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Artificial Intelligence for 5G Hardware Optimization

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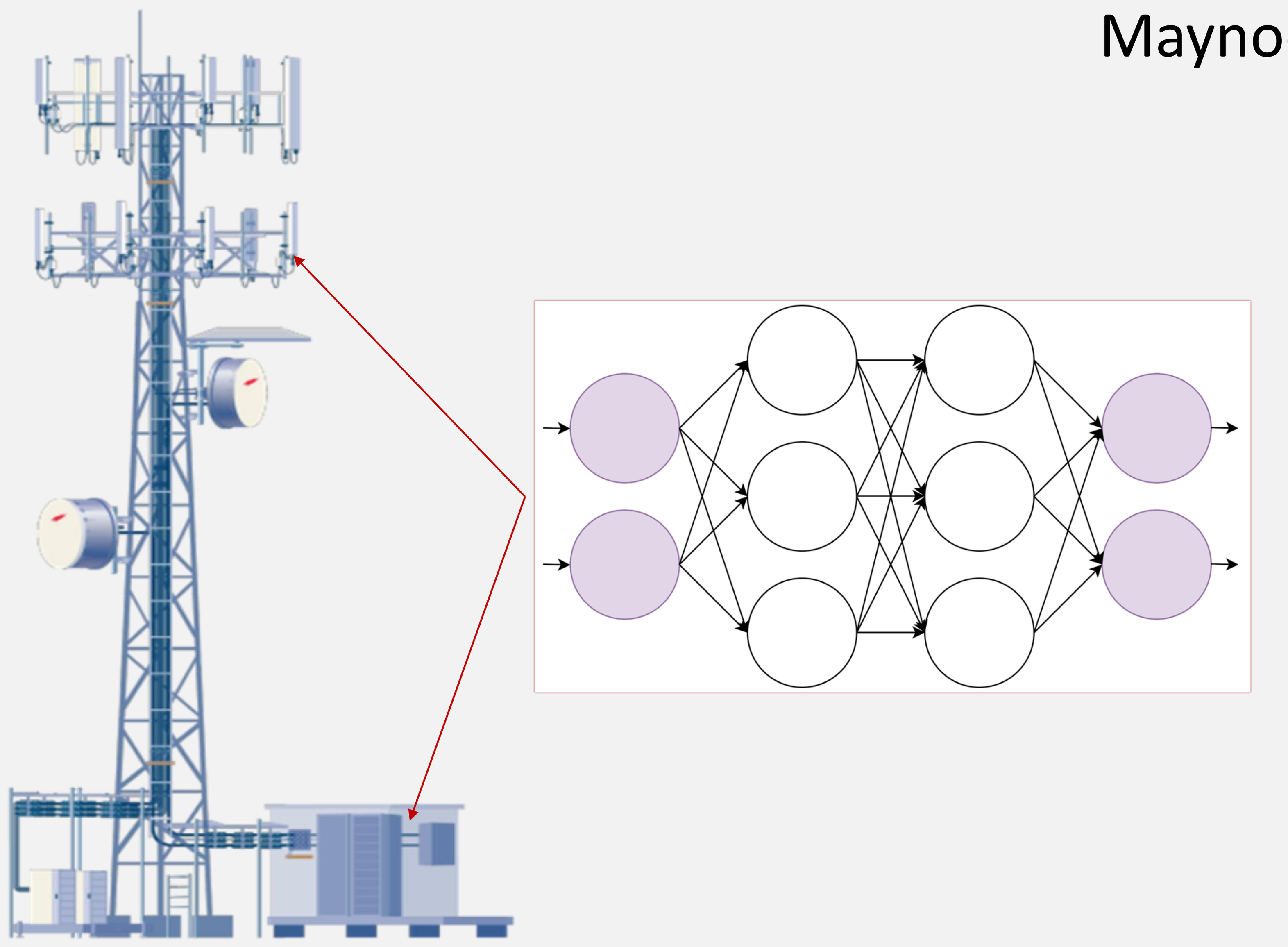

Figure 1: Artificial intelligence embedded into radio hardware

$$
\begin{aligned}
y_{\mathrm{GMP}}(n) = & \sum_{k=0}^{K_a-1} \sum_{l=0}^{L_a-1} a_{kl} x(n-l) \left|x(n-l)\right|^k \\
& + \sum_{k=1}^{K_b} \sum_{l=0}^{L_b-1} \sum_{m=1}^{M_b} b_{klm} x(n-l) \left|x(n-l-m)\right|^k \\
& + \sum_{k=1}^{K_c} \sum_{l=0}^{L_c-1} \sum_{m=1}^{M_c} c_{klm} x(n-l) \left|x(n-l+m)\right|^k .
\end{aligned}
$$

