Executive Summary

In this activity, the concept of solid-state power amplifier (PA) design for 17.3-20.3GHz large-scale active arrays in space-qualified SiGe BiCMOS technology is proved. Two tape-outs and three PAs (shown in Fig. 1) are done and fabricated, they are namely

- **Original PA without stabilization RC network**: provides higher small-signal gain and higher simulated power-added efficiency (PAE) in large-signal region. However, in measurement, parametric oscillation was found in large-signal region.
- **Modified PA with stabilization RC network**: degradation of small-signal gain by roughly 3dB at 18.8GHz but the PA is stable all over the input signal range. The maximum PAE achieves 37.7% with 22.8dBm output power at 18.8GHz.
- **Balanced PA based on modified PA**: to provide immunity to load variation from antenna, balanced PA is designed with on-chip miniaturized quadrature coupler. The PA achieves 25.5% PAE with 24.3dBm output power at 18.8GHz. The simulation shows at VSWR 3:1, the output power variation is within 2dB and gain variation within 1dB.

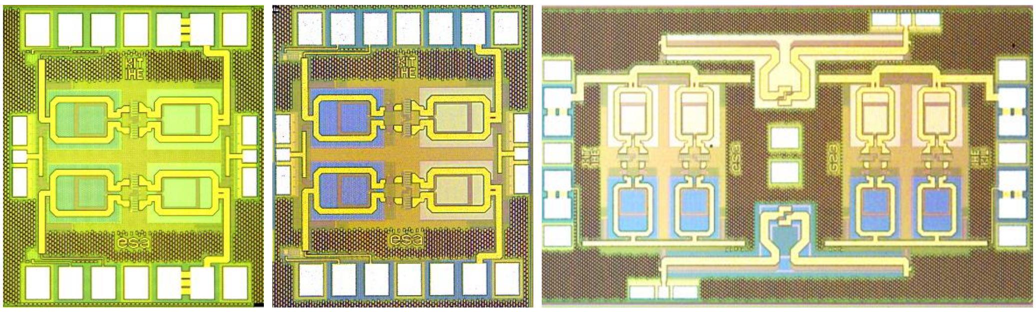

Fig. 1. Original, modified and balanced PAs (left to right).

In the early phase of the activity, the circuit topology was investigated. To achieve the specified power level, cascode is normally used. However, in this technology and the targeted frequency range, return gain was found at small-signal region which makes cascode difficult to use. Therefore, common-emitter with capacitive neutralization is adopted. After the original PA was fabricated, parametric oscillation was however found in large-signal region because of nonlinear parasitics in HBTs. This indicates the drawback of the common-emitter topology on the other hand. To summarize, more considerations in stability should be made in terms of toplogy selection.

- **Cascode** is commonly used in SiGe PA, but it can present negative impedance at the output in small-signal region. Selection of bias conditions also has an impact on stability.
- **Common-emitter with capacitive neutralization** shows stable in small-signal region. However, the nonlinear parasitics make the neutralization network fail in large-signal region. This causes parametric oscillation. Therefore, common-emitter topology should be by all means equipped with an additional stabilization network at the cost of gain.

Investigation is conducted on the feasibility of (orthogonal) load-modulated balanced PA (O-LMBA) to reconfigure the load. Although the injected signal provides another degree of freedom of tuning, the impedance is only tuned at the interface of HBT and matching network (namely collector terminal and transformer network in the proposed PA). Impedance at the interface of 90° coupler and load (where antenna impedance is shown) is not tunable; hence, the immunity to load variation from antenna does not exist. Instead of an LMBA, a conventional balanced PA is designed based on the following facts:

- **Conventional balanced PA** provides sufficient immunity to load variation. Although the antenna mismatch is not compensable, the immunity to phase variation at constant VSWR 3:1 is proved in simulation.
- To save the chip area, **miniaturized quadrature coupler** with additional capacitor networks is designed to shorten the length from 1.9mm to 950µm (by one half). The shrinkage of size is essential in the targeted frequency range whereas the performance is likely degraded. The simulation results shows output power variation within 2dB and gain variation within 1dB at VSWR 3:1.

Finally, the noise-power-ratio (NPR) measurement is demonstrated by using the prestige vector signal generator from Keysight. To accommodate to different applications for the time being and for the future, several experiments are conducted with the modified PA:

- Two 500-MHz channels with 25-MHz notch: the PA shows 19-19.5dBm with 22-24.5% PAE at NPR 15dB.
- At 18.8GHz, different bandwidth with 5% notch: the PA shows 19.7dBm with 25.6% PAE at NPR 15dB.
- Three 500-MHz channels with two 25-MHz notch: the PA shows 16dBm with 13.5% PAE at NPR 15dB.

Despite the experimental results of NPR shown above, some more considerations will further be taken:

- The estimated peak-to-average power ratio (PAPR) is calculated by iqtools as 5.2-5.4dB. This would be further characterized and verified.
- The influence of signal bandwidth is shown in the above experiments.

To conclude, the milestones that have been achieved in the activity and results from simulation and measurement are listed in this summary. Further information can be found in the final report.