PPS-Project "Todesstrahlen vom Antennenmast"

Introduction to the Global System for Mobile Communications (GSM)

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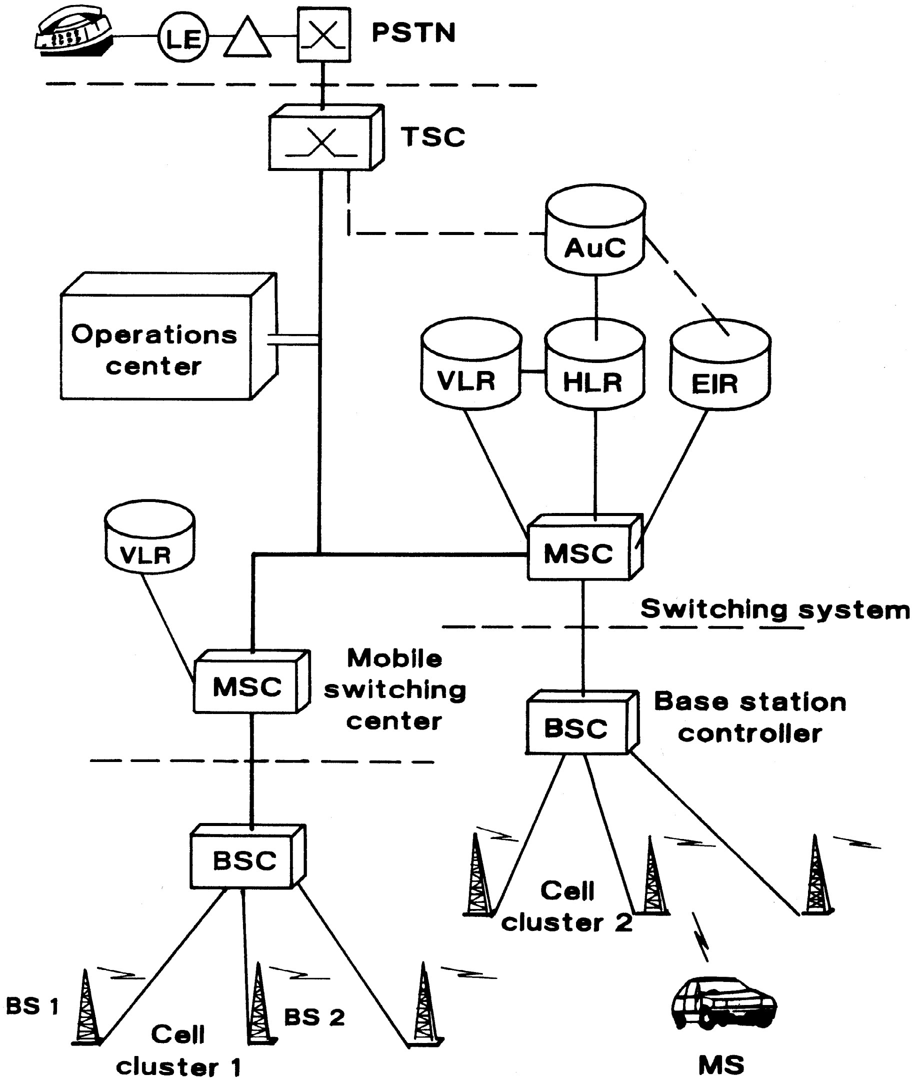
GSM System Overview

System Architecture



A fixed network infrastructure supporting a cellular radio system.

PSTN	Public Service Telephone Network	BSC	Base Station Controller
TSC	Telephone Switching Center	BS	Base Station
AuC	Authentication Center	MS	Mobile Station
MSC	Mobile Switching Center		

MSC - It is the central component of the network and switching subsystem. The MSC performs the switching functions of the network. It also provides connection to other networks.

BSC - The BSC controls a group of base stations and manages their radio ressources. A BSC is principally in charge of handovers, frequency hopping, exchange functions and control of the radio frequency power levels of the BSs.

