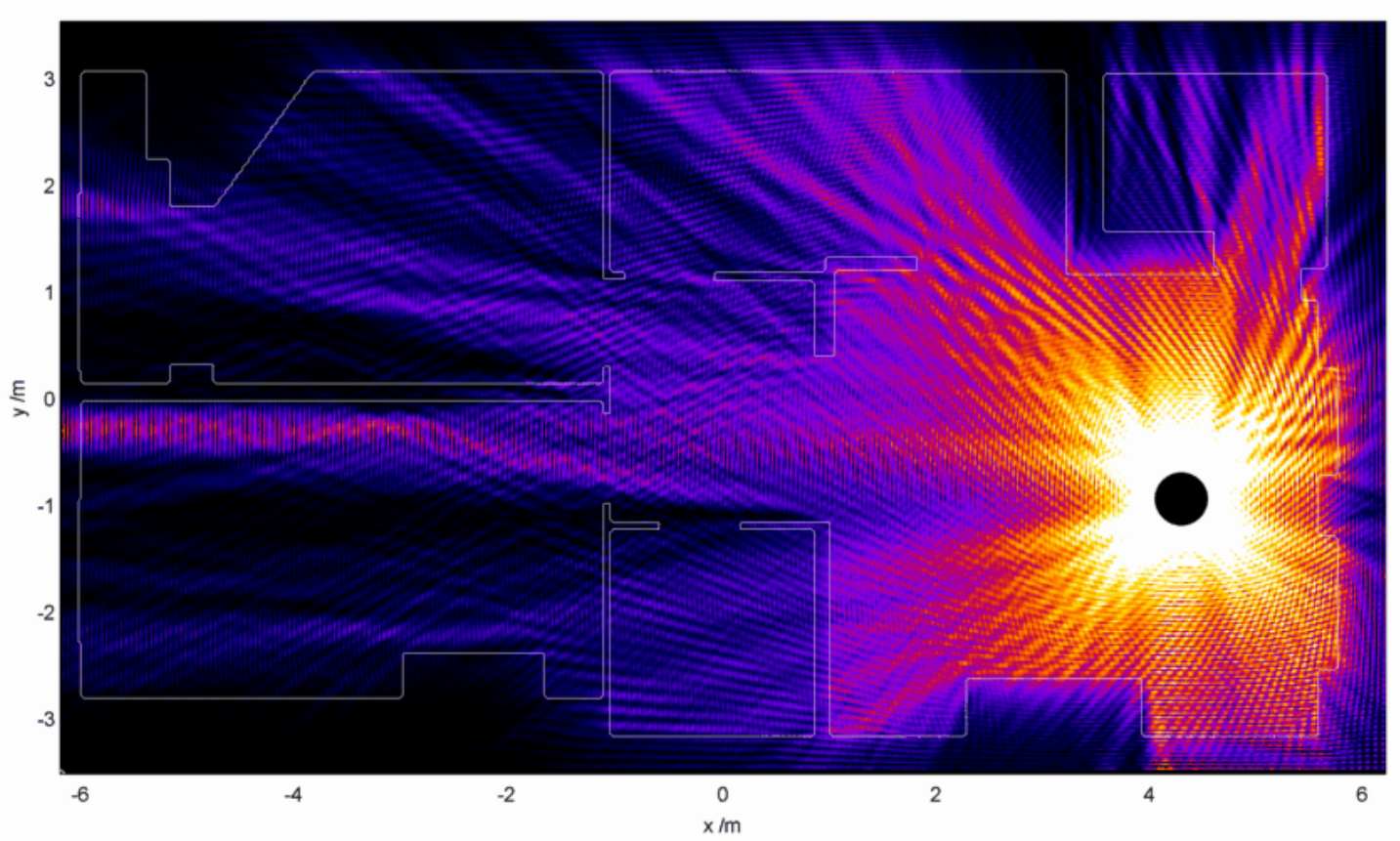
On the Scalability of Constructive Interference in Low-Power Wireless Networks

Claro Noda, Carlos Pérez-Penichet, Balint Seeber,
Marco Zennaro, Mário Alves, Adriano Moreira

EWSN 2015

Radio Signal Propagation

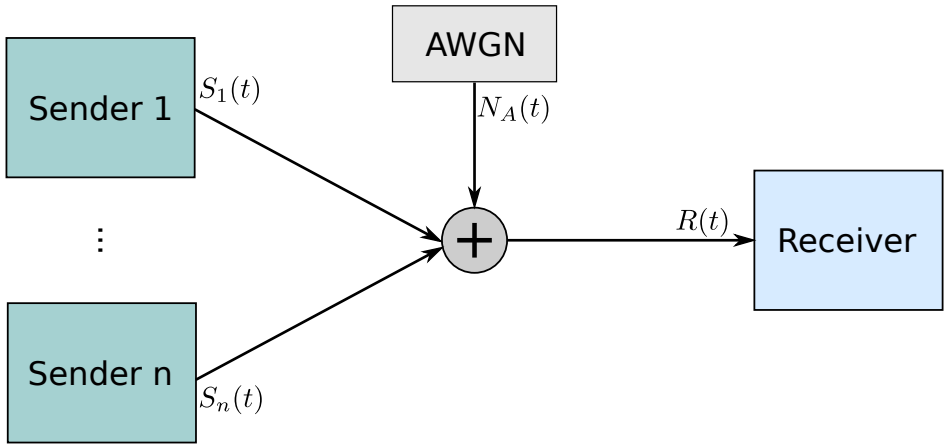


Helmhurts by Jason Cole (ICL)

CBI Scalability

- CBI is an effective technique used in wireless networks
- As the number of concurrent repeaters increases, the **composite signal** becomes **vulnerable to noise**
- Link quality is compromised, **unless** there is enough **power imbalance**

CBI Explained



$$R(t) = S_1(t) + S_2(t) + ... + S_n(t) + N_A(t)$$

$$R(t) = R_I(t) + R_Q(t) + N_A(t)$$

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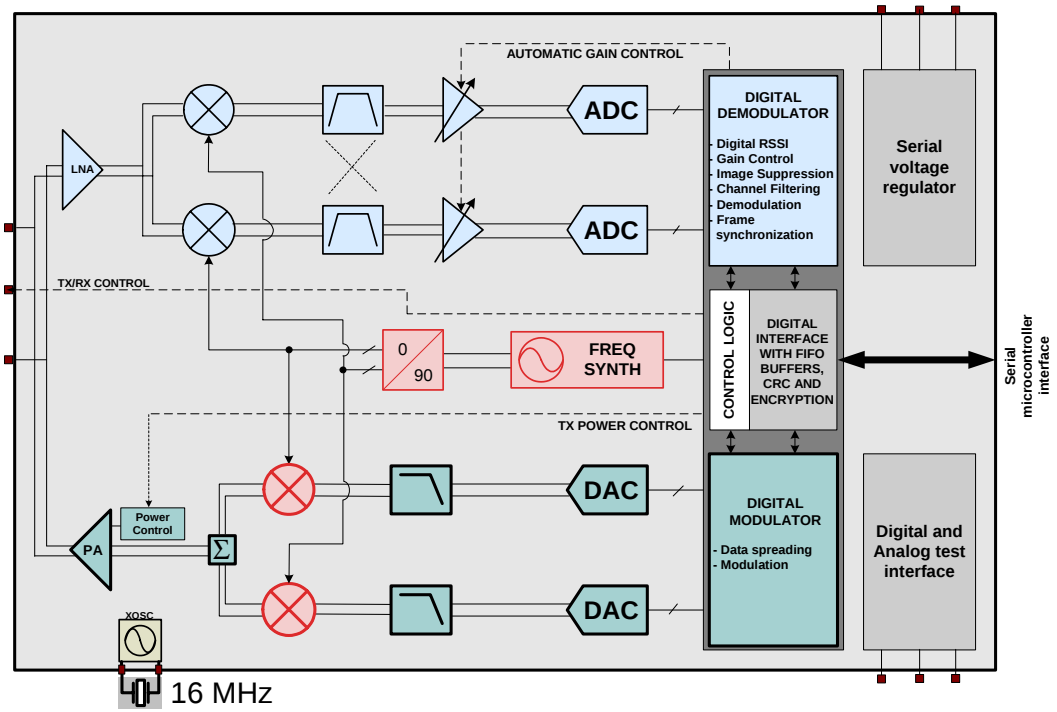

$$S(t) = a_I(t)\cos\left(\frac{\pi t}{2T}\right)\cdot A\cos(\omega_c t) + a_Q(t)\sin\left(\frac{\pi t}{2T}\right)\cdot A\sin(\omega_c t)$$

