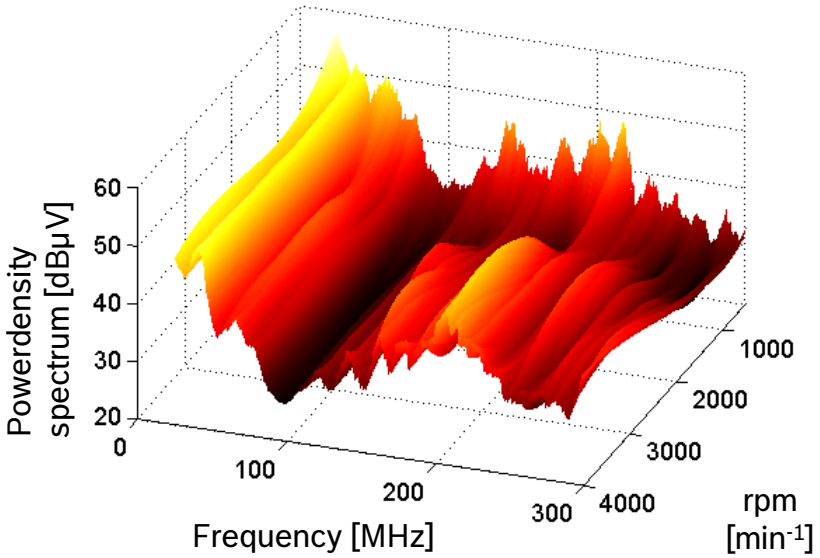
Impulse Noise Model

The following presentation was part of a research project at Robert Bosch on automotive Power Line Communications

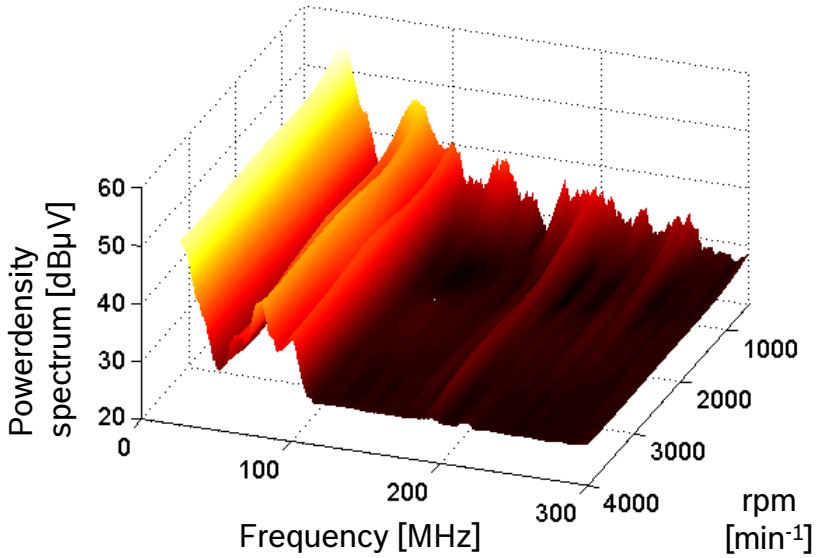
Presenter: Thomas Hogenmüller (Bosch)

Analysis of Impulsive Noise Environment (1)

Impulsive noise spectrum at battery mounted in engine compartement



Impulsive noise spectrum at fuse box in rear trunk

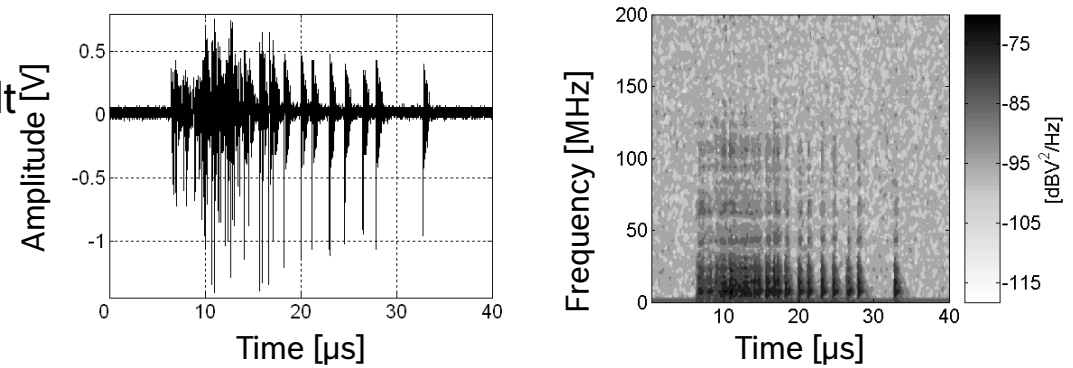


Different noise spectra at different locations within car

Analysis of Impulsive Noise Environment (2)

