UNIK 4700

A-Basics of Communication

- Electromagnetic Signals
- Radio Communication Principles
- Digital communication: Signal/Noise Ratio
- Signal strength and Capacity: Shannon

B-Antennas and Propagation

- Free Space Propagation
- Antennas, Gain, Radiation Pattern
- Multipath Propagation, Reflection, Diffraction
- Attenuation, Scattering
- Interference and Fading (Rayleigh, Rician, ...)
- Mobile Communication dependencies

C-Propagation models

- Environments (indoor, outdoor to indoor, vehicular)
- Outdoor (Lee, Okumura, Hata, COST231 models)
- Indoor (One-slope, multiwall, linear attenuation)

D-System Comparison

- Proximity: RFID, NFC
- Short Range: ZigBee, Bluetooth, ANT+,...
- WLAN/Wifi/802.11...
- Mobile: GSM, UMTS, IMT-A (WiMAX, LTE)

E-Mobility

$C = W \log_2(1 + SNR)$

$P_R = P_T g_T g_R \cdot \left(\frac{\lambda}{4\pi r}\right)^2$

Loss: attenuation ... free space loss

$\lambda\,[cm] = \frac{30}{f\,[GHz]}$

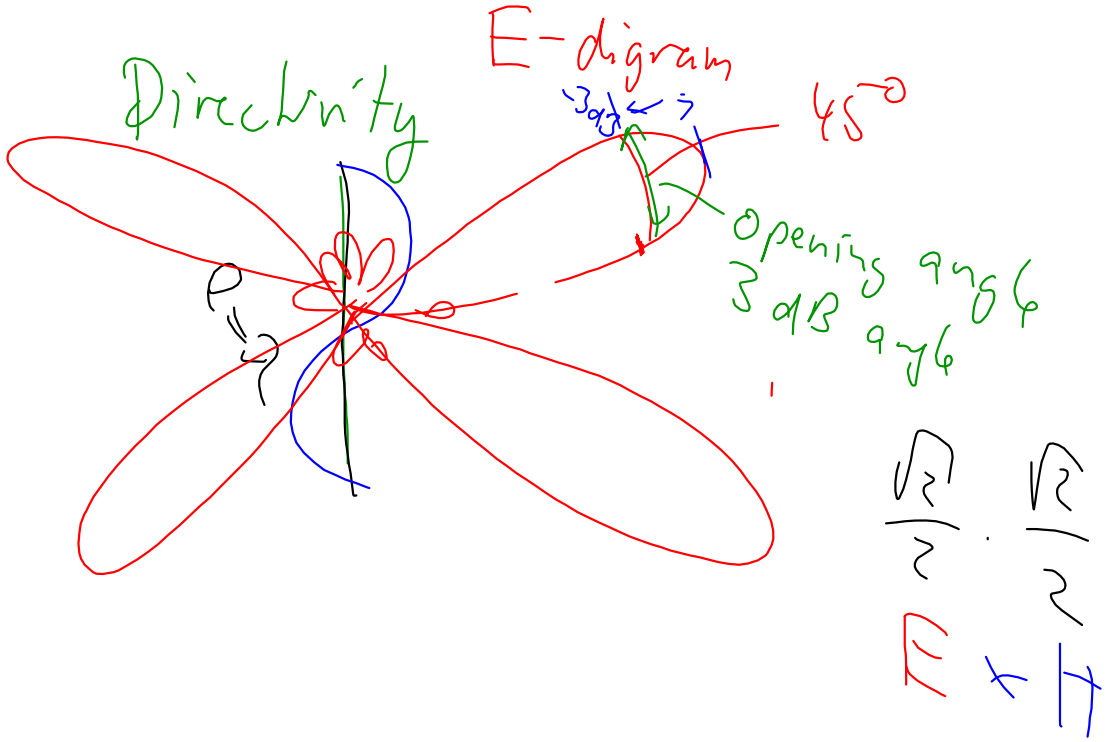
$\frac{\lambda}{20} \leq \ell \leq 2\lambda$

B2-Antenna Basics

The gain is the radiation intensity of an antenna into the main direction compared to an isotropic antenna (omnidirectional). For a perfect antenna without any losses, the gain G will be identical to the directivity D.

$$D = D_{main}/D_{isotropic}$$

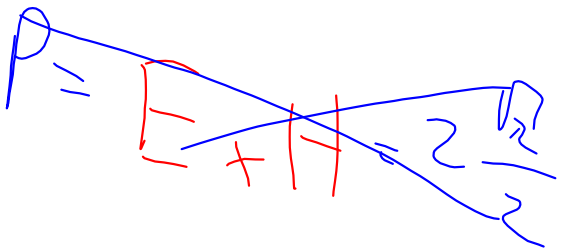
$$D_{rad} = \frac{4\pi F_{max}(\theta,\varphi)}{\int_0^{2\pi}\int_0^{\pi} F(\theta,\varphi)sin(\theta)d\theta d\varphi}$$



dB el field $20 \log\left(\frac{E}{E_0}\right)$ ~ $-3\,dB = \frac{\sqrt{2}}{2}$

power $10 \log\left(\frac{P}{P_0}\right)$

$\pm 3\,dB = 0.5$ (2)



