KTH Technology and Health

Written exam

January 15th 2015

Wireless networks

EP2950

Help material: pocket calculator and four handwritten A-4 pages.
Maximum points: 50p. The preliminary limit for passing the course is 24p.

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1. A communication link consists of two parabolic antennas. Determine the radius and effective area of the receiving parabolic antenna given that transmitted power is 20 dBm, the received power level is 10^{-8} W, the fading margin is 9 dB, the transmitting parabolic antenna diameter is 1.5 meter, the frequency is 5 GHz, the distance is 10 km. A parabolic antenna with face area A has the effective area 0.56A and the power gain $7A/\lambda^2$. (4p)
Ans: P_t=20dBm, P_r=-50dBm, fading margin=9dB, L_s=20log5000+20log10+32.44=126.42, $\lambda=3\cdot10^8/5\cdot10^9$=0.06 m, G_t=35.36 dBi gives $G_r=P_r-P_t$+fading_margin-G_t+L_s=-50-20+9-35.36+126.42=30.06 dBi, which is the gain of the receiving antenna 1014 times). $G_r=7A/\lambda^2$. The face area $A=G_r\cdot\lambda^2/7=0.52\ m^2$. The radius is 0.41 m. The effective area is $0.56\cdot0.52=0.29\ m^2$.

2. Is a carrier frequency of 1 MHz a good choice for portable devices such as mobile phones? Motivate your answer. (3p)
Ans: The wavelength is $\lambda=c/f$=300m. The antenna size would be large, e.g. a quarter-wave dipole will be 75m.

3. Free space is L_{dB}=20log(f)+20log(d)−147.56 where *f* is in hertz (Hz) and *d* is in meter (m). Derive and rewrite the equation for *f* expressed in GHz and *d* expressed in kilometer (km). (4p)
Ans: $L_{dB}=20\log(f_{Hz})+20\log(d_m)-147.56=20\log(f_{GHz})+20\log(d_{km})+20\log(10^9)+20\log(10^3)=$ $20\log(f_{GHz})+20\log(d_{km})+92.44$

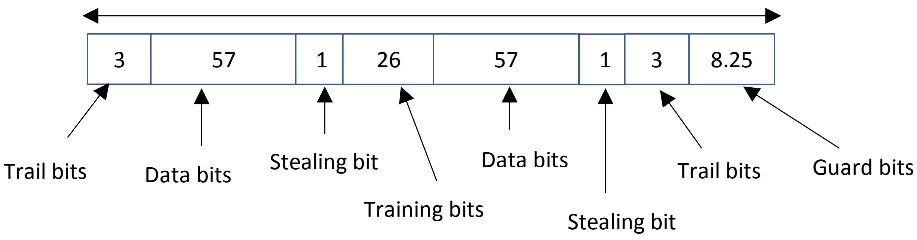
4. If the received signal power for a communication system is -151 dBW and the effective noise temperature at the receiver system is 1500 K, what is then the E_b/N_0 for a link transmitting 2400 bps? (3p)
Ans: E_b/N_0 = S/(kTR) gives –151 dBW–10log2400–10log1500+228.6 dBW=12 dBW

5. A mobile user travels along the border between two cells in a W-CDMA network. How can the mobile user and the base stations separate traffic from the two cells? (2p)
Ans: A scrambling code (a PN-sequence) is applied to obtain low cross correlation between cells. Orthogonal codes (Walsh codes) provide separation between users within a cell.

6. Assume that multipath fading causes delays between the direct beam and reflections in the order of a couple of chip intervals. Why is code division multiple access (CDMA) less sensitive to such fading effects compared to e.g. the GSM system? (2p)
Ans: The Walsh codes are not orthogonal if shifted one or several chips. CDMA filters out these delays.

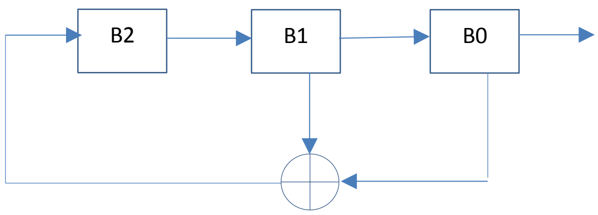
7. The figure below shows the frame format in GSM. (6p)
   a) Calculate the bit rate for the time slot and data bit rate.
   b) Explain the purpose of the training bits and the guard bits in the GSM
   c) What is the purpose of the trail bits and the stealing bits?

   The timeslot duration is 0.577 ms.



Ans: a) 148/0.577ms= 256.5 kbps and 114/0.577ms=197.6 kbps. See Stallings for b and c.

8. The linear feedback shift register below generate an m-sequence as output. The start value is 100. (6p)
   a) Calculate the m-sequence that is generated by the linear feedback shift register.
   b) Calculate the auto-correlation of the m-sequence.
   c) Would two m-sequences with two different start values using the same logic as in the figure below be orthogonal? Motivation is required.



Ans: a) The output is 0010111, which is then repeated. b) The autocorrelation is one (1). c) Two different m-sequences will never be orthogonal since the number of digits in the sequence is seven (an odd number).

9. a) Determine k in the Hamming code $(31,k)$ in order to correct one bit error? (2p)
   b) How many check bits are needed in a 15 bit codeword for single error correction and double error detection (SECDED)? (2p)
   Ans: a) $2^{(n-k)} - 1 \geq 31$, which gives n – k=5 and Hamming (31,26). b). Five (5) check bits are needed for SECDED, Hamming (15,10).

10. A computer transmits this data block: 1010101010.
   a) Construct a forward error correction code that is able to correct a single bit error. Show the transmitted codeword and how it is created. (2p)
   b) Assume that the received data bits ha a bit error (in red): 1010101011. Show how the receiver corrects the bit error. (2p)
   Ans: a) (p4, p3, p2, p1)=(1, 0, 1, 0). b) XOR between parity bits (1010) and bit positions that has ones gives (0011), which means that bit position 3 should be corrected.

11. A station in a wireless LAN transmits frames to another wireless station. The frames consist of 160 byte data (voice samples in IP telephony) and 34 byte overhead. The short IFS duration is 10 µs and the DCF IFS is 50 µs. An ACK packet is 14 byte. The transmission rate is 54 Mbps. The channel is idle when packets are sent. Calculate the user data throughput. (6p)
<u>Ans</u>: Transmission of a data frame: (160+34)·8/54M=28.74µs. Transmission of ACK packet: 14·8/54M=2.07 µs. Total time from sending until receiving the ACK: 50µs (DIFS) + 28.74µs + 2.07 µs (SIFS) = 90.81µs. Data throughput: 160·8/910.81µs=14.1Mbps.

12. In Bluetooth the logical transport link SCO (synchronous connection oriented) uses the previous ARQN (acknowledge number) and the previous SEQN (sequence number). Why? (3p)
<u>Ans</u>: The SCO logical link does not apply retransmissions.

13. Two different Bluetooth piconets exist in the same room. How can the masters and slaves separate packets belonging to the respective piconet? (3p)
<u>Ans</u>: The access code, based on the master's BD_ADDR, is unique for each piconet. This is a kind of code division multiplexing.