INTERFERENCE REJECTION MEASUREMENT REPORT

Goal:

The purpose of this test is (i) to determine the Continuous Wave (CW) interference rejection ability of the tag according to the *ISO/IEC 18000-63* [1] alternatively for the EPC™ Gen2 RFID IC [2], and (ii) to compare results of the two test setups described in this document.

Executive summary: The SDR Interference Emulator (SDR-IE) can measure the interference rejection of RAIN tags using a single RF frontend. It delivers results that match results obtained from a setup consisting or two independent generators – one generator of the intended signal and one interferer generator.

Measurement procedure and setup:

For the carrier frequency 865 MHz and 915 MHz the interferer power is increased relative to the desired electromagnetic field until the tag can no longer demodulate the desired generator command. For interference rejection test the setup is arranged as defined in ISO/IEC 18046-3:2019(E). It consists of a generator of the intended signal and a generator of an interfering signal The two generators are separate hardware units that are connected using a coupler or combiner. To provide a cost efficient solution that is easy to control and fast in executing the interference tests, a setup with single transmitter based on the SDR-IE was developed. The transmitted signal contains components of both the intended signal and the intefering signal. The two signals are built in baseband and then upconverted to the targer frequency by the frontend of the SDR-IE. The two hardware setups as depicted by Figure 1 and Figure 2 were used in order to provide comparison of results obtained using the single-transmitter SDR-IE and a setup consisting of USRP [3] and an independent signal generator.

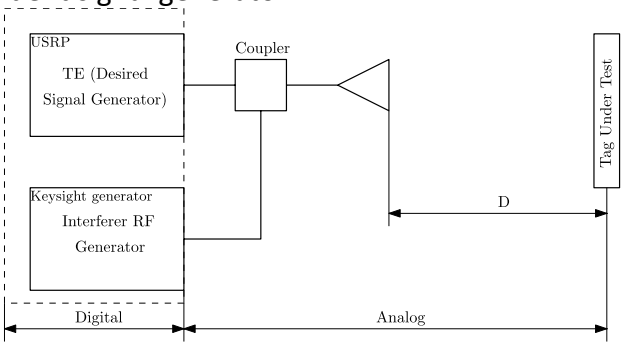

Figure 1 Test setup for interference rejection using USRP and an independent generator

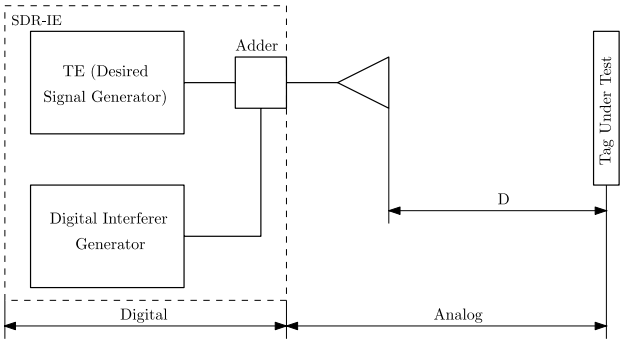

Figure 2 Test setup for interference rejection using SDR-IE only

As a measurement device the SDR-IE equipped by a compatible WBX radio frontend[1] [3] is applied. The SDR-IE is able to emulate the desired Ultra High Frequency (UHF) Radio Frequency IDentification (RFID) waveforms as well as the interferer signals as depicted by Figure 2. The measurement is also executed by a setup consisting of a USRP and an independent waveform generator to verify confidence of the SDR-IE measurement.

Results:

The ISO/IEC WD 18046-3:2019(E) specifies the interference rejection as the point where a tag can no longer demodulate the desired generator command. Then Irejection is calculated as:

$$Irejection = Prejection - Pmin + 6dB, \qquad (1)$$

where *Pmin* is defined as the minimum power threshold for identification. During the measurement process, it may happen that the tag omits the answer or does not demodulate the response at a certain level of power of the interferer, although, for increased level of the interferer power the tag is still able to respond[2]. This effect leads to false detection of rejection point. Due to false rejection effect, the measurement is performed to detect both, first missing response as well as the last detected tag response. Both detection methods for each carrier frequency are depicted by Figure 3. To verify the measurement error, results are compared with the measurement setup operating with an independent interference Radio Frequency (RF) generator depicted by black crosses (USRP + independent generator) at Figure 3. In case of measurements with independent generator and the USRP device the rejection points are detected as probability detection of tag response between 40-60% in frequency domain.

