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Modeling Communication Systems Using the SystemC AMS Building Block Library

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Outline

- A brief introduction to the SystemC AMS extensions
- Overview of the AMS Building Block Library
- Application example: Modeling of OFDM Transceiver System
- Conclusions and Future work

SystemC AMS extensions

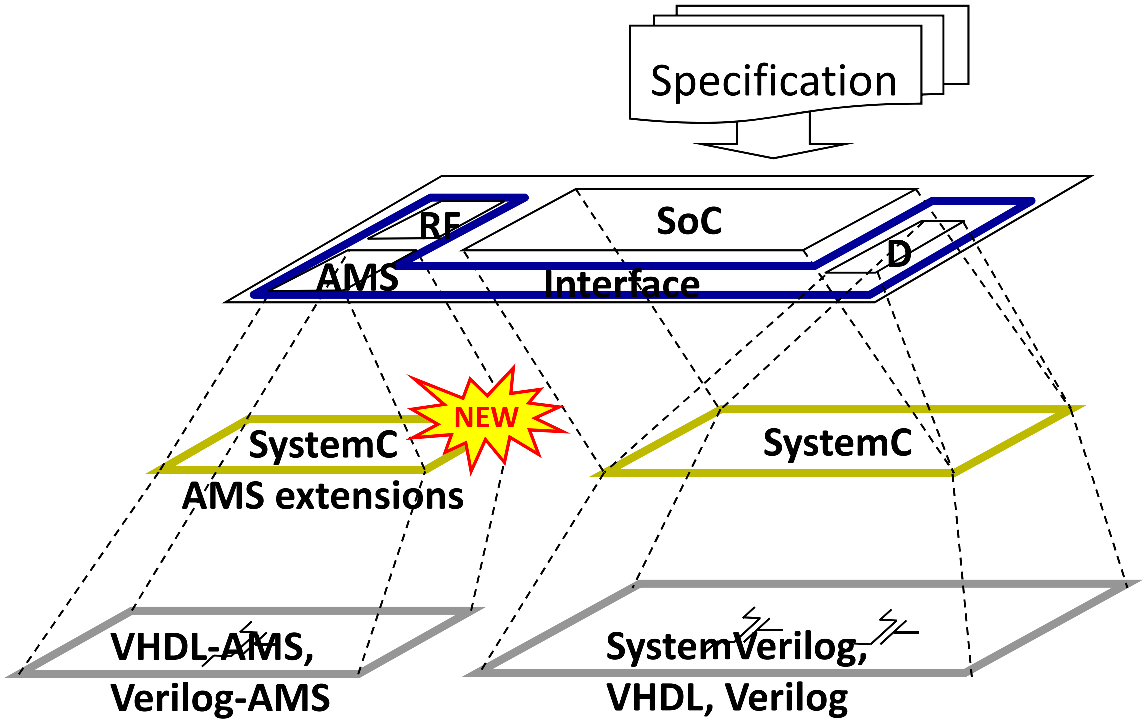
1. SystemC AMS is *not SPICE*
2. SystemC AMS is *not for circuit design – it‘s for overall system modeling!*
3. Used in appropriate way, SystemC AMS yields
   - high simulation performance
   - increased design productivity

SystemC AMS extensions

Functional

Architecture

Implementation



AMS building block library - motivation

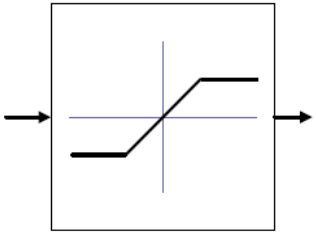
- Problems:
  - **Slow simulation** of AMS communication systems
  - Modeling of different parts of a system needs **a serious investment in time**
  - **Limitations and constraints** of closed (proprietary) models not always clear
- Possible Solutions:
  - Modeling in **Timed Data Flow** (TDF)
  - Provides **building blocks** for various AMS, RF, and digital functions
  - Using **open model-based design** approach

