Automated Measurements of 77 GHz FMCW Radar Signals

Application Note

Products:

- R&S®FSW
- R&S®FS-Z90

Frequency Modulated Continuous Wave (FMCW) radar signals are often used in short range surveillance, altimeters and automotive radars. To ensure proper functionality, signal quality measures such as frequency linearity are of great importance.

This application note focuses on fully automated, fast and accurate measurements, of linear FMCW radar signals. It explains the basic signal processing, the impact on radar key performance indicators in case of linearity deviations and explains test and measurement of linear FMCW signals in detail.

Measurement of an FMCW radar signal in the 77-81 GHz band with 500 MHz of measurement bandwidth is demonstrated.

Application Note

Dr. Steffen Heuel

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ROHDE&SCHWARZ

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1 Introduction

Radar systems in aerospace and defense or civil applications may apply different waveforms. While aerospace and defense radars often use pulse and pulse compression signals for long range surveillance, which may even be frequency agile, industrial radar sensors for high accuracy positioning of tools or altimeters in airplanes use continuous wave signals. Automotive radar sensors also apply continuous wave radar signals.

In the automotive radar market, high performance and reliability with low-cost unit prices are mandatory. This forces research, development and production to be efficient in terms of cost. It follows that test and measurement of these radar sensors needs to be fast, reliable, cost-effective and straight forward.

The test and measurement solution presented in this application note describes the basic radar signal processing of frequency modulated continuous wave signals. It addresses linearity requirements of frequency modulated radar signals and describes the effects on key performance indicators in case of non-linear effects in the transmit signal. A 77 GHz FMCW radar signal with large bandwidth will be analyzed and the measurement explained step-by-step. Among others, parameters such as chirp rate, frequency deviation (linearity) and coherent processing interval (CPI) are measured. Furthermore, the long term stability of these parameters is measured fully automatically.

2 Frequency Modulated Continuous Wave Radar Signals

Continuous wave radar signals with a linear frequency modulation are applied in many radar systems. Although the FMCW technique has been in use for many years in a number of applications, the automotive radar market is nowadays perhaps the most prevalent application for the use of this radar waveform.

Fast and high performance digital signal processors (DSP), field programmable gate arrays (FPGA) and direct digital synthesis (DDS) make it possible to build low-cost radar units which generate nearly arbitrary radar signals and compute the signal processing to support safer or even automated driving currently and in the future. This signal processing includes real-time target detection, parameter estimation, target tracking and sometimes even signal classification of multi-target situations and under all weather conditions.

FMCW radars have low transmit power compared to pulse radar systems. This allows the radar to be smaller in size and lower in cost. Another important feature is the zero blind range, as the transmitter and receiver are always on. Other advantages such as direct Doppler frequency shift measurement and the possibility to measure static targets make these radar signals very well suited in the automotive and industrial sector.

Key performance indicators of radars are, among others, the resolution, ambiguity and accuracy of range and radial velocity. While the resolutions depend on signal bandwidth and length of the coherent processing interval, high parameter estimation accuracy requires a high signal to noise of the radar echo signal in the first place. In addition, frequency measurement methods, windowing and the transmit signal quality have effects on these key performance indicators.

This section will explain the influences of the transmit radar signal quality on the aforementioned key performance indicators.

2.1 Basic Signal Processing

Figure 2-1 depicts a linear FMCW radar signal with a positive (up-chirp) and a negative (down-chirp) slope. Each frequency modulated signal has specific bandwidth f_{sweep} and chirp length (coherent processing interval T_{CPI}).

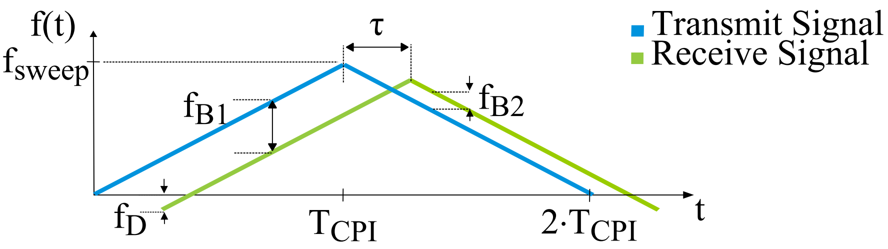


Figure 2-1: Linear FMCW radar with up-chirp and down-chirp

In case of a target reflecting the radar signal, a certain frequency shift, called beat frequency f_B is introduced. Both parameters, range R and radial velocity v_r, contribute to the measured frequency shift f_B. Thus, the beat frequency consists of a Doppler frequency f_D and a frequency shift due to signal propagation time f_τ, as shown in Equation 1.

$$f_B = f_D - f_\tau$$

Equation 1: Beat frequency.

In Figure 2-1 two chirps with different slopes are depicted. A reflected radar echo is received and holds propagation time and Doppler frequency shift after the first and second chirp.

One advantage of the triangular waveform is the ease of implementaion and the avoidance of sharp transitions compared to e.g. saw-tooth waveforms, which are used in chirp sequences (see White Paper 1MA239 [1]).

2.1.1 Beat frequency measurement

To measure the beat frequency, the receive signal is mixed with the transmit signal. This is depicted in Figure 2-2, where the beat frequency is represented as an offset from zero, which can be measured by a Fourier transformation.

A threshold, for example designed for a specific Constant False Alarm Rate (CFAR), is

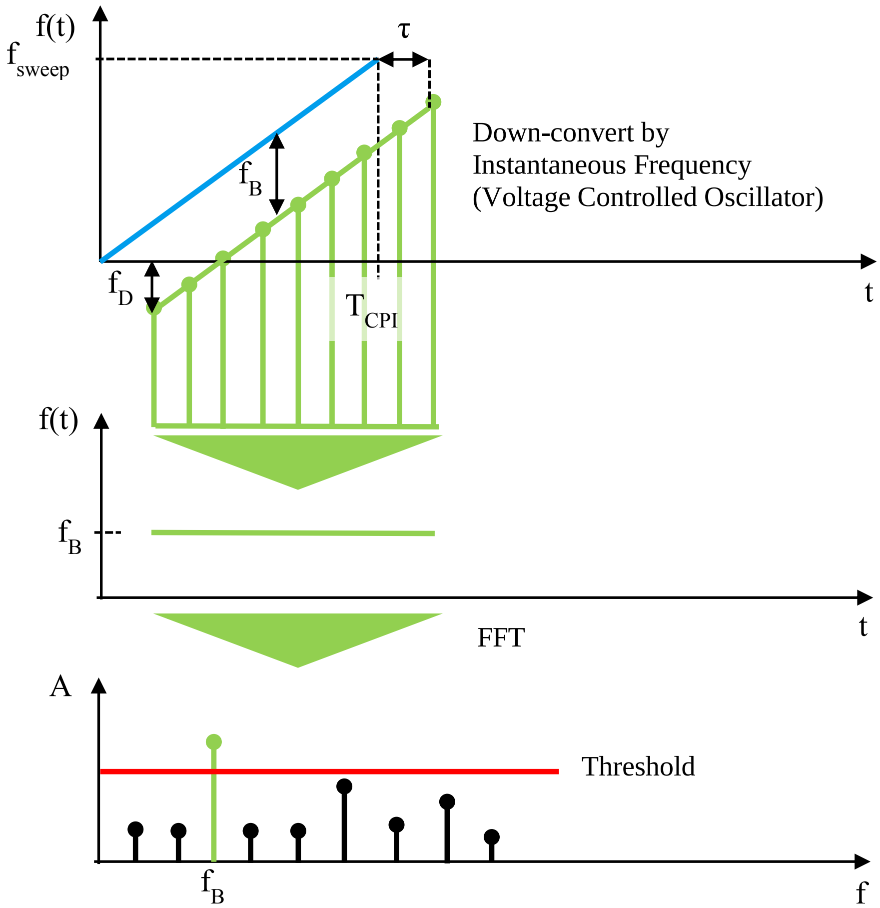


Figure 2-2: Beat frequency measurement.

set accordingly to a desired probability of false alarm rate. All beat frequencies with an amplitude above this threshold are then detected.

