**Università di Catania**
Dipartimento di Ingegneria
Elettrica, Elettronica e Informatica

**STMicroelectronics**
*Catania Site*

*Radio Frequency Advanced Design Center*

# Ph.D. Brainstorming Day

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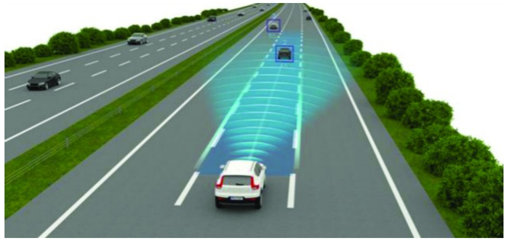
Tutor: Prof. Giuseppe Palmisano

*Catania, Oct. 29th 2019*

# Automotive radar overview

## Applications

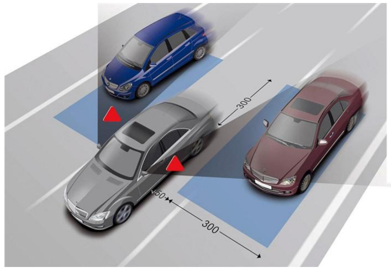
Radar sensors are the core of many *Advanced Driver Assistance Systems* (ADAS).



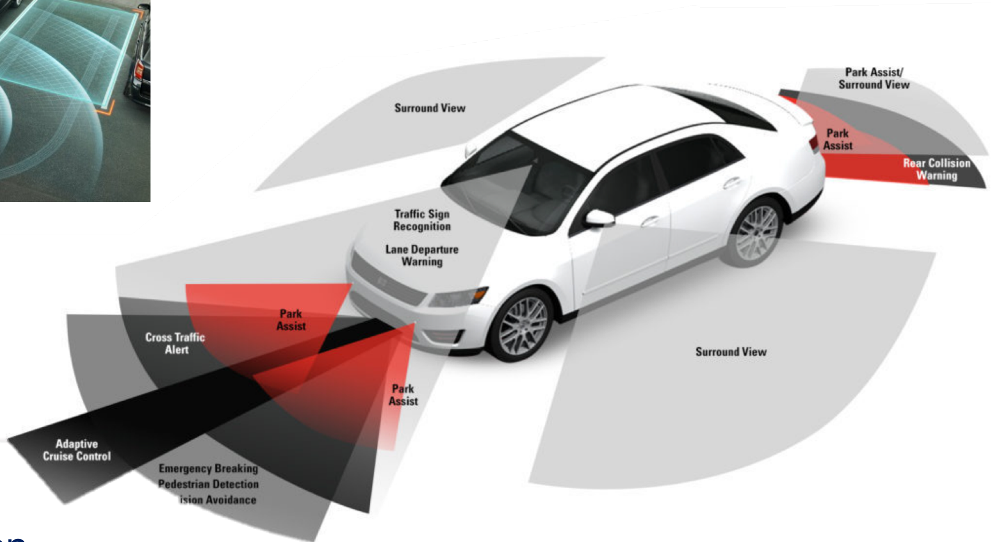
Adaptive Cruise Control

Park Assist

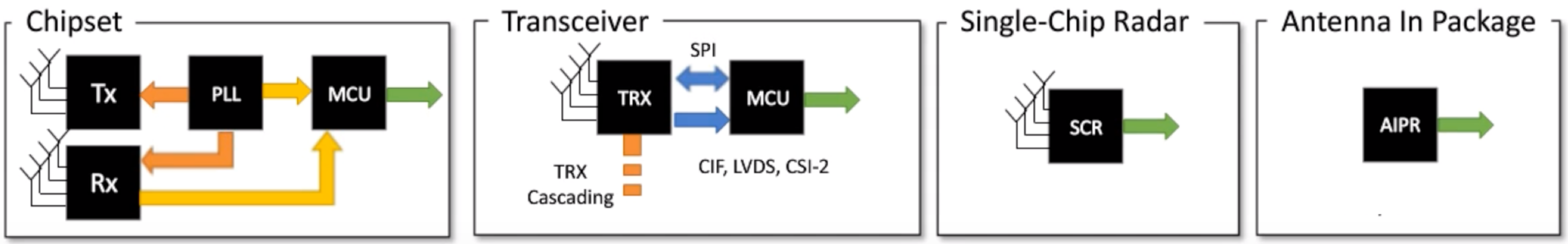

Anti-Collision System



Blind Spot Detection



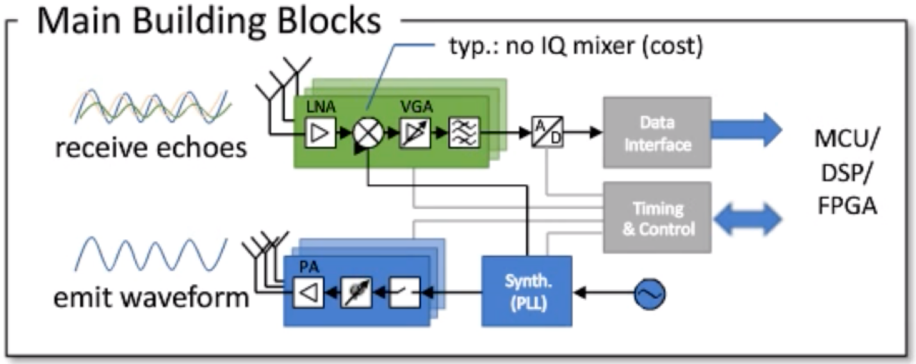

Toward a low cost solution

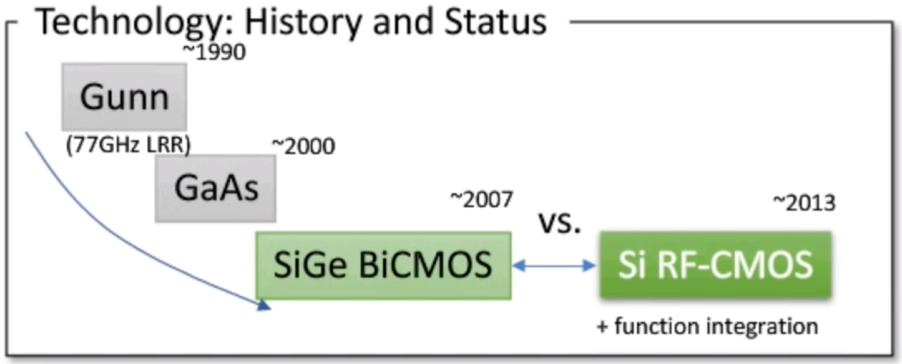


# Technology Platform

## 28-nm FD-SOI CMOS technology by STMicroelectronics

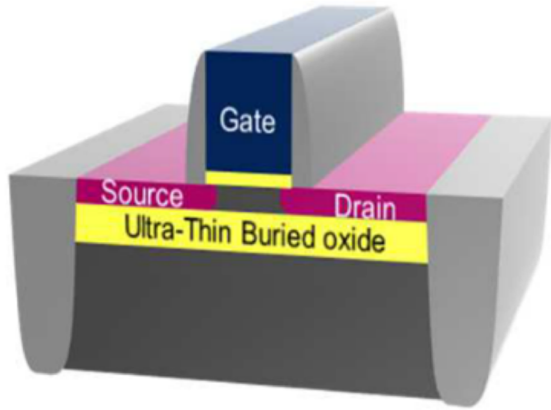
High scaled CMOS technology is mandatory for a low cost radar implementation.



