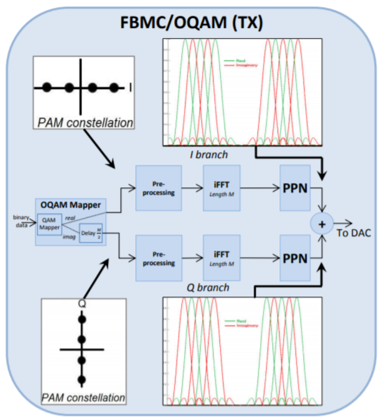
Deep learning for FBMC/OQAM systems to reduce PAPR and save power

Polytechnique Montréal - Département de génie électrique

January 2021



Filtered multicarrier systems such as Filter-bank multi-carriers (FBMC) [1] or Filtered OFDM (F-OFDM) [2] are promising technologies to improve future Internet-of-thing networks. These modulation techniques enable to support asynchronous communications [3] where the transmitters and the receivers don't need to be perfectly synchronized to a common and precise time-base to transmit data. Therefore, communication protocols can be simplified which, in turn, reduces the signalization overhead and saves power.

However, these modulations suffer from non-linearity issues of the power amplifier due to their high Peak-to-Average Power Ratio (PAPR) [4]. Their spectral shapes are distorted by the non-linearity, causing spectral regrowth [5] and interference, and therefore lose all their competitive advantages. One straightforward solution is to ensure that the average transmit power is far below the input backoff of the power amplifier so that the peak power of the signal stay within its linearity zone. However, this requires over-dimensioned and power-consuming amplifiers. Another approach is to use pre-distorsion techniques [6] at transmitter side and interference cancellation techniques at the receiver. However, these techniques can be complex to implement and may requires an accurate knowledge of the power amplifier model that may evolve with the time and the climatic conditions.

Recently, Deep Learning (DL) techniques have raised high interest in telecommunication [7] due to their abilities to efficiently provide solutions to complex non-linear problems that typical processing techniques have difficulties to deal with. Power amplifier non-linearity distortions fall into these difficult problems. Therefore, we propose to use deep learning techniques to deal with the spectral regrowth (transmitter side) and interference (receiver side) issues caused by the power amplifier on the filtered multicarrier signal. One of the challenge is to design a deep neural network (DNN) architecture with low complexity at transmitter side which is efficient enough to combat spectral regrowth. At the receiver side, there is no complexity constraints other than being realistically implementable on hardware, and have to deal with remaining interference.

Currently, a pre-distorsion algorithm based on a DNN have been proposed in [8] and applied on FBMC in [9] and demonstrate the efficiency of the approach. However, this DNN based techniques highly complexify the RF design. In fact, an additional analog-to-digital converter is needed since the DNN uses the HPA output as feedback information to digitally remove the distorted component of the signal. In [7], it has been shown that a DNN used as a detection at the OFDM receiver can greatly improve the receiver BER performance when facing interference due to clipping when reducing the PAPR. However, such observation has not been confirmed for filtered waveforms, and no DNN was employed at transmitter side to further improve the performance. Therefore, there is a lot of room for improvements.

The objective of the PhD thesis is to propose **a novel DNN-based technique that can efficiently reduce the PAPR and combat spectral regrowth of transmitted FBMC/OQAM symbols with low computational complexity**. A dedicated post-processing block can be proposed at the receiver side to deal with potential residual interference. A successful candidate should have knowledge about the following fields:

1. Wireless telecommunication in general, particularly signal modulation and demodulation techniques.
2. OFDM transmitter and receiver techniques, including channel equalization and estimation.
3. Deep neural networks in general.
4. Programming in MATLAB, Python and/or C++.
5. Some experience in at least one deep learning framework such as Pytorch, TensorFlow, Keras...

If you are interested to apply for this PhD thesis, please send an email to **both** Francois Leduc-Primeau (francois.leduc-primeau@polymtl.ca) and Jeremy Nadal (jeremy.nadal@polymtl.ca) with your curriculum vitae and university transcripts as attachments. Selected candidates will be contacted to schedule an interview, and asked to solve an assignment. This assignment serves as a base to evaluate the candidate knowledge. It is expected that the candidate completes the assignment and sends the responses 1 or 2 days before the interview. During the interview, some questions will be asked regarding how the problems have been addressed by the candidate.

References

[1] B. Farhang-Boroujeny, "OFDM Versus Filter Bank Multicarrier," *IEEE Signal Processing Magazine*, vol. 28, no. 3, pp. 92–112, 2011.

[2] J. Abdoli, M. Jia, and J. Ma, "Filtered ofdm: A new waveform for future wireless systems," in *2015 IEEE 16th International Workshop on Signal Processing Advances in Wireless Communications (SPAWC)*, 2015, pp. 66–70.

[3] Y. Medjahdi, M. Terré, D. Le Ruyet, and D. Roviras, "Asynchronous ofdm/fbmc interference analysis in selective channels," in *21st Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, 2010, pp. 538–542.

[4] S. S. K. Chaitanya Bulusu, H. Shaiek, and D. Roviras, "Impact of hpa non-linearity on coexistence of fbmc-oqam systems with pmr/ppdr systems," in *2016 IEEE 83rd Vehicular Technology Conference (VTC Spring)*, 2016, pp. 1–5.

[5] S. S. K. C. Bulusu, H. Shaiek, and D. Roviras, "Prediction of spectral regrowth for fbmc-oqam system using cumulants," in *2014 IEEE 10th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*, 2014, pp. 402–406.

[6] S. S. K. C. BULUSU, S. S. P. MADDILA, H. SHAIEK, and D. ROVIRAS, "Hpa linearization for fbmc-oqam signals with fast convergence-digital predistortion," in *2019 16th International Symposium on Wireless Communication Systems (ISWCS)*, 2019, pp. 133–138.

[7] H. Ye, G. Y. Li, and B. Juang, "Power of deep learning for channel estimation and signal detection in ofdm systems," *IEEE Wireless Communications Letters*, vol. 7, no. 1, pp. 114–117, 2018.

[8] R. Zayani, R. Bouallègue, and D. Roviras, "Adaptive predistortions based on neural networks associated with levenberg-marquardt algorithm for satellite down links," *EURASIP Journal on Wireless Communications and Networking*, vol. 2008, pp. 1–15, 2008.

[9] M. Laabidi and R. Bouallegue, "Two novel schemes to compensate hpa non-linearity on the fbmc/oqam signal," in *2018 14th International Wireless Communications Mobile Computing Conference (IWCMC)*, 2018, pp. 1404–1408.