Available modules

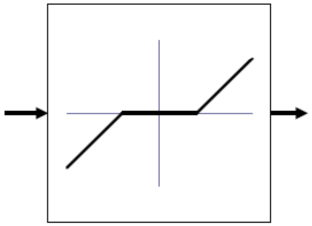
- Signal sources:
  - Sine/Cosine, bit stream (uniformly), random number (Gaussian) …
- Signal processing:
  - Basic mathematic modules: adder, multiplier, integrator …
  - Analog modules: LNA, mixer, PLL, Butterworth/Chebyschev filter …
  - Modulation processes: AM, BASK, M-FSK, M-PSK, DBPSK, OQPSK, QAM, OFDM …
  - DSP algorithm: FFT/IFFT …
  - Converter: A/D converter, D/A converter, P2S, S2P…
- Analysis tools: eye diagram, scatterplot …

Non-ideal properties of analog

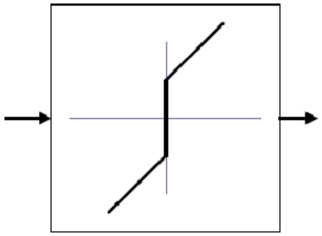
- LNA:
  - intermodulation products (IP3)
  - output limitation
- Mixer:
  - intermodulation products (IP3)
  - output limitation
- AD/DA converter :
  - gain error
  - offset error
  - output limitation
- General modules of non-idealities:



Saturation



Dead zone



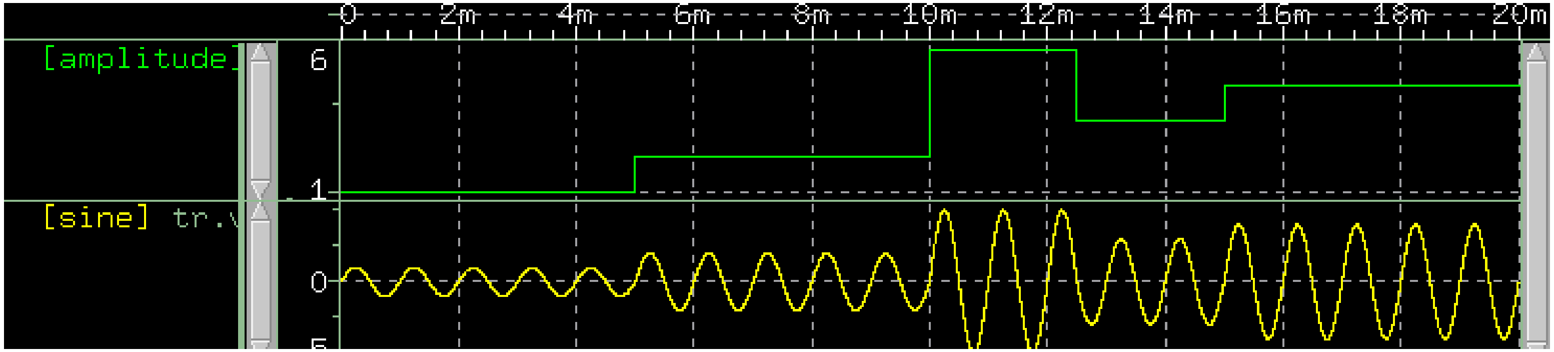
Columb function

Parameterization of modules

- Generally: Adaptivity of modules is realized by parametrization of modules; realization could be DSP SW, FPGA, maybe analog
  - setting parameters by instantiation

