



FORSCHUNGSINITIATIVE  
**K O - F A S**

# Channel Sounding for Ko-TAG Scenarios

Channel-Sounding für Ko-TAG Szenarien

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Supported by:



on the basis of a decision  
by the German Bundestag

## Goal

Understand radio channel characteristics in Ko-TAG scenarios

## Benefit

Evaluate potentials of Ko-TAG system by identifying physical restrictions of the underlying radio channel

Channel gain → Received power → Potential of Communication

Detection of strongest path delay → Potential of distance estimation

Channel Sounding  
Channel Gain  
Human body testing object  
Distance estimation

Channel Sounding

Channel Gain

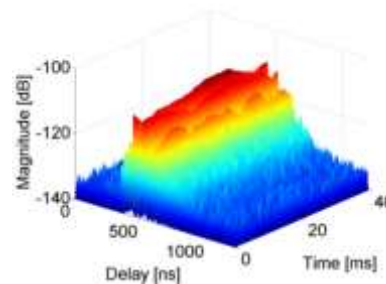
Human body testing object

Distance estimation

# HHI Channel Sounder

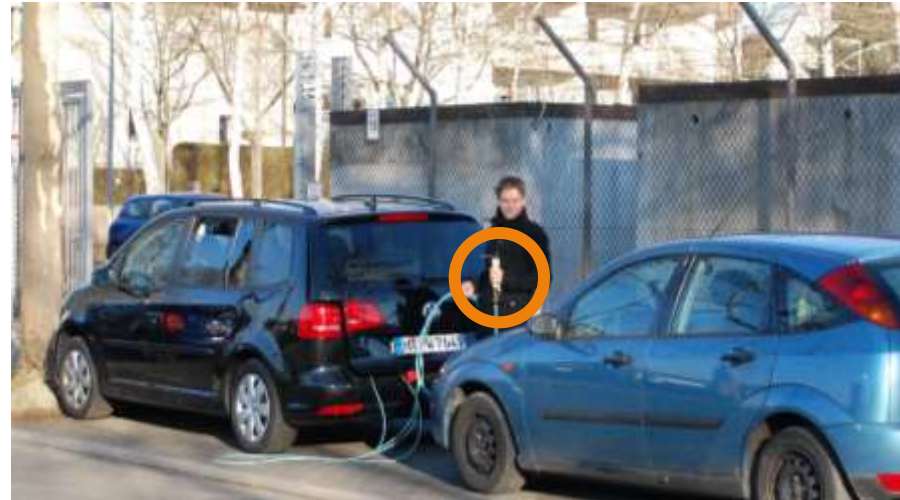


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Time-variant  
Channel Impulse  
Response

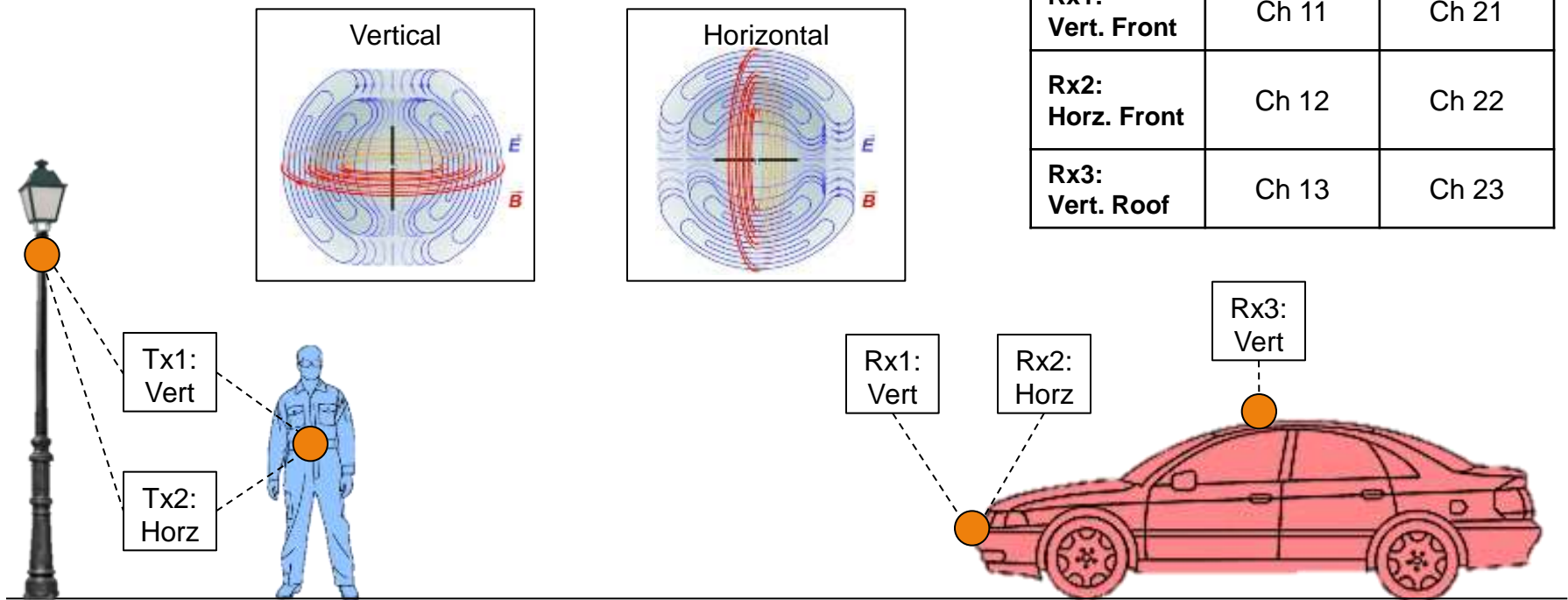
# Ko-TAG Channel Sounding



# Measurement Setup



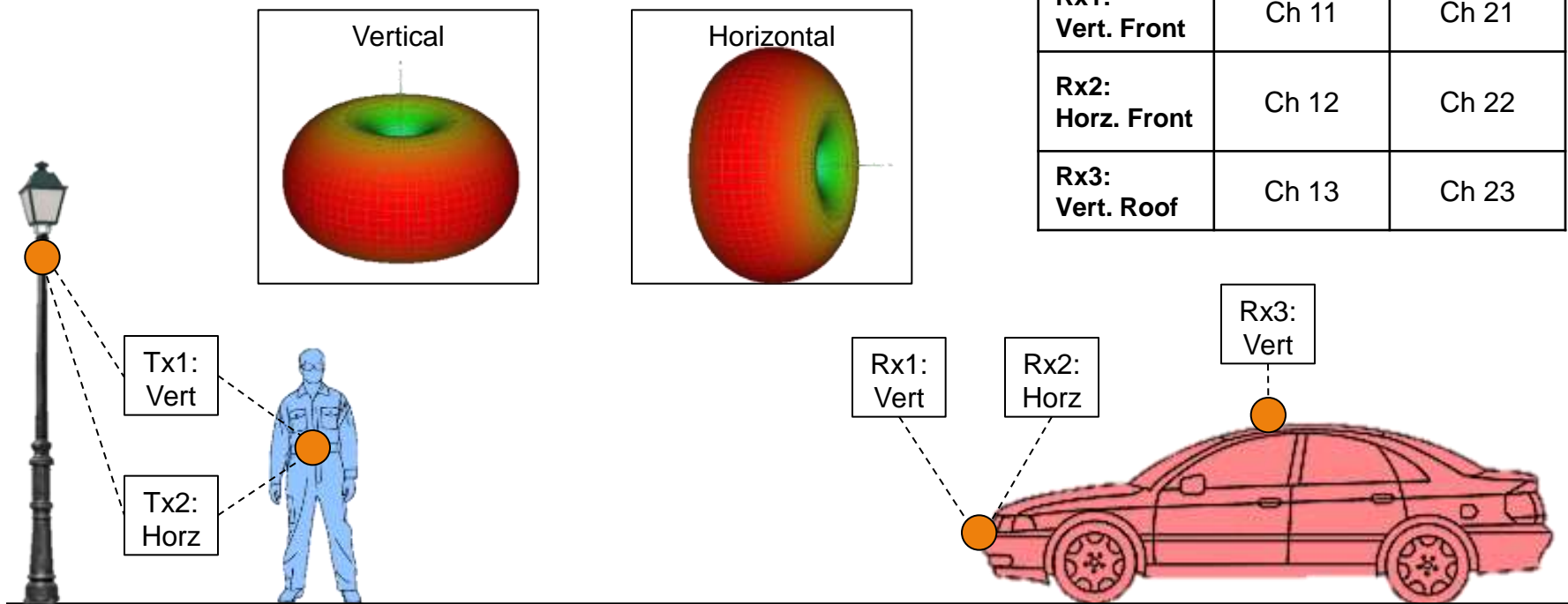
Simultaneous measurement of different antenna positions and polarizations



