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Feasibility of the MUSIC Algorithm for the Active Protection System

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Abstract

This report compares the accuracy of the doppler frequency of an incoming projectile with the use of the MUSIC (multiple signal classification) algorithm to the use of the fast Fourier transform (FFT) when applied to an active protection system (APS). Two simulated files and one measured data file were evaluated. The processing time with the MATLAB® software for the FFT is on the order of milliseconds, while for the MUSIC algorithm, it is on the order of seconds with similar accuracy. Therefore, the FFT is recommended for the application to an APS within the specified accuracy.

Contents

Figures

Table

1. Introduction

An active protection system (APS) requires accurate knowledge of the doppler frequency of an incoming projectile. In this report, I consider two methods of computing the doppler frequency—the multiple signal classification (MUSIC)[1] algorithm and power spectral density (PSD) with the use of fast Fourier transform (1024-point FFT). Normally, MUSIC has been used to improve the resolution of multiple closely spaced targets. In this application, MUSIC is used to estimate accurately a single doppler frequency. In this report, I compared the results of the estimation of the doppler frequency of an assumed head-on projectile using PSD and the MUSIC algorithm; I wanted to determine whether the MUSIC algorithm performs better than PSD in terms of accuracy and processing time. These calculations were applied to three data files in this study. Each of these (X1 and X3) had 128 samples, which were synthesized and sampled at 33 ms. The X1 data were synthesized assuming a 30-dB signal-to-noise ratio (SNR), and the X3 data were synthesized assuming a 10-dB SNR. The third was a measured data set obtained in December 1998 called F16dec.dat. For more information about how these data were collected, please contact Wolfgang Wiebach at the Army Research Laboratory.[2] The data for this data file were sampled at 2 μs. There were 625 samples.

2. Simulation Results

I ran the simulation for all three data files. All the calculations were computed by a Pentium II 400 MHz PC, with the use of MATLAB® software. Figures 1, 2, and 3 present the graphs of this data. Figures 4, 5, and 6 show the output of PSD with the use of FFT. In these figures, the peaks are the estimate of the doppler frequencies in kHz. Figures 7, 8, and 9 are the results of the MUSIC calculations. Again, the peaks from these MUSIC pseudospectra are the estimated doppler frequencies.

Table 1 shows the comparison of processing time and the estimated frequencies. We see that both FFT and the MUSIC algorithm give the same estimated doppler frequency within 0.1 percent. However, the MUSIC algorithm required much more processing time than the FFT calculations for all three data files.

[1]Ralph O. Schmidt, "Multiple emitter location and signal parameter estimation," *IEEE Trans. Antennas Propag.*, AP-34, No. 3 (March 1986), pp 276–280.

[2]Personal communication.

Figure 1. Simulated response for X1 data at 30-dB SNR.

