Investigating the Effects of Intentional Interference on Conventional and Spread Spectrum Systems

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Introduction

- Unmanned Aerial Vehicles (UAVs), also known as drones, have become more accessible due to technological advancements.
- However, concerns about the malicious use of UAVs have grown.
- Some events highlight the need for oversight and technological solutions to mitigate risks associated with UAVs.
- Studies focus on developing methods to block UAV signals, ensuring secure and controlled applications.

Introduction

- Spread Spectrum (SS) techniques have gained attention for enhancing the security of UAV communications, especially against interference.
- Recent research explores jamming techniques with applications in UAVs, IoT, and secure communication networks.
- New tests on digital communication systems and reception scenarios are needed to understand available jammers better and identify the most effective ones.

Main objective

Evaluate the performance of DSSS and conventional BPSK systems under jamming techniques: single-tone, multi-tone, narrow-band noise, tone pulse, narrow-band pulse, and swept interference. The analysis includes BER performance under varying jammer-to-signal ratio (JSR) conditions.

Intentional Interference in Communication Systems

RF Interference:

- Intrusive signal in the spectrum where communication occurs.
- Affects the **signal-to-interference-plus-noise ratio (SINR).**
- Reduced SINR decreases communication quality.

Main Types of Jamming

- Noise Jamming
- Tone Jamming
- Swept Jamming
- Pulse Jamming

Jamming Techniques: Noise and Tone

Noise Jamming

- Introduces noisy signals into the target channel.
- Types:
  - Broad-Band Noise (BBN): Covers entire spectrum, low power spectral density.
  - **Narrow-Band Noise (NBN)**: Focused on one channel, more power-efficient.
  - Partial-Band Noise (PBN): Intermediate between BBN and NBN.

Tone Jamming

- Uses continuous sinusoidal wave signals.
- Types:
  - **Single-Tone**: Concentrates power on a single frequency.
  - **Multi-Tone**: Divides power among multiple tones, increasing the probability of success.

Jamming Techniques: Swept and Pulse

Swept Jamming

- Narrow-band or tonal signal that sweeps across the spectrum over time.
- Allows interference to cover a wide frequency range.

Pulse Jamming

- Interfering signal is pulsed at periodic intervals.
- Shorter activity time $\rightarrow$ higher instantaneous interfering power.
- Effective with lower average power compared to other mentioned techniques.

Simulation Overview

Objective: Evaluate the effectiveness of interference techniques in compromising conventional and SS communications.

Implementation:

- Simulation environment: MATLAB®
- Systems: BPSK and BPSK DSSS
- Jamming techniques: Single-tone, Multi-tone, Narrowband Noise (NBN), Tone pulse, NBN pulse, and Frequency-swept jamming.

Communication System Parameters

Common parameters:

- Bit rate: $R_\text{b} = 2.5$ Mbps
- Carrier frequency: $f_\text{c} = 2450$ MHz

DSSS-specific parameters:

- Chip rate: $R_\text{c} = 25$ Mchips/s
- PN sequence length: 15 chips
- Processing gain: $\text{PG}_\text{dB} = 10$ dB

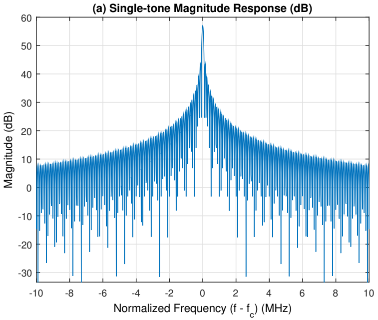
Jammer Simulation

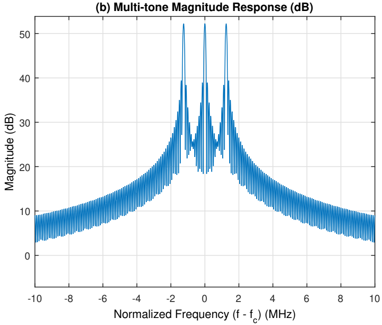
Single-tone Jamming:

- Generated by a single cosinusoidal signal.
- Target frequency: $f_c = 2450$ MHz.
- High impact on BPSK due to concentrated interference on the signal band.

Multi-tone Jamming:

- Central tone: $f_c = 2450$ MHz.
- Side tones: $f_c \pm 1.25$ MHz ($\pm R_b/2$), (2448.75 MHz and 2451.25 MHz).
- Increased disruption for DSSS.

