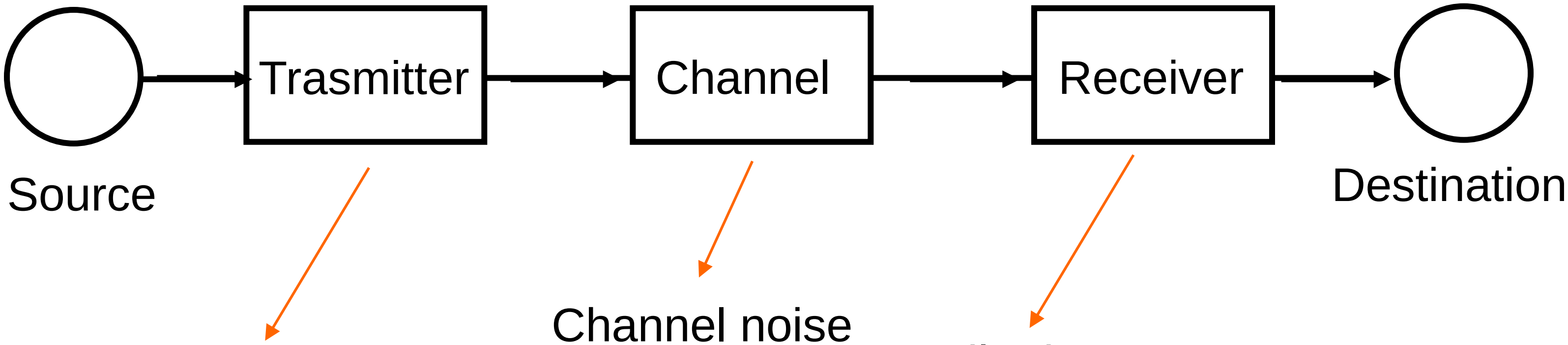
Fundamentals of Radio communications

1. Physical Layer



Channel Coding
Source Coding
Modulations

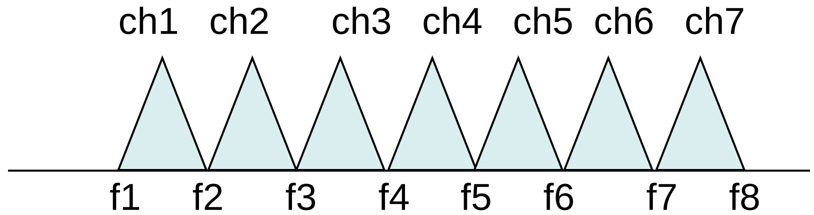
Channel noise
Interferences
Time varying
Nonlinearity

Filtering
Estimate channel characteristics
İn order to use compensation techniques
Demodulations
Decoding

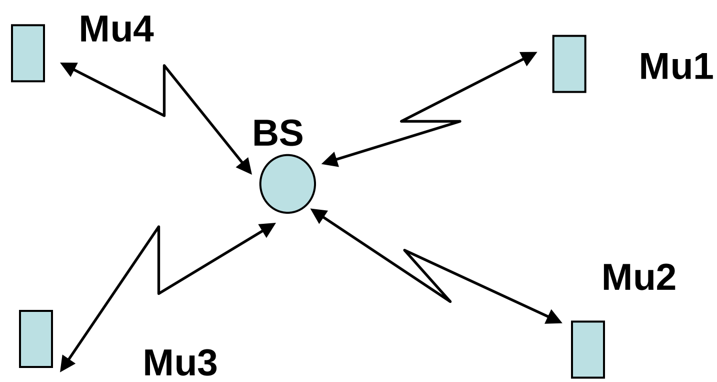
2. Data-Link Layer

General approach to sharing the physical resources among the different users.

