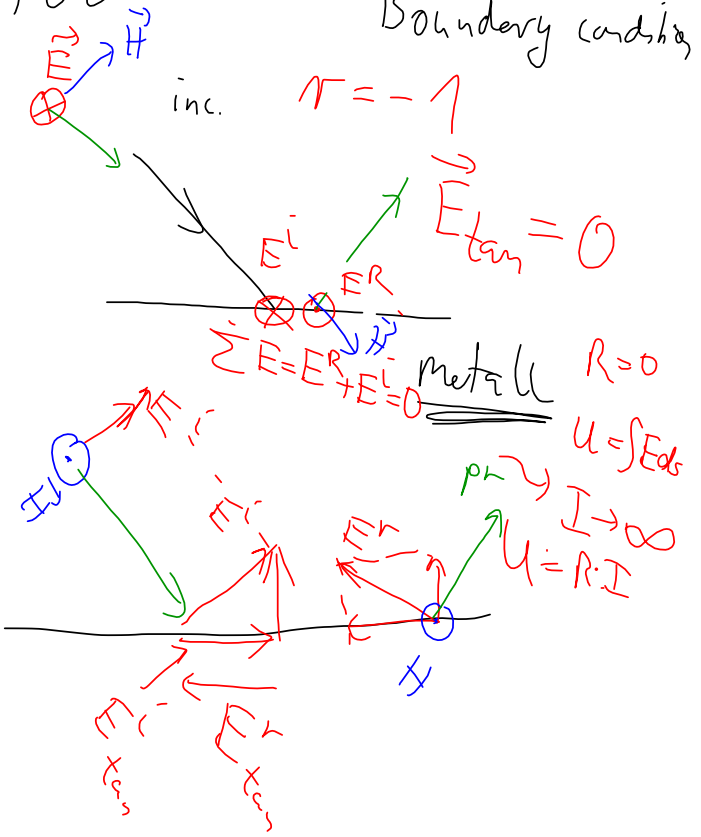
UNIK 4700

11:30

- Assignments
- $\vec{E} \times \vec{H} = \vec{P}$

Thumb rule: pointing finger = direction of traveling wave

- Interference
- Capacity
- Power received



Physics

frequency

antenna

(Power Tx)

Interference/noise

Receiver

Services — voice, video, www

Range

Capacity = f(Bit Error Rate)

Mobility

Service infrastructure

SIM

Home Location Register

HLR

System / Mobile / Wireless / Sensor

Business, Provider

P_t transmit

Loss / Wave progation
- obstacles (rain, ... buildings)
- interference, noise

antenna

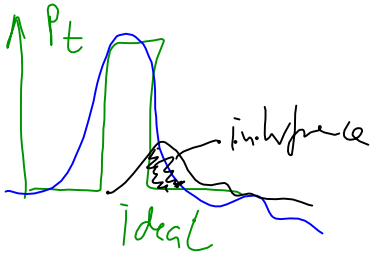
$P_{receive}$

$P_R > P_{sens}$

$P_{sensitivity}$ (amplifier)

Capacity = f (SNR)

*1 etample: Ultra Wide Band (UWB)
Spread spectrum (2-6, 2-20 GHz)
$P_s < P_{noise}$, dedicated coding



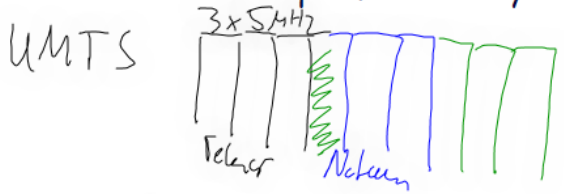
bad handset
"cheap"
lousy (?)
specs loosy
adj. ch. < 15 dB

- Bandwidth separation between signals and adjacent channel separation (ACS) [Holma2000, p183]. ACS requirements 33 dB. Measurements performed by [Potman et.al.]
- *E* versus *B*: later today

