Videos at a Fancy Bar Counter: Sub-Six 5G Flexible Low-Interference Receiver Competition

Sponsoring MTT-S Technical Committee:

MTT-6 (Microwave and Millimeter-Wave Integrated Circuits)

Competition Organizers:

- Rüdiger Quay (Ruediger.quay@ieee.org), Fraunhofer IAF, Freiburg, Germany
- Nils Pohl (nils.pohl@rub.de), Ruhr Universität Bochum, Germany
- Roger Kaul (rogerieeemtt@gmail.com), Army Research Lab. (ret.), USA

Competition Summary:

Simple: you want to use your ultimate cell phone at the newest 5G frequencies to get maximum data rate. So we use multiband amplifiers (to get the bits), and the receiver must be linear (to get something through) and rugged (to survive), as you are going to use it for sure at a cool metallic counter at a fancy bar to show the latest videos to your friends in your leisure time. However the RF reflections from the metal wall might go into your own device. This is what we engineer for.

Linear and rugged low-noise amplifiers are needed in any operational communication system to achieve fast and reliable information transfer while maintaining good ruggedness and linearity even in harsh environments over a wide frequency range from 0.7 GHz to 5.8 GHz for upcoming new bands in 5G, called the sub six regime. The students are to design a multiband device which, other than in previous years, will have to answer the challenge of providing very broad services at 0.7 GHz, 3.8 GHz and 5.8 GHz for worldwide communication services. The devices will be analyzed for overall linearity at low input, low-noise figure, and interference immunity at 0 dBm input for all three bands. The FOM will include noise figure, IMD3 linearity, DC power consumption, and remaining performance at low input and at 0 dBm input for 0.7 GHz, 3.8 GHz, and 5.8 GHz.

Competition Description and Rules:

- Competitors are required to design, construct, measure, and demonstrate **ONE** multiband high linearity, low-noise amplifier module evaluated at three remote frequencies. There can be no exchanges of the device.
- The devices will be collected at the beginning of the competition. NO CHANGES on the devices are allowed after this. There can be no modification on the broadband LNA of any kind (mechanical, electrical).

- The students can attend the measurements of their individual device.
- The amplifier may use any technology. Use of commercial amplifier subsystems and passive components is allowed.
- The amplifier shall allow for internal inspection of the circuitry.
- The amplifier shall be capable of amplifying a signal with a minimum 13-dB of small-signal gain at 0.7 GHz, 3.8 GHz, and 5.8 GHz with a 50-ohm source and load impedance.
- The noise figure must be lower than 2.5 dB at all frequencies.
- The P1dB (1dB compressed, single tone) output power should be greater than 0 dBm for all frequencies.
- The amplifier must have no DC voltage at its input and output ports.
- The amplifier must be operated at room temperature.
- The amplifier must utilize 3.5 mm SMA (female at the input, male at the output) jacks on both the input and output. The prime power shall use two wires with banana plugs at least 0.5 meter in length and it must be shielded. The hot connector must be in red with ground in black. **The device must be ruggedized and shielded to work in a noisy environment. This is a central requirement as in the past unshielded devices could not be measured in the noisy environment of an exhibition hall at IMS due to electromagnetic interference (EMI).** The LNA module enclosure should be shielded completely with a metallic top cover lid. RF absorber material may be used on the inside surface of the top cover lid if required.
- The prime DC power shall be totally derived from a single supply with a voltage of up to +5 Volts DC **or** –5 Volts DC employing two wires. A metered power supply will be provided at IMS2019 by the organizers.
- No internal batteries may be used.
- No changes are allowed on the device during the measurements.