1. FDMA



2. TDMA

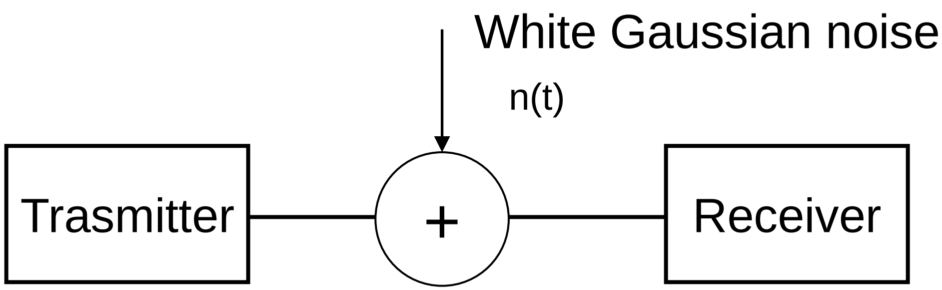


Point-to-multipoint

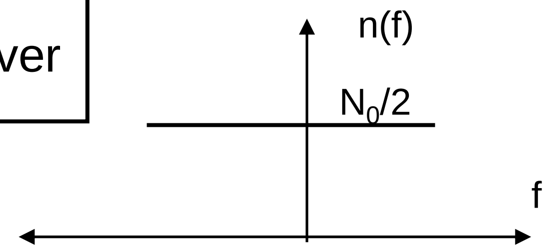
3. CDMA – using spread-spectrum strategy

3. SDMA –using focused or smart multibeam antenna instead of omnidirectional antenna

Channel Models



AWGN channel



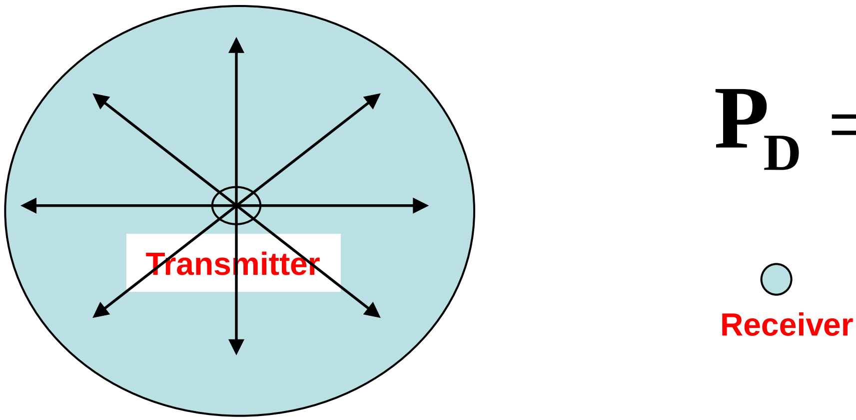
AWGN : zero mean, having Gaussian distribution and two sided power spectral density

1. Physical model-take into account the exact physics of propogation environment
   1. Free-space (line-of-site) propogation
   2. Reflection-bouncing of EW from surrounding objects(buidings, montains,..)
   3. Diffraction-bending of EW arround objects

2. Statistical model (emprical approach)-measuring propogation characteristic in a variety of environment and developping probobalistic model

Free-Space Propogation

Power Density at distance R of izotropic antenna (that transmites equally in all direction)



$$P_D = \frac{P_T G_T}{4\pi R^2}$$

Received Power:

$$P_R = A_{eff} P_D = \frac{A_{eff} P_T G_T}{4\pi R^2}$$

Receiving Antenna Effective Area:

$$A_{eff} = \frac{\lambda^2 G_R}{4\pi}$$

$$P_R = \frac{P_T G_T G_R}{(4\pi R/\lambda)^2} = \frac{P_T G_T G_R}{L}; L = (\frac{4\pi R}{\lambda})^2$$