2.1.2 Parameter Estimation

As indicated, the beat frequency f_B holds a Doppler frequency shift $f_D = -\frac{2}{\lambda} v_r$ and frequency shift due to time delay $f_\tau = \frac{2}{c}\frac{f_{sweep}}{T_{CPI}} R$, Equation 2. In order to solve Equation 2 unambiguously for v_r and R, two beat frequency measurements f_{B1}, f_{B2} are necessary in the case of a single target. One beat frequency f_{B1} is measured by transmitting the first chirp with the positive slope (up-chirp). The second beat frequency f_{B2} is measured using the second chirp (down-chirp).

$$f_{B1} = -\frac{2}{\lambda} v_r + \frac{2}{c}\frac{f_{sweep}}{T_{CPI}} R$$

and

$$f_{B2} = -\frac{2}{\lambda} v_r - \frac{2}{c}\frac{f_{sweep}}{T_{CPI}} R$$

Equation 2: Two beat frequencies due to a certain range and radial velocity.

In multi target situations, range and radial velocity cannot be resolved unambiguously using just two consecutive chirps. For example two targets would result in two beat frequencies from the up-chirp and two beat frequencies from the down-chirp; in total four beat frequencies. However, it is not known which beat frequencies pairs belong together (from the same target). The equation system cannot be solved unambiguously and would result in four targets, of which two are so called “ghost” targets. These ghost targets can only be resolved by additional chirps with different slopes.

2.2 Key Performance Indicators

In general, the range resolution of a radar system is determined by the bandwidth. For example, a signal bandwidth of 150 MHz determines a range resolution of 1m.

The radial velocity resolution, on the other hand, is defined by the length of the coherent processing interval (CPI). The CPI refers in FMCW to the length of the chirp, which is processed coherently. In chirp sequence waveforms, the CPI consists out of multiple chirps [1]. In automotive radar sensors the coherent processing interval is typically on the order of several milliseconds. For example a radar sensor operating at 77 GHz and with a coherent processing interval of 10 ms has a radial velocity resolution of 0.19 m/s. This high radial velocity resolution allows distinguishing even slowly moving pedestrians from static targets.

To verify range resolution, signal bandwidth has to be measured and further signal processing steps, e.g. windowing, have to be taken into account. A corresponding measurement need also exists for the coherent processing interval, which should be verified to guarantee the required radial velocity resolution.

In practice, the achieved range and radial velocity accuracy will greatly depend on signal to noise ratio of the radar echo signal. However, the achievable performance remains bounded by the quality of the transmitted signal and its corresponding bandwidth and CPI. Unwanted effects on the transmit signal will therefore effect the accuracy of the estimation, and in extreme cases may even be the dominating factor in determining system performance. One very important parameter of signal quality to be measured in this respect is the FM linearity.

2.3 Signal Generation and Linearity

Linearly swept frequency sources are widely used to generate the transmit signal of FMCW radar. Some advantages of FMCW radar compared to pulse radar systems have been already indicated. However, there are several aspects in the design which have to be considered. One aspect is the choice of the transmit signal source and the kind of signal generation.

Typical sweeper implementations:

- Open Loop Voltage Controlled Oscillator (VCO)
- VCO and Frequency Discriminator

In the case that VCOs are used, signal corrections are typically implemented, such as a look up table (LUT) and digital analog converter (DAC) with pre-calibrated stored control data. However, the calibration is often not static over time and temperature changes limit the achievable linearity.

VCOs with a frequency discriminator generate a voltage output signal proportional to frequency which is fed back as a closed loop correction. Unfortunately these analogue frequency discriminators have limited performance, which is why the required signal performance is often not achieved in wide-band radar systems.

Synthesizer Subsystems:

- Phase Looked Loop (PLL) Synthesizer
- Direct Digital Synthesizer (DDS)

PLLs generate and an output signal with phase related to an input signal. This output signal is fed back over a frequency divider and multiplied with the input signal. One drawback of PLLs is the increase of phase noise, which should be kept as low as possible in radar systems.

A DDS creates the output signal by reconstruction based on a look-up table (which contains amplitude values as a function of the phase) and a digital to analog converter. A typical disadvantage of the DDS approach is the increased the level of spurious emissions due to frequency multiplication. To limit these emissions, the multiplication factor should be kept as low as possible.

2.3.1 Effects of Slow Frequency Deviation

Depending on the kind of signal generation there are several effects which reduce the linearity of the signal. This linearity degradation in turn reduces the radar performance.

Slow frequency deviation from a perfect linear signal slope over a certain bandwidth may occur as depicted in Figure 2-3. Due to down-conversion of the receive signal with the instantaneous transmit frequency, the beat frequency will exhibit a trend. Hence, the Fourier transformed signal will result in a broader frequency peak. This decreases range and radial velocity parameter estimation accuracy and resolution, as the beat frequency measurement is less accurate.

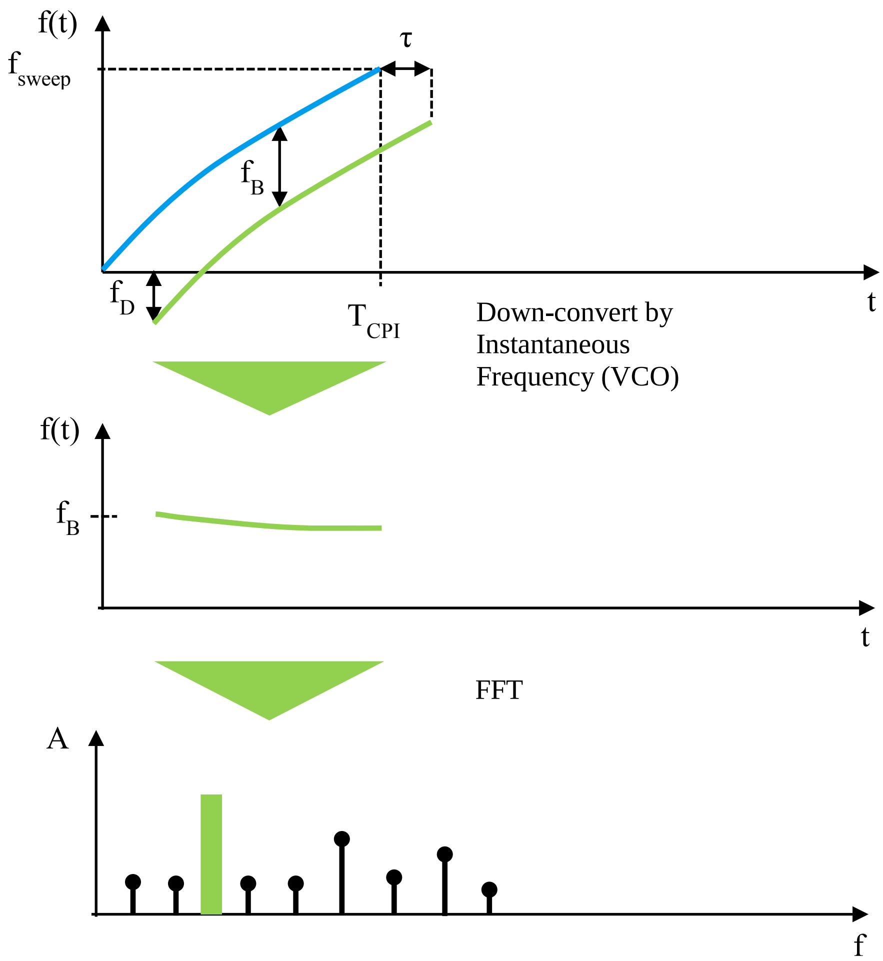


Figure 2-3: Slow frequency deviation

The linearity of the transmit signal becomes even more important for targets which are located at longer ranges, as the receive signal may be down-converted with another frequency than expected. This could even result in false range estimation, as the wrong beat frequency is measured.

2.3.2 Effects of Ripple

Another effect on transmit signals are ripples, as illustrated in Figure 2-4. This frequency deviation affects the accuracy of the beat frequency f_B measurement and causes unwanted side-lobes to appear in the IF signal spectrum. The beat frequency f_B measured by down-conversion and Fourier transformation will result in a wider frequency peak in the Fourier spectrum compared to the transmission of perfectly linear ramps. Hence resolution in both domains (range resolution ΔR, radial velocity resolution Δv_r) and accuracy are degraded during the FMCW signal processing.

