Spead Spectrum Systems

Lecture Outline

- **Overview of Spread Spectrum**

- **Direct Sequence Spread Spectrum**

- **PN Sequences and Maximal Linear Codes**

- **Synchronization**

- **RAKE Receivers**

- **Multiuser Spread Spectrum**

1. **Overview of Spread Spectrum Modulation**

   - Basic premise is to add additional modulation to the digitally-modulated signal that increases its bandwidth.

   - Spread spectrum techniques can mitigate or coherently combine ISI, mitigate narrow-band interference and jamming, hide a signal below the noise floor or make it hard to track, or enable multiple users to share the same bandwidth (multiple access).

   - There are two main types of spread spectrum modulation: direct sequence (DSSS) and frequency hopping (FH). Frequency hopping takes a narrowband signal and hops it across a wide range of frequencies. Direct sequence multiplies the bit sequence by a faster chip sequence.

2. **Direct Sequence Spread Spectrum (DSSS)**

   - Bit sequence multiplied by faster pseudorandom chip sequence.

   - Spreads bandwidth of transmitted signal by large amount.

   - The bandwidth spreading allows for multipath and narrowband interference rejection. Also hides signal below noise.

   - *Not* spectrally efficient for one user, but DSSS also allows many users to share the same bandwidth (MAC technique).

3. **Multipath and Interference Rejection in DSSS**

   - Incoming signal multiplied by synchronized copy of spreading code

   - Ideally this removes the impact of spreading on desired signal

   - Narrowband interference is spread over wide bandwidth. Demodulation process effectively filters out most of its power.

   - Multipath that is delayed by τ is attenuated by the autocorrelation of the spreading code at time τ.

4. **Pseudorandom Sequences and Maximal Linear Codes**

   - Generated using shift registers with feedback logic.

   - Autocorrelation property dictates multipath rejection.

- Ideal autocorrelation is a delta function.
- Maximal linear codes have the longest period for a shift register code ($2^n - 1$ for code of length n) and no DC component.
- Autocorrelation approximately linear
- Repeats every period. If period equals bit time get recorrelation at integer multiples of T_b (multipath with this delay not rejected). If period greater than a bit time then must deal with partial correlations.

5. **Synchronization**

- Synchronization adjusts delay of receiver spreading code to maximize peak of autocorrelation.
- For synchronization long autocorrelation tails preferable (impossible to synchronize to a delta function).
- Synchronization complicated by interference, noise, and multipath.
- Offset in syncronization of Δt reduces received signal power by $\rho(\Delta t)$.

6. **RAKE Receivers**

- DSSS removes most of the energy from multipath and the received signal component typically experiences fading. For better performance the system should synchronize to the strongest multipath component.
- A RAKE receiver has N branches that synchronize to N different multipath components.
- These different multipath components can be combined using selection diversity (pick the strongest) or other forms of diversity (Equal gain or Maximal Ratio Combining). Analysis of spread spectrum system with RAKE same as previous diversity analysis.

7. **Spread Spectrum Multiple Access**

- The premise of spread spectrum multiple access is to modulate user signals with orthogonal or semi-orthogonal codes. Then these signals can be separated out at receiver using the code properties.
- The interference between users is determined by cross correlation properties of the codes and whether the system is the downlink (base station to mobiles), where all signals are received with the same power, or the uplink (mobiles to base station), where there is near-far power imbalance.

Main Points

- DSSS spreads signal over wide bandwidth to obtain multipath and interference rejection.

- DSSS rejects narrowband interference power by roughly the spreading gain and multipath by the spreading code autocorrelation evaluated at the multipath delay. So this autocorrelation is the key to multipath rejection.

- Maximal linear codes have good autocorrelation but poor cross correlation.

- Synchronization also depends on autocorrelation properties of the spreading code.

- RAKE receivers combine energy of all multipath components using standard diversity combining techniques.

- Spread spectrum allows many users to share the same bandwidth. Cross correlation of spreading code determines interference between users, as well as channel gains in the uplink.