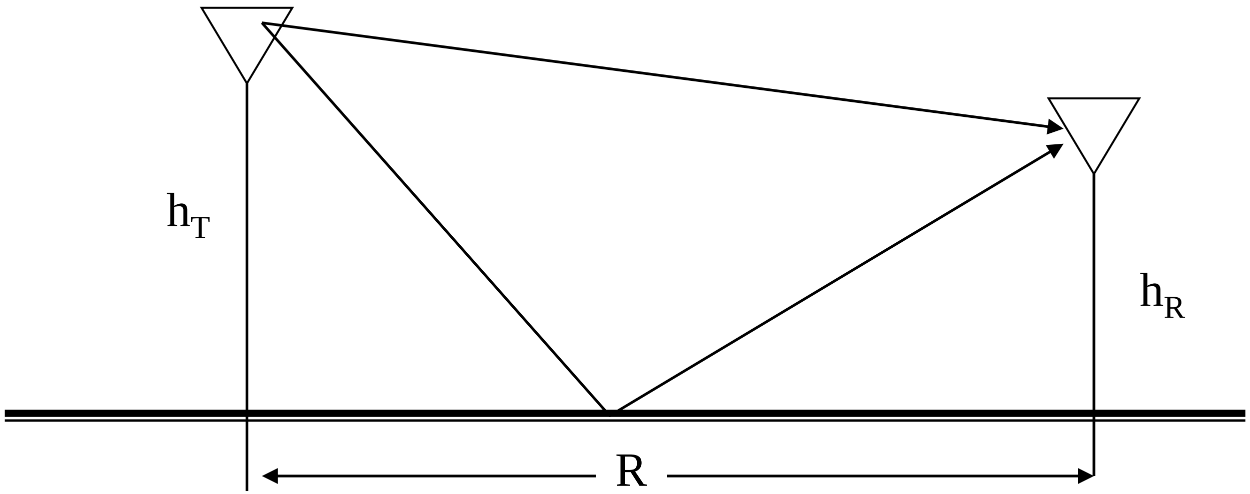
$$R = \frac{\lambda}{4\pi}\sqrt{L} = \frac{c}{4\pi}f\sqrt{L}$$

L - free-space path loss

Friis's Formula expresses the attenuation of free space

$$P_R(dB) = P_T(dB) + G_T(dB) + G_R(dB) - L(dB)$$

Plane Earth Propogation Model



$$P_R = 4P_T\left(\frac{\lambda}{4\pi\pi}\right)^2 G_T G_R Sin^2\left(\frac{2\pi h_T h_R}{\lambda R}\right)$$

If λR >>$h_T h_R$

$$P_R = P_T G_T G_R\left(\frac{h_T h_R}{R^2}\right)^2$$

$$P_R = \frac{P_T G_T G_R}{(4\pi R/\lambda)^2} = \frac{P_T G_T G_R}{(4\pi R)^2}\lambda^2$$

