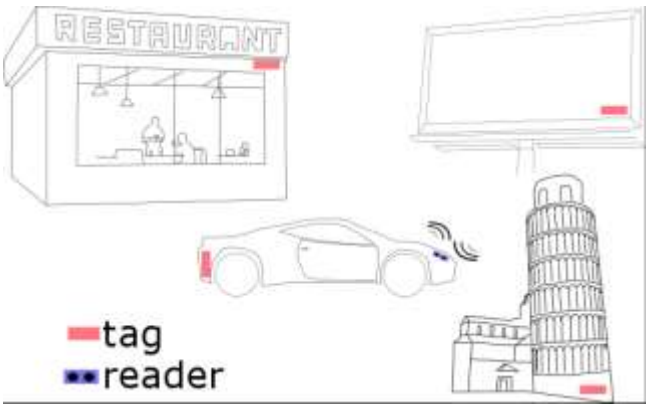
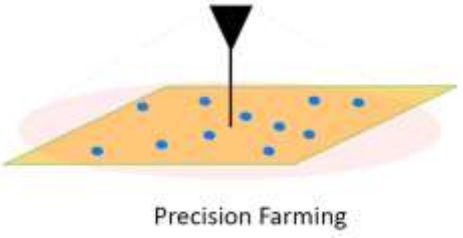
Tunnel Diodes for Backscattering Communications

Francesco Amato
May 29th 2018

What if we had a long-range backscattering communication link?





Precision Farming

Smart cities

2

RFID vs BLE

RFID	BLE
+ Simple RF front-end	+ Ubiquitous
+ Low power consumption	+ Longer communication ranges
- Short communication ranges	- Higher power consumption
	- Complex RF front-end

Idea: developing quantum tunneling-based RFIDs to achieve long ranges with low power consumption

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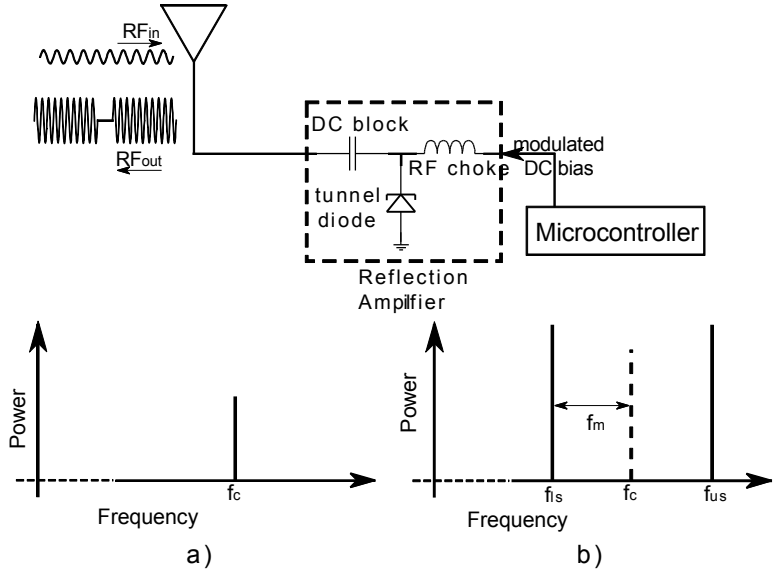
Tunneling RFID Tag



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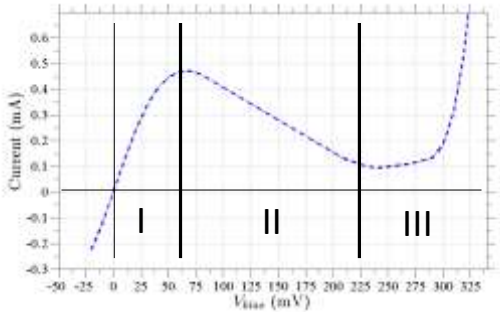
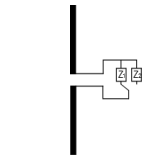
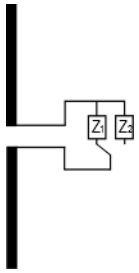
Reflection Amplifiers



