COST Action TU1208

Civil Engineering Applications of Ground Penetrating Radar

This lecture is part of the TU1208 Education Pack

Localization of people based on GPR detection of vital signs

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Lecture Layout (1/2)

- Introduction to the topic of the lecture
- UWB radar systems for the detection of vital signs
- Classification of the main types of person movements
- Detection of respiratory movement

(continues in the next slide....)

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Lecture Layout (2/2)

- Main steps of radar signal processing for the detection of a static person:
  - Raw data preprocessing
  - Increasing the SNR
  - Background subtraction
  - Enhancement of target echo
  - Target detection
  - Time-Of-Arrival estimation
  - Target localization
- Example
- Conclusions and References
- Biographies and contact details of the Authors

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Introduction

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Introduction

- A social trend at the beginning of 21st century:
  - Density of population is increasing in towns and urban agglomerations.

- Impact
  - There is a higher density of people during disasters (earthquakes, tsunamis, earth slides, avalanches, building collapses), which results in a higher number of injured persons.

- Needs, where GPR can be useful
  - Disaster surviving victim is the most critical for the survivor lifesaving. GPR can help to find the victims.

Introduction

- A social trend at the beginning of 21st century:
  - Criminality is growing and political tensions are causing terrorism.
- Impact
  - Suitable military and security operations are defined and carried out; law enforcement operations take place.
  - Monitoring of critical environments (such as reservoirs and power plants) is necessary, to detect unauthorized intrusions.
- Needs, where GPR can be useful
  - GPR represents a useful technological and technical solution, to support military and security operations, and to monitor critical environments.

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Introduction

- A social trends at the beginning of the 21st century:
  - Growth of the percentage of elderly people.
- Impact
  - Monitoring of elderly people at home to detect unexpected emergency events (such as fall down and unconsciousness, but also evil intruders).
- Needs, where GPR can be useful
  - Intruder detection and localization.
  - Detection of emergency events with ambient assisted living programs.

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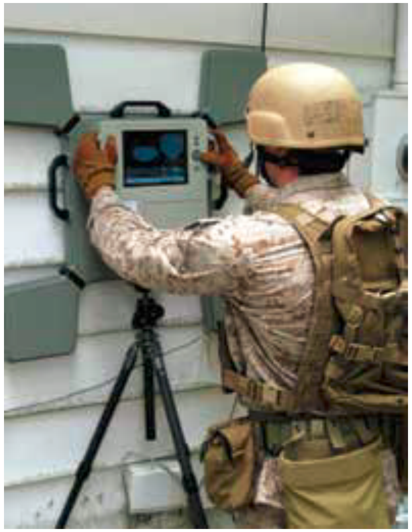
Introduction

- The general aim: Saving human beings and increasing their safety in emergency events.

- The main idea: using GPR to detect, localize and track living human beings in complex scenarios.



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Introduction

- Smart sensor networks are crucial for the achievement of the purposes described in the previous slides. Such networks include: cameras, infrared and ultrasonic sensors, microphones, LIDARS, narrowband radars, and more… but also UWB sensors, such as those used in GPR systems.

- UWB sensors present several benefits: they work during day and night, in all-weather conditions (rain, snow, dark dense smoke and presence of other particles, fog), they can detect moving people located behind obstacles, and they can detect vital signs of persons (breathing and heart beating). Additional benefits are: UWB sensors allow imaging of static objects and subsurface imaging, as well as impedance spectroscopy.

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UWB radar systems for the detection of vital signs

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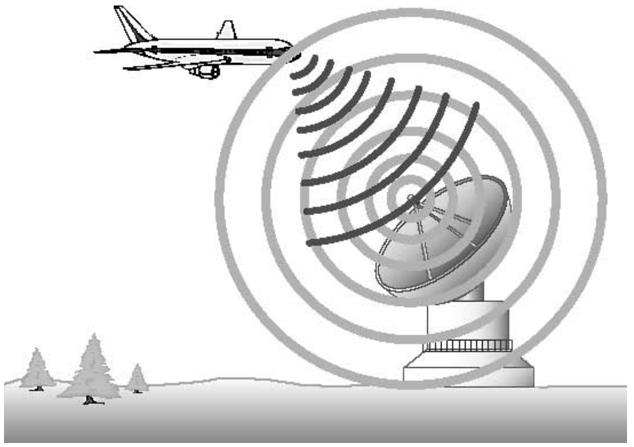
UWB radar systems: basic concepts

- UWB radar (RAdio Detection And Ranging) systems emit UWB electromagnetic signals.
- Most GPR systems are UWB radar systems.



- Main properties of UWB radar systems:
  - Absolute bandwidth of emitted electromagnetic signal > 500 MHz
  - Fractional bandwidth of emitted electromagnetic signal > 0.2
  - Resolution: 1 cm – 3 cm
  - Range: 10 m – 100 m
  - Emitted power: 1 mW – 10 mW

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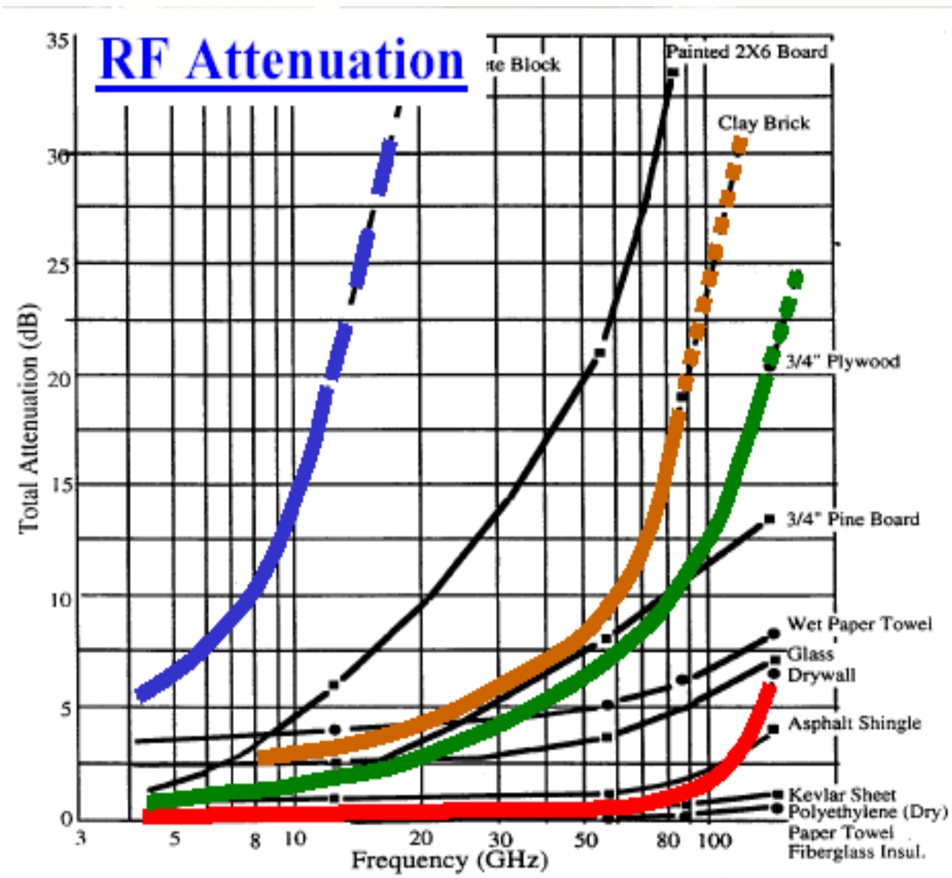
UWB radar systems: basic concepts

- Electromagnetic-signal attenuation versus frequency



Operational bandwith for through-wall localization of human beings: 0-5 GHz.

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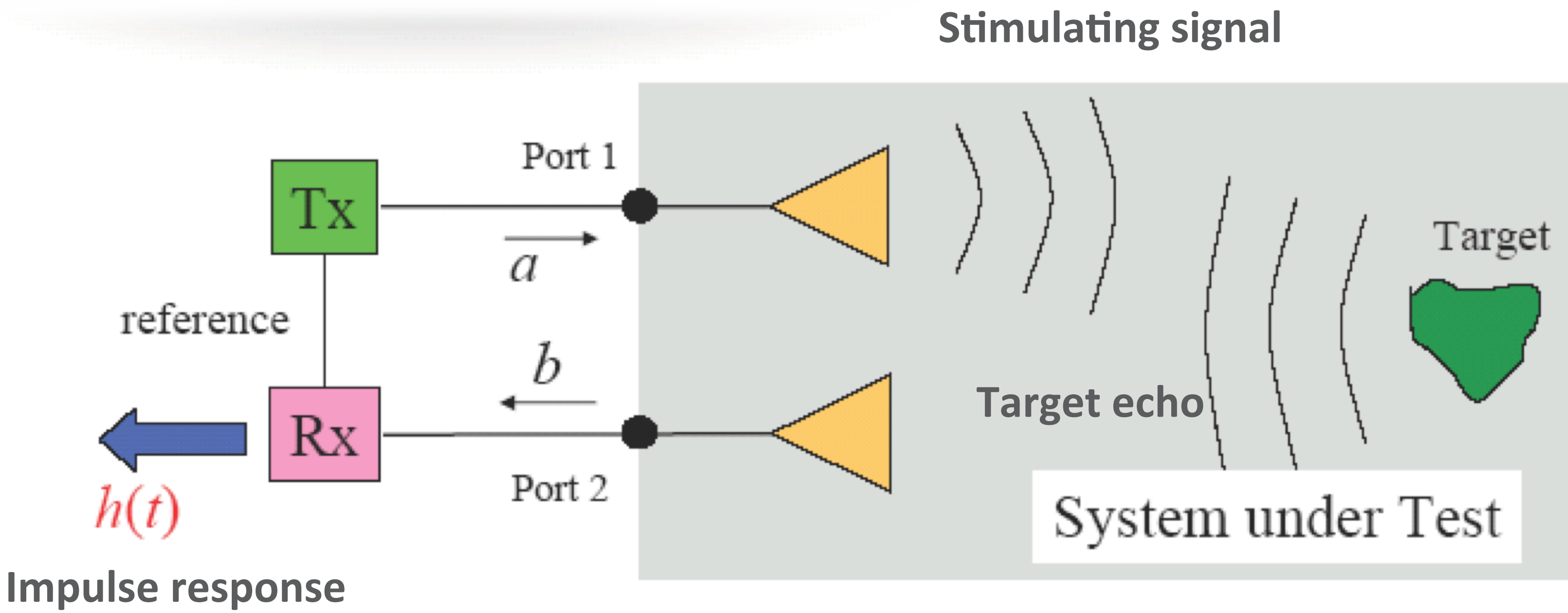
UWB radar systems: basic concepts



- Raw radar signals/data are impulse response(s) of the environment. The electromagnetic signal emitted by the radar propagates from the transmitting to the receiving antenna of the radar and is influenced by the physical and geometrical properties of the environment.

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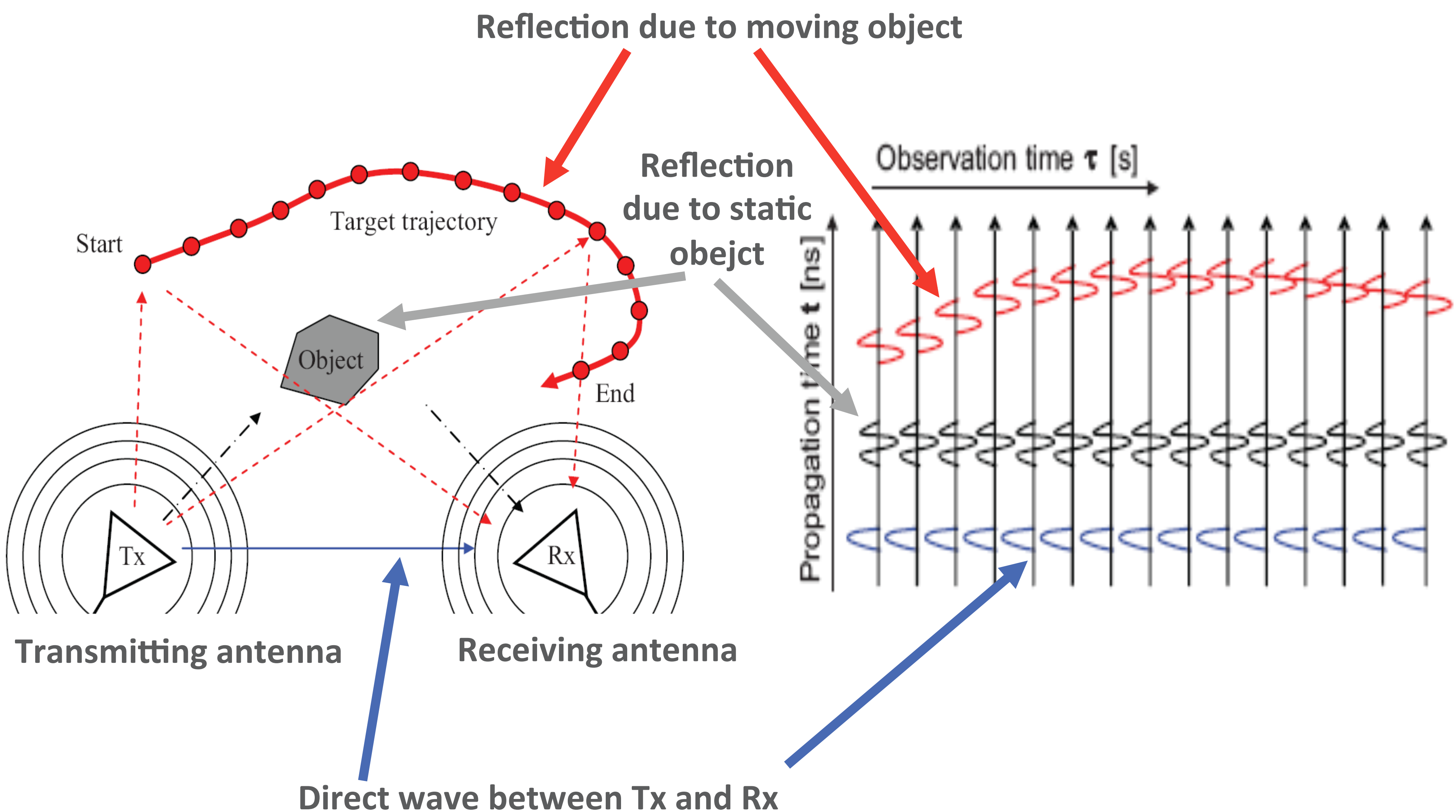
UWB radar systems: basic concepts



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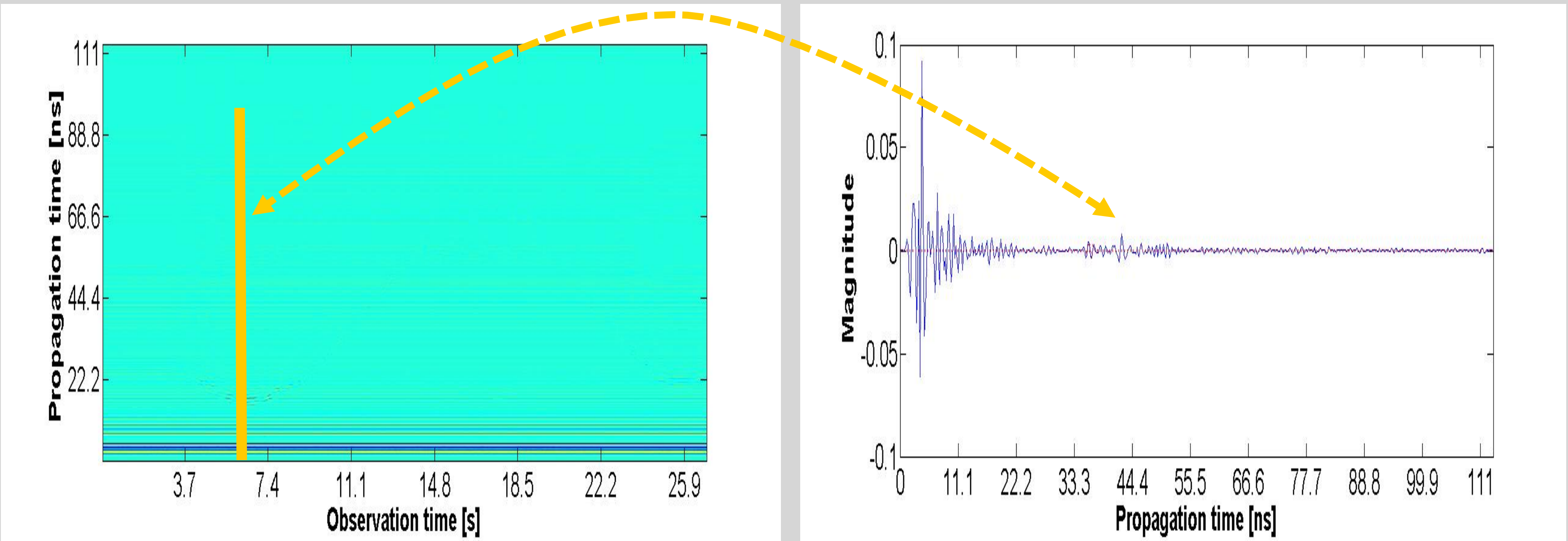
UWB radar systems: basic concepts



- A radargram is a set of impulse responses of the environment collected in different spatial points (for example, along a linear profile).