# Measurement Setup



Simultaneous measurement of different antenna positions and polarizations





Channel Sounding

Channel Gain

Human body testing object

Distance estimation

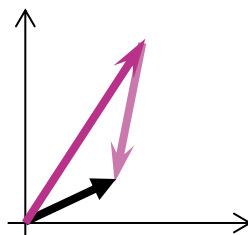
# Channel Gain



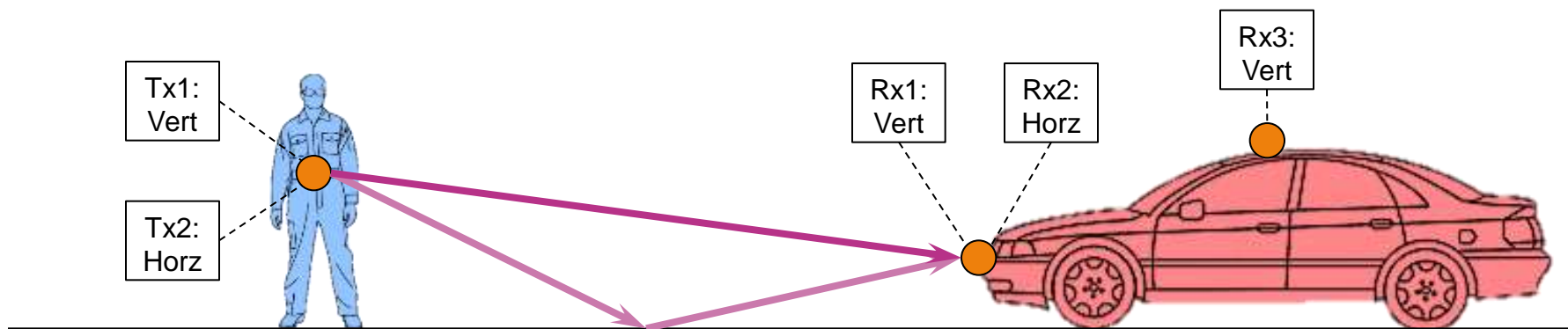
Channel gain corresponds to **received power**

$$\text{ChG} = P_{\text{Rx}} / P_{\text{Tx}}$$

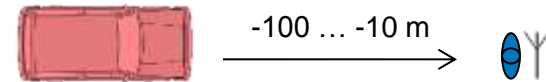
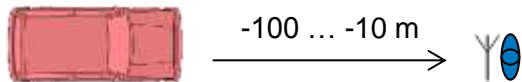
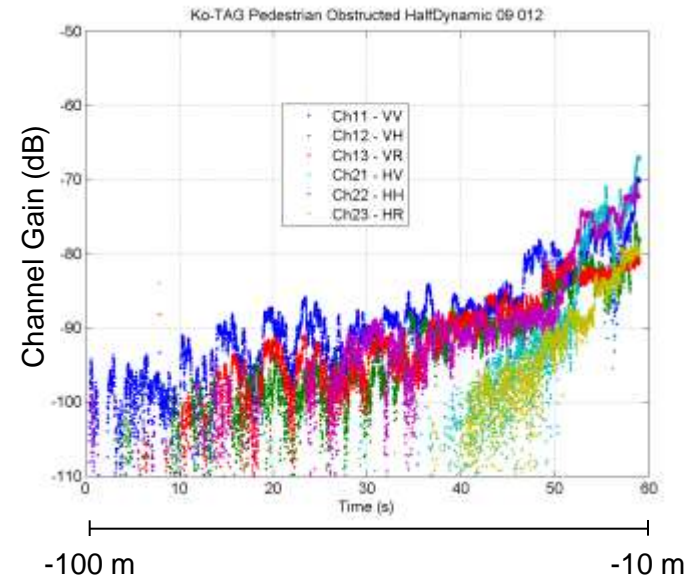
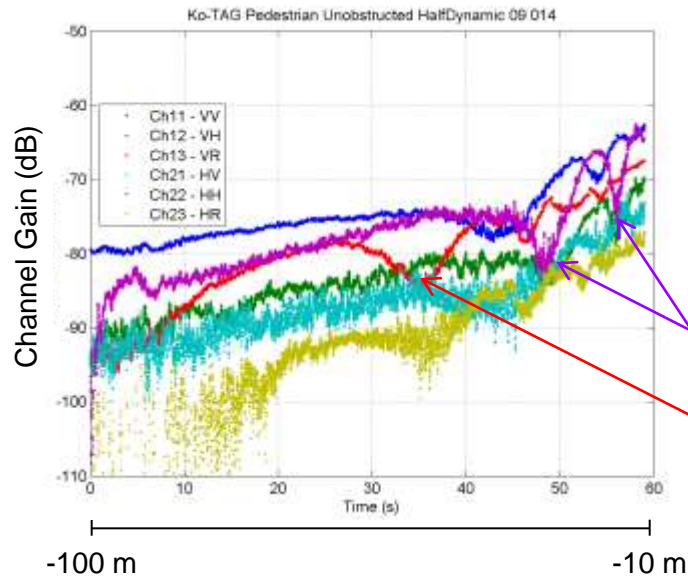
Destructive superposition of strong paths causes **fading**



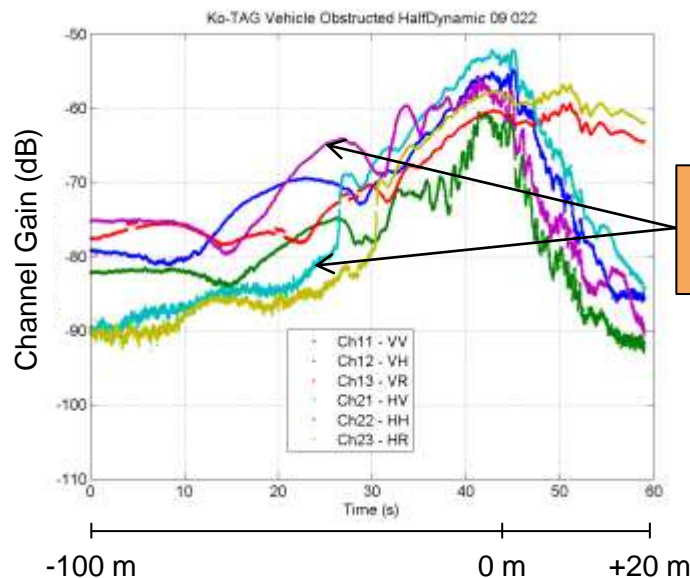
	Tx1: Vertical	Tx2: Horizontal
Rx1: Vert. Front	Ch 11	Ch 21
Rx2: Horz. Front	Ch 12	Ch 22
Rx3: Vert. Roof	Ch 13	Ch 23



