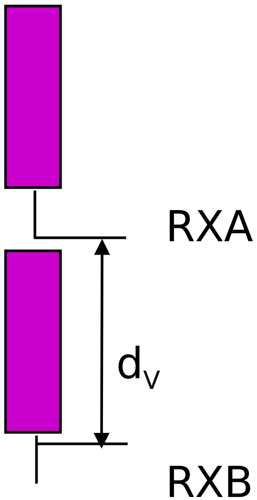
Space Diversity Systems

- Diversity gain depends on spatial separation of antennas

Horizontal separation
(e.g. Roof Top)



Vertical
separation
(e.g. Mast)

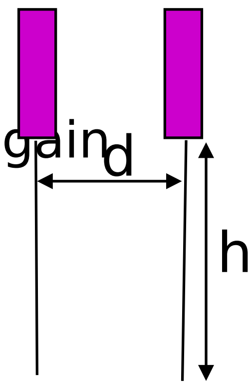


For Optimum Diversity Gain

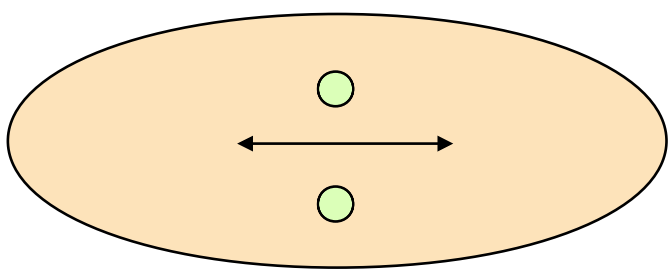
d_H = 20λ
GSM900 = 6m
GSM1800 = 3m

d_V = 15λ
GSM900 = 4.5m
GSM1800 = 2.25m

Space Diversity - General Rules



- The larger the separation the higher the diversity gain
- Prefer horizontal separation (more effective)
- The higher the antenna the higher the required separation, rule: d > h/10
- Highest diversity gain from the "broadside”
- Select orientation of diversity setup according to orientation of cell / traffic



Optimum diversity Gain

Achievable Diversity Gain

- Depends on fading conditions
  - Varies in between 2.5 - 6dB
  - Higher diversity gain in areas with multipath propagation (urban and suburban areas)

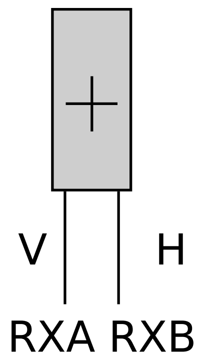
- General rule: consider diversity gain with 3dB in the link budget

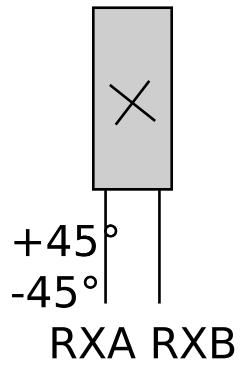
Polarization Diversity

- Diversity gain in using orthogonal orientated antennas

Horizontal / vertical polarization:
Hor/Ver Antenna

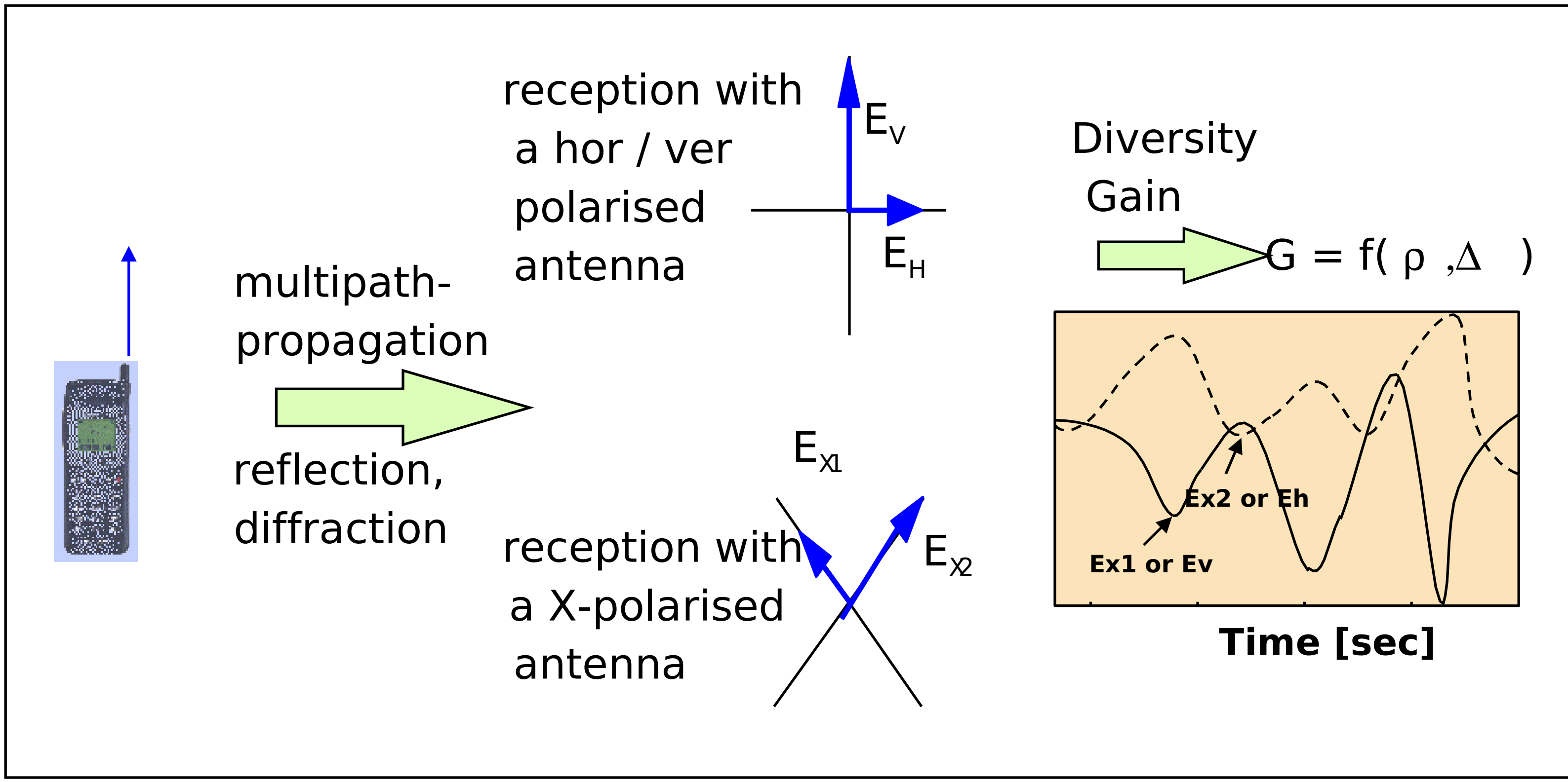
Polarization of +/- 45°:
cross polarized antenna
or Slant antenna



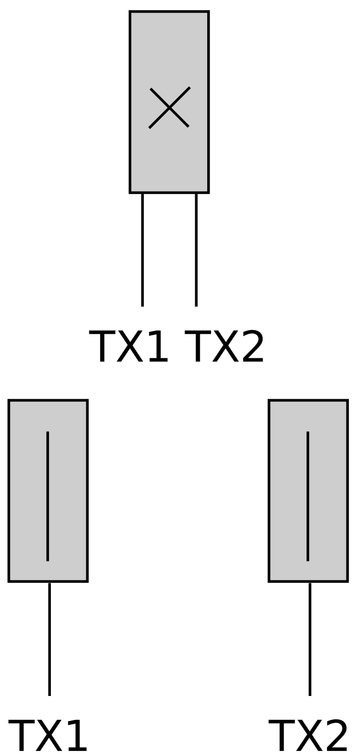


Big Advantage: Only one panel antenna is required to profit from diversity gain using this configuration

Principle of Polarization Diversity

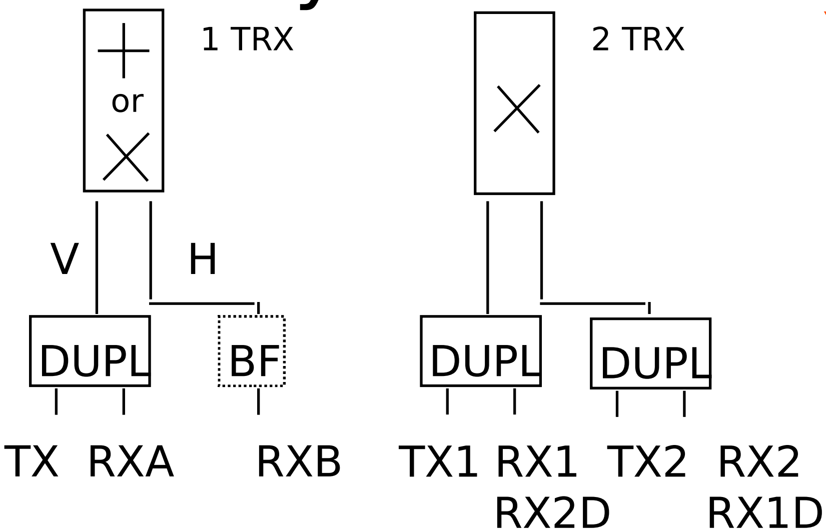


Air Combining



- Features
  - only one TX per antenna
  - combining signals "on air" and not in a combiner
  - 3dB combiner loss can be saved to increase coverage
- Can be realized with
  - two vertical polarized antennas
  - one cross polarized panel antenna

Air Combining with Polarization Diversity

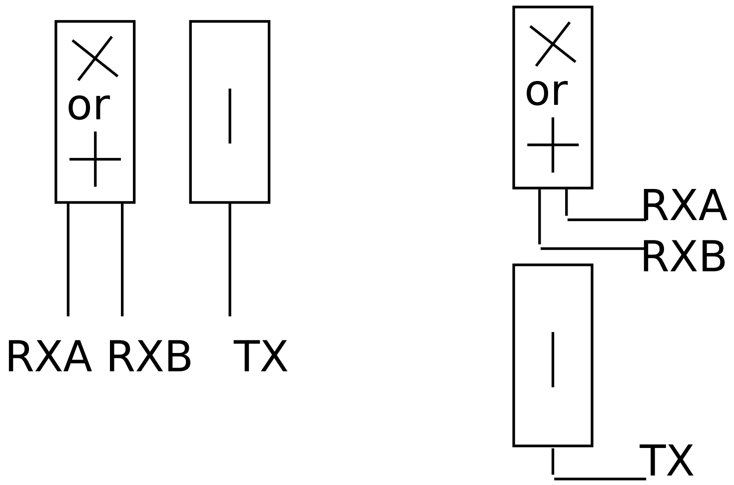


No Air combining
Bandfilter if De-coupling too low

Air combining
Recommended for Evolium BTS

- One antenna system
  - cross polarized antennas recommended for urban/suburban area (less space req.)

Air Combining with Space Diversity



- Two antenna system
  - Vertical or horizontal spacing (recommended for rural area)

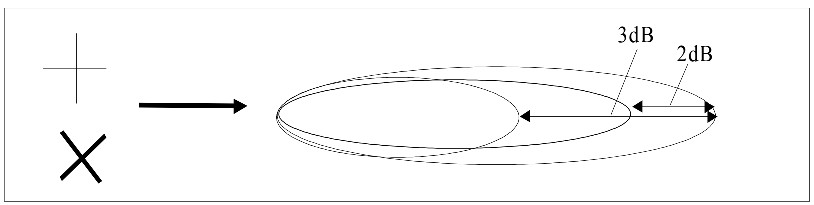
Decoupling of Signal Branches

- One antenna system: TX / RX decoupling cannot be achieved by spatial separation
- Decoupling between both polarization branches needs to be sufficiently high to avoid
  - blocking problems
  - intermodulation problems
- Required decoupling values
  - G2 BTS: 30 dB
  - Evolium A9100 BTS: 25dB (Integrated duplexer Anx)

Cross Polarized or Hor/Ver Antenna? (1)

- Receiving Application
  - same diversity gain for cross polarized and hor/ver antennas
  - in urban and suburban area polarization diversity gain equal to space diversity gain (2.5 - 6dB)
  - negligible polarization diversity gain in rural areas (not recommended)
  - accordingly consider polarization diversity gain with 3dB in the link budget

Cross Polarized or Hor/Ver Antenna? (2)



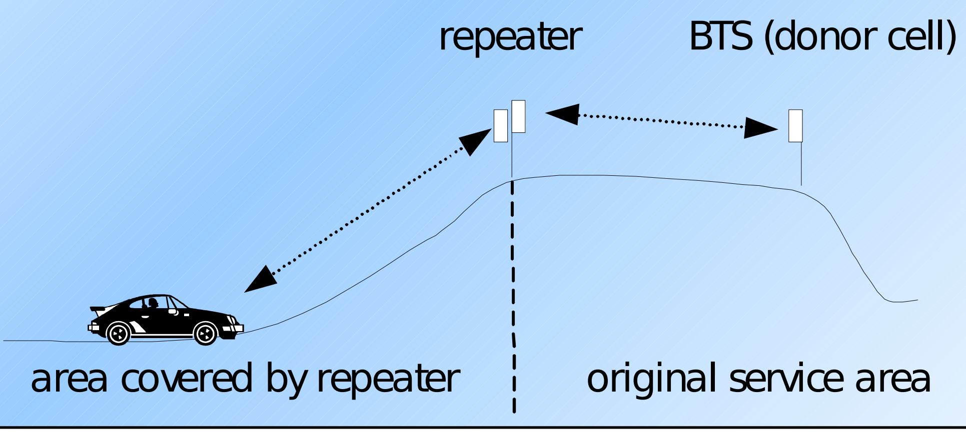
- Transmission Application: Air combining
  - 3dB loss when transmitting horizontal/vertical polarized (use of combiner)
  - 1-2dB losses when transmitting at 45° (optimum antenna is straighten vertically)
  - Air combining only recommended with cross polarized antenna

Conclusion on Antenna Diversity

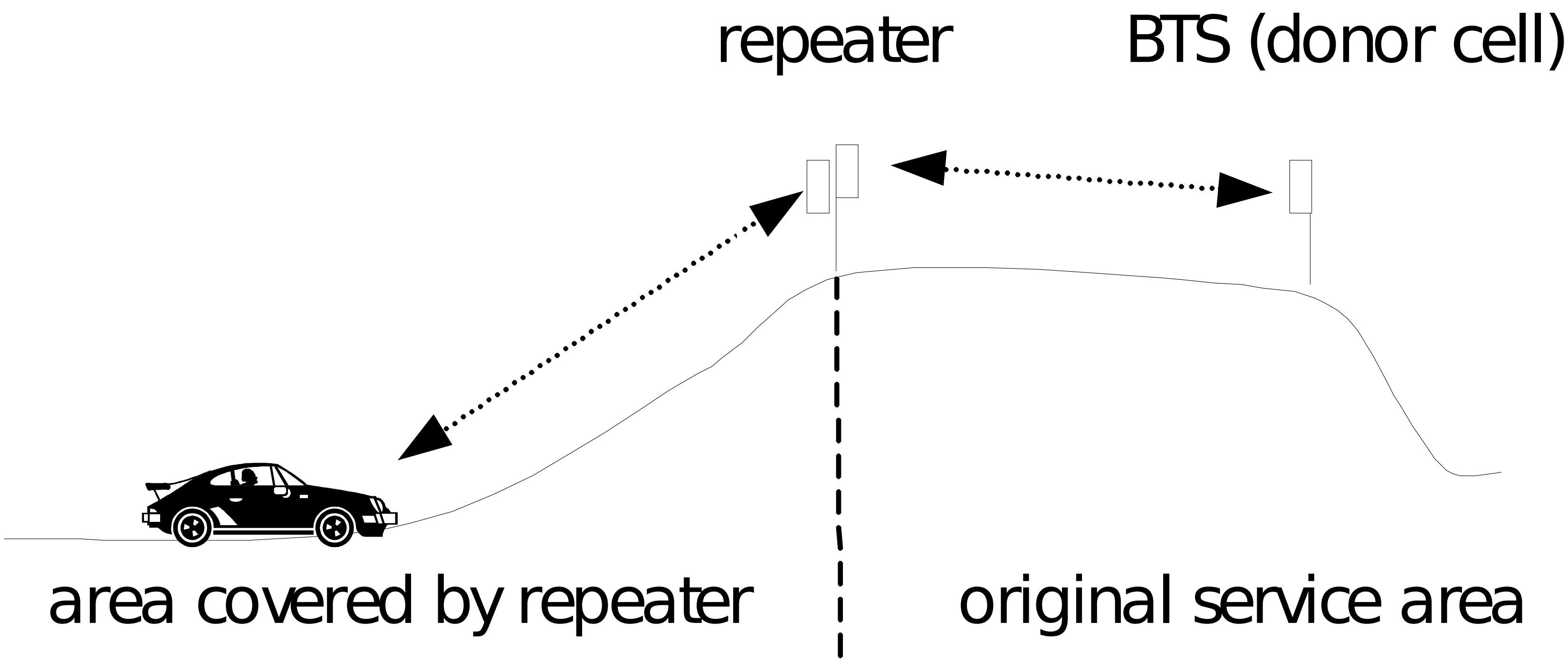
- Rural Areas
  - installation space not limited
  - apply Space Diversity (higher gain)
- Urban and Suburban Area
  - apply space or polarization diversity
  - use cross polarized antennas for air combining
- Diversity Gain
  - consider diversity gain in link budget with 3dB

Coverage Improvement

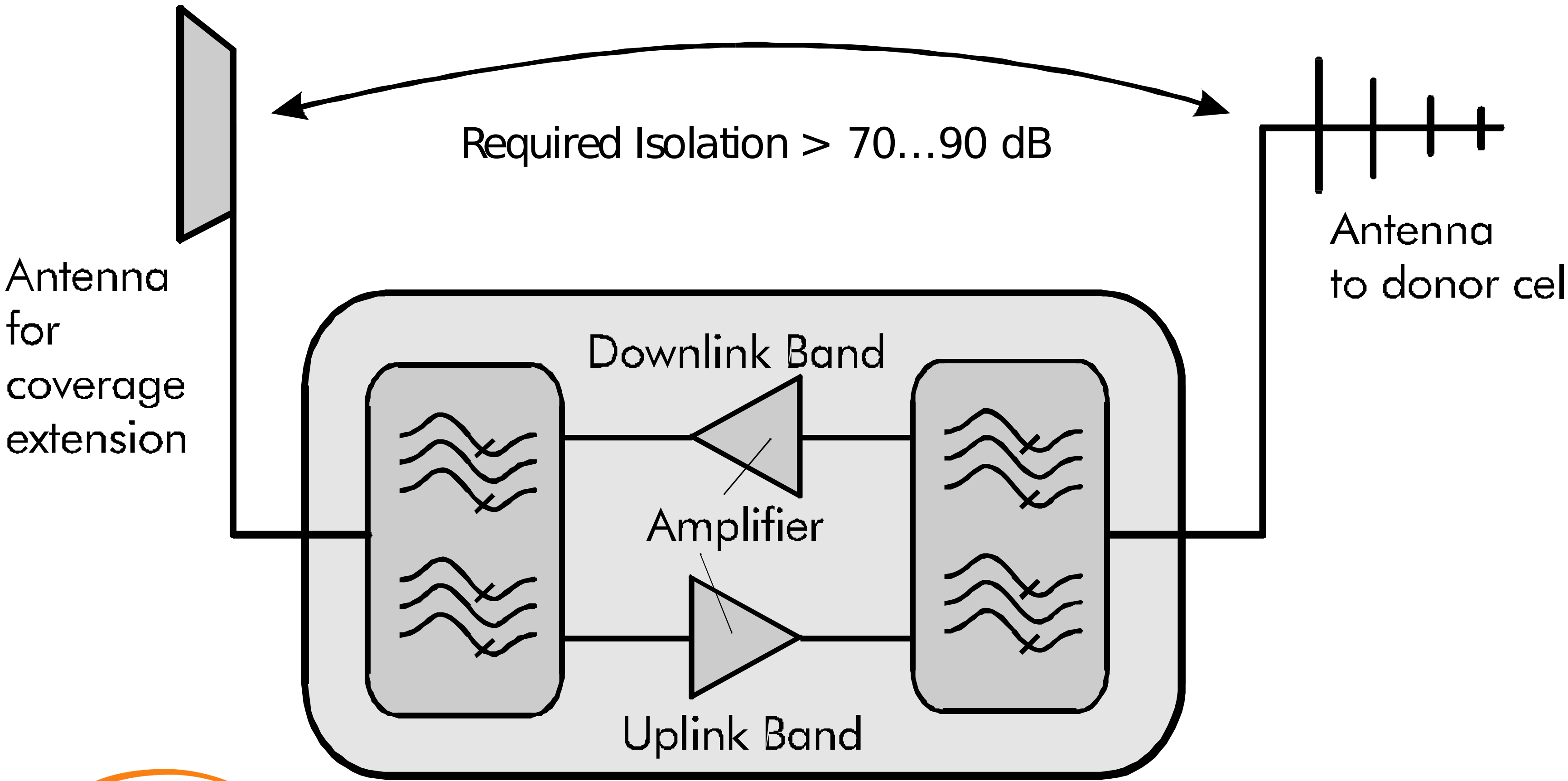
Repeater Systems



Repeater Application



Repeater Block Diagram



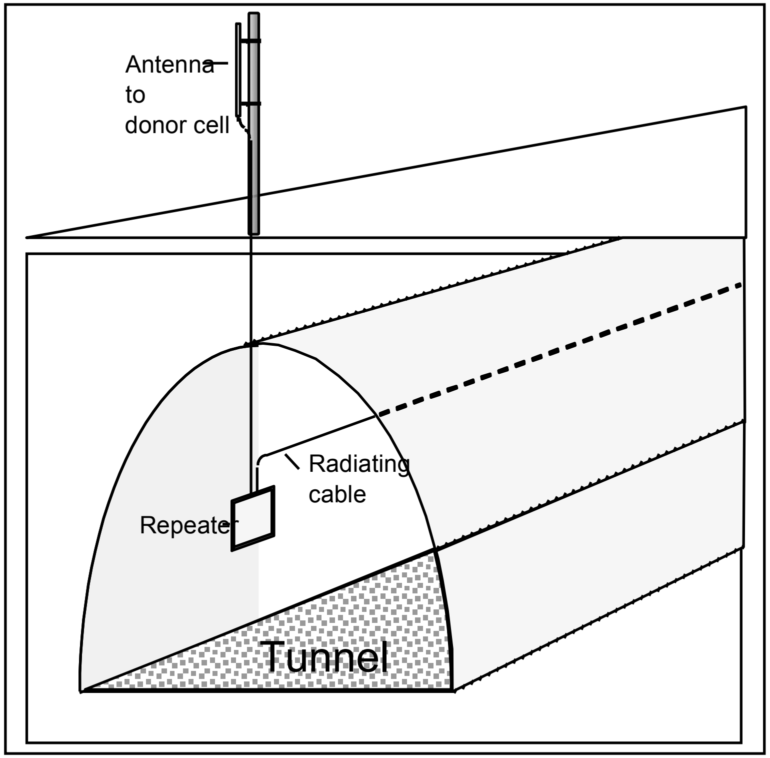
Repeater Applications

- Coverage Improvement of Cells (‘Cell Enhancer’)
  - removal of coverage holes caused by
    - topography (hills, ravines, ...)
    - man made obstacles
- Provision of tunnel coverage
  - street, railway tunnels
  - underground stations
- Provision of indoor coverage at places of low additional traffic

Repeater Types

- Channel selective repeaters
  - high selectivity of certain channels
  - high traffic areas, small cell sizes
- Band selective repeaters
  - adjustment to operator’s frequency band
  - no (accidental) usage by competitors
- Broad band repeaters
  - low cost solution for low traffic areas (rural environment)
  - medium to high repeater gain
- Personal repeaters
  - low gain
  - broad band
  - indoor coverage improvement for certain rooms

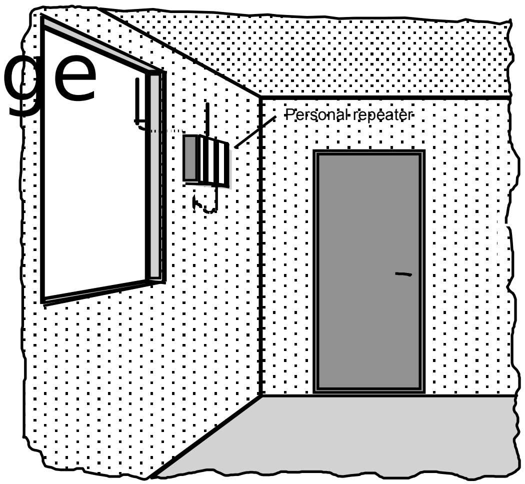
Repeater for Tunnel Coverage

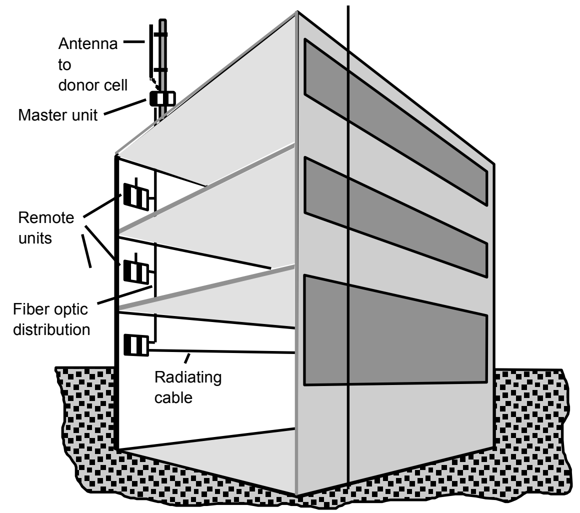


- Choice of repeater type due to
  - tunnel dimensions
  - wall materials
- feeding by
  - directional antennas
  - leaky feeder cables
- long tunnels
  - chains of several repeaters
  - fiber optic backbone for repeater feeding

Repeater for Indoor coverage

- For smaller buildings
  - Compensation for wall losses, window losses (heat insulated windows)
  - Low cost personal repeaters installed in certain rooms
- For larger buildings (shopping malls, convention centers, sport centers)
  - multispot transmission using
    - co-axial distribution network
    - fiber-optic distribution network





Planning Aspects

- Repeater does not provide additional traffic capacity
  - risk of blocking if additional coverage area catches more traffic
  - possible carrier upgrading required
- Repeater causes additional signal delay
  - delay: 4..8μ s → max. cell range of 35 km reduced by 1 to 2km
  - special care needed for total delay of repeater chain!
  - delayed signal and original signal could cause outage in urban environment if total delay exceeds 16 ... 22μ s

