

# Optimized Automotive Antenna Selection and Placement



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# Overview

- Overview on Wireless Entertainment Systems
- Overview on Vehicular Antenna Placements
- Overview on Possible Antenna Technologies
- Vehicular Measurements
- Drive Tests and Interpretation Problems
- Services and Antennas ; Pro's & Contras
  - Rod + Monopols
  - Patch Antennas
  - On-Glas Antenna
  - Glued Foil Antenna
  - Fractal Antenna
- Where to Place Diversity Antennas

# Wireless Entertainment Services in Vehicles - An Overview

## Sound-Service

AM/FM  
DAB/DMB  
DRM  
IBOC / HD Radio  
SDARS  
Worldcom

## Communication-Service

GSM CDMA UMTS  
WLAN Car2Car Bluetooth

## Video-Service

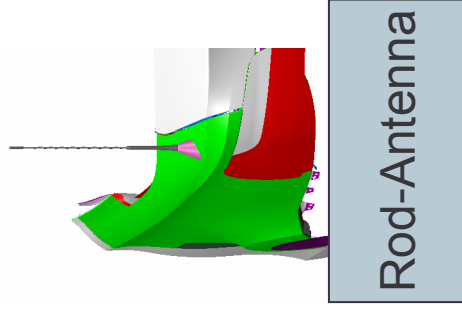
DVB-T/S/H  
DMB



Navigation-Service   GPS

# Vehicular Antennas

## An Overview



Spoiler  
Antenna

Roof  
Antenna

Windscreen  
Antenna



Rear-Window  
Antenna

Bumper  
Antenna

Side-Window  
Antenna

# Vehicular Antennas (cont.)

Convertible  
Roof Cover



Antenna in  
Fender

Antenna in / on  
Trunk Cover

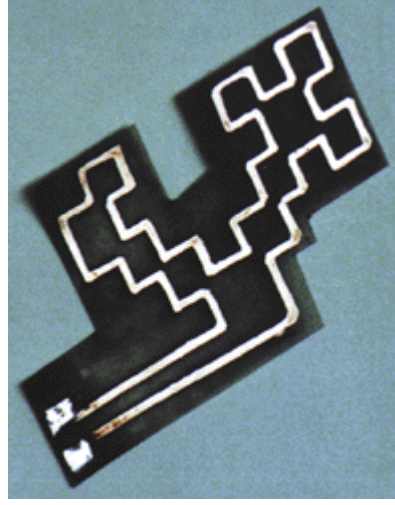
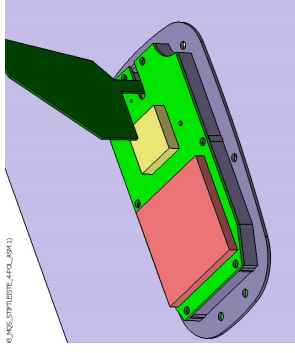
Antenna in  
Mirrors



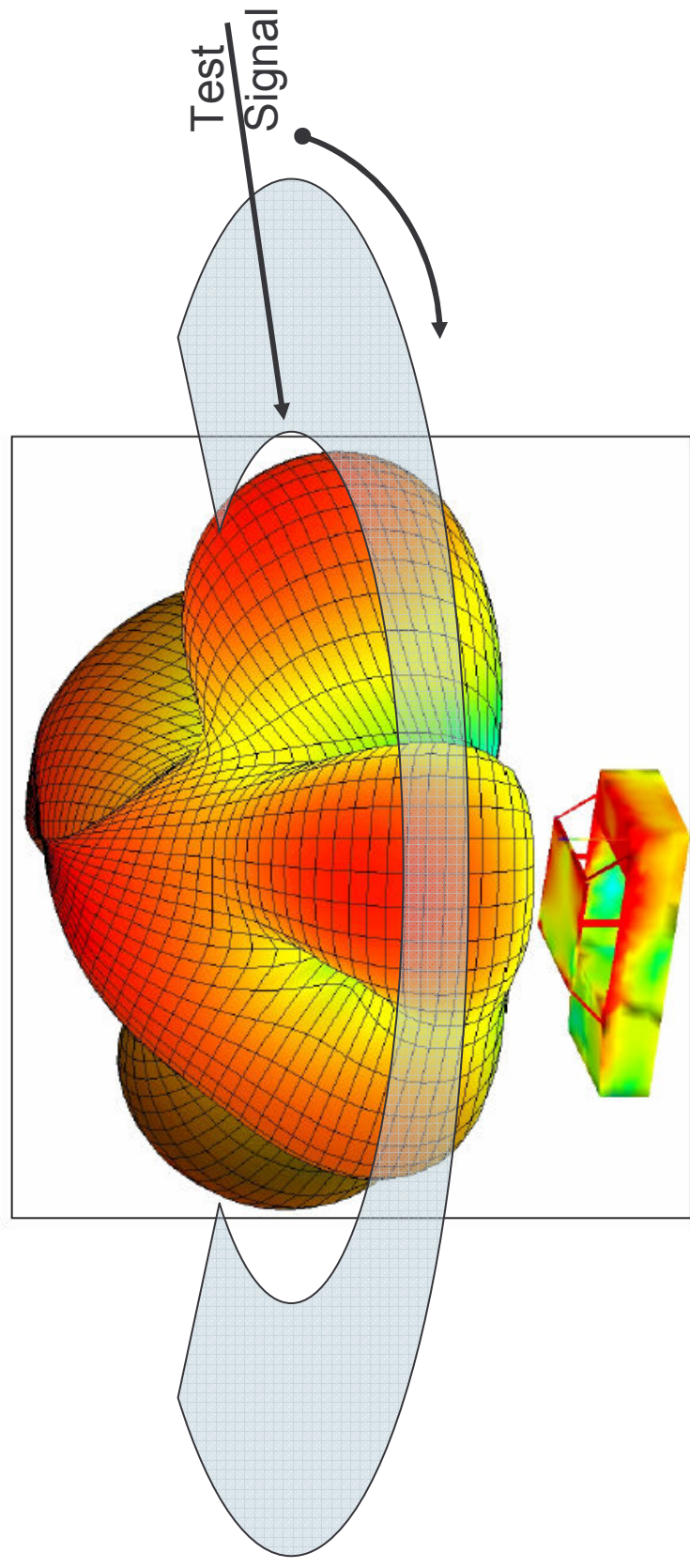


# Possible Antenna Technologies

- Monopols
- Rod Antenna
- Patch Antenna
- On-Glas Antenna
- Glued Foil Antenna
- Fractal Antenna



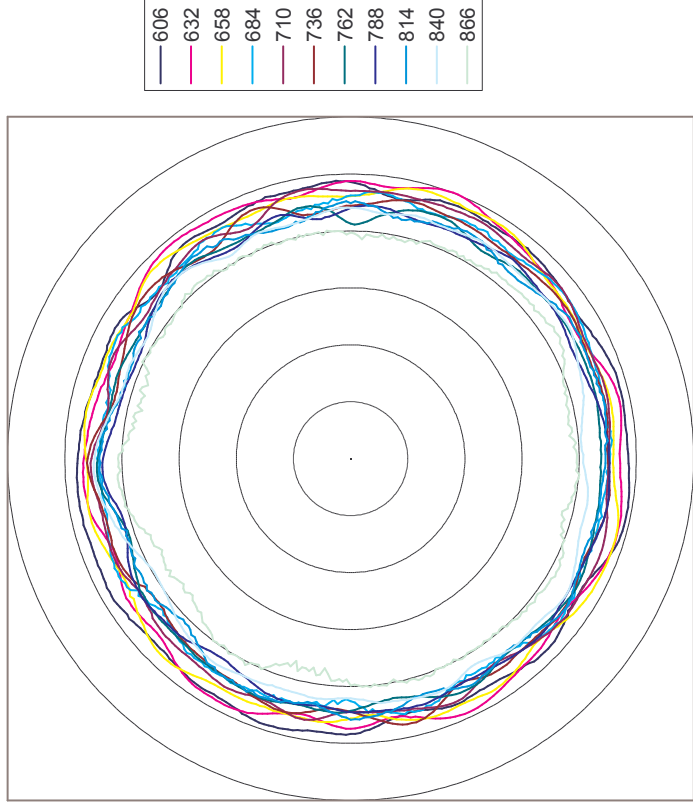
# Vehicular Antenna Measurement



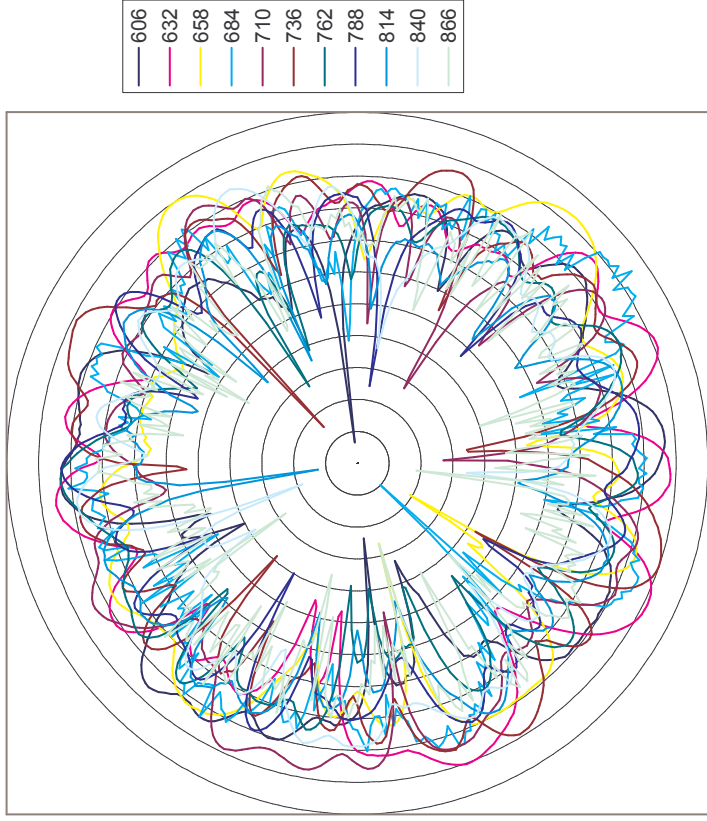
Possible 3D energy distribution around a vehicle

