A 45 µW Bias Power, 34 dB Gain Reflection Amplifier Exploiting the Tunneling Effect for RFID Applications

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Abstract

RFID applications have power constraints that limit RF tags to short range communications. A low-powered (45 µW) reflection amplifier (34 dB) with a tunnel diode [1] that exploits the *quantum mechanical tunneling effect*, can dramatically enhance the range of passive or semi-passive tags. The obtained results allow a factor of 7 range improvement to the RFID link while keeping the *bias power 10 times lower* than any other available reflection amplifier.

This poster presents this idea and focuses on the quantum tunneling effect not fully addressed in the related paper.

Improving RFID ranges

Communication Range in RFID

$$P_{R_{min}} = \frac{M P_t^2}{P_T} \qquad M = \frac{1}{4}\left|\Gamma_A - \Gamma_B\right|^2$$

- $P_{R_{min}}$: minimum power received at the reader to detect an intelligible RF signal
- P_T: reader transmitted power (In Fig. 1, P_T is assumed to be 1 W)
- P_t: minimum impinging power required for passive RFID tags
- M: modulation factor
- Γ_A, Γ_B: modulating reflection coefficients

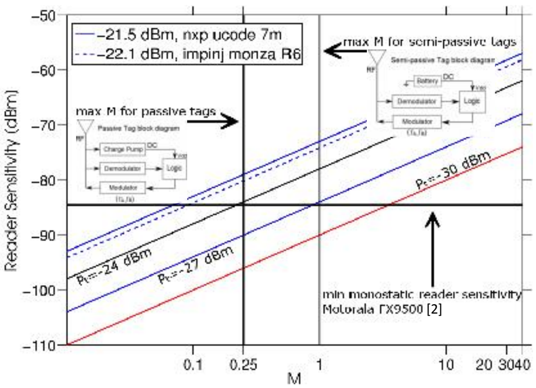


Fig. 1: In passive tags (M ≤ 0.25), if P_t keeps decreasing, the power reaching the reader reduces and eventually the reader will not be able to read the tag. Semi-passive tags (M=1) are already limited in range by the reader sensitivity.

Range improvements are achieved by a better reader sensitivity and/or using M>1

Reflection Amplifiers

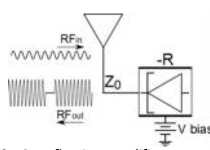


Fig. 2: Reflection amplifier concept

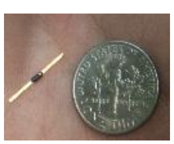


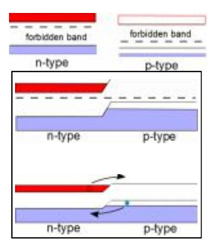
Fig. 3: Tunnel diode, MBD5057-E28.

$$|\Gamma| = \left|\frac{(-R) - Z_0}{-R + Z_0}\right| = \left|\frac{R + Z_0}{R - Z_0}\right|$$

- A reflection amplifier displays a negative resistance (-R) that increases the modulation factor M to values above 1 and reflects amplified RF signals (Fig. 2).
- Bias requirements, as reported in research literature, ranges from 0.32 mW to 1 W.
- A tunnel diode (Fig. 3) has been here used to make a low-powered (45 µW) reflection amplifier displaying a 34 dB gain at 5.45 GHz.

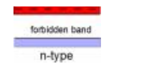
PN Junctions

Semiconductors

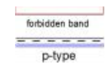


Energy band diagram, diode

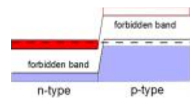
Degenerate semiconductors



Semiconductors *heavily* doped with donors (n-type) have the Fermi level up inside the conduction band



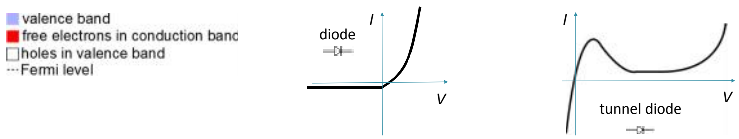
Semiconductors *heavily* doped with acceptors (p-type), have the Fermi level inside the valence band



