Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

INPT: C. Poulliat, N. Thomas, M.-L. Boucheret CNES: E. Bouisson and G. Lesthievent

charles-ugo.piat@tesa.prd.fr

Thesis Defense, November 27, 2018







Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Table of Content

Introduction

System Model CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Table of Content

Introduction

System Model CPM scheme Detection

NC TB receiver MAP versus ML Reduced vs Extended S. S.

NC-Precoding Classical approach Non-coherent precoding design

Sparse graph based code optimization Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Context

- Communication link launcher/ground stations
- Launcher Telemetry System (TM)
 - Position (GPS inertial system), Velocity, Video...
 - Rate $\sim 1 \text{Mbs}$
 - S-band



Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Open issues on the TM communication link

Issues occurring during the rocket flight :

- Disturbed channel (non-coherent)
 - Vibration spreading over the launcher
 - Flame Effects
- Impact on the signal :
 - Phase shift/Phase hopping
- Impact on the system performances
 - Rate losses/Total loss of the communication link
- Solution :
 - Robust modulation methods
 - Continuous Phase Modulations (CPMs)
 - Adequate detector
 - Efficient coding and precoding methods

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Contributions

- Novel non-coherent symbol/MAP receiver.
- Design of precoding enabling efficient decoding.
- Optimization of capacity-achieving codes.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

6/78

Table of Content

Introduction

System Model CPM scheme Detection

NC TB receiver MAP versus ML Reduced vs Extended S. S

NC-Precoding Classical approach Non-coherent precoding design

Sparse graph based code optimization Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

< (고) < (고) < (고) < (고) < (고)
 < (고) < (2)
 <

System Model

Source
$$\xrightarrow{b}$$
 Encoder \xrightarrow{c} \prod $\xrightarrow{c_{\pi}}$ Mapper \xrightarrow{u} CPM Modulator \xrightarrow{s} CPE/MM

Figure: BICM block diagram

- b ∈ GF(2)^{K_b} is encoded into a codeword c ∈ GF(2)^{N_b} using an ECC of rate R = K_b/N_b.
- c is interleaved, mapped into a sequence u = u₀<sup>N_s-1 of N_s M-ary symbols.
 </sup>
- ► u is modulated into s = s^{N_s-1}_{L-1}(t) comprises of M_s distinct waveforms following the considered CPM rule.

Nouvelle forme d'onde et écepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

 Signal s has a constant envelope and a continuous phase. [AAS13][Pro]



Figure: Binary 2GMSK h = 1/2, BT = 0.25 (a.) Amplitude (b.) Envelop.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Its Rimoldi's representation at the kth symbol interval is given as:

$$s_k(\tau) = \sqrt{Es} \cdot x_i(\tau) \cdot e^{j\phi_k}$$
 (1)

 The CPE ensures the phase continuity by accumulating the phase of each symbol.

$$\phi_{k+1} = \phi_k + 2\pi \frac{h}{u_{k-L+1}}$$

The MM maps the L symbols in memory to a continuous-time waveform.

$$x_i(\tau) = \frac{A(\tau)}{\sqrt{T}} \cdot e^{j4\pi h \sum_{n=0}^{L-1} u_{k-n}q(\tau+nT)}$$

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

(2)

(3)

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

► A(τ) is the Rimoldi representation's data independent terms.

$$A(\tau) = e^{j\pi h(M-1)\left(\frac{\tau}{T} + (L-1) - 2\sum_{n=0}^{L-1} q(\tau + nT)\right)}$$
(4)

Index i is given as follows.

$$i = \sum_{n=0}^{L-1} u_{k-n} \cdot M^{L-1-n}$$

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

(5)

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

In expression (1),(2),(3), elements are identified as follows:

- ► *T* the symbol period.
- Es the energy per symbol.
- L the memory of the CPM.
- h the modulation index.
- q(t) the phase response.

$$q(t) = \begin{cases} 0, \\ \int_0^t g(u) du, \\ \frac{1}{2}, \end{cases}$$

 $t \le 0$ $0 < t \le LT$ t > LT

(6)

Nouvelle forme d'onde et écepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

$\mathsf{NC}\operatorname{-}\mathsf{Precoding}$

Classical approach Non-coherent precoding design

Sparse graph based code

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

• g(u) the frequency pulse.

