Progress Report: Rapid Code Acquisition in UWB Systems

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Year 1 Program Review, MURI UWB Project

Year 1 Progress: Rapid Code Acquisition in UWB Systems

1. **Fixed Sample Size (FSS) tests:** Derivation and characterization of the optimal fixed-time testing techniques for impulse radio.

2. **Sequential Probability Ratio Tests (M-SPRT):** Derivation and characterization of optimal variable-time testing techniques for impulse radio.

3. **Fast Sequential Probability Ratio Tests (F-SPRT):**

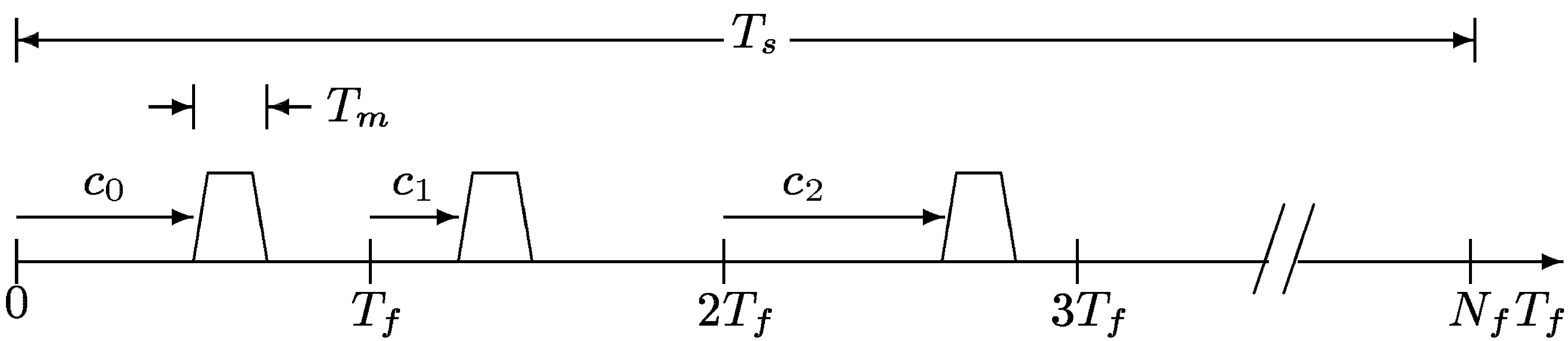
   - General theory as an acquisition technique developed.
   - Application (and optimization) for impulse radio.

4. **Multipath Aiding:** Extensions to exploit "multipath aiding" technique of [Homier and Scholtz, 2001].

Rapid Code Acquisition: Framework

Systems considered: (1) Very wideband DS/SS, and (2) Impulse radio.

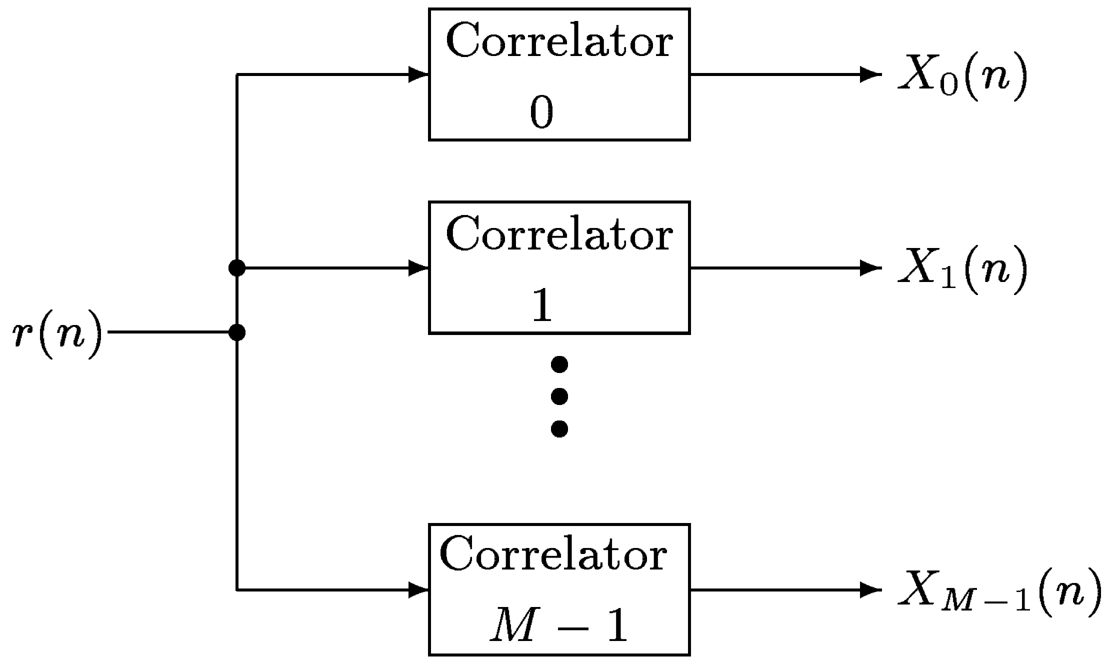
User hopping code: $(c_0, c_1, \ldots, c_{N_f-1})$.



