Success Story

Budapest University of Technology Students Design Novel Mixer Using NI AWR Software

Company Profile

The Budapest University of Technology and Economics (BME) is the most significant technological university in Hungary. Founded in 1782, it is considered the world's oldest university of technology and was the first institute in Europe to train engineers at university level. The electrical engineering and infomatics department and is renowned for excellence in research and education throughout the years of changes in the scope of engineering.

The Design Challenge

Under the direction of Dr. Tibor Berceli, head of the Optical and Microwave Telecommunication Laboratory, students at BME were challenged to design a novel mixer. Specifications for input signals to separate ports, multiplier-type operation, significantly lower LO power, cleaner spectrum, and easier separation of bands were all given at the onset.

Although mixers are typically controlled by the transistor being switched on and off by the local oscillator, in this unique device the designers tried a different approach in which the transistor was never fully off, thus decreasing the level of unwanted harmonics. Instead, the channel resistance of the drain-source junction was modulated by the local oscillator and the operation was closer to the ideal linear multiplication than a switching mixer.

A mixer is a three-port device having two inputs, radio frequency (RF) and local oscillator (LO), and one intermediate frequency (IF) output. It is used to convert the RF signal to a fixed IF. Mixers perform frequency translation by multiplying two signals using a nonlinear device and work on the principle that an LO RF drive will cause switching/modulating of the incoming RF to the IF. By making use of the nonlinear properties of a pseudomorphic high electron mobility transistor (pHEMT) the active field-effect transistor (FET) mixers provide low noise figures, reasonable conversion gain, and good port-to-port isolation with a minimum of matching network circuitry.

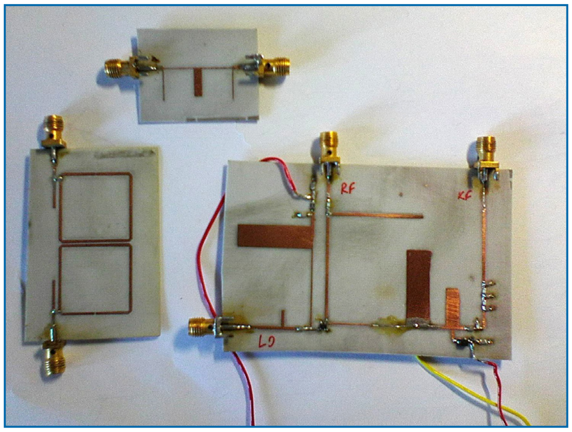

Photo of the actual mixer circuit built by BME students.

MŰEGYETEM 1782

Application:
Microwave Components
Mixers

Software:
NI AWR Design Environment
Microwave Office

"Because NI AWR Design Environment is so intuitive and we had been using the software in our engineering classes, we were able to successfully complete this relatively complex novel single-sideband mixer design and meet our specifications."

– Bence Cseppento
Budapest University of Technology
bme.hu/en

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Additionally, single-sideband mixers reduce system cost and complexity by removing the need for expensive preselection, as well as one or more stages of upconversion or downconversion. As a multiplier-type FET mixer, the team designed a single-sideband mixer (schematic and layout shown in Figures 1 and 2) with LO to be 2 GHz for an expected RF signal operating at 2.1 GHz, resulting in an IF of 100 MHz, and operating over a 20 MHz bandwidth (2.09-2.11 GHz).

The mixer uses a microstrip distributed diplexer subcircuit to separate the RF and IF signals. The LO signal drives the FET between on and off states. To optimize the on/off ratio, some gate bias was applied. The mixer operates in a reflection mode and the signals applied to the FET channel are reflected by a time-varying reflection coefficient. The FET channel under the control of the LO signal switches between a low resistance state and a high resistance state. Furthermore, the diplexer circuit contains the IF and RF filter subcircuits. It isolates the IF and RF ports from one another, but allows transmission between these ports and the common port, which is connected to the drain of the FET.

