Department of Microtechnology and Nanoscience

Wireless and Photonic System Engineering SSY085

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Teachers in charge:
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Aids: Open book examination. Any printed material and calculator of choice is allowed. Communication devices (computers, mobile phones etc) are *not* allowed.

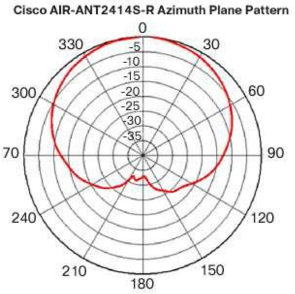
Examination checking: Contact Christian or Magnus as above.

Convince yourself that you have understood the problem before you get started. Constructive and valuable gambits will also give points. If information is lacking in the description of the task, you must yourself introduce technical plausible assumptions. Make sure you clearly state such assumptions.
Grades: 3: ≥24, 4: ≥36, 5: ≥48

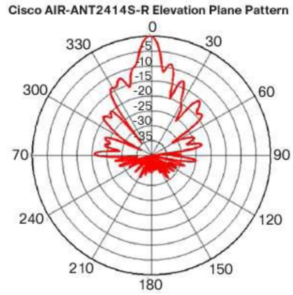
1.
Imagine that you are responsible for the design of a new nation-wide terrestrial Norwegian TV broadcasting system. Ten digital HDTV channels will be distributed across the country via a centralized geostationary satellite link and multiple terrestrial broadcast stations transmitting in the 600 MHz TV band. The communication satellite available operates at 12.5 GHz, provides EIRP >50 dBW across the country, and has a receiver G/T = 10 dB/K. How would you design the system? We want information concerning up-link and down-link, modulation format, block diagrams, antennas, output power, etc. You may assume that a compressed HDMI channel requires ca. 10 Mbit/s.

(30 points)

2.
The following graphs present the radiation pattern of a 14 dBi (main lobe gain) sectorized base station antenna for 2.14 GHz WCDMA applications.



(b) Cisco AIR-ANT2414S-R
Azimuth Plane Pattern

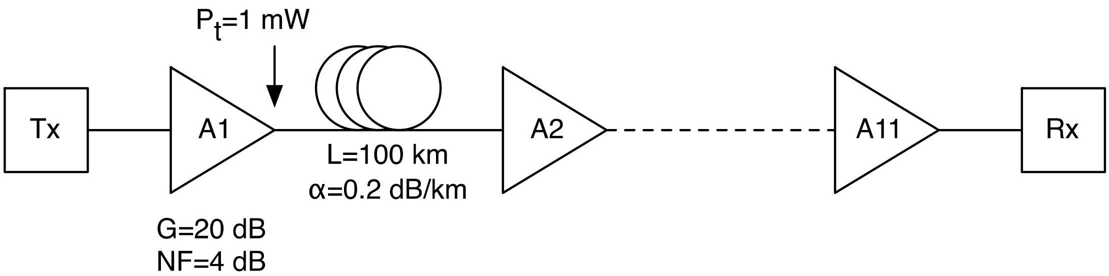


(c) Cisco AIR-ANT2414S-R
Elevation Plane Pattern

Assume that two identical base stations, each using these antennas, are placed perpendicular to each other in a shadowed urban environment. What is the minimum distance tolerated between the base stations if they should transmit in the same 5 MHz frequency band? Assume an output power of 10W and a receiver noise figure of 1.5 dB.

(10 points)

3.



An amplified fiber communication system consists of 10 fiber spans and 11 EDFAs, denoted A1...A11, each with gain 20 dB and noise figure 4 dB according to the figure. When a *pump outage* occurs, one of the pump lasers in an EDFA breaks, and that amplifier will then have a reduced gain to 10 dB and an increased noise figure to 14 dB, and the rest of the system is approximately unchanged. As a result the receiver OSNR will be reduced. Calculate the largest and smallest receiver OSNR reduction that such a pump outage can cause.

