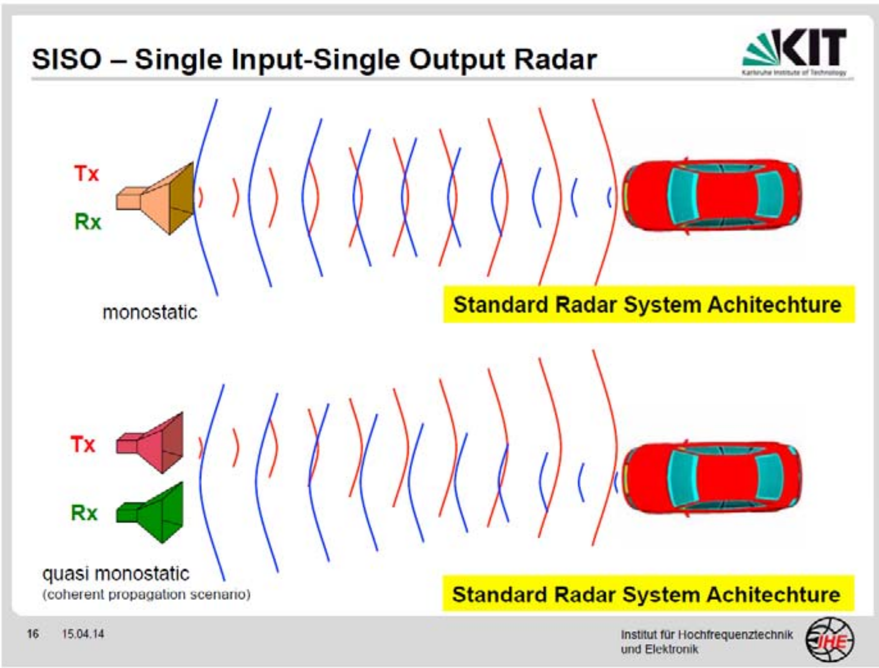
AUTOMOTIVE


SISO – Single Input-Single Output Radar
KIT
Tx
Rx
monostatic
Standard Radar System Achitechture
Tx
Rx
quasi monostatic
(coherent propagation scenario)
Standard Radar System Achitechture
16
15.04.14
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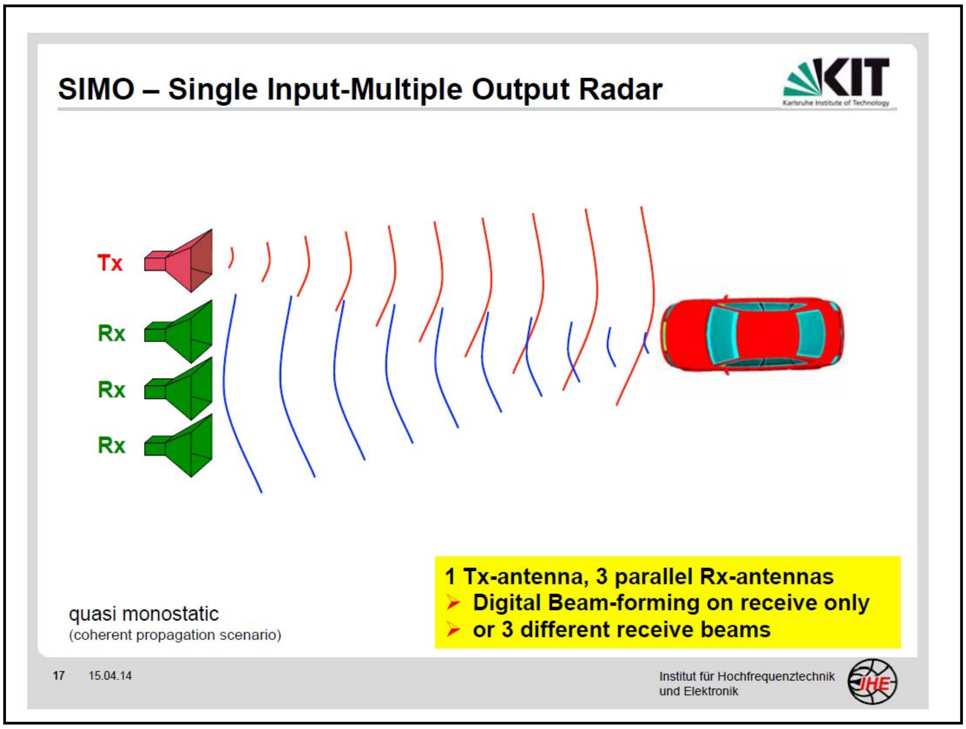
und Elektronik
IHE