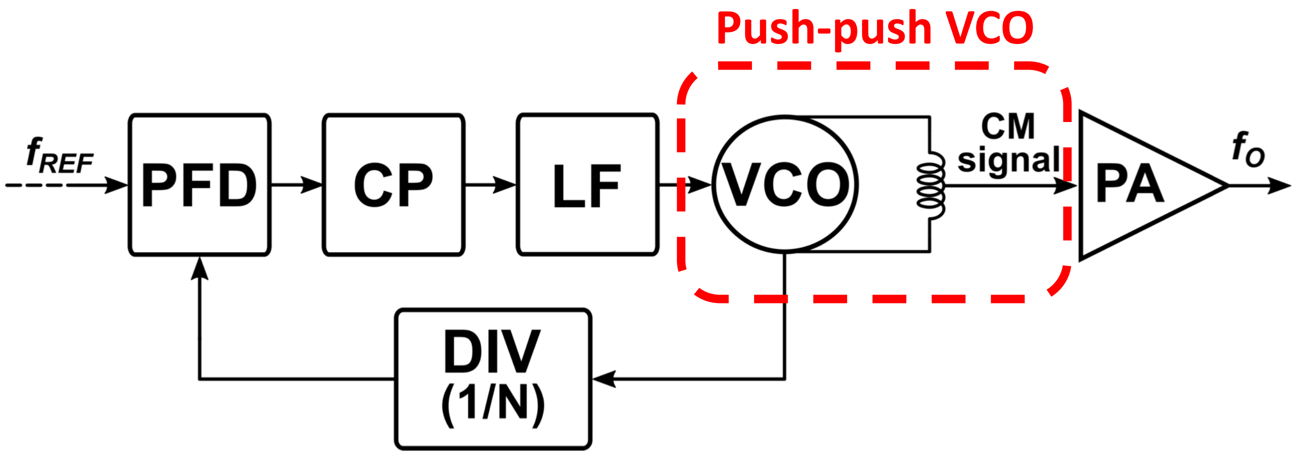

### 28-nm FD-SOI CMOS Advantages:

- Total Dielectric Isolation that allows an excellent frequency performance ($f_T \sim$ 300 GHz) to be achieved;
- High integration level (SoC);
- Low power supply $V_{DD}$ = 1V;
- Extended body biasing through the dual gate (FBB and RBB);



