Reflection of Modulated Radio (ReMoRa): Link Analysis of Ambient Scatter Radio Using Perfect Pulses

The Propagation Group

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Introduction

- Ambient Scatter Networks (ASN) will be a part of next-gen, low power communications, enabling semi-passive readers [1].
- ANS will use ambient RF energy for power *and* as the carrier, rending most canonical signaling methods unusable.
- Specialized hardware [2] and mathematical modeling of these topologies [3] have aided in the realization of this technology.
- Shrewd channel coding can address the unique obstacles posed by ambient links.

Challenges of Ambient Comms

1. Unknown, Time-Varying Carriers
2. Carriers of Non-Negligible BW
3. Primary User Interference (PUI)

A channel code is needed that addresses all concerns.

Perfect Pulses

- Antipodal signals with unique DC nulling properties [5].
- Described as the sign function of the Chebyshev polynomial.

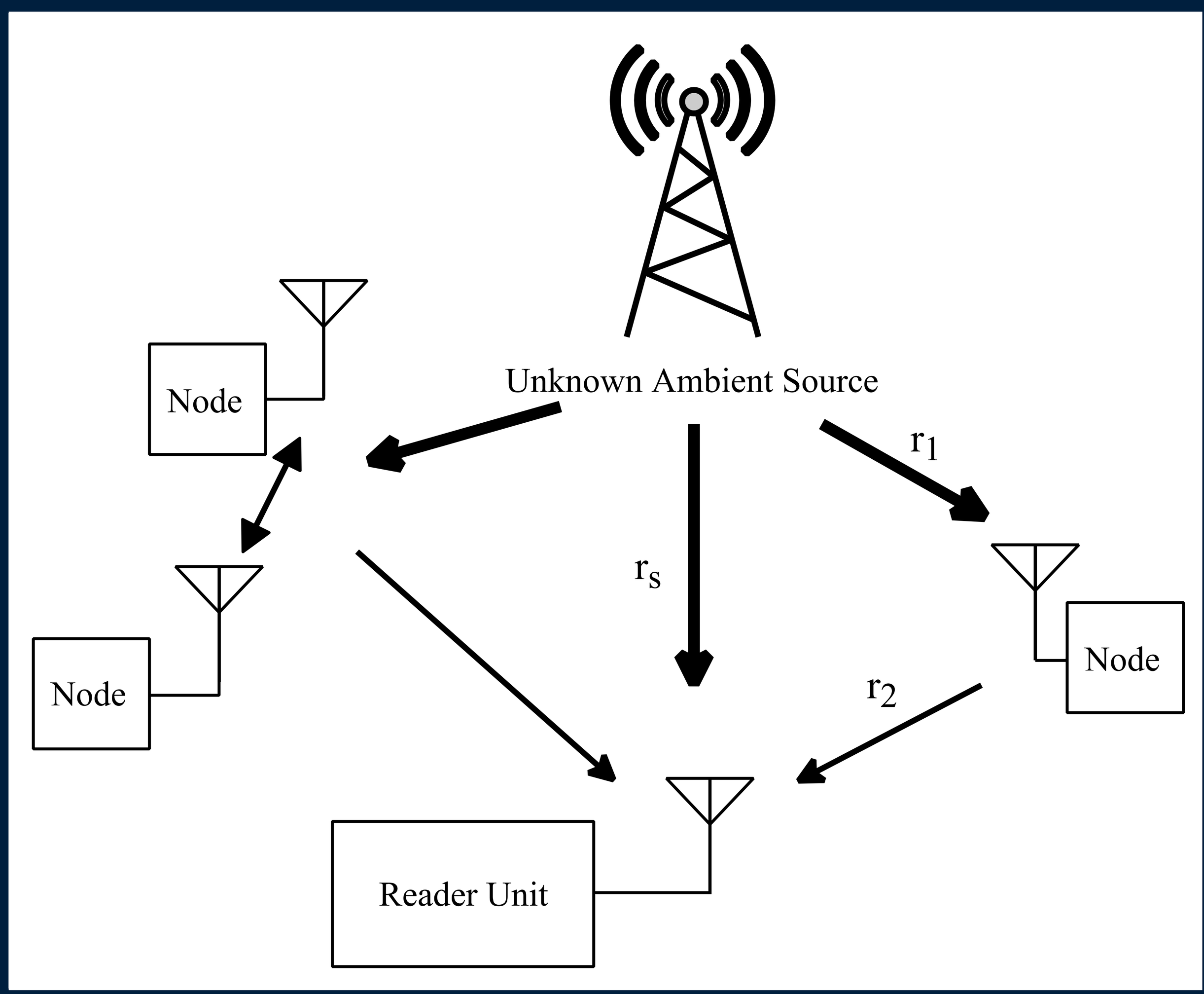
$$x_n(t) = sgn(cos(n\, cos^{-1}(\frac{2t}{T_b} - 1)$$

- Linear relationship between number of transitions and Null BW.
- Requires faster transitions than SinBOC, but deeper null and less susceptible to carrier distortion.
- Self – synchronization ability at bit level.