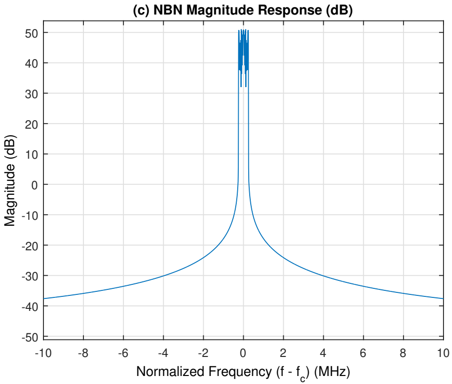




Jammer Simulation

NBN Jammer:

- NBN signal is generated from AWGN filtered through a 35th-order IIR low-pass filter.
- Cutoff frequency: 0.5 MHz (20% of the bit rate).
- Baseband samples are translated to the center frequency $f_c = 2450$ MHz.



Jammer Simulation

Tonal Pulse Jammer:

- Interfering signal active for only a fraction of the simulation time.
- Results in higher amplitude than single-tone jamming due to concentrated bursts.
- Jammer is active for 10% of the total simulation time.

NBN Pulse Jamming:

- The interfering vector signal is initially generated as a conventional NBN signal.
- The NBN signal is then limited to a specific time range, similar to tone pulse jamming.
- Active only for 10% of the total simulation time, creating concentrated disruption.
- Intermittent interference, offering brief moments of high impact while giving the system time to recover.

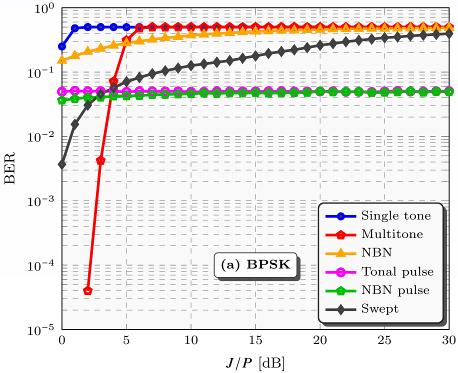
Swept Jammer:

- The jammer uses a single tone at any given time during the transmission.
- At the start of the transmission, the interference is set to 2448 MHz.
- The interference frequency increases over time, eventually shifting to 2452 MHz.
- The considered swept time for this technique is 40 ms.

Simulation Results - Conventional BPSK

Simulation Setup

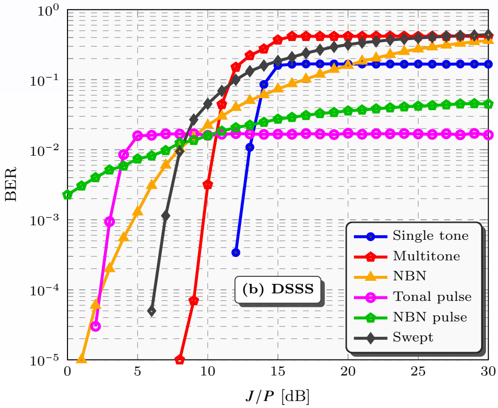
- J/P varied from 0 to 30 dB; AWGN channel with $E_b/N_0 = 20$ dB.
- **Performance Metric:** BER estimated using 10^6 transmitted bits.



- **Single-Tone Jamming:** Most effective, simple to implement.
- **Multi-Tone Jamming:** Distributed power across tones, less effective for $J/P < 6$ dB.
- **NBN Jamming:** Moderate performance (power around f_c).
- **Swept Jamming:** The effectiveness increases gradually with J/P.
- **Pulsed Techniques:** Limited disruption due to intermittent activity.

Simulation Results - DSSS

- **Key Observation:** DSSS exhibits rightward and downward BER shifts, showcasing robustness.



- Pulsed jammers (NBN and tonal) perform well at low JSR, suitable for power-limited jammers.
- At high JSR, pulsed jammers show poor performance (low BER) due to concentrated power in short durations.
- Multi-tone, swept, and NBN jammers achieve $\sim 50\%$ BER at high JSR.
- Single-tone jamming is least effective for $J/P \leq 13$ dB, as it focuses power on a single frequency, ineffective against wideband SS signals.
- DSSS processing gain is more effective against narrow-band jamming.

Conclusion

- This work advances knowledge about intentional jamming techniques against conventional and SS communication systems.
- Key findings:
  - **Conventional BPSK**: Single-tone jamming is the most effective.
  - **DSSS system**: The optimal jamming technique depends on J/P:
    - $J/P < 4\,\mathrm{dB}$: Narrow-band pulse (NBN) is most effective.
    - $4 \leq J/P \leq 8\,\mathrm{dB}$: Tonal pulse is most effective.
    - $8 < J/P \leq 11\,\mathrm{dB}$: Swept jamming is most effective.
    - $J/P \geq 12\,\mathrm{dB}$: Multi-tone jamming is most effective.
- Conclusions enhance theoretical understanding and assist in selecting the best jamming technique for specific practical scenarios.
- This is a work in progress...

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