Figure 2: Generalized memory polynomial equation

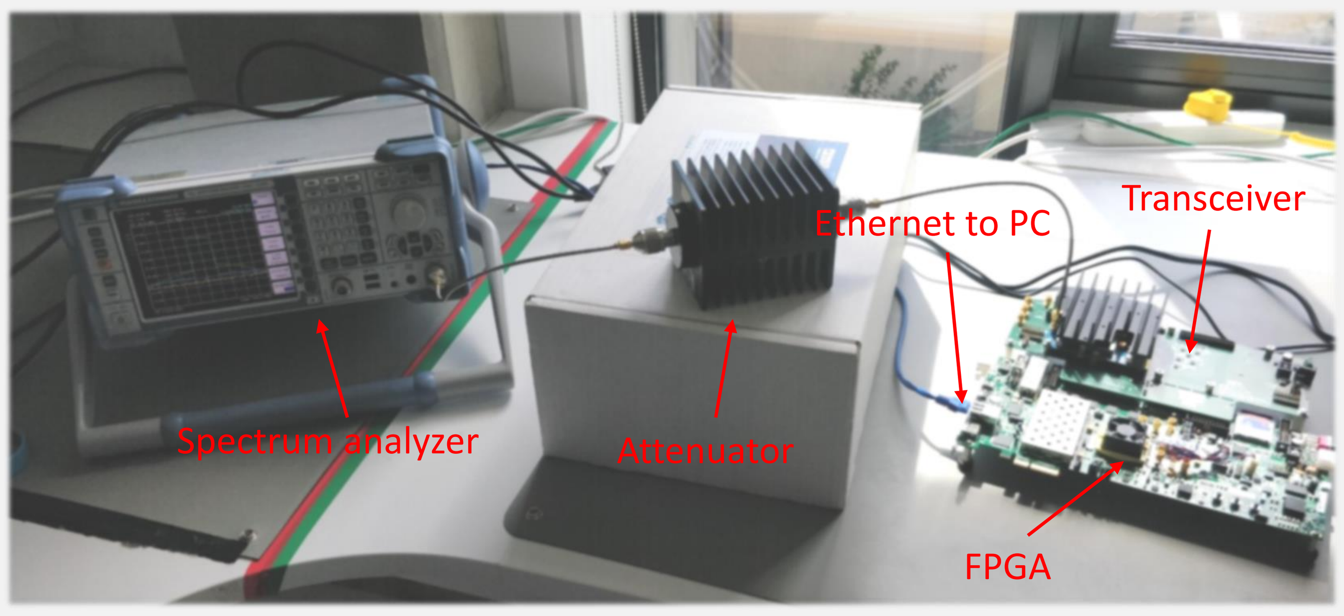

Figure 3: Experimental transceiver testbench

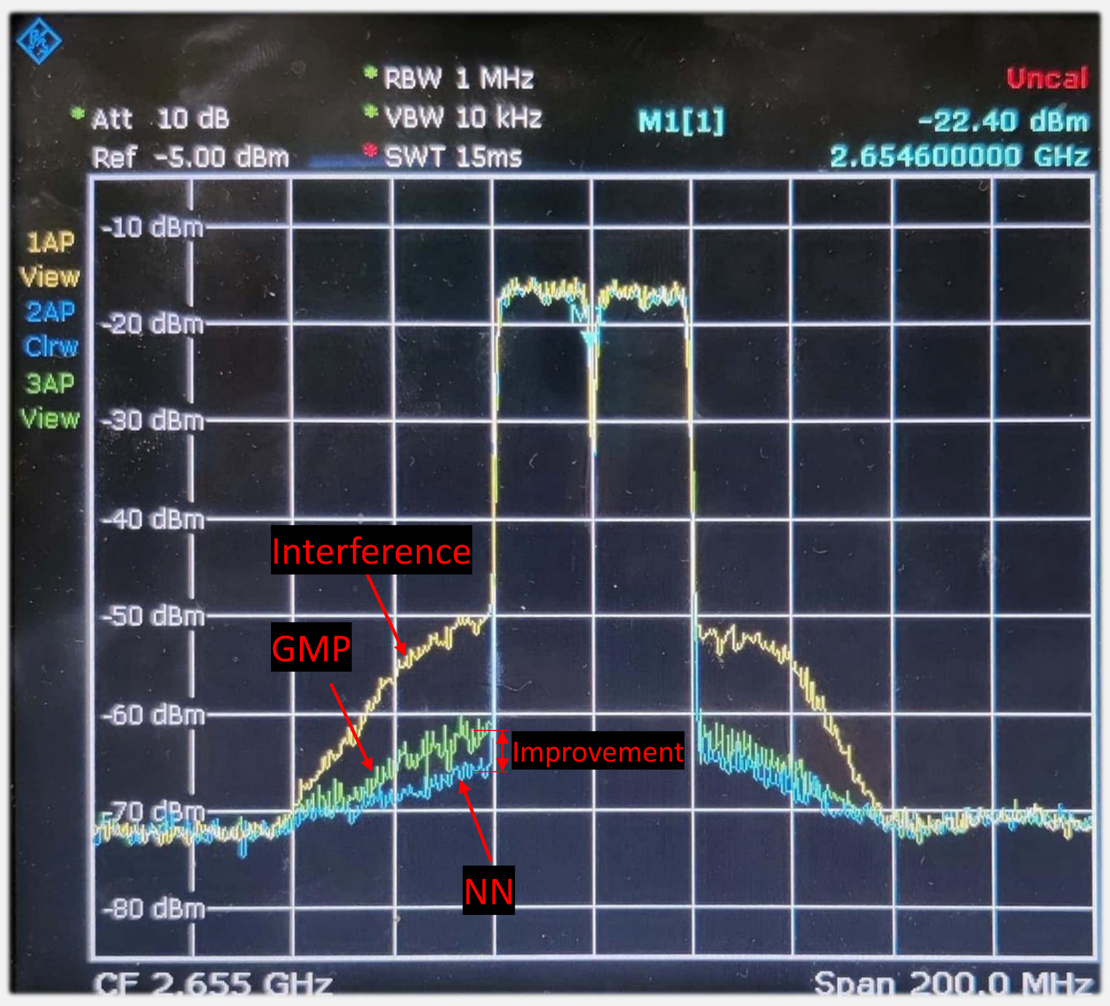

Figure 4: Capture of frequency domain signal with digital predistortion

Problem Statement

Cellular networks have low energy efficiency. Mobile base stations account for 57% of the energy consumption in a cellular network, with the most inefficient component being the power amplifier (Alsharif, Kim and Kim, 2017).

With the advent of millimeter-wave 5G networks, the efficiency of power amplifiers has become even lower than previous generations due to high-frequency power amplifiers with efficiencies as low as 17% (Asbeck *et al.*, 2019).

State of the Art Solution

Power amplifiers have greater efficiency, when they operate close to their peak power. However, this creates unwanted artifacts in the radio spectrum that creates interference with other transmissions. A set of techniques have been developed to combat these issues. The leading technique in this field is called digital-predistortion (DPD). DPD can be implemented in a variety of ways, with the current state of the art solution being based on the generalized memory polynomial (GMP). The equation for GMP is shown in figure 2 (Morgan *et al.*, 2006).

Proposed Solution

While DPD using GMP achieves good performance, new techniques based on machine learning and neural networks (NNs) are being developed. NN solutions can be just as good as, and in some cases better than, GMP based solutions. This holds true both in simulation as well as experimental validation.

