UMRR: A 24GHz Medium Range Radar Platform

Dr.-Ing. Ralph Mende, Managing Director

smart microwave sensors GmbH
Phone: +49 (531) 39023 0 / Fax: +49 (531) 39023 58 / ralph.mende@smartmicro.de
Mittelweg 7 – 38106 Braunschweig - Germany
www.smartmicro.de

Abstract
The paper describes the UMRR sensor platform, which has been developed by smart microwave sensors GmbH. The sensor operates in the 24GHz ISM band and is applicable for Advanced Driver Assistance System functions in the automotive sector but can also be used for industrial purposes. It can run both in Pulse- and in a number of Narrowband FMCW Modes. It can be part of a network formed of several UMRR sensors. Different types of antennae are available. Concept, technical and performance data of the sensor are given. Advanced features are described.

I. Concept and Technical Data

Design

The name UMRR stands for Universal Medium Range Radar. The design targets of the UMRR sensor platform were mainly flexibility and performance. It is younger than competitor designs in the 24GHz band, the intention was to build a radar for a certain range of applications, with the focus on high dynamic scenarios.

Flexibility:

- Pulse, UWB Pulse, CW and FMCW narrowband operation possible.
- Multiple planar antenna designs available (independent of microwave module).
- Stand alone or network operation.

Performance:

- Direct and simultaneous measurement of range, velocity and angle.
- Short measurement time.
- Good Minimum Range (0.75m), Medium maximum range (typ. 50-70m).
- Conformity with RegTP / ETSI EN 300-440 frequency regulations in FMCW narrowband mode.
- One-Box-Design with integrated detection, tracking and communication software.

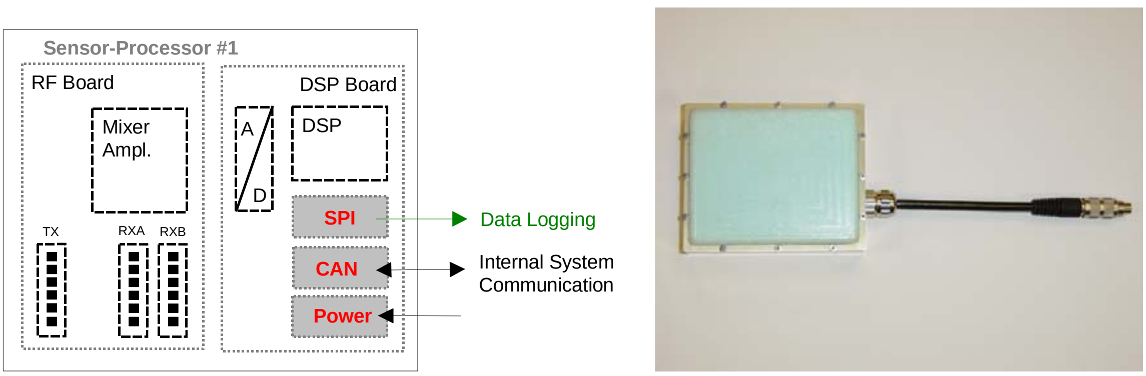

Figure 1: Block Diagram and Photograph of the UMRR Radar Sensor

A sensor unit consists of two components: RF frontend module and DSP module. This is depicted in the block diagram. A photograph is given on the right. The size of the device is only (including processor) 94x78x31mm (WxHxD).

Waveforms

A number of operational modes being different in their transmit waveform are available. Descriptions of the Pulse Mode(s) and the simpler CW Mode are not provided here, for details of a similar UWB pulsed operation system see [1] and [5]. At the moment it is not allowed to use any 24GHz sensor in UWB mode due to frequency regulations, this fact being currently under discussion at the European frequency administrations.

The technical data of two example modes are provided below. It is possible to switch between the modes, the switching dead-time has a duration of one cycle.