GSM System Overview

Operation: Registration, Call Establishment, and Handover

Registration - After a mobile is switched on, it scans the whole GSM frequency band to detect the presence of a network. When a network is detected, the mobile reads the system information on the forward channel. With this information, the mobile station is able do determine its current position within the network. If the location is not the same as it was when last switched off, a registration procedure takes place.

Call Establishment - There are two different procedures: mobile-originated call (MOC), and mobile-terminated call (MTC). The procedure for MOC includes the following steps:

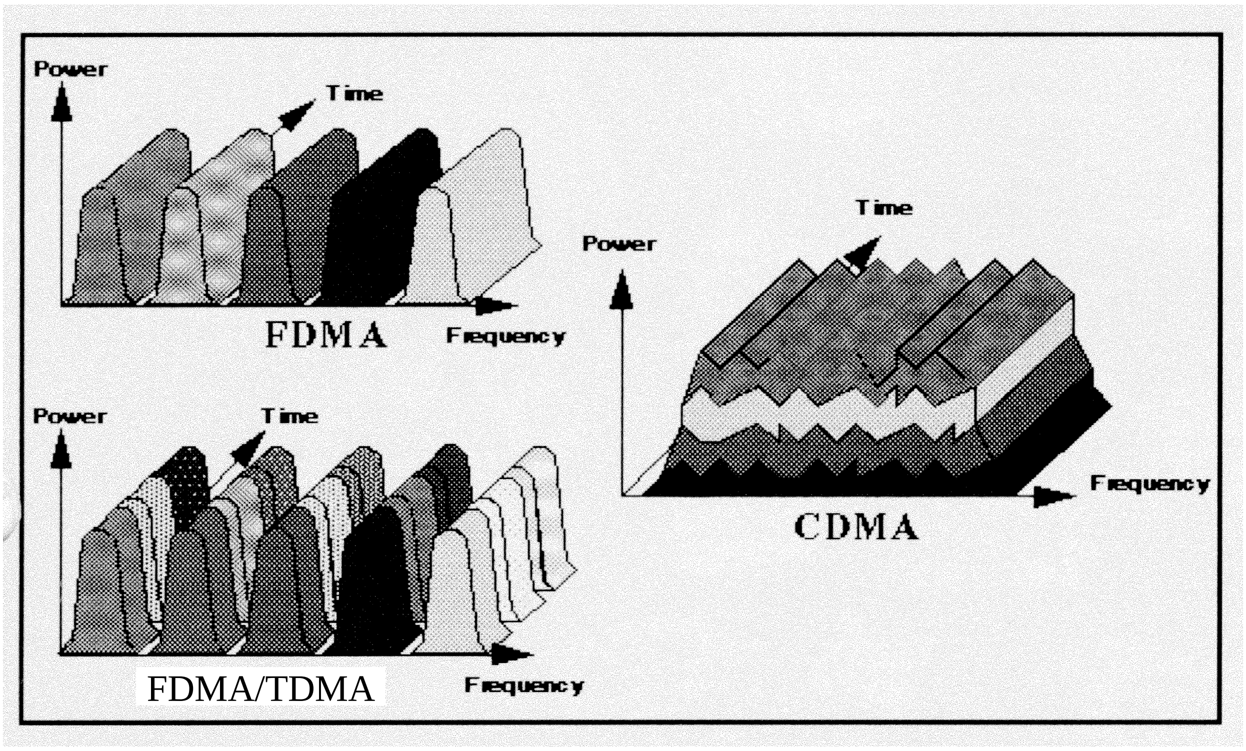
- The mobile requests a traffic channel
- The mobile authenticates itself (ciphering of data from this point on)
- Connection is established when the called phone is brought off the hook.

Handover - The user movements can produce the need to change the channel or cell, especially when the quality of the communication is decreasing. This procedure of changing the resources is called handover. Handovers are mainly controlled by the MSC. In order to perform the handover, the mobile station monitors continuously its own signal strength and the signal strength of the neighboring cells. The list of cells that must be monitored by the mobile station is provided by the base station. Measurement of received signal strength allows to decide which is the best cell in order to maintain the quality of the communication link.

The Radio Link

Access Methods: TDMA, FDMA, CDMA, SDMA

The multiple access scheme defines how different simultaneous communications, between different mobile stations situated in different cells, share the radio spectrum.