# Radiation Pattern Cuts

Radiation Pattern vs. Frequency 600-860 MHz  
Reference Antenna on Rooftop (centered)  
Vertical Polarization

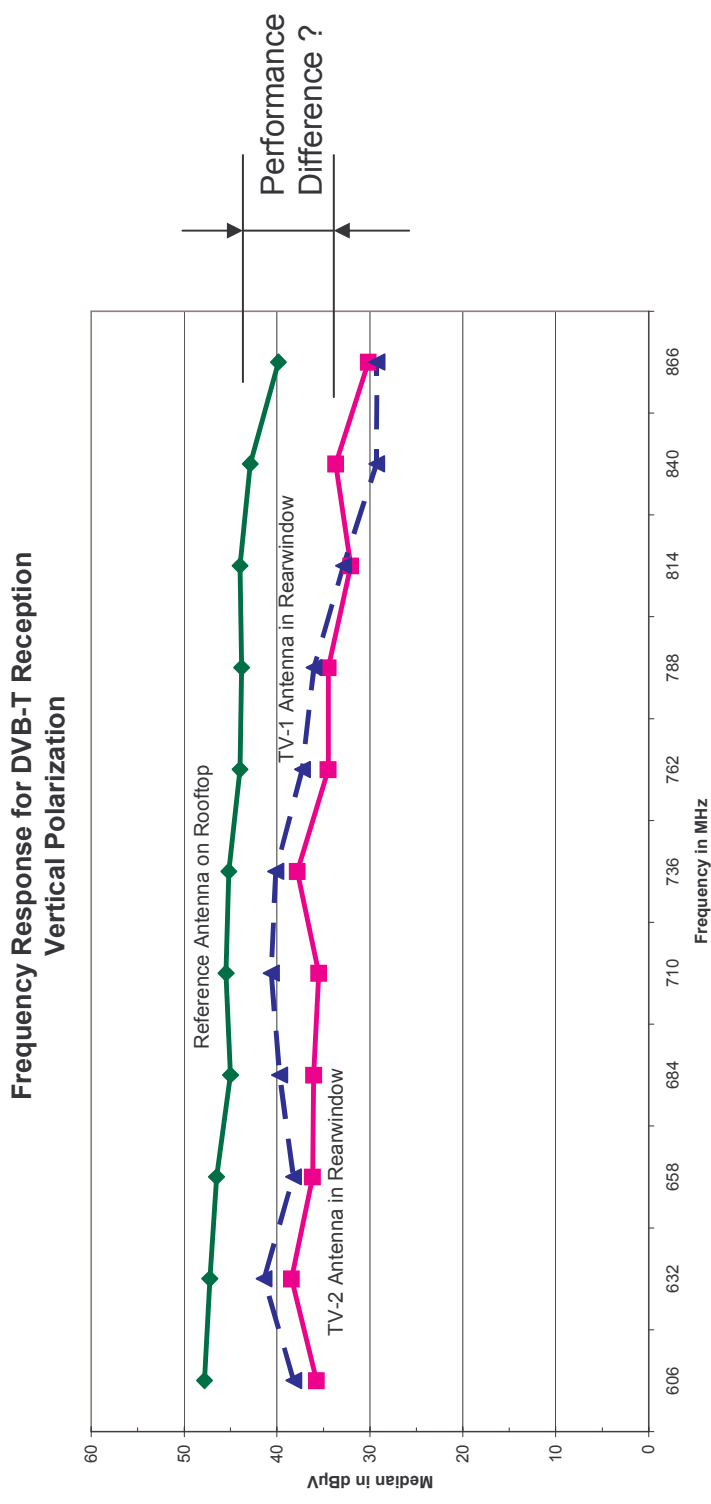


Radiation Pattern vs. Frequency 600-860 MHz  
Limousine Rearwindow Antenna  
Vertical Polarization





# Frequency Response



## Open Questions:

Does single 2D-cut represent reception performance ?

How relevant is level reduction in comparison to reference ?

When does level difference begin to get noticed by customer ?

# Drive Tests

## Pro

- Customer Related Test
- Logged data are real-world information

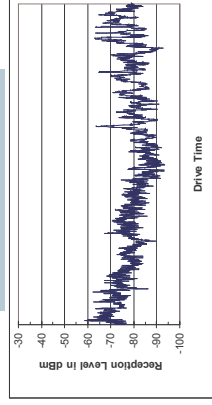
## Contra

- Fully licensed vehicles necessary
- Security limitations
- Dangerous
- Rugged portable Measurement Equipment necessary
- Excessive costs

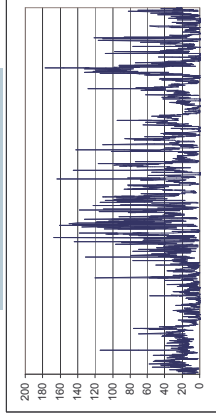


# Drive Test: Collecting Data

Field-  
Strength



Signal  
Quality



GPS-  
Position

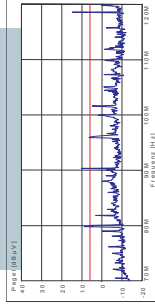
8091901A4801.0665N01156.2268E034.4153.10112052000000047  
9091904A4801.0416N01156.2479E034.4150.60112052000000174  
10091907A4801.0193N01156.2732E033.3140.20112052000000170  
11091910A4801.0027N01156.3052E032.5121.10112052000000380  
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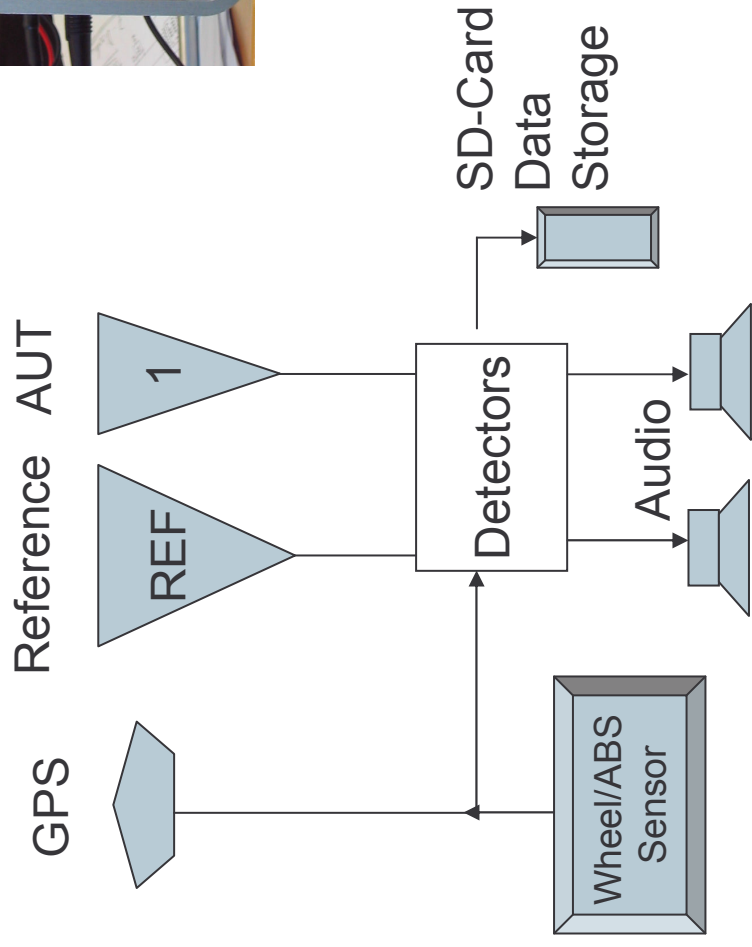
Bearing  
Speed