# 77-GHz local oscillator

## Architecture

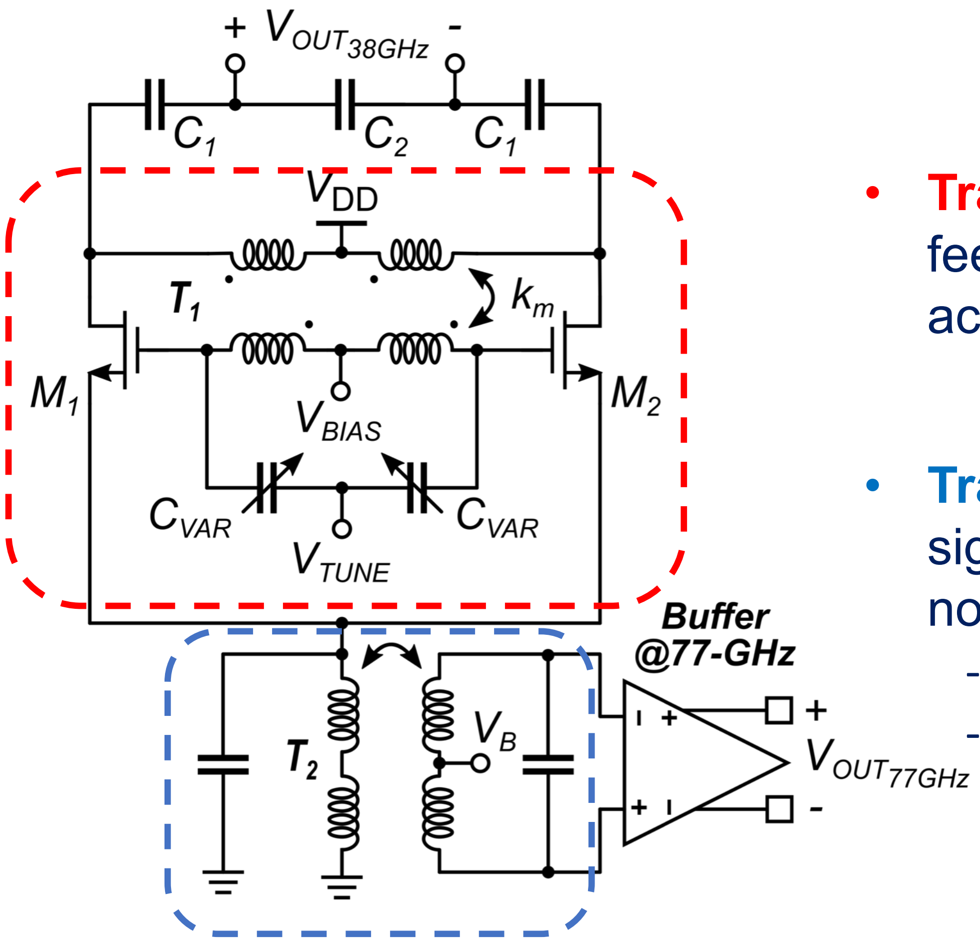



A push-push VCO allows a PLL to be operated at half of the carrier frequency. This involves:

- More relaxed trade-off between oscillator's tuning range and phase noise;
- Higher quality factor for passive components (varactors, inductors and capacitors);
- Pre-scaler divider is easier to design;
- No pulling effects from PA to the VCO.

# 77-GHz local oscillator

## Transformer-based VCO design




- **Transformer** ***$T_1$*** provides the feedback coupling between tank and active stage.

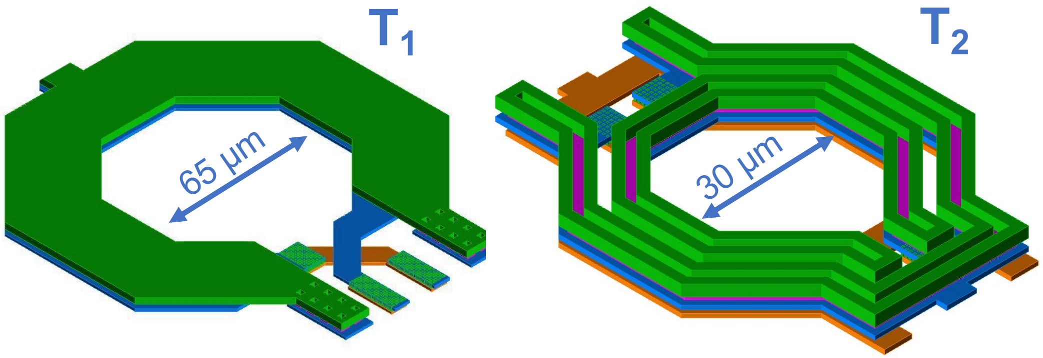
- **Transformer** ***$T_2$*** allow 2nd harmonic signal to be withdraw at the VCO tail node. It act simultaneously as:
  - 2nd harmonic filter;
  - Balun, providing a differential signal at the secondary coil.

VCO optimization calls for a careful schematic/layout co-design supported by intensive EM simulations.

# 77-GHz local oscillator

## Transformers design

EM simulations have been carried out in *ADS Momentum* by *Keysight*.