Some multiple access schemes for mobile communications.

Using **FDMA** (Frequency Division Multiple Access), a frequency is assigned to a single user. So the larger the number of users in a FDMA system, the larger the number of available frequencies must be. The limited available radio spectrum and the fact that a user will not free its assigned frequency until he does not need it anymore, explain why the number of users in a FDMA system can be "quickly" limited.

On the other hand, **TDMA** (Time Division Multiple Access) allows several users to share the same frequency. Each of the users sharing the common frequency is assigned its own burst (time slot) within a group of bursts called a frame. Usually TDMA is used with a FDMA structure. TDMA requires digital speech coding.

CDMA (Code Division Multiple Access) is a class of modulation that uses specialized codes as the basis of channelization. The codes are shared between the mobile station and the base station. In a CDMA system all channels are transmitted simultaneously and occupy the same frequency bandwidth. The use of individual codes for each cannel allows the separation of channels at the receiver (UMTS will be based on CDMA).

SDMA (Space Division Multiple Access) is used in all cellular systems. Cellular systems allow multiple access to a common RF channel (or a set of channels) on a per cell basis. Users must be separated by a distance sufficiently large to minimize the effects of co-channel interference.

The Radio Link

GSM FDMA/TDMA Scheme and Channels

A mix of Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA), combined with frequency hopping, has been adopted as the multiple access scheme for GSM.

In GSM 900, a 25 MHz frequency band is divided, using a **FDMA** scheme, into 124 carrier frequencies spaced one from each other by a 200 kHz frequency band. Each carrier frequency is then divided in time using a **TDMA** scheme. This scheme splits the radio channel, with a width of 200 kHz, into 8 bursts. A burst is the unit of time in a TDMA system, and it lasts approximately 0.577 ms. A TDMA frame is formed with 8 bursts and lasts, consequently 4.615 ms. Each of the eight bursts, that form a TDMA frame, are then assigned to individual users.

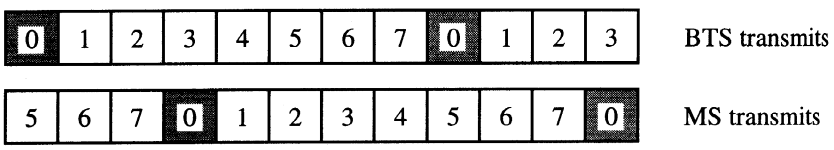
A **channel** corresponds to the recurrence of one burst every frame. It is defined by its frequency and the position of its corresponding burst within a TDMA frame. In GSM there are two types of channels:

- The traffic channels used to transport speech and data information.
- The control channels used for network management and some channel maintenance tasks.

Number of radio channels per cell:

N Ch/Cell = N Sectors/Cell x N CarrierFreq/Sector x 8 Time Slots/Carrier

Time-Division Duplex - Using TDMA, it is not necessary to transmit and receive signals at the same time. In GSM, the time difference between transmit and receive functions is 3 time slots. This temporal separation of receive and transmit greatly reduces the complexity of the transceiver in the mobile station.