Antenna Gain

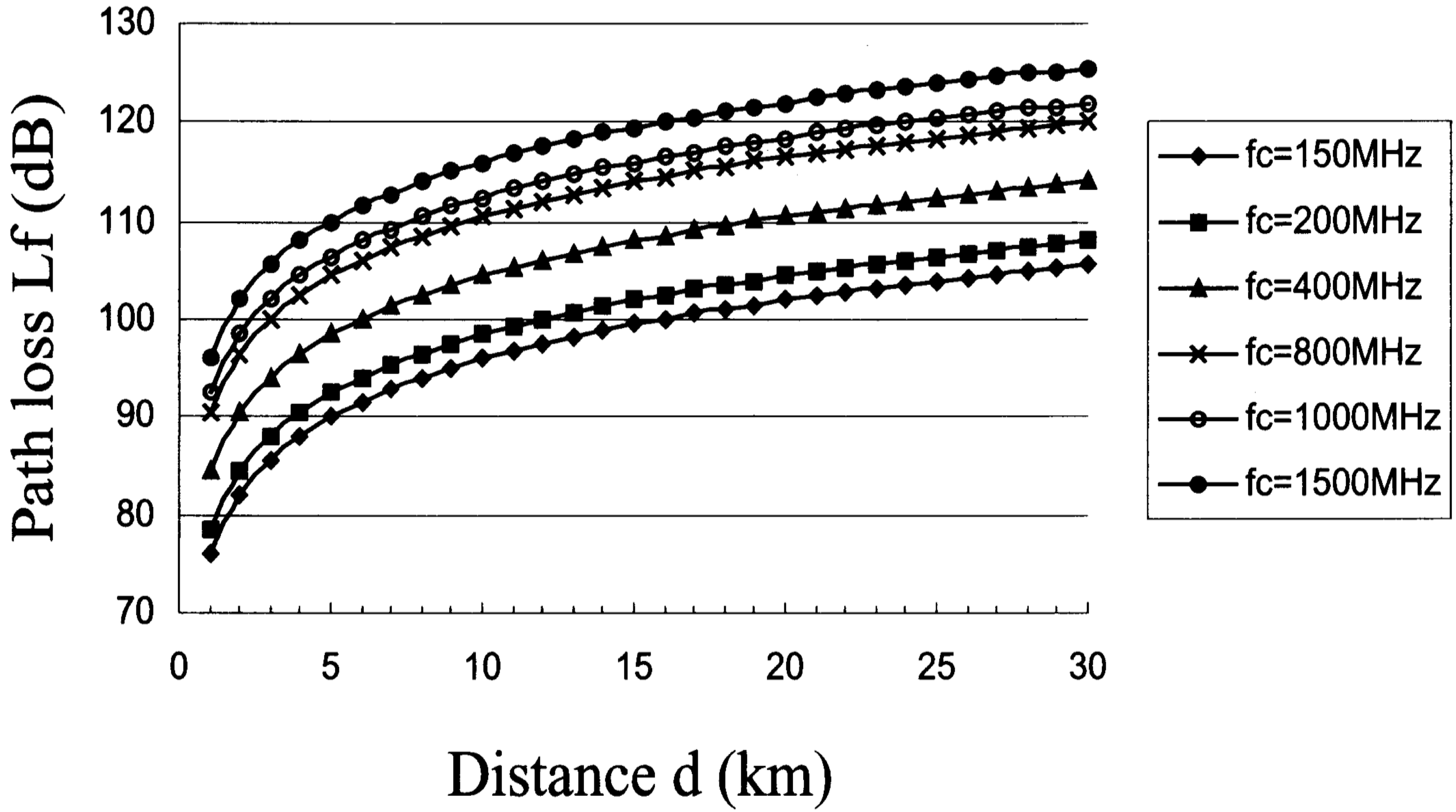
$$\mathbf{G = \frac{4\pi}{\lambda^2} A_e}$$

For Parabolic Antenna

$$\mathbf{A_e} = \eta \, \frac{\mathbf{\pi D^2}}{\mathbf{4}}$$

$$\mathbf{G = \frac{A_e}{A_i} = \frac{\eta \pi D^2/4}{\lambda^2/4\pi} = \eta\left(\frac{\pi D}{\lambda}\right)^2}$$

<u>Antenna efficiency</u> η =0.5-0.7


130
120
110
100
90
80
70
Path loss Lf (dB)
0
5
10
15
20
25
30
Distance d (km)
fc=150MHz
fc=200MHz
fc=400MHz
fc=800MHz
fc=1000MHz
fc=1500MHz

Terrestrial Propogation:Statistical Model

1. **Median Path Loss**
2. **Local Variations**

$$\frac{P_R}{P_T} = \frac{\beta}{r^n}$$

n-path-loss exponent , n=2-5;

$\beta = F(f, h_R, h_T)$

Right-side hand can be written

Environment	n
Free-space	2
Flat rural	3
Rolling rural	3.5
Suburban, low rice	4
Dence urban	4.5

$$\mathbf{L_p = \beta_0(dB) - 10\log_{10}(r/r_0)}$$

β_0(dB) – free-space path loss at reference distance r_0

Local Propogation Loss. Log-Normal Shadowing

Log normal distribution describe the random shadowing effect thjat is releted variation of median path loss with local characteristics