Parameter	UWB Pulse Mode	Narrowband Mode
Operation Principle	UWB Pulsed	Single chirp FMCW
3dB Bandwidth	< 3GHz	< 200MHz
Minimum Range	0.25m	0.75m
Maximum Range	15m	60m+
Cycle Time	8ms	<30ms
Velocity Interval	-10...+10m/s	-25...+50m/s
Carrier Frequency	24.125GHz	
Maximum Transmit Power	20dBm	
Antenna Type	Patch Antenna	
Field of View (Example)	40° (Azimut) x 13° (Elevation)	
Supply/Interface	12V/CAN	

Table 1: UMRR Technical Data

The narrowband FMCW waveforms have higher performance in most applications. As an example, a FMSK signal [2] is described below. This combination of FSK and LFM waveform design principle offers the possibility of an unambiguous and simultaneous target range and velocity measurement. The transmit waveform consist in this case of at least two linear frequency modulated up-chirp or down-chirp signals (the intertwined signal sequences are called A and B). The two chirp signals will be transmitted in an intertwined sequence (ABABAB...), where the stepwise frequency modulated sequence A is used as a reference signal while the second up-chirp signal is shifted in frequency with f_{Shift}. The received signal is down converted into base band and directly sampled at the end of each frequency step. The combined and intertwined waveform concept is depicted in Figure 3.

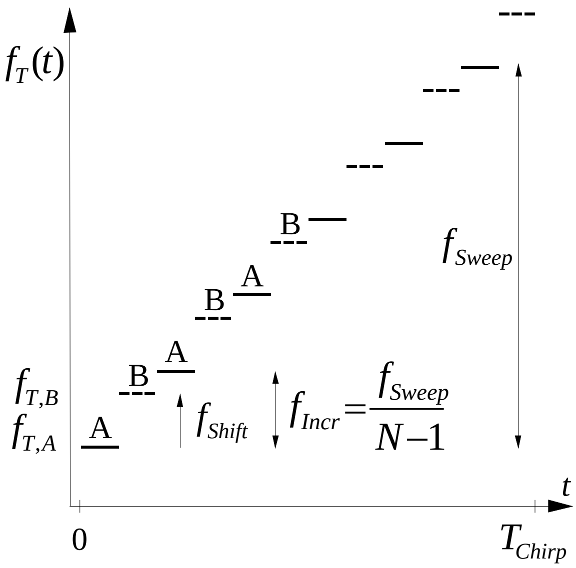

Figure 3: FMSK-2 Transmit Waveform

RF Waveform and the corresponding detection and tracking software are thus quite flexible. UMRR can be optimized for different requirements, i.e. maximized object separation and/or maximum sensitivity etc., depending on the situation.

Antennae

Beside the operational modes, the field of view can be customized by selecting an appropriate antenna pattern. A planar antenna structure is used. Antenna and RF Module are designed separately. The antenna can either be a separate board or one layer of a multi layer RF board. The antenna can therefore easily be modified and customized for many applications. The sensor itself remains identical. A dual RX antenna setup was selected to allow for monopulse based direct angle measurement.

An example of a single sensor wide beam antenna and a two sensor narrow field of view setup can be seen in the pictures. One of the advantageous features is that the measurement of all parameters is possible even in the side lobe zones, this effect being very welcome, for in many applications the desired field of view is defined in Cartesian co-ordinates in rectangular shape (for instance all three lanes in front of a passenger car). Therefore antennae with intentionally designed side lobes can usefully be applied.

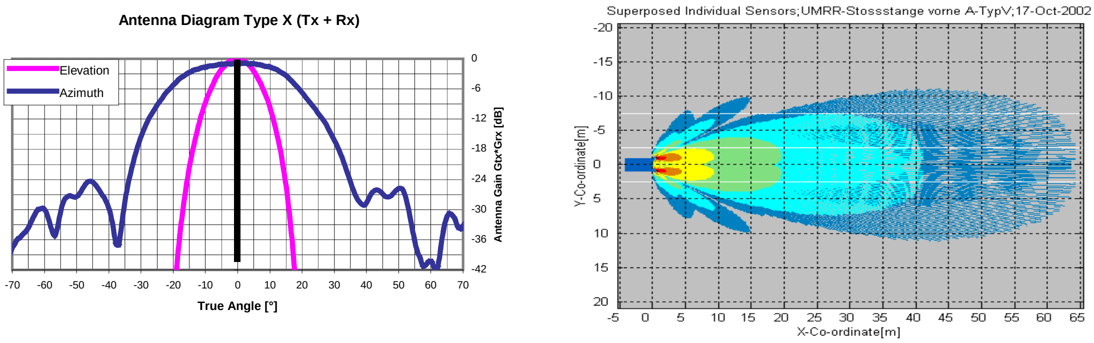

Figure 4: Example Antenna diagram and Dual Sensor configuration on a test car.