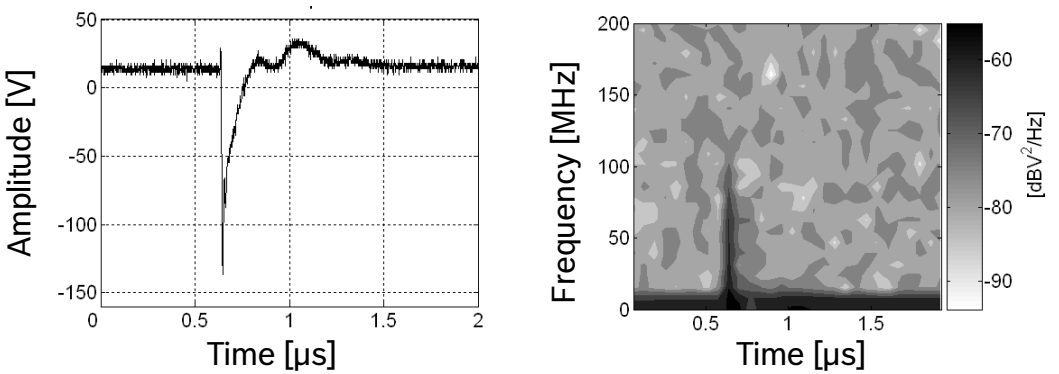
Typical measurement result of a manual switch operation in cars

(e.g. terminal 15 switch operation)



Simulation of the measurment with ISO-pulse

(e.g. test pulse 3a)



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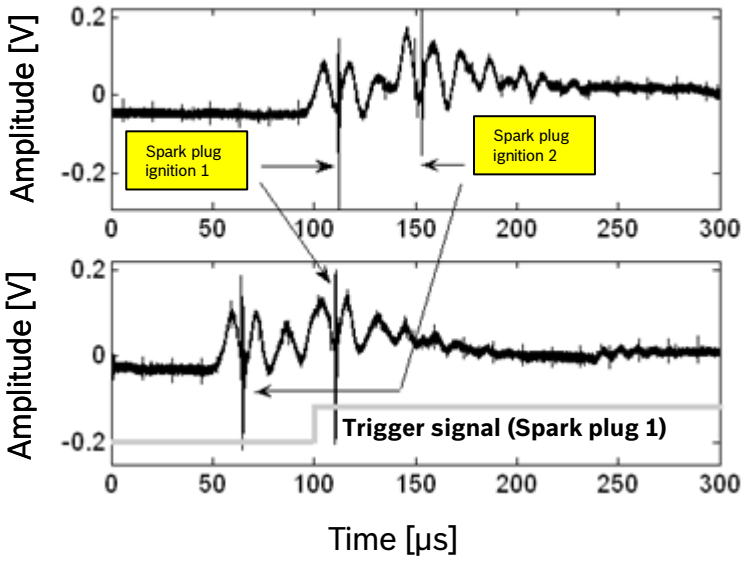
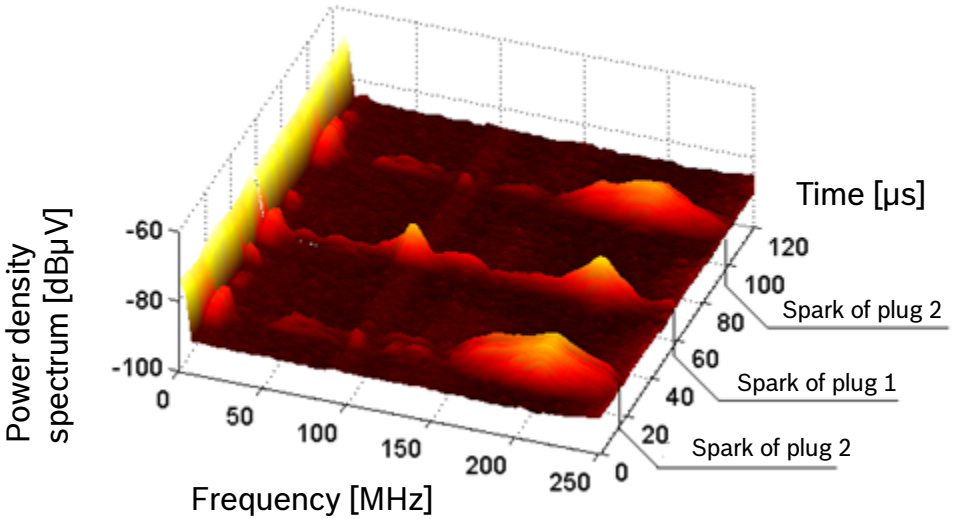
Analysis of Impulsive Noise Environment (3)