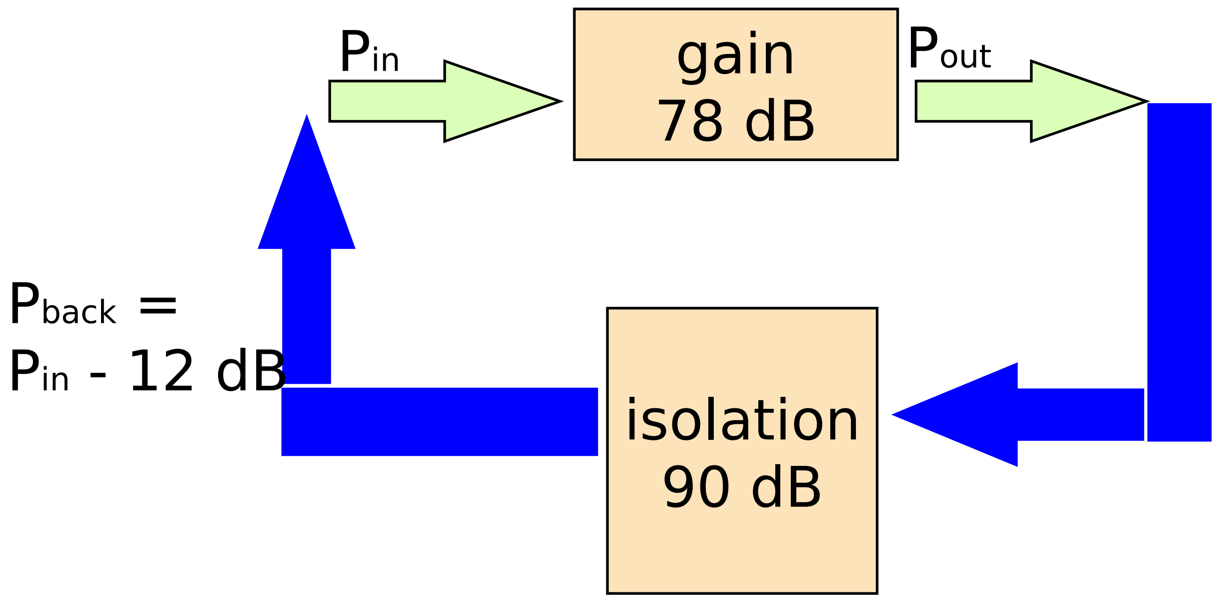
Repeater Gain Limitation (1)

- Intermodulation products should be low
  - when amplifier reaches saturation point, intermodulation products go up
- Signal to noise ratio should be high
  - when amplifier reaches saturation point, signal to noise ratio is getting worse
- Antenna isolation between transmission and receiving antenna should be high
  - if signal feedback from transmission antenna to receiving antenna is too high, amplifier goes into saturation

Repeater Gain Limitation (2)

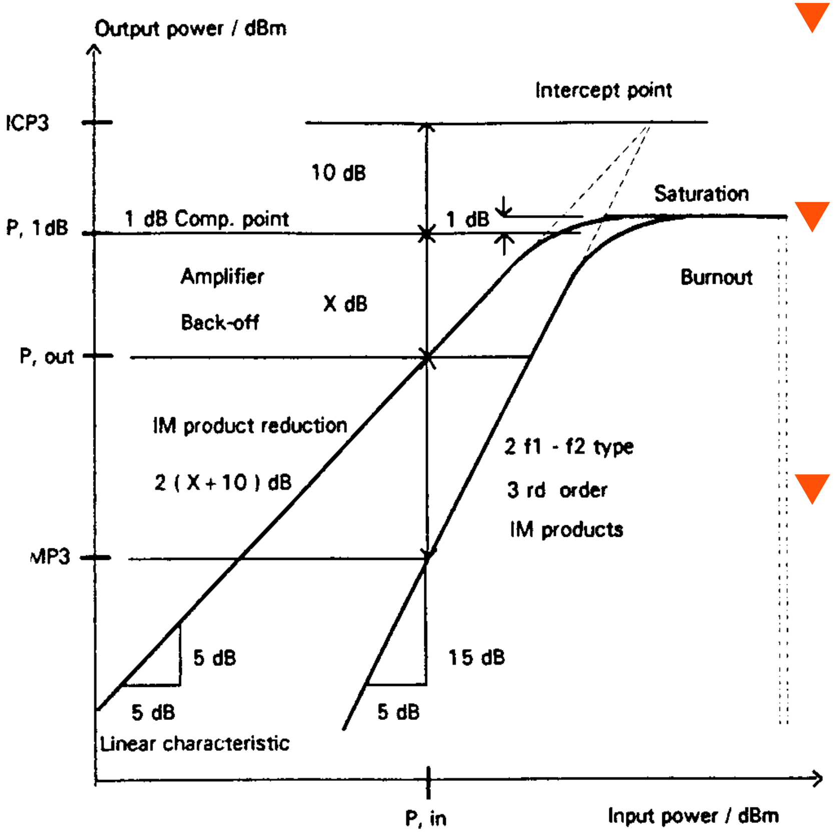
- Repeater gain limited by antenna

$G_{Repeater} < I_{Donor, Repeater} - M$ M (Margin) ~ 12 dB



Measure isolation after installation

Intermodulation Products



- A Non-linear system
  - produces higher-order intermodulation products as soon as output power reaches the saturation point
- Parameter
  - 1 dB compression point
  - 3rd order intercept point (ICP3)
  - Intermodulation reduction (IMR)
  - Amplifier back-off
- GSM900/GSM1800 requirements
  - IM products ≤ -36 dBm or
  - IM distance > 70 dBc whichever is higher

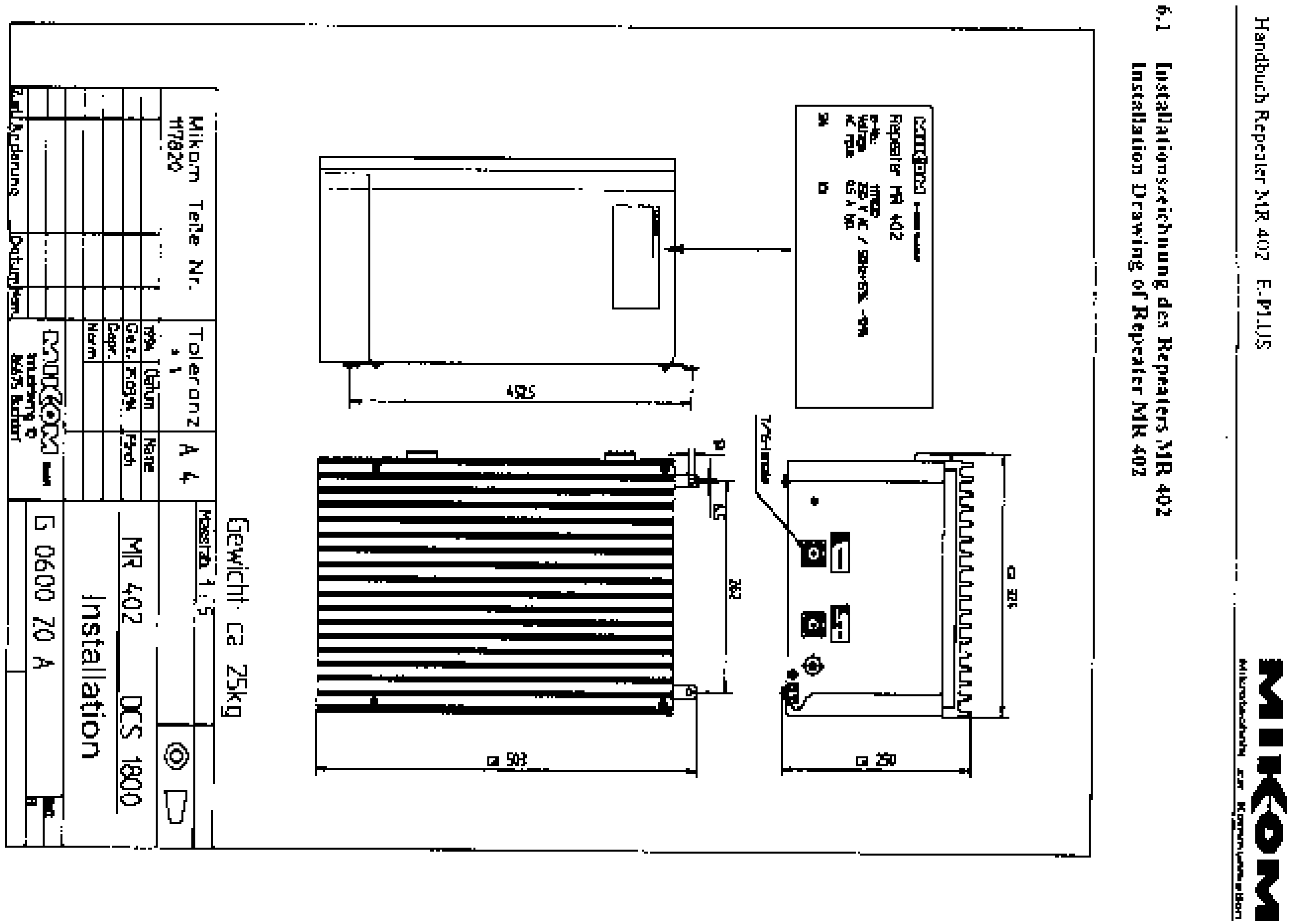
Repeater Link Budget

- Uplink Loss = Downlink Loss ⇒ Uplink Gain = Downlink Gain

Downlink Path	Unit	Value
Received power at repeater	dBm	-65
Link antenna gain	dBi	+19
Cable loss	dB	-2
Repeater input power	dBm	-48
Repeater gain	dB	+78
Repeater output power	dBm	30
Cable loss	dB	-2
Repeater antenna gain	dBi	+18
EIRP	dBm	46

- Different gains may be needed in Up- and Downlink if the sensitivity of the repeater is worse than the sensitivity of the BTS

Example: Repeater MR 402



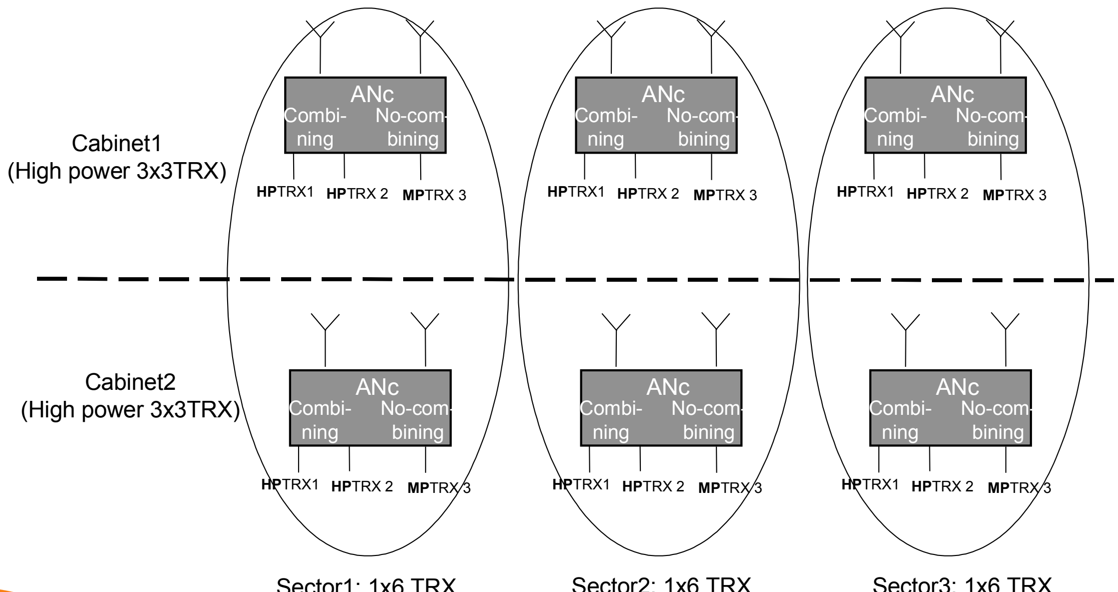
High Power TRXs

- High Power TRXs: solution for coverage improvement
- HP must be used together with TMA: due to unbalanced Link Budget
- A9100 BTS supports
  - High Power TRX
  - Medium Power
  - TRX type is chosen by:
    - environment conditions
    - required data throughput (GPRS/EDGE)

TX power of EVOLIUM™ Evolution step 2 TRX :		
Frequency band	TX output power, **GMSK**	TX output power, **8-PSK (EDGE)**
GSM 900 HP	60 W = 47.8 dBm	25 W = 44.0 dBm
GSM 1800 HP	60 W = 47.8 dBm	25 W = 44.0 dBm

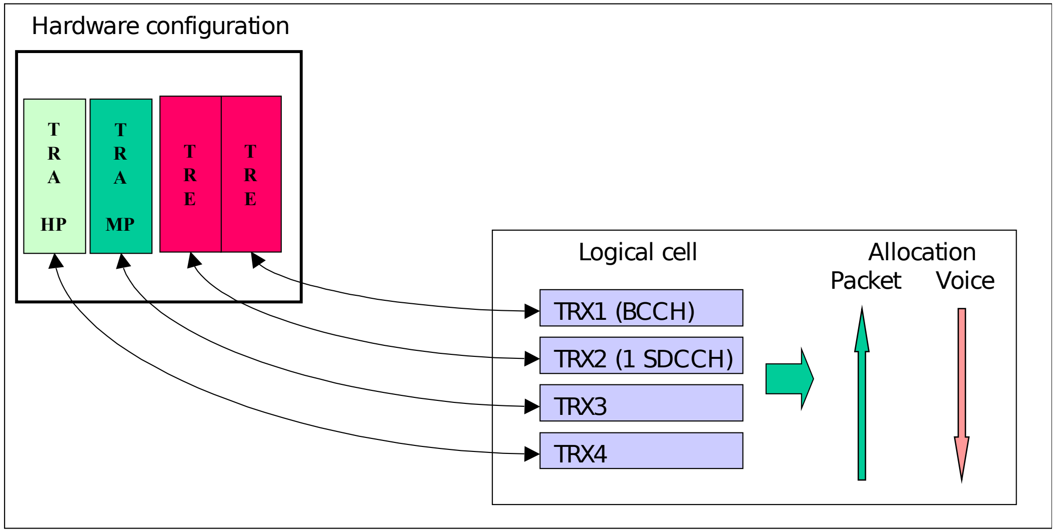
3x6 TRXs High Power Configuration

- Configuration made with EVOLIUM™ A9100 Base Station
- Obs:
  - All TRX are HP
  - The configuration is using cell split feature



Mixed TRX Configuration

- BTS EVOLIUM™ supports a mix of:
  - EVOLIUM™ TRX (TRE) - supports GSM/GPRS and EDGE
  - EVOLIUM™ Evolution step 2 TRX (TRA) with Medium Power
  - EVOLIUM™ Evolution step 2 TRX (TRA) with High Power



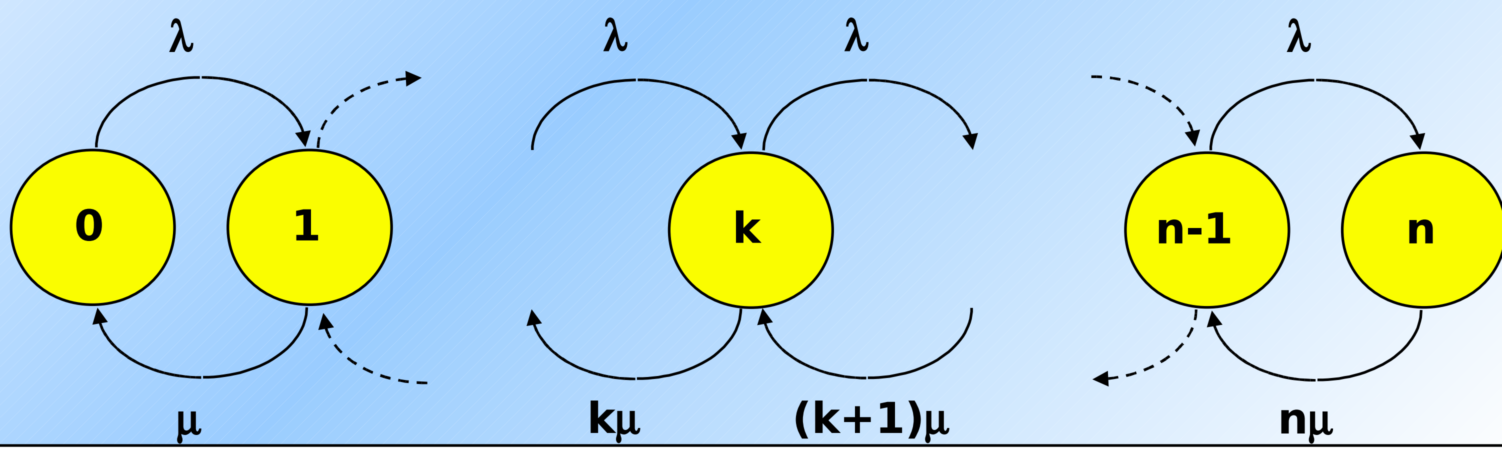
GSM Radio Network Engineering Fundamentals

Traffic Planning & Frequency Planning

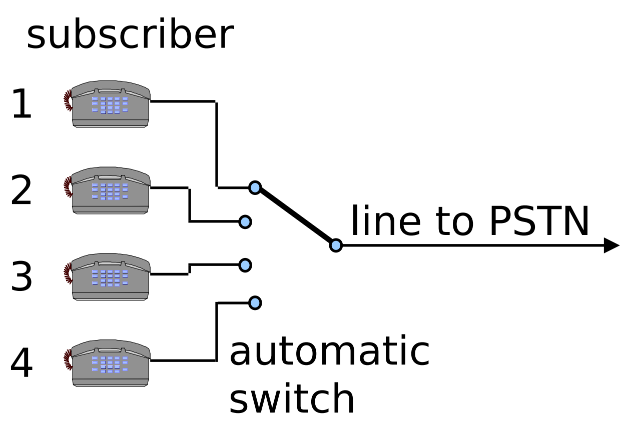
Contents

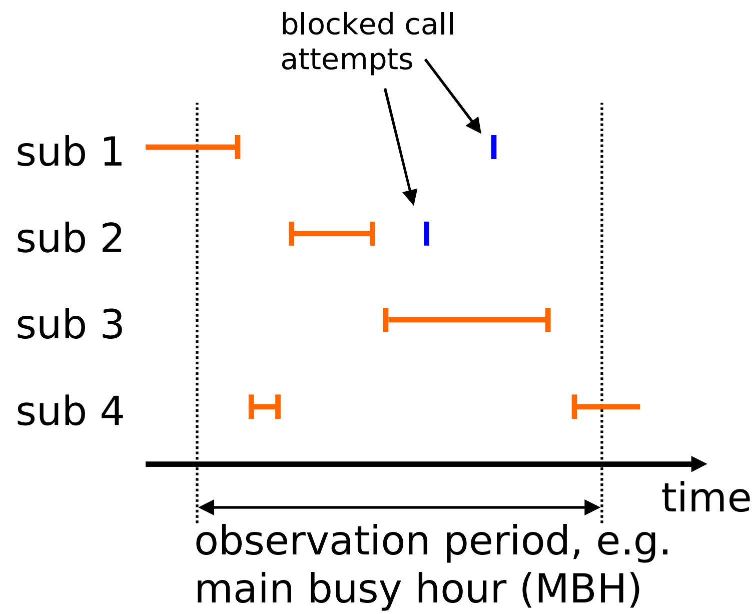
Traffic Planning
Frequency Planning

Traffic Capacity



Telephone System





Parameters:

λ : arrival rate [1/h]

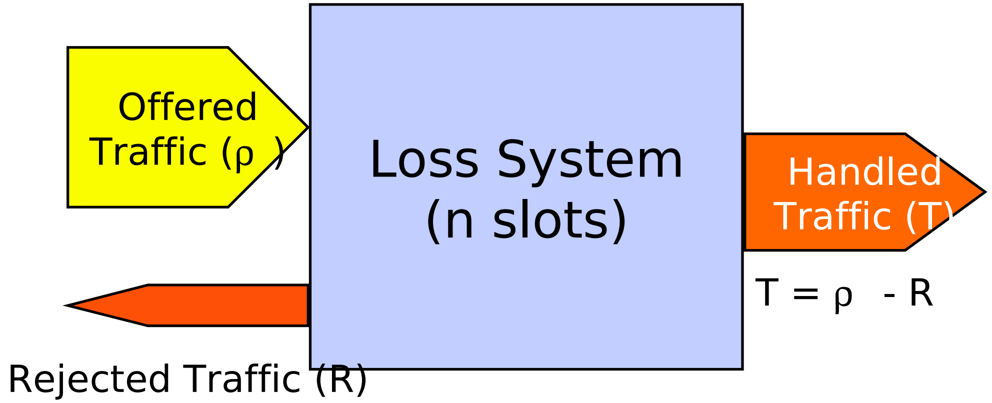
μ : release rate [1/h]

$1/\mu$: mean holding time [sec]

"offered" traffic = # of calls arriving in MBH $\times$ mean holding time

$$\rho = \lambda \times \mathbf{1}/\mu \quad \text{[Erlang]}$$

Offered Traffic and Traffic Capacity



- Handled Traffic, Traffic Capacity: **T**
- Blocking Probability, Grade of Service (GoS): $\mathbf{p}_{block} = R / \rho$
- System load: $\tau = T / n$, i.e. T < n

Definition of Erlang

- ERLANG : Unit used to quantify traffic

$$T = {}^{(\text{resource usage duration})}/_{(\text{total observation duration})} \text{ [ERLANG]}$$

Call Mix and Erlang Calculation

- CALL MIX EXAMPLE
  - 350 call/hour
  - 3 LU/call
  - TCH duration : 85 sec
  - SDCCH duration : 4,5 sec
- ERLANG COMPUTATION
  - TCH = (350 * 85)/3600 = 8,26 ERLANG
  - SDCCH = [(350 + 350*3) * 4,5] / 3600 = 1.75 ERLANG

Definition of Erlang B

- ERLANG B LAW
  - Relationship between
    - Offered traffic
    - Number of resources
    - Blocking rate

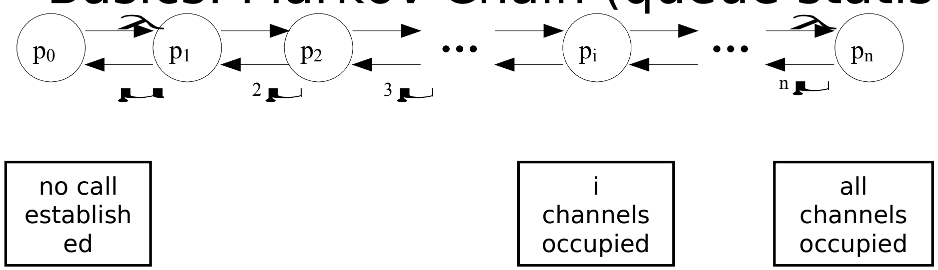
- call request arrival rate (and leaving) is not stable
  - number of resources = average number of requests mean duration
  - is <u>sometime</u> not sufficent => probability of <u>blocking</u>

- => Erlang B law
  - Pblock : blocking probability
  - N : number of resources
  - E : <u>offered</u> traffic [Erlang]

  - Calculated with Excel - Makro or Table

Erlang´s Formula

- How to calculate the traffic capacity T?
- Basics: Markov Chain (queue statistics)



- Calculation of the blocking probability using Erlang´s formula (Erlang B statistics):

$$p_{block} = \frac{\rho^n}{n!} \Big/ \sum_{i=0}^{n} \frac{\rho^i}{i!}$$

- Varation of ρ until p_{block} reached: $\rho \rightarrow T$

Blocking Probability (Erlang B)

Nr. of channels	Blocking Probability Erlang B											
	0.1%	0.2%	0.5%	1%	**2%**	3%	4%	5%	10%	15%	20%	50%
1	0.001	0.002	0.005	0.010	**0.020**	0.031	0.042	0.053	0.111	0.176	0.250	1.000
2	0.046	0.065	0.105	0.153	**0.223**	0.282	0.333	0.381	0.595	0.796	1.000	2.732
3	0.194	0.249	0.349	0.455	**0.602**	0.715	0.812	0.899	1.271	1.602	1.930	4.591
4	0.439	0.535	0.701	0.869	**1.092**	1.259	1.399	1.525	2.045	2.501	2.945	6.501
5	0.762	0.900	1.132	1.361	**1.657**	1.875	2.057	2.218	2.881	3.454	4.010	8.437
6	1.146	1.325	1.622	1.909	**2.276**	2.543	2.765	2.960	3.758	4.445	5.109	10.389
7	1.579	1.798	2.157	2.501	**2.935**	3.250	3.509	3.738	4.666	5.461	6.230	12.351
8	2.051	2.311	2.730	3.128	**3.627**	3.987	4.283	4.543	5.597	6.498	7.369	14.320
9	2.557	2.855	3.333	3.783	**4.345**	4.748	5.080	5.370	6.546	7.551	8.522	16.294
10	3.092	3.427	3.961	4.461	**5.084**	5.529	5.895	6.216	7.511	8.616	9.685	18.273
11	3.651	4.022	4.610	5.160	**5.842**	6.328	6.727	7.076	8.487	9.691	10.857	20.254
12	4.231	4.637	5.279	5.876	**6.615**	7.141	7.573	7.950	9.474	10.776	12.036	22.238
13	4.831	5.270	5.964	6.607	**7.402**	7.967	8.430	8.835	10.470	11.867	13.222	24.224
14	5.446	5.919	6.663	7.352	**8.200**	8.803	9.298	9.730	11.473	12.965	14.413	26.212
15	6.077	6.582	7.376	8.108	**9.010**	9.650	10.174	10.633	12.484	14.068	15.608	28.201
16	6.721	7.258	8.099	8.875	**9.828**	10.505	11.059	11.544	13.500	15.176	16.807	30.191
17	7.378	7.946	8.834	9.652	**10.656**	11.368	11.952	12.461	14.522	16.289	18.010	32.182
18	8.046	8.644	9.578	10.437	**11.491**	12.238	12.850	13.385	15.548	17.405	19.216	34.173
19	8.724	9.351	10.331	11.230	**12.333**	13.115	13.755	14.315	16.579	18.525	20.424	36.166
20	9.411	10.068	11.092	12.031	**13.182**	13.997	14.665	15.249	17.613	19.647	21.635	38.159
21	10.108	10.793	11.860	12.838	**14.036**	14.885	15.581	16.189	18.651	20.773	22.848	40.153
22	10.812	11.525	12.635	13.651	**14.896**	15.778	16.500	17.132	19.692	21.901	24.064	42.147
23	11.524	12.265	13.416	14.470	**15.761**	16.675	17.425	18.080	20.737	23.031	25.281	44.142
24	12.243	13.011	14.204	15.295	**16.631**	17.577	18.353	19.031	21.784	24.164	26.499	46.137
25	12.969	13.763	14.997	16.125	**17.505**	18.483	19.284	19.985	22.833	25.298	27.720	48.132
30	16.684	17.606	19.034	20.337	**21.932**	23.062	23.990	24.802	28.113	30.995	33.840	58.113
35	20.517	21.559	23.169	24.638	**26.435**	27.711	28.758	29.677	33.434	36.723	39.985	68.099
40	24.444	25.599	27.382	29.007	**30.997**	32.412	33.575	34.596	38.787	42.475	46.147	78.088
45	28.447	29.708	31.656	33.432	**35.607**	37.155	38.430	39.550	44.165	48.245	52.322	88.079
50	32.512	33.876	35.982	37.901	**40.255**	41.933	43.316	44.533	49.562	54.029	58.508	98.072

BTS Traffic Capacity (Full Rate)

Number of			Speech Traffic (Erlang B)			Signalling Traffic (Erlang B)		
TRX	SDCCH	***TCH***	1%	***2%***	5%	0.1%	0.2%	0.5%
1	4	***7***	2.501	***2.935***	3.738	0.439	0.535	0.701
2	8	***14***	7.352	***8.2***	9.73	2.051	2.311	2.73
3	8	***22***	13.651	***14.896***	17.132	2.051	2.311	2.73
4	16	***29***	19.487	***21.039***	23.833	6.721	7.258	8.099
5	16	***37***	26.379	***28.254***	31.64	6.721	7.258	8.099
6	24	***44***	32.543	***34.682***	38.557	12.243	13.011	14.204
7	24	***52***	39.7	***42.124***	46.533	12.243	13.011	14.204
8	32	***59***	46.039	***48.7***	53.559	18.205	19.176	20.678

Traffic Planning
Frequency Planning

Network Evolution

Network Evolution - Coverage Approach

- The roll out of a network is dedicated to provide coverage
- Network design changes rapidly
- Planning method must be flexible and fast (group method)
- Manual frequency planning possible

Network Evolution - Capacity Approach (1)

- With the growing amount of subscribers, the need for more installed capacity is rising
- Possible Solutions:
  - Installing more TRXs on the existing BTS
  - Implementing additional sites
- Discussion!