UMTS

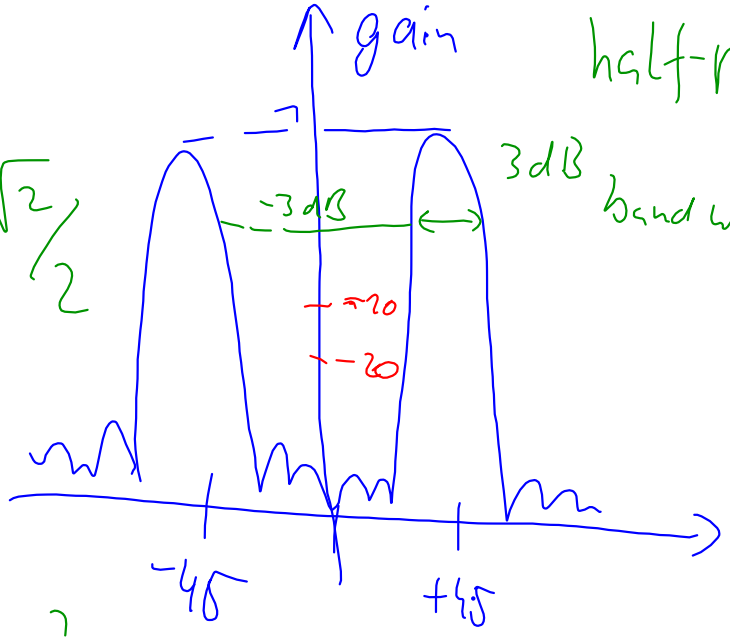
Bandpass filter

-14 dB

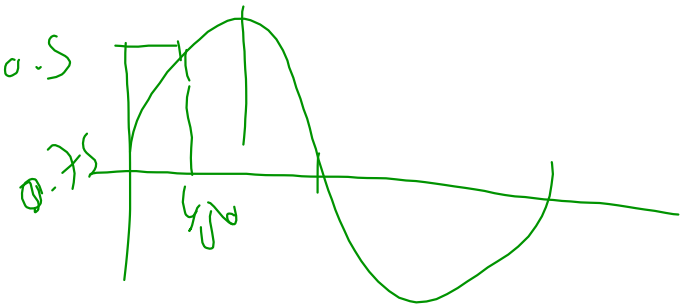
	sin	cos
45°	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2}}$

$\frac{1}{\sqrt{2}} \times \frac{\sqrt{2}}{\sqrt{2}} = \frac{\sqrt{2}}{2}$

λ-dipol



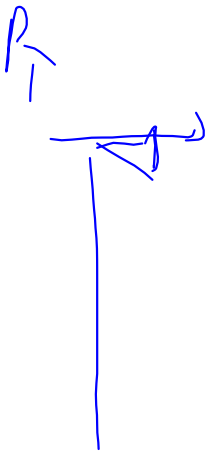
0	0	0
$\frac{\sqrt{2}}{2}$	30	0.5
$\frac{\sqrt{2}}{2}$	45	$\frac{\sqrt{2}}{2}$
$\frac{\sqrt{3}}{2}$	60	$\frac{\sqrt{3}}{2}$
$\frac{\sqrt{4}}{2}$	90	1



Gain of an antenna

typically: $g = \frac{\text{Power main direction}}{\text{Total Power all directions}}$

Measurements:

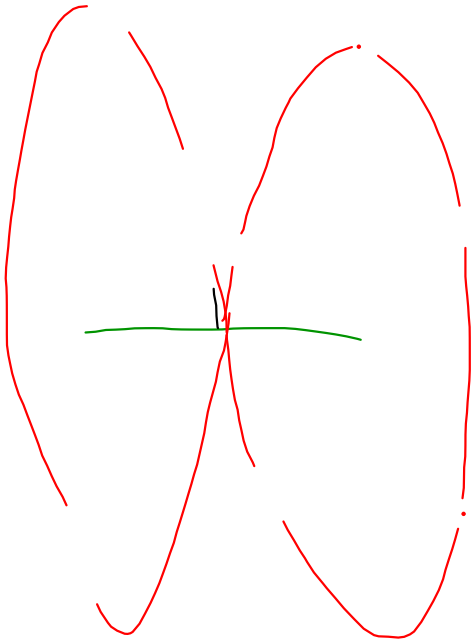


$g = g_{\text{measured main}} - g_{\text{reference antenna}} + g_{\text{reference}}$

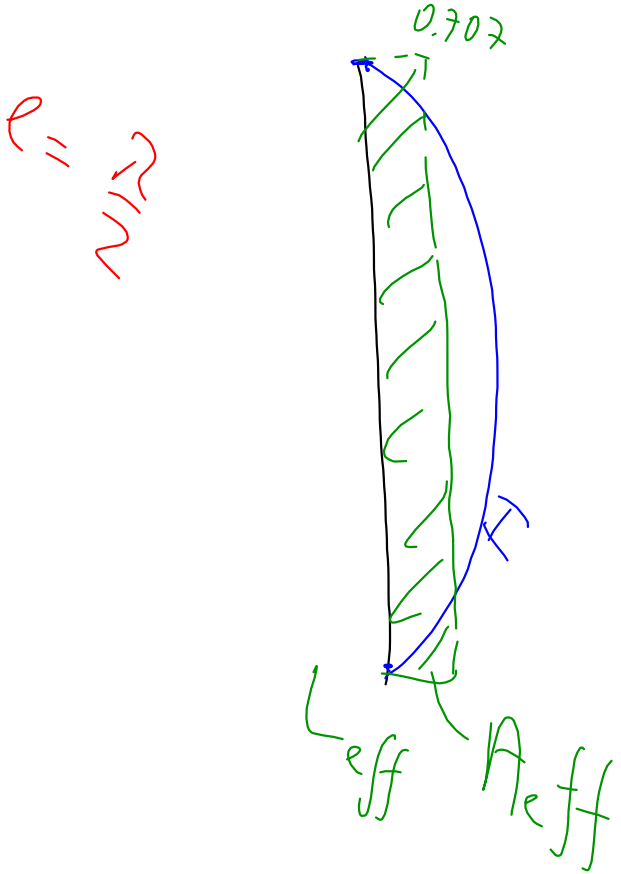
(2) - (1)