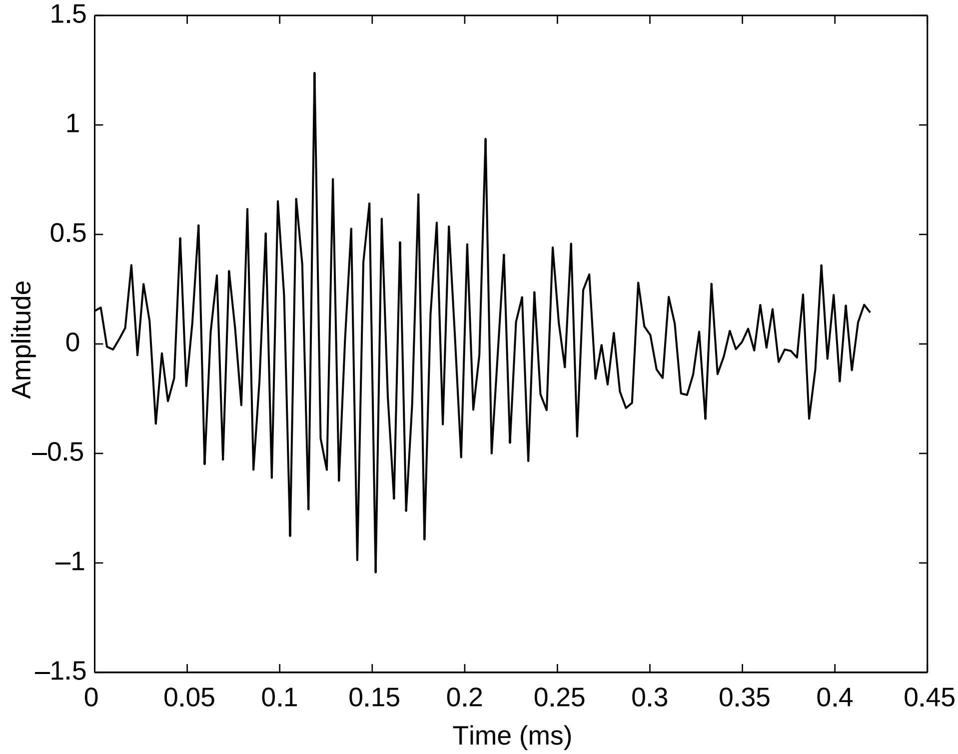

Figure 2. Simulated response for X3 data at 10-dB SNR.

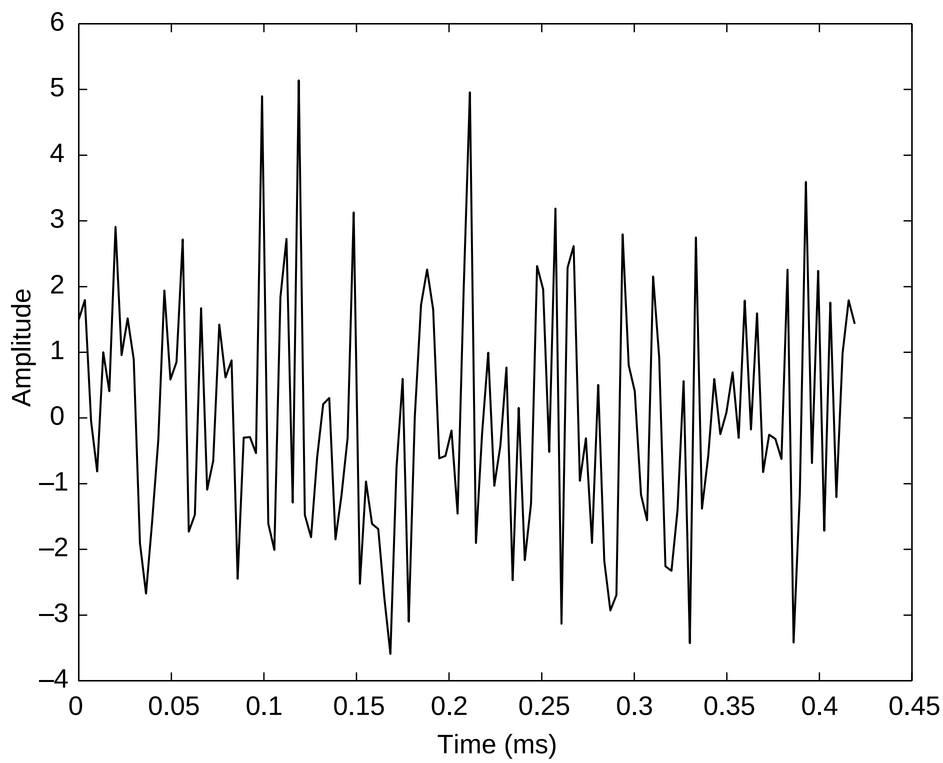

Figure 3. Measured response for F16dec.dat.

