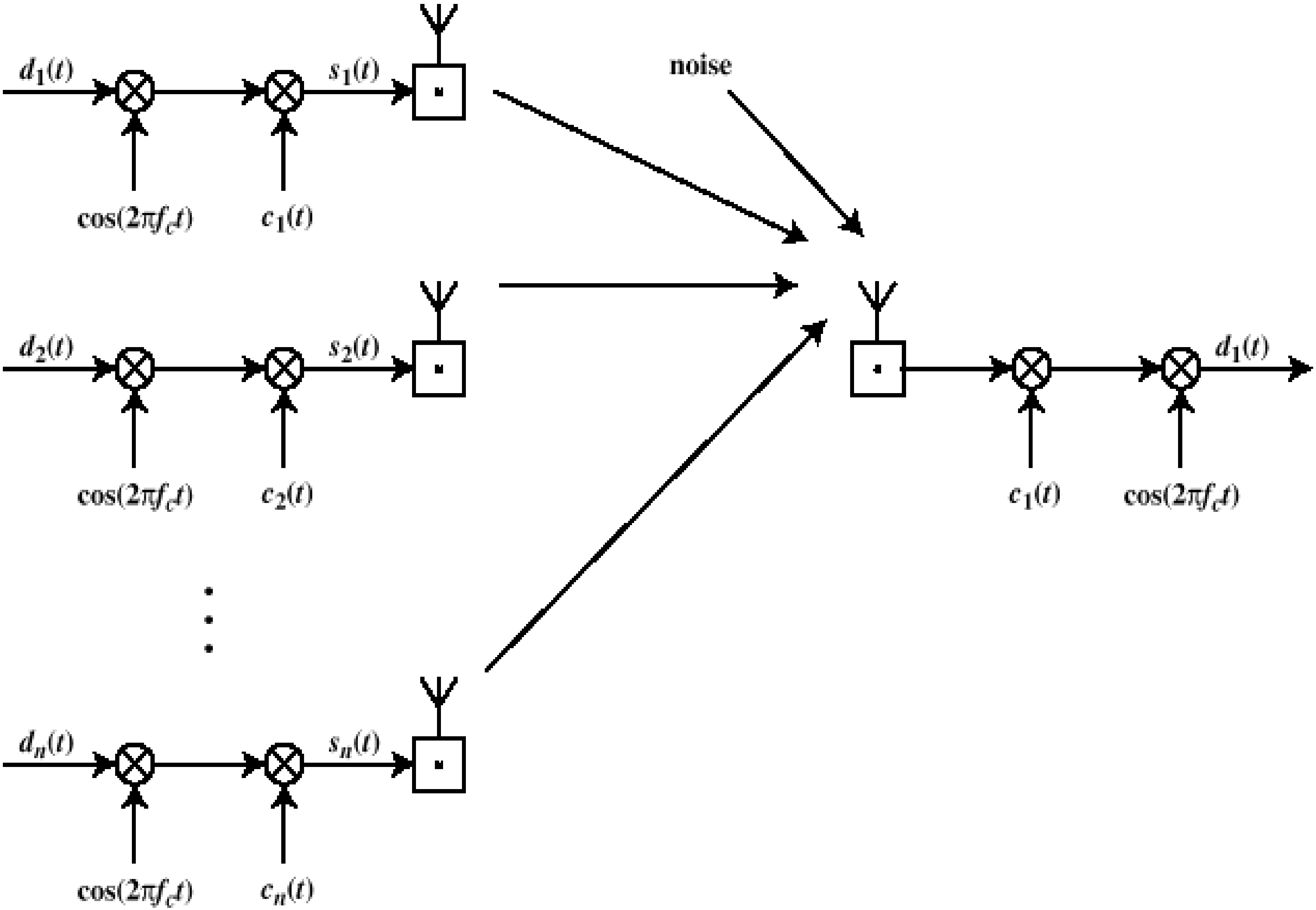
CODE DIVIDION MULTIPLE ACCESS

CDMA

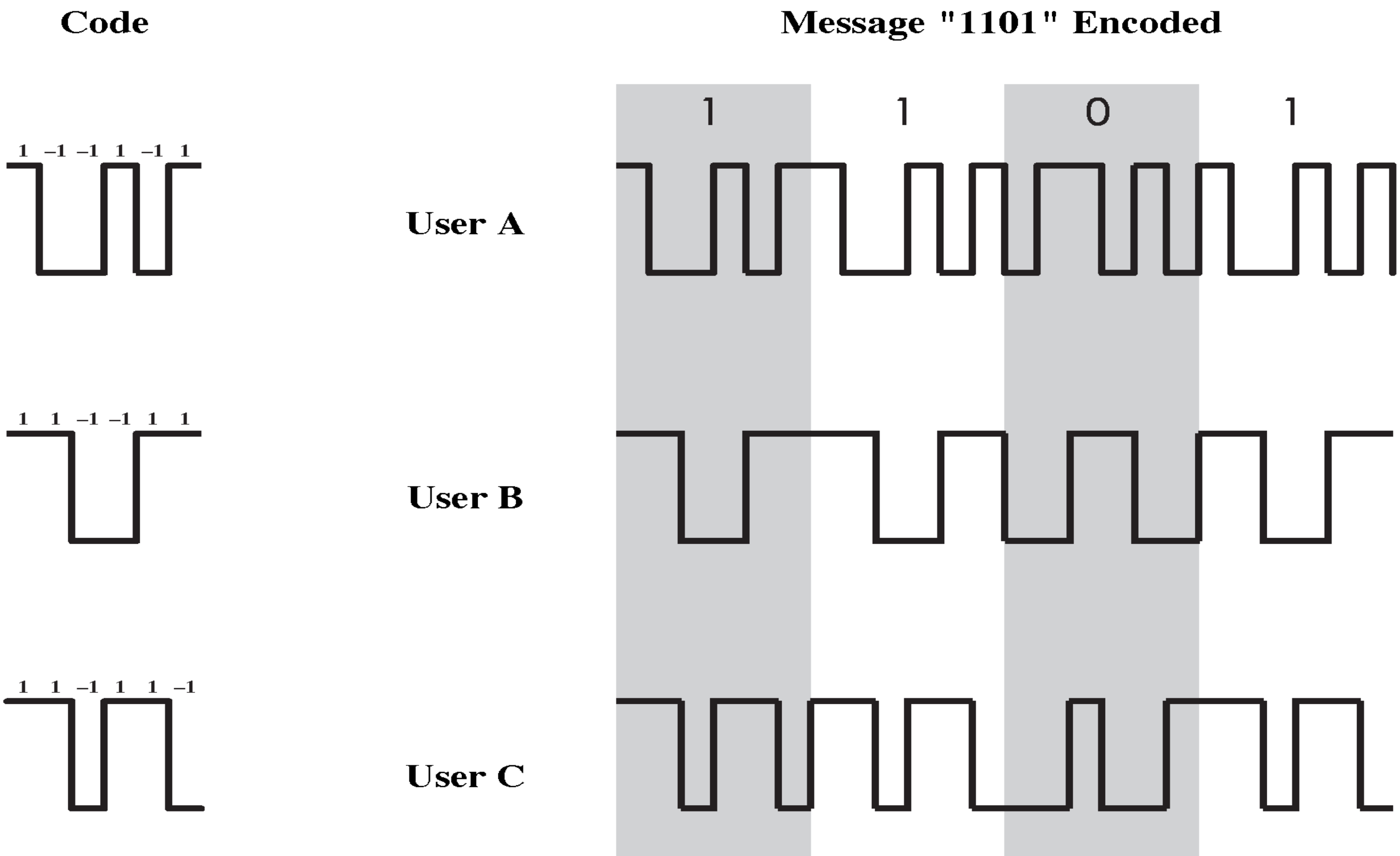
- CDMA is multiple access scheme that allows many users to share the same bandwidth
  - 3G (WCDMA), IS-95
- Basic Principles of CDMA
  - Each user is assigned a unique spreading code
  - The processing gain protects the useful signal and reduces interference between the different users

G_P = (Bandwidth after spreading)/(Bandwidth before spreading)



$d_1(t)$
$s_1(t)$
noise
$\cos(2\pi f_c t)$
$c_1(t)$
$d_2(t)$
$s_2(t)$
$d_1(t)$
$\cos(2\pi f_c t)$
$c_2(t)$
$c_1(t)$
$\cos(2\pi f_c t)$
$d_n(t)$
$s_n(t)$
$\cos(2\pi f_c t)$
$c_n(t)$

CDMA Example



- **Consider a CDMA system with two users**
- **The received signal can be written as**

$$r(t) = s_1(t)c_1(t) + s_2(t)c_2(t) + \text{noise}$$

- **Assume that the receiver is interested in decoding user 1**

$$y(t) = r(t)c_1(t) = s_1(t) + s_2(t)c_2(t)c_1(t) + \text{noise}$$

  - **Because $s_2(t)$ is not de-spreaded by the code $c_1(t)$, it will create very little interference to $s_1(t)$**
  - **The signal $s_1(t)$ can then be decoded with little or no degration**

- **User A code** $c_A = \{+1, -1, -1, +1, -1, +1\}$
- **User B code** $c_B = \{+1, +1, -1, -1, +1, +1\}$
- **The received pattern can be written as**

$$
\begin{aligned}
d &= \{d_1, d_2, d_3, d_4, d_5, d_6\} \\
&= b_A \times \{+1, -1, -1, +1, -1, +1\} + b_B \times \{+1, +1, -1, -1, +1, +1\}
\end{aligned}
$$

