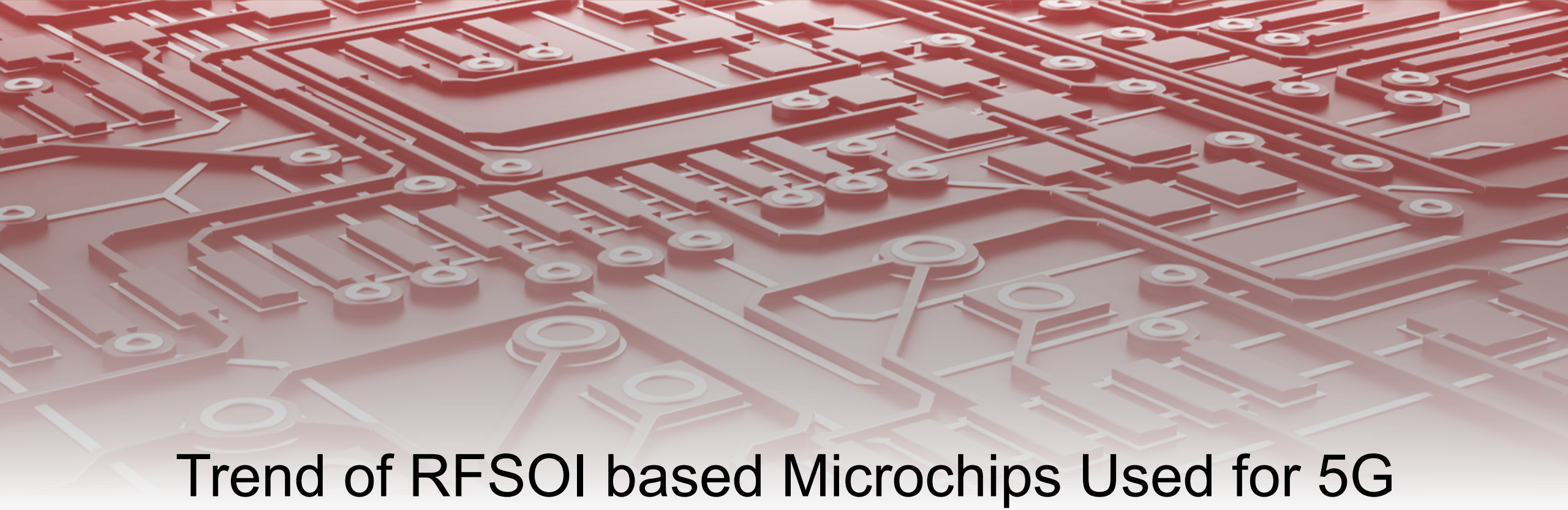


Trend of RFSOI based Microchips Used for 5G Mobile Devices

October 24th, 2023

Dr. Morin Dehan

CanaanTek Co. LTD

Provides High Performance RF Front-End Microchips for Mobile Devices
Customers First with High Efficiency

CanaanTek Brief Introduction

Highlights of CanaanTek

Team and Talents	■ **Founded and led by leading tech and business veterans in cellular phone industry.** More than 15 core people each with over 15-year direct experiences from Qorvo, Skyworks, Hisilicon，ZTE, IDT, IMEC and Comlent etc. ■ One of the **most focused RFSOI CMOS players in mainland China**, able to quickly adapt new technologies for customers. ■ Multiple innovative products with **0 quality issues**
Market Opportunities	■ RF FRONT-END Chip Market Size about 27B USD by 2028 by Yole Group ■ 5G supports 99 bands much larger than 4G applications. 4G conversion to 5G and 5G+ is still going on strong ■ **RFSOI Antenna Tuner, 5G switches, LNABANK and SOI/SAW module chips contribute to increasing opportunities**
Full Product Portfolio	■ Ranked for 2nd position in China in terms of antenna tuners and 5G switches ■ Accumulatively more than 5 billion chips shipped with ever more China domestic supplier chain ■ **LNABANK and DiFEM already in production with LDiFEM and FEMiD to be fully developed**
Customers	■ **Xiaomi, OPPO, VIVO, Transsion, ZTE and Samsung as 1st-tier customers with Transsion having as major market share** ■ Having **multiple ODM customers** such as Wingtech, Longcheer, Tinno, Chinoe and Foxcom with some as 1st-supplier ■ **Occupies as #1 supplier position** for Quectel and Fibocom
Growth Outlook	■ Rated as one of the **fastest growing** RF companies worldwide ■ Realizing **1.5-3.0 growth rate** in during and post Covid-19 years ■ Continuous improvement of supply chain with **domestic and asia-pacific companies** ■ **Significantly increases R&D investment** in 2023. Large number of new products in the pipeline