Trigger for simultaneous  
measurement via wheel  
sensor / ABS

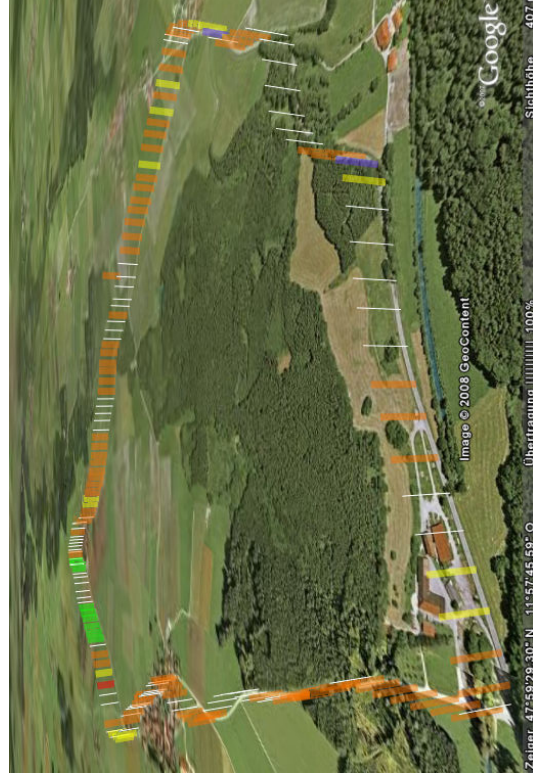
EMC  
Level



# Drive Test Setup



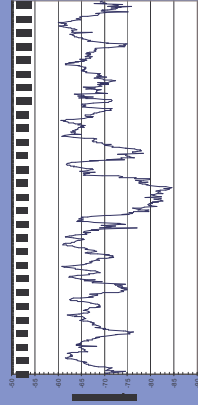
Synchronized & calibrated  
Measurements must be performed



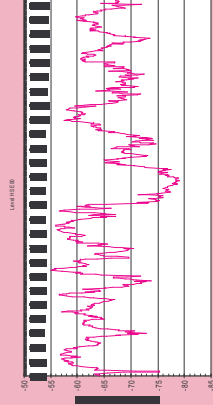


# Drive Test: Postprocessing

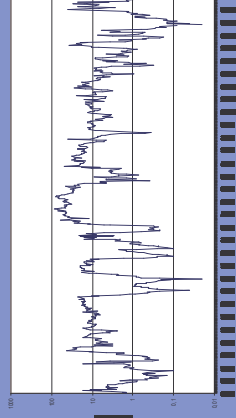
Signal Reference



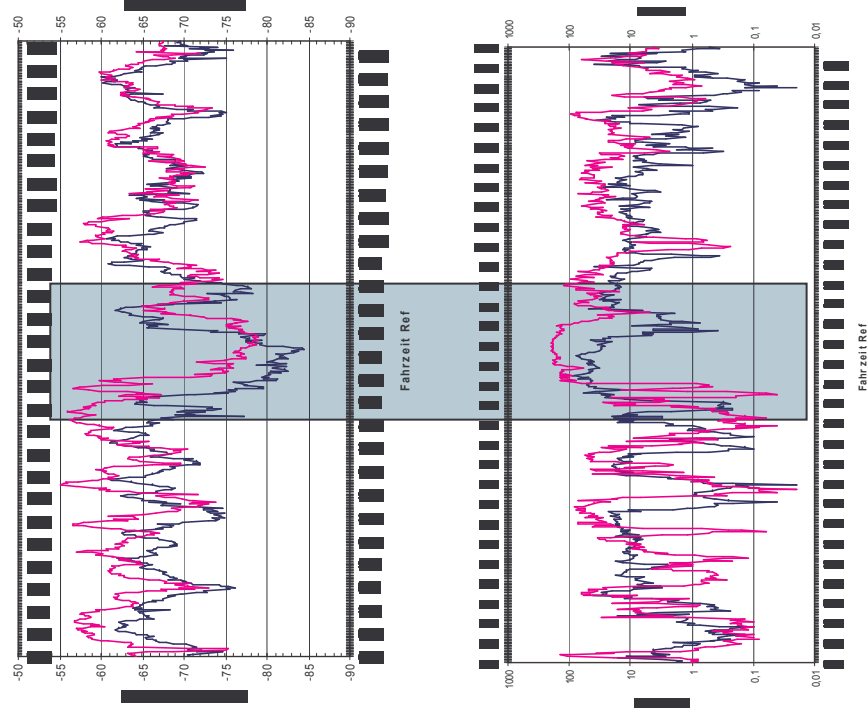
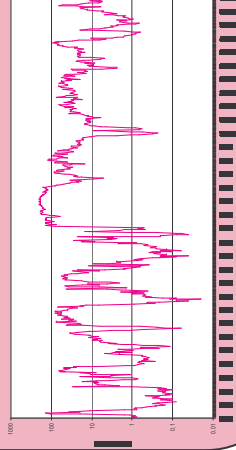
Signal AUT



BER Reference

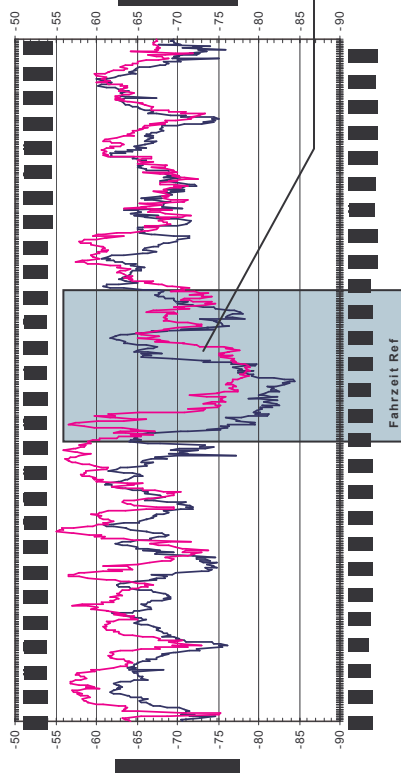


BER AUT



# Drive Test: Usable Information

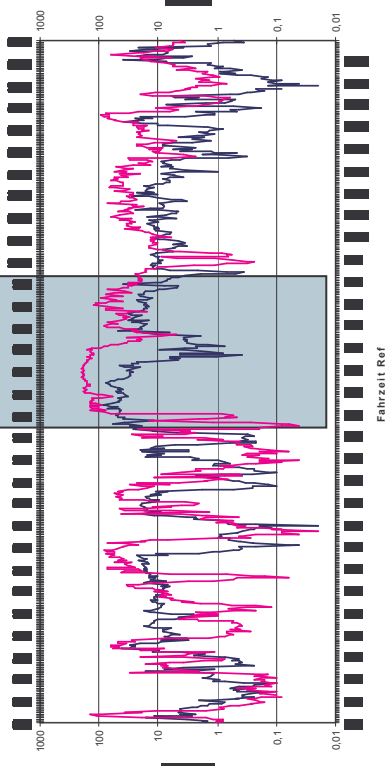
Comparing Reception Level



Antenna under test (AUT)  
provides higher reception  
level than Reference  
antenna

Delay due to AGC ?  
How relevant are differences ?  
Is it good or bad ?

Comparing BER-Level



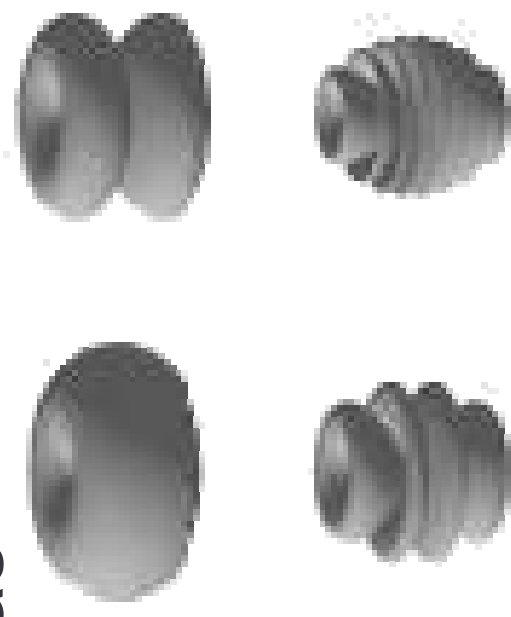
Antenna under test (AUT)  
provides higher Bit-Error  
level than Reference  
antenna

# Interpretation Problems

- Different EMC-Levels lead to different SNR
- How to interpret BER-values when EMC-level is different ?
- Strong non-linearity between SNR-BER
- How to interpret BER in fading environment ?

