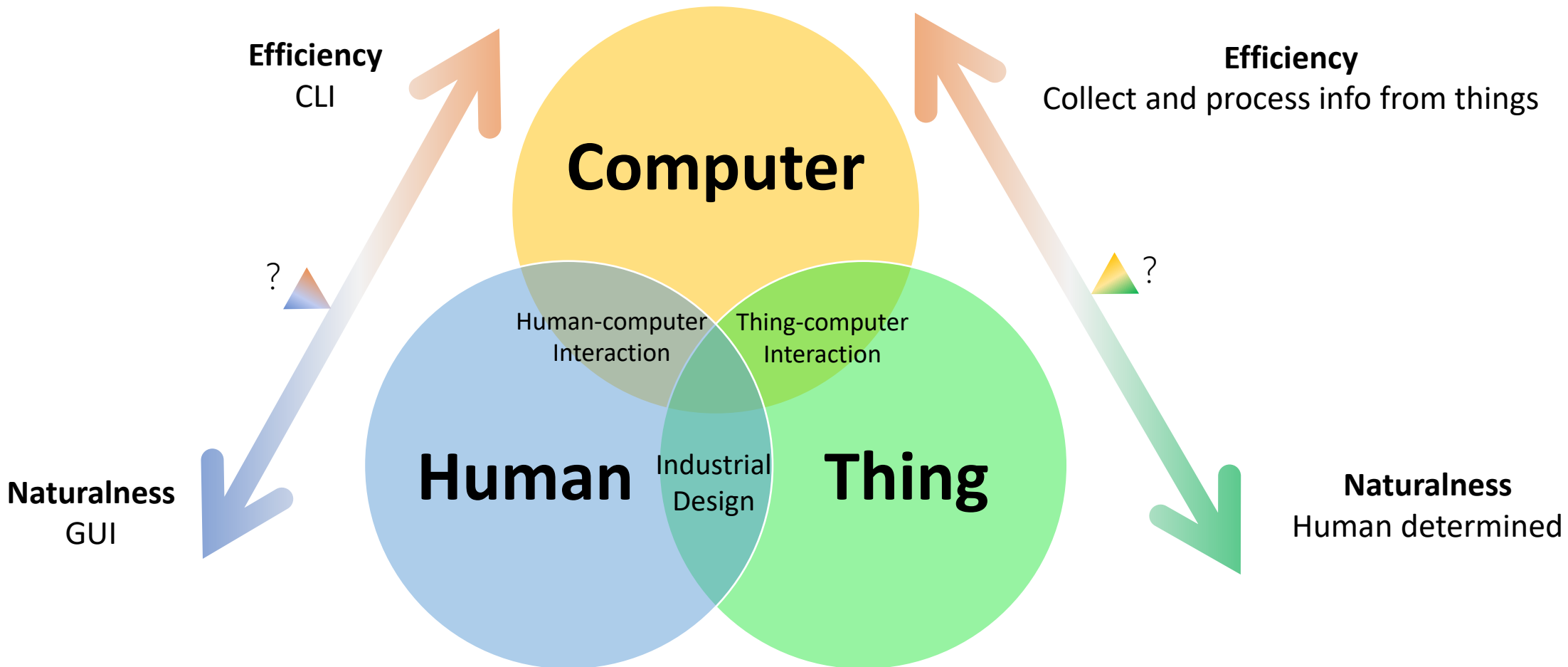




Thing-computer Interconnection

Tengxiang Zhang

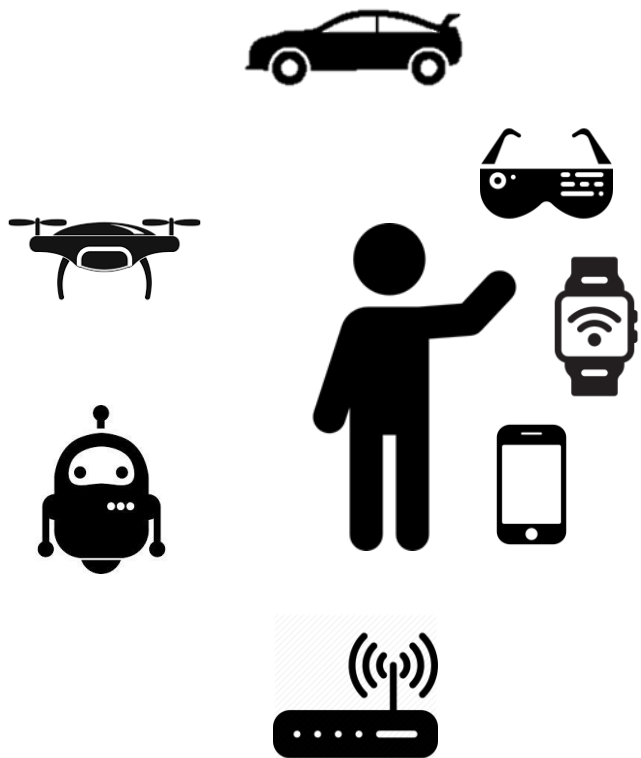
Human-Computer-Thing Ternary



Natural and efficient Information transfer and knowledge acquirement

Thing-computer interconnection

Computer
Resource-abundant



**Interconnection
Technique**

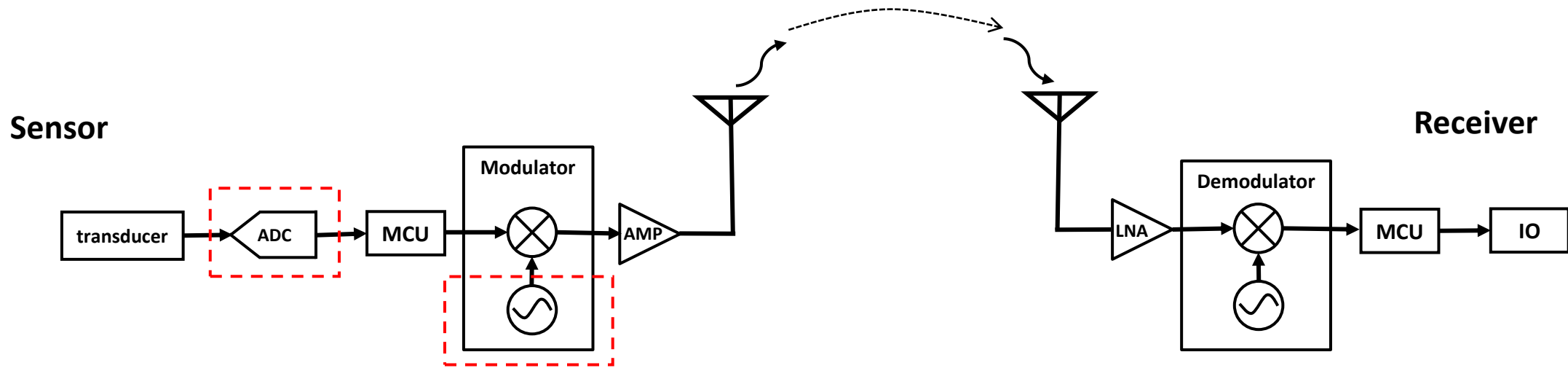


Energy
Information

Thing
