Enabling Ambient Backscatter Using a Low-Cost Software Defined Radio

Saving Energy/Low Power Communications

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- Showing that ambient backscatter using TV signals to be feasible in wider parts of the city $\rightarrow$ Significant improvement of the state-of-the-art, which is restricted to a TV towers proximity

Introduction

What is Backscattering? (1)

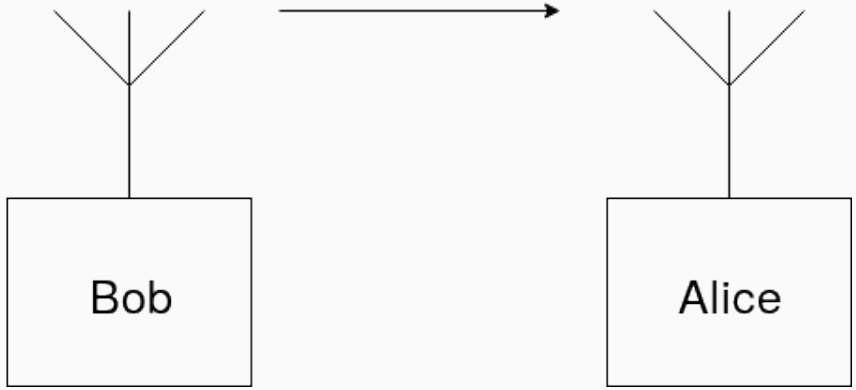

Figure 1: Simplest form of backscattering. Simplex with two subscribers.

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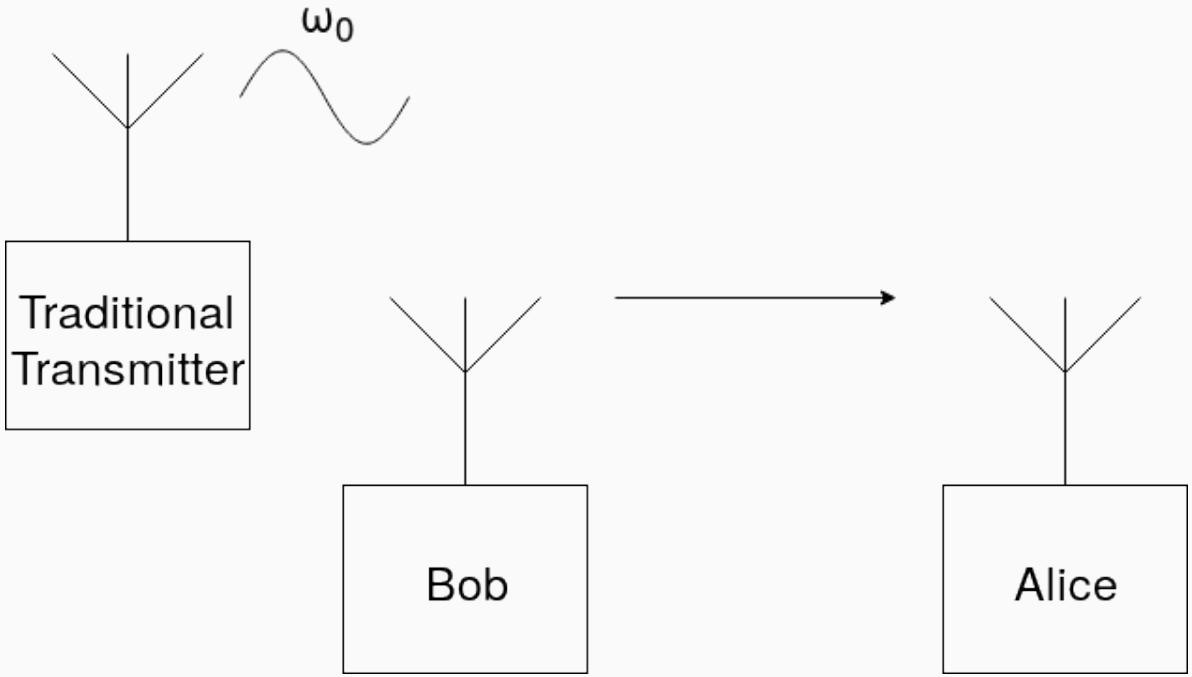

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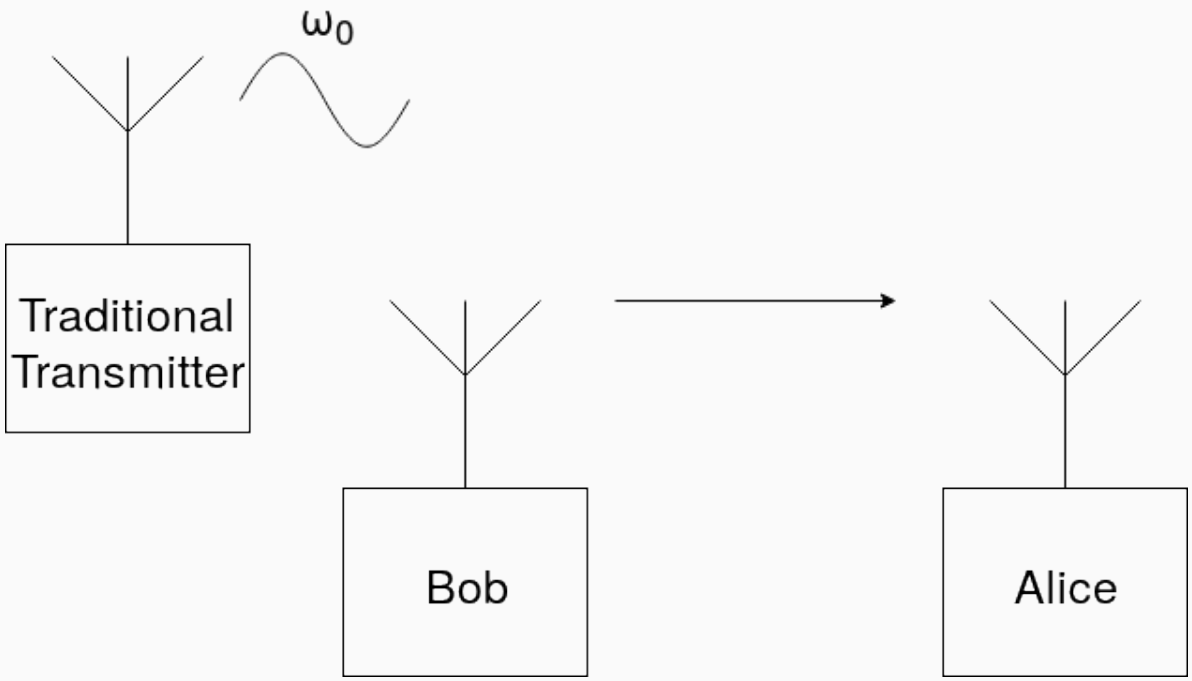

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Backscattering

Communication technique similar to passive RFID, but the transmitter has to maintain its signal.