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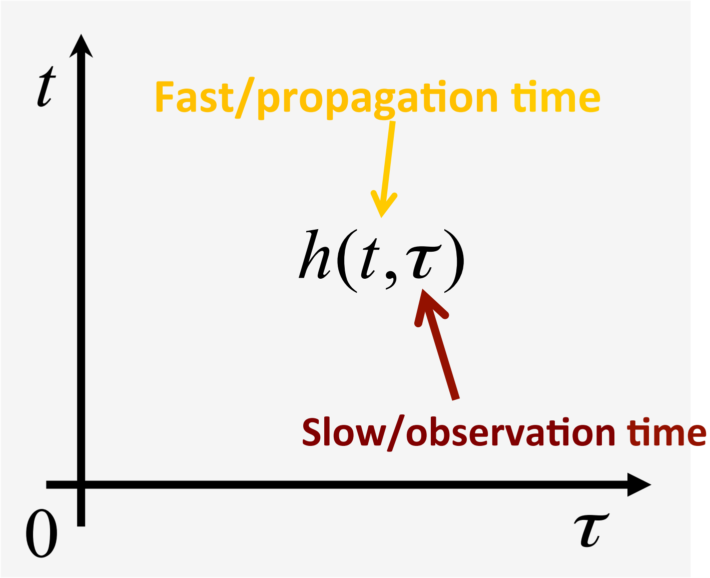
UWB radar systems: basic concepts

- An impulse response includes:
  - Direct wave
  - Target echoes
  - Noise
  - Clutter
  - Narrow-band interference



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Classification of the main types of person movements

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Classification of person movements

Person type	Description	Example	Basic principle of detection
Moving person I	Person moving within the monitored area in such a way that his/her coordinates are changing	Walking, running, crawling persons	Detection of time changes of impulse responses acquired by the radar along the observation (slow) time axis
Moving person II	Moving person, but his/her coordinates do not change	Persons whose limbs (legs, hands, head) or trunk are in motion	Detection of time changes of impulse responses scanned by the radar along the observation (slow) time axis
Static person	"Motionless" person whose coordinates are not changing	Sleeping persons, unconscious persons, person being liable as surety, etc.	Detection of person vital signs such as respiratory motions or heart beating
Person changing nature of his/her movement	The same person is static in some instants and moving in other instants	Persons walking with some stops	Joint detection of time changes of impulse responses and person vital signs

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Detection of respiratory movement

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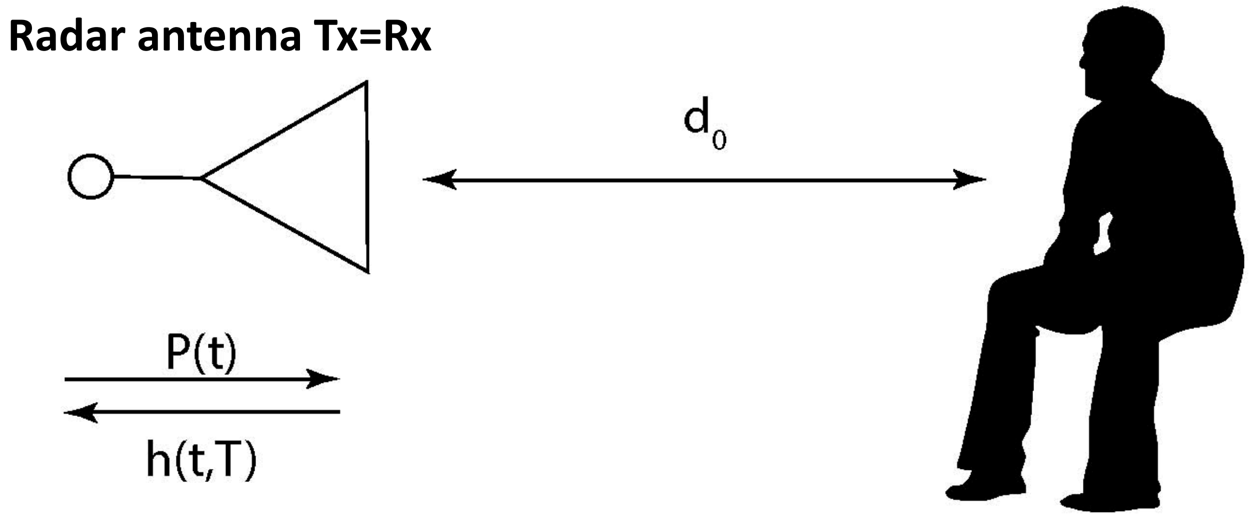
Respiratory movement detection



Emitted signal is scattered by the target

Pulse compression method

Transmitted Signal $\mathrm{p}(t,\tau)$ → Received Signal $r(t,\tau)$ → Impulse Response $h(t,\tau)$

$$h(t,\tau) = \sum_{i=1}^{N} A_i p(t,\tau) + A_0 p\big(t - t_d(\tau)\big) + n(t,\tau) = h_{bn}(t,\tau) + h_0(t,\tau) + n(t,\tau)$$

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Respiratory movement detection

- Raw signal model

$$h(t,\tau) = \sum_{i=1}^{N} A_i p(t,\tau) + A_0 p\big(t - t_d(\tau)\big) + n(t,\tau) = h_{bn}(t,\tau) + h_0(t,\tau) + n(t,\tau)$$

$h(t,\tau)$	Impulse response	
A_i	Path gain of the i-th signal path	
$p(t,\tau)$	Transmitted signal	
A_0	Reflections of the radar signal by static objects	
$t_d(\tau)$	Time delay (associated with vital signs) corresponding to the time-of-arrival (TOA) of a static person	$c = 3 \times 10^8 ms^{-1} t_d(\tau) = \frac{2d(t_0,\tau)}{c}$
$n(t,\tau)$	Gaussian noise	
$h_{bn}(t,\tau)$	Stationary clutter	$h_{bn}(t,\tau) = \sum_{i=1}^{N} A_i p(t - t_i)$
$h_0(t,\tau)$	Component due to static person	$h_0(t,\tau) = A_0 p(t - t_d(\tau))$

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Respiratory movement detection

- Raw signal model
  - Periodic changes of the distance person-radar antenna due to periodical chest movement (breathing and heartbeats)

$$d(t_0,\tau) = d_0 + m_b(\tau) + m_h(\tau) = d_0 + m_{b0}\, sin(2\pi f_b \tau) + m_{h0} sin(2\pi f_h \tau)$$

$m_{b0,}\ m_{h0}$	Breathing and heartbeat amplitude	
f_b, f_h	Breathing and heartbeat frequency	$f\_b\ \epsilon B = <0.2Hz,0.7Hz>$ Changes of the distance person-radar antenna due to breathing
$m_b(\tau)\ m_{b0}\, sin(2\pi f_b \tau)$ $m_{b0}\sin(2\pi f_h \tau)$		Changes of the distance person-radar antenna due to breathing
$t_d = \frac{2dt_0}{c} + \frac{2m_{b0}}{c}\sin(2\pi f_b \tau)$	Changes of TOA due to breathing	Changes of the distance person-radar antenna due to heartbeat

Peak-to-peak chest motion due to respiration in adults: 0.4-1.2 cm.

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Respiratory movement detection

- Raw signal model

$$h(t,\tau) = \sum_{i=1}^{N} A_i p(t - t_i) + A_0 p\left(t - \left[\frac{2d(t_0)}{c} + \frac{2m_b}{c}\sin(2\pi f_b \tau)\right]\right)$$

The signal $h_0(t,\tau)$ can be expanded in Taylor series around $t = t_0 = \frac{2d}{c}$ as follows

$$h_0(t,\tau) = A_0 p(t - t_0) + A_0 p'(t - t_0)[-m_b \sin(2\pi f_b \tau)] + \frac{1}{2} A_0 p''(t - t_0)[-m_b \sin(2\pi f_b \tau)]^2 + \cdots$$

$A_0 p(t - t_0)$	Average reflection of the body
$A_0 p'(t - t_0)[-m_b \sin(2\pi f_b \tau)]$	Main contribution of the breathing signal
$\frac{1}{2} A_0 p''(t - t_0)[-m_b \sin(2\pi f_b \tau)]^2 + \cdots$	Contribution of the breathing signal due to higher harmonics

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Respiratory movement detection

- **Conclusion 1**
  - The components of the impulse response $h(t,\tau)$ due to the respiratory movement of a person ($h_0(t,\tau)$) can be regarded as a periodic signal with the fundamental harmonic f_b (breathing frequency)
- **Conclusion 2**
  - A static person can be detected based on the detection of periodical signal components in a radargram. This correspond to a periodical movement with a frequency $f_b \in B$ with regards to the slow-time variable (τ) for a constant fast-time instant ($t = t_0$)
- **Conclusion 3**
  - The distance of a person from the radar antenna can be estimated as $d_0 = \frac{ct_0}{2}$

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Respiratory movement detection

Step	Basic idea / steps of motionless person localization
Step 1	Detection of periodical components in the radargram, corresponding to a periodical movement of human chest in the frequency band <0.2 Hz, 0.7 Hz> *Note: The frequency components considered in Step 1 have to be detected by analysing the radargram under the assumption of constant propagation time.*
Step 2	Estimation of the time-of-arrival (TOA) of the detected target *Note: TOA corresponds to the time instant of the fast-time when the target is detected.*
Step 3	Person localization by multilateration methods *Note: The UWB radar has to be equipped with at least one Tx and 3 Rx antennas.*

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Main steps of radar signal processing for the detection of a static person

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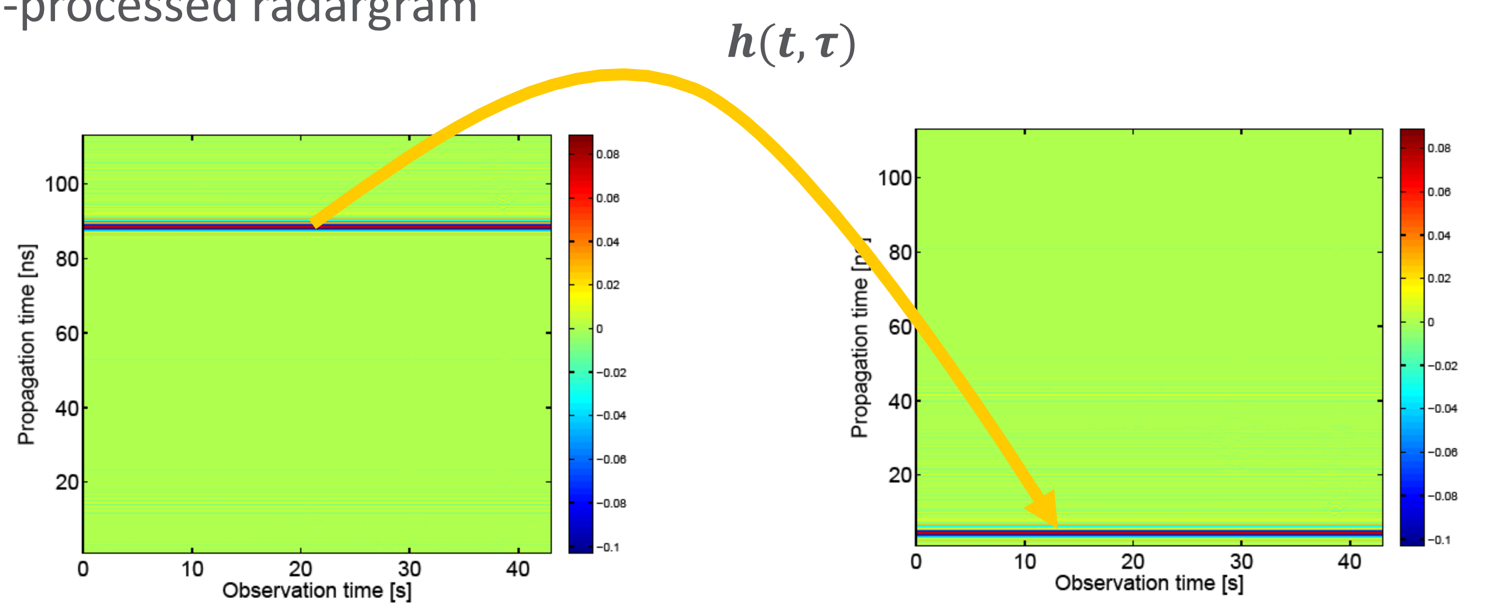
Steps (phases) for the localization of a static person

- Raw radar data preprocessing
- Increasing of useful signal (target echo)-to-noise ratio (SNR)
- Background subtraction
- Enhancement of target echo
- Target detection
- Time of arrival (TOA) estimation (TOA estimation + substitution of a distributed target with a single point target)
- Target localization (trilateration method implemented, e.g., by means of a direct localization method)

Phase 1: Raw radar data preprocessing

- **Purpose**
  - UWB radar system calibration
- **Methods**
  - Calibration by using a metal plate (calibration measurement with a metal plate in a defined position)
  - Zero-time setting based on the use of the signal cross-talk
- **Outcome**
  - Pre-processed radargram



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Phase 2: Increasing the SNR

- **Purpose**
  - Improvement of target echo-to-noise ratio (SNR)
- **Assumptions**
  - Noise is a stationary white Gaussian signal, due to antennas and electronic circuits of the radar
  - Components of impulse responses due to a target and clutter can be regarded as the same within the interval $T_\tau \in <\tau_1, \tau_2>$
- **Methods**
  - Method of impulse response averaging (usually hundreds impulse responses)
- **Outcome**
  - Radargram with higher SNR (a higher SNR allow to achieve a higher probability of target detection)