Parameter	Antenna Type 2 (left)	Antenna Type 8 (right)
3dB Azimuth	45°	30°
3dB Elevation	16°	13°

Table 2: Example Antenna Data

A test of a type 8 antenna (right figure) showed that it is possible to detect a 10m² reflector in a range of 25m in an angular field of view of ±30°, at 40m ±24°, and at 75m ±9°.

II. Performance Data

To demonstrate the sensitivity of UMRR, some more numbers can be given. The typ. max. range on pedestrians is 45m, on bicycles 50m and on passenger cars 60-70m. The speed of the object has no influence on the maximum range. All parameters are measured during only one cycle.

Typical Accuracy data are:

Range: Typical < 0.5m (under 10m, 10m...max. range: better than +- 1.25%).
Velocity: Typical < 0.25km/h.
Angle: Typical < 0.5 degree.

The radar is able to resolve (separate), handle and track multiple targets. To be separately detectable, two objects of identical reflectivity must be different in at least one of the following parameters:

Range Difference >= 1.75m
Speed Difference >= 1.94km/h.

A separation in angle with one single sensor is not possible with the actual ‘simple’ monopulse antenna concept. The results show that the measurement of the angle value in any typical scenario is quite precise. To resolve a situation where two reflectors with identical range and velocity values are placed at different lateral positions can be solved using a dual sensor setup as shown in Figure 4.

III. Special Features

Object Generation

As a number of parameters (range, velocity, angle, level, etc.) are available from one single sensor, it becomes possible to apply algorithms which interpret the detected set of reflectors in each measurement cycle and estimate – beside the accurate position and velocity vector - the shape (length and width) of the physical objects which consist of a set of individual scatterers. With only 30ms measurement time, the data rate used for advanced interpretation algorithms is quite high.

Beside the radar data, vehicle dynamics data are required. A sensor fusion algorithm is applied. One good example for the object generation (in this case it is even a classification) is the detection of crash- or other barriers at the edges of the road. Position, length and curve radius can be measured using radar only. The object generation in this case is simple, because a row of poles or other reflectors can easily be detected by UMRR. Therefor in practice very good results are achieved for guard rail detection and classification (see also Figure 9). Vehicles and trucks can also be interpreted as objects and displayed as rectangles.

IV. Automotive Applications for UMRR

A radar network consisting of two UMRR sensors has been implemented in the s.m.s owned test car for the approval of the technology in real street situations. The configuration is depicted in Figure 4 on the right. A normal Autobahn situation was recorded, the interpreted data being shown in the following figures (graphic: 60x40m).

