Courses
Mobile Commun. (4230)
Radio & Mobility (4700)
Mobile Services (4710)
Sensor Networks (47xx)
PhD Mobile Services (9710)
All Ifi/UNIK courses
Master Reporting

Master Thesis Research
Ongoing thesis
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ICT research
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History: Courses/UNIK4700radio

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UNIK4700 Radio and Mobility

Lecture 2: Basics of communications

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Josef Noll — 06 September 2009, 11:46
- Foilene fra 3 forelesningen er lastet opp

Josef Noll — 04 September 2009, 11:46
- dato til block seminar, 5.-6. Nov 2009
- Forslag til presentasjoner lenger ned

Block seminar 5.-6. Nov 2009

Practical info:
- Book flights asap (flying out: 5.Nov, 08:00, returning 6.Nov NOK)
- send copy of tickets to josef@unik.no
- discuss accommodation

Two days programme:
- Presentations and discussion of selected topics

- Measurements of attenuation
- Matlab programming

Detailed programme

Thursday 5. Nov - not updated

- Overview, Q&A radio propagation
- Presentations A,B
  - LTE - Andreas
  - WRAN - Hemdan
  - WiMAX - Reidar
  - WiBree - Anders T.
  - WiMedia - Eystein
  - Wireless USB - Simen
  - NFC - Shabnam
  - Wireless HART - Magnus

1200 lunch

- Tasks & Programming tips
- Radio Programming (slide)

Friday 10. Oct
not updated

- 0900 Measurements
- 1100 Comparison Measurements-Theory

1200 lunch

- Presentations C, D
- 1530 end of day 2

Topics for programming

Propagation Models

- indoor (statistical, deterministic), outdoor (rural, city), indoor-outdoor propagation
- comparison to satellite link

Capacity and range

- Propagation equation
- Range, Capacity
- "Real systems" capacity

System parameters

- CDMA-2000, W-CDMA (UMTS), GSM 900, WLAN 802.11b, 802.11a, Bluetooth
- Receiver sensitivity
- Noise factors
-

Mobile/wireless communications

- combine systems and discuss results

Expectations

- select papers -> list of 2 selected papers to Josef (email)
  - UiOLibrary how to use IEEE, ACM and other library information to search for papers (slideshow)
  - you are able to search without VPN, but for printout of .pdf youneed someone with access (Knut, Sarfraz)
  - Alternative: scholar.google.com
  - starting point: literature list of UNIK4700

- prepare presentation (typical 35 min), focus
  - explain content
  - point out strengths and weaknesses
- discuss with colleagues

Distribution of work

- Radiation equation josef
  - power budget, examples
- Radiation and health Rolf
  - absorption examples (see Cost259)
- Range of wireless communications
  - selected papers on comparison of theory and measurements (WLAN) - Thomas
  - selected papers for GSM900, GSM1800 and WDCDMA - Espen
- System capacity
  - selected papers on WLAN (802.11a and 802.11n) - Zahid
  - selected papers on WDCDMA - Sarfraz
- Propagation models
  - indoor, outdoor, indoor-outdoor
- Systemparamters and performance - Øystein
  - CDMA-2000, W-CDMA (UMTS), GSM 900, WLAN 802.11b, 802.11a, Bluetooth

Lecture: Radio and Mobility, Introduction

Q&A: lessons learned

-
- see Comments4700Topics

Principles of radio communication

- radio wave propagation
- Electromagnetic signals
- Nyquist Theorem
- Signal/noise ratio
- Shannon Theorem
- Signal strength

