ORI 13 MAY 2025

FPGA PROJECTS MEETUP

Welcome!

AGENDA

- What have you done?
- What do you have planned?
- What are your roadblocks?
- Do you need any resources?

THOMAS TELKAMP

BEYOND EARTH: LUNAR AND SPACE RADIO MISSIONS

WE ARE ENTERING A NEW ERA OF RADIO ASTRONOMY THAT WILL INVOLVE OBSERVING FROM OUTER SPACE.
HOWEVER, SUCH A JUMP PRESENTS CHALLENGES AND OPPORTUNITIES WHEN IT COMES TO THE STYLE OF MISSION, HOW TO HANDLE THE DATA, AND HOW TO NAVIGATE A PRISTINE ENVIRONMENT.
THIS WORKSHOP WILL BRING TOGETHER ENGINEERS AND RESEARCHERS FROM SPACE SCIENCE, MISSIONS, AND RADIO ASTRONOMY TO DISCUSS RECENT ADVANCEMENTS AND EXPLORE FUTURE COLLABORATIONS OF LUNAR AND OUTER SPACE RADIO MISSIONS.
THIS CONFERENCE IS GENEROUSLY SPONSORED BY BREAKTHROUGH INITIATIVES.

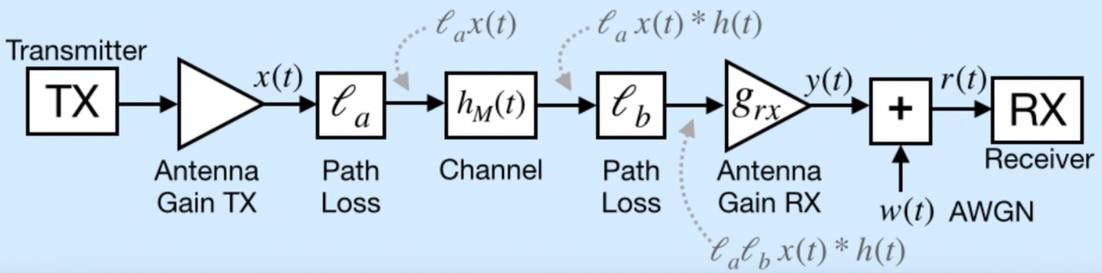
12-15 MAY 2025

MICHELLE THOMPSON

- Major update of the EVE link analysis published.
- Meeting later today with DSES principals about EVE2026.
- Annual tax form submission (Form 990s) deadline is 15 May.
- Four out of four submitted articles for QEX magazine have been accepted.
- IEEE standards group P1954 (Drone radio protocol) meeting postponed.
- Article about delay-Doppler channel communications from Pete progressing rapidly.
- Regulatory proposal article concerning legality of amateur LTE communications.
- Planned quite a bit about Opulent Voice ‘state machine’ but no lab progress yet.
- Board meeting at Omega Mart in Las Vegas at DEFCON on Sunday?
- Really nice update from Ribbit in the UI, but not seeing it yet in the web app?

Efficiently Using Transmitted Symbol Energy via Delay-Doppler Multi-Path Channels

(1) System Model



(2) Energy Transmitted Per Symbol

Symbol Duration

$$E_{tx} = \int_0^{T_s} |x(t)|^2 dt$$

Energy per Transmitted Symbol

(3) Energy Received Per Symbol

Max. Multi-Path Delay

$$E_s = \int_{\tau_{min}}^{T_s+\tau_{max}} |y(t)|^2 dt$$

Min. Multi-Path Delay

Energy per Received Symbol

(4) Energy Efficiency Metric

Energy per Received Symbol

Efficiency $\xi_M = 10\,log_{10}\left(\frac{E_s}{E_{tx}}\right)$

Energy per Transmitted Symbol

(5) Single Path Received Signal

Channel Response

$$h_1(t) = \alpha_1 \delta(t - \tau_1)$$

Path Coefficient, Path Delay

$$y(t) = \ell_a \ell_b g_{rx} x(t) * h_1(t) = \ell_a \ell_b g_{rx} \alpha_1 x(t - \tau_1)$$

(6) Single Path Waveform Energy Efficiency is <u>not</u> a Function of the Shape of x(t)

$\ell = \ell_a \ell_b$

$$E_s = |\ell \alpha_1 g_{rx}|^2 \int_{\tau_1}^{T_s+\tau_1} |x(t-\tau_1)|^2 dt = |\ell \alpha_1 g_{rx}|^2 \int_0^{T_s} |x(t)|^2 dt$$

Single-Path Efficiency

$$\xi_1 = 10\,log_{10}\left(\frac{E_s}{E_{tx}}\right) = 10\,log_{10}|\ell \alpha_1 g_{rx}|^2$$

(7) However, Multi-Path Waveform Energy Efficiency <u>is</u> a Function of the Shape of x(t)

Channel Impulse Response with M>1 Paths

$$E_s = \int_{\tau_{min}}^{T_s+\tau_{max}} |y(t)|^2 dt = |\ell g_{rx}|^2 \int_{\tau_{min}}^{T_s+\tau_{max}} |x(t) * h_M(t)|^2 dt$$

Multi-Path Efficiency for M>1

$$\xi_M = 10\,log_{10}\left(\frac{|\ell g_{rx}|^2 \int_{\tau_{min}}^{T_s+\tau_{max}} |x(t) * h_M(t)|^2 dt}{E_{tx}}\right)$$

Pete Wyckoff, KA3WCA, May 13, 2025.