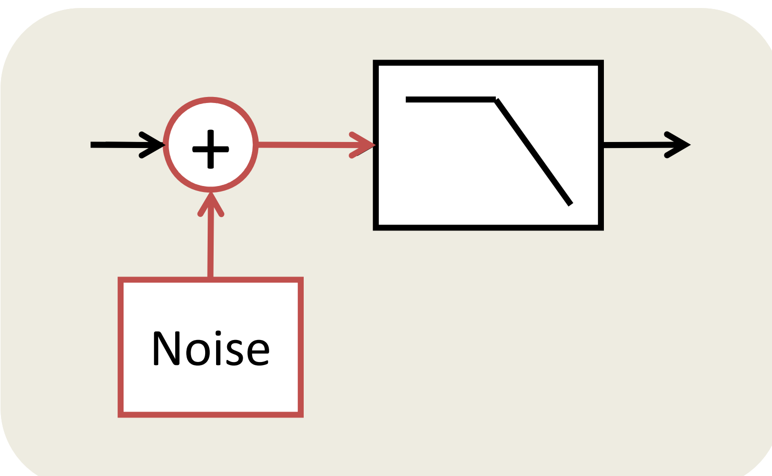
Name value	Type	Default value	Description
n	sc_module_name	-	name of instant module
_gain	double	-	gain in dB
_ip3	double	-	IP3 in dBm
_ideal	bool	-	true for simulation of ideal LNA, otherwise false

  - parameter adjustments *during* simulation possible for some modules

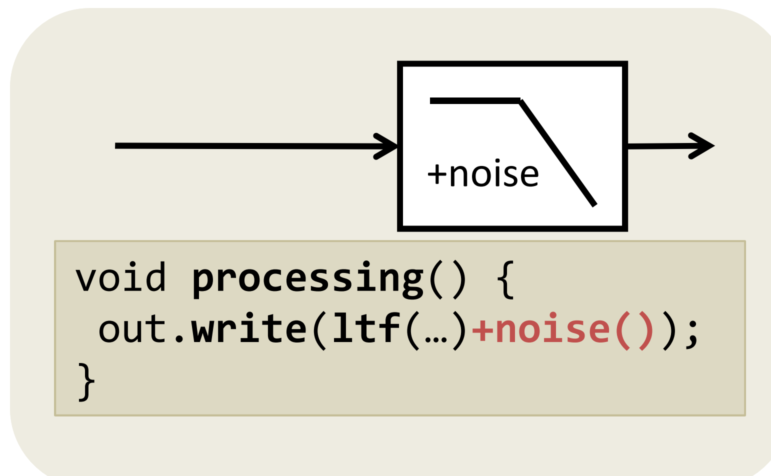


User-specific model extensions

- The ***open*** nature of the AMS building block library enables making model extensions
  - without changing the design architecture or structure!
- Example: Add non-ideal effects to the model (e.g., noise)

