LUND UNIVERSITY

Impulse-based 4 Gbps Radio Link at 60 GHz

Impulse Radio Circuit Implementation

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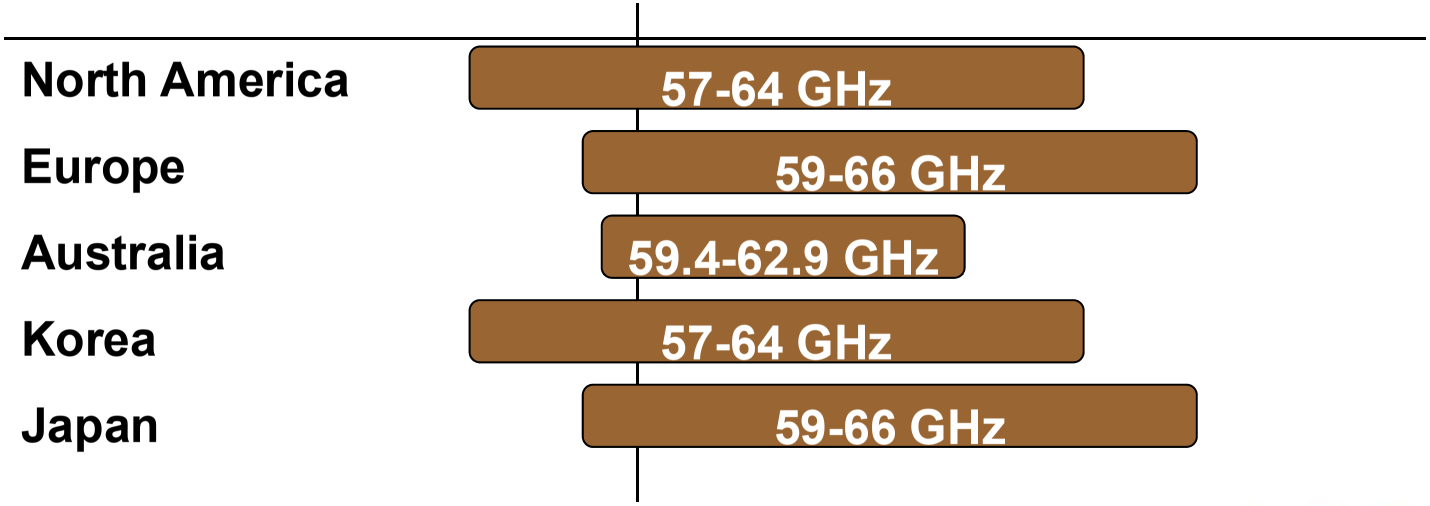
SSF HSWC
High Speed Wireless Communication

Outline

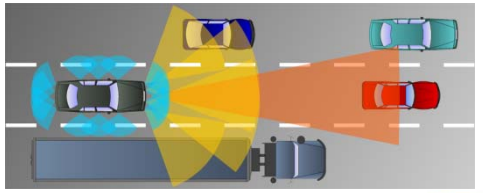
- Introduction
  - Research area
  - Implementation and fundamental performance
    - Wavelet generator
    - Super-regenerative oscillator
- Sub-nano pulses over the air
  - Radio link study
  - Impulse radar study
- 2nd generation of wavelet generators
  - Improved performance
  - Comparison