Frequency pulse and Phase response

- Differentiate the various types of CPMs
- Frequency pulse
 - GMSK : Gaussian Pulse
 - RC : Raise Cosine Pulse
 - REC : Rectangular pulse (CPFSK : REC L = 1)



Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

> Charles-Ugo Piat-Durozoi

Introduction

System Model CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Modulation index h and CPM memory L

Modulation index h

- Rational number
- ▶ *h* < 1
- h = P/Q, where P and Q are relatively prime
- Q cardinality of the set of CPM accumulated phases

CPM memory L

- Full response CPM: L = 1
- Partial response CPM: L > 1
- Large L generates large complexity

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

14/78

Impact of H and L on the signal spectrum

- Modulation index h
 - Small values of h generate small bandwidth occupancy.
- CPM memory L
 - Large values of L generate small bandwidth occupancy and small side lobes sizes.



Figure: RC (a.) quaternary L = 3 (b.) binary h = 0.5

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Channel Modelization



Figure: Channel model

The signal undergoes a phase rotation θ and is passed through an AWGN channel. At the kth symbol interval,

$$r_k(t) = s_k(t) \cdot e^{j\theta} + n(t) \tag{7}$$

Here $\mathbf{r} = \mathbf{r}_{L-1}^{N_s-1}$, θ is unknown, constant over a frame and uniformly distributed between $[0, 2\pi]$.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

$\mathsf{NC}\operatorname{-}\mathsf{Precoding}$

Classical approach Non-coherent precoding design

Sparse graph based code

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Matched filters

Sufficient statistics: r_k(t) is passed through a bank of M_s matched filters:

$$\begin{array}{c} r_{k}(t) & \xrightarrow{} & r_{0,k} \\ \vdots & & \\ \hline & & \\ & &$$

Figure: Complex matched filters for a given modulation

▶ $r_{i,k}$ results from the correlation between $r_k(t)$ and $x_i^*(t)$:

$$r_{i,k} = \int_{0}^{T} r_k(t) x_i^*(t) dt \qquad (8)$$

Notation:
$$\mathbf{r}_k = \{r_{L-1,k}, ..., r_{M_s = 1,k}\}_{\mathcal{P}}$$
 , is the set of the set of

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Mode CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Detection process

Coherent detection [Rim88]

- θ is known
- Optimal detection: Trellis-based algorithm
- BCJR/Viterbi
- Criteria MAP/ML
- Non-coherent detection
 - θ is unknown
 - Receiver:
 - Trellis-based algorithm (BCJR/Viterbi, MAP/ML, [CFR00],[DS90])

<ロト < @ ト < 直 > < 直 > 三 の へ で 18/78

Block-based algorithm ([RD99],[VCT10])

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility_____

Conclusion

Finite length simulation



Figure: SER: CPFSK L = 1, M = 4, h = 5/7

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

19/78

Asymptotic simulation



Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Mode CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Table of Content

Introduction

System Model CPM scheme Detection

NC TB receiver MAP versus ML Reduced vs Extended S. S.

NC-Precoding Classical approach Non-coherent precoding design

Sparse graph based code optimization Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

・ロト (日) (日) (日) (日) (日) (1/78)

MAP versus ML

Ref.	[CFR00]	[DS90]
Algorithm	BCJR	Viterbi
Criteria	MAP	ML
States	$\{\phi, u_{k-G},, u_{k-1}\}$	$\{u_{k-G},, u_{k-1}\}$
State Space	Extended	Reduced

Table: Comparison MAP vs ML detection.

