

Gain antenna? Numbers

Output: Receive Power
Receiver Sensitivity

SR = $\frac{P}{P_{sens}}$

TEAM 1: SYSTEM PARAMETERS
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SYSTEM PARAMETERS

Received signal power: $P_r = (P_t, G_r, G_t, L_p)$

Received Sensivity: $S_r = (E_s/N_0, kT_0, R_s, F, L_r)$

Signal to Noise: $SNR = (P_t, G_r, G_t, kT_0, BW, F, L_p, L_r)$

Energy per bit to noise: $E_s/N_0 = (SNR, BW, N_0, R_s)$

...

P_r : received power
 P_t : Transmitted power;
 G_r, G_t : Antenna Gains
 L_p : Path loss
 kT_0 : (1.38 · 10⁻²³ w/m² (290K))
 R_s : Symbol rate
 F : Noise figure
 BW : Bandwidth
 L_r : Implementation loss (2-3 dB)

noise level
fre

$T = 20^\circ C$
 $F = 1.5 \dots$

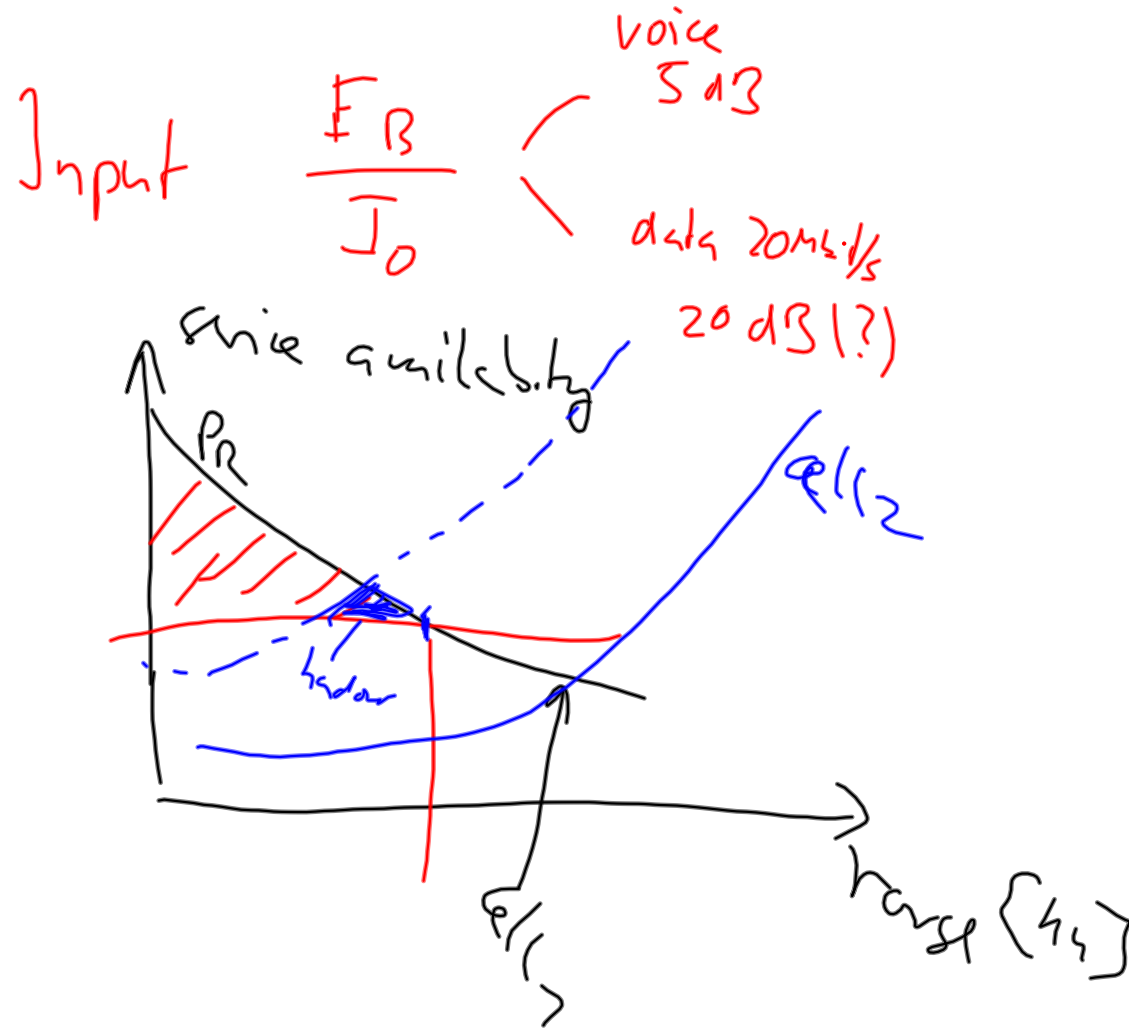
- Received Signal Power: $P_r = (P_t \cdot G_r \cdot G_t) / (L_p \cdot L_r)$
- Signal-to-Noise Ratio: $SNR = (P_t \cdot G_r \cdot G_t) / (kT_0 \cdot BW \cdot F \cdot L_p \cdot L_r)$
- Ratio of signal energy to noise power spectral density: $E_s/N_0 = SNR \cdot (BW/R_s) = (P_t \cdot G_r \cdot G_t) / (kT_0 \cdot R_s \cdot F \cdot L_p \cdot L_r)$
- Receiver Sensitivity: $SR = (E_s/N_0) \cdot kT_0 \cdot R_s \cdot F \cdot L_r$
- Radiation pattern: See "AntennaPattern.pdf"