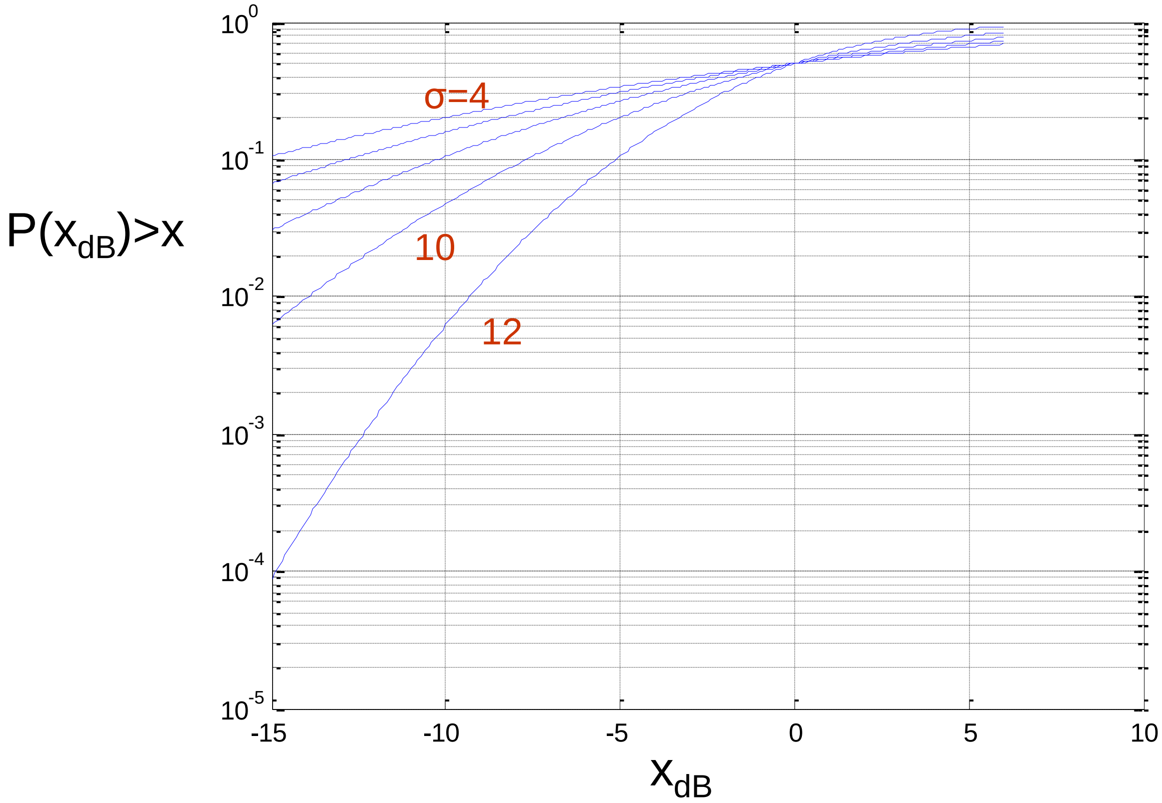
$$L_p = \beta_0(dB) - 10\log_{10}(r/r_0) + X\sigma$$

Xσ-zero mean gaussian random variable with stamdart deviation **σ**

$$f(x_{dB}) = \frac{1}{\sigma_{dB}\sqrt{2\pi}} e^{-(x_{dB}-\mu_{50}/2\sigma_{dB}{}^2}$$

σ_{dB}= 5-12 dB; μ_{50}-median value path loss; x_{dB}- random variable

$$P(x_{dB} > x) = \int_x^{\infty} f(x_{dB})dxd_B$$



P(x_dB)>x
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
σ=4
10
12
-15
-10
-5
0
5
10
x_dB

To find the probability that the recived signal level willexceed a particular level Q-function is used

$$Q(z) = \frac{1}{2\pi}\int_{z}^{\infty} e^{-\frac{x2}{2}} dx = \frac{1}{2}[1 - erf(\frac{z}{2})];$$

$$where \quad Q(z) = 1 - Q(-z)$$

The probability that the recived signal level will exceed a particular level γ can be calculated

$$P_R(P_R(R) > \gamma) = Q\left(\frac{\gamma - Lp}{\sigma}\right)$$

$$P_R(P_R(R) < \gamma) = Q\left(\frac{Lp - \gamma}{\sigma}\right)$$

The fraction of the coverage area in which the recived signal exeeds receiver sensitivity S_m can be calculated

$$\mathbf{Fu = \frac{1}{2}\left\{1 - erf(a) + e^{\frac{1-2ab}{b^2}}\left[1 - erf(\frac{1-ab}{b})\right]\right\}}$$

a=(S_m- P_{T} +β_0 + 10log10(r/r0))/$\sigma\sqrt{2}$

b=10nlog(r/r_0)/ $\sigma\sqrt{2}$

If m_0=S_m,at r=r_0 then a=0

$$\mathbf{Fu = \frac{1}{2}\left\{1 + e^{\frac{1}{b^2}}\left[1 - erf(\frac{1}{b})\right]\right\}}$$