60 GHz – unlicensed bandwidth

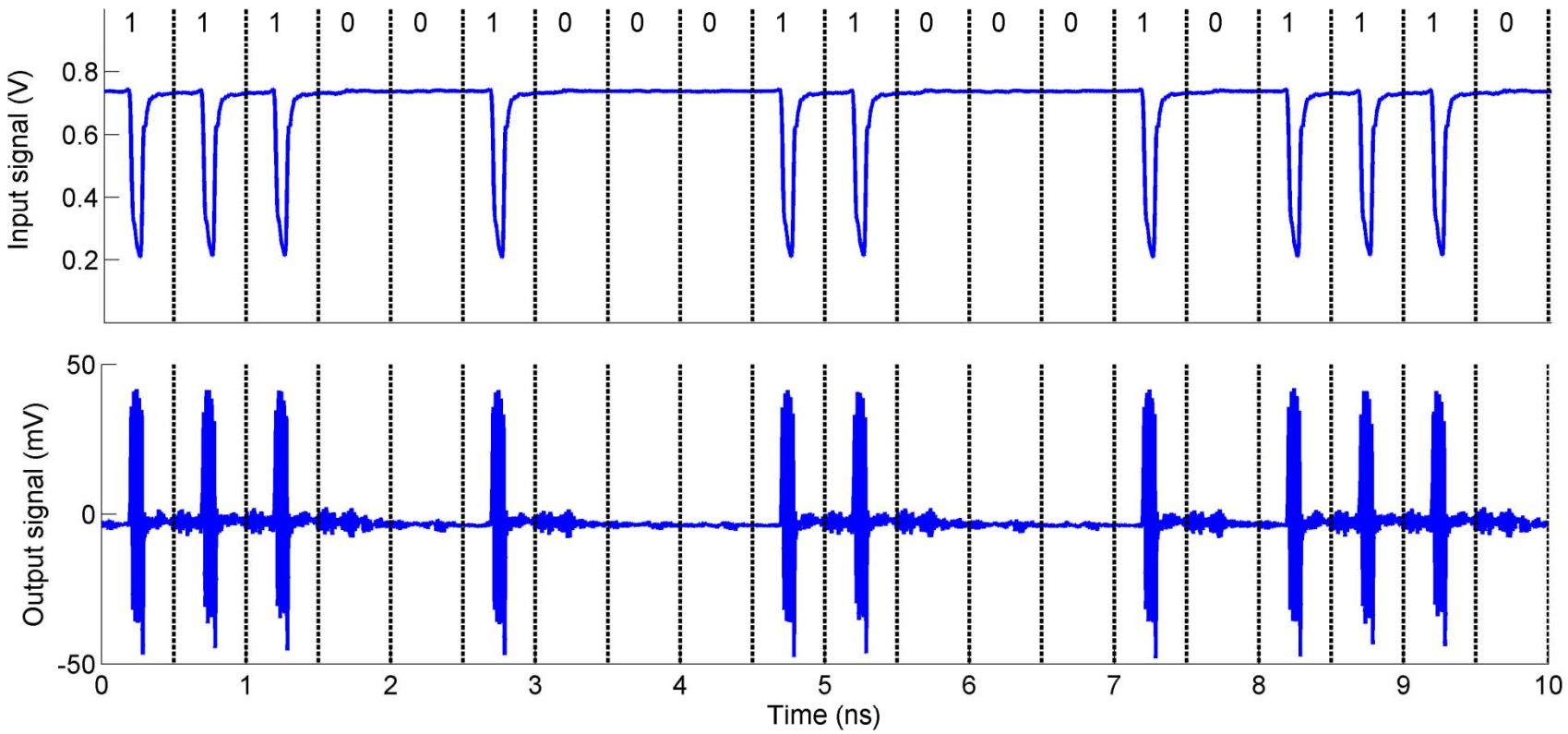


Applications

- -Wireless HDMI
- -Simple docking solutions
- -On chip communication
- -Radar, automotive and short range
- -Imaging
- -Localization



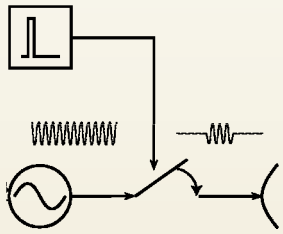
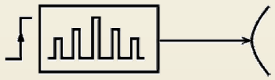
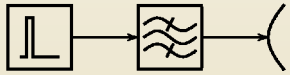
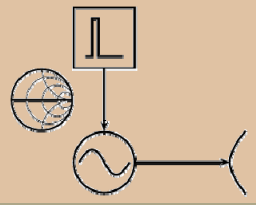
Impulse radio communication at 60 GHz



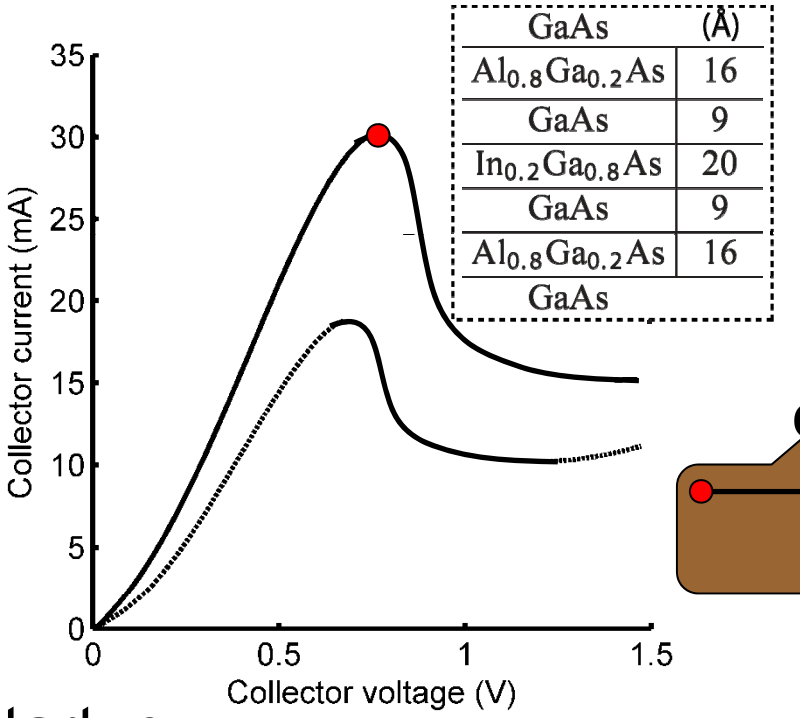
2 Gpulses/s On-off keying modulated wavelets