Map of CanaanTek

Beijing
Sales & FAE Center

Shanghai
Headquarter, R&D, Sales, Operation

Hangzhou
R&D, Operation

Shenzhen
Sales & FAE Center

Xi'An
Sales & FAE Center

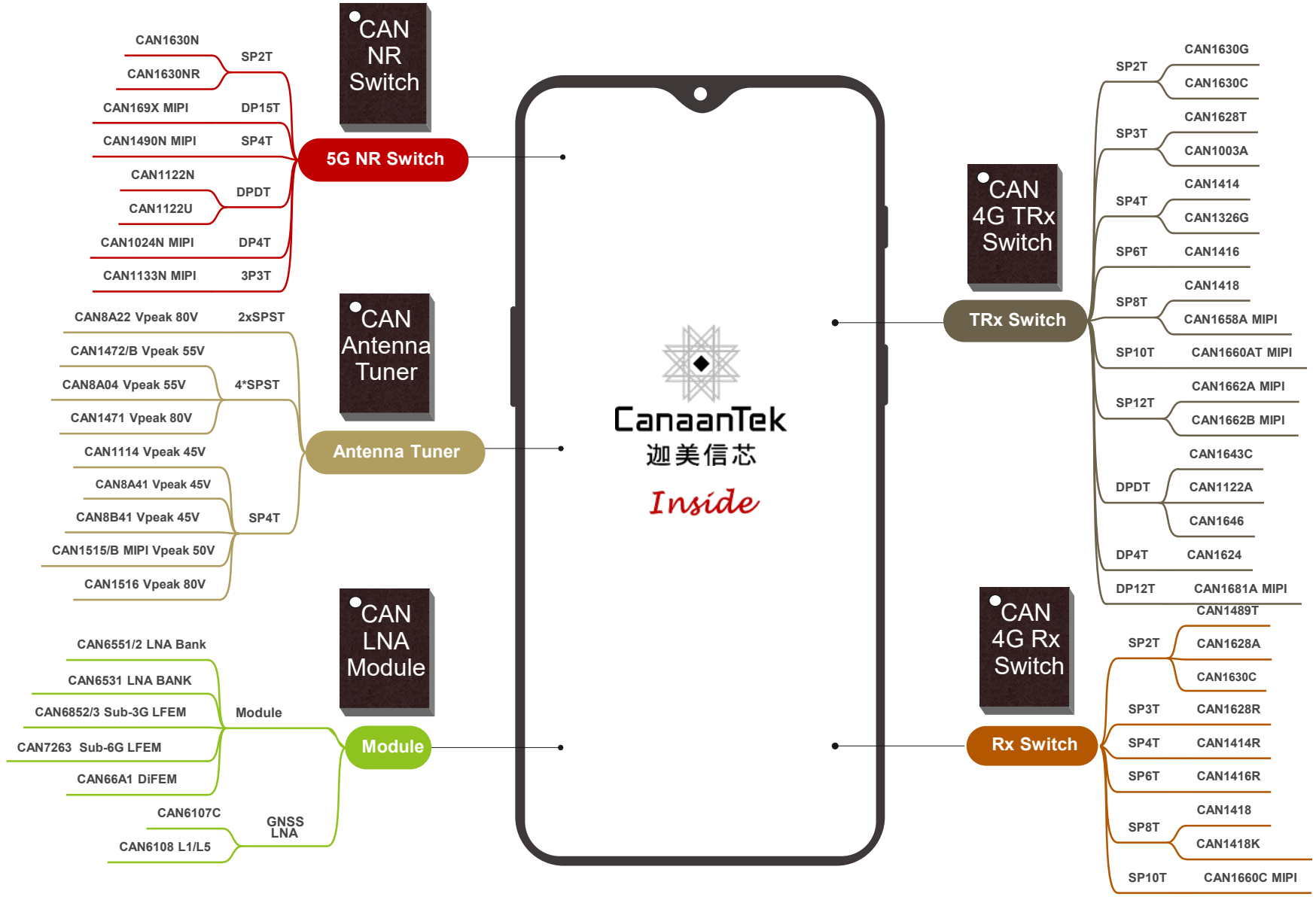
Belgium
R&D Center

CanaanTek Europe Design Center

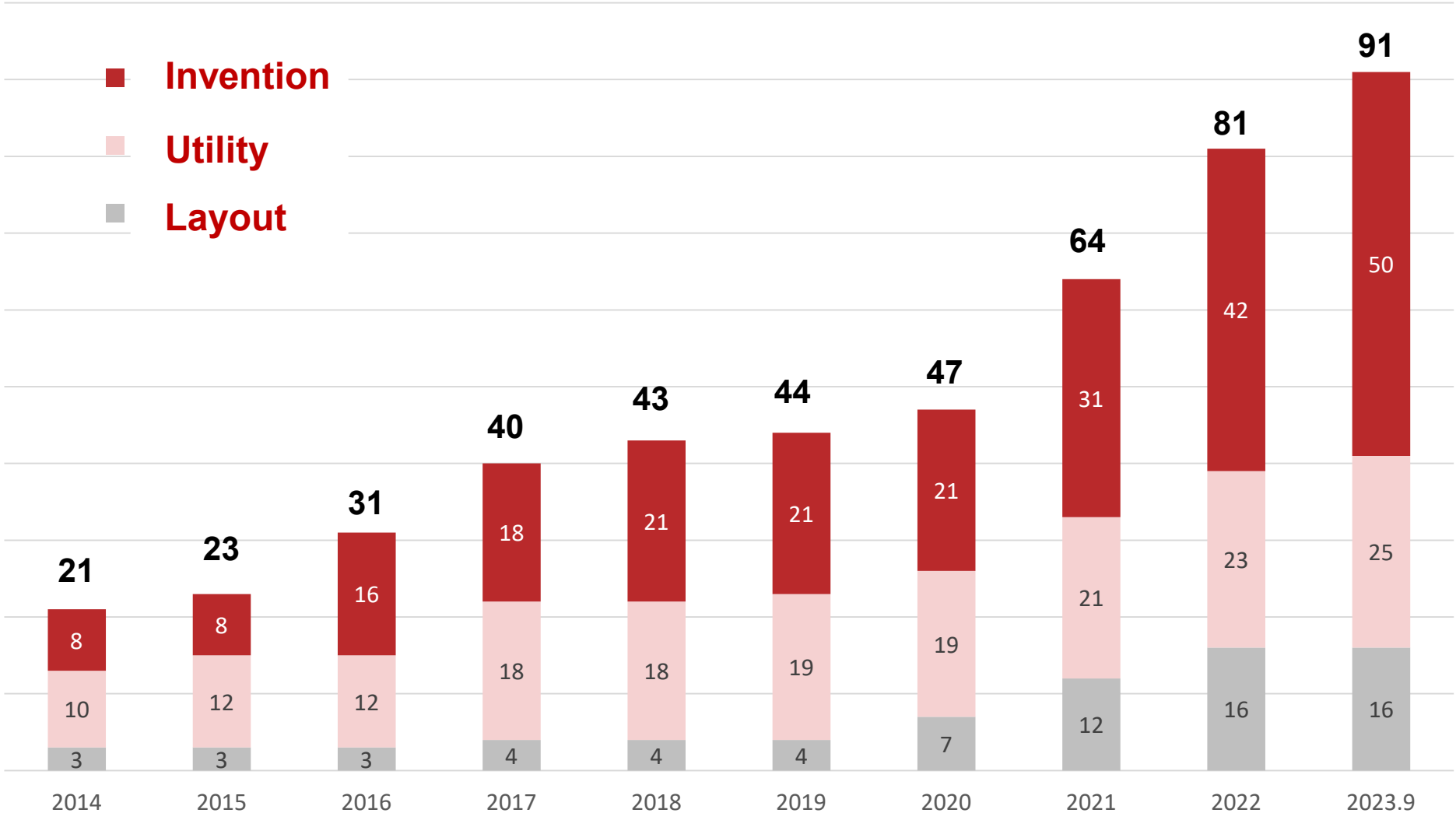
- **Established in July 2021** with Dr. Morin Dehan as the Design Site Director who has more than 20 years of device-level industry experiences and having direct experiences with RFSOI CMOS transistor modeling and characterization
- **Focused on fundamental device-level research and innovation** and to create 10 mile depth but 10 yard wide technical barrier
- Access to state-of-the-art RF probe equipment to realize high-precision measurements of SOI and POI pcells and testing structure to better understand **device-level FOM**
- Belgium with well-known IMEC, Catholic University of Leuven, Université Catholique de Louvain and Free University of Brussels provide **innovative talents and minds** to the CanaanTek Design Site.

