

Grey Systems Theory Application to Wireless Communications

Mr. Ashwin Amanna – Virginia Tech

Dr. Kay Thamvichai – Saint Cloud State University

Mr. Matthew Price – Virginia Tech

Grey Systems Theory Application to Wireless Communications

Can an obscure family of algorithms have application to Cognitive Radio?

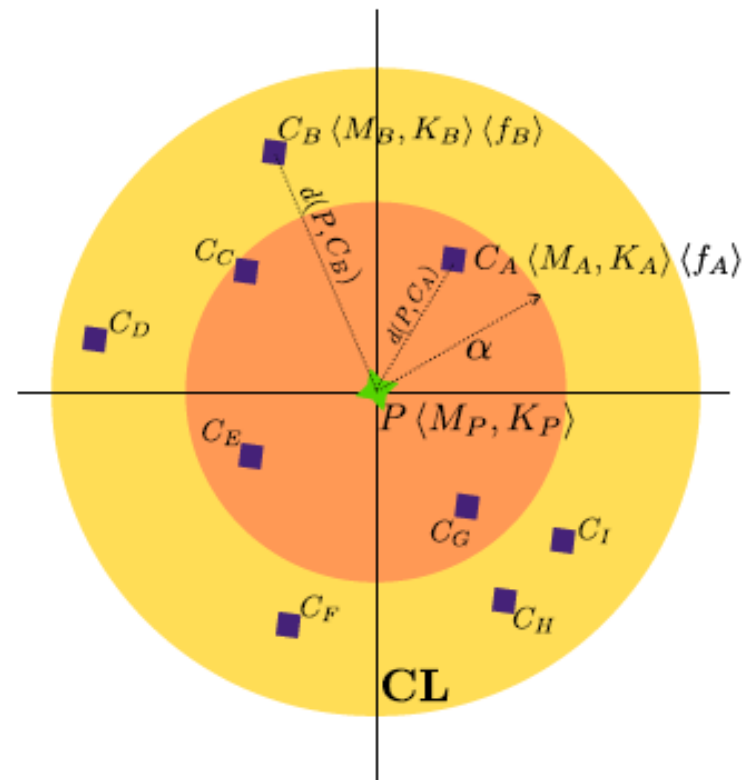
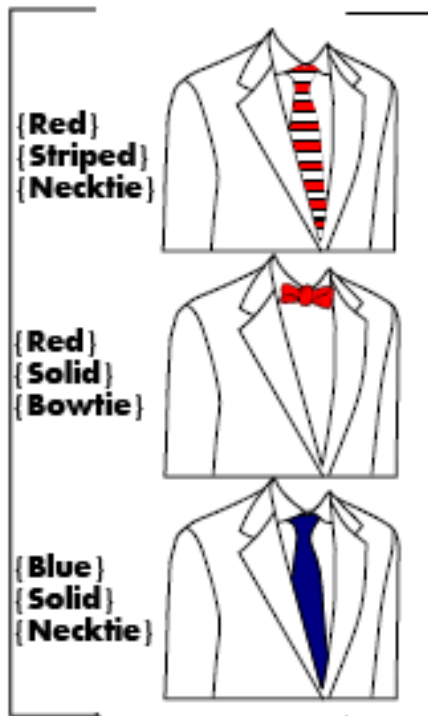


Two Current Needs in CR

- Similarity Quantification for Case Based Reasoning
 - CBR base decision engines sink or swim based on how good they measure similarity
- Automatic Modulation Classification
 - Observe Orient Decide Act
 - Key capability: Recognize incoming or enemy signals

Grey Relational Analysis (GRA)

- Algorithm for quantifying 'distance' aka similarity between a reference vector and an observed vector



