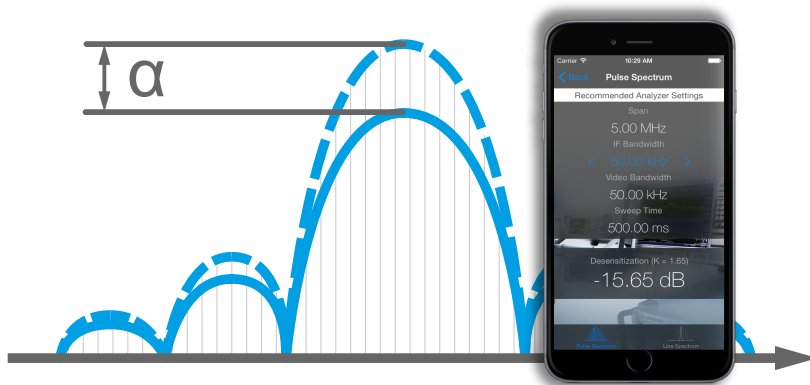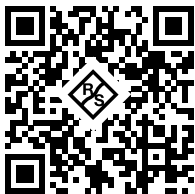# Pulsed RF Calculator
Application Note

In environments such as mobile use as well as in service shops and education, spectrum analyzers with dedicated built-in pulsed-signal analysis features are often not available. This paper describes the smartphone app Pulsed RF Calculator that aids in finding the right choice of spectrum analyzer settings to calculate the so-called pulse desensitization for manual compensation of pulsed signal amplitudes. Automatic compensation and many other features necessary for in-depth pulsed signal analysis require the use of dedicated functionalities and are outside the scope of this app.

Note:

Please find the most up-to-date document on our homepage http://www.rohde-schwarz.com/appnote/1MA240.

This document is complemented by software. The software may be updated even if the version of the document remains unchanged

Pulsed RF Calculator ─ 1MA240_0e

Frederic Schütze, Albert Winter

Application Note

ROHDE&SCHWARZ

Contents

1 Introduction

In environments such as mobile use as well as in service shops and education, spectrum analyzers with dedicated built-in pulsed-signal analysis features are often not available. This paper describes the smartphone app Pulsed RF Calculator that aids in finding the right choice of spectrum analyzer settings to calculate the so-called pulse desensitization for manual compensation of pulsed signal amplitudes. Automatic compensation and many other features necessary for in-depth pulsed signal analysis require the use of dedicated functionalities and are outside the scope of this app.

1.1 Requirements

iOS	iOS 8 or newer (min iPhone 4s or iPad 2).
Android	Android 4.0 or newer.
Windows Phone	Windows Phone 8 or newer.

The app is designed for use on a screen resolution of 1136 x 640 pixels or higher. If you use a model with lower screen resolution, you may want to scroll the screen in order to see all information.

1.2 Installation

The app can be downloaded free of charge from different app-stores, depending on your mobile operating system. To find the app easily, please use search terms "Rohde & Schwarz" or "Pulsed RF Calculator" or click on the following links to access the app landing page directly:

- **iOS:**
  https://itunes.apple.com/app/id969034080
- **Android:**
  https://play.google.com/store/apps/details?id=com.rohdeschwarz.pulsedrfcalculator
- **Windows Phone:**
  https://www.microsoft.com/store/apps/9nblggh5xn5c

2 Measuring Pulsed Signals

There are mainly 2 different ways to display the spectrum of a pulsed signal: pulse spectrum display and line spectrum display. Figure 2-1 shows a good example for a pulse spectrum display, Figure 2-2 shows a line spectrum display.
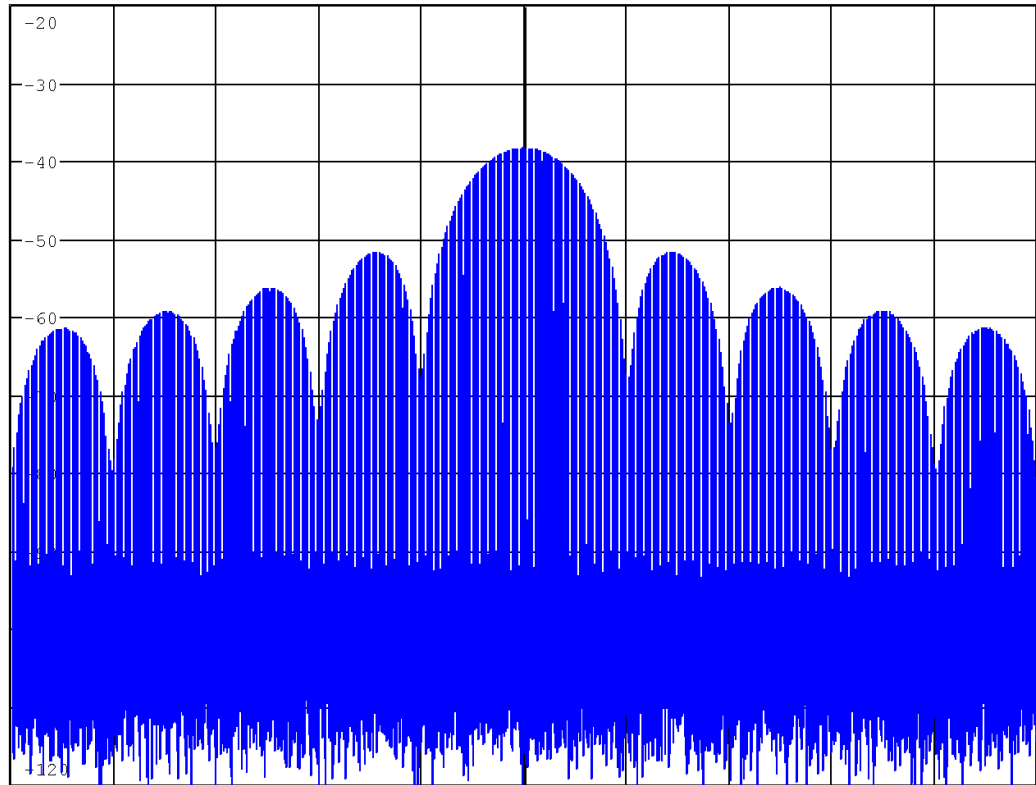