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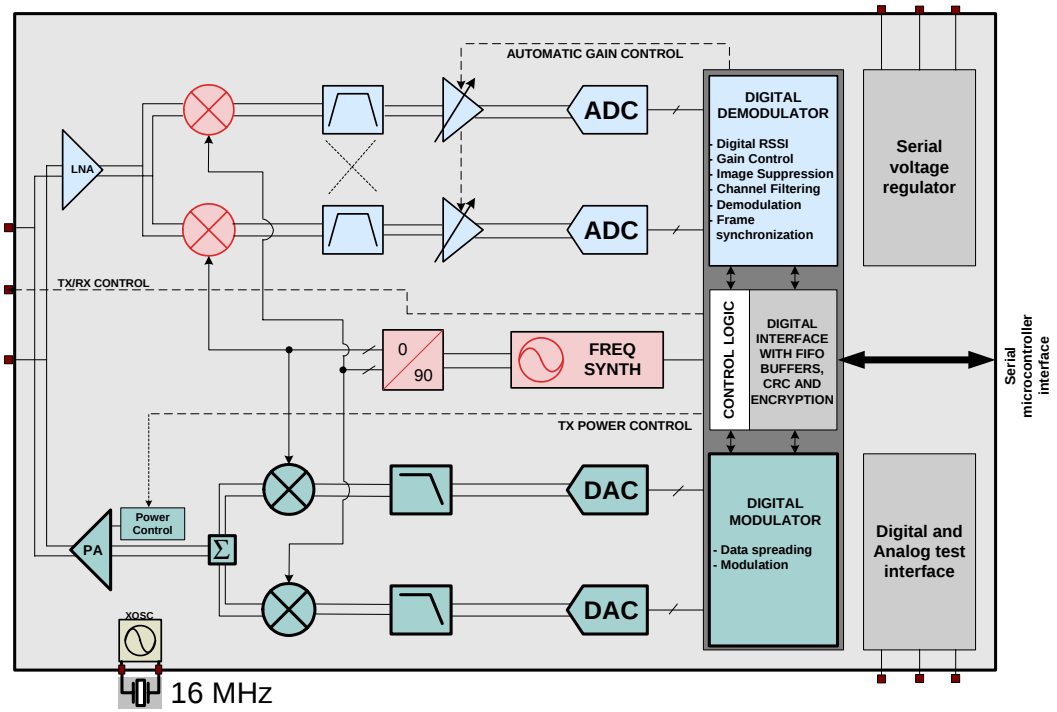

$$R_I(t) = a_I(t)\cos\left(\frac{\pi t}{2T}\right)\sum_{i=1}^{n} A_i\cos\left(\omega_{c_i}t + \theta_{c_i}\right) + N_A(t)$$

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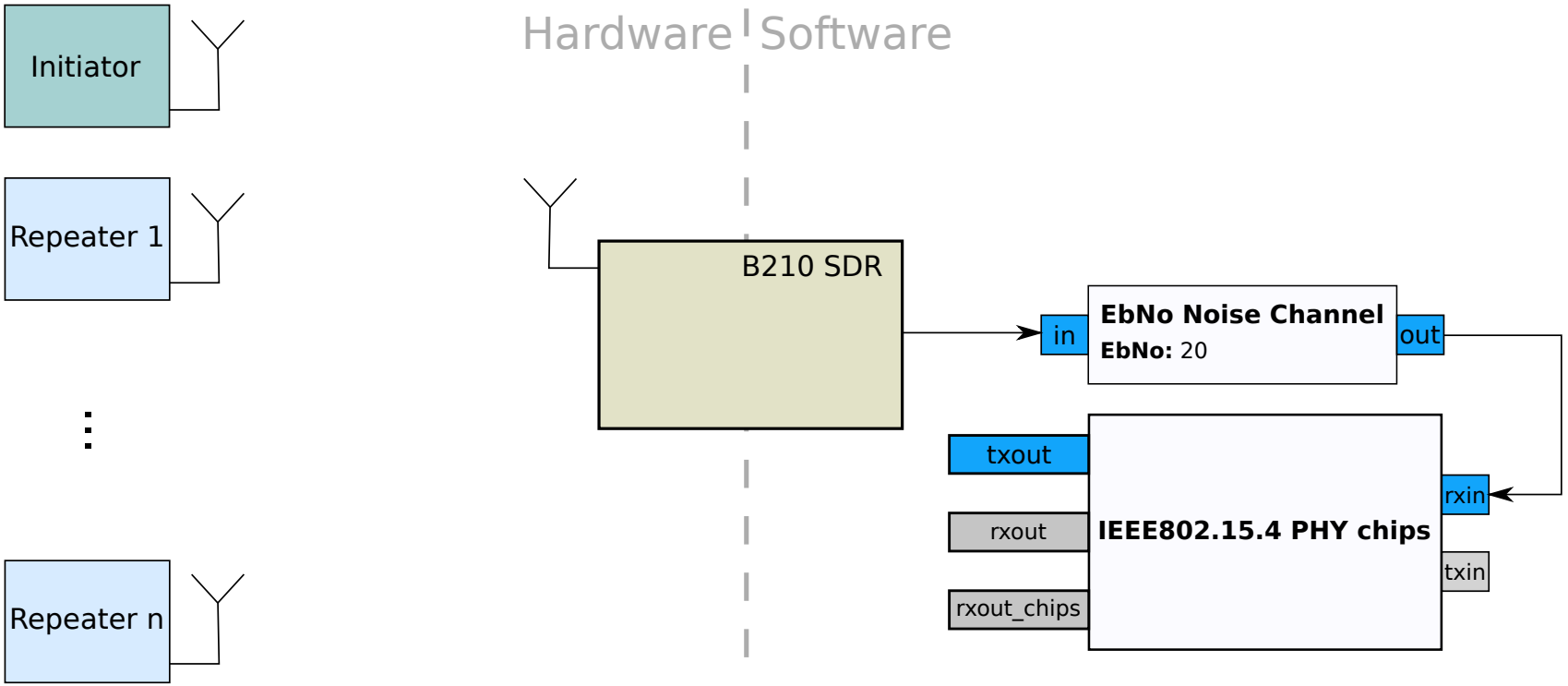
Wireless Configuration



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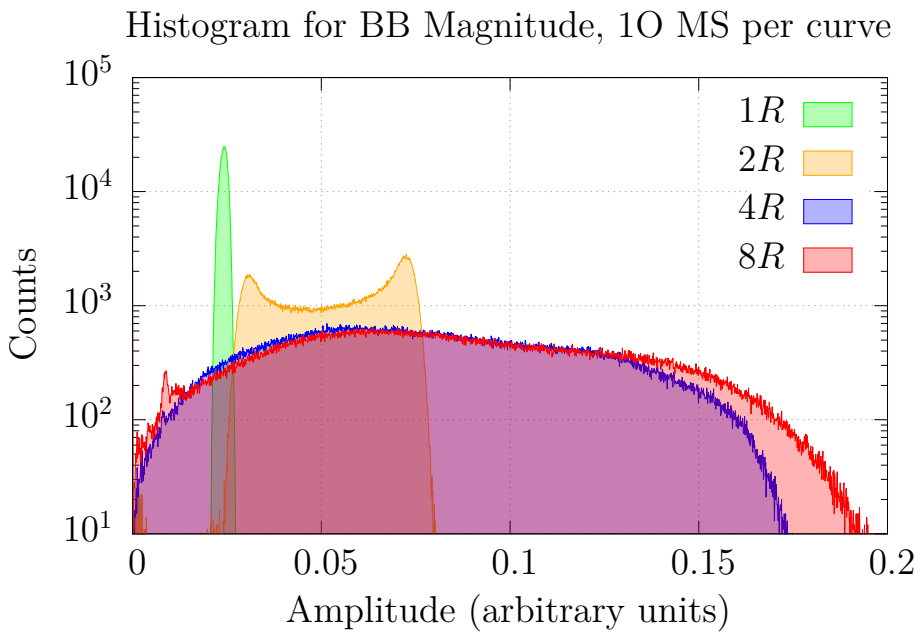

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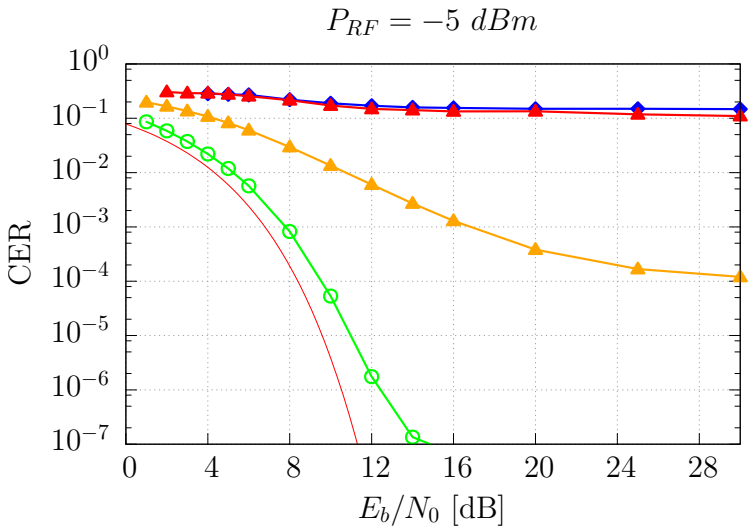

