# SECURITY AND SPECTRALL EFFICIENCY TRADE-OFF FOR SINGLE CARRIER FASTER THAN NYQUIST IoT SYSTEMS OVER SATELLITE

Joan Bas
Dept. of Array and Multisensor and Signal Processing,CTTC/CERCA, Castelldefels, Spain, joan.bas@cttc.es
Ana Pérez-Neira
Dept. of Array and Multisensor and Signal Processing, CTTC/CERCA, Castelldefels, Spain, ana.perez@cttc.es

**Abstract**

The increase of the spectral efficiency is a key issue to meet the demand for higher capacity in communication systems. This fact comes critical in satellite systems and IoT where there is a large propagation delay and the cardinality of the modulations is low. In this regard, the technique of Faster Than Nyquist (FTN), proposed by Mazo at the 70' [1], has been revisited nowadays for increasing the spectral efficiency of 5G and beyond communication systems [2]. However, it has been recently pointed out that Faster Than Nyquist so called Time-Packing technique can also provide certain level of security by controlling as a security key the temporal separation between consecutive pulse-shapes [3]. This combination of increasing spectral efficiency without bandwidth expansion and security is quite useful for the commercial success of services over IoT. From the point of view of economic impact of the IoT applications and according to Northern Sky Research, Telemetry has the largest share in terms of number of applications with an 28%. Next, Telematics/Analytics accounts for the second one in terms of applications with a (13%) and finally Asset Tracking with 11% is the third main application [4],[5]. These three applications require in general narrow band requirements and high levels of security. So, the use of packing techniques would be of great interest in these type of applications over satellite.

In narrowband IoT systems over LEO satellite, licensed and unlicensed, it is necessary to take the Doppler rate into account. That is, the variation of the Doppler shift along a frame. In this situation, the use of time-packing techniques reduces the temporal duration of the frames, which benefits to reduce the effect of Doppler rate. Furthermore, the temporal reduction of the transmitted frames is also beneficial for increasing the number of users that access to the satellite channel. However, time-packing techniques also have side effects to be considered. For example, the PAPR may limit its utility in terms of spectral efficiency. Note that the overlapping between the consecutive pulse-shapes increases the PAPR of the transmitted frames which reduces the efficiency of power amplifiers. This fact not only depends on the overlapping-degree between pulses but also on the roll-off factor and the pulse-shape that are used [6]. In this regard, we will analyze the PAPR of the FTN in terms of the roll-off and overlapping factors. Nevertheless, it is not only a question of PAPR analysis. At this point it is necessary to remark that the bandwidth of the pulse-shape signals expands linearly with the roll-off factor. Consequently, the gain in the time-domain may be partially reduced or completely lost in the frequency-domain if the desired PAPR is lower or equal than the Nyquist one. In this paper the pulse-shape has been fixed to the well-known square root cosine filter.

Results for a QPSK modulation show that if the FTN and Nyquist cases use the same roll-off factor, then the Nyquist case always have the lowest PAPR. Fortunately, FTN system can achieve still a lower or equal PAPR than the Nyquist one if it uses a larger roll-off factor or/and overlapping degree. In case of PAPR constraints, it is still possible to obtain certain gain in spectral efficiency if the gain by shrinking the temporal separation between the

transmitted pulses is larger than the bandwidth expansion by using a larger roll-off (compared to Nyquist case). In this regard, if we consider a gain in the time domain of 10% and the Nyquist signal uses a roll-factor of 0.2, then the roll-off of the FTN pulse-shapes must be lower than 0.32 to have a certain gain in spectral efficiency from FTN to Nyquist systems. However, if the optimization criteria priors the security instead of spectral efficiency, then it may be justified to use other roll-off and overlapping factors. Larger overlapping degrees reduce the temporal duration of the frames which difficult the detection and interception tasks by non-legitimate users.

Finally, note that a larger overlapping degree and/or lower roll-off factors introduce more inter-symbol interference too. So, it means that it may difficult to resort to Maximum Likelihood Sequence Detectors (MLSD) for complexity reasons. Therefore, sub-optimal iterative low complex symbol-by-symbol receivers are studied to decode FTN signals. Note also that the multi-path interference introduced by the FTN signal is known by the desired receiver but ignored totally or partially by the eavesdropper one. This is quite useful in satellite communications where the satellite channel can be considered as Line of Sight (worst case from security point of view), and covers a large extension of area, which facilitate the task of the eavesdropper [3]. Capacity expressions from the Nyquist and FTN cases permit to compute the maximum interference power tolerated by the FTN system in terms of the roll-off factor and overlapping degree. Recall that compressed data degrade the BER and signal processing is required to recover it. Overlapping degree-roll-off factor that provide maximum secrecy capacity will be provided too.

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