1. Operational description

1.1. General

The DULCOLEVEL is a FMCW radar system operating in the maximum frequency range from 77 to 81 GHz (W-band). It is intended to measure the distance to, or the level of, liquids or solids in tanks or enclosed containers or in open systems like bunkers or open containers on stock piles.
The DULCOLEVEL is delivered with fixed lens antenna, which is part of the housing.
The device has to be mounted above the solids or liquids to be measured. The antenna is pointing downwards to the surface of the solids or liquids.

1.1. Operation overview

The DULCOLEVEL generates an RF signal with a max. sweep from 77 up to 81 GHz. By means of the antenna this signal is sent from top of a tank or container downwards and is reflected by the liquid or solid surface in it. The reflected signal is received again by the antenna and analyzed in the system.
The propagation delay of the RF signal is proportional to the distance of the radar system to the liquid or solid surface and is measured by the DULCOLEVEL.
The measured value is converted into a constant current on the current output and is also transferred via the Bluetooth interface. An NFC interface is used to read basic device parameters (e.g. series number) and to simplify Bluetooth pairing.

1.2. Block diagram of DULCOLEVEL

The electronic control can be split into three main parts: the sensor part with the RF generation, the Bluetooth unit and the converter part which are located on two different PCBs.

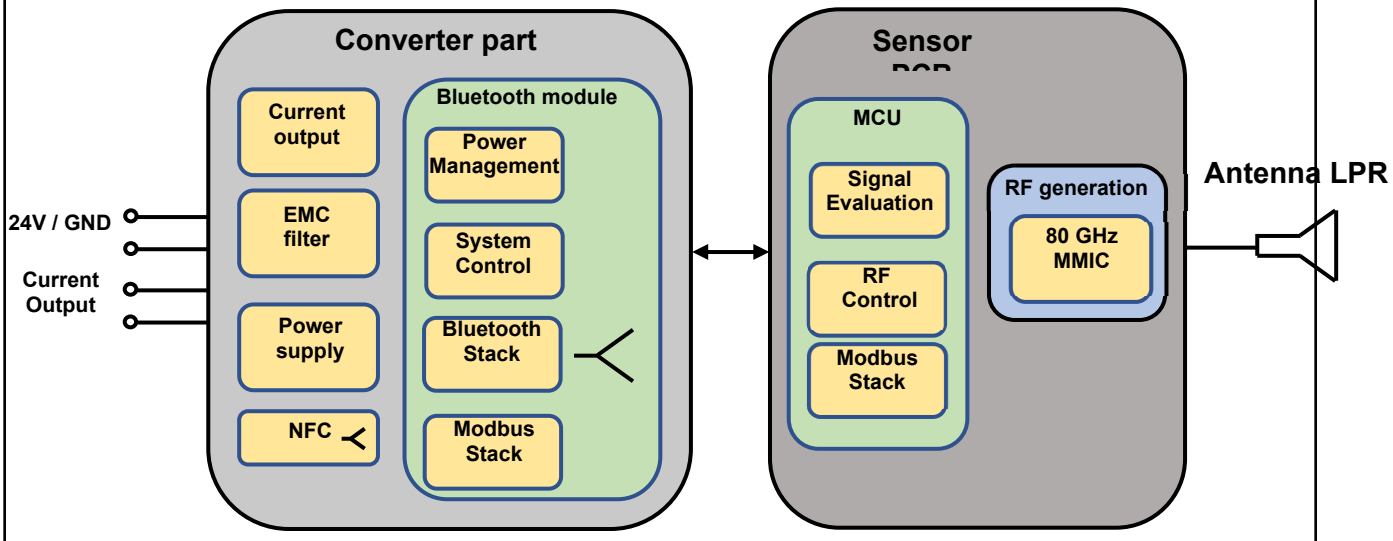

Figure 1: Block diagram DULCOLEVEL

The converter part contains the power supply, EMC filtering, current output as well as NFC and Bluetooth interface. The Bluetooth module is used as central MCU controlling the interfacing for the whole system. Furthermore, it is used for communication with the sensor part and to perform power management.

The connection to the control system is a two wire 4 to 20 mA current output. The liquid level is mapped to a dedicated current value between 4 and 20 mA. The current is measured by the control system on customer side and remapped to the liquid level.

Another communication type is the Bluetooth interface. With a pre-certified Bluetooth module, which is populated on the converter part of the device it is possible to receive or transmit measurement and configuration data for the MCU from and to mobile devices, respectively.

The NFC interface is used for transmitting basic device data (e. g. series number) to an NFC counterpart. Furthermore, it can be used to simplify and speed up the Bluetooth connection process.

The sensor part comprises the RF generation and an MCU responsible for RF control, signal evaluation and sensor converter communication via Modbus protocol.

