Frequency shift circuit for ST25R3916/16B and ST25R3920/20B devices

Introduction

In the ST25 reader family, ST25R3916/16B and ST25R3920/20B are high performance NFC universal devices, supporting both NFC reader and NFC card emulation modes.

The NFC universal device must be able to switch between reader and card mode. The antenna tuning is modified depending on the selecting mode. For instance, the ST25R3916/16B uses voltage-controlled capacitors to switch the tuning between card and reader mode. Since voltage-controlled capacitors are not available as an automotive grade device, this application note presents a different approach, which can also be used in automotive applications to switch from reader to card mode applying a frequency shift circuit without affecting the reader mode.

The loading effect test can be a challenging test during NFC universal device certification. In this test case, the loading ratio of the listener device is being tested and compared with the loading of the reference listener. The loading caused by the listener must be equal to or less than the loading caused by the reference listeners when the listener is positioned in the operating volume of the reference poller.

The DVR (delta V_{OV} ratio) is defined as the ratio between the loading of the listener under test and the loading of the reference listener, and must be smaller than 1.

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1 Influence of the loading effect

The closer the card is tuned to the reader operating frequency (13.56 MHz), the higher the loading of the reader is. In order to separate resonance frequencies between reader and card mode, the antenna tuning is shifted. As an alternative to the voltage-controlled capacitor, a circuit is required to shift the antenna resonance frequency.

Depending on the antenna geometry, the resonance frequency in card mode must be different from 13.56 MHz. A delta of +/- 1MHz (< 12.56 MHz or > 14.56MHz) is a good starting point.

Figure 1 shows the resonance frequency of the reader and the card mode. The green line is the reader mode frequency graph and the red line is the card mode frequency graph.

Figure 1. Resonance frequency of reader and card mode
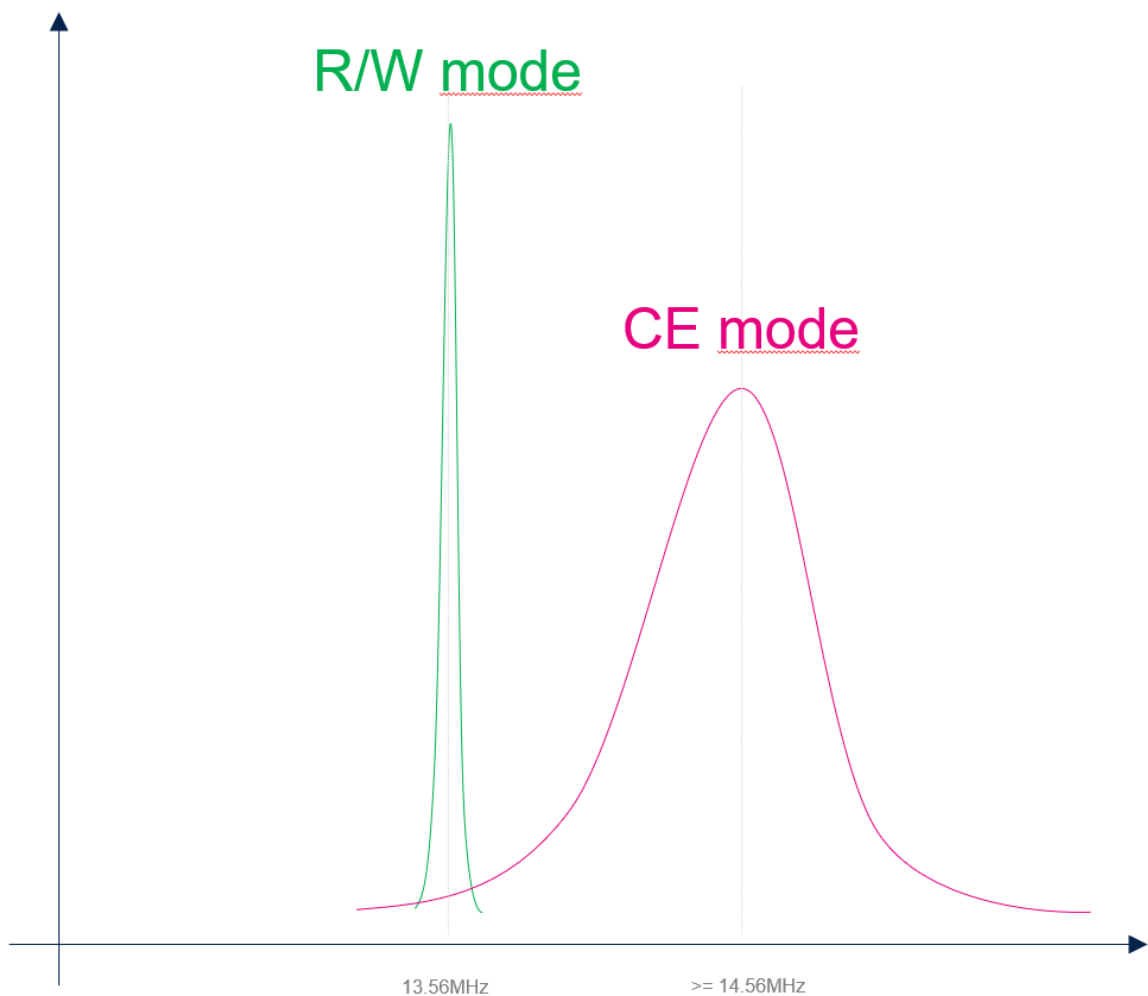
1.1 Frequency shift circuit

The frequency shift circuit is an alternative mechanism, which can be used to switch the antenna tuning between reader and card mode. It is necessary to add a small circuit consisting of a few components to the existing antenna circuit.