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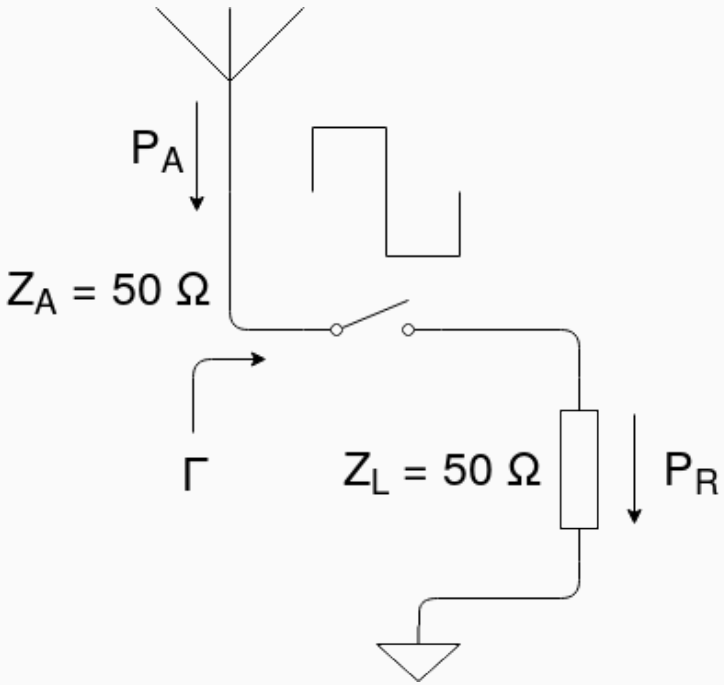

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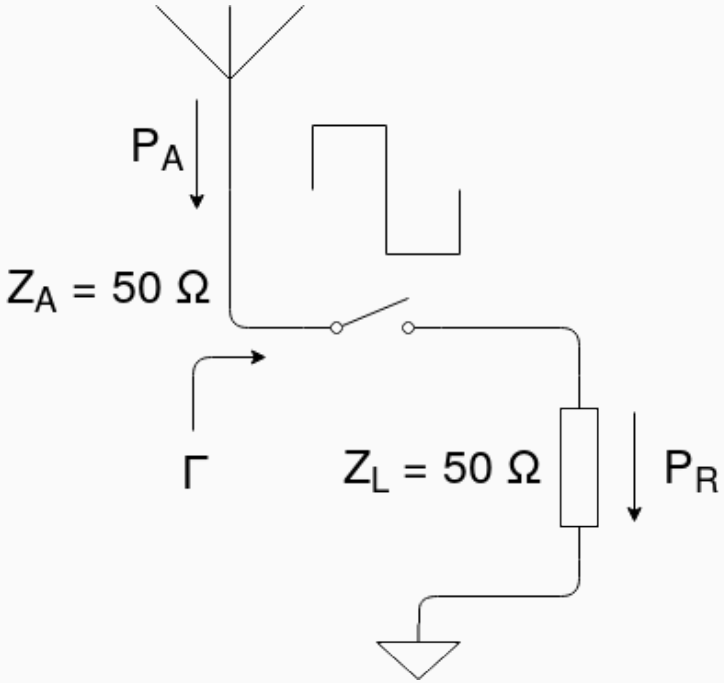

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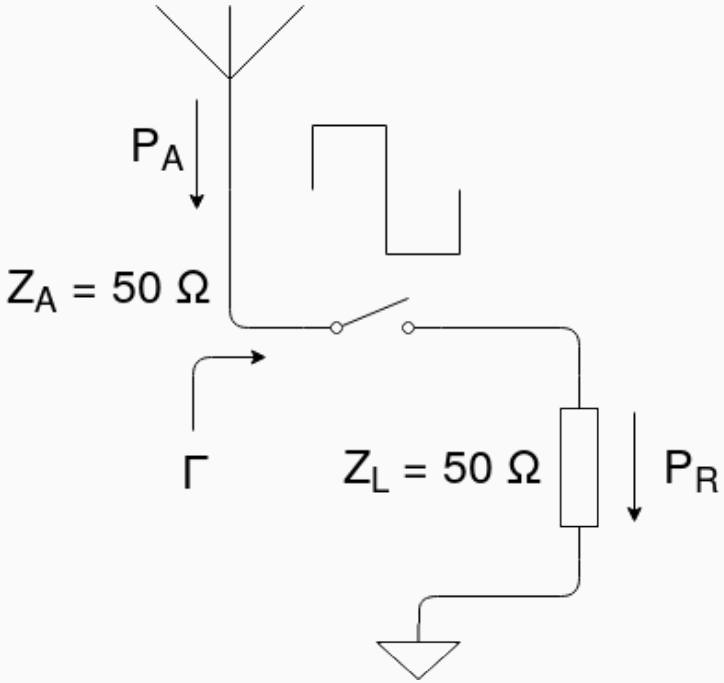

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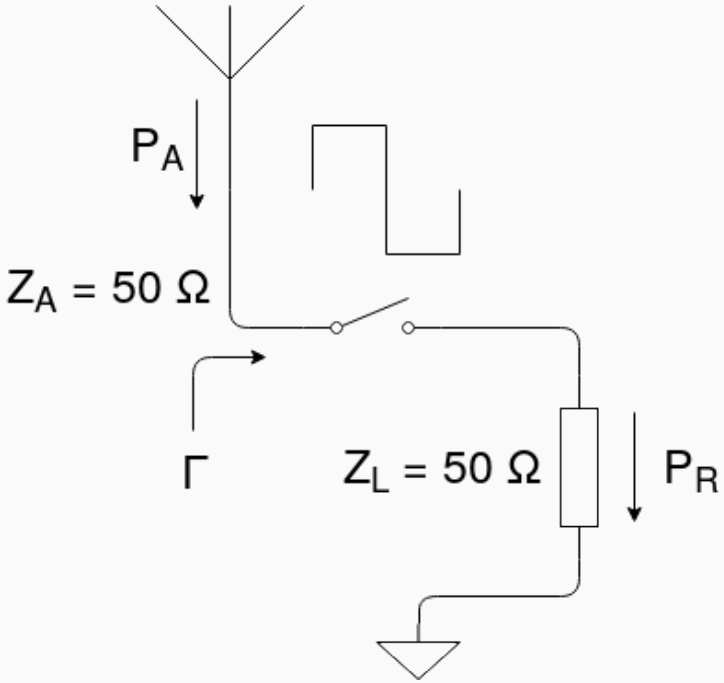

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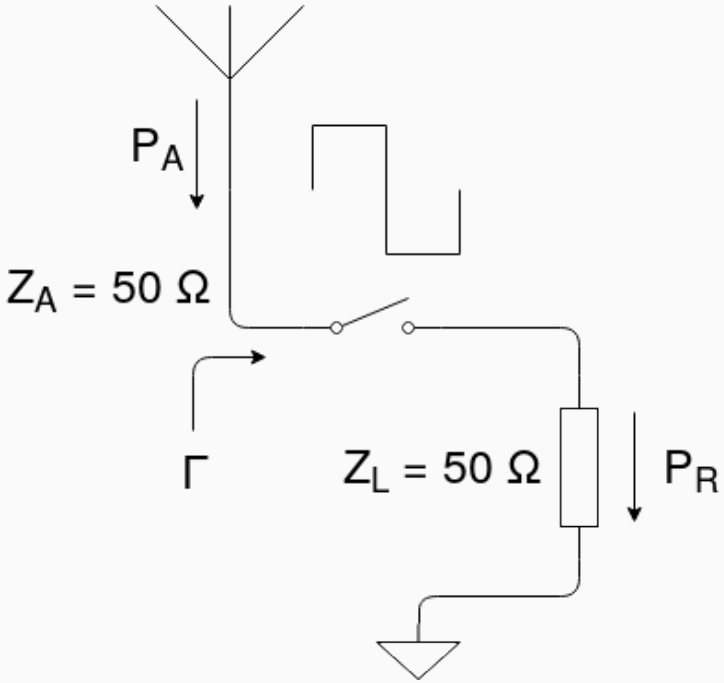

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Total absorption:

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Frequency Shift Keying With Backscatter Tags (1)