SIMO – Single Input-Multiple Output Radar
KIT
Karlsruhe Institute of Technology
Tx
Rx
Rx
Rx
quasi monostatic
(coherent propagation scenario)
1 Tx-antenna, 3 parallel Rx-antennas
➢ Digital Beam-forming on receive only
➢ or 3 different receive beams
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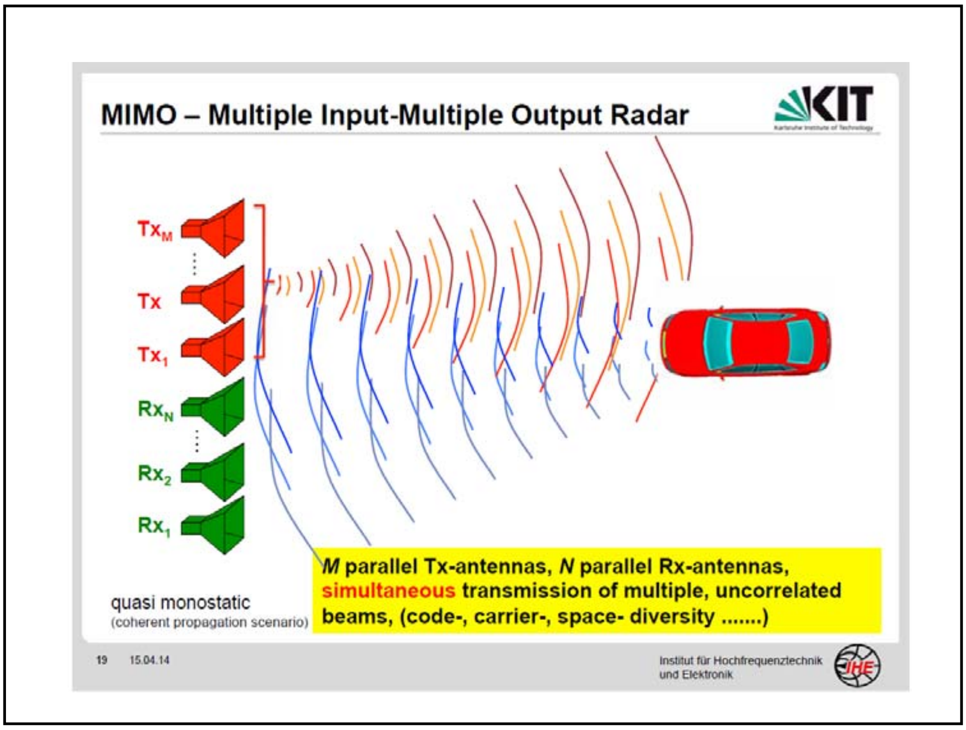
MIMO – Multiple Input-Multiple Output Radar
KIT
Tx$_M$
Tx
Tx$_1$
Rx$_N$
Rx$_2$
Rx$_1$
quasi monostatic
(coherent propagation scenario)
M parallel Tx-antennas, *N* parallel Rx-antennas,
simultaneous transmission of multiple, uncorrelated
beams, (code-, carrier-, space- diversity ....)
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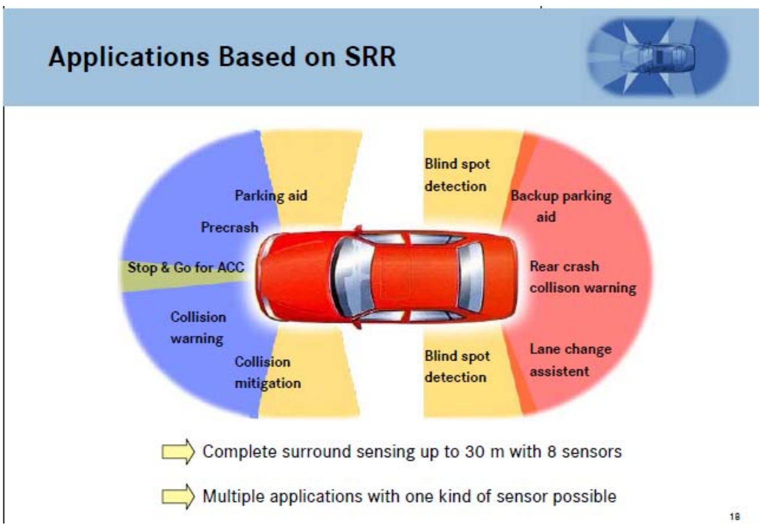
SISO