Sample Numbers: $T_s = 52.08\mu s, T_m = 0.7ns \Rightarrow T_s/T_m \approx 75,000!$

Time-Hopped Spread-Spectrum Impulse Radio

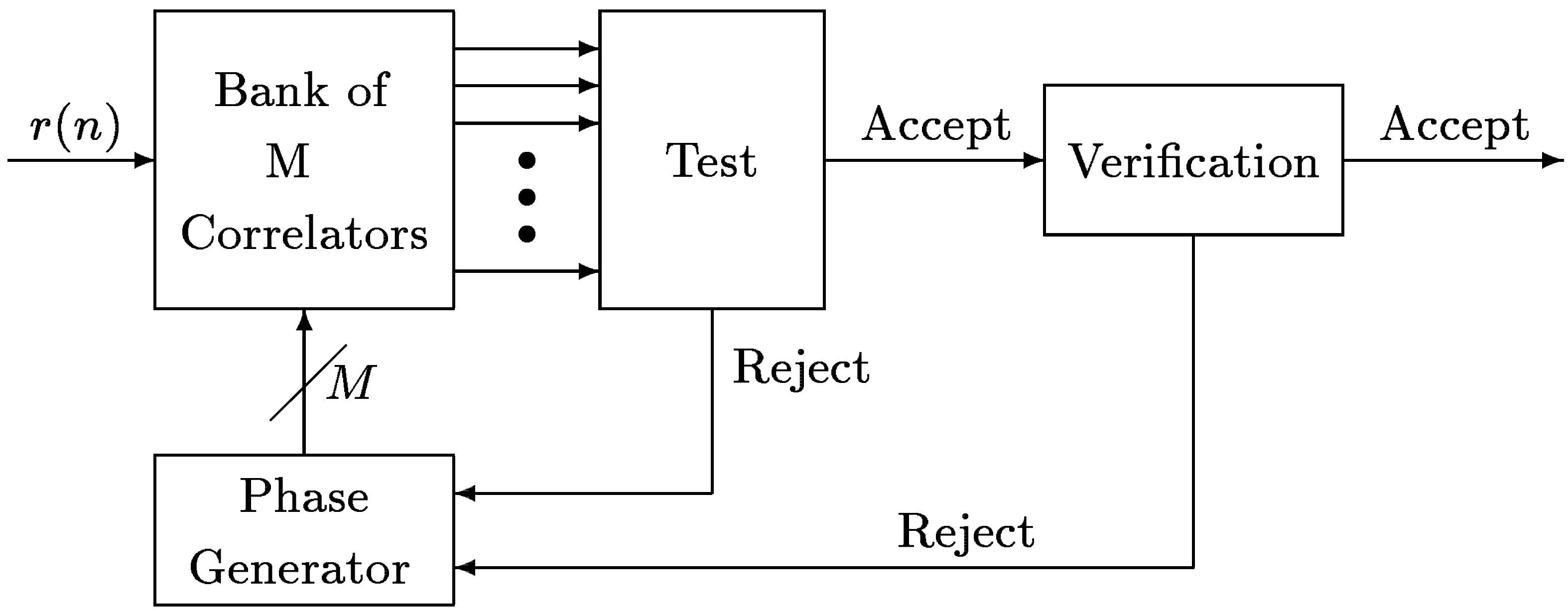
Front-End



DS/CDMA | Impulse Radio

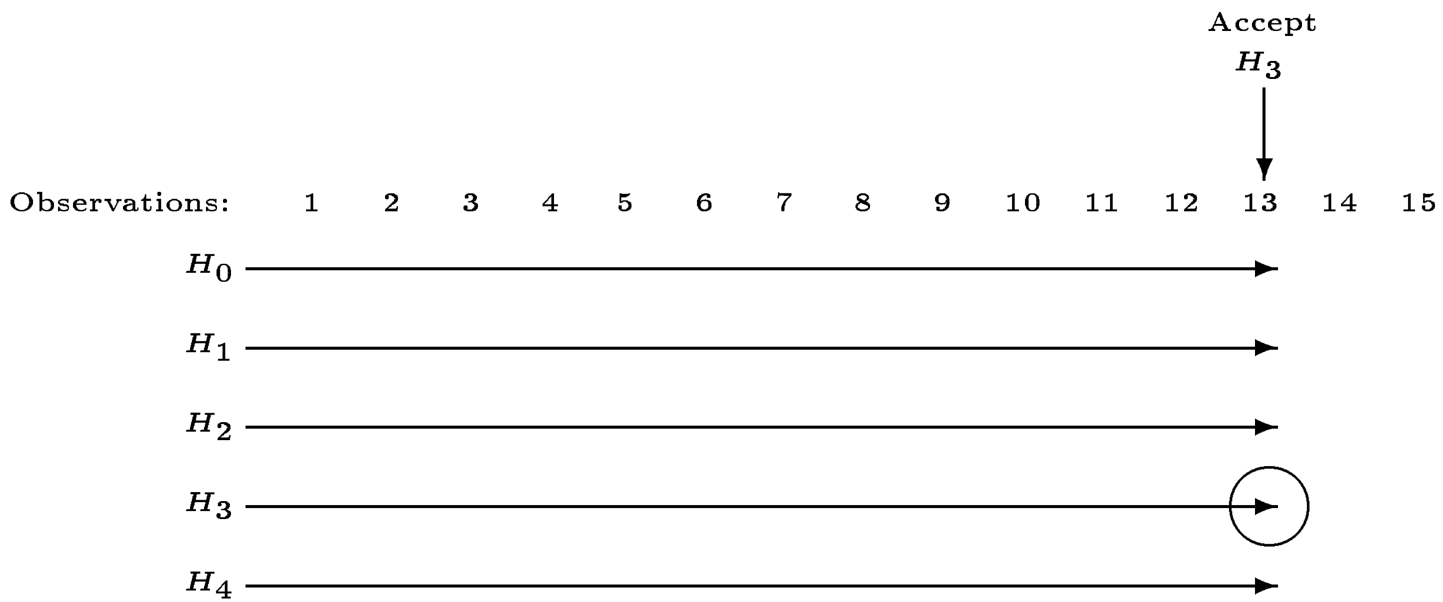
$$X_i(n) = \begin{cases} \sqrt{E_p} + W(n) & \text{“hit”} \\ \pm\sqrt{E_p} + W(n) & \text{“miss”} \end{cases} = \begin{cases} \sqrt{E_p} + W(n) & \text{“hit”} \\ I(n)\sqrt{E_p} + W(n) & \text{“miss”} \end{cases}$$