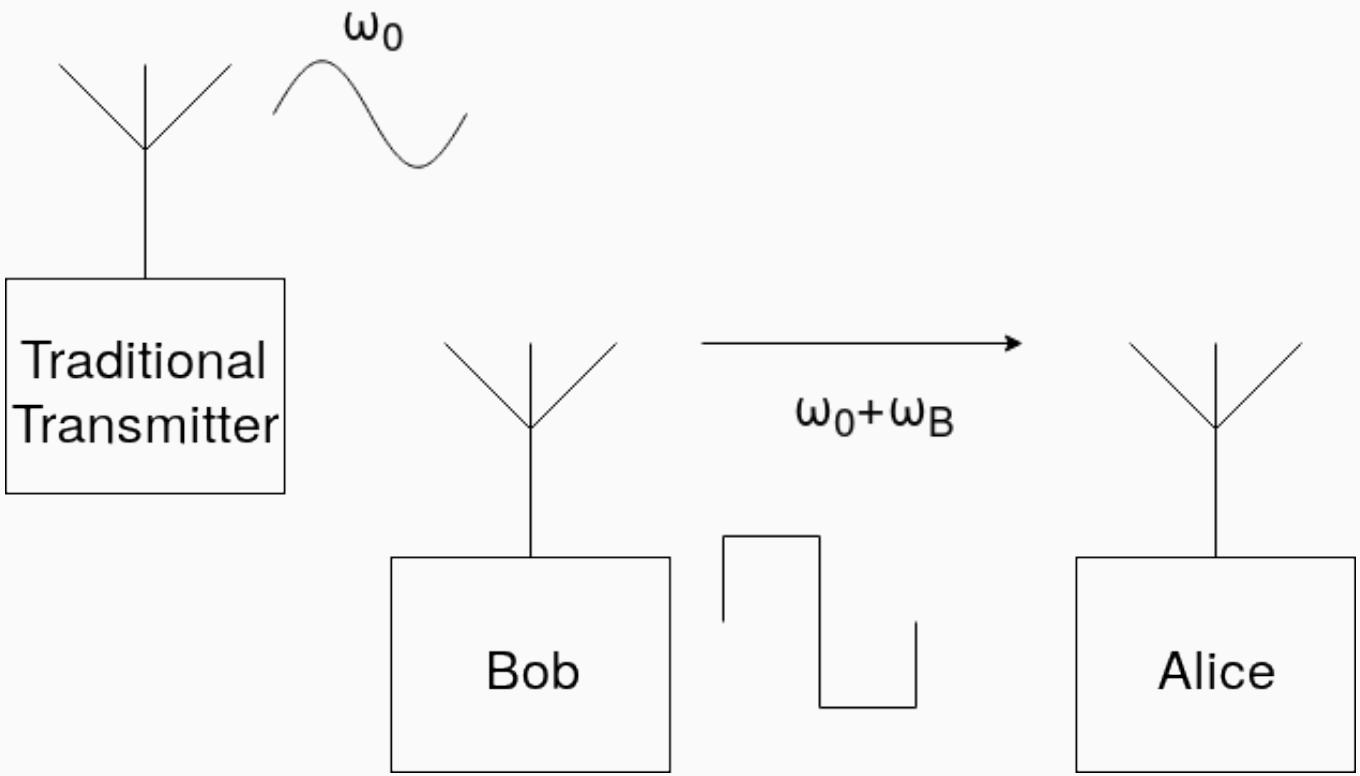

Figure 3: Frequency shift keying modulation techniques are enabled by switching with a higher frequency.

Frequency Shift Keying With Backscatter Tags (2)

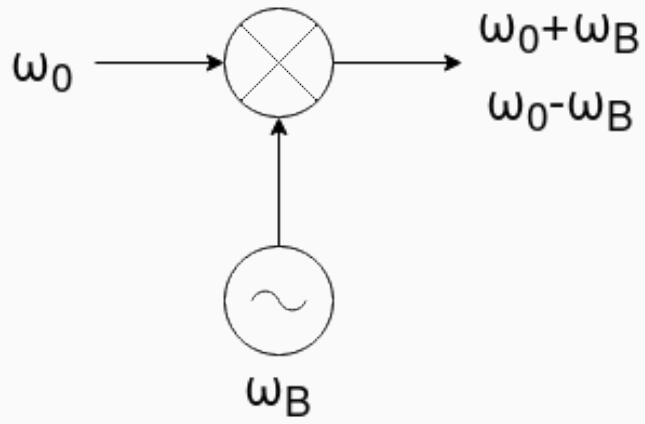

Figure 4: Classical communications engineering element: The mixer.

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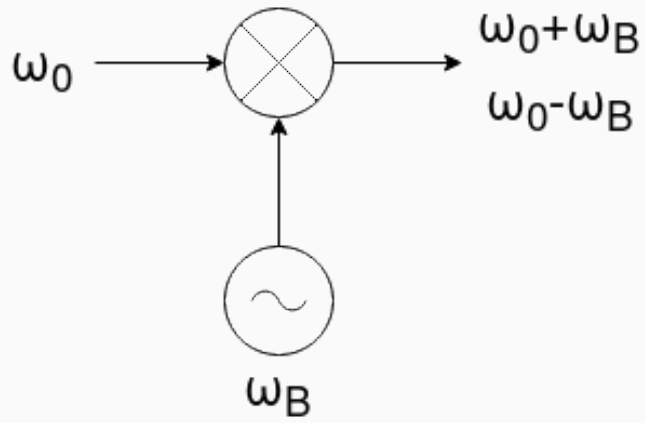

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$$2\sin(\omega_0 t)\sin(\omega_B) = \cos[(\omega_0 + \omega_B)t] - \cos[(\omega_0 - \omega_B)t] \qquad (3)$$

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- Mechanism of choice to network devices operating on harvested energy
- Communication frontends much simpler, smaller and cheaper, in comp. with traditional RF frontends

TV Signal Backscattering Application Example

Figure 5: Houses in Amsterdam. Source: reddit.com

- Houses in the Netherlands are constantly sinking

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- Sensor network with node which are highly-energy constrained

Looking for TV Signals in Uppsala

Spatial Variation of Ambient TV Signals (1)

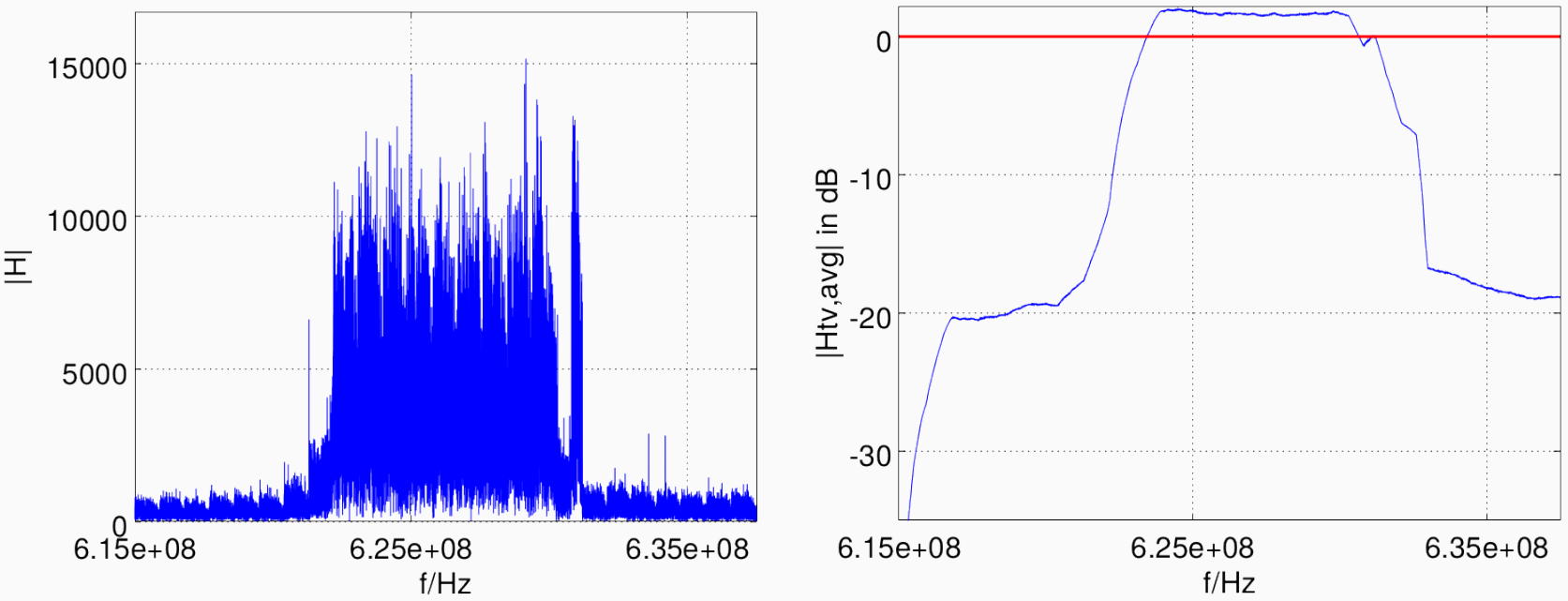
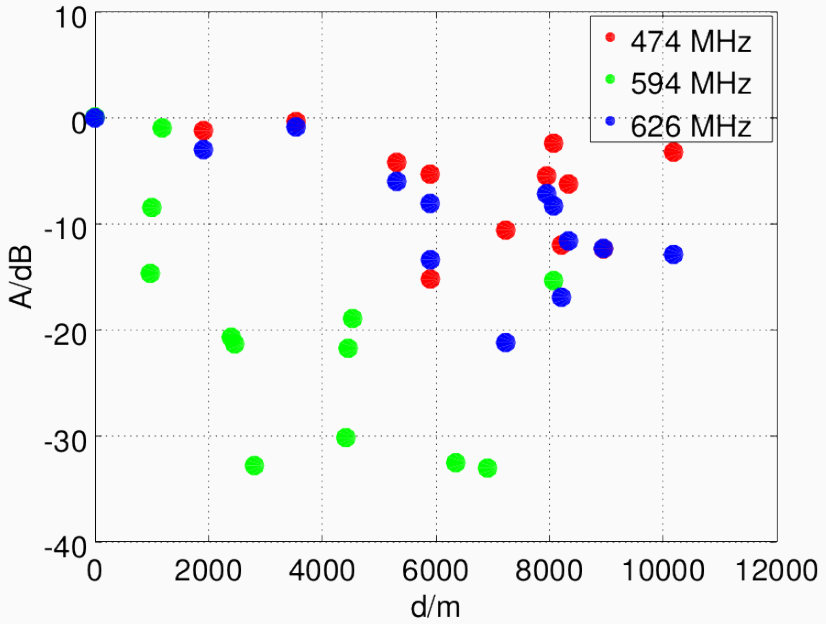