# Pro & Contra Antennas vs. Service

- Monopole and Rod Antennas

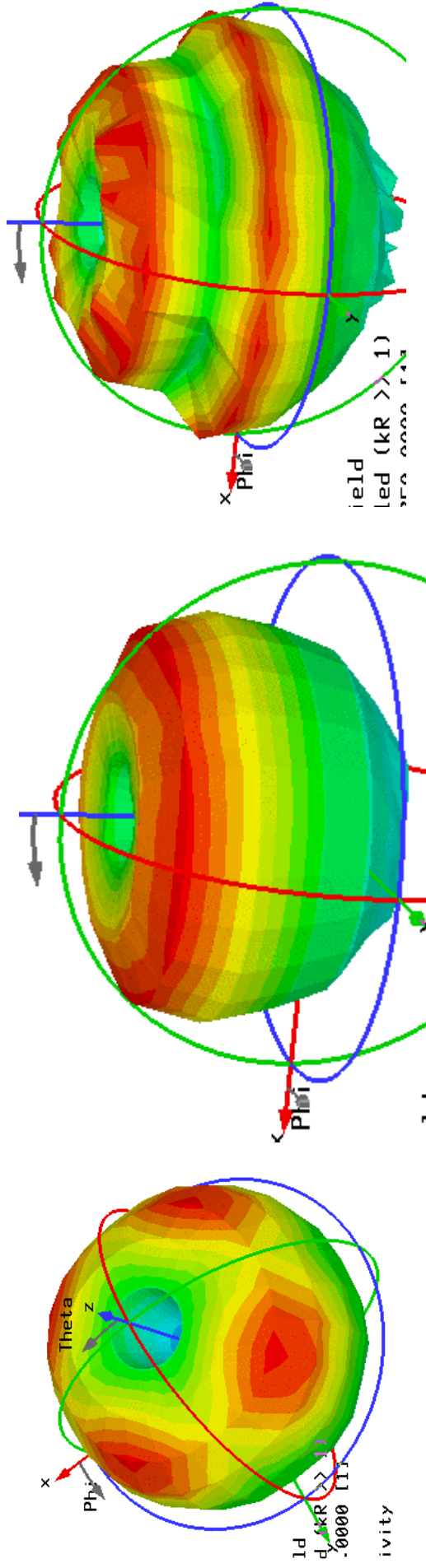
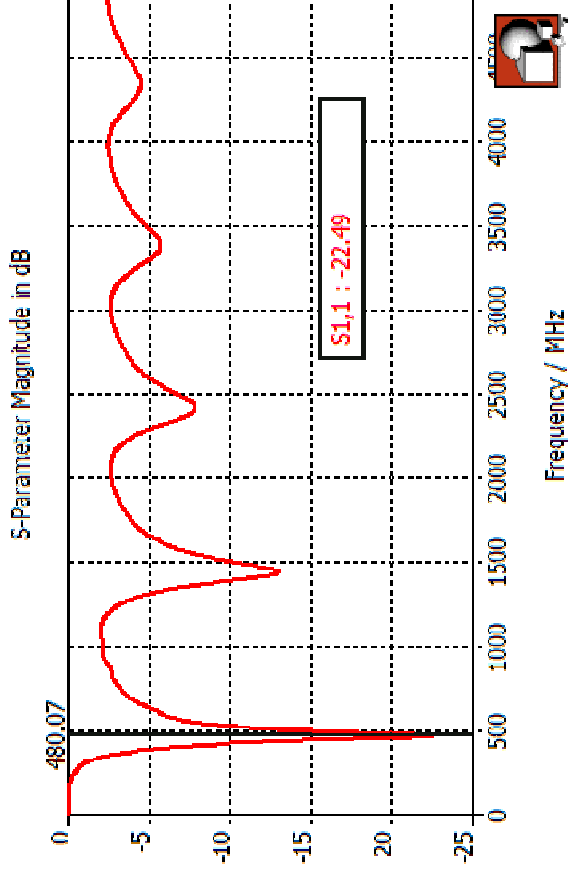


- Suitable for FM / DAB / TEL / WLAN
- *Advantages*: relatively small, uncritical
- *Disadvantage*: unaesthetic design, large ground-plane needed, multiple lobes, vertical plane lobes and elevates



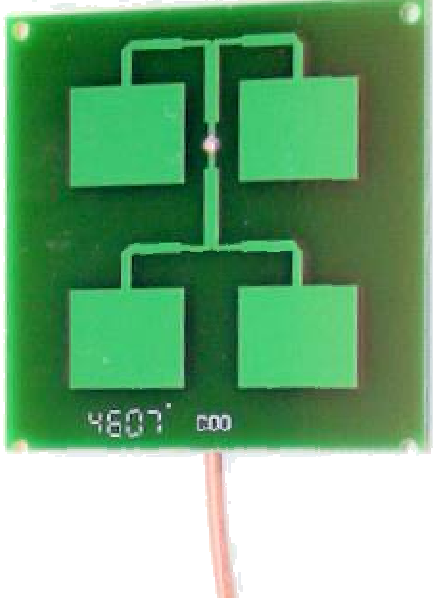
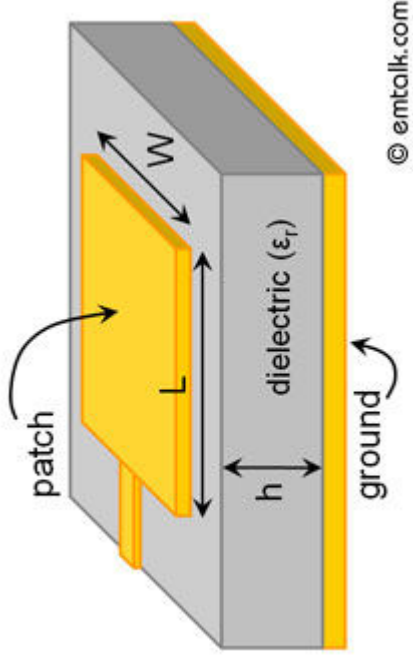
# Monopole

Multiple Resonances  
Pattern lobes with increasing  
Frequency vertically and horizontally



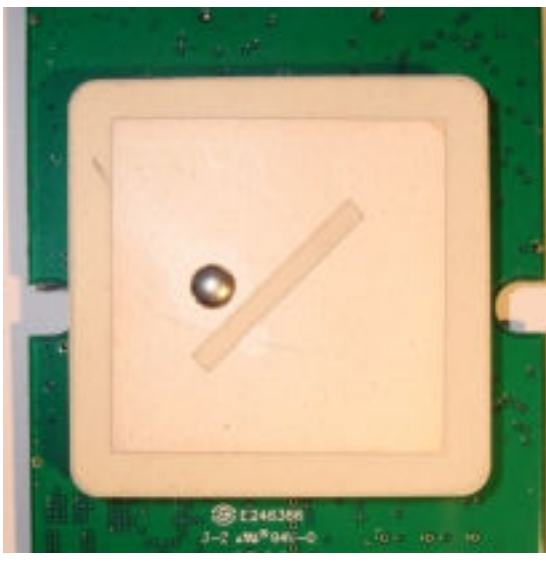
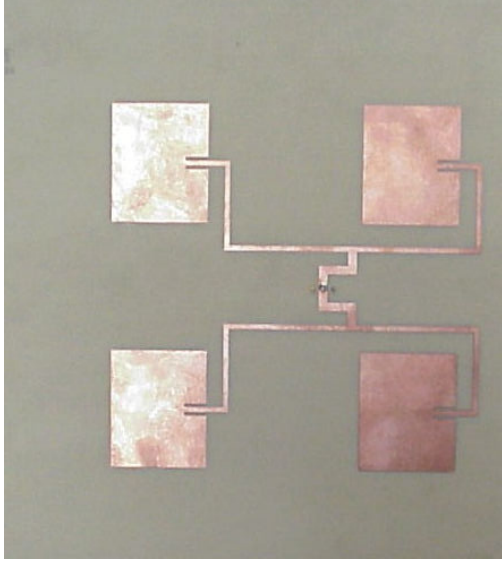
# Pro & Contra Antennas vs. Service

## Patch Antennas



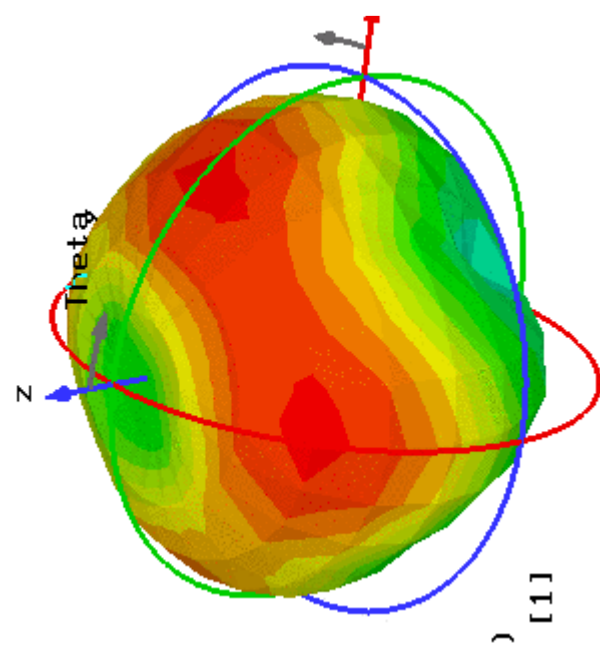
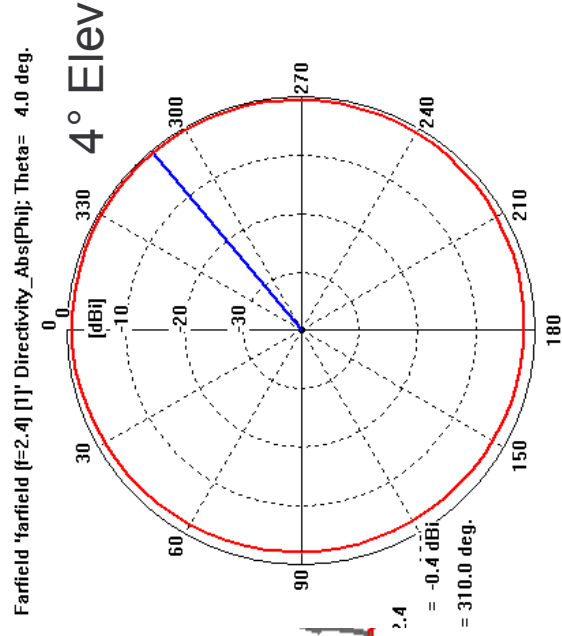
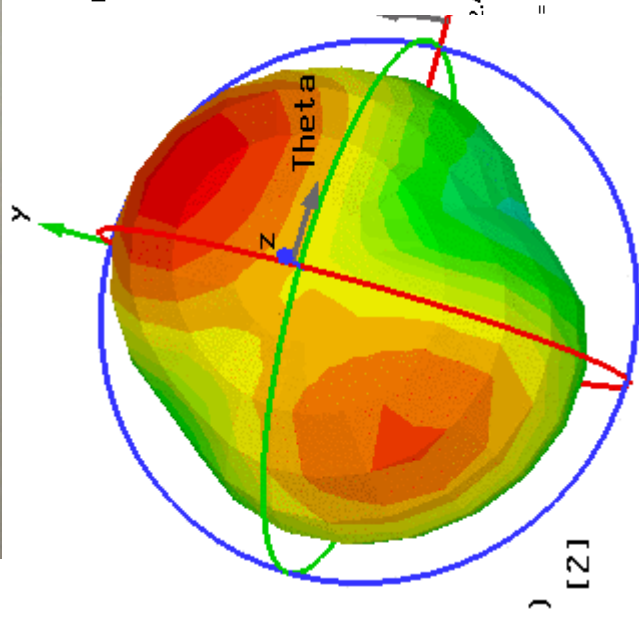
- Suitable for GPS / SDARS / TEL / WLAN
- *Advantages:* small, uncritical, linear+circular polarization, Array, Beam steering possible
  - *Disadvantage:* large ground-plane needed, main beam to sky