Previous Techniques Applied to Impulse Radio



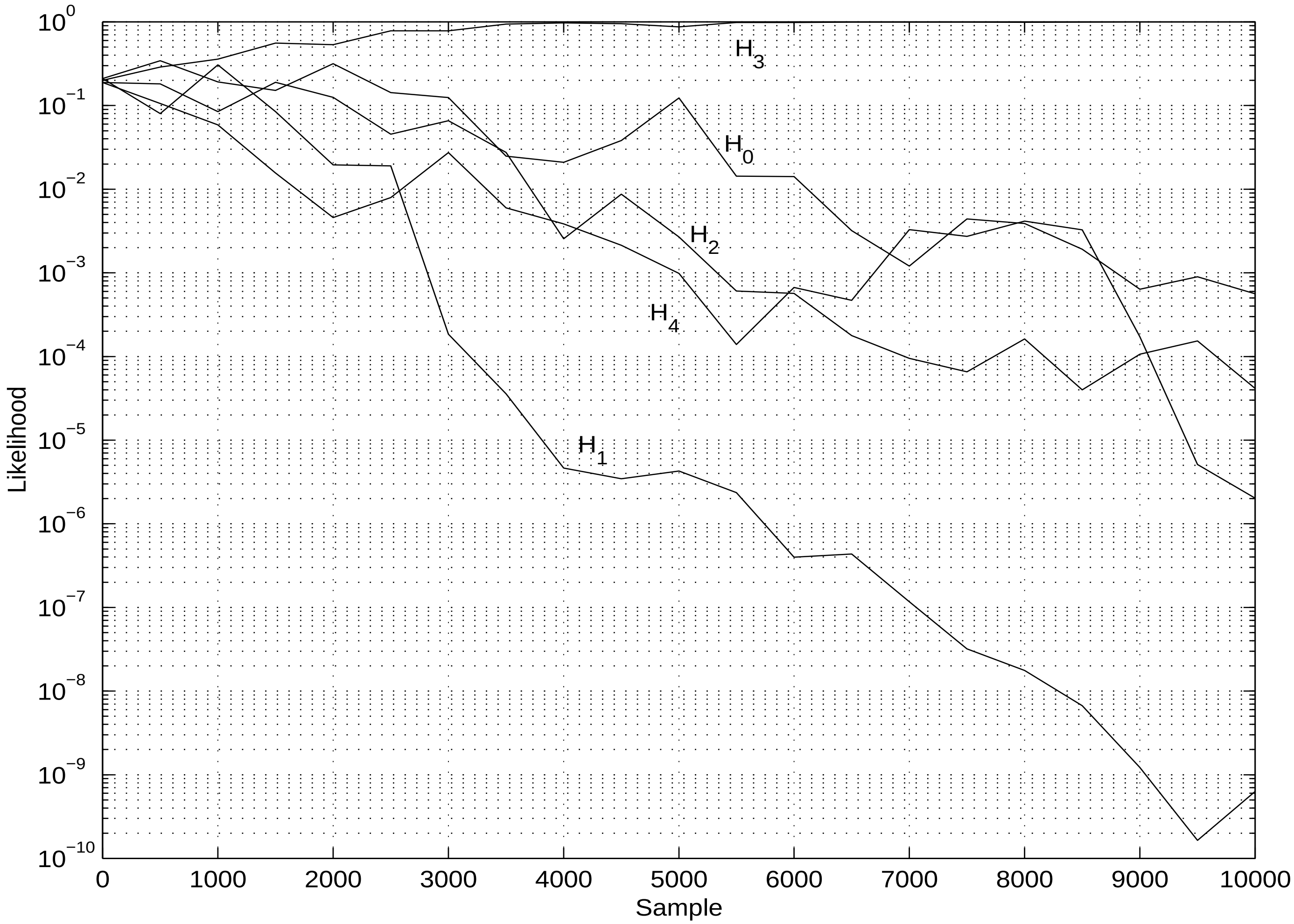
FSS or M-SPRT for Impulse Radio: modify probability density functions for “hit”, “miss”.