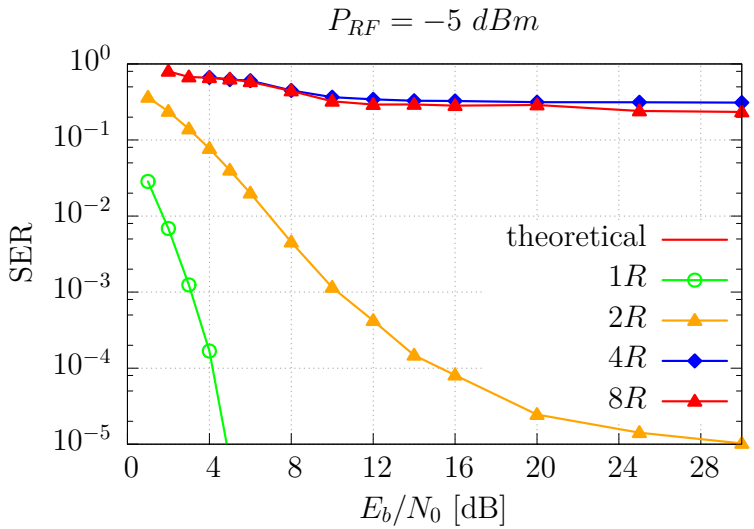

Conclusions

1. **Link quality** under CBI is **compromised** due to **multisource** carriers, **unless** there is enough **power imbalance**
2. **Low-noise** environments, **receiver's AGC** and **capture effect** disguise potential vulnerability
   - Glossy reports reliability $> 98\%$ up to 10 repeaters

Outlook

1. **Power allocation** optimization: **enhance reliability** and **add security**?
2. **Space-time** codes: introduce **diversity gain**

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References

- Hariharan Rahul, Haitham Hassanieh, and Dina Katabi. SourceSync: A Distributed Wireless Architecture for Exploiting Sender Diversity.
  In *ACM SIGCOMM 2010*, New Delhi, India, August 2010
- Federico Ferrari, Marco Zimmerling, Lothar Thiele, and Olga Saukh. Efficient Network Flooding and Time Synchronization with Glossy.
  In *ACM/IEEE IPSN*, Chicago, IL, USA, April 2011
- Federico Ferrari, Marco Zimmerling, Luca Mottola, and Lothar Thiele. Low-power wireless bus.
  SenSys, New York, NY, USA, 2012. ACM

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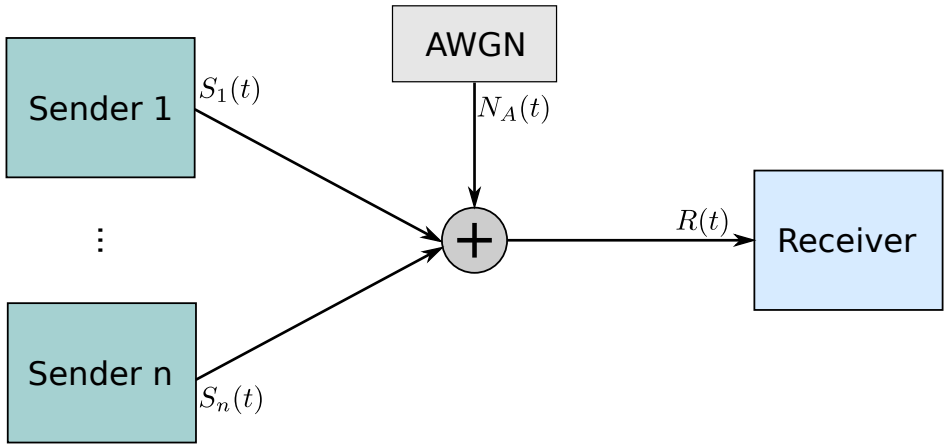

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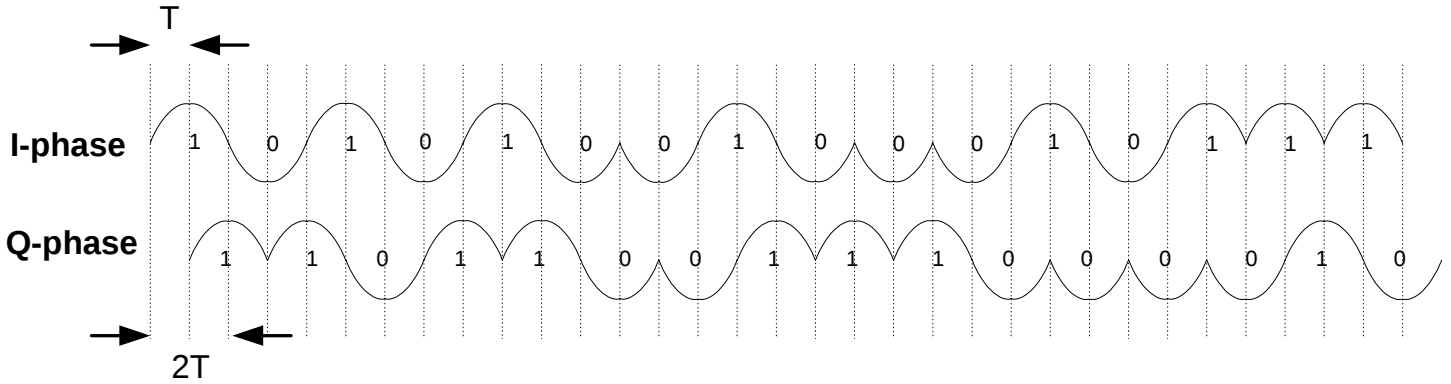
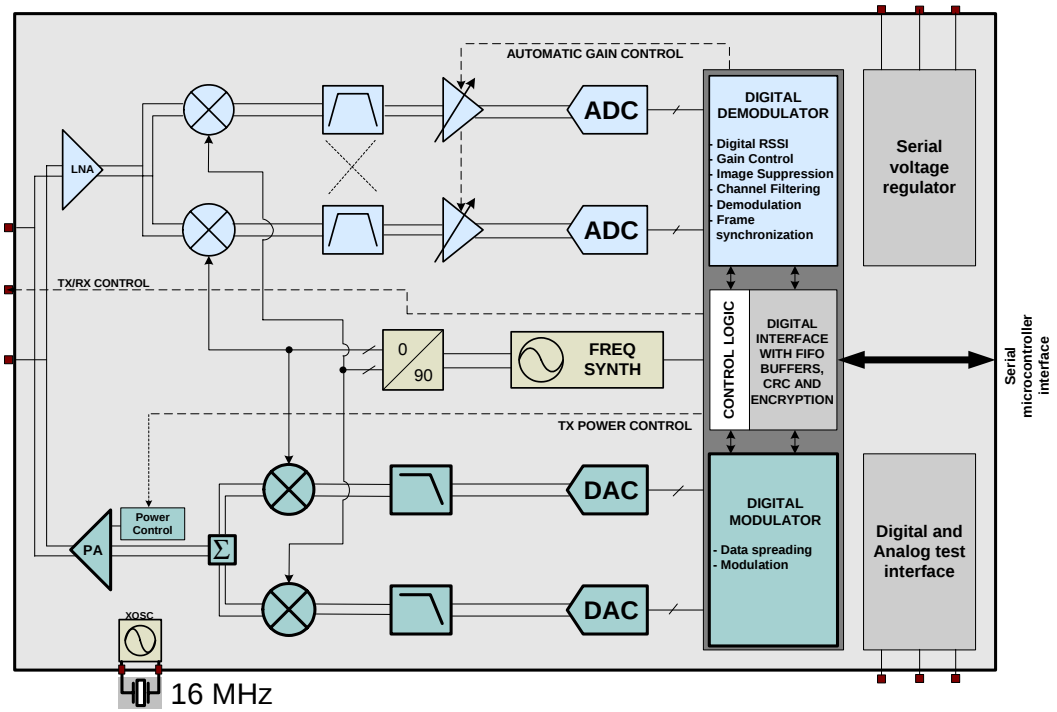


$$a_I(t) = \sum_{k=-\infty}^{\infty} \alpha_k^I \Pi\left(\frac{t-2kT}{2T}\right)$$

$$a_Q(t) = \sum_{k=-\infty}^{\infty} \alpha_k^Q \Pi\left(\frac{t-(2k+1)T}{2T}\right)$$

$$\text{I-phase}(t) = a_I(t)\cos\left(\frac{\pi t}{2T}\right) \qquad \text{Q-phase}(t) = a_Q(t)\sin\left(\frac{\pi t}{2T}\right)$$