Resource-constrained



Conventional Wireless Sensing System



高能耗部分：

1. ADC
Sensing: Digitize analog signals
2. High Frequency Oscillator (HFOSC)
Transmission: Generate carrier frequency

Typical
Power Consumption



10-15mW



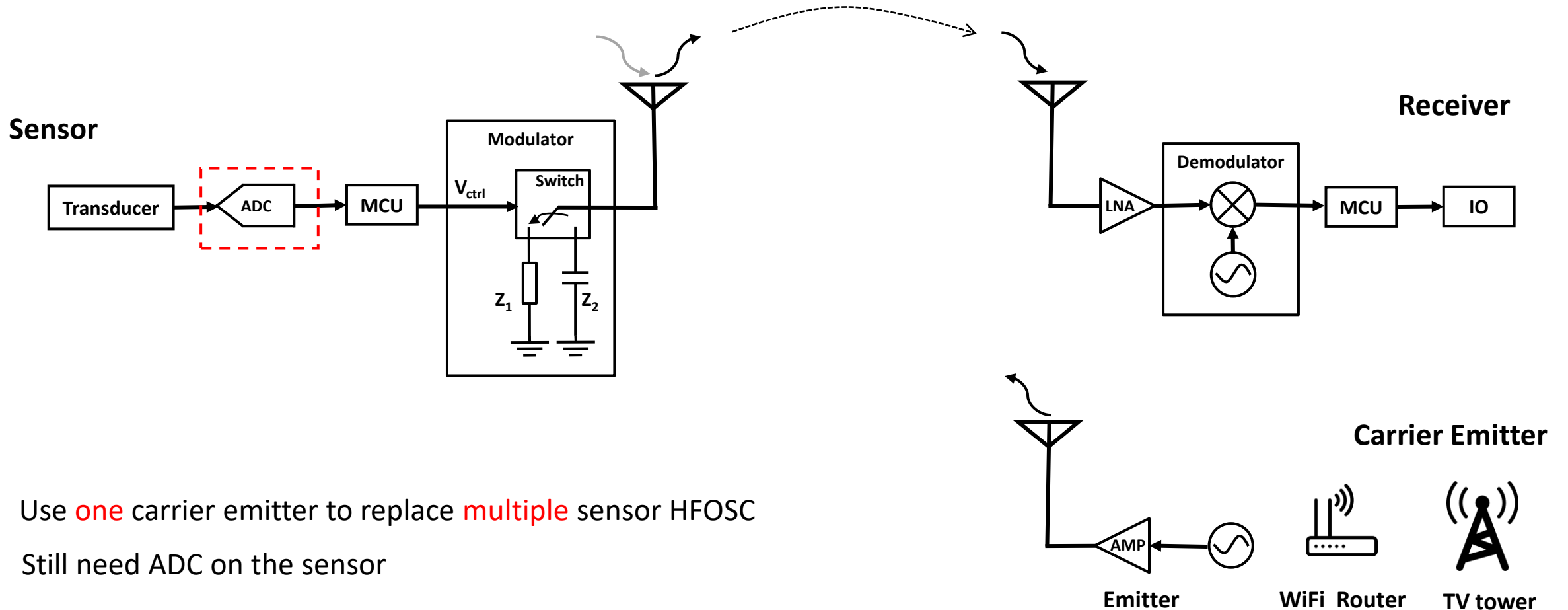
Bluetooth®

10-15mW



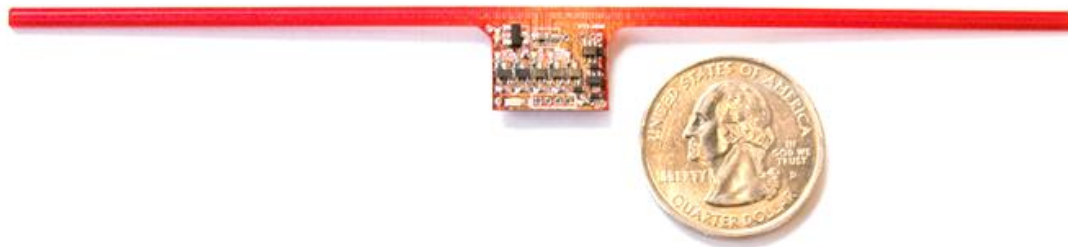
30-150mW

Digital Backscatter Sensing System

