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# Report

Fachstelle der WSV für Verkehrstechniken

## Lab tests on the suppression of interferences from other radar installations

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# Table of Content

# 1 Introduction

Conventional navigational radar for the use on inland vessels have a built-in Interference Rejection (IR) optimized to suppress interfering signals from other conventional radars operating in the same frequency band 9 300 MHz to 9 500 MHz. Conventional river radar utilize very short pulses of typically 50 ns. With the upcoming solid-state radars with their typically much longer, intra-pulse modulated signals (typical pulse length >> 1 us) the question of compatibility with existing conventional radar systems arises.

This report tries to figure out how certain key parameters of an interfering radar affect the Interference Rejection processing in a conventional radar.

# 2 General test setup

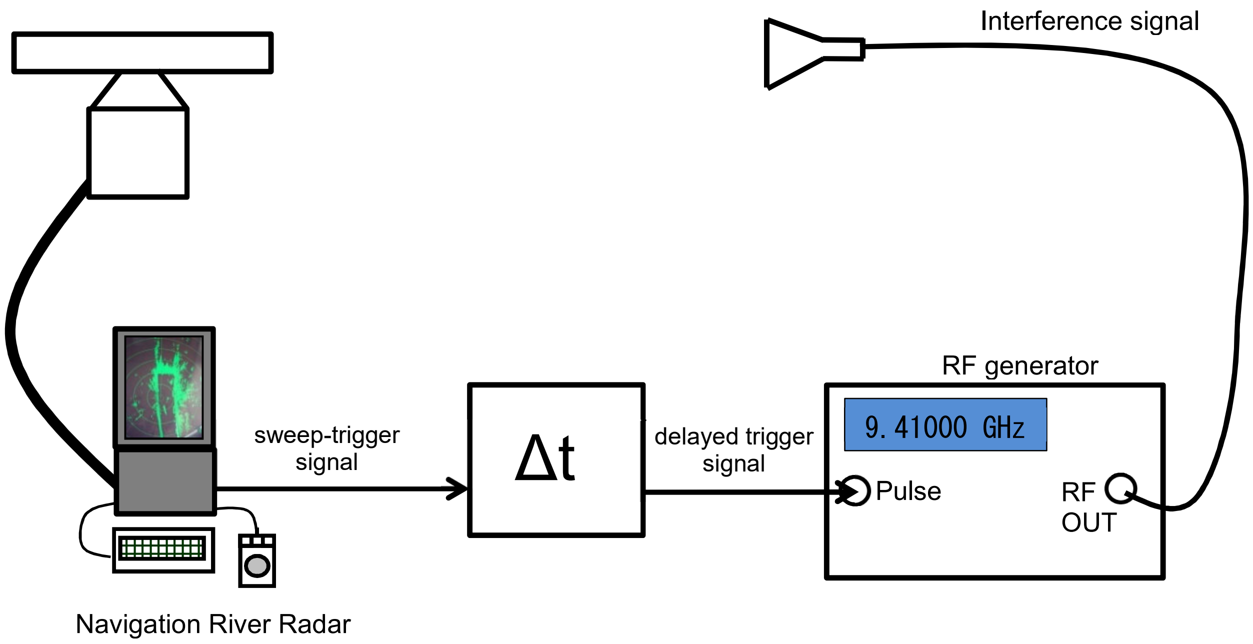


**Figure 1: General test setup to measure the inferences from other radars**

| | |
|---|---|
| Radar: | Swiss Radar JFS 364 |
| $f_{Magnetron}$ | = 9416.6 MHz |
| $f_{RX}$ | = 9416.6 MHz + Δtune (untuned) |
| PRF | = 3 kHz (range <= 2000 m) |
| PRF | = 1 kHz (range > 2000 m) |
| RF generator: | R&S Microwave Generator SMF 100A |
| Antenna: | Waveguide Horn Antenna |

The “Δt” block is a device developed by FVT. With the help of this device, an arbitrary trigger delay can be generated. In combination with the RF generator it is possible to create an echo at a defined range in the radar picture. Furthermore, it is possible to realize a “staggered PRF” by varying the trigger pulse delay from sweep to sweep.

The impact of the following parameters was measured:

- TX frequency and frequency variation,
- pulse length,
- PRF,
- power / distance and
- modulation.

The impact of rotating antennas was not considered.

# 3 Frequency variation

## 3.1 Description

Navigational river radars are permitted to be operated only in x-band in the frequency range from 9 300 to 9 500 MHz. The frequency of the transmitted signal is determined by the magnetron. Each magnetron has its own typical output frequency that is subject to certain frequency drift over life time. The frequency cannot be changed by the operator of the radar. With solid-state radar it is theoretically possible to operate the radar on any frequency within the given frequency range.

## 3.2 Test setup

For this test, the frequency of the interfering signal is changed to measure the corresponding attenuation of the radar echo shown on radar screen.
The setup of the test is shown in figure 1. The trigger signal is delayed so that a radar echo appears as a constant ring on the radar screen, figure 2.
The output power level of the RF generator is then reduced until the echo just remains visible (reference power level); now the frequency is changed in 1 MHz steps. At each step the power level is increased until the echo just appears again.