LONG RANGE RADAR

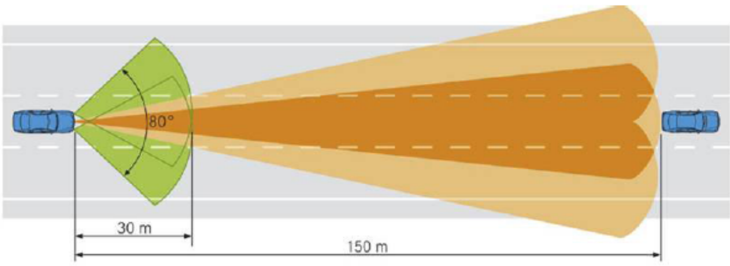
ACC == Autonomus cruise control

SHORT RANGE RADAR



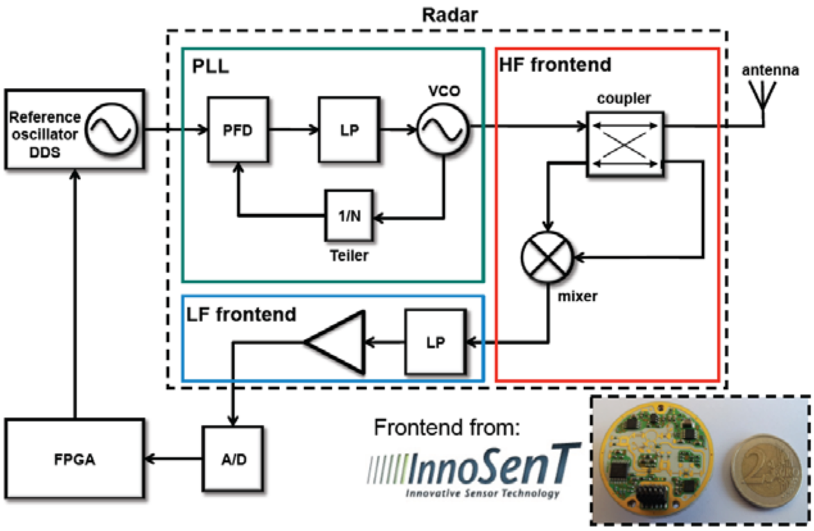
COMBINATION

DISTRONIC Plus in the New Mercedes Benz S-Class

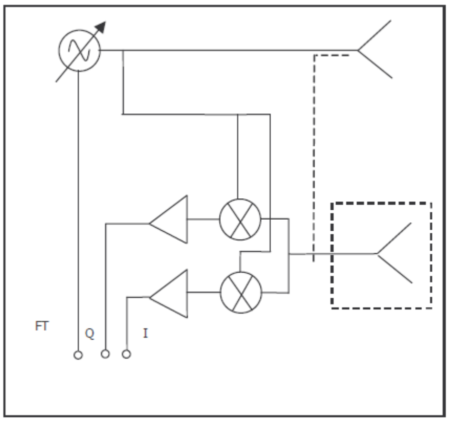


Combination of
- 76.5 GHz Long Range Radar (DISTRONIC)
- 6 x 24 GHz Ultra-Wide-Band (UWB) Short Range Radar

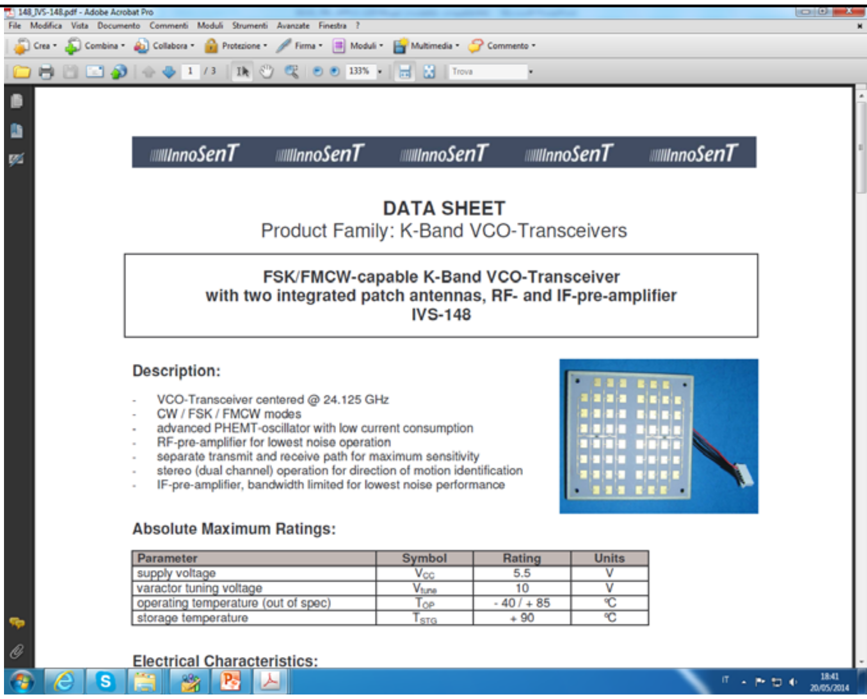
K-Band Radar



INNOSENT FMCW 24 GHz



Schematic of an InnoSenT radar frontend with separate transmit/receive antennas, common transmit/receive antenna as dotted line



InnoSenT InnoSenT InnoSenT InnoSenT InnoSenT

DATA SHEET
Product Family: K-Band VCO-Transceivers

FSK/FMCW-capable K-Band VCO-Transceiver
with two integrated patch antennas, RF- and IF-pre-amplifier
IVS-148