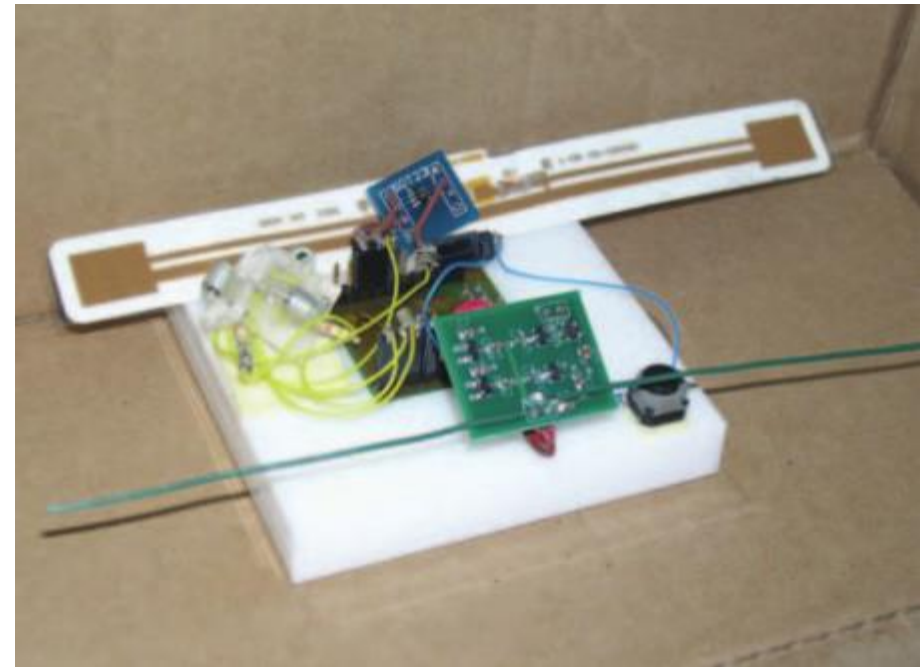


Use **one** carrier emitter to replace **multiple** sensor HFOSC
 Still need ADC on the sensor

Example-WISP



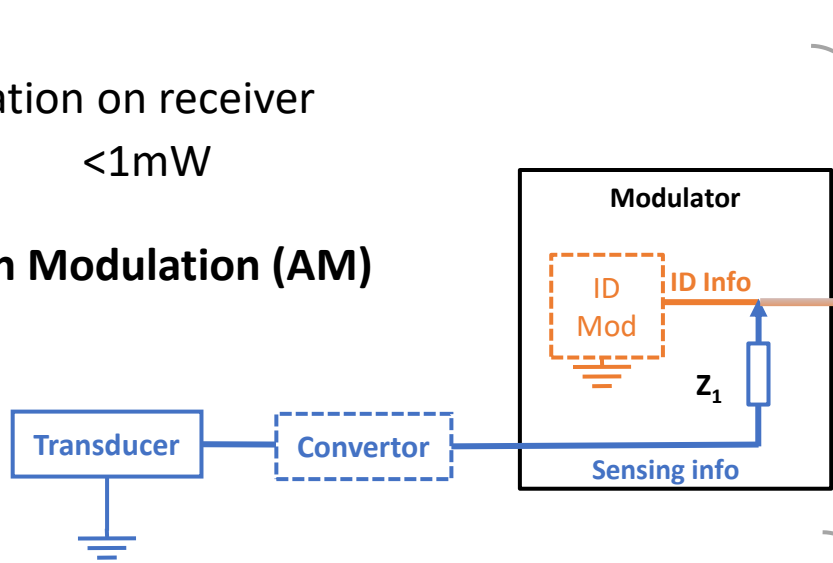
Power consumption: $\sim 1\text{mW}$
 Communication: RFID
 Computing/Storage: low-power MCU
 Sensing: IMU/Touch interface/Camera...



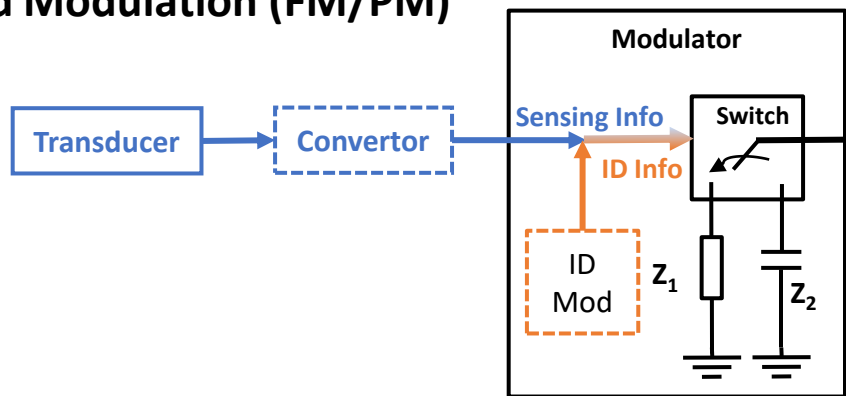
Analog(hybrid) Backscatter Sensing System

