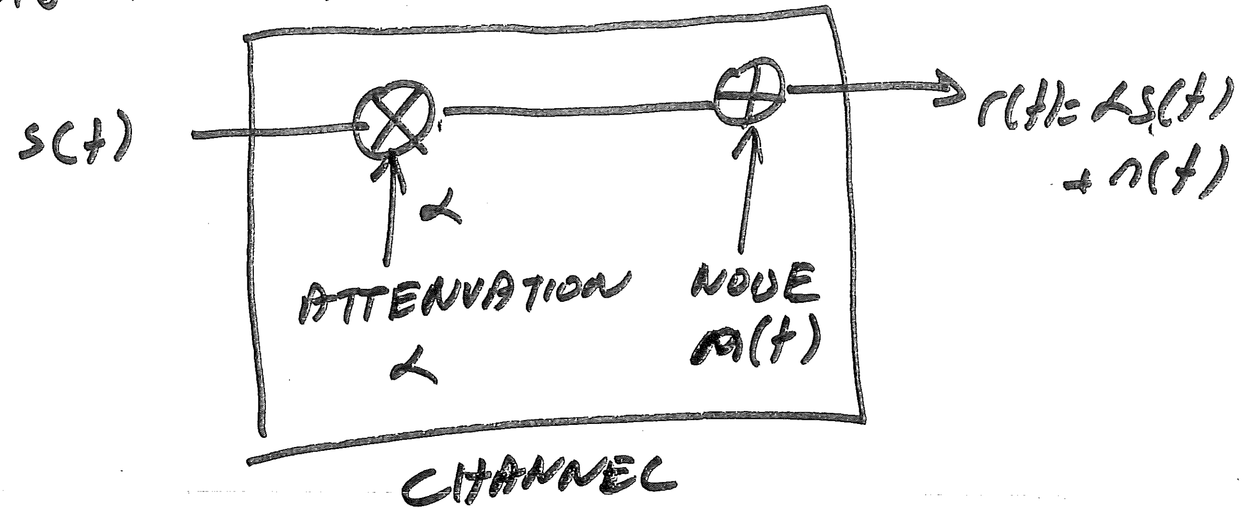
TRANSMISSION LOSSES

⇒ ADDITIVE NOISE → FILTERS → AMPLIFIERS

⇒ SIGNAL ATTENUATION



⇒ SIMPLE SOLUTION = USING AMPLIFIERS TO BOOST THE LEVEL OF THE SIGNAL

⇒ (ALSO AMPLIFIES NOISE)

$S_n(f) = \frac{N_0}{2}$ W/Hz

AMPLIFIERS ARE IDENTIED WITH NOISE FIGURE

NOISE FIGURE ⇒ RATIO OF THE OUTPUT NOISE POWER P_{no} TO THE OUTPUT NOISE POWER OF AN IDEAL (NOISELESS) AMPLIFIER ($T_0 = 290°K$)

↓ better

NOISE FIGURE ⇒ $F = \left(1 + \frac{T_e}{T_0}\right)$

T_e ⇒ EFFECTIVE NOISE TEMPERATURE

TRANSMISSION LOSSES

LOSS $\boxed{L = \frac{P_T}{P_r}}$ ⇒ Transmitted power / ⇒ Received power

or in dB

$$L_{dB} = 10\log L = 10\log P_T - 10\log P_R$$

WIRED

⇒ COAXIAL CABLE OF 1CM DIAMETER ⇒ LOSS 2dB/km at 1MHz

LOSS INCREASES WITH AN INCREASE IN FREQ.

LINE OF SIGHT COM.

$$L = \left(\frac{4\pi d}{\lambda}\right)^2 \qquad \lambda = \frac{c}{f} \text{ wavelength}$$

d = distance in meters

$c = 3.10^8$ m/sec, speed of light

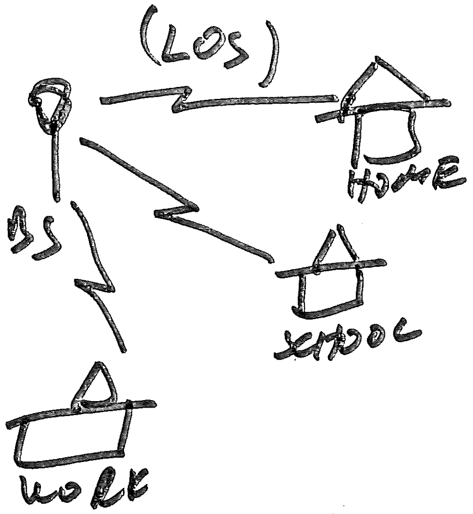
$$L = \left(\frac{4\pi d}{\lambda}\right)^2 \Rightarrow L \text{ is called FREE-SPACE PATH LOSS}$$

LINK BUDGET ANALYSIS

⇒ HOW FAR CAN IT GO?
⇒ WHAT WILL BE THE THROUGPUT?