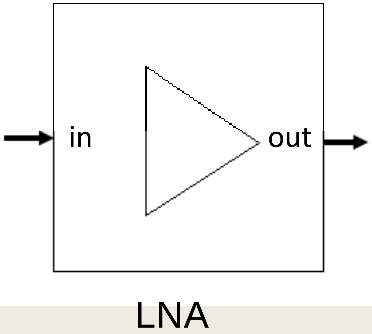


Model-based design with Matlab/Simulink®



Open model-based design approach

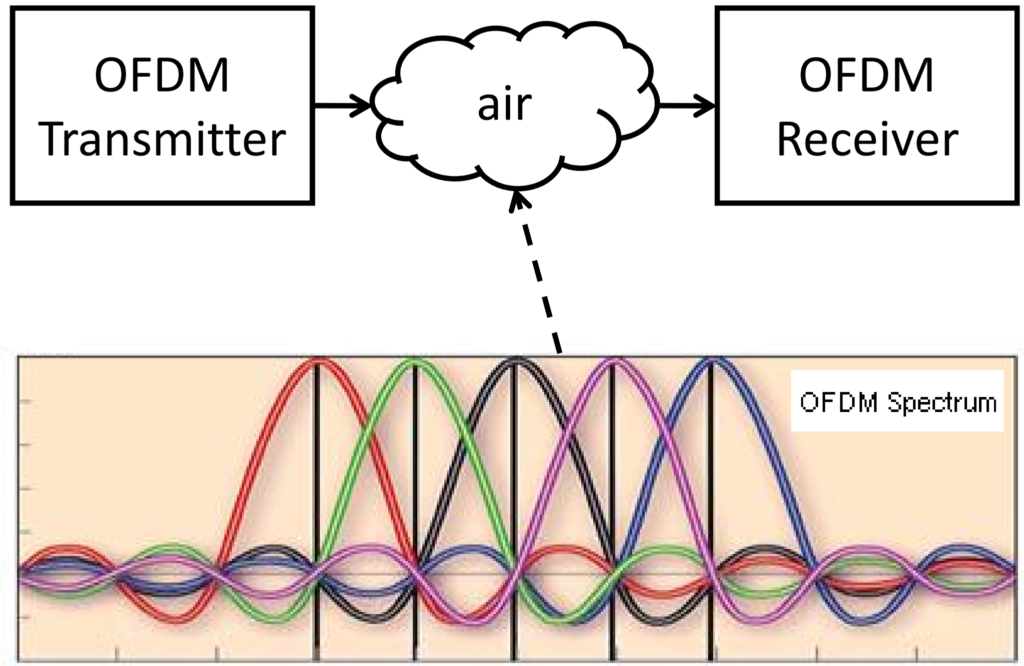
Building block example: LNA header file




```
SCA_TDF_MODULE (lna)
{
 public:
   sca_tdf::sca_in<double> in;     // Input port
   sca_tdf::sca_out<double> out;   // Output port

 private:
   double gain;                 // Gain in dB
   double ip3;                  // Third Input Intercept Point in dBm

   // Coefficients of output polynomial v = a*i - b*i*i - c*i*i*i
   double a, b, c;

   bool ideal;                  //  ideal lna or not, true --> ideal
   ...

 public:
   // Constructor: name, gain in dB, ip3 in dBm, ideal (bool)
   lna (sc_core::sc_module_name n, double _gain, double _ip3, bool _ideal);
   ...
 private:
   void processing(); // Timed Data Flow (TDF) processing method
};
```

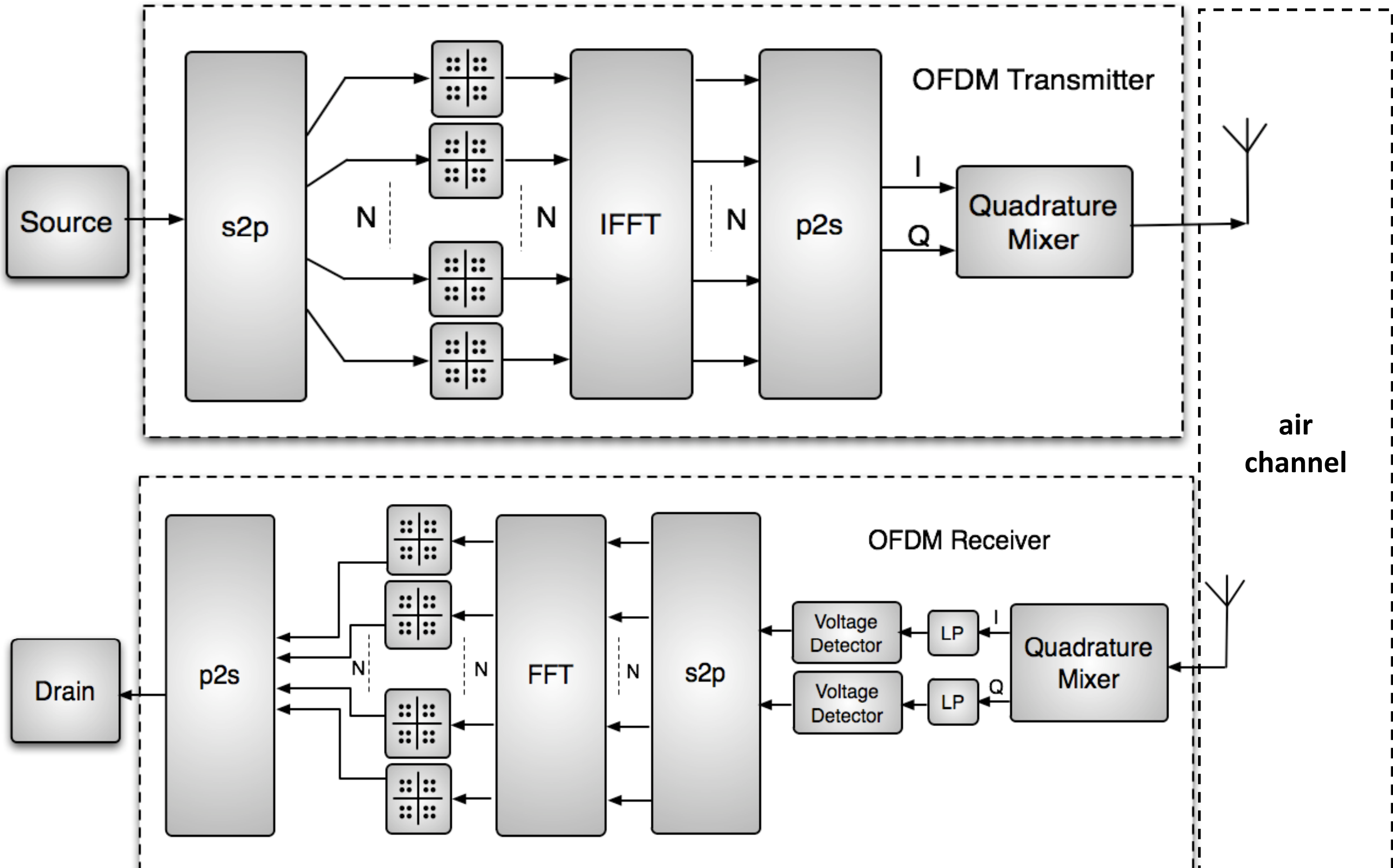
Example: OFDM transceiver (1)

