leti
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RADIO FREQUENCY

Technologies for a smart connected world

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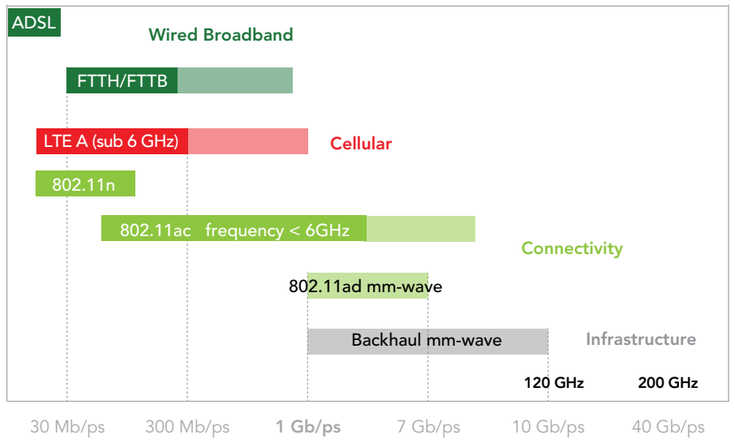
Towards 1,000× data-traffic growth

Currently, the global average worldwide connection speed of the Internet is only 6Mbps. 5G promises more capacity (few Gbps, < 2ms latency). 5G aims to connect billions of things and create new services, leveraging all information collected in the cloud.
5G will use below 1GHz technology (Narrow Band - IOT) for long range & low data rate massive IOT as well as 1 GHz to 6 GHz spectrum (Cellular) frequencies for higher throughput. It will co-exist with Wifi (802.11ac, -ax..etc). Mm-wave technologies are foreseen for short range Connectivity (802.11ad) as well as for backhaul in 5G future network.



CELLULAR
Smartphones, tablets, connected cars, etc.

Although smartphones and tablets are still the main drivers, automotive and the IoT will offer new opportunities for cellular technologies. 5GHz LTE is deployed for V2X & V2V (high-speed communication between moving vehicles). Ultralow-latency LTE in the 1ms range will be used for real-time applications and for mission-critical services (e.g. control of drones, robotics, industrial equipment). Technical trends to reach Gigabit per second:

- carrier Aggregation (CA) mode across licensed and unlicensed spectrum (sub 6 GHz)
- MIMO (multiple antennas for Multiple Inputs & Multiple Outputs)
- higher order modulation (256 QAM & more)

MOBILE TO MOBILE CONNECTIVITY
Smartphones, PCs, tablets, cameras, TVs, robots, sensors, etc.

Mobile-to-mobile connectivity enables data exchanges between devices, which can be done without using any existing network. WiFi is one existing technology enabling high-data-rate transmission between devices. Because power consumption increases with both distance and throughput, the main challenge is keeping it low enough, while increasing the data rate, to preserving battery life in mobile devices. Technical trends to increase speed at low power:

- dual band for Wifi (2.4 GHz & 5 GHz) to increase speed
- listen before talk for fair coexistence of LTE & Wifi, mm-wave to increase bandwidth
- UWB to reduce power consumption, efficient small size antennas

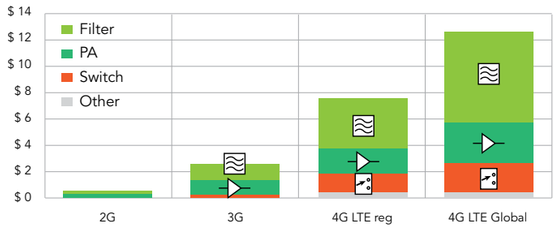
INFRASTRUCTURE
Small cells (pico, micro & macro) in 5G networks

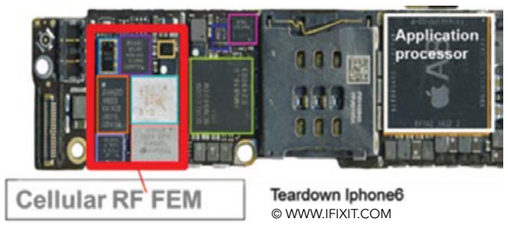
Infrastructure has to evolve to enable more capacity for users, especially in dense areas like cities. Small cells for short- to long-distance transmission (picocells, microcells, macrocells) will be deployed to increase the number of access points.