# Patch Antennas



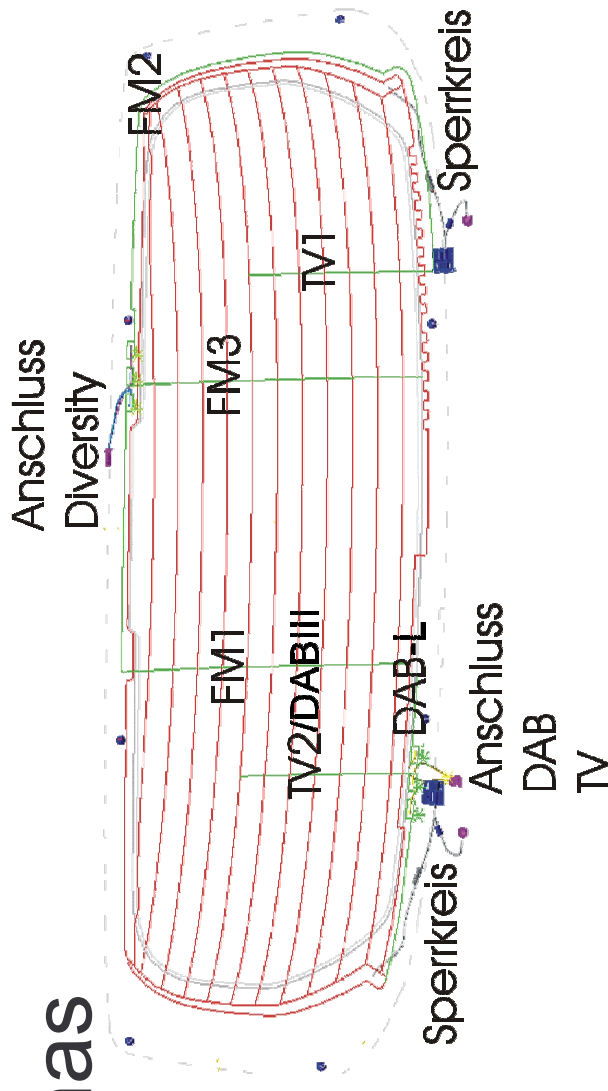
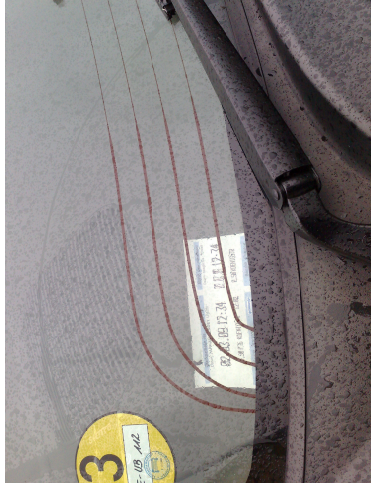
Higher modes on patches  
Can modify pattern positively.

For Example:  
Omni-Directionality  
similar Monopole



# Pro & Contra Antennas vs. Service

- On-Glas Antennas



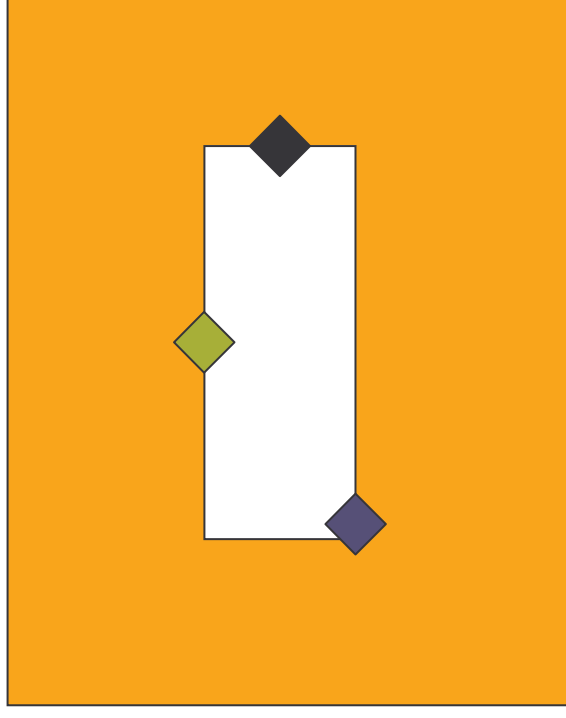
- Suitable for AM / FM / DAB / RKE / DVB / TEL / WLAN
- *Advantages:* cheap, multiple antennas
- *Disadvantage:* multiple lobes, EMC critical



# On-Glas Antennas

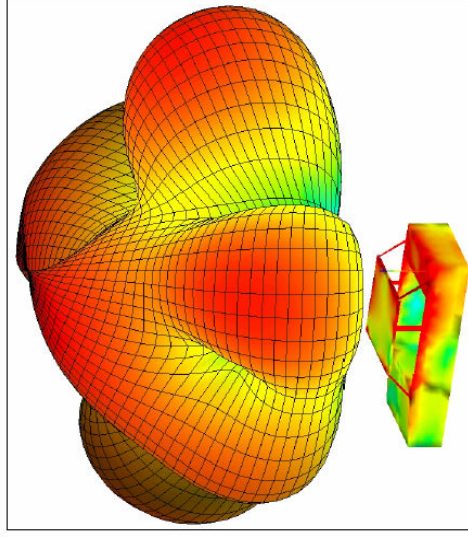


Slot Antenna Approximation

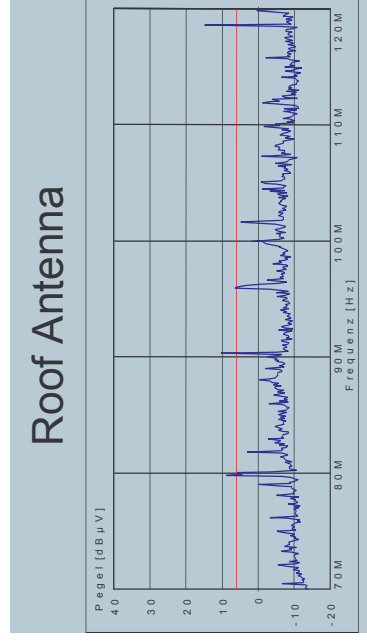


Depending on Feed point, different modes are resonant, thus changing radiation pattern & polarization.