$+ 20\,dB$

Hertz Dipol

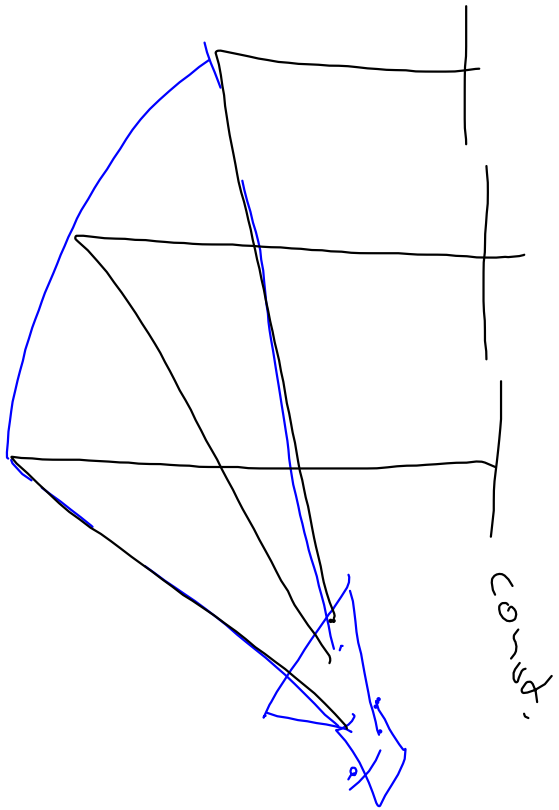


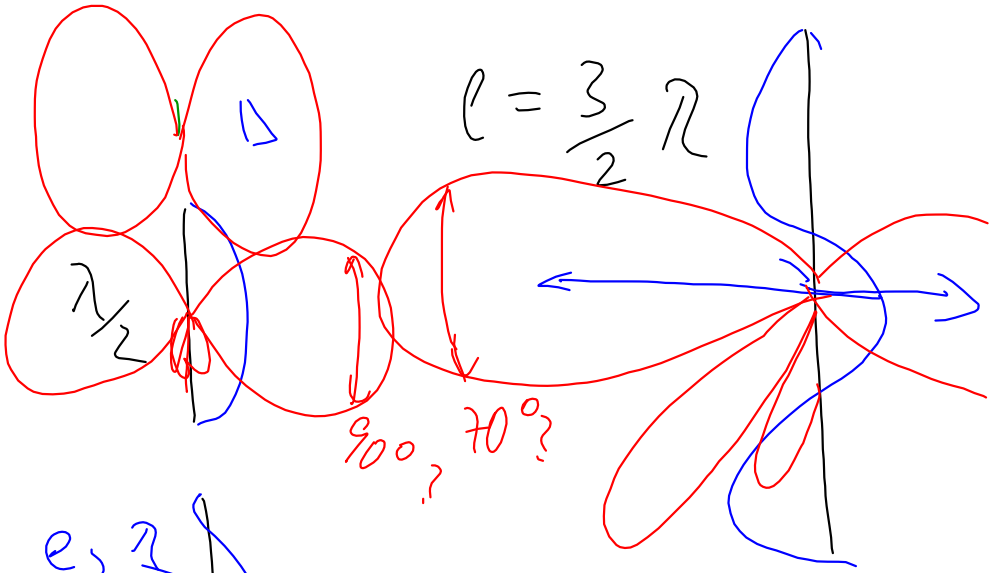
Current distribution

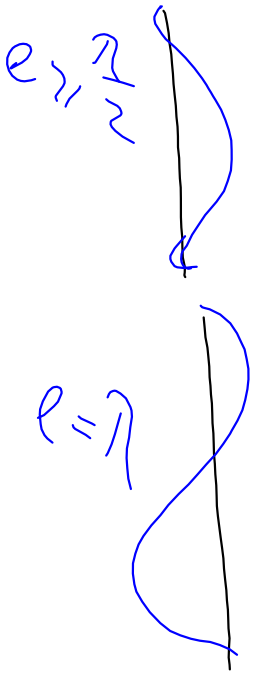


effective Aperture

