

INKJET PRINTED WIRELESS SENSORS BASED ON NANOPARTICLE INKS FOR INTERNET OF THINGS SENSING AND 5G COMMUNICATIONS

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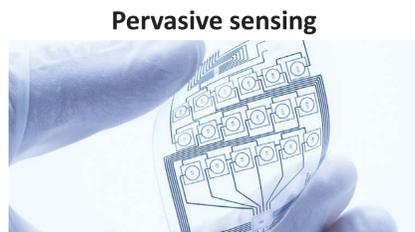
INTRODUCTION

1. Low cost and low power sensing:

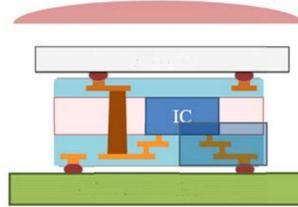
- Environmental variables monitoring.
- Presence of objects/gases.
- Automotive engineering.

2. Necessity:

- Wireless communication!
- Low cost, scalability, ultra low power.
- Sensing !
- Fast fabrication !
- Miniaturized sensors -> **Nanotechnology!!!**



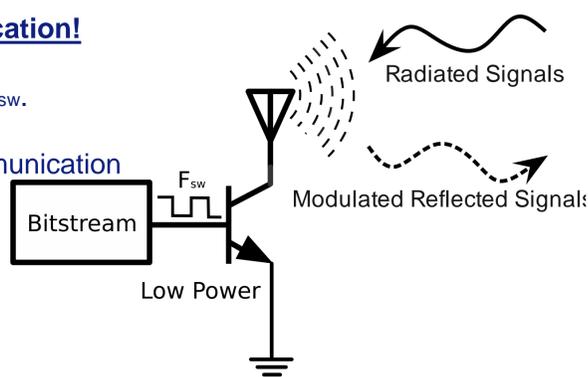
Inkjet/3D printing in nano scale using nano materials. Nanotechnology in Telecommunications



- RF/microwave and millimetre wave frequency circuits, antennas and packaging implementation.
- Ultra fast (minutes) printing.
- Resolution: 20 μm - 50 μm .
- **Nanoparticle Inks:** silver, gold, copper, carbon nanotubes, graphene oxide, polymers.

Backscatter radio Communication!

- Antenna load switching @ F_{sw} .
- Single transistor, (μW) communication (RFID operation) !



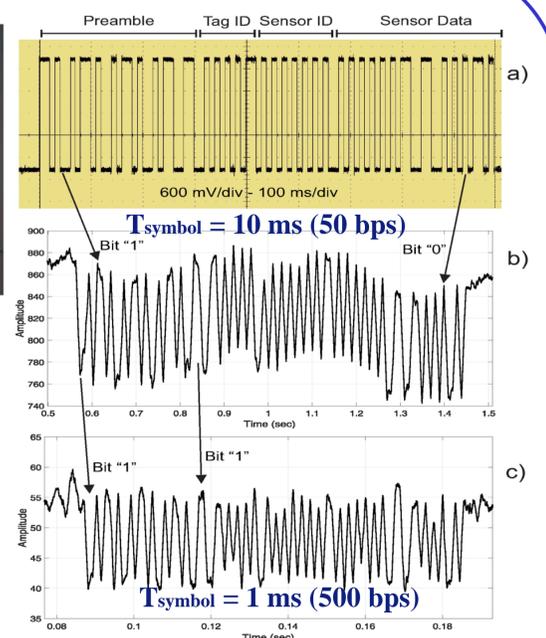
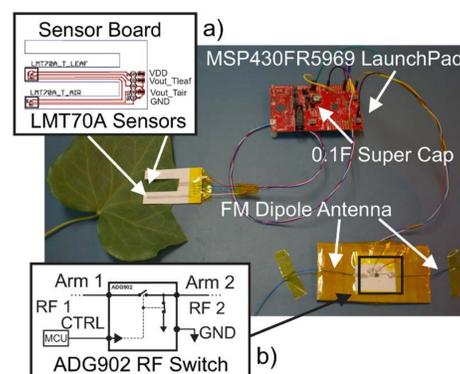
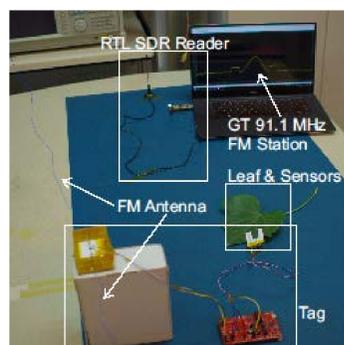
Flexible electronics

Fully printed circuits including dielectric and conducting materials.

AMBIENT BACKSCATTER

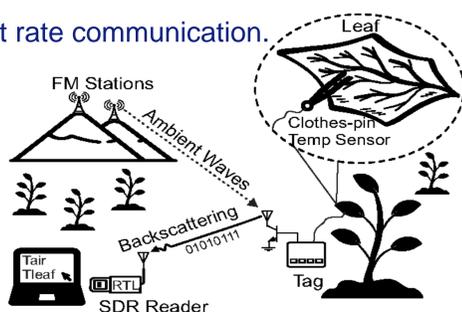
Communication with ambient signals:

- Ambient FM station signals. -> FM stations as carrier emitters.
- Backscatter AM modulation.
- Semi passive tags (Energy assisted).
- Receiver: low cost software defined radio.
- Low bit rate communication.



Channel fluctuation => Bit rate and efficient filtering trade off.

- Measure Temp difference ($T_{leaf} - T_{air}$) -> related with water stress.
- MSP430 MCU communication protocol development.
- Inkjet-printed (photo paper substrate) "Clothes-pin" temperature sensor board and RF front end.
- Duty cycle, 9 hours, super-Cap operation.
- Solar & RF harvesting for power supply (future operation).



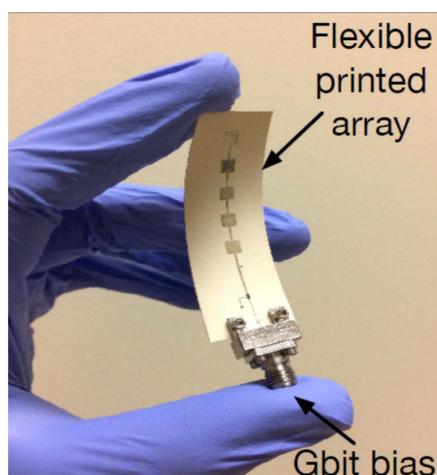
FUTURE WORK !!

• Millimeter wave backscatter:

- Large bandwidth, multiple beams, Gb/s communication.
- Printed FLEXIBLE 24 - 28 GHz tag.
- Energy efficient, < 0,15 pJ/bit.
- 3-4 orders of magnitude beyond current RFIDs.

• Ultra fast (minutes) printing.

• Microfluidic RF circuits.



• Vision of fully printed electronics for sensing, communication and energy.

• "One Use" Environmental Sensors for Agricultural Applications

- Ambient RF Harvesting for Power Supply.
- Long Range Communication.
- Ultra low Cost.



Adapt the manufacturing process to the world we are living in !!