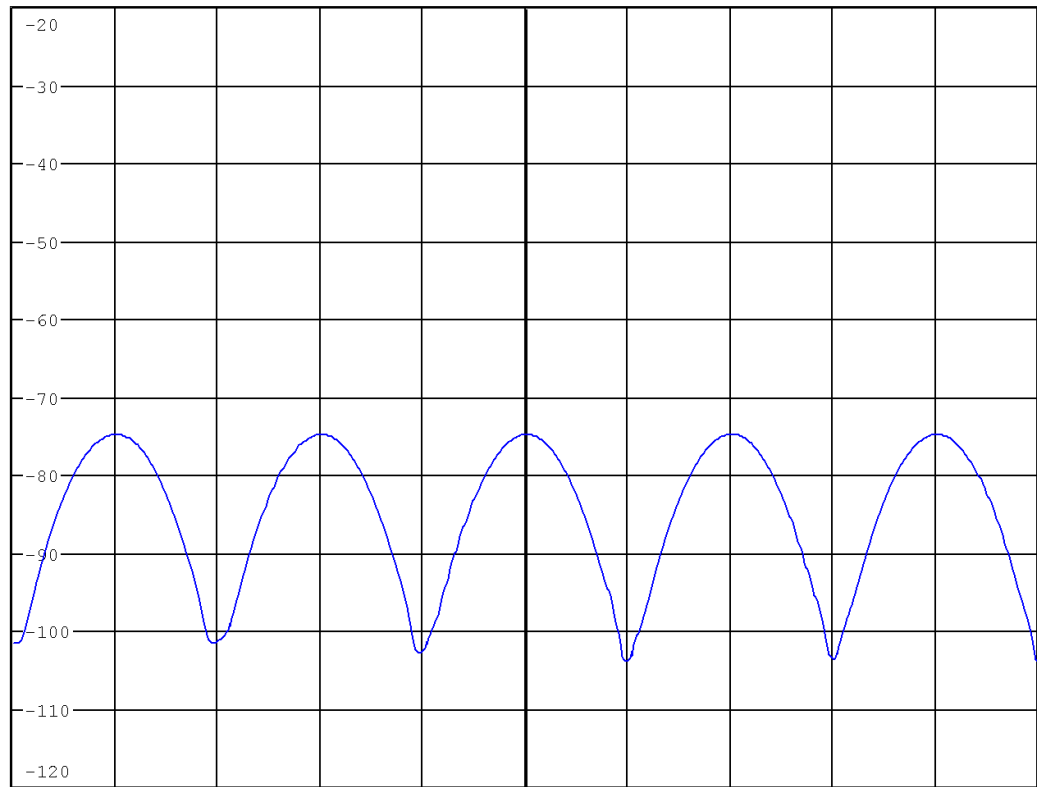*Figure 2-1: Pulse Spectrum Display of a -20 dBm pulsed signal*

Figure 2-2: Line Spectrum Display of the same -20 dBm pulsed signal as above

This brief application note assumes, that you are familiar with pulsed signals. For more in-depth information please read chapter 6.2 of [1]

Assuming the peak signal amplitude reaches the reference level value of your spectrum analyzer, both kinds of display show significantly lower signal amplitudes than expected. This effect is called Desensitization and arises from the spreading of the signal energy over a broad spectrum due to the pulse modulation and due to the duty cycle (on/off ratio) of the signal. The term Desensitization means refers to the virtual loss of sensitivity of your spectrum analyzer. As can be seen when compassing Figure 2-1 and Figure 2-2, different desensitization levels occur for pulse spectrum and line spectrum display.

3 Pulsed RF Calculator Application Program

The main purpose of this application note is to explain the capabilities and operation of the Pulsed RF Calculator app. The app gives proposals for correct settings of spectrum analyzer without dedicated functions to support pulsed signal evaluation in order to yield for Pulse Spectrum Display as well as for Line Spectrum Display. The app will calculates and output the corresponding desensitization for manual correction.

3.1 Installing the App

The Pulsed RF Calculator application program (app) is available from the Apple App-Store, Google Play Store and Windows Store. Search for Pulsed RF Calculator or search for Rohde & Schwarz. Use the usual way to download and install the app.

3.2 Operating the App

The app, requires to know some parameters of your signal. These are center frequency, pulse width and pulse period. You should also have an rough estimate of the pulse amplitude. If you do not know these values, closely enough, please turn to Chapter 4, "Determine Pulse Parameters of Your Signal", on page 15 first.

When you tap the Pulsed RF Calculator app button, the app come up with the start screen, see Figure 3-1.

When you operate the app the very first time, please enter the appropriate K-factor. Do this by selecting the Settings menu (see Chapter 3.2.5, "Settings Screen", on page 12).
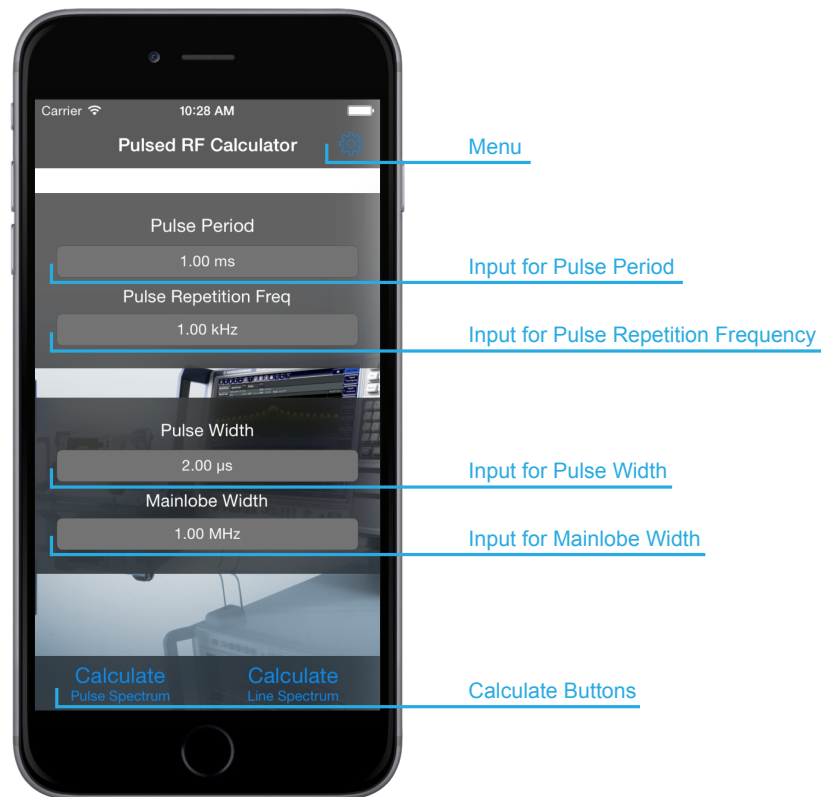
3.2.1 Start Screen