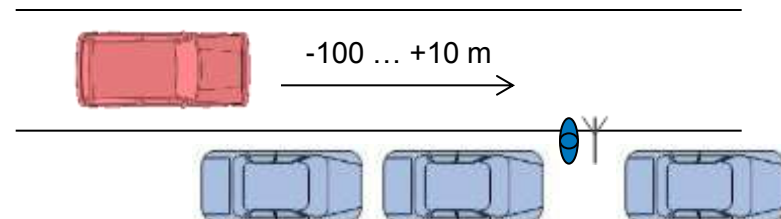
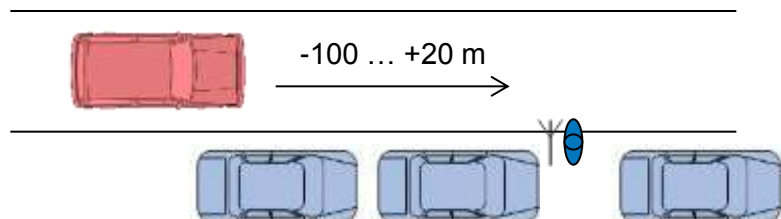
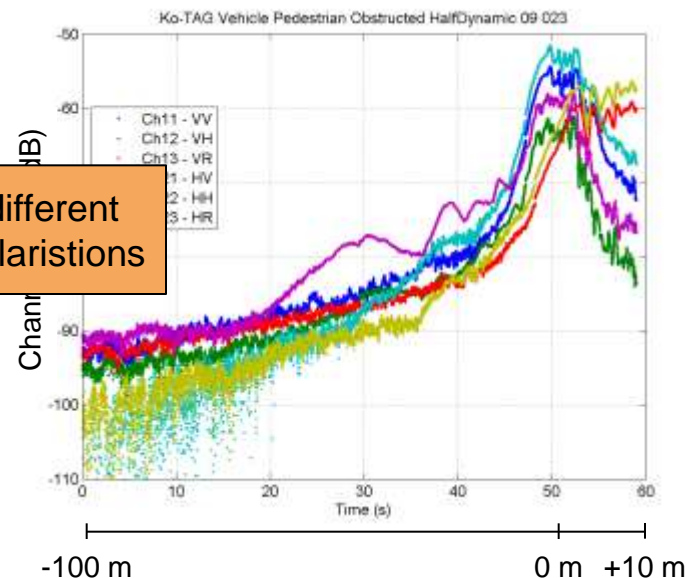
# Channel Gain with Pedestrian Obstruction



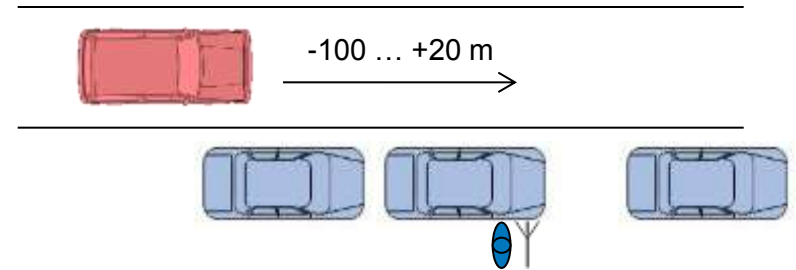
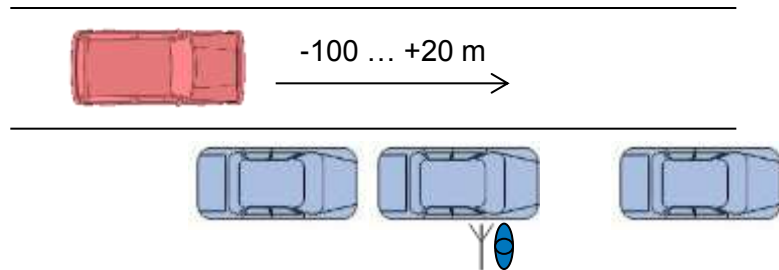
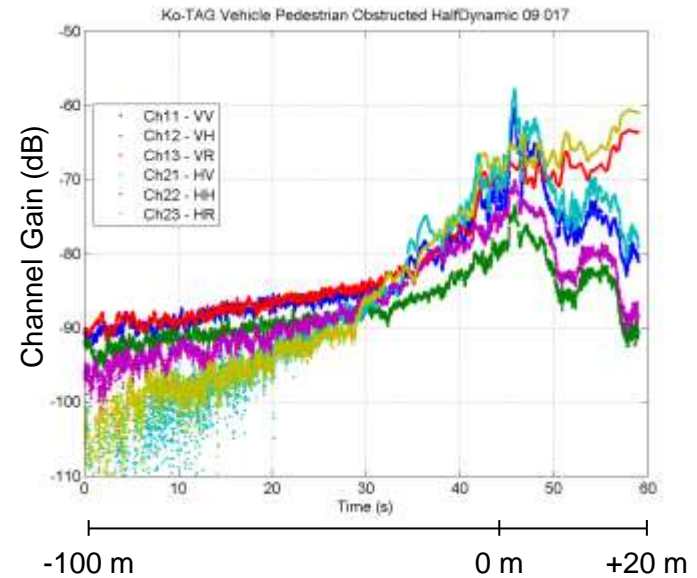
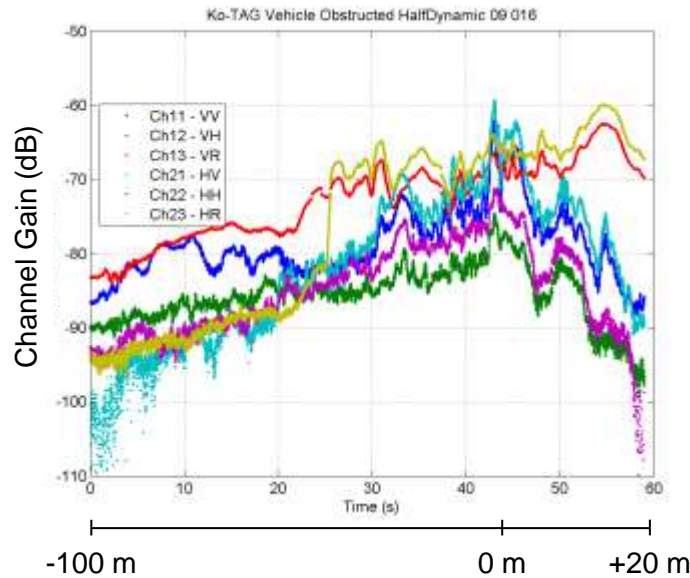
# Channel Gain at Edge of Vehicle Obstruction



