Quasi Cyclic Short Packet

Oct. 2019-Oct. 2023 https://qcsp.univ-ubs.fr/

GdR ISIS, Nov. 2021

Cyclic Code Shift Keying (CCSK) modulation: From a length q BPSK sequence $P_0(i)$, i = 0,…, q-1, generates a size q dictionary by circularly shift $P_0(i)$ as $P_k(i) = P_0(i+k \bmod q)$ => Spectral efficiency of m/q, m = $\log_2(q)$.

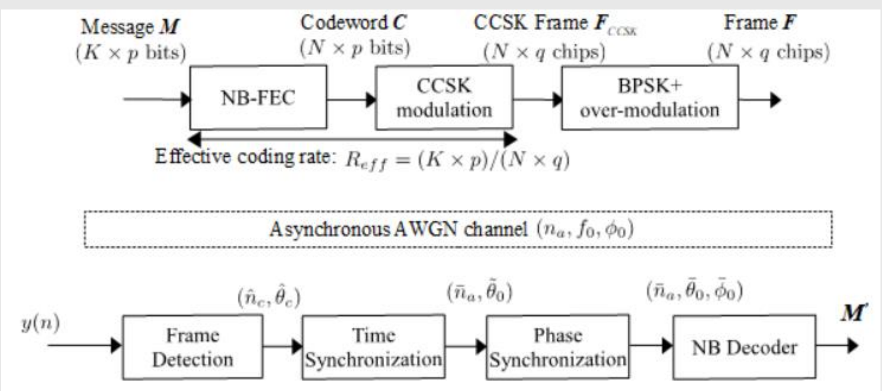
Non-Binary code: Generalization of binary code (GF(2)) over a Galois Field GF($q=2^m$). Example: Non-Binary LDPC, Non-Binary Turbo, Non Binary Polar codes.

CCSK in space: Michibiki (Japan's GPS)

NB-code in space: Beidou 3 (Chinese's GPS).

NB-CODE + CCSK for next generation of IoT?

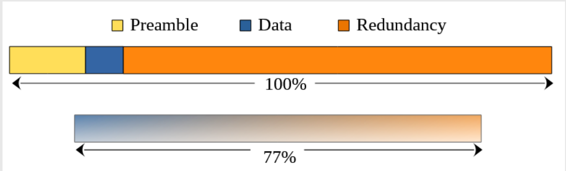
System model :



Advantage: Every frame is considered as a preamble for detection and synchronization, then as a codeword for the decoder. For example, 240 bits of information:

5G-like

QCSP

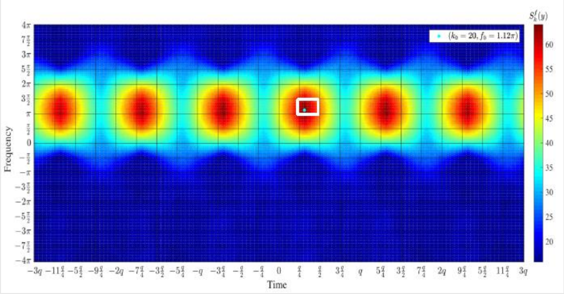


SNR = -12 dB

FER = 10^{-4}

Detection: Use a score function (somehow a match filter) adapted to the structure of a QCSP frame [1,2].

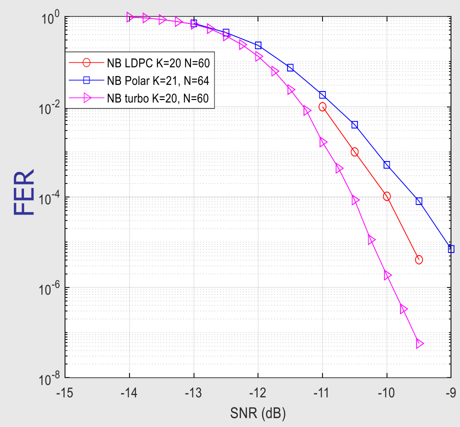
Example of score function output with time and frequency Offset.



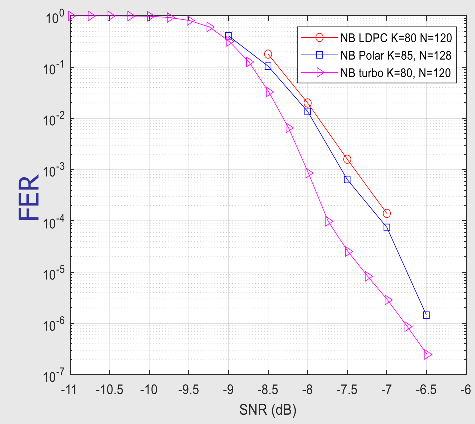
Synchronization : Two on-going patent applications for synchronization in time [3]. Synchronization in frequency is shown to be equivalent to a classical frequency estimation problem enriched by soft-information coming from demodulation and code structure [4].

Non Binary code: Construction of NB Polar, Turbo and LDPC codes. Performance evaluation and simplified hardware decoding algorithm for all codes [5,6,7,8]. Performance for QCSP over GF(64).

R ≈ 1/3, k ≈ 120 bits.



R ≈ 2/3, K≈480 bits.



Example of application: K = 120 bits, CCSK length of GF(64), rate 1/3 NB-LDPC. Transmission OK if and only if:

- Correct detection (Prob: 1 - P_d)
- Exact synchronization (Prob: 1 - P_s)
- Successful correction (Prob: 1 - P_e)

Overall Prob. of error ≈ $P_d + P_s + P_e$

=> 10^{-4} at -10 dB of E_s/N_0 (simulation result).

Optimally: $P_d \approx P_s \approx P_e$, On this example, $P_d << P_s \approx$ ¨P_e

=> Still room for optimization.

Real time demo (450 MHz ASM Band)

Frequency band and chip throughput: 1 MHz, information throughput: 32 kbit/s. Frame Error Rate of 10^{-4} at -10 dB. Oversampling of a factor 8 at receiver. Half-raised cosine filter.

A new message each second (time + frame id) with Raspberry Pi4 + ETTUS board (B205 mini).

Receiver: ETTUS Board (B205 mini) connected to a PC: detection in C, time and frequency synchronization in Matlab, NB-LDPC decoder in C.

References:

[1] K. Saied et al. "Short Frame Transmission at Very Low SNR by Associating CCSK Modulation with NB-Code", submitted to IEEE TWCOM, major revision.

[2] C. Monière et al., "Times sliding windows for the detection of CCSK frames" IEEE SiPS'2021, Portugal, Oct. 2021.

[3] K. Saeid et al. "Time-Synchronization of CCSK short frames", WiMob'2021, Bologna, Oct. 2021.

[4] L. Saeid et al. "Blind Synchronization in Quasi Cyclic Short Packet Transceivers", WCNC'2022 (Submitted).

[4] V. Savin, "Non-Binary Polar Codes for Spread-Spectrum Modulations", ISTC'2021, Montreal, Canada, Sept. 2021.

[5] F. Cochachin et al. "Reduced Complexity of a Successive Cancellation Based Decoder for NB-Polar Codes" ISTC'2021.

[6] H. le Blevec et al. "Low complexity non-binary turbo decoding based on the local-SOVA algorithm" ISTC'2021.

[7] J. Jabour et al. "The Best, The Requested and The Default Non-Binary LDPC Decoding Algorithm" ISTC'2021.

[8] C. Marchand, E. Boutillon, "Rate-adaptive Coded Modulation for Non-binary Decoders" ISTC'2021