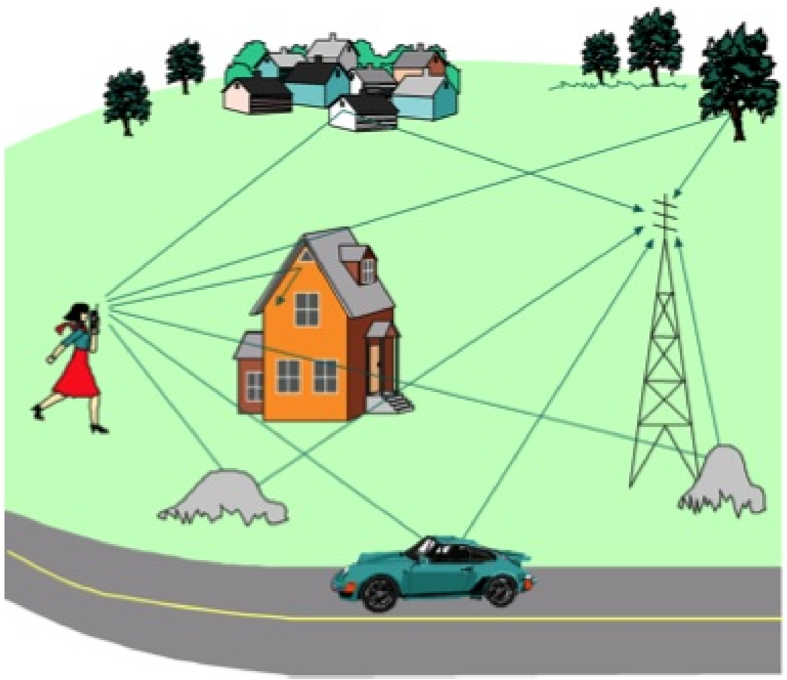
What will we learn today

- basics of radio communication
- sampling theorem
- typical radio transmission
- what effects the signal strengths

Heinrich Hertz - Radiowave propagation

Basics of wave propagation:

- The variation of an electrical field creates a magnetic field
- The variation of a magnetic field creates an electrical field

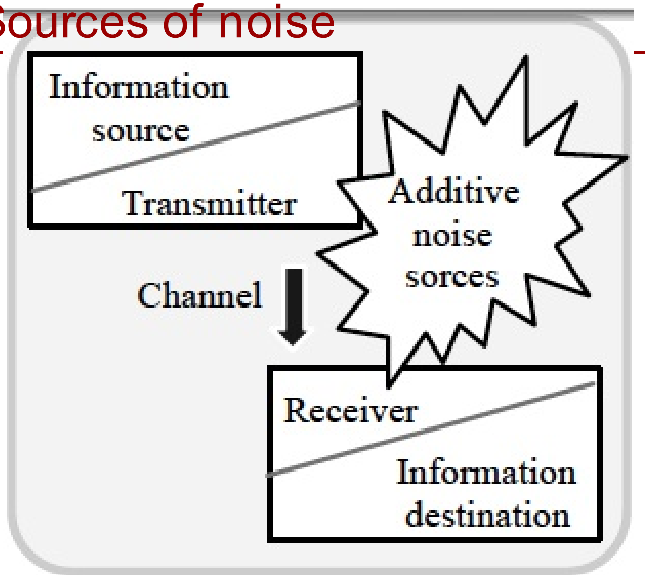


Electromagnetic channel

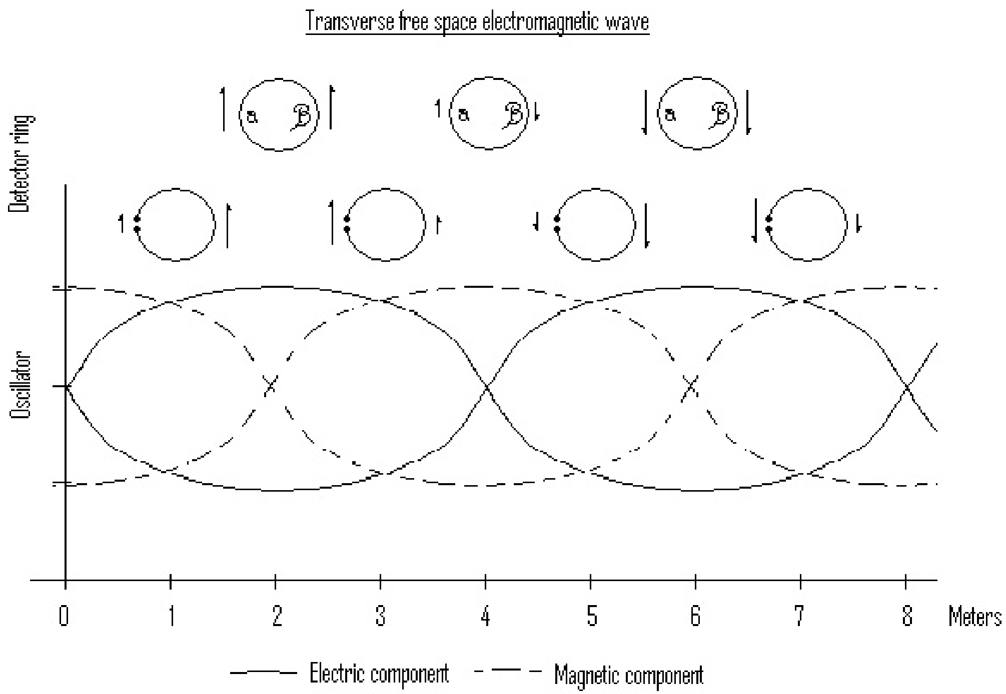
The radio channel is always affected by noise, which restricts the information flow to the receiver