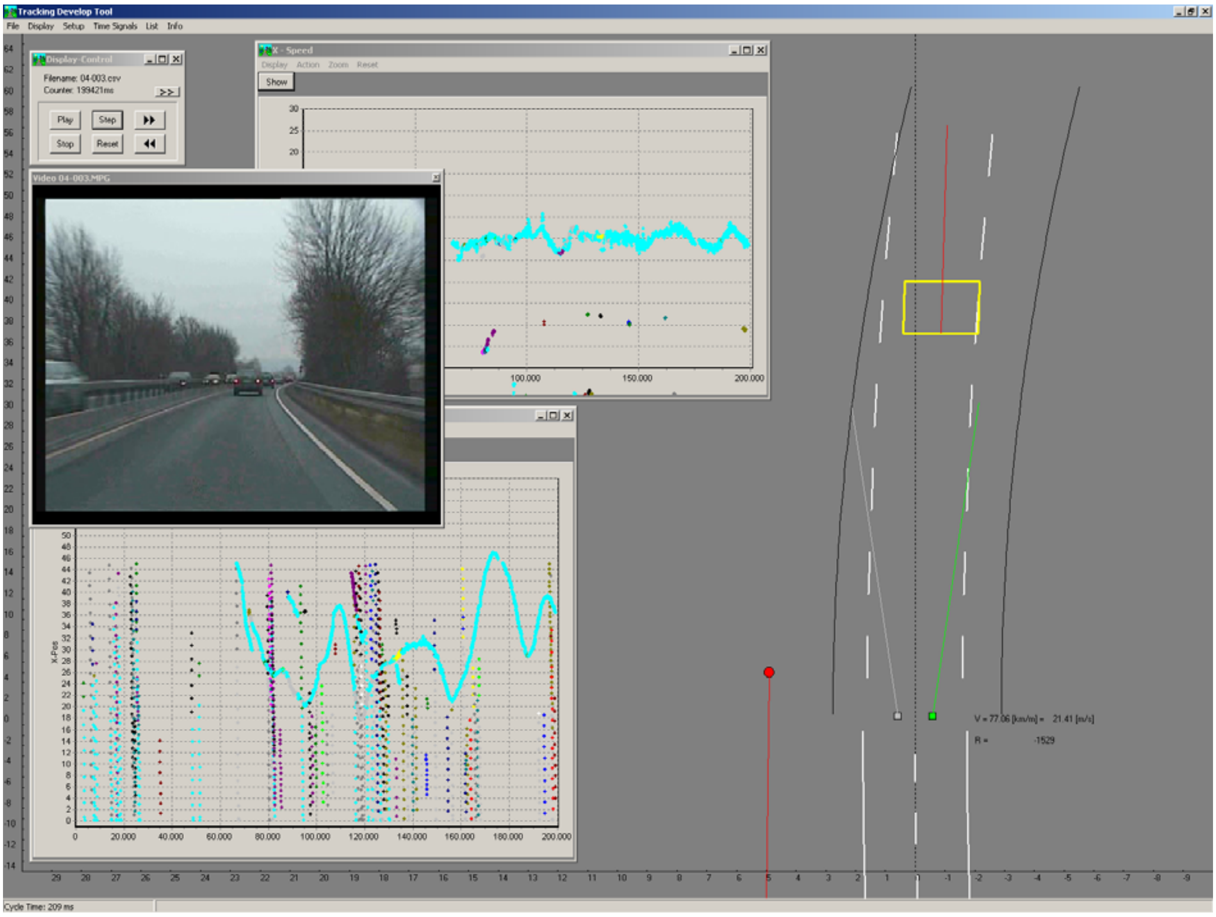

Figure 5: Interpreted Objects and photograph of the situation.

A number of applications that require short or medium range coverage can be fulfilled without violation of actual ETSI and FCC frequency allocation rules. More applications, their requirements, typical practical problems of different 24GHz sensor designs are given in [3] and [4]. The performance-optimized UMRR sensor has been tested and can be applied for the functions listed below.

Sensor and Display (Comfort):	Blind Spot Surveillance.
Vehicle Control related (Comfort + Control):	ACC plus Stop & Go.
Restraint Systems related (Safety):	Closing Velocity Sensing.
	Pre-Crash Firing for Reversible Restraints.

V. Industrial Applications

In the field of industrial sensors, from the UMRR platform a number of specialized derivatives have been under preparation:

- CW true speed over ground sensor
- range gated true speed over ground sensor
- surveillance applications
- traffic enforcement
- collision avoidance for unmanned automatic guided vehicles and other robotics applications.

In particular the ability of range gated speed or movement sensing raises the interest of industrial customers. Depending on the required numbers, industrial UMRR derivatives can be produced at reasonable cost figures.

VI. Recent Developments

The next step in the development of the UMRR platform would be the modification of the antenna concept to allow for angle measurement principles that provide true resolution (target separation) in angle. The application of antennae with a narrower field of view is possible but will enlarge the size of the UMRR housing.

VII. References

[1] Klotz, Michael; Rohling, Hermann:
A high range resolution radar system network for parking aid applications
International Conference on Radar Systems, Brest/France 1999.

[2] Meinecke, Marc-Michael; Rohling, Hermann:
Waveform Design Principles for Automotive Radar Systems
German Radar Symposium, Berlin 2000.

[3] Moritz; Pre-Crash Sensing – Its functional evaluation based on a platform radar sensor;
SAE Technical Paper Series 2000-01-2718.

[4] Hoess et. al.; The RadarNet Project
7th ITS World Congress, Torino, November 2000

[5] Skutek, Mekhaiel, Wanielik; A PreCrash System Based on Radar for Automotive Applications
Intelligent Vehicle Conference 2003 Columbo/ Ohio