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Integration of Deep Learning Methods into the Design of Microwave Transceiver Components for 5G Mid-Band System

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INTRODUCTION & AIM

Modern communication systems, RF technology, and microwave devices have advanced rapidly, enabling high data-rate transmission and driving the need for more efficient and adaptable design methods. Deep learning, a key area of artificial intelligence, has emerged as a powerful tool for modeling and optimizing microwave components such as filters, nonlinear devices, and parametric structures. Recent research shows its potential for fast frequency-domain simulations and prediction of communication-system behavior. This work evaluates deep learning as an alternative approach for designing a microwave transmitter–receiver system for mid-band 5G networks, presenting the problem context, theoretical basis, methodology, results, and conclusions.

METHOD

This work was structured following the sequence illustrated in the figure below.

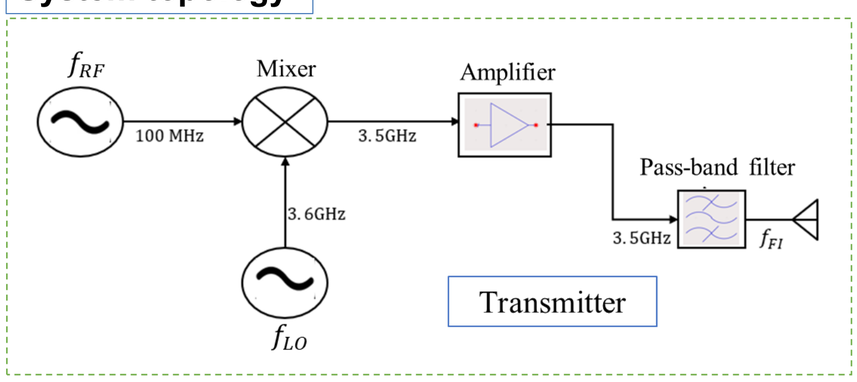
Phase 1: Define the features and components of the Transmitter-Receiver system.

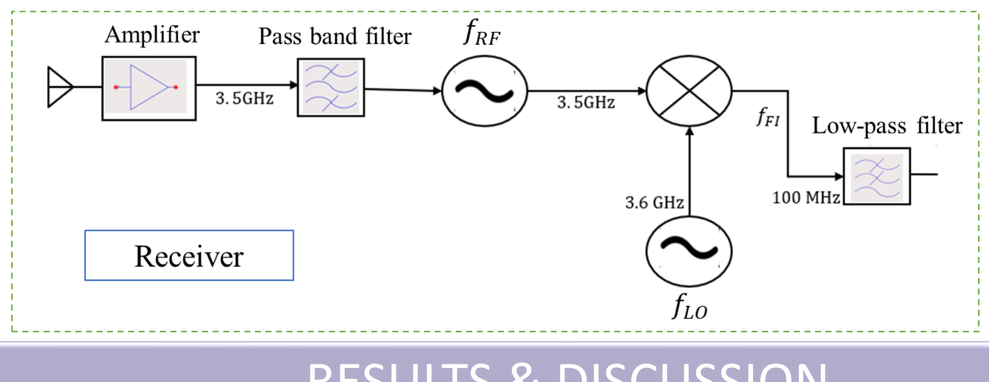
Phase 2: Data generation and application of the neural network

Phase 3: Neural network training

Phase 4: Validation and testing

System topology

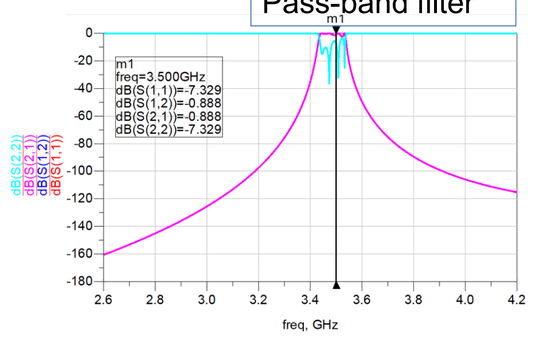




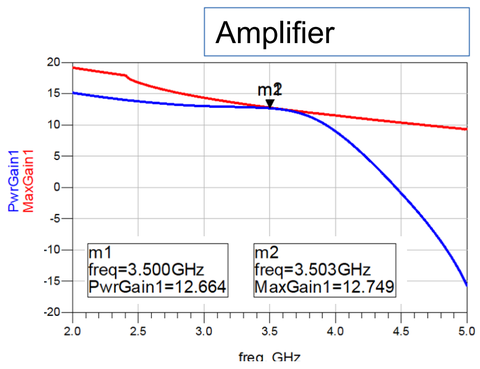
RESULTS & DISCUSSION

This section presents the base design of the system components, followed by the training results of each neural network, and finally their integration into the transmitter and receiver