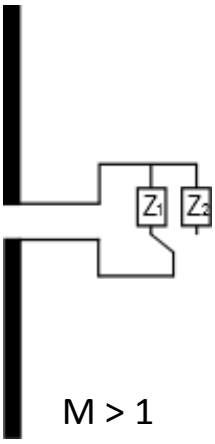
$$|\Gamma| = \left|\frac{(-R) - Z_0}{-R + Z_0}\right| = \left|\frac{R + Z_0}{R - Z_0}\right| > 1$$



M = 0.25



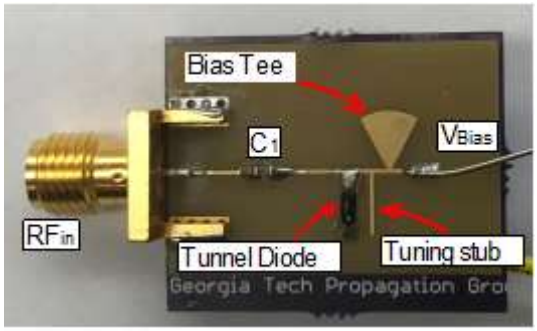
M = 1

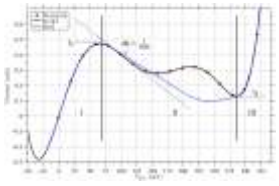


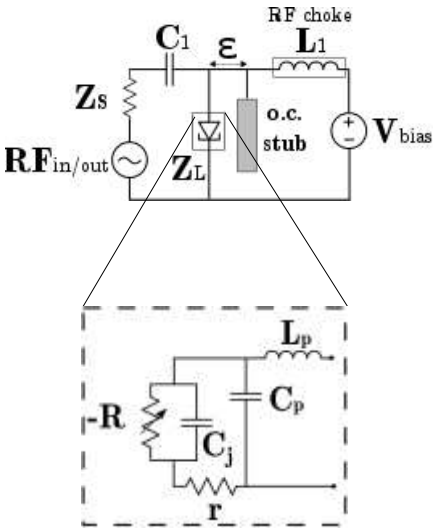
M > 1

Reflection amplifiers are active devices that, when opportunity biased, display a negative resistance (-R).

Design



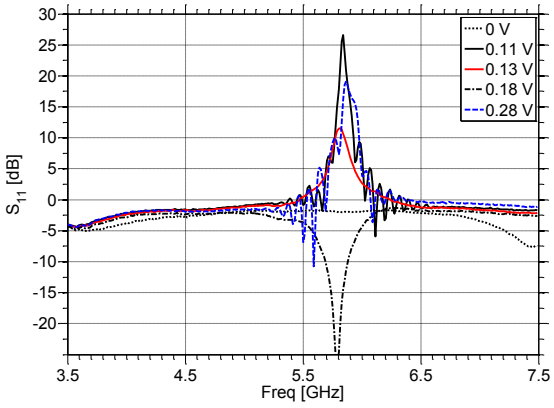




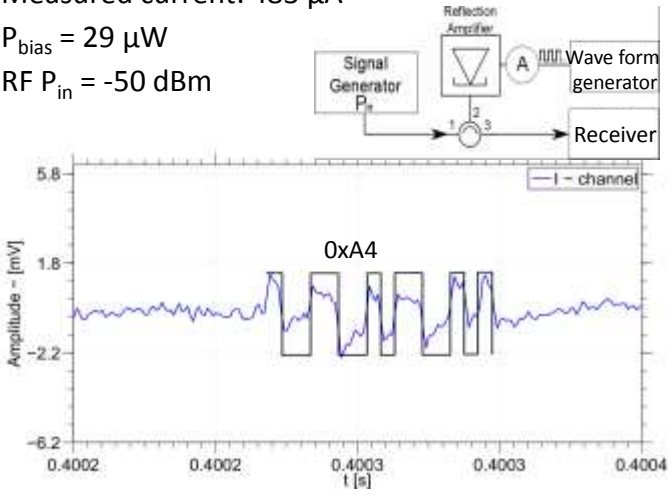
F. Amato, C. W. Peterson, B. P. Degnan, and G. D. Durgin, "A 45 *u*W Bias Power; 34 dB Gain Reflection Amplifier Exploiting the Tunneling Effect for RFID Applications," IEEE International Conference on RFID (RFID), San Diego, CA, April 2015, pp. 137-144.