- 100 ps pulse length
- 162 mV_{pp} when losses embedded
- 59 GHz center frequency

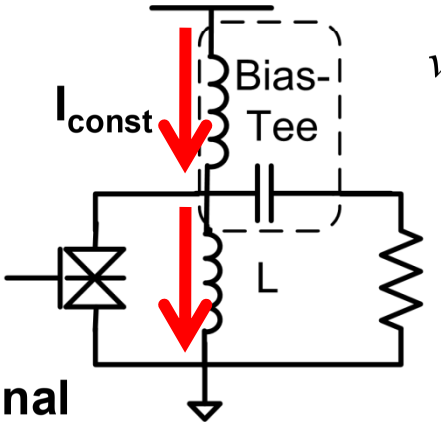
Impulse radio at 60 GHz

Method		η [%]	Pros/Cons
Mixer / RF Switch/ Switched PA		Low	Well-known devices Poor on-off ratio Noncoherent wavelets
Direct Digital		OK	External PA Frequency not stable
Matched Filter		Low	External PA Fixed output wave form
Pulsed oscillator		High	Coherent wavelets Possibility to exclude PA

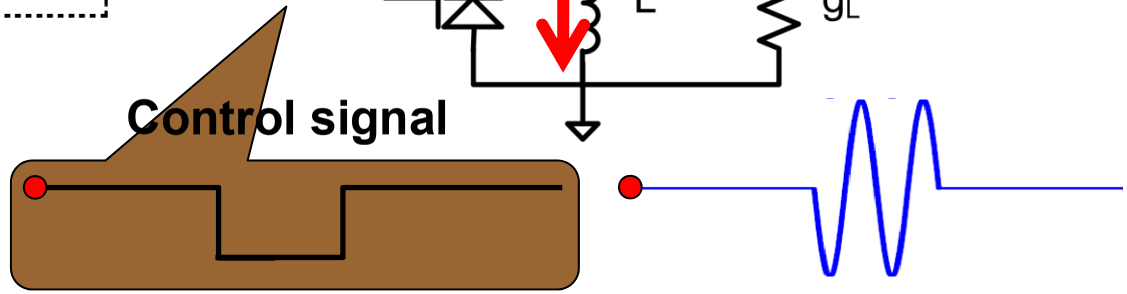
Gated tunnel diode wavelet generator



GaAs	(Å)
$Al_{0.8}Ga_{0.2}As$	16
GaAs	9
$In_{0.2}Ga_{0.8}As$	20
GaAs	9
$Al_{0.8}Ga_{0.2}As$	16
GaAs	



$$v(t) = L \cdot \frac{di}{dt}$$



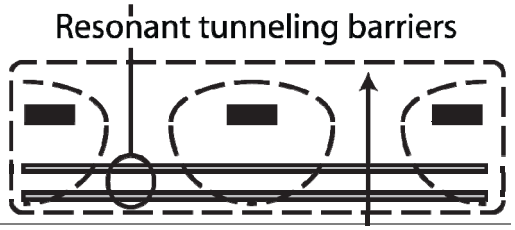
Startup

$$v(t) = \frac{2v_o}{\sqrt{1 + \left(\left(\frac{2v_0}{v(0)}\right)^2 - 1\right) e^{-c\omega_0 t}}} \cos(\omega_0 t + \varphi(0))$$