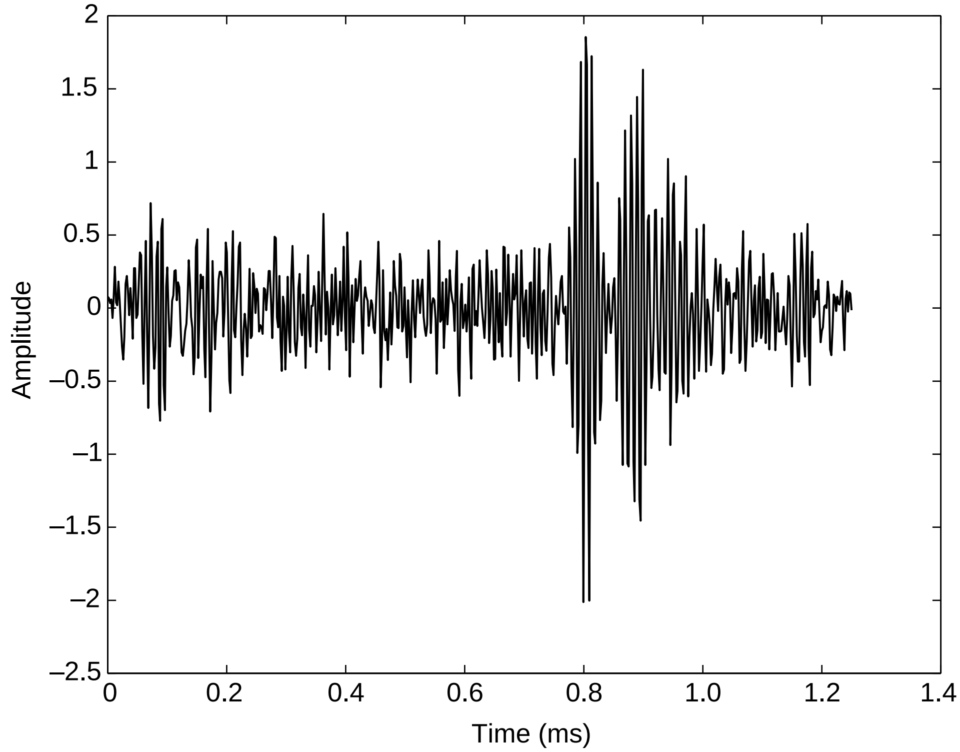

Figure 4. Power spectral density for X1 data at 30-dB SNR.

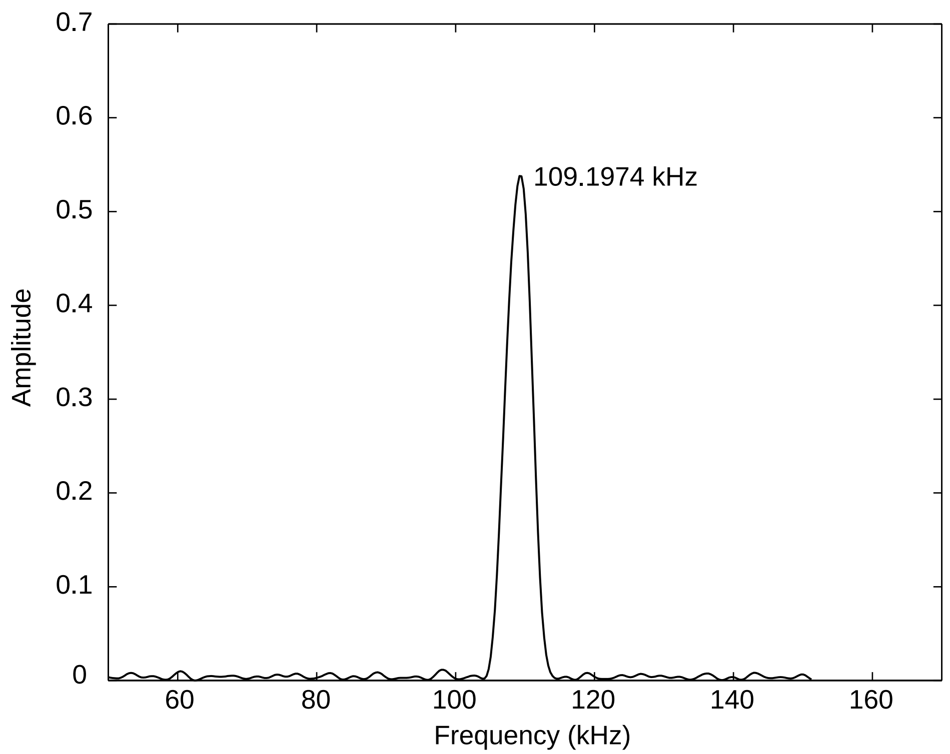

Figure 5. Power spectral density for X3 data at 10-dB SNR.