[Source:Neelakanta et. al., Fig1.2]

Sources of noise



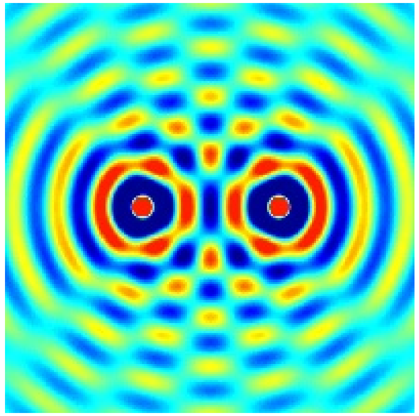
- Electronic parts of transmitter and receiver (components)
- Spurious electromagnetics (lines radiating on the chip)



- Fluctuations in power (switching CMOS circuits)

Radio

- In-band interference
- out-of band interference, e.g. GSM/NMT interference
- radio channel, e.g. scattering, multi-path



[Source:Wikipedia, "interference"]

Figure: Noise floor in a receiver

- further explanations: Telektronikk 4/95, Rækken and Løvnes, Multipath propagation[Δ]

Noise floor in receiver

N = Boltzmann x Bandwith x Temperatur [K]

GSM 200 kHz

UMTS 3800 kHz

802.11b 26.000 kHz

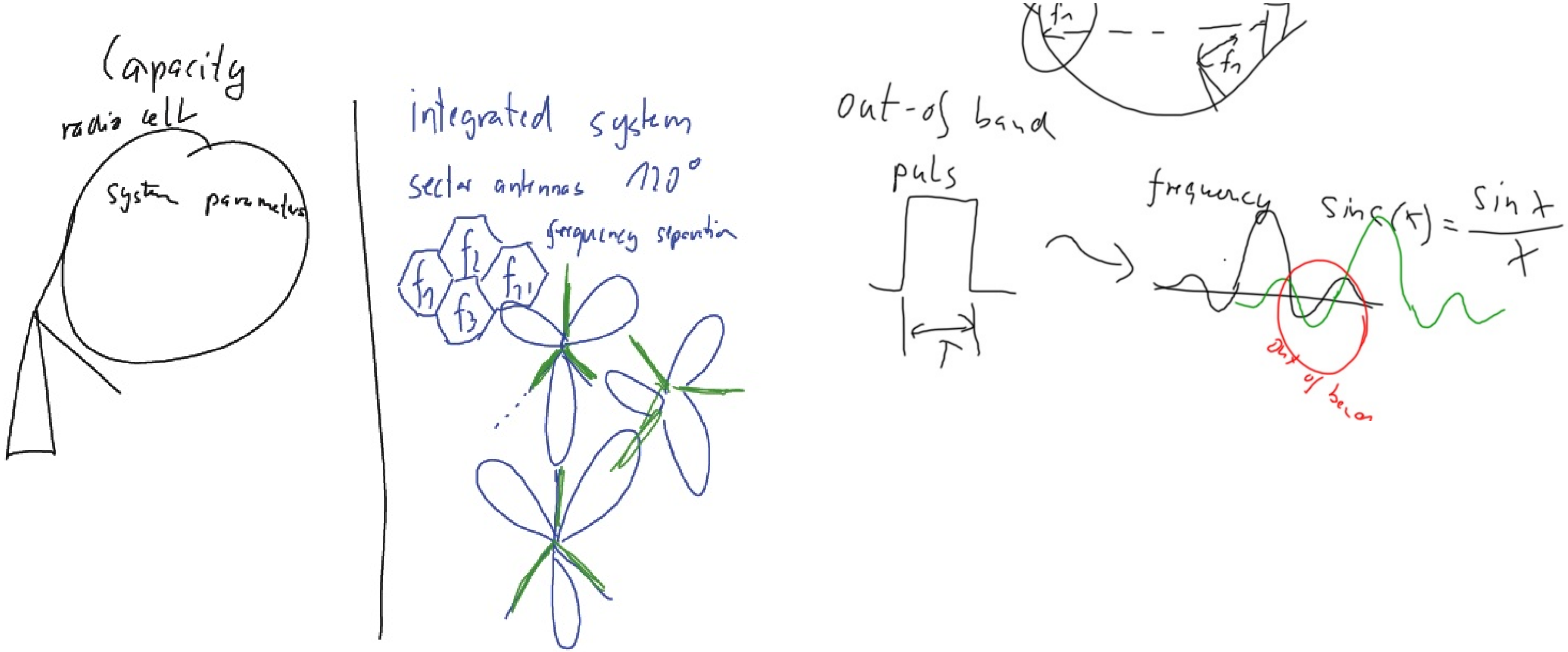
Comments

- in-band: a source having the same signal
- out-of-band: modulations/filters which are not perfect

