L3

Low Cost, Low Complexity and Low Power Radio Frequency Sensing using Tunnel Diodes

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Radio Frequency (RF) Sensing Mechanism

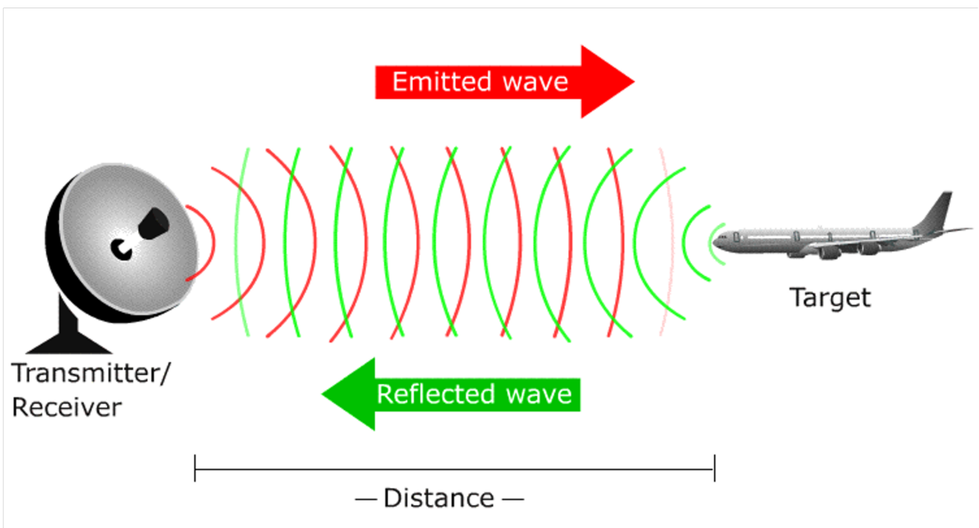


Figure 1: RF sensing is based on reflected signal.

Track changes in the wireless signal reflected from physical objects.

- signal strength
- phase
- channel state information
- frequency doppler shift

RF Sensing Applications

- **Localization system**
- **Material sensing**
- **Human hand/body gesture sensing**
- **Vital sign monitoring**

Existing System Limitations

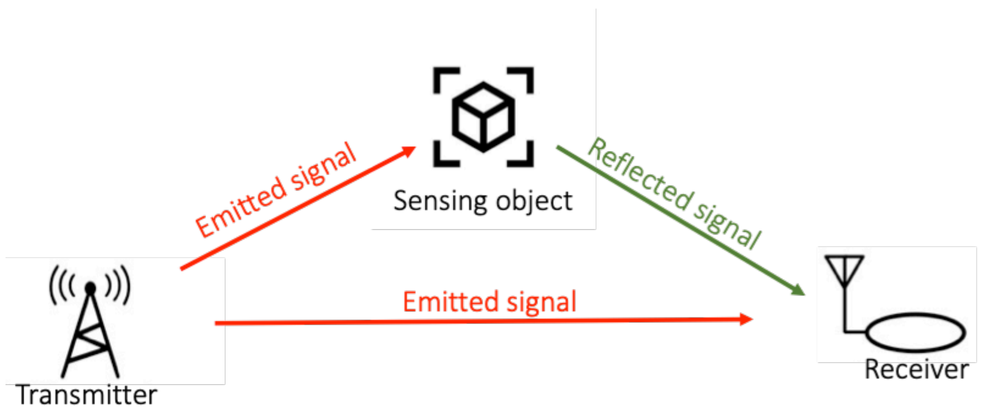


Figure 2: Conventional architecture for RF sensing applications.

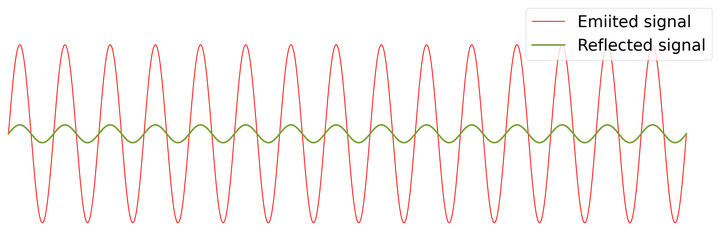


Figure 3: Reflected signal is significantly weaker than emitted signal.

Existing systems are highly complex with high cost.

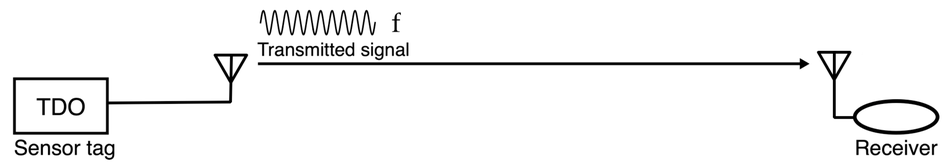
- reflected signal is weak, with co-existing emitted signal it requires self-interference cancellation hardware and software.
- extract various signal properties requires high-complexity algorithms and mechanisms.

Our solution:
a new RF sensing mechanism, we avoid measure the properties of a weak reflected signal. Instead, the physical environment impacts emitted signal's frequency from the transmitter.