Time domain



Time-frequency domain



On the contrary to manual electrical switches, spark pulses produce disturbances up to high frequencies

→ ISO-pulses are not appropriate for simulation of automotive disturbances

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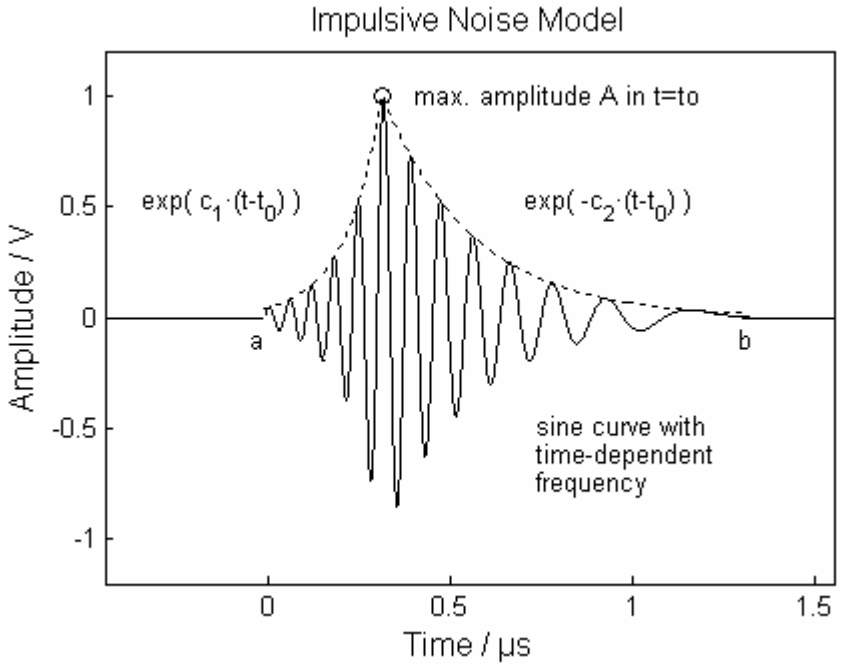
Conclusion of Impulsive Noise Analysis

- Below 100 MHz:
  - ISO pulses according to ISO7637 are applicable

- Above 100 MHz
  - Spark engine system is mainly responsible for pulse noise. Furthermore the highest level of pulse noise can be observed during engine idle.

Modelling of Impulsive Noise

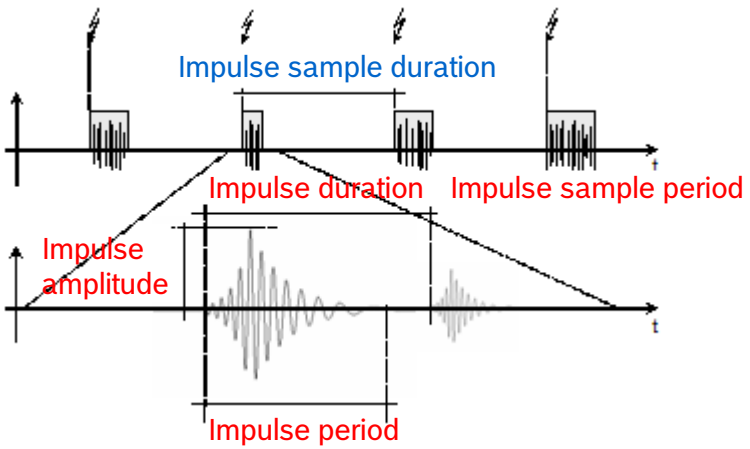
- Creation of a configurable impulsive noise model:



$$x_1(t) = \begin{cases} A \cdot \sin(2\pi \cdot f(t) \cdot t) \cdot \exp(c_1 \cdot (t - t_0)) & \text{if} \quad 0 \le t \le t_0 \\ A \cdot \sin(2\pi \cdot f(t) \cdot t) \cdot \exp(-c_2 \cdot (t - t_0)) & \text{if} \quad t_0 \le t \end{cases}$$