Photo taken in a signing ceremony in July at AWEX, Brussles, Belgium in 2021

Full Product Portfolio for 4G and 5G Smartphone

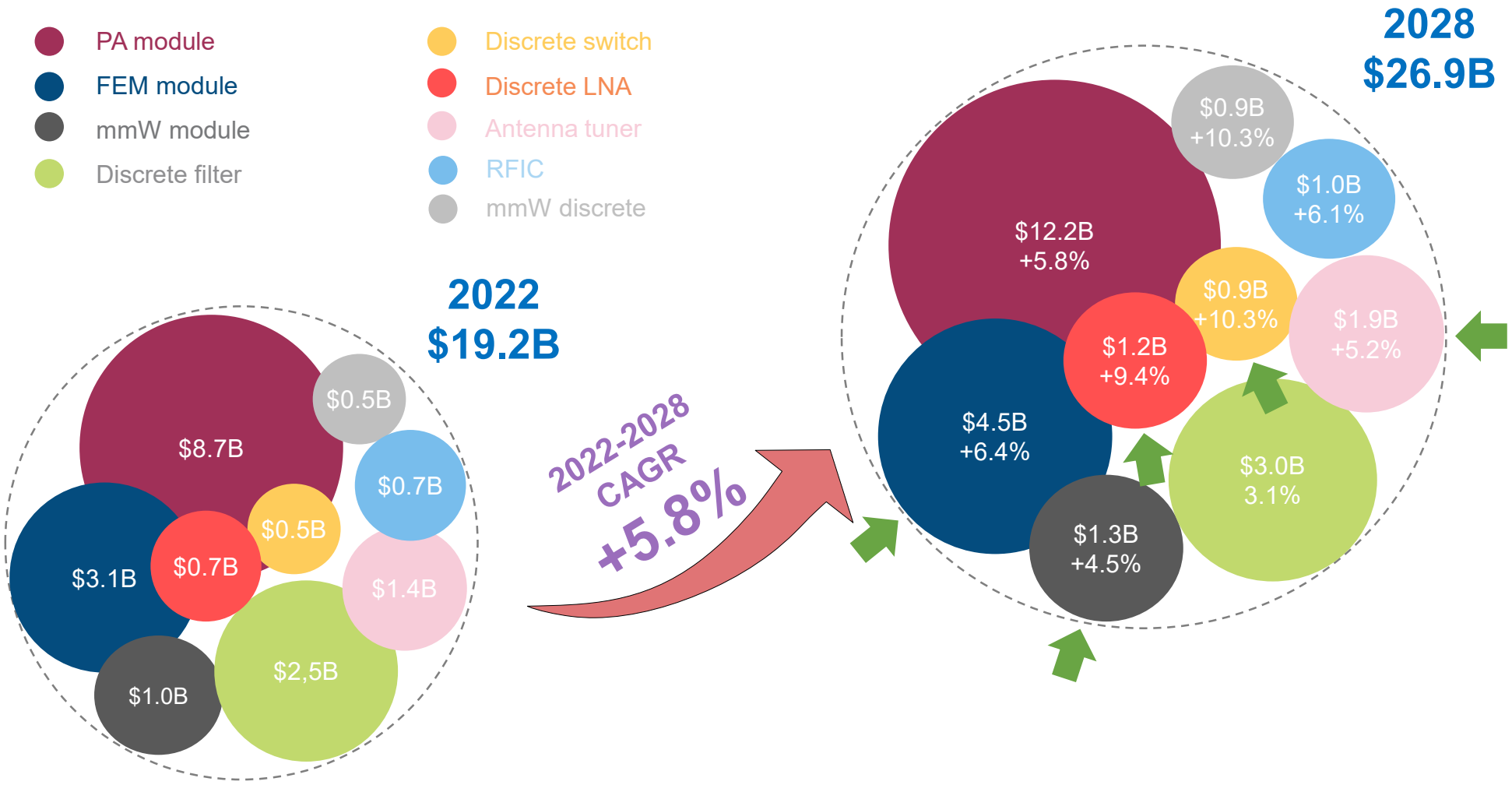


CanaanTek Patents



CanaanTek

Market Outlook



** Source: Yole*

CanaanTek Customers

Mobile Terminals

TRANSSION 传音控股 · OPPO · mi · HONOR · vivo · SAMSUNG

小天才 · FOXCONN · MobiWire · WISOL 와이솔 · ZTE中兴 · SHARP · Google

ODMs

LONGCHEER · TINNO · WINGTECH GREAT PRODUCT COMPANY · HUAQIN 华勤通讯 · CNCE中诺通讯

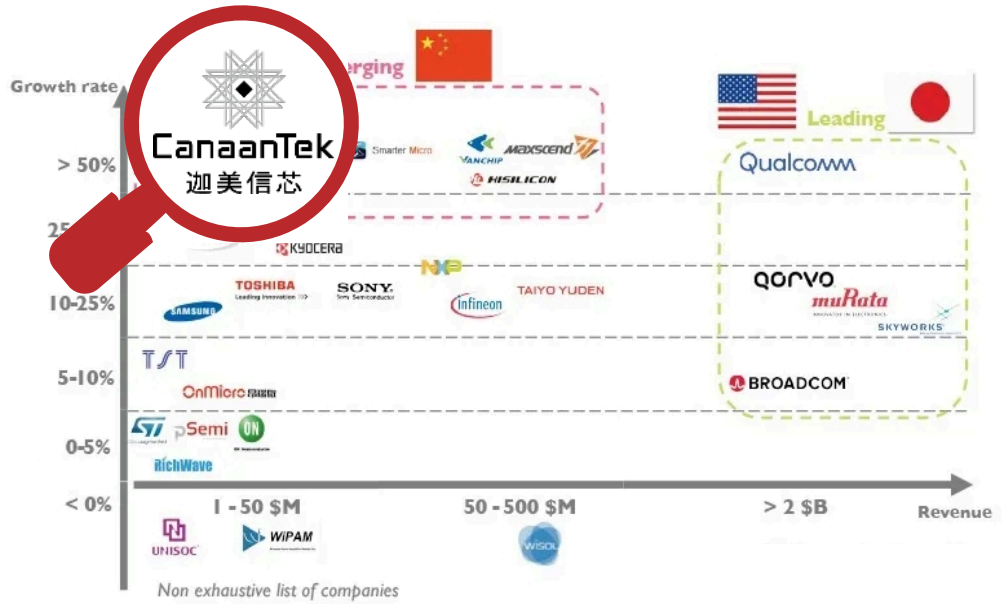
IOT Customers

MEIG 美格 · Fibocom 广和通 · QUECTEL 成就智慧地球 · neoway有方 · SUNSEA AIOT 日海智能

CanaanTek a fast growing RF company

RF front-end modules market - 2020 market shares by companies

(Source: Cellular RF Front-End Technologies for Mobile Handset 2021, Yole Développement, June 2021)



Industry Recognitions

China IC Top Awards

- **Innovative Product Award**
  Antenna Tuner 100 million shipped
- **Market Breakthrough Award**
  Antenna MIPI Switch 100 million shipped