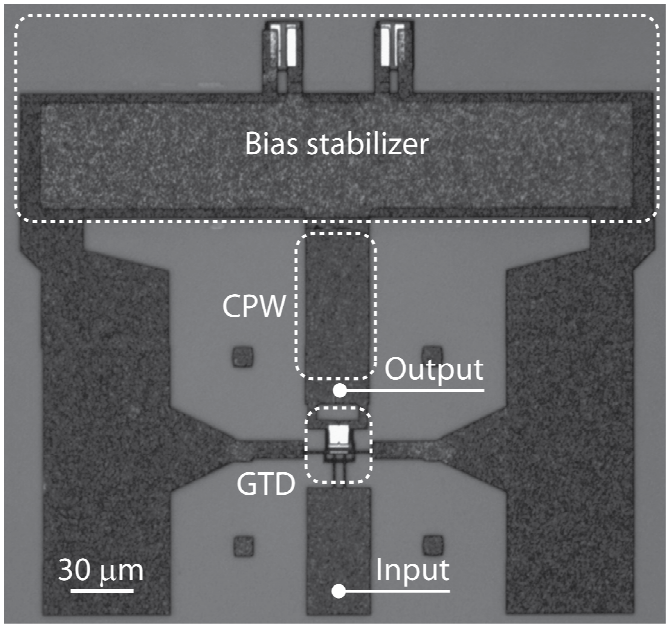
$$\epsilon = -\left(g_{oeq}(0)\sqrt{\frac{L_{eq}}{C_{eq}}} + \frac{1}{Q_{tank}}\right)$$

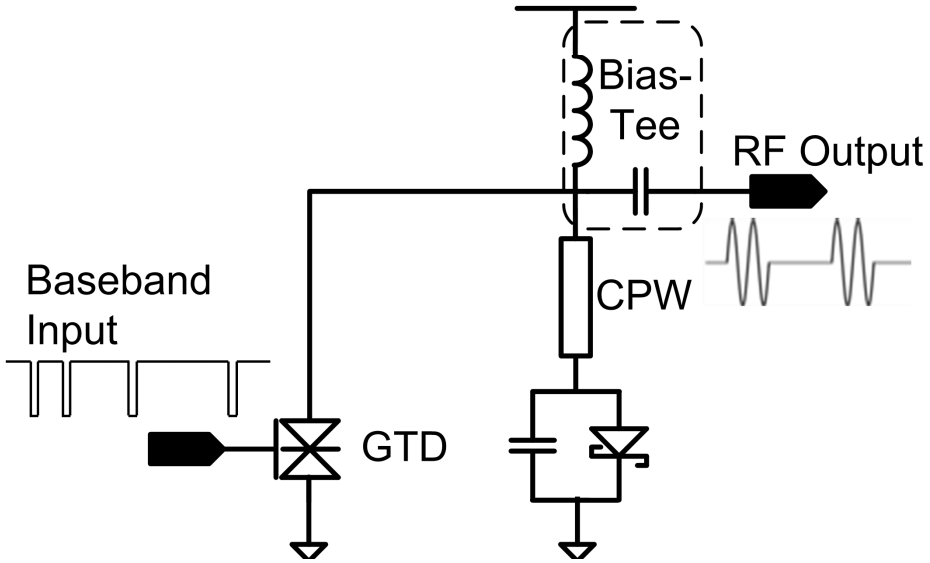
Decay

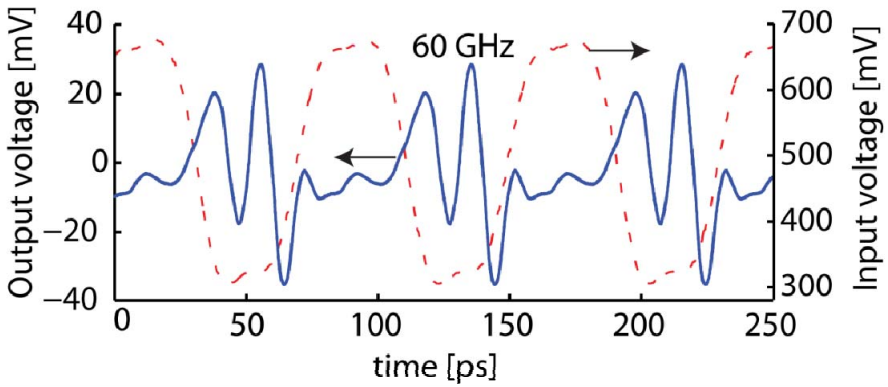
$$v(t) = V_{max} e^{\frac{-\omega_0}{2Q_{tankPDC}} t} \cos(\omega_0 t + \varphi(0))$$