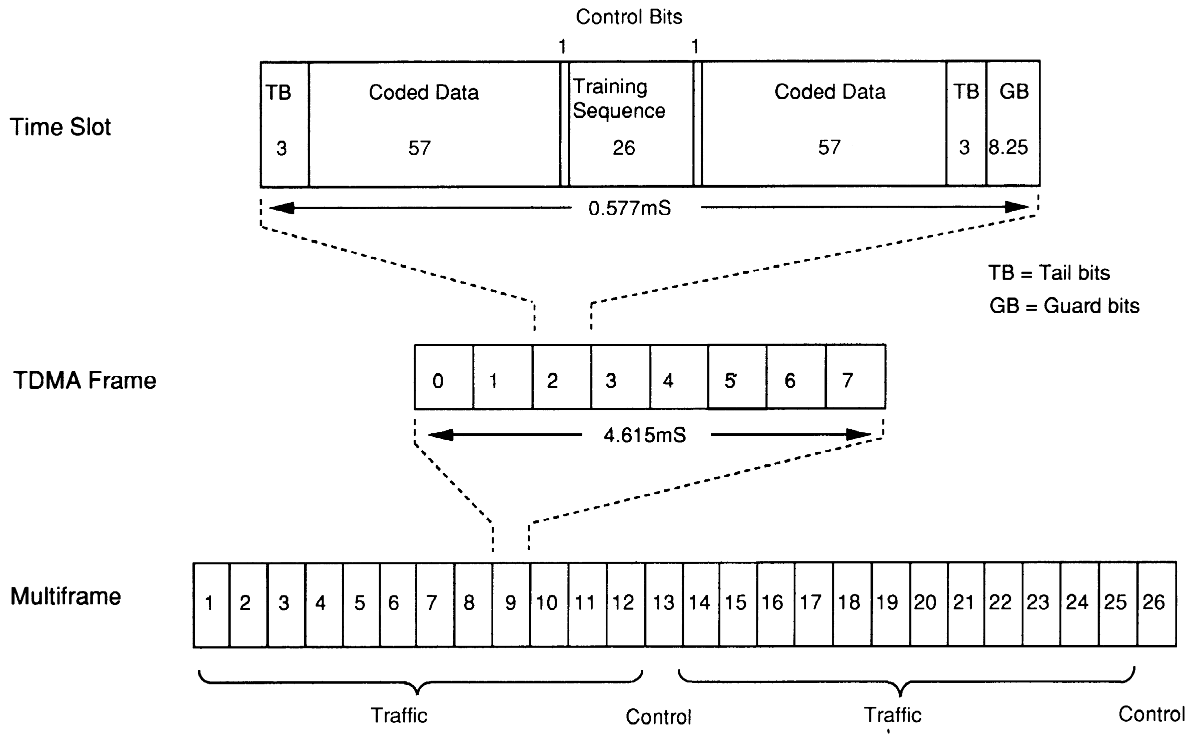


Time-division duplex in the GSM system.

In GSM 900 uplink and downlink channels are separated by 3 time slots (temporally) and 45 MHz (carrier frequency).

Frequency Hopping - In each TDMA frame the mobile and the base station transmit on a different carrier frequency. This helps to reduce the multipath fading problem. Frequency hopping is controlled by the base station and is optional.

The Radio Link
GSM Frame Structure



The structure of a GSM frame.

Number of data bits per time slot:	2 x 57 = 114
Number of TDMA frames per channel:	1 (0.5 for half rate channels)
Number of traffic frames per multiframe:	24
Duration of a multiframe:	0.120 s

Bitrate per channel: 114 x 1 x 24 x (1 / 0.120) = 22.8 kb/s

Time slot gros bitrate: 114 / 577 µ = 270.8 kb/s

Advantages of a Digital System

+ Information storage possible
+ Error detection and correction (FEC, ARQ)
+ Encryption
+ Compression

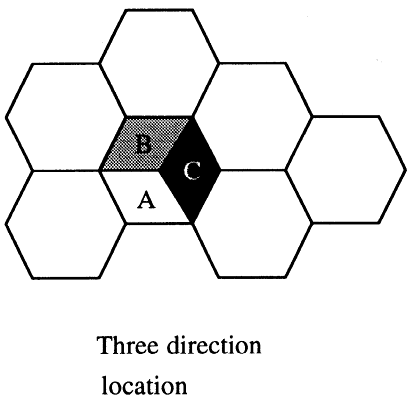
→ Spectrum efficient modulation possible
→ Quality of service maintained under difficult reception conditions
→ Security

The Radio Link

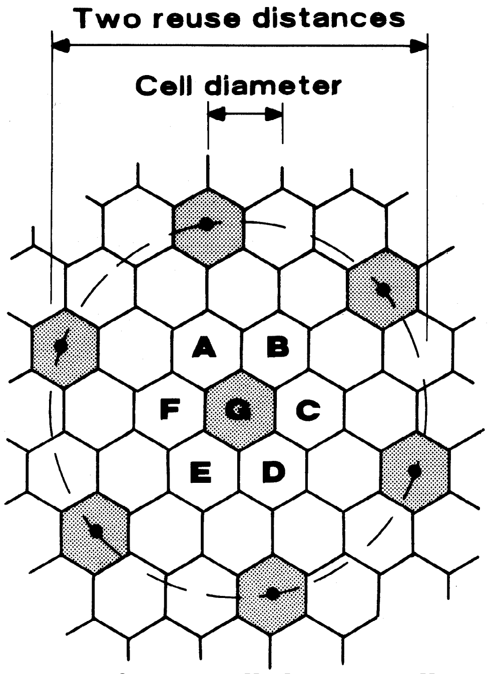
Cellular Network Topology

Cell: geographically limited area, covered by one transmitter (BS)