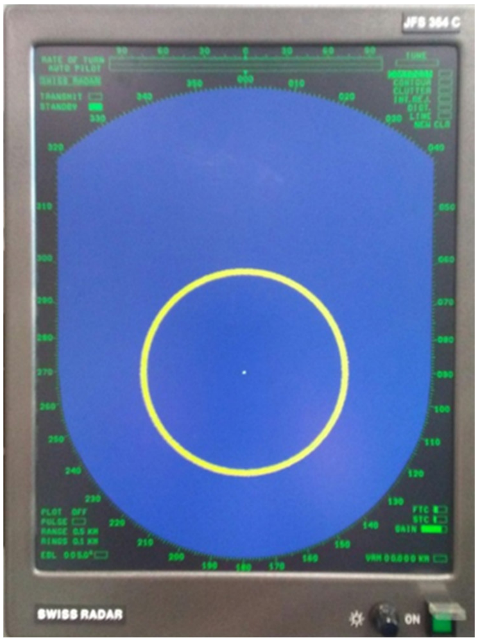


Figure 2: Testing the impact of frequency variation

## 3.3 Test result

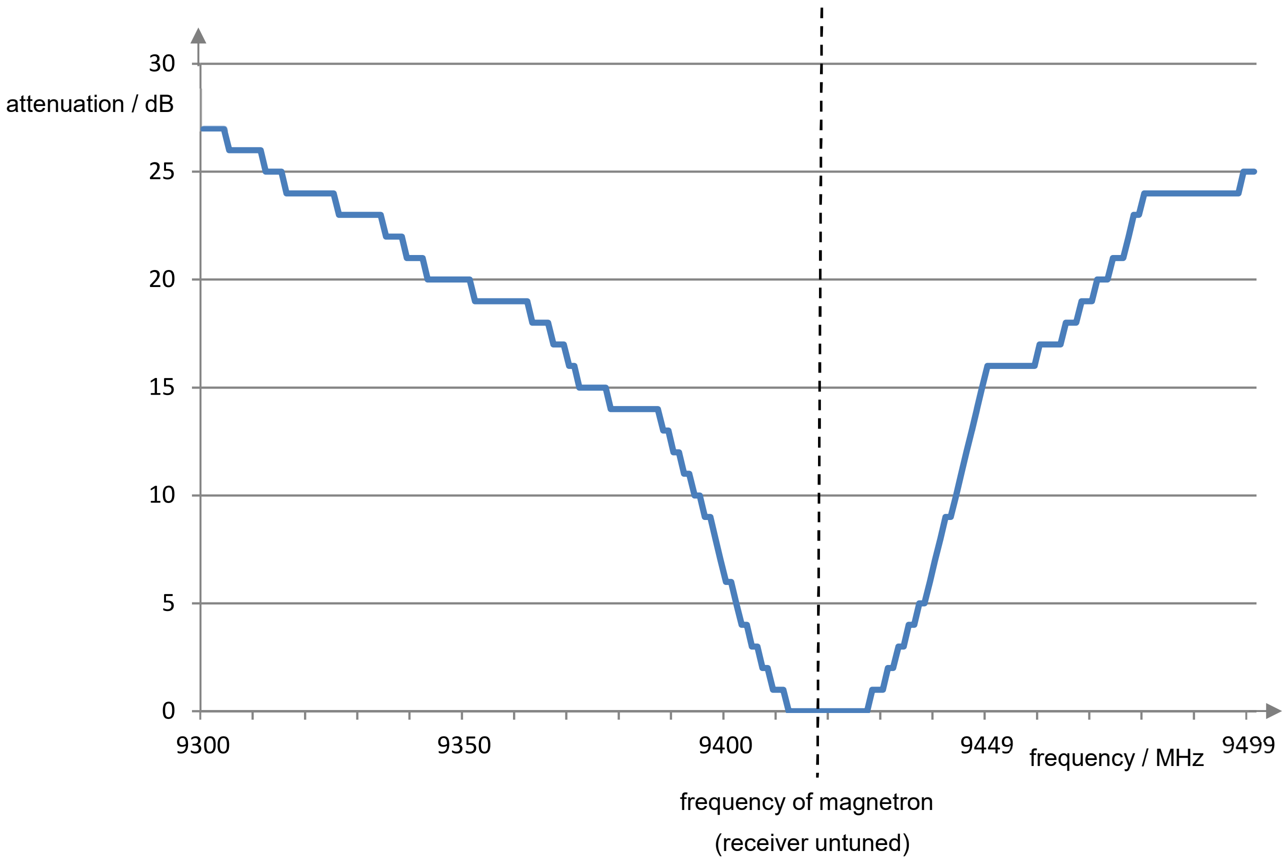


Figure 3: Impact of varying the frequency of the interfering signal

Figure 3 shows the amount of additional power needed to compensate the attenuation due to frequency variation. In [2] possible band allocation is discussed.

# 4 Pulse length

## 4.1 Description

The pulse length of the interfering radar signal is one of the key parameter with respect to interferences for two reasons:

a) The longer the pulse length, the longer is the echo on the radar screen and therefore the more present is the interference to the user (test A).

b) The longer the pulse length the higher is the probability that echoes of consecutive sweeps overlap, resulting in artifacts that cannot be suppressed completely by the Interference Rejection (IR) (test B).

Solid-state radar utilizes significant longer pulse lengths!

## 4.2 Test setup - test A

The setup of the test is shown in figure 1. An interfering signal with a pulse length of 50 ns and 2 µs is applied (synchronized transmission with constant trigger delay).

## 4.3 Test result - test A

The result of the test is shown in figure 4. Without Interference Rejection it is obvious that the echo of the signal with a pulse length of 2 µs covers much more area of the radar picture. This increases the probability of masking out other objects.

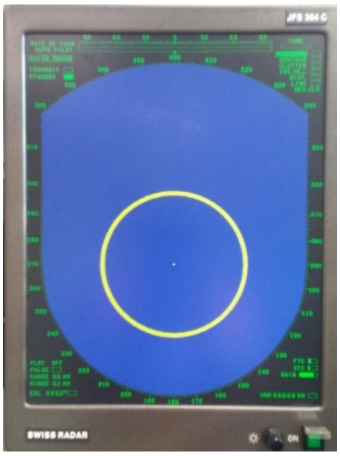


Figure 4: 50 ns pulse, range = 500 m


2 µs pulse, range = 800 m

## 4.4 Test setup - test B

The setup of the test is shown in figure 1. To demonstrate Interference Rejection (IR), the transmission of the interfering signal is synchronized with the trigger signal of the radar. An interfering signal with a pulse length of 50 ns is applied. The time delay is linear increased over eight consecutive sweeps. Afterwards, the test is repeated with a pulse length of 2 µs.