explain Fourier-transform and overlap

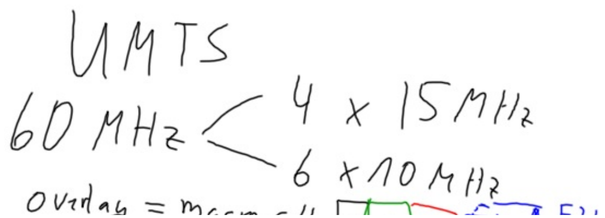
Figure: In-band (top) and out-of-band interference (bottom)

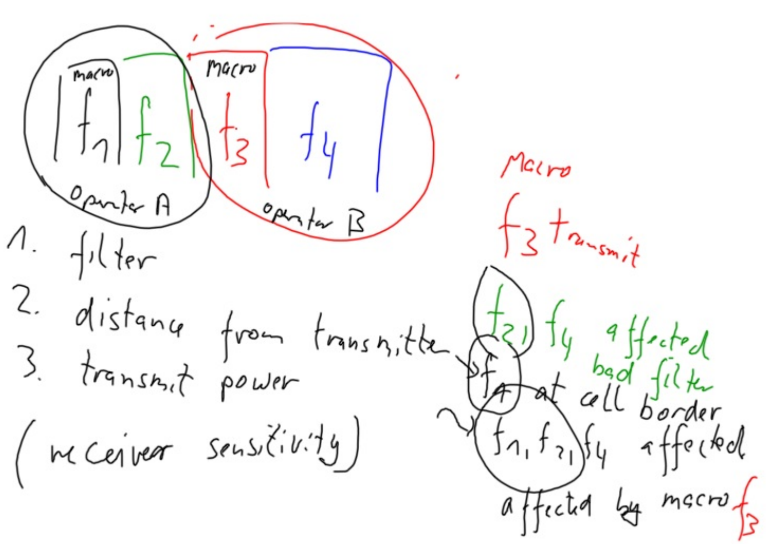
IN-band



The capacity of a system consists of both the cell capacity (depending mainly on Figure: Cell capacity (left) and system capacity (right) OSI layer 1-3) and on network design, meaning: how much interference do I get from other cells.

In a Figure: UMTS macro and microcells in a 6-operator environment network where the available 60 MHz in the UMTS band are distributed to 6 operators, each operator will only have 2x 10 MHz available for operation, which typically means that one frequency block (5MHz) will be used for micro-cells and the other frequency block (5 Unik/MHz) will be used for macro-cells.