- OFDM: Orthogonal frequency-division multiplexing



Example: OFDM transceiver (2)

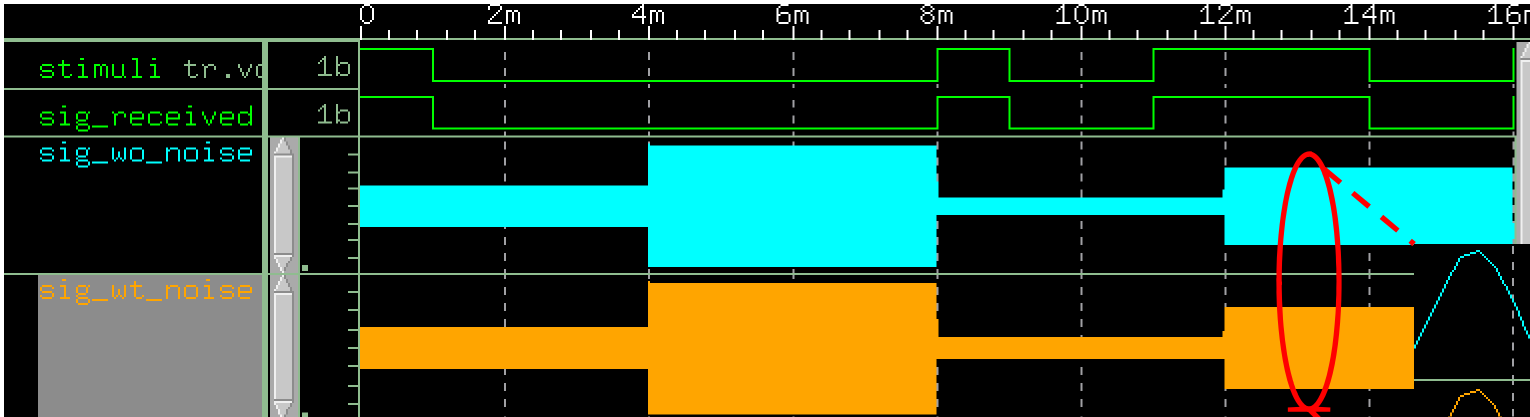
- Structure of the application:

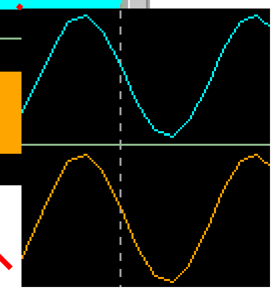


Example: OFDM transceiver (2)

```
/***   instantiate stimuli generator ***/
rand_bool i_stimuli("stimuli",16);
i_stimuli.out(sig_stimuli);
i_stimuli.out.set_timestep(1/freq_bit,SC_SEC);

/***   instantiate OFDM transmitter ***/
ofdm_se<8> i_tran("transmitter",freq_carrier,constl_dim,freq_bit,data_rate,ampl_se);
i_tran.in(sig_stimuli);
i_tran.out(sig_out);

/***   instantiate channel module ***/
air i_air("air",attent,"gauss_white",n_va);
 i_air.in(sig_out);
i_air.out(sig_noise);

/***   instantiate OFDM receiver ***/
ofdm_re<8> i_receiver("receiver",freq_carrier,constl_dim,freq_bit,data_rate,ampl_re);
 i_receiver.in(sig_noise);
 i_receiver.out(sig_received);

/***   instantiate signal drain ***/
drain drn("drn");
drn.in(sig_received);
```

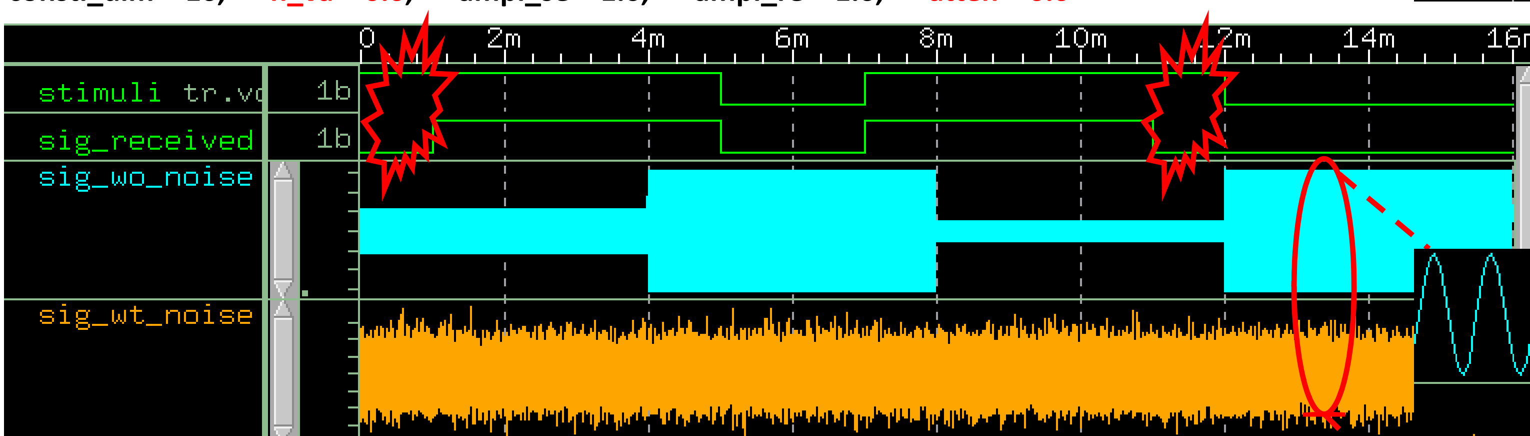
Simulation results (1)