CBI Explained



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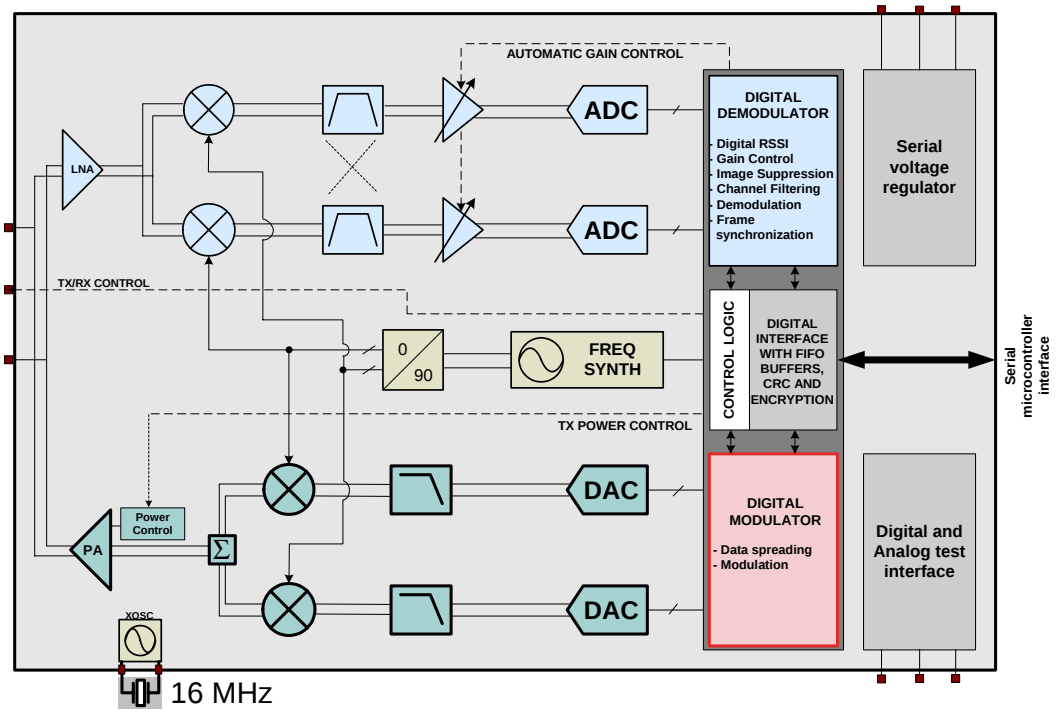

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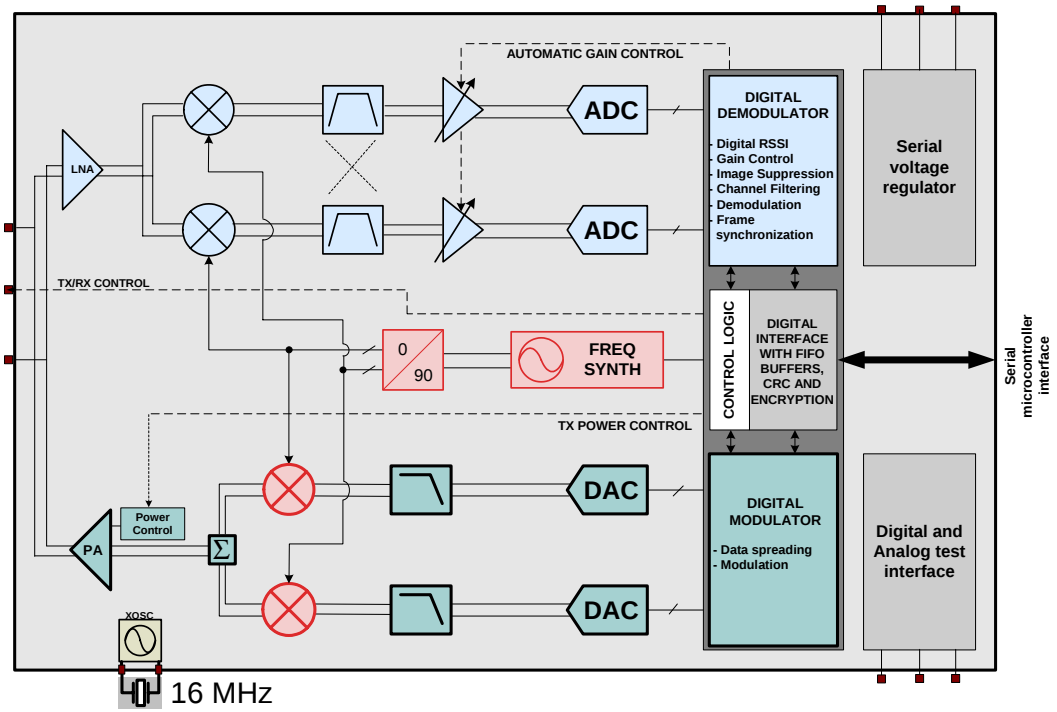

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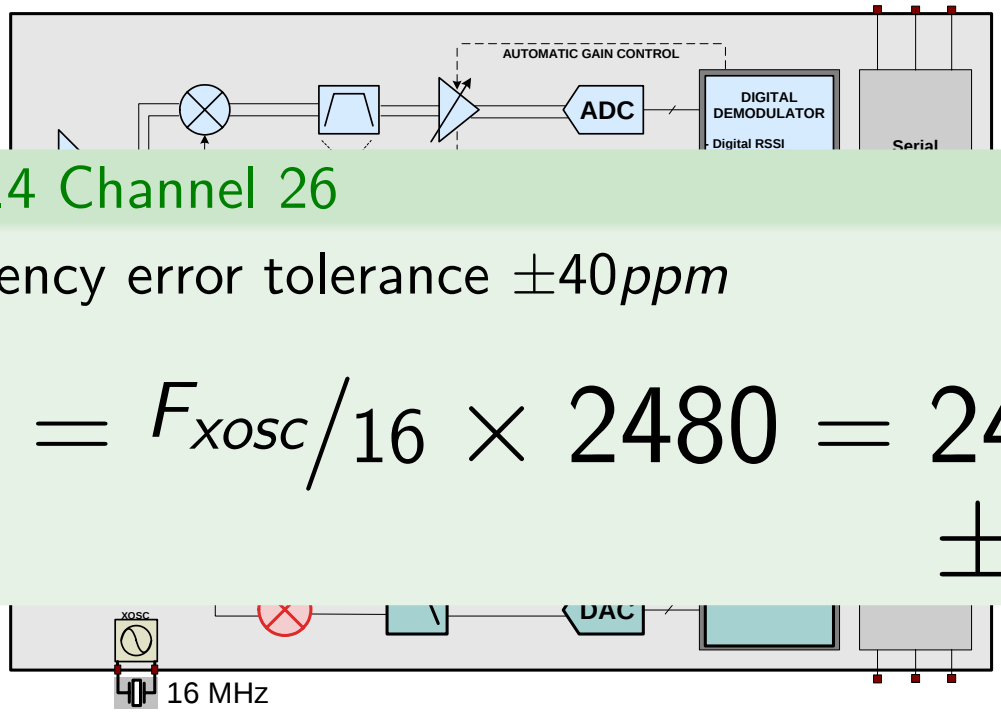

IEEE 802.15.4 Channel 26

Carrier frequency error tolerance $\pm 40 ppm$

$$\omega_c/2\pi = F_{xosc}/16 \times 2480 = 2480 MHz \pm 100 kHz$$

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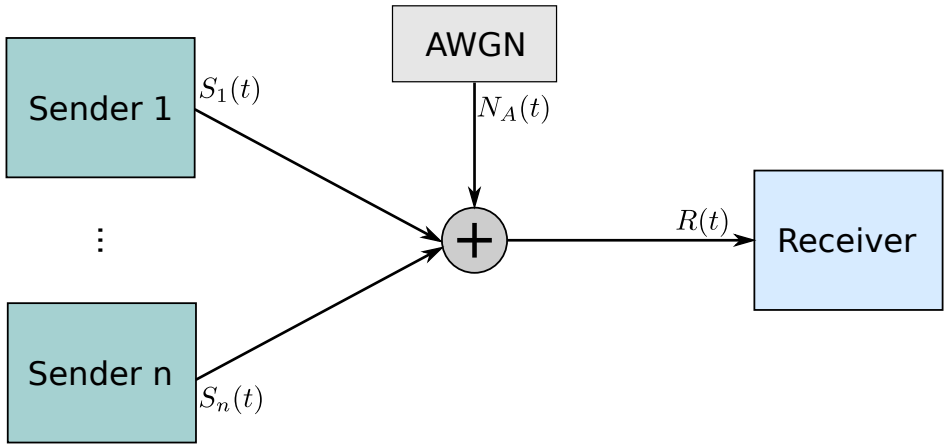