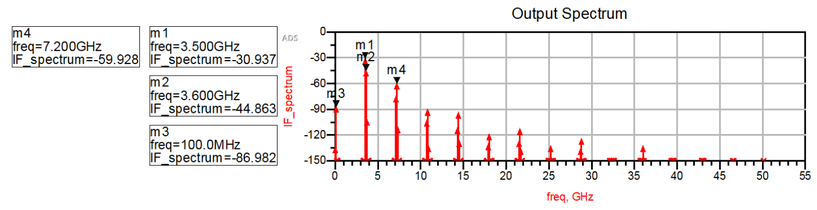
Pass-band filter



Amplifier

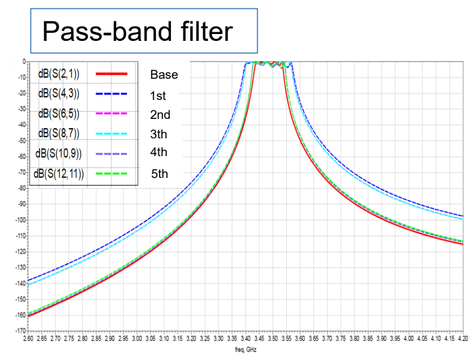


Mixer



This section presents the training results for each component, where each neural network was adjusted to fit the device and the nature of the compiled data. The evolution of MSE and MAE errors is included, along with ADS simulations using the obtained values.

Pass-band filter



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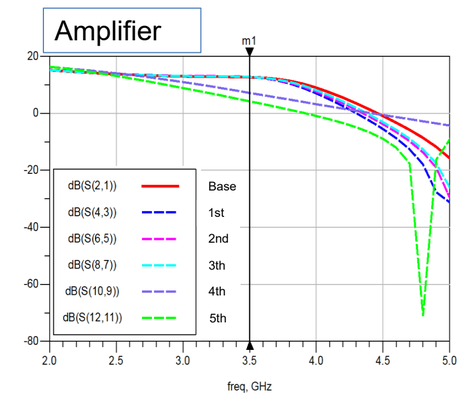
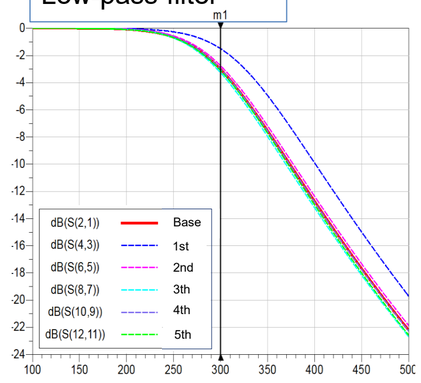


Low-pass filter

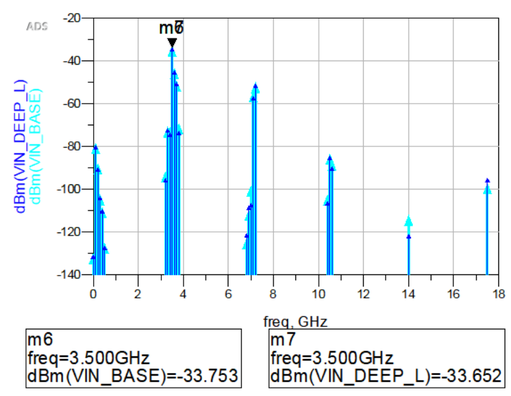


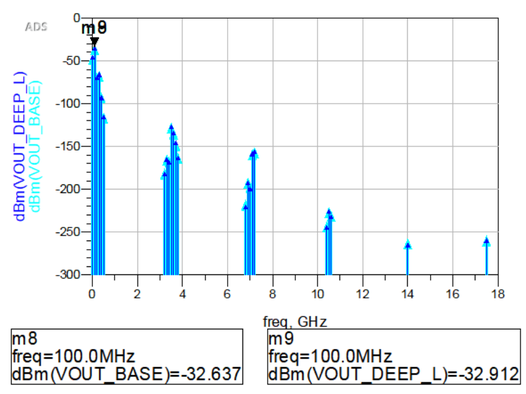
The results show high error in early training sessions, meaning the model initially struggled to learn the component's behavior. By the final session, the error drops sharply, indicating effective learning and a significant improvement in model accuracy.

Base design and Deep learning

Based on the signals obtained through the simulation, it is possible to compare the power and gain between the base design and the Deep Learning–based design. These values are presented in figure below.

Power análisis receiver





Power – Base design	
Input	-33.753 dBm
Output	-32.637 dBm
Gain	1.116 dB

Deep Learning - Base design	
Input	-33.652 dBm
Output	-33.912 dBm
Gain	0.738 dB

CONCLUSION

Deep learning models have been applied to microwave device design, but mostly for single components. This work advances the field by integrating multiple devices within a full communication system. A deep neural network architecture combining convolutional and sequential models was implemented to capture complex input–output relationships. A base system with four components and four neural networks was trained using 24,232 data points and 338 layers. Results show over 90% error reduction (MAE and MSE), confirming strong data-pattern fitting. System evaluation indicates a 3.5 GHz transmission, 100 MHz recovered signal, –32.912 dBm output power, and 0.738 dB gain, suitable for 5G environments.

FUTURE WORK / REFERENCES

Future work will explore expanding the neural network models to include additional microwave components and full end-to-end system optimization. Incorporating real-world measurement data, testing under varying 5G conditions, and comparing alternative deep learning architectures could further improve accuracy, robustness, and adaptability for next-generation communication systems.