AN4970
Application note

Reflected RF level indicator for ST25RU3993

Introduction

Performance of RF devices can be impacted by reflections of not perfectly matched antennas, by reflections caused by objects in the antenna environment, and by imperfections of the directional device. These effects cause leakage of the transmitted carrier signal into the RX mixers inputs: the noise of the relatively strong transmitted signal is demodulated, increasing the received noise floor and consequently the error probability. In the most severe cases it is possible to overload input mixers.

The RX mixers overload due to reflected transmitting carrier power can be detected by the host system (MCU) by triggering a measurement of RF input level via the internal ADC (Analog to Digital Converter) embedded in ST25RU3993 devices.

The reflected carrier signal present on the two RX mixers inputs is directly down-converted to a proportional, input phase dependent, zero frequency (DC) level. The two DC levels on the internal RX mixers are a measure for the level of the reflected carrier.

The ST25RU3993 datasheet, available on *www.st.com*, is to be considered as a reference for this document. Concerning notation, the 0x prefix indicates numbers in hexadecimal notation (example: 0x29), while binary numbers are followed by a b suffix (example: 00b).

Contents

List of tables

List of figures

1 Measurement setup and calculation

The two internal RX mixer output DC levels can be connected to the internal ST25RU3993 ADC by setting the option bits msel<3:0> in the Measurement Control Register (0x10). The appropriate settings for the I and Q channels are, respectively, 0001b and 0010b. The conversion is triggered by the direct command 'Trigger AD Conversion' (0x87).

Before the result of the AD conversion can be read from the paged ADC Readout /Regulator Setting Display Register (0x2D) the option bits r2Dpage<1:0> of the Status Readout Page Setting Register need to be set to 00b. The result of the AD conversion is valid 20 µs after triggering the direct command.

If the irq_cmd bit in register 0x36 (Enable Interrupt Register 2) is set, an IRQ will be sent when the conversion is finished.

The calculation of the reflected power requires both DC levels of the I and Q channel. The recommended procedure is:

1. In register 0x29 set r2Dpage<1:0> bits to 00b
2. Send direct command Enable RX (0x97)
3. In register 0x10 set msel<3:0> bits to 0001b
4. Trigger the AD conversion (direct command 0x87)
5. Wait 20 µs and read the I channel result from register 0x2D
6. Set msel<3:0> bits to 0010b and repeat steps 4 and 5 for the Q channel
7. Send direct command Block RX (0x96)

The input power is calculated according to the following formulas:

$$AbsMixDC = \sqrt{MixDCA^2 + MixDCB^2}$$

$$Pin(dBm) = 20 \cdot \log\frac{AbsMixDC}{G}$$

where

- MixDCA and MixDCB are the two orthogonal values acquired via the internal ADC
- AbsMixDC is the absolute value calculated from MixDCA and MixDCB
- Pin is the RF input carrier signal power expressed in dBm
- G is a constant depending on register 0x0A (RX Mixer and Gain).

G values for different devices (differential and single ended mixers) are shown, respectively in tables *1* and *2*. The behavior of MixDC and of Pin error are shown in figures *1*, *2*, *3* and *4*.

Table 1. Values of G for differential RX mixer(1)

mix_ir<1:0>	id2x	G	Comments
01b (0x0A:01)	0b (0x04:0x)	17	Differential input mixer, internal attenuator
00b (0x0A:00)	0b (0x04:0x)	40	Differential input mixer, no internal attenuator
10b (0x0A:02)	0b (0x04:0x)	129	Differential input mixer, increased mixer gain
10b (0x0A:02)	1b (0x04:4x)	286	Differential input mixer, increased mixer gain, increased DC path gain

1. For differential input mixer id1x5=0.

Figure 1. Differential RX mixer – MixDC level (code) vs. Pin (dBm)