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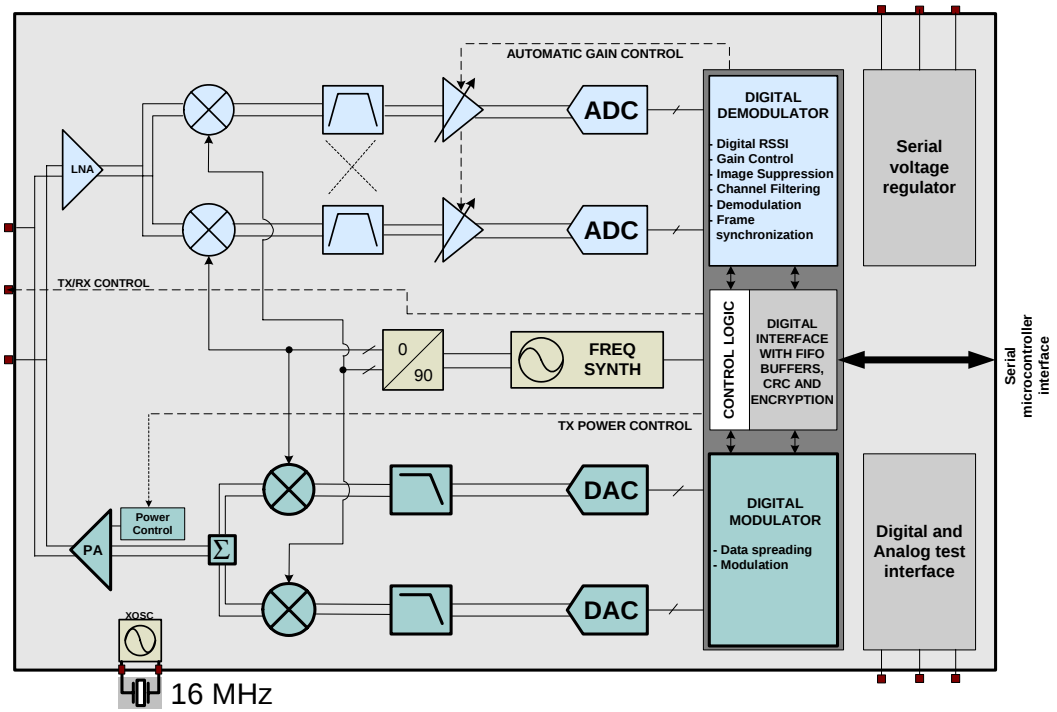

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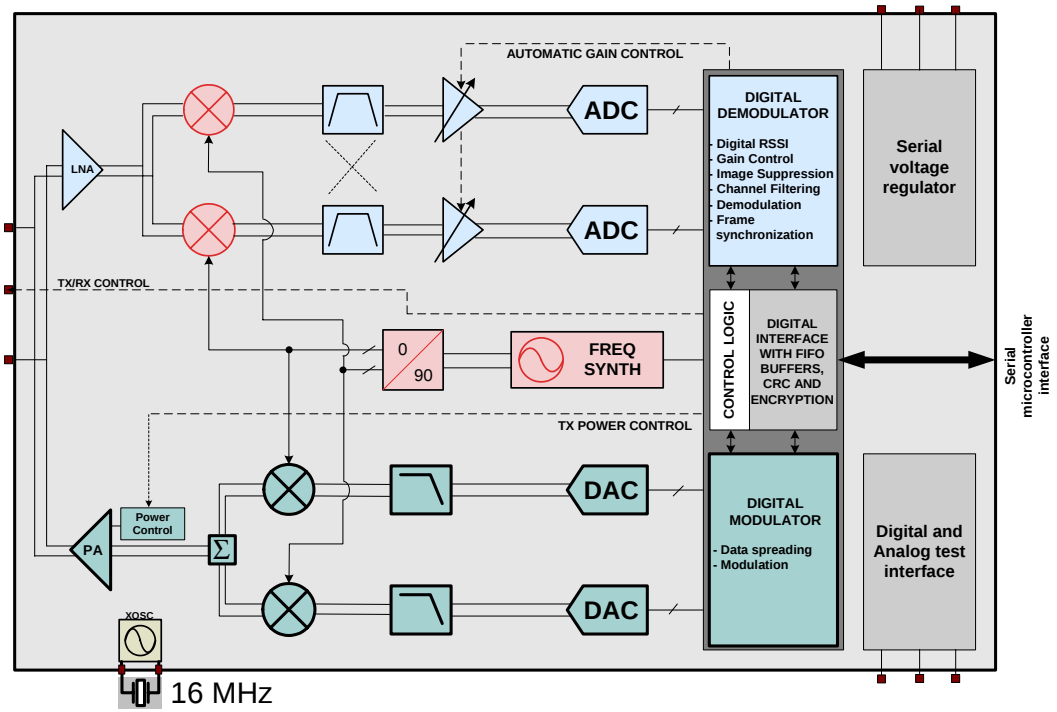

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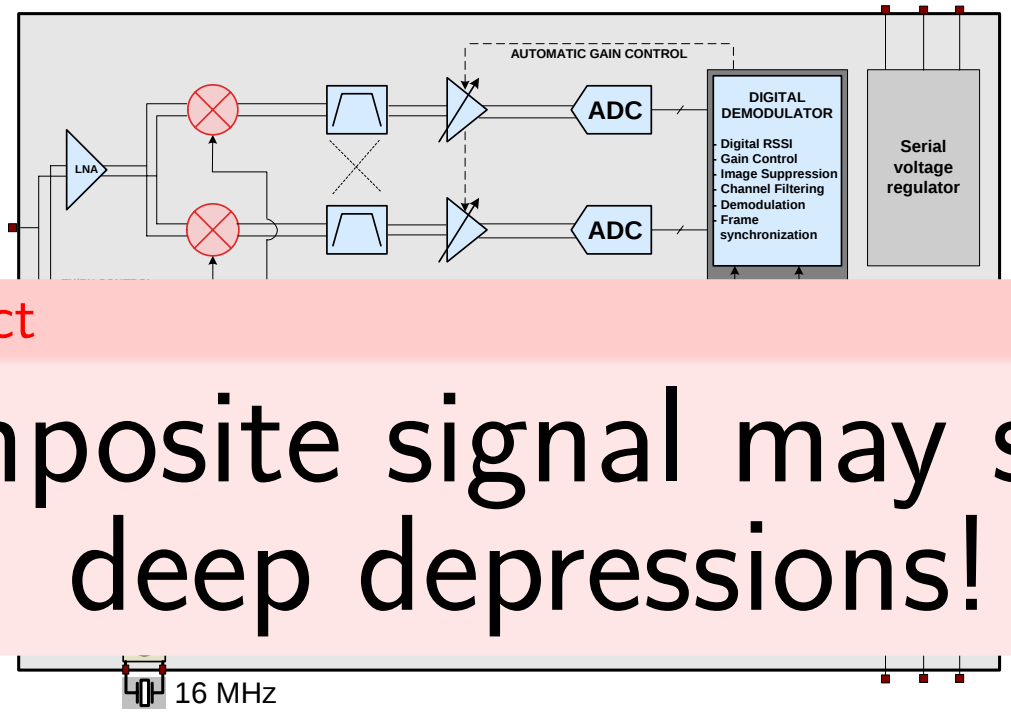

Beating effect

Composite signal may suffer deep depressions!

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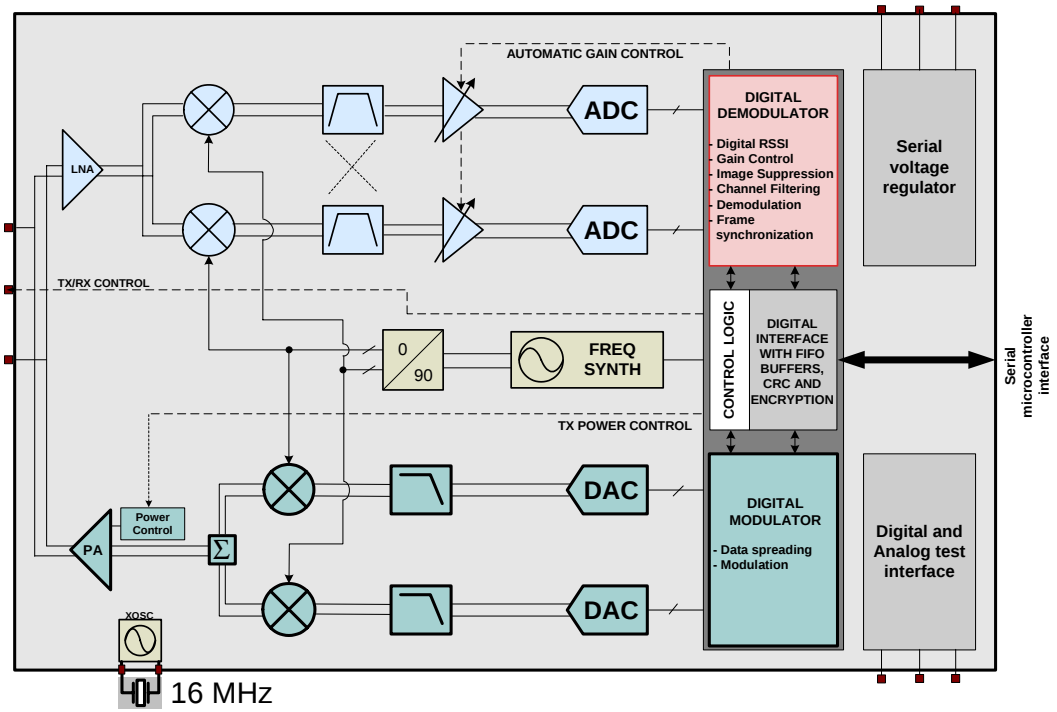