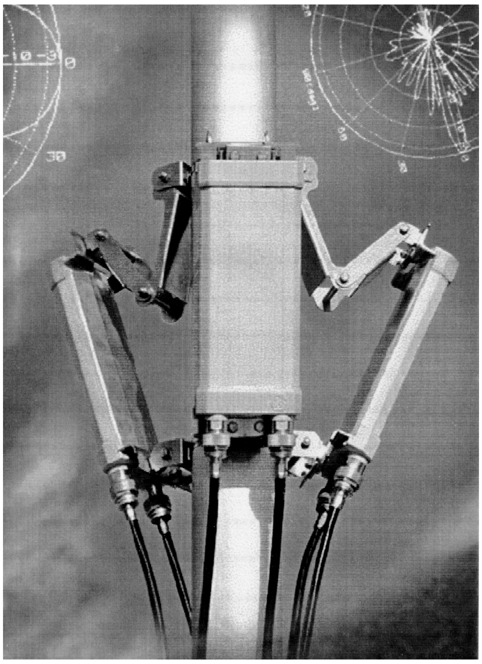
SDMA: Subdivision of a radio network into cells (→ frequency reuse)



A **sectored cell** for coverage of individual 120º sectors (rather than 360º omnidirectional coverage). Sectors have individual carrier frequencies.



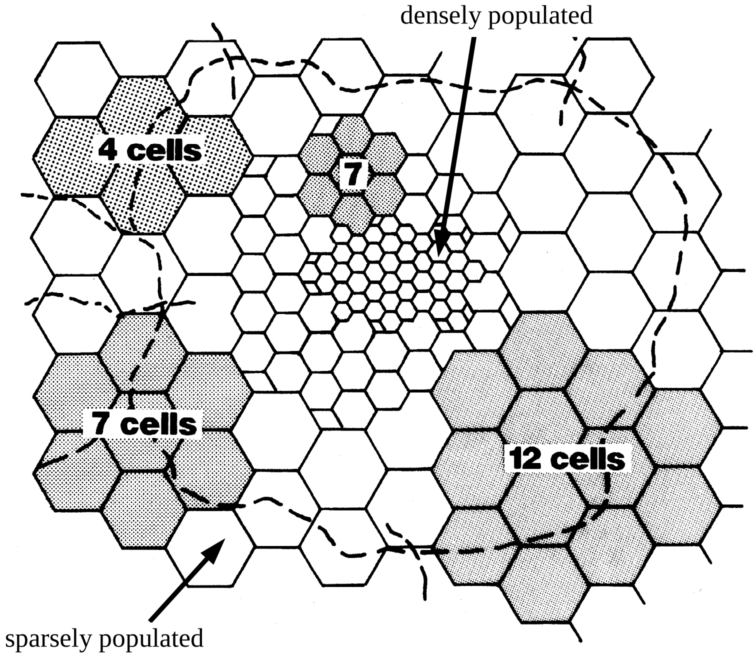
A set of seven-cell clusters. Cells **A** through **G** form a **cluster**. Shaded cells can have the same operating frequency set because they are separated by the reuse distance.