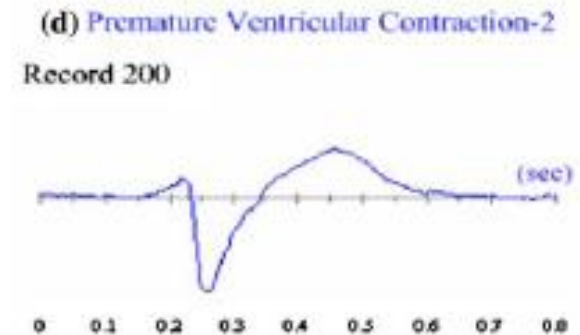
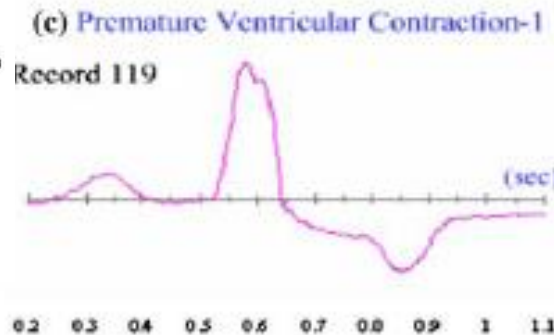
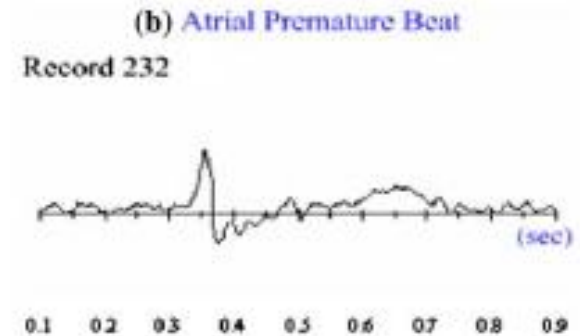
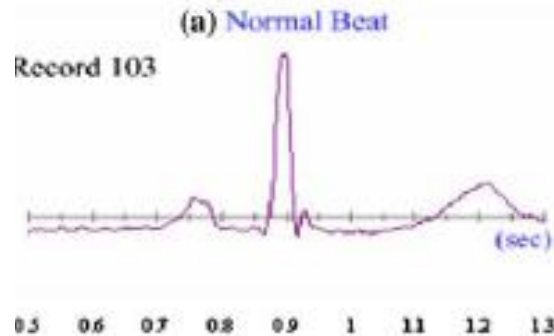
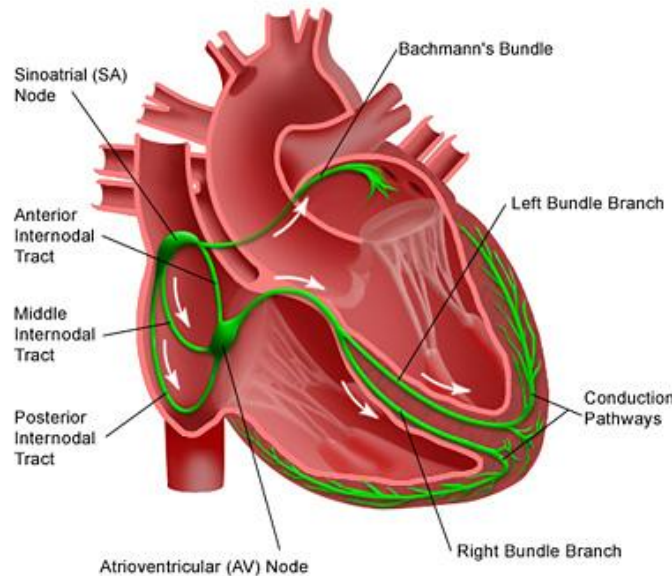
What makes it different?

- Several methods for quantifying distance – such as Euclidean Distance (ED)
- GRA adds a twist to simple ED
- GRA incorporates a relational aspect between all the elements within your reference library

$$r(k) = \exp \left[\xi \left(\frac{ED(k)}{\Delta\varphi_{max} - \Delta\varphi_{min}} \right)^2 \right]$$