Figure 2 shows the frequency shift circuit and antenna circuit including EMI filter with the matching network.

The right side shows the normal matching topology with:

- EMC filter
- serial capacitor
- parallel capacitor
- the voltage divider capacitors
- and the antenna.

The left side shows the frequency shift circuit, which is composed for each antenna connection by the:

- capacitor
- transistor
- resistor connected to the gate of the transistors

Note: *Important components for this circuit are the capacitors C_{switch} (C318, C319), which are placed in parallel to the antenna to change the resonance frequency of the reader mode.*

Figure 2. Frequency shift circuit
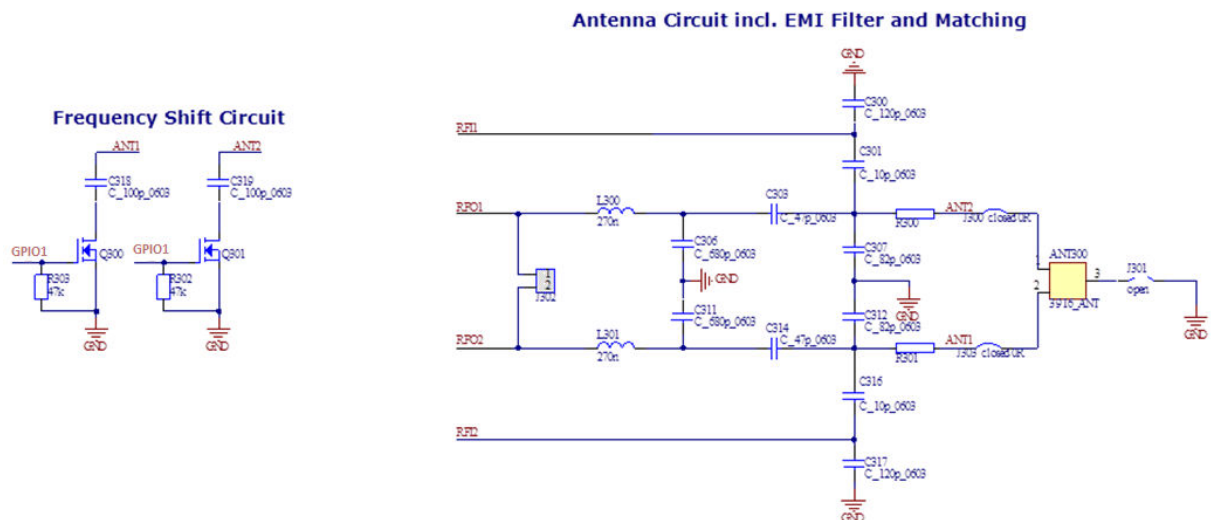
In this circuit, the C_{switch} capacitors are significant for the resonance frequency of the antenna.

As a starting point we have chosen the following value: C_{switch} = 56 pF, and compared it in both modes.

Q300 and Q301 are n-channel MOS transistors. Their drain-source voltage should be equal or higher than 30V and their R_{ds}(on) resistance lower or equal to 1 Ω.

Table 1. Resonance frequency on card mode and reader mode when C$_{switch}$ = 56 pF