path loss

noise

System
UMTS
GSM
200kHz
RIS

TEAM 2: FADING



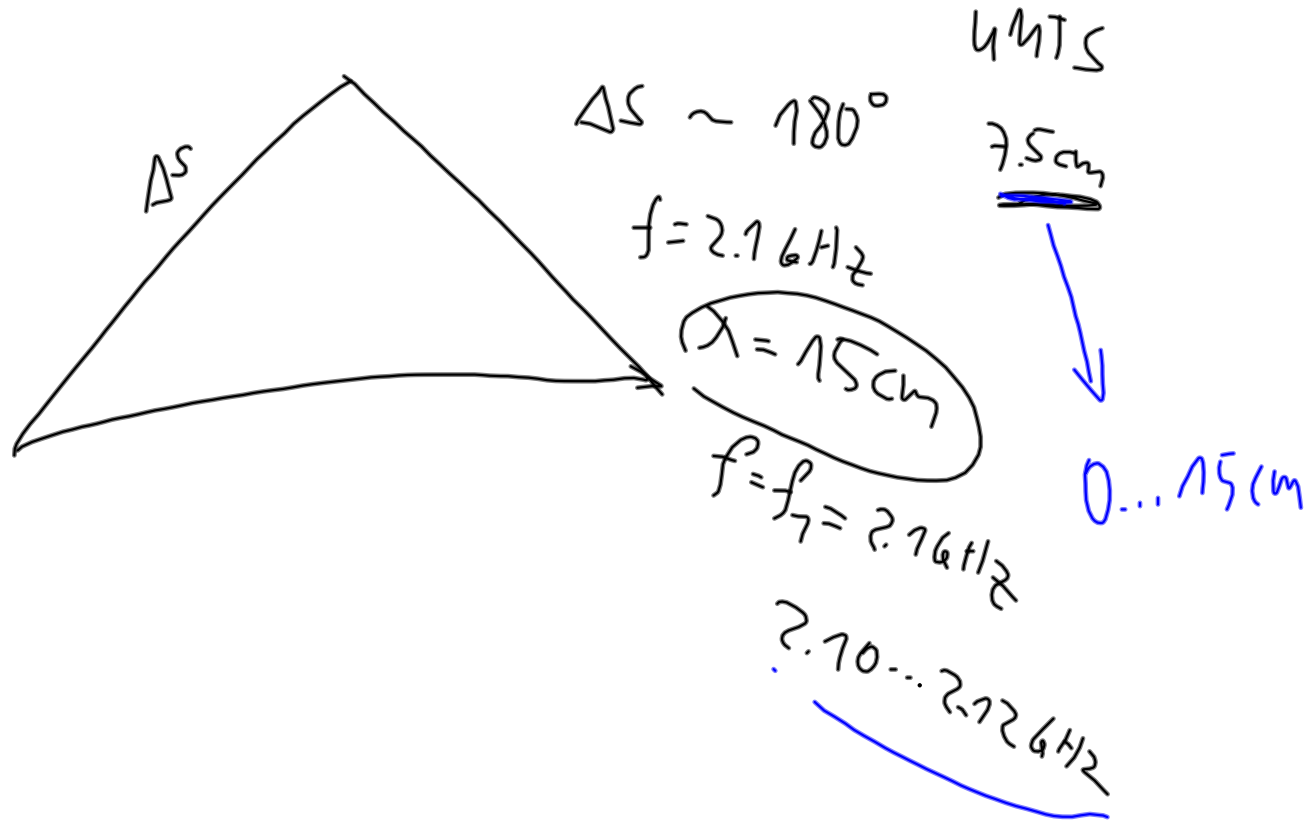
sections, all the quantities in the link budget are described in more detail. For more information please refer for instance to [1].

