Lecture 16: a. DSSS- Direct sequence spread spectrum

GSM and CDMA Systems

DI05011011: Mobile Communication

Agenda for Today

- 1. Recap of Spread Spectrum Concept
- 2. Direct Sequence Spread Spectrum (DSSS) Overview
- 3. DSSS Spreading and De-spreading Process
- 4. Advantages of DSSS
- 5. Frequency Hopping Spread Spectrum (FHSS) Overview
- 6. Hopping Patterns and Types (Slow vs. Fast)
- 7. Advantages of FHSS
- 8. Comparison: DSSS vs. FHSS
- 9. Real-world Examples
- 10. Summary

Spread Spectrum Recap

- **Concept:** Transmission of a signal over a bandwidth much larger than the minimum required bandwidth.
- **Purpose:** Reduces interference, increases security, and allows multiple users to share the same frequency band.
- **Key Mechanism:** Spreading is accomplished using a Pseudo-Noise (PN) sequence, which is independent of the original data.
- **Two Main Types:**
- - Direct Sequence Spread Spectrum (DSSS)
- - Frequency Hopping Spread Spectrum (FHSS)

Direct Sequence Spread Spectrum (DSSS)

- **Definition:** DSSS multiplies the original data signal directly with a high bit-rate Pseudo-Noise (PN) code.
- **Chipping Code:** The PN code bits are called 'chips'. The chip rate is significantly higher than the data bit rate.
- **Effect on Bandwidth:** The multiplication spreads the narrow-band data signal over a wide frequency band.
- **Noise-like Appearance:** The resulting wideband signal looks like random noise to anyone without the exact PN code.

DSSS Spreading Process

- **1. Data Signal:** Original information signal with bit rate Rb.
- **2. PN Sequence Generator:** Generates a high-speed pseudo-random sequence with chip rate Rc (Rc ¿¿ Rb).
- **3. Modulation/Multiplication:** The data signal is XORed (multiplied) with the PN sequence.
- **4. RF Carrier Modulation:** The spread baseband signal then modulates an RF carrier (e.g., using BPSK) for transmission.
- **Processing Gain:** Defined as the ratio of Chip Rate to Data Rate (Rc / Rb).

DSSS De-spreading Process

- **Synchronization:** The receiver must locally generate the *exact* same PN code, perfectly aligned in time with the received signal.
- **Correlation:** The received wideband signal is multiplied by the synchronized local PN code.
- **Result:** This operation 'collapses' the wideband signal back into the original narrow-band data signal.
- **Interference Rejection:** Any narrow-band interference picked up during transmission is actually *spread* by this process, reducing its impact on the data.

Advantages of DSSS

- **Jamming Resistance:** Highly resistant to narrow-band jamming and intentional interference.
- **Low Probability of Intercept (LPI):** Hard for eavesdroppers to detect the signal since it operates near or below the noise floor.
- **Multi-Path Mitigation:** DSSS can resolve multipath components using a RAKE receiver, actually improving signal quality.
- **Multiple Access:** Basis for CDMA, allowing many users to share the channel simultaneously using different orthogonal PN codes.

Frequency Hopping Spread Spectrum (FHSS)

- **Definition:** The carrier frequency of the transmitted signal changes ('hops') rapidly according to a pseudo-random sequence.
- **Mechanism:** Instead of spreading the baseband signal, FHSS jumps across many narrow frequency channels over time.
- **Bandwidth Usage:** At any instant, the signal is narrow-band. Over time, it covers a wide frequency band.
- **Requirement:** Both transmitter and receiver must agree on the hopping sequence and be strictly synchronized.

How FHSS Works

- **1. Digital Data:** Modulates a baseband signal (e.g., FSK).
- **2. PN Sequence Generator:** Drives a frequency synthesizer.
- **3. Frequency Synthesizer:** Outputs a different carrier frequency based on the PN code.
- **4. Mixer:** The baseband signal is mixed with the hopping carrier frequency.
- **5. Transmission:** The signal is transmitted on the new frequency for a short duration (dwell time) before hopping again.

Slow vs. Fast Frequency Hopping

- **Slow FHSS:**
- - Hopping rate is slower than the symbol rate.
- - Multiple symbols (data bits) are transmitted per frequency hop.
- - Cheaper to implement, used in GSM (for interference averaging).
- **Fast FHSS:**
- - Hopping rate is faster than the symbol rate.
- - One symbol is transmitted over multiple frequency hops.
- - High resistance to narrow-band jamming, highly secure (military use).

Advantages of FHSS

- **Avoids Interception:** Difficult for unauthorized receivers to follow the rapid frequency changes.
- **Mitigates Interference:** If a specific frequency is jammed or noisy, only a small fraction of data is lost (easily corrected with error coding).
- **Near-Far Problem Resilience:** Much less susceptible to the near-far problem compared to DSSS.
- **Coexistence:** Multiple FHSS networks can coexist in the same area if they use orthogonal hopping sequences.

Comparison: DSSS vs. FHSS

- — Feature — DSSS — FHSS —
- ————————
- — **Spreading Method** — Multiplies baseband with PN code — Changes carrier frequency via PN code —
- — **Bandwidth usage** — Occupies full band simultaneously — Occupies narrow band at any instant —
- — **Near-Far Problem** — Highly susceptible, needs tight power control — Resistant —
- — **Hardware Complexity**— High (complex correlators, RAKE) — Moderate (agile synthesizers) —
- — **Data Rates** — Generally higher — Generally lower —

Engineering Example: Wi-Fi vs. Bluetooth

- **Wi-Fi (Early 802.11b):**
- - Uses **DSSS** to achieve higher data rates (up to 11 Mbps).
- - Spreads the signal across a 22 MHz channel in the 2.4 GHz band.
- - Better for continuous, high-throughput data transfer.
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- **Bluetooth:**
- - Uses **FHSS**.
- - Hops across 79 channels (1 MHz wide) at 1600 hops per second.
- - Better for low-power, robust connections in noisy environments, avoiding interference from Wi-Fi.

Lecture Summary

- Spread spectrum techniques (DSSS and FHSS) provide security, interference rejection, and multiple access capabilities.
- **DSSS** spreads the signal by multiplying it with a high-rate chipping sequence, appearing as noise.
- **FHSS** spreads the signal by rapidly changing the carrier frequency across a wide band.
- DSSS offers higher data rates and multi-path mitigation but is susceptible to the near-far problem.
- FHSS is robust against jamming and the near-far problem but generally supports lower data rates.

Next Lecture Preview

- In the next lecture, we will perform a comprehensive comparison between the two major 2G/3G technologies:
- **1. GSM vs CDMA:** The ultimate showdown.
- **2. Multiple Access:** TDMA/FDMA vs CDMA.
- **3. Performance Metrics:** Capacity, Security, and Handoffs.
- **4. Introduction to limitations of both technologies.**