## 4.5 Test result - test B

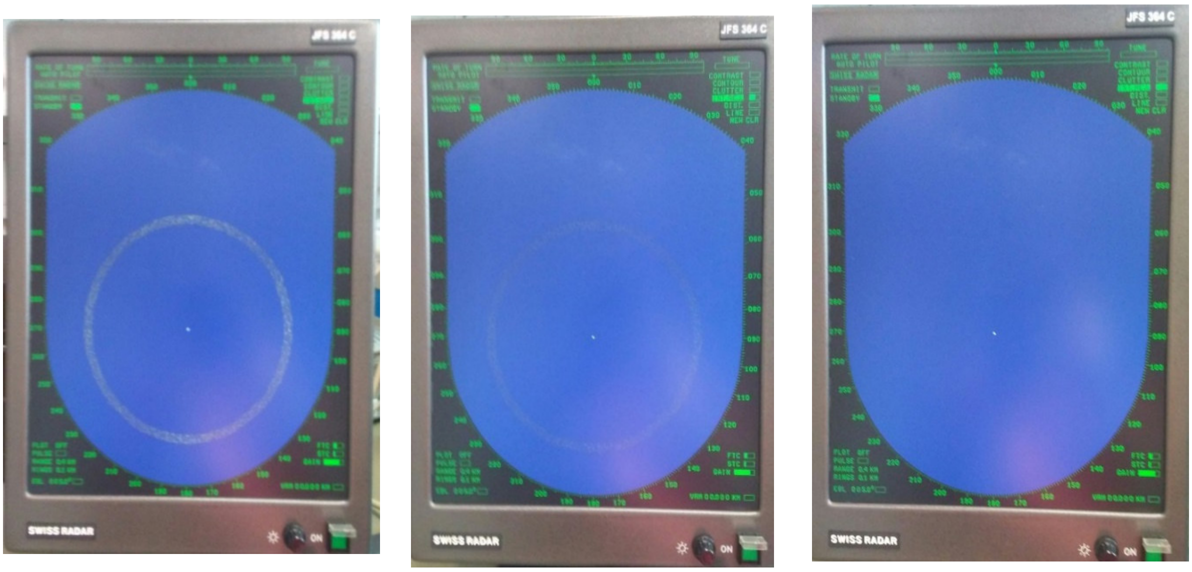


**Figure 5: Pulse length = 50 ns, pulse – to –pulse delay: 20 ns**

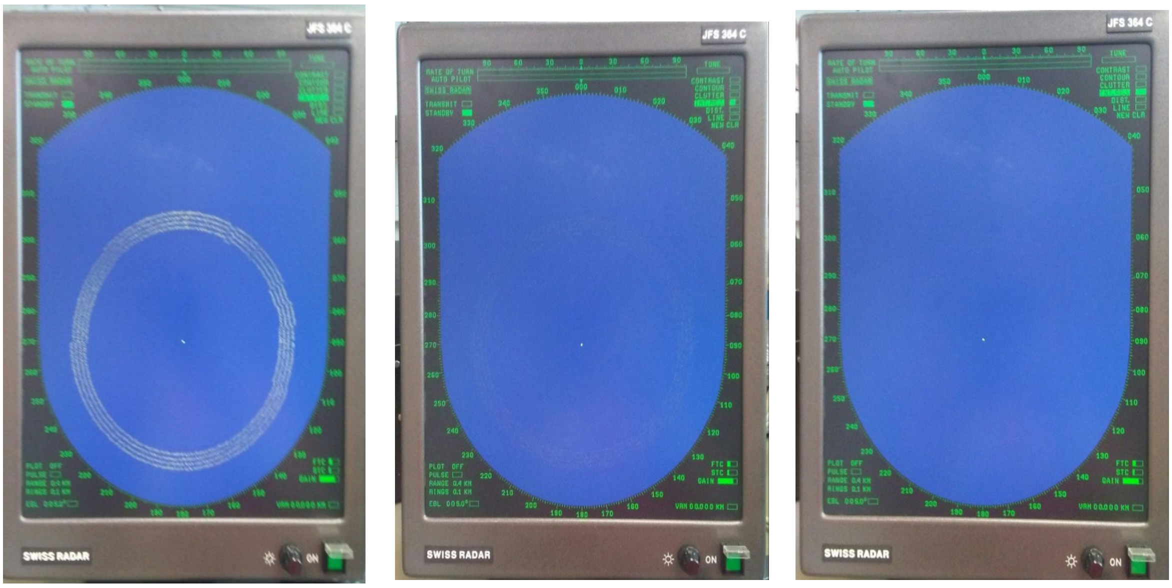


**Figure 6: Pulse length = 50 ns, pulse – to –pulse delay: 40 ns**

With no Interference Rejection (IR) (left hand side pictures of figure 5 and figure 6), the interfering signal is not suppressed. Presuming a 1-out-of-5 algorithm, all echoes are displayed, see figure 7 and figure 8[1].