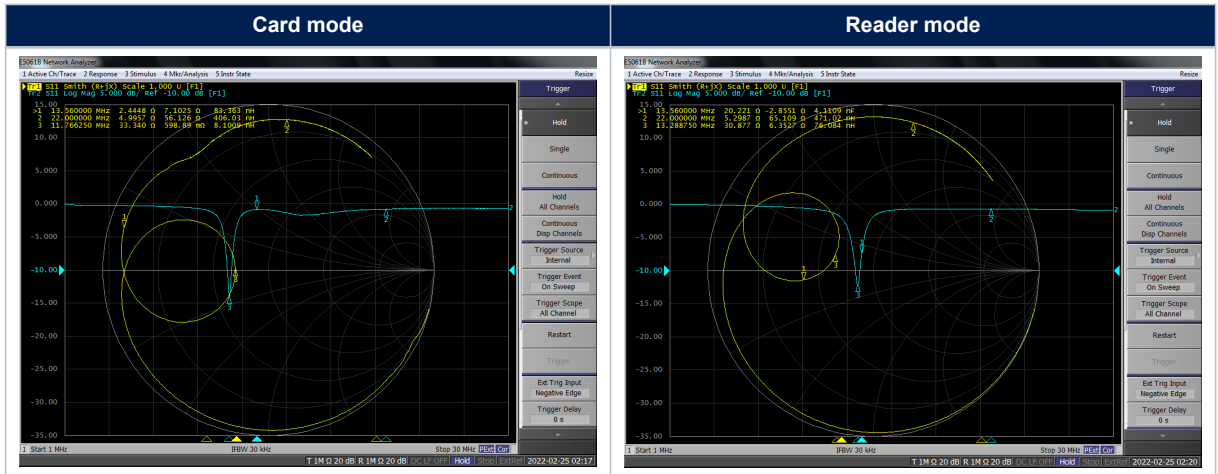| Card mode	Reader mode

Table 1 shows the comparison of the antenna matching between card and reader mode. As can be seen, the resonance frequency of the antenna from card mode to reader mode has been changed from 11.7 MHz to 13.56 MHz.

Note: *In this example, the loading effect is being measured according to NFC Forum standard.*

Table 2 shows the measurement results of the DVR in reader mode and card mode with poller 0.

Table 2. DVR for C$_{switch}$ = 56 pF

Position	DVR-CE	DVR-Reader
000	1.040	1.151
010	1.025	1.144
011	1.015	1.138
012	1.022	1.141
013	1.040	1.149

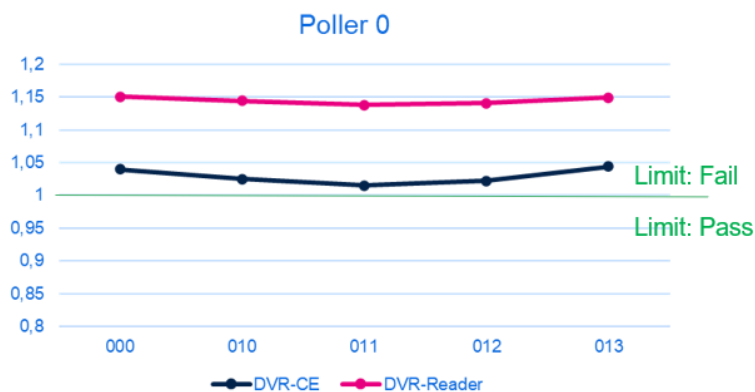**Figure 3. DVR graph for C$_{switch}$ = 56 pF**

Table 2 and also on Figure 3 show that this combination it is not compliant with the loading effect requirements. The DVR measurement value in any position is bigger than 1.

The values show in the column "DVR-reader" of Table 2 outline the impact of C$_{switch}$ and the necessity of the frequency shift circuit. Nevertheless, a C$_{switch}$ of 56 pF does not sufficiently change the resonance frequency to pass the test cases.

The same measurement process has been executed with the higher value of the C_{switch}. Table 3 shows the measurement results with $C_{switch} = 100pF$.

Table 3. DVR for $C_{switch} = 100pF$

Position	DVR-CE	DVR-reader
000	0.949	1.151
010	0.897	1.144
011	0.910	1.138
012	0.942	1.141
013	0.928	1.149

Figure 4. DVR graph for $C_{switch} = 100$ pF
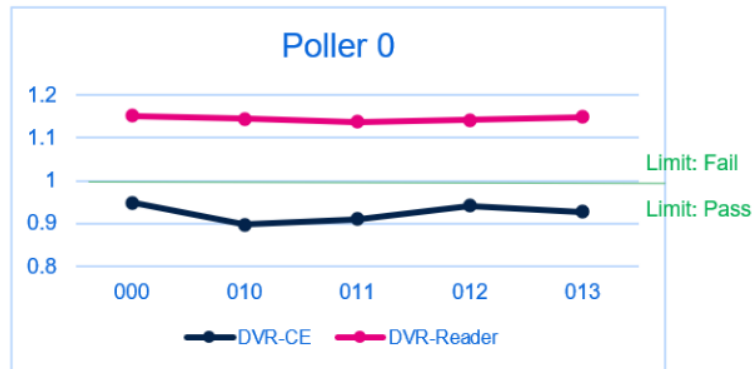
The range of the frequency shift depends on the value of C_{switch}. With the increased value of C_{switch}, the DVR of the card is reduced. The DVR of the card mode is less than 1, so the test for this value of the C_{switch} pass.

The different value of C_{switch} has no influence on the reader mode.

1.2 Controlling the frequency shift circuit

To use this alternative circuit, it is necessary to connect the frequency shift circuit to the GPIOs (General purpose inputs/outputs) pins of the MCU.

To put the device in card mode, the GPIO must be set to high and for reader mode the GPIO must be set to low.

2 Conclusion

This application note presents an alternative method of switching, between reader and the card mode, using the frequency shift circuit.

The C_{switch} value must be adjusted to a higher or lower value, depending on the antenna geometry and the coupling factor with the reference poller.

The NFC Forum test has been executed for reader and card mode. The complete NFC Forum test showed that the frequency shift circuit had no influence on the reader functionality.

Revision history

Table 4. Document revision history

Date	Version	Changes
08-Mar-2023	1	Initial release.

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