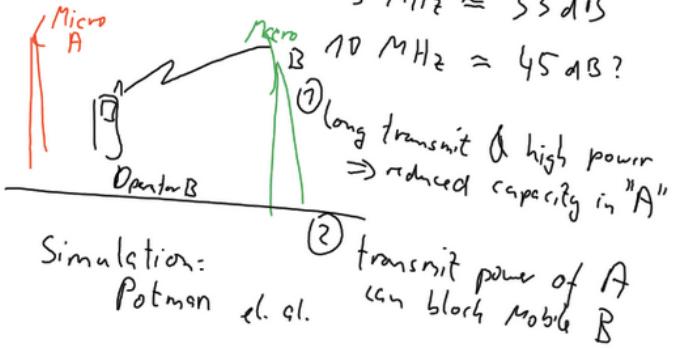
Comments

Figure: Illustrating reduction of capacity in network A (top) and blinding of phones in cell (B)

More detailed discussions on these effects can be found in the literature indicated above.

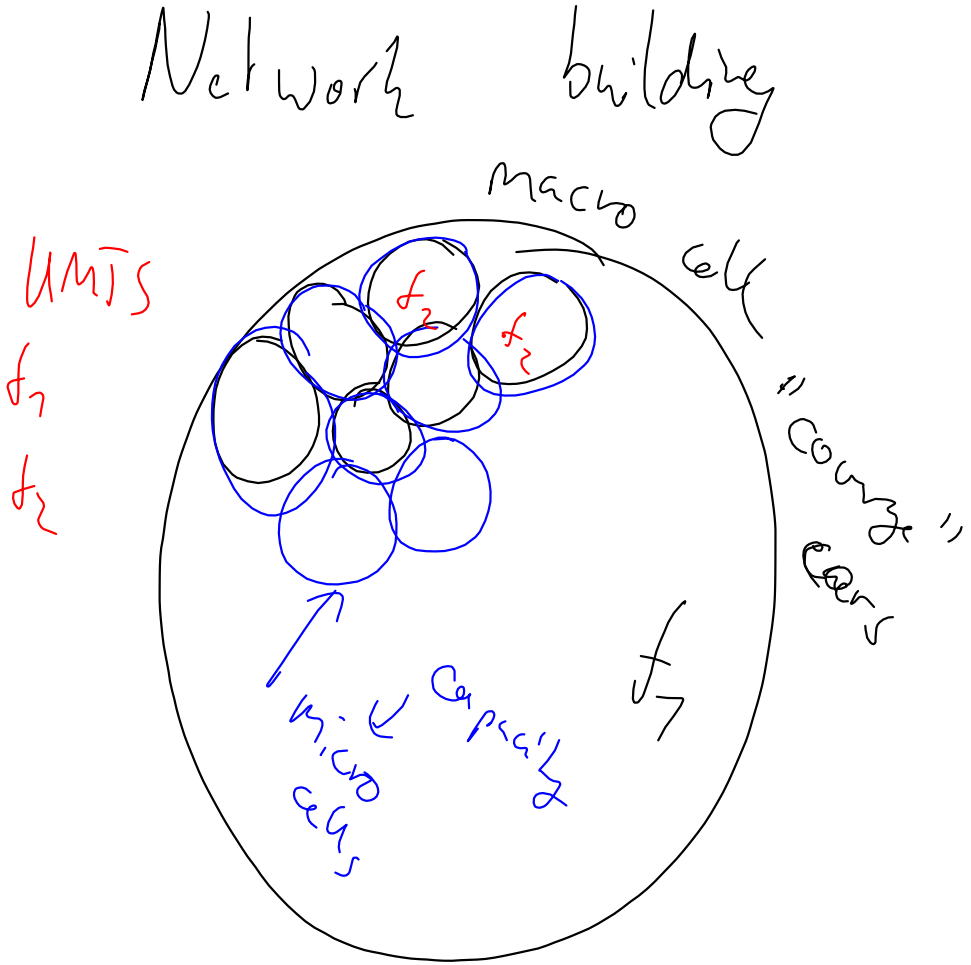


UMTS
Holma et al p. 88 ACLR
5 MHz ≈ 33 dB
10 MHz ≈ 45 dB?