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Phase 2: Increasing the SNR

- **Purpose**
  - Improvement of target echo-to-noise ratio (SNR)
- **Basic idea**

$$h(t,\tau) = s(t,\tau) + c(t,\tau) + n(t,\tau)$$

$$E[h(t,\tau)] = E[s(t,\tau) + c(t,\tau) + n(t,\tau)] = E[s(t,\tau) + c(t,\tau)] + E[n(t,\tau)]$$

$$E[n(t,\tau)] \to 0$$

$$E[h(t,\tau)] \to s(t,\tau) + c(t,\tau)$$

$$E[h(t,\tau_2)] \approx \frac{1}{\tau_2 - \tau_1 + 1} \sum_{\tau=\tau_2-\tau_1}^{\tau_2} h(t,\tau) \approx s(t,\tau_2) + c(t,\tau_2) + n_0(t,\tau_2)$$

The residual white noise

Phase 3: Background subtraction

- **Purpose**
  - Improvement of target echo to-clutter ratio (SCR)
- **Assumption**
  - Clutter is a stationary signal
- **Methods**
  - Mean, median
  - Adaptive exponential averaging Gaussian background
  - Gaussian mixture method
  - Moving target indicator (e.g., using FIR filtering)
  - Prediction
  - Principal component analysis
  - Mean subtraction and linear-trend subtraction
  - Exponential averaging method
- **Outcome**
  - Radargram with subtracted background
- **Comments**
  - For the detection of a static person the background subtraction method needs a longer memory, for a moving person shorter memory shall be used

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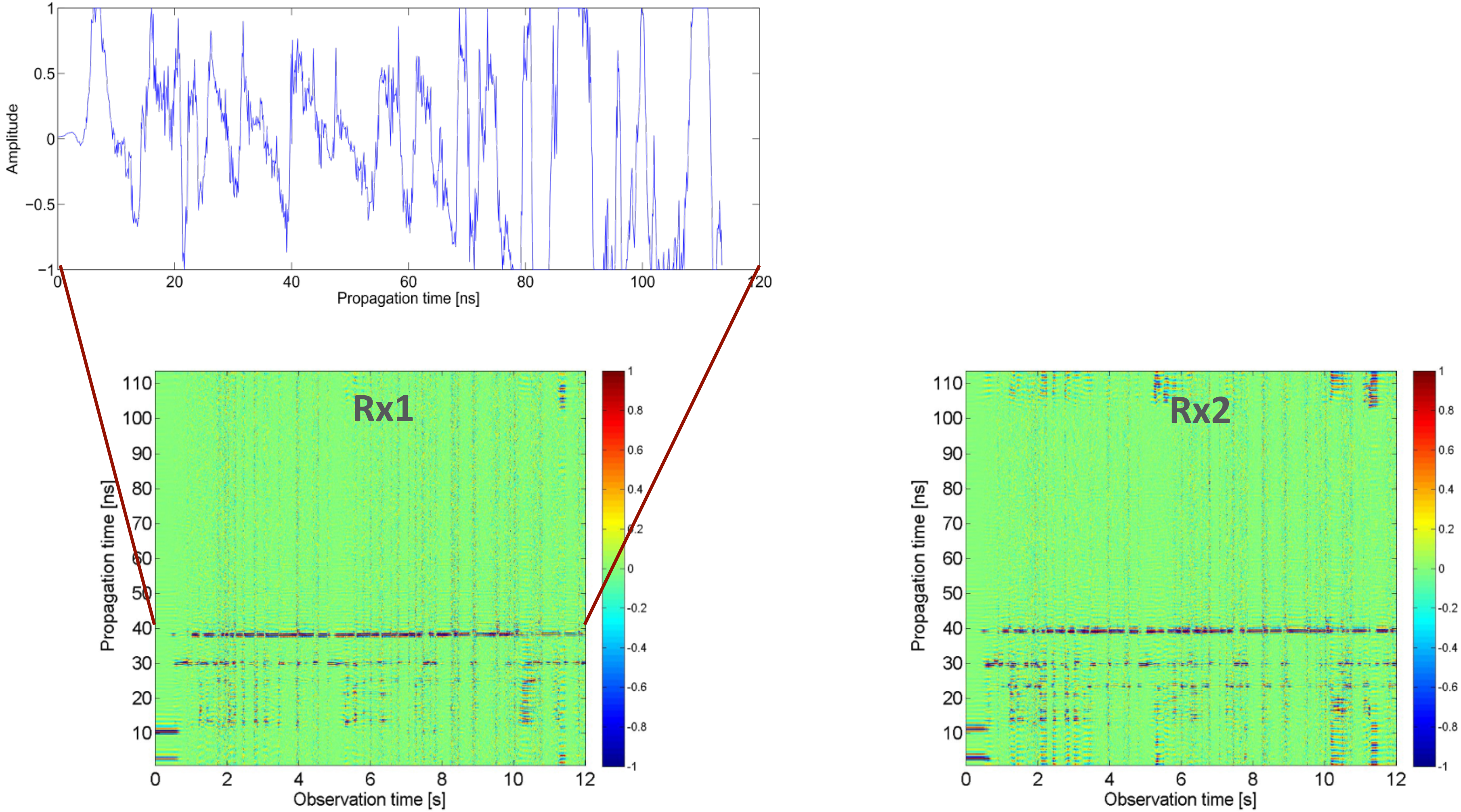
Phase 3: Background subtraction

- **Exponential averaging method: illustration Output signal: $h_b(t, \tau)$**



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Phase 4: Enhancement of target echo

- **Purpose**
  - Improvement of target echo to-noise-and clutter ratio (SNCR)
- **Outcome**
  - Radargram with highlighted (enhanced) echo of traget
- **Method 1**
  - Range filtering using band-pass FIR or IIR filters (phase characteristic has to be considered)
  - **Note: frequency band 0.4 – 1.4 GHz has been recommended**
- **Method 2**
  - Slow-time filtering using low-pass or bandpass FIR or IIR filters
  - **Note: frequency band 0 Hz – 0.8 Hz or 0.2 Hz – 0.8 Hz has been recommended**
- **Method 3**
  - Singular value decomposition (SVD)
- **Method 4**
  - CLEAN algorithm
  - **Note: CLEAN algorithm used to estimate the impulse response from observation region is applied for the advanced elimination of false alarms**

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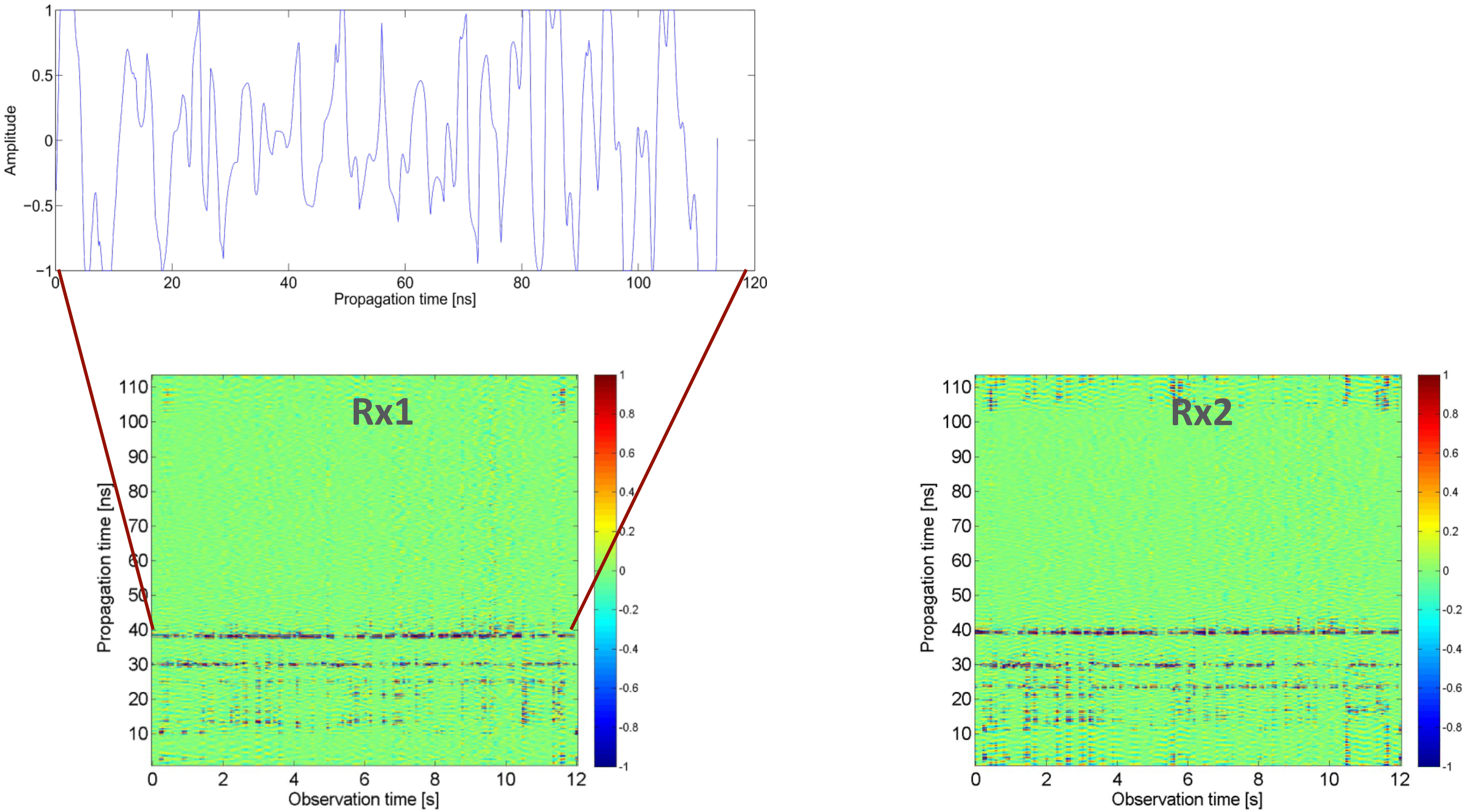
Phase 4: Enhancement of target echo

- **Slow-time filtering using bandpass IIR filters: illustration Output signal: $h_E(t,\tau)$**



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Phase 5: Target detection

- **Purpose**
  - Detection methods reach the decision whether a signal scattered by a moving target is present or absent in the analyzed impulse response
- **Basic approach**
  - Detection of periodical components in the radargram corresponding to a periodical movement of human chest in the frequency band <0.2 Hz, 0.7 Hz>
- **Method 1**
  - Estimation of power spectrum or its modification of signal $h(t\_k,\tau)$. Target is visualized as a hot spot of the function $H(t\_k,f)$
  - Methods of spectrum analyses:
  - Magnitude spectrum
  - Welch periodogram method
  - Hilbert-Huang transformation
  - S-tranformation
  - **Note: Using this approach, TOA is usually not estimated**

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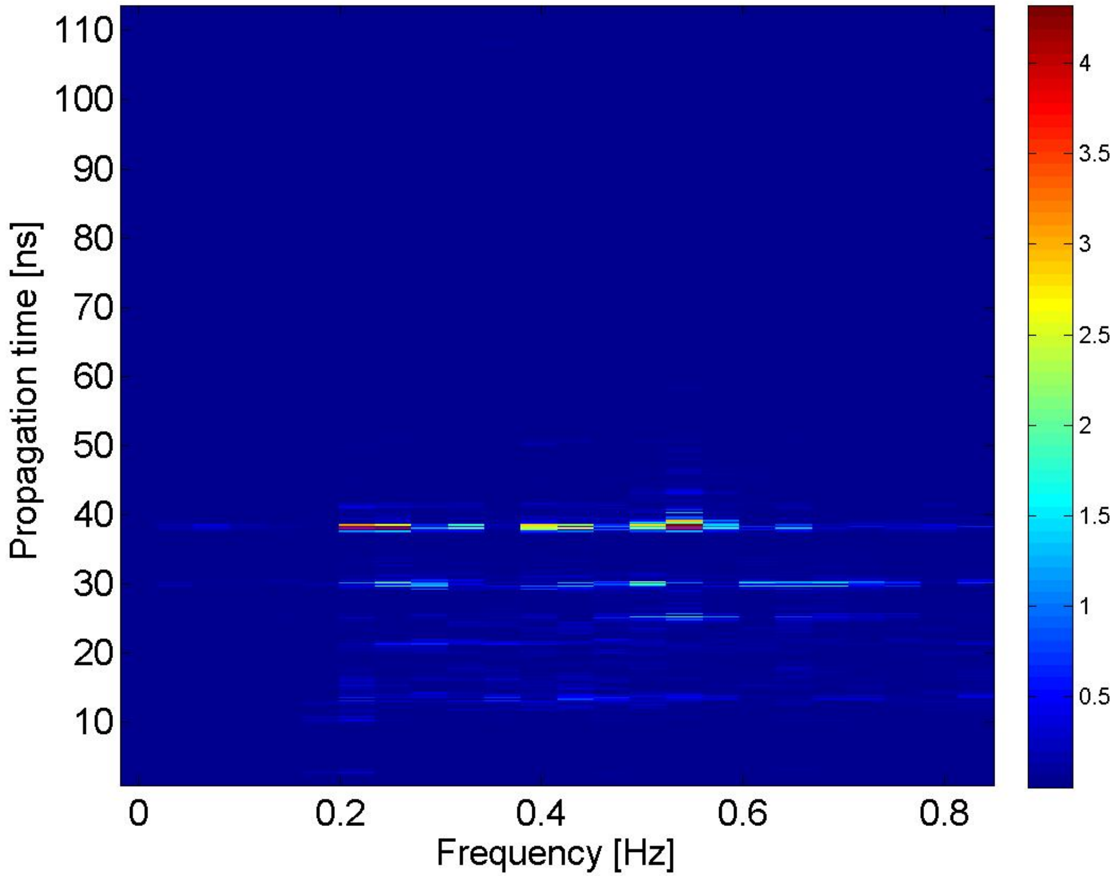
Phase 5: Target detection

- **Method 1**
  - Example: Welch periodogram method



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Phase 5: Target detection

- **Method 2**
  - Two-stage detector
- **Outcomes**
  - The detector output is represented as a binary signal $h_D(t)$
  - The value $h_D(t_1) = '' \ 1 \ ''$ means that a target is detected at the time instant t_1
  - The value $h_D(t_1) ='' \ 0 \ ''$ means that no target is detected at the time instant t_2

  - **Note: Using this approach, TOA can be estimated by using the detector output**
- **Description**
  - A detector consists of the combination of a power spectrum estimator, order-statistic constant false alarm rate (OS-CFAR) detector and a simple threshold detector (TD)