CELLULAR

SMARTPHONES & TABLETS
SMALLER, CHEAPER RF FRONT-END MODULES

Evolution from 3G to 4G has increased the RF content in smartphones, as shown below. The size of the cellular RF FEM section in a smartphone is comparable to the application processor! Leti is currently working on the next technology pathfinders to reduce the cost of multi-mode, multi-band RF front-end modules.





WHAT NEXT?

SHORT TERM

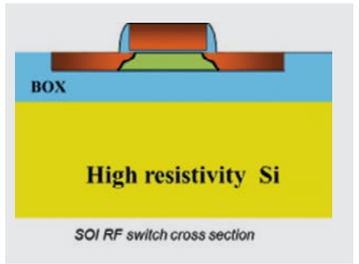
- High-performance resonator technology based on a thin piezo layer (< 1µm)

MID TERM

- Wideband LTE Pa PA on SOI (instead of AsGa)
- Innovation in passives & packaging to increase integration
- Tunable or switchable filters using high-performance resonators
- Innovation in materials for RF switches for re-configurable FEM

LONG TERM

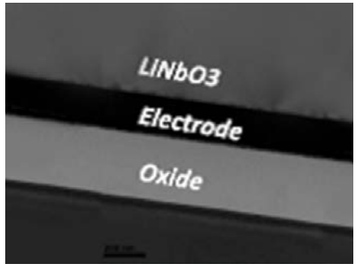
- Highly integrated reconfigurable RF FEM tunable components & wideband PA
- Increase operating frequency



SOI RF switch cross section

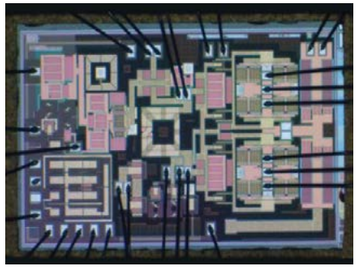
RF SWITCHES

Fabricated on a SOI substrate, instead of pin-diodes or GaAs P-HEMT, these switches are now the mainstream, with a volume higher than 2 billion in 2016. Leti is currently working on new technologies to increase the figure of merit of RF switches (target: Ron*Coff < 10fs), without degrading power handling (> 30dBm) and linearity (H2, H3 < - 90dBm).



FILTERS

Filters are the most expensive part of an RF module and isolation between frequency bands is difficult due to CA (with adjacent channels). Leti has a deep background in substrate engineering, which can enable higher-performance acoustic resonators. In order to increase electro-acoustic coupling factor k^2, advanced new concepts of resonators are also studied, using new, thin piezo materials like $LiNbO_3$, fabricated by a thin-layer transfer process, which is a specific area of expertise at Leti.



POWER AMPLIFIERS (PA)

Multi-mode multi bands PA in RF FEM are currently fabricated on GaAs. Leti, has demonstrated the feasibility of efficient PA, using LDMOS devices on SOI (IEDM 2014, RFIC 2016 & 2017). Next step is to work on tunable wideband linear PA. The challenges are: high efficiency at high frequencies, high bandwidth under limited voltage, high linearity with high-bandwidth signals (> 60MHz), integration of output matching network with low losses and wideband characteristics.

MOBILE-TO-MOBILE CONNECTIVITY

MM-WAVE-BASED LOW POWER, **HIGH-DATA-RATE CONNECTIVITY**

First mm-wave links using WiGig standard (802.11ad) @ 60GHz have revealed power consumption is a critical challenge. Leti's G-Link solution, presented at CES 2015, has demonstrated a 10-20× lower-power solution for a high-speed wireless link over short distances. G-Link 2nd generation provides increased data rate (6Gbps) at lower power consumption (30mW). Leti is cooperating closely with industrial companies to bring this technology to mass-market as well as to define future generations of chips. Keeping low power consumption at system level with a higher distance range and a higher data rate requires a global system optimization, including antenna and packaging, RX and TX circuits, as well as frequency synthesis and modulation/demodulation scheme.

