Lecture 27. Sep 2012

- Propagation 2h (EIRP open dB)
- Assignments 2nw Christine, Hige

NFC, RFID Ali 28.9.

Thomas 5.10 Johan 5.10.

Bluetooth, ZigBee, wireless HART

Wifi Sushma 12.10.

Ns Ove 12.10.

handover Naji

WiMAX, GSM, LTE

- Block Seminar

Antennas → typical values

Speed in free space

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} \quad \left[\frac{m}{s}\right]$$

$$\mu_0 = 4\pi \, 10^{-7} \, \frac{V \cdot s}{A \cdot m}$$

$$\varepsilon_0 = 8.854 \, 10^{-12} \, \frac{F}{m} \qquad F \doteq \frac{Q}{V} = \frac{As}{V}$$

$$c = \sqrt{\frac{Am}{Vs} \, \frac{Vm}{As}} \qquad 1/\mu_0$$

$$c = \frac{1}{\sqrt{4\pi \cdot 8.854 \cdot 10^{-19}}} = 0.3 \cdot E9 \left[\frac{m}{s}\right]$$

$$12 \cdot 8.854 \; 10^{-18}$$

$$\sqrt{111} \approx 3.3$$

$$c = 3E8 \, \frac{m}{s}$$

$$3E10 \, \frac{cm}{s}$$

$$Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \qquad \left[\sqrt{\frac{VS}{AM} \cdot \frac{Vm}{AS}} = \frac{V}{A}\right]$$

PROPAGATION CONSTANT

unit = consistency

- Maxwell's equations
- γ - Propagation constant (m)

  $$\gamma = \alpha + j\beta$$

  ~~[m] = [Np/m] + [rad/m]~~ wrong

- α - Real part: attenuation constant (*Np/m*)
- β - Imaginary part: phase constant (*rad/m*)

look wave attenuation = $\alpha \cdot e^{j\beta}$

phase velocity

$$C = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

$\mu_0 = 4\pi\, 10^{-7}\ F/m$

$\varepsilon_0 =$

$$\vec{E} = E_0 \, e^{j\varphi} \quad \xrightarrow{\text{wave}} \quad \vec{E} = E_0 \, e^{j(\omega t - \vec{k}\vec{r})}$$

E_0 ↑ static E_0 ↑ ampl.

$\omega = 2\pi f \; \left[\frac{1}{s}\right]$

t = time $[s]$

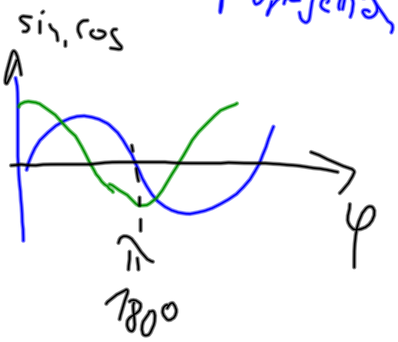
$\lambda = \frac{c}{f} \;\leftarrow\; \vec{k} = \frac{2\pi}{\lambda}\begin{pmatrix} k_x \\ k_y \\ k_z \end{pmatrix} \; \left[\frac{1}{m}\right]$

$\vec{r}$ = radiant vector

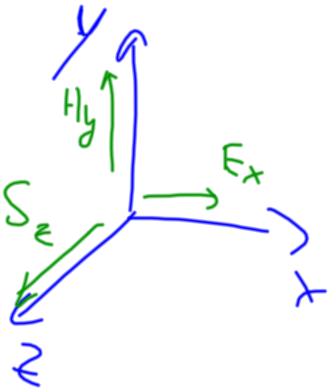
Wave propagation

$$e^{j\varphi} = \cos(\varphi) + j\sin(\varphi)$$

φ: [1]
- rad ... π
- deg $45°$



Coordinate system



$$\vec{k} \cdot \vec{r} =$$

$$\vec{r} = \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

$$\vec{E} : \vec{k}$$

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

$$\vec{E} = \vec{E}_0 e^{j(\omega t - \vec{k}\vec{r})}$$

$$\begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} \cdot \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

$$E_0 e^{j(k_x x + k_y y + k_z z)}$$

$$t = 0$$

Linear multiplication

$$\begin{pmatrix}h_x\\ h_y\\ h_z\end{pmatrix}\cdot\begin{pmatrix}x\\ y\\ z\end{pmatrix} = h_x x + h_y y + h_z z$$