Table 1. Example of uplink link budget for 12.2 kbps speech.

Service:Speech 12.2 kbps, channel model veh A 120 km/h, suburban environment, in-car		
UE TX power	21 dBm	Class 4
Noise density	-174 dBm/Hz	
Chip rate	3840 kcps	
BS Noise figure	4 dB	Assumption
BS Noise power	-104 dBm	$-174+10\log(3840000)+4$
Noise Rise	3 dB	Load dependent
Bitrate	12.2 kbps	Speech
Eb/lo	5 dB	Assumption
SIR	-20 dB	$5-10\log(3840/12.2)$
BSsens	-121 dBm	$-104+3-20$
UE antenna gain	0 dBi	
Body loss	3 dB	
In-car loss	8 dB	
In-building loss	-	
BS antenna gain	18 dBi	

Widerrind 36PP

fast fading \leftrightarrow slow fading



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TEAM 2: FADING
Ali Zaher
Johan Tresvig

FADING

Slow fading effects: $L_b(d) = (L(d), \sigma(x,y))$
Fast fading effects: $L_b(d) = (L(d), \sigma(x,y), R(x,y))$
 $L(d) = L_0 + 10n \log d$
...

Input:

$L(d)$: Loss distance d
 $\sigma(x,y)$: Gaussian random variable
 $R(x,y)$: Rayleigh random variable

$w = \text{speed } (3, 50, 120 \text{ kph})$
 $t = \text{signal time } 10 \text{ ms}$
 $p = \text{probability of edge coverage } 95\% - 99\%$

Output:
FM: fade margin in dB

- See: <http://www.mathworks.se/help/comm/ug/fading-channels.html>

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TEAM 3: PATH LOSS & CELL SIZE
 Joachim Tingvold
 Thomas Aasebø
 Dag Ove Eggum

Input: f distance, antenna height
 Output: Path loss

Free space
 Okumura
 HATA Urban
 Suburban
 Open
 Lee
 Philadelphia
 New ARK
 Tokyo
 Keenan Motley
 → indoors WLAN