Figure 3-1: Pulsed RF Calculator Start Screen

Pulse Period (T) and Pulse Repetition Frequency (PRF)

Touch the entry field for Pulse Period. Enter a value using the on screen keyboard. Select the appropriate unit from the unit selection field Confirm values with OK button The corresponding value Pulse Repetition Frequency (PRF) is calculated automatically. If you prefer to enter a value for Pulse Repetition Frequency (PRF), Pulse Period is calculated automatically.

Pulse Width (τ) and Main Lobe Width (MLW)

Enter the value for Pulse Width and select unit as above. The corresponding value Main Lobe Width (MLW) is calculated automatically. You can also enter a Main Lobe Width (MLW) value, then Pulse Width will be calculated automatically.

Calculation

Touch button "Calculate Pulse Spectrum" or "Calculate Line Spectrum" depending on your desired results.

The app is designed for viewing on a screen resolution of 1136 x 640 pixels or larger. If you use a lower resolution display, you may need to scroll your screen in order to see all Input-Fields.

3.2.2 Pulse Spectrum Display Screen

After having entered the "K-Factor" of your analyzer and after having supplied some characteristics of the signal, you can select the "Calculate Pulse Spectrum" button from the start screen. The Pulse Spectrum Display screen pops up, as shown in Figure 3-2.
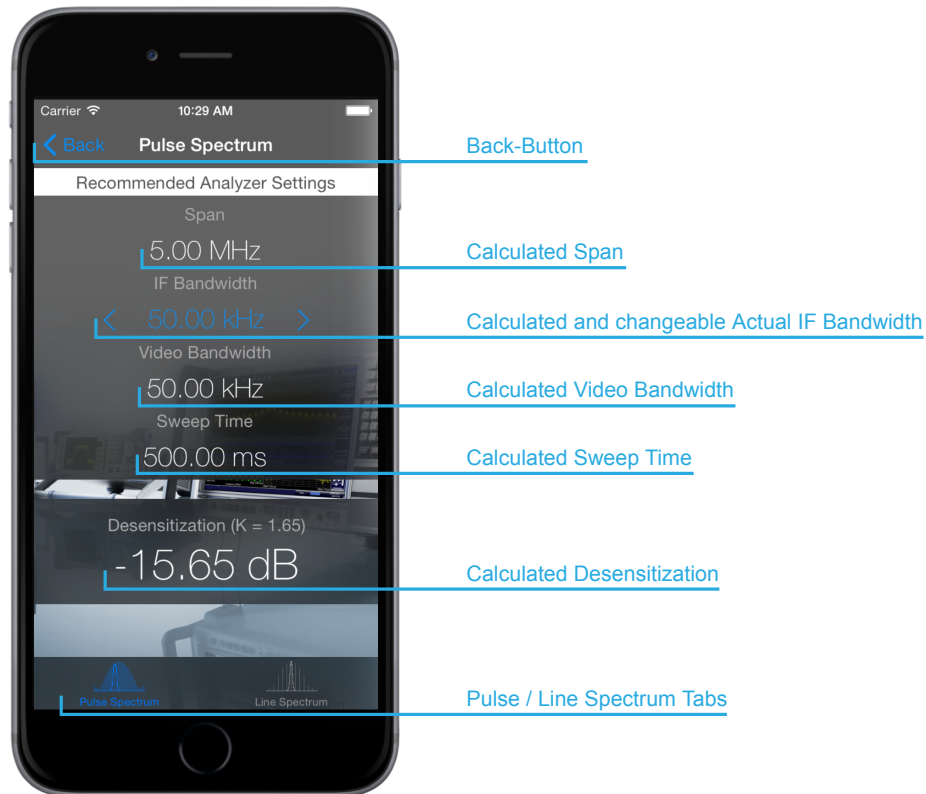

Figure 3-2: Pulse Spectrum Screen

The screen propose a number of spectrum analyzer settings for a display of the pulse spectrum. Read the values for Span, IF Bandwidth, Video Bandwidth and Sweep Time and set your spectrum analyzer accordingly. If your spectrum analyzer does not allow to set exactly these values, use instead of the available values the calculated ones.