- The two references for the non-coherent detection ([CFR00],[DS90]) give equivalent performances.
- The ML returns the most likely sequence.
- The MAP maximizes the probability of each symbol.

$$\hat{u}_{ML,k} = \underset{u_0^{N_s-1}}{\arg \max} \{ p(\mathbf{r}_{L-1}^{N_s-1} | u_0^{N_s-1}) \}$$
$$\hat{u}_{MAP,k} = \underset{u_k}{\arg \max} \{ p(u_k | \mathbf{r}_{L-1}^{N_s-1}) \}$$

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

(9)

Line of thought

- Perform soft detection
- Implement ref. [CFR00]
- Strong complexity
- Looking for complexity reduction
- Ref. [DS90] implemented ML detection with reduced state space
- Derive MAP equations with the reduced state space
- Implement and simulate the MAP detector based on both state space
 - Asymptotic simulation
 - Finite length simulation

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lance<u>urs</u>

> Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility_____

Conclusion

Exit charts analysis

Mutual information between X and L [Hag04]:

$$I(X, \mathcal{L}) = \frac{1}{2} \sum_{x=-1, 1} \int_{-\infty}^{+\infty} p(I|X = x)$$

$$\cdot \log_2 \left(\frac{2p(I|X = x)}{p(I|X = -1) + p(I|X = 1)} \right) dI$$
(10)

<ロ> < (日) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1) < (1)

- A priori information $I_a = I(X, \mathcal{L}_a)$ ([TB01]).
- Extrinsic information $I_e = I(X, \mathcal{L}_e)$.
- EXIT chart: plot *I_e* vs *I_a*.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Exit charts analysis



Figure: EXIT charts: 2GMSK h = 1/2, M = 2 and BT = 0.25 and 2RC with h = 1/4, M = 4 (N = 3)

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Asymptotic simulation



Figure: Spectral Efficiency: quaternary 2RC with h = 1/4.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

<ロト < @ ト < 臣 > < 臣 > 臣 の < @ 26/78

Finite length simulation



Figure: BER: 2GMSK with h = 1/2, M = 2, BT = 0.25, Weigthed AV CPM [SG13] h = 1/3, M = 4, 2RC h = 1/3, M = 4. (N = 3)

Nouvelle forme d'onde et écepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

CPM scheme Detection

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

▲□▶ ▲□▶ ▲■▶ ▲■▶ ■ 釣�♡ 27/78

Outcome

- Taking into account the accumulated phase in the non-coherent state space can be shown to be useless
 - no information gain
 - Higher complexity
 - The reduced state space can be shown minimal

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

On the link between MAP and ML equations

The metrics of the novel Non-coherent TBR:

$$\gamma(\delta_{k} \to \delta_{k+1}, \mathbf{r}_{k-N+1}^{k}) = \frac{1}{Q} \sum_{\{\phi_{k-N+1}\}} \gamma(\delta'_{k} \to \delta'_{k+1}, \mathbf{r}_{k-N+1}^{k})$$
$$\alpha_{k}(\delta_{k}) = \sum_{\{\phi_{k-N+1}\}} \alpha(\delta'_{k})$$
$$\beta_{k}(\delta_{k}) = \frac{1}{Q} \sum_{\{\phi_{k-N+1}\}} \beta_{k}(\delta'_{k})$$

(11)

Nouvelle forme d'onde et écepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

optimization Unprecoded with

coherent compatibility Precoded with coherent compatibility

Conclusion

Contributions

- Complexity reduction:
 - [CFR00] approach : $\mathcal{O}(8(N+Q)M^{N+L-1})$.
 - Novel approach : $\mathcal{O}(8NM^{N+L-1})$.
- Phase information is unknown in non-coherent regime
- The Extended State Space is a good tool to study, in the meantime, both regimes.

Journal Paper : *Piat-Durozoi, C. U.*, Poulliat, C., Boucheret, M. L., Thomas, N., Bouisson, E., & Lesthievent, G. Minimal state non-coherent symbol MAP detection of Continuous-Phase-Modulations. IEEE Communication Letter, 2018.

Journal Paper : *Piat-Durozoi, C. U.*, Poulliat, C., Boucheret, M. L., Thomas, N., Bouisson, E., & Lesthievent, G. On the link between non-coherent and coherent symbol MAP detection of Continuous-Phase-Modulations. In preparation, 2018. **B** SOC 30/78 Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Table of Content

Introduction

System Model CPM scheme Detection

NC TB receiver MAP versus ML Reduced vs Extended S. S.