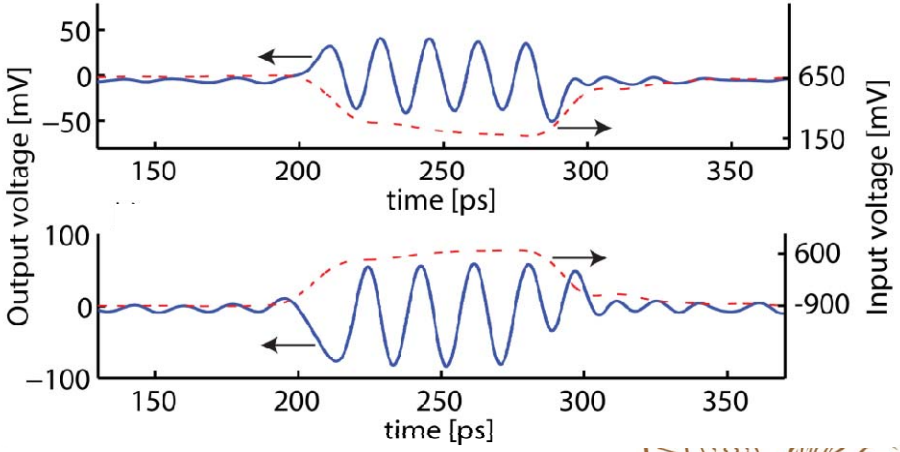


Gated tunnel diode wavelet generator

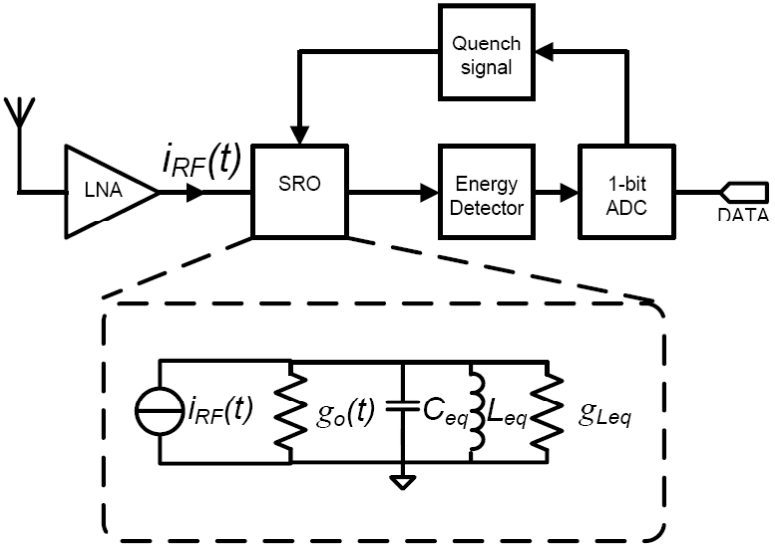








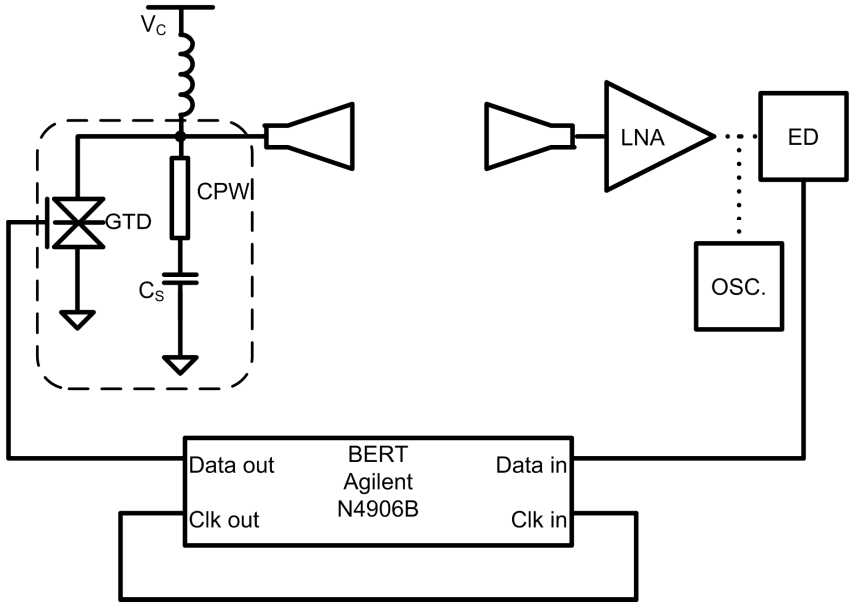
Gated tunnel diode super-regenerative osc.