Properties

- Optimum bias voltage: 60 mV
- Measured current: 483 µA
- P_{bias} = 29 µW
- RF P_{in} = -50 dBm

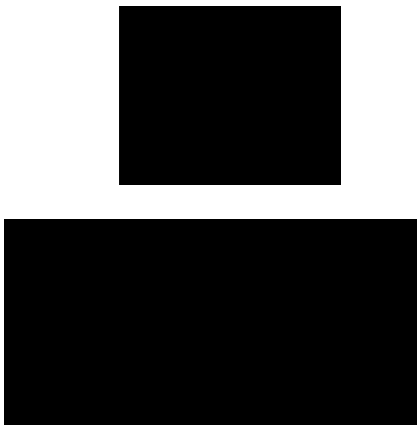


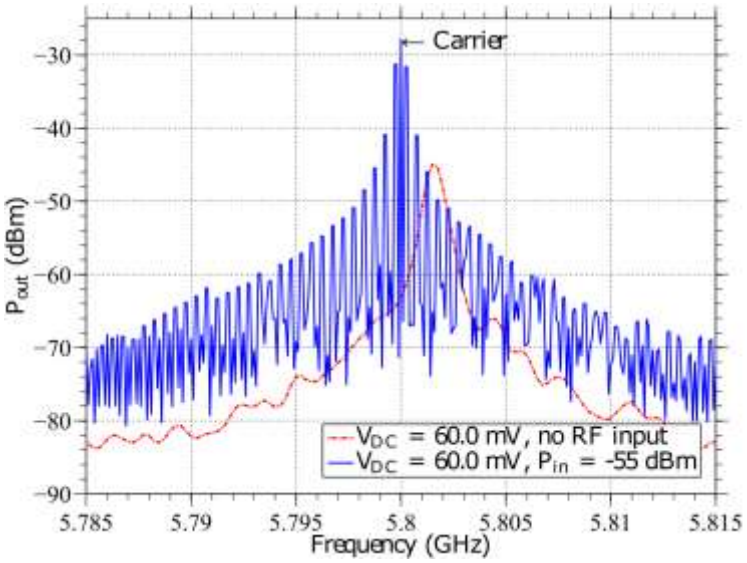
No oscillations occur, there is no amplification outside the 5.8 GHz band



Modulation and Manchester encoding can be achieved by applying a modulated bias to the reflection amplifier

Injection Locking





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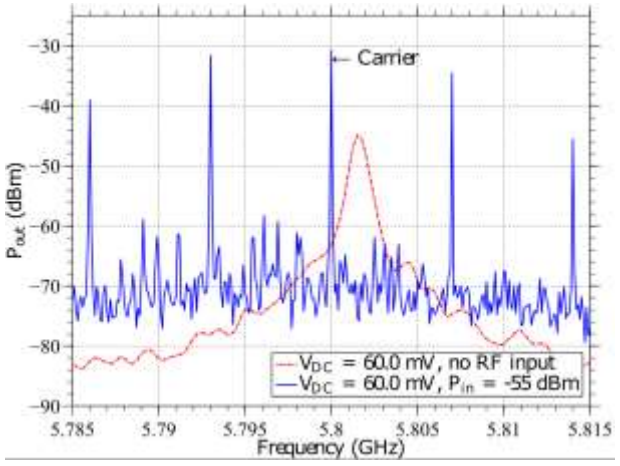
The locking range

Power and Energy:

V_{DC} = 60 mV, I_{DC} = 340 uA

Power: 20.4 uW,

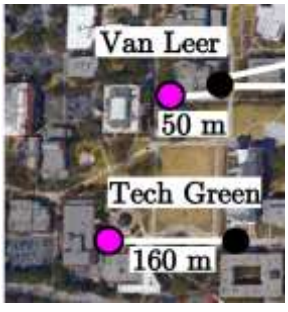
Energy: 2.9 pJ/bit @ 7 MHz



F. Amato and G. D. Durgin, "Signal-to-Noise Ratio Measurements for IoT Communications Using Tunneling Reflectors," IEEE 3rd World Forum on IoT, Washington D. C., December 2016.