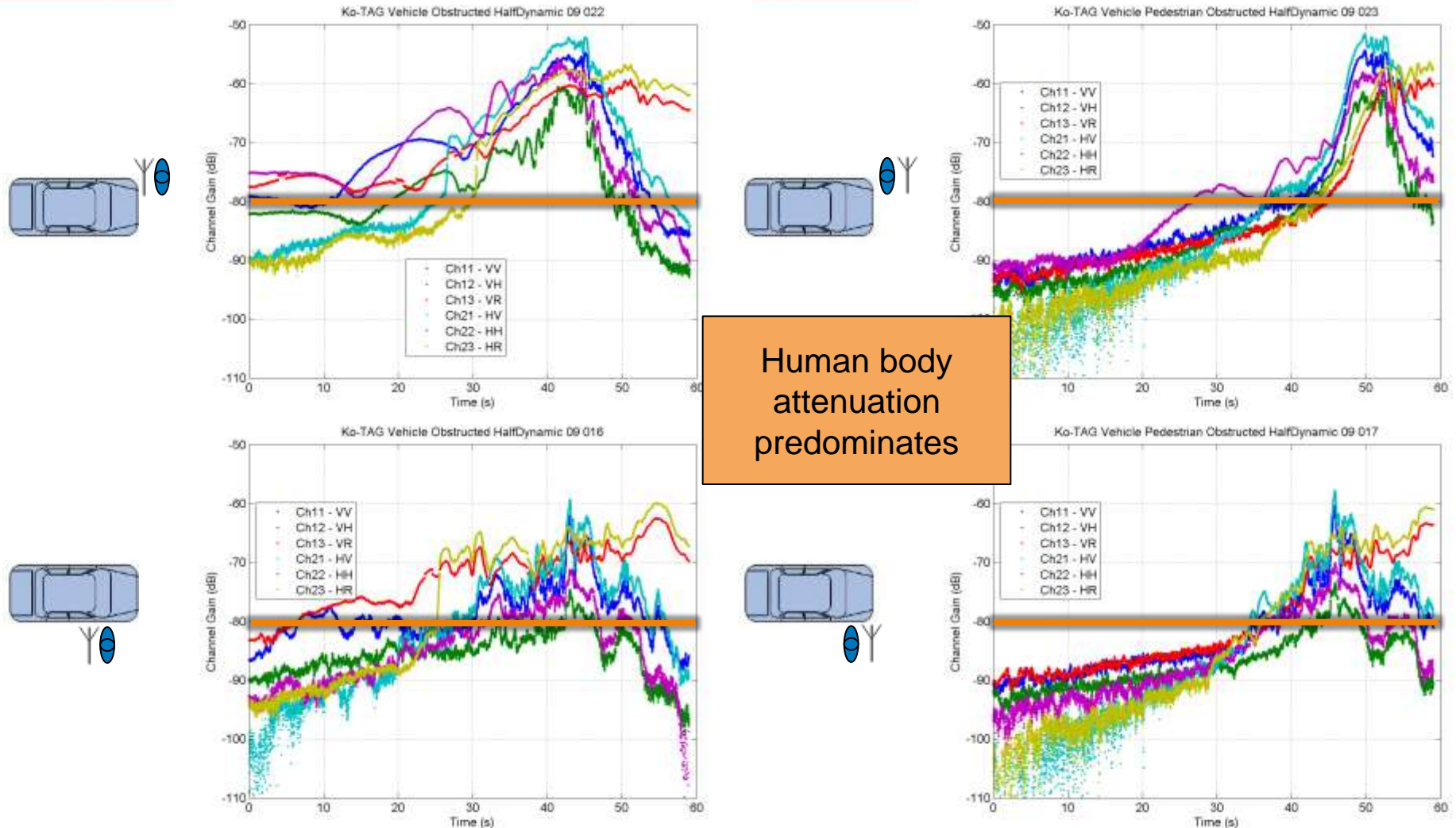
Effect of different antenna polarisations



# Channel Gain with Vehicle and Pedestrian Obstruction



# Comparison of Measurement Results



Channel Sounding

Channel Gain

Human body testing object

Distance estimation

## Goal

Define an easy-to-use and cheap testing object with realistic human body occlusion characteristics for standardized measurement procedures

## Method

Measurement of transmission and reflection characteristics

Investigated occlusion bodies:

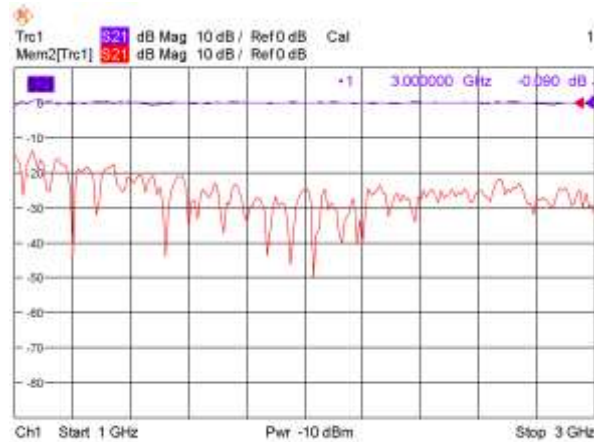
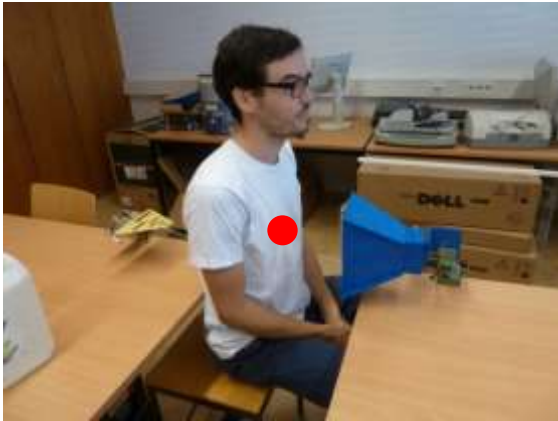
- Container filled with water
- Panel of pyramid absorber
- Metal plate
- Test person



# Transmission Measurements



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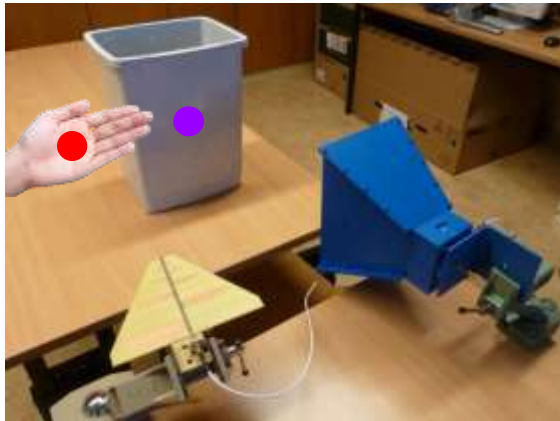
Date: 13.09.2012 14:50:22



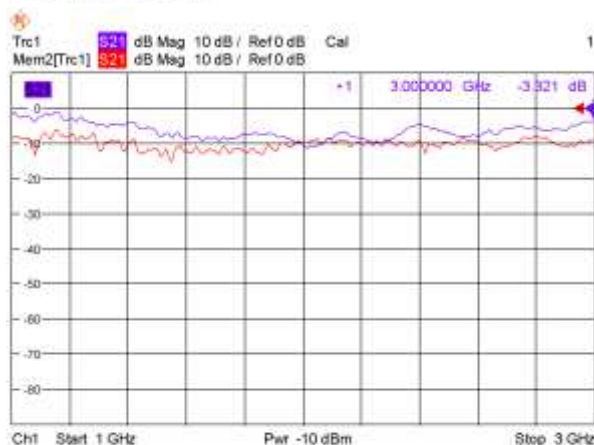
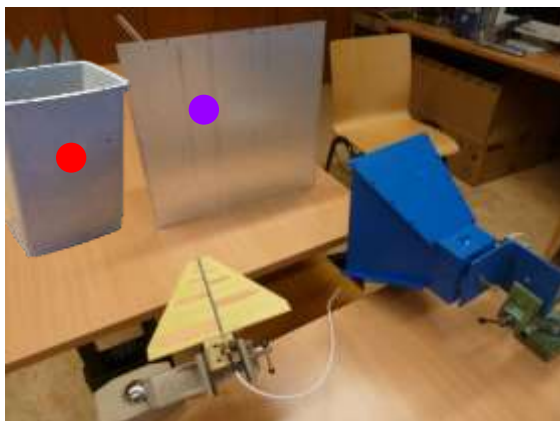
Date: 19.09.2012 16:50:12