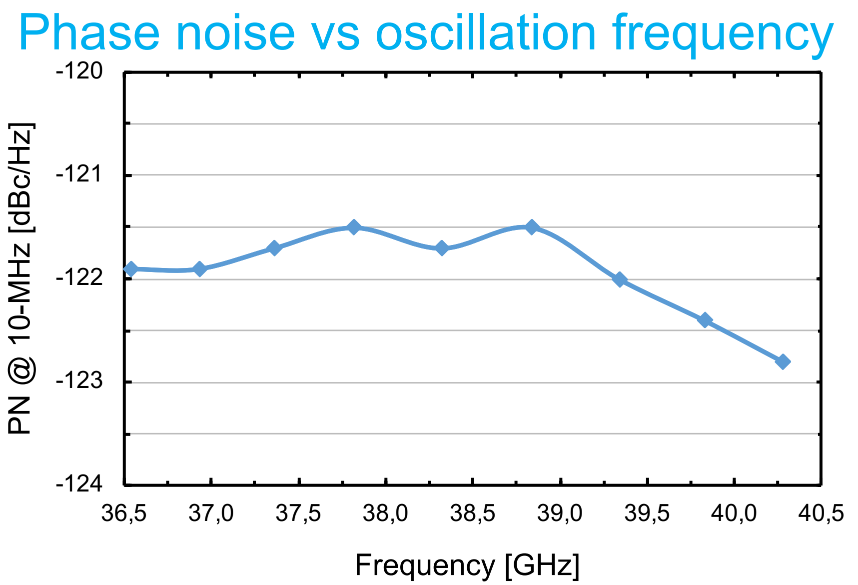


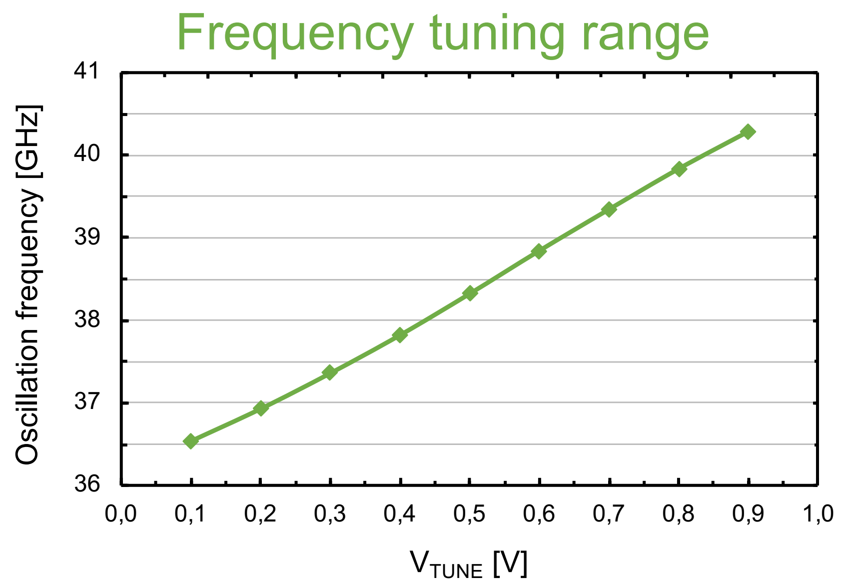

| Parameters | $T_1$ (valuted @ 38GHz) | $T_2$ (valuted @ 77GHz) | Units |
|---|---|---|---|
| $L_P$ / $L_S$ | 109 / 128 | 58 / 58 | [pH] |
| $Q_P$ / $Q_S$ | 29 / 23 | 18 / 18 | - |
| $f_{SR}$ | 150 | 144 | [GHz] |
| *k-factor* | 0.68 | 0.74 | - |
| TCR | 1.1 | 0.72 | [kΩ] |

- Transformers exploit the three upper metal layers to reduce resistance losses and parasitic capacitances;
- Transformers design has been carried out to simultaneously achieve high *Q*–factor and *k*–factor;
- Inductance values have been selected for the desired oscillation frequency;
- No pattern ground shield (PGS) has been used.