NC-Precoding Classical approach Non-coherent precoding design

Sparse graph based code optimization Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Adopted strategy

- Design simple and efficient serially concatenated coded CPM scheme in non-coherent regime
- Investigate classical existing system of transmission based on coded CPM scheme.
- Return channel of DVB-RCS2: CPM + convolutional code (CC)
- Evaluate its behaviour over non-coherent regime

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

32/78

Serially concatenated coded CPM scheme

- Carry on a joint iterative detection between the CPM demapper and a convolutional code (CC).
- EXIT charts analysis of both SISO components



Figure: Coded interleaved CPM scheme with iterative decoding

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

< □ ▶ < @ ▶ < 필 ▶ < 필 ▶ _ 필 · _ 외۹(° 33/78

Exit charts: quaternary 2RC



Figure: Exit charts: 2RC with h = 1/4, M = 4, $E_s/N_0 = 4.5 dB$.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Finite length simulation



Figure: BER N.C. quaternary 2RC with h = 1/4 (natural mapping)

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

CPM scheme Detection

MAP versus ML Reduced vs Extended S. S.

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Open issues for serially concatenated coding scheme

- Classical approach:
 - Iterate between the CPM demodulator and the CC is not efficient in non-coherent regime
 - Due to EXIT charts convergence issue
- Issue
 - The detection procedure is blocked at a given iteration.
 - This interruption triggers an error floor
- Solution proposed
 - Design and optimize a precoding schemes which make the EXIT charts converge to the point (1,1) and unblocks the decoding process

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion
Diagram of the non-coherent precoding



Figure: CPM modulator: quaternary CPM with $\mathbf{F} = [1313]$, L = 2 and N = 3 Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Modelization of the non-coherent precoding

Precoded symbols:

$$\bar{u}_k = u_k \oplus d_k$$

- \oplus is the sum over \mathbb{Z}_2^m ,
- Precoded state : $\bar{\delta}_k = \{\bar{u}_{k-N-L+2}, ..., \bar{u}_{k-1}\}$

The *m* bits of u_k are added modulo 2 to the *m* bits of d_k.

$$\boldsymbol{d}_{k} = [\boldsymbol{\bar{u}}_{k-1}, ..., \boldsymbol{\bar{u}}_{k-L+1}, \boldsymbol{\nu_{k}}] \cdot \boldsymbol{\mathsf{F}}^{\top}$$
(13)

• is the matrix product and

$$\nu_k = \sum_{i=k-N-L+2}^{k-L} \bar{u}_i$$

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

(12)

(14)

38/78

System Model CPM scheme

Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Modelization of the non-coherent precoding

F is a m × r-dimensional matrix whose components belong to Z₂

$$r = m \cdot (L-1) + \lceil \log_2(Q) \rceil,$$

- $\left[\cdot\right]$ rounds to the next larger integer.
- $m = log_2(M)$
- d_k (respect. ν_k, u_k) is the binary representation of d_k (respect. ν_k, u_k).

<ロト < @ ト < 直 > < 直 > 三 の < で 39/78

• \sum_{Q} is the sum *modulo* Q.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

ntroduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

- Different EXIT charts trajectories
- Same Area under the curve.
- Same Information Rate.



Figure: EXIT charts 1REC (h = 0.25 M = 4) for various F

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Mode

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

- Different EXIT charts trajectories
- Same Area under the curve.
- Same Information Rate.



Figure: EXIT charts 1REC (h = 0.25 M = 4) for various F

Nouvelle forme d'onde et écepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Mode

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

- Different EXIT charts trajectories
- Same Area under the curve.
- Same Information Rate.



Figure: EXIT charts 1REC (h = 0.25 M = 4) for various F

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Mode

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

- Different EXIT charts trajectories
- Same Area under the curve.
- Same Information Rate.



Figure: EXIT charts 1REC (h = 0.25 M = 4) for various F

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Mode

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

- Different EXIT charts trajectories
- Same Area under the curve.
- Same Information Rate.