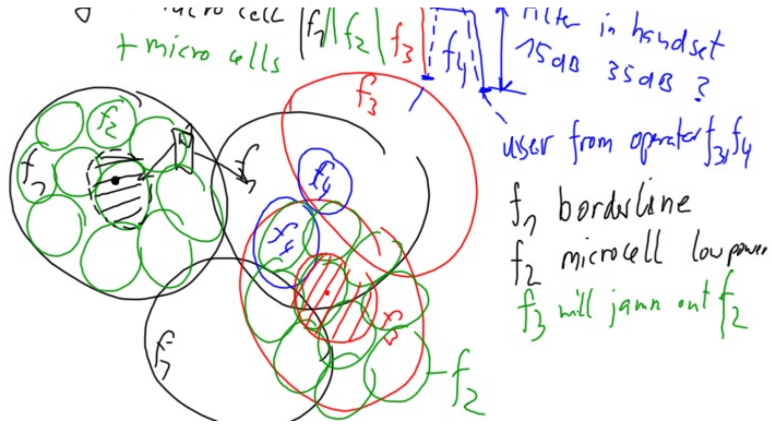


Figure: Factors influencing interference (6-operator environment)

The amount of interference will depend on

1. the filter characteristics of the handset (check separation)
2. the distance from the transmitter
3. the transmit power

Receiver sensitivity might play a role, but is considered as being constant in the selected frequency band.

see also: UMTS9902Planning.ppt

802.11b has only three non-overlapping channels, ch 1, 6, and 11. In a normal business building radio waves will propagate not only along one floor, but also through the roof/floor. The visibility of WLAN will make it necessary to plan the frequencies in order to support the person on the ground floor with wireless access.

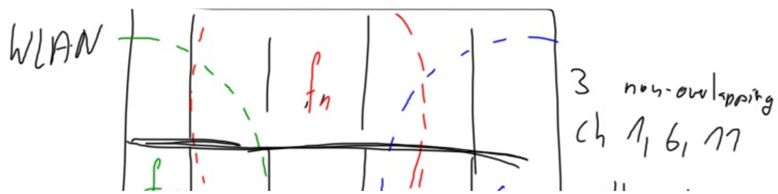
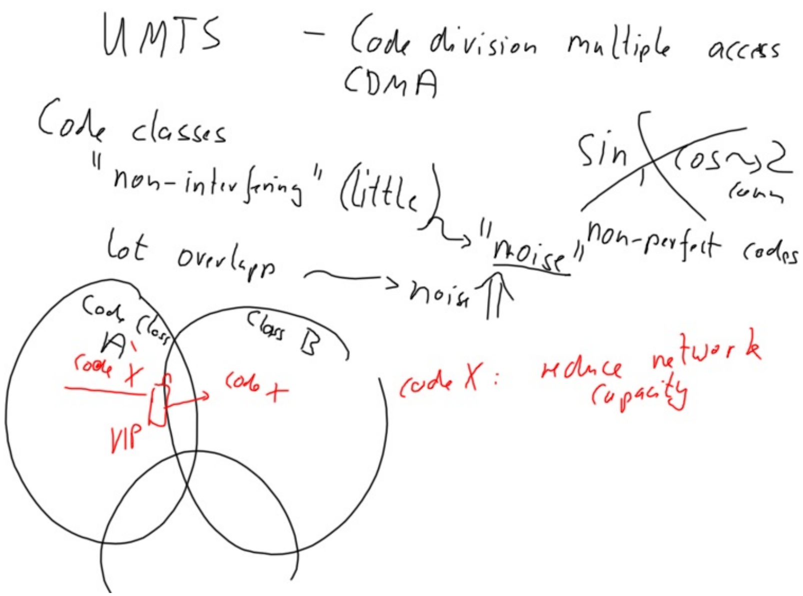


