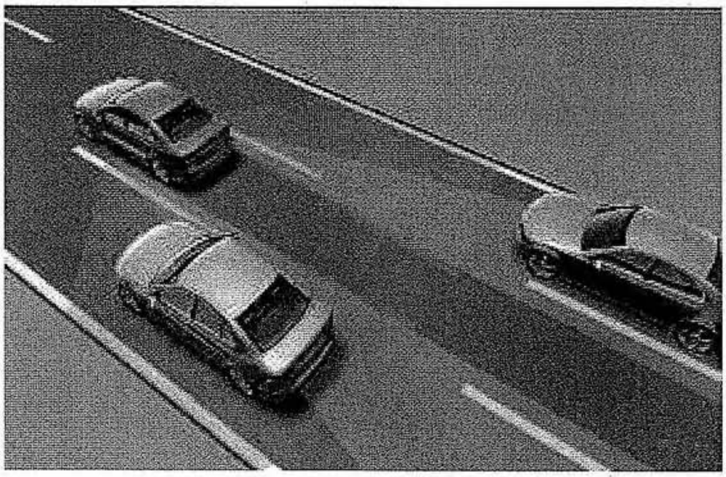
Functional description

Operational Description for 24 GHz Blind-Spot Radar Sensor



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2 Introduction

2.1 Purpose

In this document an operational description of the 24 GHz blind spot radar sensor intended for the US market with start of production in mid 2007 is given. Sufficient information is provided to understand the operation principle, the set up and the tuning of the radar sensor.

2.2 Abbreviations and Definitions

Abbreviation	Denotation
BP	bandpass
BSD	Blind Spot Detection
DRO	dielectric resonant oscillator
HW	hardware
IF	nntermediate frequency
FH	frequency hopping
FMCW	frequency modulated continous wave
FCC	Federal Communications Commission
LF	Low Frequency
RF	Radio Frequency
UPCON	Upconverter
SV	Siemens VDO Automotive AG
SW	software
TBD	to be defined
VCO	voltage controlled oscillator

Table 1 Abbreviations

3 BSD sensor component description

The BSD sensor consists of the following components:

- aluminum sensor housing with sensor connector, RF sealing and plastic cover
- NF board which is mounted into the aluminum housing and connects to the customer connector
- RF board which is plugged into the housing and connects to the NF board

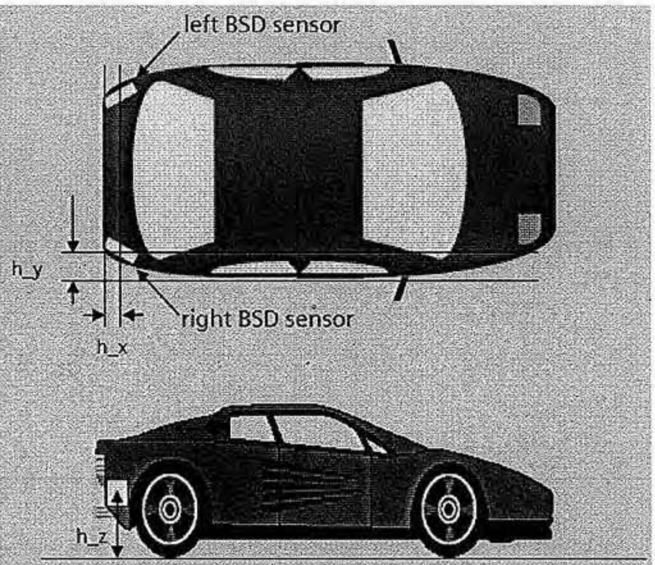
3.1 BSD Sensor mounting location

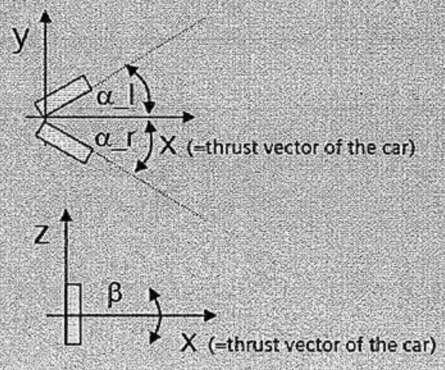
The BSD radar sensors are installed behind the rear bumper on the left and right side of the vehicle. The typical mounting dimensions and requirements are shown in Figure 1. Both sensors are typically tilted by 25 degrees to the rear.