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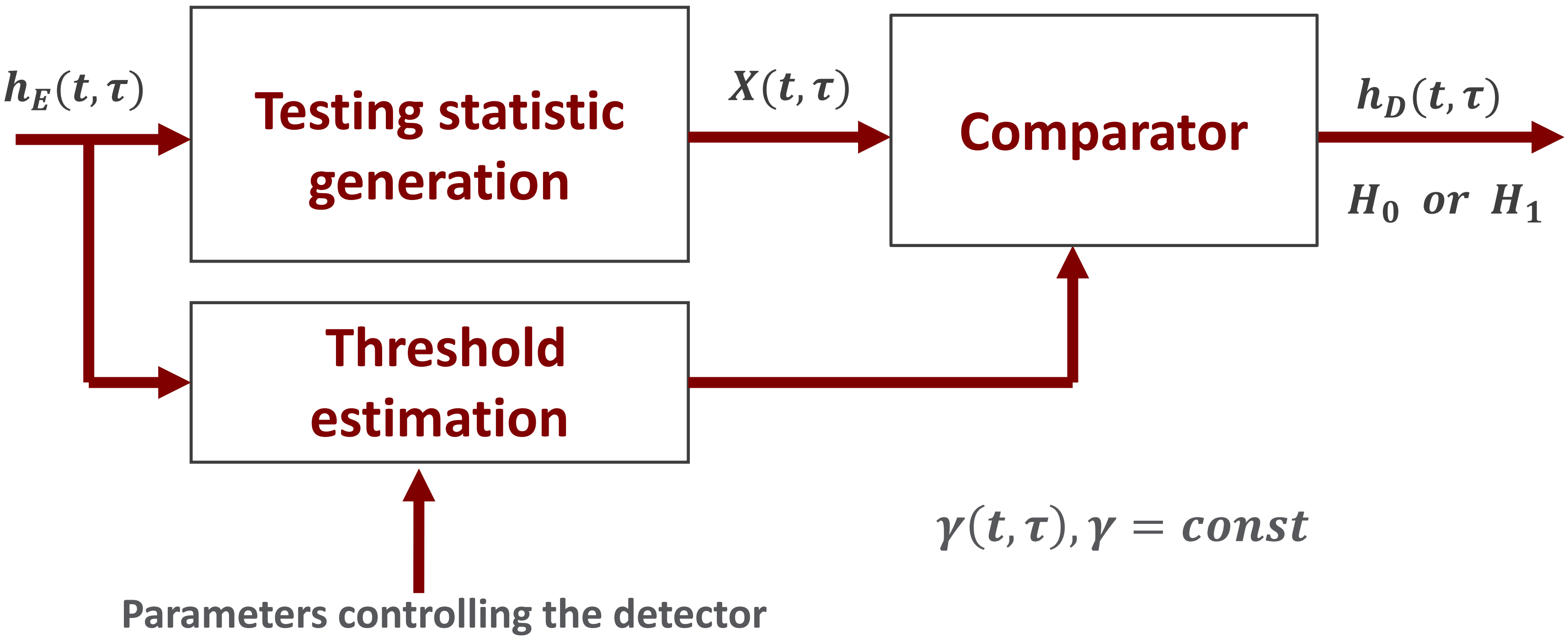
Phase 5: Target detection

- General scheme of a detector
- Simple constant threshold detector

$$h_d(t,\tau) = \begin{cases} H_0 & if\ X(t,\tau) \le \gamma \\ H_1 & if\ X(t,\tau) > \gamma \end{cases} \quad H_0 = 0, H_1 = 1$$



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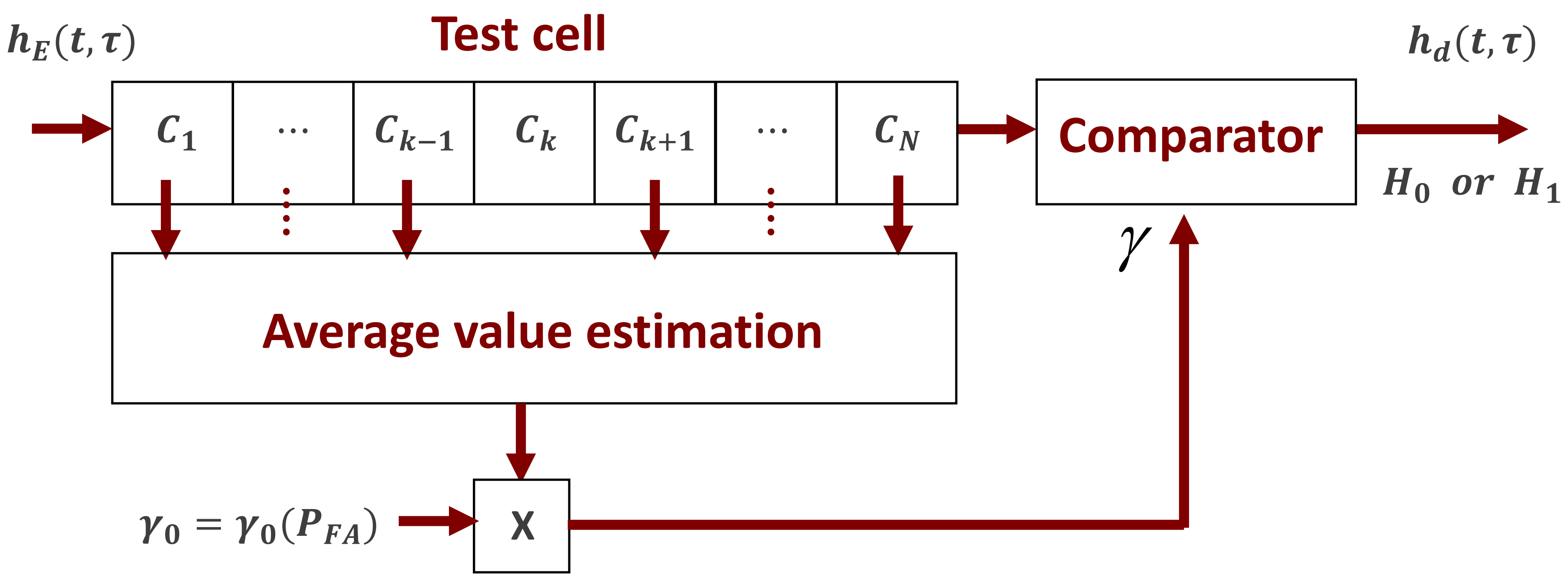
Phase 5: Target detection

- Basic scheme of a constant false alarm detector (CFAR): Cell averaging CFAR detector (CA-CFAR)



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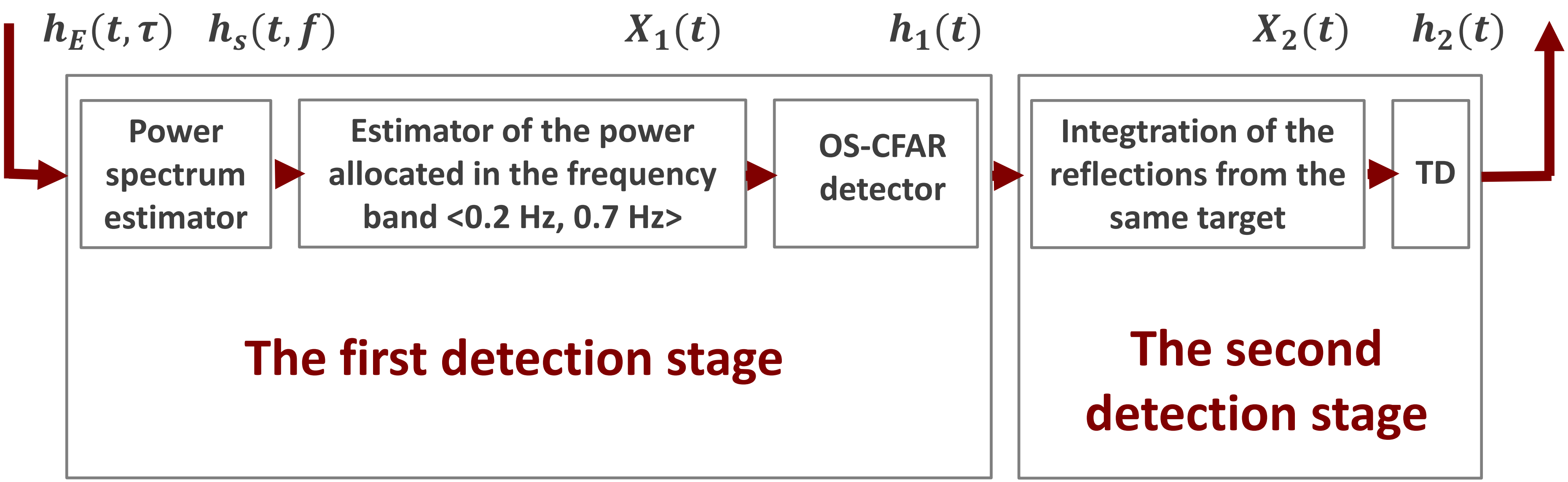
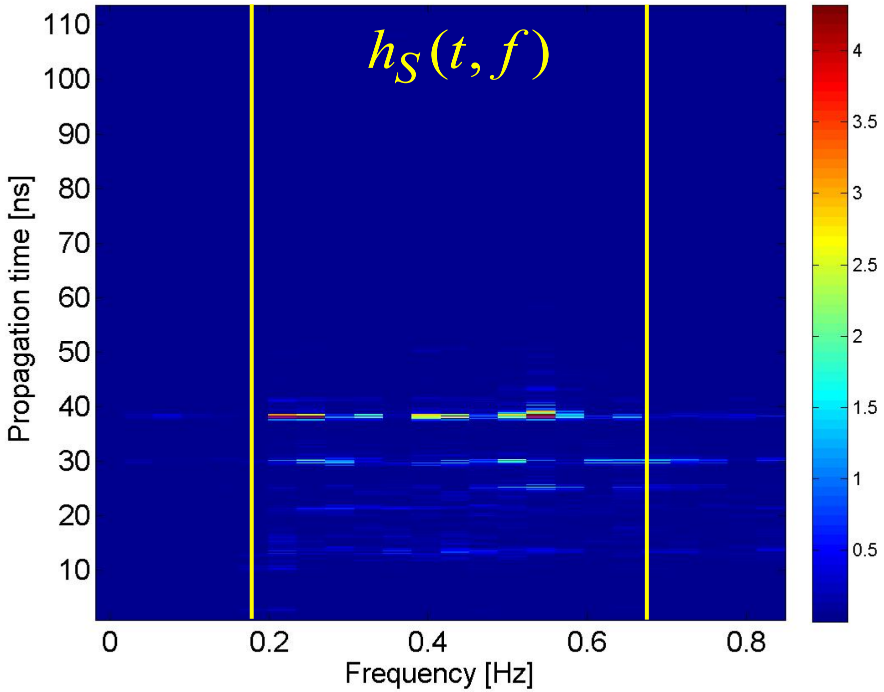
Phase 5: Target detection

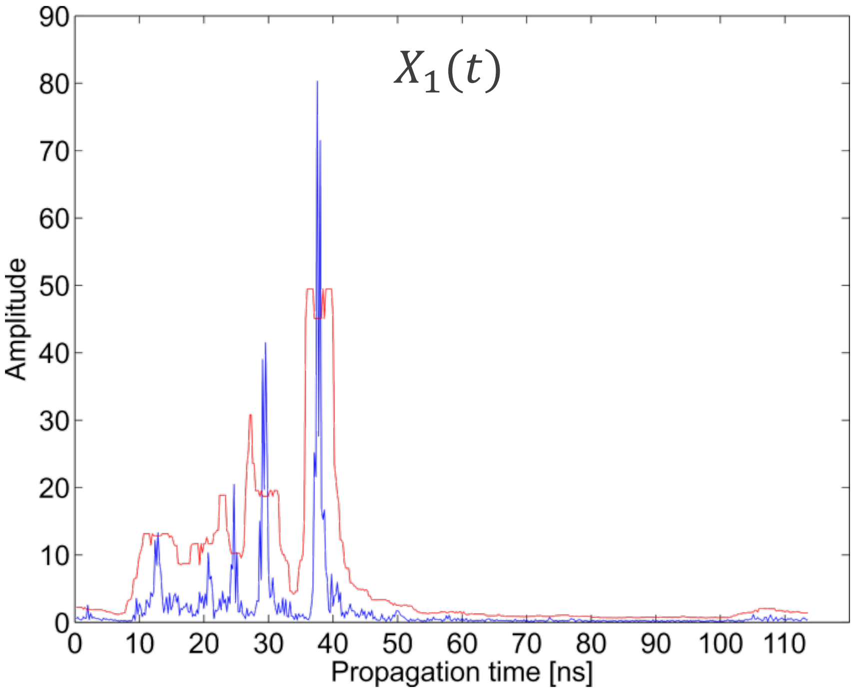
- **Method: Static person localization based on power spectrum estimation using Welch periodogram**



Phase 5: Target detection

- **Method: Static person localization based on power spectrum estimation using Welch periodogram**
- **Block: Estimator of the power allocated in the frequency band <0.2Hz, 0.7Hz>**





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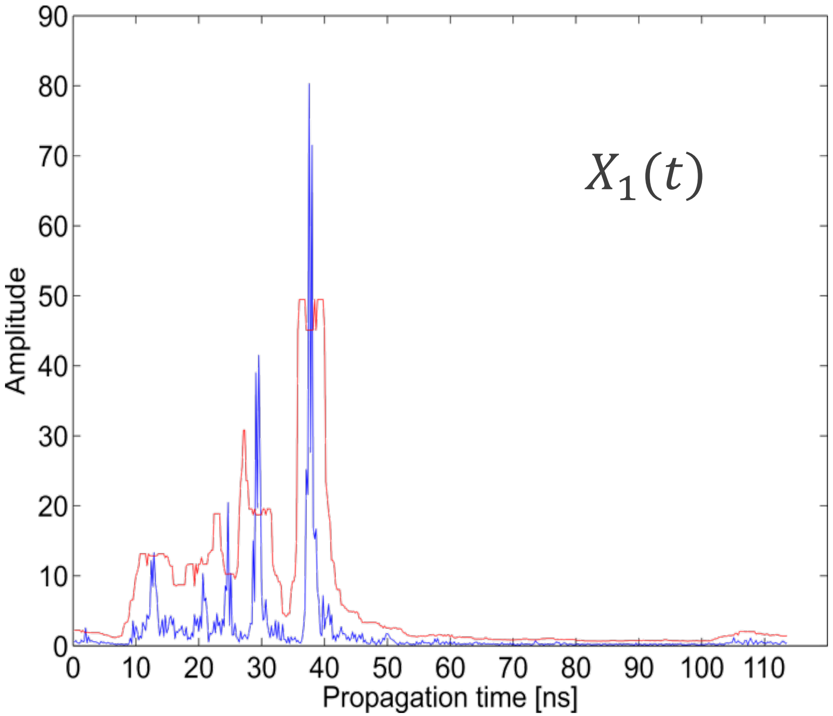
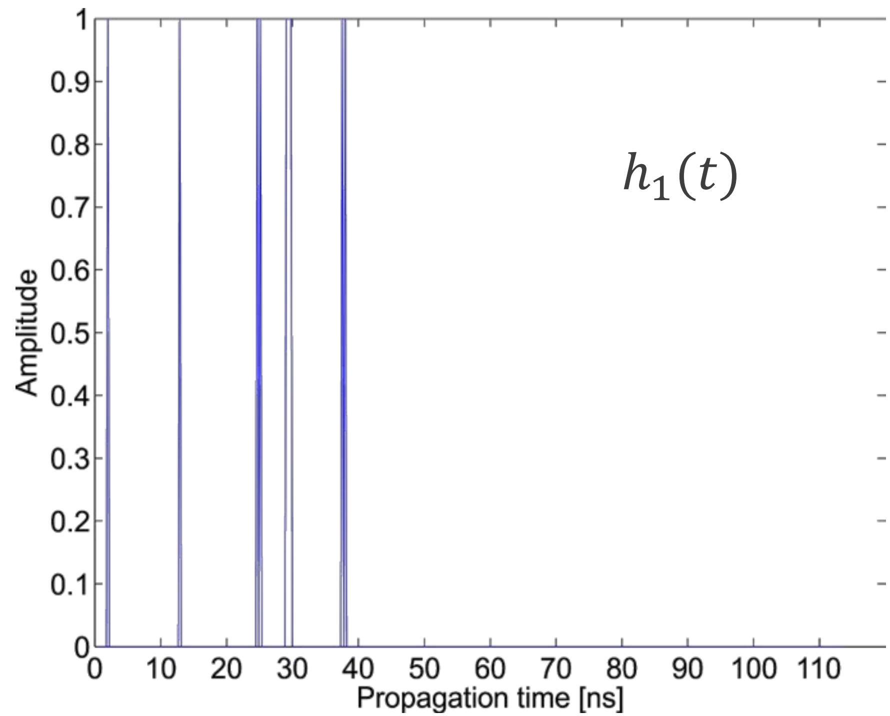
Phase 5: Target detection