Transsion Best Core Supplier Awards

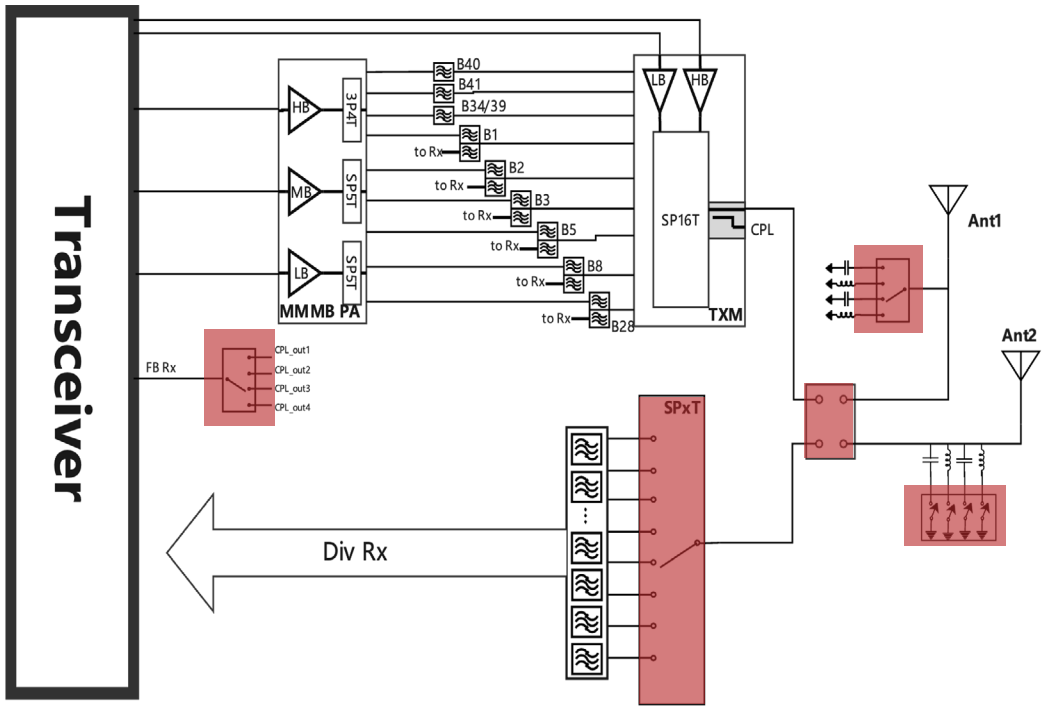
For 2020, 2021 and 2022

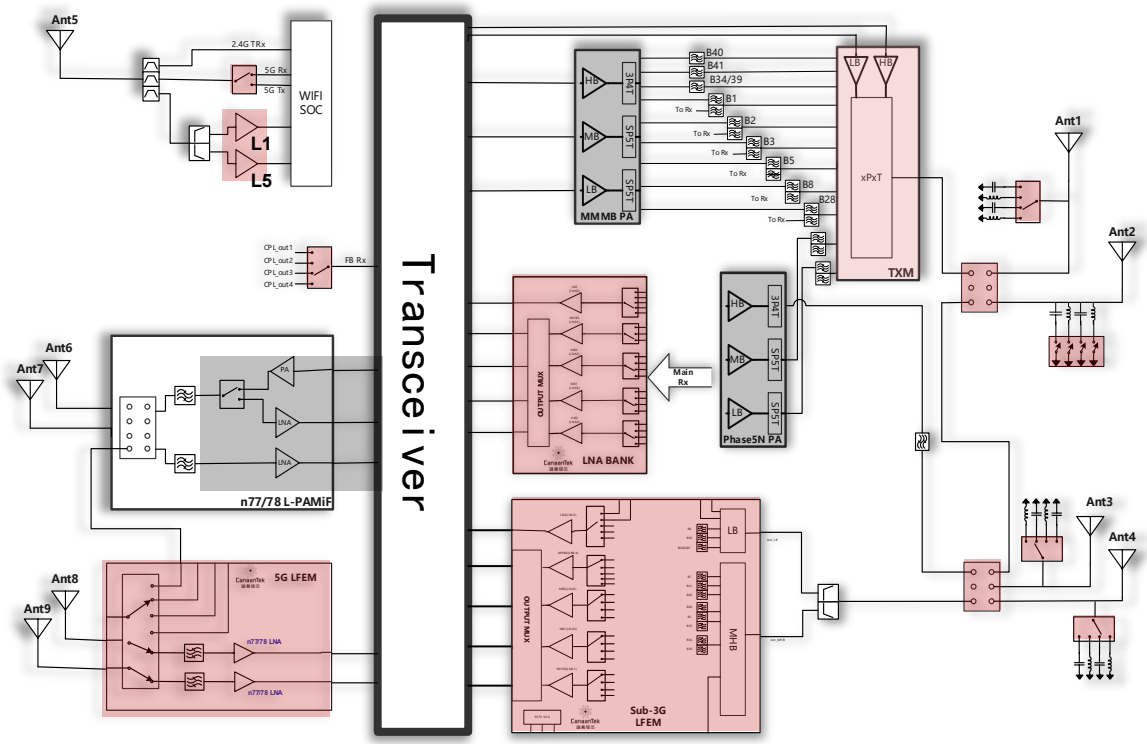
** Source: Cellular RF Front-End Technologies for Mobile Handsets 2021 Report, Yole, 2021*

Trend of RF Front-end Chip (Architecture More Complicated)

4G Phones RF Components less

5G Phones more bands and more RF Components





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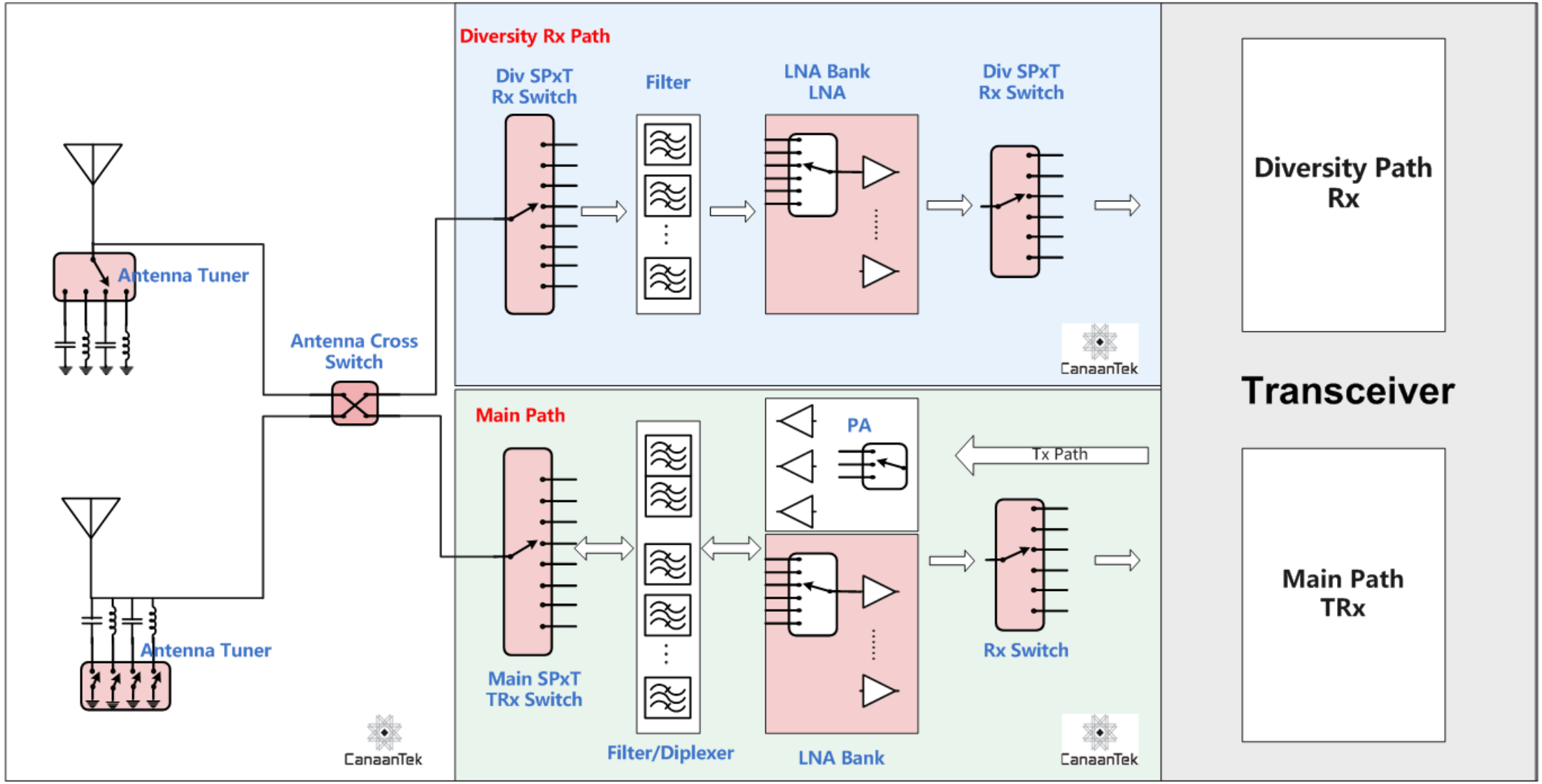
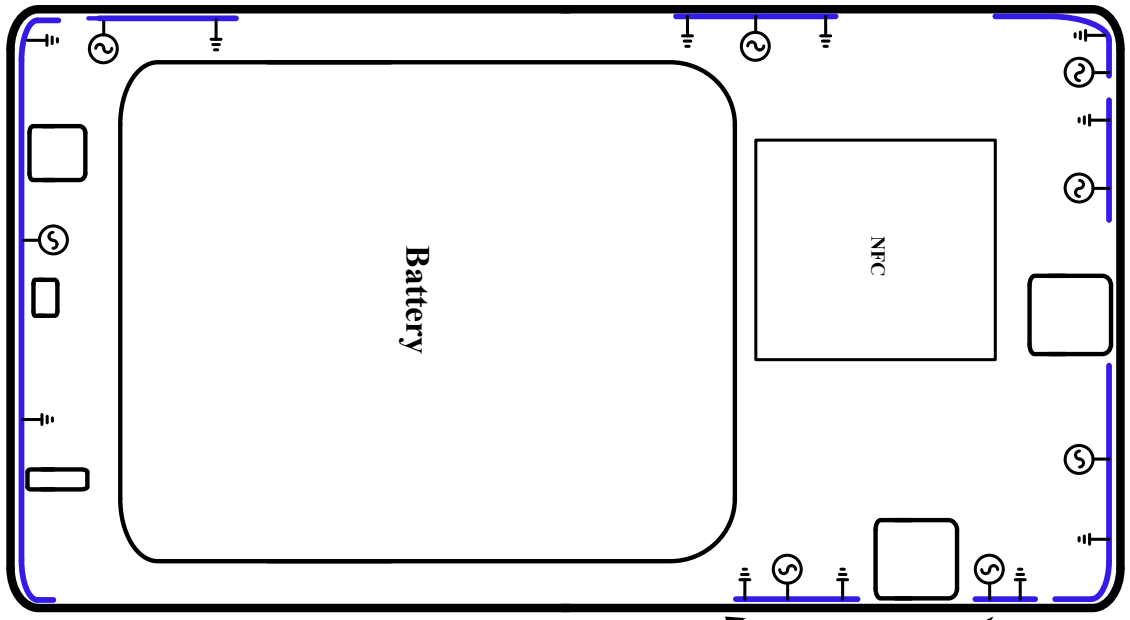
Trend of RF Front-end Chip (More Integrated Modules)