Digitalization on receiver
<1mW

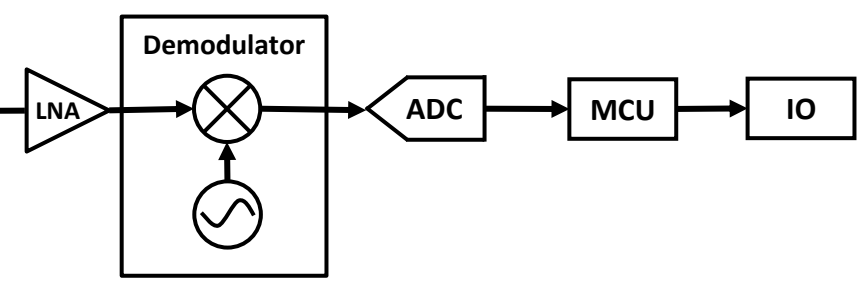
1. Direction Modulation (AM)



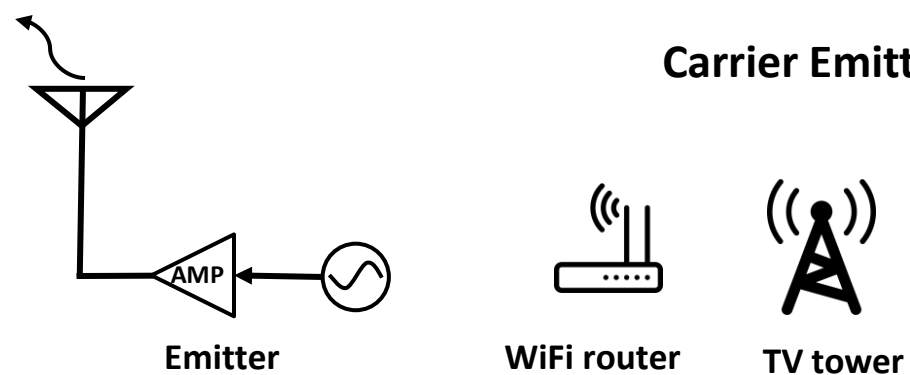
2. Sideband Modulation (FM/PM)



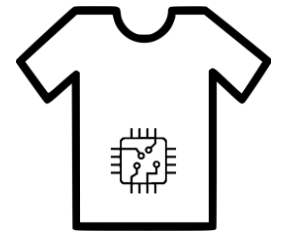
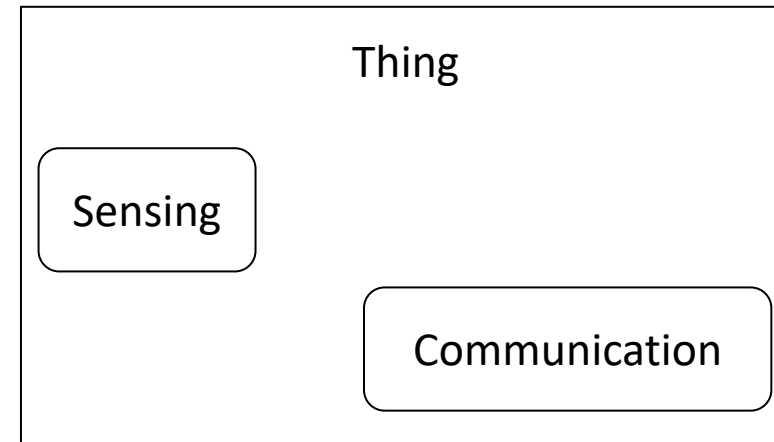
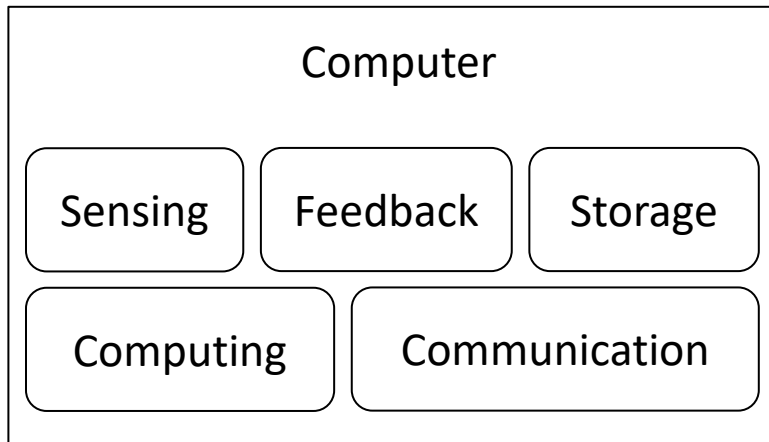
Receiver