1 long transmit & high power ⇒ reduced capacity in "A"
2 transmit power of A can block mobile B

Simulation: Potman et. al.


Network
macro
cell
UMTS
f_1
f_2
f_2
f_2
micro cells
Capacity
f_1

Signal/Noise Ratio

$$\mathrm{SNR} = \frac{P_{\mathrm{signal}}}{P_{\mathrm{noise}}}$$

$$\mathrm{SNR(dB)} = 10\log_{10}\left(\frac{P_{\mathrm{signal}}}{P_{\mathrm{noise}}}\right),$$

where *P* is average power

- why talking about noise?
- dB, $2\mathrm{dB}_m$, dB_a
- near-far problem

[source: Wikipedia]

$$P_{dB} = 10 \log_{10} P_{lin}$$

$$E_{dB} = 20 \log_{10} E_{lin}$$

$$\vec{P} = \vec{E} \times \vec{H}$$

$$P = E \cdot H = E\frac{E}{Z_0} = \frac{|E|^2}{Z_0}$$

$$= 10$$

Shannon

$$C_{apacity} = W \cdot \log_2(1 + SNR) \quad \left[\frac{bits}{s}\right]$$

(W: Bandwidth)

$$SNR = \frac{P}{N_0 W}$$

N_0 white noise

W

	GSM	UMTS	LTE	802.11b	802.11a
900 MHz	0.2 MHz	5 MHz	2 ... 40 MHz	2.4 GHz	5.x GHz
1800 MHz				26 MHz	100 – 200 MHz
2655 MHz					

~25, 20 ... 200, ~100, ~500 ... 1000

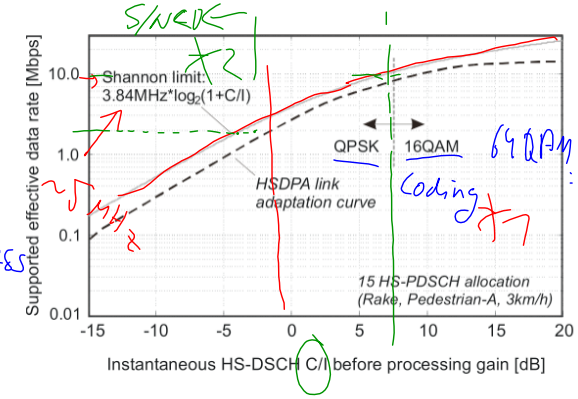
2 ... 40 MHz ← Galaxy Alpha (2014) LTE CAT6 20+20 MHz

typical capacity
- GPRS ~ 20 – 30 kbit/s
- EDGE ~ 128 – 200 kbit/s
- UMTS: UMTS ~ 1 ... 3 Mbit/s
- HSPA 7 ... 14 MbA/s
- LTE 20 Mbit/s

- 802.11b ~ 5 Mbit/s
- 802.11a ~ 20 Mbit/s
- 802.11n ~ 50 – 150 Mbit/s (⇒ Mimo)

Cell Capacity In UMTS

UMTS has good efficiency with respect to Shannon



High Speed Downlink Packet Access

HSPA

HSDPA = Download

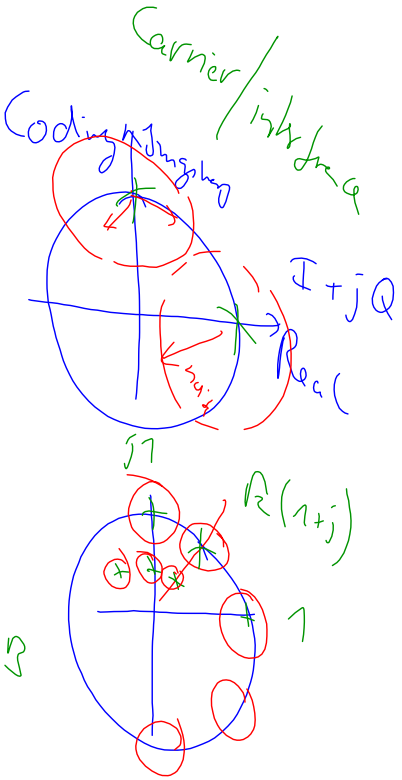
HSUPA Upload

*2 SNR < 0 dB

"before processing"