BSD housing mounting requirements

dimension	min	typ.	max.
h_x	0.05m	0.15m	0.25m
h_y	0.05m	0.10m	0.25m
h_z	0.50m	0.70m	1.00m

Note: all dimensions referred to housing center





BSD orientation requirements

dimension	min	*typ.	max.
α_l (azimuth)	23°	25°	28°
α_r (azimuth)	-23°	-25°	-28°
β (elevation)	0°	+3°	+6°

*Some flexibility in typical mounting angle possible

Figure 1: BSD sensor mounting requirements

3.2 BSD sensor surveillance zone

To cover the blind spot area beside the vehicle a two beam approach is used, as shown in Figure 2. A broad beam with a maximum range of ca. 8m and a smaller beam, that is tilted by 33° to the boresight direction of the broad beam is used. The smaller TILT beam has a maximum detection range of ca. 15 m. Despite the higher antenna gain of the TILT beam the maximum e.i.r.p. emitted power is identical with the BROAD beam. This is realized by changing the input power at the antenna ports accordingly.

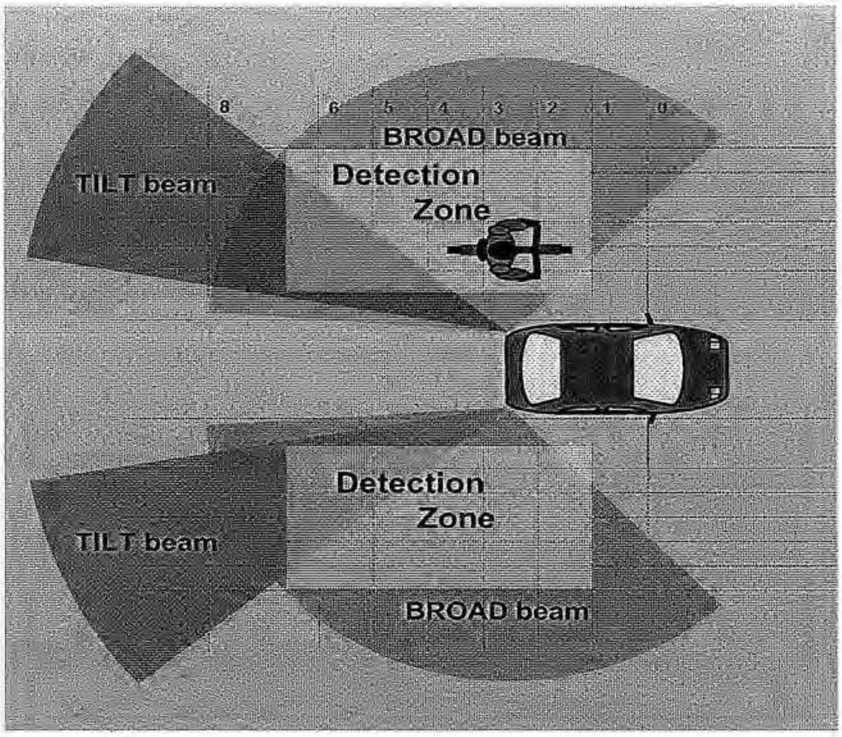


Figure 2: BSD surveillance zone two beam concept

3.3 BSD Sensor antenna diagramm

In Figure 3 the vertical and horizontal antenna patterns of the BROAD and TILT beam are sketched.