Figure: EXIT charts 1REC (h = 0.25 M = 4) for various F

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Mode

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

- Different EXIT charts trajectories
- Same Area under the curve.
- Same Information Rate.



Figure: EXIT charts 1REC (h = 0.25 M = 4) for various F

Nouvelle forme d'onde et écepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

- Different EXIT charts trajectories
- Same Area under the curve.
- Same Information Rate.



Figure: EXIT charts 1REC (h = 0.25 M = 4) for various F

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Mode

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

- Different EXIT charts trajectories
- Same Area under the curve.
- Same Information Rate.



Figure: EXIT charts 1REC (h = 0.25 M = 4) for various F

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Optimization procedure

- \mathcal{F} the set of precoding $m \times r$ -dimensional matrix **F**.
- card(\mathcal{F}) = 2^{*rm*}.
- F_c ⊂ F the set of matrix enabling the convergence to point (1, 1).
- Select among \mathcal{F}_c the one which generates the higher $I_e(0)$.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Exit charts analysis



Figure: Exit charts quaternary 2RC with h = 1/4, $E_s/N_0 = 4.5 dB$.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

·□▶ ◀@▶ ◀돌▶ ◀돌▶ · 돌· ∽��° 42/78

Finite length simulation



Figure: BER N.C. quaternary 2RC with h = 1/4 (natural mapping)

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Contribution

Conference Paper: *Piat-Durozoi, C. U.*, Poulliat, C., Boucheret, M. L., Thomas, N., Bouisson, E., & Lesthievent, G. (2018, October). Precoding for Non-coherent detection of continuous phase modulations. MILCOM, 2018 in process, Los-Angeles California USA.

Journal paper: *Piat-Durozoi, C. U.*, Poulliat, C., Boucheret, M. L., Thomas, N., Bouisson, E., & Lesthievent, G. A novel nonbinary precoding for continuous phase modulations. To be submitted.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

<ロト < @ ト < 直 > < 直 > 三 の < で 44/78

Table of Content

Introduction

System Model CPM scheme Detection

NC TB receiver MAP versus ML Reduced vs Extended S. S.

NC-Precoding Classical approach Non-coherent precoding design

Sparse graph based code optimization Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Open issues for capacity-achieving code

- Design capacity-achieving codes (sparse graph codes)
- Suited for both the coherent and non-coherent regimes
- Solution proposed
 - Consider LDPC coding scheme.
 - Optimization through EXIT chart analysis.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Serially concatenated coded CPM scheme



Figure: Coded interleaved CPM scheme with iterative decoding

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

LDPC codes

- Linear block codes
- Comprised of Variable Nodes (VN,λ,dv_{min},dv_{max}), Check Nodes (CN,ρ,dc_{min},dc_{max}) and edges



Figure: Tanner graph binary LDPC code

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

LDPC codes

Low density of the parity matrix H

 LDCP optimization principle: distribution NV, CN and edges Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

(15)

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Serially concatenated CPM with irregular LDPC



Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Mode

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Optimization principles

Maximize the rate

$$\mathcal{R} \geq 1 - \sum_{i=dc_{min}}^{dc_{max}} rac{
ho_j}{j} / \sum_{i=dv_{min}}^{dv_{max}} rac{\lambda_i}{i}$$

- ► MI between VNs and CNs : $I_{vn,cn}^{l+1} = F(\lambda, T(.), I_{cn,vn}^{l})$
- Mixture constraint : $\sum_{dv_{min}}^{dv_{max}} \lambda_i = 1$
- Proportion constraint : $\lambda_i \in [0; 1]$
- Convergence constraint : $I_{vn,cn}^{l+1} > I_{vn,cn}^{l}$

► Stability
condition :
$$\begin{cases}
 d^{\circ}1 : \lambda_{1} < \frac{1}{T'(1)\sum \rho_{j} \cdot (j-1)} (T(1) = 1) \\
 d^{\circ}2 : \lambda_{2} < \frac{e^{[J^{-1}(T(1))]^{2}/8}}{\sum \rho_{j} \cdot (j-1)} (T(1) < 1)
\end{cases}$$

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

(16)