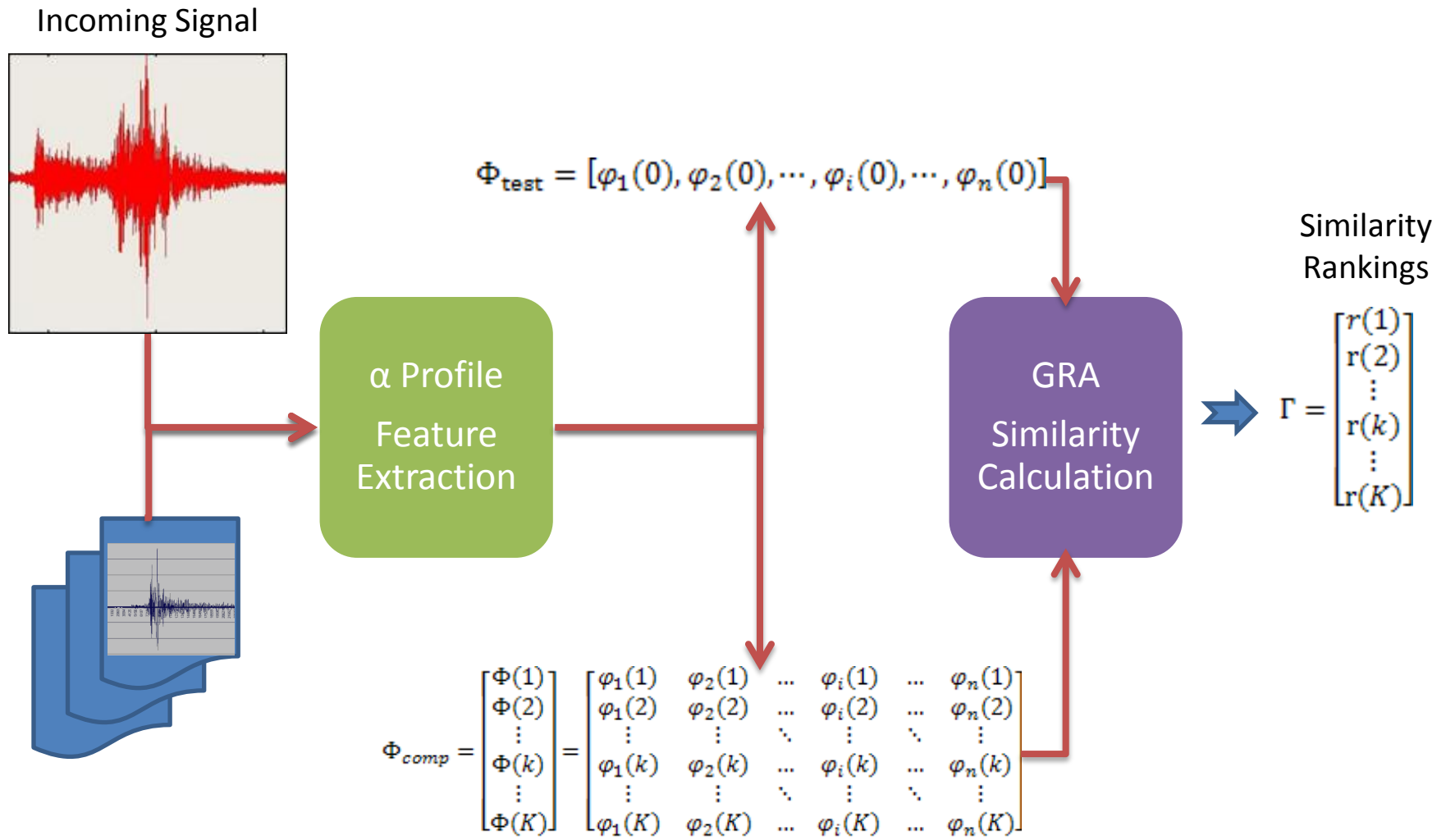
Used for Identifying Cardiac Arrhythmia

Electrical System of the Heart



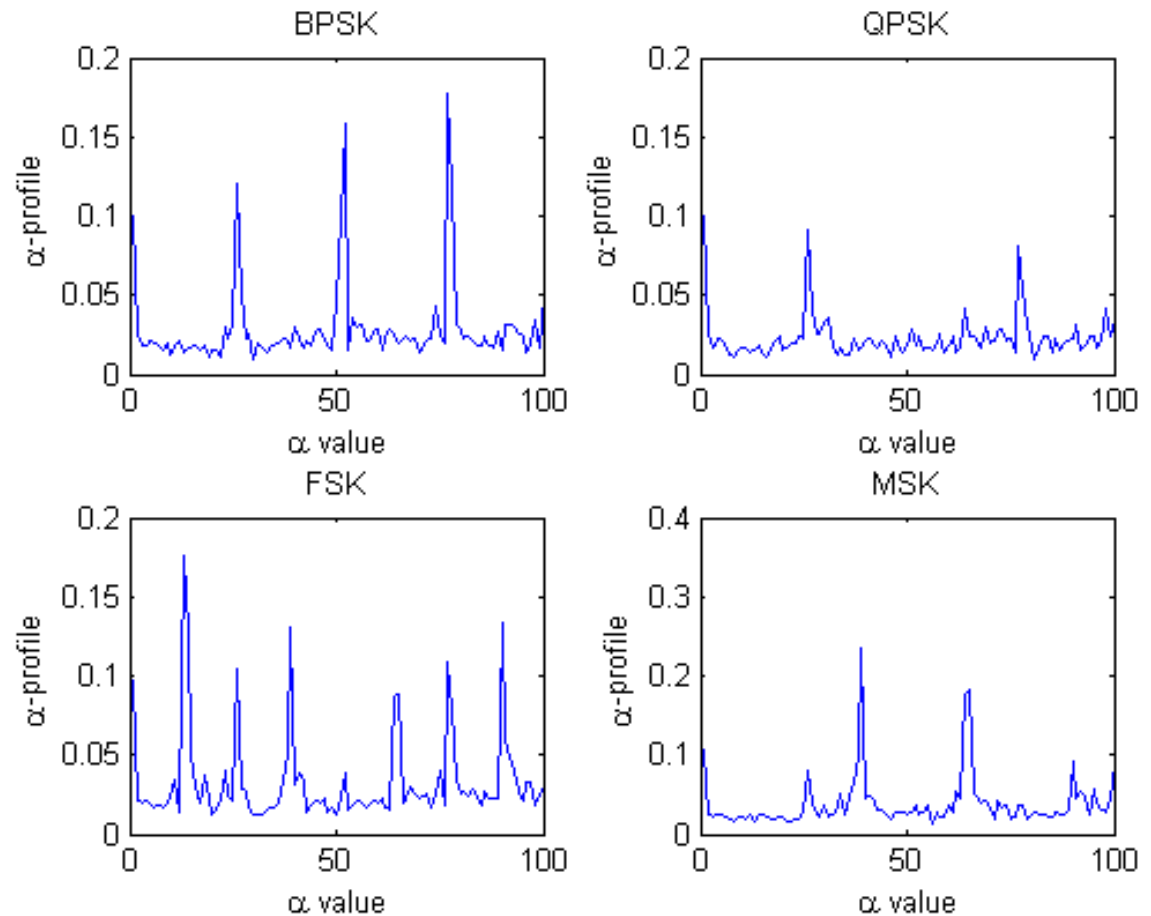
<http://afibcryoablation.com>

- C.-H. Lin, Y.-C. Du, Y.-F. Chen, and T.-S. Chen, "Multiple ECG Beats Recognition in the Frequency Domain Using Grey Relational Analysis," in *Proceedings of the 28th IEEE EMBS Annual International Conference, New York City, 2006*