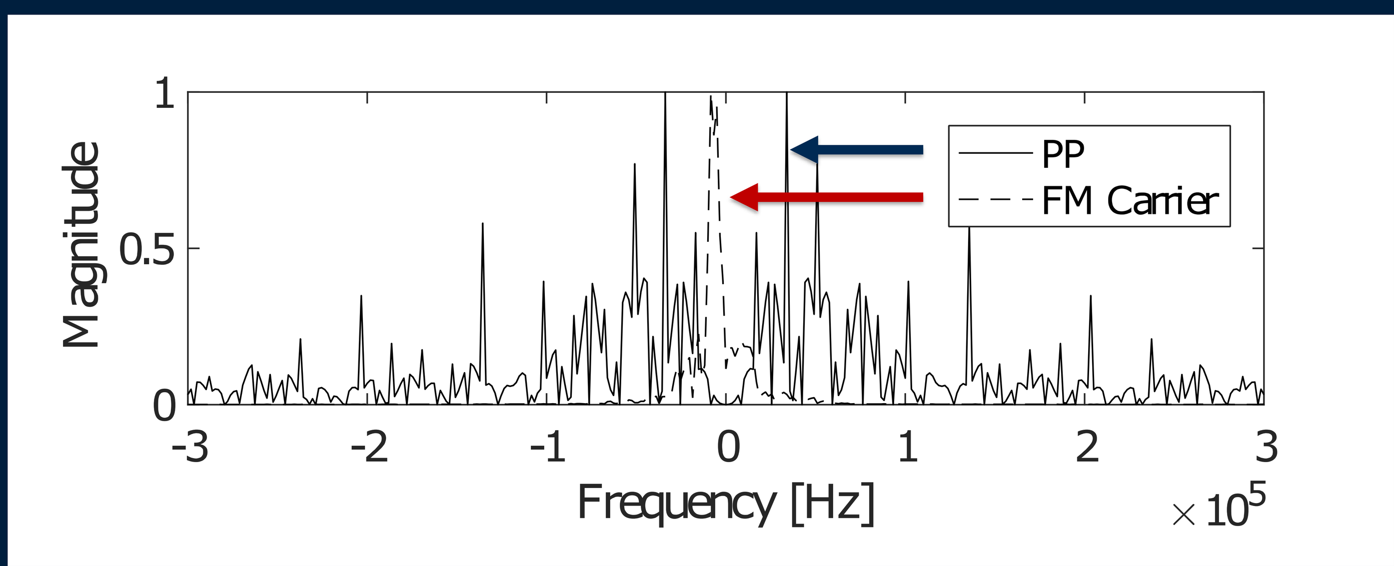
Conclusions

- Three unique signal processing obstacles of ASN are addressed
- Perfect Pulses are suggested as a potential solution, with further exploration of their unique properties.
- A realistic link budget for ASN is proposed and example situation presented.
- If the ReMoRa signal can be properly extracted, ranges upwards of 1000 m can be achieved without an amplifier.