Description:

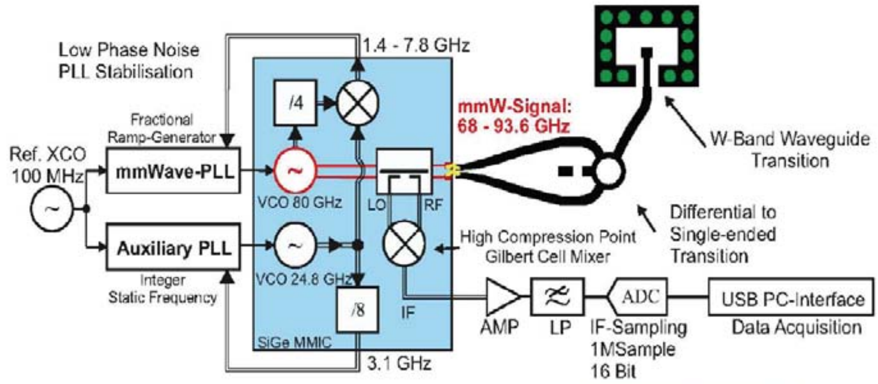
- VCO-Transceiver centered @ 24.125 GHz
- CW / FSK / FMCW modes
- advanced PHEMT-oscillator with low current consumption
- RF-pre-amplifier for lowest noise operation
- separate transmit and receive path for maximum sensitivity
- stereo (dual channel) operation for direction of motion identification
- IF-pre-amplifier, bandwidth limited for lowest noise performance

Absolute Maximum Ratings:

Parameter	Symbol	Rating	Units
supply voltage	V_{CC}	5.5	V
varactor tuning voltage	V_{tune}	10	V
operating temperature (out of spec)	T_{OP}	- 40 / + 85	°C
storage temperature	T_{STG}	+ 90	°C

Electrical Characteristics:

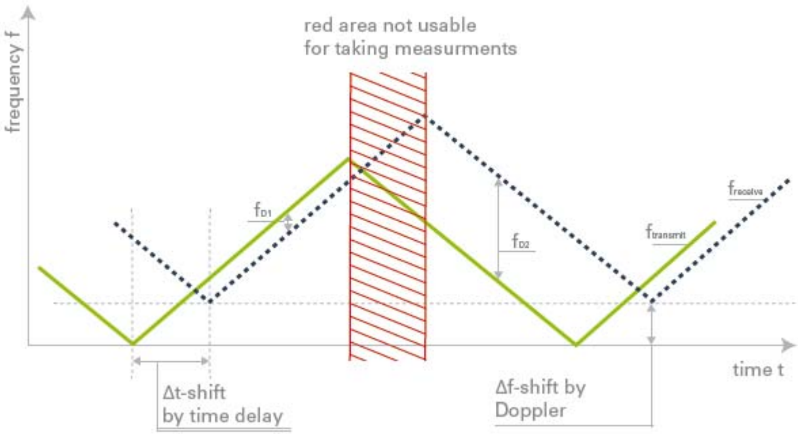
W-Band Radar



Frontend from:
Ruhr-Universität Bochum

RUB

FMCW RADAR



RADAR EQUATIONS

$$f_D = 2 f_0 \cdot \frac{v}{c_0} \cdot \cos\alpha \qquad (2)$$

$f_{Doppler}$ frequency shift by Doppler effect, caused by object motion,

- v magnitude of velocity of the moving object
- c_0 velocity of light
- a angle between the actual direction of motion and the connecting line sensor-object

$$f_{delay} = 2R \cdot \frac{\Delta f}{(c_0 \cdot T)} \qquad (4)$$

f_{delay} frequency shift by delay effect of the transmit signal, caused by range between object and sensor see (4)

- Δf frequency deviation
- T sawtooth repetition time period
- R distance of a reflecting object
- c_0 speed of light

$$f_{D1} = f_{Doppler} - f_{delay} \qquad (6)$$

$$f_{D2} = f_{Doppler} + f_{delay} \qquad (7)$$

f_{D1} differential frequency at mixer output in the upward branch, measured value

f_{D2} differential frequency at mixer output in the downward branch, measured value