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Code profiles optimization based on Exit charts

- Exit curves converge to point (1,1), then degree one VNs are allowed (Benaddi [Ben15]).
- Exit curves do not converge to point (1,1), then VNs are constrained in degree 2
- Coherent regime dv_{min} => 1 and Non-coherent regime dv_{min} => 2
- Issue:
 - ► A code suited to both regimes leads to LDPC profiles with dv_{min} => 2.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Code design algorithm (curve fitting)

Fix a SNR

- Compute the CPM EXIT curve T(.) (polynomial approach)
- Fix dv_{max} and dv_{min}
- Initialize the code rate $\mathcal{R}_{opt} = 0$
- Fix ρ by generating a set C of concentrated CN profiles ρ
- For each ρ in C do
 - Solve linear programming and get the {λ_i}
 - Compute the new rate ${\cal R}$ from λ and ρ
 - If $\mathcal{R}_{opt} < \mathcal{R}$

•
$$\mathcal{R}_{opt} = \mathcal{R}, \{\lambda_i\}_{opt} = \{\lambda_i\} \text{ and } \{\rho_i\}_{opt} = \{\rho_i\}$$

End if

End for

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

> Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Parameters optimization

- Coherent VNs profile of Degree 2 > in NC regime
- Use the NC optimized coding schemes for both regime

Channel\Coding Optim.	С.	NC
С.	stable	stable
NC	unstable	stable

Table: Coding scheme stability

	d _c	d_v	ρ	λ
C.	{5,6}	{2,3,8}	$\{0.99, 0.01\}$	{ <mark>0.4</mark> , 0.58, 0.02}
NC.	{5,6}	{2,3}	$\{0.04, 0.96\}$	{ <mark>0.03</mark> , 0.97}

Table: Degree distribution from coding optim (2RC, $\mathcal{R} = 1/2$).

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

> Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

<ロト < @ ト < 臣 > < 臣 > 臣 の < で 54/78

Asymptotic simulation



Figure: Information Rate: 2RC h = 1/4, M = 4

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

<ロ > < 合 > < 言 > < 言 > 言 の < で 55/78

Optimization of precoded systems

Issue:

- Differential code profiles in both regimes
- Degrees 2 variable nodes may generate a capacity penalty
- Degrees 1 lead to better codes [Ben15]; [Ben+14].

Solution proposed:

- Optimized code profiles of precoded systems
- Design code profile with degree 1
- Expected result:
 - Minimized the capacity penalty between the theoretical threshold and the optimized one

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Exit chart analysis



Figure: EXIT charts: 2GMSK h = 1/2, M = 2, BT = 0.3 and 2RC h = 1/4, M = 4

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Parameters optimization

- ▶ Coherent VNs profile of Degree 1 > in NC regime
- Use the NC optimized coding schemes for both regime

Channel\Coding Optim.	С.	NC (w/ precoding)
С.	stable	stable
NC (w/ precoding)	unstable	stable

Table: Coding scheme stability

	d _c	d_v	ρ	λ
C.	$\{3, 4\}$	$\{1, 2, 8\}$	$\{0.14, 0.86\}$	{ <mark>0.26</mark> , 0.47, 0.27}
NC.	$\{4, 5\}$	$\{1, 2, 8\}$	$\{0.04, 0.96\}$	$\{0.06, 0.6, 0.34\}$

Table: Degree distribution from coding optim (2RC, $\mathcal{R} = 1/2$).

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

> Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Asymptotic simulation



Figure: Information Rate: 2RC h = 1/4, M = 4

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

<ロト < @ ト < 注 > < 注 > 注 の < で 59/78

Contribution

Conference Paper: *Piat-Durozoi, C. U.*, Poulliat, C., Thomas, N., Boucheret, M. L., & Lesthievent, G. (2017, June). On sparse graph coding for coherent and noncoherent demodulation. In Information Theory (ISIT), 2017 IEEE International Symposium on (pp. 2905-2909). IEEE, Aachen Germany.