Similar  
transmission  
characteristics

# Reflection Measurements

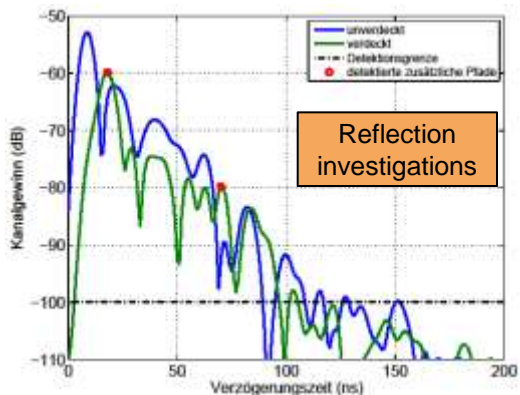
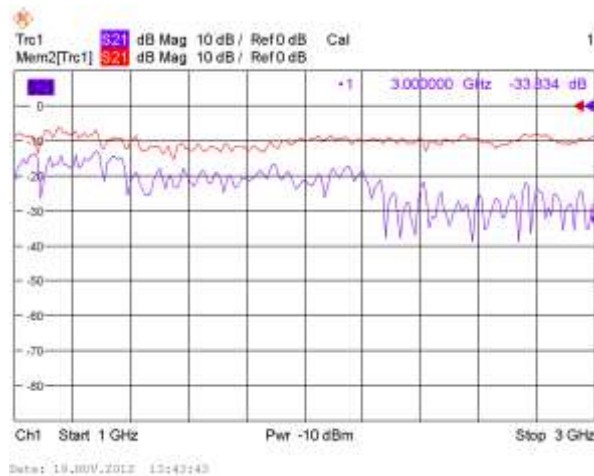
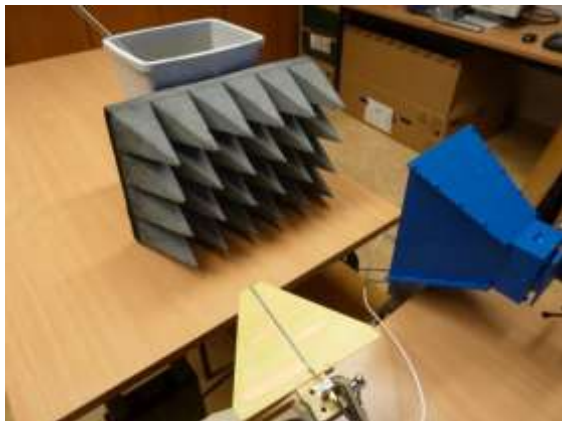


Different reflection characteristics

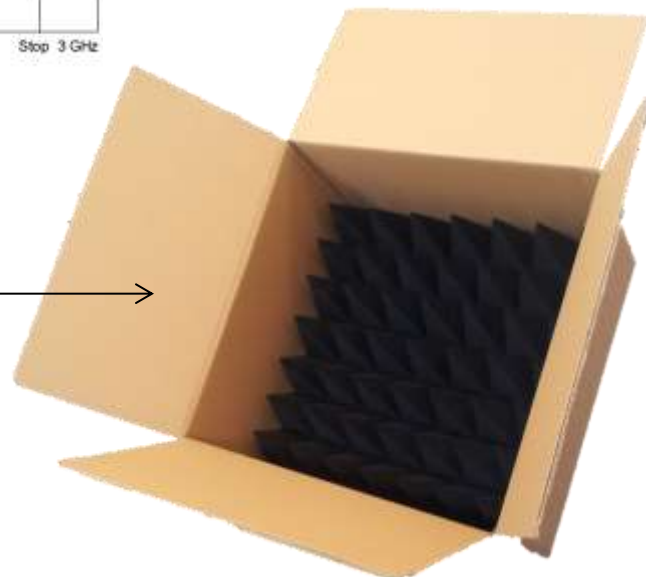


Similar reflection characteristics

# Pyramid Absorber Measurements

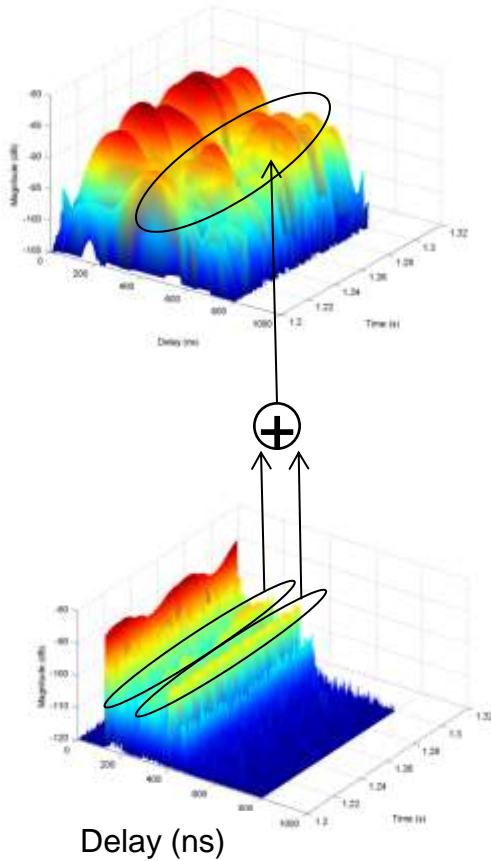


Suggested solution



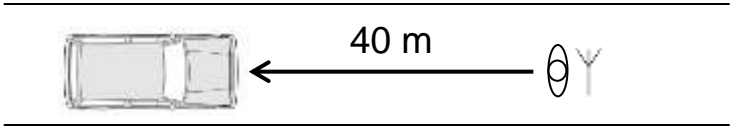
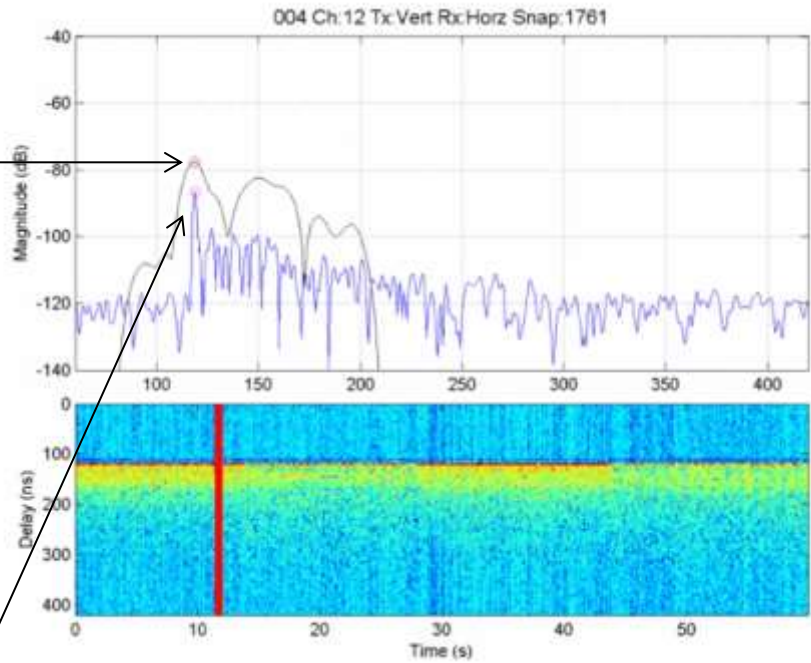
Channel Sounding  
Channel Gain  
Human body testing object  
Distance estimation