Automotive Impulsive Noise Modelling

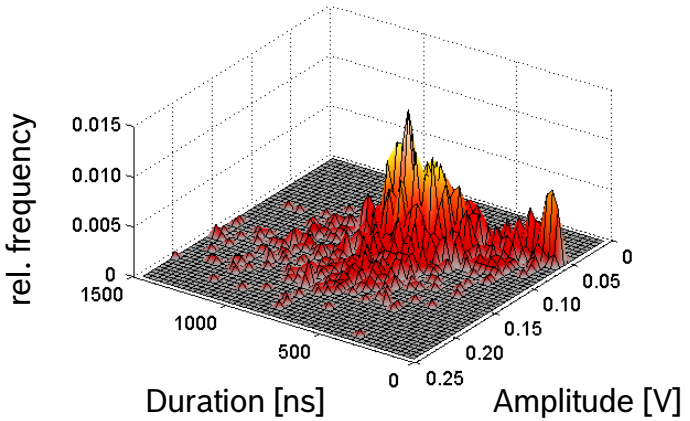
Periodic sequence of impulse pattern



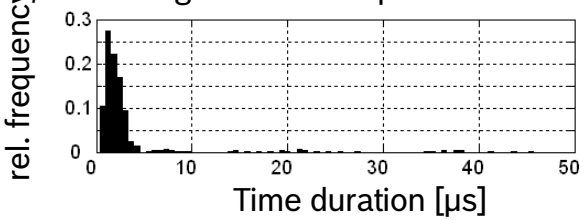
Aperiodic sequence of impulsive noise

→ Generation of stochastic random variables with Quantiltransformation

2D-Histogram of pulse duration and pulse amplitude

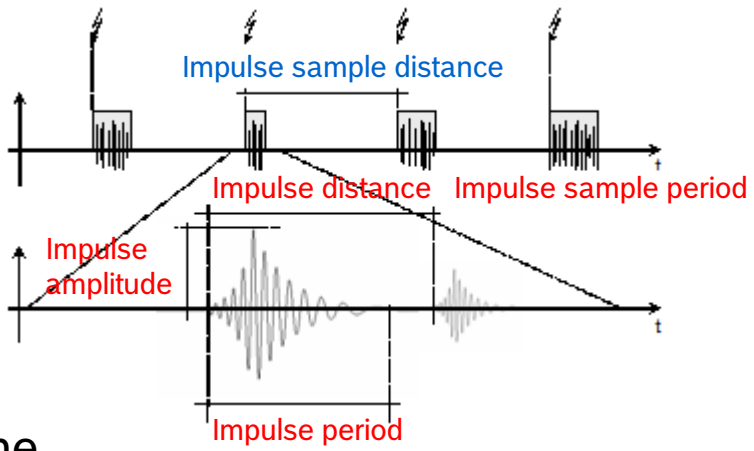


Histogramm des Impulsabstands



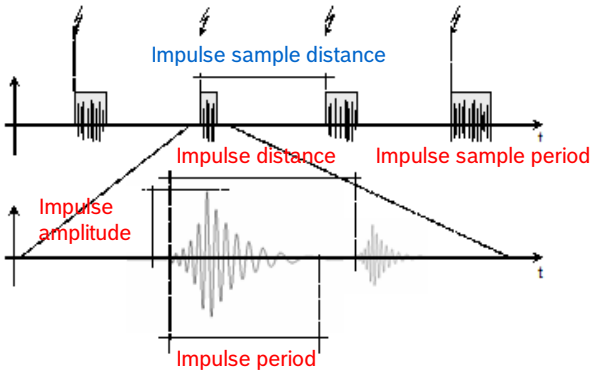
Spark Impulsive Noise (SIN) Parameter

- Spark impulsive noise can be defined with 5 parameters:
  - impulse distance,
  - impulse amplitude,
  - Impulse period and
  - Impulse sample distance
- which are stochastical values. The fifth parameter
  - Impulse sample period,
- is a deterministic value depending on the engine speed