Figure 6: Single measurement at one point in space. Left: Raw spectrum. Right: Spectrum where average power had been determined.

Spatial Variation of Ambient TV Signals (2)



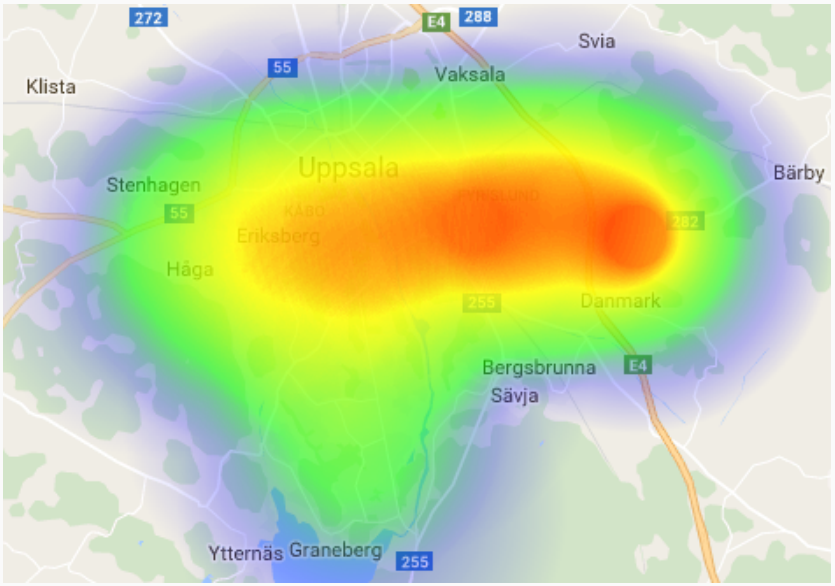


Figure 7: Multiple measuremnets in space. Left: Signal attenuation vs. distance from TV tower. Right: Interpolated heatmap for the 626 MHz.

Backscattering a Local Signal

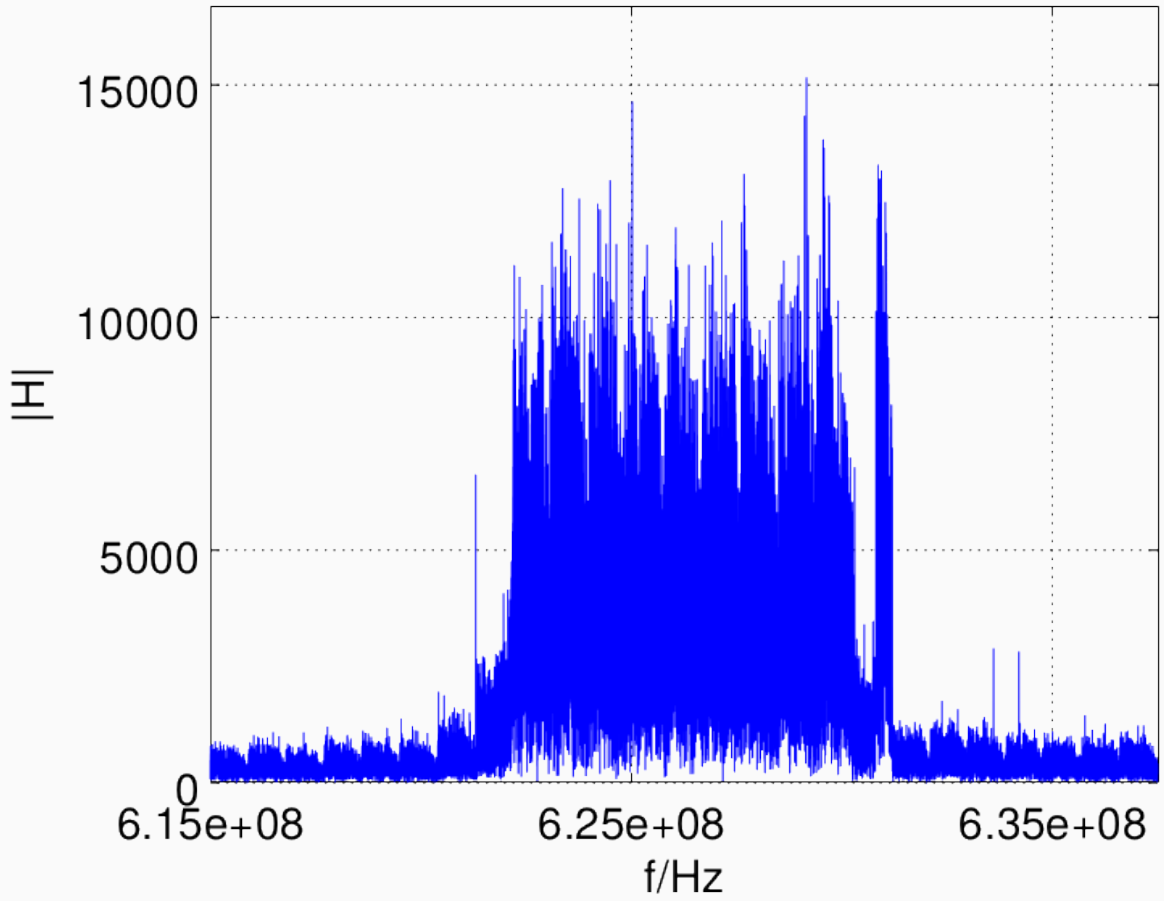


Figure 8: Spectrum of a local TV signal. Center frequency is 626 MHz.