Recent Trend of RFSOI based RF Microchips

Trend of RFSOI Antenna Tuners

- Multiple antennas are located near the peripheral cellphone case frame
- Phone metal case frames themselves are antennas
- Multiple RFSOI antenna tuners are needed to tune to the best band coverage
- The smaller the package size the better
- Low cost of the tuners is also important

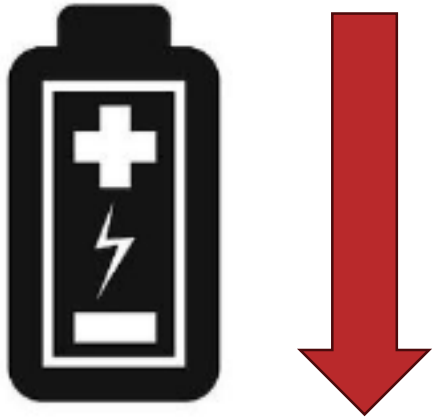


Trend of RF Tuners (Package Size Smaller)

Tuner Part Number	Tuner Config	Size	Breakdown Voltage	Year
CAN1119	GPIO SP4T	1.6mmX1.6mm	40V	2016
CAN1114	GPIO SP4T	1.1mmX1.5mm	45V	2018
CAN1515B	MIPI SP4T	1.1mmX1.5mm	45V	2020
CAN8B41	MIPI SP4T	0.95mmX1.3mm	45V	2023
CAN8C41	MIPI SP4T	0.95mmX1.3mm	80V	2024

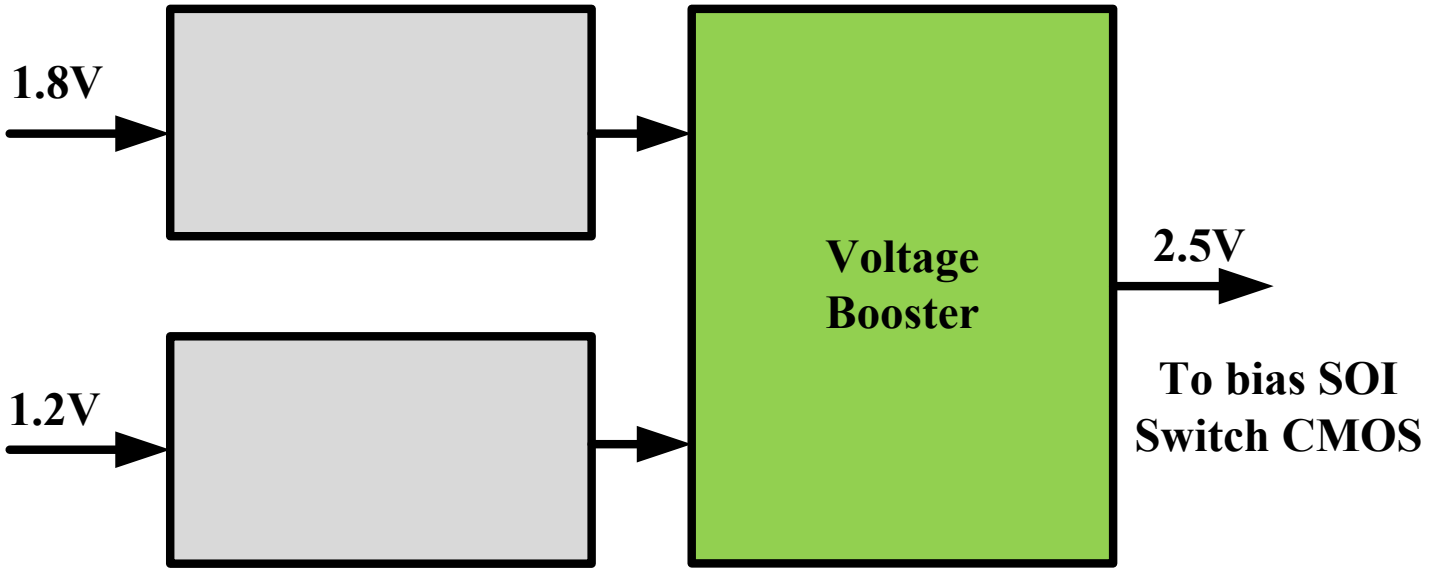
- Not only package size is smaller, FOM is also decreasing from 200fs to 100fs
- Most difficult one is the 80V tuner with 0.95mmX1.3mm package size
- A few generation of CanaanTek tuners as an example to see the trend of small package size

Trend of RF microchips (Voltage Decreasing)



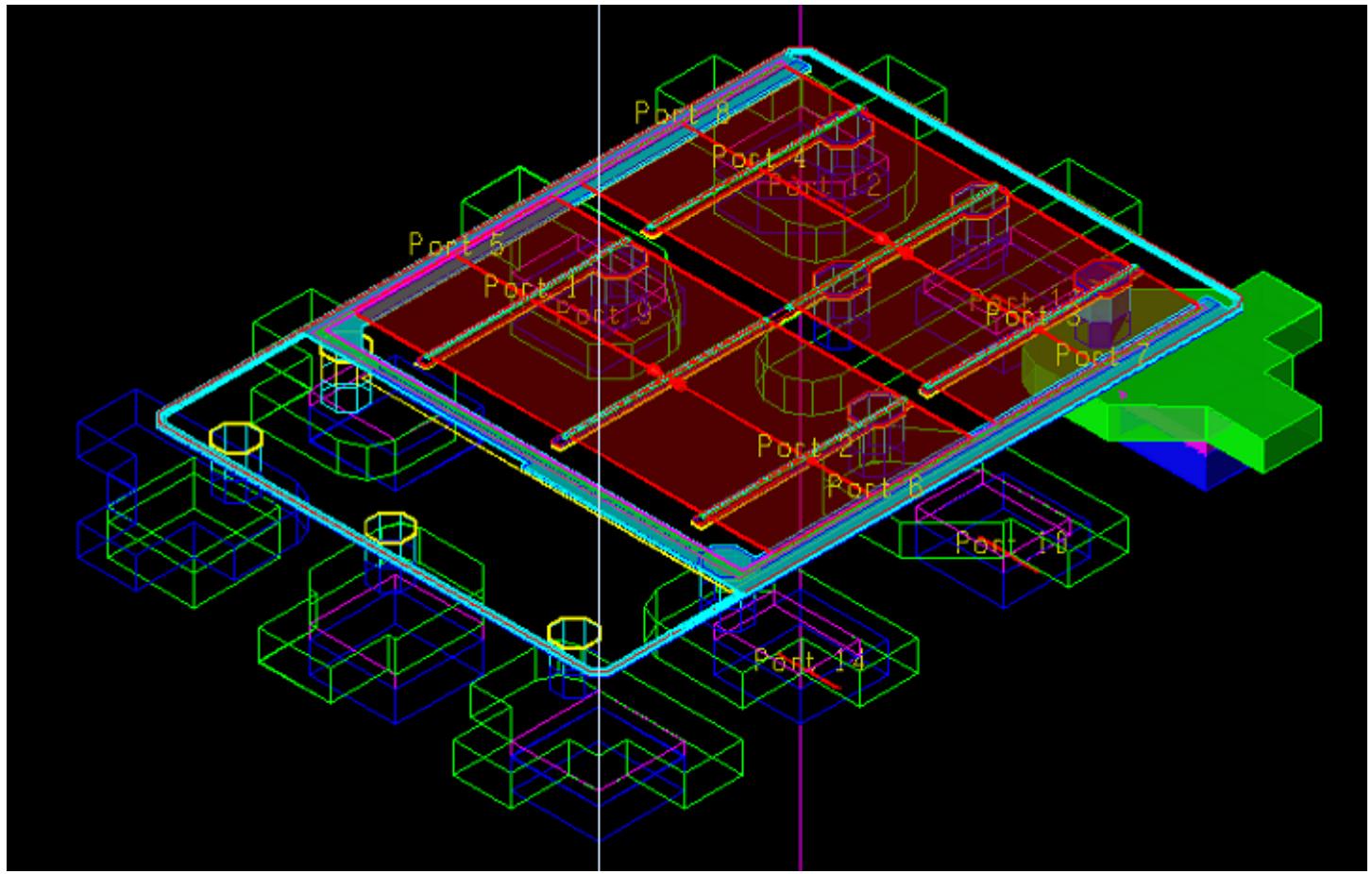
Single Voltage Supply VIO Low Power:

2.85V → 1.8V → 1.2V



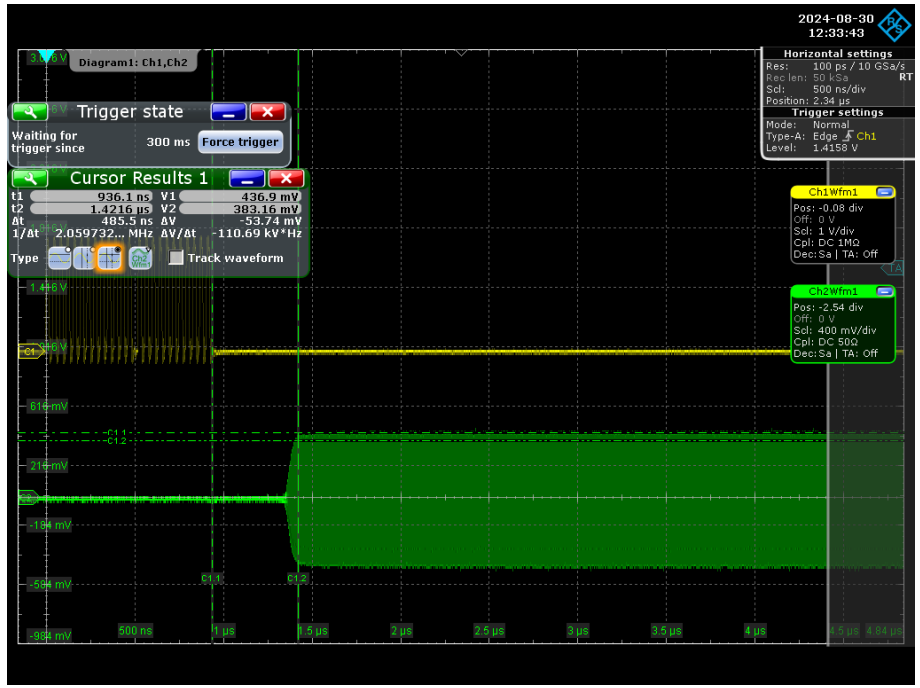
Therefore more analog and digital noises will be introduced. Both NF and H2/H3 need to be taken carefully. Also Tsw will be affected.

Challenges of Smaller Packages



- Ron, Coff and Breakdown Voltage plus size are simultaneous requirements
- Die size has to be designed in a small enough size to fit inside the small package
- Small die size will affect RF performances such as isolation, port to port interaction, Ron and Coff etc.
- Most annoying effects will be the analog/digital circuitry to affect overall performances like NF, H2/H3 harmonics etc.

5G NR SRS Tx/Rx Switching Time Ever Smaller

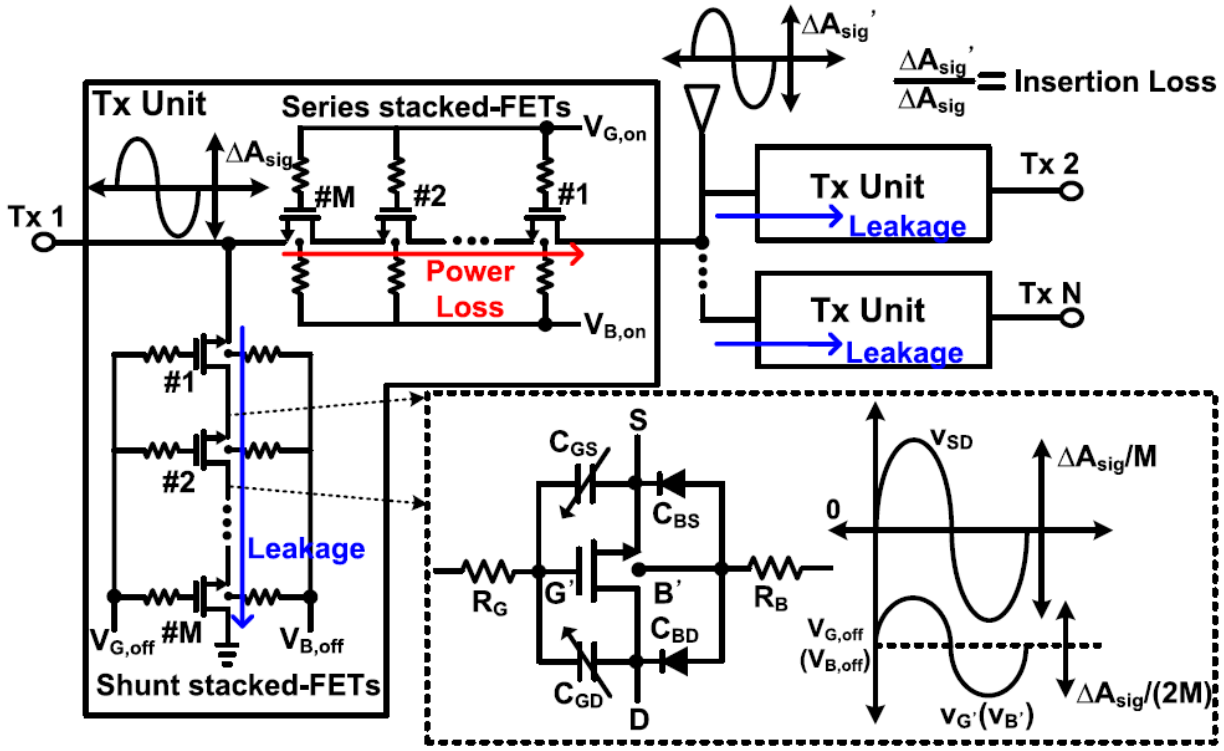


4us → 2us → <1us

Subcarrier Spacing (Khz)	15	30	60	120	240
OFDM Symbol Duration (us)	66.67	33.33	16.67	8.33	4.17
Cyclic Prefix Duration (us)	4.69	2.34	1.17	0.57	0.29
OFDM Symbol including CP (us)	71.35	35.68	17.84	8.92	4.46

RFSOI Device Level Work

Illustration of a RFSOI Switch (Tuner)