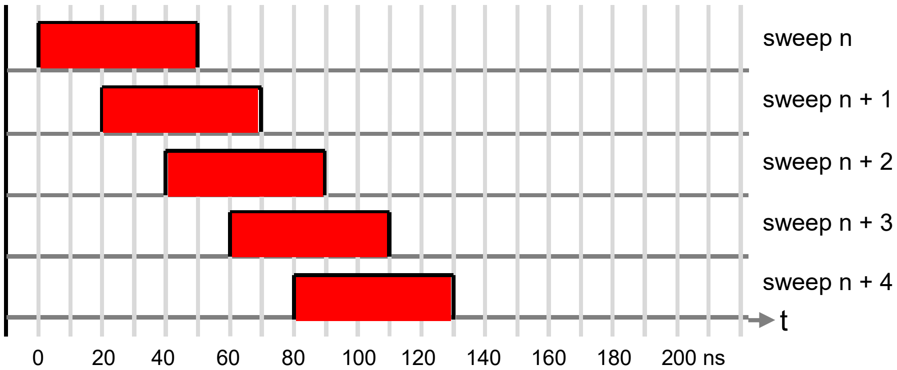


**Figure 7: Pulse-to-pulse delay = 20 ns, no IR**

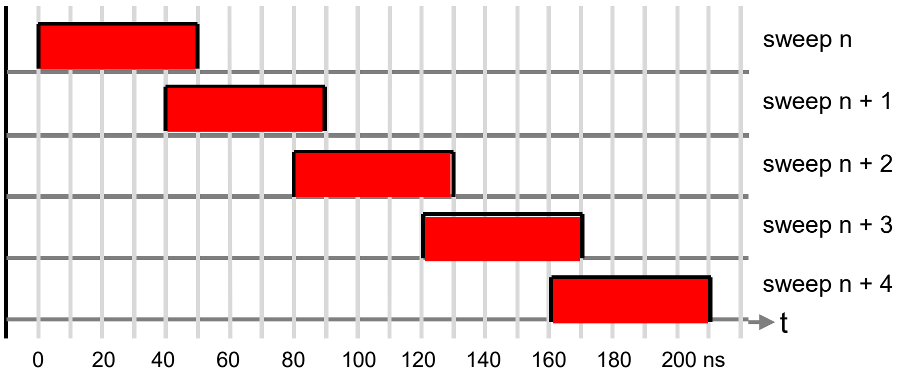


**Figure 8: Pulse-to-pulse delay = 40 ns, no IR**

With Interference Rejection (IR) step 1, IR can remove parts of the interfering signal but some artifacts are still left (see picture in the middle of figure 5 and figure 6). Presuming a 2-out-of-5 algorithm, figure 9 and figure 10 give the explanation.

In a 5-out-of-5 scenario, i.e. Interference Rejection (IR) step 2, all artifacts are removed (right hand side pictures in figure 5 and figure 6). Figure 11 and figure 12 give the explanation.

[1] The pulse presentation in figure 7 to figure 12 is simplified to demonstrate the effect of Interference Rejection (IR). In reality, the received pulses have a distorted shape and IR might be more sophisticated.

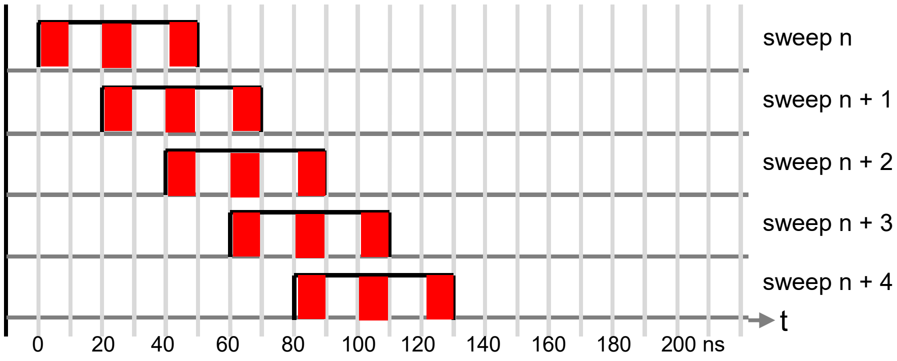


Figure 9: Pulse-to-pulse delay = 20 ns, IR-1 (2/5)

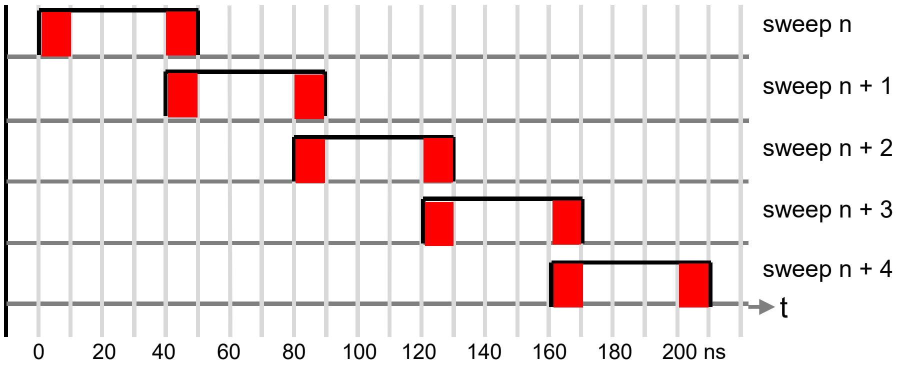


Figure 10: Pulse-to-pulse delay = 40 ns, IR-1 (2/5)

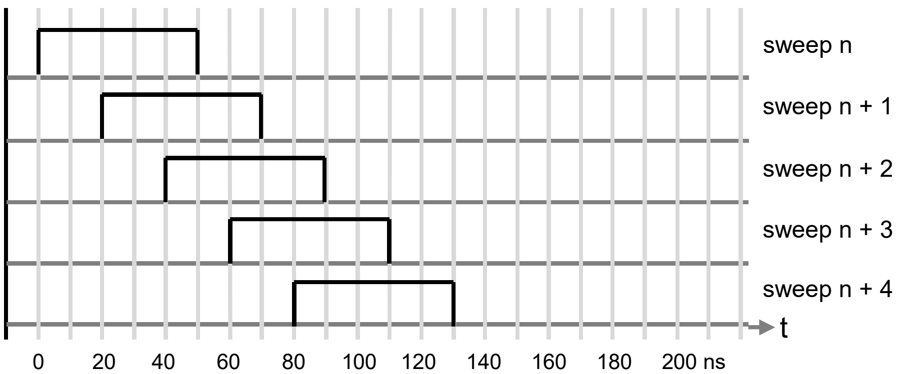


Figure 11: Pulse-to-pulse delay = 20 ns, IR-2 (5/5)