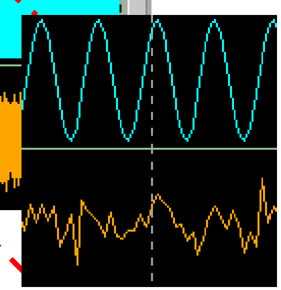




Parameters for simulation: (no noise, no attenuation)

constl_dim = 16, n_va = 0.0, ampl_se = 1.0, ampl_re = 1.0, atten = 0.0

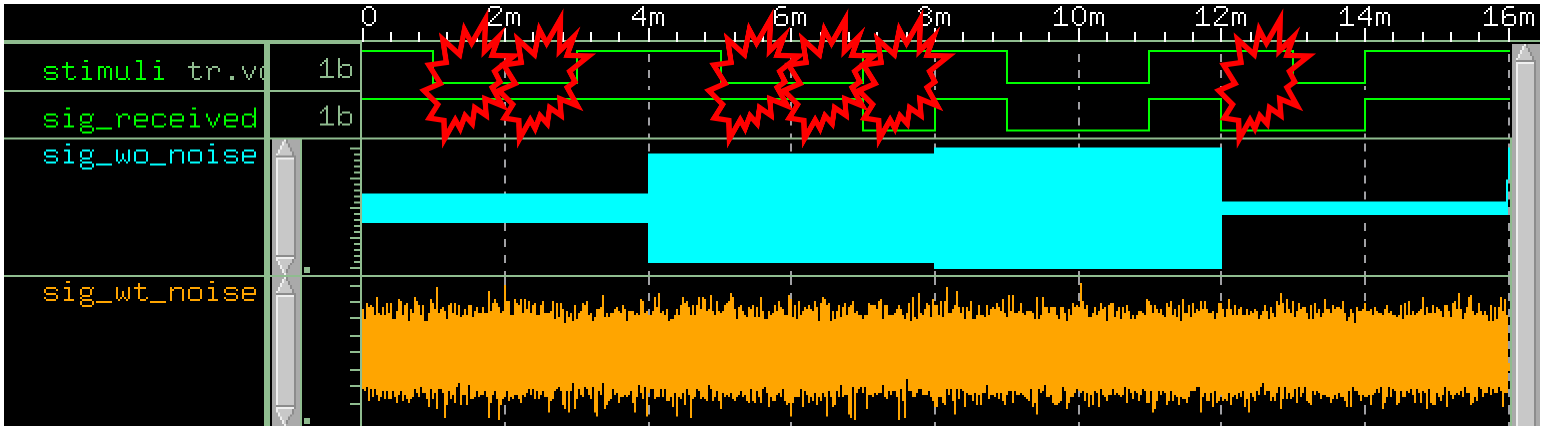




Parameters for simulation: (with strong white noise, no attenuation)

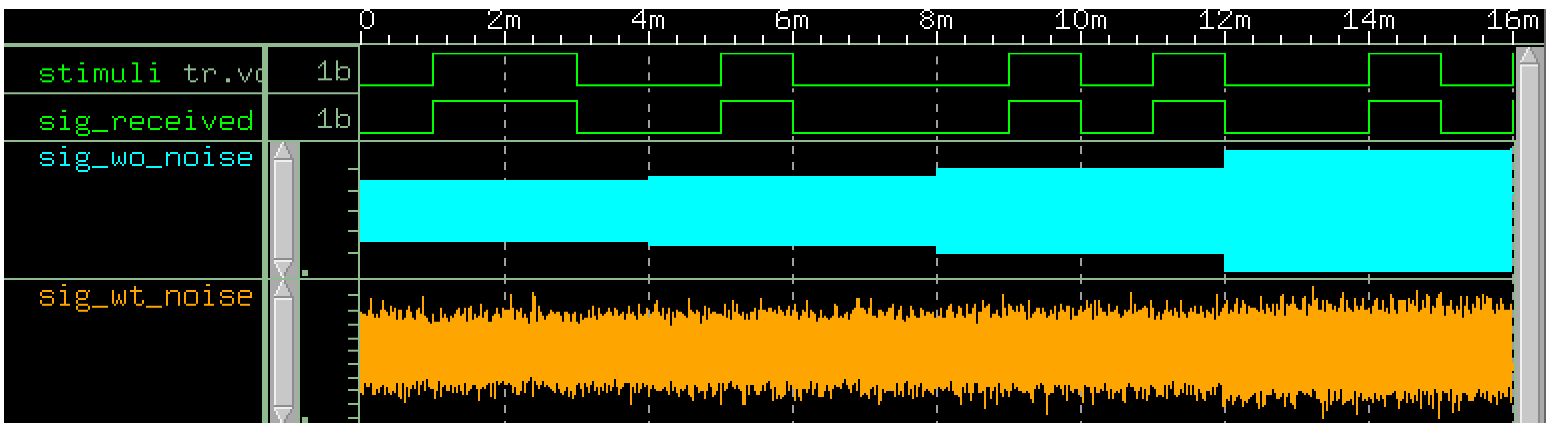
constl_dim = 16, n_va = 90.0, ampl_se = 1.0, ampl_re = 1.0, atten = 0.0