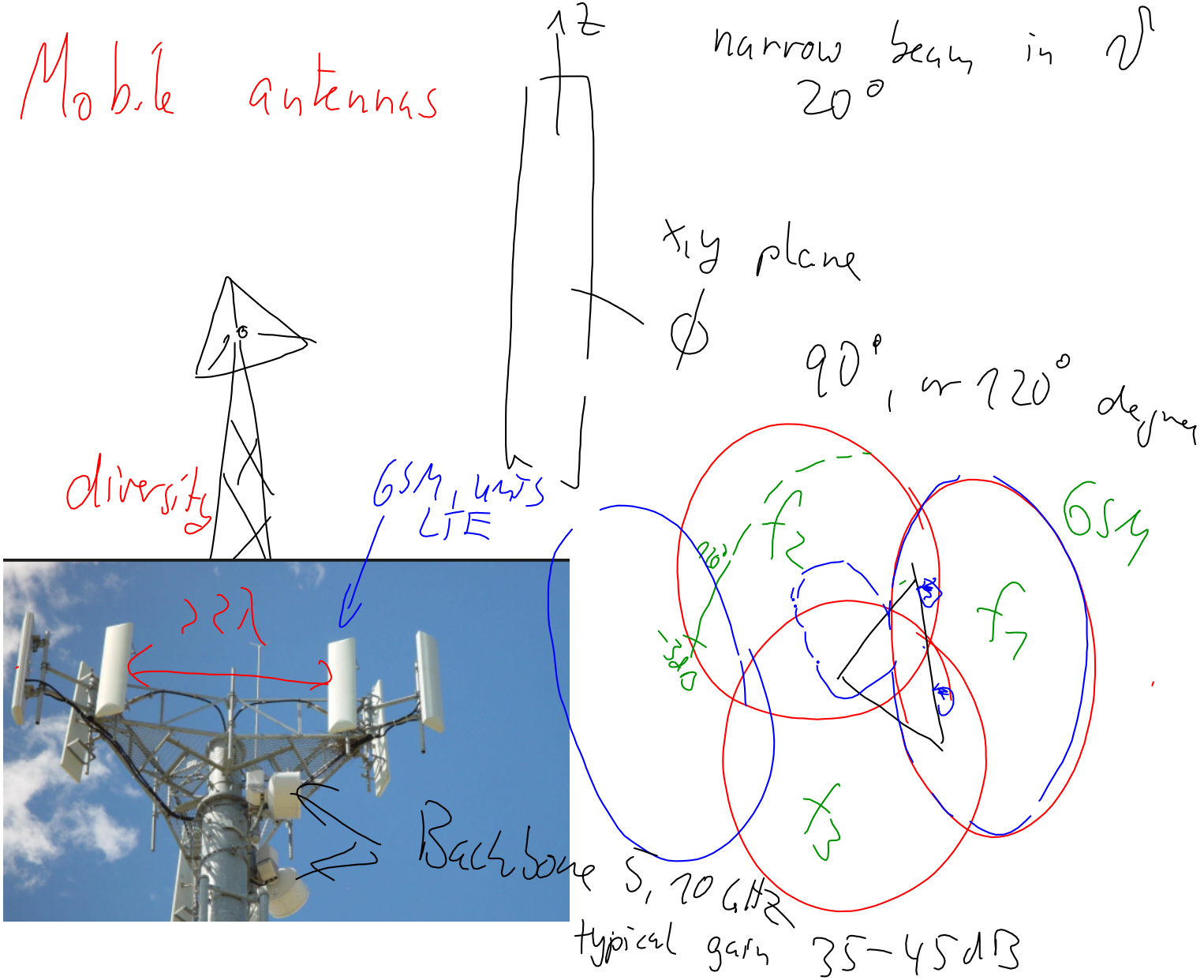
increase

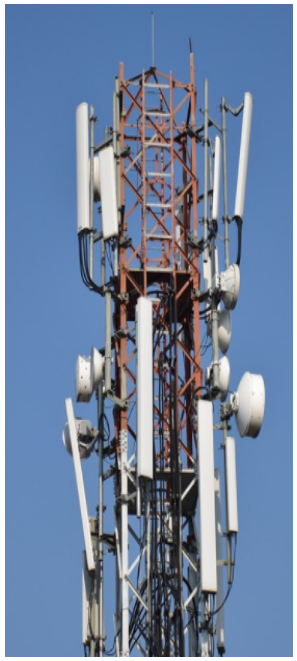


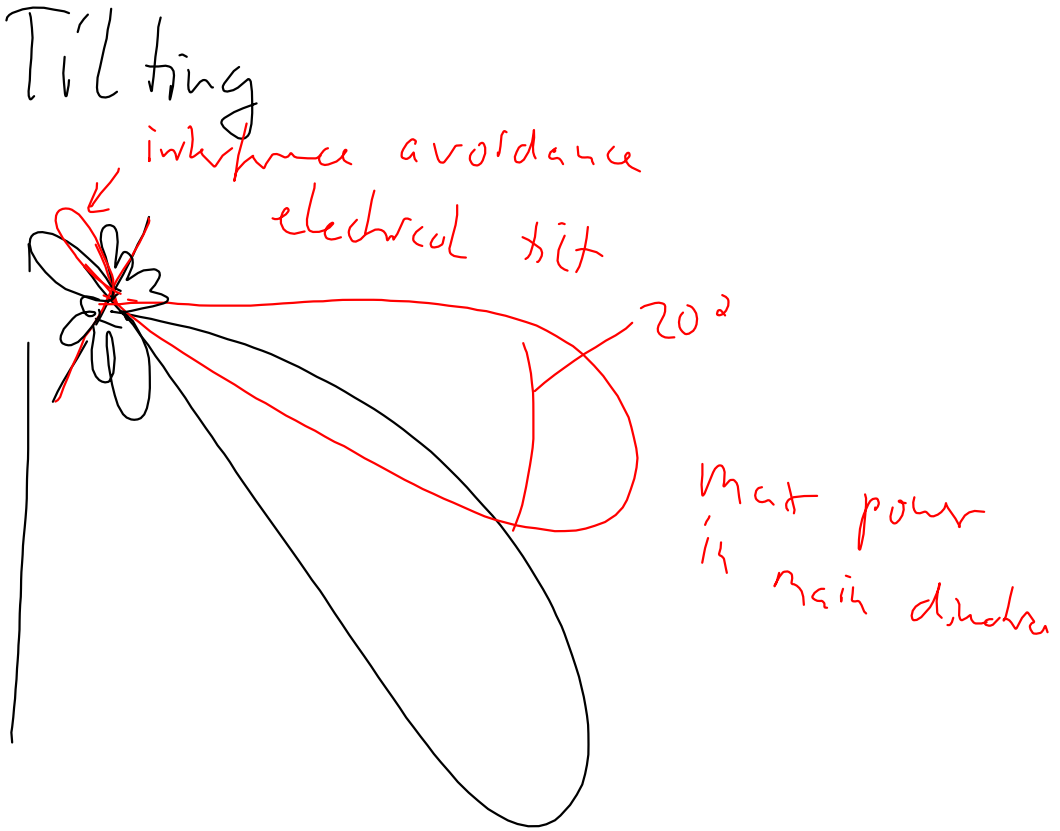




Mobile antennas



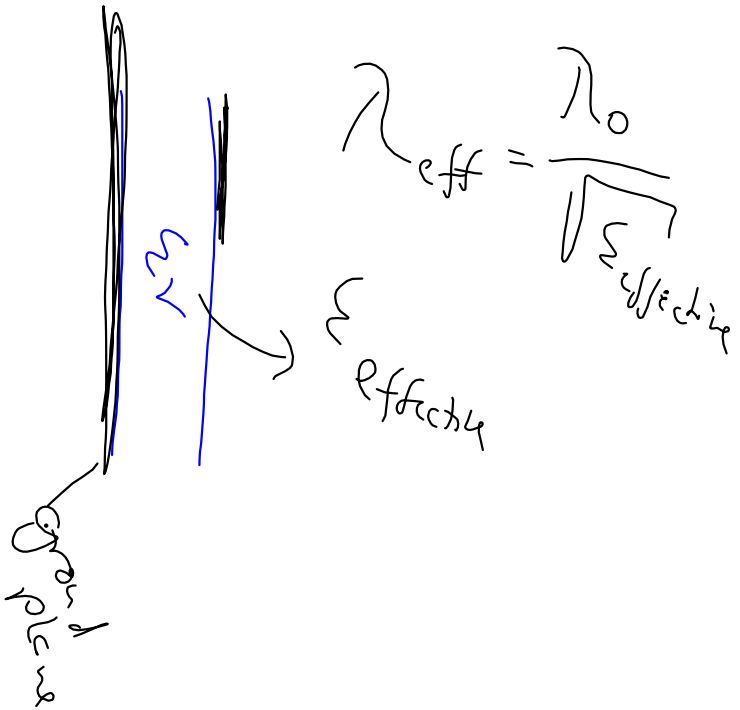