- **Decoding the bit of user A we get**

$$
\begin{aligned}
d \times c_A = b_A &\times \{+1, +1, +1, +1, +1, +1\} \\
&+ b_B \times \{+1, -1, +1, -1, -1, +1\}
\end{aligned}
$$

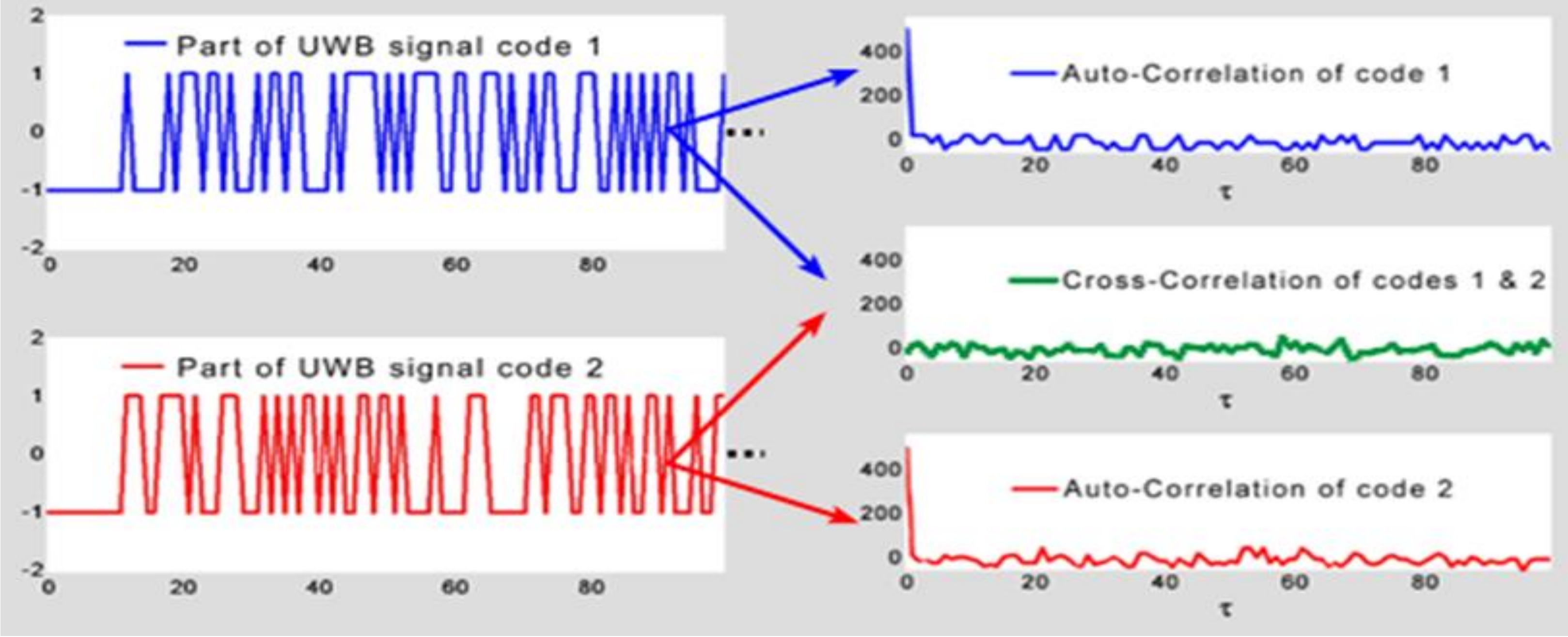
and

$$S_u(b_A) = \mathrm{Sgn}\,\{b_A \times 6 + b_B \times 0\} = b_A$$

and the bit of user A is decoded correctly

Orthogonal Codes

- Orthogonal codes
  - All pairwise cross correlations are zero
  - For CDMA application, each mobile user uses one sequence in the set as a spreading code
    - Provides zero cross correlation among all users



Walsh Codes

- Set of Walsh codes of length *n* consists of the n rows of an *n* x *n* Walsh matrix:

$$H(2^1) = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix},$$

$$H(2^2) = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix},$$

and in general

$$H(2^k) = \begin{bmatrix} H(2^{k-1}) & H(2^{k-1}) \\ H(2^{k-1}) & -H(2^{k-1}) \end{bmatrix}$$

  - Every row is orthogonal to every other row and to the logical not of every other row
  - Requires tight synchronization
    - Cross correlation between different shifts of Walsh sequences is not zero

Spreading in Cellular CDMA Systems

- Cellular CDMA systems use two layers of spreading
- Channelization codes (orthogonal codes)
  - Provides orthogonality among users within the same cell
- Long PN sequences (scrambling code)
  - Provides good randomness properties (low cross correlation)
  - Reduces interference from other cells