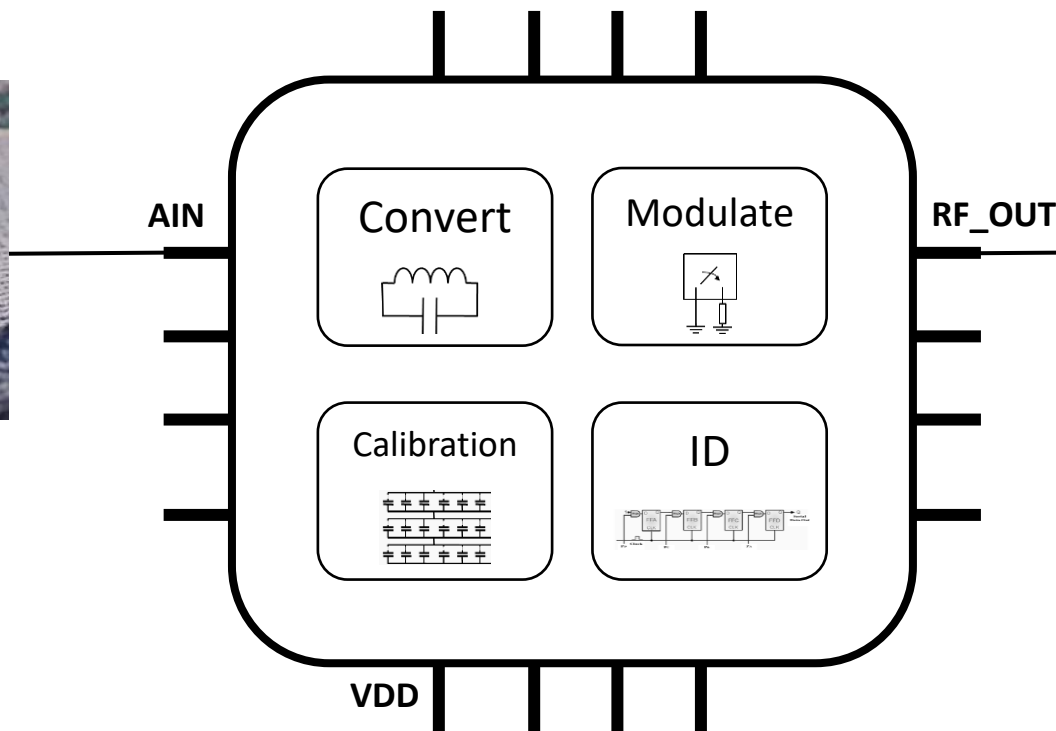
Carrier Emitter



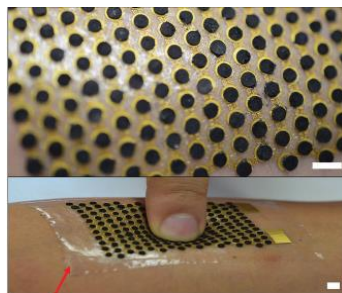
Offloading functions to computers



Self-sustainable wireless sensor



1.2mW/cm²
Bioenergy (sweat)^[2]



0.5mW
Triboelectric + Sun
(fabric area 4cmX5cm ,
Light intensity 80mW/cm²)^[1]

1. Jun Chen, Yi Huang, Nannan Zhang, Haiyang Zou, Ruiyuan Liu, Changyuan Tao, Xing Fan, and Zhong Lin Wang. 2016. Micro-cable structured textile for simultaneously harvesting solar and mechanical energy. *Nature Energy* 1: 16138.
2. Amay J. Bandodkar, Jung-Min You, Nam-Heon Kim, Yue Gu, Rajan Kumar, A. M. Vinu Mohan, Jonas Kurniawan, Somayeh Imani, Tatsuo Nakagawa, Brianna Parish, Mukunth Parthasarathy, Patrick P. Mercier, Sheng Xu, and Joseph Wang. 2017. Soft, stretchable, high power density electronic skin-based biofuel cells for scavenging energy from human sweat. *Energy & Environmental Science*.

Analysis vs Design

Signal Analysis

How to acquire knowledge from existing information?



Feature Design

What information is needed to acquire the knowledge?

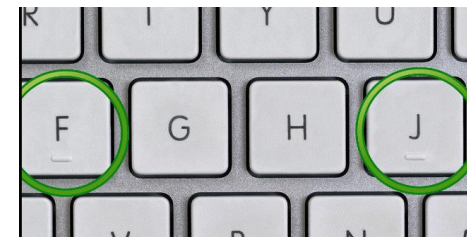
Existing things are designed for human 'sensors'