Using the given values, you should get a useful pulse spectrum display of the signal on your spectrum analyzer similar to Figure 3-3 below.

```
                                        * RBW  50 kHz
                                        * VBW  50 kHz
Ref  -20 dBm              Att   5 dB    * SWT 500 ms
```
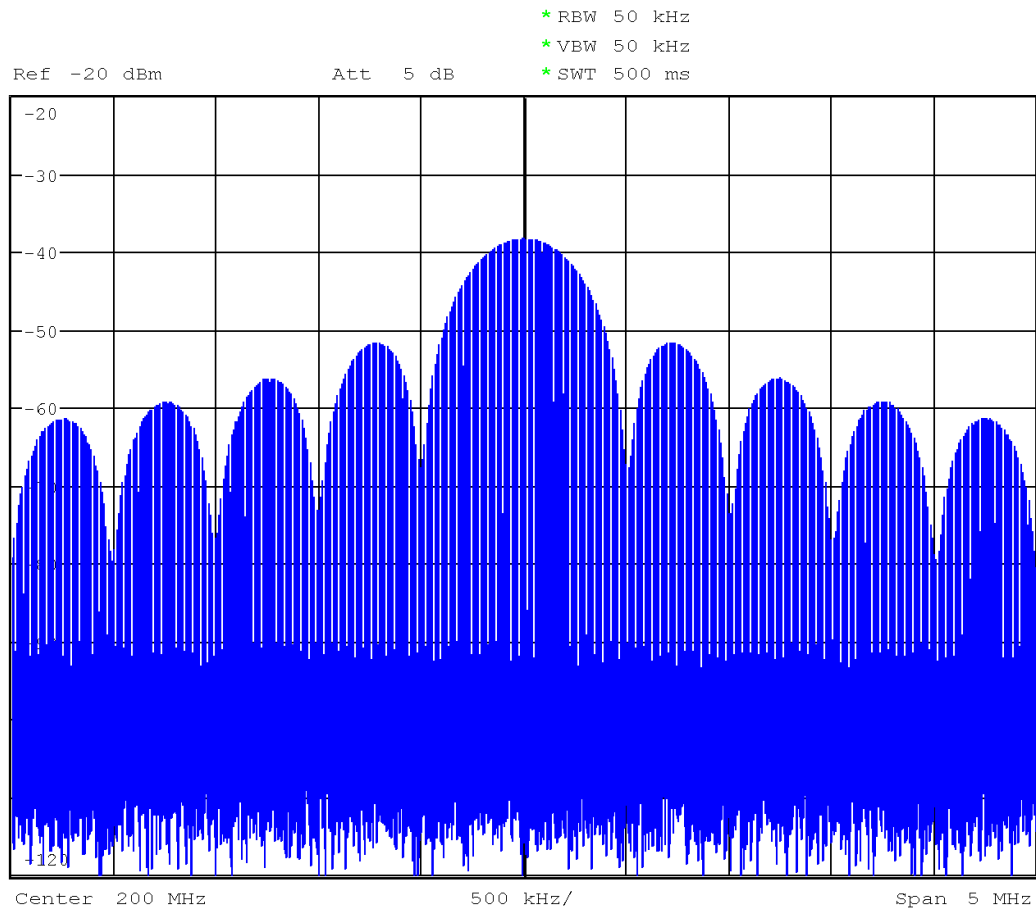
Figure 3-3: Pulse Spectrum Display with given values

Of course you can modify your spectrum analyzer settings. Take care not to overcome the capabilities of your spectrum analyzer. Pay attention to any Uncal warnings on your spectrum analyzer.

Actual IF Bandwidth:

Initially this value corresponds to the calculated IF Bandwidth value above.

If you do not use this value or if you change the IF bandwidth of your spectrum analyzer later, you may enter the new value in the Actual IF Bandwidth entry field. This will immediately calculate a new value for the Desensitization.

Desensitization:

Use this calculated Desensitization value to correct the amplitude level display of your spectrum analyzer. Some spectrum analyzers allow to set a reference level offset. You can use this function for this purpose.

Please be aware, that the peak amplitude of the signal is the sum of displayed level and desensitization. Be careful not to set the reference level of your spectrum analyzer to a lower value, otherwise nonlinearities may affect your analyzer display or your analyzer may even get damaged.

The Back button on top of the app screen leads you back to the Start screen.

3.2.3 Line Spectrum Display Screen

When you selected the button Calculate Line Spectrum in start menu (Figure 3-1), the following window pops up.
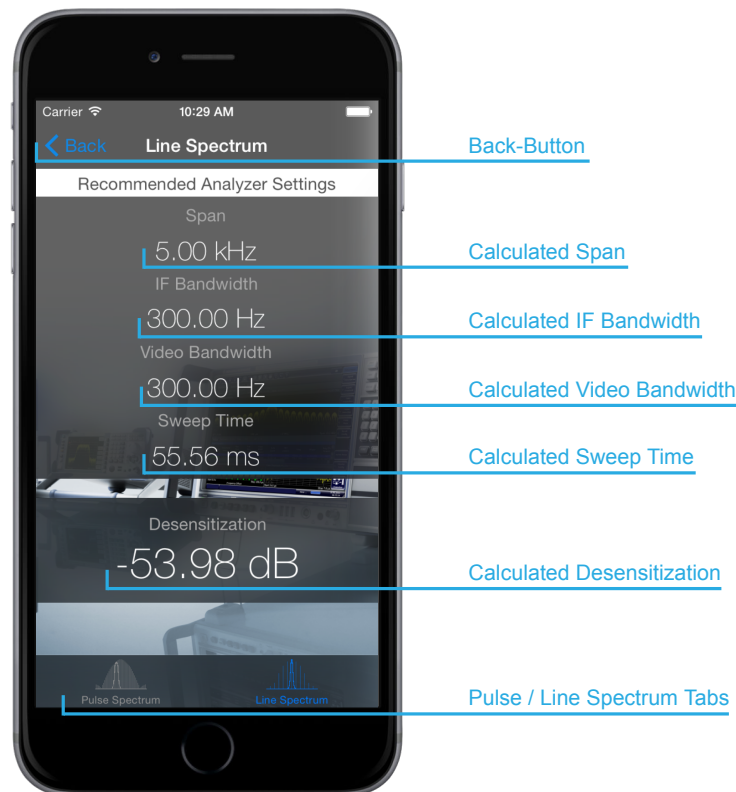

Figure 3-4: Line Spectrum Screen

Similar to the Pulse Spectrum this screen shows a settings proposal for configuring a line spectrum display on your spectrum analyzer.

Read the given values for Span, IF Bandwidth, Video Bandwidth and Sweep Time and set your spectrum analyzer accordingly.

Use available values closest to the calculated ones, if your spectrum analyzer does not allow to set exactly the values recommended by the app.