$f_{Doppler}$ frequency shift by Doppler effect, caused by object motion,

see (2) ($f_D = 2 f_0 \cdot \frac{v}{c_0} \cdot \cos\alpha$ (2))

f_{delay} frequency shift by delay effect of the transmit signal, caused by range between object and sensor see (4)

$$f_{delay} = 2R \cdot \frac{\Delta f}{(c_0 \cdot T)} \qquad (5)$$

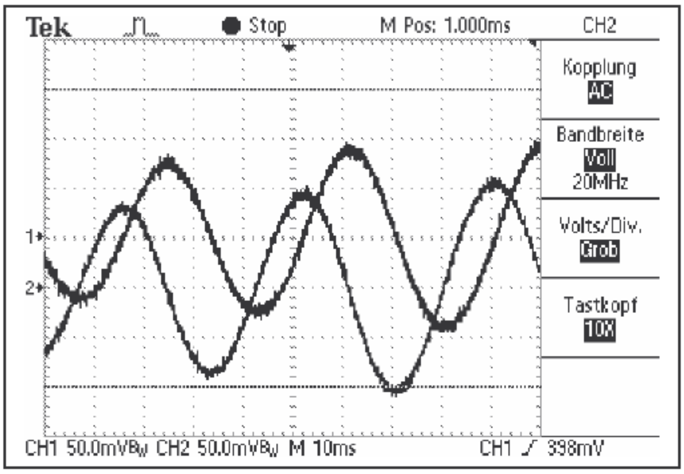
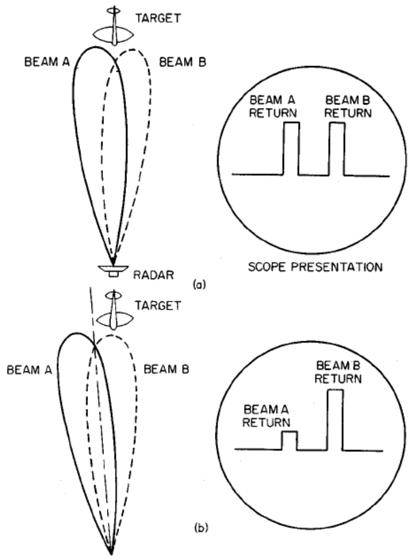


Fig. 5: Typical scope shot of the 2 I/Q outputs of a radar sensor from a monotonously moved target

SIMO

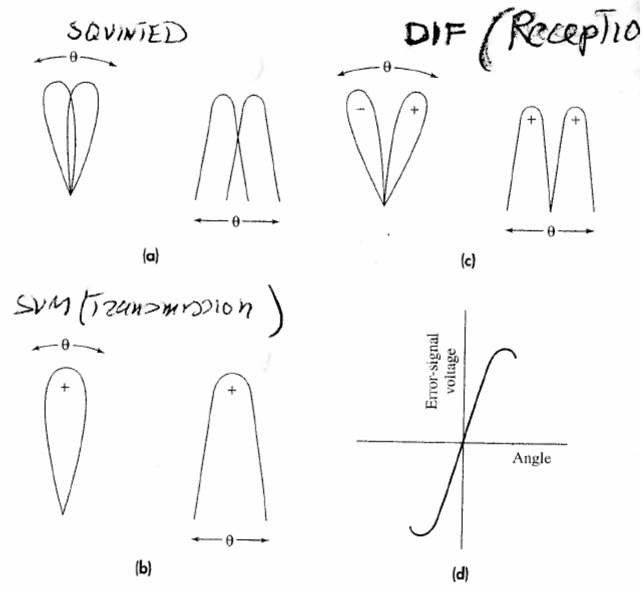
RADAR MONOPULSE IN AMPIEZZA



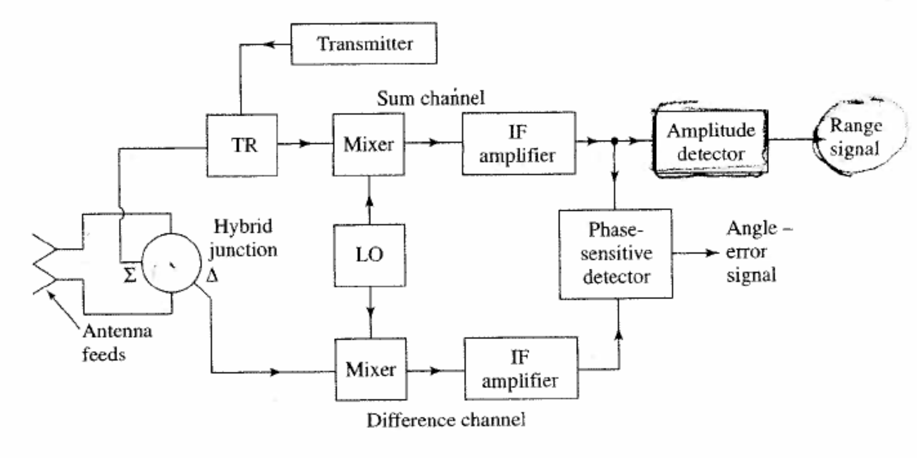
Il puntamento viene variato meccanicamente fino ad avere i due ritorni uguali

Se le due antenne sono dei «phased array» il puntamento può essere variato elettronicamente,
oppure si può calibrare
il segnale differenza in termini di angolo