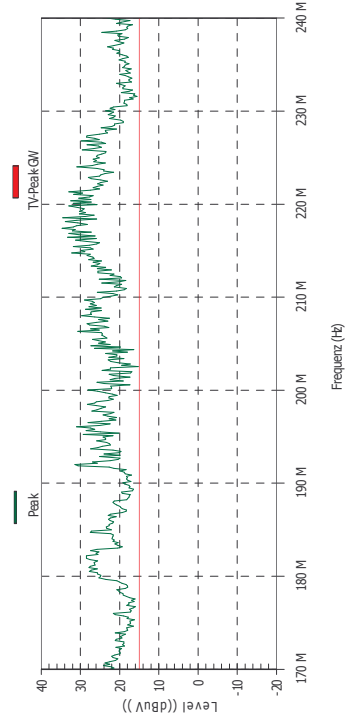
**Disadvantage:**  
complex feed impedance



# Influence of EMC-Situation due to Antenna Concept



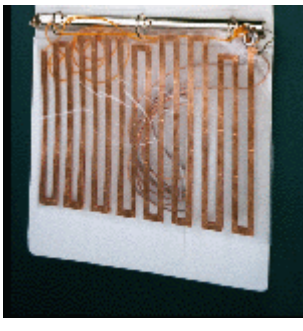
Rear Window Antenna



Depending on position of antenna  
different EMC-levels are measured

# Pro & Contra Antennas vs. Service

- Glued Foil Antennas

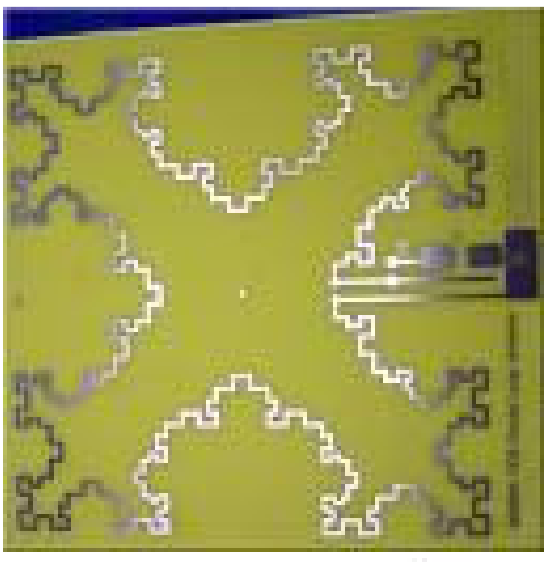
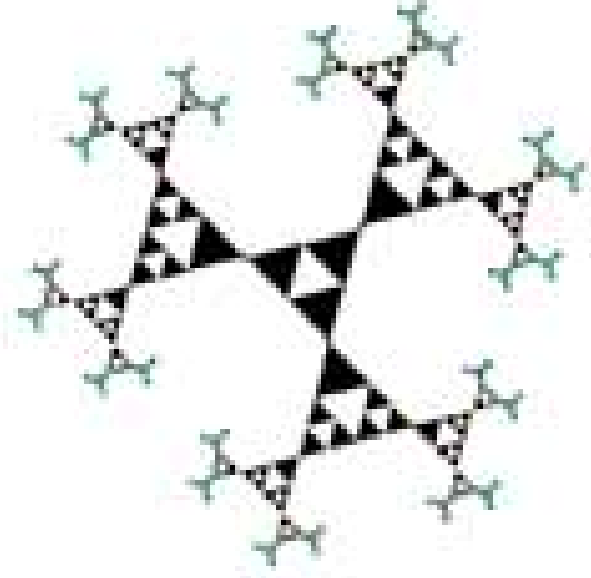
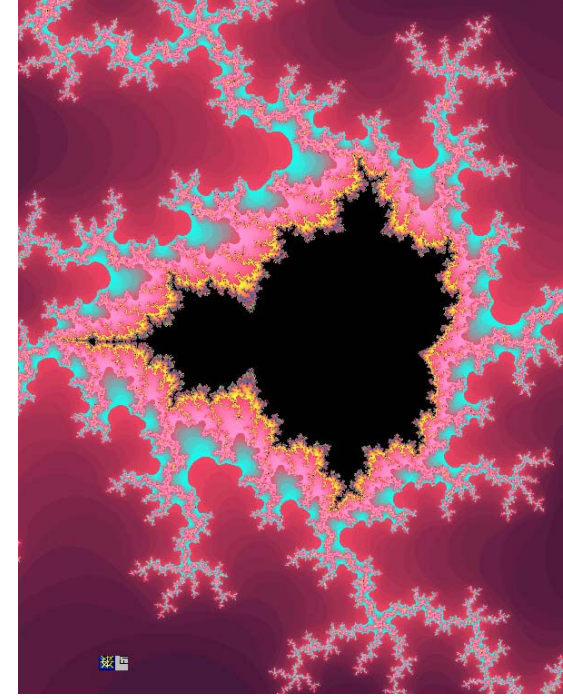


- Suitable for short range communication
- *Advantages:* easy integration
- *Disadvantage:* very narrow bandwidth



# Pro & Contra Antennas vs. Service

## Fractal Antennas

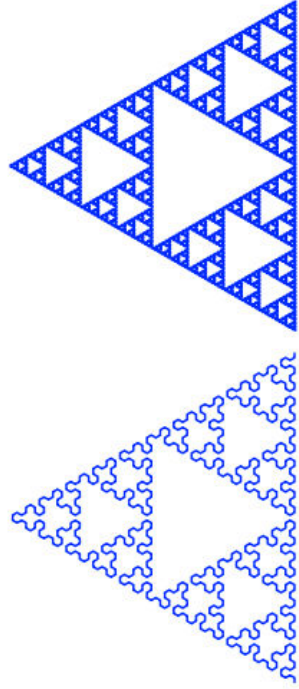
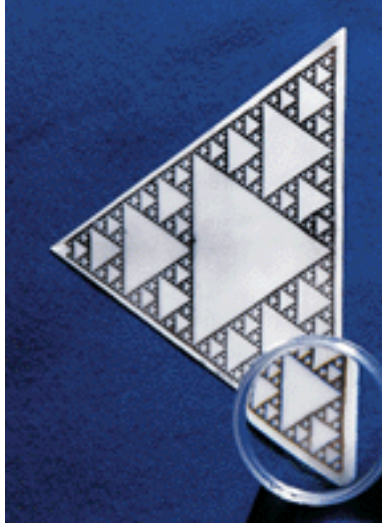
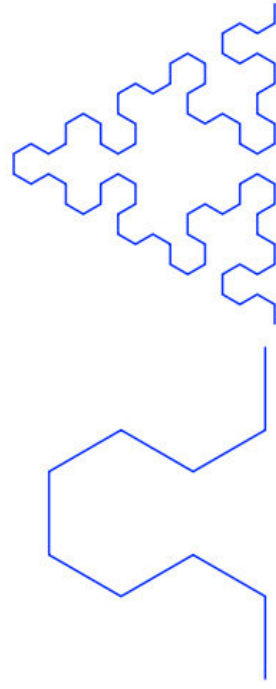


Not (yet) Suitable for Automotive

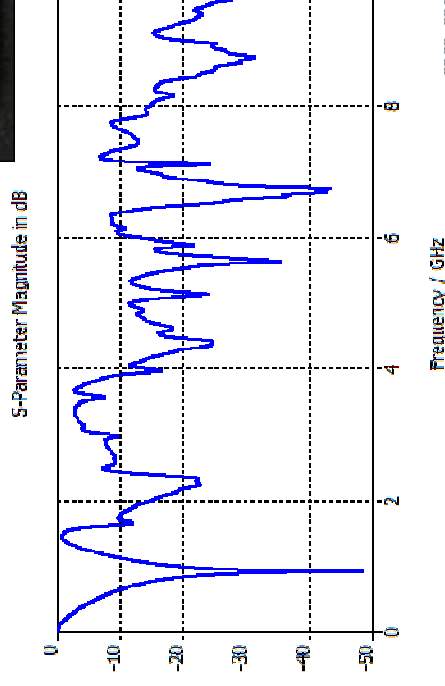
- *Advantages*: multiple resonances, relatively small
- *Disadvantage*: very narrow bandwidth, pattern uncontrollable, many lobes and nulls



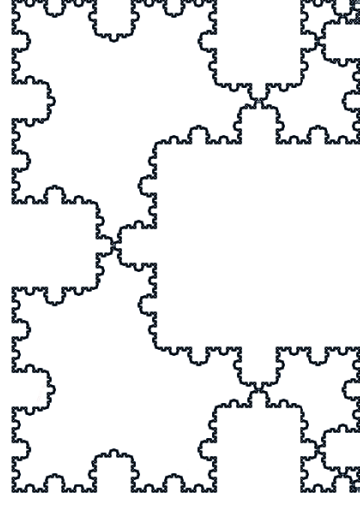
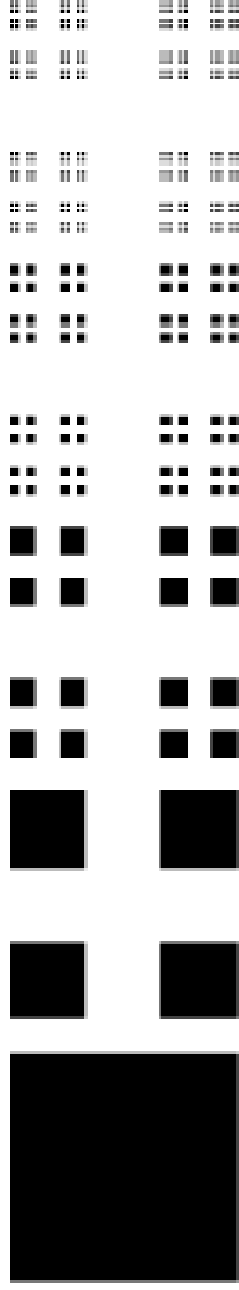
# Fractal Antenna Process