- **Method: Static person localization based on power spectrum estimation using Welch periodogram**





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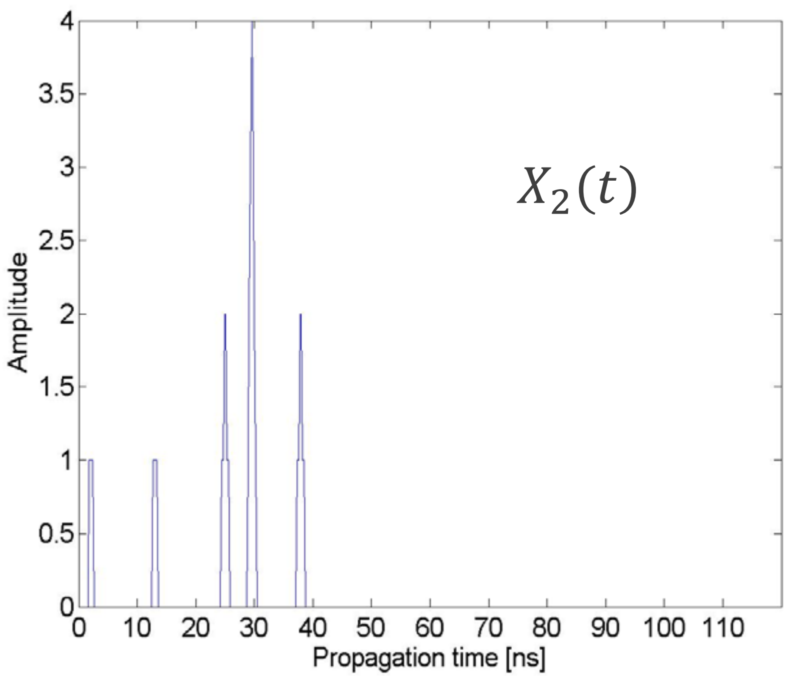
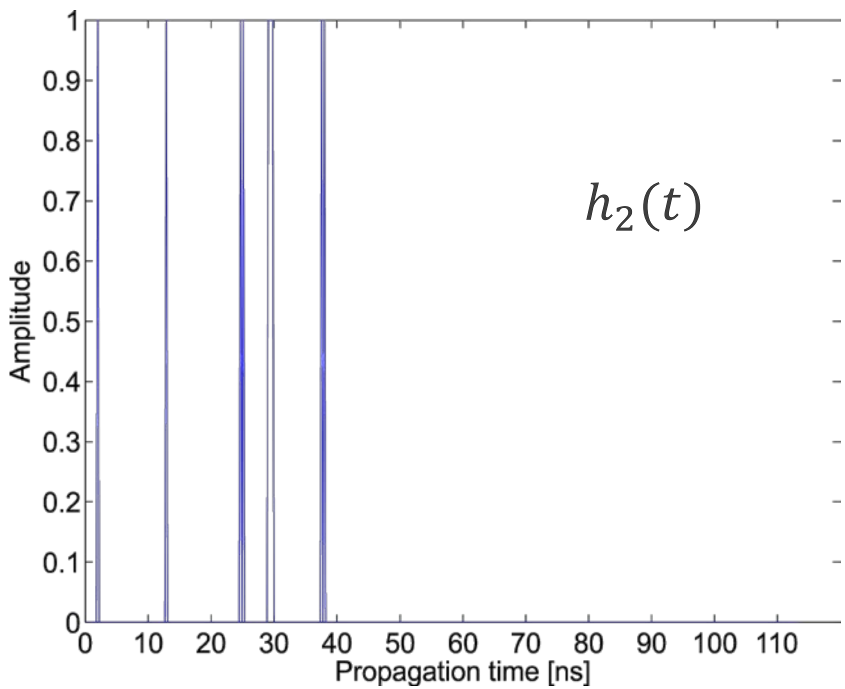
Phase 5: Target detection

- **Method: Static person localization based on power spectrum estimation using Welch periodogram**
- **Block: Order Statistic-CFAR detector (OS-CFAR, OS-CFAR is a modification of CA-CFAR)**





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Phase 6: TOA estimation

- **Purpose**
  - Estimation of TOA / TOA pair for each target and each pair
- **Basic approach**
  - Persons are considered as distributed targets, i.e., several reflections from the same person can be received by Rx
  - Several different TOAs correspond to the same distributed target
  - The basic idea of the distributed target localization consists in a substitution of the set of TOA corresponding to the same target with only one non-zero properly estimated TOA referred to as the TOA of the distributed target
- **Methods**
  - Trace online
  - Trace connection
- **Outcome**
  - TOA / TOA pair for each target and for each pair of antennas (Rx and Rxi)

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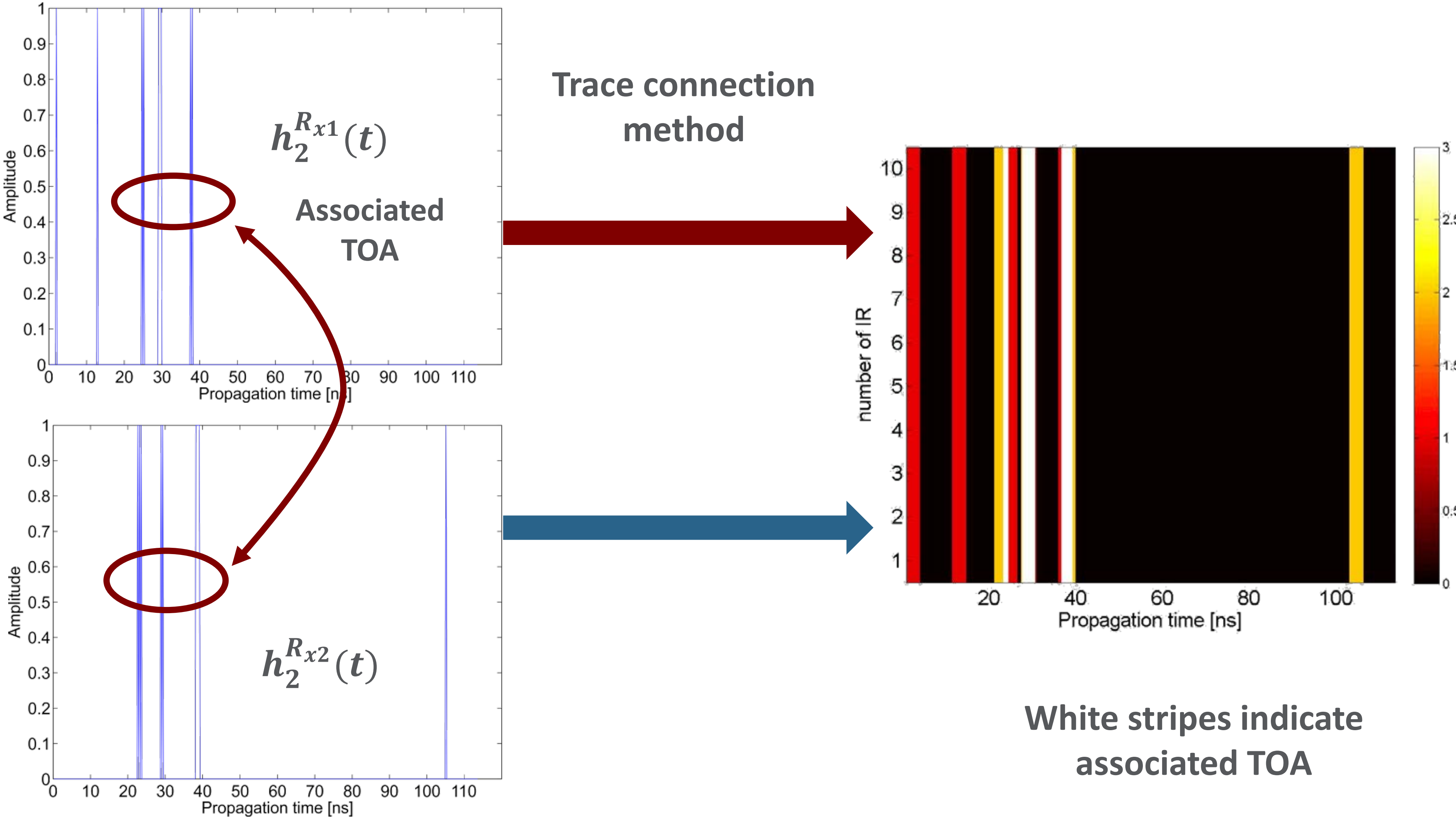
Phase 6: TOA estimation

- **Trace connection method: illustration.**



White stripes indicate associated TOA

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Phase 7: Target localization

- **Purpose**
  - Estimation of target coordinates
- **Assumption**
  - Target is localized using UWB sensor equipped (at least) with 1 Tx and 2 Rx
- **Methods**
  - Direct localization method (trilateration, multilateration method)
- **Comments**
  - Geometrical interpretation of target localization. The target position is represented by an intersection of two ellipses constructed by using knowledge about Tx and Rx coordinates and estimated associated pair of TOAs
- **Outcome**
  - Target coordinates
  - Target trajectory estimation

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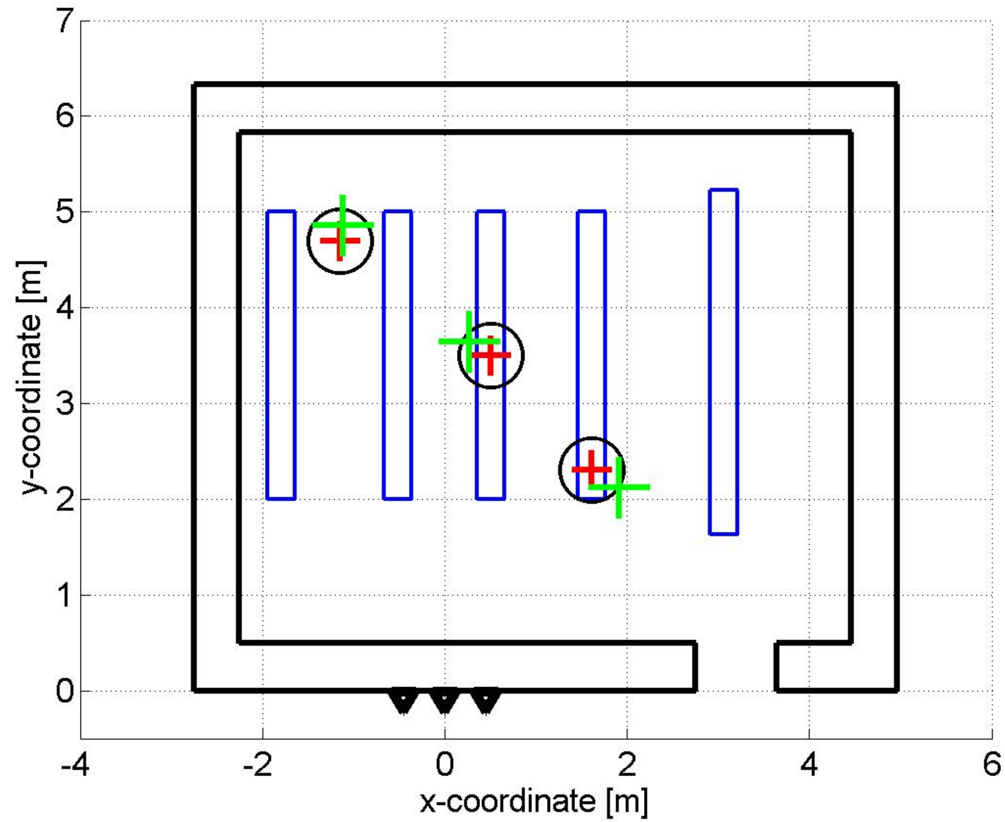
Phase 7: Target localization

- **Direct localization method. Illustration of multiple-target localization.**
  - Red mark: True target position
  - Green mark: True target position
  - Black circles: Tolerance area, covered by a person



Example

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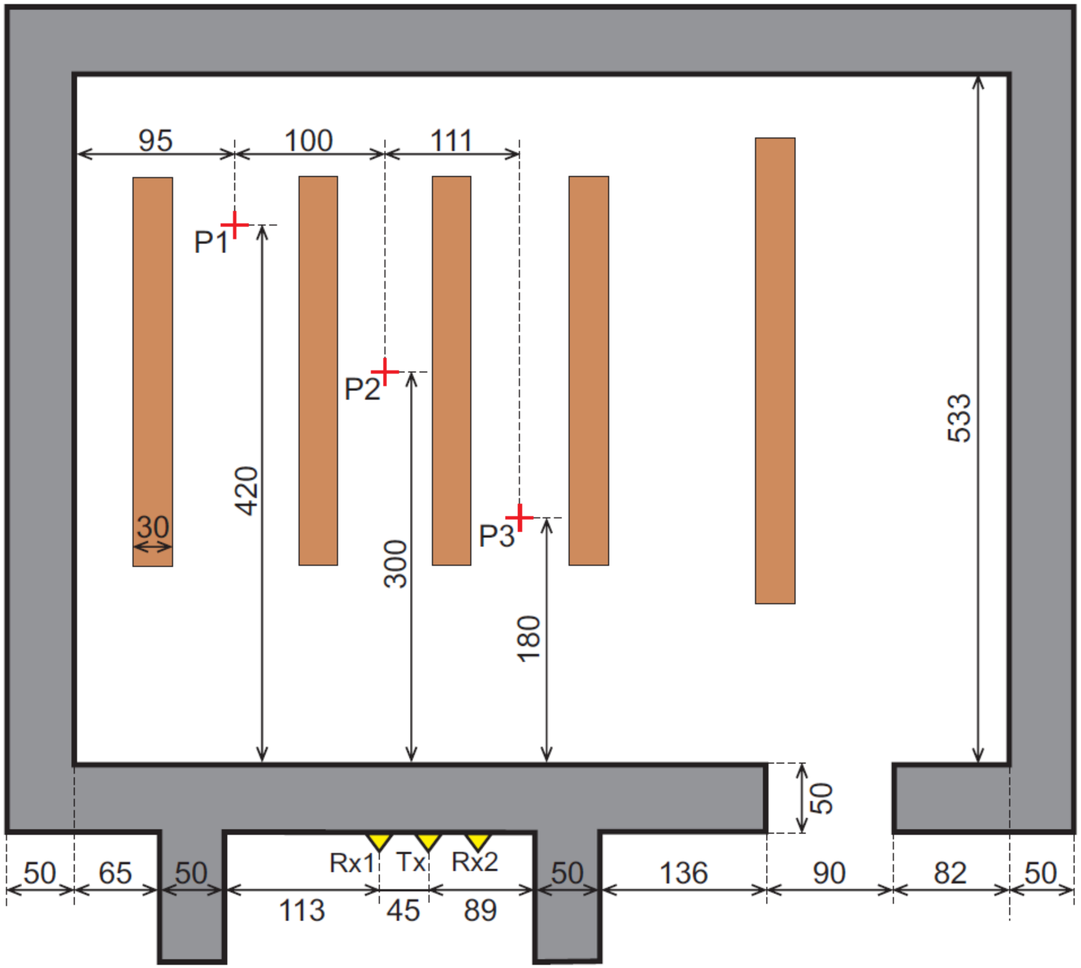
Illustrative scenario