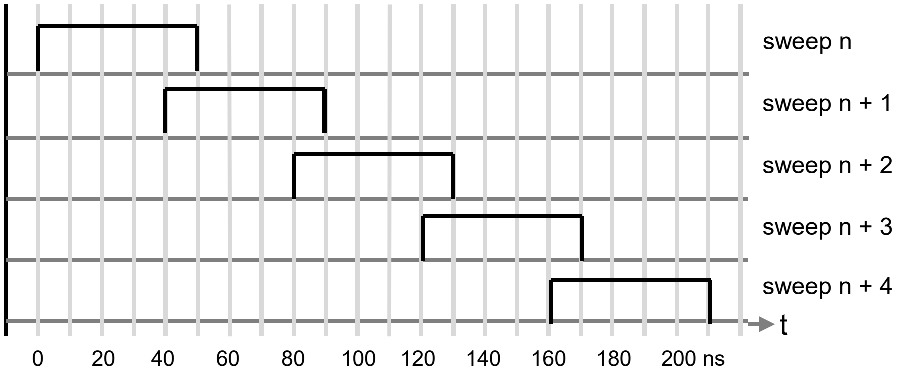

Figure 12: Pulse-to-pulse delay = 40 ns, IR-2 (5/5)

Figure 13 and figure 14 show the result for a pulse length of 2 µs. As the pulses are longer, the pulse-to-pulse delay also have to be much longer to allow IR to suppress the interferer.

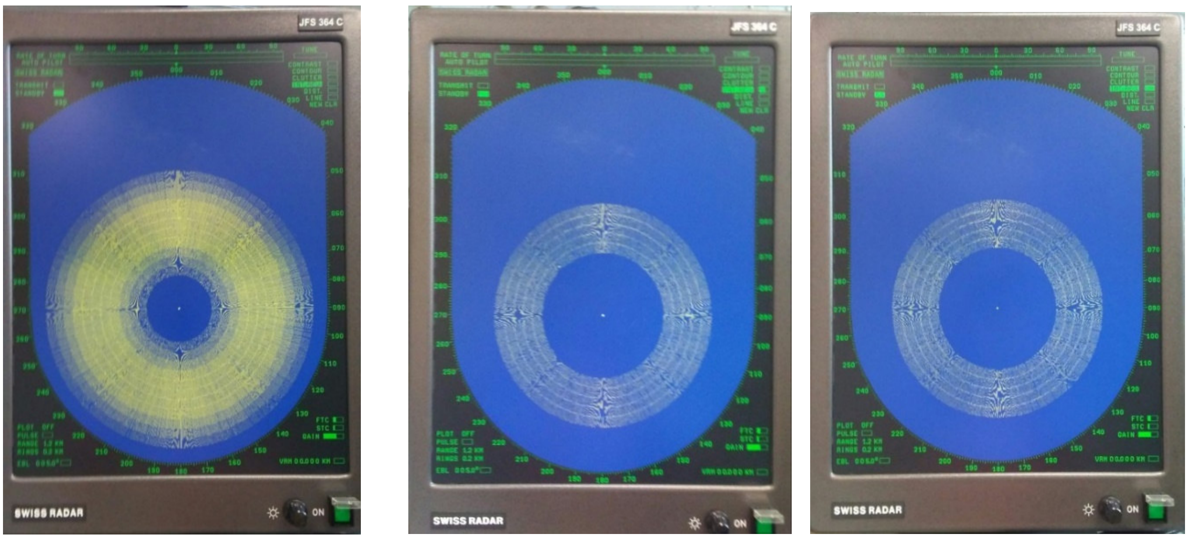


Figure 13: Pulse length = 2 µs, pulse – to –pulse delay: 500 ns

A pulse-to-pulse delay of 500 ns (figure 13) is insufficient low so that even IR-2 cannot remove the interference completely. Increasing the pulse-to-pulse delay to 1500 ns (figure 14) allows IR-1 to suppress the interfering signal.

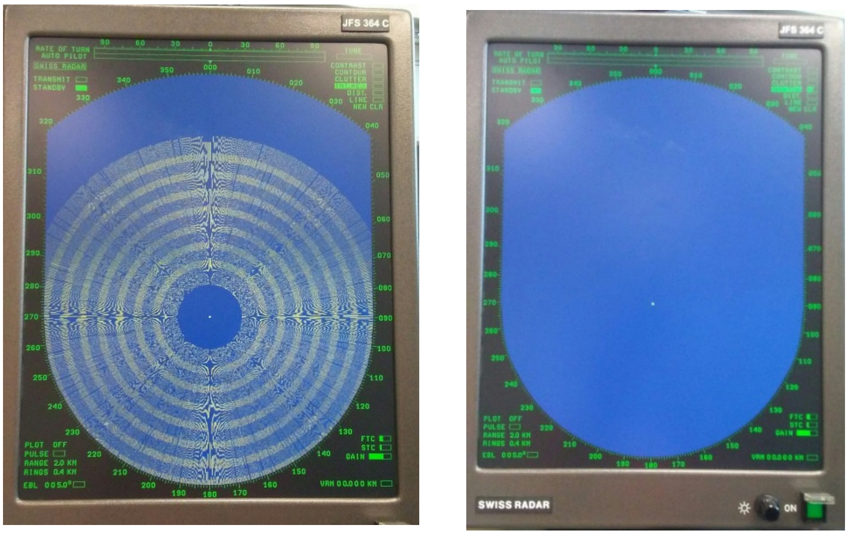


**Figure 14: Pulse length = 2 µs, pulse – to –pulse delay: 1500 ns**

As a result, Interference Rejection (IR) can successfully remove interference echoes (under test conditions), if the echoes do not overlap or just partly overlap over a number of consecutive sweeps.