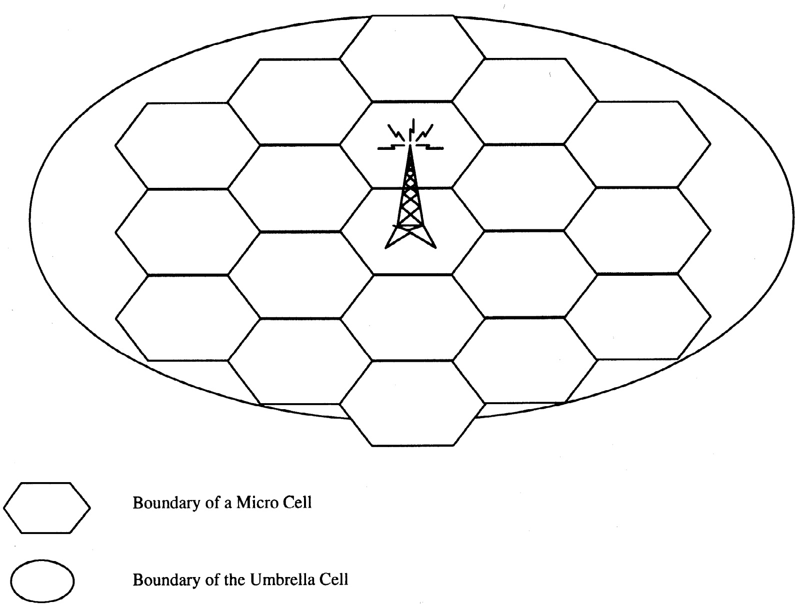
A base station antenna tower with **sector antennas**.

The Radio Link

Cellular Network Topology



A **cell layout plan** typical for a city, showing cell sizes and possible cluster sizes.



An **umbrella cell**. Mobiles travelling at high speed are handed over to the umbrella cell, so the network will not be tied up with fast series of handovers

Smaller Cell Size leads to:

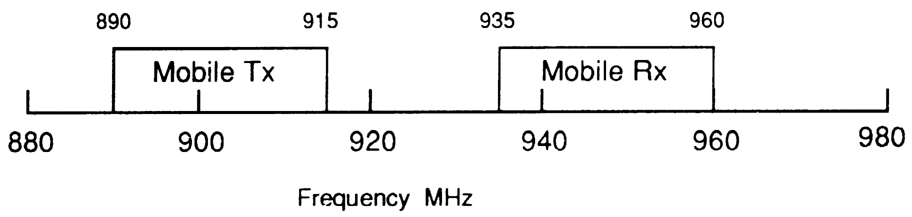
+ better frequency reuse → increased network capacity
+ reduced transmit power → reduced bio-electromagnetical effects
– more cells → increased cost of infrastructure

The Radio Link

GSM Specifications

Table of **Radio Link** Specifications.

Parameter	GSM	DCS 1800
Transmit Frequency		
Mobile Station (uplink)	890 ... 915 MHz	1710 ... 1785 MHz
Base Station (downlink)	935 ... 960 MHz	1805 ... 1880 MHz
Transmit Power (max.)		
Mobile Station	0.8 ... 8 W	0.25 ... 2 W
Base Station	... 300 W	...
Cell Size (max. radius)	35 km	8 km
Carrier Bandwidth	200 kHz	200 kHz
Modulation	GMSK, 270 kb/s	GMSK, 270 kb/s
Number of Carriers	125	375
Time Slot Duration	577 µs	577 µs



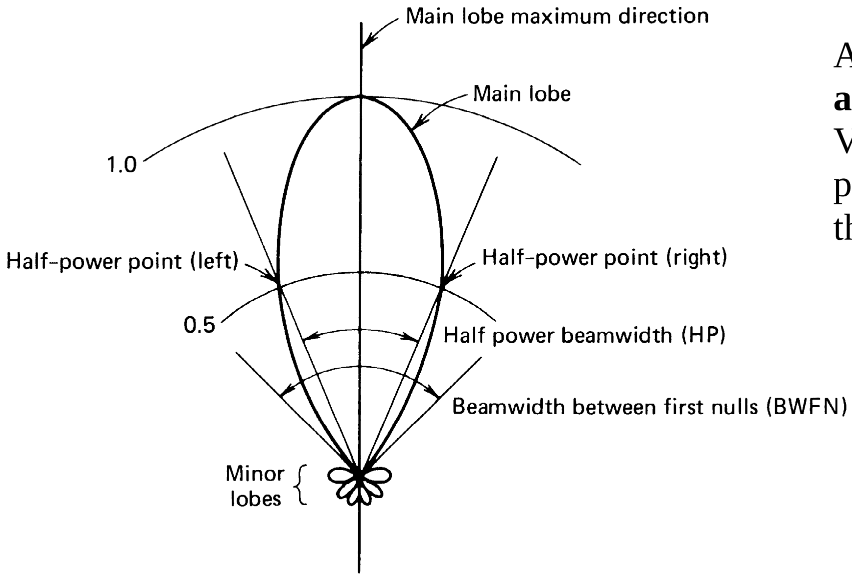
Spectrum allocation for GSM 900.