Journal: *Piat-Durozoi, C. U.*, Poulliat, C., Thomas, N., Boucheret, M. L., & Lesthievent, G. (2017, June). Precoding for non-coherent detection of continuous phase modulation. In preparation.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Table of Content

Introduction

System Model CPM scheme Detection

NC TB receiver MAP versus ML Reduced vs Extended S. S

NC-Precoding Classical approach Non-coherent precoding design

Sparse graph based code optimization Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

< □ ▷ < 큔 ▷ < 토 ▷ < 토 ▷ · 토 · ♡ < ♡ · 61/78

Conclusion

- Derivation of a non-coherent symbol/MAP receiver with minimal state space
- Design of non-coherent precoding enabling efficient iterative decoding between CPM and CC.
- Optimization of LDPC code profiles suited to both coherent and non-coherent regimes

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Other contributions

- Non-binary precoding for low complexity coherent detection of coded CPM.
- Optimization of NB-LDPC for non-binary precoded system.
- Non-binary precoding for non-coherent detection of coded CPM (SICM).

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Perspectives

- Protograph based solution for efficient coding scheme.
- Finite length simulation of the LDPC code optimization
- Extension to multi-h (adaptive rate)
- Channel estimation of the launcher's communication link
- Joint equalization and detection in non-coherent regime.

Nouvelle forme d'onde et écepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

List of publications

Journal paper

- Piat-Durozoi, C. U., Poulliat, C., Boucheret, M. L., Thomas, N., Bouisson, E., & Lesthievent, G. Reduced state non-coherent symbol MAP detection of Continuous-Phase-Modulations. IEEE Communication Letter, 2018.
- Piat-Durozoi, C. U., Poulliat, C., Boucheret, M. L., Thomas, N., Bouisson, E., & Lesthievent, G. A novel nonbinary precoding for continuous phase modulations. To be submitted.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion
List of publications

International conference papers

- Piat-Durozoi, C. U., Poulliat, C., Thomas, N., Boucheret, M. L., & Lesthievent, G. (2017, June). Multisymbol with memory non-coherent detection of CPFSK. In Acoustics, Speech and Signal Processing (ICASSP), 2017 IEEE International Conference on (pp. 3794-3798). IEEE. New-Orleans USA.
- Piat-Durozoi, C. U., Poulliat, C., Boucheret, M. L., Thomas, N., Bouisson, E., & Lesthievent, G. (2017, March). On sparse graph coding for coherent and non-coherent demodulation. In Information Theory (ISIT), 2017 IEEE International Symposium on (pp. 2905-2909). IEEE, Aachen Germany.
- Piat-Durozoi, C. U., Poulliat, C., Boucheret, M. L., Thomas, N., Bouisson, E., & Lesthievent, G. (2018, October). Precoding for Non-coherent detection of continuous phase modulations. MILCOM, 2018 in process, Los-Angeles California USA.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

> Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

List of publications

National conference paper

Piat-Durozoi, C. U., Poulliat, C., Thomas, N., Boucheret, M. L., Bouisson, E., & Lesthievent, G. (2017, Sept). Détection non-cohérente souple par bloc ou à mémoire des CPM. In Groupe de recherche sur le traitement du signal (GRETSI), Juan-Les-Pins France.

<ロト < 課 > < 注 > 注 の へ で 67/78

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

Non-binary precoding for low complexity coherent detection of coded CPM.



Figure: 2REC h = 1/4, M = 4, RC h = 1/4 M = 4 (a.) Non-binary EXIT charts at $E_s/N_0 = 0 dB$ (b.) Spectral Efficiency Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References



Figure: SER : 3REC h = 1/2 M = 2, 2REC h = 1/4, M = 4 and RC h = 1/4 M = 4

<ロト < @ ト < 臣 > < 臣 > 臣 の < @ 69/78

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model CPM scheme

Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion



Figure: Non-binary EXIT charts (R = 1/2) (a.) RC with h = 1/4 and M = 4 and (b.) 2REC with h = 1/4 and M = 4.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Mode CPM scheme

Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

<ロト < @ ト < 臣 > < 臣 > 臣 の < で 70/78

 Optimization of NB-LDPC for non-binary precoded system.