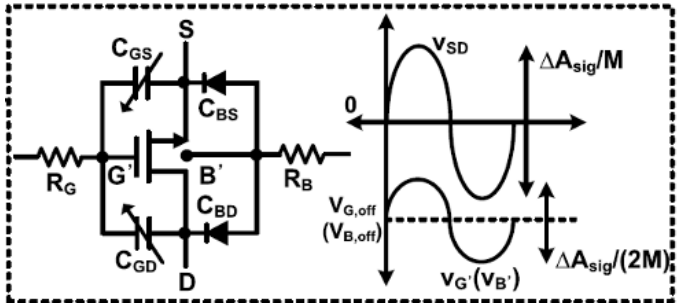
Challenges:

- ❑High Break down voltages (up to 80V)
- ❑Insertion Loss / Isolation
  >> high FoM (Ron x Coff)
- ❑High power (Current in Closed branch)
  - ❑Reliability / Life time

➢ Design optimization:
Tx sizing, number of FETs

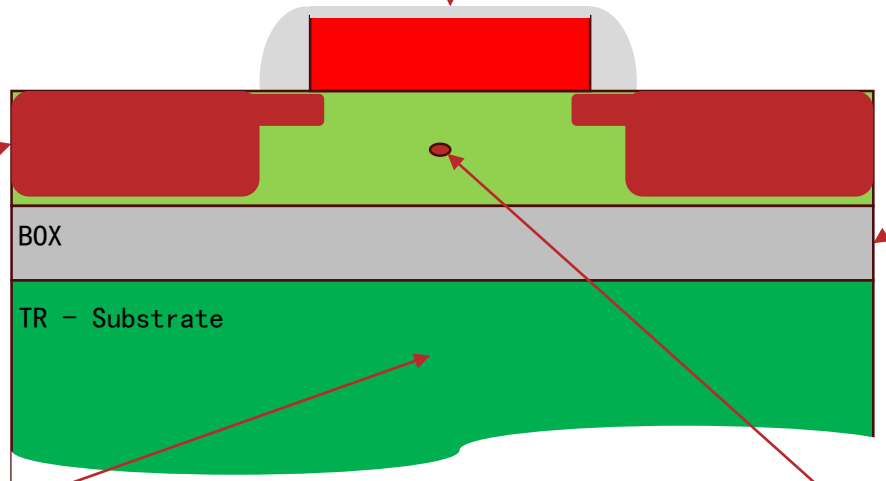
➢ Device optimization

Illustration of a RFSOI – Device Cross Section



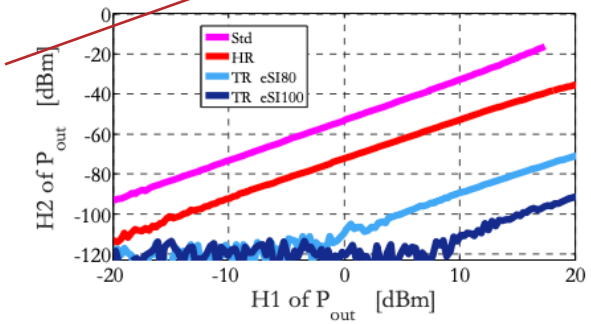
PD SOI – Cost effective Solution with good Breakdown, and Ron

SOI structure For low junction capacitors



Substrate Isolation for low parasitics

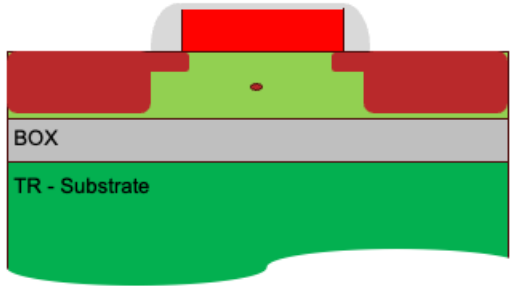
Trap-Rich substrate for low loss, high linearity substrate



Body biasing for improved performances

CanaanTek

Illustration of a RFSOI – Device Optimization for Tuners



Switch (Tuner) Device optimization:

- Foundry – Improved device performances (Ron / Coff / Break down)
- Designer – Optimal geometries / **BEOL optimization**

➢ **Optimal Ron-Coff Trade-off**
  - **Requires parametrized layout for fast iteration**
  - **Accurate BEOL modeling**
  - **Hardware validation**