Important System Features

- Voice (LPC 13 kb/s) and data (9,6 kb/s)
- Authentification and ciphering (SIM card)
- Short message system (SMS)
- Handover
- International roaming

The Base Station Antenna

Antenna Fundamentals



A typical polar plot of an **antenna power pattern**. Vertical and horizontal cut patterns usually don't have the same beam widths.

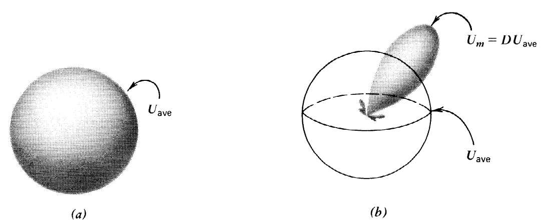
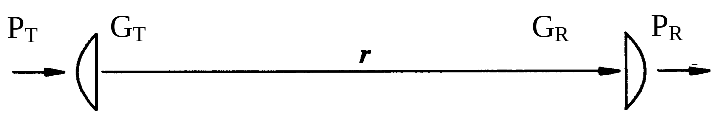


Illustration of **directivity**. a) Radiation intensity distributed isotropically, b) radiation intensity from an actual antenna.



Radio link. P_T and P_R are transmitted and received power, G_T and G_R denote antenna gain, and r is transmission distance.

Antenna gain is the product of directivity times antenna efficiency. The power received at the transmitter is given by (free space, no interfering objects):

$$P_R = \frac{P_T}{4\pi r^2} G_T \cdot \frac{\lambda^2}{4\pi} G_R = \frac{P_T}{A} \qquad \text{(wavelength } \lambda = \frac{c_0}{f}\text{)}$$

The first term is the power flux at the receiver, the second term represents the effective absorption area of the receiving antenna. Path loss A is usually given in decibel (dB, a logarithmic unit of a ratio):

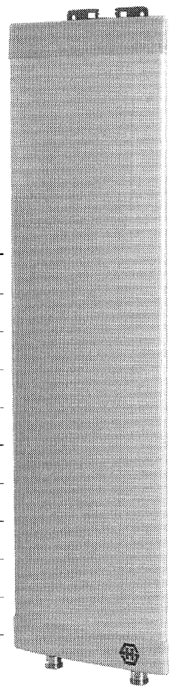
$$A_{dB} = 10 \ \log_{10}(A)$$

The Base Station Antenna

Example Antenna Datasheet

SUHNER® PLANAR ANTENNA
FOR WIRELESS COMMUNICATION

SPA 920/65/14/6/DS



Technical Data

Electrical Properties	
Frequency range	870 - 960 MHz
Impedance	50 Ω
VSWR	1.3
Polarization	dual linear, ±45 °slant
Gain	14.0 dBi
3 dB beamwidth horizontal	65°
3 dB beamwidth vertical	20°
Downtilt	6°
Front to back ratio	25 dB
Isolation between ports	30 dB
Permitted power on entrance	300 W (CW) at 25 °C

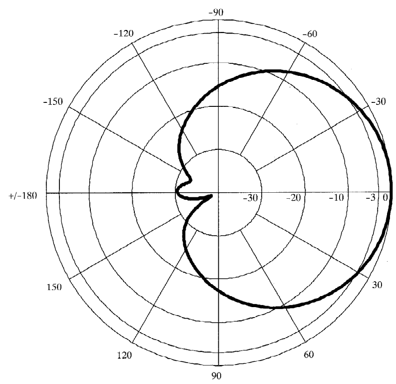
Mechanical Properties	
Dimensions	1055 x 319 x 74 mm (41.54″ x 12.56″ x 2.91″)
Weight	7.2 kg (15.88 lbs.)
Radome material	ASA
Radome color	RAL 9002 (grey-white)
Operating temperature range	- 40° C to + 80° C
Storage temperature range	- 40° C to + 80° C
Windload	550 N at 160km/h (100mph)