2 Mbit/s at $SNR_{before} = 0$ dB

10 Mbit/s at $SNR_{low} \sim -7.5$ dB



Range Versus SNR

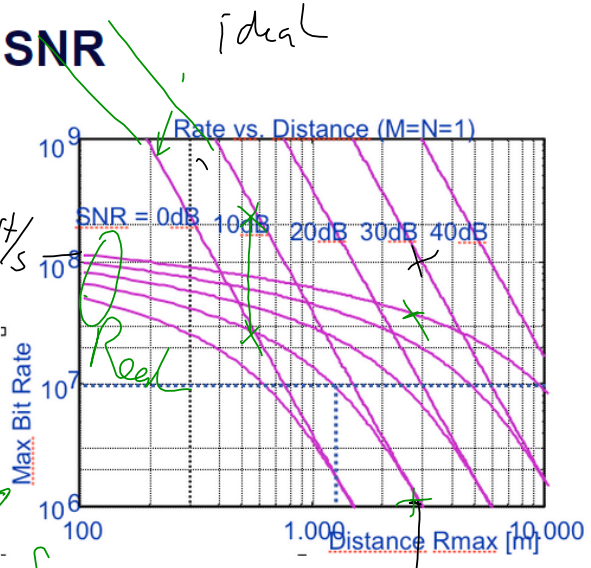
$R_{max} = \log_2(1 + SNR)$ [Source:Valenzuela, BLAST project] ~ year 2000

Comments

Real system

SNR	Range	Capacity
0	600 m	10 Mbit/s
30	300 m	60 Mbit/s
10	3 km(?)	1 Mbit/s (UMTS all capacity)

real systems < 50...100 Mbit/s



100 Mbit/s

ideal - Shannon

real system

ideal

3000 m 100 Mbit/s SNR 30

3000 m 1 Mbit/s 10

3000 m

[Source Valenzuela, BLAST project]

why is there no relation to frequency?