Illustration of a RFSOI – Device Optimization for Tuners

■Ron / Coff trade-off

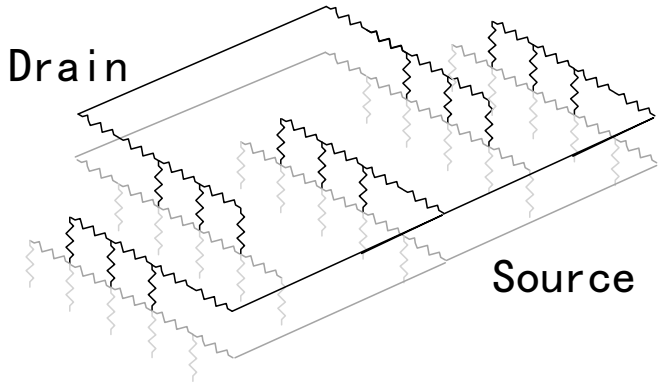
➢Ron = Ron_Intrinsic + Ron_BEOL

➢Coff = Coff_ Intrinsic + Coff_BEOL

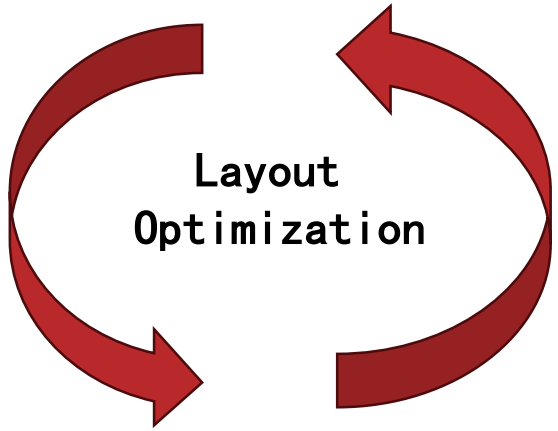
Imposed by Technology

Layout Based

Ron_BEOL



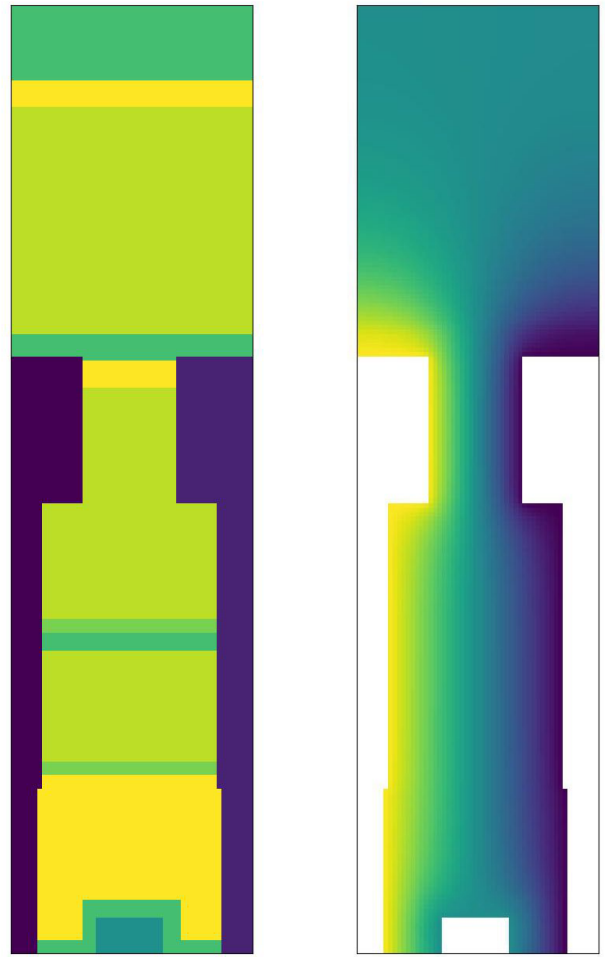
Lumped Equivalent circuit



Coff_BEOL

2D or 3D
Simulations

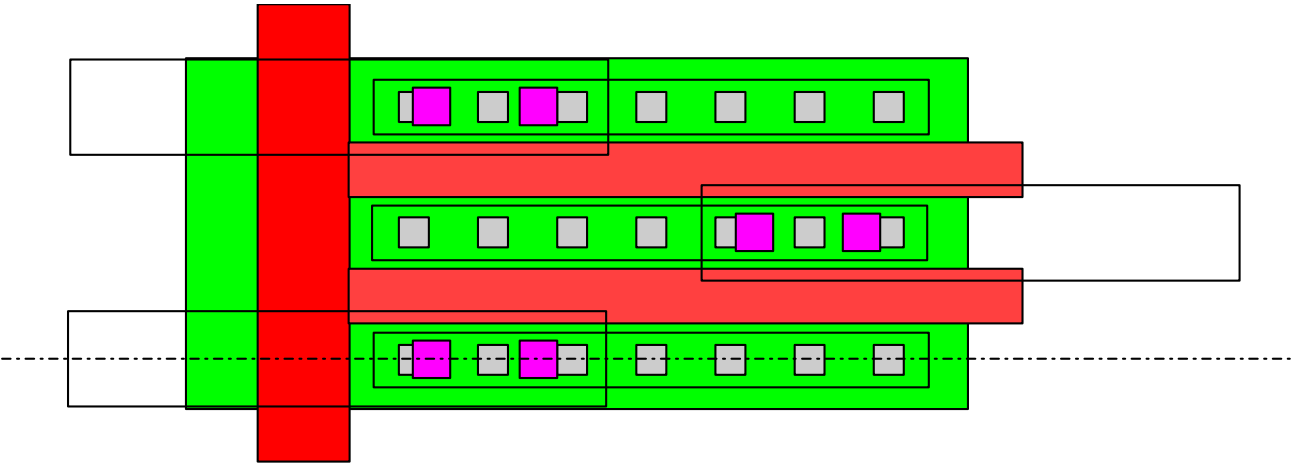
Electrostatic or EM

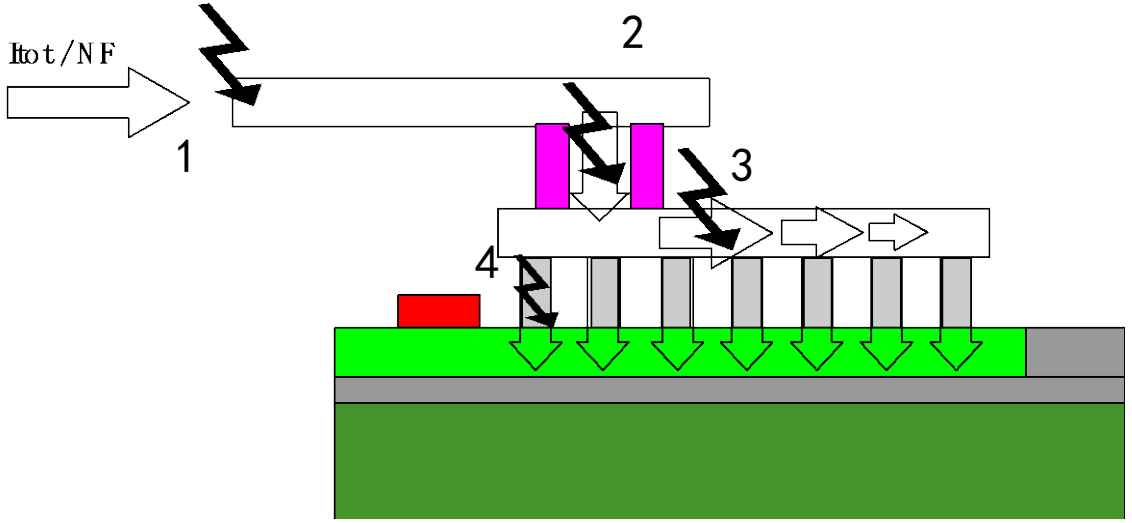


Not representative of actual BEOL scheme

Illustration of a RFSOI – Device Optimization for Tuners

FET Layout optimization: Reliability requirements





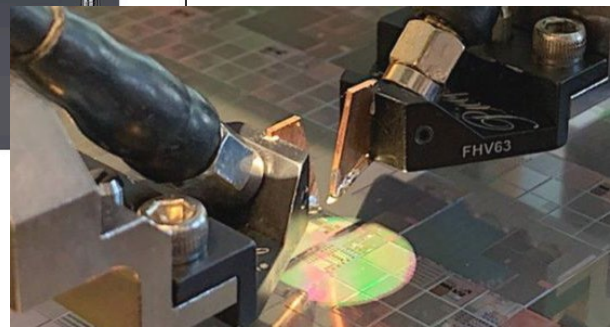
- Reliability consideration
  - For a target Total width
  - BEOL hot spot from High AC current
  - Verification at all levels – MEx / VIAs / CT

Hotspots:

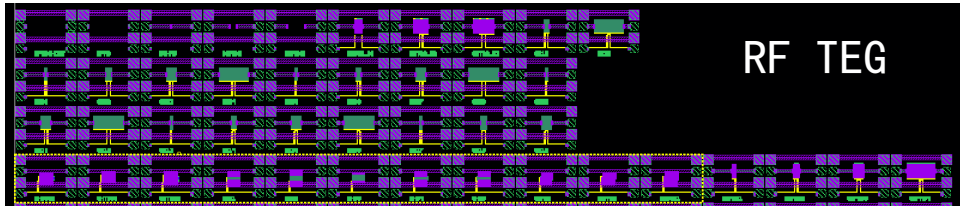
1. I(M2): f(NF) >> Minimal number of fingers
2. I(V1): f(NF & Wf) >> Minimal #VIA
3. I(M1): f(NF & Wf) >> Minimal M1 / Width
4. I(CT): f(NF & Wf) >> Minimal contact density

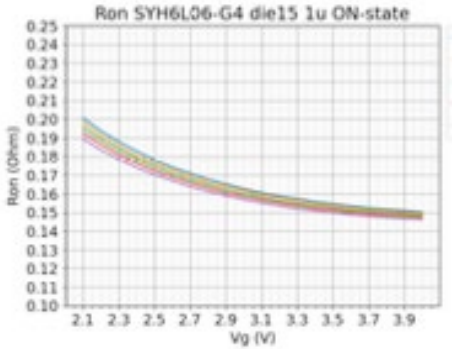
Illustration of a RFSOI – Device Optimization for Tuners

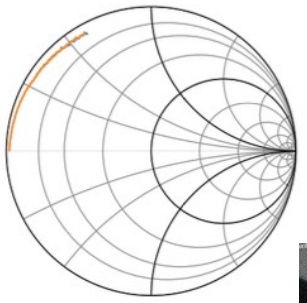
- Device Validation
  - On-Wafer measurements
  - Device and performance assessment

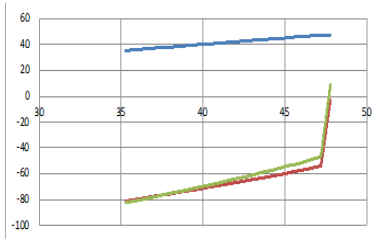


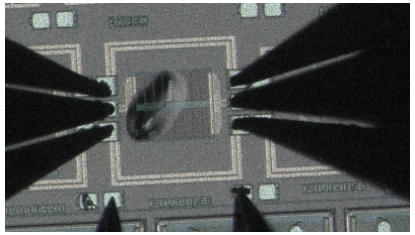
- On-Wafer analysis
  - DC, CV
  - S-parameters
  - HD
  - Vpeak











THANK YOU

Q&A