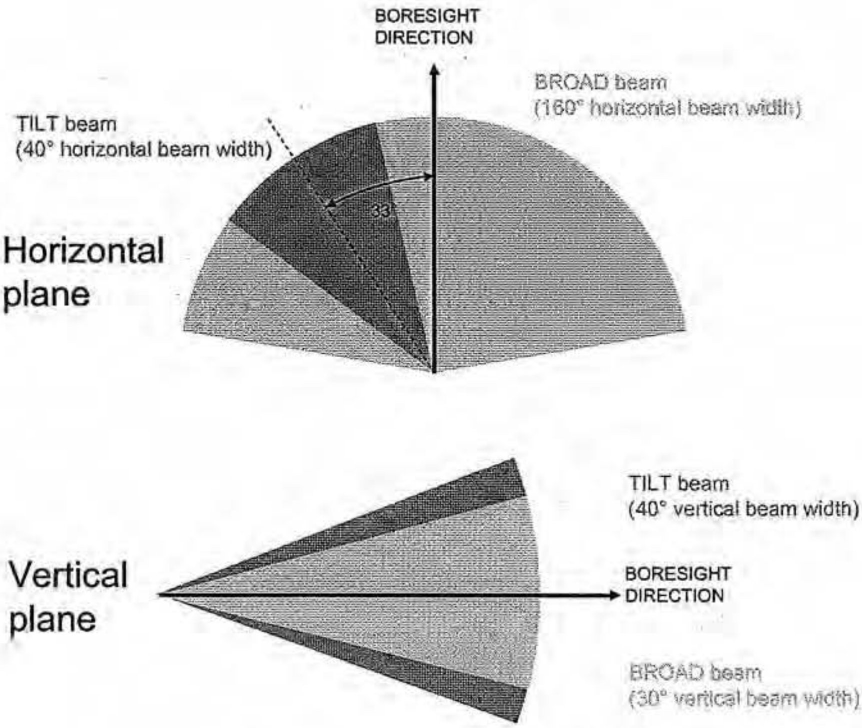


Figure 3: Antenna pattern (horizontal and vertical)

3.8 Pulsed FMCW radar operation principle

The radar is operated in a pulsed frequency hopping mode. A linear rising frequency signal (up-ramp) and a linear falling frequency signal (dn-ramp) are used. One measurement consists of one up-ramp and one consecutive dn-ramp sequence. Therefore, the time delay between the up- and dn-ramp of one measurement should be relatively short (< 2 ms). The transmit RF signal has, due to the 25 ns pulse width and the 1 µs repetition interval, an intermittent, discrete frequency value that is changed consecutively by each repetition of a pulse. So over time the transmit frequency is hopping over a given set of discret frequencies, which are typically a few hundred values or frequency steps, respectively.
An instantaneous frequency spread of ca. 40 MHz occurs due to the 25 ns pulse width (see Figure 8).

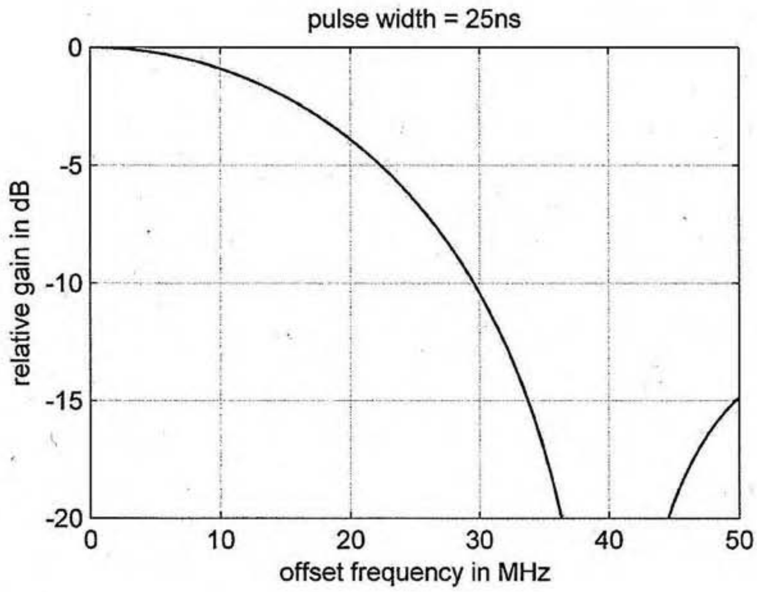


Figure 8 Spectrum of 25 ns pulse (20log[Amplitude])