Tilting
interference avoidance
electrical tilt
20°
Most power
in main lobe

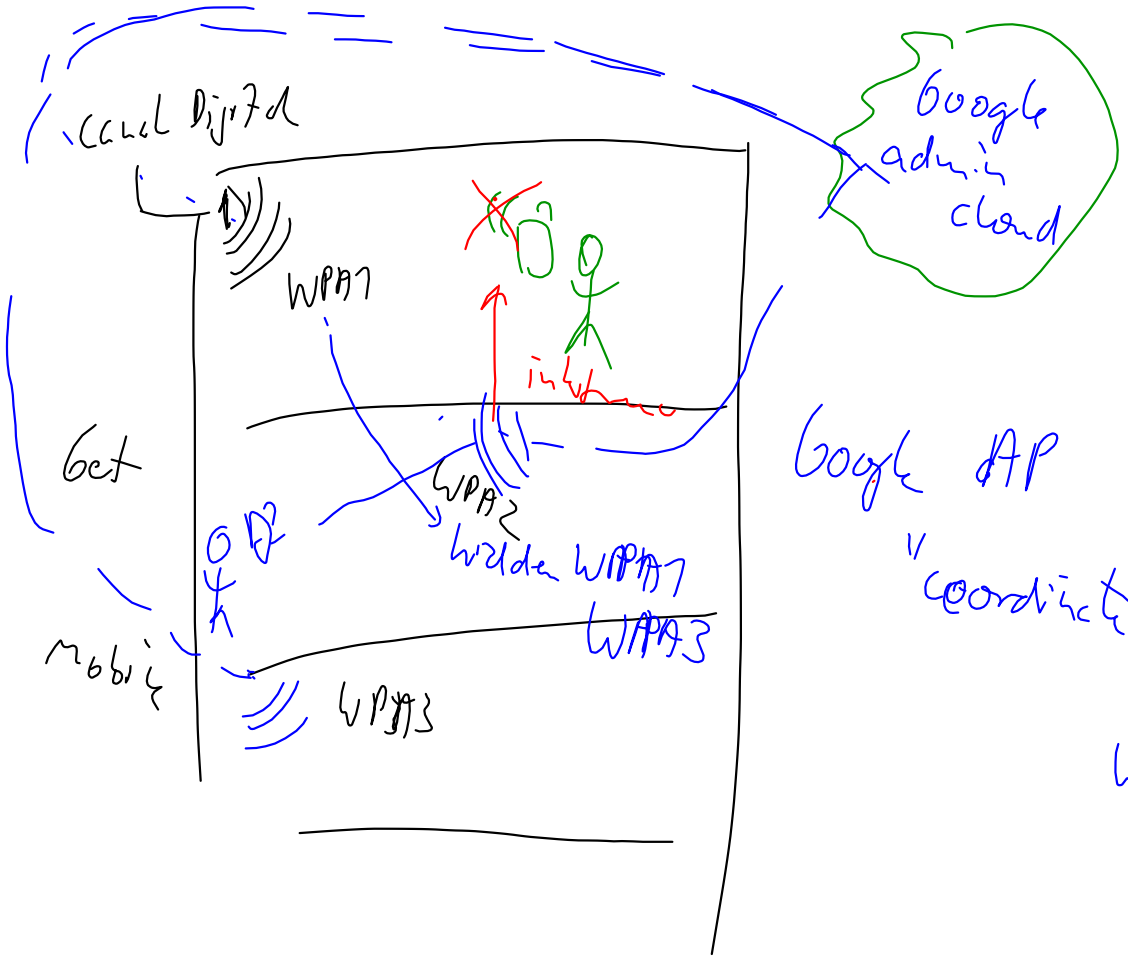
Home Modem

900, 1800, 2100, 2655 MHz Mobile +

2400, 5100 -- 5800 MHz WLAN