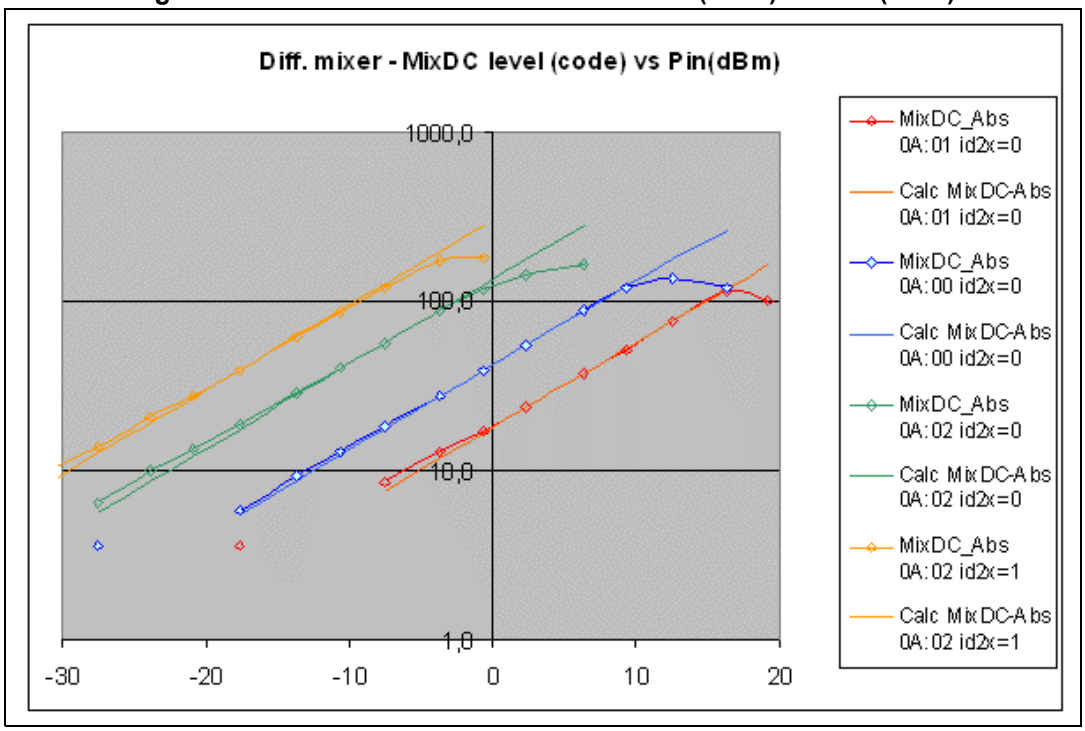


Figure 2. Differential RX mixer – Pin error (dB) vs. Pin (dBm)

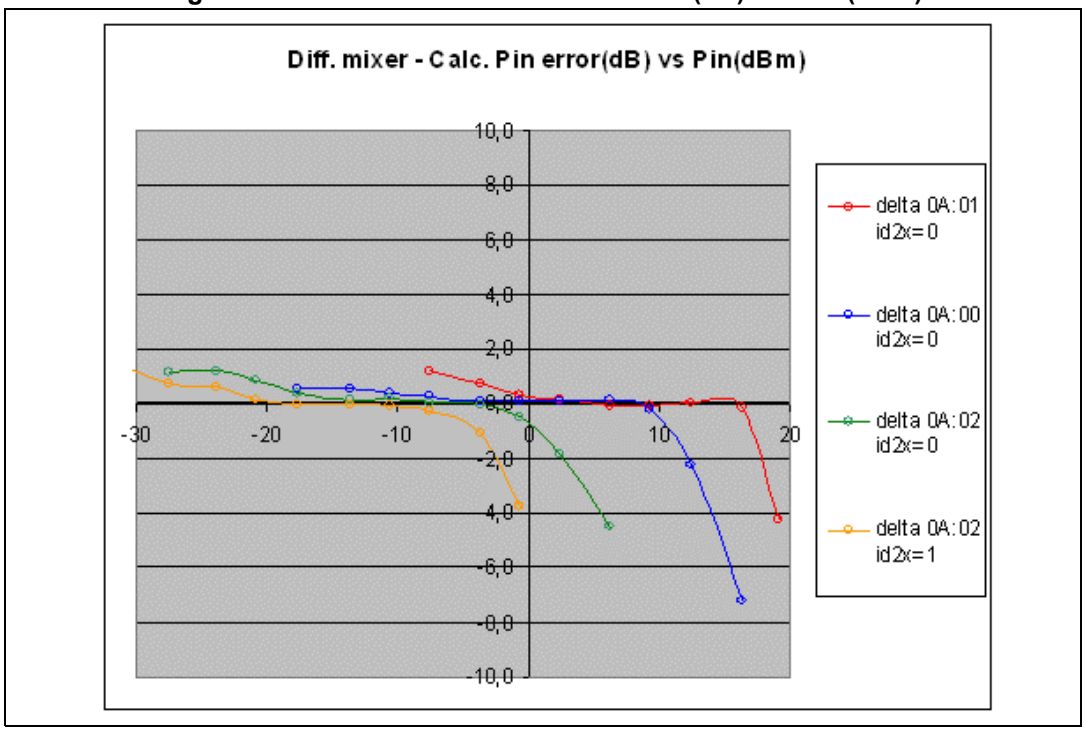


Table 2. Values of G for single ended RX mixer(1)