Network Evolution - Capacity Approach (2)

- Installing more TRXs - Advantages
  - No site search/acquisition process
  - No additional sites to rent (saves cost)
  - Trunking efficiency ➪ Higher capacity per cell
- Installing more TRXs - Disadvantages
  - More antennas on roof top (Air combining)
  - Additional losses if WBC has to be used
    - Less (indoor) coverage
  - More frequencies per site needed
  - Tighter reuse necessary ➪ decreasing quality

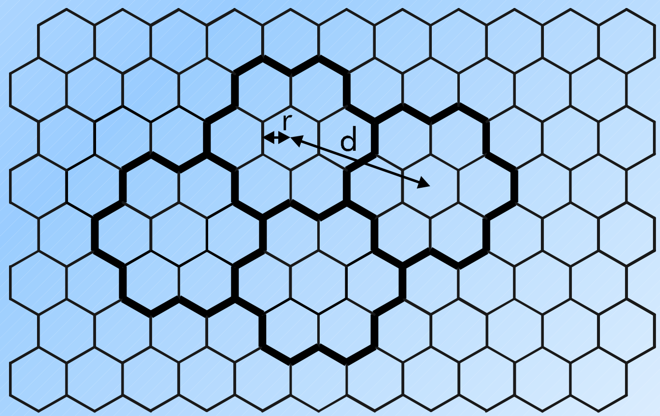
Network Evolution - Capacity Approach (3)

- Implementing additional sites - Advantages
  - Reuse can remain the same (smaller cell sizes)
  - Needs less frequency spectrum
    - higher spectrum efficiency

- Implementing additional sites - Disadvantages
  - Additional site cost (rent)
  - Re-design of old cells necessary (often not done)

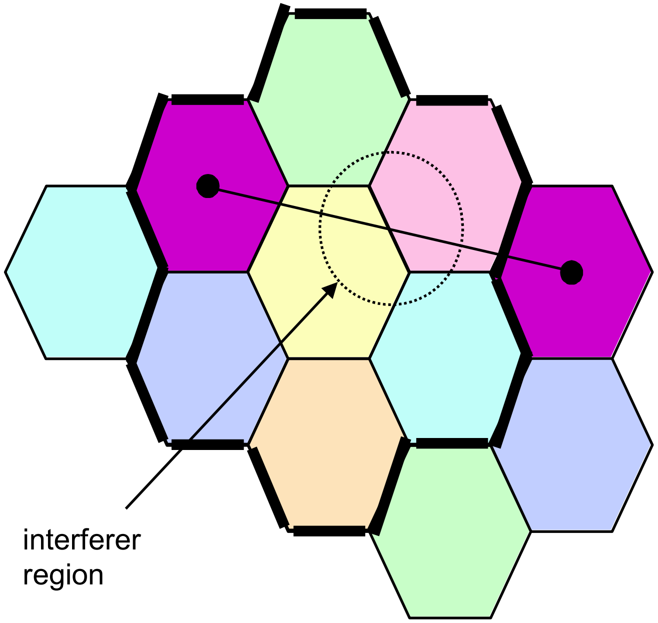
Traffic Planning
Frequency Planning

Cell Structures

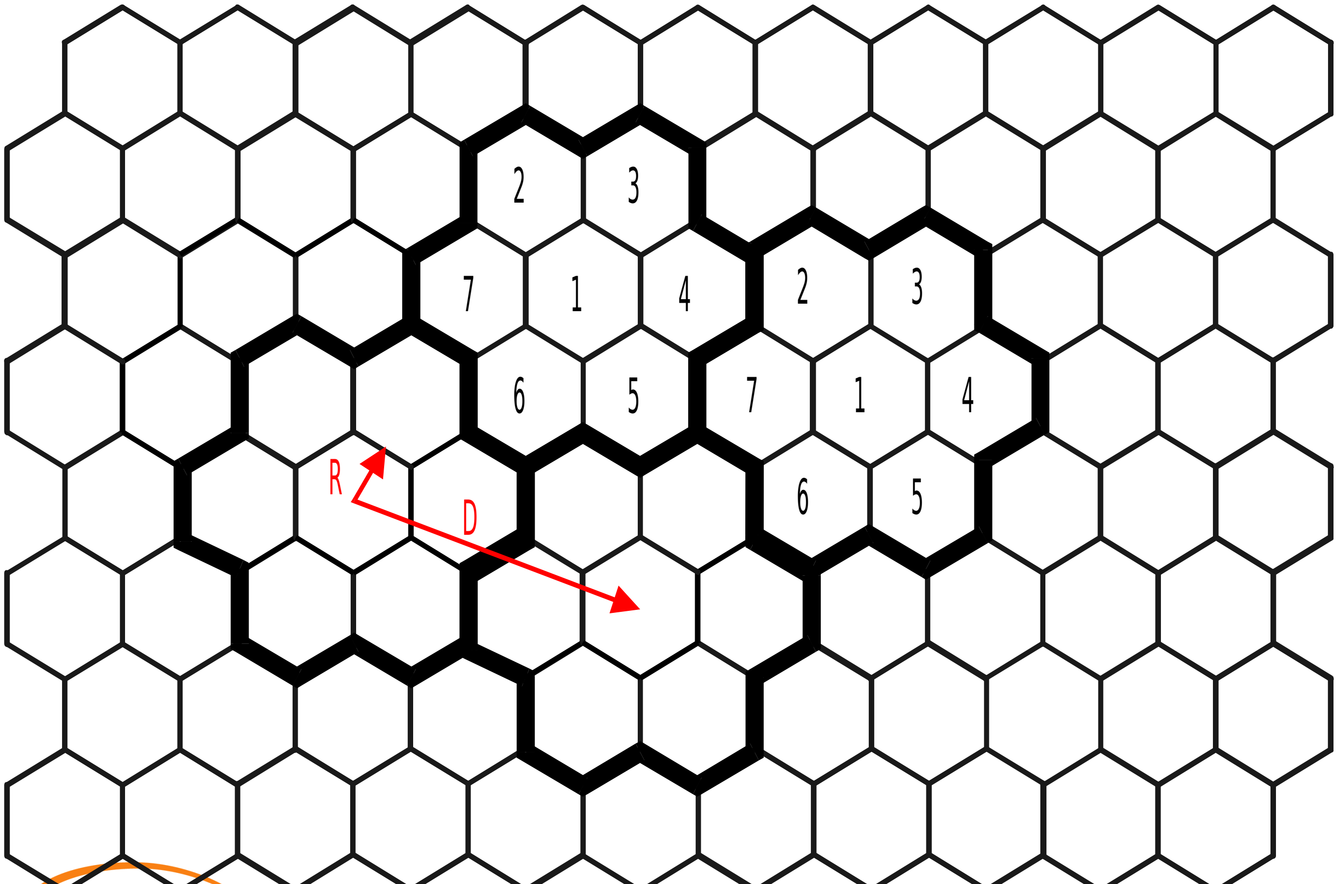


Cell Structures and Quality

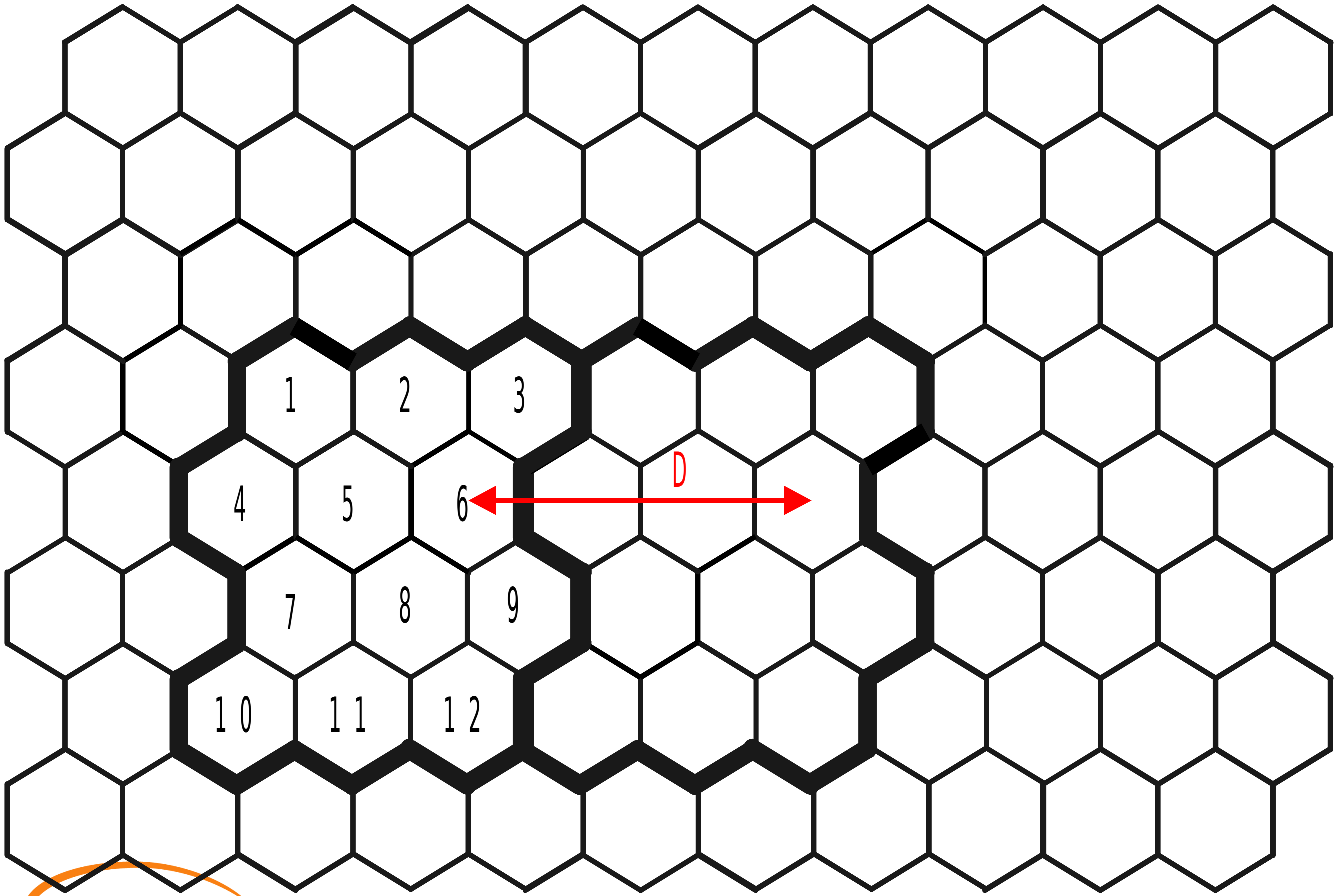
- Frequency re-use in cellular radio networks
  - allow efficient usage of the frequency spectrum
  - but causes interference
- Interdependence of
  - Cell size
  - Cluster size
  - Re-use distance
  - Interference level
  - Network Quality



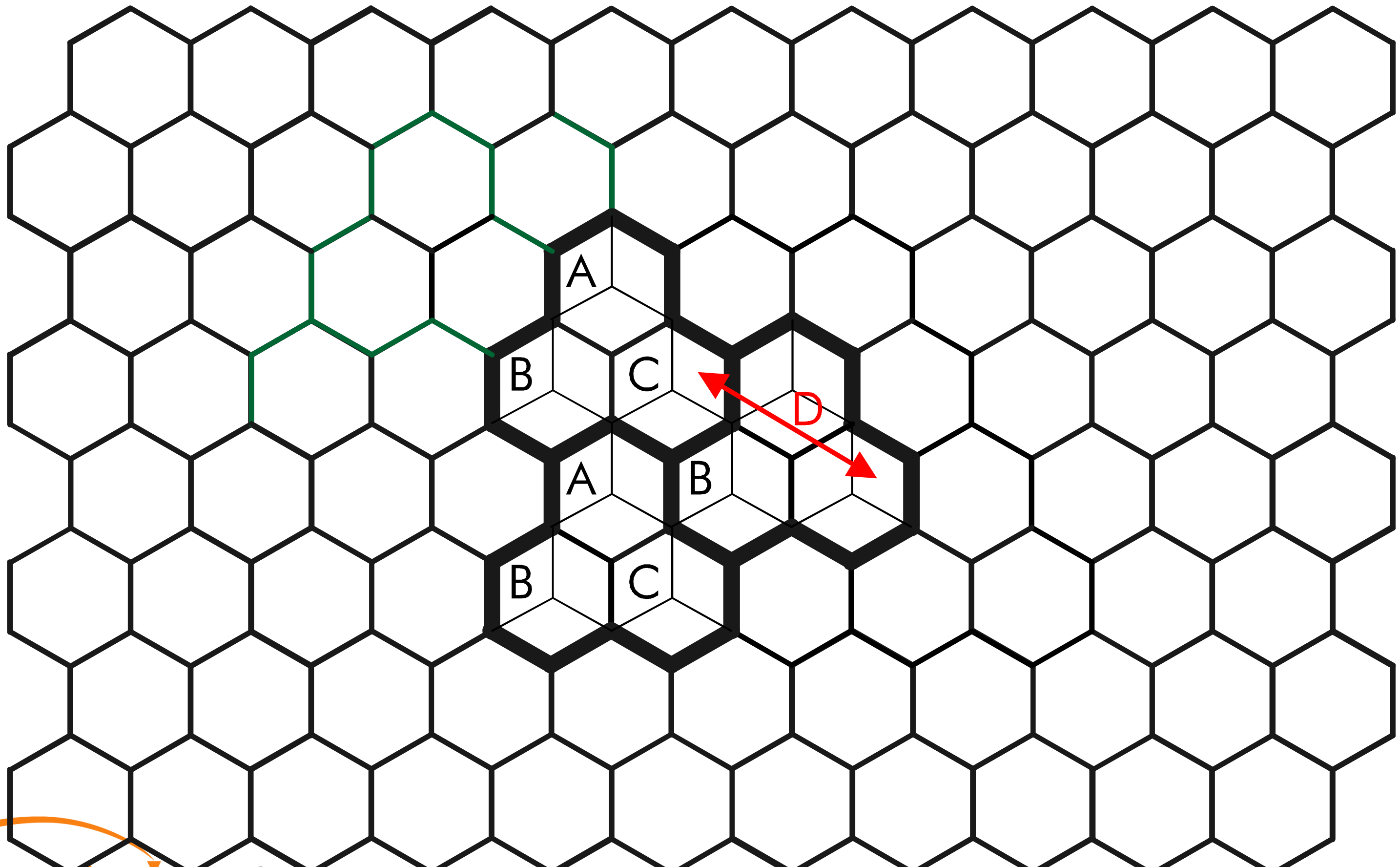
7 Cell Re-use Cluster (Omni Sites)



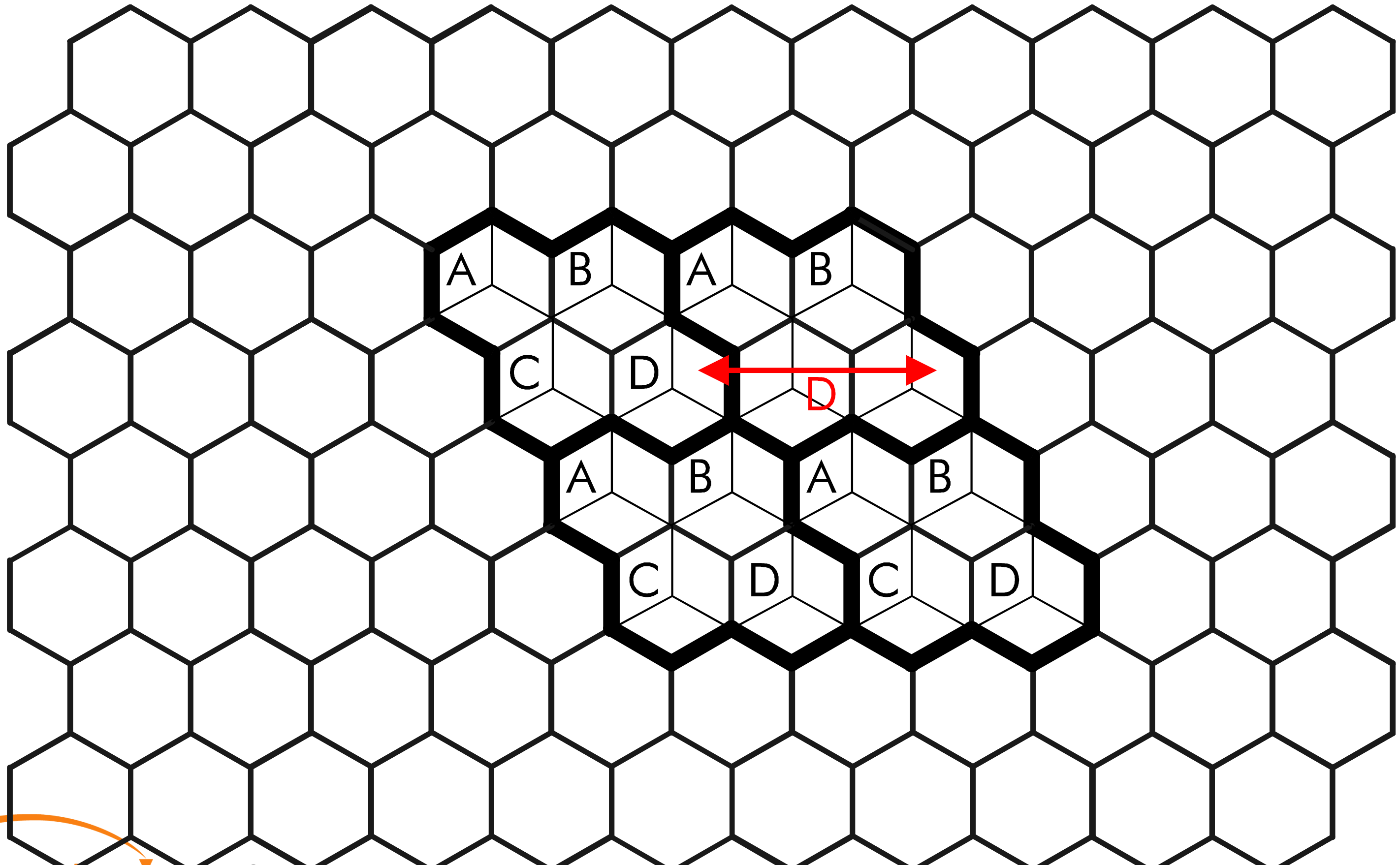
12 Cell Re-use Cluster (Omni Sites)



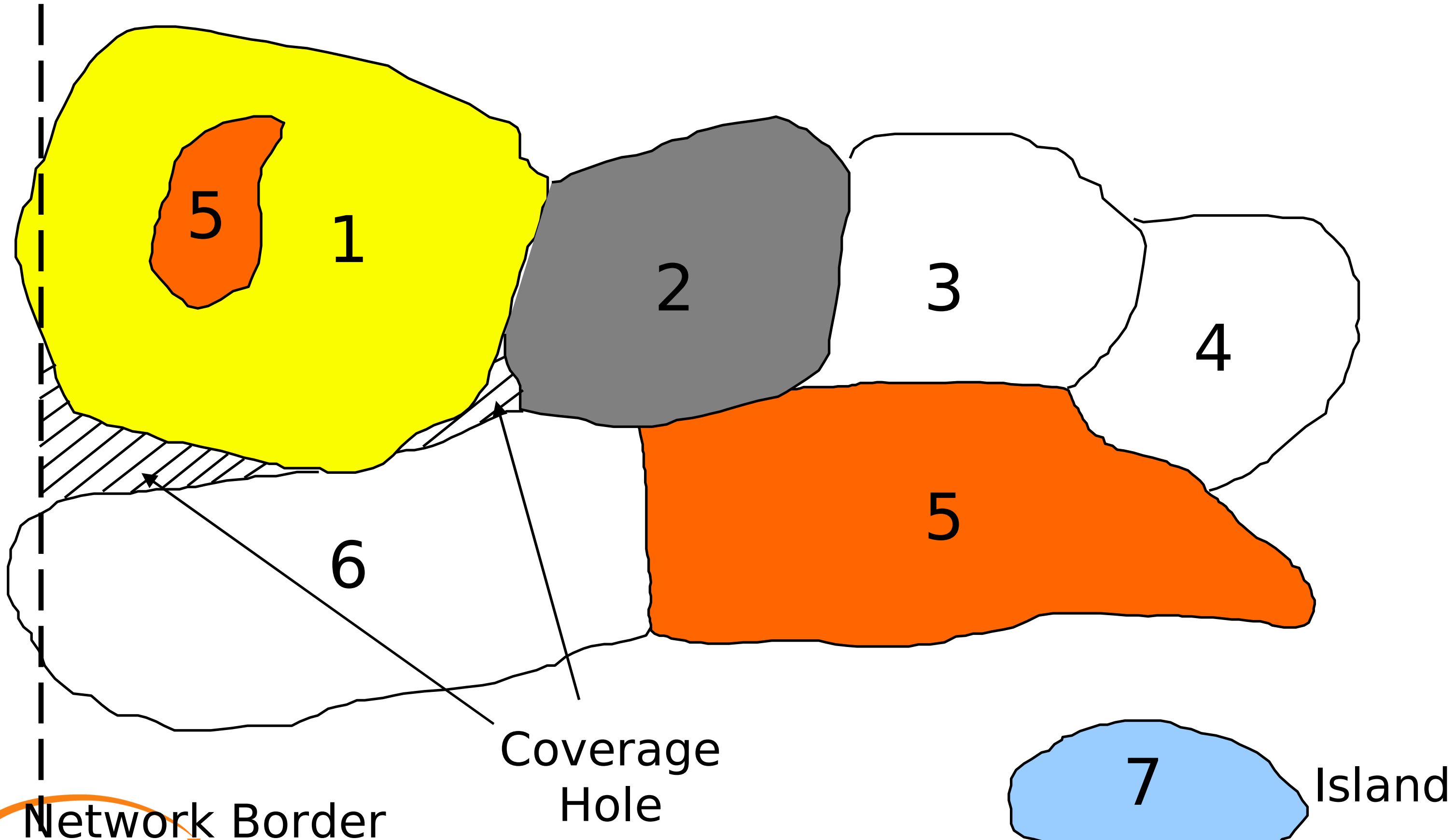
3x3 Cell Re-use Cluster (Sector Site)



4x3 Cell Re-use Cluster (Sector Site)

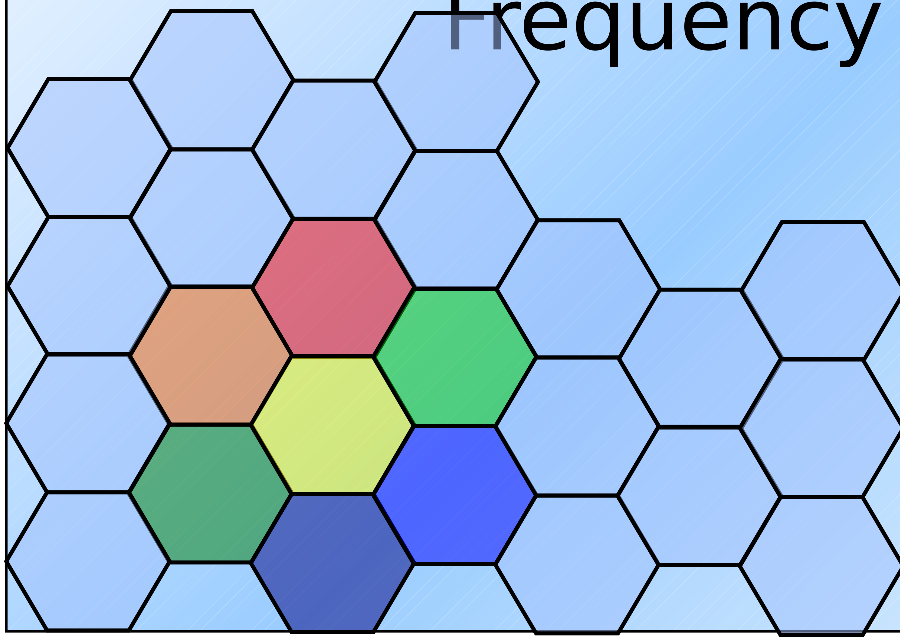


Irregular (Real) Cell Shapes



Traffic Planning
Frequency Planning

Frequency Reuse



GSM Frequency Spectrum

- GSM 900
  - DL: 935-960 MHz UL: 890-915 MHz
  - 200 kHz channel spacing ➪ 124 channels
  - ARFCN 1 - 124
- E-GSM
  - DL: 925-935 MHz UL: 880-890 MHz
  - 200 kHz channel spacing ➪ Additional 50 channels
  - ARFCN 0, 975 - 1023
- GSM 850
  - DL: 869-894 MHz UL: 824-849 MHz
  - 200 kHz channel spacing ➪ 124 channels
  - ARFCN: 128 - 251
- GSM 1800
  - DL: 1805-1880 MHz UL: 1710-1785 MHz
  - 200 kHz channel spacing ➪ 374 channels
  - ARFCN 512 - 885

Impact of limited Frequency Spectrum

- Bandwidth is an expensive resource
- Best usage necessary
- Efficient planning necessary to contain good QoS when the traffic in the network is increasing
  - smaller reuse
  - MRP usage
  - implementation of concentric cells / microcells/dual band
  - implementation of Frequency Hopping
    - Baseband
    - Synthezised

What is frequency reuse?

