Blind Digital Modulation Classification based on M^{th}-Power Nonlinear Transformation

Vincent Gouldieff[1,2], Jacques Palicot[1], Steredenn Daumont[2]

[1]CentraleSupelec/IETR, Rennes, France
[2]Zodiac Data Systems/Zodiac Aerospace, Caen, France

December 9, 2016

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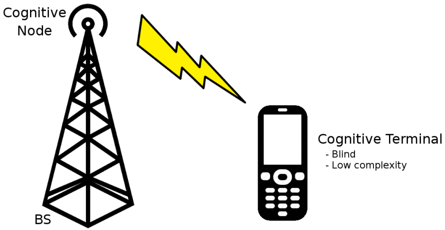
Motivation

- Cognitive Radio Context



- Cognitive Node
  - Senses its environment
  - Decision: $C \in \mathcal{C}$
- Cognitive Terminal
  - **Blind** estimation of C
  - No prior knowledge
  - **Low complexity**

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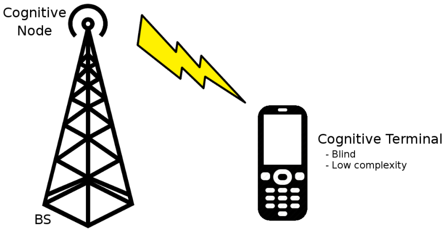

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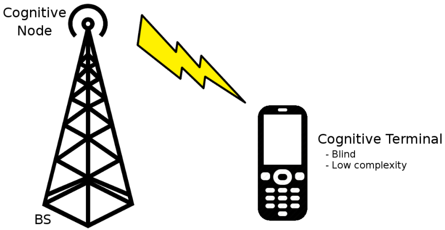

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Motivation

Is the "M^{th}-Power Nonlinear Transformation" a good candidate for the estimation of C?

Agenda

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- AMC: a short Review
- System Model & Assumptions
- Basics on M^{th}-Power Transform (MPT)
- Computation of the References
- Performance and Complexity
- Conclusion and Perspectives

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Automatic Modulation Classification [1]

[1] O. A. Dobre et al., Survey of AMC Techniques: Classical Approaches and New Trends, *IET Communications, 2007*

Automatic Modulation Classification [1]

Likelihood-based [2]

Feature-based [3]

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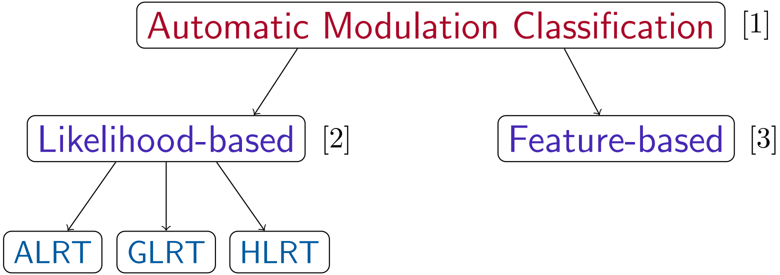

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AMC: a short Review

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- Automatic Modulation Classification [1]
  - Likelihood-based [2]
    - ALRT
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    - Statistics
    - Mom.-Cumul. [4]
    - CMs-CCs [5]

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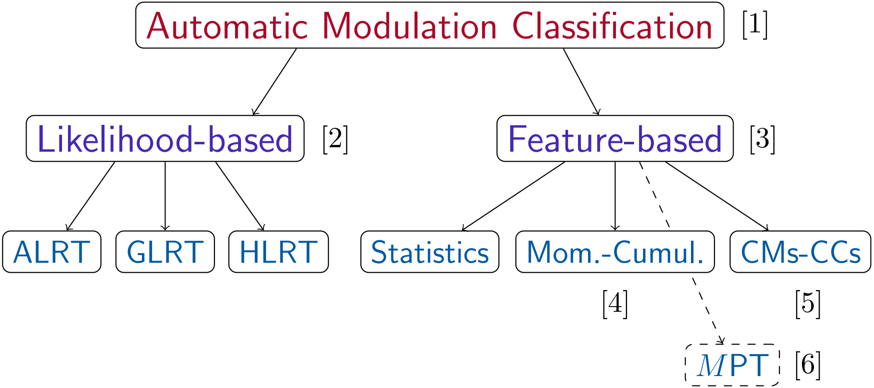

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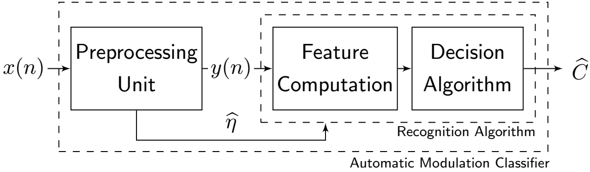
System Model