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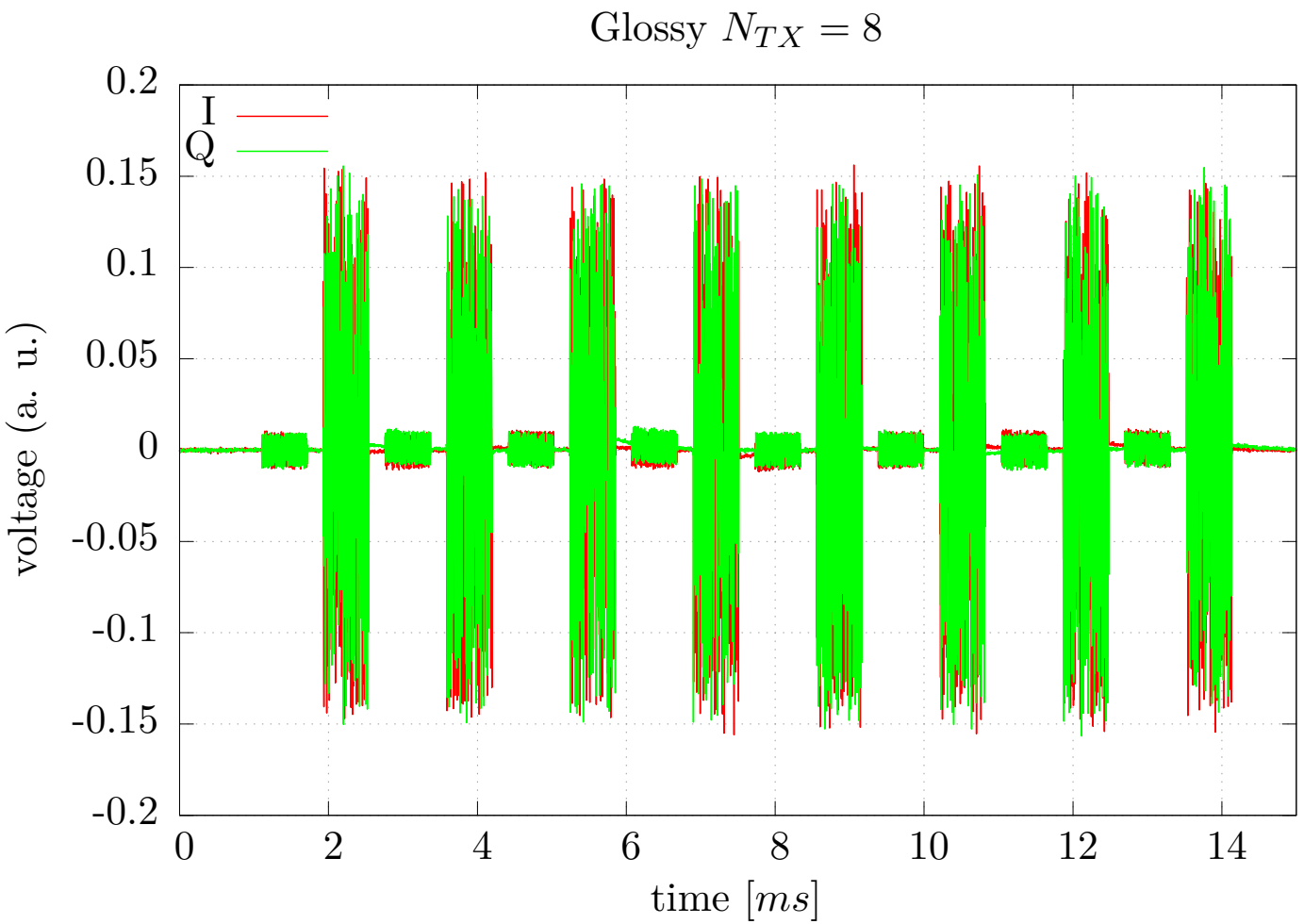
Received Signal



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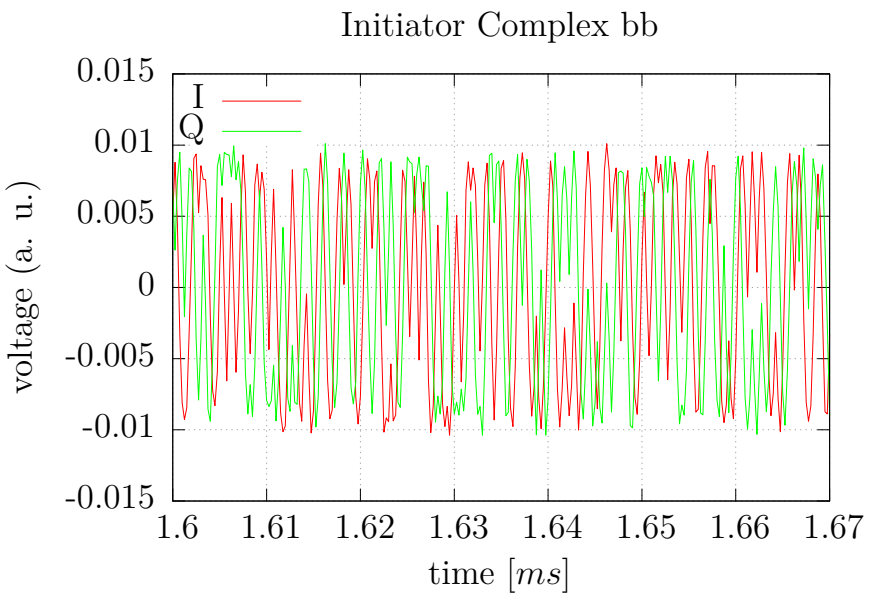

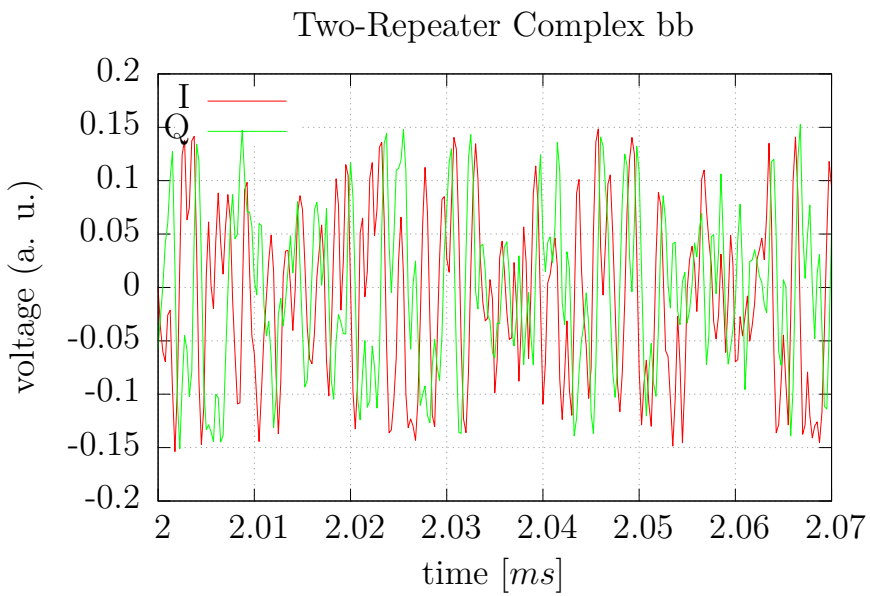

Experimental Setup

- TMote Sky sensor nodes
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- **Customised** AWGN channel (GNU Radio)
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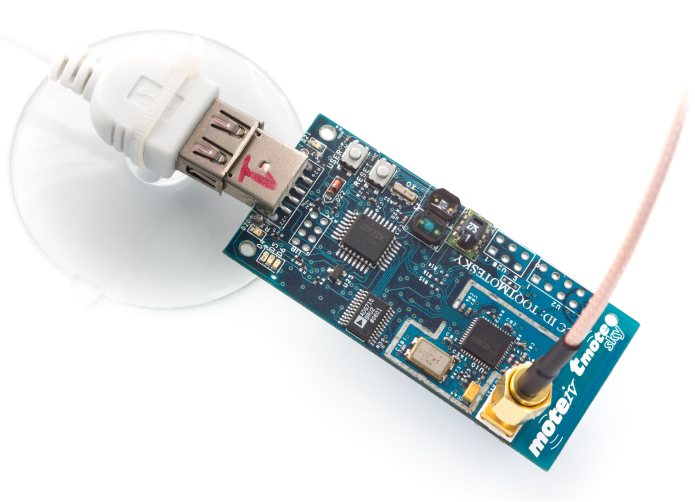

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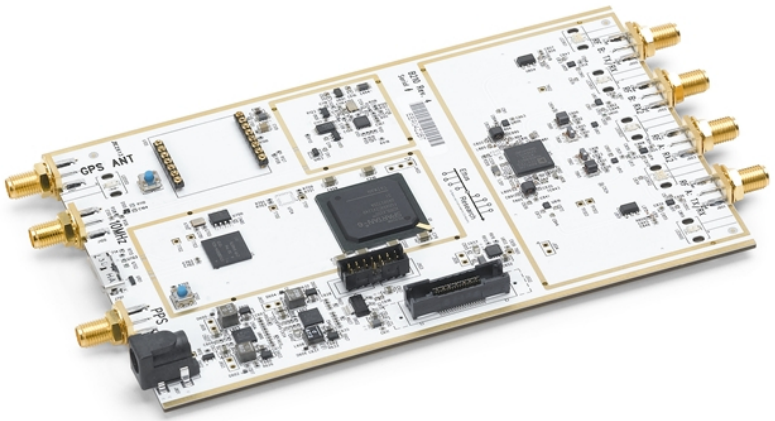