# Simulation results

## VCO performance



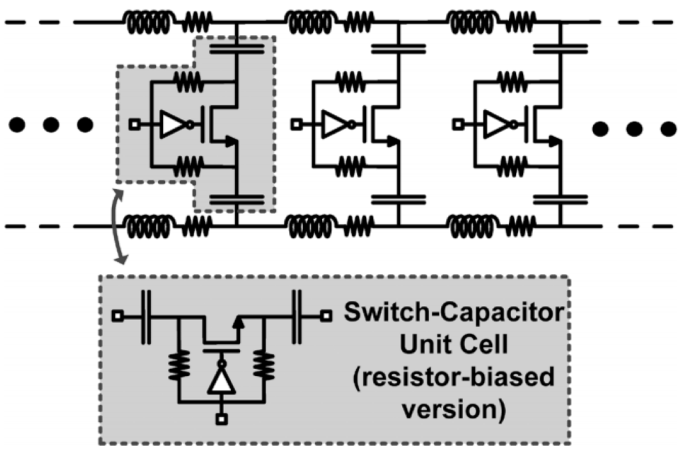

| Technology | $f_O$ (GHz) | TR (%) | $V_{DD}$ (V) | $P_{diss}$ (mW) | PN@10-MHz (dBc/Hz) | FoM (dBc/Hz) | $FoM_T$ (dBc/Hz) |
|---|---|---|---|---|---|---|---|
| 28-nm FD-SOI CMOS | 38,4 | 9,8 | 1 | 29 | - 121/-122 | -178/-179 | -177,8/-178,8 |

# Future developments

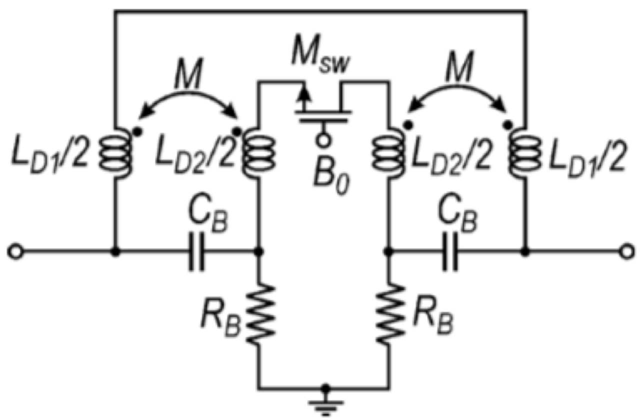
## Double-band Local oscillator

Typically radar transciever supports both LRR and SRR applications by employing two separate VCOs:

- one to optimize the phase noise from 76 to 77 GHz for LRR application;
- another to optimize the tuning range from 77 to 81 GHz for SRR application.




(D. Murphy, JSSCC, 2011)




(A. Italia, T-CAS I, 2012)

**Solutions:**

- Single VCO which simultaneously meets both low-noise and wide tuning range requirements;
- Switched-capacitor and switched-inductor resonator could be exploited to this aim.

# PhD results

## Conference presentation

- *6th Conference on Applications in Electronics Pervading Industry Environment and Society, ApplePies, Pisa, Italy, 2018*.

## Courses

- *"Topics on Microelectronics", in Milan, Italy, from September 10th to September 12th, 2019.*
- *"BCD DAYS 3.0", in Catania, Italy, from May 7th to May 09th, 2019.*

## Publications (1/2)

- G. Papotto, C. Nocera, A. Finocchiaro, A. Parisi, **A. Cavarra**, A. Castorina, E. Ragonese, and G. Palmisano, "A 27mW 77GHz radar receiver with TX leakage suppression in 28-nm FDSOI CMOS", submitted in *IEEE Solid-State Circuits Conf., (ISSCC)*.
- **A. Cavarra**, C. Nocera, G. Papotto, E. Ragonese, G. Palmisano, "Transformer Design for 77-GHz Down-Converter in 28-nm FD-SOI CMOS Technology". In: S. Saponara, A. De Gloria (eds) *Applications in Electronics Pervading Industry, Environment and Society. ApplePie*s 2018. *Lecture Notes in Electrical Engineering, vol 573. Springer, Cham*, 2019.

# PhD results

## Publications (2/2)

- **A. Cavarra**, G. Papotto, E. Ragonese and G.Palmisano, “Mixer in tecnologia CMOS FD SOI da 28 nm per un ricevitore radar a 77 GHz”, *STMicroelectronics internal report*, TR_16178_2018, July 2018.
- C. Nocera, **A. Cavarra**, E. Ragonese, G. Papotto, and G. Palmisano “Down-converter solutions for 77-GHz automotive radar sensors in 28-nm FD-SOI CMOS technology,” in *14th Conf. on Ph.D. Research in Microelectronics & Electronics (PRIME 2018)*, Prague, Czech Republic, 2018, pp. 153 156.