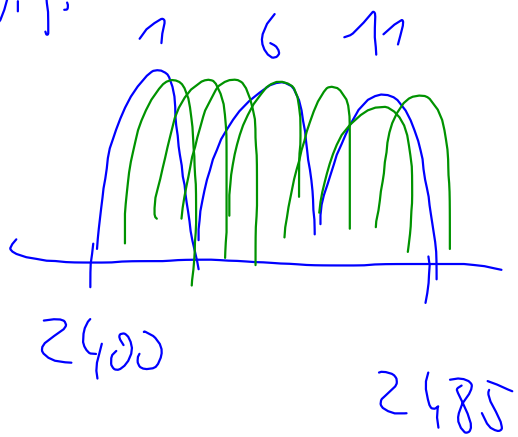
$$\lambda_{eff} = \frac{\lambda_0}{\sqrt{\varepsilon_{effective}}}$$

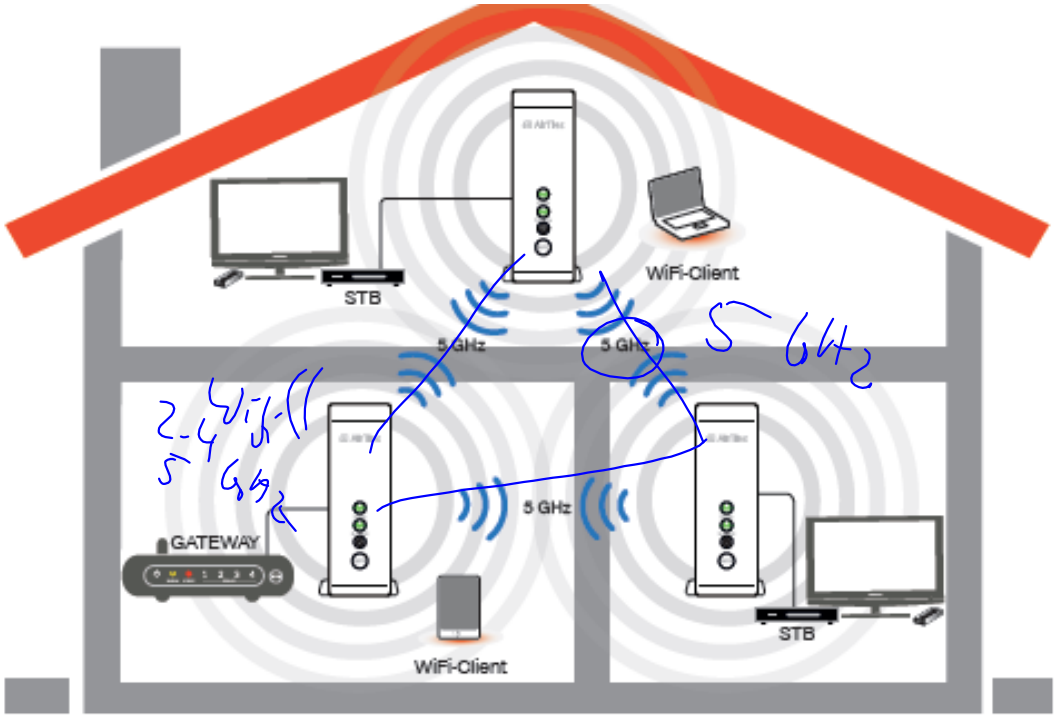


Google AP
"coordinate"