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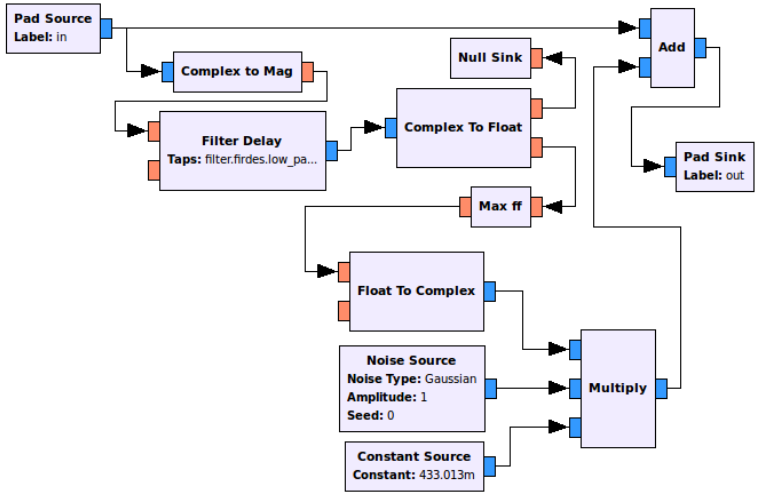

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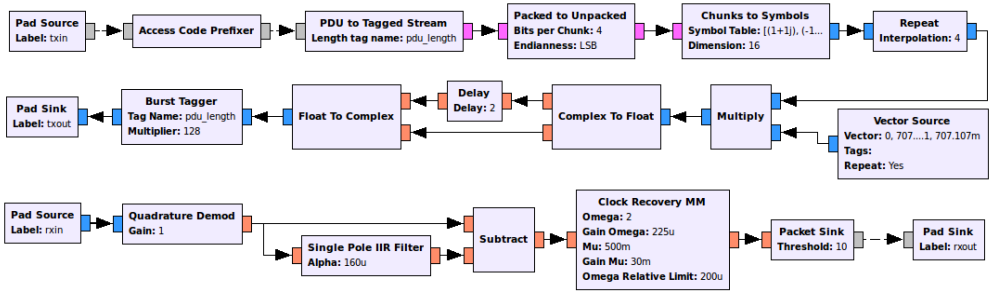
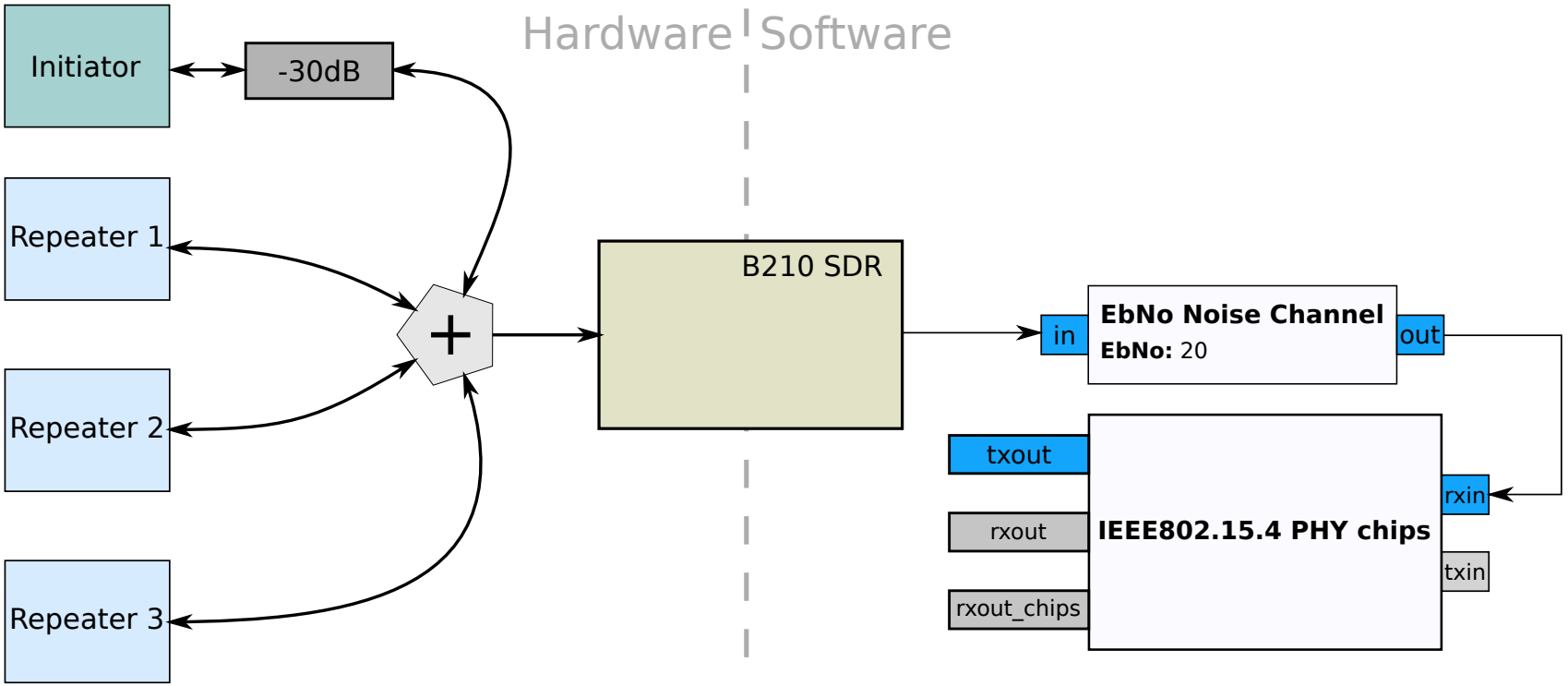
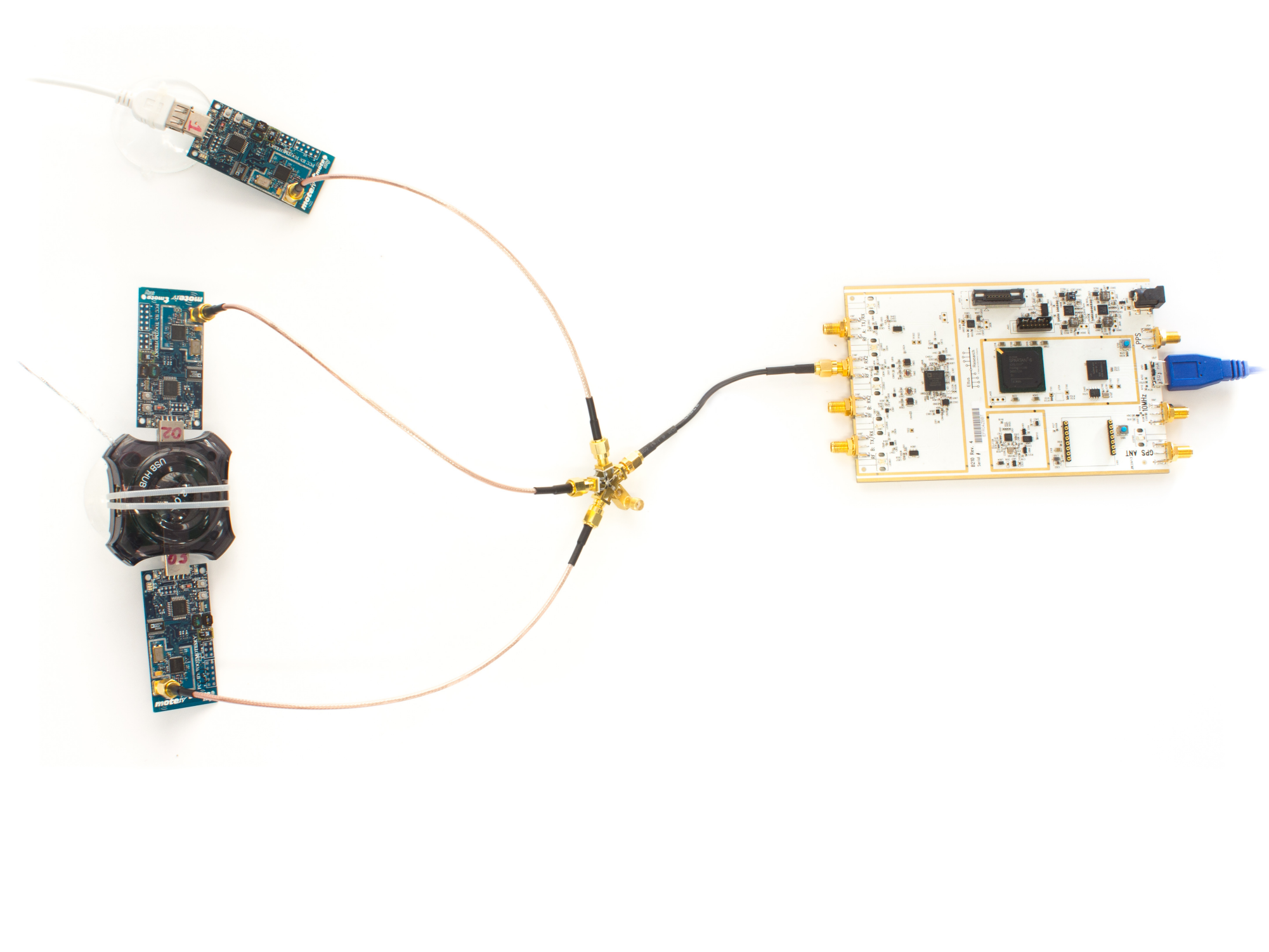
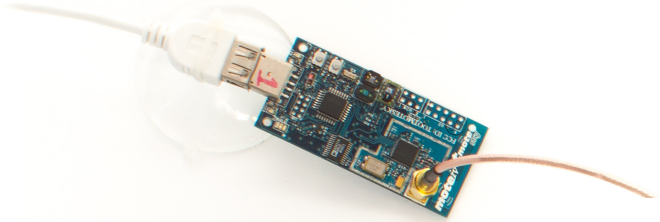


