Enabling Ambient Backscatter Using a Low-Cost Software Defined Radio

Saving Energy/Low Power Communications

Maximilian Stiefel*, Elmar van Rijnswou*
Carlos Prez-Penichet*, Ambuj Varshney*, Christian Rohner*and Thiemo Voigt †
*Uppsala University
†Uppsala University and RISE SICS

May 21, 2017

13th Swedish National Computer Networking Workshop

Table Of Contents

Introduction

What is Backscattering? (1)

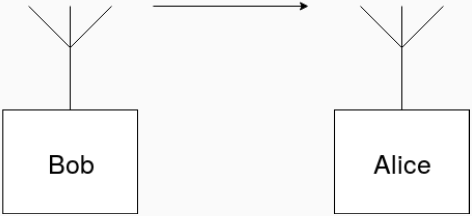

Figure 1: Simplest form of backscattering.

What is Backscattering? (1)

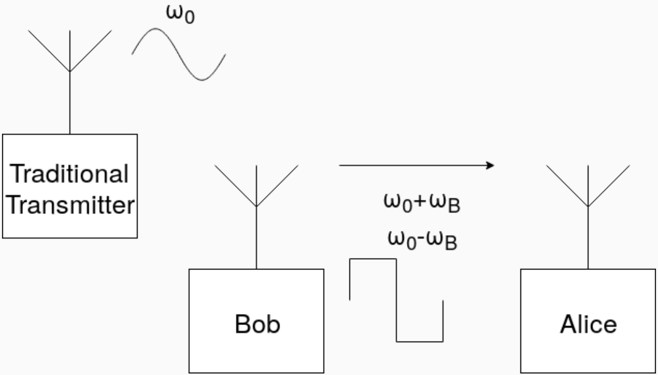

Figure 1: Simplest form of backscattering.

What is Backscattering? (2)

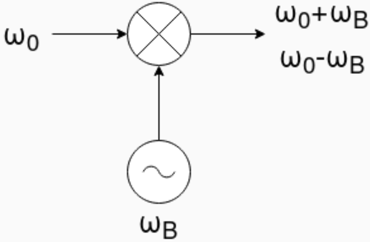

Figure 2: Classical communications engineering element: The mixer.

What is Backscattering? (2)

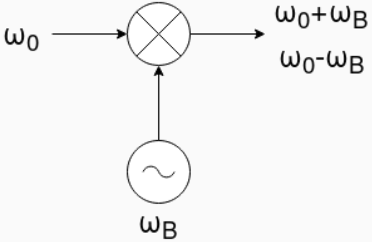

Figure 2: Classical communications engineering element: The mixer.

$$2\sin(f_c t)\sin(\Delta f t) = \cos[(f_c + \Delta f)t] - \cos[(f_c - \Delta f)t] \quad (1)$$

What is Backscattering? (3)

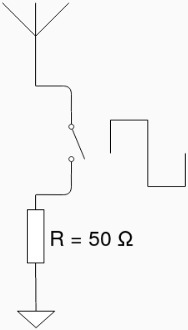

Figure 3: 50 Ω connected to a RF switch do the trick.

What is Backscattering? (3)

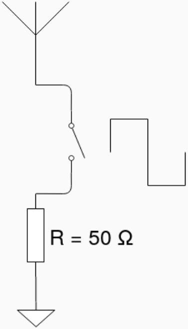

Figure 3: 50 Ω connected to a RF switch do the trick.

$$\Gamma = \frac{Z_L - Z_A}{Z_L + Z_A} \tag{2}$$

Why Backscattering?

- Ultra-low power wireless transmissions by reflecting/absorbing EM waves (in orders of μW) [2]

Why Backscattering?

- Ultra-low power wireless transmissions by reflecting/absorbing EM waves (in orders of μW) [2]
- Leverage existing signals such as coming from WiFi [4, 1] or TV towers [2, 3]

Why Backscattering?

- Ultra-low power wireless transmissions by reflecting/absorbing EM waves (in orders of μW) [2]
- Leverage existing signals such as coming from WiFi [4, 1] or TV towers [2, 3]
- Mechanism of choice to network devices operating on harvested energy

Why Backscattering?

- Ultra-low power wireless transmissions by reflecting/absorbing EM waves (in orders of μW) [2]
- Leverage existing signals such as coming from WiFi [4, 1] or TV towers [2, 3]
- Mechanism of choice to network devices operating on harvested energy
- Communication frontends are much simpler, smaller and cheaper, than traditional RF frontends

Background

What is Backscattering?

- Different backscattering research has already been done (e.g. [?])
- Also a lot of things about the RTL2832U can be found (e.g. [?])