- As the GSM spectrum is limited, frequencies have to be reused to provide enough capacity
- The more often a frequency is reused within a certain amount of cells, the smaller the frequency reuse
- Aim:
  Minimizing the frequency reuse for providing more capacity
- REUSE CLUSTER:
  Area including cells which do not reuse the same frequency (or frequency group)

RCS and ARCS (1)

- Reuse Cluster Size - RCS
  - If all cells within the reuse cluster have the same amount of TRXs, the reuse per TRX layer can be calculated:

$$RCS = \frac{B}{\#TRX / cell}$$

- Average Reuse Cluster Size - ARCS
  - If the cells are different equiped, the average number of TRXs has to be used for calculating the average reuse cluster size:

$$ARCS = \frac{B}{\overline{\#TRX} / cell}$$

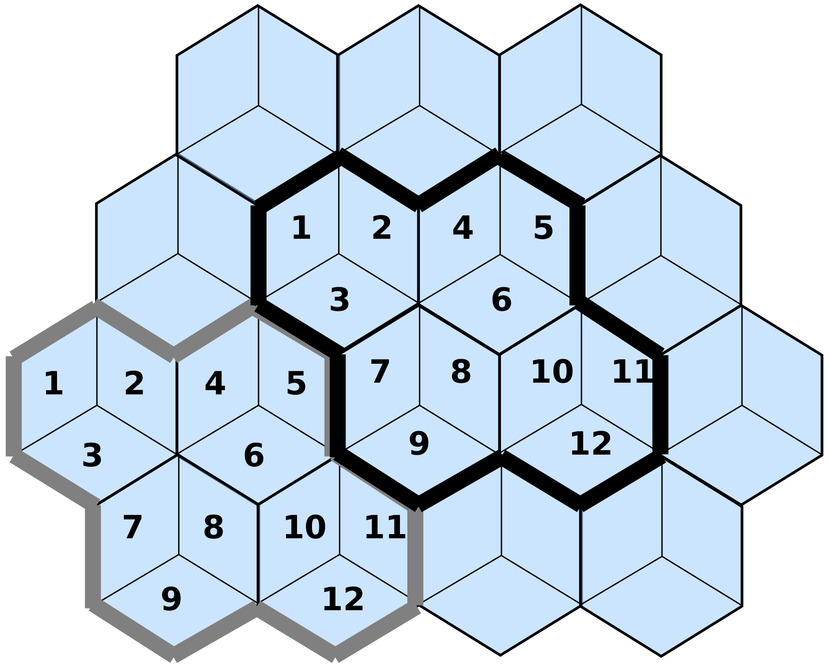
RCS and ARCS (2)

- The ARCS is giving the average reuse of the network when using the whole bandwidth and all TRXs per cell
- E.g: if we want to have the reuse of all non hopping TCH TRXs, we have to use the dedicated bandwidth and the average number of non hopping TCH TRXs per cell to get the ARCS of this layer type.
- Each cell has only one BCCH. Therefore the BCCH reuse is an RCS and not an ARCS!

Reuse Cluster Size (1)

- Sectorized sites
- 4 sites per reuse cluster
- 3 cells per site

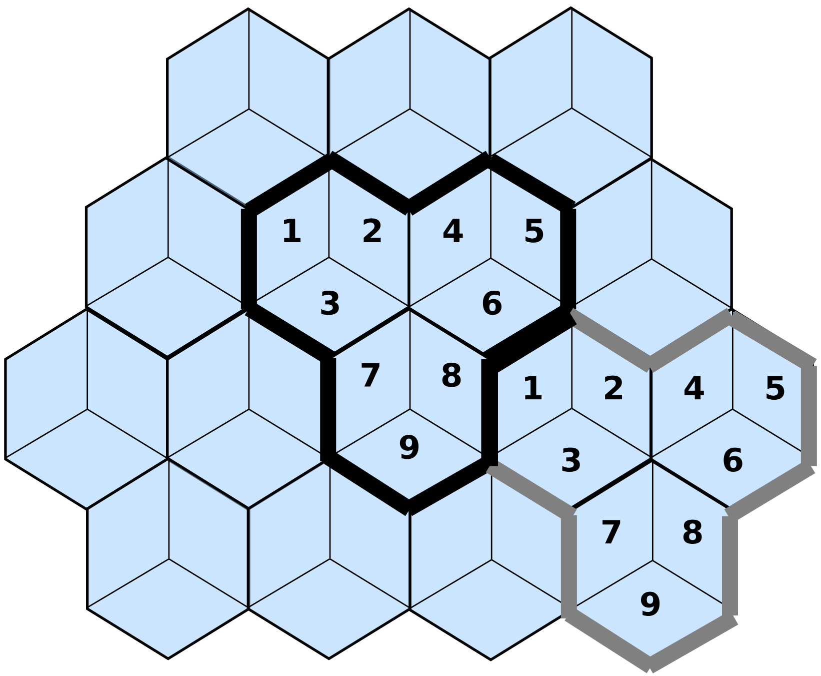
- REUSE Cluster Size:
  4X3 =12



Reuse Cluster Size (2)

- Sectorized sites
- 3 sites per reuse cluster
- 3 cells per site

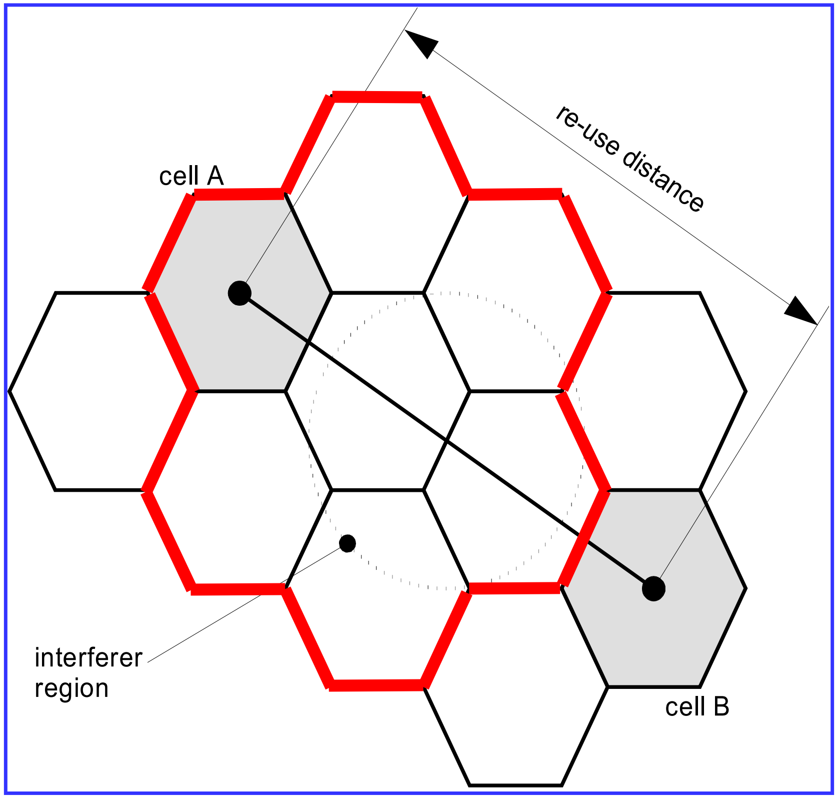
- REUSE Cluster Size
  3X3 = 9



Reuse Distance

$$D = f \cdot R \cdot \sqrt{3 \cdot RCS}$$

$$f = \begin{cases} 1 & \text{omnidirectional cells} \\ \frac{2}{3} & \text{three - sectorized cells} \end{cases}$$



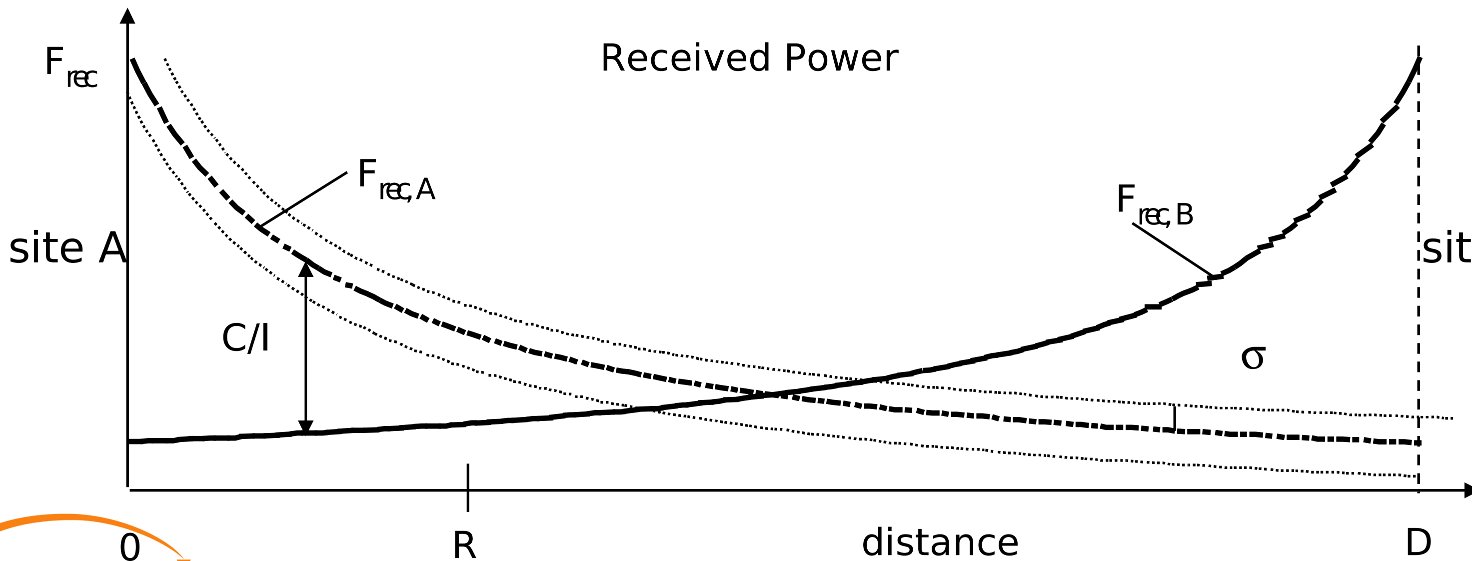
Frequency Reuse Distance

D = distance between cell sites with the same frequencies
R = service radius of a cell
B = number of frequencies in total bandwidth
RCS = reuse cluster size, i.e. one cell uses B/RCS frequencies

In hexagonal cell geometry: $D/R = \sqrt{f \cdot 3\ RCS}$

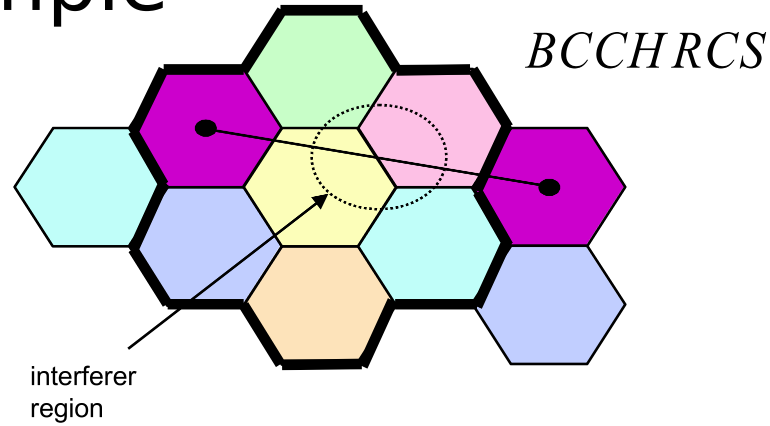
omni cells: f=1; sector cells: f=2/3

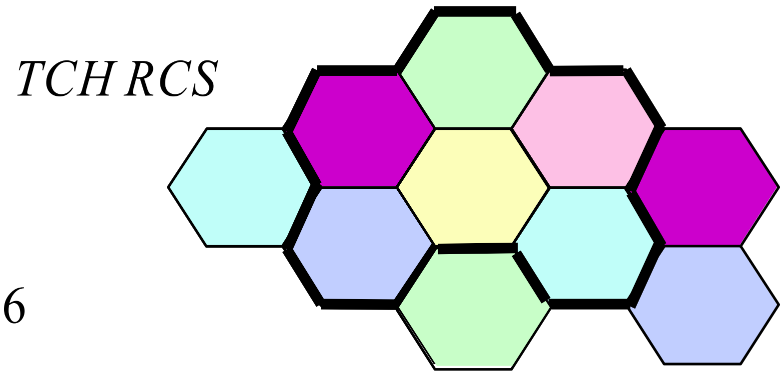
Examples (omni):
RCS = 7: D/R = 4.6
RCS = 9: D/R = 5.2
RCS =12: D/R = 6.0



Frequency Reuse: Example

- No sectorization
- 7 cells per cluster
  - BCCH RCS = 7
- TCH Reuse: Depending on BW and Number of installed TRXs per cell
- Example:
  - B= 26
  - 4TRXs per cell





$$TCH\,RCS = \frac{26 - 7BCCH - 1Guard}{3} = 6$$

Traffic Planning
Frequency Planning

Cell Planning - Frequency Planning

Cell Planning - Frequency Planning (1)

- Can frequency planning be seen independently from cell planning?

Discussion

Cell Planning - Frequency Planning (2)

- Bad cell planning
  - Island coverage ➪ disturbing the reuse pattern
  - Big overlap areas ➪ bigger reuse necessary
- Good cell planning
  - Sharp cell borders ➪ good containment of frequency
  - Small overlap areas ➪ tighter reuse possible

Influencing Factors on Frequency Reuse Distance

- Topography
  - Hilly terrain ➪ Usage of natural obstacles to define sharp cell borders ➪ tighter frequency reuse possible
  - Flat terrain ➪ Achieveable reuse much more dependent on the accurate cell design
- Morphology
  - Water ➪ low attenuation ➪ high reuse distance
  - City ➪ high attenuation ➪ low reuse distance

Conclusion

- In cellular mobile networks, the frequency reuse pattern has a direct influence on the interference and hence the network quality
- Regular hexagonal patterns allow the deduction of engineering formulas
- In real networks, cell sizes and shapes are irregular due to
  - Variation in traffic density
  - Topography
  - Land usage

➡ Engineering formulas allow the assessment of the network quality and worst-case considerations, but the real situation must be proved!

Examples for different frequency reuses

- Big city in the south of Africa:
  - BCCH reuse 26
    - Irregular cell design
    - Mixed morphology
    - Lots of water
    - Flat terrain plus some high sites

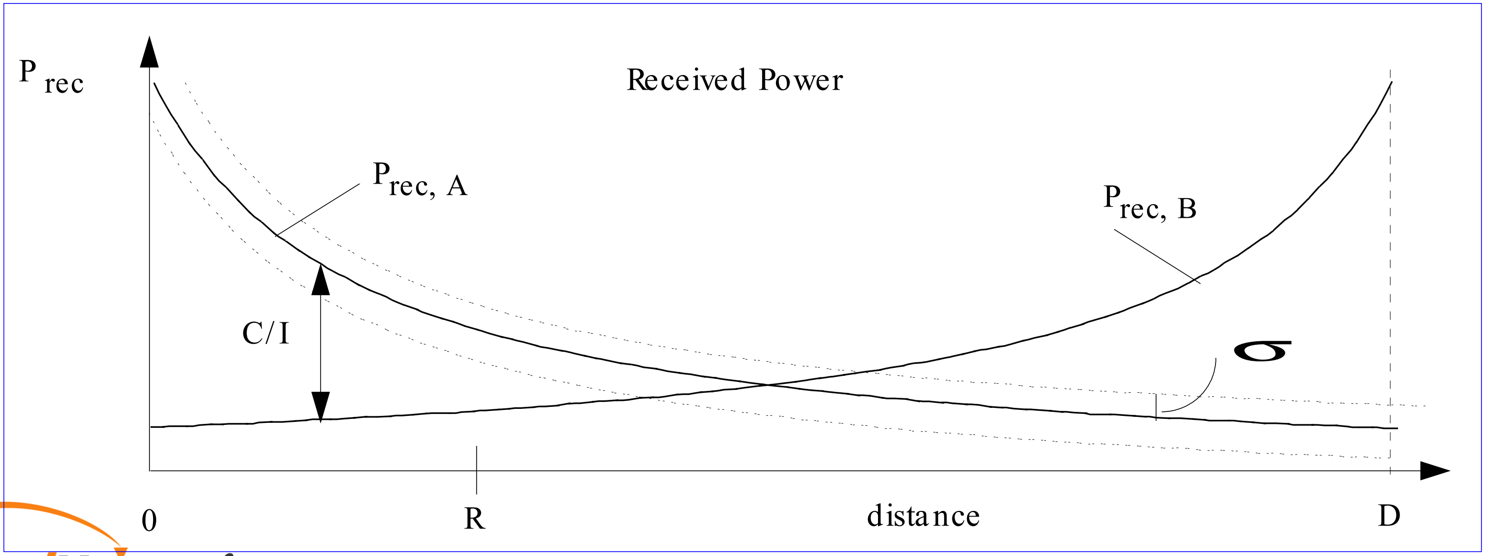
- Big city in eastern Europe
  - BCCH reuse 12
    - Regular cell design
    - Flat area
    - Only urban environment

Traffic Planning
Frequency Planning

Interference Probability

Interference Theory (1)

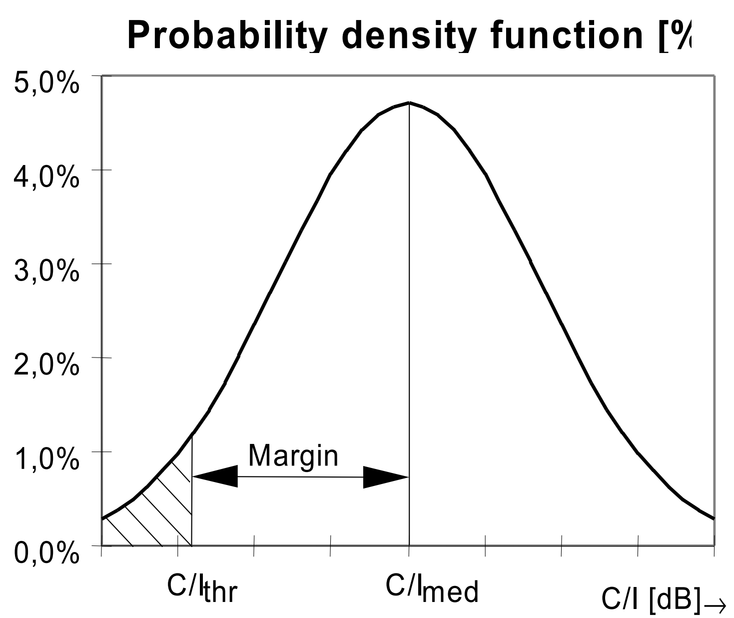
- C/I restrictions
  - 9dB for co-channel interference
  - -9 dB for adjacent channel interference

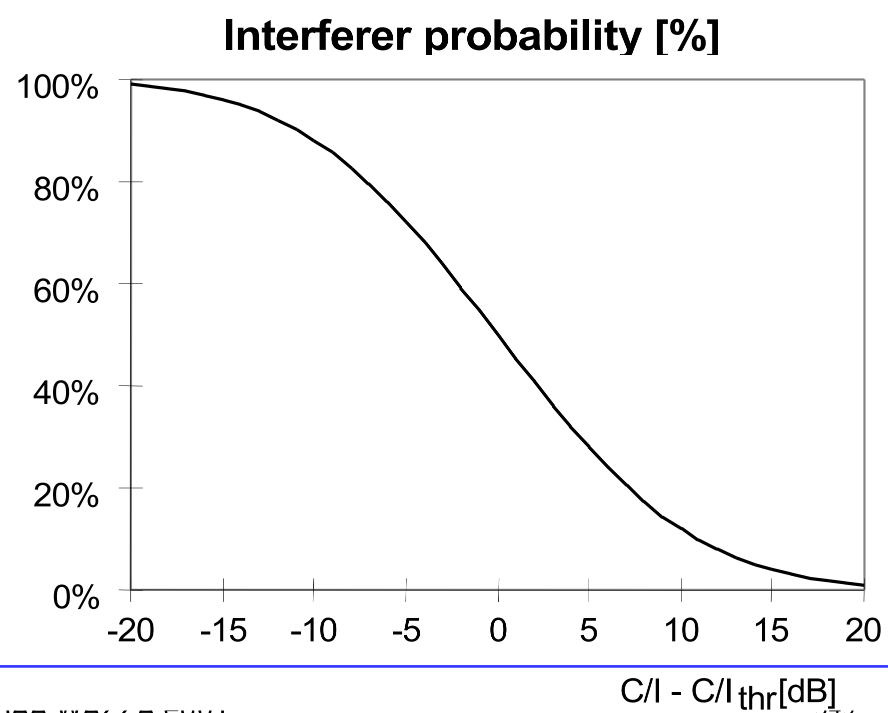


Interference Theory (2)

ARCS	Pint[%]
6.5..9.0	10
7.0..9.5	7.5
8.5..11.0	5.0
12.0..16.0	2.5

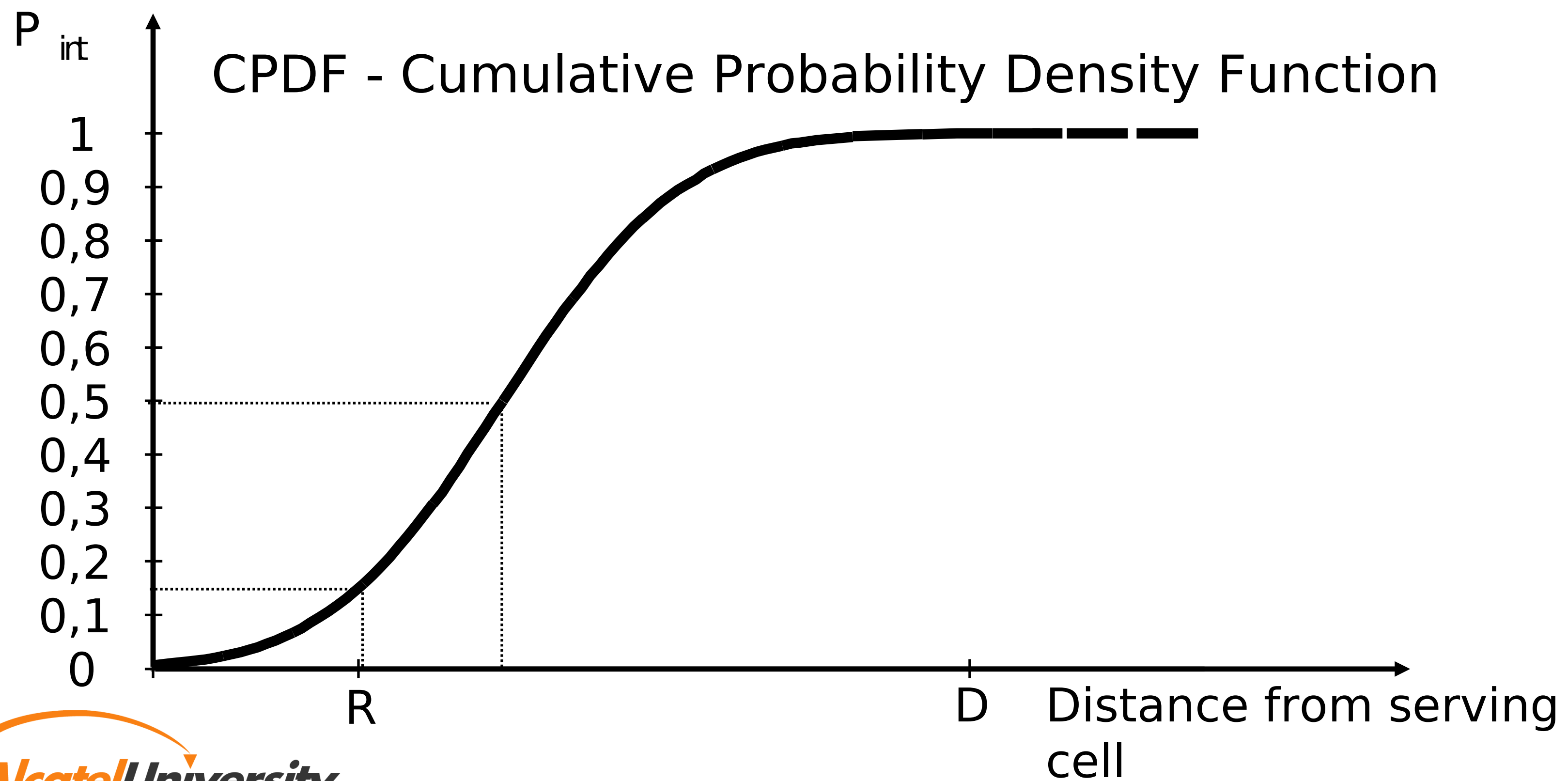
- Interference probability
  - C/I_{med} is the calculated carrier to interference ratio at a certain location (pixel)