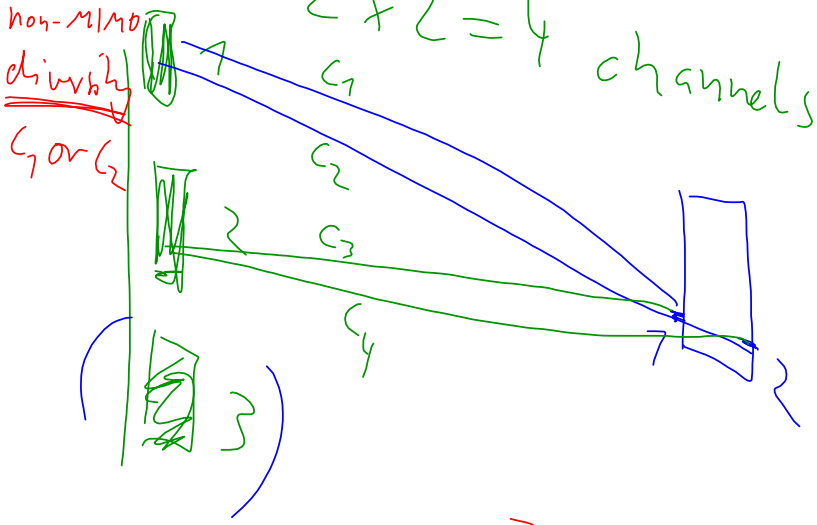
Capacity ~ $\frac{1}{\text{Range}}$

Capacity ~ f ← Real System

MIMO Multiple input / output

MIMO → capacity 2 x 2 = 4 channels

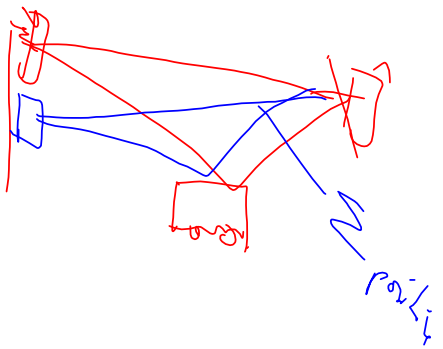
non-MIMO diversity C_1 or C_2

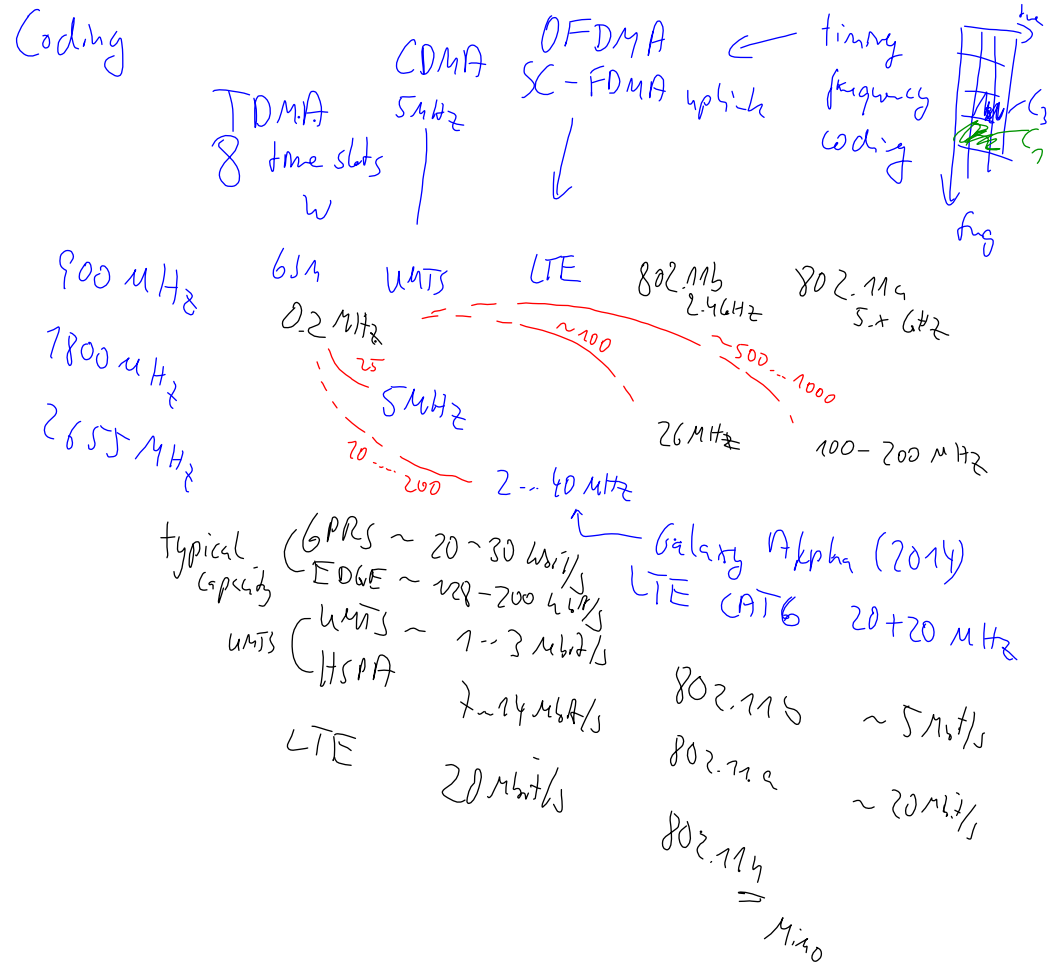


Total capacity

$C_1 + C_2 + C_3 + C_4$

Example: diversity




Coding
TDMA
8 time slots
CDMA
5 MHz
OFDMA
SC-FDMA uplink
timing
frequency
coding
900 MHz
1800 MHz
2655 MHz
GSM
UMTS
LTE
802.11b
2.4GHz
802.11a
5.x GHz
0.2 MHz
5MHz
25
70
200
~100
~500 ... 1000
26 MHz
100 - 200 MHz
2 .. 40 MHz
typical capacity
GPRS ~ 20 - 30 kbit/s
EDGE ~ 128 - 200 kbit/s
UMTS ~ 1 .. 3 Mbit/s
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LTE 20 Mbit/s
Galaxy Alpha (2014)
LTE CAT6 20+20 MHz
802.11b ~ 5 Mbit/s
802.11a ~ 20 Mbit/s
802.11n ⇒ MIMO
~ 50 - 150 Mbit/s

Recall: Plane Wave Propagation

Assume a plane wave: E_x, H_y. Show that $\frac{E_x}{H_y} = Z_0 = \sqrt{\mu_0/\varepsilon_0}$

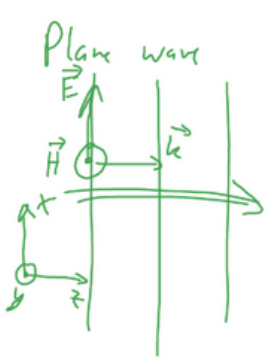
What is the relation between a plane wave and an omnidirectional wave?

Comments

Real material

$\varepsilon_r \cdot \varepsilon_0$

(μ_r)



$\vec{E} = E\,\vec{u}_x \; e^{j(\omega t - k_z z)}$

$\vec{H} = H\,\vec{u}_y \; e^{j(\omega t - k_z z)}$

$\nabla \times \vec{E} = -\mu_0 \frac{\partial \vec{H}}{\partial t}$