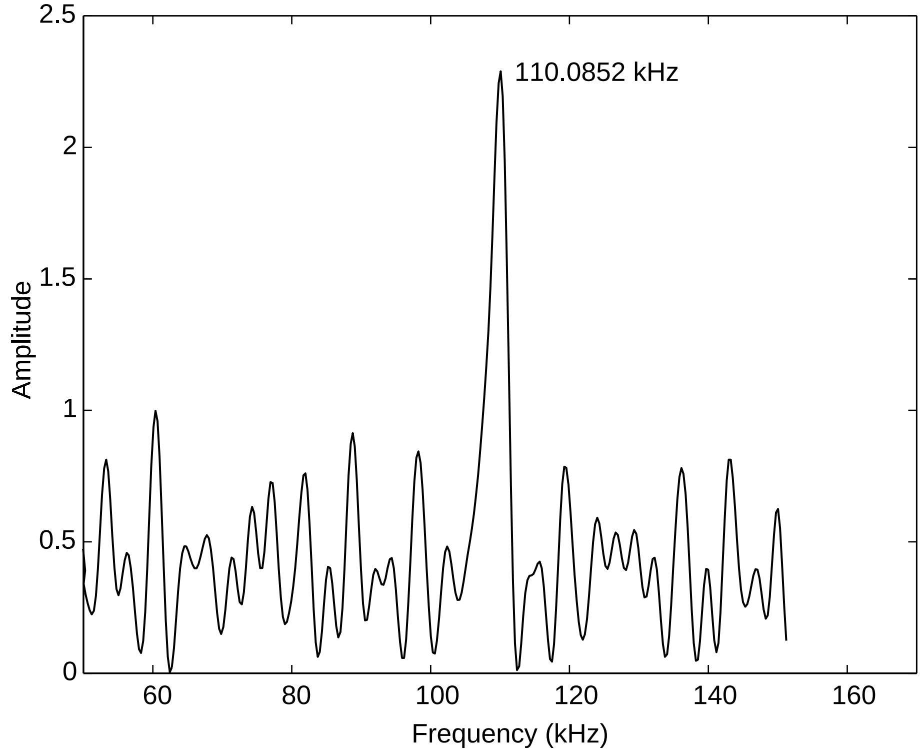

Figure 6. Power spectral density for F16dec.dat.

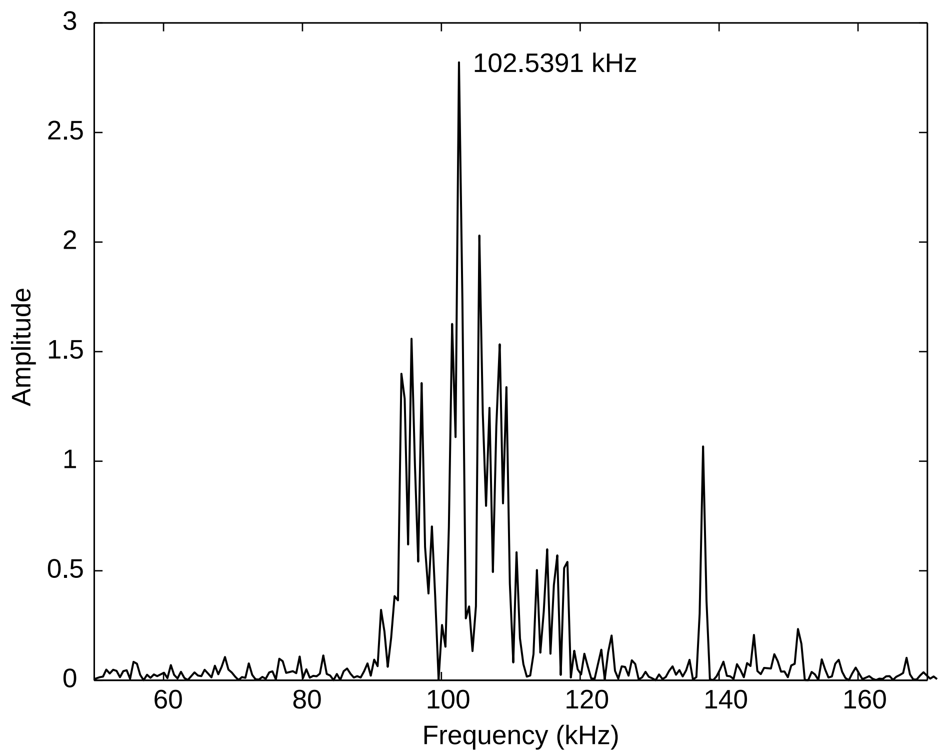

Figure 7. MUSIC result for X1 data at 30-dB SNR.