# Influence of Bandwidth on Distance Estimation



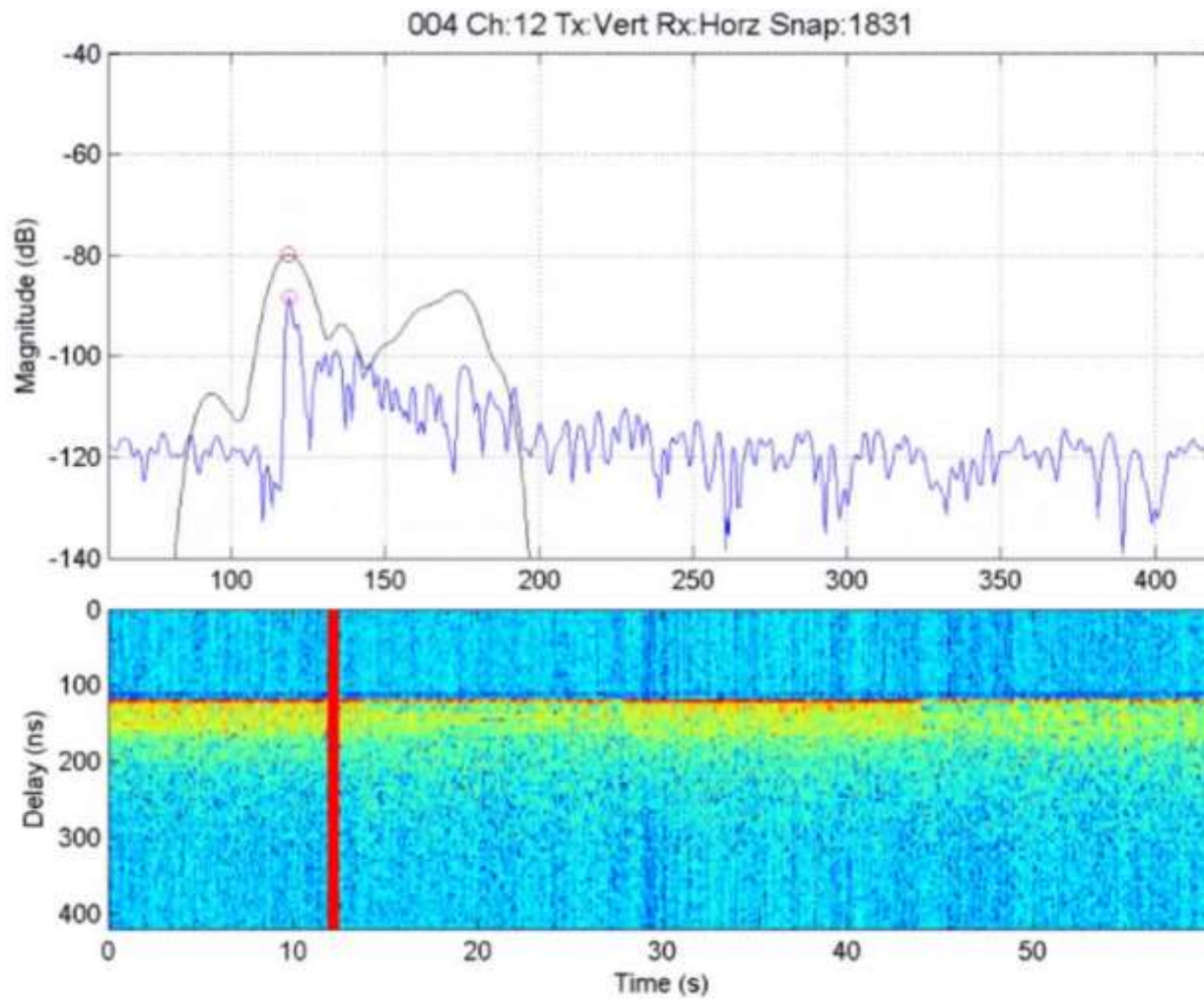
50 MHz:  
Ko-TAG  
distance  
estimation

1 GHz:  
HHI Channel  
Sounder  
bandwidth

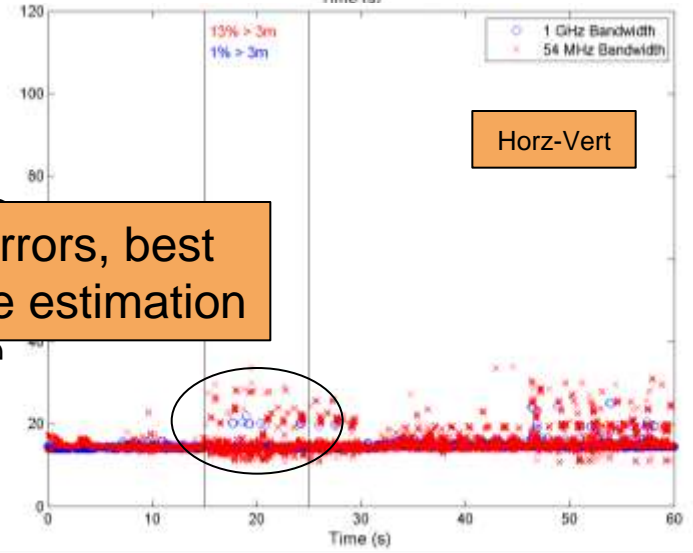
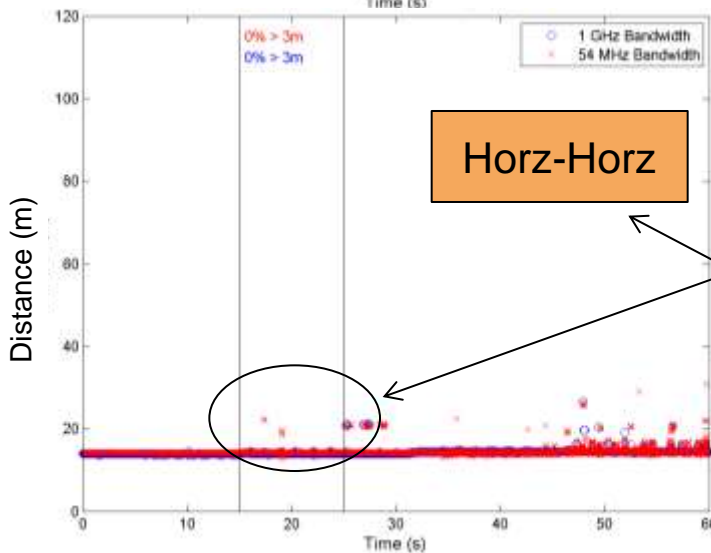
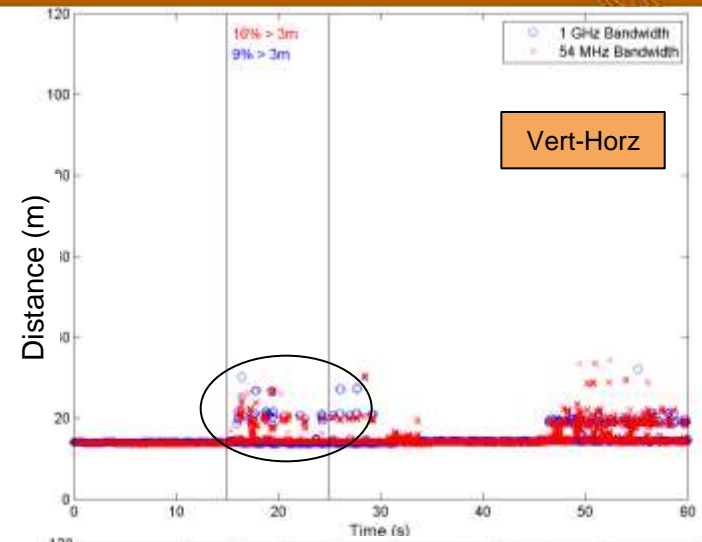
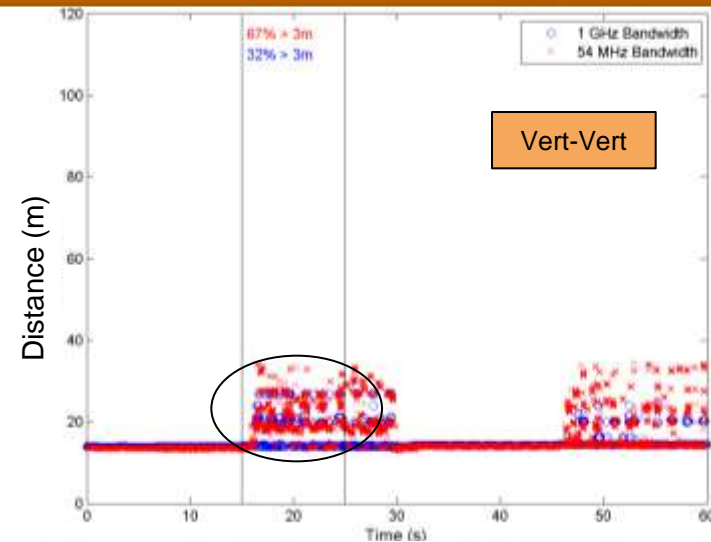