[1] The WBX is a wide bandwidth (50-2200 MHz) transceiver providing up to 100 mW of output power and a noise figure of 5 dB.

[2] The position of blue crosses and red circles may variate, this effect can be described by example for certain frequency: if increasing power of interference cause uniform transition from state where tag respond to state where tag is not able to respond described by vector …11110000… the **last detected** point describes lower interferer power level than **first missing answer**. If the transition is nonuniform described by vector …11101100… then **last detected** point describe higher interferer power level than **first missing answer.** Lower/higher denoting interference power level depicted in Figure 3 as y axis. 1 and 0 denoting detection or non-detection respectively of the tag answer at certain power level of interferer signal, vector length denoting all interferer power level measurements.

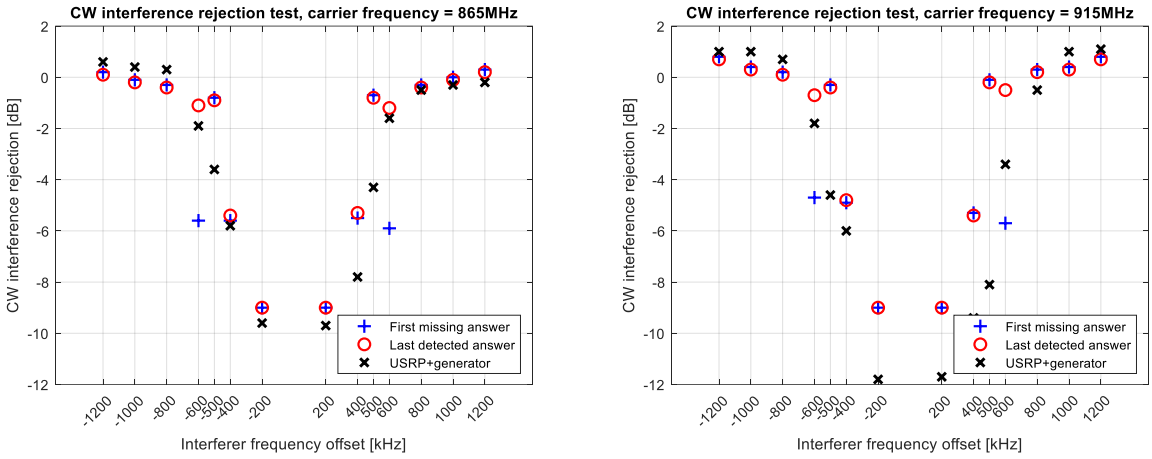

Figure 3 CW interference rejection test

In case of emulating of interferer signal by the SDR-IE, the measurement is affected by the IQ imbalance resulting in an image frequency at 864,5 MHz and 914,5 respectively and formation of higher order harmonics products by imperfections in baseband paths and WBX frontend as is depicted by Figure 4. The dispersion around center frequency in Figure 4 is caused by triggering of the spectral analyzer to the part of the modulated reader command which differs to the measurement with USRP where the spectral analyzer measure spectrum out of the reader command. The measured spectra of the USRP with the independent generator are shown in Figure 5. Contrary to the SDR-IE the independent generator-based setup suffers to phase noise.