- Illustrative scenario: description.
  - Red mark: True target position



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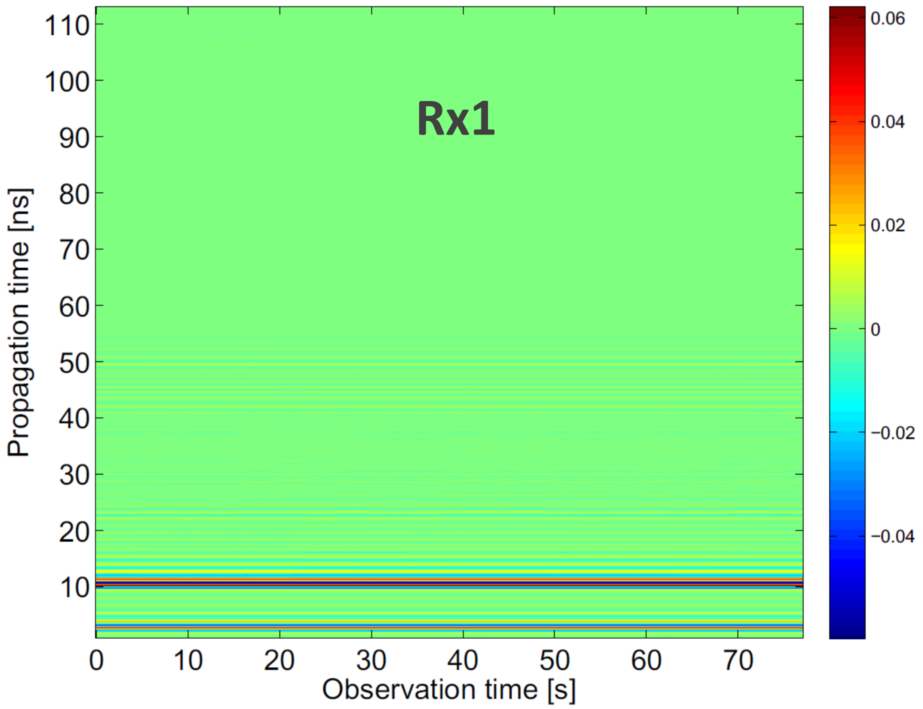
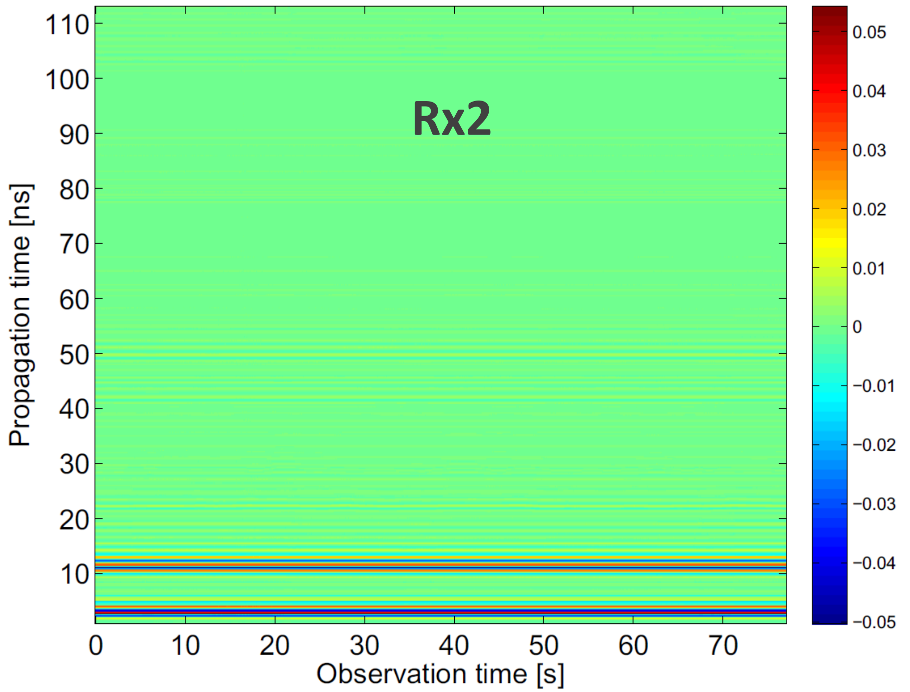
Illustrative scenario

- Chip clock rate: 4,5 GHz
- The period of M-sequences samples/time length: 511 chips, 114 ns
- Frequency band: DC-2,25 GHz
- Antennas (Tx, Rx): Horn antennas
- Output power: 1mW
- Unambiguous range: cca 17 m
- Measurement rate: 13,5 IR per second

Illustrative scenario

- Illustrative scenario: Raw radar signals.





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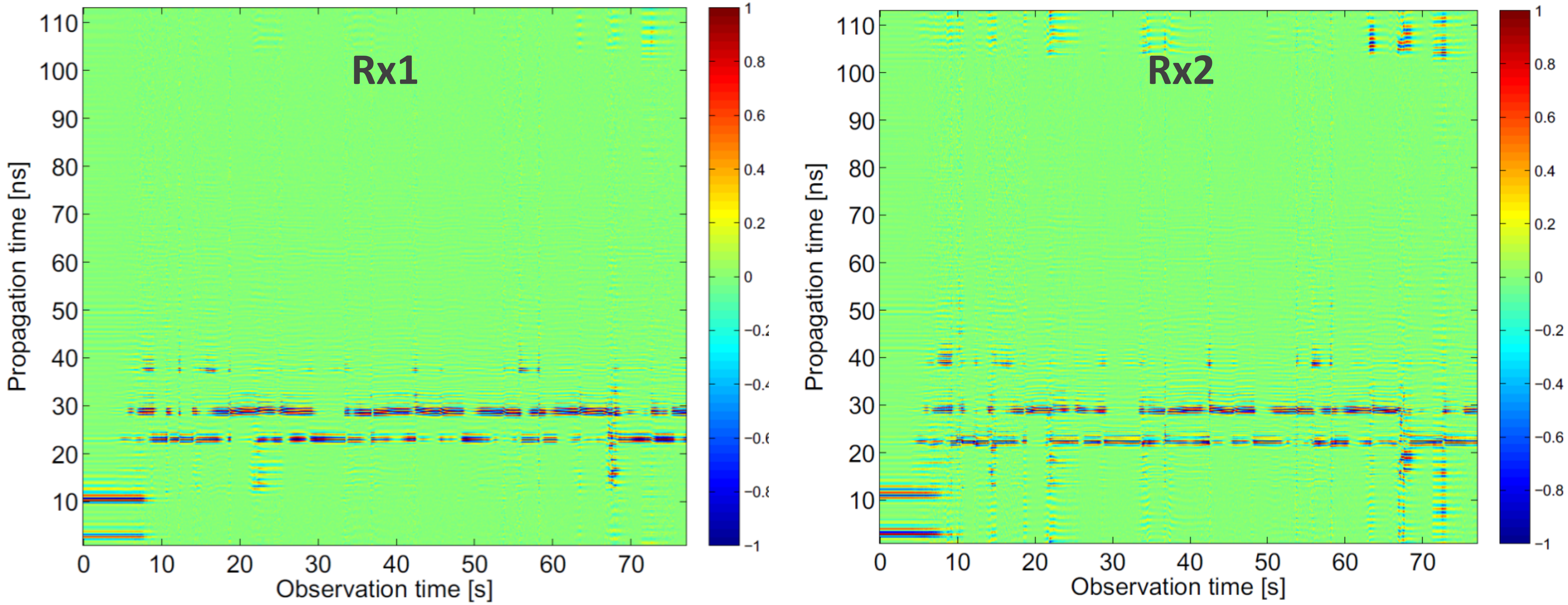
Illustrative scenario

- Illustrative scenario: Radargram with subtracted background.



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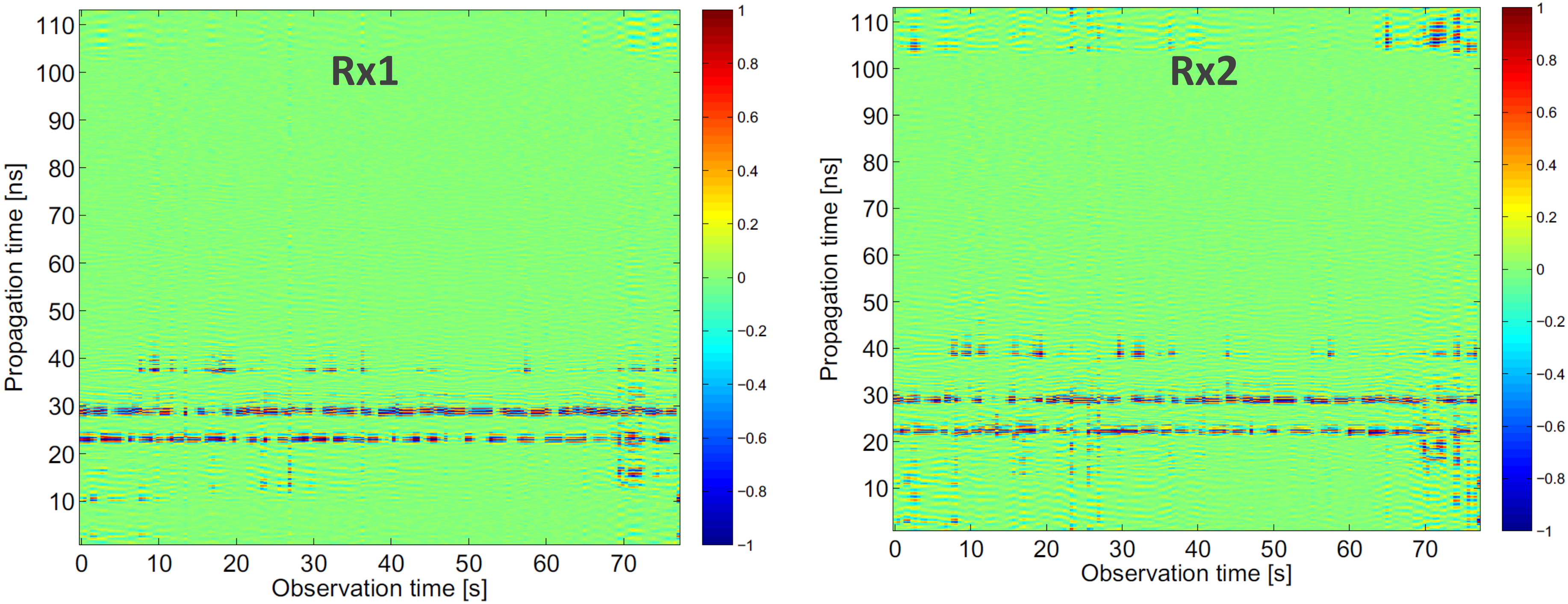
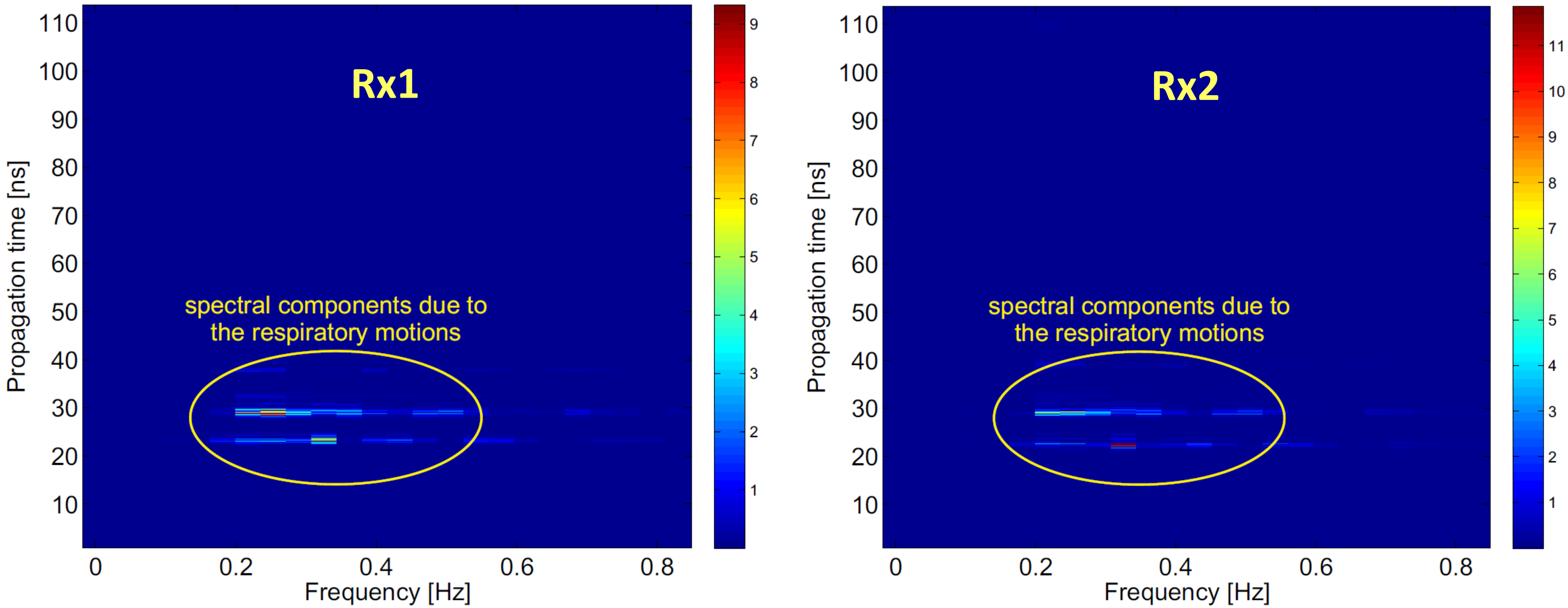
Illustrative scenario

- Illustrative scenario: Enhancement of target echo. Slow-time filtering using bandpass IIR filters.



Illustrative scenario

- Illustrative scenario: Target detection. Welch periodogram of radargram.