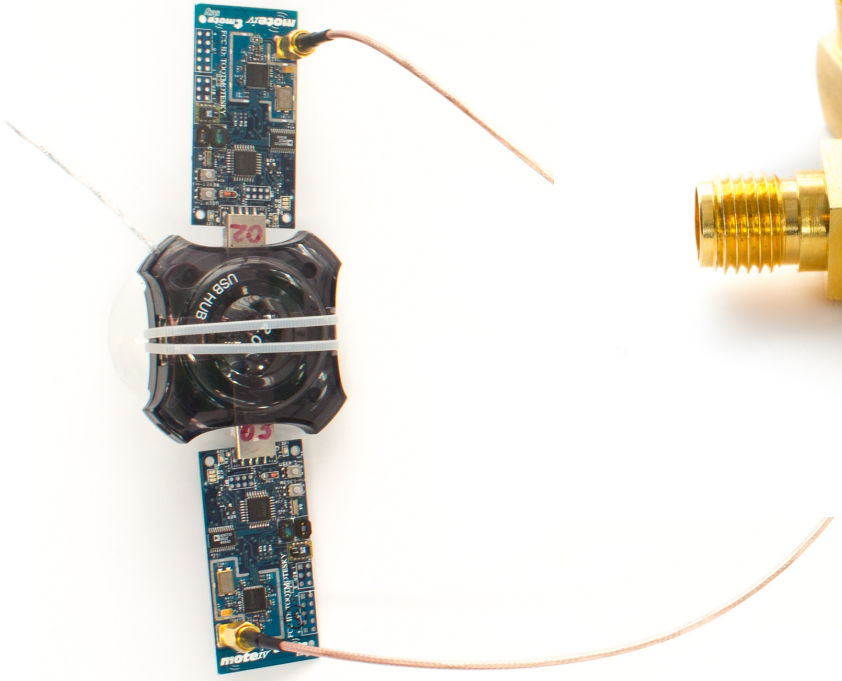
Bastian Bloessl, Christoph Leitner, Falko Dressler, and Christoph Sommer.
A GNU Radio-based IEEE 802.15. 4 Testbed.
12. GI/ITG FACHGESPRÄCH SENSORNETZE, 2013

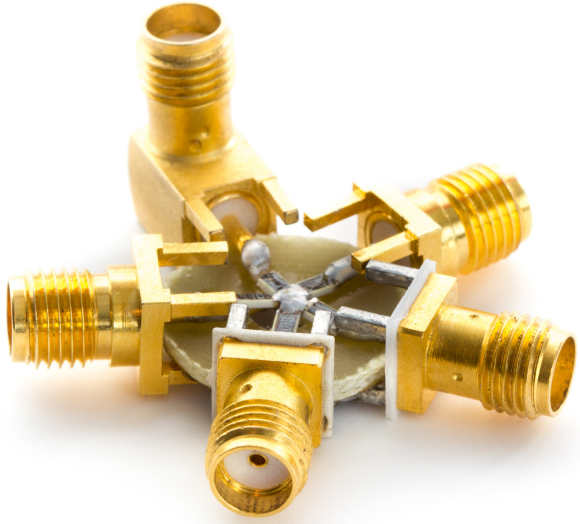
Wired Configuration

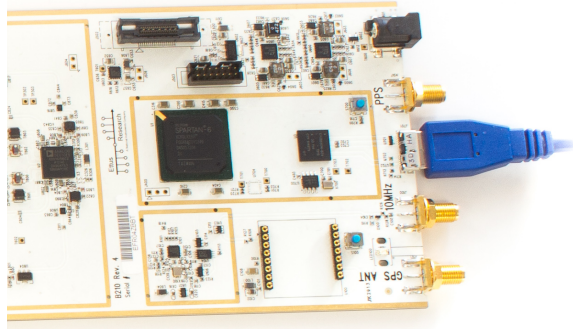



USB HUB
PPS
10MHz
GPS ANT




USB HUB




PPS
10MHz
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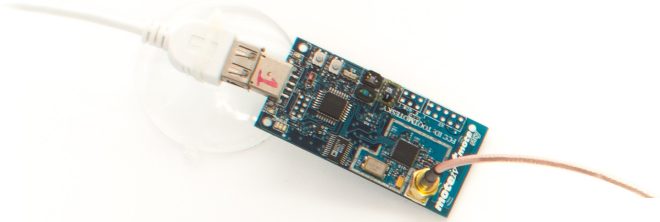

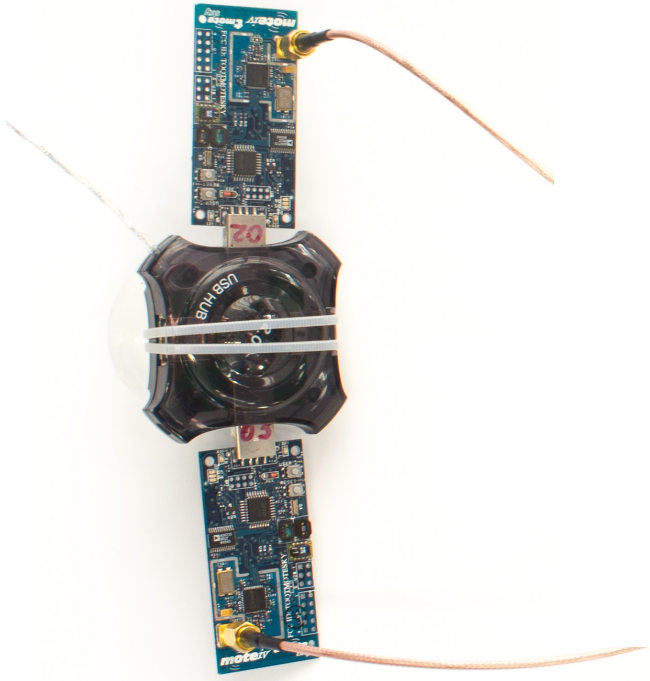
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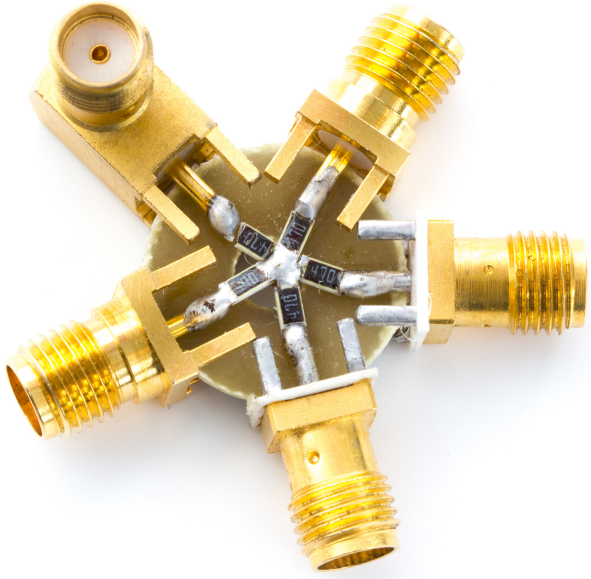

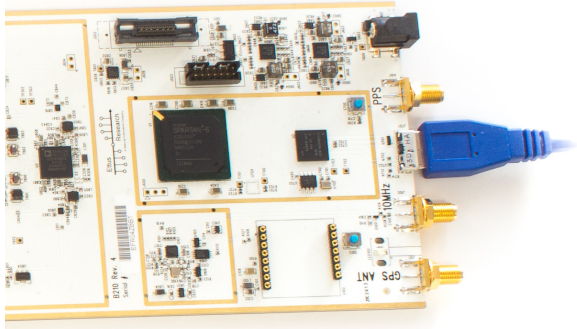
PPS
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Wired Configuration

Power imbalance