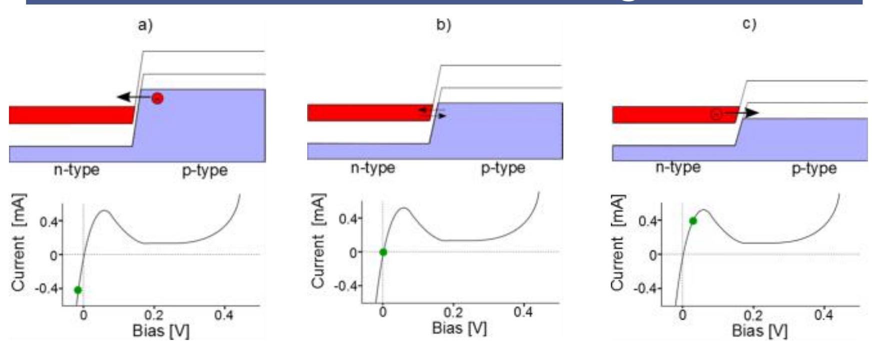
Energy band diagram, tunnel diode

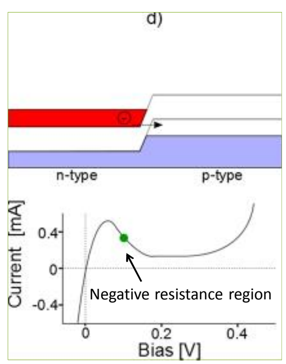
When a p-n junction is formed, a thin junction region is created as result of keeping the continuity of the Fermi level

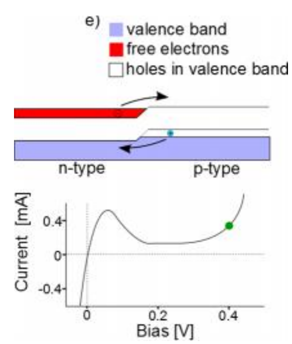
This results in a finite probability that electrons overcome the energy barrier when a small biasing voltage is applied (**quantum tunneling** [3])



Quantum Tunneling







Experimental Results

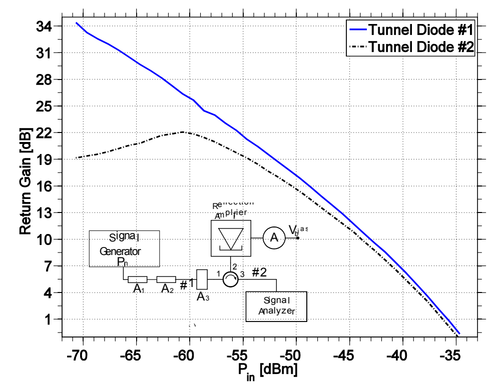


Fig. 4: Measurement setup and return gains as function of the RF power, Pin, at the reflection amplifier input.

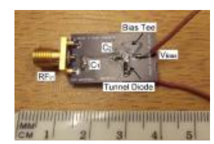


Fig. 5: realized prototype

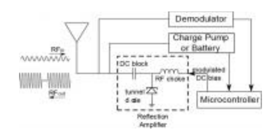


Fig. 6: conceptual block diagram of a tunnel diode-based reflective system

What's next?

On Friday 17 (10.30 am, room 31C), an in-depth review of this poster followed by procedures used to realize and test the reflection amplifier (Fig. 5) will be presented with experimental results. A comparison with reflection amplifiers available in the research literature will be shown.

References

[1] L. Esaki, "New phenomenon in narrow germanium p-n junctions," Phys. Rev., vol. 109, pp. 603–604, Jan. 1958. [Online]. Available: http://link.aps.org/doi/10.1103/PhysRev.109.603
[2] Motorola. (2012). [Online]. Available: http://www.motorolasolutions.com/web/Business/Products/RFID/RFID\%20Readers/FX9500/Documents/FX9500 Specifications.pdf
[3] G. N. Roberts, "Tunnel diodes operation and application," Electronic Technology, vol. 37, no. 6, pp. 217–222, June 1960.