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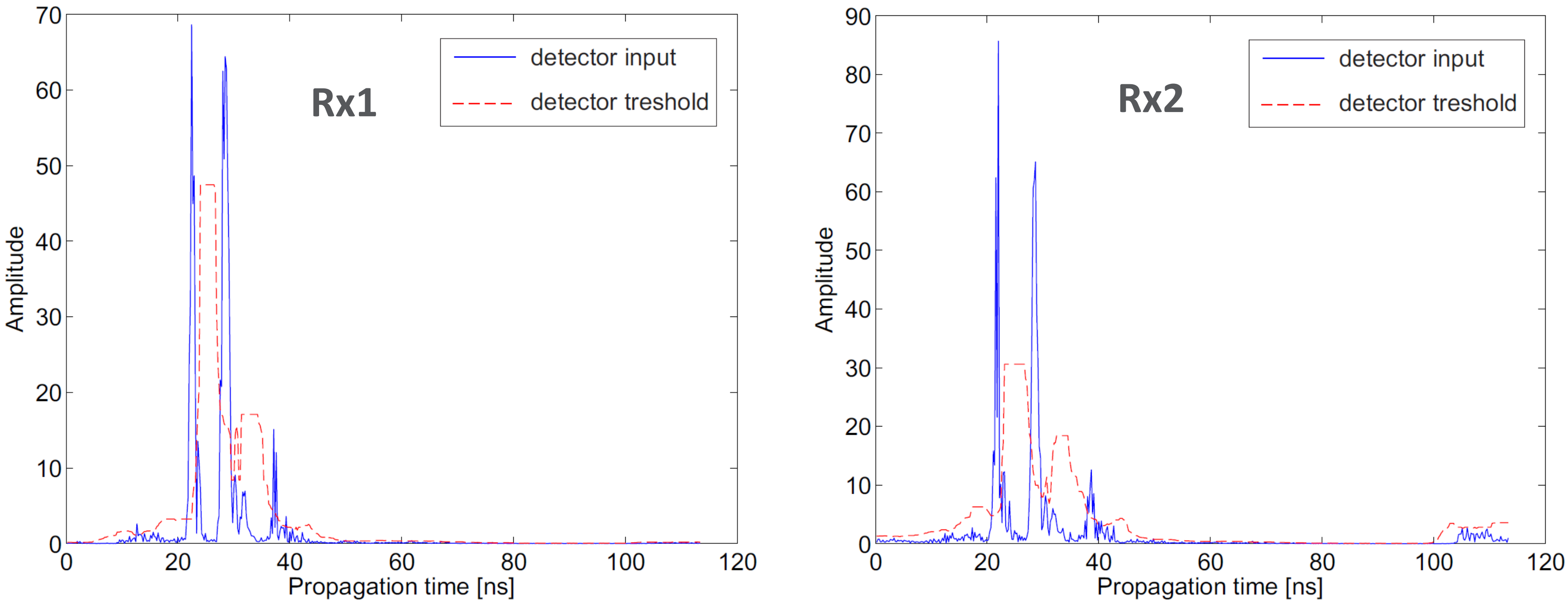
Illustrative scenario

- Illustrative scenario: Target detection. OS-CFAR detector performance illustration.



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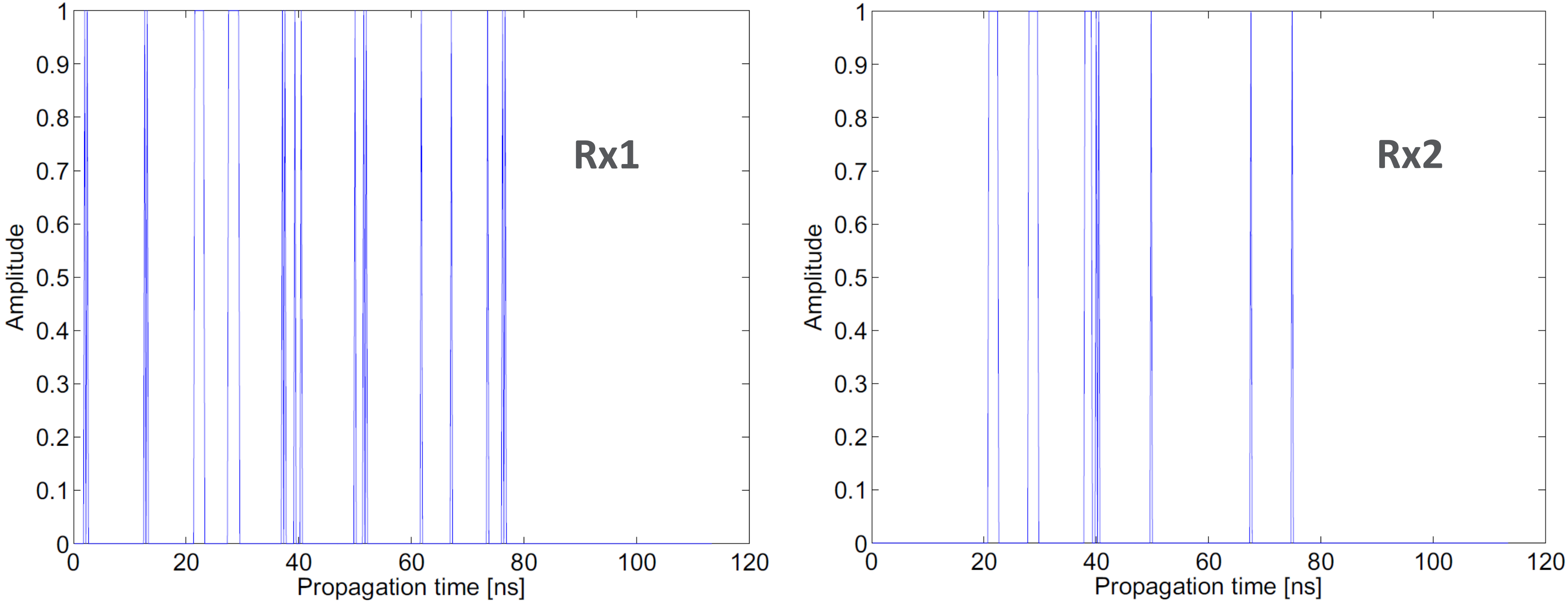
Illustrative scenario

- Illustrative scenario: Target detection. OS-CFAR detector output.



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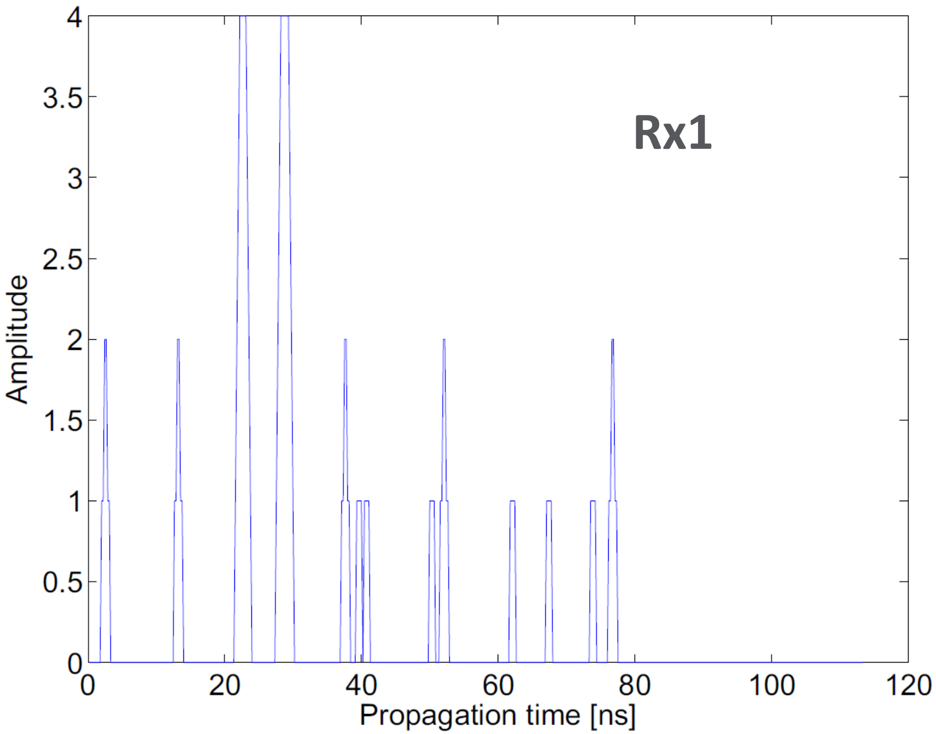
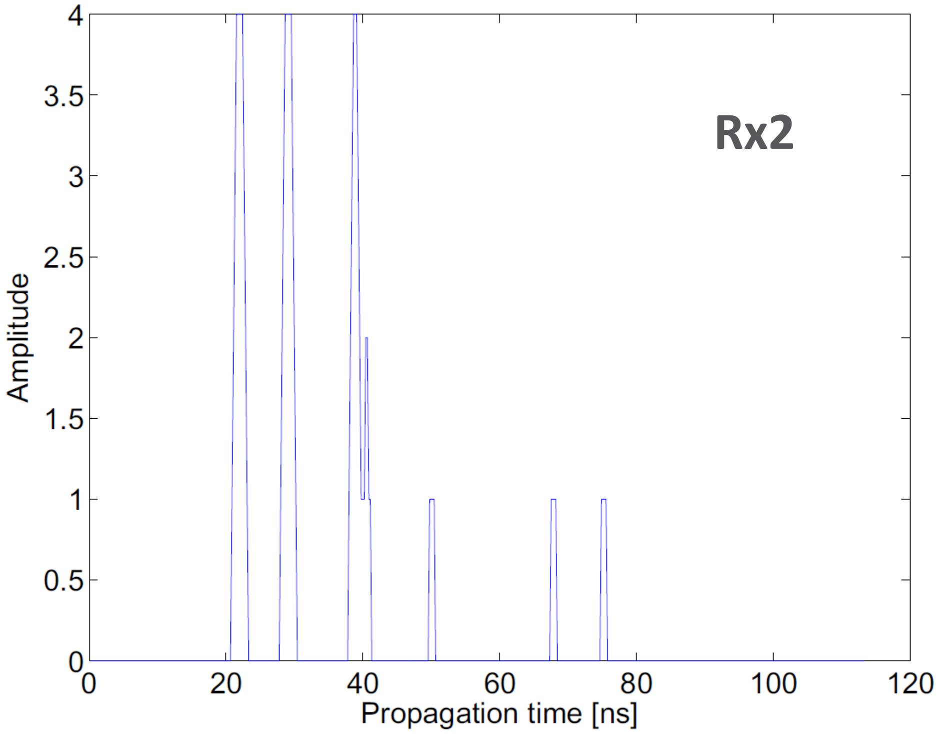
Illustrative scenario

- Illustrative scenario: Target detection. TD input.





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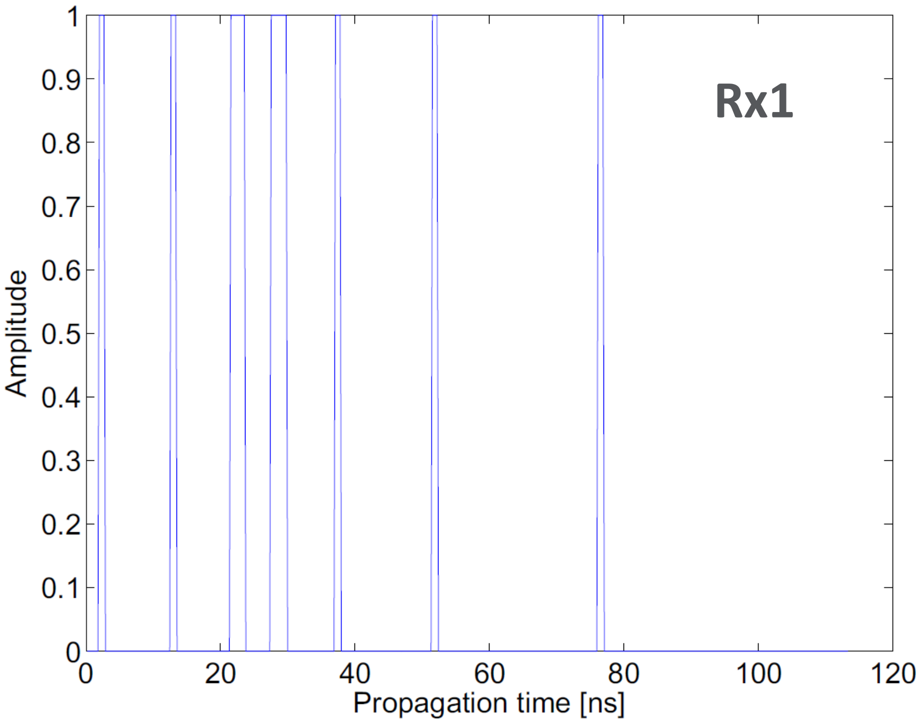
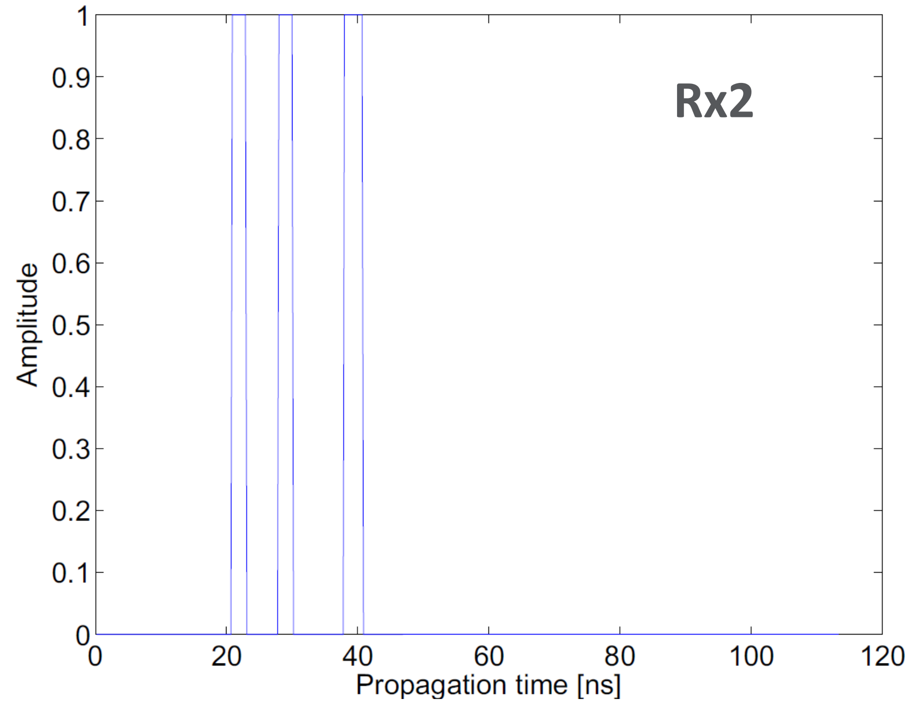
Illustrative scenario

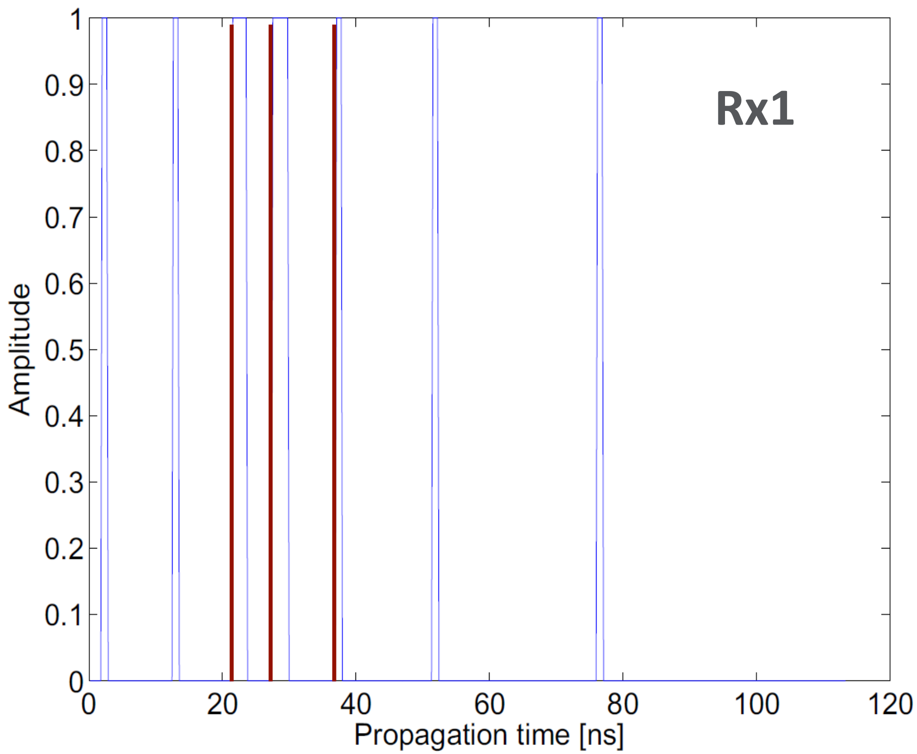
- Illustrative scenario: Target detection. TD output.