Example $\vec{E} = E_0 \begin{pmatrix}1\\ 0\\ 0\end{pmatrix}$

$\vec{H} = H_0 \begin{pmatrix}0\\ 1\\ 0\end{pmatrix}$

Vector multiplication

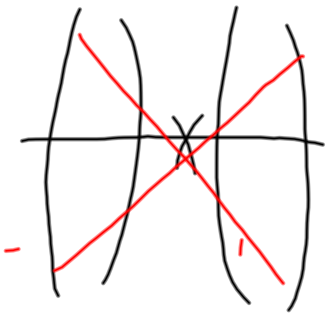
$$\vec{S} = \vec{E} \times \vec{H} = E_0 H_0 \cdot \begin{pmatrix}E_x\\ E_y\\ E_z\end{pmatrix} \times \begin{pmatrix}H_x\\ H_y\\ H_z\end{pmatrix} = \begin{pmatrix}E_y \cdot H_z - E_z H_y\\ -\,E_x \cdot H_z + E_z H_x\\ E_x \cdot H_y - E_z H_x\end{pmatrix} = \begin{pmatrix}0\\ 0\\ 1\end{pmatrix}$$

$$\vec{S} = E_0 \cdot H_0 \cdot e_z$$

Line 1

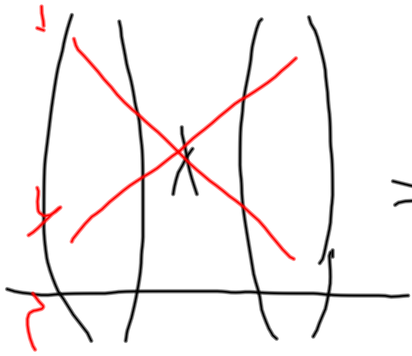
$= E_y \cdot H_z - E_z \cdot H_y$

Line 2



$= \left(-(E_x H_z - E_z H_x) \right)$

Line 3



$= \left(E_x H_y - E_y H_x \right)$

free space $\varepsilon_0 \; \mu_0$

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

$$Z = \sqrt{\frac{\mu_0}{\varepsilon_0}}$$

medium $\vec{\varepsilon} = \varepsilon_0 \vec{\varepsilon}_r$