Figure: Interference of WLAN cells in a 3-floor building

In



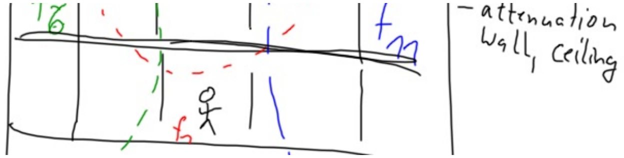


Figure: UMTS code usage for capacity and coverage

UMTS coverage and capacity can be adopted not only through the power level of the transmitting unit, but also through the selection of codes. If the same code or code-class is selected in neighbouring cells, a simulaneous connection to the mobile phone can be achieved. This will increase the coverage (why?) but decrease the total capacity of the system (why?)

space for comments

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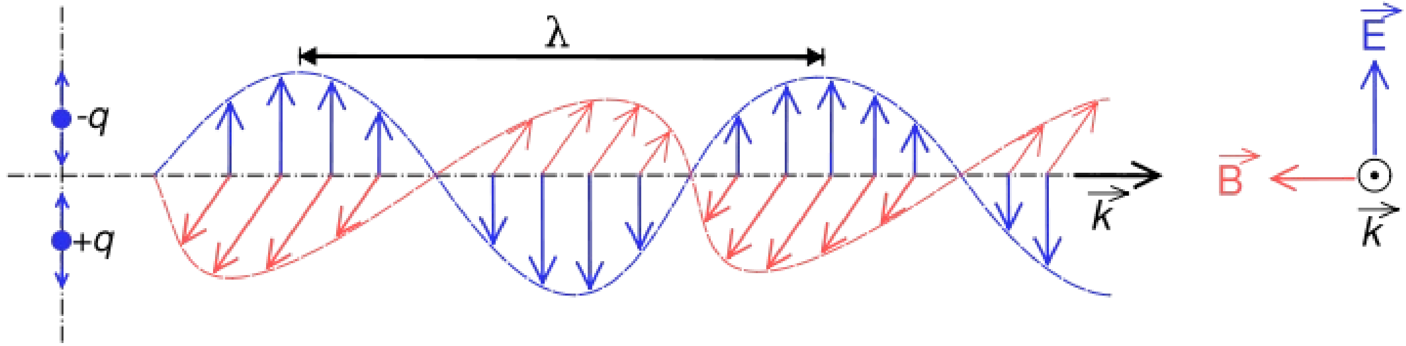
Electromagnetic signals

- Prerequisite: Ohm's law, current, dielectric constant ϵ_r, conductivity σ
  - "Pappa, what is voltage?"



- Alternating electric and magnetic field
- Direction of wave from "right-hand rule"

[Source: Wikipedia]

Maxwell's Equation in a source free environment

Source free environment and free space:

$$\nabla \cdot \vec{E} = 0 \qquad (1)$$

$$\nabla \times \vec{E} = -\frac{\partial}{\partial t} \vec{B} \qquad (2)$$

$$\nabla \cdot \vec{B} = 0 \qquad (3)$$

$$\nabla \times \vec{B} = \mu_0 \epsilon_0 \frac{\partial}{\partial t} \vec{E} \qquad (4)$$

where div is a scalar function

$$\mathrm{div}\, \vec{v} = \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} = \nabla \cdot \vec{v}$$

and curl is a vector function

$$\mathrm{curl}\ \vec{v} = \left(\frac{\partial v_z}{\partial y} - \frac{\partial v_y}{\partial z}\right) i + \left(\frac{\partial v_x}{\partial z} - \frac{\partial v_z}{\partial x}\right) j + \left(\frac{\partial v_y}{\partial x} - \frac{\partial v_x}{\partial y}\right) k = \nabla \times \vec{v}$$

[Source: Wikipedia]

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Wave equation

Taking the curl of Maxwell's equation

$$\nabla\times\nabla\times\vec{E} = -\frac{\partial}{\partial t}\nabla\times\vec{B} = -\mu_0\varepsilon_0\frac{\partial^2\vec{E}}{\partial t^2}$$

$$\nabla\times\nabla\times\vec{B} = \mu_0\varepsilon_0\frac{\partial}{\partial t}\nabla\times\vec{E} = -\mu_o\varepsilon_o\frac{\partial^2\vec{B}}{\partial t^2}$$

yields the wave equation:

$$\frac{\partial^2\vec{E}}{\partial t^2} - {c_0}^2\cdot\nabla^2\vec{E} = 0$$

$$\frac{\partial^2\vec{B}}{\partial t^2} - {c_0}^2\cdot\nabla^2\vec{B} = 0$$

with $c_0 = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = 2.99792458\times10^8$ m/s