Available Types	
1309.17.0050	N female
1309.41.0050	7/16 female

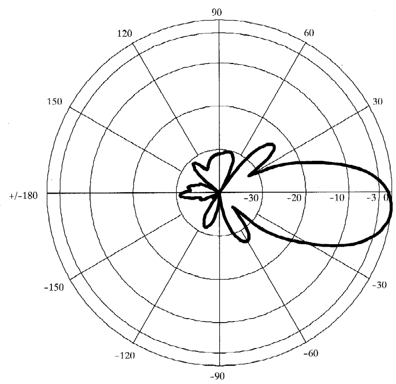
Mounting Hardware	
9091.99.0073	downtilt bracket

Mast and wall mounting material (2 metal bands) included, mast diameter 45-90 mm (1.77″ - 3.54″)

Radiation Pattern



horizontal



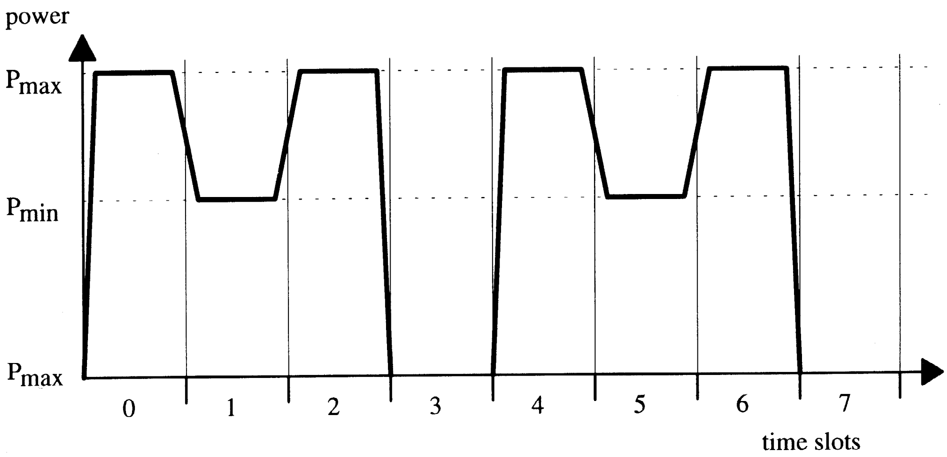
vertical

The Base Station Antenna

Transmitter Signal Power and Field Strenght Limits

Discontinuous Transmission - Minimizing co-channel interference is a goal in any cellular system, since it allows better service for a given cell size, or the use of smaller cells, thus increasing the overall capacity of the system. Discontinuous transmission (DTX) is a method that takes advantage of the fact that a person speaks less that 40 percent of the time in normal conversation, by turning the transmitter off during silence periods. An added benefit of DTX is that power is conserved at the mobile unit.

Power Control - To minimize co-channel interference and to conserve power, both the mobiles and the Base Transceiver Stations operate at the lowest power level that will maintain an acceptable signal quality. Power levels can be stepped up or down in steps of 2 dB from the peak power down to a minimum of 13 dBm (20 milliwatts). The mobile station measures the signal strength or signal quality (based on the Bit Error Ratio), and passes the information to the Base Station Controller, which ultimately decides if and when the power level should be changed.



Pulsed transmit signal at the base station. Time slots number 1 and 5 carry calls to nearby mobiles, thus transmit power is reduced. Time slots number 3 and 7 are not used.

Maximum allowed electrical field strength E_{max} (human exposure):

CH, standard: 40 V/m (WHO recommendation)
CH, sensitive: 4 V/m

Note that pulsed radiation may not cause the same bio-electromagnetical effects as continuous wave radiation.

Sources

Graphs and text in this introduction were adopted from the following sources:

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