Ambipolar radiofrequency applications for the next generation of microwave engineers

F. Pasadas, A. Medina-Rull, A. Toral-Lopez, F. G. Ruiz, A. Godoy, E. G. Marin

Pervasive Electronics Advanced Research Laboratory (PEARL), Departamento de Electrónica y Tecnología de Computadores, Universidad de Granada (Spain)

Introduction

Graphene and related materials (GRM) based electronic devices could offer big opportunities in many fields such as **high-frequency electronics** and they have become potential candidates for the deployment of **emergent flexible and wearable electronics**. This scenario is of particular relevance for the **students in telecommunications and electronics degrees**, who will face the new challenges arising with this potential paradigm shift in the prevailing electronic technology.

Objectives

The **technology computer-aided design** (TCAD) **tools** can be exploited by the engineering students **to explore ambipolar electronics** opening the possibility to 1) redesigning and simplifying of conventional circuits; and 2) seeking of new functionalities for analogue radiofrequency electronics.

Methods

By using TCAD tools of graphene field-effect transistors embedded into commercial microwave circuit simulators usually employed by students in telecommunications and electronics degrees, we present **new insights** for the design of graphene-based RF **frequency multipliers** and **mixers** that specifically exploit the inherent intrinsic ambipolarity of graphene from an engineering perspective.

Results

The use of TCAD tools has resulted in (i) **increasing the interest** of students for emergent novel technologies; (ii) the design and exploration of **new concepts for radiofrequency designs** such as a frequency tripler (Figure 2) and a subharmonic mixer (Figure 3); and (iii) **providing better understanding** in the design of microwave integrated circuits.

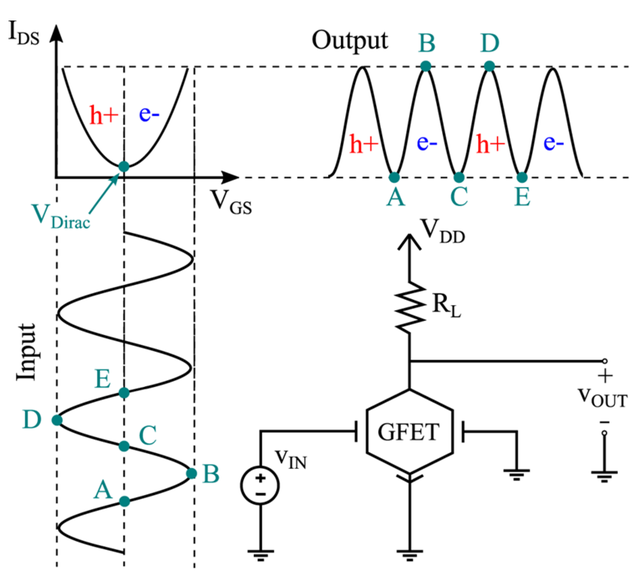

Figure 1. Ambipolar operating principle

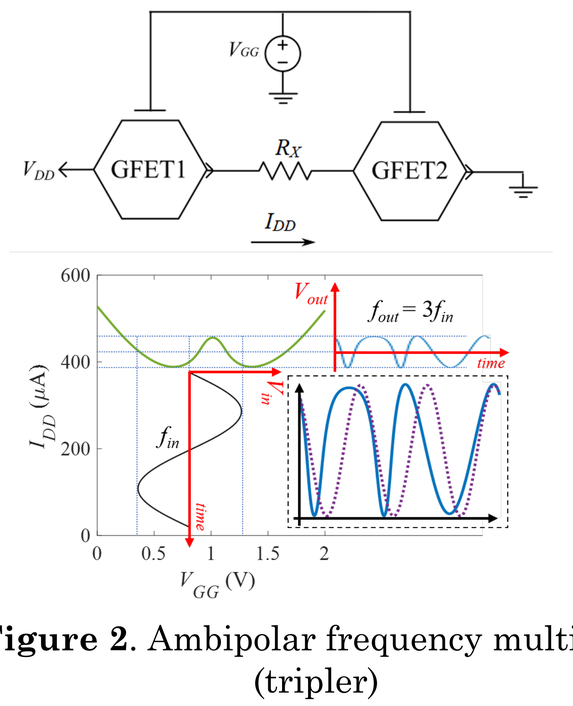

Figure 2. Ambipolar frequency multiplier (tripler)

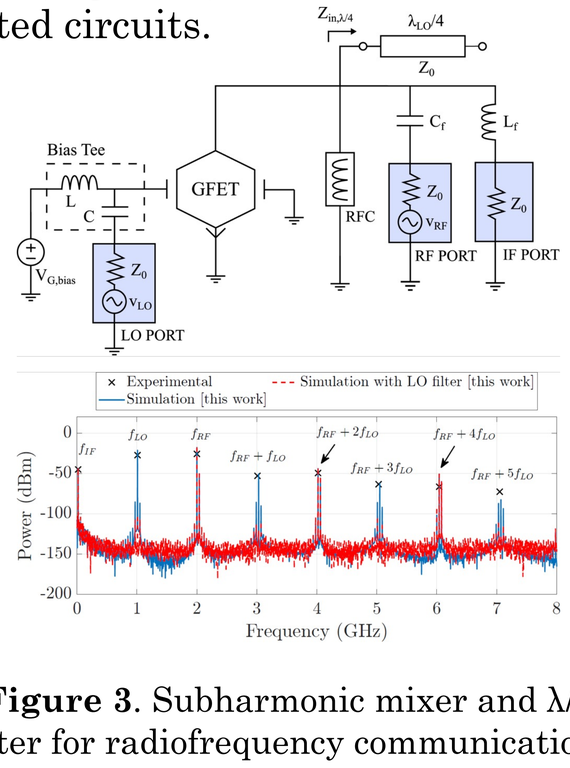

Figure 3. Subharmonic mixer and λ/4 filter for radiofrequency communications

Conclusion

Ambipolar electronics offers huge opportunities for the future design of microwave integrated circuits. In this context, we have implemented a set of circuit models to be exploited in conventional circuit simulators used in engineering degrees to **seek out new functionalities**, to **simplify the circuit topologies** or even to **improve the circuit performance**. This work gives insights for engineering students about how the accurate control of graphene ambipolarity can be exploited for the development of frequency multipliers and mixers.

References

Medina-Rull, A., Pasadas, F., Marin, E. G., Toral-Lopez, A., Cuesta, J., Godoy, A., Jiménez, D., Ruiz, F. G., (2020). A Graphene Field-Effect Transistor Based Analogue Phase Shifter for High-Frequency Applications. *IEEE Access, 8*, 209055–209063. https://doi.org/10.1109/ACCESS.2020.3038153

The TCAD tools for GFET circuit simulations are available from the corresponding authors upon reasonable request (fpasadas@ugr.es; egmarin@ugr.es).