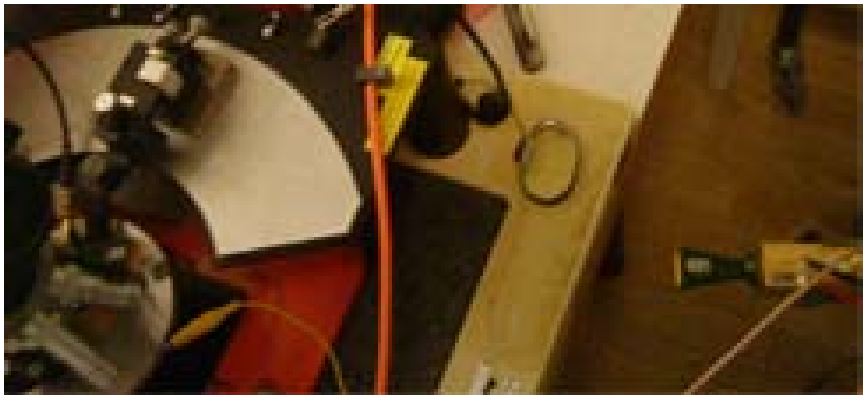


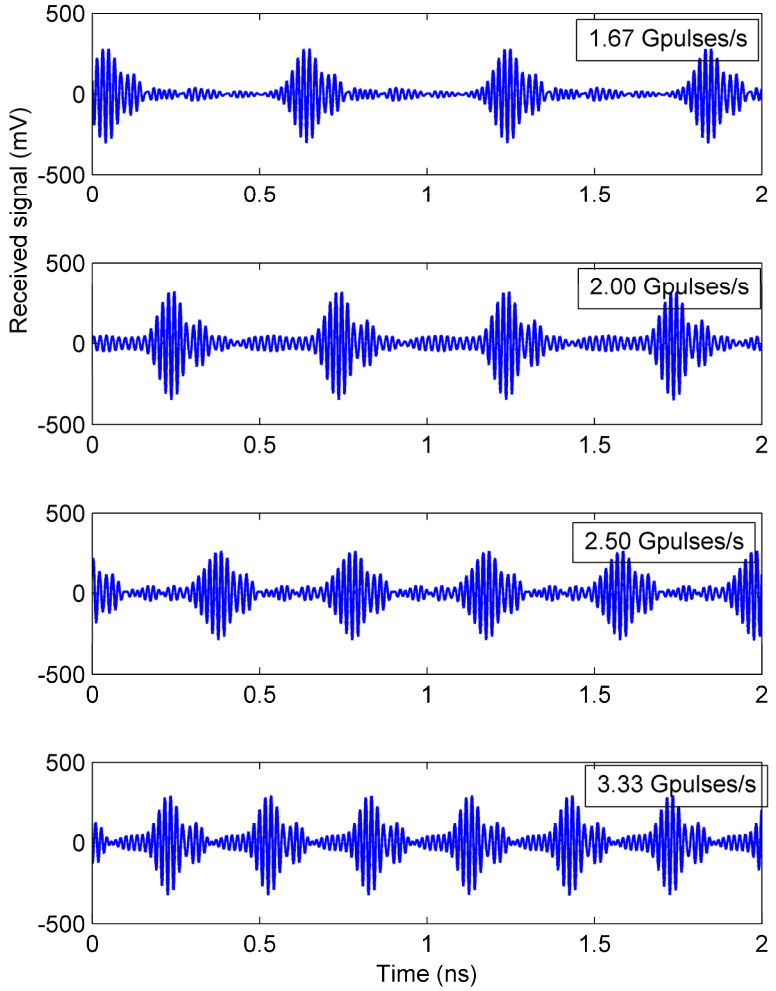
- 40 GHz
- 250 ps
- mean power -62.4 dBm
- 20.4 mV, 31.25 Msamples/s