PATH LOSS & CELL SIZE

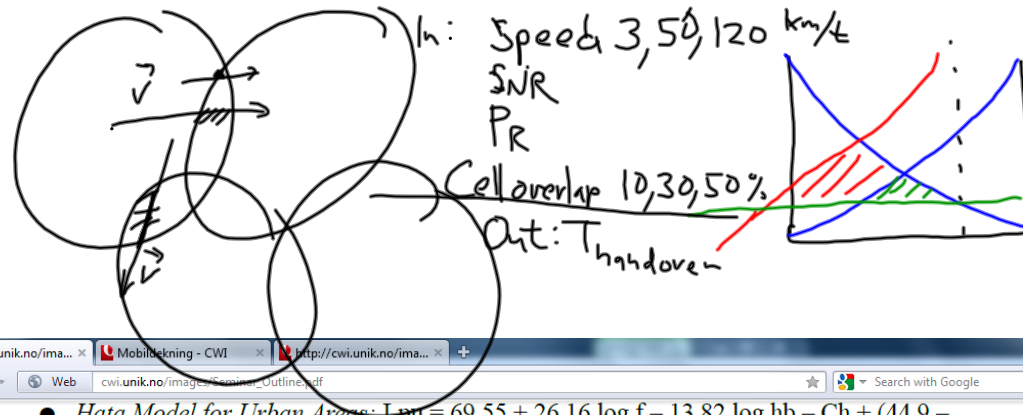
Path loss (Free s): $L_p = (4\pi d / \lambda)^2 = (4\pi d f / c)^2$
 Okumura-hata model: $L_p = (f, h_m, h_b, d)$

(Cell) Efficiency = (Nc, BW, Ac)
 ...

d: distance
 λ : wavelength
 Fc: Frequency
 C: light speed
 Nc: Number of channels per cell
 BW: Bandwidth
 Ac: Area of cell.
 hb: Height of base station Antenna
 hm: Height of mobile station Antenna
 f: Frequency of Transmission

- Free Space: $L_p = (4\pi d / \lambda)^2 = (4\pi d f / c)^2$
- Hata Model for Urban Areas: $L_{pu} = 69.55 + 26.16 \log f - 13.82 \log h_b - C_h + (44.9 - 6.55 \log h_b) \log d$
- Hata Model for Suburban Areas: $L_{psu} = L_{pu} - 2 (\log (f/28))^2 - 5.4$
- Hata Model for Open Areas: $L_{po} = L_{pu} - 4.78 (\log f)^2 + 18.33 \log f - 40.94$
- See: <http://www.mathworks.com/matlabcentral/fileexchange/2096-rf-wave-toolbox/content/RFWave/hata.m>
- Cell range versus cell edge throughput, See: cells.pdf

TEAM 4: PATH CHANGES & MOBILITY
 Christine Askeland Thuen
 Hege Flokktveit Kvalheim



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- *Hata Model for Urban Areas:* $L_{pu} = 69.55 + 26.16 \log f - 13.82 \log h_b - Ch + (44.9 - 6.55 \log h_b) \log d$
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TEAM 4: PATH CHANGES & MOBILITY
 Christine Askeland Thuen
 Hege Flokketveit Kvalheim

PATH CHANGES & MOBILITY

If a mobile constant velocity:
 $|\Delta d| = vt$
 $\Delta \phi_k(t) = -2\pi v / \lambda c \cdot \cos(\psi_k) t = -2\pi v / c \cdot f_c \cos(\psi_k) t$
 ...

$|\Delta d|$: distance between old and new position
 v : velocity of the mobile
 $\Delta \phi_k(t)$: phase