M-SPRT Approach

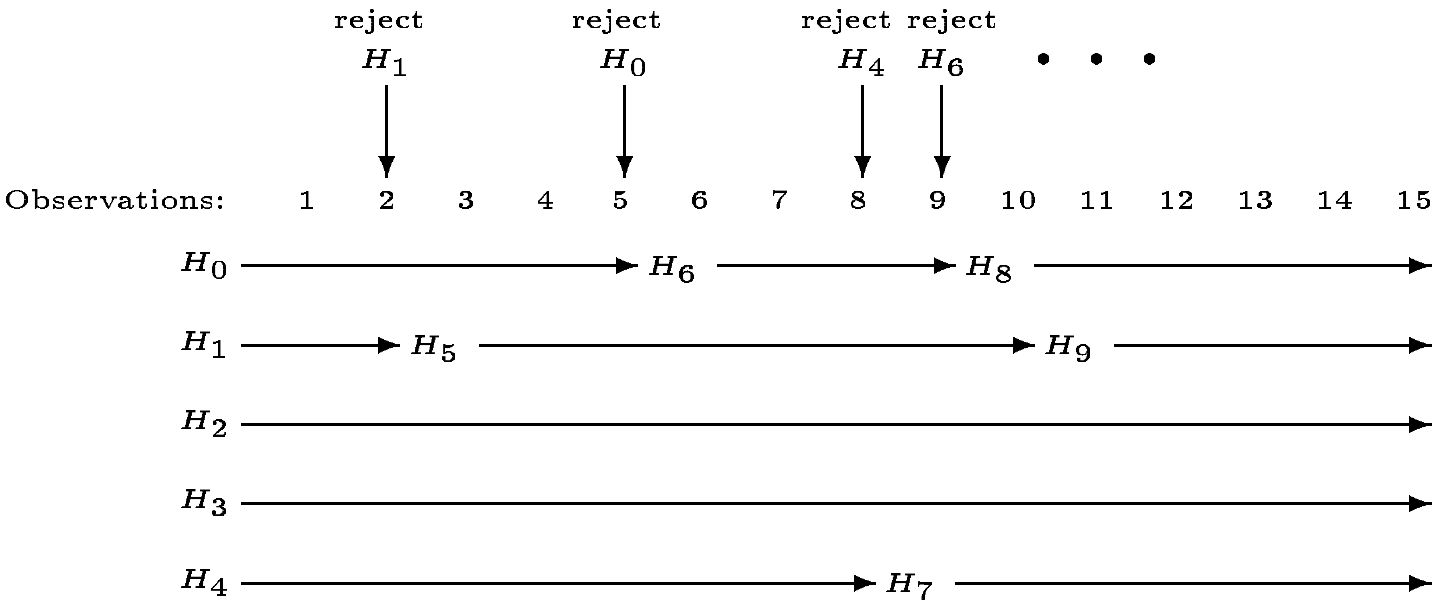


- Hypothesis H_3 is accepted once its likelihood is high enough (variable time).
- Reduces acquisition time by a factor of 2 to 4 for DS-SS systems (Veeravalli and Baum, 1996)

F-SPRT: Motivation



Fast SPRT Approach



A hypothesis is discarded as soon as its likelihood is small enough (variable time).

Analysis

Can show analytically that for long acquisition times (low SNRs, conservative threholds), threshold a:

$$\text{M-SPRT:} \quad \frac{E[N]}{-\log(a)} \xrightarrow{\text{a.s.}} \frac{1}{\min_{i \neq j} D(f_i, f_j)}$$

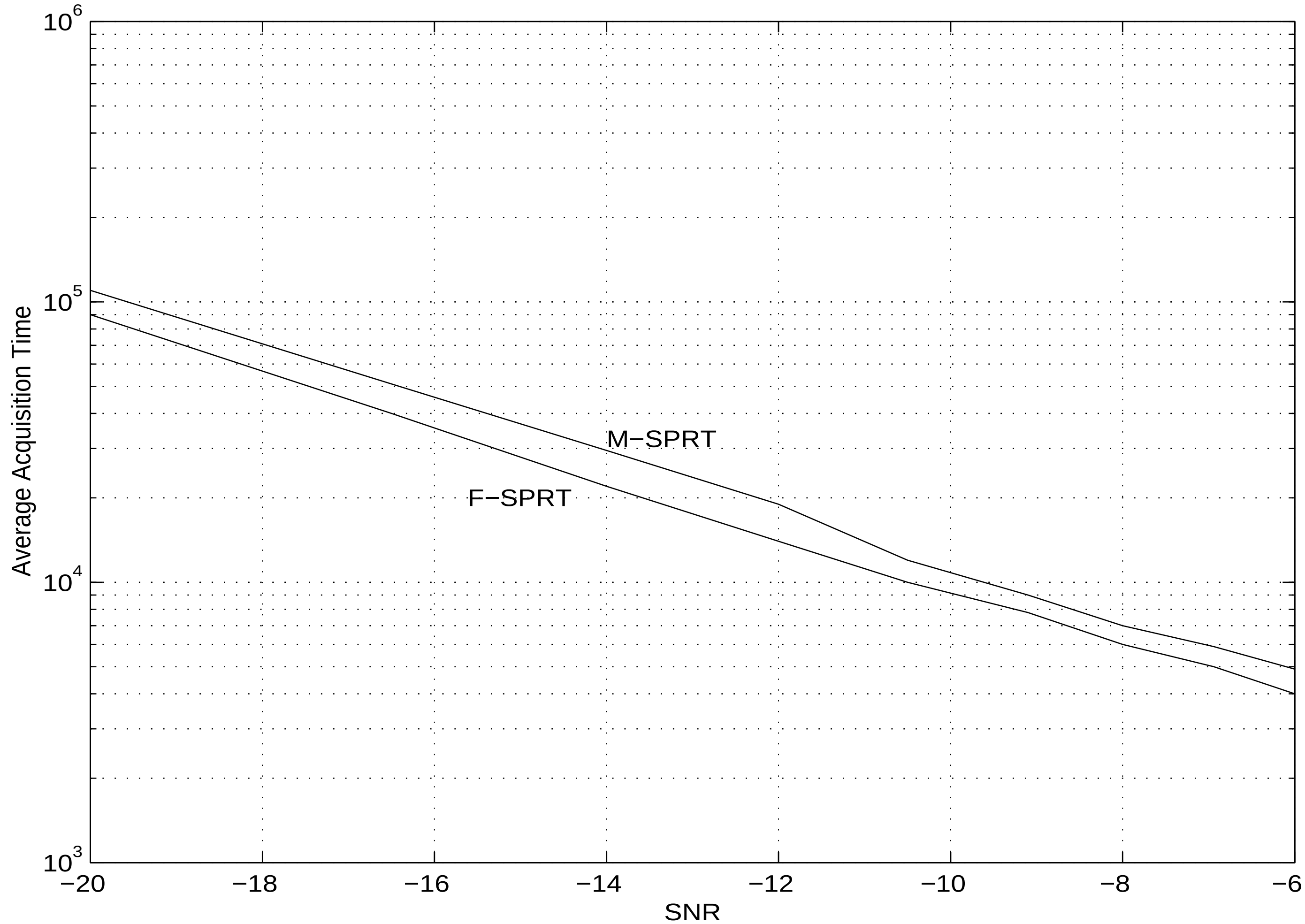
$$\text{F-SPRT:} \quad \frac{E[N]}{-\log(a)} \xrightarrow{\text{a.s.}} \frac{1}{\max_{i \neq j} D(f_i, f_j)}$$