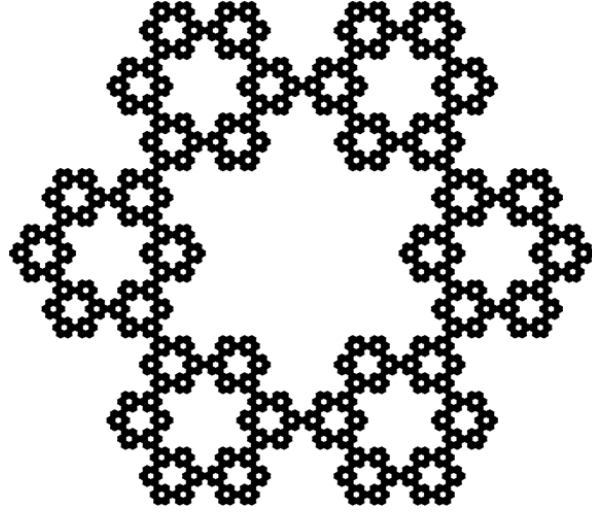
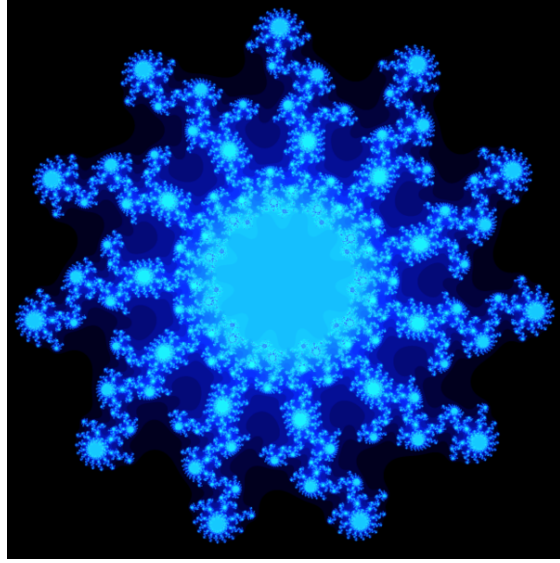


Sierpinski Structure Development



Koch Structure Development



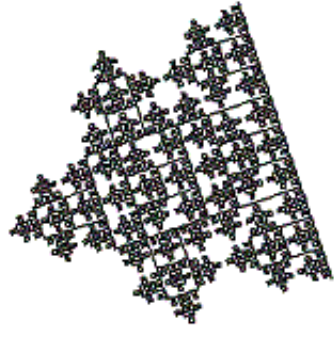
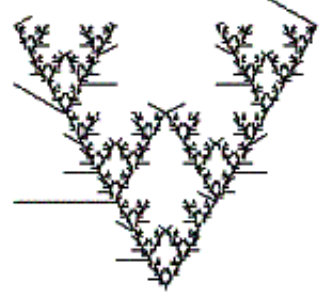
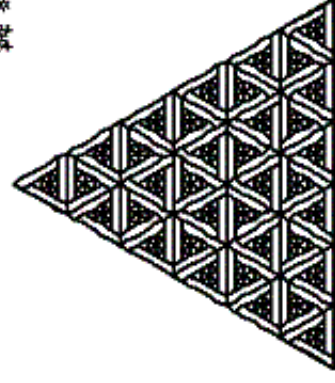
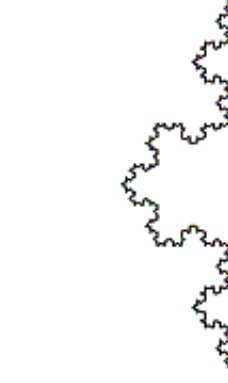


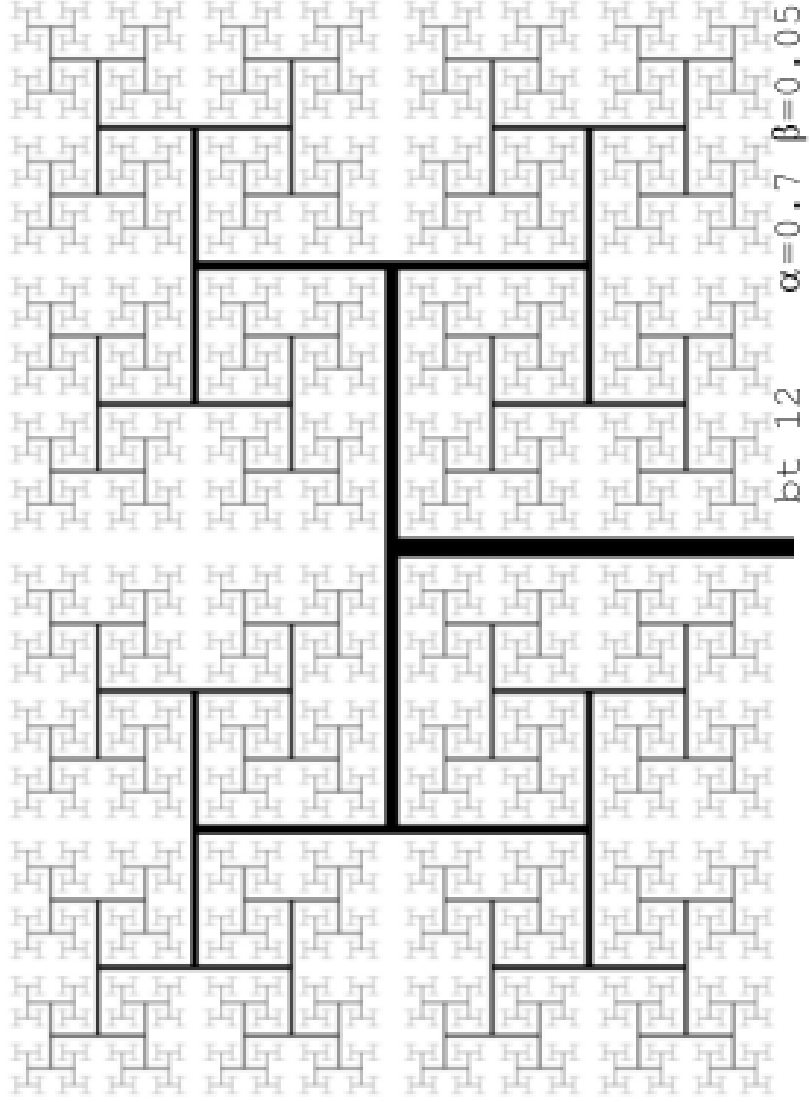
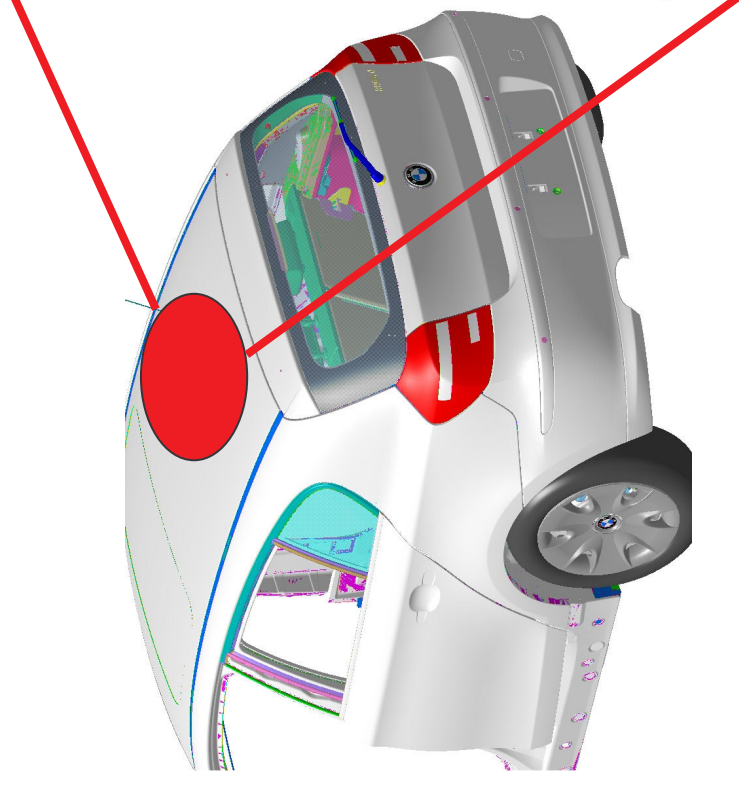
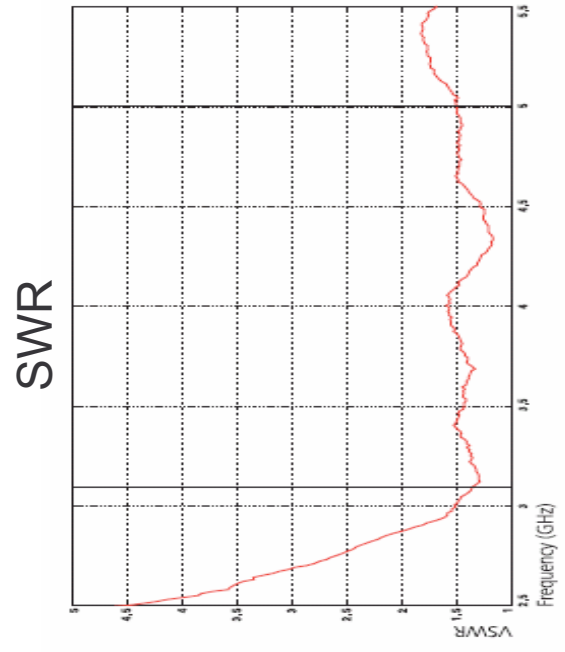
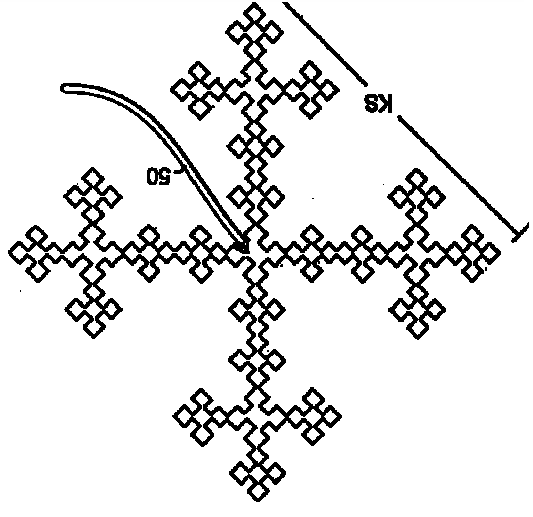
Frequency Range	3.1 - 5 GHz
Efficiency	> 60%
Peak Gain	< 4 dBi
Gain Flatness	< $\pm 2$ dB
VSWR	< 2:1
Weight	0.20 g
Temperature	-40 to +85°C
Impedance	50 $\Omega$ unbalanced
Dimensions	10 x 10 x 0.8 mm