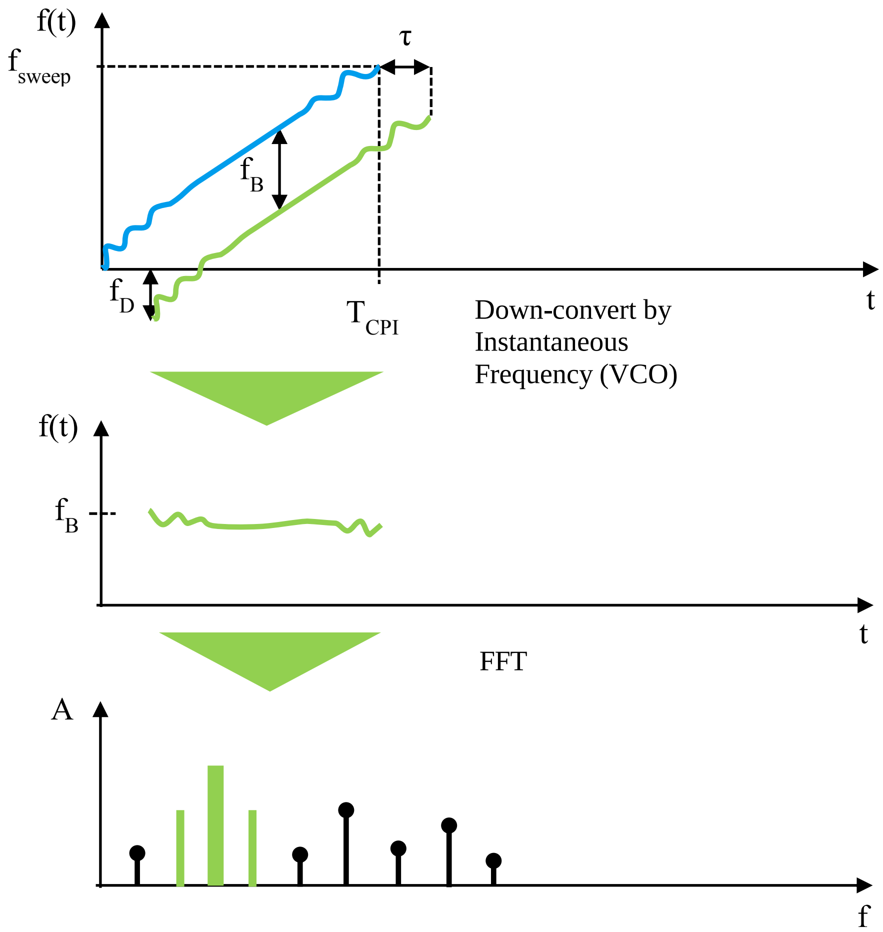


Figure 2-4: Ripple

2.3.3 Spurious Emissions

Along with signal linearity, spurious emissions should be very low or practically not present. Spurious emissions in modern radar systems are often due to harmonics, out-of-band mixer products or oscillator leakage.

Spurious emissions may disturb other services in adjacent frequency bands. One example is Air Traffic Control (ATC) radar in the S-Band and adjacent Long Term Evolution (LTE) services in the 2.7 GHz domain. In automotive radar spurious emissions may impact the performance of other transmit and receive services or even the operation of space borne passive sensing instruments, e.g. the multi-channel microwave radiometer "Advanced Microwave Sounding Unit-A" (AMSU-A) [2] which operates in the 24 GHz band.

Spurious emissions from automotive radar in the 76-77 GHz band could occur in the 148.5 - 151.5 GHz and 226 - 231.5 GHz bands. These frequency bands are allocated to passive services, mm-wave radio astronomy in particular (see Committee on Radio Astronomy Frequencies (CRAF), ITU-R Footnote 5.340 [3]). The level of spurious emissions is regulated by authorities.

3 Automated Signal Analysis

The signal and spectrum analyzer option R&S®FSW-K60 addressed in this application note is designed to analyze transient signals, for example linear FMCW radar signals and frequency hopping sequences, for example Multi-Frequency Shift Keying (MFSK) radar signals. The extension FSW-K60C automatically detects FMCW chirps, burst types and non-burst types and measures chirp rate (slope), chirp duration (coherent processing interval) and linearity.

In the following sections a typical 77 GHz radar signal is analyzed in basic and in detailed measurements. Each measurement is explained step by step.

3.1 Measurement Requirements

The radar signal measured requires a certain frequency range and bandwidth of the spectrum analyzer.

- Radar signal carrier frequency f_C: 77.0 GHz
- Radar signal bandwidth f_{sweep}: 480 MHz
- Chirp duration / coherent processing interval T_{CPI}: 1 ms

These figures have to be consistent with the R&S®FSW Signal and Spectrum Analyzer which is available in frequency range from 2 Hz to 8/13.6/26.5/43.5/50/67 GHz and with external harmonic mixers from Rohde & Schwarz up to 110 GHz with an analysis bandwidth of up to 500 MHz. The total measurement duration depends on the analysis bandwidth and can be as long as 0.769 seconds in case of 500 MHz analysis bandwidth.

Hardware and software requirements:

- R&S®FSW Signal and Spectrum Analyzer
- R&S®FS-Z90 Harmonic Mixer
- R&S®FSW-B500 500 MHz Analysis Bandwidth
- R&S®FSW-B21 LO/IF Ports for External Mixers
- R&S®FSW-K60 Transient Measurement Application
- R&S®FSW-K60C Transient Chirp Measurements

3.2 Basic Signal Measurements

Preset the R&S®FSW Signal and Spectrum Analyzer.

Press PRESET

Start the Transient Analysis application and set Frequency, Span, Measurement Time and Analysis Region (AR).

MODE: Transient Analysis

INPUT/OUTPUT: External Mixer Config: configure and activate external mixer input (e.g. E-band)

FREQ: 77.0 GHz

SPAN: 500 MHz

SWEEP: Meas Time: 10 ms

MEAS CONFIG: Data Acquisition: Link AR to Full

- Bandwidth: On
- Time: On

Run Single

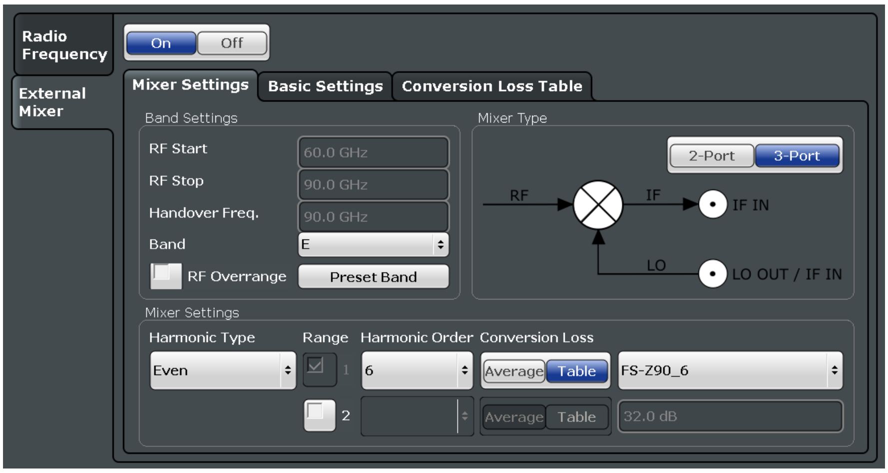


Figure 3-1: External mixer settings

Select the signal model "Chirp" to start an automated analysis.