Traffic lights designed for eyes

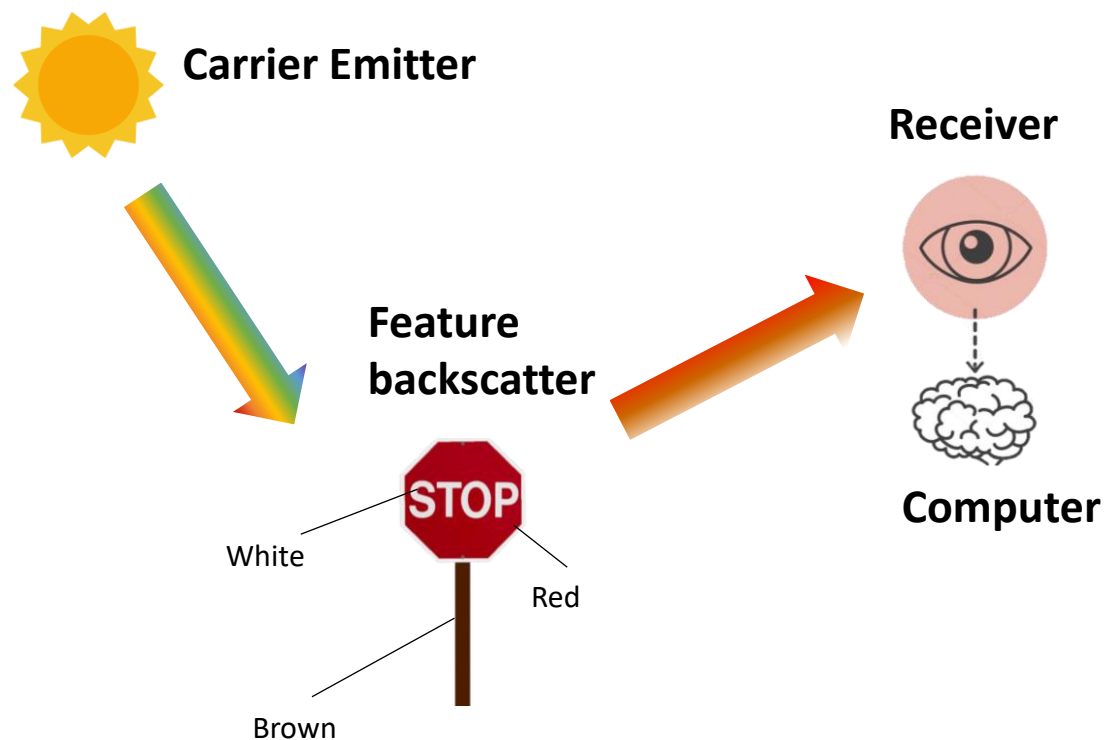


Alarm clock designed for ears



Key grooves designed for fingers

Analog Backscatter Sensing: An Example

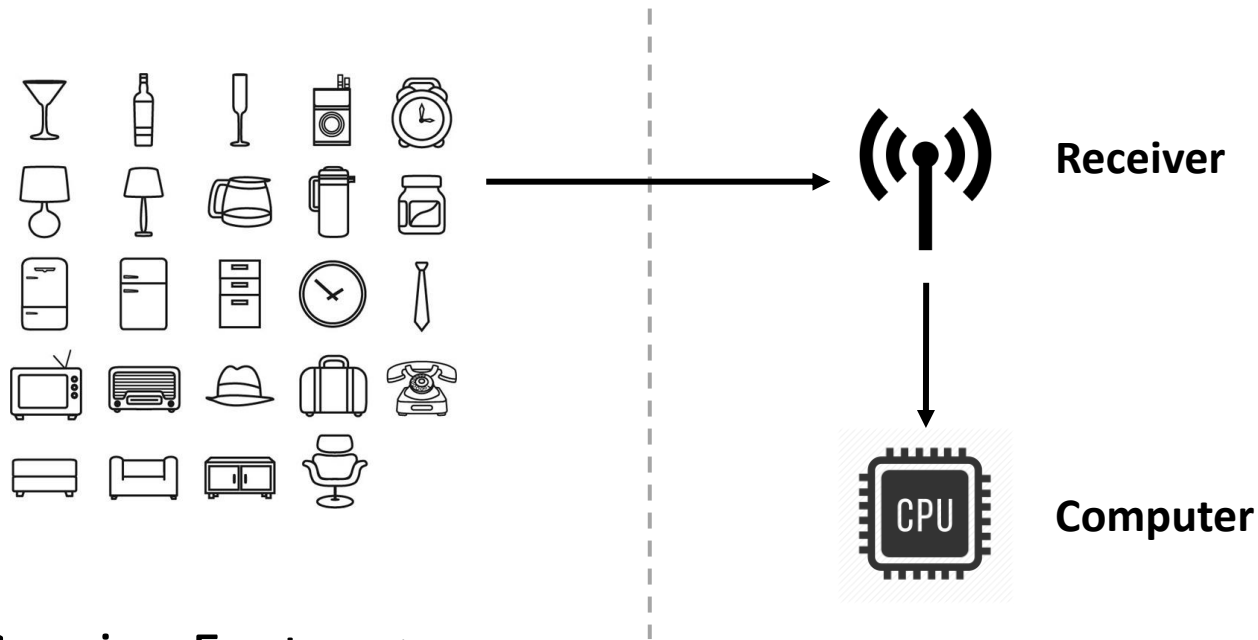


- Information: 400-760nm EM spectrum
- Sensing/coding: eyes
- Feature: color
 - Frequency domain: Amplitude, Frequency;
 - Space domain: color shape
- Speed: Speed of light
- Computing/Storage: brain
- Knowledge: object name, concept, abstractions

CV is powerful because many things are already designed for visual recognition!