Measured results from a reference evaluation board of 36.5 x 20 mm



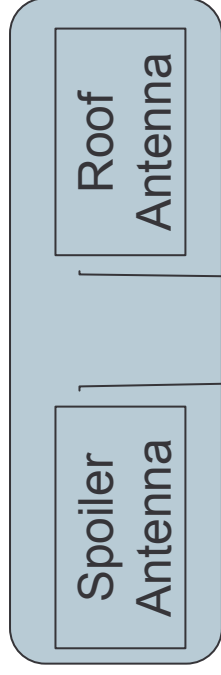
By Michael Michalek







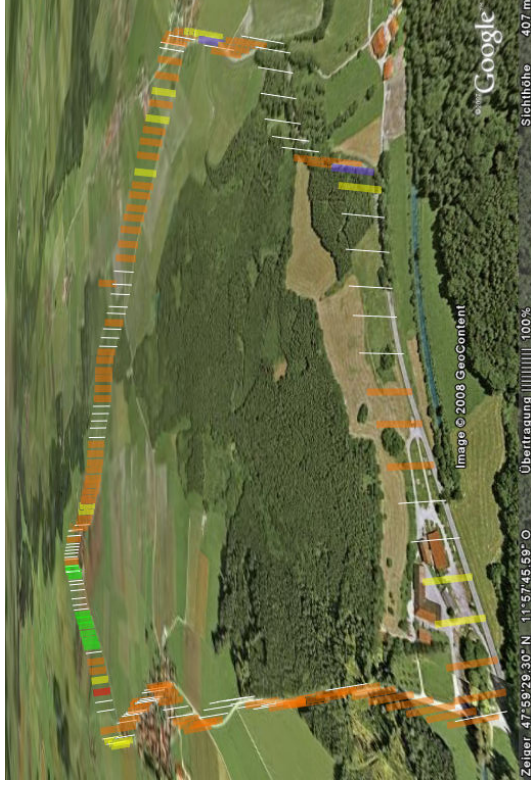
# Where to Place Diversity Antennas ?



Side-Window  
Antenna

Rear-Window  
Antenna

1. DECOUPLED
2. UNCORRELATED
3. EQUALLY LEVELLED
4. FLAT RESPONSES
5. LOW EMC-INTERFERENCE



# Examples (Negative)

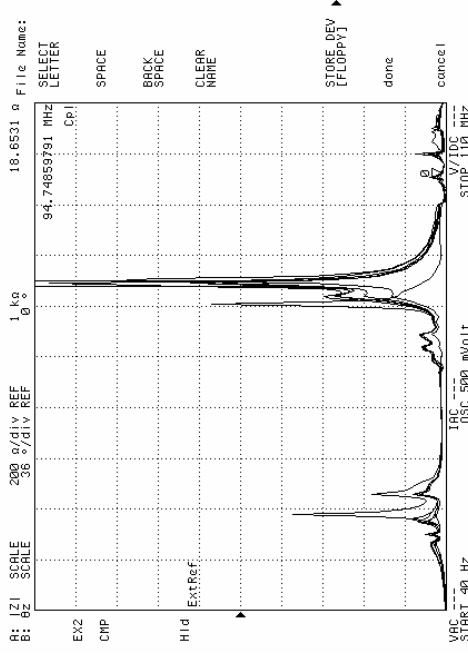
Example A

2-Branch  
Rear-Window



Example B

2-branch side-  
window (left-right)

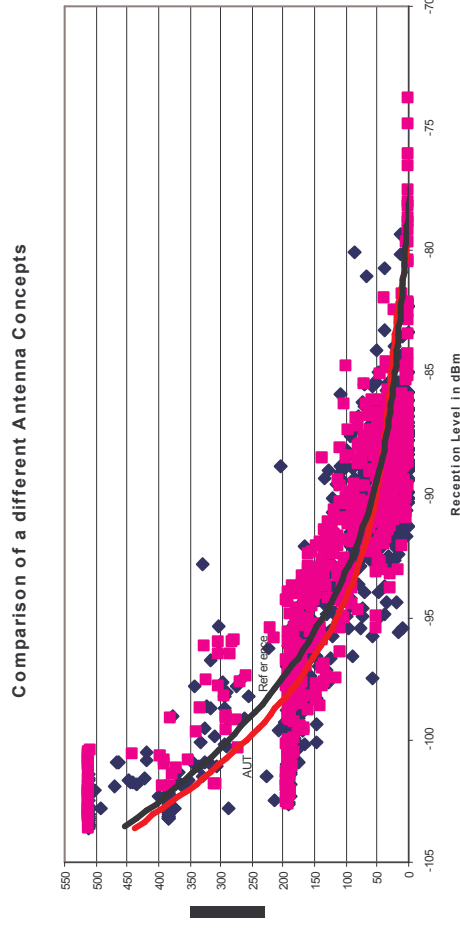
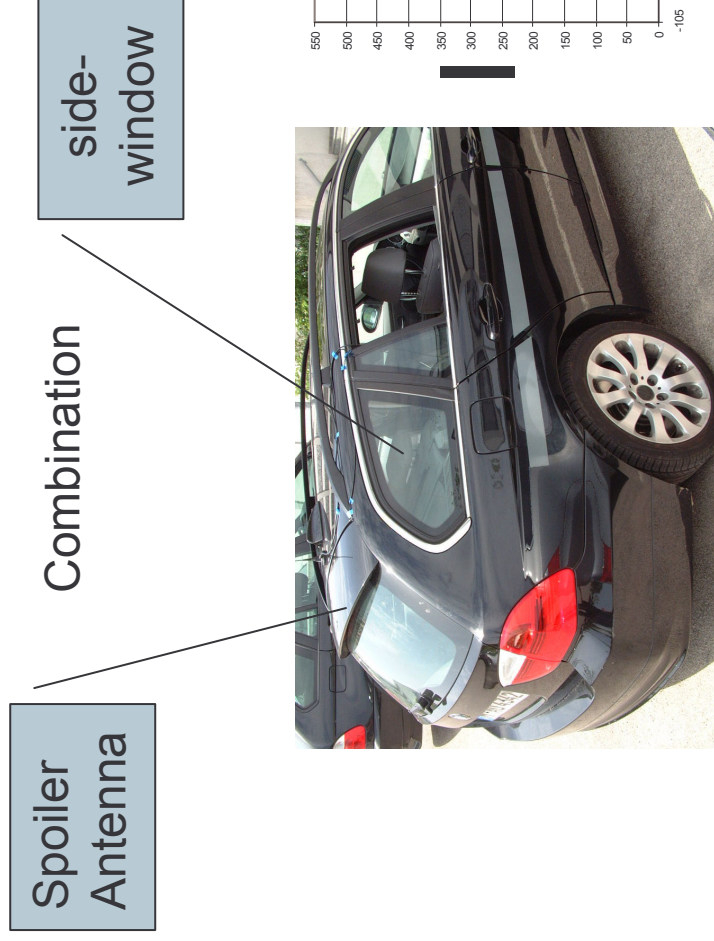


Antennas are too identical, meaning

- To close to each other – signal is correlated
- Antennas are mutually coupled
- EMC-interference is equal



# Examples (Positive)



Antennas are optimal, meaning

- both are high positioned related to ground
- Antennas are orthogonal to each other
- both antennas can utilize hor-vert polarization
- EMC-interferences are shielded

# Summary

## Different Antenna Technologies

- Rod + Monopols
- Patch Antennas
- On-Glas Antenna
- Glued Foil Antenna
- Fractal Antenna

There are only 3 things to keep in mind:

- Select & Place antennas carefully
- Always check the coherence and correlation
- Perform drive test with right equipment

In case you need further information, please feel free contacting me at any time: ***niels.koch@altran.com***

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