Experimental Validation

To validate the NN solution for DPD, an experimental radio transceiver testbench was set up as shown in figure 3. A spectrum analyzer was used to help visually inspect the performance of the technique. The graph in figure 4 shows the transmitted signal in the frequency domain, where the yellow line is the signal without DPD, green represents the GMP solution, and blue is the NN solution. As shown from the results, the NN solution exceeds the performance of GMP, resulting in less frequency artifacts.

Future Work

In the current NN scene, the biggest issues relate to their complexity and training. In the future, the complexity and size of NNs must be reduced to make them more efficient. Optimizing NNs currently is not as efficient as GMP models and as such it is important to work towards finding less computationally intensive methods.

Alsharif, M. H., Kim, J. and Kim, J. H. (2017) 'Green and Sustainable Cellular Base Stations: An Overview and Future Research Directions', *Energies*. MDPI AG, 10(5), p. 587. doi: 10.3390/en10050587.

Asbeck, P. M. *et al.* (2019) 'Power Amplifiers for mm-Wave 5G Applications: Technology Comparisons and CMOS-SOI Demonstration Circuits', *IEEE Transactions on Microwave Theory and Techniques*. Institute of Electrical and Electronics Engineers Inc., 67(7), pp. 3099–3109. doi: 10.1109/TMTT.2019.2896047.

Morgan, D. R. *et al.* (2006) 'A Generalized Memory Polynomial Model for Digital Predistortion of RF Power Amplifiers', *IEEE TRANSACTIONS ON SIGNAL PROCESSING*, 54(10). doi: 10.1109/TSP.2006.879264.

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