MEAS CONFIG: Signal Description: Signal Model: Chirp

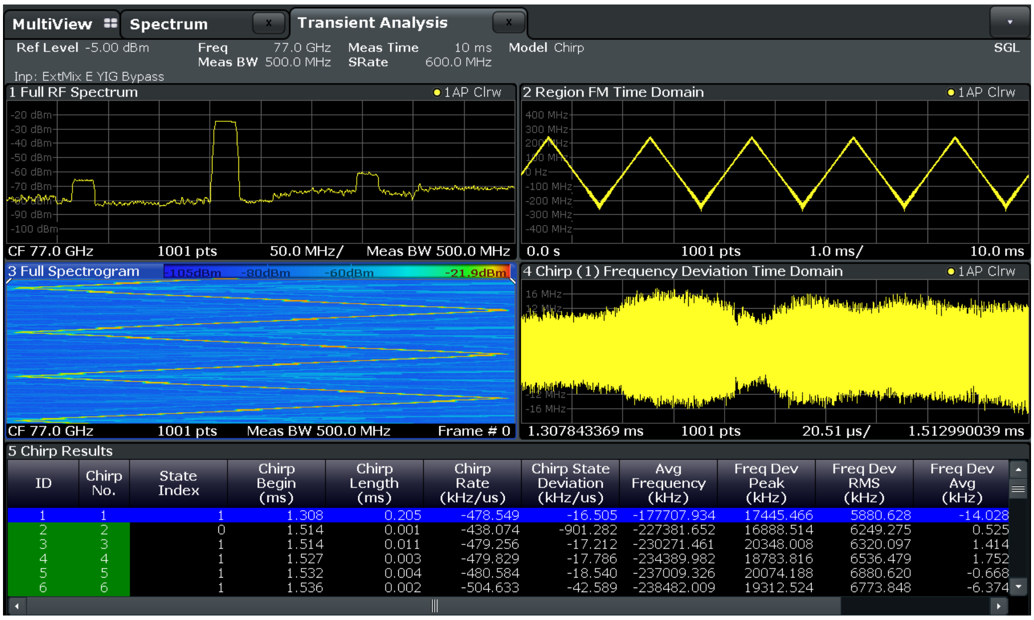


Figure 3-2: Standard measurement display

As depicted in Figure 3-2 the device under test (DUT) transmits an up-chirp and a down-chirp as shown in display "Region FM Time Domain". This is necessary to resolve multi-target situations as explained in section 2.1.

3.2.1 Amplitude, Frequency and Phase vs. Time Measurements

The standard view of the R&S®FSW-K60C Transient Analysis Option (used here: release 1.93) shows the following five measurement displays:

1. Full RF spectrum,
2. Region FM Time Domain,
3. Full Spectrogram,
4. Chirp (1) Frequency Deviation Time Domain,
5. Chirp Results table.

There are several other measurement displays that can be added or can replace existing displays on the screen. To add or replace a measurement display, select and drag the display icon to the desired position on the screen.

For the example shown in Figure 3-3, the "PM Time Domain" display has replaced the "Chirp Frequency Deviation Time Domain" measurement from the default layout. Depending one measurement requirements, the phase vs. time trace data can be displayed with “wrapped” or “unwrapped” phase values.

MEAS: Display Config: select and drag "PM Time Domain" onto the screen.

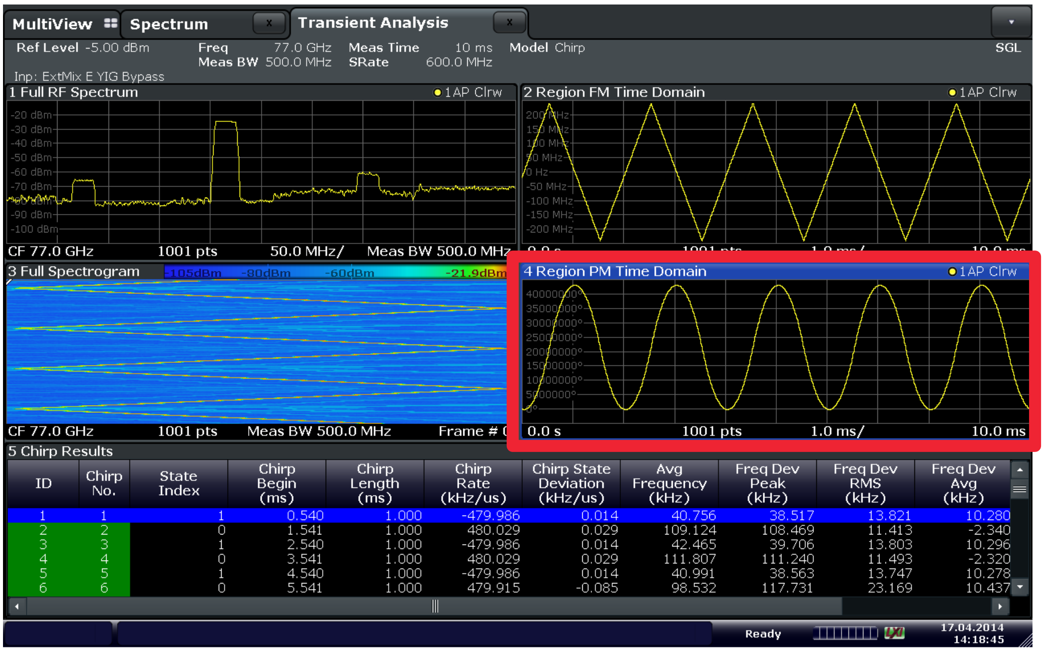


Figure 3-3: PM Time Domain Measurement

The "Region PM Time Domain" display shows a phase vs. time trace for the defined "Analysis Region". In contrast, Figure 3-2 applied "Chirp (1)" as a measurement range for the measurement.

3.2.2 Measuring Chirp Rate

Multiple automated measurements are performed when the "Chirp" signal model is applied:

- Chirp begin (with respect to the beginning of data acquisition, e.g. trigger event)
- Chirp length
- Chirp rate
- Chirp rate deviation from nominal chirp state chirp rate
- Average chirp frequency (with respect to center of the chirp)
- Max deviation of chirp frequency from an ideal linear frequency trajectory
- RMS deviation of chirp frequency from an ideal linear frequency trajectory
- Average deviation of chirp frequency from an ideal linear frequency trajectory
- Average chirp power

Initially all detected chirp values are shown in the "Chirp Results" table. Therefore an automated chirp detection is implemented, which analyses the captured data, derives chirp rates and deviations and fills this into a "signal state" list. It is also possible to define specific signal states if these are known (e.g. for verification purposes).

The signal state defines the slope and timing of the chirps, as shown in Figure 3-4. In this example, initially delete the automatically detected chirps and define the slope accordingly to the expected chirp states:

MEAS CONFIG: Signal Description: Signal States: Chirp States > Auto Mode: Off

- Delete states
- Insert expected chirp states

Insert the expected "Chirp Rate" (in kHz / µs) and "Tolerance" and add as many chirp states as should be searched for. In this example the transmitted chirp has a bandwidth of 480 MHz and a length of 1 ms. This defines the chirp rates as follows:

The up-chirp has a positive slope:

Chirp Rate: 480 kHz / µs Tolerance: 480 kHz / µs

The down-chirp has a negative slope

Chirp Rate: -480 kHz / µs Tolerance: 480 kHz / µs

Define the expected timing. This step is optional and can be performed in order to filter out unwanted chirp signals, or to avoid unwanted detections due to noise, where random fluctuations may correspond to a “chirp” over a short time duration. E.g. in this example a minimum chirp length of 50 µs is used to avoid detections due to noise,

MEAS CONFIG: Signal Description: Signal States: Chirp States > Timing: Off

- Min Chirp Length: 50 µs
- Max Chirp Length: 2 ms

As soon as the settings are **saved** the signal states are applied to the measurement values. This will automatically update the "Chirp Results" table.

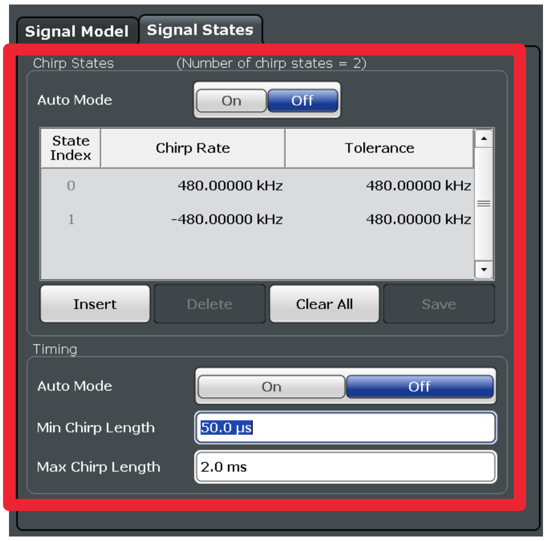


Figure 3-4: Signal States

All chirps are measured and analyzed automatically according to the defined signal states.