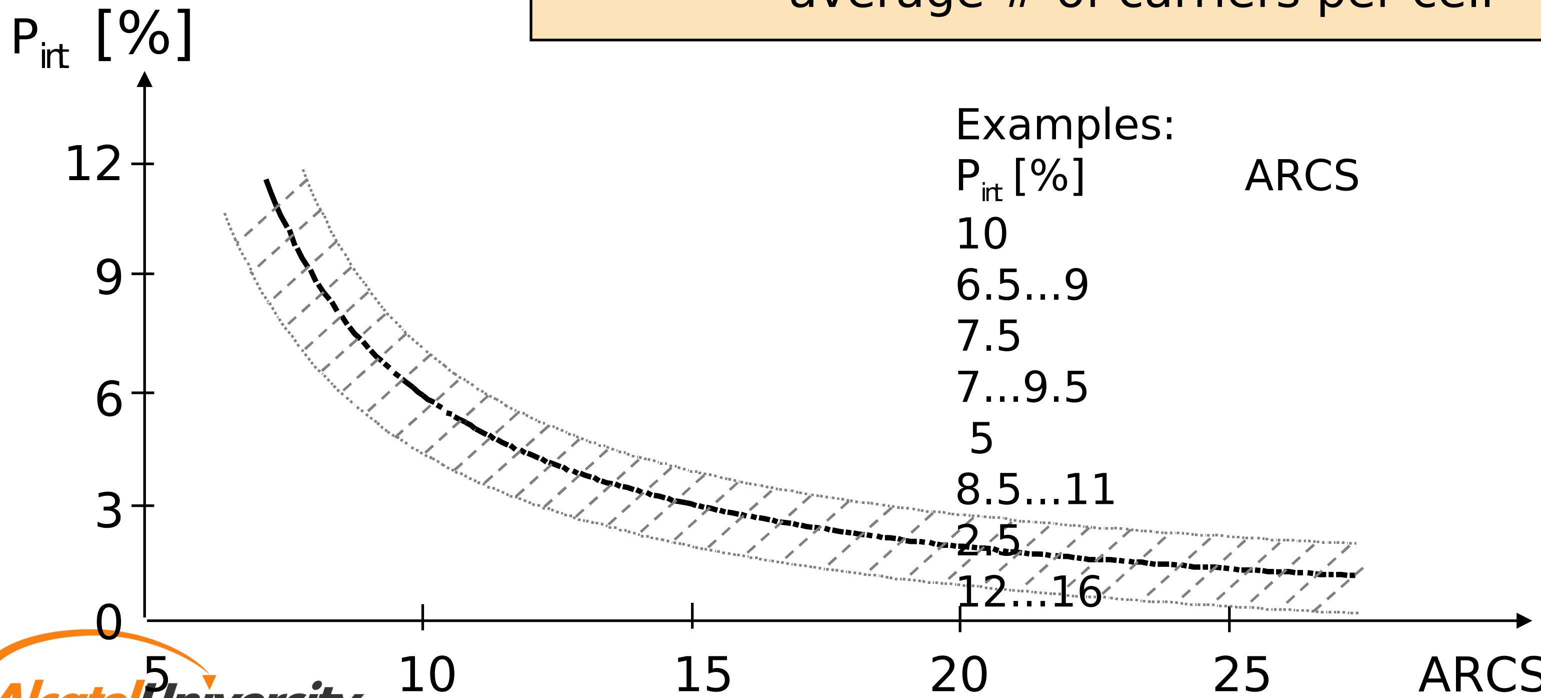
Interference Probability

$P_{int} = P(C/I < C/I_{thr})$



Interference Probability dependent on Average Reuse Cluster Size (ARCS)

$$\text{ARCS} = \frac{\text{\# of frequencies in used bandwidth}}{\text{average \# of carriers per cell}}$$



Examples:

P_{int} [%] ARCS

10

6.5...9

7.5

7...9.5

5

8.5...11

2.5

12...16

Traffic Planning
Frequency Planning

Carrier Types
Multiple Reuse Pattern
Intermodulation

Carrier Types - BCCH carrier

- BCCH frequency is on air all the time
- If there is no traffic/signaling on TS 1 to 7
  ⇨ dummy bursts are transmitted
- PC (Power Control) and DTX (Discontinuous Transmission) are not allowed
- Important for measurements of the mobile

Carrier Types - TCH carrier

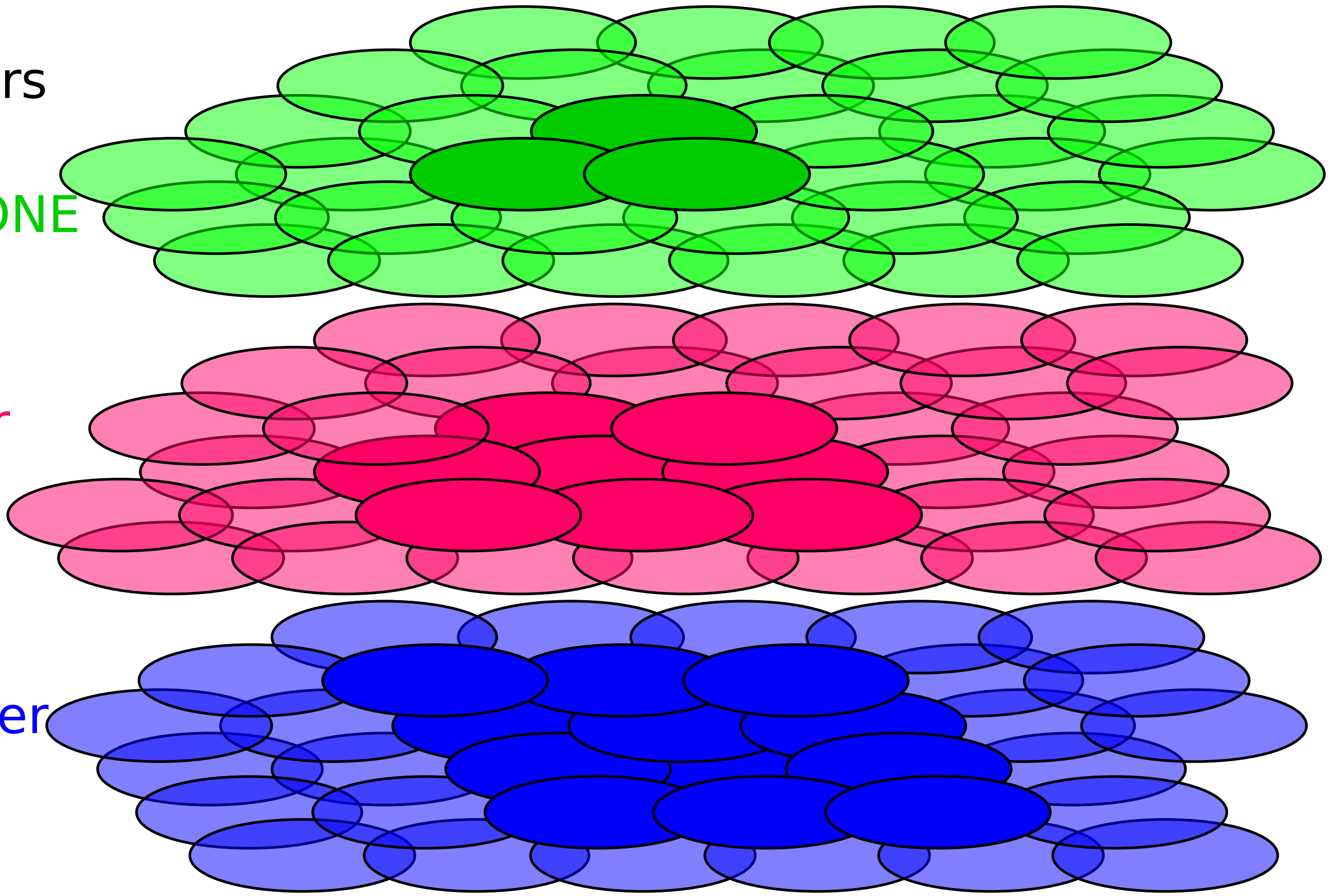
- PC allowed and recommended for UL <u>and</u> DL
  - Reduction of transmit power according to the actual path loss
  - Careful parameter tuning for DL necessary
- DTX allowed and recommended for UL and DL
  - Discontinuous Transmission
  - If there is no speech, nothing is transmitted
  - Generation of comfort noise at receiving mobile
- TCH not in use ⇨ no signal is transmitted
- Special case: Concentric cells
  - Different re-uses for inner and outer zone are possible

Multiple reuse pattern (1)

- For different types of carriers, different interference potential is expected
- As the BCCH carrier has the highest interferer potential because of being on air all the time and the BCCH channel itself is accepting only low interference, the REUSE on the BCCH layer is higher then on other layers
- TCH layers can be planned with a smaller REUSE
- Inner zones of concentric cells are able to deal with the smallest reuse in non hopping networks

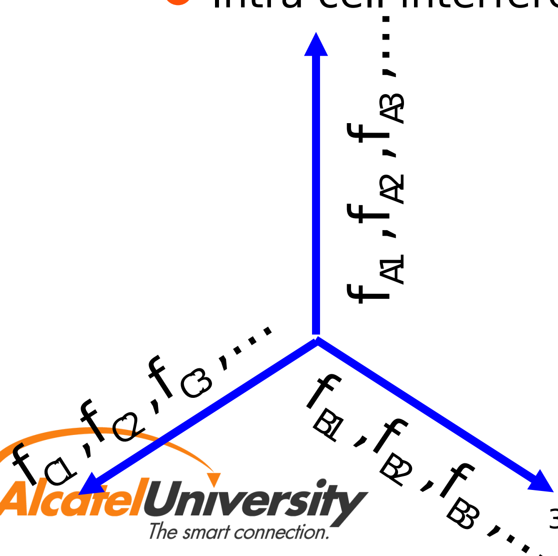
Multiple reuse pattern (2)

- REUSE clusters for
  - INNER ZONE layer
  - TCH layer
  - BCCH layer



GSM restrictions

- Intra site minimum channel spacing ➪ 2
- Intra cell minimum channel spacing ➪ 2 (ETSI recommends 3, but with Alcatel EVOLIUM capabilities this value can be set to 2)
  - constrains:
    - Uplink power control enabled
    - Intra cell interference handover enabled



Frequencies fAx,fBx,fCx,… must have at least 2 channels spacing

Frequencies fx1,fx2,fx3,… must have at least 3 channels spacing

Intermodulation problems (1)

- IM Products GSM900
  - In a GSM 900 system intermodulation products of 3rd and 5th order can cause interference
    - $2 * f_{1,t} – f_{2,t} = f_{2,r}$ / $2 * f_{2,t} – f_{1,t} = f_{1,r}$
    - $3 * f_{1,t} – 2 * f_{2,t} = f_{2,r}$ / $3 * f_{2,t} – 2 * f_{1,t} = f_{1,r}$
  - Frequency planning must avoid fulfilling these equations
  - Both frequencies must be on the same duplexer
  - To avoid intra band IM inside GSM900 the following frequency separations shall be avoided:
    - 75/112/113 channels

IM5 IM3

Intermodulation problems (2)

- IM Products GSM1800
  - In a GSM 1800 system, only intermodulation products of 3rd order can cause measurable interference
  - $2 * f_{1,t} - f_{2,t} = f_{2,r}$ / $2 * f_{2,t} - f_{1,t} = f_{1,r}$
  - Frequency separations to be avoided
    - 237/238 channels
- IM Products Dual Band (GSM900/GSM1800)
  - $f_{1800,t} - f_{900,t} = f_{900,r}$
  - Decoupling between the GSM 1800 TX path and the GSM 900 RX path is less than 30 dB (e.g. same antenna used!)

Intermodulation problems (3) - Summary

INSIDE Problem: IM3 / IM5		Problem can be solved by hopping over more than 10 frequencies
	carrier/antenna	restriction
G3 900	1	no
G3 900	2 ore more	112/113 (IM3) and 75 (IM5)
G3 1800	1	no
G3 1800	2 or more	237/238 (IM3) no IM5 quality degradation measurable
	carrier/antenna	
G2 900 w/o dupl	1	no
	2 or more	no
G2 900 with dupl	1	no
	2 or more	112/113 (IM3) and 75 (IM5)
G2 1800 w/o dupl	1	no
	2 or more	no
G2 1800 with dupl	1	no
	2	dud2(high Power) -> no
	2	dupd -> 237/238

OUTSIDE Problem: Dual Band		Problem only for non hopping and BCCH carriers
Colocated BTSs		
G3 900	G2/G3 1800	f(1800,t) - f(900,t) = f(900,r)
G2 900 w/o dupl	G2/G3 1800	no
G2 900 with dupl	G2/G3 1800	f(1800,t) - f(900,t) = f(900,r)

Treating “neighbor” cells

- Cells, which are not declared as neighbor cells but are located in the neighborhood may use adjacent frequencies if it is not avoidable, but no co channel frequencies

- Cells which are declared as neighbors, thus have HO relationships, must not use co or adjacent frequencies
  - If an adjacent frequency is used, the HO will be risky and at least audible by the user

Where can I find neighbor cells?

- At the OMC-R for each cell a list of neighbor cells is defined
- Maximum number of neighbors: 32
- The list of neighbors and their frequencies is transmitted to the mobile to be able to perform measurements on these frequencies
- In case of a HO cause, the HO will be performed towards the best neighbor

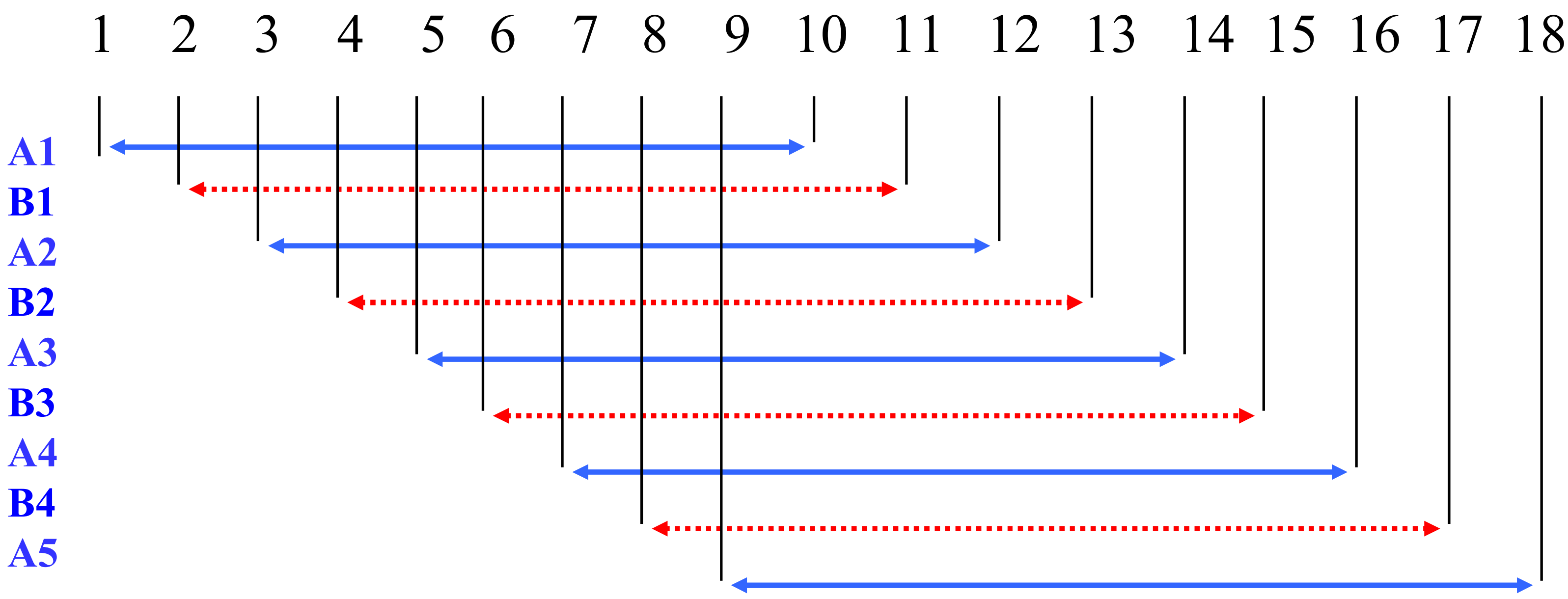
Traffic Planning
Frequency Planning

Manual Frequency Planning

Manual frequency planning (1)

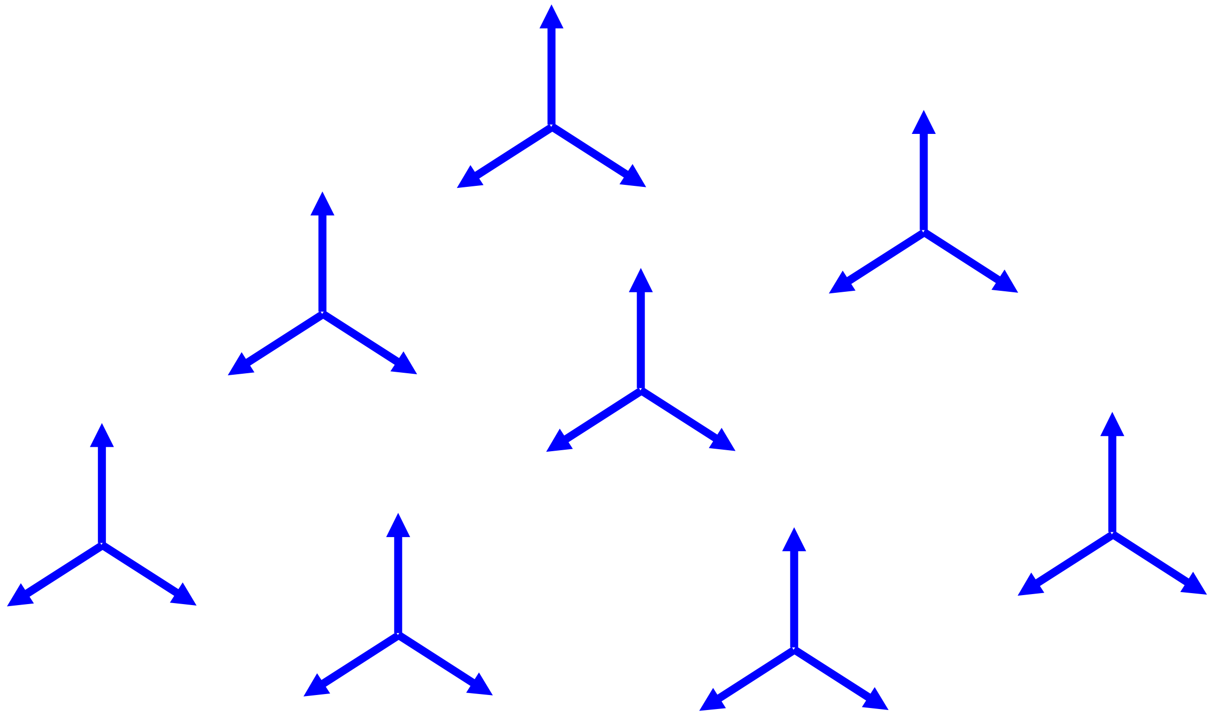
- No fixed method
- Free frequency assignment possible, but very time consuming for larger networks
- For easy and fast frequency planning: use group assignment
- Example:
  18 channels, 2TRX per cell ⇨ ARCS 9

Manual frequency planning (2)

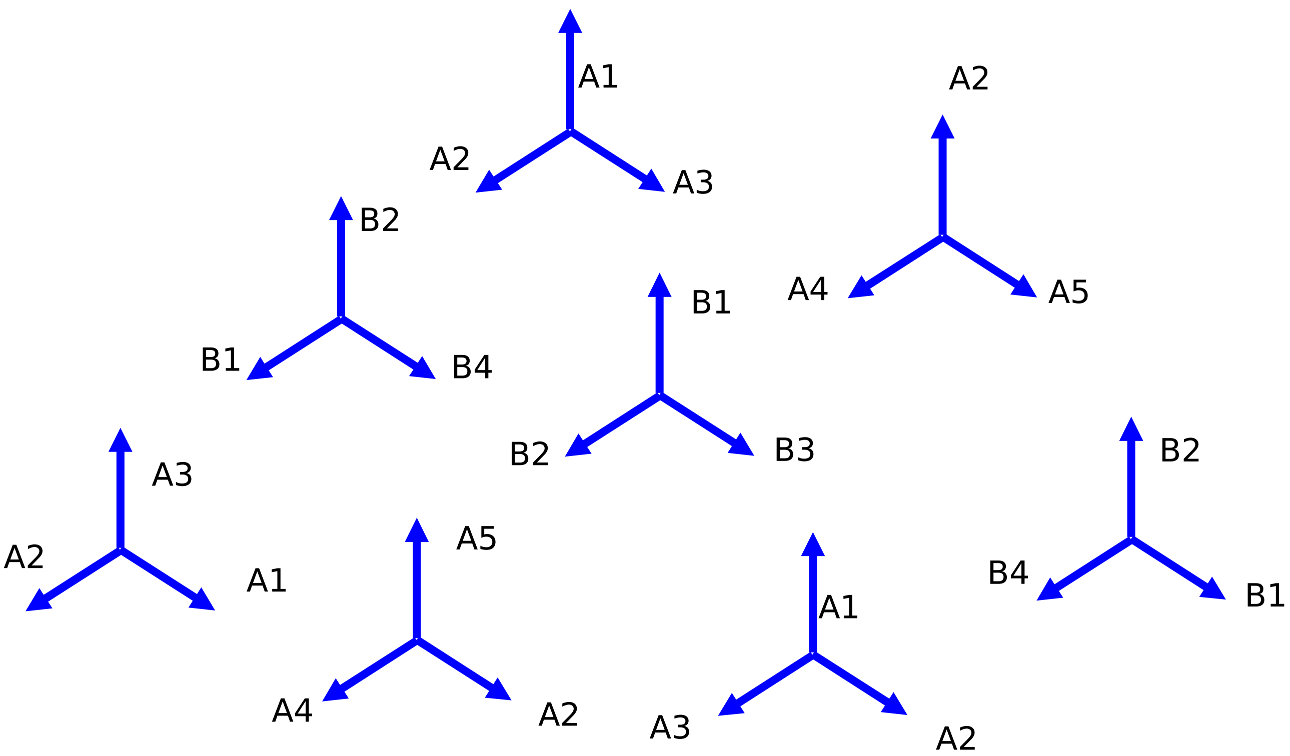


- GSM restrictions are automatically fulfilled, if on one site only groups A* or only B* are used

Exercise: Manual frequency planning (3)



Exercise: Manual frequency planning (4)



Discussion: Subdivide Frequency Band?

- Any subdivision of the frequency band is reducing the spectrum efficiency!
- Separations should be avoided if possible!
- As the BCCH has to be very clean, it is nevertheless recommended to use a separated band and select a bigger reuse

Hint for creating a future proofed frequency plan

- If a frequency plan is implemented, using all available frequencies in the most efficient way, it is very difficult to implement new sites in the future!
- New sites would make a complete re-planning of the surrounding area or the whole frequency plan necessary
- To avoid replanning every time when introducing new sites, it is recommended to keep some Joker frequencies free
- These Joker frequencies can be used for new sites (especially BCCH TRXs) unless it is impossible to implement new sites without changing a big part of the frequency plan

➡ New frequency plan necessary!

Implementing a frequency plan

- If only a few frequencies have to be changed, the changes can be done at the OMC-R
  - Disadvantage: Every cell has to be modified separately
  - ☞ Downtime of the cell approx. 5 minutes
- If lots of changes have to be done, it is of advantage to use external tools
  - Since B6.2 the complete frequency plan can be uploaded from the OMC
  - the uploaded file can be modified by the tool (A9155 PRC Generator)
  - the the new plan is downloaded into the network and activated at once

Traffic Planning
Frequency Planning

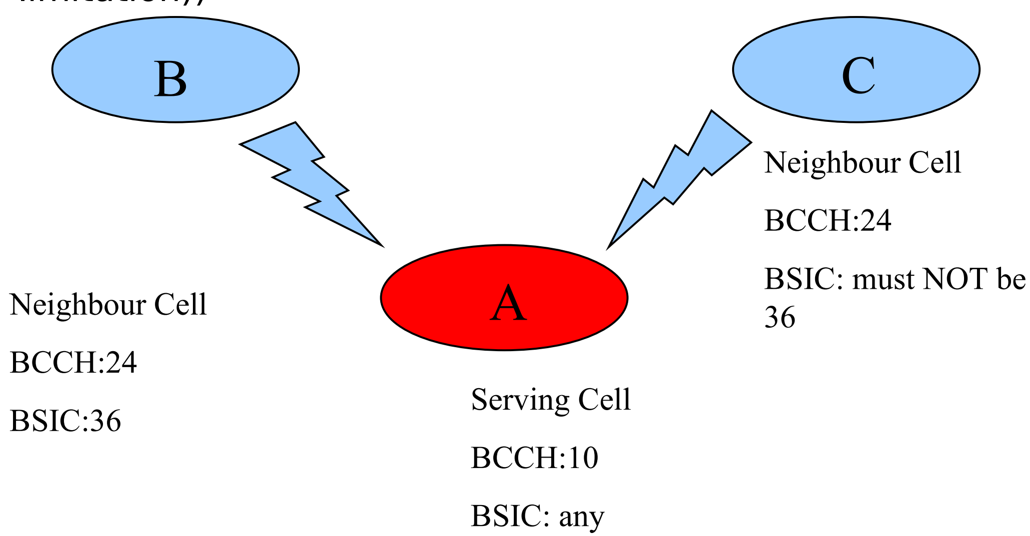
BSIC Planning

BSIC allocation

- Together with the frequencies the **B**ase Transceiver **S**tation **I**dentity **C**ode (BSIC) has to be planned
- The BSIC is to distinguish between cells using the same BCCH frequency
- BSIC = NCC (3bits) + BCC (3bits)
  - NCC Network (PLMN) Colour Code BCC - Base Transceiver Station (BTS) Colour Code
- BSIC planning is supported by the A9155 (Alcatel Radio Network Planning Tool)

BSIC Planning Rules

- The same combination BCCH/BSIC must not be used on cell influencing on each other (having a mutual interference <>0)
- BSIC allocation rules:
  - Avoid using same BCCH/BSIC combination of:
    - neighbours cells
    - second order neighbour cells (the neighbours of neighbour cell (OMC limitation))



Spurious RACH

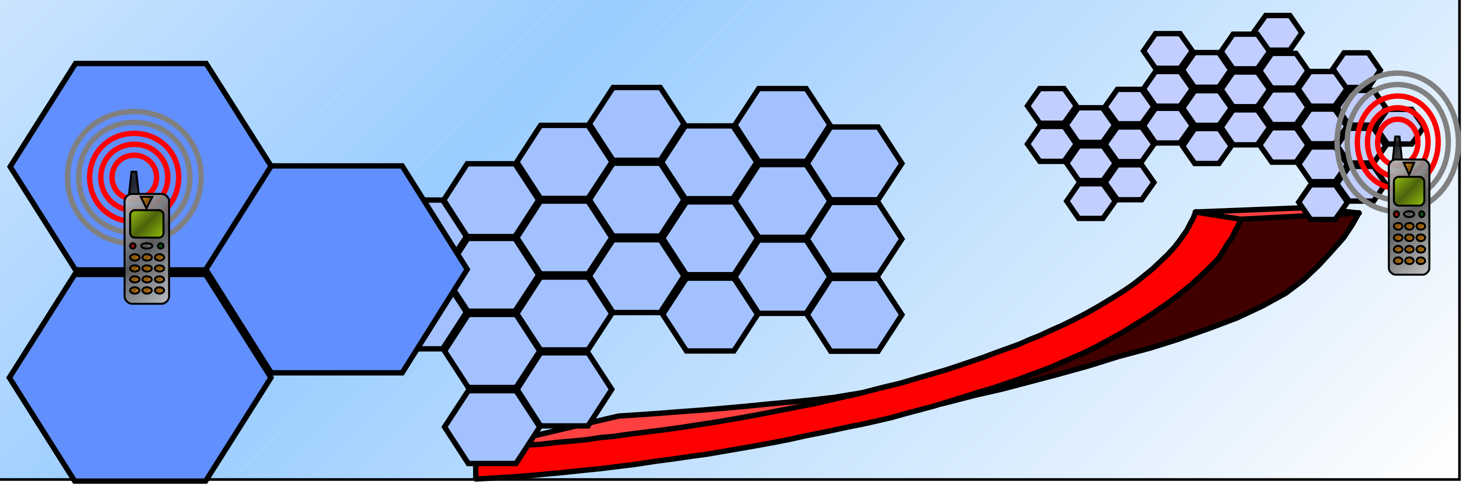
- Bad BSIC planning can cause SDCCH congestion cause by the spurious RACH problem, also known as “Ghost RACH”
- This problem occurs, when a mobile sends an HO access burst to a TRX of cell A using the same frequency as a nearby cell B uses on the BCCH
- Both cells using the same BSIC and Training Sequence Code TSQC, the HO access burst is understood by the cell B as a RACH for call setup
- Therefore on cell B SDCCHs are allocated everytime a HO access burst is sent from the mobile to the cell A