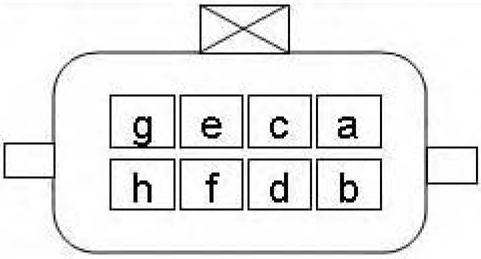
When looking on the emitted spectrum over time for some frequency hops, a spectrum as depicted in Figure 9 occurs. The sequence of the individual frequency hops doesn't play any role when the whole frame time is used as the observation time. From the two most common methods, the linear hopping and the random hopping, the linear FH has some technical advantages (e.g. VCO linearization) that make it the preferred operation mode.

4 Tune up information

4.1 Equipment authorization specific tune up procedures

When installed in a vehicle the BSD radar sensors normally communicate with the vehicles CAN interface to exchange diagnostic information, the switch on or off status and failure mode detection and avoidance procedures.
For frequency measurements dedicated to conduct equipment authorization test reports a special SW version is flashed into the microcontroller that doesn't need any communication with an external interface to operate in its normal mode.
The sensor starts operation once a 12 V battery supply is applied to pin IGN_BSD and the battery ground is applied to the GND pin. Only one operational mode exists for the BSD radar sensor. This operational mode is described in detail in Exhibit 12 (Operational description).
The BSD radar sensors operate, when switched on via the vehicle infrastructure and after a short start-up procedure with power-on self-tests, in this mode during their complete lifetime in the host car.

View toward module's connector



Pin assignments

	BSD Module_Lh (Slave)	BSD Module_Rh (Master)
a	GND	GND
b	IGN_BSD	IGN_BSD
c	N.C.	N.C.
d	Mirror_LED	Mirror_LED
e	N.C.	Switch
f	N.C.	N.C.
g	CAN_L	CAN_L
h	CAN_H	CAN_H

Table 9 Sensor connector

4.2 Standard tune-up procedure during production line assembly

To assure equal behavior and performance for all BSD radar units and to stay within the allowed frequency range and power emission limits some calibration and tuning of the individual radar devices after assembly on the production line is necessary.
Basically two calibration methods are possible:

1. SW compensation of deviations by individual storage of correction values within a Flash-PROM

2. Hardware correction by changing tunable components (e.g. laser-trimming or screw-trimming)

For the end-of-line calibration of the BSD radar sensor both methods are used in parallel.
The parameters that have to be tuned and controlled by the device are:

1. Maximum radiated emission power for both the TILT and BROAD beam
2. Absolute frequency range and bandwidth of the emissions

The BSD radar sensor is equipped with a temperature sensor to compensate for frequency and output power changes due to temperature drift. A standard frequency vs. temperature and output-power vs. temperature curve is stored in the microprocessor which controls these two parameters from the respective temperature/frequency or temperature/power tables.

4.2.1 Calibration of RF output power

The RF circuit is designed in such a way that the RF output power can be controlled using variable gain control amplifiers in the final power amplifier stages for adjustment of the intentional radiation of TILT and BROAD transmit beam. In the production line the following procedure is done for power calibration:

- set sensor boresight angle to +33°
- activate TILT beam operation, deactivate radiation from BROAD transmit beam
- adjust the desired output power level (-43,3 dBm/MHz RMS value) with the sensor SW program
- set sensor boresight angle to 0°
- activate BROAD beam operation, deactivate radiation from TILT beam
- adjust the desired output power level (-43,3 dBm/MHz RMS value) with the sensor SW program
- store the sensor internal calibration data to nonvolatile sensor memory
- verify temperature controlled output power emissions at different temperature ranges
- initialize the sensor and activate sensor SW for product application

A test setup configuration to tune the emission power of the two radar beams (TILT and BROAD) is shown in Figure 1.