You should now get a useful line spectrum display of the signal on your spectrum analyzer similar to Figure 3-5 below.
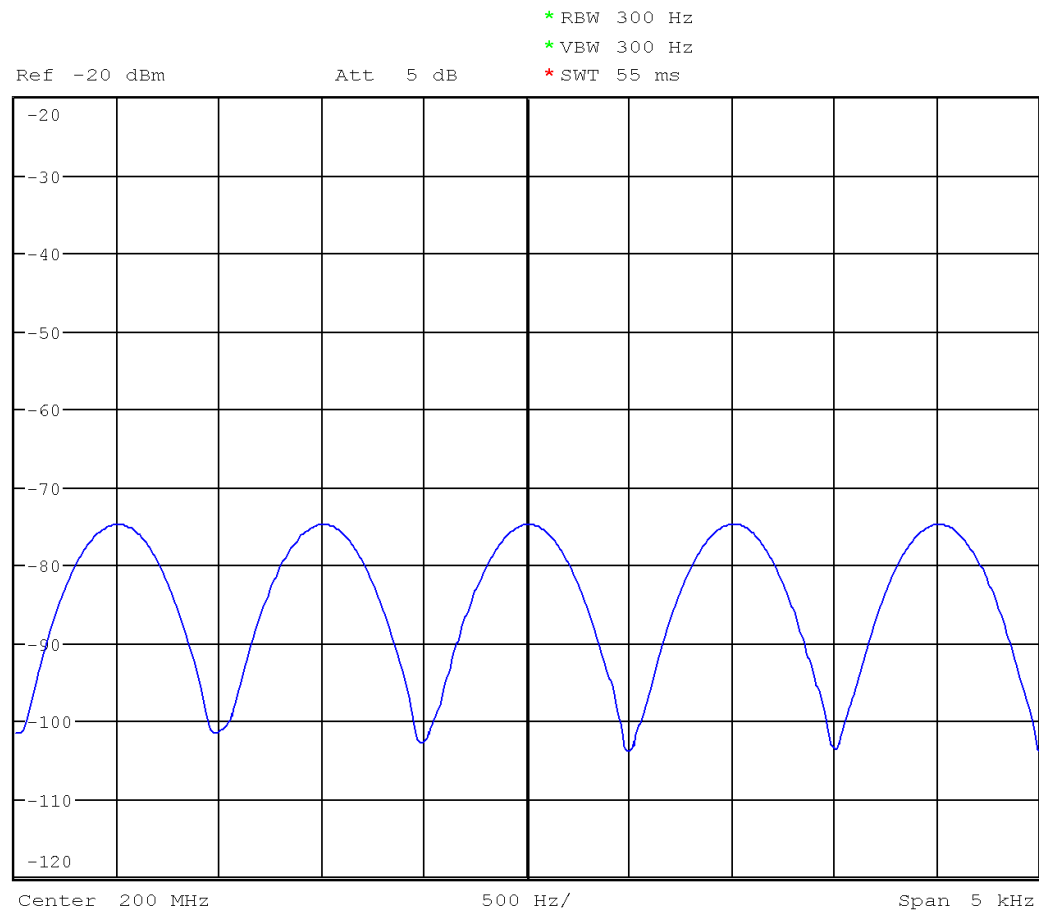

Figure 3-5: Line Spectrum Display with given values

You can modify your spectrum analyzer settings also for Line Spectrum Display. Again take care not to overcome the capabilties of your spectrum analyzer. Observe any Overload or Uncal warnings on your spectrum analyzer.

Desensitization:

Use the calculated Desensitization value to correct the amplitude level display of your spectrum analyzer. As mentioned in Chapter 3.2, "Operating the App", on page 6, some spectrum analyzers allow to set a reference level offset. You can use this function for this purpose. As shown in the example, desensitization by more then -53.98 dB is not unusual. Take care, that the set reference level of your spectrum analyzer corresponds to the peak signal level.

An Actual IF Bandwidth entry field is not available for line spectrum mode of the app, since line spectrum Desensitization only depends on the pulse duty cycle (i.e. the ratio of pulse width and pulse repetition rate. More line spectrum desensitization is independent from the K-factor setting.

If you want to change the values for Pulse Width and Pulse Period (or Main Lobe Width and Pulse Repetition Frequency), the Back button on top of the app screen leads you back to the Start screen.

3.2.4 Menu

Click the gears-icon on the top of the screen to open the menu.
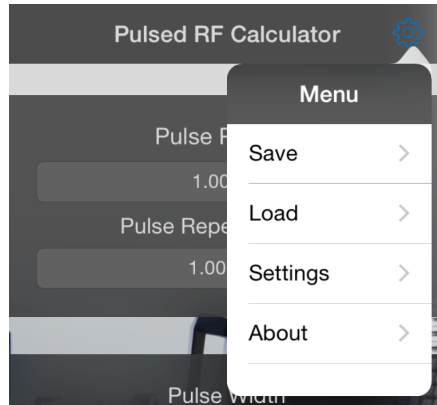
**Save:** Saves the current entries for Pulse Repetition Rate, Pulse Width and K-Factor.

Load: Reloads the saved entries for Pulse Repetition Rate, Pulse Width and K-Factor.

Settings: Opens the settings described in Chapter 3.2.5, "Settings Screen", on page 12.

About: Shows information about the app.

3.2.5 Settings Screen

Access the settings screen by touching the Settings button, the following menu pops up.
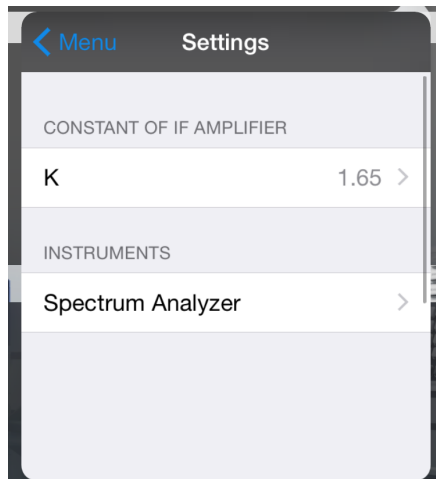
K-Factor: Enter the correct K-factor for your analyzer. K-factor range is usually 1.5 to 1.8 depending on the characteristics of the IF filters of your spectrum analyzer. Default value is K=1.65. You have to enter the K-factor only once unless you change the type of your spectrum analyzer. Some analyzers however change the characteristics of their IF filters depending on the set bandwidth. In this case you have to change the K-factor accordingly. See the manual of your spectrum analyzer.

The results of your desense calculation will vary by approximately 0.8 dB when you change K-Factor from 1.65 to 1.5 or to 1.8, respectively. If you can live with this uncertainty, you don´t have to care too much about the K-factor and you can use the default setting of 1.65.