Figure 3-5 illustrates the chirp detection process in terms of "chirp rate vs. time," with a tolerance region applied to the nominal chirp rate states. A chirp state is detected when the measured chirp rate remains within the tolerance region of a particular state for at least the required "Min Chirp Length" but not longer than the "Max Chirp Length". This

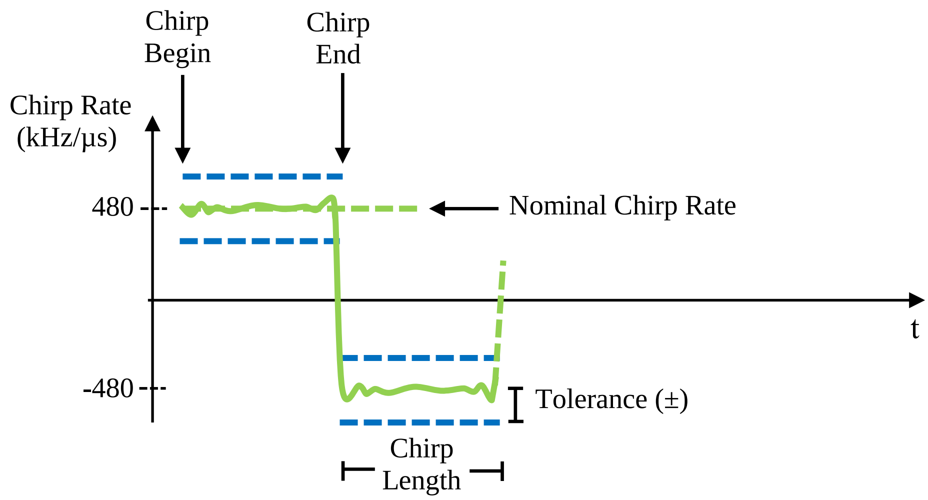


Figure 3-5: Definition of the main chirp parameters and characteristic values

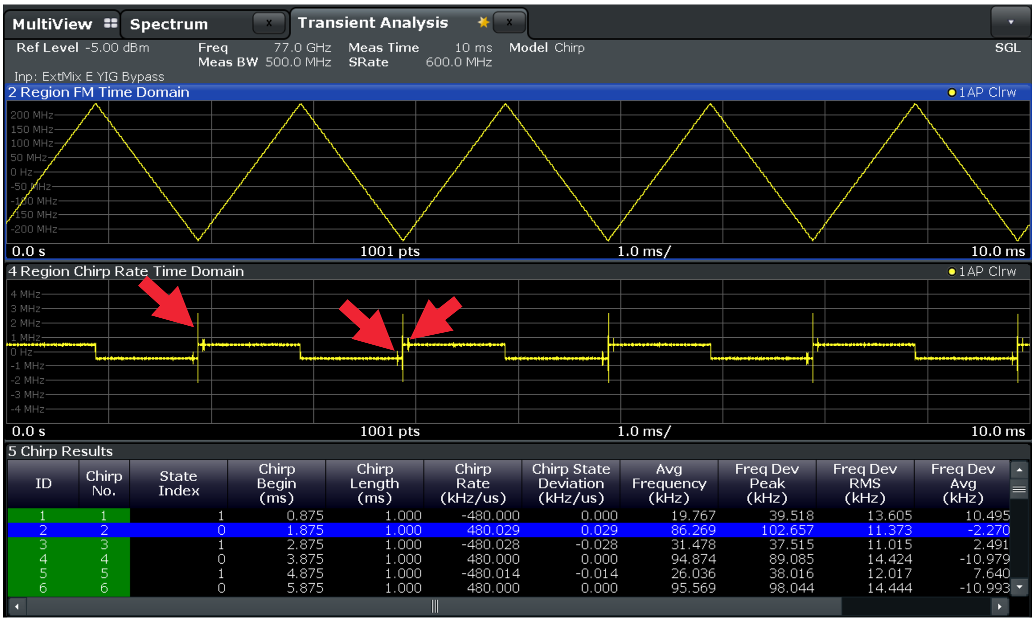
indicates how the chirp rates and tolerances, which are entered into the signal state table, as well as the configuration of the Timing parameters, should be chosen.

Select the "Chirp Rate Time Domain" from the display config and choose the measurement range to be "Analysis Region".

MEAS: Display Config: Select and drag "Chirp Rate Time Domain"

MEAS: Analysis Region

The measurement result shows the changing chirp rates from consecutive chirps. As indicated with the red arrows, there are some spikes in the change from down-chirp to the up-chirp and at the end of the down-chirp and the beginning of the up-chirp.



ID	Chirp No.	State Index	Chirp Begin (ms)	Chirp Length (ms)	Chirp Rate (kHz/us)	Chirp State Deviation (kHz/us)	Avg Frequency (kHz)	Freq Dev Peak (kHz)	Freq Dev RMS (kHz)	Freq Dev Avg (kHz)
1	1	1	0.875	1.000	-480.000	0.000	19.767	39.518	13.605	10.495
2	2	0	1.875	1.000	480.029	0.029	86.269	102.657	11.373	-2.270
3	3	1	2.875	1.000	-480.028	-0.028	31.478	37.515	11.015	2.491
4	4	0	3.875	1.000	480.000	0.000	94.874	89.085	14.424	-10.979
5	5	1	4.875	1.000	-480.014	-0.014	26.036	38.016	12.017	7.640
6	6	0	5.875	1.000	480.000	0.000	95.569	98.044	14.444	-10.993

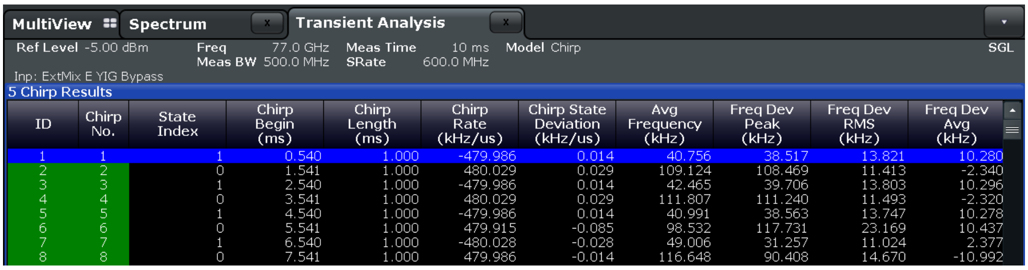
Figure 3-6: Chirp rate measurement

Double click on the "Chirp Results" measurement display, which opens up in a full-screen viewing mode.

The table below shows the state index (corresponding to "Signal State" table) and the signal properties such as chirp length or frequency deviation.

For example, chirp no. 1 with the state index 1 has a length of 1 ms and a chirp rate of -479.986 kHz/µs. There is a chirp-rate deviation (from the defined state) of 14 Hz/µs. Additional parameters such as the maximum frequency deviation (from ideal linear) are also displayed.

It can be seen that the up-chirp (state index 0) has higher frequency deviation peaks than the down-chirp (state index 1).