Figure 4: The IQ demodulator RTL2832U is available for less than 10 $. Source: Ebay

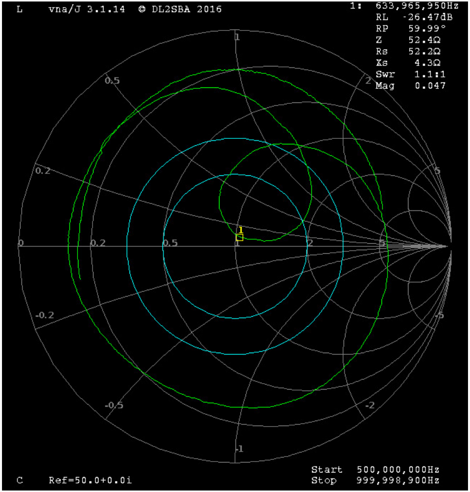

Figure 5: Smitchart sweep of selfmade ground-plane antenna for 634 MHz (checkout [?]).

Background And Literature (3)

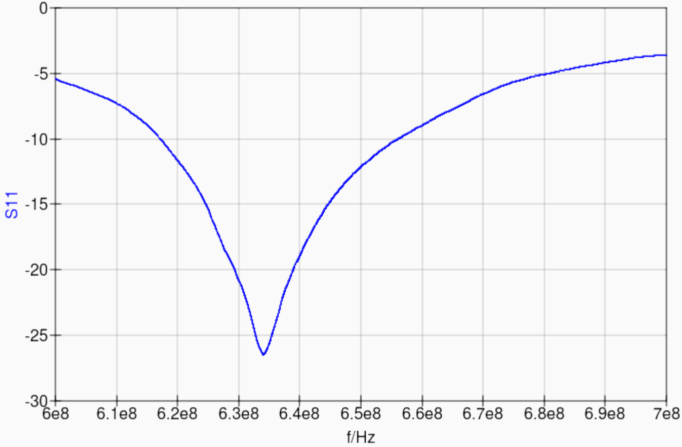

Figure 6: S11 out of the S parameter file of the VNA plotted with Qucs.

Design

State Of The Project (1)

Backscatter Tag	
Manchester encoding	✓
Weak error protection	✓
Shifting by 2 MHz	✓
Advanced frame design	✓
Antenna	
Roughly tuned and matched	✓
Mechanical stability	
Lumped elements tuning	

Table 1: Backscatter tag and antenna

State Of The Project (2)

Receiver	
Signal processing	✓
Reception with certain bit error rate	✓
Efficient infrastructure	✓
Fast	
Measurements	
Processing and Measurement environment	✓
Massive amount of samples	

Table 2: Receiver and measurements

State of the project (3)

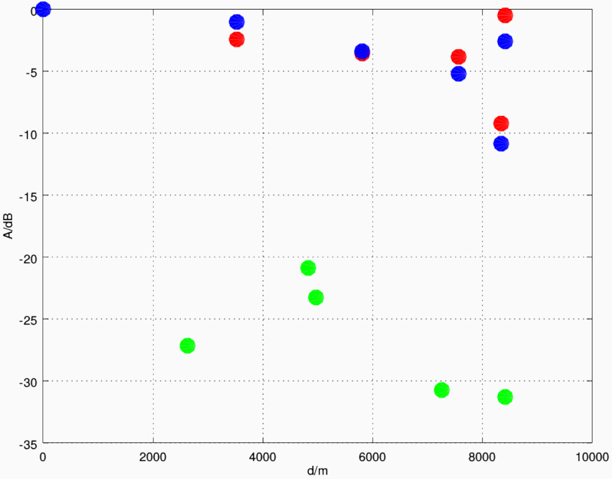

Figure 7: Signal strength depending on the distance of different frequencies.

State of the project (3)

```
function d = haversine (lat1,lat2,lon1,lon2)
        R = 6371e3;                                                                 % Earth radius
        rad = pi/180;

        phi1 = lat1*rad;
        phi2 = lat2*rad;
        dphi = (lat2-lat1)*rad;
        dlambda = (lon2-lon1)*rad;

        a = sin(dphi/2)*sin(dphi/2) + cos(phi1)*cos(phi2)*sin(dlambda/2)*sin(dlambda/2);
        c = 2*atan2(sqrt(a), sqrt(1-a));
        d = R*c;
endfunction;
```

State of the project (3)

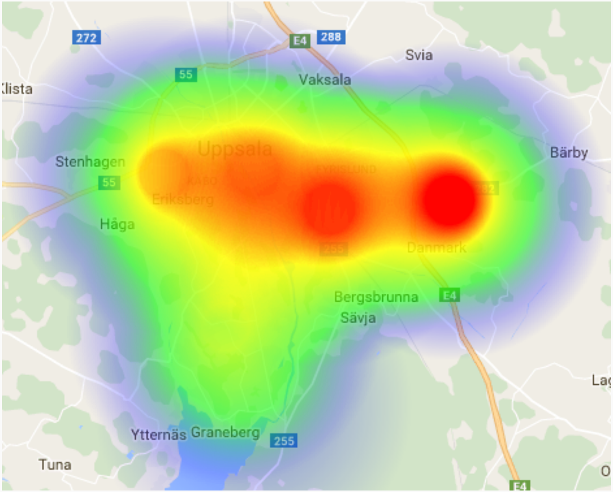

Figure 8: Signal strength heatmap of 626 MHz signal.