Analyzer: If you want to configure your analyzer via remote control, you can set the analyzer here. The app will automatically find all instruments in the local network. The list can be refreshed by pull the list down with the fingers.

All R&S spectrum analyzer with ethernet connection can be configured remotely, excepting the R&S®FSH and the R&S®FSC

3.2.6 Remote Control

If an analyzer is chosen in the app settings, the analyzer can be controlled remotely. So you can send the calculated Span, IF Bandwidth, Video Bandwidth and Sweep Time to the instrument.

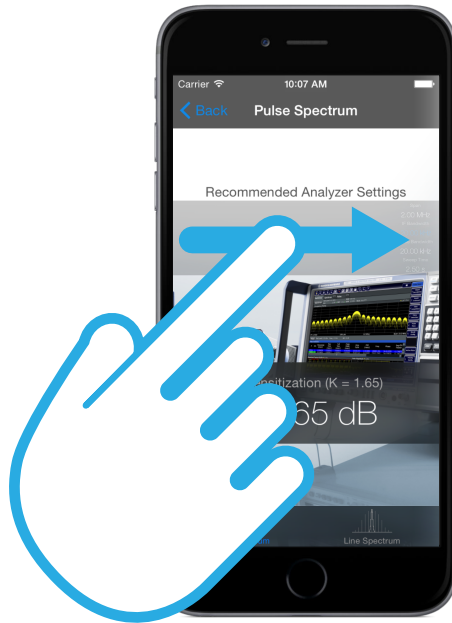As shown in Figure 3-6, the calculated values can be send by swiping the "Recommended Analyzer Settings" to the right.

Figure 3-6: Swipe Gesture for Remote Control

4 Determine Pulse Parameters of Your Signal

You must know some parameters of your signal (or have a rough estimate of them) before you can calculate desensitization. These are the carrier frequency of the signal, the pulse width and the pulse period of the modulated signal. You should also have an estimation of the peak power level of your pulsed signal in order to set the reference level of your spectrum analyzer to this (or a slightly higher) value.
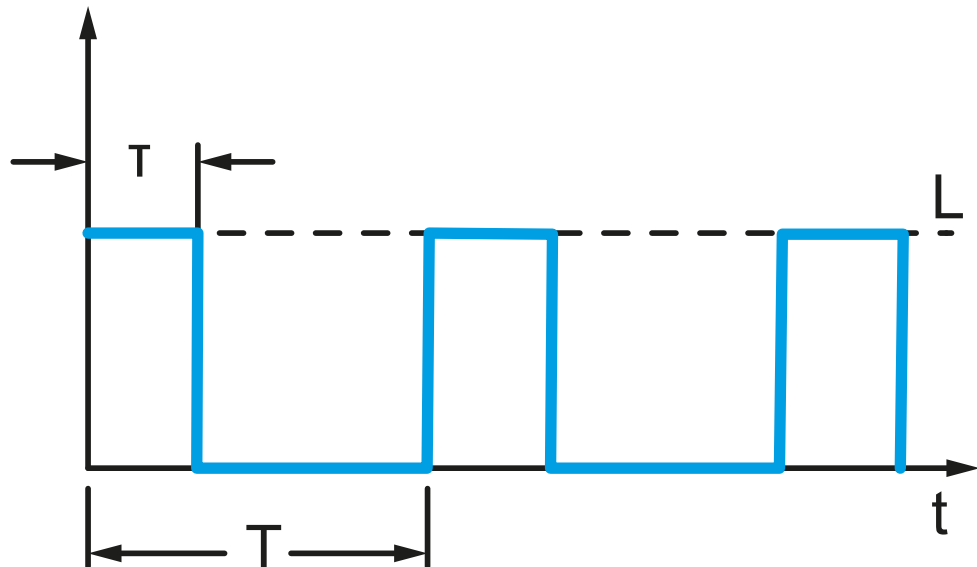
τ is the pulse width of the modulation signal

T is the pulse period of the modulation signal

L is the peak level of the signal.

In most cases the carrier frequency of the signal is known or can easily be determined by switching off pulse modulation. Sometimes also a rough estimation of the carrier frequency is sufficient for the initial setting of the spectrum analyzer.

If you do not know pulse width and pulse repetition frequency of your signal, you can get a first rough estimation by performing an overview measurement. In order to do so

*   Set Reference Level of your spectrum analyzer to the estimated peak signal level.
*   Set Center Frequency of your spectrum analyzer to the carrier frequency of your signal.
*   Set frequency span to Zero Span.
*   Set IF Bandwidth and Video bandwidth to the maximum values of your spectrum analyzer.
*   Set Sweep Time to a rather long value, 1s / Div or so.

You should now get a display similar to Figure 4-1.
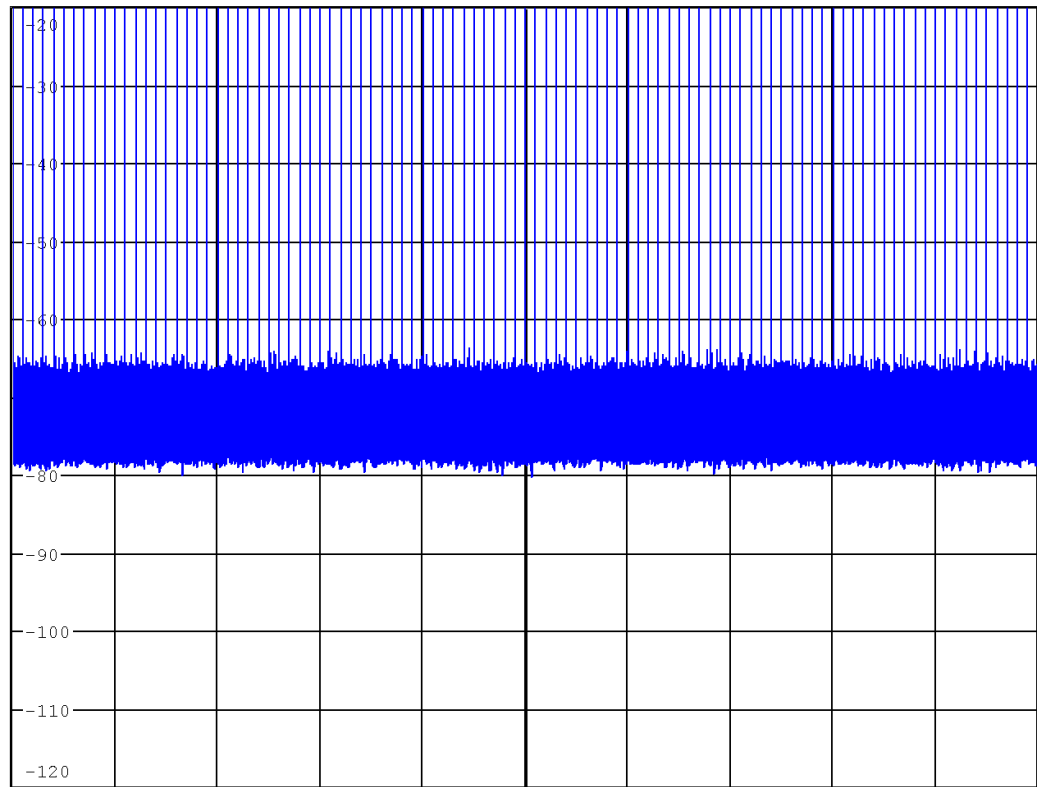
Figure 4-1: Spectrum with ZeroSpan and dense pulse display