ID	Chirp No.	State Index	Chirp Begin (ms)	Chirp Length (ms)	Chirp Rate (kHz/us)	Chirp State Deviation (kHz/us)	Avg Frequency (kHz)	Freq Dev Peak (kHz)	Freq Dev RMS (kHz)	Freq Dev Avg (kHz)
1	1	1	0.540	1.000	-479.986	0.014	40.756	38.517	13.821	10.280
2	2	0	1.541	1.000	480.029	0.029	109.124	108.469	11.413	-2.340
3	3	1	2.540	1.000	-479.986	0.014	42.465	39.706	13.803	10.296
4	4	0	3.541	1.000	480.029	0.029	111.807	111.240	11.493	-2.320
5	5	1	4.540	1.000	-479.986	0.014	40.991	38.563	13.747	10.278
6	6	0	5.541	1.000	479.915	-0.085	98.532	117.731	23.169	10.437
7	7	1	6.540	1.000	-480.028	-0.028	49.006	31.257	11.024	2.377
8	8	0	7.541	1.000	479.986	-0.014	116.648	90.408	14.670	-10.992

Figure 3-7: Chirp results table

3.2.3 Measuring Chirp Linearity

As previously discussed, the chirp linearity is of great importance for radar parameter estimation accuracy and resolution. Therefore the "Frequency Deviation Time Domain" result is selected from the display configuration and the measurement range is set to "Analysis Region", as shown in Figure 3-8.

MEAS: Display Config: Select and drag "Frequency Deviation Time Domain"

MEAS: Analysis Region

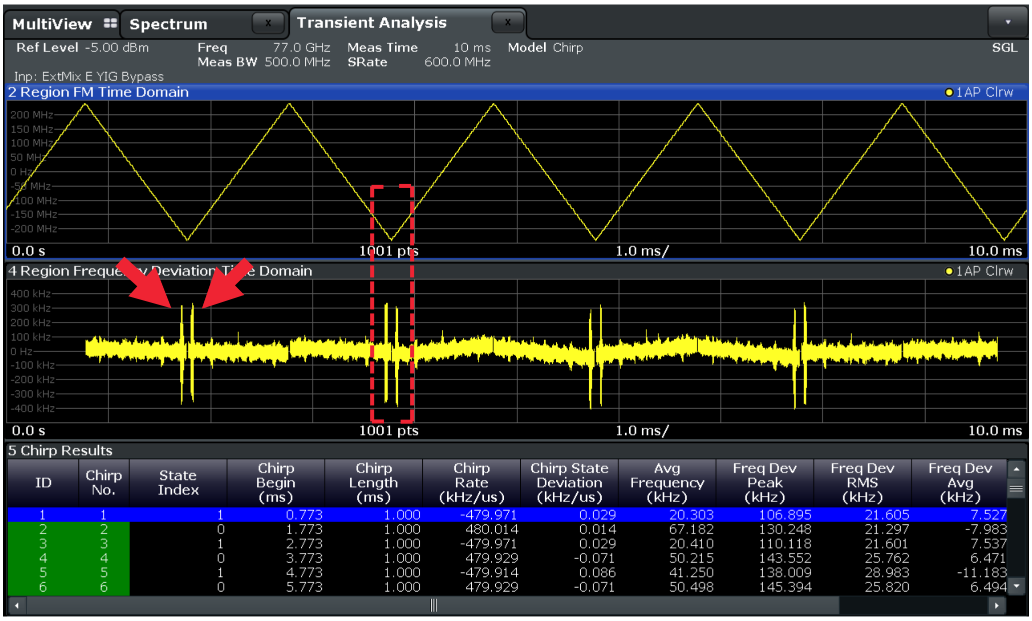


Figure 3-8: Chirp linearity measurement

The measurement shows the frequency deviation of all chirps detected according to the "signal states" table. The time axis of both measurement displays is aligned.

The spikes at the beginning of the up-chirp and at the end of the down-chirp are clearly visible in the frequency deviation display, but not in the FM time domain display. However, the frequency deviation display is dominated by noise. Noise can be reduced by using statistical averaging techniques, applied to the "Frequency Deviation Time Domain" trace for single measurements (i.e. "video" filtering) or over multiple measurements (i.e. trace averaging) as explained in the next section.

3.2.4 Detailed Chirp Linearity Measurement

For detailed analysis of the chirps we are initially interested in this down-chirp signal, as there was a spike visible inside the measurement range.

Change the measurement range of the relevant result displays to "Chirp".

Select the FM Time Domain and press

MEAS: Chirp

Select the Frequency Deviation Time Domain and press

MEAS: Chirp

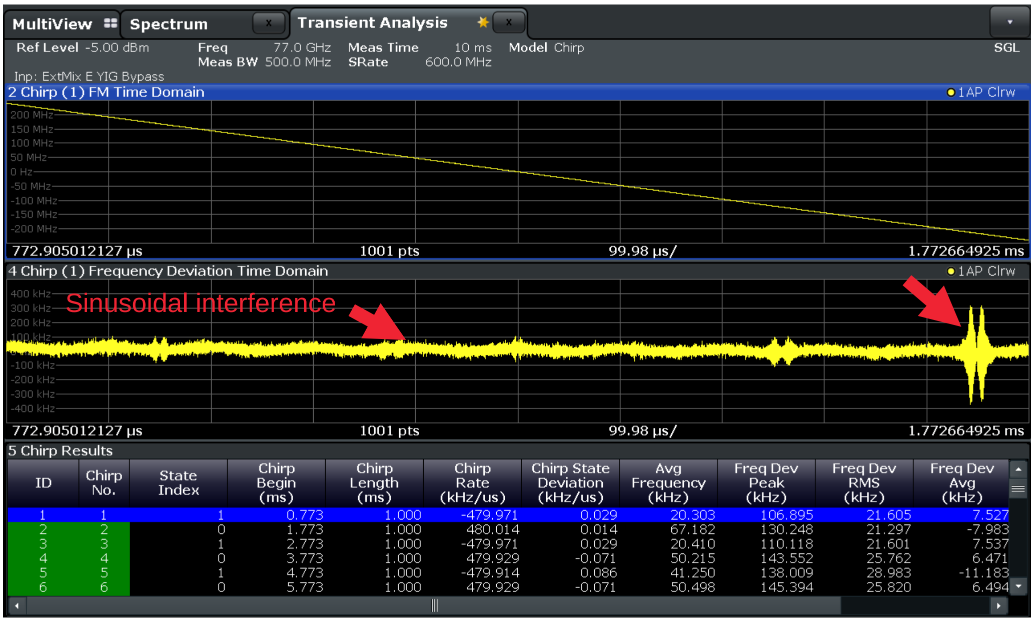


Figure 3-9: Detailed chirp analysis

In the frequency deviation a sinusoidal interference can be barely recognized. There are also some spikes within the signal. To make this inference clearly visible, the displayed noise bandwidth can be reduced by decreasing the FM "video" bandwidth (VBW) value.

BW: FM Video BW: Low Pass 1% BW

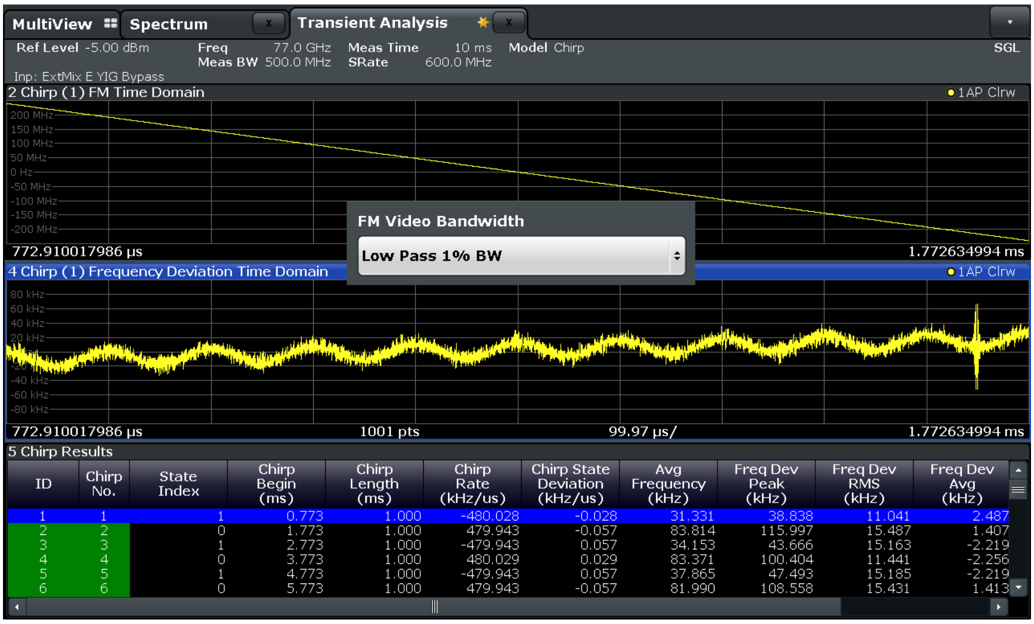


Figure 3-10: FM Video Bandwidth, Low Pass 1% BW Filter applied

Select the Frequency Deviation Time Domain display and add a trace. Note that the measurement range of this display can be set to show the entire "Analysis Region" or to be focused on a single "Selected Chirp".