The longer the pulse length the more time delay is required to separate the pulses or – in other words - the higher the probability of signal overlapping that cannot be suppressed by Interference Rejection (IR).

In real world, the received radar signal comprises both, the interfering signal and the own returning signal from real targets, making the work of IR more difficult!

# 5 PRF

## 5.1 Description

Normally the transmissions of two radars are not synchronized. An unsynchronized interfering signal appears typically as transient radial streaks or spiral patterns of dots (sometimes called “running rabbits”) on the radar screen.

## 5.2 Test setup

The setup of the test is shown in figure 1, but the RF generator is not connected to the radar device. The pulse trigger of the interfering signal is running free. To demonstrate the typical interfering pattern, a slightly different PRF is used: $PRF_{Radar}$ = 3 kHz , $PRF_{Interferer}$ = 3.33 kHz.

## 5.3 Test result

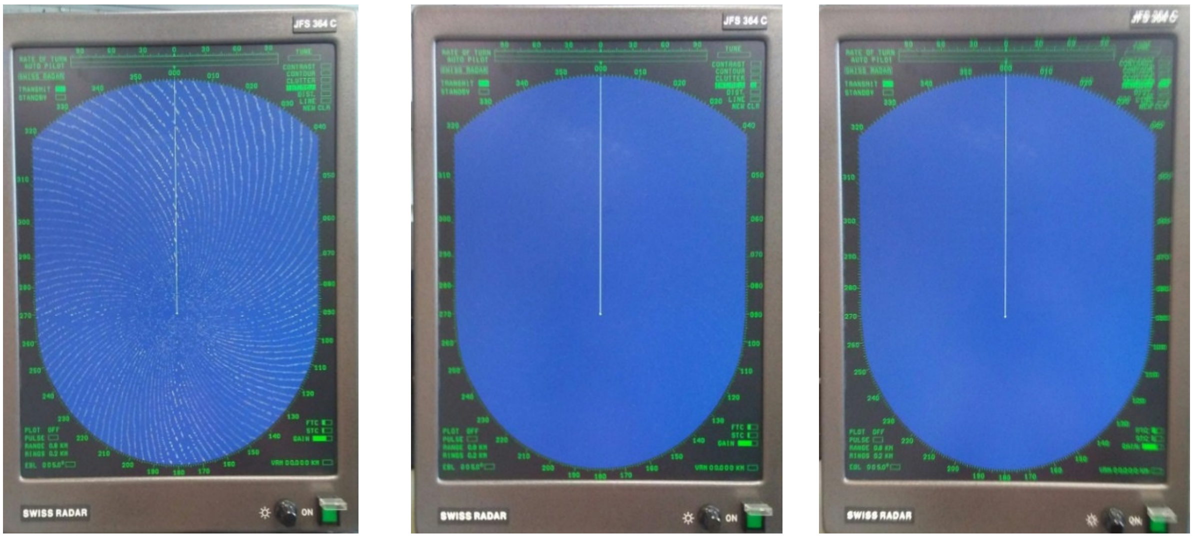


**Figure 15: Typical interference pattern, pulse length = 50 ns**

Figure 15 shows the typical interference pattern on the radar screen (pulse length = 50 ns), with no Interference Rejection (IR) (left picture), IR-1 (picture in the middle) and IR-2 (right picture). With IR-1 there are still some artifacts left, with IR-2 the picture is clean. Using a long pulse length (2 µs) with an intra-pulse modulated signal, the pattern looks different but the result is the same: IR-1 is able to reduce most of the interfering signal, with IR-2 the screen is completely clean, see figure 16.

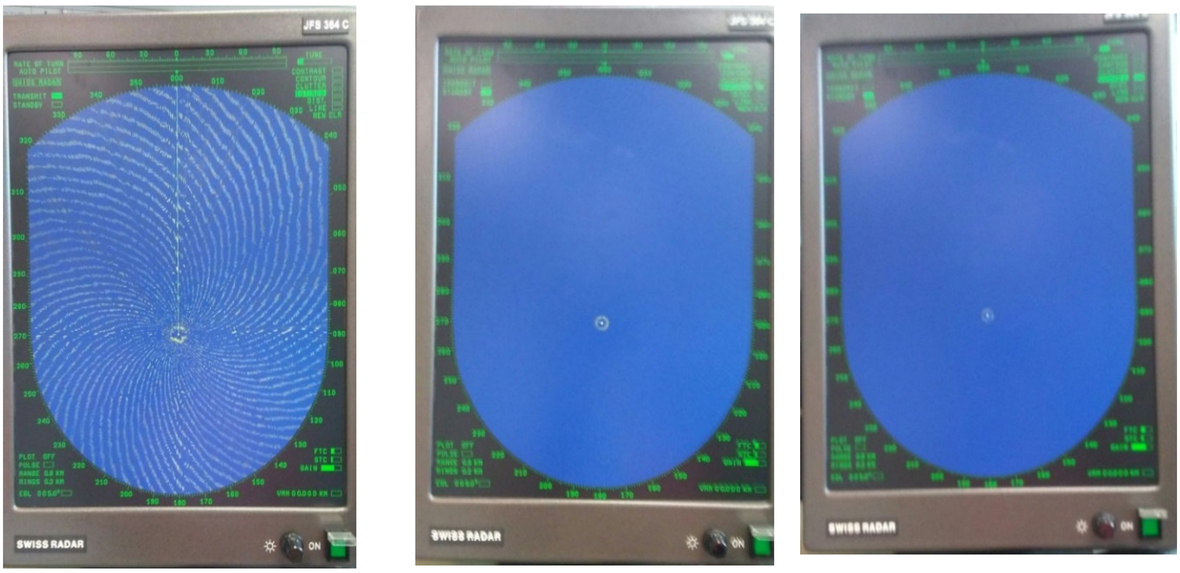


**Figure 16: Interference pattern, pulse length = 2 µs, modulated pulse**

# 6 Power / distance

## 6.1 Description

The impact of the output power of the interfering signal on the Interference Rejection is tested.