Beyond the Limits of Classic Backscattering Communications

F. Amato, H. M. Torun, and G. D. Durgin, "Beyond the Limits of Classic Backscattering Communications: a Quantum Tunneling RFID Tag," IEEE International Conference on RFID, 2017



	Setup I
EIRP (dBm)	6
P_T (dBm)	0
G_{tx} (dBi)	6
G_{rx} (dBi)	24
G_t (dBi)	6
G (dB)	15

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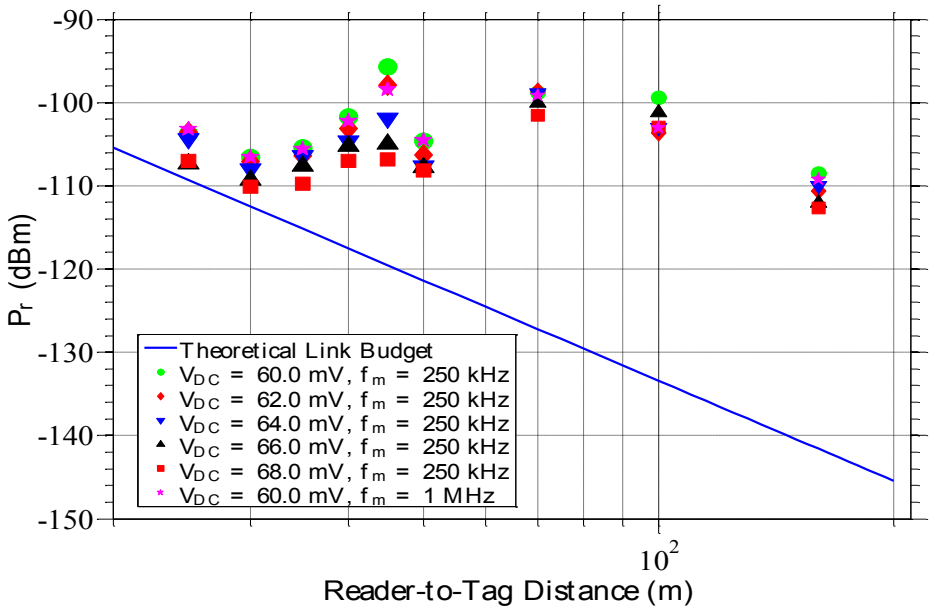
-90
-100
-110
-120
-130
-140
-150
P_r (dBm)
10^2
Reader-to-Tag Distance (m)
Theoretical Link Budget
V_{DC} = 60.0 mV, f_m = 250 kHz
V_{DC} = 62.0 mV, f_m = 250 kHz
V_{DC} = 64.0 mV, f_m = 250 kHz
V_{DC} = 66.0 mV, f_m = 250 kHz
V_{DC} = 68.0 mV, f_m = 250 kHz
V_{DC} = 60.0 mV, f_m = 1 MHz