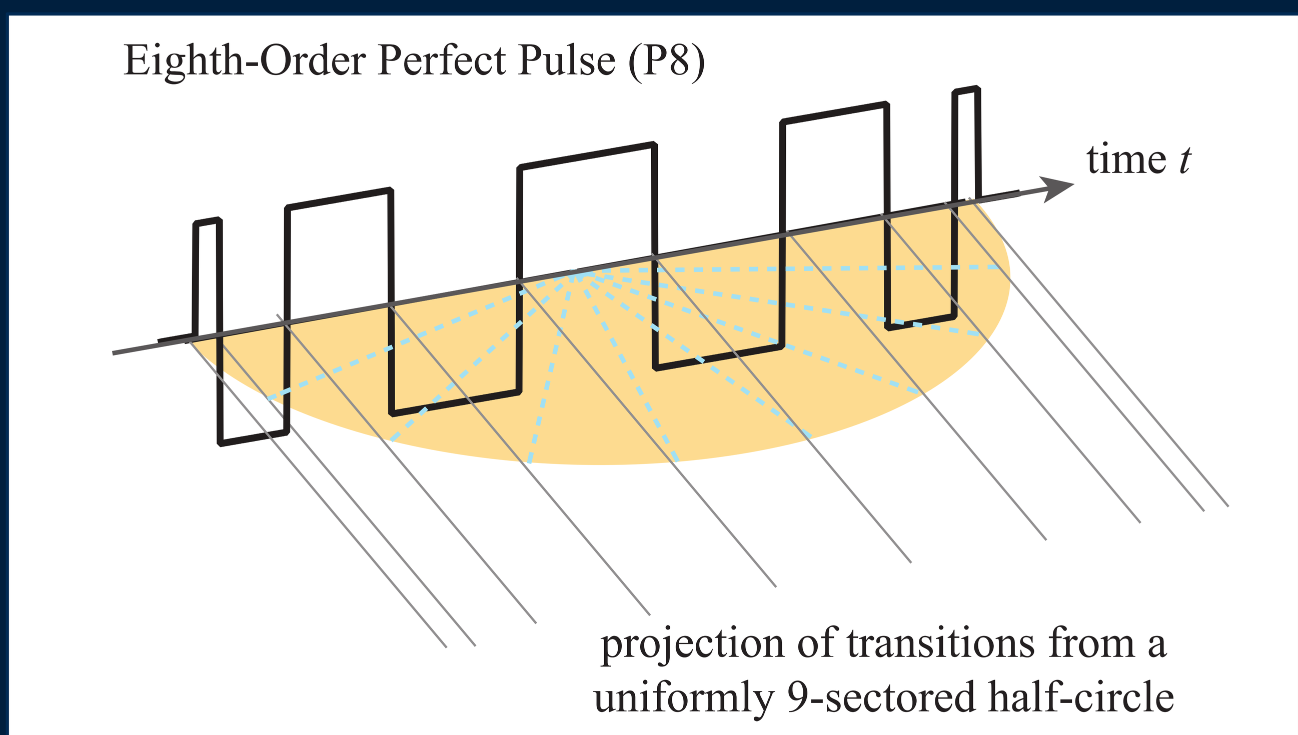
ReMoRa Wireless Network

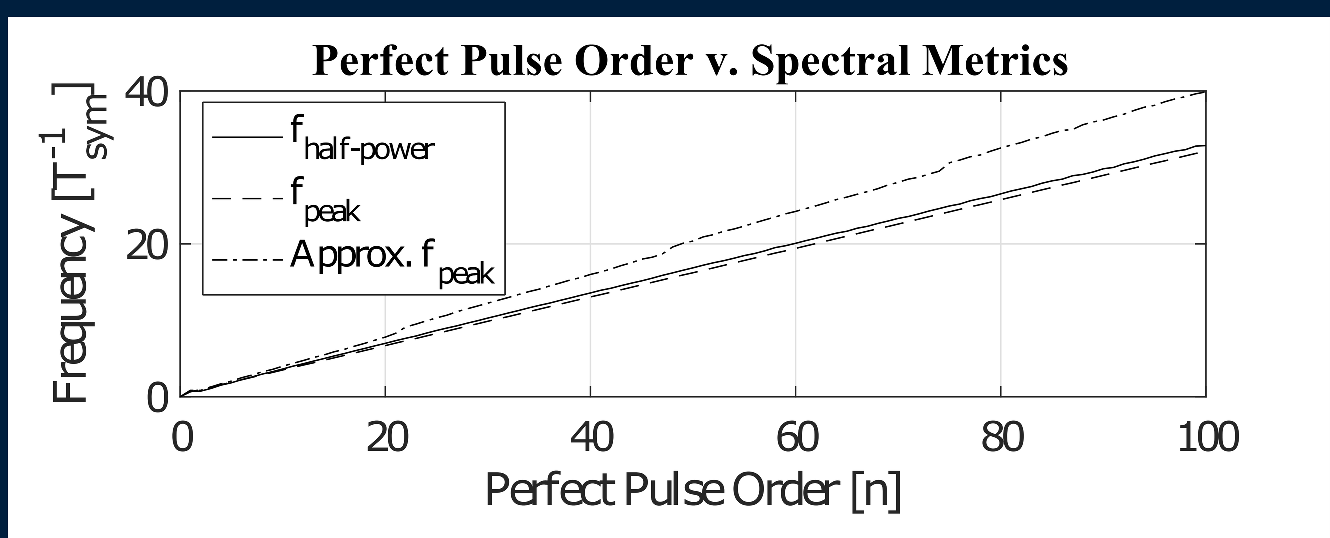


Spectrum Allocation



Pulse Metrics





Future Work

- Continue exploring unique properties of perfect pulses and their applications to wireless comms
- Constructing a baseband over-the-wire testbed for PP based communications.
- Link Budget Measurements