distance = delay x speed of light

# Distance Estimation Video



# Influence of Antenna Polarisation on Estimation Errors



Few errors, best distance estimation

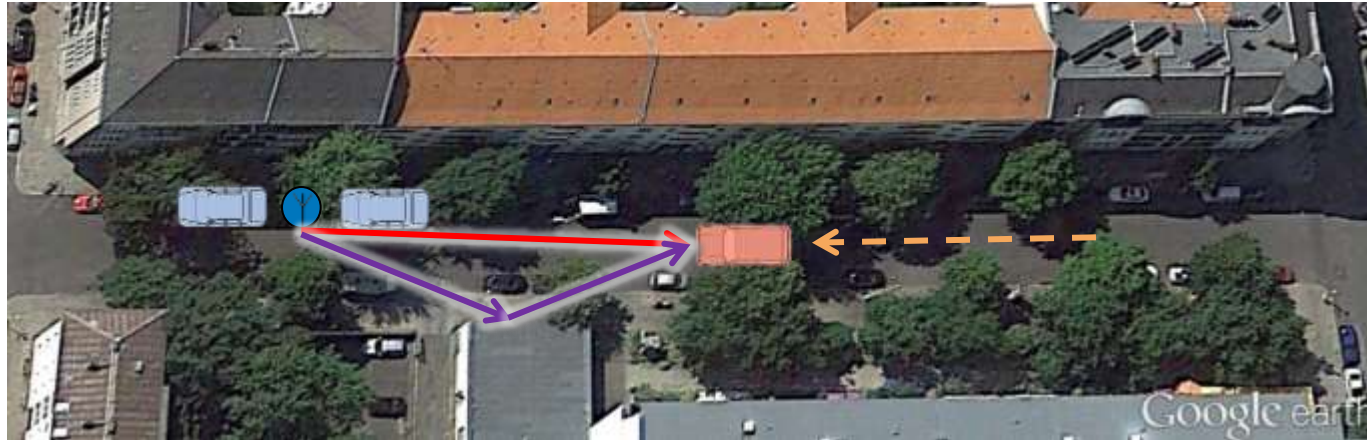
# Statistical Evaluation of Polarisation Influence on Estimation Errors

Distance (m)	Vert-Vert (%)	Vert-Horz (%)	Vert-RoofVert (%)	Horz-Vert (%)	Horz-Horz (%)	Horz-RoofVert (%)
20	67	16	64	13	0	55
30	15	22	22	7	4	15
40	28	24	10	34	6	19
50	12	9	50	17	5	28
60	13	5	13	10	2	10
70	6	4	9	7	2	16
80	3	2	5	2	0	13
90	3	1	12	3	0	12
100	6	4	38	9	0	27
<b>Mean</b>	<b>17</b>	<b>9,6</b>	<b>24,7</b>	<b>11,3</b>	<b>2,1</b>	<b>21,6</b>

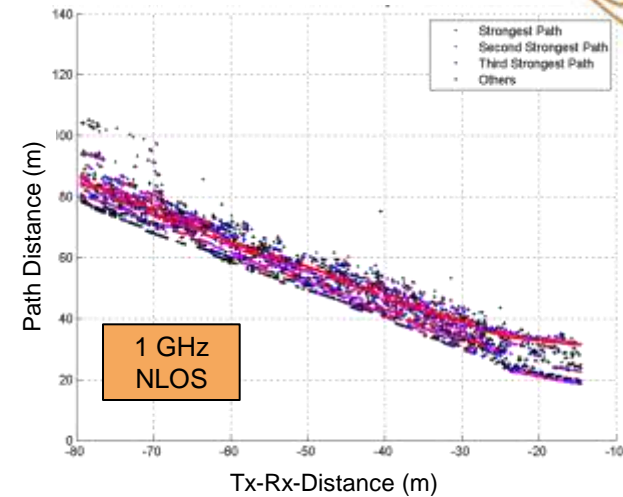
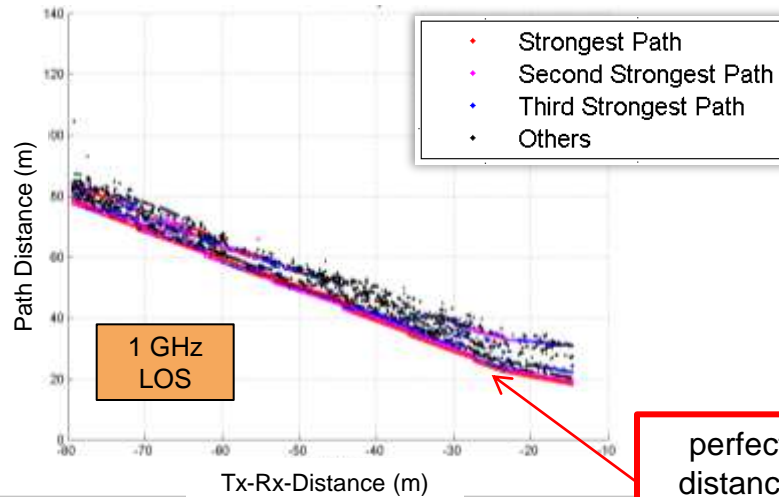
Antenna polarisation affects distance estimation performance