[Source: Wikipedia]

Homogeneous electromagnetic wave

single frequency

$$\vec{E}(\vec{r}) = E_0 e^{j(\omega t - \vec{k}\cdot\vec{r})},$$

$$\vec{B}(\vec{r}) = B_0 e^{j(\omega t - \vec{k}\cdot\vec{r})},$$

where [Source: Wikipedia]

- $\vec{r} = (x, y, z)$ and $\vec{k} = (k_x, k_y, k_z)$ so?
- j is the imaginary unit
- $\omega = 2\pi f$ is the angular frequency, [rad/s]
- f is the frequency [1/s]
- $e^{j\omega t} = \cos(\omega t) + j\sin(\omega t)$ is Euler's formula

with $c = \frac{c_0}{n} = \frac{1}{\sqrt{\mu\varepsilon}}$ and $n = \sqrt{\frac{\mu\varepsilon}{\mu_0\varepsilon_0}}$

room for comments

Figure: Difference between a static and a dynamic field Attach:Static-Unik/DynamicField.png Δ

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Josef Noll, UniK? — **19 September 2008, 07:25**

develop the relations for a plain wave

Josef Noll, UniK? — **19 September 2008, 07:24**

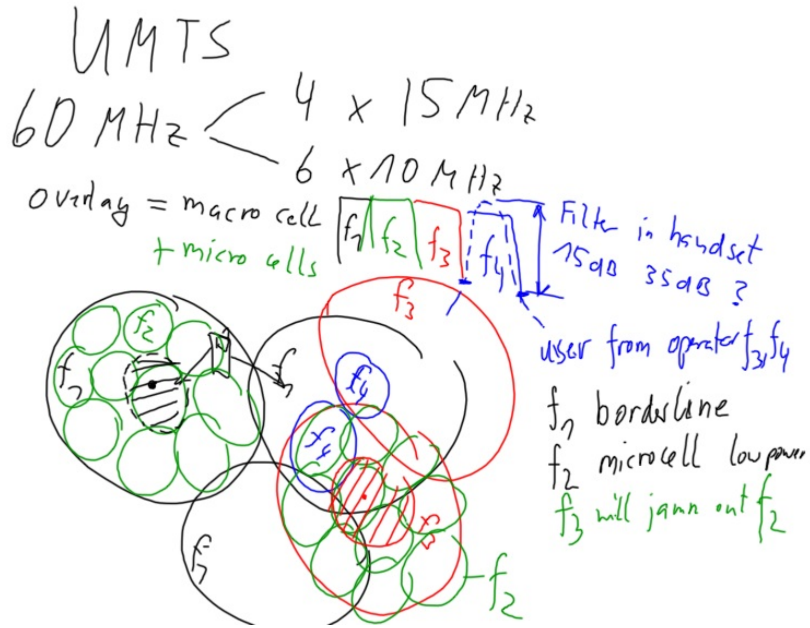
Assume a plane wave: E_x, H_y. Show that $\frac{E_x}{H_y} = Z_0 = \sqrt{\mu_0/\varepsilon_0}$

Boundary conditions

- What is happening on electrical walls, magnetic walls?