Evaluation Criteria

- The performance of the amplifier is based on the output third-order intercept parameters and noise figure at f1, f2, an f f3 measured with a signal analyzer using a noise diode source. Two isolated signal generators (e.g., Rohde & Schwarz model SMA, SMB, or equivalent) will provide the two signals for the third-order measurements.
- The third-order intercept measurement will be performed, first using two -20 dBm AND in a second run, 0dBm input signals around f1, f2 and f3 GHz with a tone spacing of 20 MHz.
- The amplifier circuit with the highest LNA figure of merit shall be declared the winner.
- **The overall LNA figure of merit** (LNAFOM) is determined by the following relationship based on the three frequencies f1, f2, f3.

We will set f1 = 0.7 GHz, f2 = 3.8 GHz, and f3 = 5.8GHz using the most important new 5G frequencies in one amplifier.

LNAFOM = (LNAFOM_up + LNAFOM_mid + LNAFOM_low)/3

LNAFOM_low = (OIP3_low/Pdc)/NFdB_low (at frequency 1)

LNAFOM_mid = (OIP3_mid/Pdc)/NFdB_mid (at frequency 2)

LNAFOM_up = (OIP3_up/Pdc)/NFdB_up (at frequency 3)

(NFdB_up, NFdB_mid, NFdB_down is set to 2.5 dB for all contestants after the go/no go decision)

where:

LNAFOM_low, LNAFOM_mid, LNAFOM_up = LNA figure of Merit at frequency f1,2, and 3

OIP3_low = Output third order intercept point IP3 of LNA in milliwatts for the lower tone (based on a two-tone measurement with tones at f1-10 MHz and f1+10MHz with 20 MHz spacing and taking the lower IP3 around f1)

OIP3_mid = Output third order intercept point IP3 of LNA in milliwatts for the upper tone (based on a two-tone measurement with tones at f2-10 MHz and f2+10 MHz with 20 MHz spacing and taking the upper IP3 around f2)

OIP3_up = Output third order intercept point IP3 of LNA in milliwatts for the upper tone (based on a two-tone measurement with tones at f3-10 MHz and f3+10 MHz with 20 MHz spacing and taking the upper IP3 around f3)

Pdc = DC power drawn by power supply in milliwatts for both low and high excitation

NFdB_low, NFdB_mid, NFdB_up = LNA noise figure in dB = 2.5 dB set for all those passing the test at f1, f2 and f3.

OIP3dBm_low= Po_low + 0.5 (Po_low - P3rd_low)

OIP3dBm_mid = Po_mid + 0.5 (Po_mid - P3rd_mid)

OIP3dBm_up = Po_up + 0.5 (Po_up - P3rd_up)

Po_low, Po_mid, Po_up = Output power of the f1-10 MHz and f2+10 MHz, f3+10 MHz signal in dBm

P3rd_low, P3rd_mid, P3rd_up = Output power of the third order products around f1, f2 and f3 in dBm

OIP3_low = 10^(OIP3dBm_low/10) in milliwatts for the lower tone.

OIP3_mid = 10^(OIP3dBm_mid/10) in milliwatts for the middle tone.

OIP3_up = 10^(OIP3dBm_up/10) in milliwatts for the upper tone.

These three OIP will be taken for both linear input powers -20 dBm and at high compression 0 dBm and then again averaged.

In the unlikely situation of contestants with the same LNA figure of merit, the one with the lowest overall DC power will be selected.

Due to the broadband operation and the variety of frequencies, that might be chosen, the asymmetry of the intermodulation powers will not be considered.

Prizes:

The winner(s) will receive a prize of $2,000 (USD) and will be invited to submit a paper describing his/her project to the IEEE Microwave Magazine.

Eligibility Criteria:

- Enrollment in a university or colleges
- It is open to both undergraduate and graduate students
- Groups of up to four members are admitted

How to Participate:

- Submit an entry form to both Ruediger Quay and the Student Design Competition chair by 1 April 2019 giving names, affiliations.
- A short description of the modules is to be provided. A schematic of the circuit shall be brought to the IMS.
- Provide a support letter by your professor stating that you are working on this project and that at least one person will be able to join IMS 2019.
- Sponsoring professors are encouraged to introduce this competition as a course project for their students in order to acquaint them to system and circuit level design.