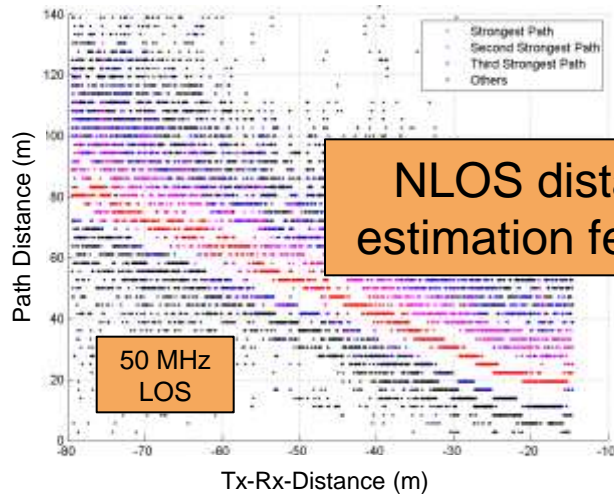
# Real Traffic Measurements



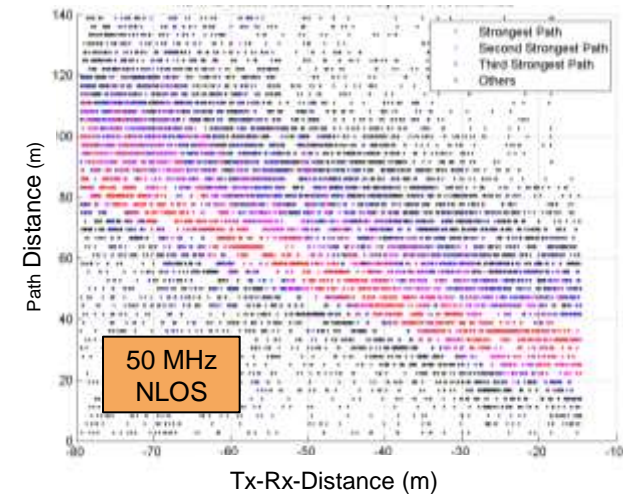
# NLOS vs. LOS



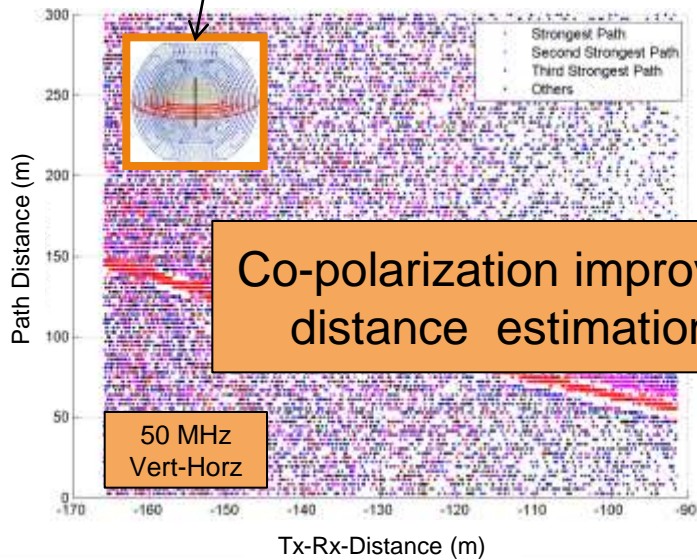
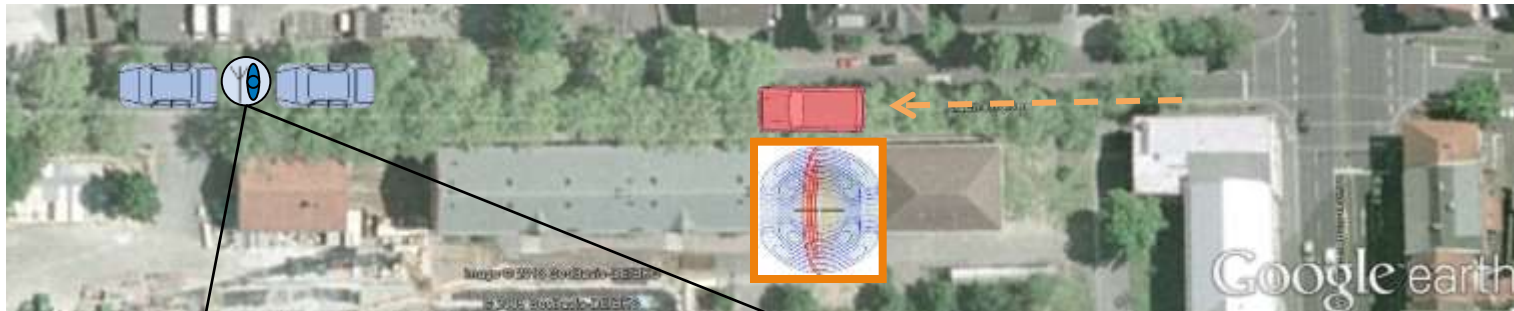
perfect  
distance  
estimation



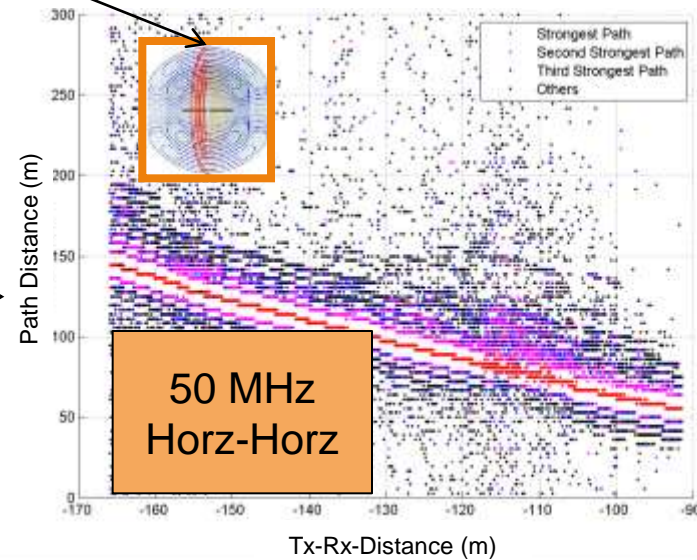
NLOS distance  
estimation feasible



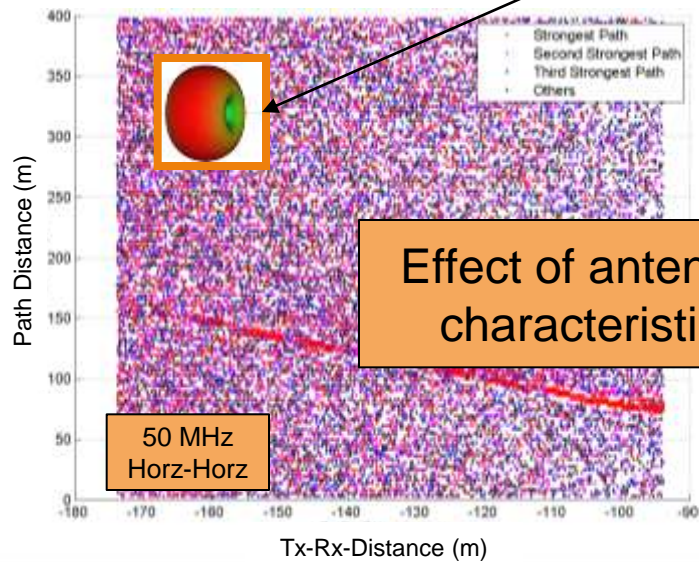
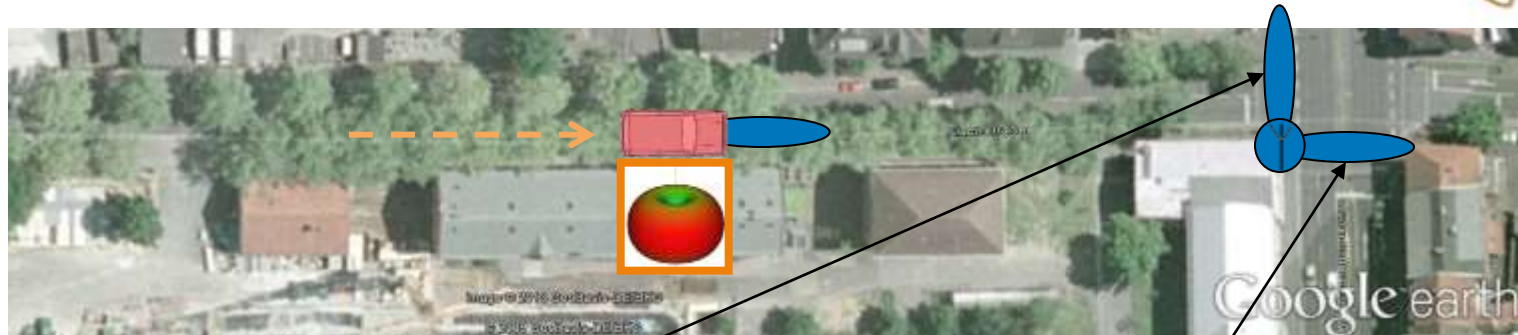
# Cross-Polarized vs. Co-Polarized



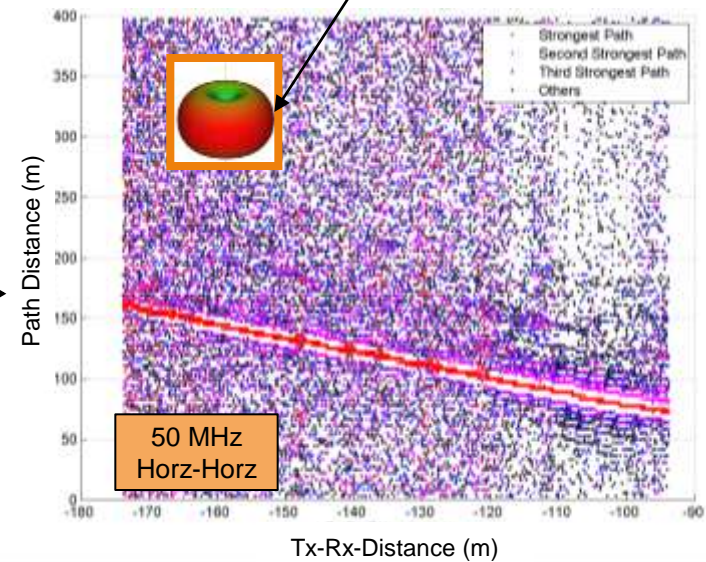
Co-polarization improves distance estimation



# Co-Polarized Perpendicular vs. Co-Polarized Parallel



Effect of antenna characteristic



Channel Sounding  
Channel Gain  
Human body testing object  
Distance estimation

Analysis of HHI Channel Sounder measurement data enabled us to

**identify physical restrictions** of the underlying radio channel

and **evaluate potentials** of the Ko-TAG system

# Thank you for your attention!

BMW Group  
Forschung und Technik



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