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## **Learn, Investigate and Create with libLTE – An Open Source SDR library for 3GPP LTE**

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Software-Defined Radio (SDR) is often seen as a valuable tool for low-cost and rapid prototyping and research through testbed-based experimentation. GUI tools like GNURadio Companion, OSSIE or MATLAB's Simulink enable one to create a full communications system in a few minutes. Signal visualization is extremely useful not only throughout the developing process, but also as an educational tool: students see the effects of hardware or channel impairments and learn how to deal with them through real-time experimentation.

However, the communications systems created in these experiments are often too simplistic versions of modern communications systems. A simple OFDM waveform, for instance, is very useful to teach or experiment with channel estimation, frequency offsets and synchronization. However, it is not a representative model of a commercial LTE system. LTE has very particular synchronization and reference signals, multi-cell interference patterns, modulation/coding or multi-antenna schemes. Assembling a testbed for teaching or investigating any of these features is too challenging, expensive and time-consuming. A simulator is not useful if we want to deal with real signals in real-time. A commercial product is good for end-to-end system verification, but lacks the flexibility to modify or create new features. Thus, resorting to a simplistic communications system is often the best solution.

LibLTE is an open source library of DSP blocks for the 3GPP LTE Release 8 standard. It is highly modular and very flexible and is specifically designed for experimentation-based learning, testbed-based research and low-cost prototyping of new systems. Simple GUI tools allow students to visualize over-the-air LTE signals (coming from commercial LTE networks), see the constellation, learn and play with the different synchronization algorithms, see what happens when we move the receiver to the cell edge, learn how to deal with neighbour cells interference, etc. LibLTE is a perfect tool to create small lab experiments for specific LTE features in just a few minutes. Its modular structure allows replacing or adding components and quickly seeing the effect to the complete system. Inter-module dependencies are kept to a minimal, so that replacing the Turbo or Viterbi decoders by another implementation, for instance, is as simple as renaming a function call. This makes libLTE an ideal platform for testbed-based research and creation of new advanced UE or eNodeB implementations that take LTE as the basis on top of which extended functionalities or features are added.

This tutorial will be highly interactive. We will create and run a simple LTE lab experiment that will receive real signals coming from commercial LTE networks, to show the potential of libLTE as an educational tool. We will explain how libLTE is organized by looking at the code. Then, we will modify an existing LTE UE implementation and visualize the impact on the final end-to-end performance again using real-time LTE signals.