Guideline for SIN Simulation

1. Generation of a switch signal depending on engine rotation speed for identification of a spark event (→ impulse sample distance and impulse sample period)
2. Rectangular signal overlay according to trigger time aperiodic disturbance pulses within one pulse pattern (→ impulse period and impulse distance)
3. Increase of background noise for the duration of an aperiodic impulse noise (→ impulse amplitude)



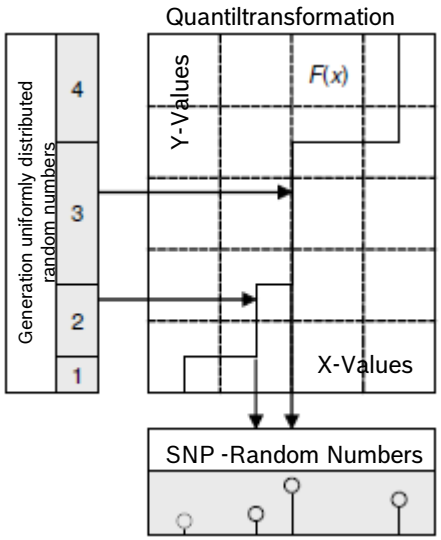
Quantiltransformation

- Distribution function

$$F_X(x) = \sum_{x_i \le x} f_X(x_i).$$

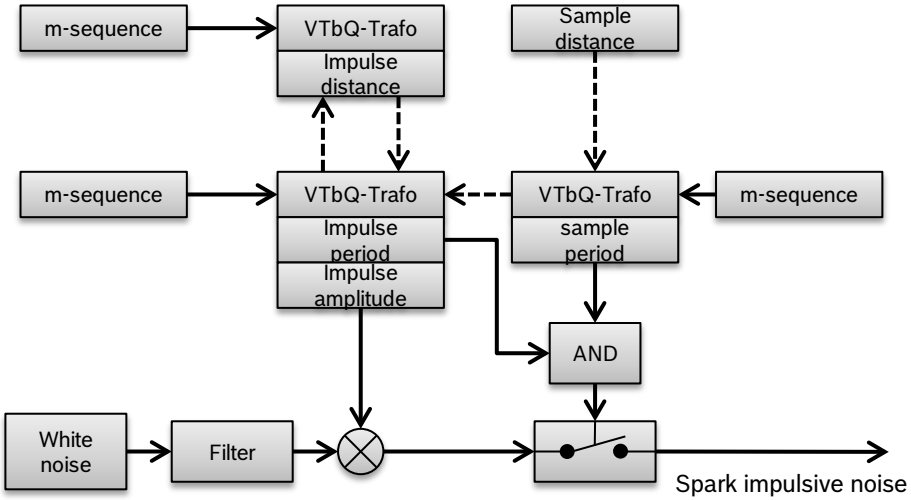
- Quantiltransformation

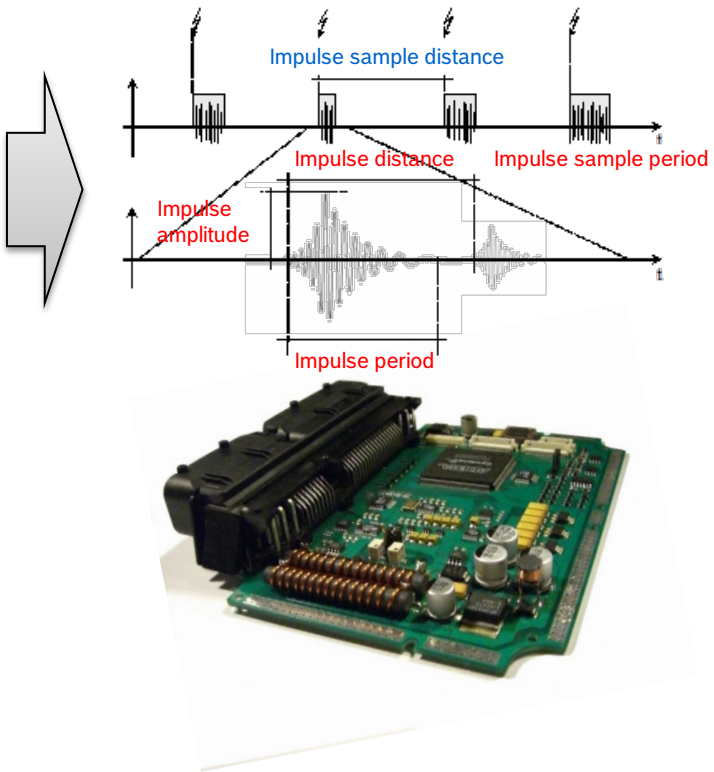
$$F_X^{-1}(u) = \inf\{x_i \in \mathbb{R} \mid F_X(x_i) \ge u\}.$$