High sampling rate SRO

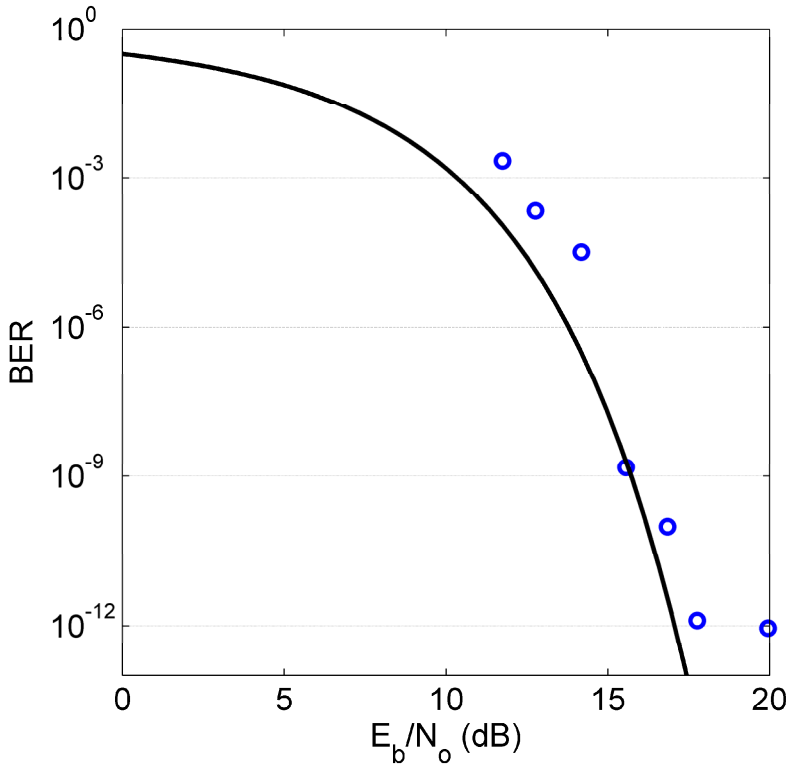
Wireless impulse radio link





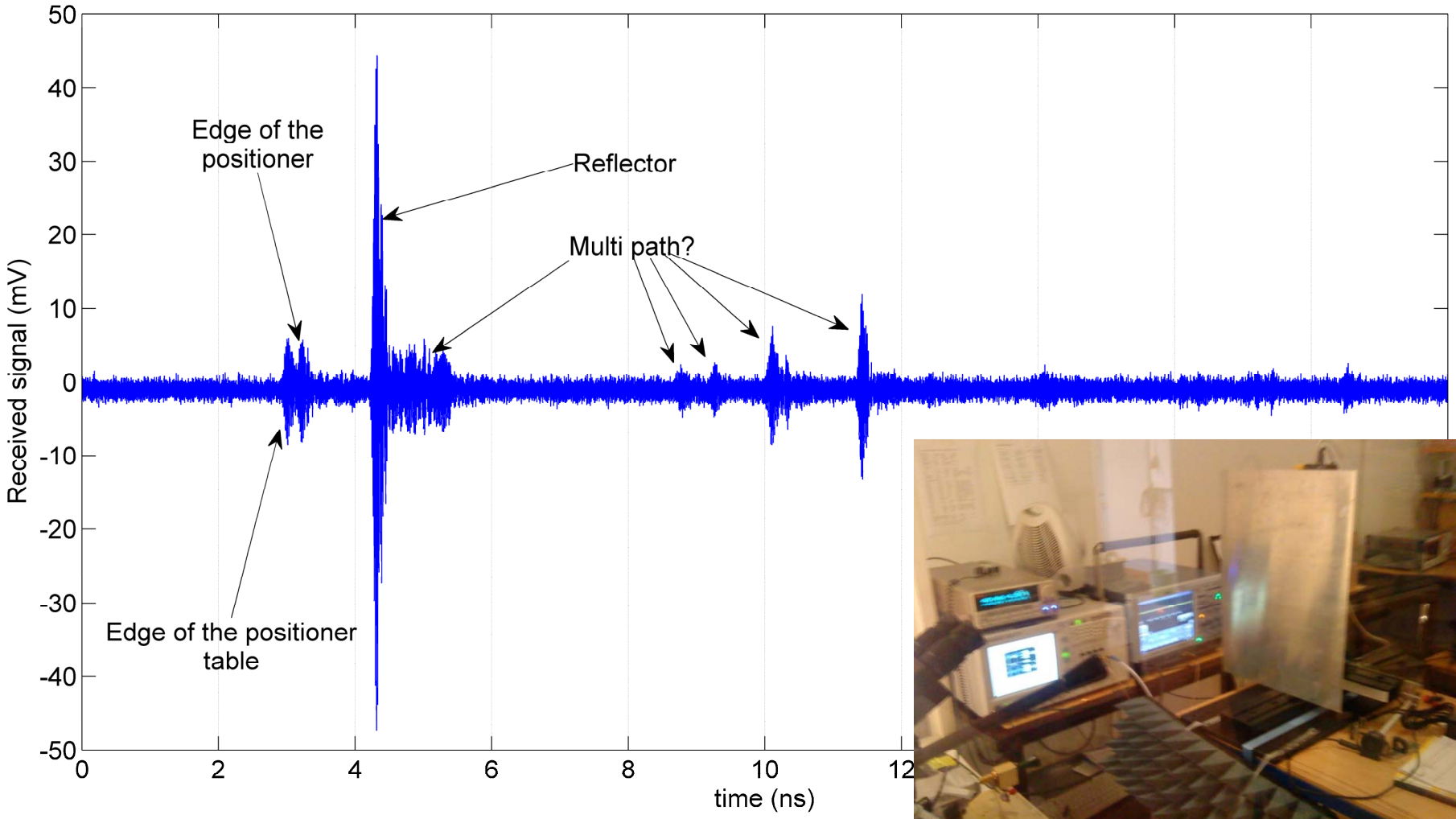


BER test for IR-OOK, 4 Gpulses/s

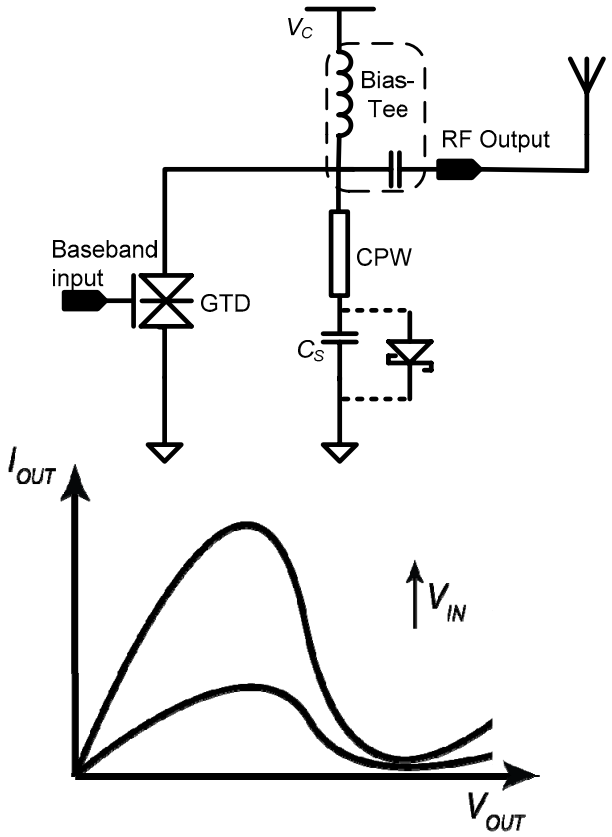


Tx peak output voltage	90	mV
Tx normalized energy per wavelet	0.2	pV^2/Hz
Bit rate	4	Gbps
Tx peak output power	-11	dBm
Tx mean output power	-23.9	dBm
Tx/Rx antenna gain	20	dBi
Wavelet center frequency	60	GHz
Path loss	62	dB
Implementation loss	2	dB
Rx bandwidth	22	GHz
Rx mean power	-47.7	dBm
LNA gain	30	dB
Noise figure	6	dB
Rx noise power per bit (N_o)	-64.6	dBm/bit
E_b/N_o	16.9	dB
ED conversion gain	10	mV/mW
Rx baseband signal	10.4	mV_{pp}
Measured BER	10^{-10}	

Impulse radar



2nd generation of wavelet generators



Good electrostatic control
But high off current

The gate adds paracitics to the fast RTD which limits the resonance
frequency

Other III-V combinations offer higher
output power

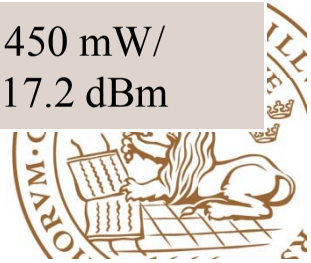
Change the processing towards lean production

2nd generation wavelet generators