Select "Frequency Deviation Time Domain"

TRACE: Trace Config: Traces

- Trace 1 Max Hold and switch "Hold" on
- Trace 2 Average and switch "Hold" on
- Trace 3 Min Hold and switch "Hold" on

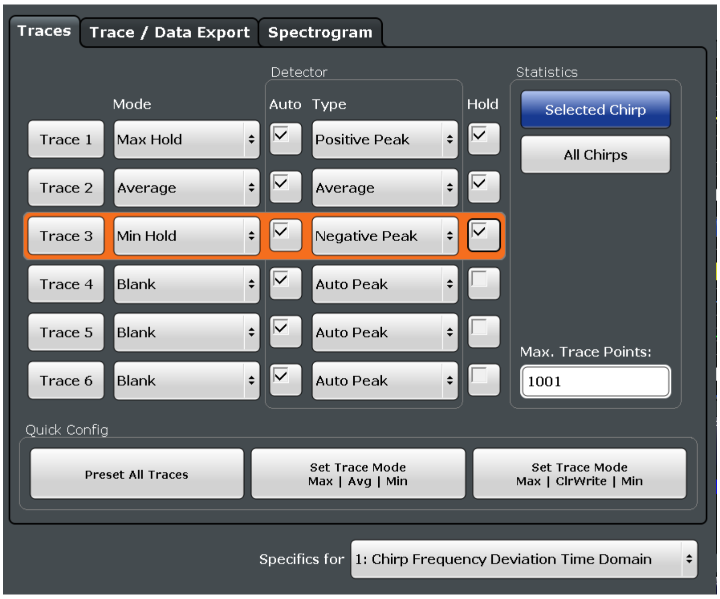
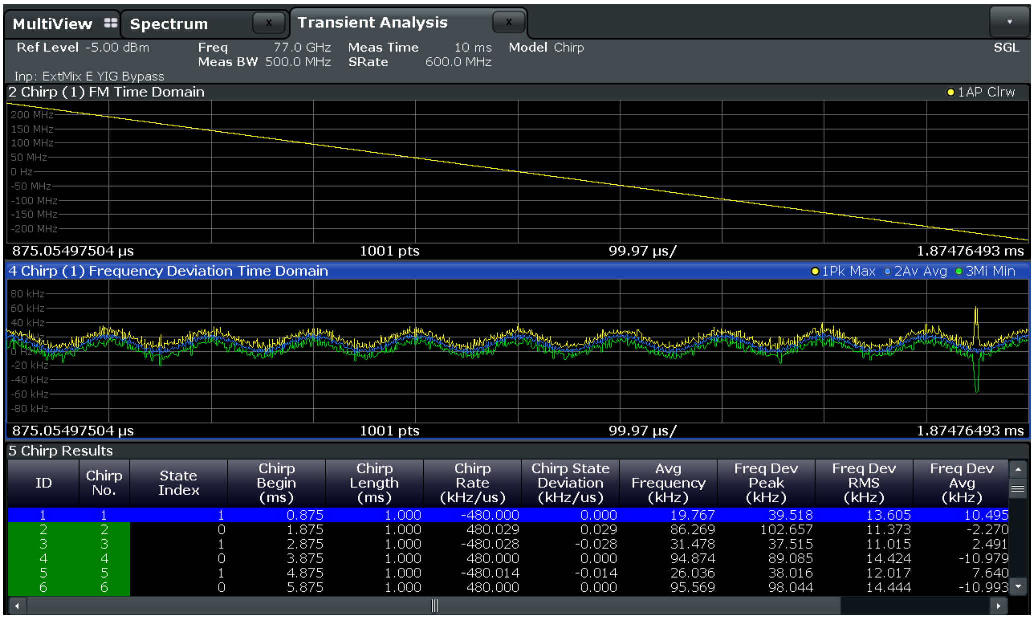


Figure 3-11: Add traces to "Frequency Deviation Time Domain" measurement.



ID	Chirp No.	State Index	Chirp Begin (ms)	Chirp Length (ms)	Chirp Rate (kHz/us)	Chirp State Deviation (kHz/us)	Avg Frequency (kHz)	Freq Dev Peak (kHz)	Freq Dev RMS (kHz)	Freq Dev Avg (kHz)
1	1	1	0.875	1.000	-480.000	0.000	19.767	39.518	13.605	10.495
2	2	0	1.875	1.000	480.029	0.029	86.269	102.657	11.373	-2.270
3	3	1	2.875	1.000	-480.028	-0.028	31.478	37.515	11.015	2.491
4	4	0	3.875	1.000	480.000	0.000	94.874	89.085	14.424	-10.979
5	5	1	4.875	1.000	-480.014	-0.014	26.036	38.016	12.017	7.640
6	6	0	5.875	1.000	480.000	0.000	95.569	98.044	14.444	-10.993

Figure 3-12: Traces in the "Frequency Deviation Time Domain" measurement

Figure 3-12 shows the sinusoidal frequency deviation on the chirp with deviation of +/- 10 kHz. The spike is also still visible. Note that in this example, the +/- 10 kHz sinusoidal was intentionally synthesized in the measured signal for demonstration purposes. This expected "error" in the device under test could be clearly discerned and accurately quantified using the stated measurement equipment, measuring at an RF frequency of 77 GHz.

3.2.5 Measuring Single Chirps

The other detected chirps are also of interest. After a number of chirps have been detected, it is possible to select a particular chirp of interest for further analysis and to step through the consecutive chirps listed in the result table. The "Frequency Deviation Time Domain" Display (and any other result display with a measurement range set to "Chirp") will automatically update its content accordingly, to show trace data for the selected chirp. A blue highlight in the "Chirp Results" table indicates the "Selected Chirp" on display.

MEAS: Select Chirp

Step through the detected chirps

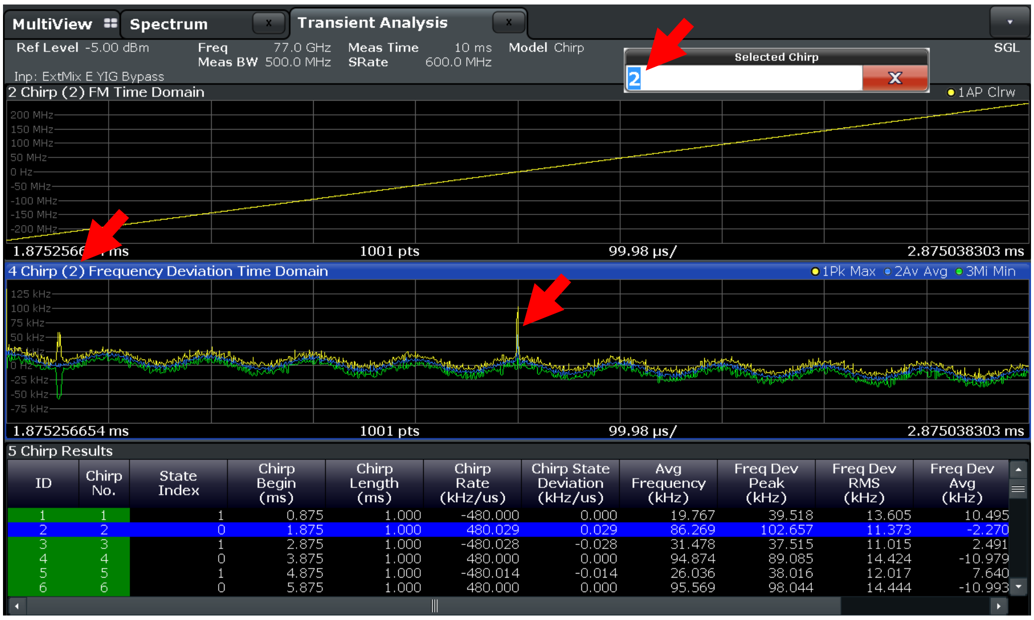


Figure 3-13: Selecting single chirps

The detected up-chirp (chirp no. 2) also shows a sinusoidal frequency deviation and several spikes on the signal.