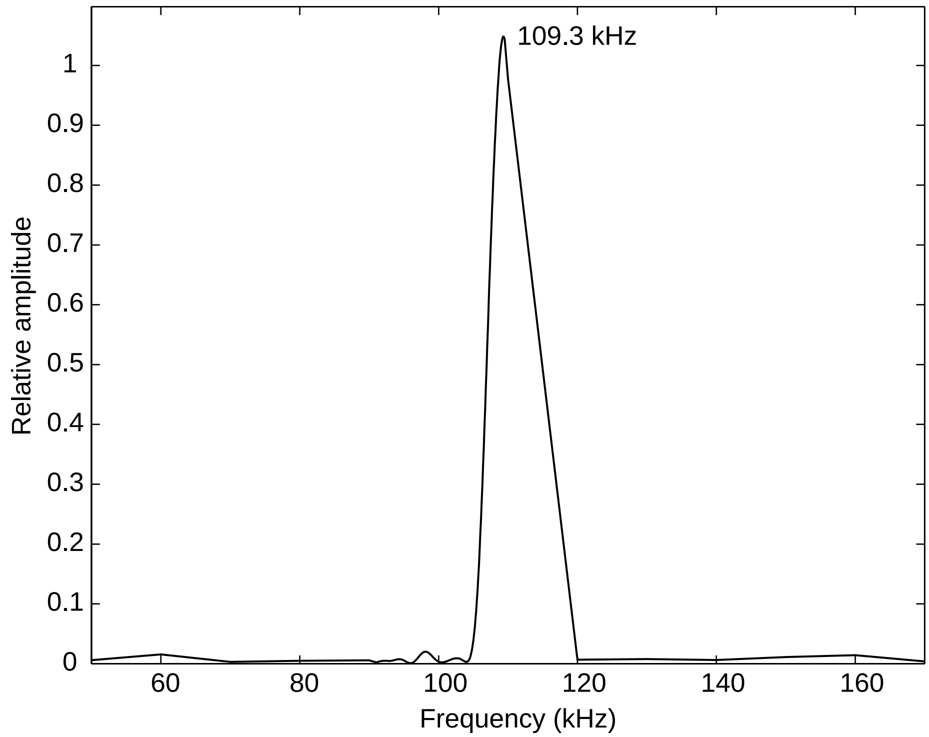

Figure 8. MUSIC result for X3 data at 10-dB SNR.