Register settings	G	Comments
0x0A:00, 0x22:17	26	Single ended mixer, low sensitivity
0x0A:01, 0x22:14	50	Single ended mixer, medium sensitivity
0x0A:03, 0x22:12	90	Single ended mixer, high sensitivity
0x0A:03, 0x22:00	160	Single ended mixer, high (LBT) sensitivity

1. For single ended RX mixer id1x5=id2x=0.

Figure 3. Single ended RX Mixer – MixDC level (code) vs. Pin (dBm)

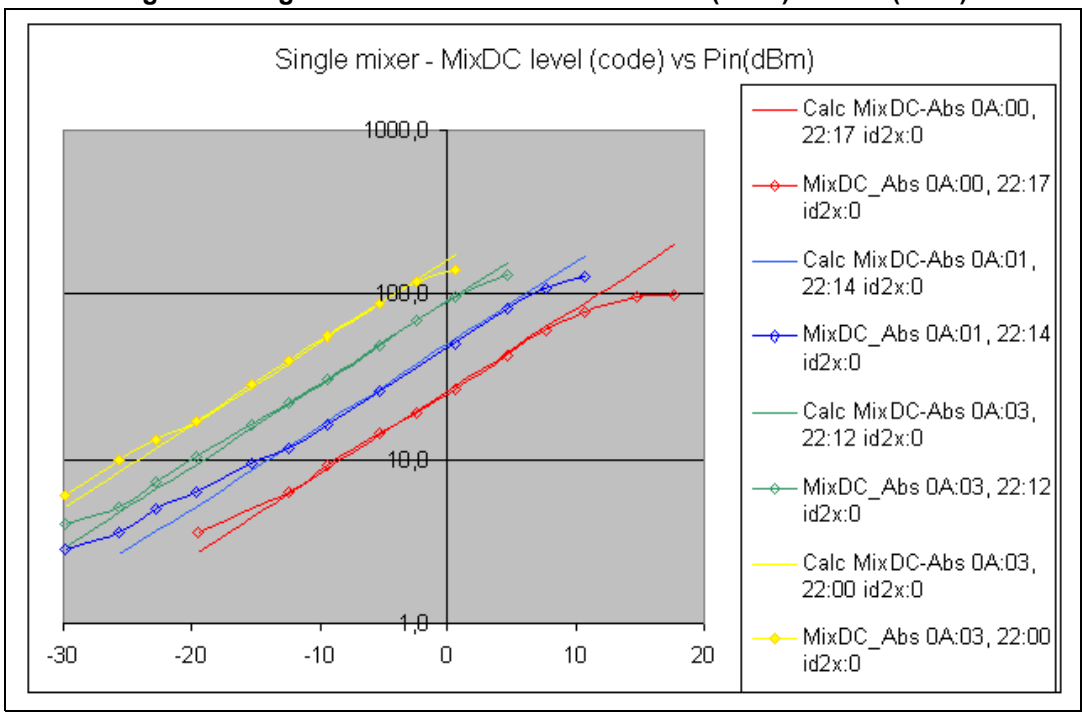
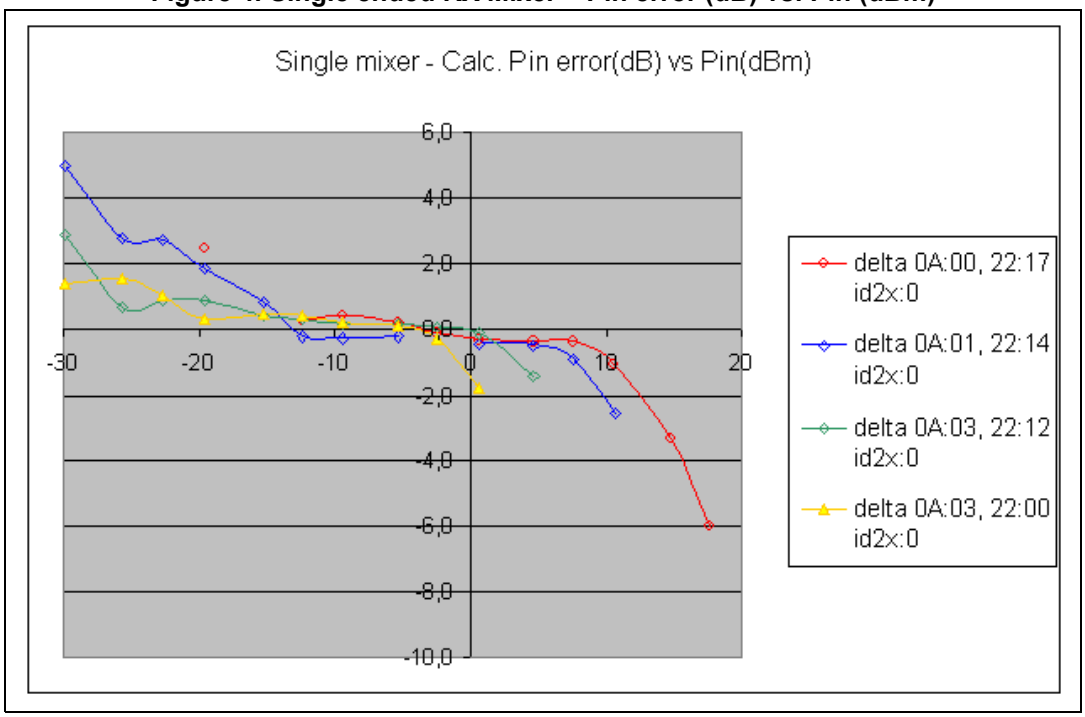