⇒ INPUTS ⇒ 1) OUTPUT POWER
2) AVAILABLE BW
3) RECEIVER SENSITIVITY
4) ANTENNA GAINS
5) RADIO TECHNOLOGY
6) ENVIROMENTAL CONDITIONS

LINE OF SIGHT (LOS) LINK BUDGET



RECEIVED POWER (dBm)

= TX POWER (dBm) + GAINS (dBm)
− LOSSES (dBm)

WHAT IS THE RECEIVER SENSITIVITY
⇒ LOWEST POWER LEVEL AT WHICH THE RECEIVER CAN DETECT AN RF SIGNAL AND <u>DEMODULATE</u> DATA. THIS VALUE IS INDEPENDENT OF TX.

⇒ THE AMOUNT RECEIVED POWER EXCEEDS RECEIVER SENSITIVITY IS CALLED <u>LINK MARGIN</u>.

LINK MARGIN = RECEIVED POWER − RECEIVE SENSITIVITY

FREE SPACE PATH LOSS (FSPL)

$$FSPL = L(dB) = 10\log_{10}\left(\frac{4\pi d f}{c}\right)^2$$

$$FSPL(dB) = 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{c}\right)$$

$$= 20\log_{10}(d) + 20\log_{10}(f) - 147.55$$

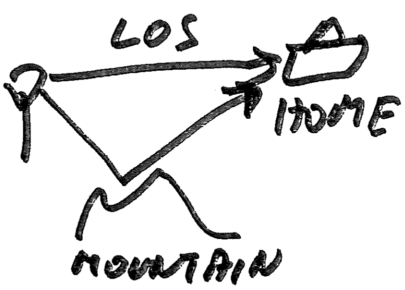
$f \Rightarrow Hz$ $\quad d \Rightarrow$ meters $\quad c = 3\times10^8\, m/s$

EXAMPLE

	FSPL(dB)		
DISTANCE	f 900MHz	f 2,4GHz	f 5,8GHz
1km	91.53	100.05	107.72
5km	105.55	114.03	121.70
10km	111.53	120.05	127.72
50km	125.51	134.03	141.70

MULTIPATH AND FADE MARGIN

⇒ WAVES TRAVELS DIFFERENT PATHS AND CAUSE UNWANTED INTERFERENCE.



⇒ FADING CAN CAUSE A SIGNAL REDUCTION OF MORE THAN 30 dB

⇒ IN REAL SYSTEM WE ADD FADE MARGIN IN LINK BUDGET. TO OVERCOME FADING

FOR RAYLEIGH FADING MODEL

TIME AVAILABILITY	FADE MARGIN
%90	8 dB
%99	18 dB
%99.9	28 dB

SIGNAL TO NOISE RATIO

⇒ MODULATION ALSO DETERMINE THE SYSTEM RELIABILITY.

⇒ TRADE OFF BETWEEN DATA RATES AND DISTANCE.

⇒ 64 QAM REQUIRES HIGH SNR
BPSK " LESS SNR

EXAMPLE ⇒ (GIVEN BW, GIVEN PER)

MODULATION & CODING	DATARATE	SNR dB
BPSK 1/2	6 mbps	8 dB
QPSK 1/2	12 mbps	11 dB
16 QAM 1/2	24 mbps	16 dB
64 QAM 3/4	54 mbps	25 dB

DESIGN EXAMPLE

6

DISTANCE = 5km
FREQ = 5.8GHz
LINK = Point to Point ⇒ (Free SPACE)
LOS ⇒ YES
TX POWER = +23dBm = 200mW
ANTENNA GAIN ⇒ TX = 10dBi
⇒ RX = 10dBi

54Mbps ⇒ -72dBm
RECEIVER SENSITIVITY
24Mbps ⇒ -82dBm

$10 \log_{10}(200\,mW) = 23\,dBm$

CALCULATE RECEIVE POWER?

FIRST Path LOSS ⇒ 5.8GHz and 5km ⇒ 121.70dB

RECEIVED POWER = TX POWER + ANTENNA GAINS - LOSSES

= 23 + 10 + 10 - 121.70dB

= -78.7

MAXIMUM CHANNEL NOISE FOR 54Mbps ⇒ SNR = 25

MAXIMUM CHANNEL NOISE = REC. POWER - SNR(dB)
= -78.7 - 25
= -103.7

OUR RECEIVED POWER -78.7 < -72dBm so 54 Mbps can not be supported.

⇒ 24 Mbps -82dBm < -78.7 so we can support 24 Mbps.