Simulation results (2)



Parameters for simulation: (with strong Gaussian noise and 50% attenuation)

constl_dim = 16, n_va = 90.0, ampl_se = 1.0, ampl_re = 1.0, atten = 0.5

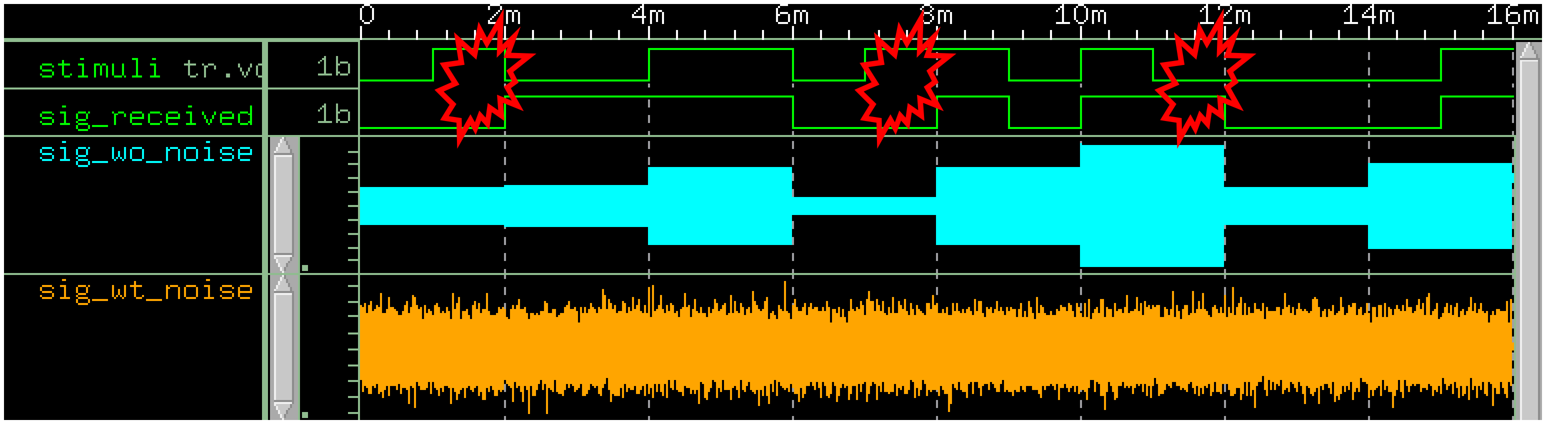


Parameters for simulation: (with strong white noise and 50% attenuation)

constl_dim = 16, n_va = 90.0, ampl_se = 20.0, ampl_re = 0.1, atten = 0.5

With higher transmission power, we can reproduce the correct signals again!

Simulation results (3)



Parameters for simulation: (with strong Gaussian noise and 50% attenuation)

constl_dim = 4, n_va = 90.0, ampl_se = 1.0, ampl_re = 1.0, atten = 0.5

Or, we can also slow down the transmission to improve the Bit Error Rate (BER).

Conclusions and future work

- It is convenient to model communication systems using the AMS building block library
  - Open Source building block library is published and can be downloaded from http://www.systemc-ams.org/
  - Already used by several companies for research purpose
- Extend the library with technology dependent information
  - Evaluation of area and power consumption
  - Enabling architecture exploration use cases

Thank you

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