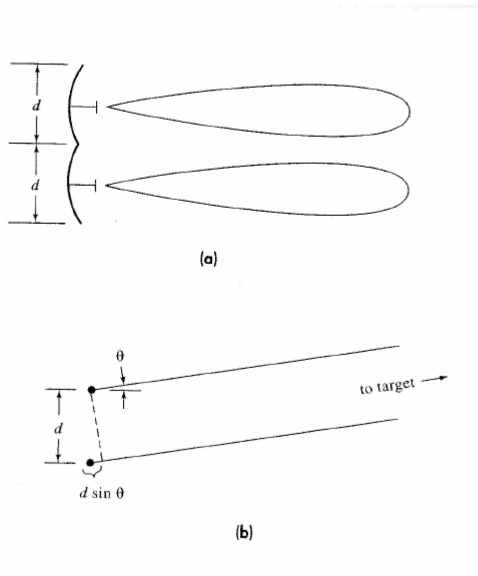
RADAR MONOPULSE IN AMPIEZZA



RADAR MONOPULSE IN AMPIEZZA



RADAR MONOPULSE IN FASE



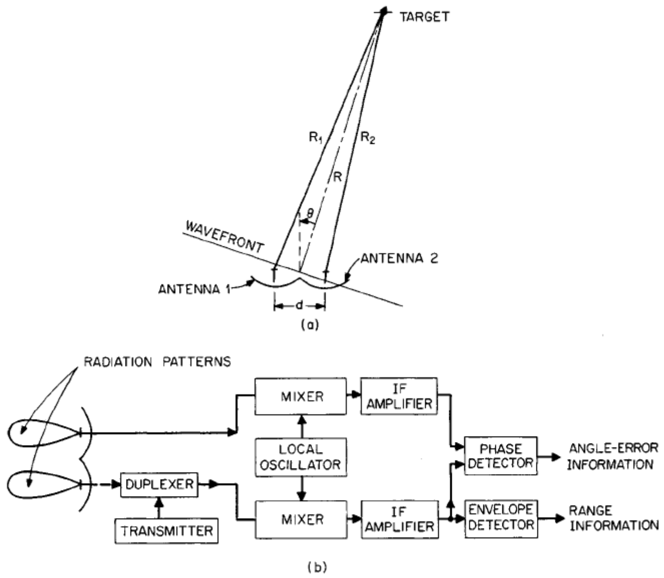


FIG. 18.17 (*a*) Wavefront phase relationships in a phase comparison monopulse radar. (*b*) Block diagram of a phase comparison monopulse radar (one angle coordinate).

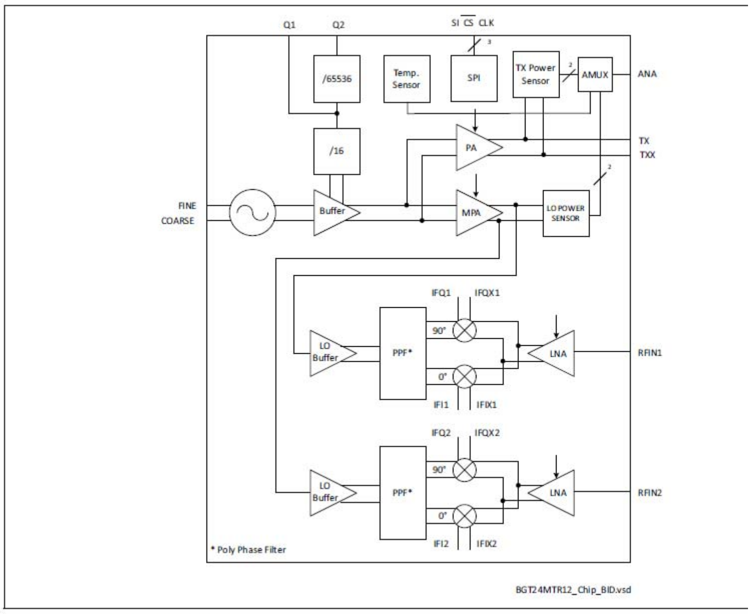
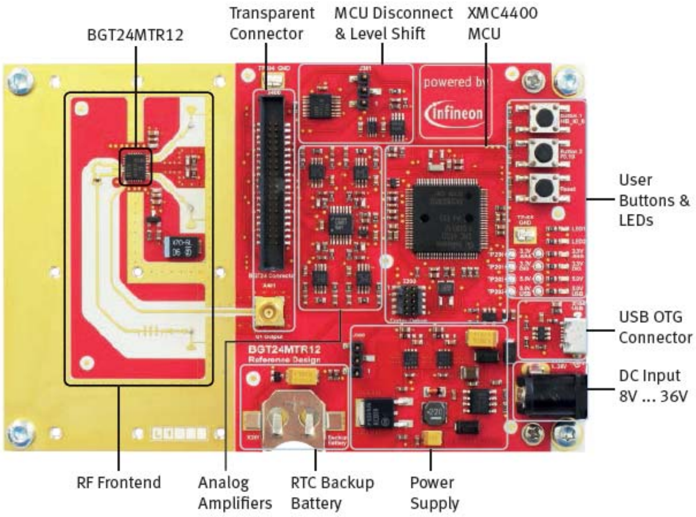
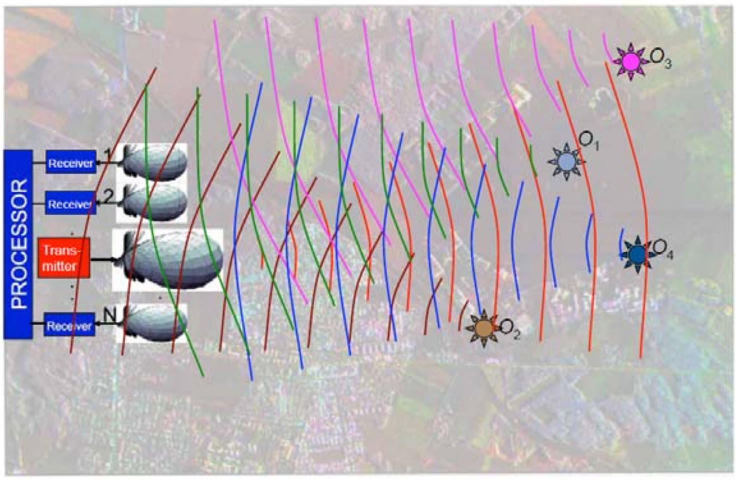