where $D(f, g)$ is the Kullback-Leibler distance between f and g.

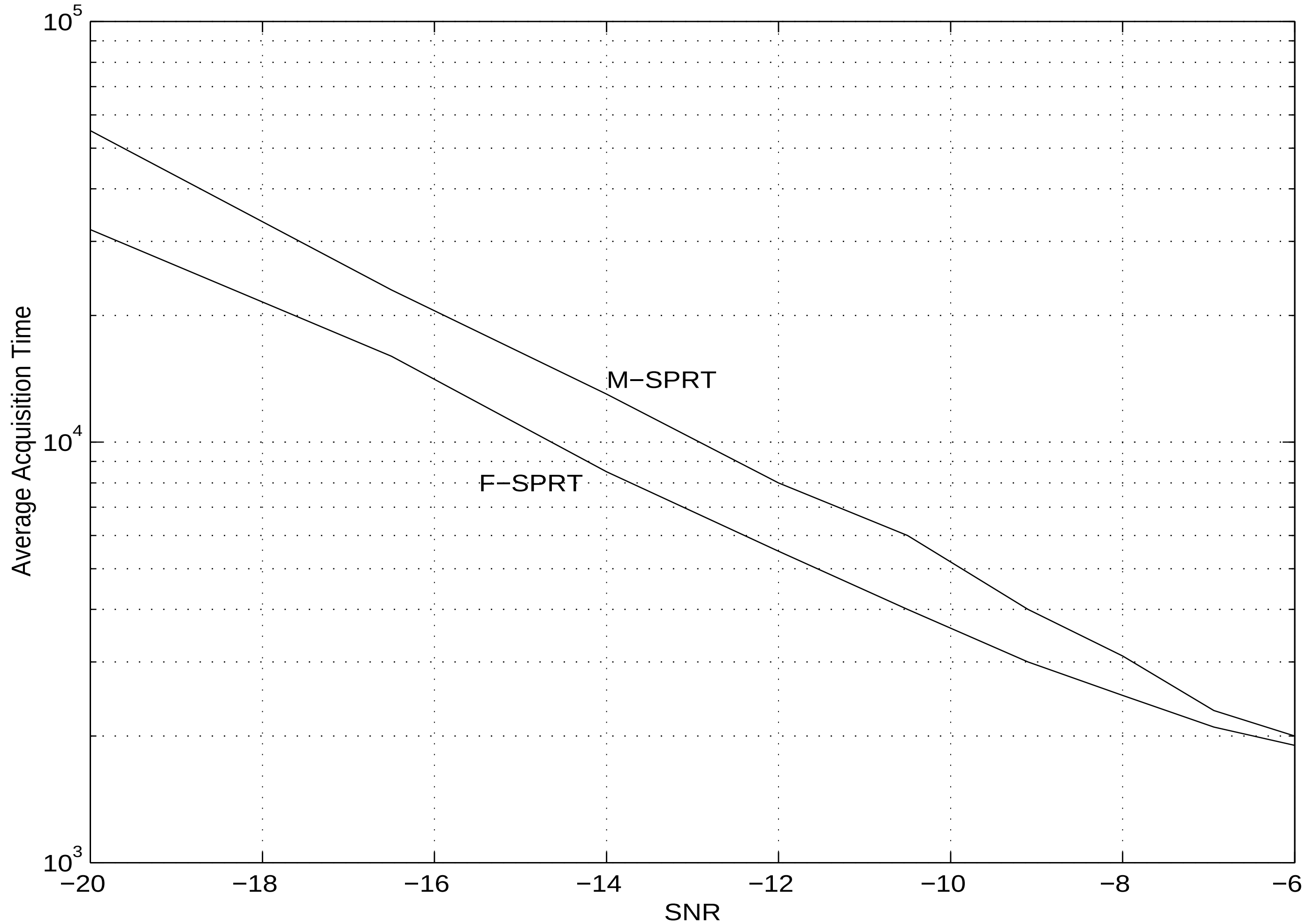
Problem(?): For our acquisition problem,