- Scheme of **Feature-based** AMC



- Single-carrier digital signal in AWGN

$$x(n) = a \cdot e^{i\cdot(2\pi f_r \cdot n+\phi)} \cdot \sum_k s(k) \cdot h(nT_e - kT - \tau) + \omega(n)$$

- No synchronization/demodulation
- No prior knowledge

$\rightarrow$ **Blind** & **Robust** AMC method

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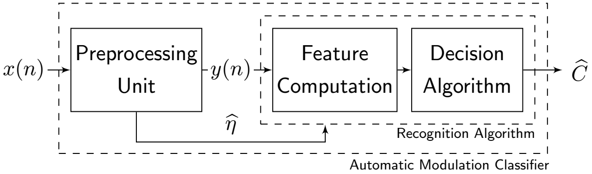

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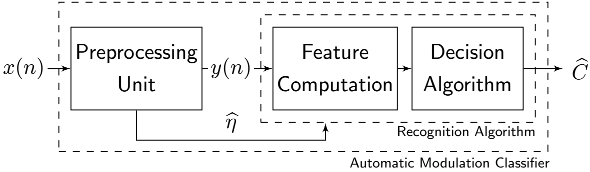

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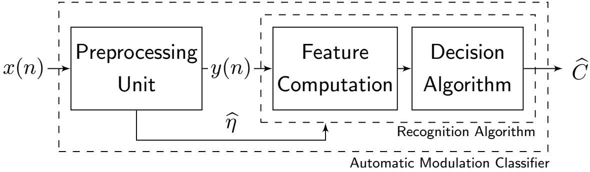

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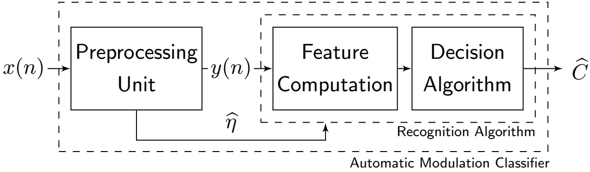

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System Model

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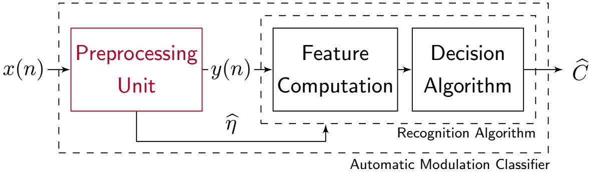
Preprocessing Unit: some details



Based on 1PT (classical PSD):

- Normalization step: $y(n)$ has unit useful power ($a = 1$)
- Spectral centering: $f_r \approx 0$
- Output parameters: $\widehat{\eta} = \{\widehat{\sigma}_\omega^2, \widehat{\rho}, \widehat{\beta}, \ldots\}$

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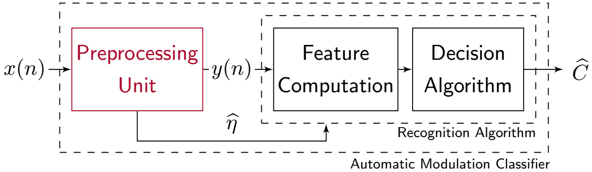

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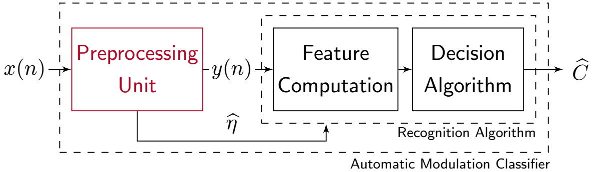

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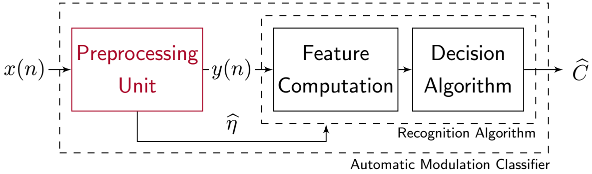

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Basics on MPT

- MPT function:

$$\mathrm{MPT}_y(f) = \left| \frac{1}{N_s} \cdot \sum_{n=0}^{N_e-1} y^M(n) \cdot e^{-2i\pi n f} \right|^{\frac{2}{M}} = \sqrt[M]{\Gamma_n \left[y^M \right](f)}$$

$$CM_y^{n,p,\boldsymbol{\tau}}(f) = \frac{1}{N_s} \cdot \sum_{n=0}^{N_e-1} \prod_{i=1}^{n} y^{(*)_i}(n+\tau_i) \cdot e^{-2i\pi n f}$$

- Behavior:

$\rightarrow$ **Minimum Distance** Classification

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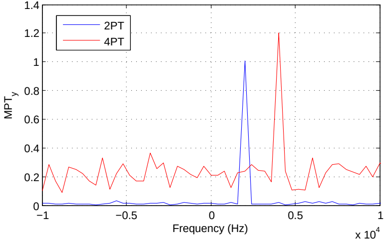

