TSKS03, Wireless Systems

Solutions of exam problems 2015-06-03

1. a) From a simple model with isotropic antenna we find the evenly distributed power of the transmitter as $P_T * (A_e/(4\pi R^2))$, where A_e is the effective area of a receive antenna and R is the distance from the transmitter.
b) Putting $S = P_T A_e/(4\pi R^2))$ for $A_e = \lambda^2/4\pi$ and $\lambda = c/f$ we find $R = c/(4\pi f) * sqrt(P_T/S)$.

2. a) For narrowband systems the FDMA is well suited since a large number of channels can be accommodated within the available band. For wideband systems the TDMA or CDMA techniques are better to avoid the tradeoff between the system bandwidth and the number of channels. In practice, however, FDMA is combined with the other techniques in order to increase the system capacity.
b) The maximum number of users (channels) in FDMA is the ratio of the system bandwidth and channel bandwidth (channel spacing). In CDMA the spectrum spreading is used so the number of users operating at one frequency is limited by the mutual interference that occurs like noise. In TDMA the limitation comes from the required effective bit rate and an acceptable latency time (cycle). The larger the bandwidth the higher the actual bit rate can be that means less time per user and consequently, more users within one cycle.

3. a) When amplitude of a modulated carrier remains constant then the modulation is referred to as the *constant amplitude*. This is advantageous in terms of amplification on the transmitter side since nonlinear distortions are avoided even with a nonlinear amplifier. This is important since power-efficient amplifiers (like class C, E, F) are quite nonlinear. Other modulation schemes with large PAPR require linear amplification at the expense of increased power loss.
b) Pulse shaping like in GFSK prevents sharp edges in the baseband signal. Recall that a rectangular pulse (unshaped) of width T has a Fourier transform $2/\omega * \sin(\omega T/2)$ which makes its spectrum relatively wide. Shaping keeps the channel spectrum narrower and thereby saves the available band and limits spectrum leakage to adjacent channels.

4. a) Equalization is used to combat ISI (inter-symbol interference) evoked by multipath propagation esp. in time varying environment (channel) also referred to as the selective fading. Equalization can be achieved by discrete time filtering, like FIR filtering with adaptively tuned coefficients (LTF) or by other techniques, like decision feedback or maximum likelihood algorithm. In any case the distorted frequency characteristics of the channel undergo correction.
b) *See Ch.7.6 in the course book or the lecture notes.*

5. For a voice bandwidth limited to B = 3.4 kHz the required sampling frequency according to the Nyquist theorem can be f_s = 8 kHz. Using N-bit quantization (A/D conversion) we have bit rate $R = Nf_s$. For moderate voice quality N = 8 can be chosen resulting in R = 64 kb/s. Then the null-to-null bandwidth of the encoded voice is equal to R. The attained performance can be improved by non-uniform quantization (e.g. μ-law) or by using more advanced voice coding, like LPC or Vocoders.

6. a) Block coding, convolutional coding, turbo coding. b) *See Ch.7.14-7.18 in the course book or the lecture notes.*

7. a) Firstly, the OFDM as a multicarrier modulation system can provide huge data rates. Simple modulation schemes with low data rates per carrier are used. As a consequence, the OFDM proves robust in a multi-path environment according to long symbol duration on each carrier. This is also supported by a cyclic prefix guard inserted to each transmitted block. *For more details one can see the current project report on LTE available on the course page*.

b) One drawback of OFDM is a large PAPR which requires highly linear up-conversion mixers and amplifiers (in the transmitter). The latter creates a tradeoff between the spectral efficiency (large data rate) and power efficiency (more linear amplifiers have lower efficiency). Another challenge is created by intermodulation distortion (IMD). In particular the equally spaced OFDM carriers are prone to IMD evoked by 3^{rd} and 5^{th} order nonlinearities in the transmitter. Another issue is inter-carrier interference (ICI) created by oscillator phase noise both in a transmitter and receiver.

Observe that this answer is more than expected on the exam.

8. a) Scheduling is a key element of the LTE system. It aims at maximizing the system throughput by assigning channel resources to individual users. With OFDM it is done by splitting the number of carriers into smaller blocks (can be of different size) and using them in different time intervals (1 ms subframes) for different users that secures multiple access in the system. This can be considered a combination of FDMA and TDMA where individual data rates can be assigned for optimum performance. The scheduler uses current channel estimations to take the assignment decision for a user. In this way also the inter-cell interference (ICI) is reduced. A part of ICI strategy is power control in up-link where individual carrier frequencies are assigned making FDMA.

b) The reason is to save energy of the battery in a user terminal (mobile). This is achieved by avoiding large PAPR that prevents using OFDM in the up-link. Then, a more power efficient amplifier can be used in a mobile station and thereby the battery can be saved.

9. a) DAB is the digital audio broadcasting system based on MPEG4 coding and OFDM scheme. Unlike other communication systems it is one-way, that means, no up-link is necessary.

b) Multiplexing is used to combine several different audio signals in so the called *ensemble* to be processed in one transmission. The audio signals are interleaved, convolutional encoded, and organized in Common Interleaved Frames (CIF). The transmission frame is composed of Synchronization Channel, followed by Fast Information Channel (FIC), which contains information about the configuration in the Main Service Channel (MSC), closing the frame. The transmission cycle amounts for 24 ms.