Normal:
- auto band
- reduce transmit power
  → range ↓

Wifi:





802.11 ac

mesh

MIMO beam forming

3 antennas / box

5 GHz regulation

"no interference" ⇒ 30 dBm

higher MIMO antennas gain

MCS index 9

MCS Value Achieved by Clients at Various Signal to Noise Ratio Levels (SNR)

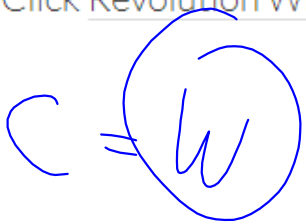
Protocol	Channel	1	2	3	4	5	6	7	8	9	10
802.11b	20MHz	None	None	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	MCS 1
802.11a/g	20MHz	None	MCS 0	MCS 0	MCS 1	MCS 2	MCS 2	MCS 2	MCS 2	MCS 3	MCS 3
802.11n	20MHz	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MCS 2
802.11n	40MHz	None	None	None	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1
802.11ac	20MHz	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MCS 2
802.11ac	40MHz	None	None	None	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1
802.11ac	80MHz	None	None	None	None	None	None	None	MCS 0	MCS 0	MCS 0
802.11ac	160MHz	None	None	None	None	None	None	None	None	None	None

Modulation Key
None = Grey
BPSK = Red
QPSK = Orange
16-QAM = Yellow
64-QAM = Blue
256-QAM = Green

SNR in dB		11	12	13	14	15	16	17	18	19	20
802.11b	20MHz	MCS 2	MCS 2	MCS 2	MCS 2	MCS 2	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3
802.11a/g	20MHz	MCS 4	MCS 4	MCS 4	MCS 4	MCS 5	MCS 5	MCS 5	MCS 6	MCS 6	MCS 7
802.11n	20MHz	MCS 3	MCS 3	MCS 3	MCS 3	MCS 4	MCS 4	MCS 4	MCS 5	MCS 5	MCS 6
802.11n	40MHz	MCS 1	MCS 2	MCS 2	MCS 3	MCS 3	MCS 3	MCS 3	MCS 4	MCS 4	MCS 4
802.11ac	20MHz	MCS 3	MCS 3	MCS 3	MCS 3	MCS 4	MCS 4	MCS 4	MCS 5	MCS 5	MCS 6
802.11ac	40MHz	MCS 1	MCS 2	MCS 2	MCS 3	MCS 3	MCS 3	MCS 3	MCS 4	MCS 4	MCS 4
802.11ac	80MHz	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MCS 2	MCS 3	MCS 3	MCS 3	MCS 3
802.11ac	160MHz	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MCS 2	MCS 3

802.11 Type Key
802.11b
802.11ag
802.11n
802.11ac

Click Revolution Wi-FI MCS to

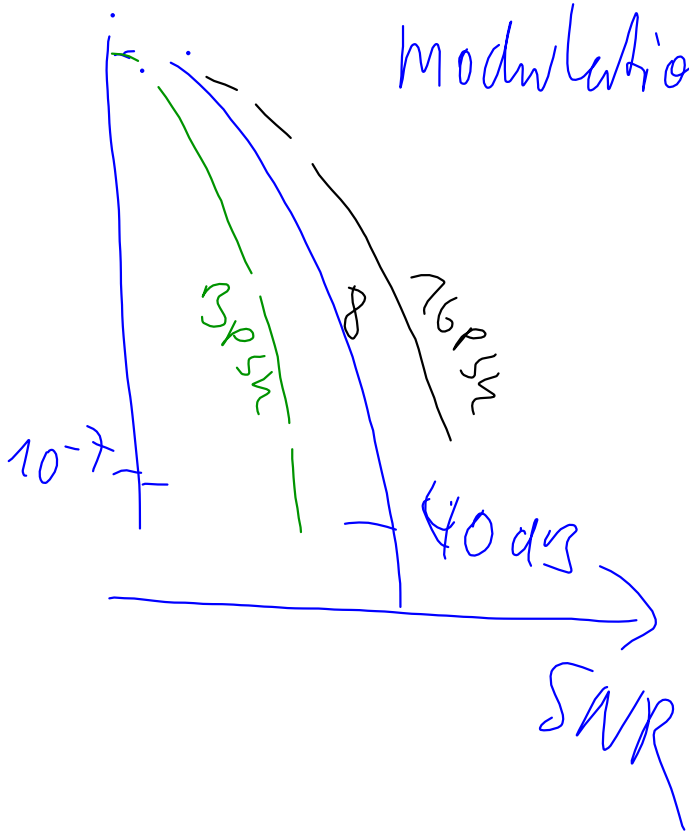


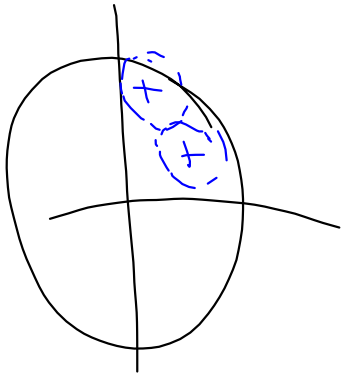
- Newly introduced in 802.11ac
  - five to eight spatial streams
  - 160 MHz channel bandwidths (contiguous 80+80)
  - 80+80 MHz channel bonding (discontiguous 80+80)
  - MCS 8/9 (256-QAM)