Now you can increase the sweep speed of your spectrum analyzer (i.e. decrease the sweep time per division) and use the video trigger capabilities until you get a display similar to Figure 4-2:
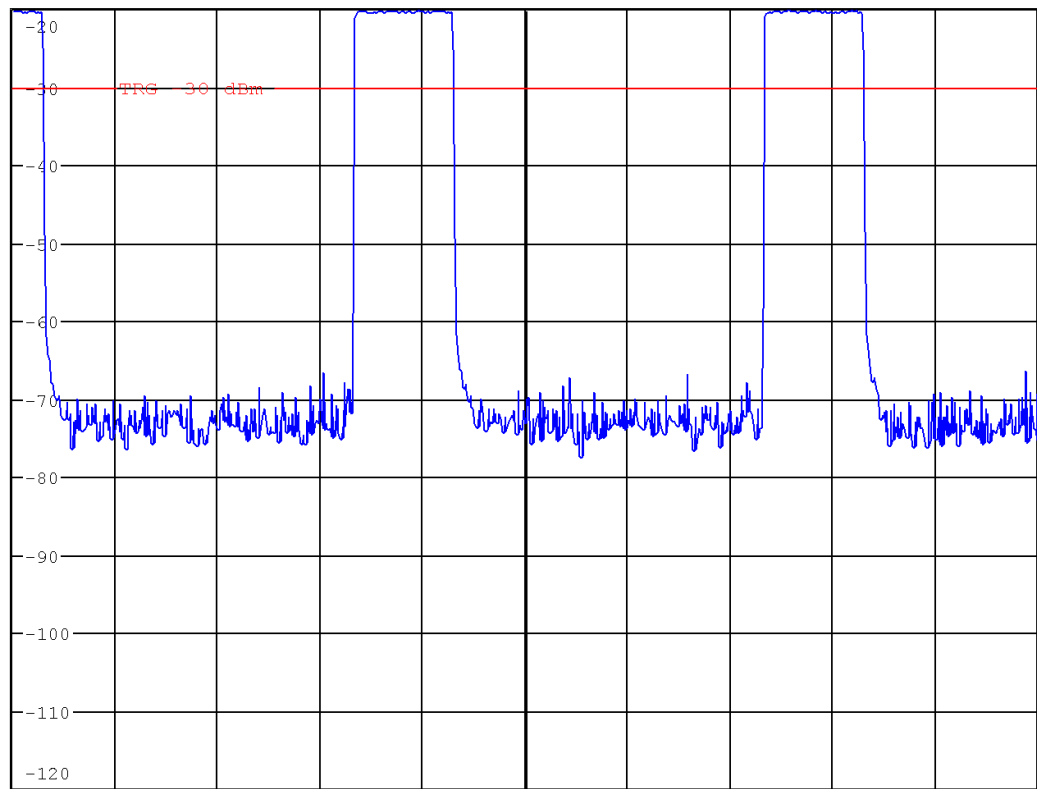
Figure 4-2: Spectrum with increased sweep speed and video trigger

Read pulse width and pulse repetition rate. The marker functions of your spectrum analyzer will help you to determine the values.

5 Explanation of Used Formulas

This chapter gives only a short overview on the used formulas. See [1] for a detailed description.
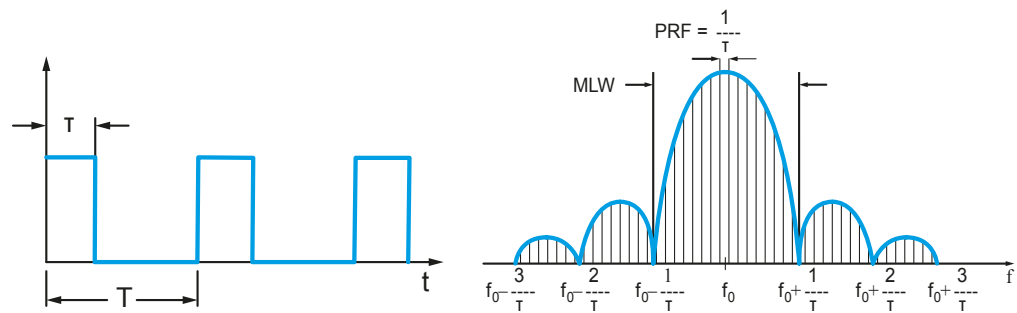
5.1 Pulse Parameters

Figure 5-1: Pulse signal over time and the corresponding signal spectrum

The pulse signal is characterized by its pulse width τ and the pulse period T. You may also specify the pulse repetition frequency PRF:

$$PRF = \frac{1}{T}$$

The spectrum of this pulse signal shows a sin(x)/x (sinc function) shape. The notches adjacent to the carrier frequency define the main lobe width MLW. MLW only depends on the pulse width τ.

$$MLW = \frac{2}{\tau}$$

The energy of the carrier signal is spread over many spectral lines. These lines are spaced by the pulse repetition frequency PRF and are only dependent on the pulse period T.