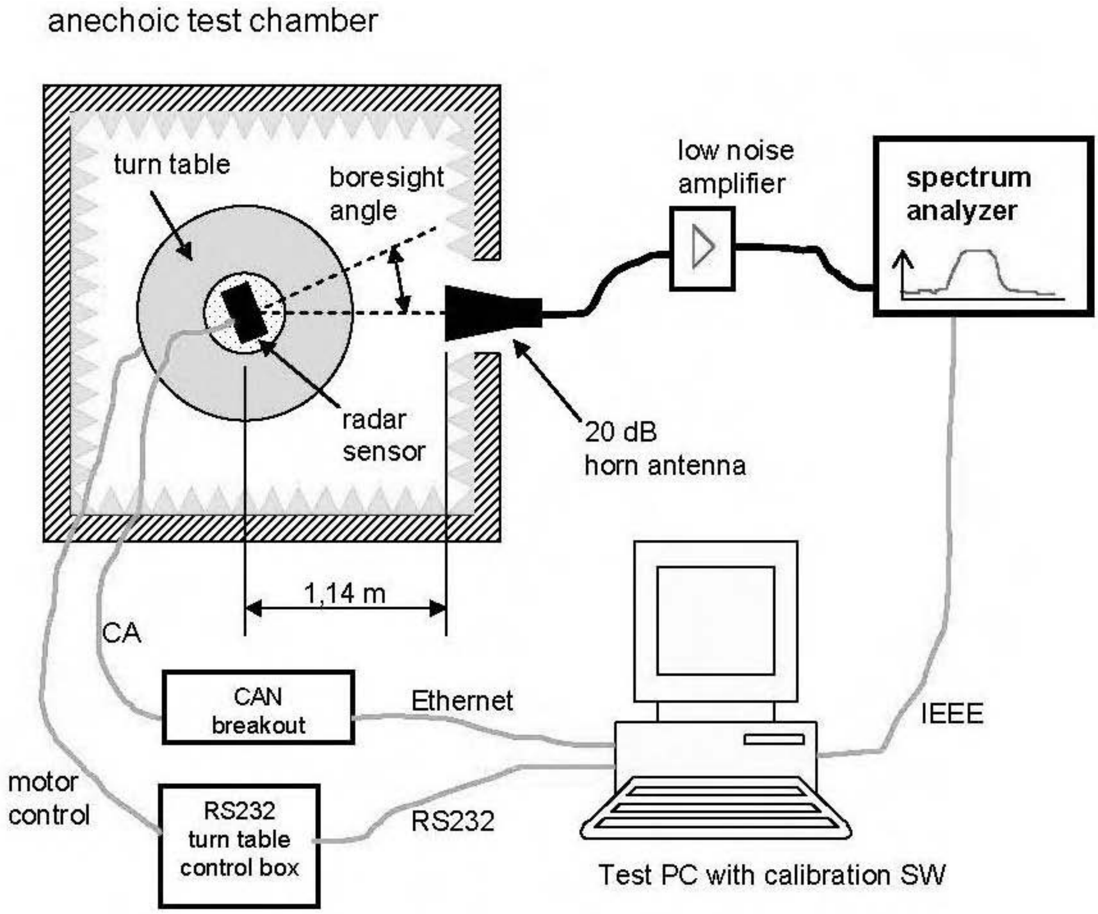


Figure 1 RF setup for power calibration

4.2.2 Calibration of absolute frequency and maximum frequency drifts

The absolute frequency value of the different BSD radar sensors may vary due to DRO resonator tolerances in the order of a few hundred MHz. With a mechanical screw tuning facility incorporated in the DRO shielding box each DROs can be adjusted to compensate for the resonator's mechanical dimension tolerances.
Each BSD radar sensor is operated at it's individual optimum operational frequency range, however within a maximum allowed frequency ranges, as shown in Figure 2.
The worst case frequency drift scenario of a BSD radar sensor is shown in Figure 3. The possible lowest frequency of all BSD radar sensors is always above 24.25 GHz. This frequency represents the end of the SRD (or ISM) band from 24.05 GHz to 25.25 GHz. By staying above 24.25 GHz any interference from high-power SRD or ISM devices is reduced to a minimum. The upper frequency limit of 25.10 GHz is arbitrarily chosen and may be changed for further applications beyond BSD functionality that may need a higher operational bandwidth.