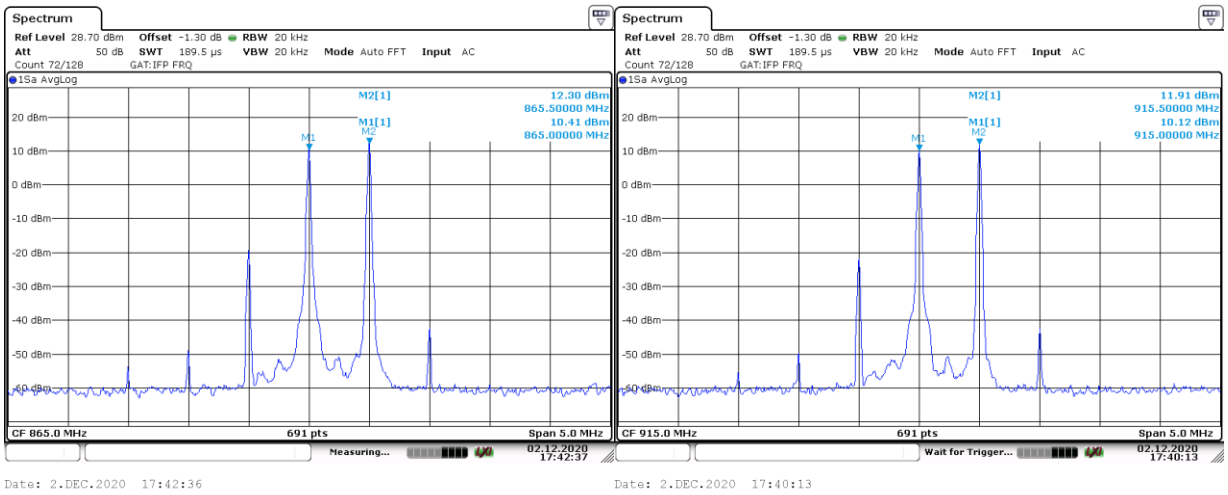

Figure 4 Spectra of SDR-IE based setup

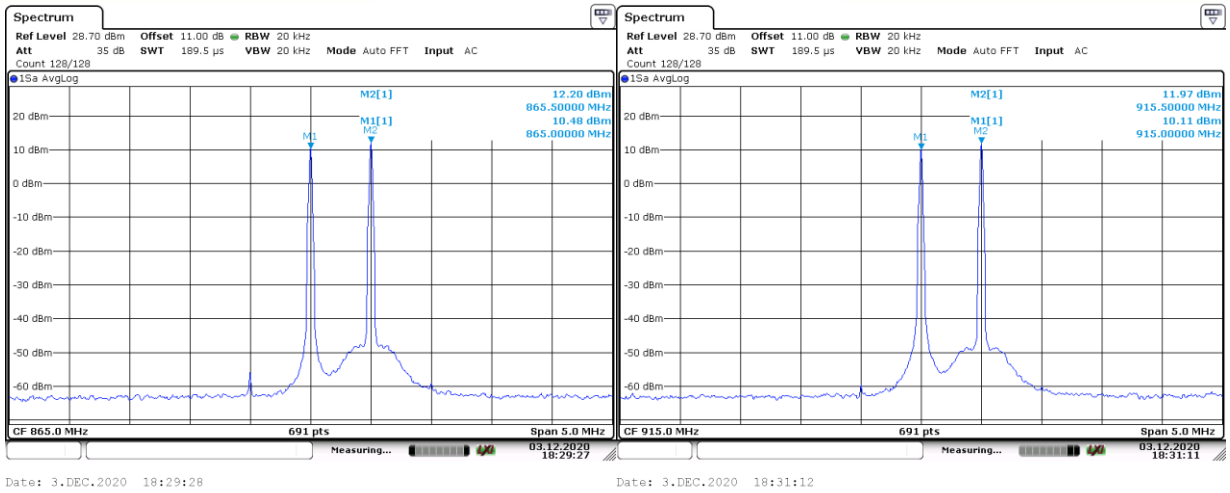

Figure 5 Spectra of USRP based setup with independent interferer generator

Conclusion:

The measurement of continuous wave interference rejection of Ultra High Frequency Radio Frequency Identification (UHF RFID) tags by SDR Interference Emulator (SDR-IE) provides comparable results to the system based on USRP [3] and independent interference generator.

According to Figure 3 the interference rejection result value shows high variation at frequency offsets +/-500 kHz and +/-600 kHz. The variation between first missing and last detected tag answer is caused by non-detected responses at low interference power levels, while after increasing of the interferer signal power the RFID tag recovers to responding. Therefore, the last detected answer is a more appropriate technique to rejection point detection. Other frequency offsets are not affected by this effect and provide consistent results. The difference between results of the two measurement setups around +/- 1dB. Frequency offsets +/- 200 kHz are limited by SDR-IE due to improper measurement settings working with lowest power level of interferer -9dB.