Area versus Distance coverage model with shadowing model

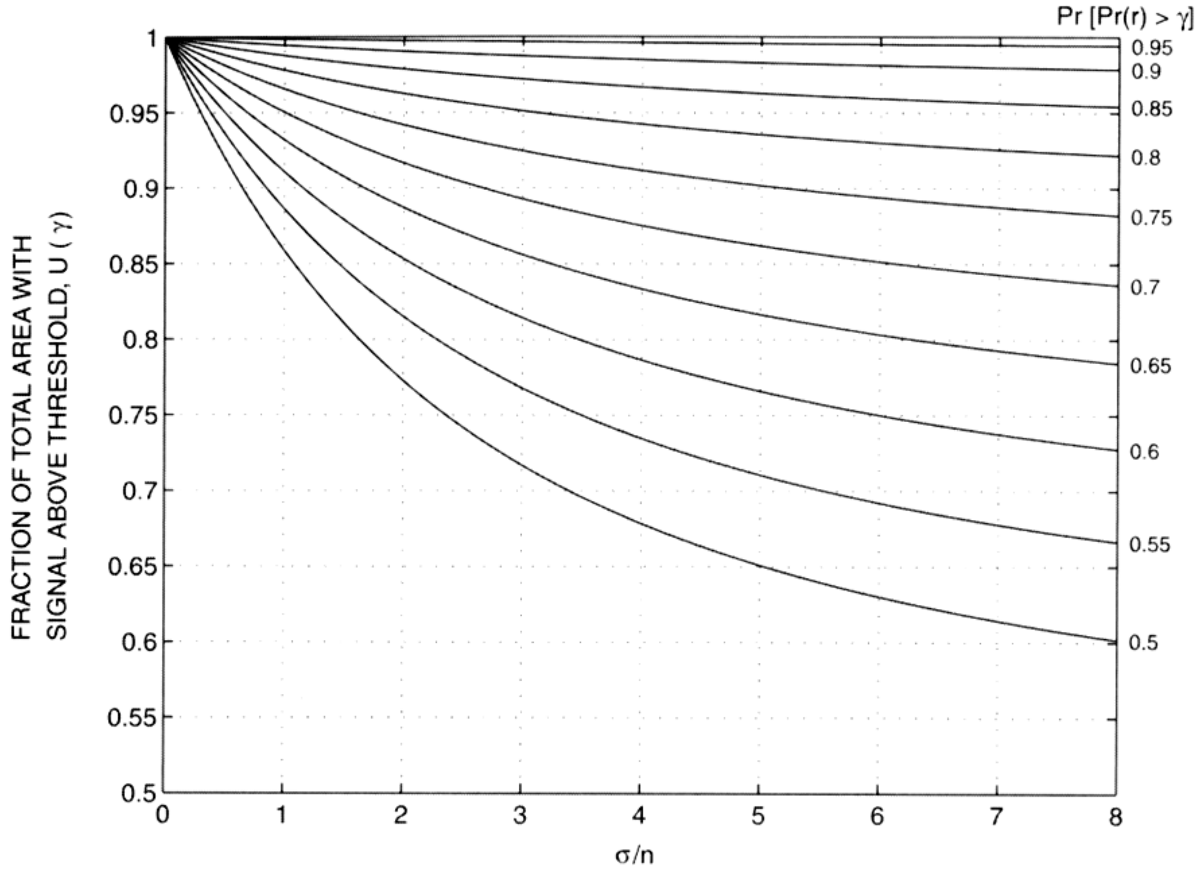


Figure 4.18 Family of curves relating fraction of total area with signal above threshold, $U(\gamma)$ as a function of probability of signal above threshold on the cell boundary.