For the explanations given here we assume that pulse width τ and the pulse period T do not vary over time. Further we assume that no pulse shaping occurs for the modulating pulse signal. Some modern Radar signals use random, time-varying values for pulse width τ and pulse period T and or use phase modulation during the pulse width. The formulas given here do not apply for these signals.

5.2 Spectrum Analyzer Settings

Depending on what you want to measure, pulse spectrum or line spectrum, you have to use different settings for your spectrum analyzer. All settings given here are propos-

als for the initial settings of your spectrum analyzer. They have been chosen to give you a good compromise between frequency resolution, precise amplitude display and fast measurement speed. You may vary these settings according to your preferences.

5.2.1   Pulse Spectrum Display

For display of a pulse spectrum we recommend the following settings for your spectrum analyzer:

Frequency Span:

A span of 5 times the main lobe width or 10 times 1/τ is chosen for the pulse spectrum display. This gives a good overview on the pulsed signal.

IF Bandwidth:

The IF Bandwidth should be much larger than the pulse repetition frequency (otherwise you get a line spectrum display) and much smaller than the main lobe width (otherwise you won´t be able to observe the pulse spectrum notches). We suggest to use a value of 5% of the main lobe width or 1 % of the frequency span. If you set your spectrum analyzer to a different value, you have to enter this value manually in the app in order to get the correct desensitization level.

On the analyzer, this value names Resolution Bandwidth. This parameter can be changed by pressing the RBW or RES BW button.

Video Bandwidth:

We suggest to use the same value as the IF Bandwidth for the Video Bandwidth as initial value. You may reduce the Video Bandwidth significantly in order to smooth the display, but this will increase the necessary sweep time settings.

On the analyzer, this value can be changed by pressing the VBW or VIDEO BW button.

Sweep Time:

The sweep time should be much larger than the pulse period T. We suggest to use an initial value of 500 times T. Observe your spectrum display and a possible Uncal warning, when you reduce sweep time.

Desensitization for Pulse Spectrum Display

The displayed signal level is significantly lower than the peak level of your pulsed signal. The difference is called Desensitization α_P. The desensitization for pulse spectrum display depends on the pulse width τ of your signal, the K-factor (see below) and the actual IF bandwidth of the spectrum analyzer. It is calculated according to this formula:

$$\alpha_P = 20 \cdot \log\left(\tau \cdot K \cdot B\right)$$

The result is actually a negative value in dB (decibels). Use it to calculate the correct signal level:

$$L_{Display} = L_{Peak} + \alpha_P$$

or rearranged

$$L_{Peak} = L_{Display} - \alpha_P$$

where $L_{Display}$ is the displayed signal level and L_{Peak} the peak level of the pulse signal.

K-Factor:

Pulsed signals should be measured using filters with rectangular shape. Since rectangular filters show considerable ringing and overshoot, they are not suited for spectrum analyzers. Spectrum analyzers use gaussian filters. You may however calculate an equivalent rectangular filter from the 3dB bandwidth of a spectrum analyzer using the K-factor. The K-factor depends only on the design of the IF filters of your spectrum analyzer. Rohde&Schwarz spectrum analyzers use 4 or 5 pole analog filters with gaussian response characteristic or digital filters, also with gaussian filter shape. The corresponding K-factor values are 1.806 (4-pole), 1.727 (5-pole) and 1.506 (digital) respectively. See page 192 of [1] for further details. We selected K=1,65 as default value for the app, which gives ± 0.8 dB maximum deviation in the above mentioned K-factor range. You can use this default value unless you want to get more exact calculation results. Then you have to enter the correct K-factor in the Settings menu of the app. The K-factor is only relevant for the pulse spectrum display. The line spectrum display is not affected by the K-factor.

5.2.2 Line Spectrum Display

The following settings are recommended for a line spectrum display on your spectrum analyzer:

Frequency Span:

The spectral lines are spaced by the pulse repetition frequency. Since you want to see these lines, we suggest to set the frequency span to 5 times the pulse repetition frequency. This gives a good view on the spectrum lines every 2nd grid division of your spectrum analyzer display. You may increase the span, but this will result in a slower measurement speed (higher values for sweep time required).

IF Bandwidth:

For line display the IF Bandwidth should be much smaller than the line spacing (which equals the pulse repetition frequency). Use a value of 0.3 * PRF or smaller. Using smaller values will result in longer measurement times (sweep times).

On the analyzer, this value names Resolution Bandwidth. This parameter can be changed by pressing the RBW or RES BW button.

Video Bandwidth:

We suggest to use the same value as the IF Bandwidth for the Video Bandwidth as initial value. You may increase the Video Bandwidth if the signal to noise ratio of your signal is good.

On the analyzer, this value can be changed by pressing the VBW or VIDEO BW button.

Sweep Time:

The sweep time must be large enough not to violate the sweep / bandwidth relation of your spectrum analyzer. Observe your spectrum display and a possible Uncal warning, when you reduce sweep time.

Desensitization for Line Spectrum Display

The desensitization α_L for line spectrum display only depends on the duty cycle τ/T of the pulsed signal. It is calculated according to this formula:

$$\alpha_L = 20 \cdot \log\left(\frac{\tau}{T}\right)$$

As explained above, the result is actually a negative value in dB (decibels). Again use it to calculate the correct signal level:

$$L_{Display} = L_{Peak} + \alpha_L$$

or rearranged

$$L_{Peak} = L_{Display} - \alpha_L$$

where $L_{Display}$ is the displayed signal level and L_{Peak} the peak level of the pulse signal.

6 References

[1] Christof Rauscher, Fundamentals of Spectrum Analysis, http://www.books.rohde-schwarz.com

7 Rohde & Schwarz

Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established more than 80 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

Sustainable product design

- Environmental compatibility and eco-footprint
- Energy efficiency and low emissions
- Longevity and optimized total cost of ownership

Certified Quality Management	Certified Environmental Management
ISO 9001	ISO 14001
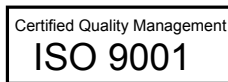
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