Figure 1 BGT24MTR12 Block Diagram



Patched antennas are on the backside of the RF Frontend PCB (not shown in the picture).

The Digital Beam-Forming System Concept



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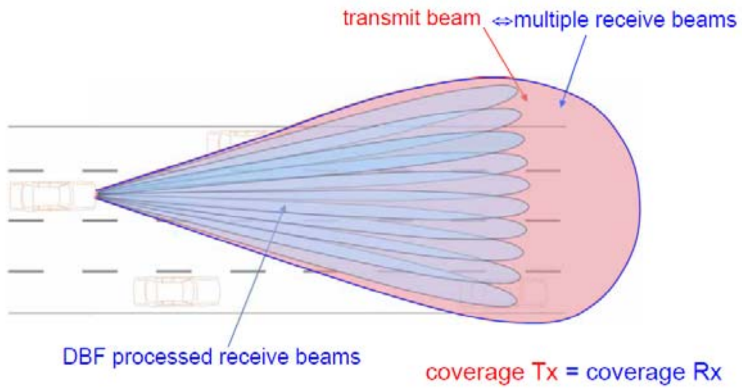
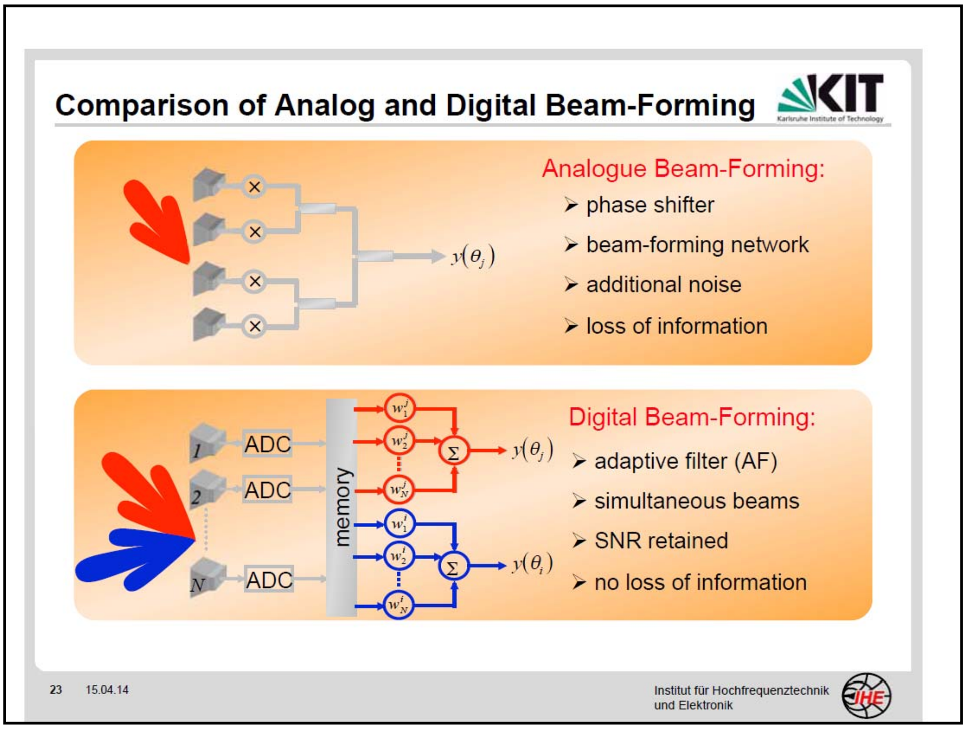
“Digital Beam-Forming on Receive only” Radar