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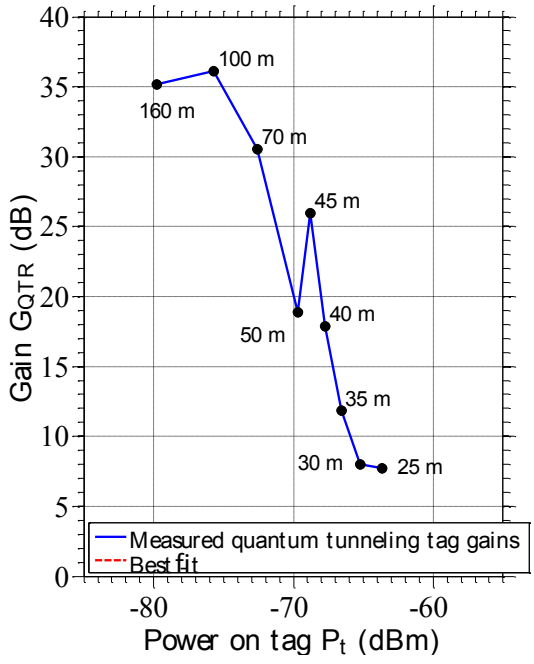
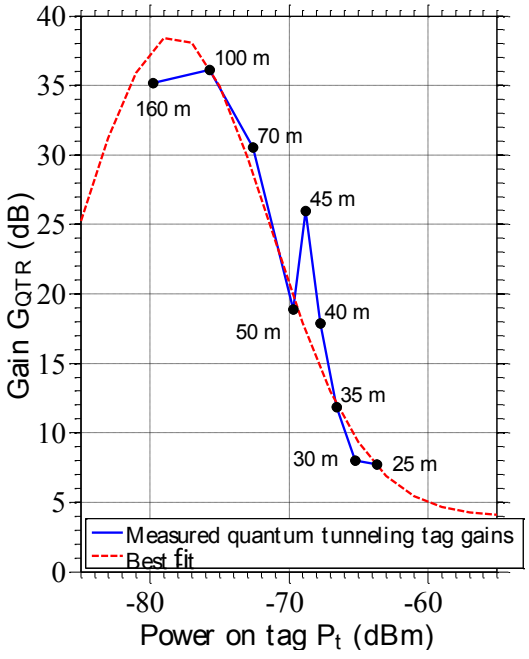

Gain G_{QTR} (dB)
Power on tag P_t (dBm)
160 m
100 m
70 m
45 m
50 m
40 m
35 m
30 m
25 m
Measured quantum tunneling tag gains
Best fit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40 m
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30 m
25 m
Measured quantum tunneling tag gains
Best fit

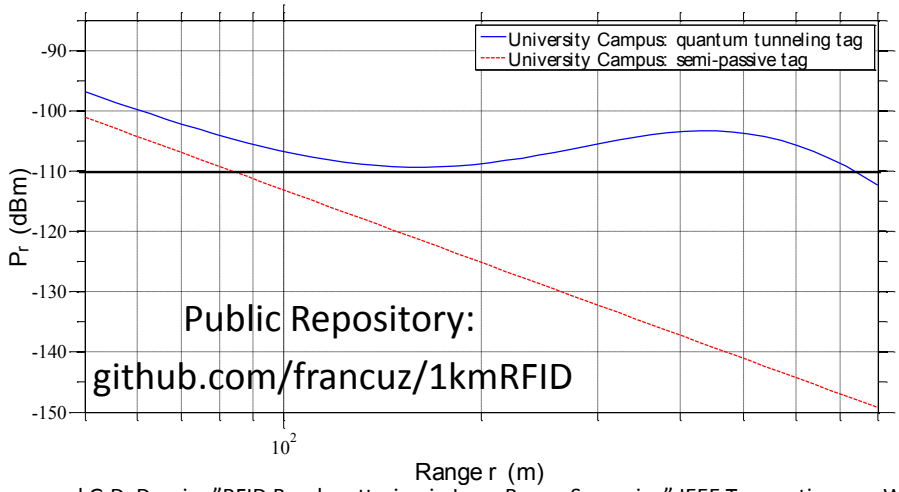
13

RFID long range scenarios

Variables	Description	Ranges
P_T	Reader Transmitted power	[-20, 30] (dBm)
G_{tx}	Reader transmitting antenna gain	[0, 6] (dBi)
G_{rx}	Reader receiving antenna gain	[0, 30] (dBi)
G_t	Quantum tunneling tag	[1.76, 14] (dBi)

Scenario	Est Range (m)
Town House	20
Football Field	50
Warehouse	100
Skyscraper	300
University Campus	700
Crop Field	1000
Airport	1500
City	2000

Scenario	EIRP (dBm)	P_T (dBm)	G_{tx} (dBi)	G_{rx} (dBi)	G_t (dBi)
University Campus (700 m)	16.3	14.5	1.8	28	9



F. Amato, H. M. Torun and G.D. Durgin, "RFID Basckscattering in Long Range Scenarios" IEEE Transactions on Wireless Communications, Feb. 2018

Thank You

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