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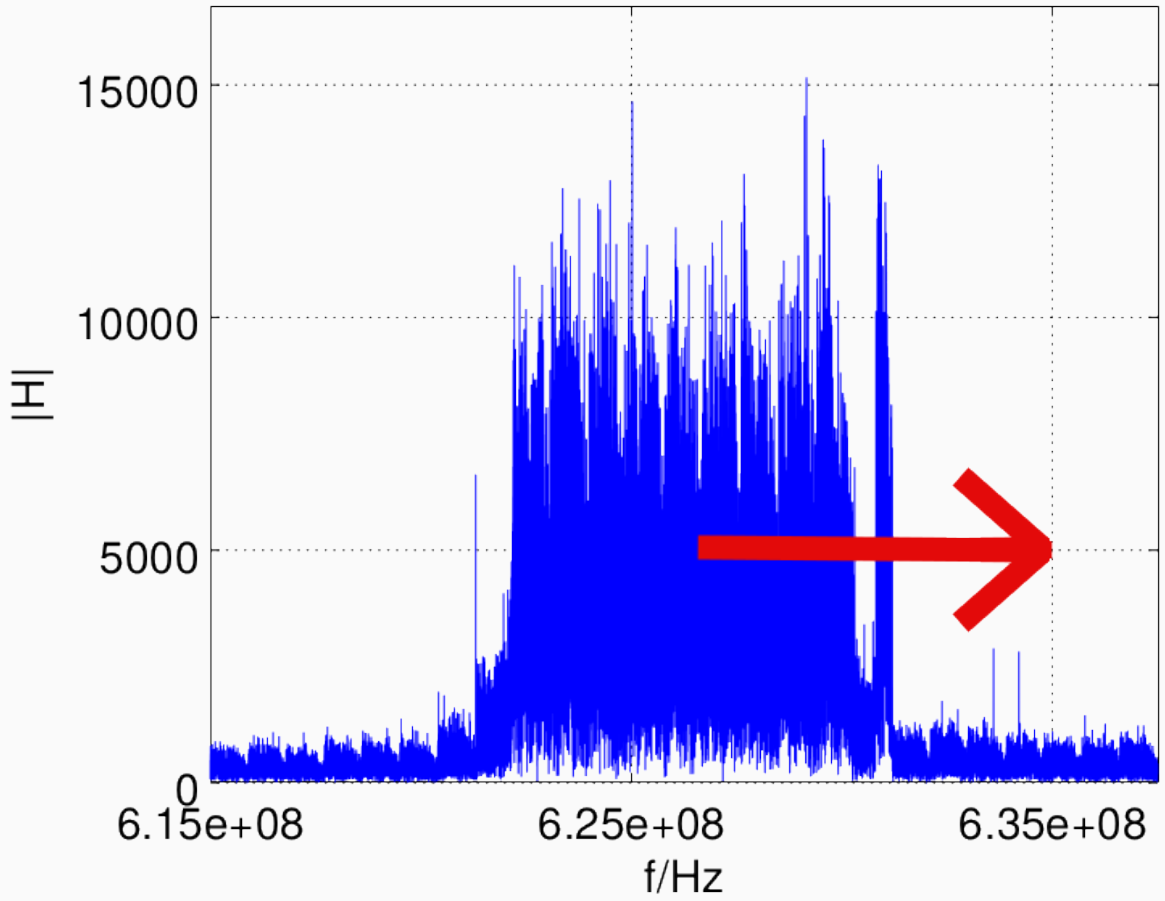

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Communication System Design

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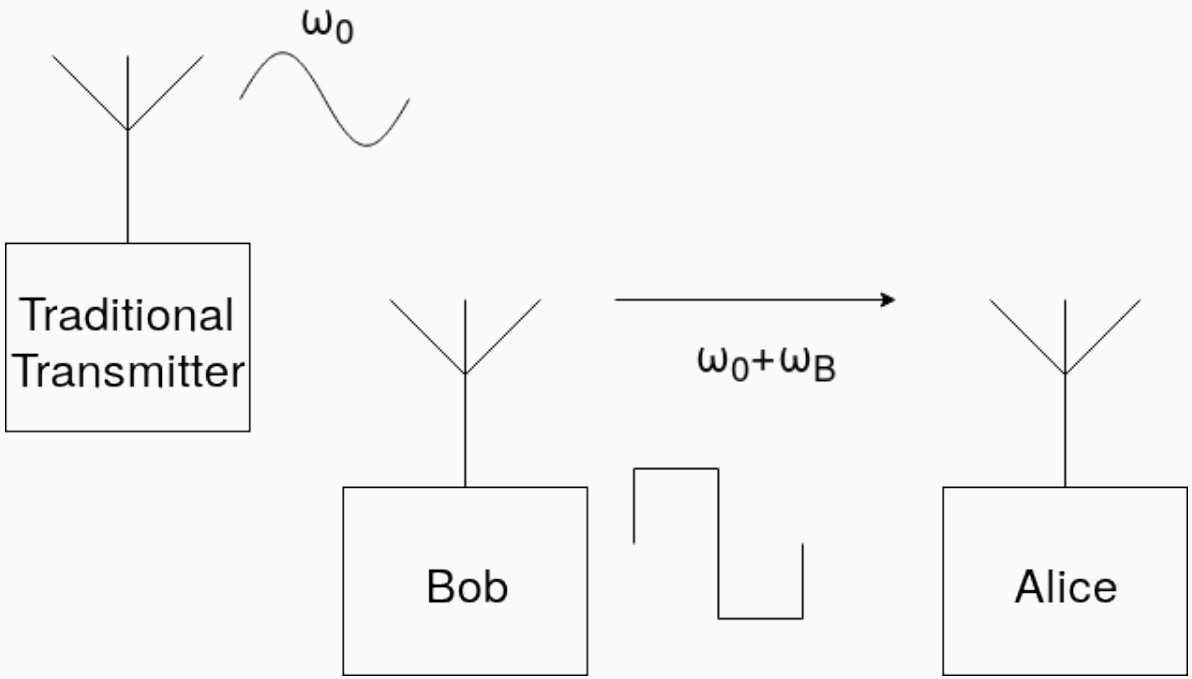

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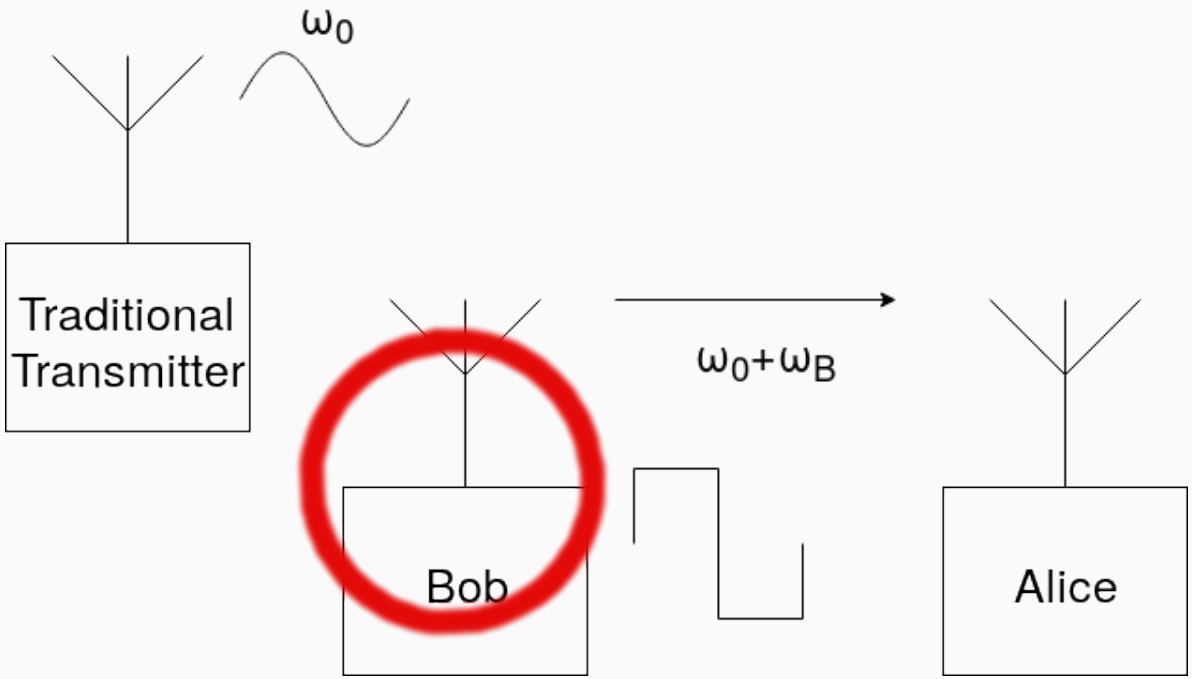