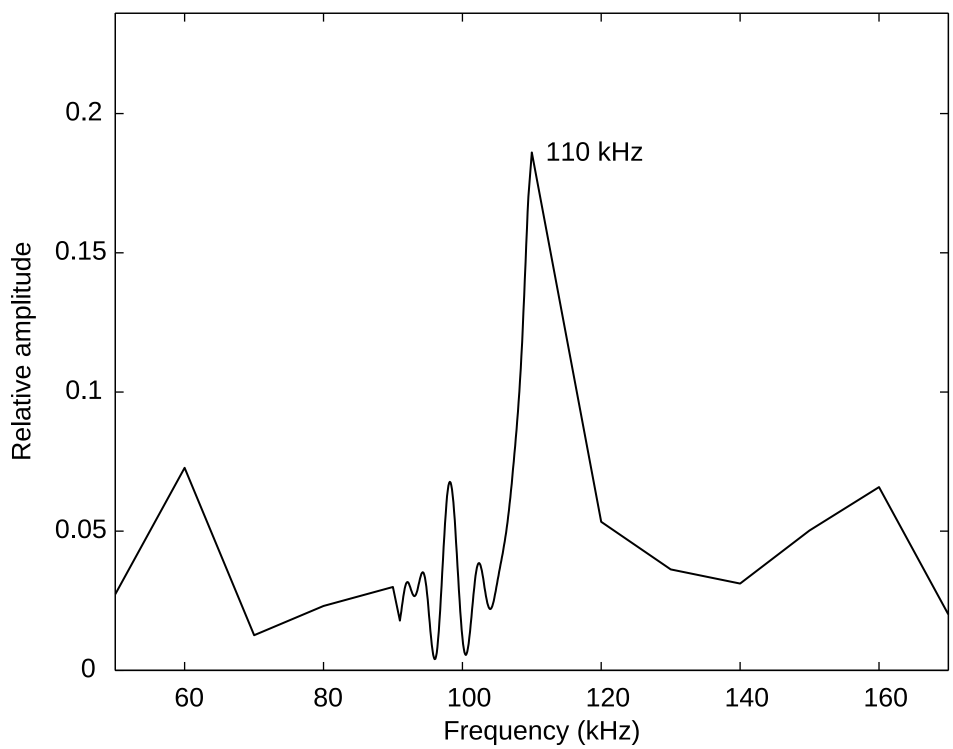

Figure 9. MUSIC result for F16dec.dat.

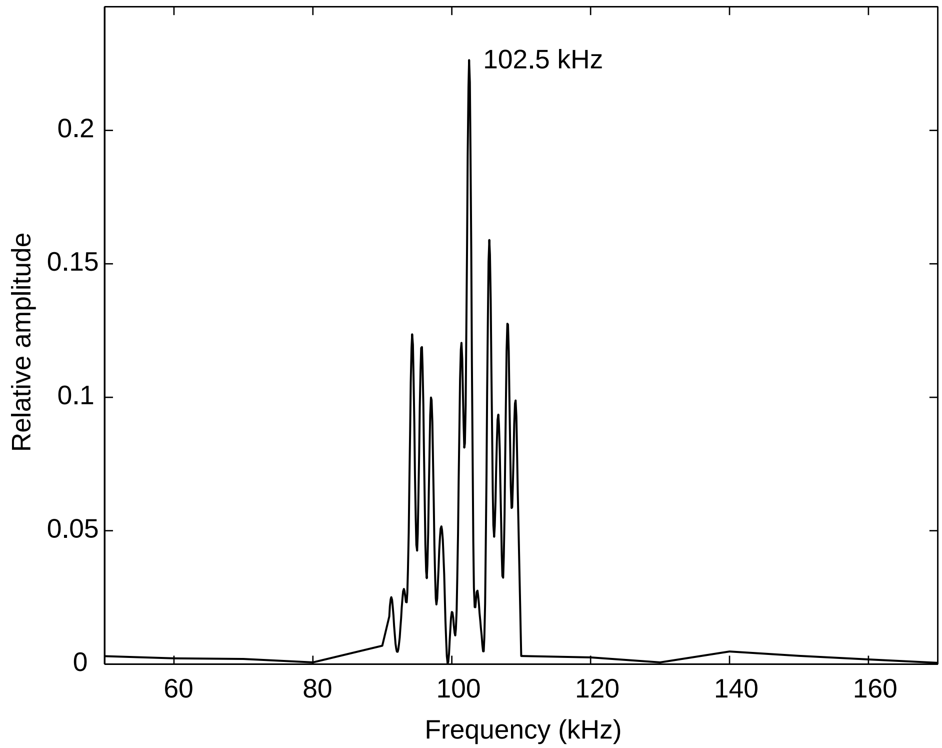

Table 1. Comparison of FFT and MUSIC algorithm.

	FFT		MUSIC	
Data file	Doppler frequency (kHz)	Time for calculation (s)	Doppler frequency (kHz)	Time for calculation (s)
X1	109.20	0.011	109.3	1.121
X3	110.09	0.012	110.0	1.152
F16dec.dat	102.54	0.011	102.5	43.79

3. Conclusions

I have shown the accuracy of the estimation of doppler frequency and the processing time for the APS with the use of PSD with 1024-point FFT and the MUSIC algorithm. The accuracy of doppler frequency estimates with the use of both PSD and MUSIC is within 0.1 percent of each other. However, with the requirement of an APS (fast speed and short processing time), I would recommend the use of PSD for this application rather than its counterpart.

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