Goal: Generate multiple, high resolution, virtual receive beams

The Digital Beam-Forming Idea

- **separate Transmitter and Receiver, i.e. two sub-systems**
- **illuminate the whole area of interest simultaneously**
- **receive the echo with multiple antennas or sub-arrays**
- **digitize the received signal from each sub-array**
- **simultaneously focus on each resolution cell within the imaged area**
- **use super resolution algorithms**


Comparison of Analog and Digital Beam-Forming
KIT
Analogue Beam-Forming:
➢ phase shifter
➢ beam-forming network
➢ additional noise
➢ loss of information
$y(\theta_j)$
Digital Beam-Forming:
➢ adaptive filter (AF)
➢ simultaneous beams
➢ SNR retained
➢ no loss of information
ADC
ADC
ADC
memory
$y(\theta_j)$
$y(\theta_i)$
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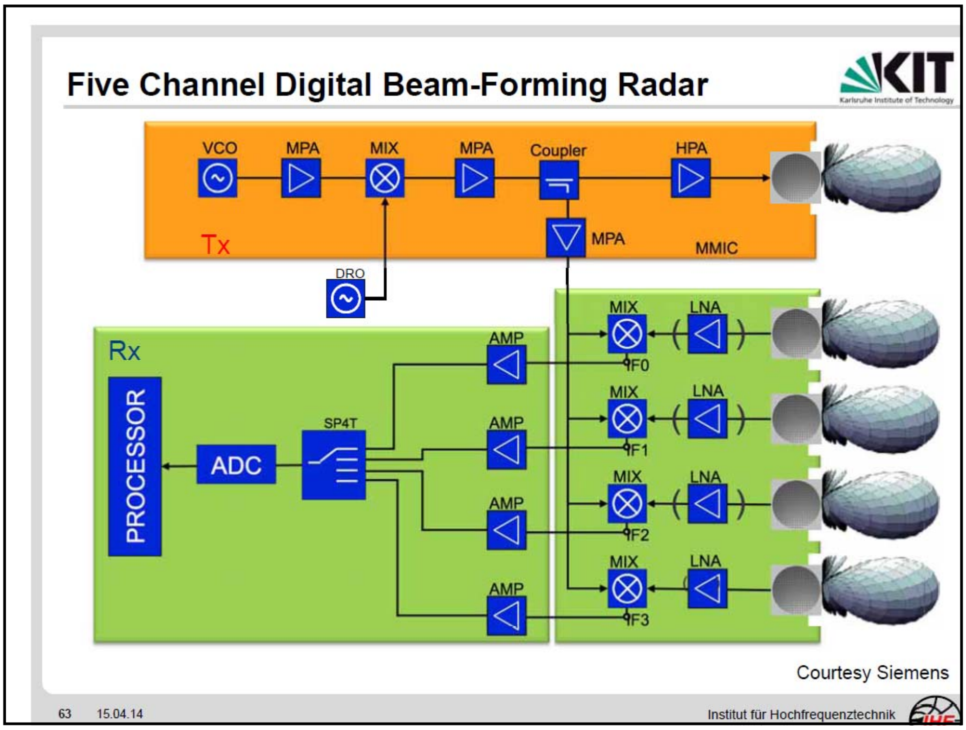
Five Channel Digital Beam-Forming Radar
KIT
VCO
MPA
MIX
MPA
Coupler
HPA
Tx
MPA
MMIC
DRO
Rx
PROCESSOR
ADC
SP4T
AMP
AMP
AMP
AMP
MIX
LNA
IF0
MIX
LNA
IF1
MIX
LNA
IF2
MIX
LNA
IF3
Courtesy Siemens
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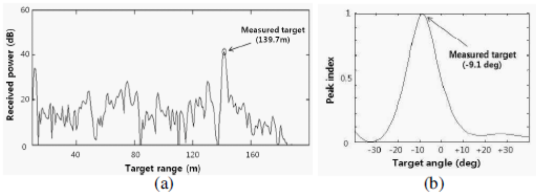

Figure 9. Measured signal power of a target reflector at the long range and narrow angle beam for (a) range and (b) angle.

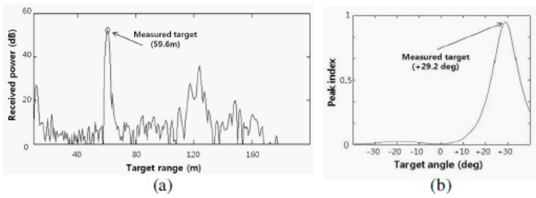

Figure 10. Measured signal power of a target reflector at the short range and wide angle beam for (a) distance and (b) angle.