Figure 4. Single ended RX Mixer – Pin error (dB) vs. Pin (dBm)

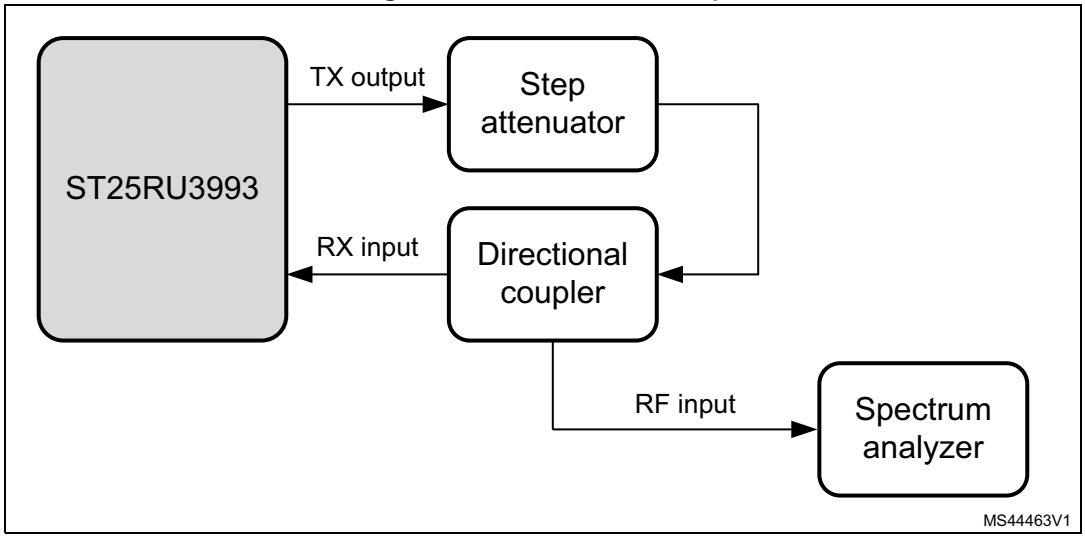


2 How to get the G value

For a new PCB design and accurate reflected RF level reading at the antenna terminal it is suggested to check the matching between the calculated power and the actual reflected input power, G values should be adjusted accordingly. An adjusted G value would take RF losses caused by the PCB, filters, and other factors into account.

The setup shown in *Figure 5* includes the ST25RU3993 UHF RFID reader PCB under test with separated TX output and RX input terminals, a step attenuator, a directional coupler and a spectrum analyzer.

Figure 5. Measurement setup



To acquire a new G value the procedure below should be followed:

1. Set the appropriate RF carrier level at the RX input.
2. Measure the actual input power via the spectrum analyzer, which is connected to a coupled part of the input power.
3. Read out I and Q mixer DC levels from the reader chip, and calculate the approximate input power.
4. Calculate the new G value.

3 Mixer setting guidelines

For optimal performance it is advised to follow a procedure using an adaptive mixer setting approach during the inventory round. An example is shown in *Table 3*.