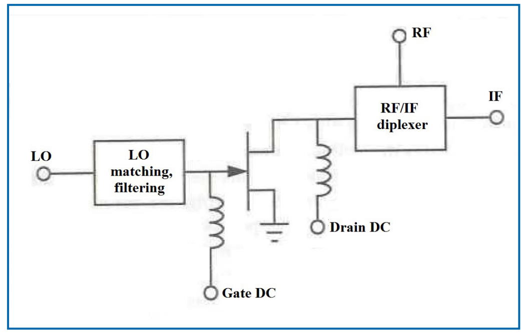

Figure 1: Schematic of the mixer.

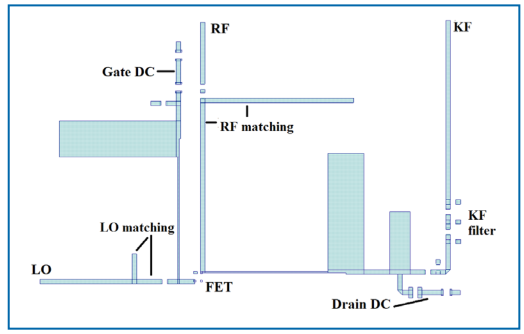

Figure 2: Layout of the mixer.

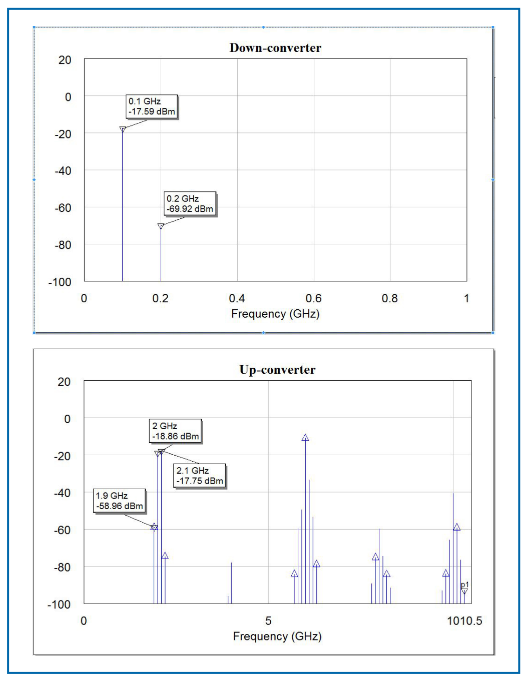

Figure 3. Spectral output of the SSB FET mixer showing mixer products for both up- and down-converted signals.

The Solution

The students at BME used NI AWR Design Environment, specifically Microwave Office circuit design software, to achieve this novel design. The steps they followed included the design of the gate and drain bias network providing the necessary isolation of the DC bias injection ports from high-frequency signals, the development of the impedance matching circuit for the gate of the FET (source) at the 2.0 GHz LO frequency, as well as the development of impedance matching networks for the RF input and IF output signals, as well as filtering of the RF signal at the IF port. Microwave Office was used throughout the design and simulation phases of this mixer development, including the determination of the optimum bias conditions and transistor input (gate and drain) impedances under nonlinear operating conditions with the help of the Microwave Office harmonic balance circuit simulator. The harmonic balance simulation for the mixer was set up with RF drive sources specified (with defined frequency and power) for the RF and LO ports.

The physical implementation of the impedance matching circuitry and diplexer, which are based on distributed transmission lines and open-circuited stubs, was conducted using standard transmission line models available in Microwave Office. The simulated mixer products generated by the nonlinearities of the FET include the upconverted and downconverted signals, respectively, as shown in Figure 3.

Finally, the circuit was simulated, fabricated, and measured. The students met their specifications of comparatively low LO power (4-5 dBm), easier separation of frequency bands, and a clean IF spectrum output.

Why NI AWR Design Environment

Because NI AWR Design Environment is so intuitive, the BME students were able to quickly and successfully complete this complex single-sideband FET mixer design quickly and effectively. The students were also grateful to NI for making the software platform available to them through the AWR University Program, which donates free software to member universities.