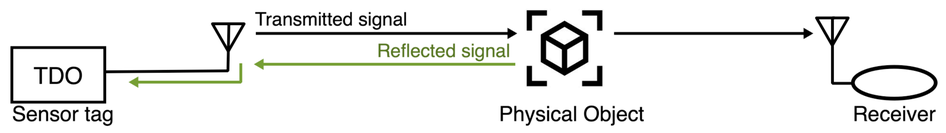
L3 RF Sensing System based on Tunnel Diode

A low cost, low power and low complexity RF sensing mechanism base on tunnel diodes.

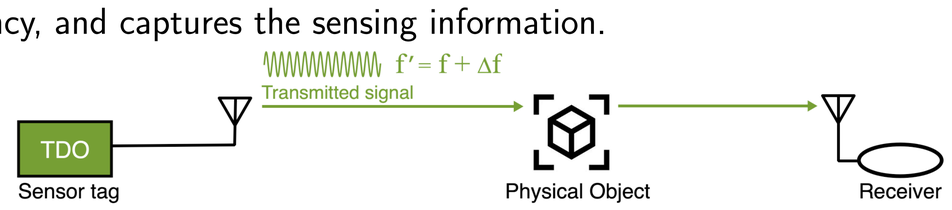
- **Step 1**: Tunnel diode oscillator (TDO) can emits a single-tone carrier at RF frequency, while only consumes sub-100 μWs of power.



- **Step 2**: Surrounding physical objects reflect the signal emitted by TDO. Then reflected signals travel back to the TDO and alter its frequency.



- **Step 3**: The receiver tracks the TDO's frequency, processes the drift in its frequency, and captures the sensing information.



Preliminary Experiment

The sensing object size, shape, material, as well as the distance between sensing object and TDO all have impacts on the emitted signal frequency.

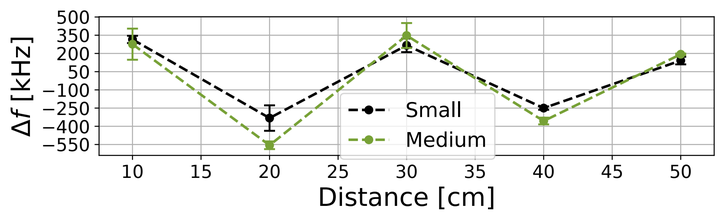


Figure 4: *Impact of size of an object in anechoic chamber.* The frequency shifts are more pronounced when a larger object is closer to the tunnel diode oscillator. This is because of the larger magnitude of the reflected signal traversing back to the TDO.

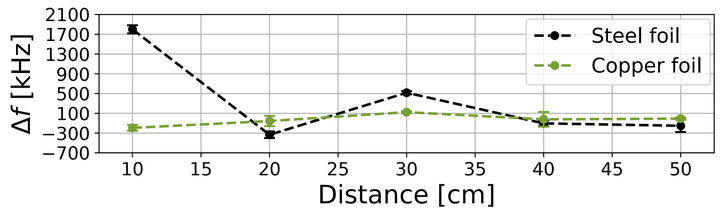


Figure 5: *Impact of material in indoor environment.* The choice of material for physical object influences frequency drifts. This is because of the different permittivity of the material, thus resulting in different strengths of the reflected signal. We vary the distance between the object and the TDO.

Application - Hand Gesture Sensing

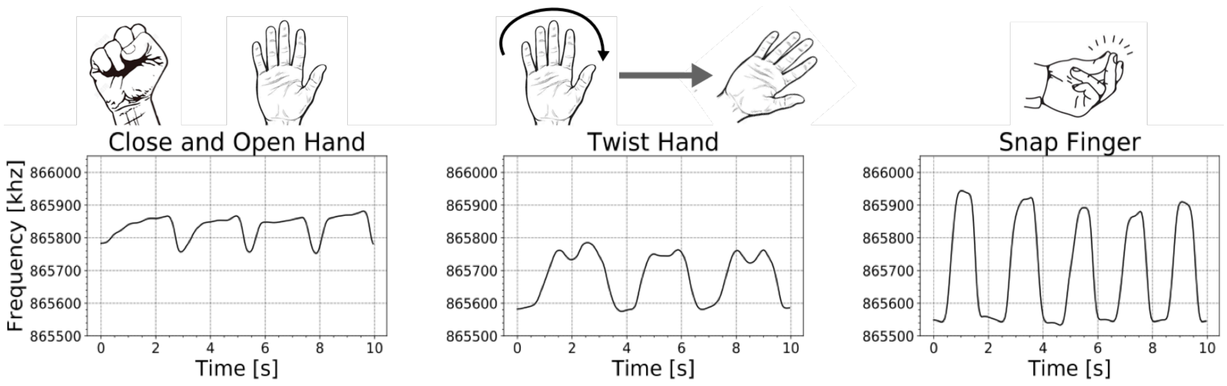


Figure 6: We perform three different hand gestures near the tdo.

Figure 7: Three different gestures causes unique drifts in the frequency of the emitted signal. We observe several distinguishable patterns in the frequency-time plot obtained from a RF spectrum analyser.