As explained in section 2.3, a sinusoidal interference will affect the accuracy of the beat frequency measurement. This results in a wider local maximum in the Fourier spectrum and reduces range and radial velocity resolution and the accuracy of the beat frequency measurement.

4 Measuring Long Term Stability

Long term stability measurements are important to determine if spikes, frequency deviations or sinusoidal oscillations occur just in single chirps at certain times or if these effects are more frequent. This type of measurement can also be used to analyze the behavior of the radar signal e.g. in the case of temperature changes.

4.1 Statistics and Trend Analysis

In the next measurement the statistics and long term stability of the up-chirp is of interest, as this signal had a significant spike and some sinusoidal interference.

Reduce the signal states to the up-chirp only, which automatically updates the measurement data.

MEAS CONFIG: Signal Description: Signal States: Chirp States

Delete the chirp states, but leave the up-chirp with "state index 0"

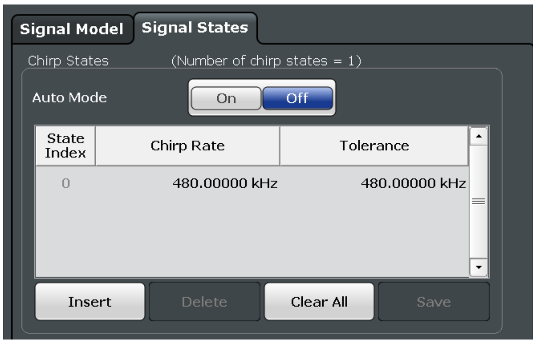


Figure 4-1: Signal States

Change the display configuration to show "Frequency Deviation", "Chirp Rate" and "Chirp Statistics"

MEAS: Display Config

Select and drag "Frequency Deviation Time Domain", "Chirp Rate Time Domain" and "Chirp Statistics" onto the display layout.

Select certain measurements to appear in the "Chirp Statistics" table by switching each single parameter on or off.

MEAS CONFIG: Result Config: Table Config

Switch the "state index" and "average frequency" off.

Figure 4-2: Statistics table configuration

The result shows the frequency deviation, chirp rate and statistics. Inside the chirp statistics the blue line indicates the statistics of the currently selected chirp (in this case it is chirp no 2). In green the statistics of the current acquisition (10 ms) are shown. The statistic with black background is cumulative of all chirps detected in multiple acquisitions (100 "sweeps").

Set the number of sweeps for the cumulative statistic. The count indicator in the upper right corner indicates the actual sweep.

SWEEP: Sweep Count: 100

Run Single

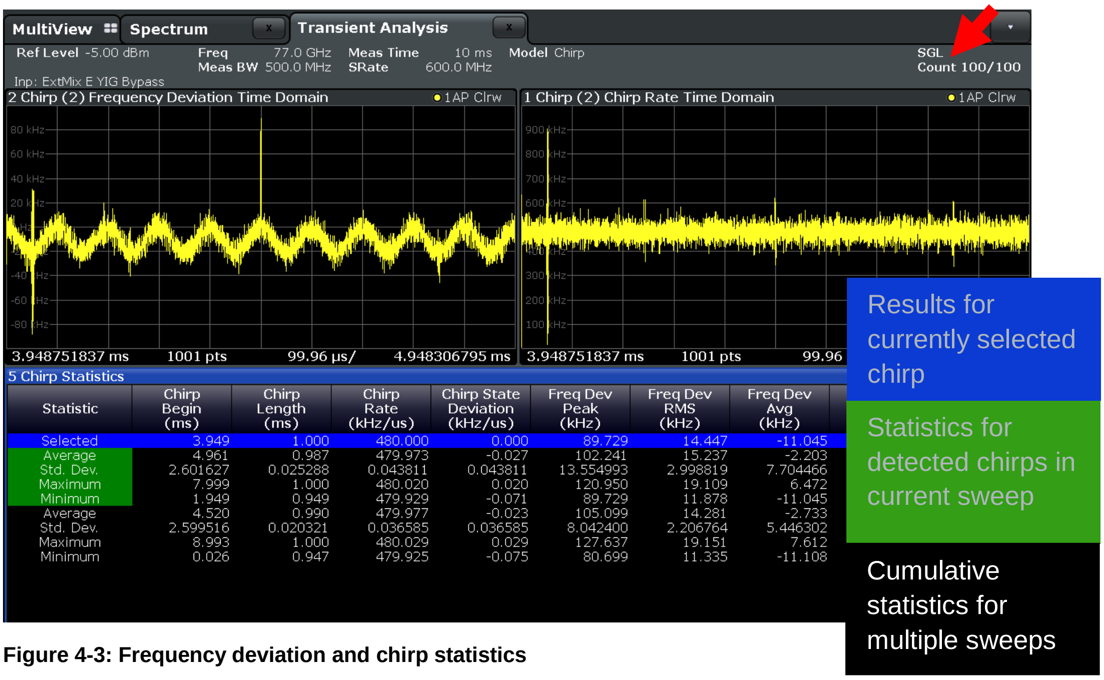


Figure 4-3: Frequency deviation and chirp statistics

5 Summary

Radar systems serve many needs in terms of target detection, parameter estimation, tracking and recognition. To ensure proper functionality of the radar system, one requires both effective signal processing and very good RF performance. In linear frequency modulated continuous wave radar signals, as they are applied for automotive radar sensors or portable short range surveillance radars, signal linearity is one of the most important parameter to be verified.

This application note explained the basic signal processing of linear FMCW radar systems and indicated the impact of non-linear effects in the transmit signal (e.g. drift or ripple) on the key performance indicators such as accuracy and resolution.

It described measurements step by step performed on a 77 GHz radar with linear FMCW signal with 480 MHz of bandwidth, using an R&S®FSW Signal and Spectrum Analyzer and the Transient Measurement Application (FSW-K60C).

Using this application note one is able to measure signal quality of linear frequency modulated transmit signals in a fully automated manner and to identify potential signal impairments, which can negatively impact the performance of the radar.

Literature

[1] Rohde & Schwarz, White Paper 1MA239 "Radar Waveforms for A&D and Automotive Radar", www.rohde-schwarz.com/appnote/1MA239

[2] EUMETSAT, The advanced Microwave Sounding Unit-A (AMSU-A) is designed to measure global atmospheric temperature profiles, retrieved from www.eumetsat.int, April 15th, 2014

[3] Committee on Radio Astronomy Frequencies, ITU-R Footnote 5.340, retrieved from www.craf.eu/s5_340.htm, April 22nd, 2014

6 Ordering Information

Designation	Type	Order No.
	R&S®FSW26	
500 MHz Analysis Bandwidth	R&S®FSW-B500	1313.4296.02
LO/IF Ports for External Mixers	R&S®FSW-B21	1313.1100.26
Transient Measurement Application	R&S®FSW-K60	1313.7495.02
Transient Chirp Measurement	R&S®FSW-K60C	1322.9745.02

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Regional contact

Europe, Africa, Middle East
+49 89 4129 12345
customersupport@rohde-schwarz.com

North America
1-888-TEST-RSA (1-888-837-8772)
customer.support@rsa.rohde-schwarz.com

Latin America
+1-410-910-7988
customersupport.la@rohde-schwarz.com

Asia/Pacific
+65 65 13 04 88
customersupport.asia@rohde-schwarz.com

China
+86-800-810-8228 /+86-400-650-5896
customersupport.china@rohde-schwarz.com

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Rohde & Schwarz GmbH & Co. KG
Mühldorfstraße 15 | D - 81671 München
Phone + 49 89 4129 - 0 | Fax + 49 89 4129 – 13777

www.rohde-schwarz.com