Transmitter (2)

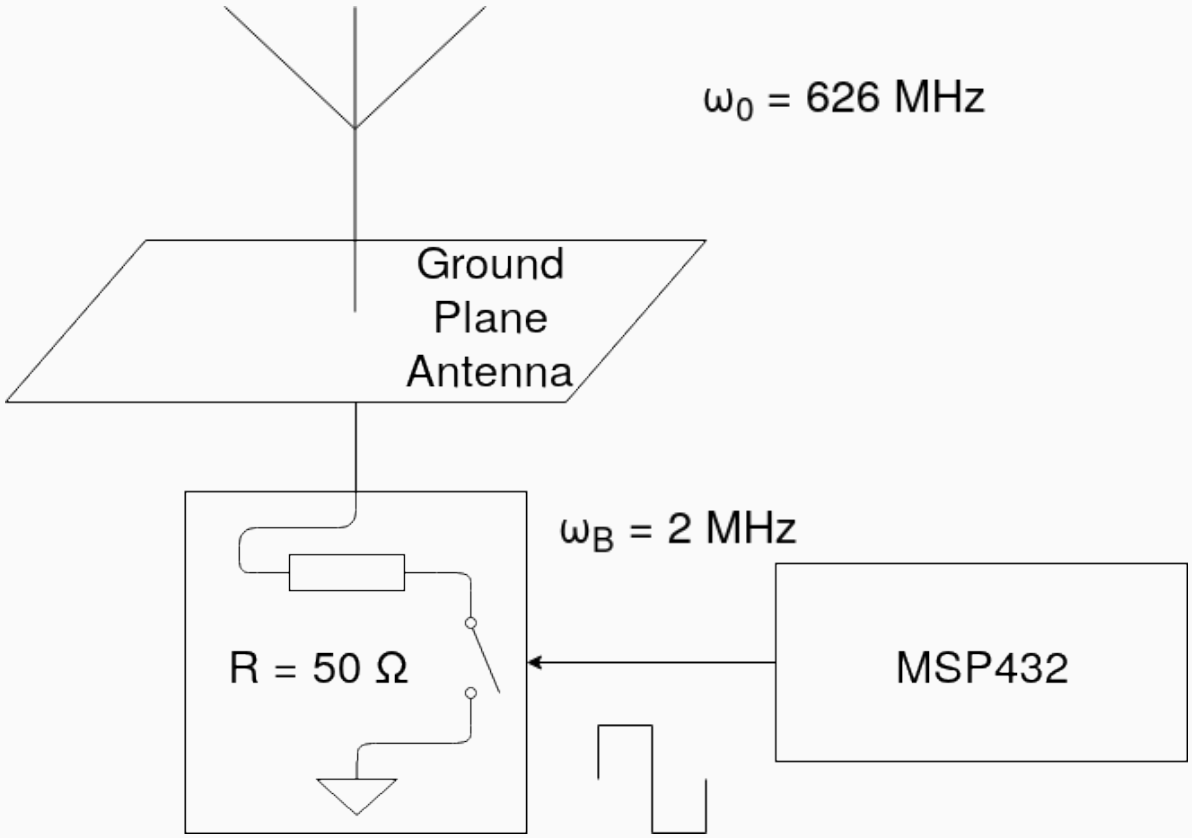
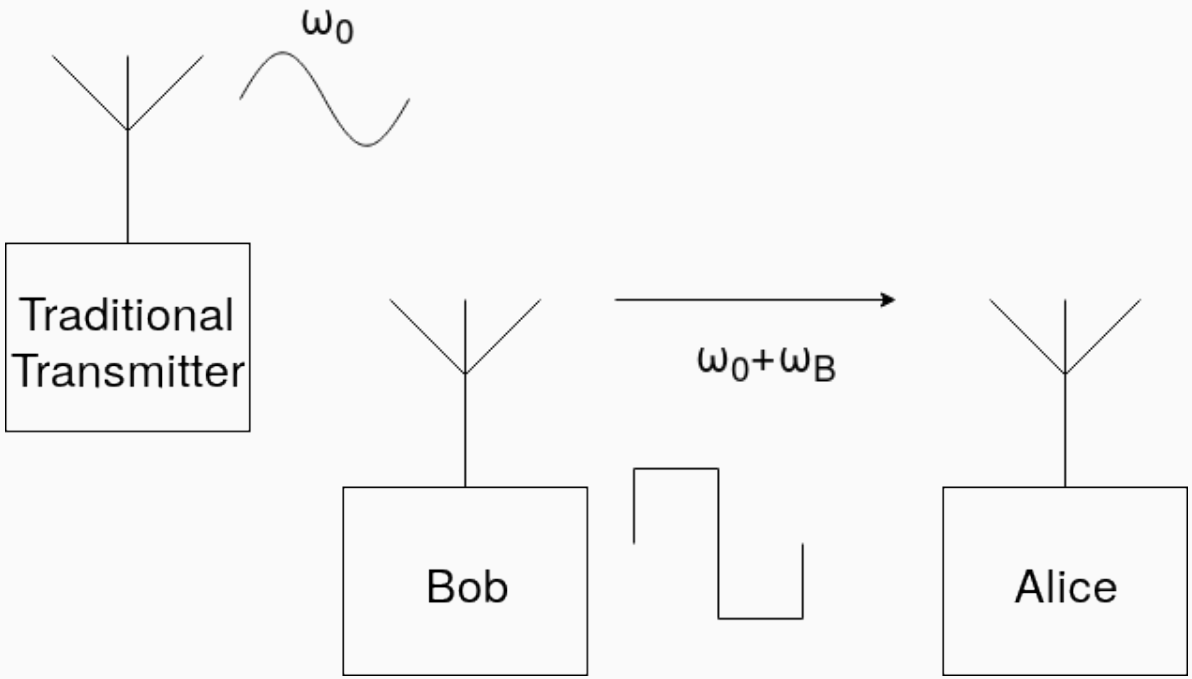


Figure 9: Transmitter architecture. Ground plane antenna roughly tuned to TV signal center freq. (626 MHz). Microcontroller steers a RF switch with a rectangular signal shifting the TV wave in another band.