Table 3. Mixer setting procedure (differential RX mixer)

Step	Action	Comments
1	Issue EPC SELECT command	Optional
2	Set reg 0A: 01	Turn on the internal attenuator (8 dB)
3	Readout I and Q Mixer DC level	-
4	If I and Q mixer DC levels > 10 start inventory round (Query, QueryRep, QueryAdjust…), and use these settings as long as new tags are found.	If I and Q mixer DC levels are lower than 10 skip this inventory round (this occurs mainly when a 10 dB directional coupler is used as a directional device)
5	Set reg 0A: 00	Turn off the internal attenuator
6	Readout I and Q Mixer DC levels	-
7	If I and Q mixer DC levels < 80 continue the inventory round (Query, QueryRep, QueryAdjust…), and use these settings as long as new tags are found.	Run this part of inventory round when the reflected power is reasonably low compared with the expected tag readings (Prefl < 10 dBm).
8	Set reg 0A: E0	Turn off Internal attenuator; Increased base band gain.
9	Readout I and Q Mixer DC levels	-
10	If I and Q mixer DC levels < 50 continue the inventory round (Query, QueryRep, QueryAdjust…), and use these settings as long as new tags are found.	Run this part of inventory round when the reflected power is reasonably low compared with the expected tag readings (Prefl < 5 dBm).
11	Set reg 0A: 02	Increase mixer gain
12	Readout I and Q Mixer DC levels	-
13	If I and Q mixer DC levels < 80 continue the inventory round (Query, QueryRep, QueryAdjust…), and use these settings as long as new tags are found.	Run this part of inventory round when the reflected power is reasonably low compared with the expected tag readings (Prefl < 0 dBm).
14	Set reg 0A: E2	Increased mixer gain, increased BB gain.
15	If I and Q mixer DC levels < 50 continue the inventory round (Query, QueryRep, QueryAdjust…), and use these settings as long as new tags are found.	-

For a typical application it is not necessary to implement all steps, only those expected (for a specific application) should be used, among them:

- TX output power
- Directivity device: Circulator or directional coupler
- Antenna configuration: Mono-static or Bi-static
- Expected directivity device leakage
- Expected antenna reflectivity

For the single ended RX mixer input a similar procedure (see *Table 4*) should be used, starting with low sensitivity and moving towards higher (better) sensitivity, as long as reflected power is low enough to have an appreciable gain increase.

Table 4. Mixer setting procedure (single ended RX mixer)

Step	Action	Comments
1	Issue EPC SELECT command	Optional
2	Set Registers 0A: C0, 22h:14	Low mixer gain, min. BB gain
3	Readout I and Q Mixer DC level	-
4	If I and Q mixer DC levels > 10 start inventory round (Query, QueryRep, QueryAdjust…), and use these settings as long as new tags are found.	If I and Q mixer DC levels are lower than 10 skip this inventory round (this occurs mainly when a 10 dB directional coupler is used as a directional device)
5	Set reg 0A: 00, 22h:1	Turn off internal attenuator
6	Readout I and Q Mixer DC levels	-
7	If I and Q mixer DC levels < 80 continue the inventory round (Query, QueryRep, QueryAdjust…), and use these settings as long as new tags are found.	Run this part of inventory round when the reflected power is reasonably low compared with the expected tag readings (Prefl < 10 dBm).
8	Set reg 0A: 01, 22h: 12	Turn off Internal attenuator; Increased base band gain.
9	Readout I and Q Mixer DC levels	-
10	If I and Q mixer DC levels < 50 continue the inventory round (Query, QueryRep, QueryAdjust…), and use these settings as long as new tags are found.	Run this part of inventory round when the reflected power is reasonably low compared with the expected tag readings (Prefl < 5 dBm).
11	Set reg 0A: 03, 22h: 11	Increase mixer gain
12	Readout I and Q Mixer DC levels	-
13	If I and Q mixer DC levels < 80 continue the inventory round (Query, QueryRep, QueryAdjust…), and use these settings as long as new tags are found.	Run this part of inventory round when the reflected power is reasonably low compared with the expected tag readings (Prefl < 0 dBm).
14	Set reg 0A: E3, 22h: 00	Increased mixer gain, increased BB gain.
15	If I and Q mixer DC levels < 50 continue the inventory round (Query, QueryRep, QueryAdjust…), and use these settings as long as new tags are found.	-

4 Conclusion

The level of leakage of the TX signal into the receiver (caused by imperfections of the directional device) and the reflections by the antenna back into the receiver can be measured by the ST25RU3993 device thanks to a dedicated circuit block.

The receiver overload can be prevented by measuring the reflected RF level. The procedure described in this document can be used to get the G value used for the calculation of the reflected RF level for both the differential and single ended receiver types.

A measurement setup has also been described, it can be used to determine the G value for a specific reader implementation. A procedure that enables to fine tune the receive gain stages to optimize sensitivity and hence reception performance is detailed in the last part of this application note.

5 Revision history

Table 5. Document revision history

Date	Revision	Changes
03-Jan-2017	1	Initial release.