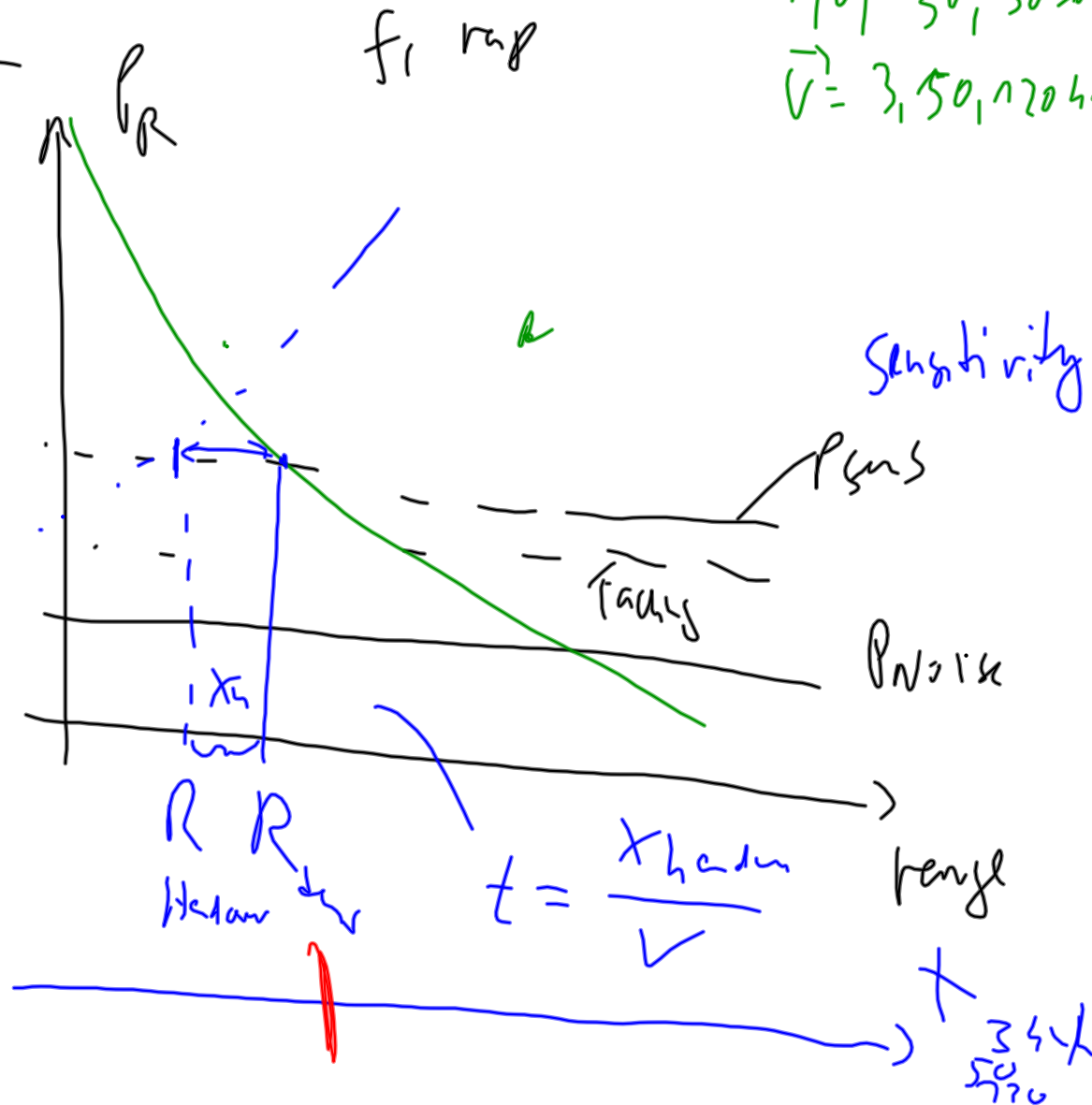
Diagram illustrating the geometry of path changes and mobility. It shows two positions: 'Old Position' and 'New Position'. A 'k-th ray' is shown originating from the 'Old Position' and passing through the 'New Position'. The distance between the two positions is labeled Δd . The angle between the ray and the horizontal axis is labeled ψ_k . The horizontal component of the displacement is labeled $|\Delta d| \cos(\psi_k)$ and the vertical component is labeled $|\Delta d| \sin(\psi_k)$.

- *Path-Changes Induced by Mobility,* See: Mobility.pdf (page 41-47)

	f [MHz]	BW [MHz]	PT download [dBm]	Spd time [km/h]	G_R, G_T 1.5...3 dB	P_{sens} = SR dBm <i>look for SR</i>
GSM	1800 (900)	0.2	25W	3,50,120 100ms	1, 14	-105 (-115) <i>check SR</i>
UMTS	2100	3.84	25W	10ms	1.5..3 14	-115
802.11 a	<u>5200</u>	40	100mW	350 10ms	omni, directional 2...9	-95
802.11 b	<u>2400</u>	20	100mW	95% probability 100ms	3, 2...9	-95 dBm

Output

70, 30, 50% anhang
 $\vec{V} = 3,50, 1,204 \dots$



Reflection at a perfectly plane gives a reflection coefficient $r = -1$. When the surface gets rougher, reflection is still in the main direction, but the reflected power is spread around the main reflection angle. Assuming that no absorption takes place, then the total reflected power is constant.

