EXTENTION OF THE MUSIC ALGORITHM TO AM-FM SIGNALS

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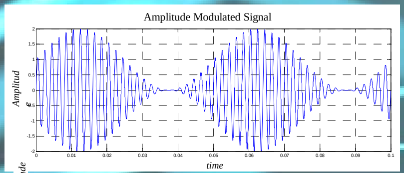
ABSTRACT

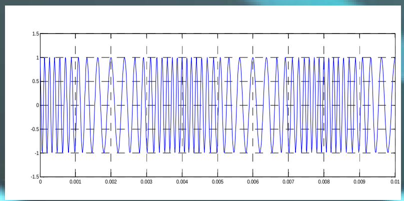
The goal of this project is to extend the stationary MUltiple SIgnal Classification (MUSIC) algorithm to non-stationary Amplitude and Frequency Modulated (AM-FM) signals.
Classical approaches to amplitude and frequency estimation assume a stationary data model, i.e., both the amplitude and frequency of the signal are constant and do not vary with time. Non-stationary harmonic signals are, however, ubiquitous in various applications such as speech, music, seismic, radar, sonar, and biology. We are particularly interested in biological applications. Recent studies in cell biology have shown that a number of cell types respond to external stimulation by encoding cellular information in their amplitude (AM) and frequency (FM).

FORMS OF ANALOG MODULATION

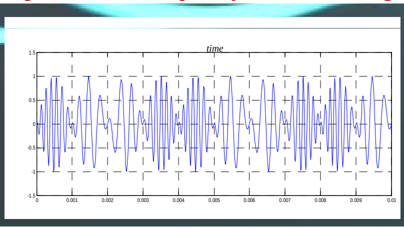
Amplitude Modulated Signal



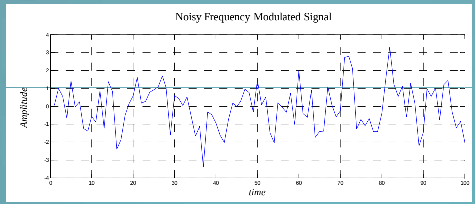
Frequency Modulated Signal



Amplitude and Frequency Modulated Signal



THE EFFECT OF NOISE



THE STATIONARY MUSIC ALGORITHM

The MUSIC algorithm gives a high-resolution (higher than the spectrum) estimation of frequency parameters based on the eigendecomposition of a given stationary signal

$$x[n] = \sum_{i=1}^{p} A_i e^{j(\omega_i n + \varphi_i)} + w[n]$$

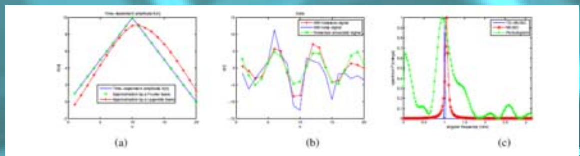
THE PROPOSED AM-FM MUSIC ALGORITHM

Our approach relies on a basis decomposition of the time-dependent amplitude and frequency signals. We show that the introduction of a basis representation reduces the non-stationary estimation problem to a stationary one.

AM MUSIC

$$x[n] = \sum_{i=1}^{p} A_i e^{j(\omega_i[n] + \varphi_i)} + w[n]$$

$$\omega_i[n] = \sum_{k=1}^{M} d_{i,k} f_k[n]$$

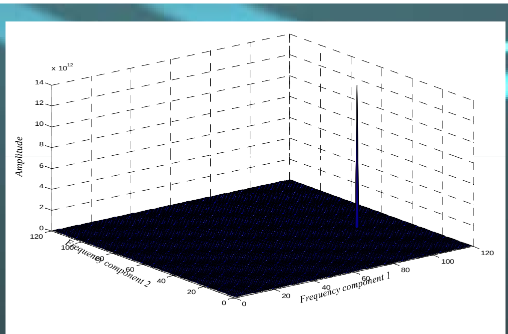


(a) The Time-dependent amplitude $A[n]$ and its Fourier and Legendre basis representations; (b) The pure sinusoidal signal, its noiseless AM modulated version, and its noisy AM modulated version with SNR = 0 dB; (c) The TD-MUSIC pseudo-spectrum, the MUSIC pseudo-spectrum, and the periodogram of the noisy AM modulated signal.

FM MUSIC

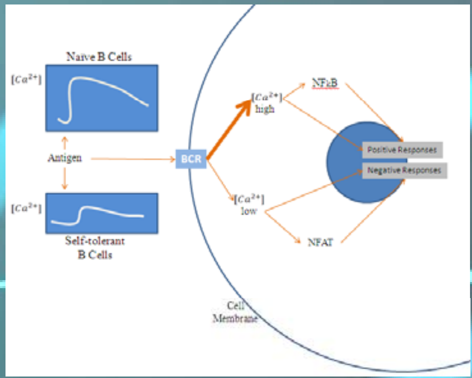
$$x[n] = \sum_{i=1}^{p} A_i e^{j(\omega_i[n] + \varphi_i)} + w[n]$$

$$\omega_i[n] = \sum_{k=1}^{M} d_{i,k} f_k[n]$$



BIOLOGICAL APPLICATION

The proposed algorithm will be assessed using the AM-FMN calcium signaling response in lymphocite cells [1]. AM-FM signaling modes can help us detect the deleterious processes in cancerous cells, for which there is a discrepancy in either the amplitude or the period of the gene's expressions between normal and cancerous cells.



CONCLUSIONS AND FUTURE RESEARCH

- Similarly to the stationary case, the AM and FM MUSIC have higher resolutions (in terms of frequency separation) than the non-parametric time-frequency decomposition methods.
- The next step is to develop the AM-FM MUSIC algorithm.
- We will, subsequently, investigate the statistical properties of the amplitude and frequency estimates by computing their respective Camer-Rao lower bounds (CRLB).

ACKNOWLEDGEMENT

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REFERENCES

[1] M.J. Berridge, "The AM and FM of Calcium Signalling" *Nature*, vol. 386, pp. 759-760, 1997.