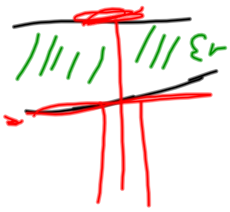
$\mu = \mu_0 \vec{\mu}_r$

$$v \simeq \frac{c}{\sqrt{\varepsilon_r}} \quad (\mu_r = 1)$$

slower

$$Z = \frac{Z_0}{\sqrt{\varepsilon_r}}$$

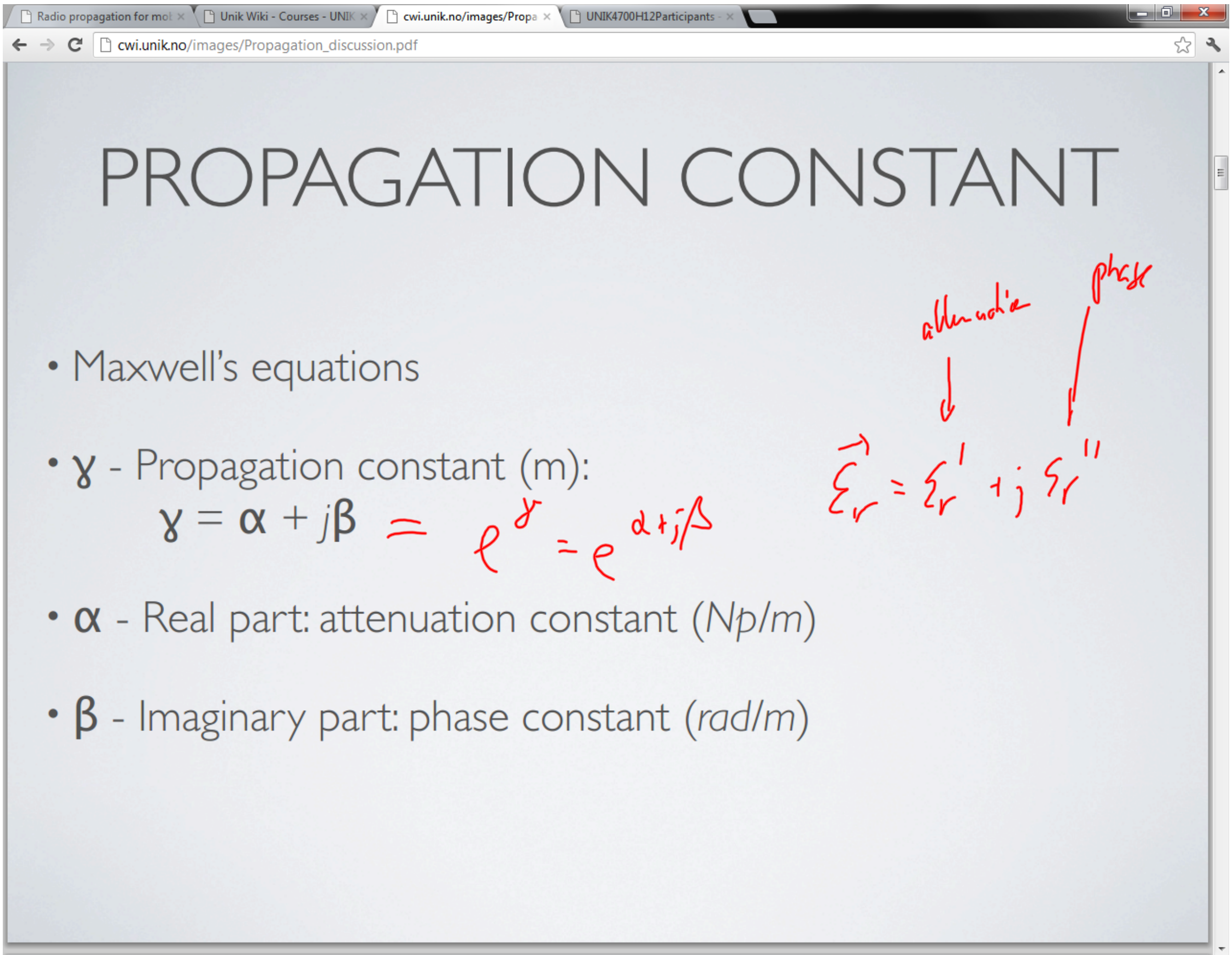
patch antenna



$$t_0 = 0 \rightsquigarrow e^{\overbrace{j(k_x x + k_y y + k_z z)}^{}} \quad \alpha + j\beta$$

attenuation $\vec{\varepsilon} = \varepsilon_r' + j\varepsilon_r''$

$j(\text{Real} + j\,\text{Im})$


Radio propagation for mob
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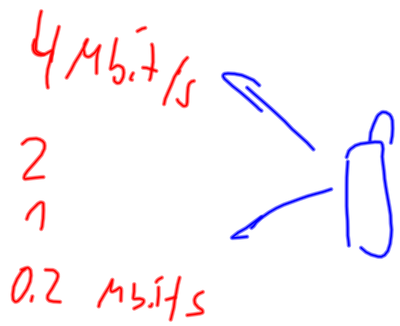
cwi.unik.no/images/Propagation_discussion.pdf
PROPAGATION CONSTANT
• Maxwell's equations
• γ - Propagation constant (m):
γ = α + jβ = e^γ = e^{α+jβ}
• α - Real part: attenuation constant (Np/m)
• β - Imaginary part: phase constant (rad/m)
attenuation
phase
ε_r = ε_r' + j ε_r''