When the surface becomes extremely rough, and with roughness $\gg \lambda$, then the reflected wave will be scattered into any direction.

Measurements in rural farmland

- Typical IR from Farm_1, 1718 Unik/MHz. Total received power was -84 dBm, 20 dB above GSM sensitivity level

$V = \frac{S}{t} \Rightarrow S = v \cdot t$ (edit)

$\Delta t = 0.5 \mu s \Rightarrow 150 m$
 $0.8 \mu s \Rightarrow 240 m$
 $\Delta S = 358 \frac{m}{s} \cdot 0.5 \mu s$
 $= 358 \cdot 0.5 \cdot 10^{-6} m$
 $= 150 m$

[Source: R Rækken, G. Løvnes, Teletronikk]

These questions are valid for all of the following impulse responses

- from delay, calculate reflection factor and free space attenuation
- describe characteristics of reflection

(edit)

Measurements in rural farmland

- Typical IR from Farm_2, 953MHz. Total received power was -93dBm

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- Typical IR from Farm 2, 953MHz. Total received power was -93dBm

dB

0

-5

-10

-15

-20

-25

0 10 20 30 40 50 60 μ s

$\Delta t = 2 \mu s$

$\Delta s = 3E8 \cdot 2E-6 m$

$= 600 m$

$\Delta t = 5 \mu s$

$\Delta s = 1500 m$

[Source: R Rækken, G. Løvnes, Teletronikk]

(edit)

Measurements in cities

- Typical IR from City street measurements, 1950 Unik/MHz, Oslo. Output power 25 dBm (in mW?). Omnidirectional $\lambda/4$ -Dipoles used as transmit and receive antennas.

dB

0

-10

-20

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Measurements in cities

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dB

0

-10

-20

-30

-40

0 100 200 300 400 500 600 700 800 900 1000

b ns

nst

$\lambda_1 = 3E8 \cdot 70E-9 = 21\text{ m}$

$\lambda_2 = 45\text{ m}$

-13 dB

70-80 ns

70 ns

150 ns

[Source: R. Rækken, G. Løvnes, Teletronikk]

why almost equal distribution? What effect?

Relation between parameters in mobile communications

Hard Ware

- TX Power
- TX Gain
- EIRP
- RX Gain
- RX Sensitivity
- Noise Density
- Information Rate
- Fade Margin
- ...

Path Loss $L_p(d)$

Link Budget Template

Coverage Efficiency $\frac{\text{km}^2}{\text{Cell}}$

max. Cell Size

Spectral Efficiency Capacity per Cell $\frac{\text{Mbit/s}}{\text{MHz}}$

max. Traffic per Cell

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Hand-drawn diagram of an antenna radiation pattern. The main lobe is labeled with a gain of 20 dB. Two side lobes are labeled with gains of 12 dB and 10 dB. The main lobe is also labeled with a half-power beam width of 60°.

Hand-drawn diagram of a parabolic antenna. The gain is labeled as 30 dB. The diameter is labeled as $D = 57 \lambda$. The focal length is labeled as $f = \frac{D}{2} \approx 28.5 \lambda$. The gain formula is given as $G \sim \left(\frac{D}{\lambda}\right)^2$. The half-power beam width is labeled as $\theta \approx 54^\circ$.

Graph showing Gain (dB) on the y-axis (0 to 18) versus horizontal half-power beam width (degrees) on the x-axis (45° to 360°). The graph displays several curves representing different vertical half-power beam widths: 6.5°, 13°, 25°, and 78°. A vertical line is drawn at 60° horizontal beam width, intersecting the 13° vertical beam width curve at approximately 14 dB gain. The number 200 is written in green near the 13° curve.

Gain dB

horizontal half-power beam width

vertical half-power beam width

6.5°

13°

25°

78°

360°

200

14

18

16

12

10

8

6

4

2

0

45°

60°

90°

120°

180°

270°

360°

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