Summary

- For optimal usage of your frequency spectrum a good cell design is essential
- Use larger reuse for BCCH frequencies
- Use spectrum splitting only when necessary

Traffic Planning
Frequency Planning

Capacity Enhancement Techniques



Capacity enhancement by planning

- Interference reduction of cells
  - Check of antenna type, direction and down tilt
    - This is a check of cell size, border and orientation
  - Check of proper cabling
    - Is TX and RX path on the same sector antenna?
  - Check of the frequency plan
    - Introduction of a better frequency plan

Capacity enhancement by adding feature

- Frequency hopping
  - Base band hopping
  - Synthesized frequency hopping
- Concentric cells
- Half rate

Capacity enhancement by adding TRX

- Adding TRX to existing cells
- Multi band cells
- Concentric cells

Capacity enhancement by adding cells

- Adding of cells at existing site locations
- Adding new cell = adding new BCCH
- Dual band
  - Adding cells using another frequency band
- Cell splitting
  - Reduction of cell size
  - Change of one omni cell into several cells/sector cells

Capacity enhancement by adding sites

- Dual band/multi band network
  - Adding of new sites in new frequency band
- Multi layer network
  - Adding of new sites in another layer
    - E.g. adding micro cells for outdoor coverage
- Indoor coverage
  - Adding micro cells indoor coverage
  - Adding macro cells indoor coverage

GSM Radio Network Engineering Fundamentals

Radio Interface

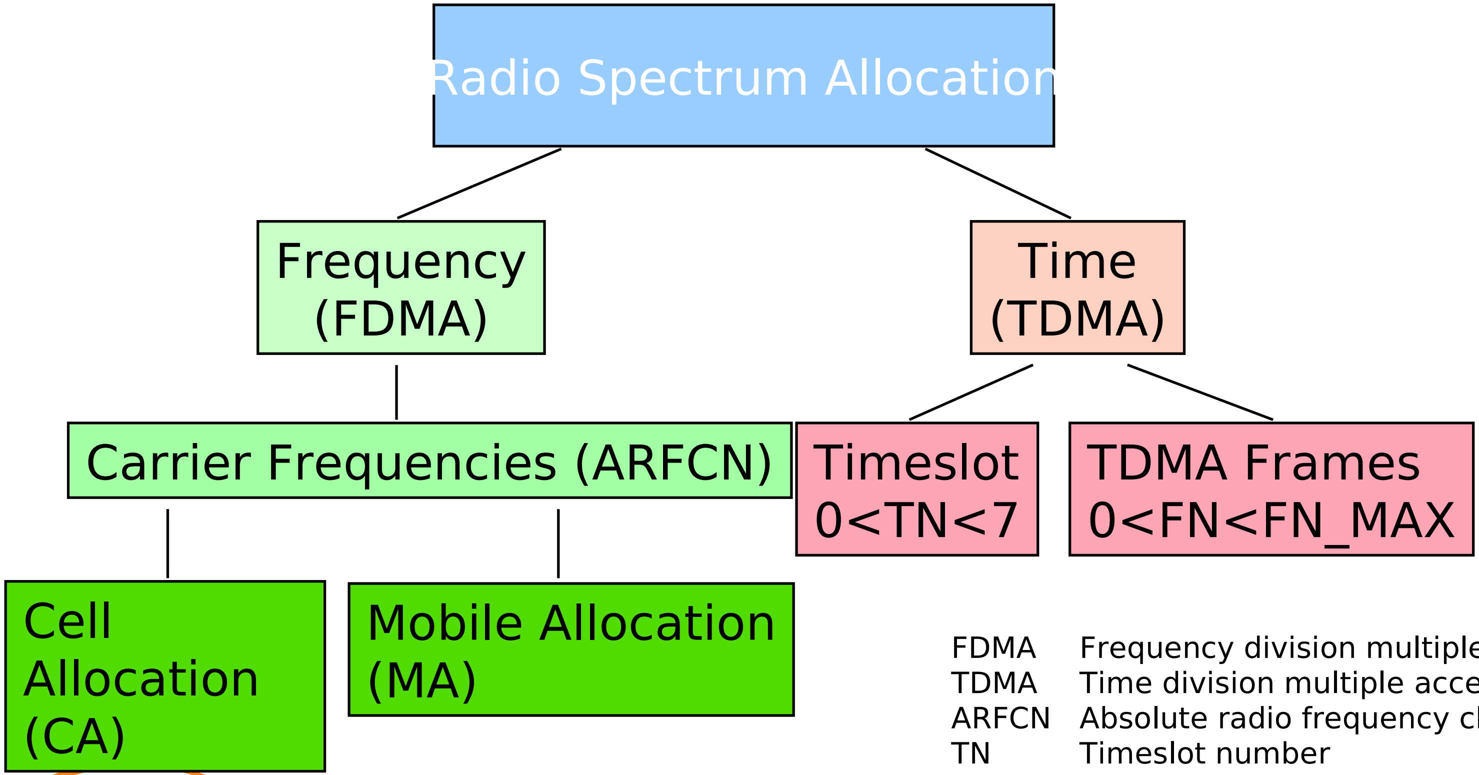
Contents

- GSM Air Interface
- Channel Coding
- Performance Figures

Quality of Service

GSM Air Interface

Radio Resources



FDMA	Frequency division multiple access
TDMA	Time division multiple access
ARFCN	Absolute radio frequency channel number
TN	Timeslot number
FN	Frame number

GSM Transmission Principles (1)

- FDMA and TDMA with 8 time slots per carrier
- RF frequency band
  - (E)GSM: (880) 890 ... 915 MHz Uplink (MS → BS)
    (925) 935 ... 960 MHz Downlink (BS → MS)
  - GSM1800: 1710 ... 1785 MHz Uplink
    1805 ... 1880 MHz Downlink
- 200 kHz bandwidth
- Number of carriers: 124 (GSM); 374 (DCS); 49 (E-GSM)

GSM:	$F_{lower}(n) = 890 + 0.2 \cdot n$	MHz	with $1 \leq n \leq 124$	
E-GSM:	$F_{lower}(n) = 890 + 0.2 \cdot n$	MHz	with $0 \leq n \leq 124$	
	$F_{lower}(n) = 890 + 0.2 \cdot (n - 1024)$	MHz	with $975 \leq n \leq 1023$	
DCS :	$F_{lower}(n) = 1710.2 + 0.2 \cdot (n - 512)$	MHz	with $512 \leq n \leq 885$	

(E)GSM: $F_{upper}(n) = F_{lower}(n) + 45$ MHz

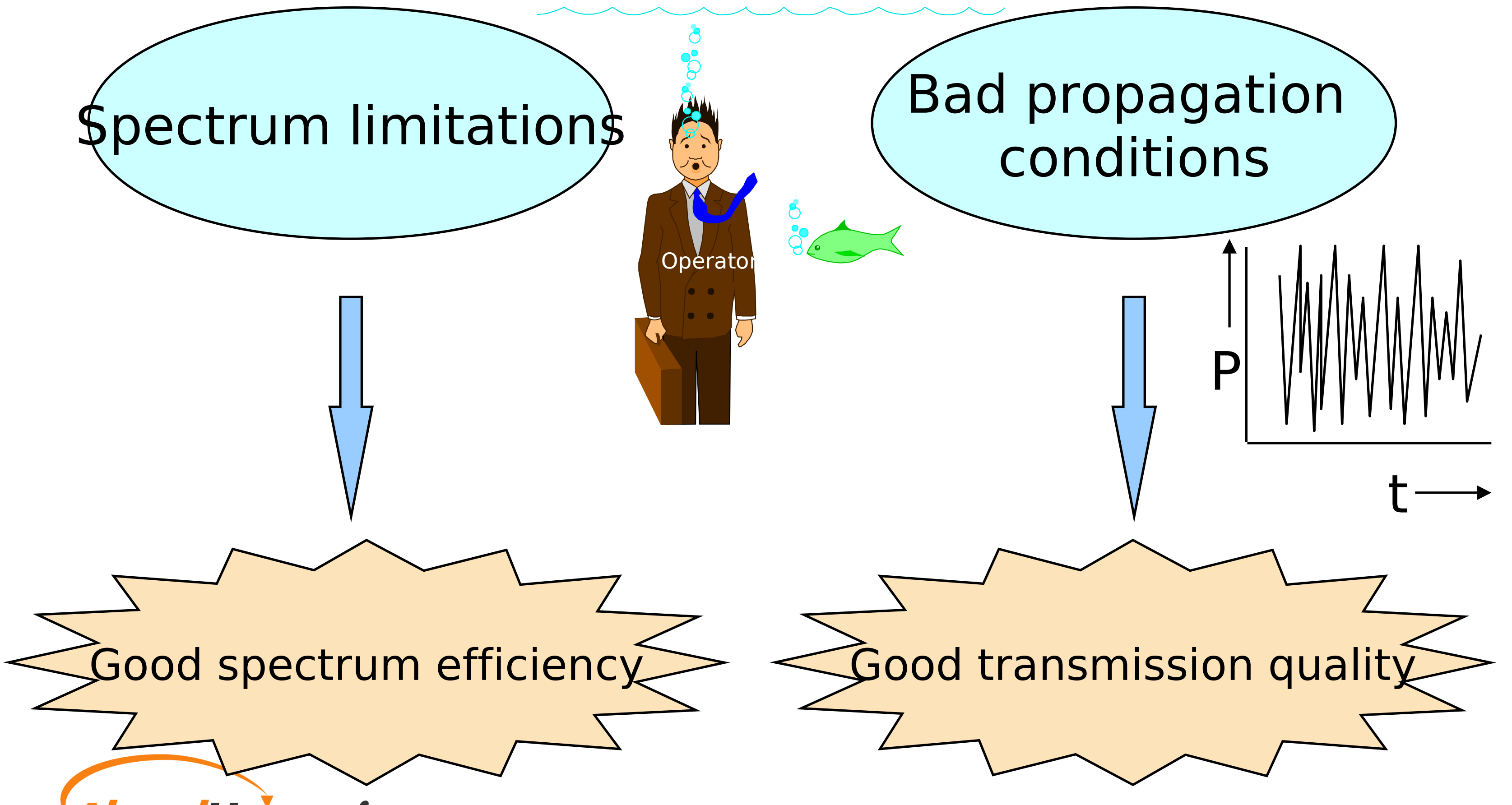
DCS: $F_{upper}(n) = F_{lower}(n) + 95$ MHz

GSM Transmission Principles (2)

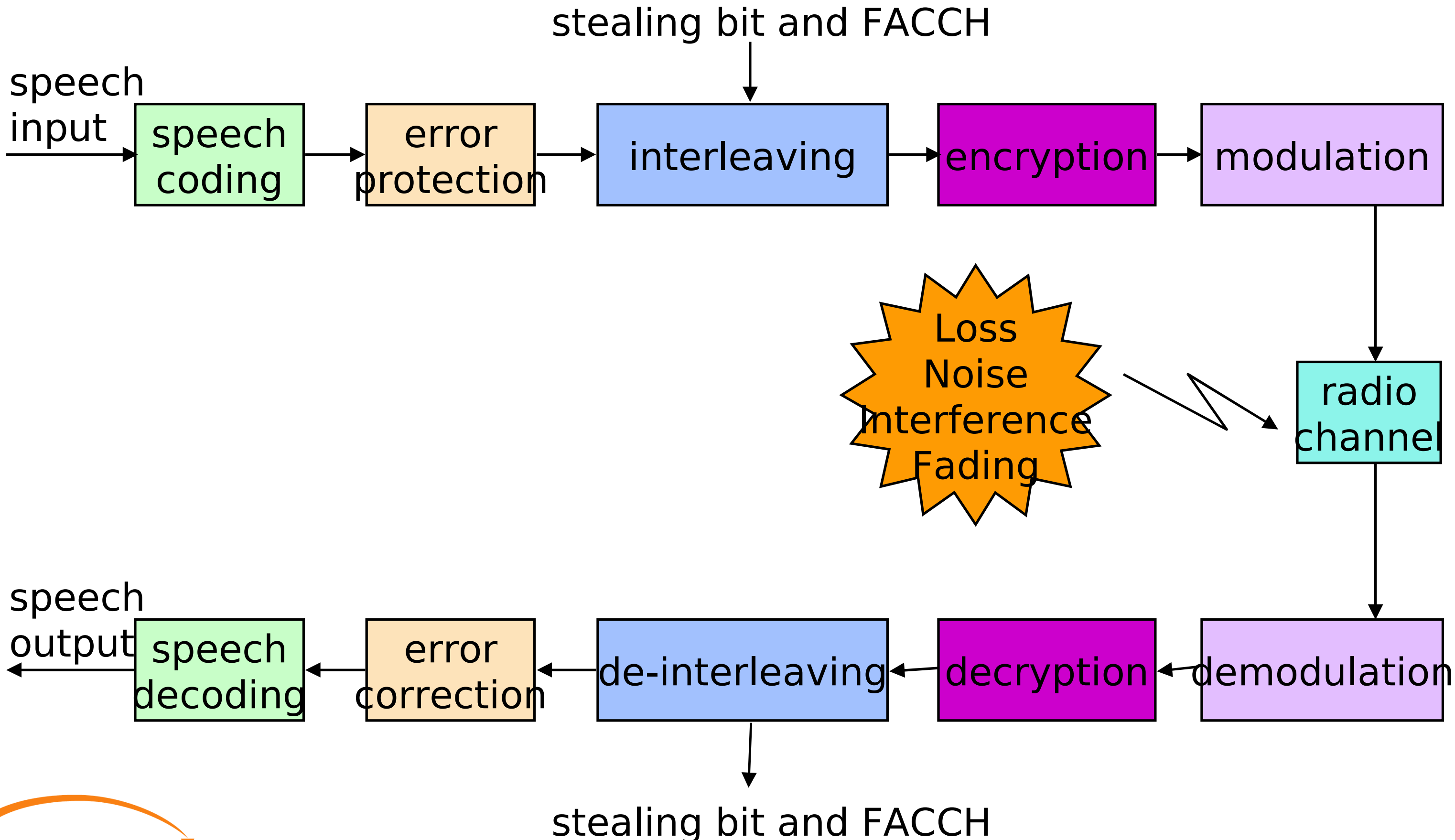
- **Channel types**
  - Traffic Channels (TCH)
    - Full rate
    - Half rate
  - Control Channels (CCH)
    - Broadcast Control Channel (BCCH)
    - Common Control Channel (CCCH)
    - Dedicated Control Channel (DCCH)

- **TDMA frame cycles**
  - 26 cycle for traffic channels
  - 51 cycle for control channels

Advantages of Signal Processing

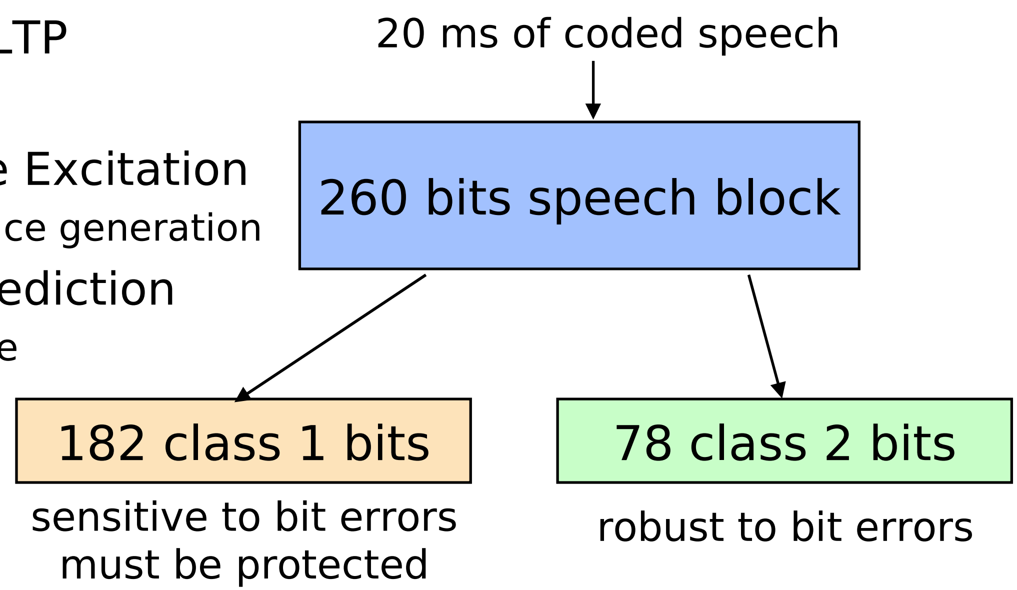


Signal Processing Chain



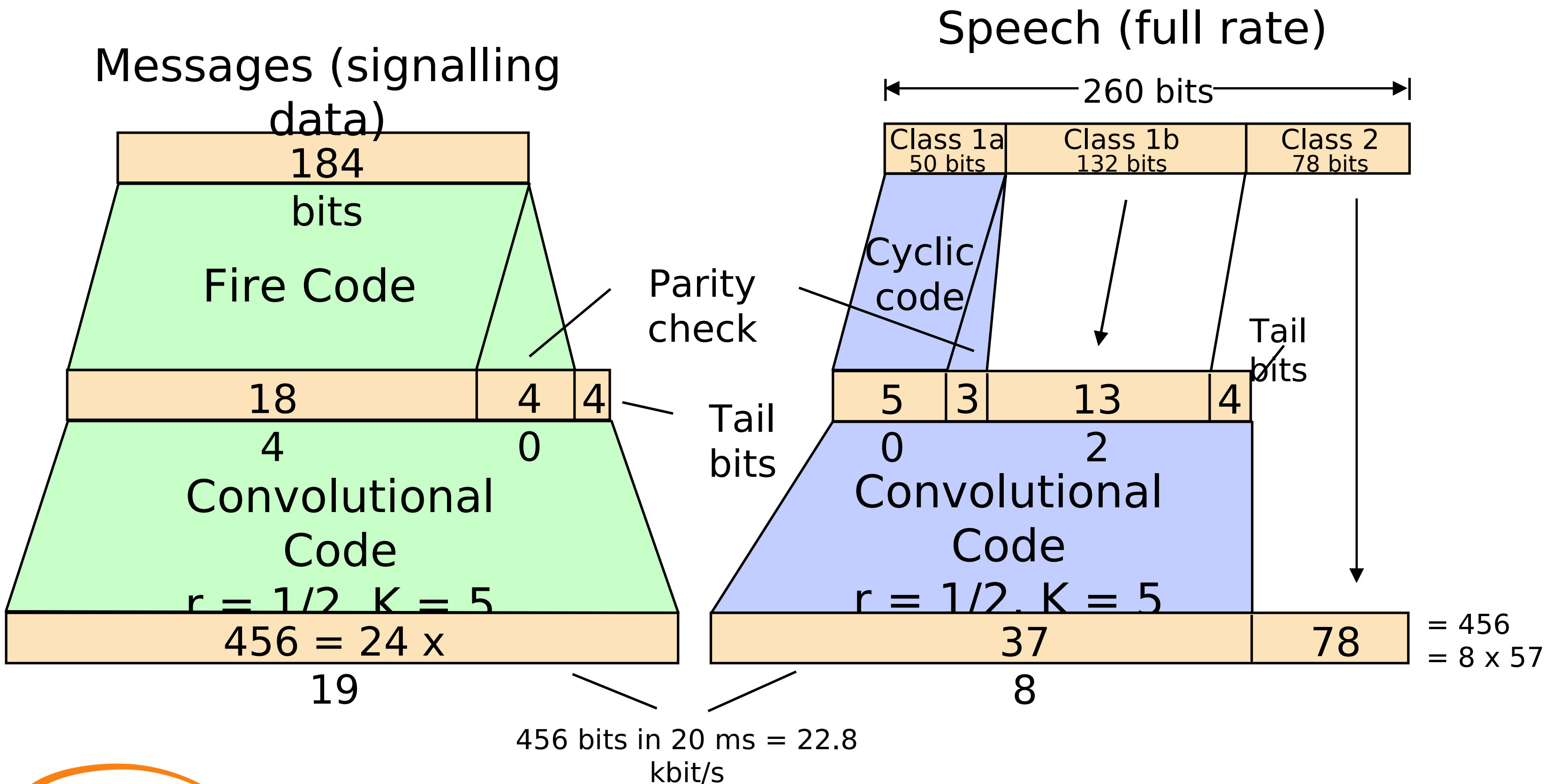
Speech Coding

- Coding algorithm: RPE-LTP
  - Pre-computation
  - RPE = Regular Pulse Excitation
    - Model of human voice generation
  - LTP = Long Term Prediction
    - Reduction of bit rate
- ➨ Bit rate: 13 kBit/s