Receiver (1)



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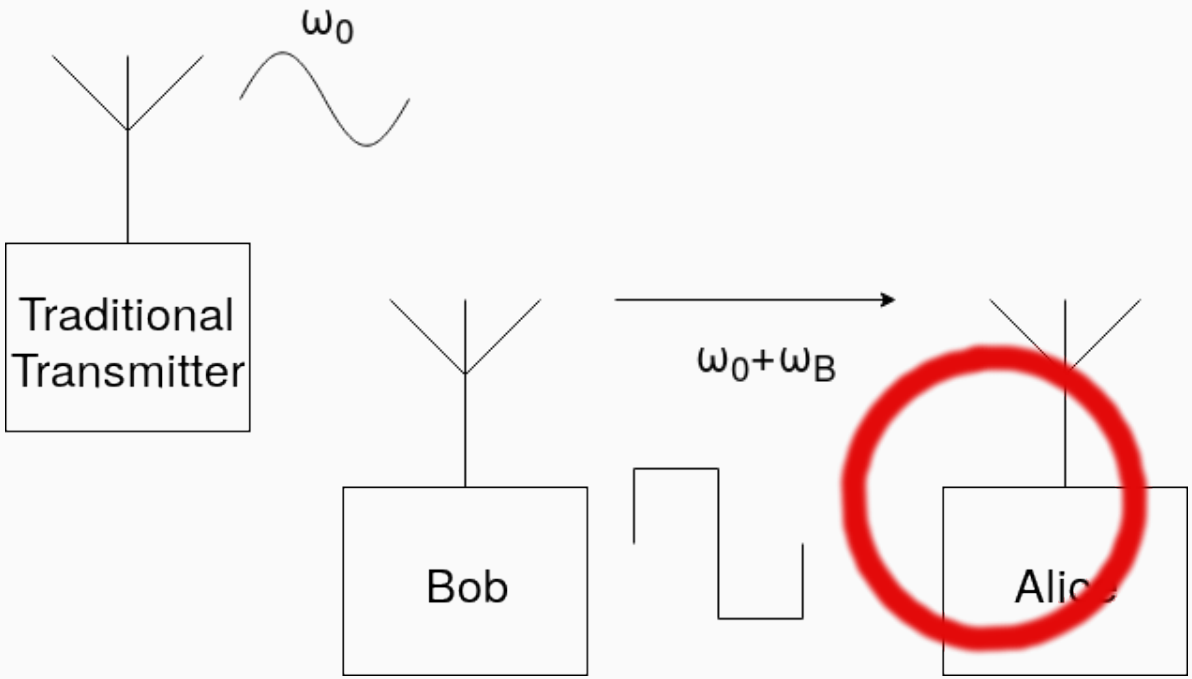

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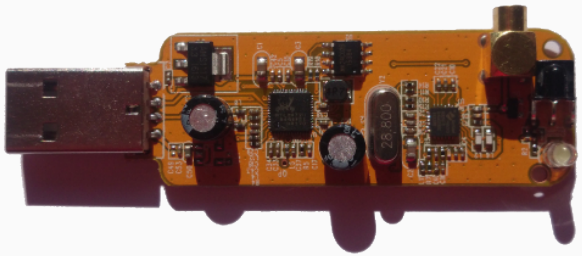

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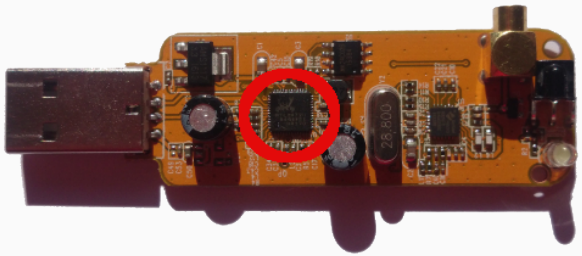

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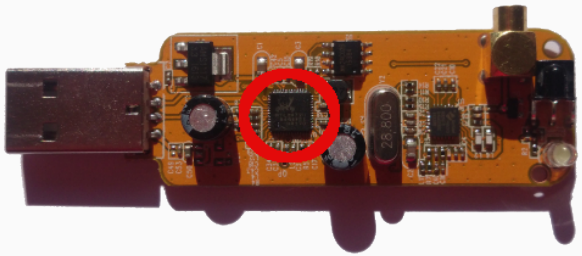

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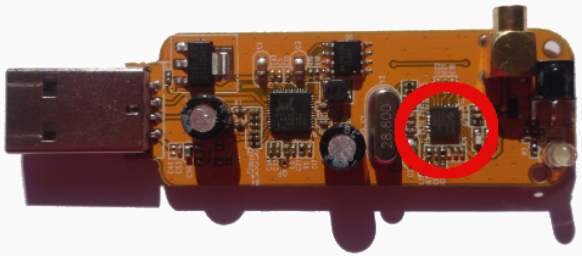

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- Tuner (LNA, filters etc.) included

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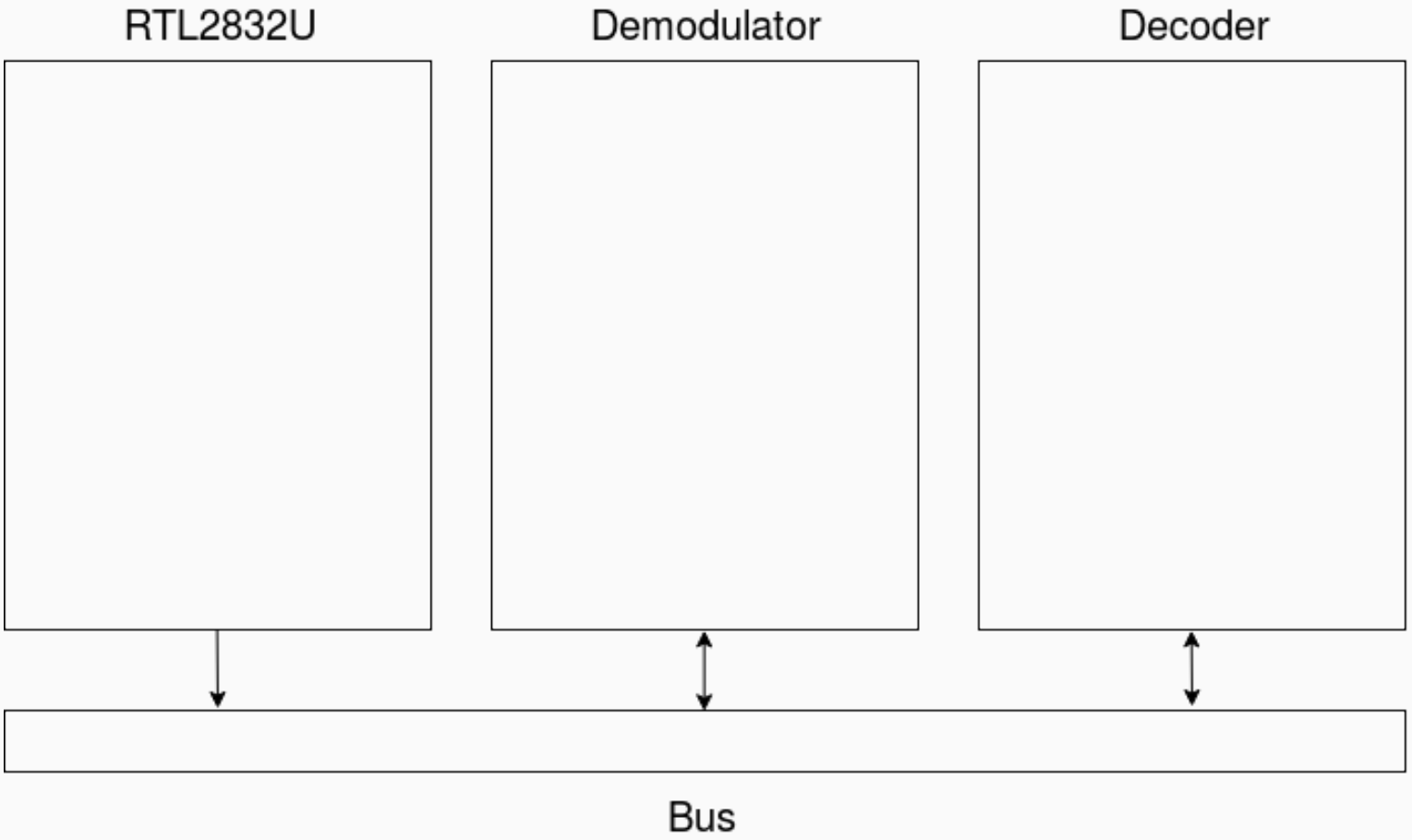

