

PHD THESIS IN SIGNAL PROCESSING:
Faster-than-Nyquist receivers based on Monte Carlo methods



Context and expected outcomes

In the race for spectral efficiency, the idea of a “**faster-than-Nyquist**” (FTN) transmission has been proposed several decades ago [Maz75]. Nonetheless, a symbol rate greater than the occupied bandwidth necessarily generates interpulse interference (IPI) and still challenges the symbol detection task. While FTN seems particularly suited to power-constrained channels (*e.g.*, satellite, optical fiber, mobile) [Col11, PMCA13], its intrinsic IPI problem has been essentially considered in simple scenarios (*e.g.*, perfectly synchronized receivers in presence of AWGN, sometimes assorted with multipath channels) [RA09, BFC09, PA12, MRSS17].

During this PhD thesis, we ambition to explore the benefits of FTN in more realistic channels (*e.g.*, including residual synchronization offsets and/or partially unknown scatterers). We will rely on **Markov Chain Monte Carlo (MCMC) receivers** [DW05]. In particular, hybrid sampling/factor-graphs techniques could be investigated. Firstly, we will determine asymptotic performance metrics *via* computationally intensive simulations (*e.g.*, information rates) [ML13]. Secondly, we will focus on the design of less complex receivers either with efficient sampling techniques or *via* deterministic approximations (*e.g.*, variational Bayesian techniques) [YWWK16].

Host institution and place of work

Located in **Toulouse** (France), **ISAE-SUPAERO** is a public higher education and research institute focused on aerospace applications. More particularly, the department of electronics, optronics and signal processing (DEOS) has an extensive expertise in electrical engineering applied to aerospace systems. The “Communications and Information Theory” (ComIT) research team conducts activities in digital communications, radar, channel access techniques. Applications include space systems, commercial and military aviation, cellular networks and the Internet of things. Our webpage: <http://isae.fr/deos/comit>.

Candidate profile and application

Applicants should be last-year master students or hold a master degree. A strong background in **signal processing and statistics** is required. Good communication skills in English are necessary (written and oral). A prior experience in Monte Carlo sampling would be particularly appreciated.

⇒ Applications (resume, motivation letter, transcript, in English or in French) and informal inquiries are to be emailed to

- damien.roque@isae-supaeo.fr;
- stephanie.bidon@isae-supaeo.fr.

Application deadline: 21-Mar-2022.

Misc.:

- We also propose an internship as a prelude to this PhD thesis: <https://www.isae-supaero.fr/IMG/pdf/mcmc-ftn-receivers-en.pdf> (not mandatory).
- Start between October and December 2022 (36 month fixed-term contract).
- Various opportunities during the PhD thesis: teaching, international mobility, supervision experience (internships, teaching projects...), relations with defense and aerospace industry.
- EU citizenship is required by the funding agency.

References

- [BFC09] A. Barbieri, D. Fertoni, and G. Colavolpe. Time-frequency packing for linear modulations: spectral efficiency and practical detection schemes. *IEEE Trans. Commun.*, 57(10):2951–2959, October 2009.
- [Col11] G. Colavolpe. Faster-than-Nyquist and beyond: How to improve spectral efficiency by accepting interference. In *IEEE Eur. Conf. and Exhib. on Optical Commun.*, pages 1–25, September 2011.
- [DW05] A. Doucet and Xiaodong Wang. Monte Carlo methods for signal processing: a review in the statistical signal processing context. *IEEE Signal. Proc. Mag.*, 22(6):152–170, December 2005.
- [Maz75] James E. Mazo. Faster than Nyquist signaling. *Bell System Technical Journal*, 54:1451–1462, October 1975.
- [ML13] M. Molkaraie and H. Loeliger. Monte Carlo algorithms for the partition function and information rates of two-dimensional channels. *IEEE Trans. Inf. Theory*, 59(1):495–503, 2013.
- [MRSS17] A. Marquet, D. Roque, C. Siclet, and P. Siohan. FTN multicarrier transmission based on tight Gabor frames. *EURASIP J. on Wireless Commun. and Netw.*, 2017(1):97, May 2017.
- [PA12] A. Prlja and J. Anderson. Reduced-complexity receivers for strongly narrowband intersymbol interference introduced by faster-than-Nyquist signaling. *IEEE Trans. Commun.*, 60(9):2591–2601, September 2012.
- [PMCA13] A. Piemontese, A. Modenini, G. Colavolpe, and N. S. Alagha. Improving the spectral efficiency of nonlinear satellite systems through time-frequency packing and advanced receiver processing. *IEEE Trans. Commun.*, 61(8):3404–3412, August 2013.
- [RA09] F. Rusek and J.B. Anderson. Multistream faster than Nyquist signaling. *IEEE Trans. Commun.*, 57(5):1329–1340, May 2009.
- [YWWK16] W. Yuan, N. Wu, H. Wang, and J. Kuang. Variational inference-based frequency-domain equalization for faster-than-Nyquist signaling in doubly selective channels. *IEEE Signal. Proc. Lett.*, 23(9):1270–1274, 2016.