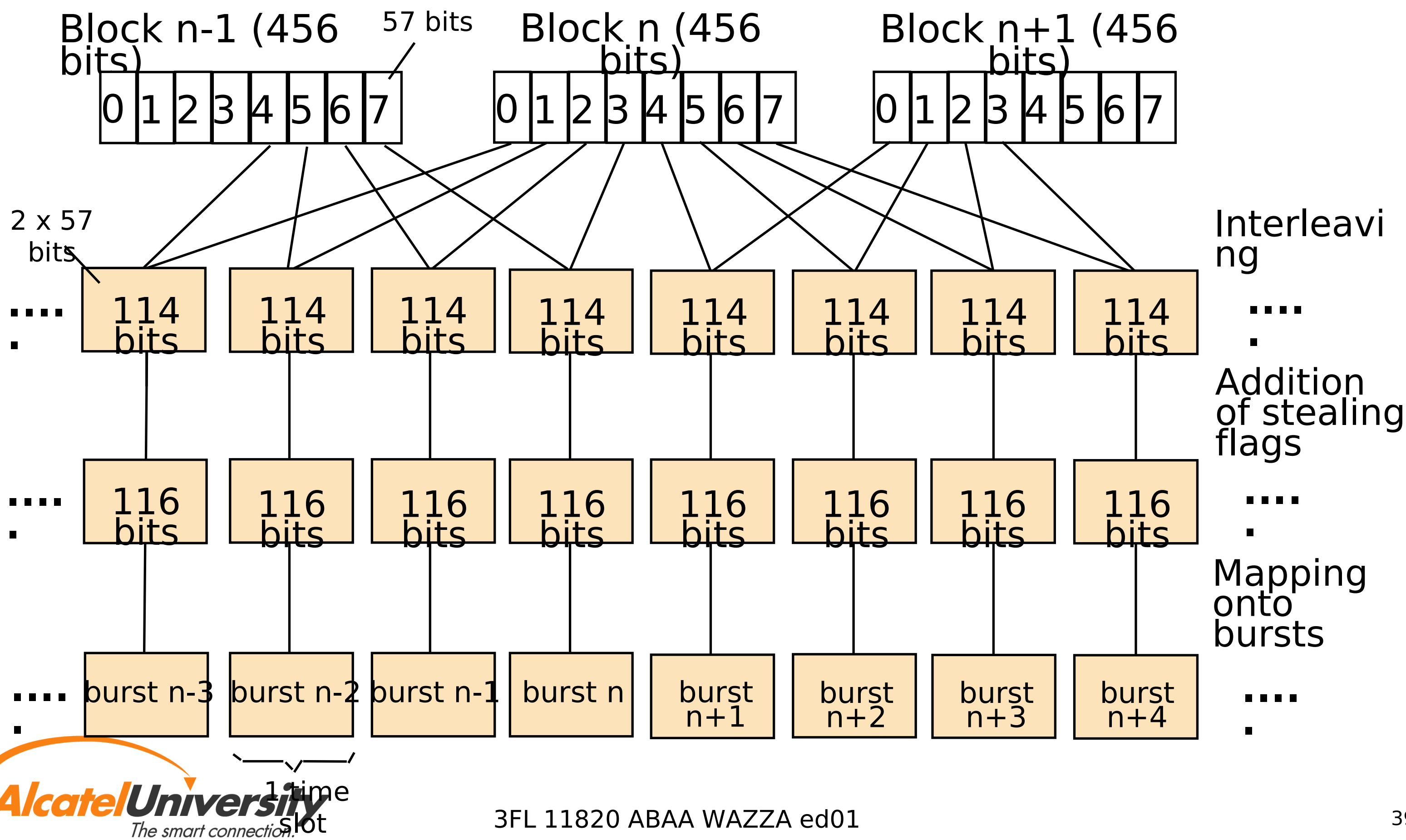


- Coding at fixed network: PCM A-law
- ➨ Bit rate: 64 kBit/s

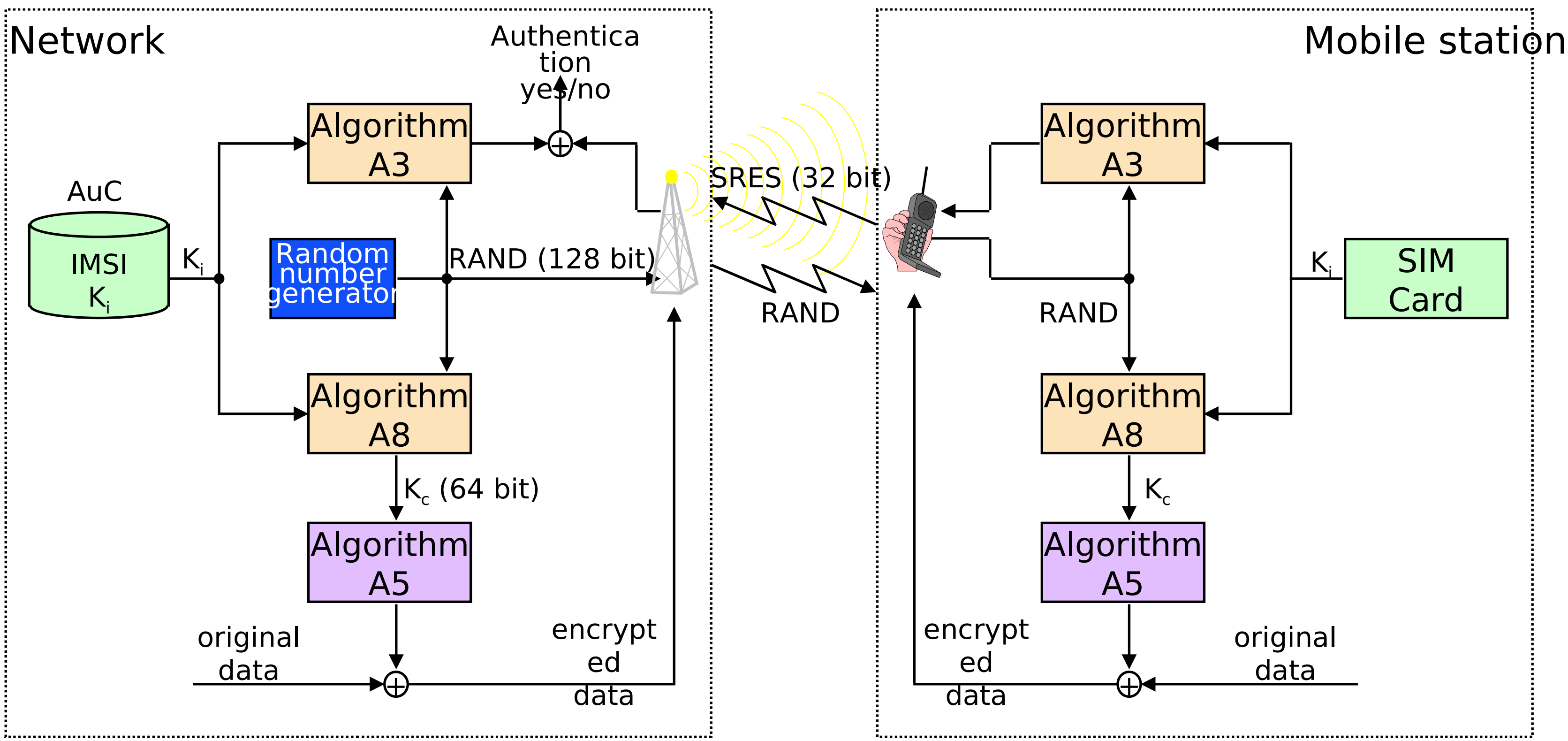
Error Protection



Interleaving and TDMA Frame Mapping



Encryption

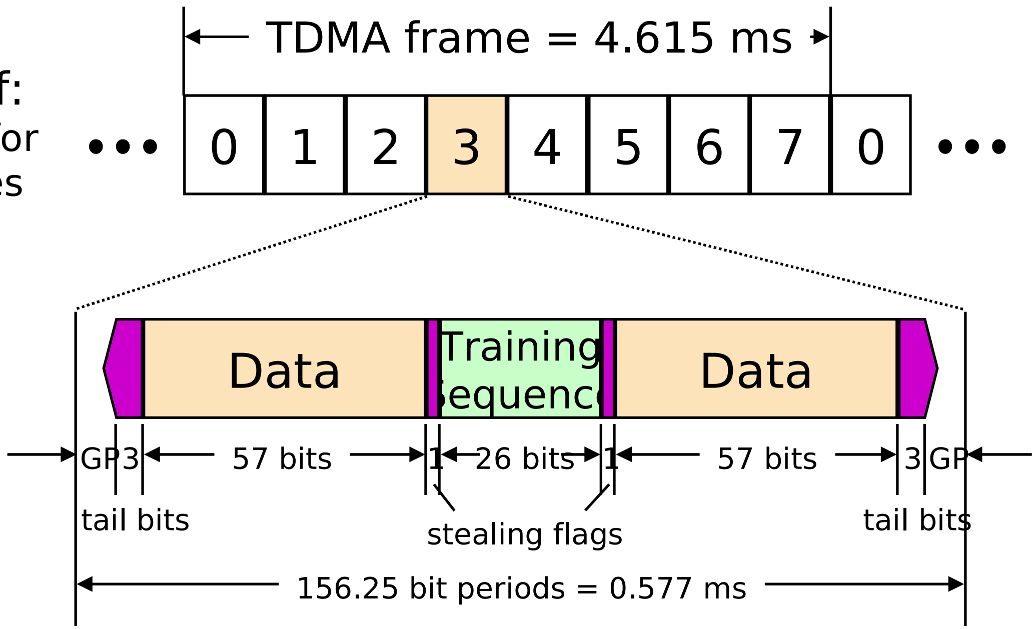


Network
Authentication yes/no
AuC
IMSI
K i
K i
Algorithm A3
Random number generator
RAND (128 bit)
Algorithm A8
K c (64 bit)
Algorithm A5
original data
encrypted data
SRES (32 bit)
RAND
Mobile station
Algorithm A3
RAND
K i
SIM Card
Algorithm A8
K c
Algorithm A5
encrypted data
original data

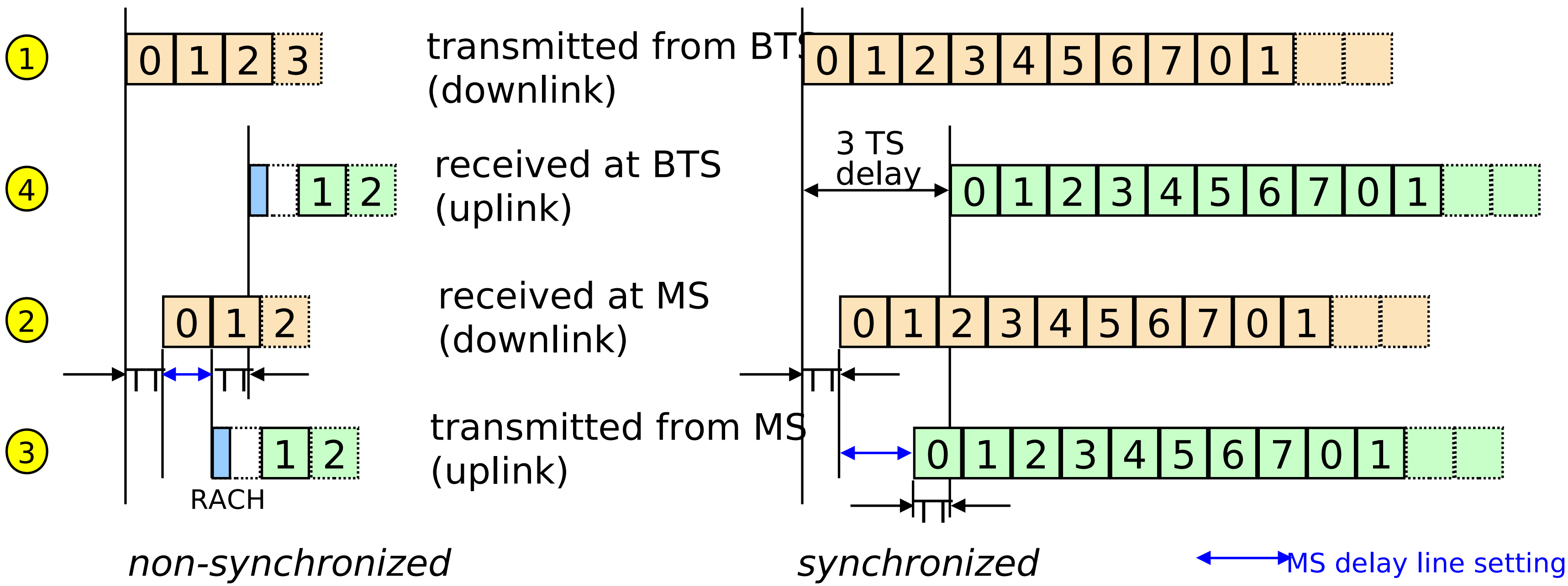
Burst Structure

- A burst contains one data "portion" of one timeslot
- TDMA frame: time between two bursts with same timeslot number
- The burst also consists of:
  - Guard period (GP): allows for transition and settling times
  - Tail bits: allow for small shifts in time delay (synchronisation)
  - Stealing flags: to indicate FACCH (control channel) data
  - Training sequence: for equalization purposes

Normal Burst



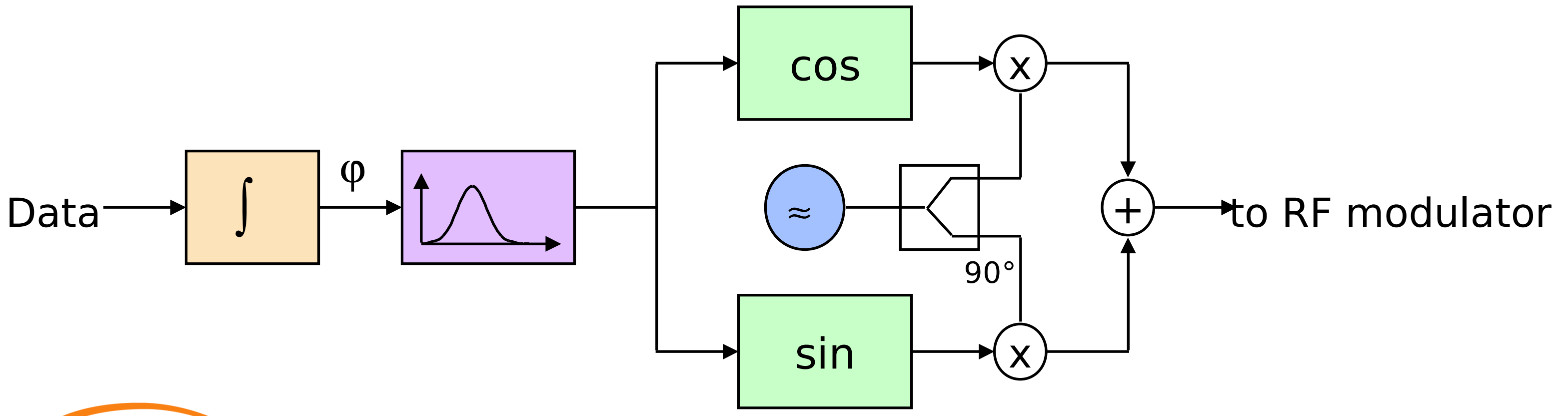
Synchronisation



- Transmitted bursts need a travelling time (TT) to the receiver
- For network access, the MS sends a (non-synchronized) shortened RACH burst
- The BSS measures the TT and generates a timing advance value TA which is transmitted to the MS

Modulation

- Gaussian minimum shift keying
  - Based on phase shift keying
  - Reduction of required bandwidth
    - Maximum phase change during one bit duration
    - Baseband filtering to achieve continuous phase changes



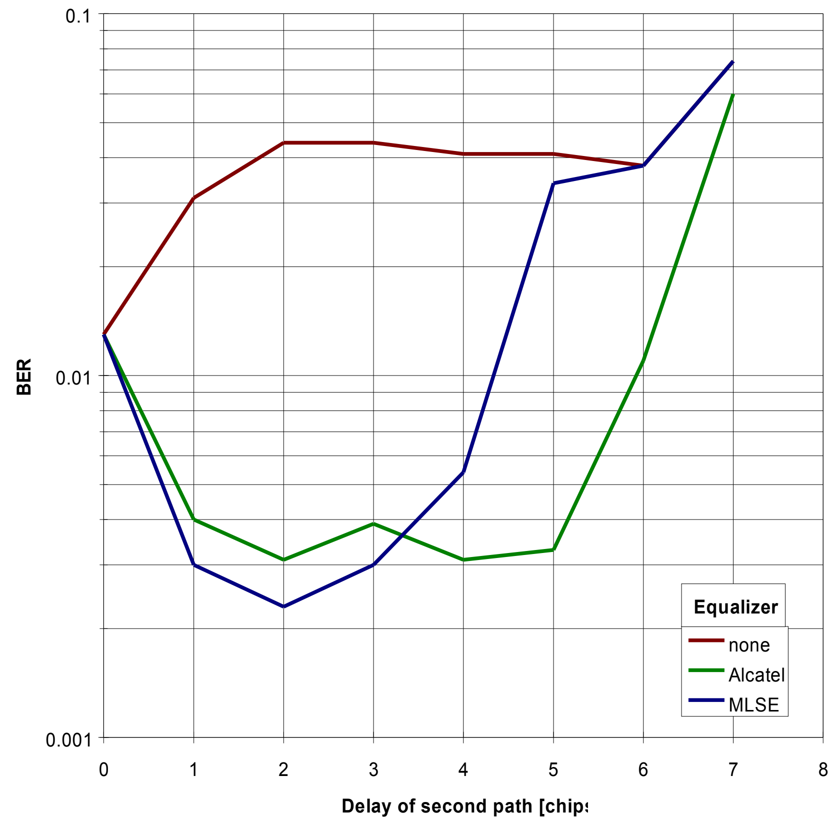
Propagation Environment

- Radio propagation is characterised by dispersive multi-path caused by reflection and scattering
- Moving MS causes Doppler spectrum
  $\rightarrow$ Definition of propagation models in the time domain to allow channel simulations
  - TUxx (Typical Urban)
  - RAxx (Rural Area)
  - HTxx (Hilly Terrain)
  - xx = speed in km/h

see also GSM 05.05, 11.20, 11.21

Equalizing

- Purpose: equalize distortions in transmission spectrum
- Adaptive filtering required
  - Filter parameters determined out of the training sequence
  - Filter parameters change from burst to burst
- Equalizer takes advantage from multipath propagation (path diversity)



Definition of Bit Error Rates

- FER = Frame Erasure Rate
  - Ratio of corrupted frames, indicated by a wrong CRC (cyclic redundancy checksum) and BFI (bad frame indicator)
- RBER = Residual Bit Error Rate
  - considering corrupted frames not recognized as bad frames
- BER = total bit error rate
- Consideration of class 1 or 2 bits $\rightarrow$ e.g. RBER1b, RBER2

see also GSM 05.05, 11.20, 11.21

Speech Quality

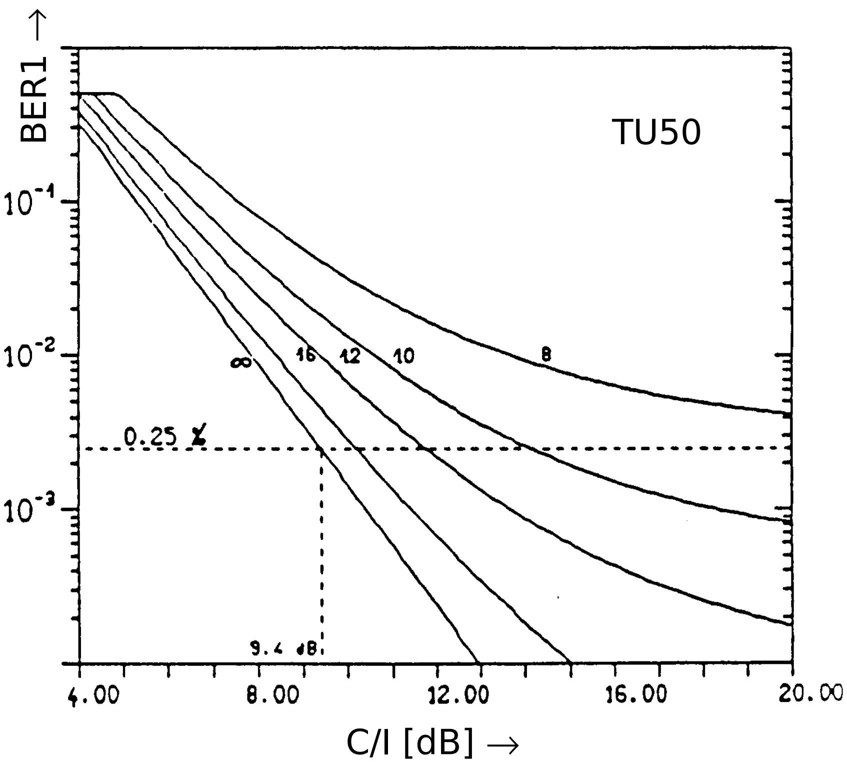
BER	Quality
>0.01	no communication
<0.005	"bad"
<0.0025	"marginal"
<0.0003	"good"
<0.0001	"excellent"

Thresholds:

C/I:	9 dB
E_c/N_o:	8 dB
BTS (GSM900):	-104 dBm
HH (GSM900):	-102 dBm
BTS (GSM1800):	-104 dBm
HH (GSM1800):	-100 dBm

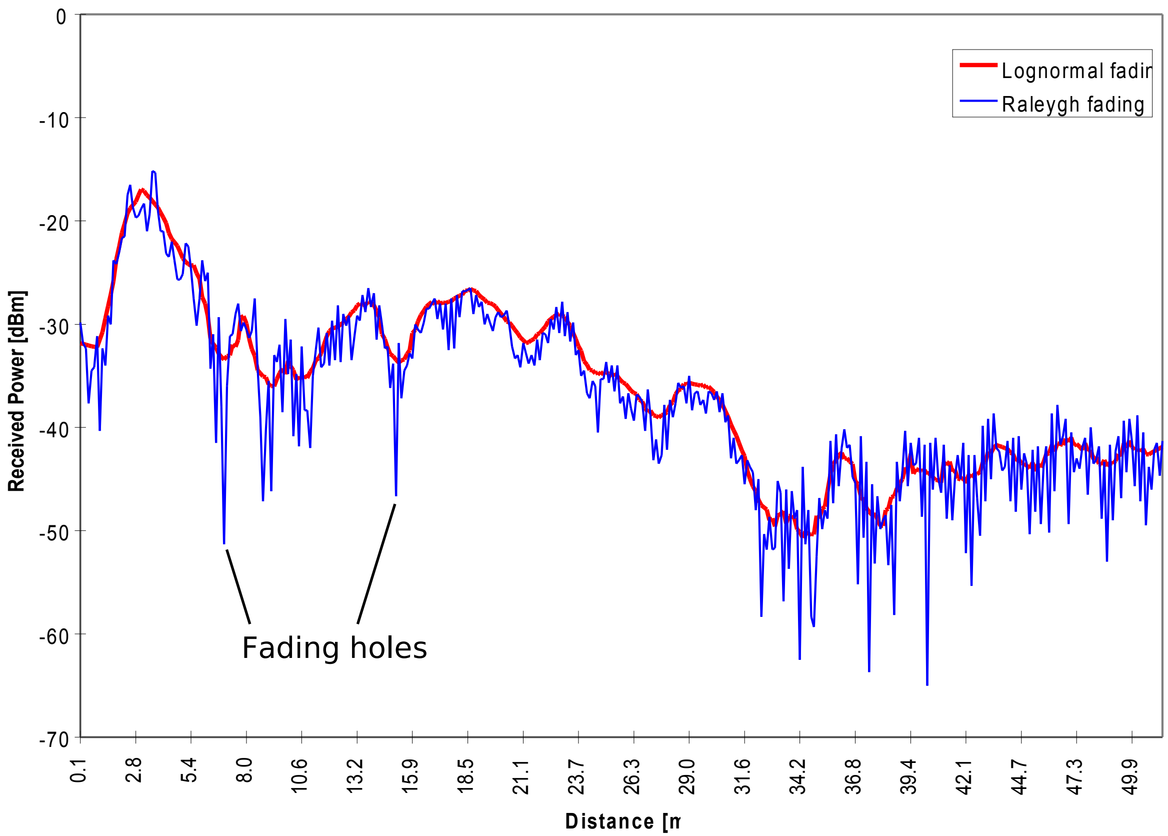
Dependence of BER on Noise and Interference (1)

- Variation of BER1 over C/I
- Parameter: E_c/N_0
- How to find a quality figure?
  - BER1 for marginal speech quality: 0.25%
  - ➡ required C/I ≈ 9 dB for TU50 environment
  - but: signal must not be close to noise floor!



Frequency Hopping (1)

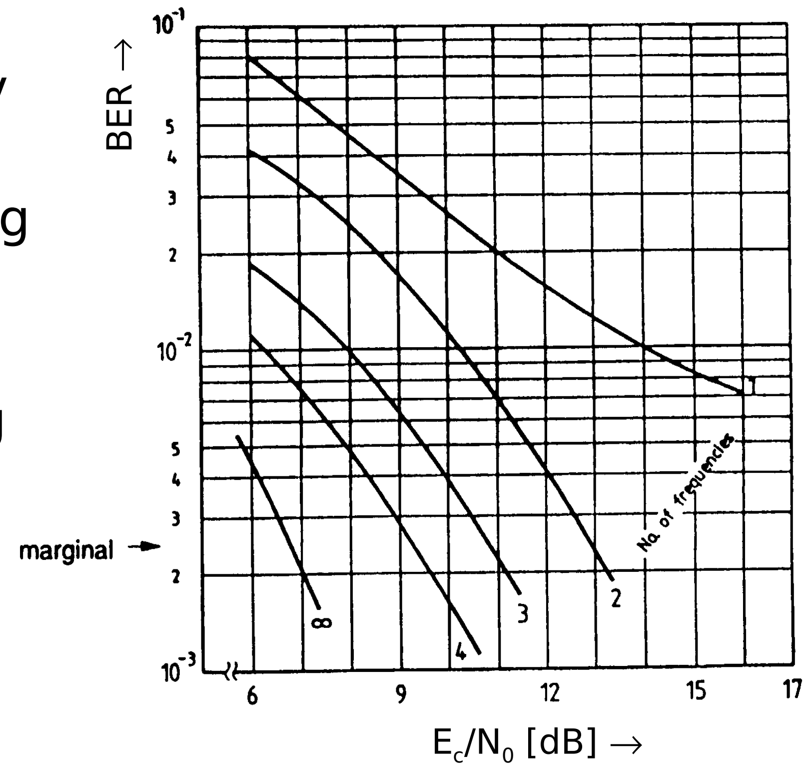
- Problem: specific fading pattern for each used frequency
- Fast MS cope with the situation (due to signal processing)
- Slow MS suffer from fading holes
- Solution: change the fading pattern by frequency hopping



Frequency Hopping (2)

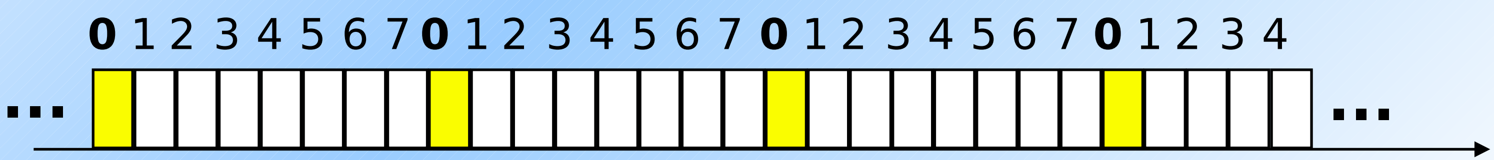
- Variation of BER1 over E_c/N_0
- TU environment, flat fading, v = 0 km/h (worst case)
- Parameter: number of hopping frequencies

➡ Compensation with 4 hopping frequencies possible

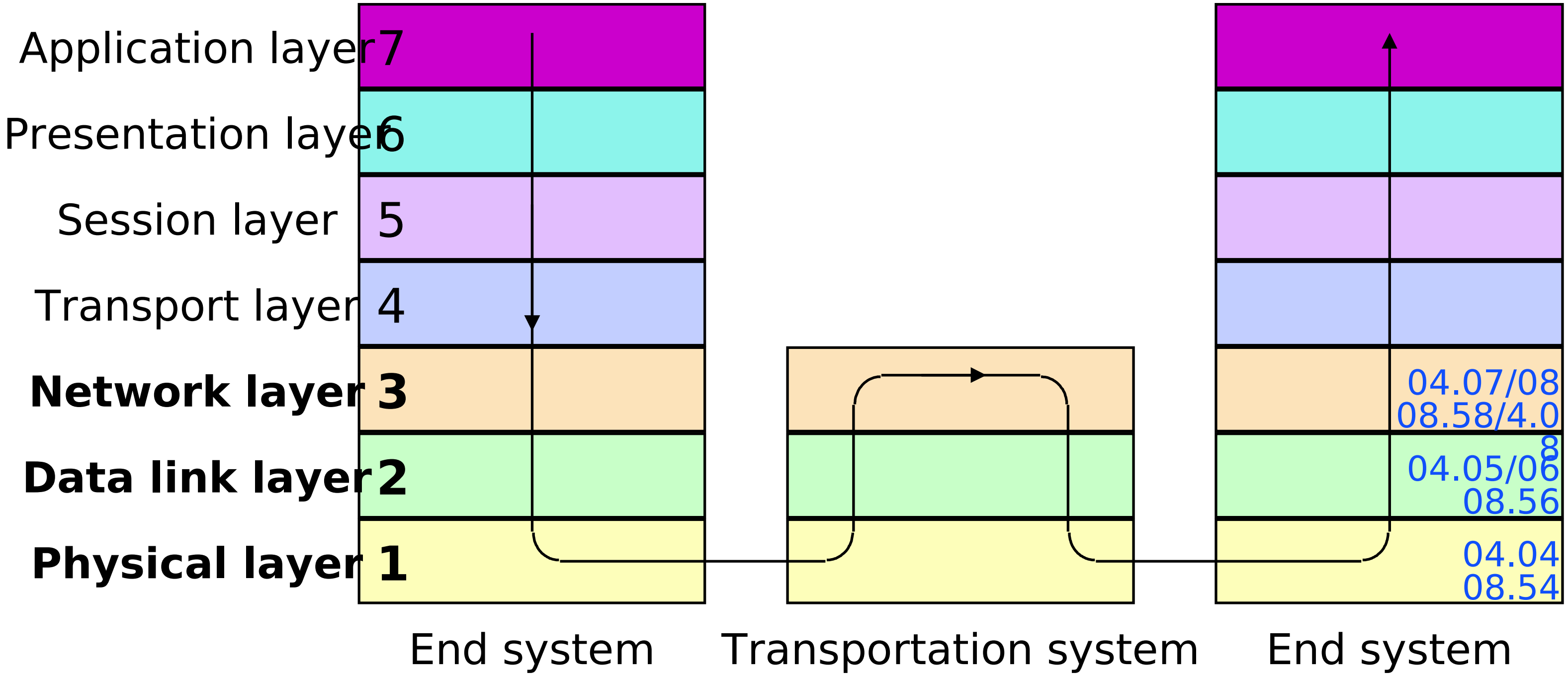


Quality of Service

Channel Coding



The OSI Reference Model

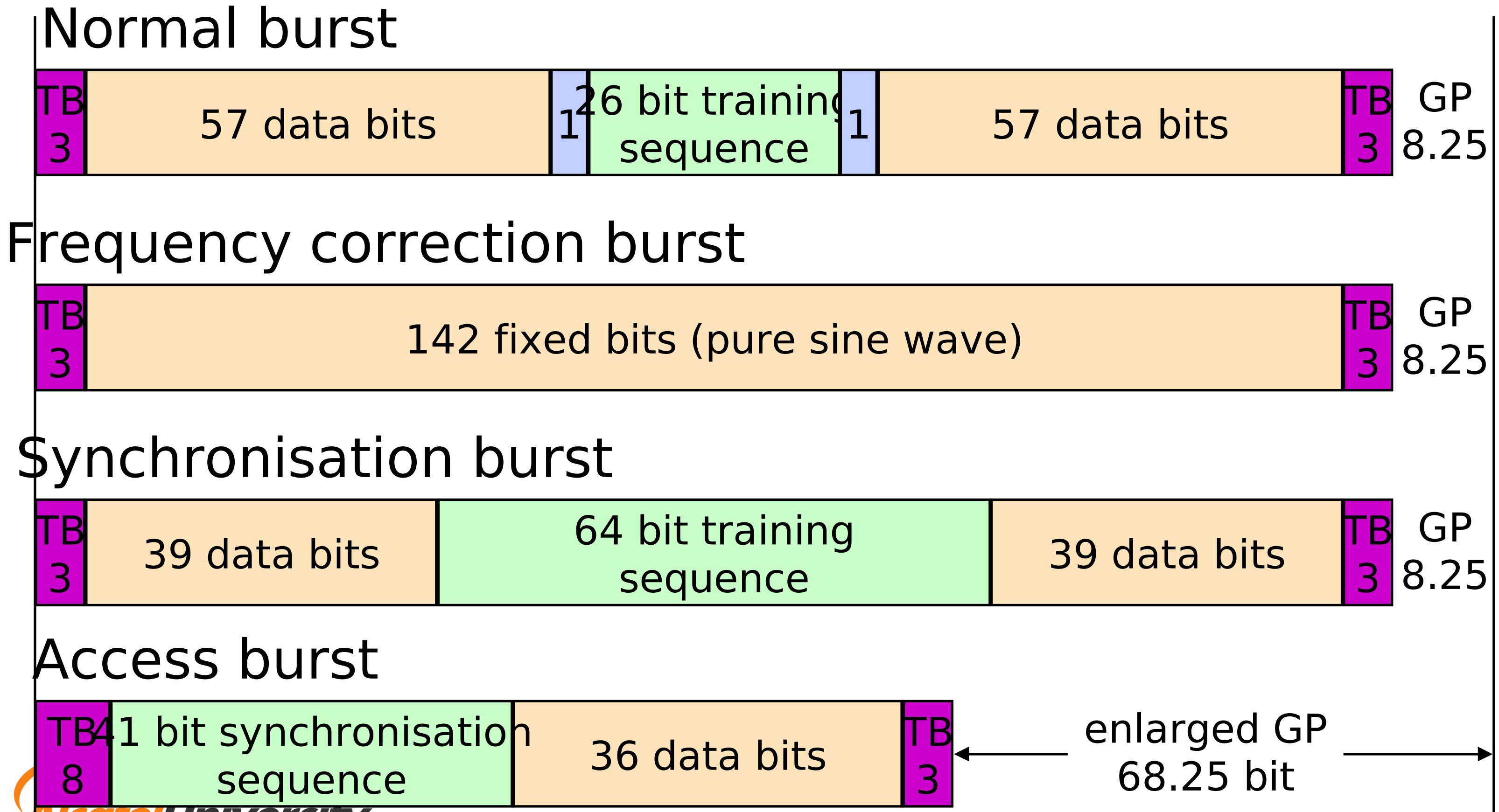


- Definition in GSM recommendations: layers 1 to 3
  - Notion of "Physical" channels and "Logical" channels