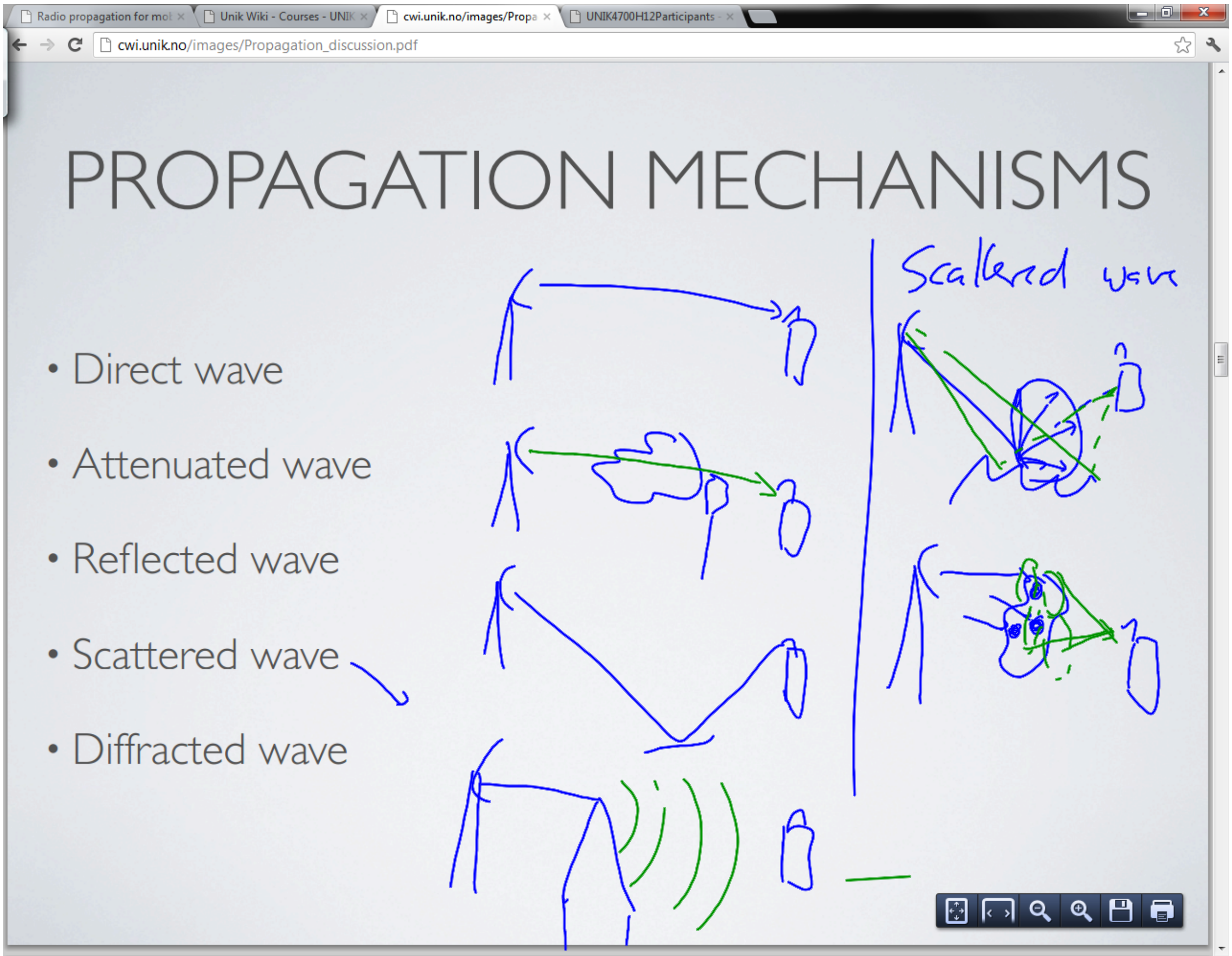
Video experience

output "reduced quality"