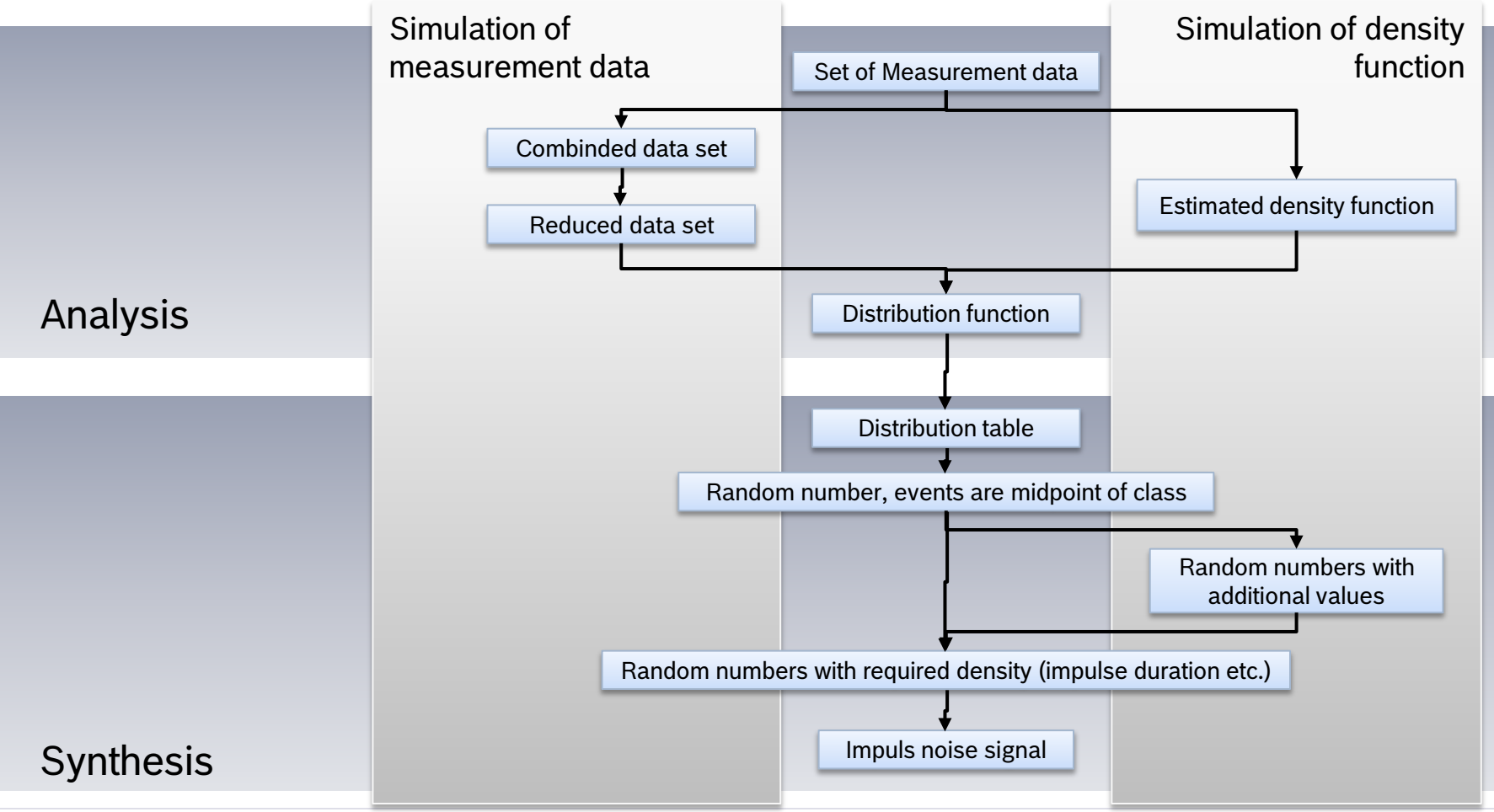
SIN Composition

- Block diagram of spark impulsive noise generator



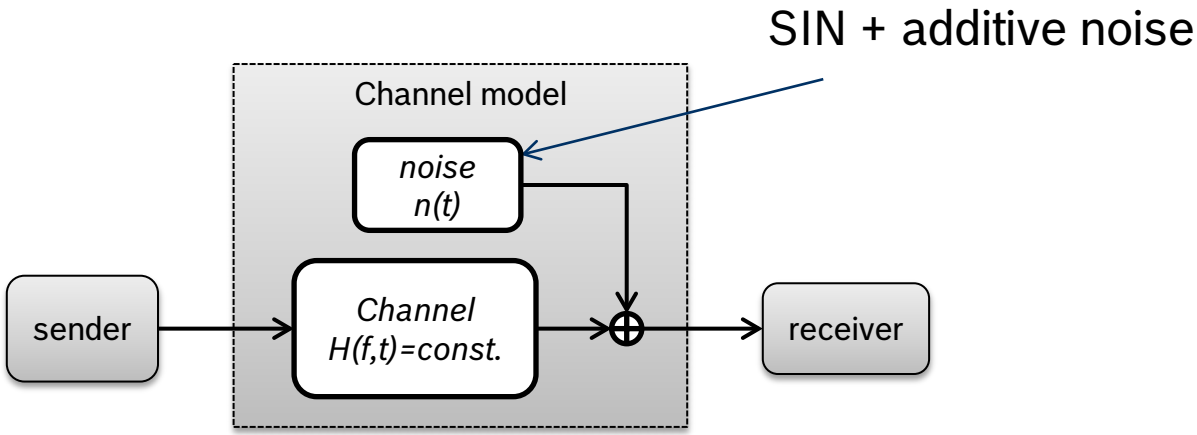


Flowchart for Impulse Noise Model



Frequency Response

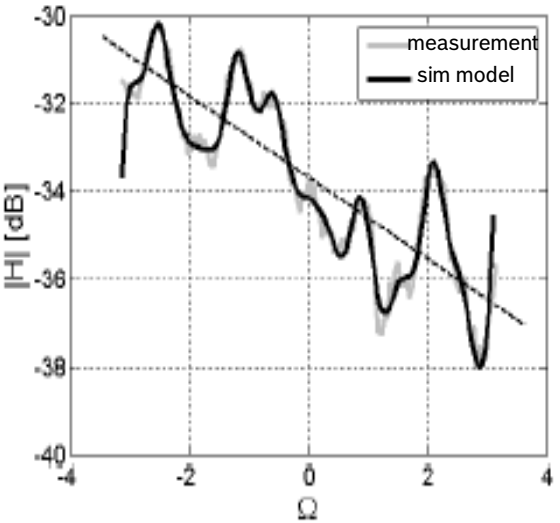
- Frequency range 100 MHz ≤ *f* ≤ *300 MHz*
- With center frequency *f0 = 200 MHz*
- *Sample frequency denoted as fa*



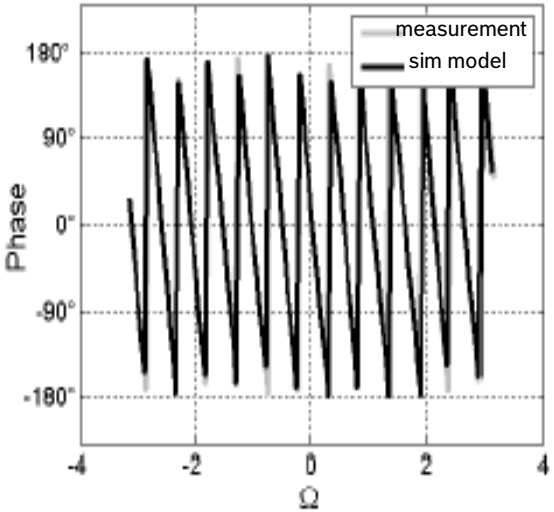
Frequency Response

- Frequency response is simulated with an IIR filter of order 12.
- Frequency band is normalized to center frequency f_0=200 MHz and sample frequency f_a=200 MHz

(a) Frequency response



(b) Phase response



Conclusion

- ISO pulses are not sufficient to model impulse noise in vehicle
- Main impulse noise source are spark plugs
- What's available:
  - Measurement data base for power lines
  - Mathematical description of noise
  - FPGA based emulator (for automotive use)

- PhD-Thesis of Thorsten Huck is available in German at Shaker publisher for 50 € (I try to find out if the relevant part can be published at IEEE)