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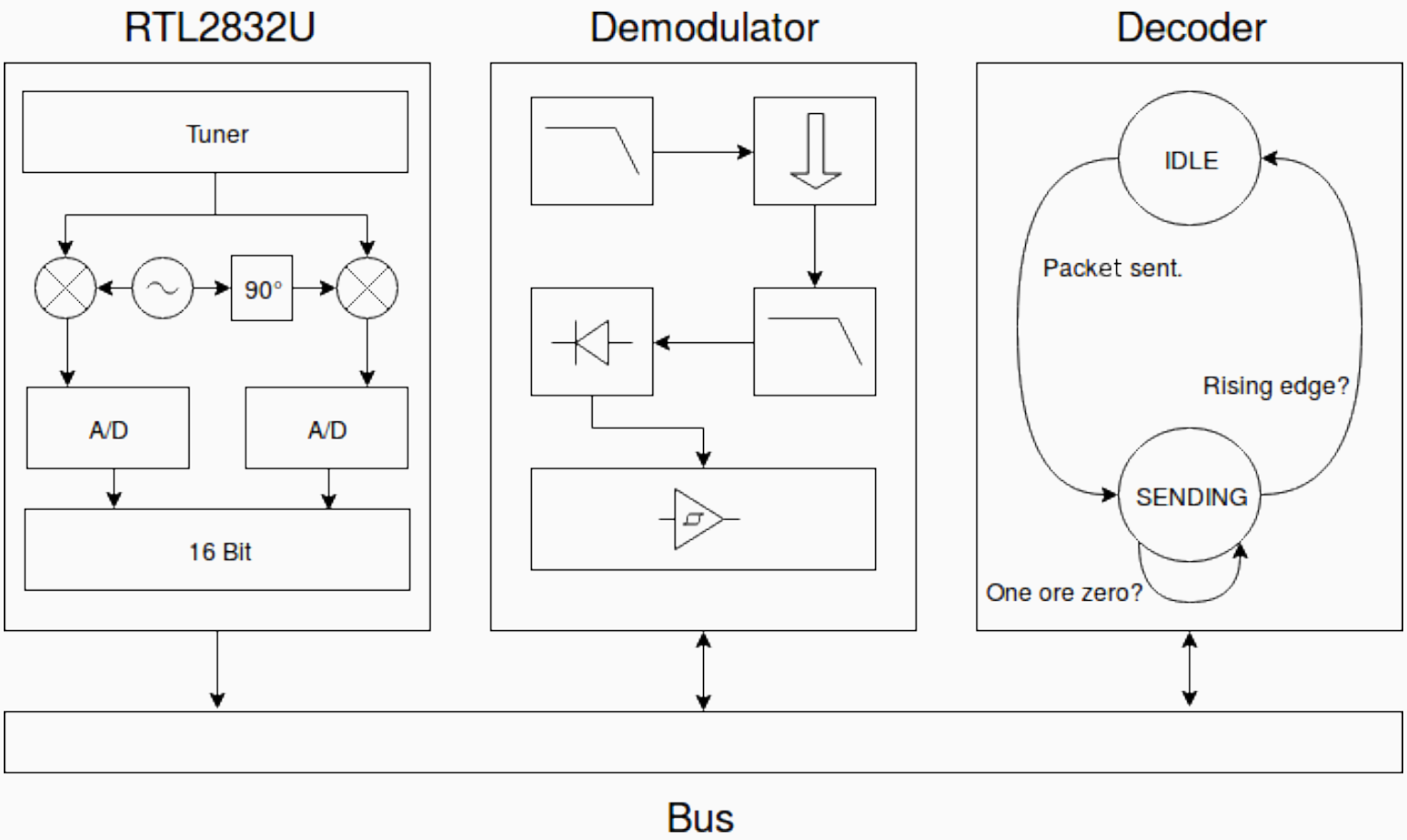

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Results and Outlook

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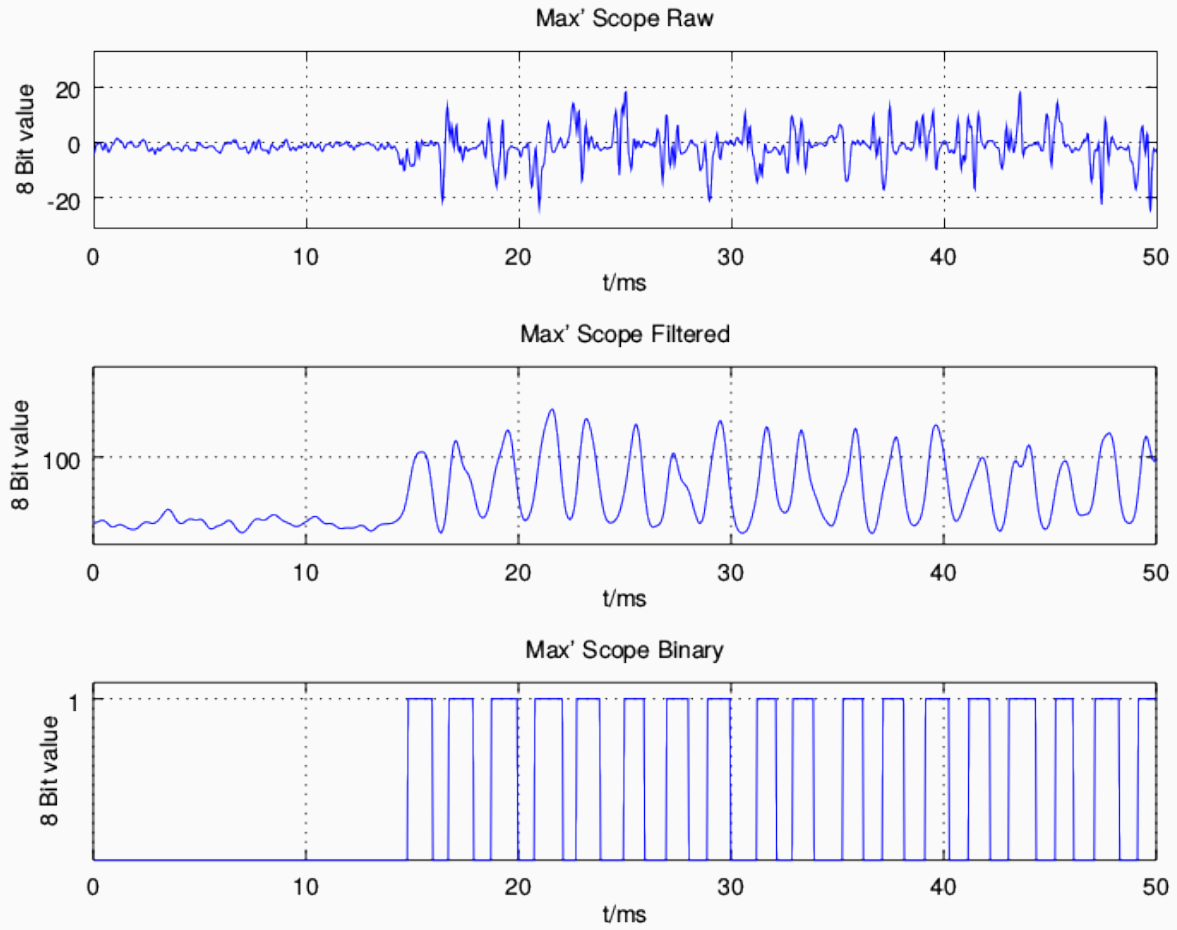

Figure 12: Start of a transmission. Different signal processing steps are visible. First: Raw downsampled signal amplitude. Second: Signal after low-pass filter. Third: Signal after Schmitt trigger.

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- High bit error rate is due to the not yet customized HW

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- Standard cable and antenna of the RTL-SDR (included in the 10 USD budget) are unsuiteable for our application as we realized
- The filters involved are setscrews as well as the coding used by the communication system

Thank you for your attention.

References I

Kellogg, B., Parks, A., Gollakota, S., Smith, J. R., and Wetherall, D. (2015).
Wi-fi backscatter: Internet connectivity for rf-powered devices.
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