MCS

MCS index[a]	Spatial Streams	Modulation type	Coding rate	Data rate (in Mbit/s)[7][b]							
				20 MHz channels		40 MHz channels		80 MHz channels		160 MHz channels	
				800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI
0	1	BPSK	1/2	6.5	7.2	13.5	15	29.3	32.5	58.5	65
1	1	QPSK	1/2	13	14.4	27	30	58.5	65	117	130
2	1	QPSK	3/4	19.5	21.7	40.5	45	87.8	97.5	175.5	195
3	1	16-QAM	1/2	26	28.9	54	60	117	130	234	260
4	1	16-QAM	3/4	39	43.3	81	90	175.5	195	351	390
5	1	64-QAM	2/3	52	57.8	108	120	234	260	468	520
6	1	64-QAM	3/4	58.5	65	121.5	135	263.3	292.5	526.5	585
7	1	64-QAM	5/6	65	72.2	135	150	292.5	325	585	650
8	1	256-QAM	3/4	78	86.7	162	180	351	390	702	780
9	1	256-QAM	5/6	N/A	N/A	180	200	390	433.3	780	866.7
0	2	BPSK	1/2	13	14.4	27	30	58.5	65	117	130
1	2	QPSK	1/2	26	28.9	54	60	117	130	234	260
2	2	QPSK	3/4	39	43.3	81	90	175.5	195	351	390
3	2	16-QAM	1/2	52	57.8	108	120	234	260	468	520
4	2	16-QAM	3/4	78	86.7	162	180	351	390	702	780
5	2	64-QAM	2/3	104	115.6	216	240	468	520	936	1040
6	2	64-QAM	3/4	117	130.3	243	270	526.5	585	1053	1170
7	2	64-QAM	5/6	130	144.4	270	300	585	650	1170	1300
8	2	256-QAM	3/4	156	173.3	324	360	702	780	1404	1560
9	2	256-QAM	5/6	N/A	N/A	360	400	780	866.7	1560	1733.4
0	3	BPSK	1/2	19.5	21.7	40.5	45	87.8	97.5	175.5	195
1	3	QPSK	1/2	39	43.3	81	90	175.5	195	351	390

BER





GSM SS7 signalling 1985

3 types A_3, A_5, $A_{8(?)}$

40bit

set-up call

Voice

- coverage
- 4G voice

(2015)

Why GSM network?

- alarm
- (mobile FAT)
- payment terminals

From 2024 (Norway)

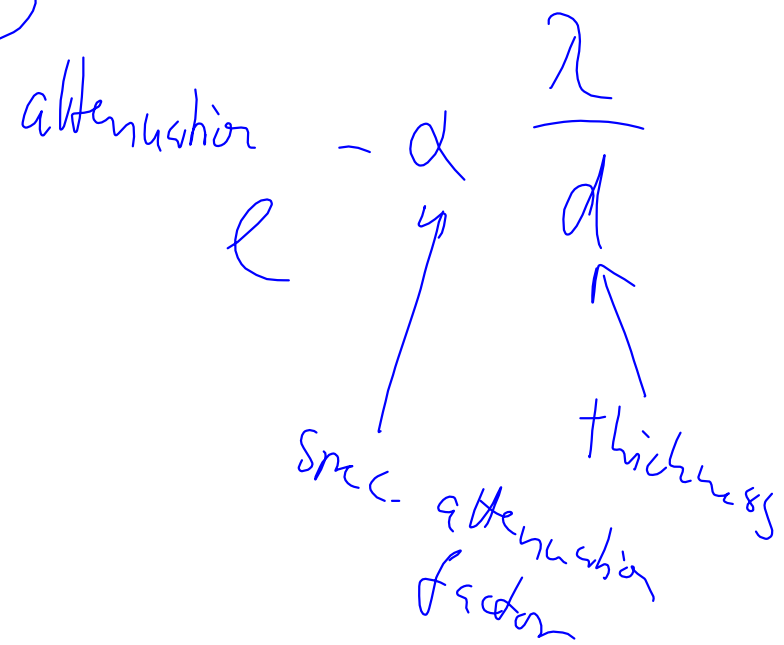
2G, 4G, (5G)

Attenuation Parameters For 2.4 GHz

Obstacle	Attenuation [dB]
Brick wall with window	2
Brick wall next to metal door	3
Cinder Block wall	4
Office wall	6
Metal door in office wall	6
Metall door in brick wall	12.4
Floor	30

Measurements performed for European building

(Source:Hydra Deliverable D5.4, p 12)



	WiFi b	WiFi g	Bluetooth 1.2	ZigBee
Power (type)	20 dBm	20 dBm	0,4,20 dBm	0 dBm
Spreading	DSSS	DSSS/OFDM	AFHSS	DSSS
Access	CSMA/CA	CSMA/CA	FH	CSMA/CA
LoS Range	100m	100m	10,50,100m	10m
Bandwidth	22 MHz	22 MHz	1 MHz	5 MHz
Rate	11 Mbit	54 Mbit	0.72 Mbit	0.25 Mbit
Sensitivity	-84 dBm	-84 dBm	-89 dBm	-92 dBm

Table 5: Wireless Communication Technologies in the ISM Band

GSM UMTS

-106dBm -114dBm

$P_R > F_{fading\ margin} + P_{Sensitivity}$