# Çankaya University – ECE Department – ECE 376

**2013 Spring Term** **May 2013**

**Experiment 10** : Detection in DS systems

**MATLAB code, DS_Experiment10.m available on course webpage**

**Theoretical background**

Assume that we have the block diagram of a DS system consisting of two users as shown in Fig. 2.2 of notes entitled, "Spread spectrum systems_2013_HTE". Instead of handling the detection of the symbols, ${}_1a_0$ and ${}_2a_0$ belonging to users 1 and 2 respectively, we combine the outputs of the correlator, $z_1$ and $z_2$ to arrive at a decision for the transmitted symbols of the two uses simultaneously, rather than one by one. Such a technique is named multiuser detection and this is the one used in practice, since it is more successful than single user detection described in the notes.

By assigning different received levels for the two users, i.e. $A_1$ and $A_2$, and adding noise scaled to the received amplitude of the respective signal, $z_1$ and $z_2$ will become

$$\begin{aligned} z_1 &= A_1\,{}_1a_0\int_0^{T_b} e_1^2(t)\,dt + A_2\,{}_2a_0\int_0^{T_b} e_1(t)e_2(t)\,dt + \overbrace{0.5A_1 + 0.7A_2}^{Noise} \\ z_2 &= A_1\,{}_1a_0\int_0^{T_b} e_1(t)e_2(t)\,dt + A_2\,{}_2a_0\int_0^{T_b} e_2^2(t)\,dt + \overbrace{0.5A_1 + 0.7A_2}^{Noise} \end{aligned} \tag{1}$$

where $e_1(t)$ and $e_2(t)$ are the maximum length spreading (PN) sequences as defined in (3.3) and (3.4) of notes entitled, "Spread spectrum systems_2013_HTE". Thus

$e_1(t)$ and $e_2(t)$

$$\begin{aligned} e_1(t) &\rightarrow \mathbf{e}_1 = [-1\ -1\ 1\ 1\ 1\ -1\ 1] \\ e_2(t) &\rightarrow \mathbf{e}_2 = [-1\ -1\ 1\ -1\ 1\ 1\ 1] \end{aligned} \tag{2}$$

This way,

$$\int_0^{T_b} e_1^2(t)\,dt = 7 \quad , \quad \int_0^{T_b} e_1(t)e_2(t)\,dt = 3$$

$$z_1 = 7A_1\,{}_1a_0 + 3A_2\,{}_2a_0 + 0.5A_1 + 0.7A_2 \quad , \quad z_2 = 3A_1\,{}_1a_0 + 7A_2\,{}_2a_0 + 0.5A_1 + 0.7A_2$$

$$\mathbf{z} = \begin{bmatrix} z_1 \\ z_2 \end{bmatrix} = \begin{bmatrix} 7A_1\,{}_1a_0 + 3A_2\,{}_2a_0 + 0.5A_1 + 0.7A_2 \\ 3A_1\,{}_1a_0 + 7A_2\,{}_2a_0 + 0.5A_1 + 0.7A_2 \end{bmatrix} \tag{3}$$

The Matlab file DS_Experiment10.m makes detection by using $\mathbf{z}$ .

1. By setting $\begin{bmatrix} {}_1a_0 \\ {}_2a_0 \end{bmatrix} = \begin{bmatrix} -1 \\ 1 \end{bmatrix}$ and $\begin{bmatrix} A_1 \\ A_2 \end{bmatrix} = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$, we see that, we have no errors. But if we change to $\begin{bmatrix} A_1 \\ A_2 \end{bmatrix} = \begin{bmatrix} 1 \\ -1/30 \end{bmatrix}$, then an error occurs.

2. By running DS_Experiment10.m, for all possible values of ${}_1a_0$ and ${}_2a_0$, $A_1$ and $A_2$, complete the following graph and identify correct decision and error regions and mark them on this graph.

3. Estimate the ratio of the correct decision regions to error regions.

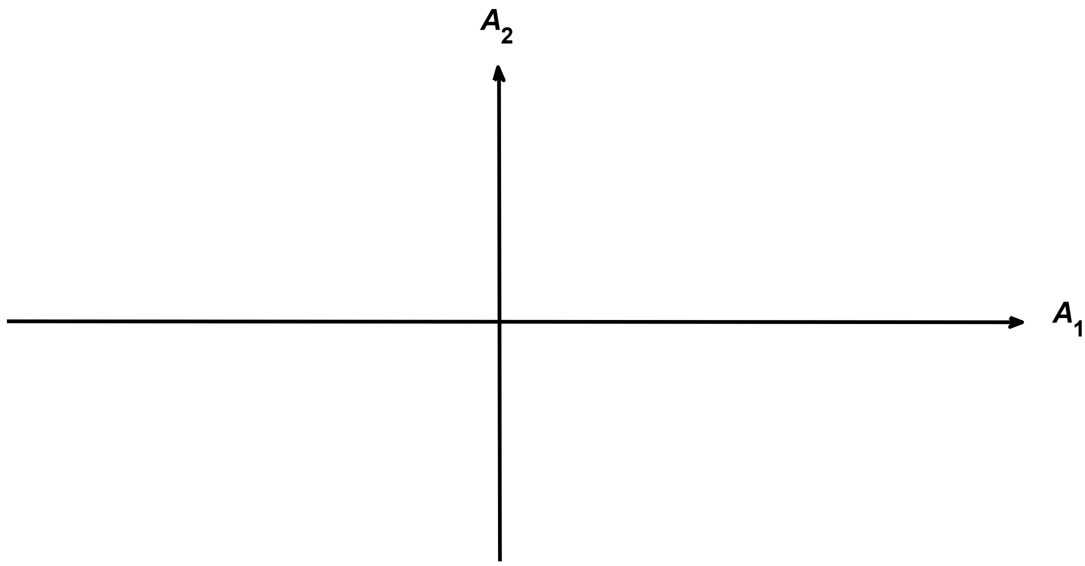


Fig. 1 Signal space for received levels for the two users, i.e. $A_1$ and $A_2$ .