Feature Design on Things

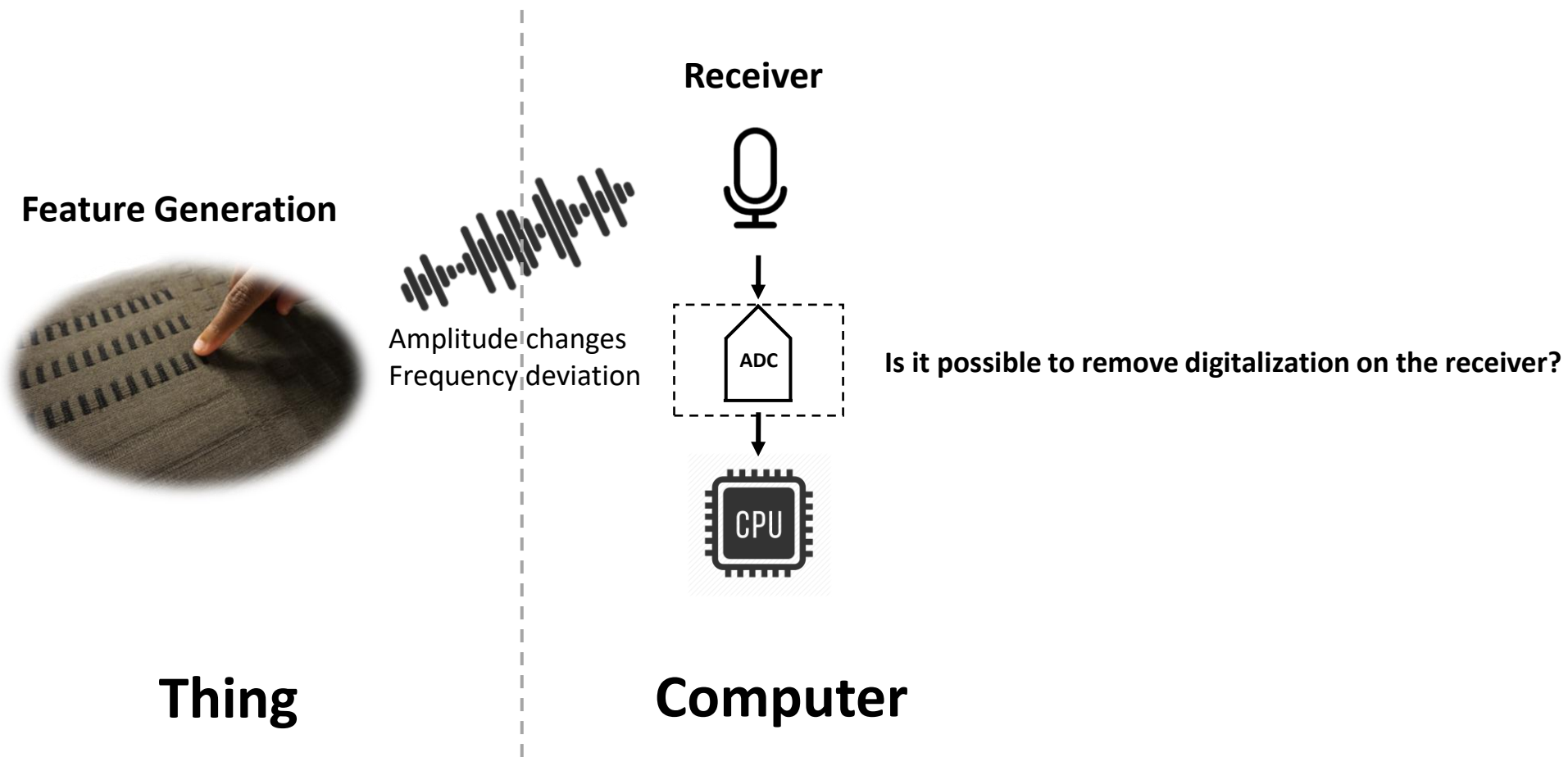
How to design **analog features** on things for **computers**?