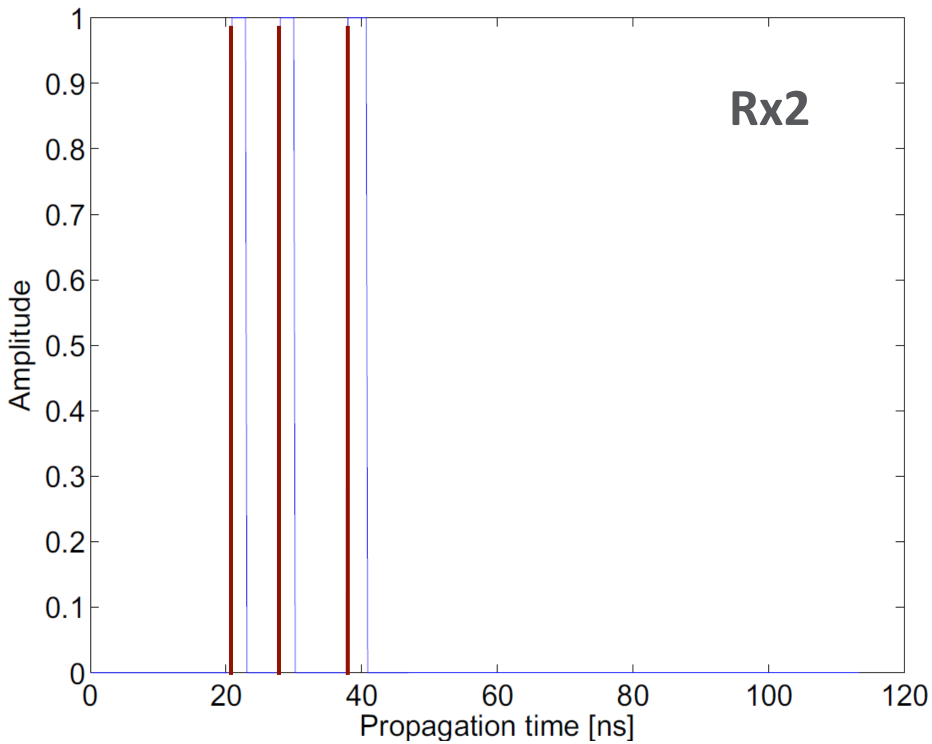




Illustrative scenario

- Illustrative scenario: TOA estimation.





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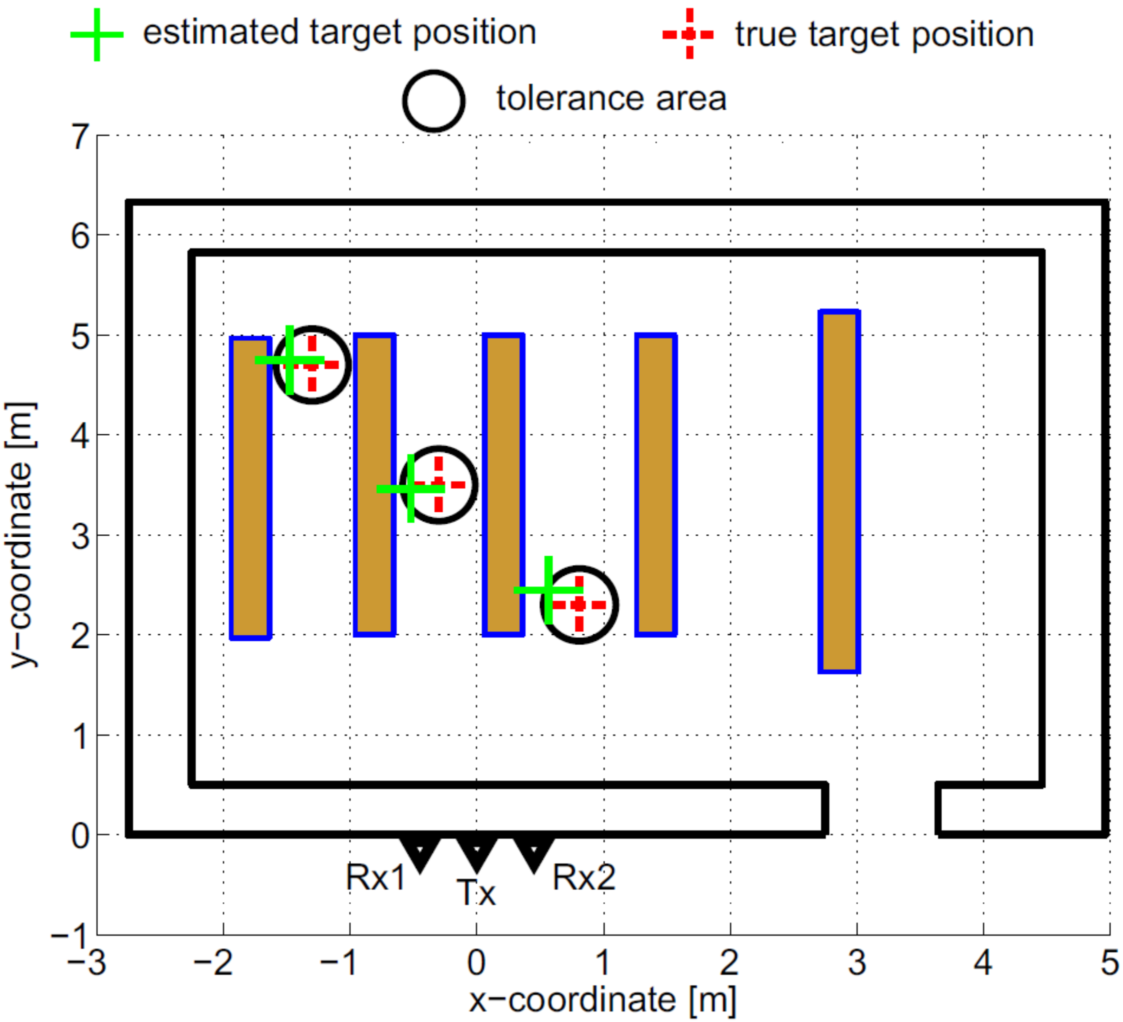
Illustrative scenario

- Illustrative scenario: Target localization.



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Conclusions and References

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Conclusions

- This lecture covers the localization of people based on the detection of their vital signs.
- The sensor considered in this lecture is a GPR, which is an UWB radar.
- The main focus of the lecture is on the signal processing procedure for the localization of a static person. Basic information is given also for the localization of a moving person.
- The described approach can be used for humanitarian purposes and in particular for the localization of people trapped under debris or snow, after disasters such as earthquakes, collapses of buildings, avalanches, explosions.

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References

[1] NOVÁK, Daniel; KOCUR, Dušan. Multiple static person localization based on respiratory motion detection by UWB radar. In: 2016 26th International Conference Radioelektronika (RADIOELEKTRONIKA). IEEE, 2016. p. 252-257.

In this paper, a novel method for person localization, based on the respiratory motion, is introduced. This approach is referred to as the "WP-STAPELOC method" and is based on the combination of a power-spectrum estimator (using Welch periodogram) and an order-statistic constant false alarm (OS-CFAR) detector. A simple technique for breathing rate estimation of the detected person is outlined in the paper as well.

[2] KOCUR, Dušan; NOVÁK Daniel; ŠVECOVÁ Mária. UWB Radar Signal Processing for Localization of Persons with the Changing Nature of Their Movement. In: Sensors & Transducers, Vol. 207, Issue 12, December 2016, pp. 50-57

In the last decade, it has been shown that short-range ultra-wide band radar systems can provide the efficient solution for human being localization, for line-of-sight and non-line-of-sight scenarios. To correctly localize people by using this technology, the corresponding detection and localization methods have to be selected according to the nature of the person movement. In that respect, two basic kinds of persons can be identified: moving and static persons. In this paper, a radar signal processing procedure that allows a joint detection and localization of moving and static persons is introduced.

References

[3] NOVÁK, Daniel. Non-invasive Detection, Localization and Estimation of Breathing Frequency of Static Persons by UWB Radar System. In: SCYR 2016 Košice. 2016. p. 192-193.

In this paper, we consider as static persons those persons whose only movement is their respiration. It is shown in the paper that a basic principle of static person localization consists in the detection of radar signal components having a significant power level in the frequency band 0.2–0.7 Hz (that is, the frequency band of a human respiratory rate) corresponding to a constant range between the target and radar. A method is also presented in the paper, employing Welch periodogram for radargram power spectrum estimation, which allows to detect and localize static persons.

[4] ROVŇÁKOVÁ, Jana; KOCUR, Dušan. UWB Radar Signal Processing for Positioning of Persons Changing Their Motion Activity. In: Acta Polytechnica Hungarica, 2013, 10.3.2013. p. 165-184.

In many applications of UWB radar a character of target motion is a priori not known and can naturally differ within a group of multiple targets. Usually a signal processing aimed at the positioning of only moving persons or only static persons leads to a loss of information. To solve this task, the utilization of combined processing based on detection of non-stationary signal components in the time domain and human respiratory motions in the frequency domain is proposed in this paper.

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References

[5] NEZIROVIĆ, A. N. Trapped-victim detection in post-disaster scenarios using ultra-wideband radar. Dissertation for Ph.D. degree. TU Delft, Delft University of Technology, Netherlands. 2010.

Detection of trapped victims using ultra-wideband radar is considered a highly challenging task due to multiple unknown parameters and generally very low signal-to-noise-and-clutter ratio conditions. The dissertation is devoted to a whole range of problems to be solved in the case of trapped person detection. Besides of the state-of-the art, new methods for stationary and non-stationary clutter suppression, low-level target echo enhancement and narrowband interference suppression are introduced in the theses. The dissertation represents a good reference for studying the fundamental problems of trapped person detection.

[6] ZAIKOV, Egor; SACHS, Juergen. UWB radar for detection and localization of trapped people. INTECH Open Access Publisher, 2010.

This publication is focused on selected problems of detection and localization of trapped people in 2D and 3D space. Firstly, hardware for breathing-detecting radar system is introduced. Then, a statement of the problem of human being breathing detection is given. The next parts of the publication are focused on detection of the signal components due to person breathing, on non-stationary clutter reduction, and finally, on person localization. The efficiency of the proposed solution is demonstrated via the presentation of detection and localization results in challenging scenarios.

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References

[7] LAZARO, Antonio; GIRBAU, David; VILLARINO, Ramon. Analysis of vital signs monitoring using an IR-UWB radar. In: Electromagnetics Research, 2010, p. 265-284.

This paper focuses on the feasibility of estimating vital signs — specifically breathing rate and heartbeat frequency — from the spectrum of recorded waveforms, using impulse-radio (IR) UWB radar. Here, an analytical model is developed to perform and interpret the spectral analysis of raw radar signals. Both the harmonics and the intermodulation between respiration and heart signals are addressed. It is shown that an IR-UWB radar can meet the requirements of biomedical applications such as non-invasive heart and respiration rate monitoring.

[8] LAZARO, Antonio; GIRBAU, David; VILLARINO, Ramon. Techniques for clutter suppression in the presence of body movements during the detection of respiratory activity through UWB radars. In: Sensors, 2014, 14.2: p. 2595-2618.

The paper focuses on the feasibility of tracking the chest wall movement of a human subject during respiration from the waveforms recorded using impulse-radio ultra-wideband radar. The paper describes the signal processing to estimate sleep apnoea detection and breathing rate. Some techniques to solve several problems in these types of measurements, such as the clutter suppression, body movement and body orientation detection are described. In the paper, a very useful fundamental model of breathing signal due to a person is developed, as well.

References

[9] NEZIROVIC, Amer; YAROVOY, Alexander G.; LIGTHART, Leo P. Signal processing for improved detection of trapped victims using UWB radar. In: IEEE Transactions on Geoscience and Remote Sensing, 2010, 48.4: p. 2005-2014.

Detection of trapped victims using ultra-wideband radar is considered a highly challenging task due to multiple unknown parameters and generally very low signal-to-noise-and-clutter ratio (SNCR) conditions. In this paper, a novel detection algorithm is proposed. It is designed for detection of periodic motion caused by respiratory motion of the persons for low SNCR conditions. The algorithm performs stationary-clutter removal, high-level noise, and nonstationary-clutter suppression, indicates presence of the trapped victim, and estimates its range.

[10] ADIB, Fadel, et al. Smart homes that monitor breathing and heart rate. In: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems. ACM, 2015. p. 837-846.

In this paper, the authors study how to use smart environments to monitor human vital signs remotely, without instrumenting human bodies. They introduce a Vital-Radio concept as a wireless sensing technology that monitors breathing and heart rate without body contact. Vital-Radio exploits the fact that wireless signals are affected by motion in the environment, including chest movements due to inhaling and exhaling and skin vibrations due to heartbeats. The basic problems of extracting breathing and heart rate are addressed in the paper as well.

References

[11] SACHS, Jürgen. Handbook of Ultra-wideband Short-range Sensing: Theory, Sensors, Applications. John Wiley & Sons, 2013.

This publication is an excellent book dealing with the theoretical basis of UWB sensors via implementation issues and their applications. This book bridges the gap between designers and appliers working in civil engineering, biotechnology, medical engineering, robotic, mechanical engineering and, safety and homeland security, etc.

[12] SACHS, Jürgen, et al. Remote vital sign detection for rescue, security, and medical care by ultra-wideband pseudo-noise radar. In: Ad Hoc Networks, 2014, 13: p. 42-53.

The vitality of a human being is closely connected to temporal variations of its body geometry. This is quite obvious in the case of walking. But also when resting, the motion of inner organs causes geometric alterations which may be registered by high resolution UWB radar. Since the radio waves radiated by such radars are harmless, they may be deployed for monitoring of resident activities helping to ensure health, safety, and well-being of aged or needy people. These waves may also penetrate most of building materials which makes them useful to detect earthquake and avalanche survivors, too. The most challenging task is the registration of respiration activity of an unconscious person. The principle of breathing motion detection by radar is explained and the major handicaps as well as appropriate counter measures are discussed. The possible structure of a survivor and residential injury detection radar system is considered and some results from field trials are summarized in the paper.

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