S-72.227 Digital Communication Systems (Spring 2005)

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Naser Tarhuni <ntarhuni@cc.hut.fi>

OFDM in a wideband fading channel

1.

    a. How does OFDM solve the multipath problem?
    b. How are signals transmitted in parallel without interference in OFDM?
    c. What are main problems of OFDM?

2.

The number of subcarriers N, the bandwidth of each subcarrier $1/NT$, the bandwidth of the system $B \approx 1/T$, and the length of the cyclic prefix Δ are all important parameters in the design of an OFDM system. We have the following restriction on the number of subcarriers

$$\tau B << N << \frac{B}{f_d} \qquad (1)$$

where f_d is the maximum Doppler frequency.

UMTS has been assigned frequencies in the 2.2 GHz band. Operators expect to be assigned 5 MHz for uplink and 5 MHz for downlink transmission and therefore in the following we assume a sample frequency of 5 MHz. A proper design of a radio interface based on OFDM depends on the characteristics of the radio environment in these bands. For the evaluation of the UMTS, consider the worst values for the Doppler frequencies and channel delay spreads for the vehicular channel model with a mobile speed of 120 km/h and if we want our system to accommodate echoes up to about 10 μ sec. Evaluate the range of possible number of subcarriers and the cyclic prefix.

Multi-user CDMA

3.

Consider a two-user, synchronous CDMA transmission, where the received signal is

$$r(t) = \sqrt{\varepsilon_1}b_1 g_1(t) + \sqrt{\varepsilon_2}b_2 g_2(t) + n(t), \qquad 0 \le t \le T$$

and $(b_1, b_2) = (\pm 1, \pm 1)$. The noise process $n(t)$ is zero-mean Gaussian and white, with spectral density $N_0/2$. The demodulator for $r(t)$ is shown in Fig. 1.

    a. Show that the correlator outputs r_1 and r_2 at $t = T$ may be expressed as,

$$r_1 = \sqrt{\varepsilon_1}b_1 + \sqrt{\varepsilon_2}b_2\rho + n_1$$

$$r_2 = \sqrt{\varepsilon_1} b_1 \rho + \sqrt{\varepsilon_1} b_2 + n_2$$

b. Determine the variances n_1 and n_2 and the covariance of n_1 and n_2.

$g_1(t)$

Received signal

r_1

Output

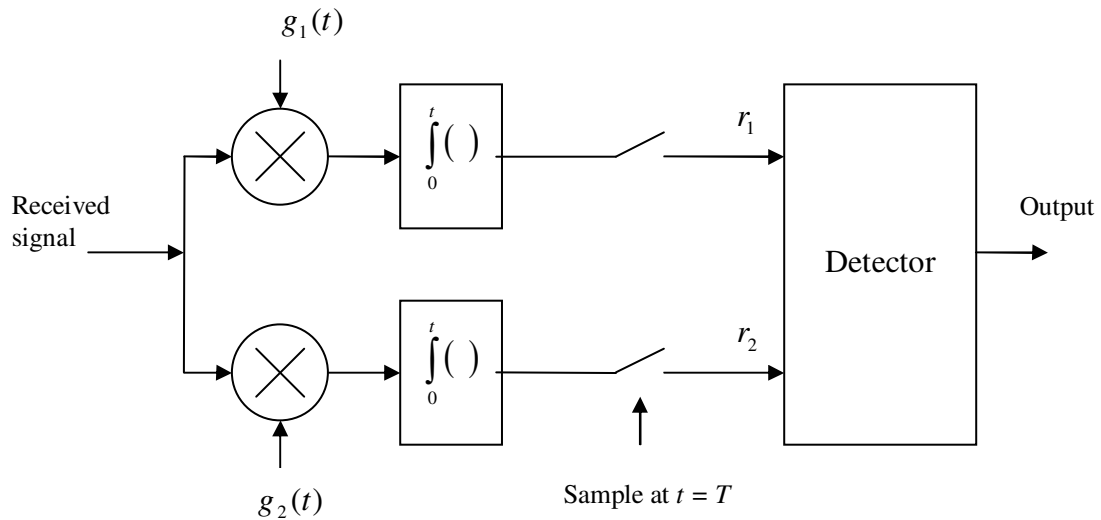Detector

r_2

$g_2(t)$

Sample at $t = T$

Fig. 1.

4.

For the CDMA system in Problem 3, the conventional single-user detector for the information bits b_1 and b_2 gives the outputs

$b_1 = \mathrm{sgn}(r_1)$

$b_2 = \mathrm{sgn}(r_2)$

Assuming that $\Pr(b_1 = 1) = \Pr(b_2 = 1) = \dfrac{1}{2}$, and b_1 and b_2 are statistically independent, determine the probability of error for this detector.

5.

For the CDMA system in Problem 3, Determine the probability of error fpr each user that employs a decorrelating detector when $\varepsilon_1 \neq \varepsilon_2$.

Hint: Apply the inverse of the signal correlation matrix to signals at the output of the correlators of Fig. 1.