-Output power increased
by a factor **5**
- Power consumption decreased
by a factor **5,** depends on PRF
-Measured frequencies up to
110 GHz, scalable!

Comparison

Group	Specifications of interest			
	Technology	*Technique*	*RF Pulse duration*	*DC/RF Power*
Our work	GaAs GTD	Direct conversion	30 ps	30 mW/ -10 dBm
Our work	InGaAs RTD/MOSFET	Direct conversion	Sub 100 ps	~5 mW/ 3 dBm
Y. Nakasha et al	InP HEMT	Filtering baseband pulse	80 ps	790 mW/ -22 dBm
M. Devulder et al	ST Microelectronics BiCMOS	RF switch	350 ps	150 mW/ 9 dBm
N. Deparis et al	CMOS-SOI	Pulsed ILO	500 ps	5 mW/ -5 dBm
A. Arbabian et al	0.13 um SiGe BiCMOS	Pulsed PA	26 ps (90 GHz)	450 mW/ 17.2 dBm



Summary and outlook

- Design and fabrication of wavelet generators for impulse radio applications ranging from 20 GHz to 110 GHz
  - Sub-period start-up time
  - Very fast quench
  - High peak output power
  - Low power consumption

- Future research goals
  - Wideband antennas and interface
  - The properties of the channel
  - Optimum receiver topology