## 6.2 Test setup

The setup of the test is shown in figure 1. An interfering signal with a pulse length of 50 ns and a pulse-to-pulse delay of 20 ns is applied with an output power level of 0 dBm and 30 dBm. The echoes on the radar screen are observed with no IR, IR-1 and IR-2.

## 6.3 Test result

The result of this test is shown in figure 17 and figure 18. With a power level set to 0 dBm, all artifacts can be removed with IR-2. Increasing the power level to 30 dBm, IR-2 is not able to remove all interfering echoes. This shows that Interference Rejection depends on the power level of the received signal (see also footnote 1 above).

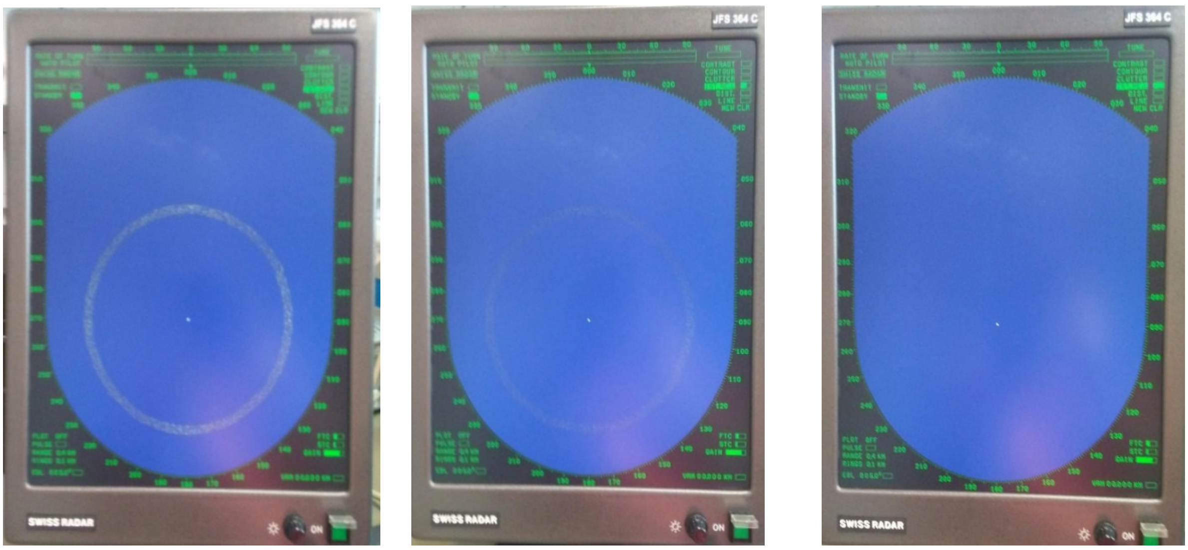

Figure 17: Power level = 0 dBm

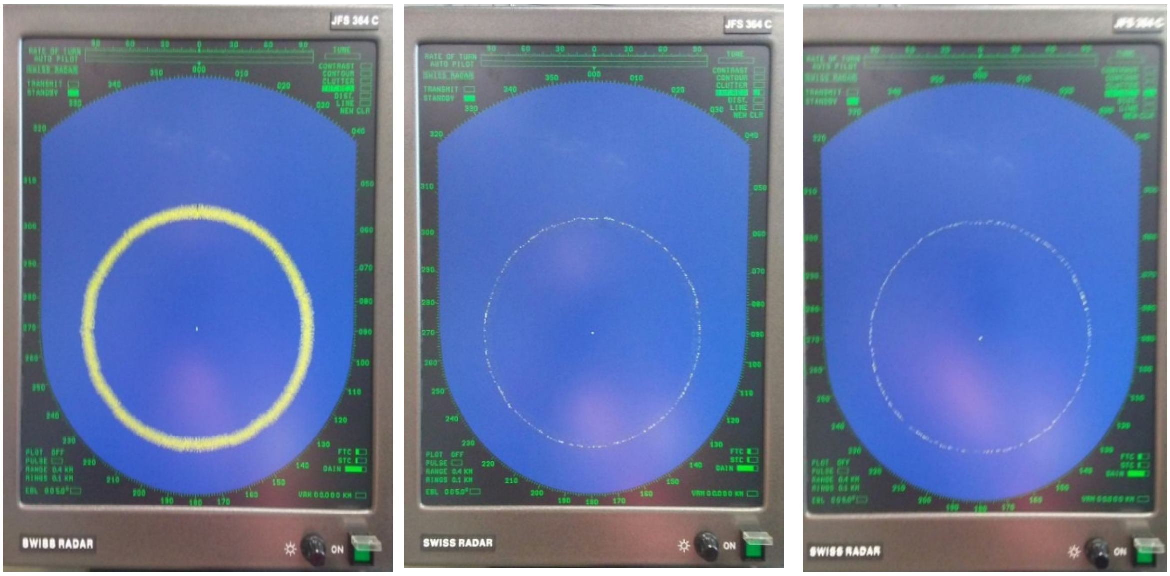

Figure 18: Power level = 30 dBm

# 7 Intra-pulse modulation

## 7.1 Description

Solid-state radars are using in general much longer pulses. In praxis they typically send out a combination of longer and shorter, linear FM modulated pulses ("chirps"), separated in frequency and time domain. This test is about finding out how effective Interference Rejection (IR) of conventional river radar processes intra-pulse modulated signals.

## 7.2 Test setup test A

The setup of the test is shown in figure 1. The RF generator synthesizes a signal with a pulse length of 2 µs. Each pulse is FM modulated ("up-chirp") with a bandwidth of 10 MHz, see figure 19.