The RF generation is done by an mmWave integrated chip (MMIC) based on FMCW technique capable of operating in the frequency range 77 to 81 GHz.
The MCU triggers an RF sweep of 342 µs up to 2 times per second.

Output power at the antenna port is typically 0 dBm.

The RF signal sent out by the antenna is reflected at the surface of the liquid or solid, received again by the antenna and fed to the RF input of the MMIC.
Due to the frequency sweep and the propagation delay of the reflected signal, the actual frequency of the LO input of the integrated mixer is lower than the reflected signal frequency at the RF input. The difference frequency of the IF signal of the integrated mixer is proportional to the delay of the reflected signal and to the distance of the reflection, respectively.
The IF signal frequency is in the range of 175 kHz up to 15 MHz.

This signal is sampled by an A/D converter integrated in the MMIC. On the sampled data an FFT is performed. Determination of the frequency of the IF signal is done on the sensor MCU. With the known dimensions of the tank or container the sensor MCU calculates the liquid or solid level in the tank or container.

The antenna is constructed in a two-step approach:
First the TX output signal is fed into a short round horn antenna by electrically coupling from the PCB into the horn feed. Therefore, the horn is directly mounted above the round antenna coupling on the PCB. Secondly, the horn beams onto a dielectric lens, which makes the final beam forming. The dielectric lens is a separate part inside the device housing.

The supply voltages for the MMIC are generated by DC/DC converters. A low voltage detection implemented in the MCU abort RF generation if the supply voltage level is not sufficient.

1.3. Technical specifications

Technical Specifications of DULCOLEVEL		
General		
FMCW Radar working in W-Band frequency range with digital signal processing and crystal controlled PLL frequency stabilisation. Compact instrument, 4 wire connection		
Supply Voltage	24 V ± 25%	
Supply Current	< 150 mA	
Temperature Range	-10°C…+75°C	
RF Transmitter		
Bandwidth	77…81 GHz	
Sweep time $\mathbf{T}_{Sweep}$	342 µs	
Measuring interval time $\mathbf{T}_{Cycle}$	500 ms	
Peak transmitted power at antenna port (conducted)	typ. 0 dBm	
Bluetooth		
Precertified Bluetooth module including antenna	BGM220PC22HNA (see datasheet attached)	
Antennas		
Maximum Side lobe level	-10.2 dB	
Maximum Beam width, 3 dB	E-Plane	6.2°
	H-Plane	7.8°
Maximum Transmitted Power EIRP	+28.3 dBm	
Maximum Gain	28.3 dBi	

Table 1: Technical specifications of DULCOLEVEL

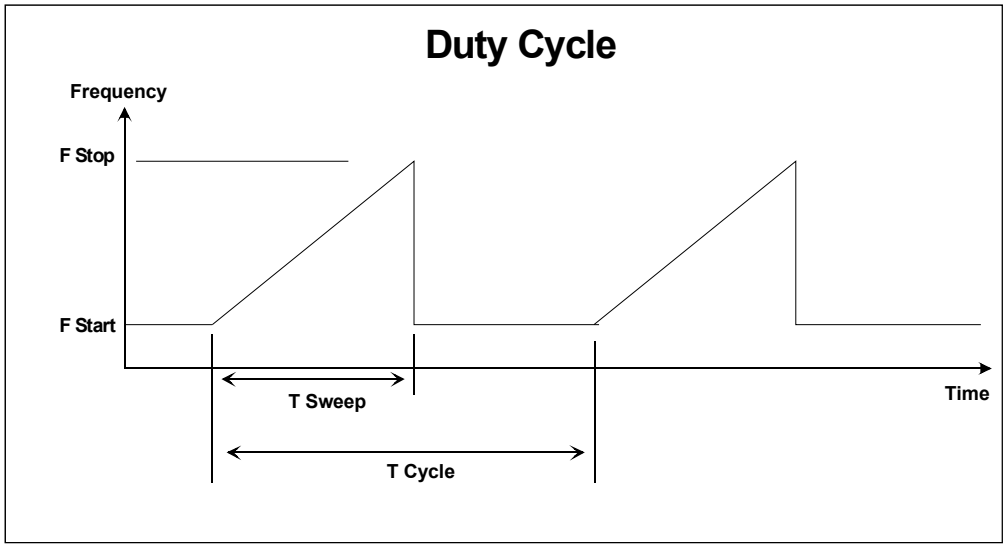

Figure 2: Duty Cycle

1.4. Antenna characteristics

Type	Gain [dB]	Angular width E- / H-plane [°]
PEEK / DN40 (1.5”) Lens	28.3	6.2 / 7.8

Table 2: Antenna characteristics