S-72.2205 Digital Transmission Methods

Exercise session 5 13.12.2007

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1 CDMA

In many systems several users must share the same resources and multiple access (MA) schemes is needed to do so. For example, in GSM a combination of FDMA and TDMA is used. The third way of sharing resources is code division multple access (CDMA). In CDMA the users transmit simultaneously at same frequency but the users are separated by spreading codes. The spreading code spreads the information bandwidth R_b to occupy a much larger transmission bandwidth R_c. It is the interference attenuation property of spread spectrum that allows multiple users to occupy the same bandwidth at the same time.

1. Define chip rate, bit rate and processing gain.
2. What is actually this interference attenuation property? Where this results from?

1.1 Some system level issues on CDMA

In downlink direction, all channels that are emitted by the same base station can be synchronized and thus it is possible to select codes that result in zero or minimal multiple access interference. In uplink the the users can nor be synchronized and consequently there is multiple access interference. The interefence change as the number of active users N change. This results in ceel breathing. In a CDMA-system the interference margin is $IM = 10\log_{10}\frac{1}{1-\eta}$ that depends on the up-link fractional load η. The up-link fractional load can be calculated as follows

$$\eta = (1+f)\sum_{i=1}^{N}\frac{\rho_i\gamma_i}{G_i}$$

where f is other-cell to own cell interference factor, ρ is the activity of a user, γ is the SNR of the user and G is the spreading factor.

1. How many speech user ($\rho_i = 0.4, 10\log_{10}\gamma = 8dB, G_i = 265$) can be served when the other cell to own cell interference ratio is $f = 0.75$, and the fractional load *target* is 0.7?

2. A new data user ($\rho_{N+1} = 1, 10\log_{10}\gamma_{N+1} = 8dB, G_i = 32$) is admitted in the own cell. How many dB must the interference margin be increased from the value of the previous task to maintain all the connections?

3. In WCDMA the chip rate is 3.84 Mchip/s. How many users in a cell can theoretically be simultaneously served in the up-link direction of a *single cell* system, when the user bit rate after channel coding is 15 kbit/s and the Eb/Io requirement for proper reception is 5 dB. The user activity factor is 0.4 and noise is not considered.

4. Repeat the calculation for a multicell system, when the other to own cell interference ratio is 0.6.

5. How many users received with 10 times higher power can exist in a cell before the total number of users is halved? Do the estimation both for a single-cell network and a multi-cell network.

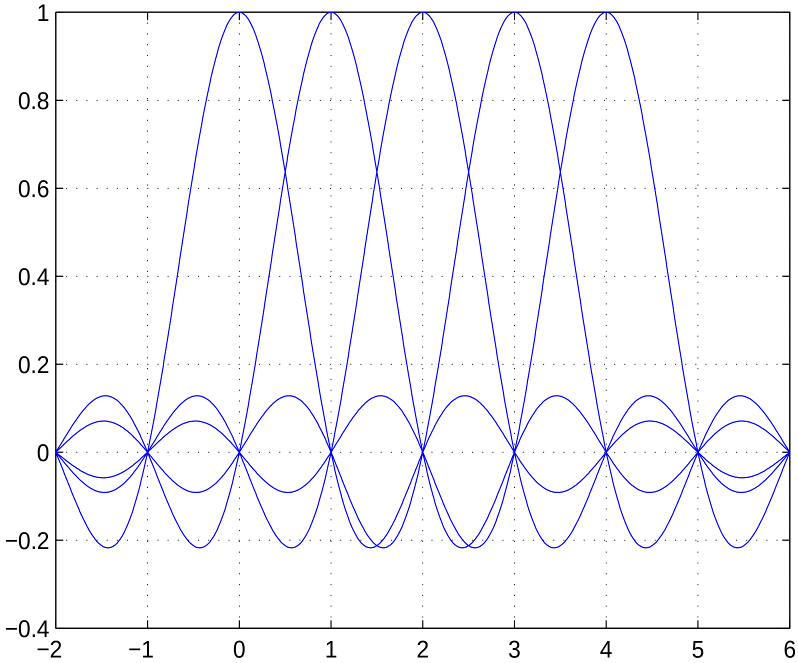

Figure 1: Orthogonal subcarriers

2 OFDM

Orthogonal frequency division multiplexing is a special case of multicarrier transmission method. Multicarrier transmission means that the assigned frequency band is divided into subchannels with subcarriers and each subcarrier is modulated by lower rate data streams. Modulation methods used are QAM and PSK. These lower rate data streams are then simultaneously transmitted over a number of subcarriers resulting in a high speed data transmission. At the transmitter the complex, frequency domain (QAM/PSK) symbols are denoted as $A_k, k = 0, ..., N-1$, where N is the number of carriers. To get the time domain samples of the signal an IFFT is made

$$s_n^m = \frac{1}{N}\sum_{k=0}^{N-1} A_k e^{jnk2\pi/N}$$

The carrier orthogonality is achieved by spacing subcarriers in frequency domain at integer multiples of symbol frequency of a single subcarrier. Fig. 1 demonstrates orthogonal carriers in frequency domain. It can be seen from the figure that the carriers have zeros at integer multiples of symbol frequencies which means that the other carriers are zero when one carrier takes on its maximum value.

1. Show how adding cyclic prefix transforms the linear convolution with the channel into a cyclic one.
2. By using FFT *matrices* show how CP-OFDM transforms the frequency selective multipath channel into N flat fading narrowband channels.
3. Assume 4 subcarriers and a three tap channel. What is the SNR on each subcarrier after FFT? The channel has snap shot values $h(0) = -0.6033 - 0.0177i, h(1) = -0.2757 - 0.0323i$ and $h(2) = -0.0051 - 0.0044i$ and transmit SNR is 15dB.
4. Name and discuss two disadvantages of OFDM signal.

Any comments concerning the material of the excercises 3, 4 or 5 should be sent to helka.maattanen@tkk.fi.