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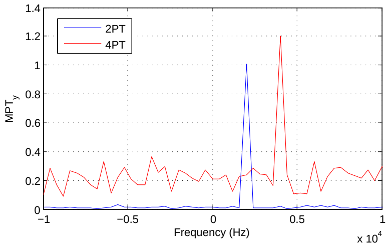

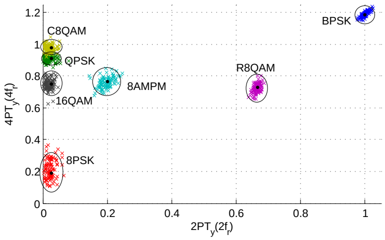

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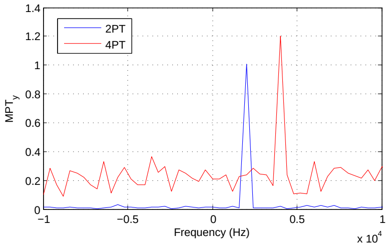

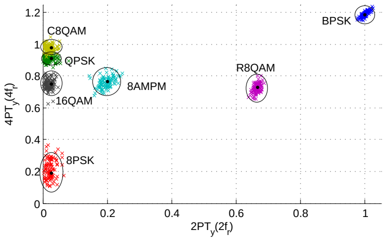

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References

- **Asymptotic:** Poisson Summation Formula [7]

$$\sum_{n=-\infty}^{+\infty} g(t+na) = \frac{1}{a} \sum_{m=-\infty}^{+\infty} G\left(\frac{m}{a}\right) \cdot e^{i2\pi f \frac{m}{a} t}$$

- Theory for $M = 2$:

$$2\mathrm{PT}_{th}^{C} = \left|\mathbb{E}[s^2] H_2(0)\right|$$

- Theory for $M = 4$:

$$4\mathrm{PT}_{th}^{C} = \left|\frac{1}{T}\left(\mathbb{E}[s^4] H_4(0) + 6\left(\mathbb{E}[s^2]\right)^2 \sum_{k>0} H_{22}^{(k)}(0)\right)\right|^{\frac{1}{2}}$$

- **Distributions** for accurate references (or corrective terms)

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Theory and **Simulation** results

- Distance Matrix

- Correct Classification Rate (CCR)

		Constellation						
		BPSK	QPSK	8PSK	8AMPM	R8QAM	C8QAM	16QAM
Constellation	BPSK	0	1.004	1.419	0.905	0.564	0.988	1.055
	QPSK		0	0.761	0.219	0.656	0.068	0.159
	8PSK			0	0.639	0.861	0.829	0.602
	8AMPM				0	0.468	0.268	0.161
	R8QAM					0	0.677	0.629
	C8QAM						0	0.227
	16QAM							0

- PSK/QAM/PAM
- 35% Root-Raised-Cosine

- 1024 symbols
- $\rho = 2$
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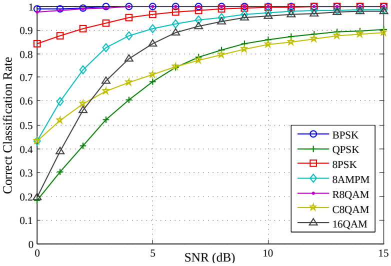

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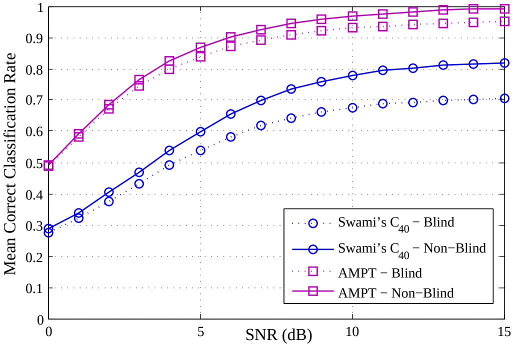
Performance and Complexity

Comparison between M**PT** and **Cumulant**-based classification



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  - More robustness to noise/uncertainty
  - Low complexity (FFTs)

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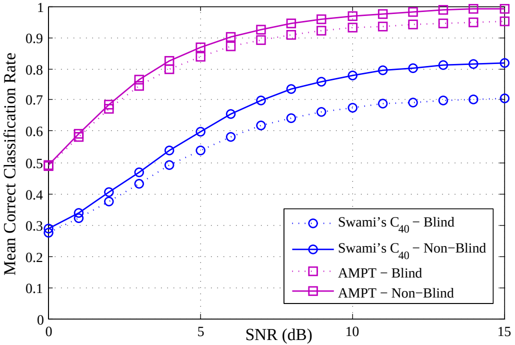

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This work:

- MPT = great tool for AMC (but not only!)
- Basic theory
- Blind performance

Future work:

- Distributions & theoretical CCR
- Other contexts (channel, interference,...)

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