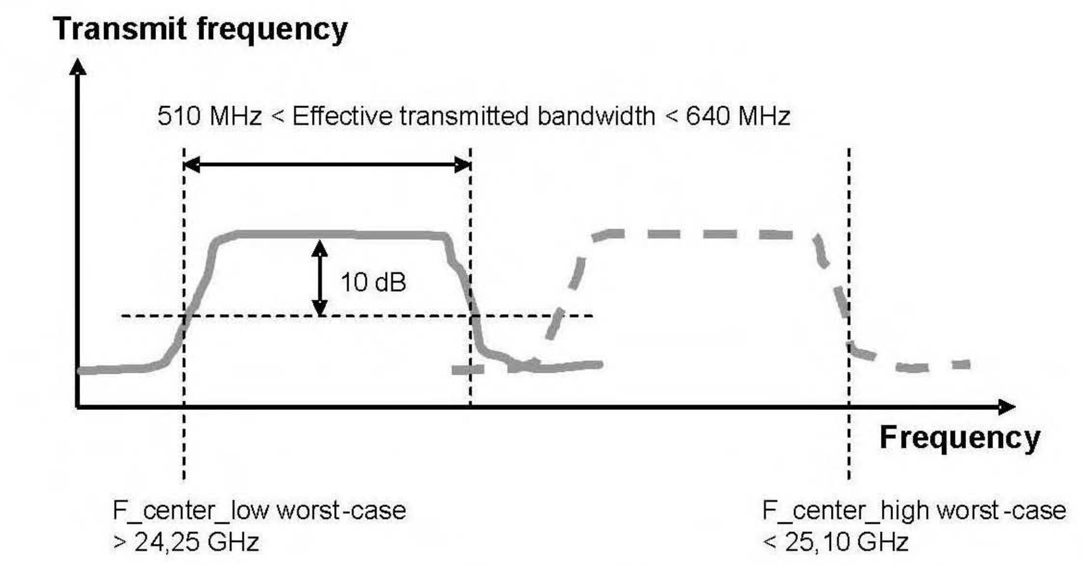


Figure 2 Intentional radiation frequency range

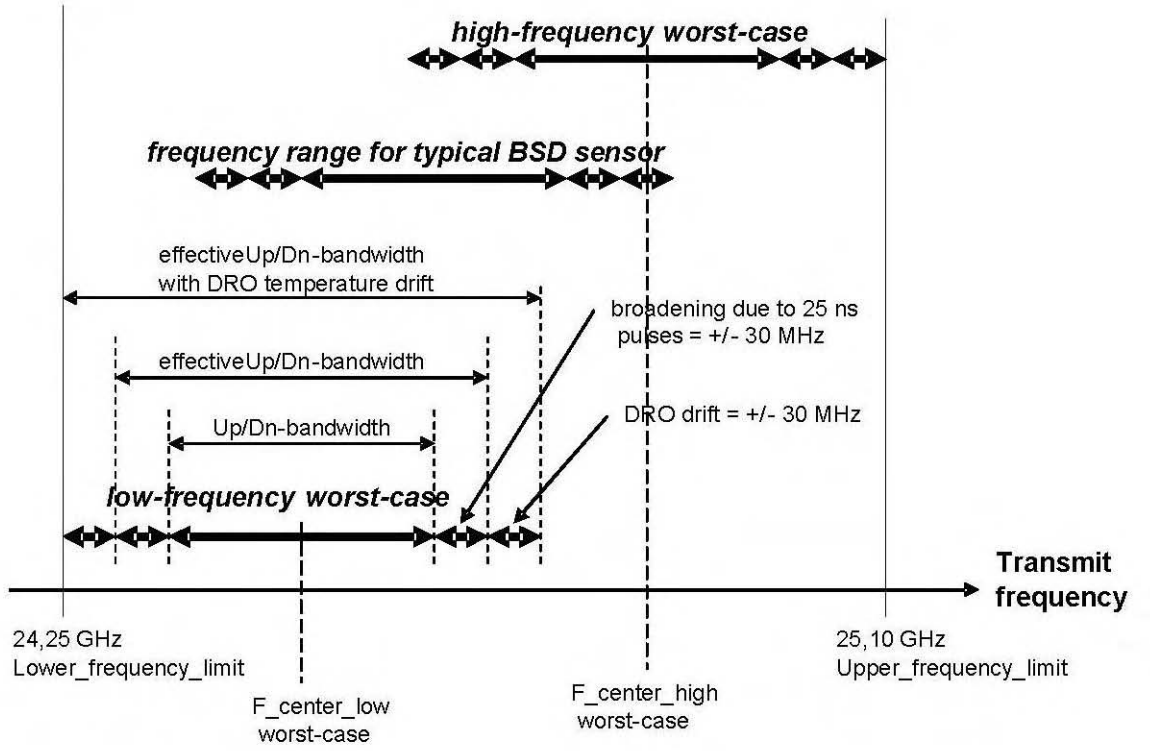


Figure 3 Worst case scenarios for operation frequency

Parameter	Explanation	Nominal value	Tolerance
Up_bandwidth	Nominal bandwidth for the up-sweep, this bandwidth does not include the spectral broadening due to the transmitted 25 ns pulses (1 MHz repetition frequency), this bandwidth is the used net-bandwidth for the BSD algorithm	500 MHz	+/- 50 MHz
Dn_bandwidth	Nominal bandwidth for the dn-sweep, this bandwidth does not include the spectral broadening due to the transmitted 25 ns pulses (1 MHz repetition frequency), this bandwidth is the used net-bandwidth for the BSD algorithm	500 MHz	+/- 50 MHz
Up_bandwidth_eff	Effective transmitted bandwidth of intentional radiation for the up-sweep resulting from a spectral broadening of +60 MHz due to the transmitted 25 ns pulses (-10 dB degradation at the band edges)	560 MHz	+/- 50 MHz
Dn_bandwidth_eff	Effective transmitted bandwidth of intentional radiation for the dn-sweep resulting from a spectral broadening of +60 MHz due to the transmitted 25 ns pulses (-10 dB degradation at the band edges)	560 MHz	+/- 50 MHz
Upper_frequency_limit	Upper frequency limit for the effective intentional radiation, this limit frequency shall be fulfilled for the entire temperature range (-40/+85°)	< 25,10 GHz	-
Lower_frequency_limit	Lower frequency limit for the effective intentional radiation, this limit frequency shall be fulfilled for the entire temperature range (-40/+85°)	> 24,25 GHz	-