- sharing
- worst link ?

Microsoft Silverlight
parallel streams




Radio propagation for mol
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UNIK4700H12Participants
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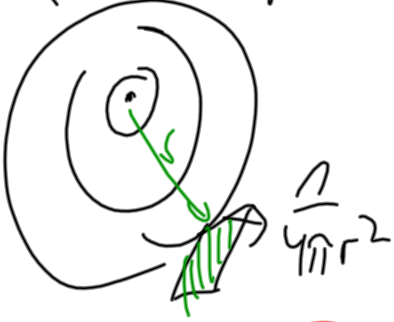
PROPAGATION MECHANISMS
• Direct wave
• Attenuated wave
• Reflected wave
• Scattered wave
• Diffracted wave

Propagation equation

EIRP emitted isotropic radiated power

$\left[\frac{W}{m^2}\right]$



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

P_t transmitted Power $[W] = [V \cdot A] = \left[\frac{V}{m} \cdot Am\right]$

WLAN box = 20 dBm

dB = dB_W

Logarithmic

dB_m

dB_A

Richter

Power $= \frac{E^2}{Z} = E \cdot H$

$P[dB] = 10 \cdot \log P[W]$

$P[dB_m] = 10 \cdot \log P[mW]$

Field (E, H)

$E_{dB} = 20 \log (E[\frac{V}{m}])$

$P_{dB} = P_{dB_m} + 30$

± 3 dB = double power / half power

10 dB = 10 times power

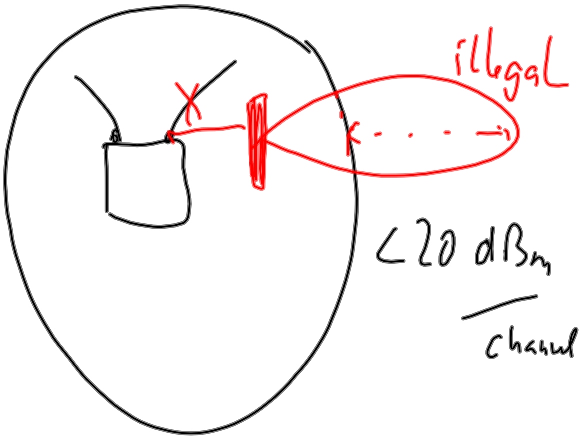
20 times power

+13 dB

$\log(a \cdot b) = \log a + \log b$

20   3 + 10

WLAN = 20 dBm (2.4 GHz) EIRP



Radiated energy

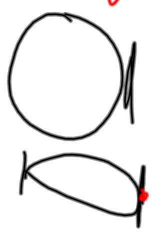
$P_t \cdot G_{ain} < 20\,dBm$

100 mW

↑

20 dBm + 0 dB

10 dBm + 10 dB



$$P_R = P_t \cdot G_T \cdot G_R \cdot L_{free}$$

$G_T \leftarrow \left(\frac{e}{x}\right)^2$

$L_{free} \leftarrow$ free space attenuation

$\hookrightarrow$ convert to dB

dB

dB_m

$f \begin{bmatrix} MHz \\ GHz \end{bmatrix}$

$R = \begin{bmatrix} km \\ m \end{bmatrix}$

$$L = \frac{\lambda^2}{4\pi R^2}$$

$R^2 \leftarrow$ sphere

next week