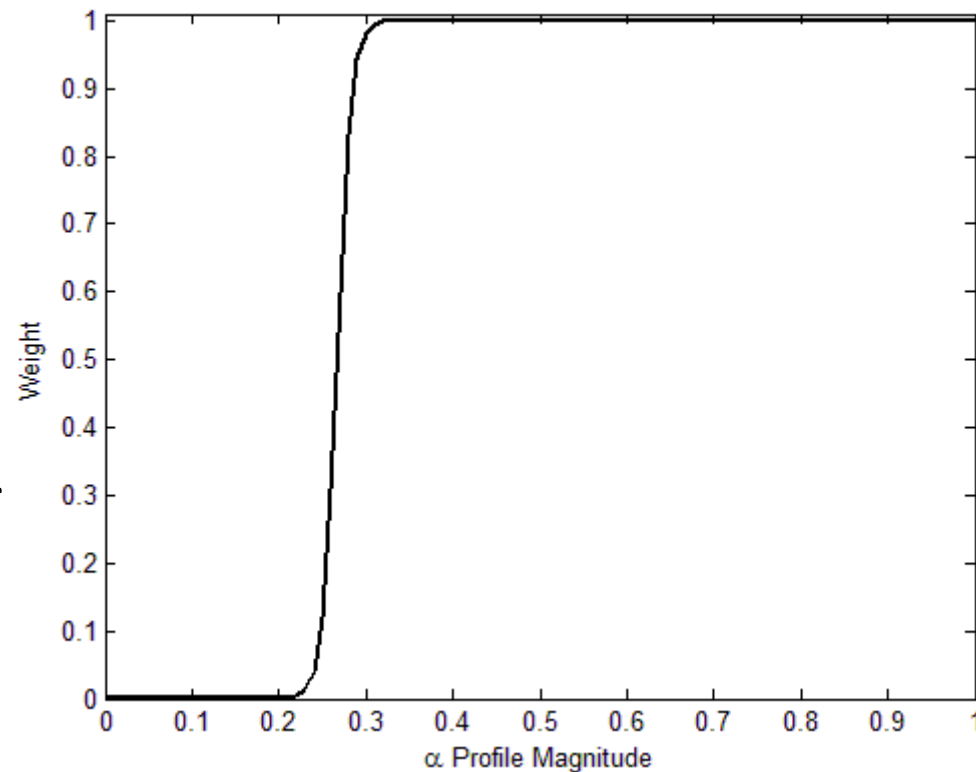
Feature Extraction

- α profile
 - Distinct patterns for different type of digital modulations

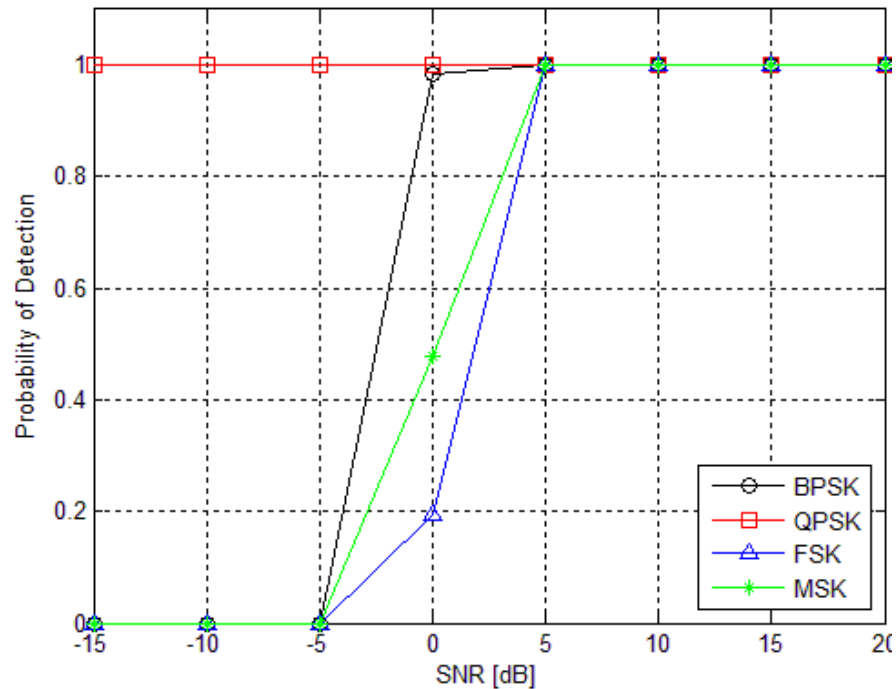


Optional Preprocessing

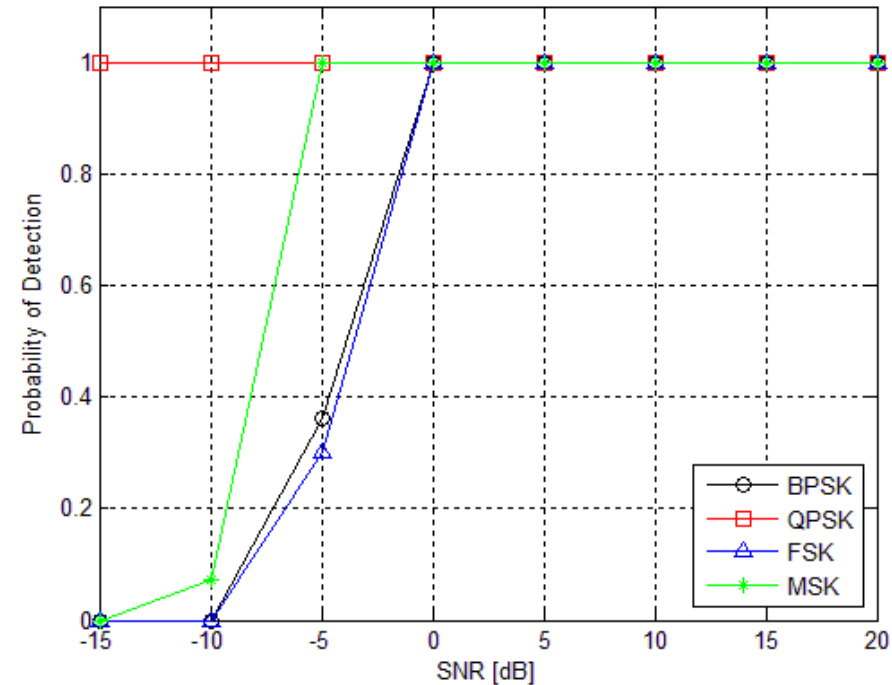
- Normalization
 - Several methods
 - Maximum Value (normalized to highest value)
- Weighting
 - Increase importance of the peaks