Table: Degree distribution NB-LDPC (R = 1/2).

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

> Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

<ロ> < @ > < E > < E > E の < で 71/78



Figure: Information Rate (R = 1/2) (a.) RC with h = 1/4.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

<ロト < @ ト < 臣 > < 臣 > 臣 の < で 72/78



Figure: Information Rate 2REC with h = 1/4 and M = 4.

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model CPM scheme

Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

Réponse aux questions

- Complexité du récepteur par bloc: 8NM^{N+L-1} + 2M^{N+L} - M
- Complexité du récepteur par treillis: $8NM^{N+L-1} + 2M^{N+L} \cdot \frac{4}{M} - M$

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

Charles-Ugo Piat-Durozoi

Introduction

System Model

CPM scheme Detection

VC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

74/78

References I

John B Anderson, Tor Aulin, and Carl-Erik Sundberg. *Digital phase modulation*. Springer Science & Business Media, 2013 (cit. on p. 9).

Tarik Benaddi et al. "Design of unstructured and protograph-based ldpc coded continuous phase modulation". In: *Information Theory (ISIT), 2014 IEEE International Symposium on.* IEEE. 2014, pp. 1982–1986 (cit. on p. 63).

Tarik Benaddi. "Sparse graph-based coding schemes for continuous phase modulations". PhD thesis. 2015 (cit. on pp. 59, 63). Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

> Charles-Ugo Piat-Durozoi

Introduction

System Mode

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References

<ロト < @ ト < 臣 > < 臣 > 臣 の < で 75/78

References II

Giulio Colavolpe, Gianluigi Ferrari, and Riccardo Raheli. "Noncoherent iterative (turbo) decoding". In: *IEEE Transactions on Communications* 48.9 (2000), pp. 1488–1498 (cit. on pp. 18, 22, 23, 30).

Dariush Divsalar and Marvin K Simon. "Multiple-symbol differential detection of MPSK". In: *IEEE Transactions on Communications* 38.3 (1990), pp. 300–308 (cit. on pp. 18, 22, 23). Joachim Hagenauer. "The EXIT chart-introduction to extrinsic information

transfer in iterative processing". In: *Signal Processing Conference, 2004 12th European.* IEEE. 2004, pp. 1541–1548 (cit. on p. 24).

John G Proakis. Digital Communications Fourth Edition, Chapter 11, 2001. (Cit. on p. 9). Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

> Charles-Ugo Piat-Durozoi

Introduction

System Mode CPM scheme

Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References III

Dan Raphaeli and Dariush Divsalar. "Multiple-symbol noncoherent decoding of uncoded and convolutionally coded continuous phase modulation". In: *Journal of Communications and Networks* 1.4 (1999), pp. 238–248 (cit. on p. 18).

Bixio E Rimoldi. "A decomposition approach to CPM". In: *IEEE Transactions on Information Theory* 34.2 (1988), pp. 260–270 (cit. on p. 18).

DVB Second Generation. "Digital Video Broadcasting (DVB); Second Generation DVB Interactive Satellite System". In: (2013) (cit. on p. 27). Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

> Charles-Ugo Piat-Durozoi

ntroduction

System Model

CPM scheme Detection

IC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph based code

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion

References IV

Stephan Ten Brink. "Convergence behavior of iteratively decoded parallel concatenated codes". In: *IEEE transactions on communications* 49.10 (2001), pp. 1727–1737 (cit. on p. 24).

Matthew C Valenti, Shi Cheng, and Don Torrieri. "Iterative multisymbol noncoherent reception of coded CPFSK". In: *IEEE transactions on communications* 58.7 (2010), pp. 2046–2054 (cit. on p. 18).

Nouvelle forme d'onde et récepteur avancé pour la télémesure des futurs lanceurs

> Charles-Ugo Piat-Durozoi

Introduction

System Mode

CPM scheme Detection

NC TB receiver

MAP versus ML Reduced vs Extended S. S.

NC-Precoding

Classical approach Non-coherent precoding design

Sparse graph

optimization

Unprecoded with coherent compatibility Precoded with coherent compatibility

Conclusion