$$\min_{i \neq j} D(f_i, f_j) = \max_{i \neq j} D(f_i, f_j)$$

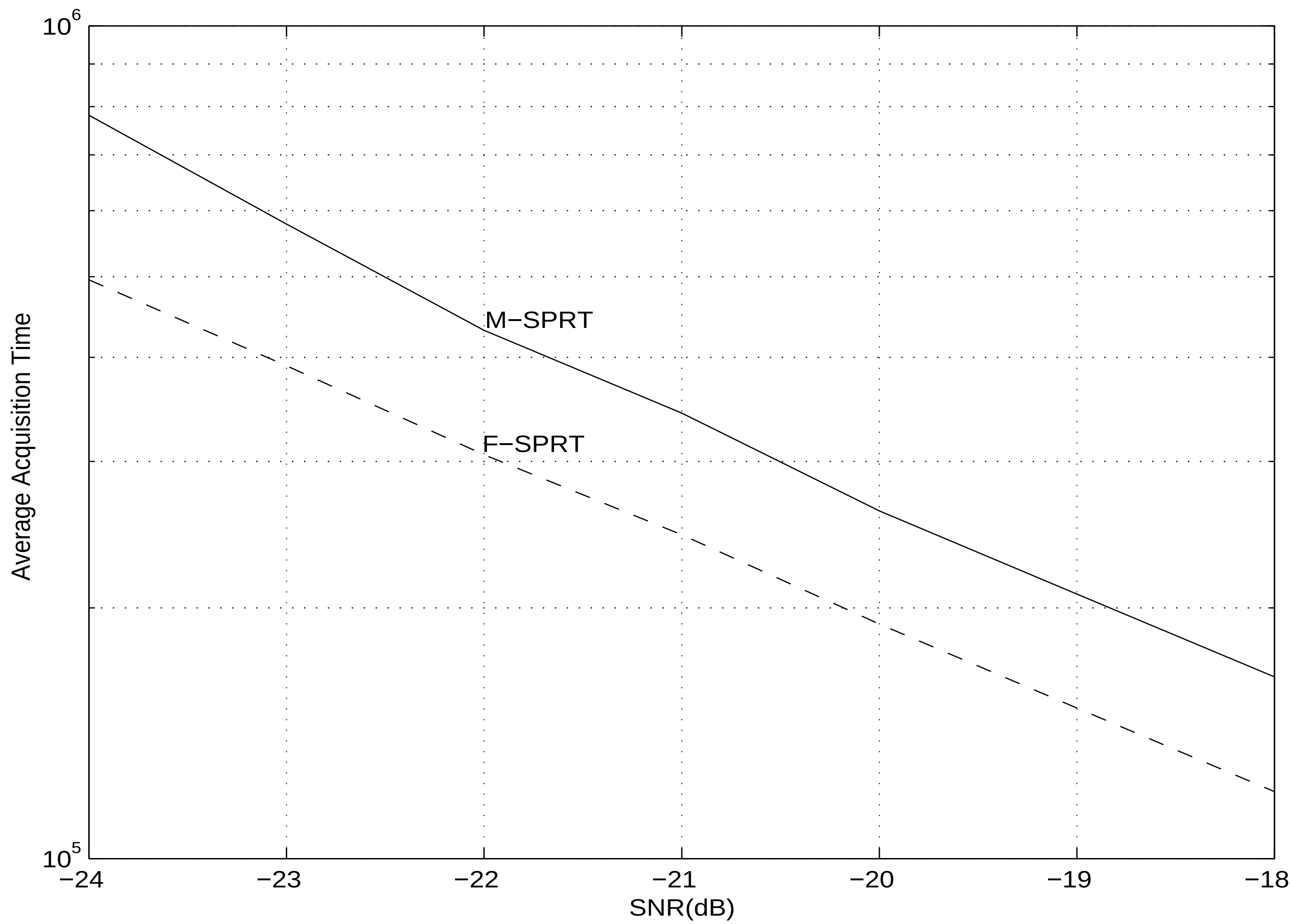
Numerical Results (M=5), DS-SS



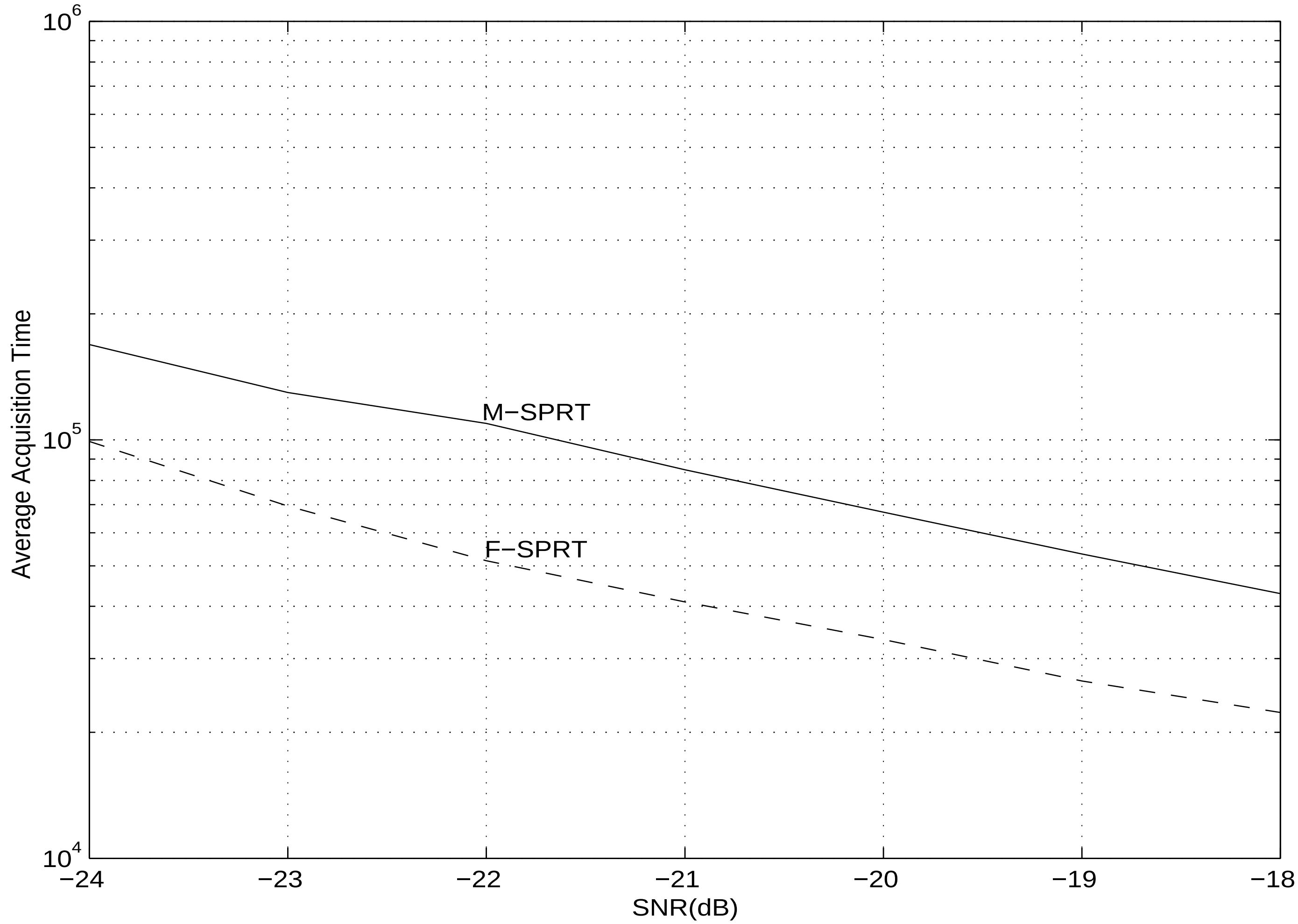
Numerical Results (M=21), DS-SS



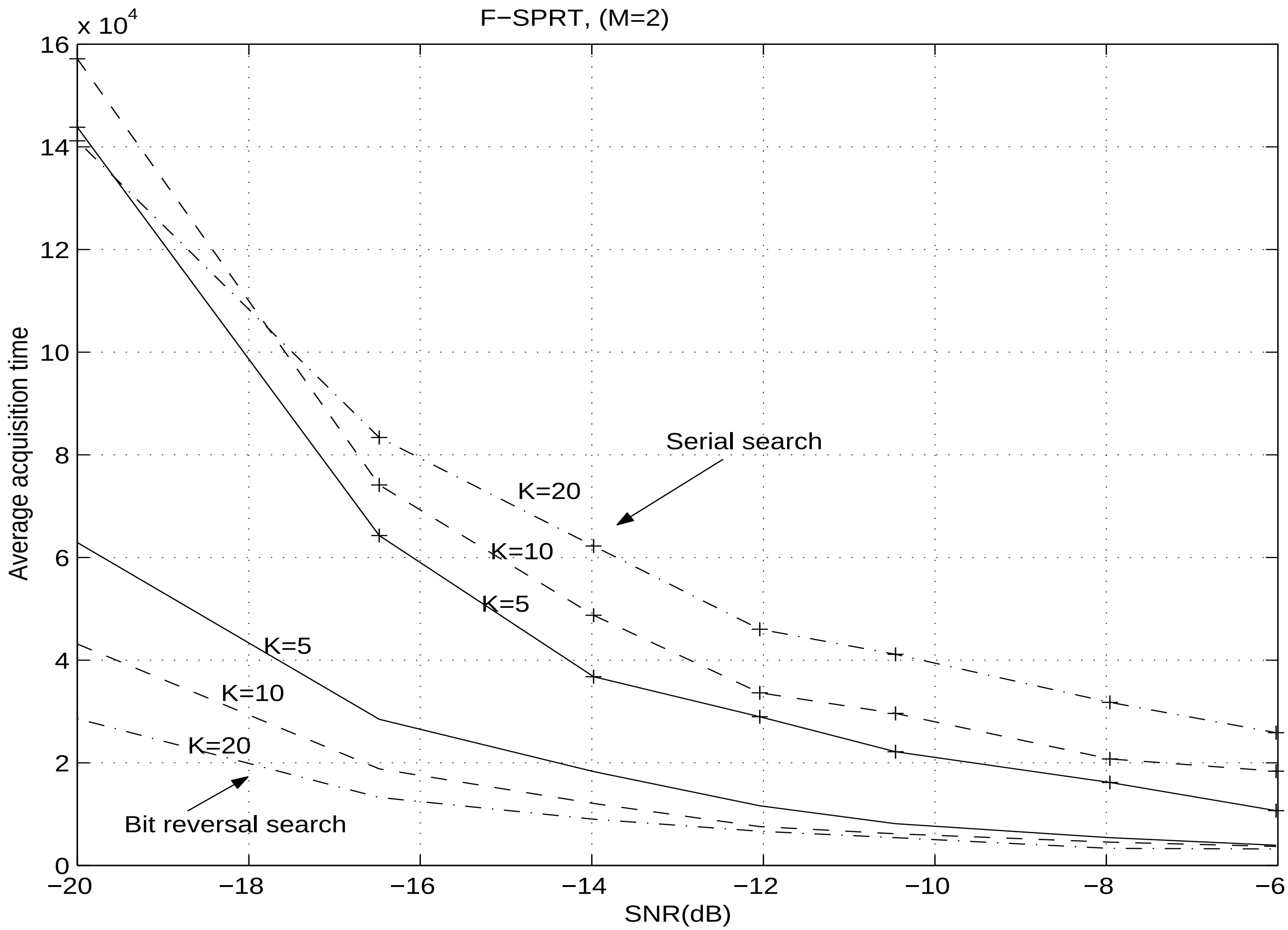
Numerical Results (M=5), Impulse



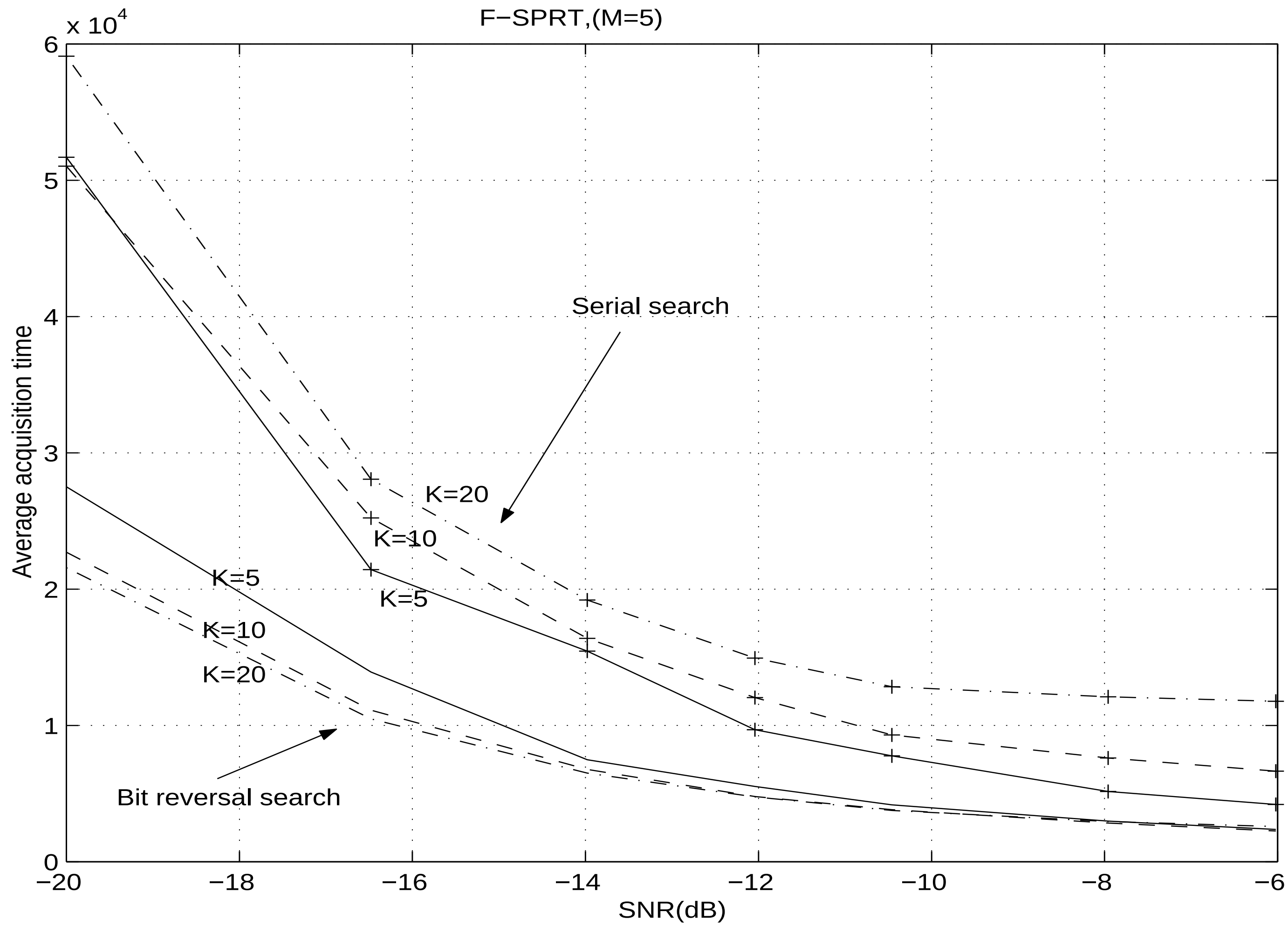
Numerical Results (M=21), Impulse



Numerical Results (Multipath Aided, M=2)



Numerical Results (Multipath Aided, M=5)



Analysis

Proposed scheme shows significant gains for:

1. Large numbers of correlators.
2. Low pre-processing SNRs.

Both will hold in UWB systems that require fast acquisition in almost all environments, and it degrades to the M-SPRT when assumptions are violated.

Further work:

- Practice: Include finite wordlength front-end.
- Theory: Is this the minimal acquisition time test?

Current Work: Receiver Design

Interest is in interference-rejecting receivers for highly-oversampled low-resolution front-ends to combat:

1. Multi-user interference:
   (a) Quasi-synchronous: approach of (Yang and Giannakis,2002), acquisition and finite wordlength effects.
   (b) Asynchronous
2. Multipath fading to which we are not locked.
3. Non-System Interference:
   (a) Known sources
   (b) Unknown sources