Figure: Reflection of an electromagnetic wave at the ground plane

Scattering, reflection and diffraction (explain differences) are the three major components in wave propagation. Ideal reflection environments are characterised through $|r| = 1, \ \phi_r = 180 \deg$



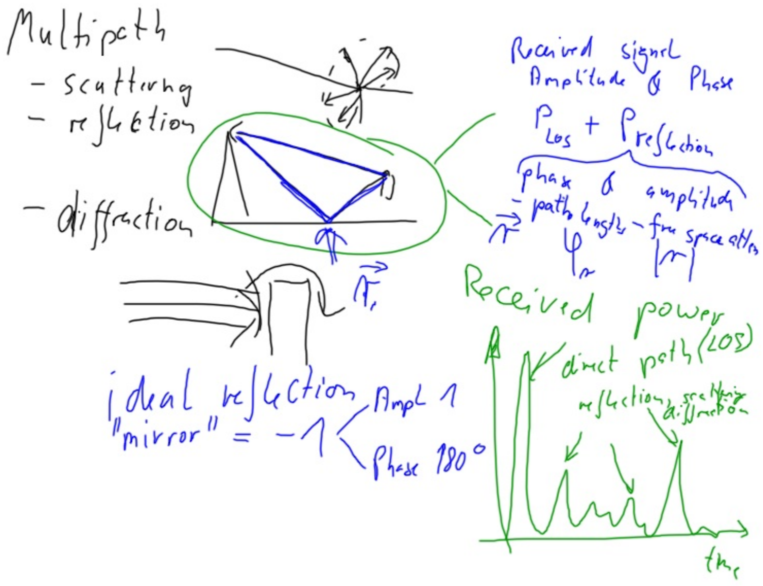


Figure: UMTS macro and microcells in a 6-operator environment

room for comments

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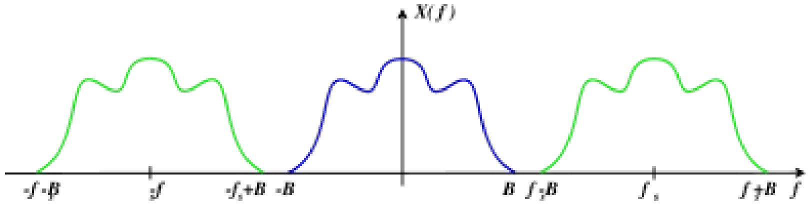
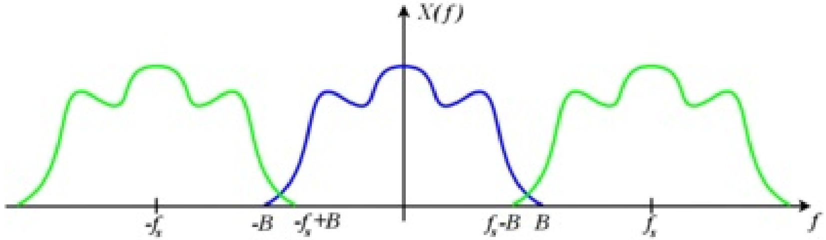
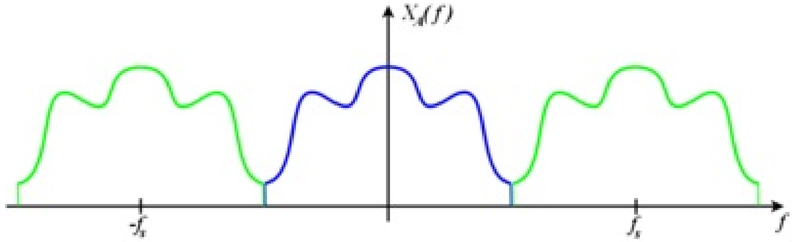
Nyquist Theorem

- Shannon: If a function $f(t)$ contains no frequencies higher than W [cycles/s], it is completely determinded by giving its ordinates at serires of points spaced $\frac{1}{2W}$ seconds apart







- band-limitation versus time-limitation
- Fourier transform

[source: Shannon, 1948]

Signal/noise ratio

$$\mathrm{SNR} = \frac{Psignal}{Pnoise}$$

$$\mathrm{SNR(dB)} = 10\log_{10}\left(\frac{Psignal}{Pnoise}\right),$$

where *P* is average power

- why talking about noise?
- dB, dB_m, dB_a
- near-far problem

[source: Wikipedia]

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Shannon Theorem

Shannons theorem will be part of next lexture...

Summary

- radio wave propagation *explain*
- Electromagnetic signals
- Nyquist Theorem
- Signal/noise ratio
- (Shannon Theorem -> next lecture)
- (Signal strength -> next lecture)

back to overview