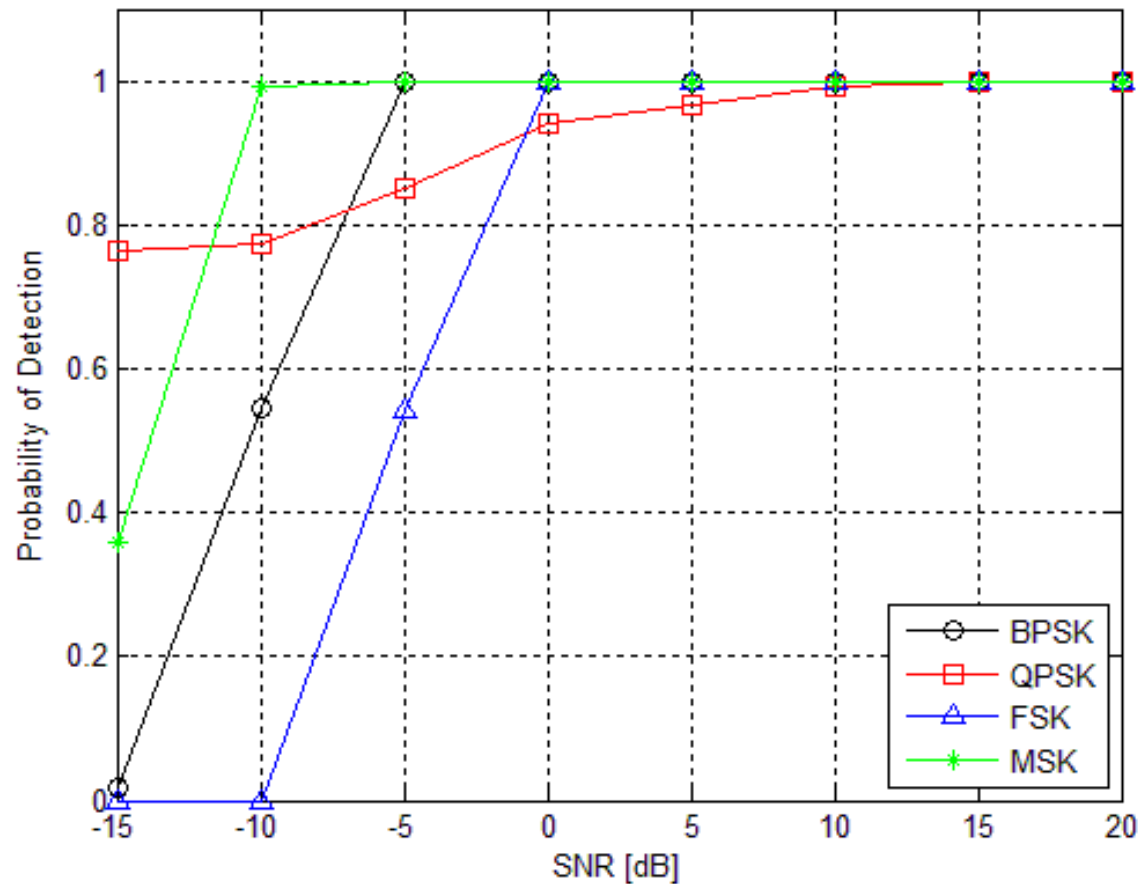
No Modifications



Normalized



Normalized and Weighted



- Confuses BPSK for QPSK

Table 2 GRA-based AMC Confusion Matrix

$\begin{matrix} \text{Tx} \\ \text{Rx} \end{matrix}$	BPSK	QPSK	FSK	MSK
BPSK	1229	0	0	0
QPSK	33	1200	0	22
FSK	0	0	1178	118
MSK	0	0	0	1220

Grey Relational Values: Received BPSK Signal

SNR	BPSK	QPSK	FSK	MSK
10 dB	0.8602	0.1357	0.0025	0.0016
5 dB	0.6941	0.2888	0.0102	0.0069
0 dB	0.5819	0.3912	0.0148	0.0120
-5 dB	0.2995	0.6326	0.0434	0.0244

Limitations

- Current method assumes known Carrier frequency
- Pre-processing required
- Need a method for incorporating offset in carrier frequencies between reference library and received signal

Future Research

- Multi-level decision making
- Separate out I and Q and perform GRA on those vectors
- Improve weighting scheme
- Compare against different normalization schemes
- Incorporate GRA in CBR cognitive engine