Ambient Link Budget

- ReMoRa link budget resembles that of the bistatic equation in radar.

$$P_R = \frac{P_T G_T G_R G_t^2 \lambda^4}{(4\,\pi)^4\, r_1^n r_2^n}$$

- The path loss exponent, n, represents the environment. A value of 2.7 can be used to describe urban/sem-urban topologies [4].
- The table serves as an illustration for the expected returns of a realistic link

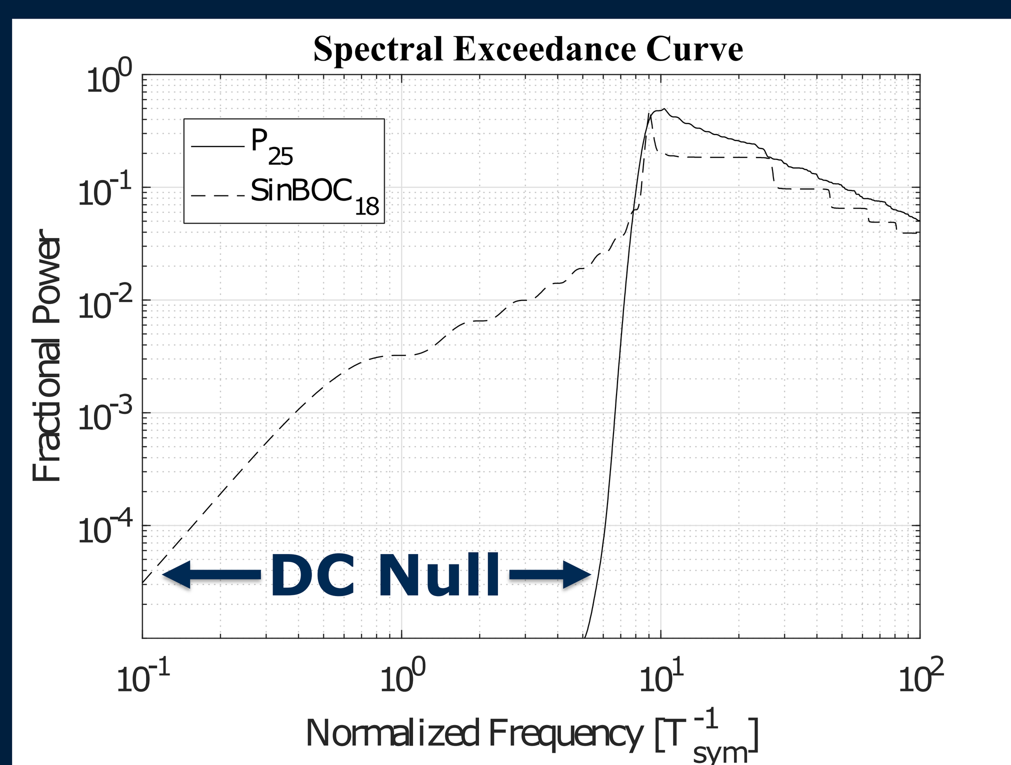
Quantity	Passive	w/ Ref Amp
TX power, P_T	42 dBW	42 dBW
TX Gain, G_T	8 dBi	8 dBi
RX Gain, G_R	2.1 dBi	2.1 dBi
Tag Gain, G_t	2.1 dBi	2.1 dBi
Reflection Amp Gain	0 dB	34 dB
TX - tag separation, r_1	1000 m	3000 m
tag separation - RX, r_2	1000 m	3000 m
RX power, P_T	**-90.8 dBm**	**-90.8 dBm**

Spectral Exceedance

- A metric for representing spectral power concentration for a given waveform.

$$CS(F) = \int^{F} |P_n(f)|^2 df$$

- Used here to determine the depth of a PP and SinBOC nulls of equal BW.
- PP null is much deeper, but requires more transitions.



References

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[2] J. Kimionis, A. Georgiadis, S. Kim, A. Collado, K. Niotaki, and M. Tentzeris, "An enhanced-range RFID tag using an ambient energy powered reflection amplifier," in Microwave Symposium (IMS), Tampa, FL, June 2014.
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[5] M. Varner, R. Bhattacharjea, and G. Durgin, "Realizing ReMoRa (Reflection of Modulated Radio) Ambient Scatter Communication Links With Perfect Pulses," pp. 59–67, Sept 2017.