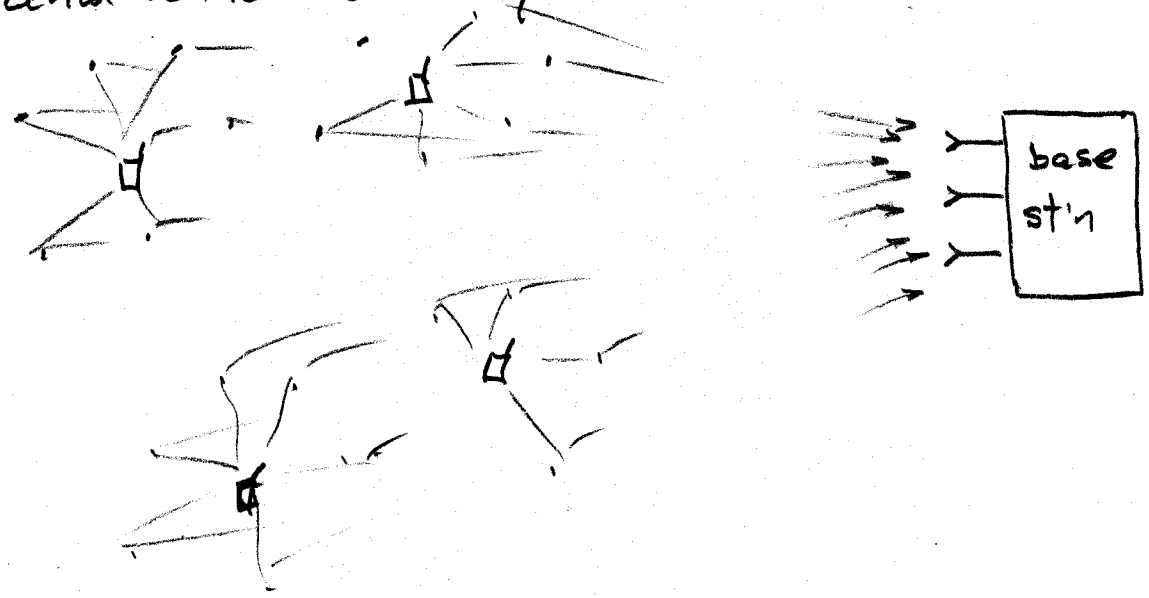
2. THE CDMA SIGNAL ENVIRONMENT

- We can't discuss MUD without a model of the signals and the transmission environment, as well as low-level receiver processing. That's what we'll do in this section.

  In addition, we'll use an elementary example to expose some dominant ideas in MUD and give plausibility to some of the claims.

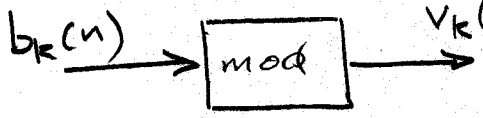
- We are working with the uplink, scatterers and antenna arrays



mobiles in local scatterers

2.1 The Transmitted Signals

- Modulation in DS CDMA is linear, frequently time-varying. At the antenna of user k (of K total)



(complex envelope)

- Simplest form — synchronous, short code

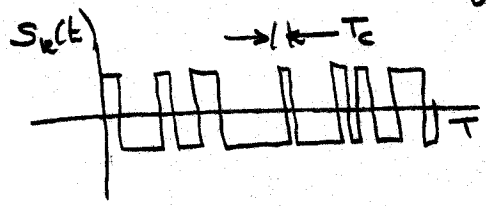
$$v_k(t) = A_k \sum_n b_k(n)\, s_k(t - nT), \quad k = 1..K$$

where

- data $b_k(n)$ is symbol n

$|b_k(n)| = 1$, so BPSK, QPSK, etc

- pulse shape is unique to user k; more detail:



the "signature sequence"

nominal duration T

- N_c chips, each nominal duration $T_c = T/N_c$
- N_c often termed "spreading ratio", "processing gain"
- chip shape typically rectangular or root raised cosine
- unit energy $\int_{-\infty}^{\infty} |s_k(t)|^2 dt = 1$

– amplitude $A_k = \sqrt{2 E_{sk}}$ (energy/sym)

- Note factor $\frac{1}{2}$ in power calculations with complex envelopes:

$$P_k = \lim_{T_W \to \infty} \frac{1}{T_W} \frac{1}{2} \int_{-T_W/2}^{T_W/2} |V_k(t)|^2 \, dt$$

- Vector form (get used to it):

$$V_k(t) = A_k \underline{s}_k(t) \underline{b}_k \qquad \text{truncate to } n = 0 \ldots N-1$$

where $\underline{s}_k(t) = \left(s_k(t), s_k(t-T), \cdots, s_k(t-(N-1)T)\right)$

$$\underline{b}_k = \left(b_k(0), b_k(1), \cdots b_k(N-1)\right)^T$$

and if samples at N_s times chip rate, period t_s

$$\underline{V}_k = \left(V_k(0), V_k(t_s) \cdots V_k(i t_s) \cdots V_k((NN_s-1)t_s)\right)^T$$

$$= A_k S_k \underline{b}_k$$

where

$$S_k = \begin{bmatrix} \underline{s}_k & \underline{0} & \cdots & \underline{0} \\ \underline{0} & \underline{s}_k & & \vdots \\ \underline{0} & \underline{0} & & \vdots \\ \underline{0} & \underline{0} & & \vdots \\ \underline{0} & \underline{0} & & \underline{0} \\ \underline{0} & \underline{0} & & \underline{s}_k \end{bmatrix}$$

$N N_s \times N$

with $\underline{s}_k = \begin{bmatrix} s_k(0) \\ s_k(t_s) \\ \vdots \\ \vdots \\ \vdots \\ s_k((N_s-1)t_s) \end{bmatrix}$

- CDMA commonly uses a long spreading code, so signature sequence changes, symbol to symbol.

$$v_k(t) = A_k \sum_n b_k(n)\, s_k^{(n)}(t - nT)$$

This randomizes cross correlations between different user signature sequences, but it creates problems for some MUD methods.

- Users are normally asynchronous (propagation delays, free-running clocks):

$$v_k(t) = A_k \sum_n b_k(n)\, s_k(t - nT - \tau_k)$$

or

$$v_k(t) = A_k \sum_n b_k(n)\, s_k^{(n)}(t - nT - \tau_k)$$

- Both long codes and asynch can be put into vector form in similar ways to preceding page.