F_center_low	Center frequency of the measured effective transmit spectrum resulting from sweeps which are only from up- or dn-sweeps for T = 20°, value includes a bandwidth of 500 MHz, peak broadening due to 25 ns pulses, +/- 30 MHz DRO temperature drift (see Figure 3)	-	> 24,56 GHz (worst-case value)
F_center_high	Center frequency of the measured effective transmit spectrum resulting from sweeps which are only from up- or dn-sweeps for T = 20°, value includes a bandwidth of 500 MHz, peak broadening due to 25 ns pulses, +/- 30 MHz DRO temperature drift (see Figure 3)	-	< 24,79 GHz (worst-case value)

Table 5 Timing parameters for transmit signal

Radiation Hazard

This BSM (blind spot monitoring) device emits intentional electromagnetic radiation in the 24 GHz to 25 GHz frequency range. The total radiated average power over the entire bandwidth is below – 14 dBm (40 µW). The active emitting antenna surface is 72 cm^2; therefore the radiated power density in front of the BSM device is 0.55 µW/cm^2. This value is far below the legal human exposure protection limit of 1 mW/ cm^2 (MPE) in Europe and US.

Equipment Authorization

This BSM devices complies with part 15 of the FCC rules (15.252), with RSS-220 of Industry Canada and with EN 302288 of ETSI/CEPT on a Class1 basis.

Operation is subject to the following conditions:

1. This device may not cause harmful interference, and
2. This device must accept any interference received, including interference that may cause undesired operation.
3. This device may only work when the vehicle is in operation.