$$\nabla \times \vec{E} = \begin{vmatrix} \vec{u}_x & \vec{u}_y & \vec{u}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ E_x & E_y & E_z \end{vmatrix}$$

$\frac{E_x}{H_y} = Z_0 = 377\,\Omega$

19 Sep Free Space propagation, Antennas

26 Sep Yun Ai, Raul

Assignments

Select any topic related to the course, and present a 20-25 min presentation on the topic

- 1. find and select papers/books related to your topic
- 2. come with a suggestion on the direction of your presentation

Topics

- Antennas,
- Wave Propagation
- Radiation equation
- Interference
- Propagation models: Yun Ai ← next time
- Range of wireless communications - Raul ← 10 min
- GSM and UMTS
- LTE - Solomon ← 5 min
- Voice in LTE - Mikhail Yakubovich
- WiFi
- WiMAX - Qihaoli ← next time
- Security in NFC - Seraj ← next time
- System capapcity
- Basic Internet (free access to basic information (text & pictures) on the Internet)
- inverse MVNO: the customer owns the access network
- WLAN system for video communication
- ... (any other topic which you might find interesting)

Time for Questions

LTE:
→ smart adoption
message ↔ broadband
→ "radio"
(→ range, near/far)

Josef: UMTS cell breathing
+ add. comm → + noise
2 0 noise
3 10 %
4 20 %

Range: el. mg. wave → f
→ BW = 4, 5
→ P_T
mobile & IEEE 802.11
GSM -- LTE 802.11a -- 802.11g
802.11e
Urban, indoor
"Comparable parameters"
LTE 800 LTE 2600
GSM 900 GSM 1800
Albuquerque
- Max range GSM extended cell
- LTE 800 vs GSM 900
- Speed 10 Mbit/s
5 miles