State Of The Project (4)

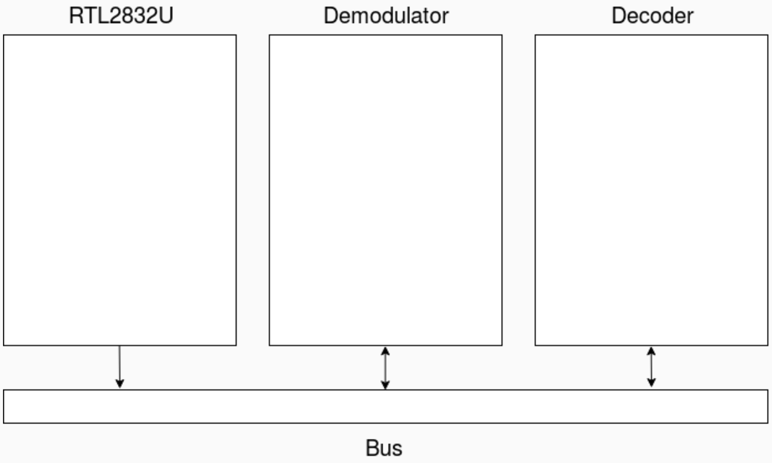

Figure 9: System architecture of the receiver.

State Of The Project (4)

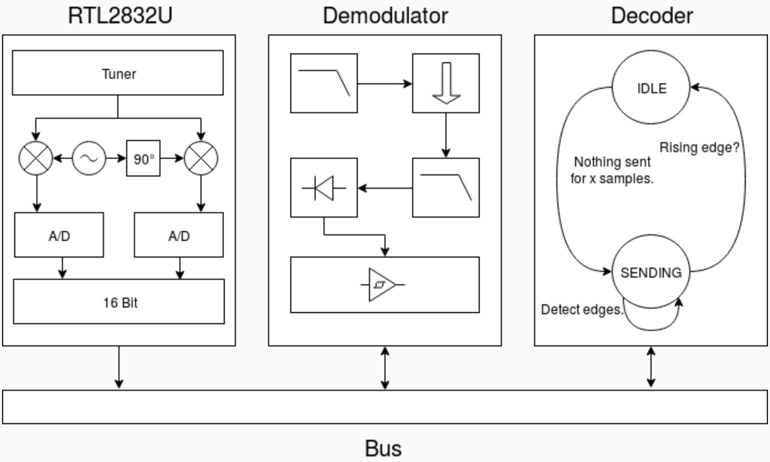

Figure 9: System architecture of the receiver.

State Of The Project (5)

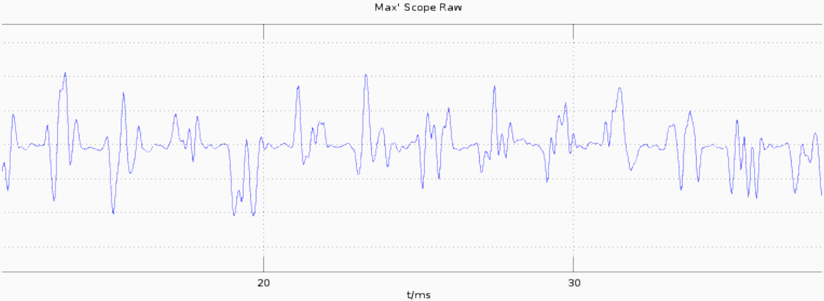

Figure 10: Octave oscilloscope written for debugging purposes.

Evaluation

Conclusion

- Working receiver ✓
- Spectrum anlayzer based on the RTL2832U ✓
- Working backscatter tag ✓
- Lot of help from the communication group ✓

Outlook

- Reliable communication (e.g. hamming code)
- More advanced signal processing (e.g. oversampling)
- Better (selfmade) antenna
- Other receiver hardware?

Contact Information

E: Elmar.Vanrijnswou.9818@student.uu.se

E: Maximilian.Stiefel.8233@student.uu.se

https://github.com/m3x1m0m

Happy Coding :)

References I

B. Kellogg, A. Parks, S. Gollakota, J. R. Smith, and D. Wetherall.
Wi-fi backscatter: Internet connectivity for rf-powered devices.
ACM SIGCOMM Computer Communication Review, 44(4):607–618, 2015.

V. Liu, A. Parks, V. Talla, S. Gollakota, D. Wetherall, and J. R. Smith.
Ambient Backscatter: Wireless Communication out of Thin Air.

In *Proceedings of the ACM SIGCOMM 2013 Conference on SIGCOMM*, SIGCOMM '13, pages 39–50, New York, NY, USA, 2013. ACM.

A. N. Parks, A. Liu, S. Gollakota, and J. R. Smith.
Turbocharging Ambient Backscatter Communication.
In *Proceedings of the 2014 ACM Conference on SIGCOMM*, SIGCOMM '14, pages 619–630, New York, NY, USA, 2014. ACM.

P. Zhang, D. Bharadia, K. Joshi, and S. Katti.
Hitchhike: Practical backscatter using commodity wifi.
In *Proceedings of the 14th ACM Conference on Embedded Network Sensor Systems CD-ROM*, SenSys '16, pages 259–271, New York, NY, USA, 2016. ACM.