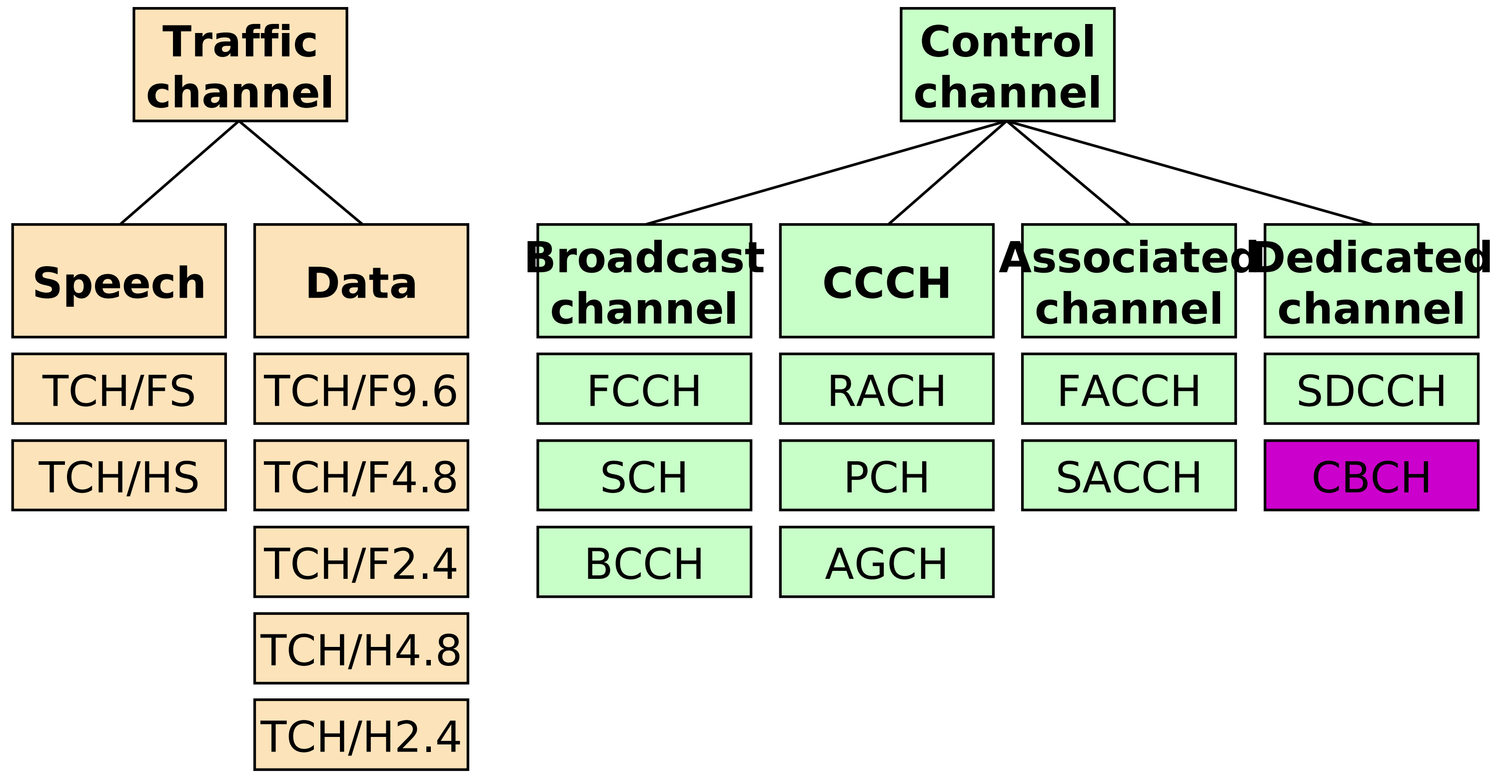
GSM Burst Types (1)

- Normal Burst
  - For regular transmission
- Frequency Correction Burst
  - Contains 142 zeros (0) $\rightarrow$ pure sine wave
  - ➨ Allows synchronisation of the mobile's local oscillator
- Synchronisation Burst
  - Consists of an enlarged unique training sequence code (TSC)
  - Contains the actual FN $\rightarrow$ time synchronisation
- Access Burst
  - Shortened burst (unique TSC and enlarged guard period)
  - ➨ Timeslot overlapping avoided at BTS when MS accesses network
- Dummy Burst
  - "Filler" for unused BCCH timeslots $\rightarrow$ BCCH permanently on air
  - Similar to normal burst (defined mixed bits for data, no stealing flag)

GSM Burst Types (2)



Logical Channels

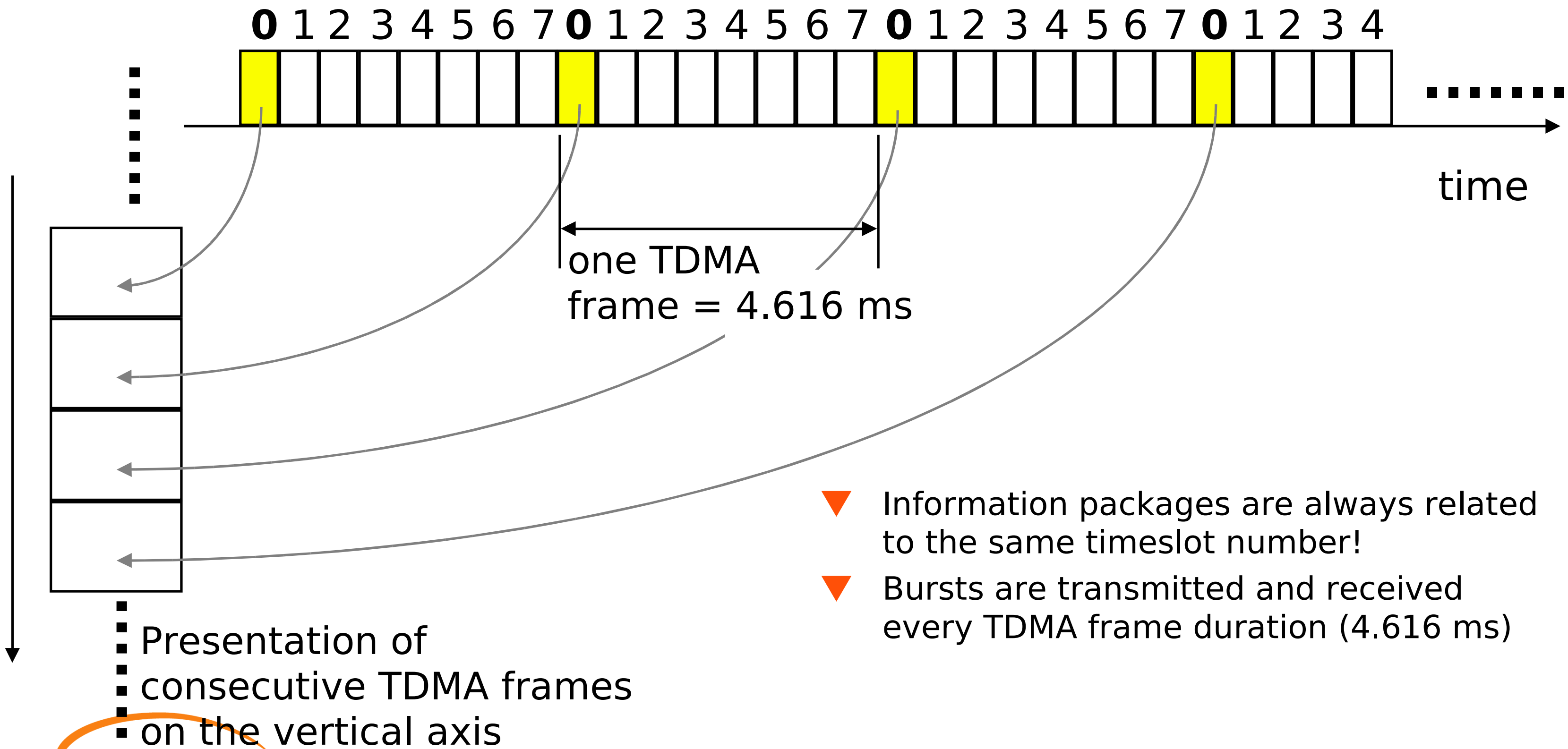


Possible Channel Combinations

1	TCH/F+FACCH/F+SACCH/TF
2	TCH/H(0.1)+FACCH/H(0.1)+SACCH/TH(0.1)
3	TCH/H(0.0)+FACCH/H(0.1)+SACCH/TH(0.1)+TCH/H(1.1)
4	FCCH+SCH+BCCH+CCCH
5	FCCH+SCH+BCCH+CCCH+SDCCH/4(0..3)+SACCH/C4(0..3)
6	BCCH+CCCH
7	SDCCH/8(0..7)+SACCH/C8(0..7)

- CCCH = PCH+RACH+AGCH
- Combination 4 and 5 is only possible on TS0 of the first (BCCH) carrier
- Combination 6 is possible on TS2, TS4, or TS6 of the BCCH carrier

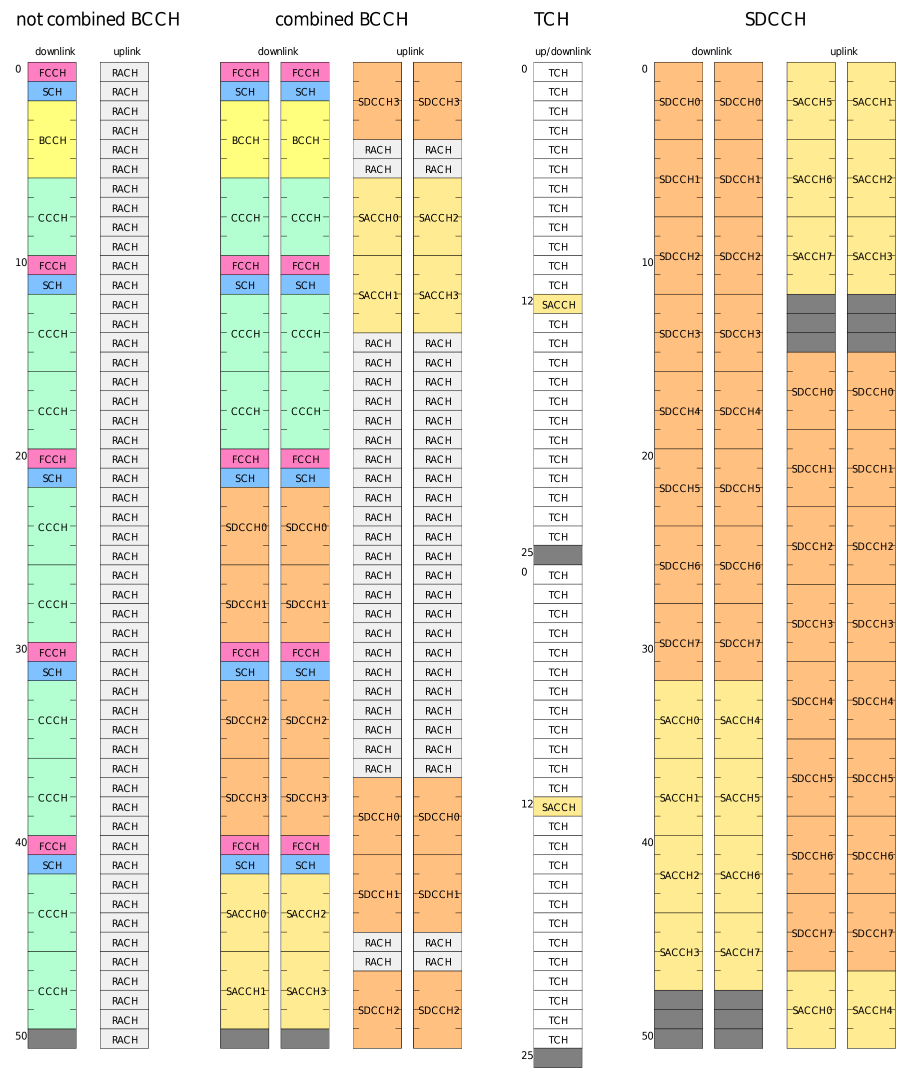
Channel Mapping (1)



- Information packages are always related to the same timeslot number!
- Bursts are transmitted and received every TDMA frame duration (4.616 ms)

Channel Mapping (2)

- Control channels
  - Follows a 51-cycle
  - Duration: 235.4 msec
  - Consists mostly of four consecutive blocks
  - Synchronisation with FCCH and SCH
- Traffic channels
  - Follows a 26-cycle
  - Duration: 120 msec



TDMA Frame Structure for TCHs

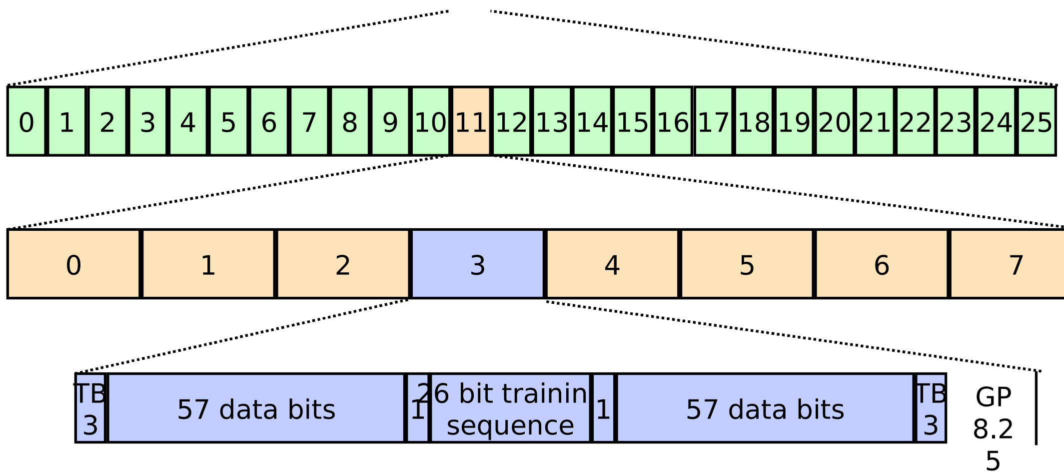
Hyperframe 2048 superframes of 6.12 s duration 3 h 28 m 53 s

Superframe 51 multiframes of 120 ms duration 6.12 s

Multiframe 120 ms

Frame 4.615 ms

Time slot 0.577 ms



Quality of Service

Performance Figures

Performance Figures (1)

- Interference Probability P_{int}
  - measure for co/adjacent channel interference
- Coverage Probability P_{cov}
  - measure for sufficient received power
- Call Success Rate (CSR)
  - CSR = "Coverage" AND (NOT "Interference“)
  - $CSR = P_{cov} \cdot (1 - P_{int})$
- Outage Probability P_{out}
  - complementary to CSR
  - $P_{out} = 1 - CSR$

Abbreviations

AMR	Advanced Multi Rate (TC)
AMSS	Aeronautical Mobile Satellite Services
AN	Antenna Network (BTS)
ARCS	Average Reuse Cluster Size
ARFCN	Absolute Radio Frequency Channel
AS	Access Switch (BSC)
AS	Alarm Surveillance (O&M)
ASMA	A-ter Submultiplexer A
ASMB	A-ter Submultiplexer B
AuC	Authentication Center
BC	Broadcast
BCU	Broadcast Unit
BCLA	BSC Clock A
BCR	Broadcast Register
BCU	Broadcast Unit
BCCH	Broadcast Common Control Channel (GSM TS)
BCF	Base station Control Function (BTS)
BG	Border Gate (GPRS)
BIE	Base Station Interface Equipment
BIEC	Base Station Interface Equipment (BSC)
BIUA	Base Station Interface Unit A
BPA	Back Panel Assembly
BSC	Base Station Controller
BSIC	Base Transceiver Station Identity Code
BSS	Base Station (sub)System
BSSGP	Base Station System GPRS Protocol (GPRS)
BTS	Base Transceiver Station
CAE	Customer Application Engineering
CAL	Current Alarm List (O&M)
CBC	Cell Broadcast Center
CBCH	Cell Broadcast Channel (GSM TS)
CBE	Cell Broadcast Entity
CCCH	Common Control Channel (GSM TS)
CCU	Channel Coding Unit

MA	Code Division Multiple Access
	Control Element (BSC)
K	Control Element Kernel
	Carrier to Interferer ratio
K	Clock
SI	Custom Large Scale Integrated circuit
A	Configuration Management Application (O&M)
DA	Common Memory Disk A
FA	Common Memory Flash A
R	Common Processor (Type: CPRA, CPRC)
C	Cyclic Redundancy Check
	Circuit Switching (Telecom)
	Coding Scheme (GPRS): CS-1, CS-2, CS-3, CS-4
	Carrier Unit (BTS)
E	Data Circuit Terminating Equipment
N	Data Communication Network
	DownLink

DLS	Data Load Segment
DMA	Direct Memory Access
DRFU	Dual Rate Frame Unit
DRX	Discontinuous Reception (GSM TS)
DSE	Digital Switching Element
DSN	Digital Switching Network
DTX	Discontinuous Transmission (GSM TS)
DTC	Digital Trunk Controller (Type: DTCA, DTCC)
DTE	Data Terminal Equipment
EDGE	Enhanced Data rates for GSM Evolution
EI	Extension interface
EML	Element Management Level
EPROM	Erasable Programmable Read Only Memory
ETSI	European Telecom Standard Institute
FPE	Functional and Protective Earth
FR	Full Rate (GSM TS)

R	Frame Relay (Telecom)	HLR	Home Location Register
RDN	Frame Relay Data Network (Telecom)	HMI	Human Machine Interface
U	Frame Unit (BTS)	HO	HandOver
W	Firmware	HR	Half Rate
CR	Group Call Register	HW	Hardware
GSN	Gateway GPRS Support Node (GPRS)	IDR	Internal Directed Retry
MLC	Gateway Mobile Location Center	ILCS	ISDN Link Controller
MM	GPRS Mobility Management (GPRS)	IMT	Installation and Maintenance Terminal (MFS)
MSC	Gateway Mobile Switching Center	IND	Indoor (BTS)
PRS	General Packet Radio Service	IP	Internet Protocol
PU	GPRS Packet Unit	ISDN	Integrated Services Data Network
S-1	Group Switch of stage 1 (BSC)	IT	Intelligent Terminal
S-2	Group Switch of stage 2 (BSC)	LA	Location Area (GSM TS)
SL	GPRS Signalling Link	LAC	Location Area Code (GSM TS)
SM	Global System for Mobile Communications	LAN	Local Area Network
SM TS	GSM Technical Specification	LED	Light Emitting Diode
AL	Historical Alarm List (O&M)	LEO	Low Earth Orbit (Satellite)
DSL	High rate Digital Subscriber Line	LCS	Location Services
DLC	High Level Datalink Control		

LLC	Logical Link Control (GPRS)
LMU	Location measurement unit
MA	Mobile Allocation (GSM TS)
MAC	Medium Access Control (GPRS)
MAN	Metropolitan Area Network
MAN	MicroBTS Antenna Network (BTS)
MCB	Multiplex Channel Block
MFS	Multi-BSS Fast Packet Server (GPRS)
MLU	Massive Logical Update
MMI	Man Machine Interface
MO	Managed Object (O&M)
MRP	Multiple Reuse Pattern
MS	Mobile Station
MSC	Mobile Switching Center
MSUM	MicroBTS Station Unit Module (BTS)
NMI	Non Maskable Interrupt
NPA	Network Performance Analyser
NSS	Network SubSystem
NTL	Network Termination Line
NW	Network
OBC	On Board Controller
OBCI	On Board Controller Interface
OC	Originating Call
ODMC	On Demand Measurement Campaign (O&M)
O&M	Operation and Maintenance
OMC	Operation and Maintenance Center
OMC-R	Operation and Maintenance Center - Radio
OML	Operation and Maintenance Link
OMU	Operation and Maintenance Unit (BTS)
OS	Operating System
OUT	Outdoor (BTS)
PBA	Printed Board Assembly
PBCCH	Packet Broadcast Common Control CHannel (GPRS)
PC	Personal Computer
PCCCH	Packet Common Control Channel (GPRS)

PCH	Paging CHannel (GSM TS)
PCM	Pulse Coded Modulation
PCU	Packet Control Unit (GPRS)
PDCH	Packet Data CHannel
PDN	Packet Data Network (Telecom)
PDU	Protocol Data Unit (generic terminology)
PLL	Phase Locked Loop
PLMN	Public Land Mobile Network
PMA	Prompt Maintenance Alarm (O&M)
PMC	Permanent Measurement Campaign (O&M)
PPCH	Packet Paging CHannel (GPRS)
PRACH	Packet Random Access CHannel (GPRS)
P_{rec}	Received Power
PRC	Provisioning Radio Configuration (O&M)
PSDN	Packet Switching Data Network (Telecom)
PSTN	Public Switching Telephone Network (Telecom)
PTP-CNLS	Point To Point CoNnectionLeSs data transfer (GPRS)
QoS	Quality of Service
RA	Radio Access
RACH	Random Access CHannel (GSM TS)
RAM	Random Access Memory
RCP	Radio Control Point
RLC	Radio Link Control (GPRS)
RLP	Radio Link Protocol (GSM TS)
RML	Radio Management Level
RNO	Radio Network Optimisation
RNP	Radio Network Planning
RSL	Radio Signalling Link

RTS	Radio Time Slot
RxLev	Received Level
RxQual	Received Quality
SACCH	Slow Associated Control Channel (GSM TS)
SAU	Subrack assembly unit (BSC)
SC	Supervised Configuration (O&M)
SCC	Serial Communication Controller
SCP	Service Control Point
SCCP	Signalling Connection Control Part
SCSI	Small Computer Systems Interface
SDCCH	Standalone Dedicated Control Channel (GSM TS)
SDU	Service Data Unit (generic terminology)
SGSN	Serving GPRS Support Node (GPRS)
SIEA	SCSI Interface Extension A
SM	Submultiplexer
SMLC	Serving Mobile Location Center
SMP	Service Management Point
SMS	Short Message Service
SMS-CB	Short Message Service - Cell Broadcast
SM-GMSC	Short Message Gateway Mobile Switching Center
SRAM	Static RAM
SRS	SubRate Switch
SS7	Signalling System ITU-T N°7 (ex CCITT)
SSD	Solid State Disk
SSP	Service Switching Point
SW	Software
SWEL	Switch Element
TBF	Temporary Block Flow (GPRS)
TAF	Terminal Adaptor Function

TC	Transcoder
TC	Terminating Call
TCC	Trunk Controller Chip
TCH	Traffic CHannel (GSM TS)
TCIL	TransCoder Internal Link
TCSM	TransCoder / SubMultiplexer equipment
TCU	TRX Control Unit (Type: TCUA, TCUC)
TDMA	Time Division Multiple Access
TFO	Tandem Free Operation (TC)
TFTS	Terrestrial Flight Telecom Systems
TLD	Top Level Design
TMN	Telecommunication Management Network
TRAC	Trunk Access Circuit
TRAU	Transcoder and Rate Adapter Unit
TRCU	Transcoder Unit
TRE	Transceiver Equipment
TRS	Technical Requirement Specification
TRU	Top Rack Unit
TRX	Transceiver
TS	Time Slot
TS	Technical Specification (GSM TS)
TSS	Time Space Switch
TSCA	Transmission Sub-System Controller A (BSC)
TSU	Terminal Sub Unit (BSC)
TU	Terminal Unit (BSC)
UL	UpLink
UMTS	Universal Mobile Transmission System
USSD	Unstructured Supplementary Services Data
VBS	Voice Broadcast Service
VGCS	Voice Group Code Service
VLR	Visitor Location Register
VPLMN	Visited PLMN
VSWR	Voltage Standing Wave Ratio (BTS)
WAN	Wide Area Network
WAP	Wireless Application Protocol
WBC	Wide Band Combiner