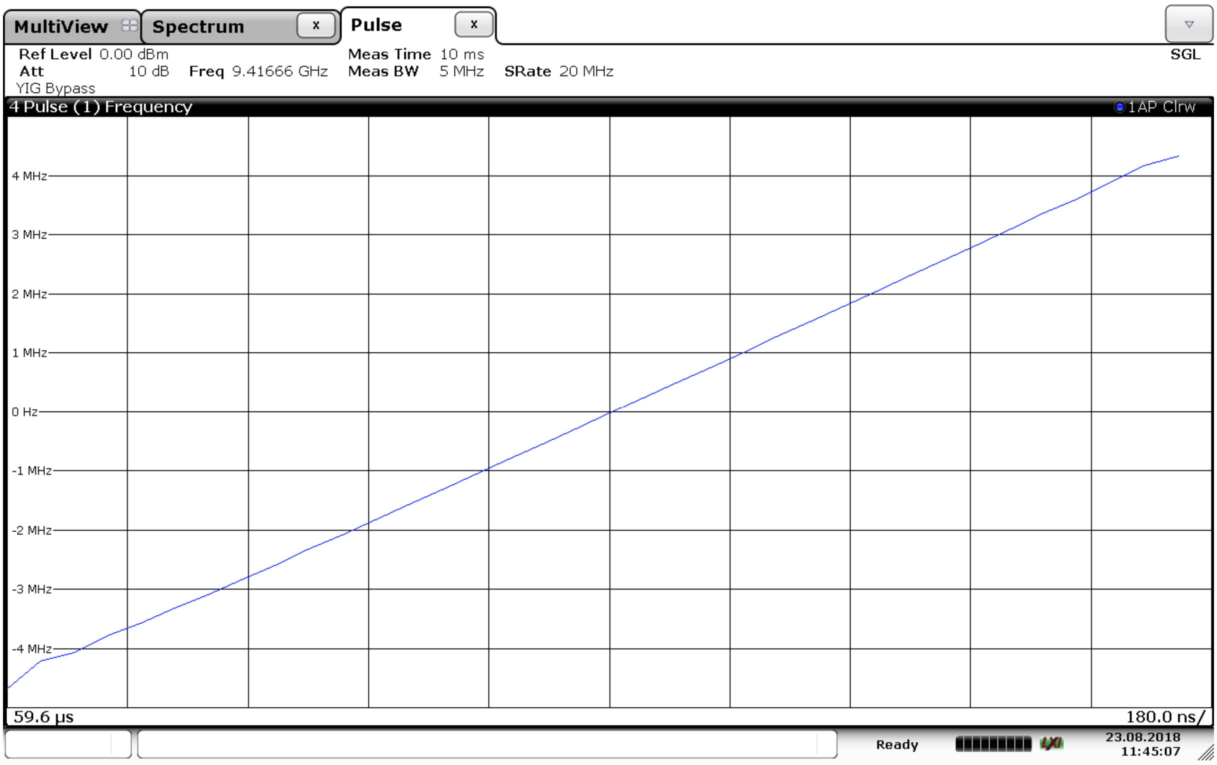


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Figure 19: Chirp signal with a bandwidth of 10 MHz

## 7.3 Test result

Interference Rejection (IR) of conventional river radar seems to process modulated pulse signals the same way and with no differences compared to unmodulated pulses.


Figure 20: Unmodulated pulses

Figure 20 shows an unmodulated signal with a pulse length of 2 µs and a pulse-to-pulse delay of 500 ns. Interference Rejection (IR) is not able to remove all echoes not even in IR-2 as the overlapping part is too high. No difference can be observed applying the same signal with an intra – pulse modulated signal (figure 21).

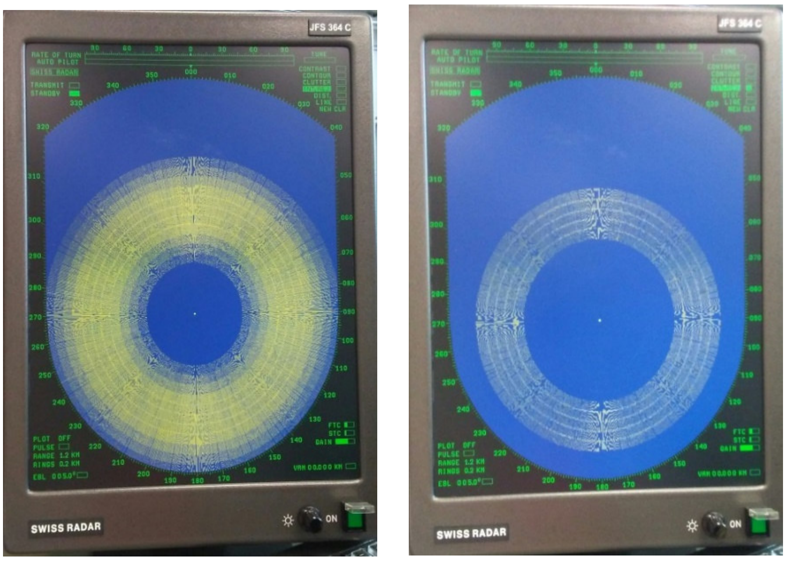


**Figure 21: Modulated pulse**

With a pulse-to-pulse delay time of 1500 ns, IR-1 can already remove all interfering modulated pulse signal (see figure 22).


**Figure 22: Modulated pulse with long pulse-to-pulse delay time**

# 8 References

[1] Position Paper on ETSI EN 302 194 – clause 8.1.13 Suppression of interference from other radars, Mario Walterfang, Fachstelle der WSV für Verkehrstechniken, 25.09.2018

[2] “Compatibility problems related with pulsecompression, solid-state marine radars”, Gaspare Galati, Gabriele Pavan, Francesco De Palo, www.ietdl.org, 2015

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