T6 - Intelligent Mobile Terminal

T6.3. : Source separation and classification
CORRIDOR  COgnitive Radio for Railway through Dynamic and Opportunistic spectrum Reuse.

Sub-task 6.3  Source Separation and Classification

Objective

Development of Automatic digital Modulation Recognition (AMR) algorithms

Responsible

IEMN

Partners

IFSTTAR

UBO-Lab-STICC
Automatic Modulation Recognition (AMR): Why?

Coexistence of different wireless technologies ➔ Opportunistic use of the radio-frequency spectrum ➔

Spectrum Detection

"Classical" spectrum sensing

- Binary detection (presence/absence of primary users)

"Advanced" spectrum sensing (AMR, code detection...)

- Identification of standards in presence
- Security (PU emulation detection by SU)
- Blind demodulation (Military)
Automatic Modulation Recognition (AMR): How?

System Block Diagram

- Input symbols
- Modulation
- Channel
- Classifier sub-systems
- Features extraction sub-system
Outline of the presentation

– Expertise in AMR at the beginning of the CORRIDOR project

– Main contributions
  • Multiple antennas (MIMO) context
  • MIMO and high mobility context
  • MIMO, high mobility and impulsive noise context

– Conclusion and perspectives
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Automatic Modulation Recognition Using Wavelet Transform and Neural Network

CWT: Continuous Wavelet Transform
HOM: High Order Moment
Full-class AMR performance

**Modulation Recognition Scenarios**

- Inter-class Recognition
- Intra-class Recognition
- Intra-class & Inter-class (Full-class) Recognition

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<th>QAM32</th>
<th>QAM64</th>
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SNR=4dB, AWGN channel

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AMR in spatially-correlated MIMO context (1/2)

Received signal: \( \hat{y}(n) = H \hat{x}(n) + \tilde{b}(n) \)

AMR in spatially-correlated MIMO context (2/2)

- BSS (Source separation) → SCMA algorithm

SCMA: Simplified Constant Modulus Algorithm

\[ z(n) = \hat{x}(n) = W^T y(n) \]
\[ = W^T H x(n) + \tilde{b}(n) \]

\[ \min_w J_{SCMA} = \sum_{i=1}^{N_t} E \left\{ (\Re(z_i(n))^2 - R)^2 \right\} \]

s.t. \( W^H W = I_{N_t} \)

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MIMO 2x4
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PhD S. Kharbech

« Application de la radio intelligente dans le contexte ferroviaire : identification aveugle du type de modulation pour les canaux à grandes vitesses »

April 2012 – March 2015
MIMO and high mobility context (1/4)
Evaluation of the previous approach over high mobility
(Rayleigh channel with Jakes Doppler spectrum)

ANN is trained to take into account the variation of both
SNR and velocity

MIMO and high mobility context (2/4)
- Source separation using sliding window (SW-SCMA)
- Multi ANN

SW-SCMA: Sliding Window SCMA
MIMO and high mobility context (3/4)

Source separation using sliding window (SW-SCMA)

\[ \mathcal{L} = \psi f_s T_c \]

\[ \mathcal{L}_{\text{SW-SCMA}}^{*} = \psi_{\text{SW-SCMA}}^{*} f_s T_c \]

\[ \psi_{\text{SW-SCMA}}^{*} = \arg \max_{0 < \psi \leq \frac{n_s}{f_s T_c}} \frac{\sum_{i \in \theta} \theta_i}{\sum \theta_i} \]

Multi ANN

Training according to multi SNR ranges

\[ \mathcal{L}_{\text{SNR}}^{*} = \psi_{\text{SNR}}^{*} f_s T_c \]

\[ \psi_{\text{SNR}}^{*} = \arg \min_{0 < \psi \leq \frac{K}{f_s T_c}} \mathbb{E} \left( (\hat{\rho} - \rho)^2 \right) \]

SNR estimation based on eigenvalues decompositon of the received signal covariance matrix.
MIMO and high mobility context (4/3)
- Results

\[
\theta' = \{\text{B-PSK, Q-PSK, 8-PSK}\}
\]
\[
\theta'' = \{\text{B-PSK, Q-PSK, 8-PSK, 4-ASK, 8-ASK, 16-QAM}\}
\]
MIMO 2 × 6

Blind Digital Modulation Identification for Time-Selective MIMO Channels,
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MIMO, high mobility and impulsive noise context

Origin of impulsive noise
MIMO, high mobility and impulsive noise context
Proposed AMR

\[ y(n) = H(n)x(n) + b(n) \]
\[ b \sim CS_{\alpha S_\alpha}(\gamma, 0) \]

“Multiple-Antennas Based Blind Spectrum Sensing in the Presence of Impulsive Noise”
IEEE TVT, 2013.

Blind estimation of \( \alpha \)-stable noise (\( \alpha \) and \( \gamma \) parameters)

\[
\hat{\beta} = \arg\min_{\beta \in \{x(i)\}_{i=1}^N} \prod_{i=1}^N \left\{ k^2 + |x(i) - \beta|^2 \right\}
\]

\[
k = \sqrt{\left( \frac{\alpha}{2 - \alpha} \right)^{1/\alpha}}
\]

- SW-SCMA
- Estimation de \( k \) et filtrage MyS
- Fusion des d\'écisions
- Exaction ANN des HOS
- Exaction ANN des HOS
- Detection Modulation

Workshop final – Villeneuve d’Ascq – 25 juin 2015
MIMO, high mobility and impulsive noise context

- Results

\[ \theta' = \{ \text{B-PSK, Q-PSK, 8-PSK} \} \]
\[ \theta'' = \{ \text{B-PSK, Q-PSK, 8-PSK, 4-ASK, 8-ASK, 16-QAM} \} \]
MIMO 2 × 6, \( T_s f_e = 20 \)

"Blind AMC for Time-Selective MIMO Channels over Impulsive Noise environment", under submission.
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Conclusion and perspectives (1/2)

• Achievements
  – Reinforced and new partnerships
  – Development of new AMR algorithms dedicated to high-speed railway communications
  – Dissemination (journal publication, seminars and conferences)
  – 1 PhD

• Perspectives
  – Projects in progress with some partners (Region, ANR, CPER)
  – Towards a complete blind demodulator
  – Wideband AMR (OFDM)
  – Intelligent Mobile Terminal ➔ intelligent sensing
Conclusion and perspectives (2/2)
AMR in MIMO relaying broadcast channels