The spectrum analysis of both systems is depicted by Figure 4 and Figure 5. The SDR-IE outperforms the USRP-generator based setup in case of phase noise of the interferer. In contrary, the image rejection (864,5 MHz and 914,5 MHz) of the SDR-IE (Figure 4) is worse than the USRP-generator based setup. The application of independent generator provides frequency mismatch and thus slightly nonsymmetrical characteristic in rejection measurement due to lack of synchronization between the interferer and the desired signal generator (USRP).

It is shown that the SDR-IE based system is capable to measure the CW interference rejection according to the ISO/IEC 18046-3:2019 for the RFID UHF systems defined by the *ISO/IEC 18000-63* [1] alternatively by the EPC™ Gen2 RFID IC [2].

References:

[1] International Organization for Standardization, "ISO/IEC 18000-63:2015," 10 2015. [Online]. Available: https://www.iso.org/standard/63675.html. [Accessed 1 12 2020].

[2] GS1, "EPC UHF Gen2 Air Interface Protocol," 7 2018. [Online]. Available: https://www.gs1.org/standards/epc-rfid/uhf-air-interface-protocol. [Accessed 1 12 2020].

[3] Ettus Research, 12 2020. [Online]. Available: https://www.ettus.com/. [Accessed 1 12 2020].

Appendices:

Protocol 1

Test: Interference rejection (I-REJECTION) Frequency carrier = 875 MHz		
Mounting Material: paper		
Distance: D = 30cm		
Temperature: 23 °C	Humidity: 50%	
Tag Protocol: *ISO/IEC 18000-63*	Identifier:	
	UII: 0x	
	TID: 0x	
Forward Link		
Modulation index: *90%*	Data rate information:	Data coding: *PIE*
Modulation type: DSB-ASK	Tari = 12,5 µs	
	Tari-1 = 1,5 Tari-	
Command(s) including time between commands:		
Select (01b1010, Target=000, Action=000, MemBank=10, Pointer=0, Length=0, Mask=empty, Truncate=0)		
T4 = 1 ms		
Query (0b1000, DR=64/3, M=4, TRext=1, Sel=00, Session=00, Target=A, Q=0)		
Return Link		
Data rate: kbps	Data coding:	
RTcal = 2.5 Tari	M=4	
TRcal = 2.133 Trcal		

Test Results (last detected answer)

Interferer frequency Offset (kHz)	CW interference rejection	CW interference rejection USRP and independent generator
-1200	0.7	0.6
-1000	0.3	0.4
-800	0.1	0.3
-600	-0.7	-1.9
-500	-0.4	-3.6
-400	-4.8	-5.8
-200	-9	-9.6
0		
200	-9	-9.7
400	-5.4	-7.8
500	-0.2	-4.3
600	-0.5	-1.6
800	0.2	-0.5
1000	0.3	-0.3
1200	0.7	-0.2

Protocol 2

Test: Interference rejection (I-REJECTION) Frequency carrier = 915 MHz		
Mounting Material: paper		
Distance: D = 30cm		
Temperature: 23 °C	Humidity: 50%	
Tag Protocol: *ISO/IEC 18000-63*	Identifier:	
	UII: 0x	
	TID: 0x	
Forward Link		
Modulation index: *90%*	Data rate information:	Data coding: *PIE*
Modulation type: DSB-ASK	Tari = 12,5 µs	
	Tari-1 = 1,5 Tari-	
Command(s) including time between commands:		
Select (01b1010, Target=000, Action=000, MemBank=10, Pointer=0, Length=0, Mask=empty, Truncate=0)		
T4 = 1 ms		
Query (0b1000, DR=64/3, M=4, TRext=1, Sel=00, Session=00, Target=A, Q=0)		
Return Link		
Data rate: kbps	Data coding:	
RTcal = 2.5 Tari	M=4	
TRcal = 2.133 Trcal		

Test Results (last detected answer)

Interferer frequency Offset (kHz)	CW interference rejection	CW interference rejection USRP and independent generator
-1200	0.1	1
-1000	-0.2	1
-800	-0.4	0.7
-600	-1.1	-1.8
-500	-0.9	-4.6
-400	-5.4	-6
-200	-9	-11.8
0		
200	-9	-11.7
400	-5.3	-9.4
500	-0.8	-8.1
600	-1.2	-3.4
800	-0.4	-0.5
1000	-0.1	1
1200	0.2	1.1