(10 points)

4.
A metro-ring-network has 5 nodes and utilizes a standard single-mode fiber pair at the wavelength 1310 nm (attenuation: 0.35 dB/km, dispersion: 1 ps/nm km) or 1550 nm (attenuation 0.18 dB/km, dispersion 17 ps/nm km); i.e. one fiber in each direction for backup/restoration purposes to sustain a cable break. Each node is addressed in a TDMA fashion, with a total data rate of 10 Gb/s transmission. The lasers are directly-modulated with OOK and has a bandwidth of 0.3 nm and an average output power of 1 mW. No optical amplifiers are used, but direct detection p-i-n diodes, with a quantum efficiency of 90 %. How long can the ring be, if you require 20 dB of SNR in the receiver, and no more than 25% of the bit slot for dispersive broadening? Which wavelength is best? Can it cover an area around Gothenburg, approximated as a circle with radius of 10 km?

(10 points)

Solutions

Problem 1:

Problem 2:

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F = 10^0.15; % 1.5 dB noise figure
B = 5e6;
TA = 290; % Ambient noise temperature in urban areas
R0 = 100; % Estimated distance to first obstacle
f = 2.14e9;
lambda = 3e8/f;
N = 4; % Shadowed urban propagation constant.
k = 1.38e-23;
Pt = 10;
Gt = 10^((14-12)/10); % Side lobe level in azimuth plane
Gr = 10^(14/10); % Receiver in main lobe direction

Te = (F-1)*290;
Pn = k*B*(Te + TA);

R = ((Pt * (Gr * Gt) * lambda^2) / (Pn * (4*pi*R0)^2 ))^(1/N)*R0;
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R = 11.5 km

Problem 3:

Normal system:

The received OSNR for the normal system is $OSNR_1=P_t/(11P_{ASE0})$, where P_{ASE0} is the optical noise power emitted by one amplifier (G=20 dB, NF=4 dB).

For a pump outage:

The broken amplifier will have the same noise output power P_{ASE0}, (since G*NF=24 dB is unchanged). However the signal power and the noise power of the amplifiers preceding the broken EDFA will be reduced by 10 dB.

Assume the outage occurs for amplifier k ($1 \le k \le 11$). The first k-1 amps will produce a noise power $(k-1)P_{ASE0}$, that will be attenuated 10 dB when it hits the receiver.

Amplifier k to 11 (there are 12-k of those) will produce a noise power P_{ASE0} and the total ASE power is then $P_{ASE0}[(k-1)/10+12-k]$.

Worst case: This expression is largest $11P_{ASE0}$ for k=1 (when the first amp breaks), when the noise power is the same and the signal power reduced 10 dB, i.e. the maximum OSNR reduction is 10 dB.

Best case: For k=11 (the last amp breaks) the total noise power is $2P_{ASE0}$, the OSNR is $P_t/(10*2P_{ASE0})$, and the reduction compared to $OSNR_1$=is 20/11=2.6 dB.

Problem 4:

Obviously this is a power- and time budget problem. First the rise time budget:
The dispersive broadening in ps is $T=DL\Delta$ where Δ is the bandwidth in nm. For T=25 ps and Δ=0.3 nm we find L_{max}=25/0.3=83 km for 1310 and 25/(0.3*17)=4.9 km for 1550.
Then the SNR:
The p-i-n responsivity is R=0.9 q/hv= 0.95 A/W at 1310 and 1.12 at 1550 (i.e. 1.55/1.31=0.73 dB higher at 1550). The thermal noise is $\sigma_t^2=4kT\Delta f/R_L=3.3e\text{-}12$ [A^2], (using T=300 $R_L=50\Omega$). For 20 dB of SNR we need an optical received power of 10 σ_t /R= 1.92e-5 [W]= -17.2 dBm for 1310, and -17.9 dBm for 1550. Thus a fiber length of 17.2/0.35=49 km is possible at 1310 and 17.9/0.18=99 km for 1550.
The 1310 link is almost enough to cover Gothenburg, but not quite, as such a circle would be 63 km. Thus the 1310 link would be closest (maximum 49 km, attenuation limited) and would benefit by either APD receivers or optical amplifiers. The 1550 link (maximum 4.9 km, dispersion limited) would instead benefit from dispersion compensation (with e.g. compensating fibers or Bragg gratings).