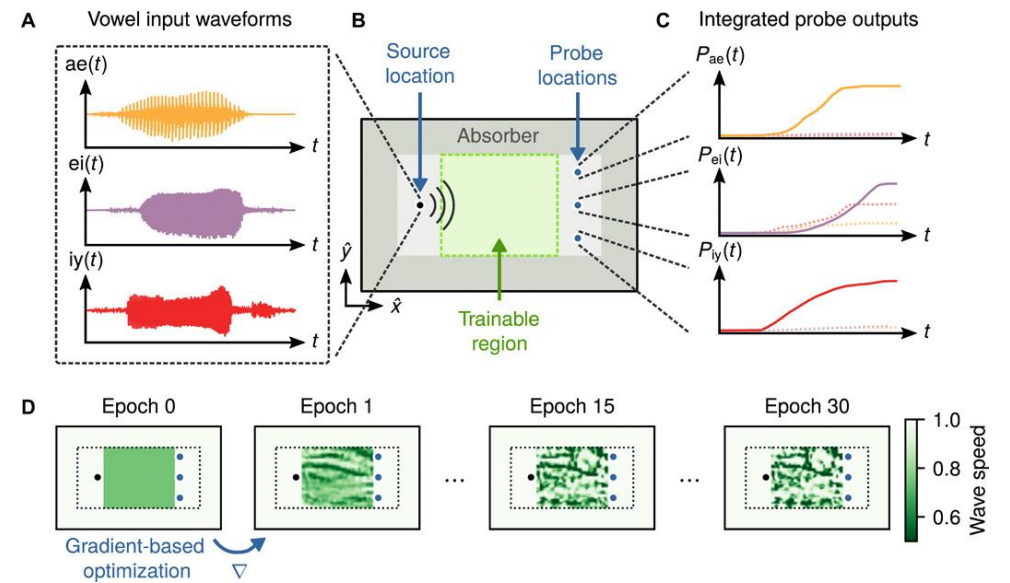
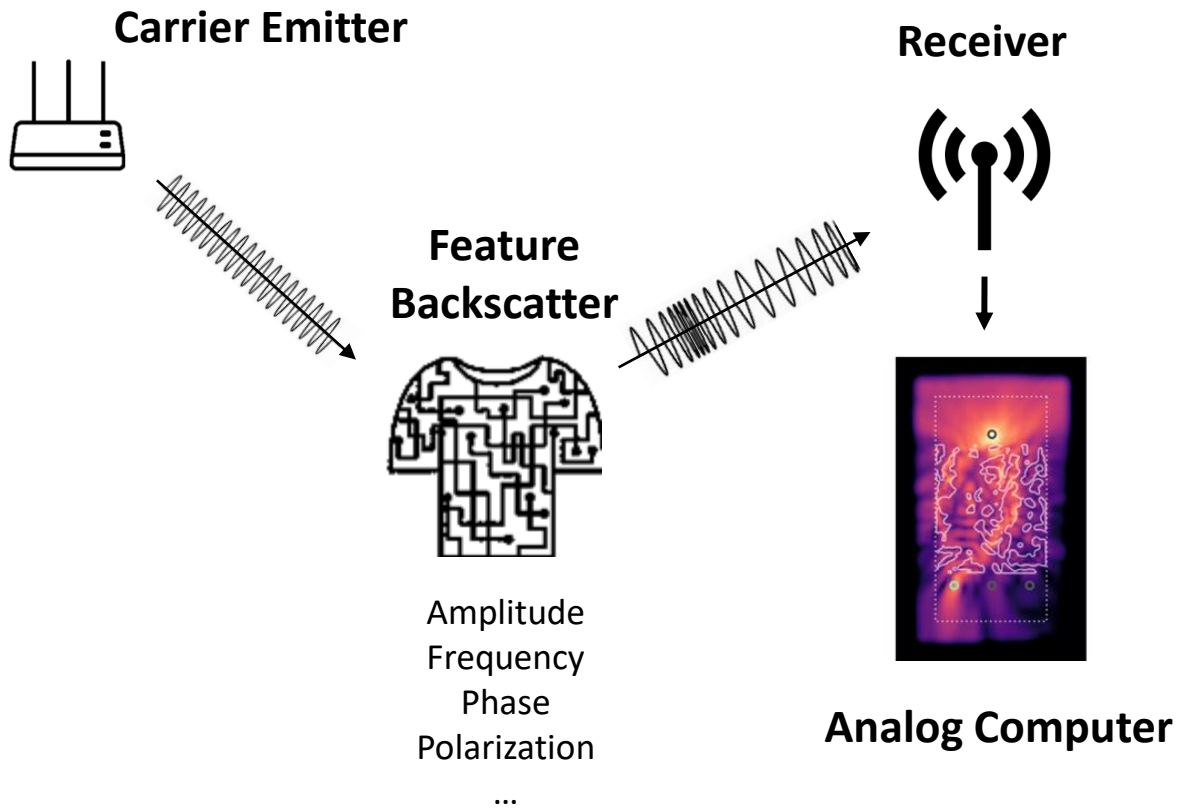
Sensing Feature:

1. Ultra-low cost
2. Ultra-low power/Passive
3. Easy to integrate

Design Audio Features for Touch Sensing: An Example



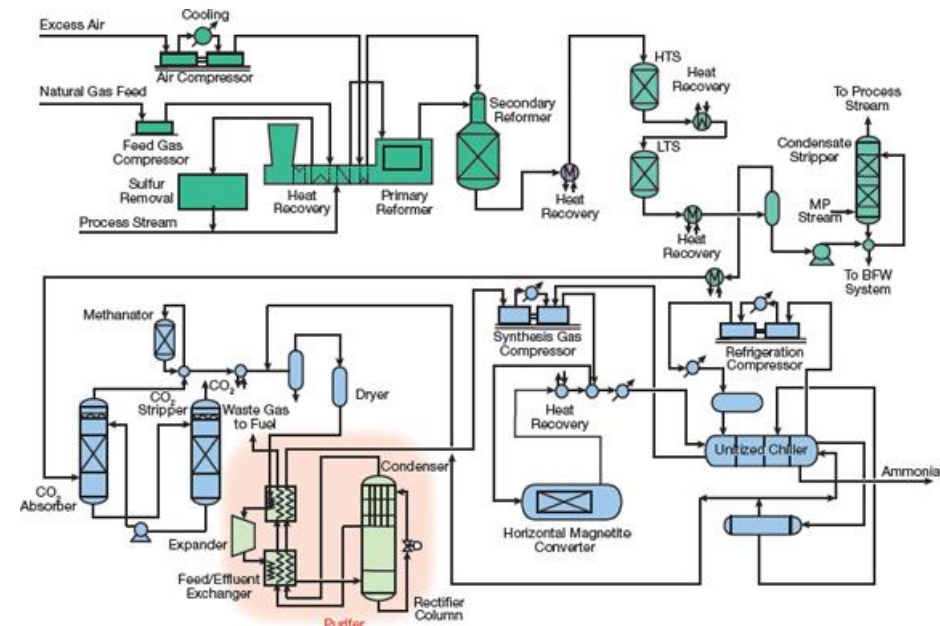
Analog Computing



An analog vowel classifier [1]

Computing Materials: A Vision

- Ubiquitous deployment of transistors are too expensive!
 - One transistor costs $\sim \$5 \times 10^{-8}$
 - Add sensing capability to all roads around the world
\$170 Billion!
- Bulk manufacturing of computing materials
 Synthesis-Purify
- New computing element measured in mol





Thanks

Tengxiang Zhang

<https://txzhang.me>