**SIMO – Single Input-Multiple Output Radar**

- 1 Tx-antenna, 3 parallel Rx-antennas
- Digital Beam-forming on receive only
- or 3 different receive beams

**MIMO – Multiple Input-Multiple Output Radar**

- M parallel Tx-antennas, N parallel Rx-antennas, simultaneous transmission of multiple, uncorrelated beams, (code-, carrier-, space-diversity ....)
SISO
LONG RANGE RADAR

Applications Based on LRR

- Collision Warning
- ACC
- Limited Stop & Go
- Limited Collision Mitigation
- Limited Pre-Crash

Lexus RX: Pre-Crash Brake Assistant
Honda Inspire: Collision Mitigation

ACC == Autonomus cruise control

SHORT RANGE RADAR

Applications Based on SRR

- Parking aid
- Pre-cruise
- Stop & Go for ACC
- Collision warning
- Blind spot detection
- Backup parking aid
- Rear crash collision warning
- Lane change assistant

Complete surround sensing up to 30 m with 8 sensors
Multiple applications with one kind of sensor possible
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

Frontend from: InnoSenT

Innovative Sensor Technology
INNOSENT FMCW 24 GHz

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

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

Absolute Maximum Ratings:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Rating</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage</td>
<td>Vcc</td>
<td>3.5</td>
<td>V</td>
</tr>
<tr>
<td>Input operating voltage</td>
<td>Vin</td>
<td>10</td>
<td>V</td>
</tr>
<tr>
<td>Operating temperature (out of spec)</td>
<td>Tcase</td>
<td>-40 / 85</td>
<td>°C</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>Tstg</td>
<td>100</td>
<td>°C</td>
</tr>
</tbody>
</table>

Electrical Characteristics:
FMCW RADAR

red area not usable for taking measurements

Δf-shift by Doppler

Δt-shift by time delay
**RADAR EQUATIONS**

\[ f_D = 2f_0 \cdot \frac{v}{c_0} \cdot \cos \alpha \] (2)

- **\( f_{\text{Doppler}} \)**: frequency shift by Doppler effect, caused by object motion,
- **\( v \)**: magnitude of velocity of the moving object
- **\( c_0 \)**: velocity of light
- **\( \alpha \)**: angle between the actual direction of motion and the connecting line sensor-object

\[ f_{\text{delay}} = \frac{2R \cdot \Delta f}{(c_0 \cdot T)} \] (4)

- **\( f_{\text{delay}} \)**: frequency shift by delay effect of the transmit signal, caused by range between object and sensor see (4)
- **\( \Delta f \)**: frequency deviation
- **\( T \)**: sawtooth repetition time period
- **\( R \)**: distance of a reflecting object
- **\( c_0 \)**: speed of light

\[ f_{D1} = f_{\text{Doppler}} - f_{\text{delay}} \] (6)

\[ f_{D2} = f_{\text{Doppler}} + f_{\text{delay}} \] (7)

- **\( f_{\text{D1}} \)**: differential frequency at mixer output in the upward branch, measured value
- **\( f_{\text{D2}} \)**: differential frequency at mixer output in the downward branch, measured value
- **\( f_{\text{Doppler}} \)**: frequency shift by Doppler effect, caused by object motion,

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

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

\[ f_{\text{delay}} = \frac{2R \cdot \Delta f}{(c_0 \cdot T)} \] (5)
Fig. 5: Typical scope shot of the 2 I/Q outputs of a radar sensor from a monotonously moved target.

SIMO
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

[Image 126x503 to 471x676]
[Image 207x120 to 385x336]
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).
Patched antennas are on the backside of the RF Frontend PCB (not shown in the picture).
“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

Analogue Beam-Forming:
- phase shifter
- beam-forming network
- additional noise
- loss of information

Digital Beam-Forming:
- adaptive filter (AF)
- simultaneous beams
- SNR retained
- no loss of information

Five Channel Digital Beam-Forming Radar

Courtesy Siemens
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.