G-LINK

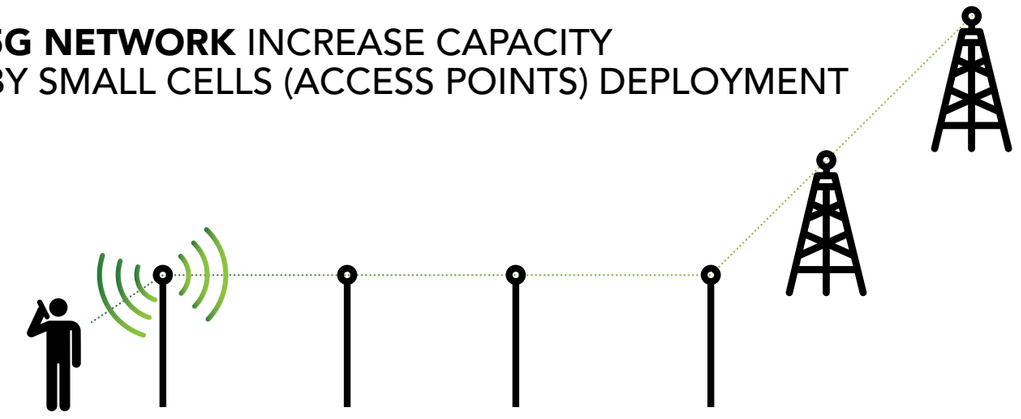
	Wifi 11ac	Leti demonstrator at CES
Frequency	< 6 GHz	60 GHz
Range	5 m	7 cm
Data rate	400 Mbps	2.5 Gbps
Chip size	-	2.1×1.9 mm²
Pdc (Tx+Rx)	2,500 mW	100 mW
Power Efficiency	6,250 pJ/bit	40 pJ/bit 5 pJ/(bit.cm)
Time to transfer 1 gigabyte between 2 users	2 min 40 s	25 s

NEXT CHALLENGES:

Increase packaging and antenna efficiency to reach higher distance
Global architecture system optimization (antenna connection to RX-TX chips, digitalcontrol and interface, RX&TX bandwidth, gain and dynamics) to increase both the data rate and the distance with a 10× reduction in power consumption!
Profit from higher bandwidth above 100GHz carrier frequency.

INFRASTRUCTURE

5G NETWORK INCREASE CAPACITY BY SMALL CELLS (ACCESS POINTS) DEPLOYMENT



Sub-6 GHz link between user and small cells (AP)

ACCESS POINT (AP) TO MOBILE (USERS)

SOI LDMOS could be a good candidate for such 6GHz links. Leti has expertise to test reliability of LDMOS, which is more critical in this case because the supply voltage has to be increased. Leti can also face the challenges in PA design on SOI to keep high efficiency and linearity.

Mm-wave link between all AP and between AP & macrocells for backhaul

BACKHAUL, LONG-DISTANCE (HIGH-POWER) MM-WAVE LINK & ANTENNA CHALLENGES

III-V lab

Short mm-wave links between AP enable LNA and PA, phase shifters, switches and antenna phase arrays to be integrated into standard CMOS technologies. However, for long-distance links in the backhaul, power amplifiers (PA) on III-V technologies are the best candidates. Leti has expertise on GaN/Si epitaxy on 200mm wafers, and III-V Lab (Nokia/Thales/CEA joint venture) has a long background on RF GaN devices and PA design (qualified GaN/SiC PA and MMICs technology on 4" wafer).

Antenna cost and efficiency are one of the main challenges. Antennas reaching specifications (> 30dBi) for backhaul in mm-wave range exist, but are expensive (>$300). Mm-wave antenna arrays have been proposed by different research laboratories, but high efficiency is not possible due to losses through interconnects behind each antenna, when more than 8x8 antennas are used. Leti has designed new antennas for the backhaul and is investigating new concepts for RF switches and phase-shifter technologies to reduce losses and handle high power in the mm-wave range.

ABOUT LETI

Leti is a technology research institute at CEA Tech and a recognized global leader in miniaturization technologies enabling smart, energy-efficient and secure solutions. Committed to innovation, its teams create differentiating solutions for Leti's industrial partners.

By pioneering new technologies, Leti enables innovative applicative solutions that ensure competitiveness in a wide range of markets. Leti tackles critical, current global issues such as the future of industry, clean and safe energies, health and wellness, safety & security…

Leti's multidisciplinary teams deliver solid micro and nano technologies expertise, leveraging world-class pre-industrialization facilities.

For 50 years, the institute has been building long-term relationships with its industrial partners providing tailor-made solutions and a clear intellectual property policy.

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