Analysis of very long radar pulse sequences

The R&S®FSW signal and spectrum analyzer now has a free upgrade to its R&S®FSW-K6 pulse measurements option that efficiently segments signals before they are analyzed. This saves memory space and increases the analysis period so that trends become visible for pulse parameters.

Pulsed radar systems transmit high-power pulses. Each pulse is followed by a pause in which echoes can be received. In many pulsed radar systems, the carrier frequency of the pulses remains constant. Only the pulse repetition interval (PRI) and the pulse width (PW) vary. The PRI determines the maximum unambiguous measurement range. The longer the PRI, the greater this range is. The pulse width of an unmodulated pulse determines the range resolution. Longer pulses have more power per pulse and therefore achieve a longer range. Shorter pulses allow detection of objects even at a lesser range. In addition, they improve the range resolution, i.e. the capability to resolve objects as separate items. However, they require a higher spectral bandwidth.

Marine and air surveillance radars regularly change their operating modes. They use different PRIs and PWs in search mode, acquisition mode or tracking mode because these require various compromises between minimum and maximum range and range resolution. Other techniques include modulation of phase or frequency during a pulse, which encompasses pulse compression (see page 37).

For development, optimization and troubleshooting of radar transmitters, pulse trains must be characterized over a long period. To capture sporadic events or small but continuous effects such as temperature drifts, it is desirable to record and measure all emitted pulses over a period of several minutes.

Pulse analysis using a spectrum analyzer

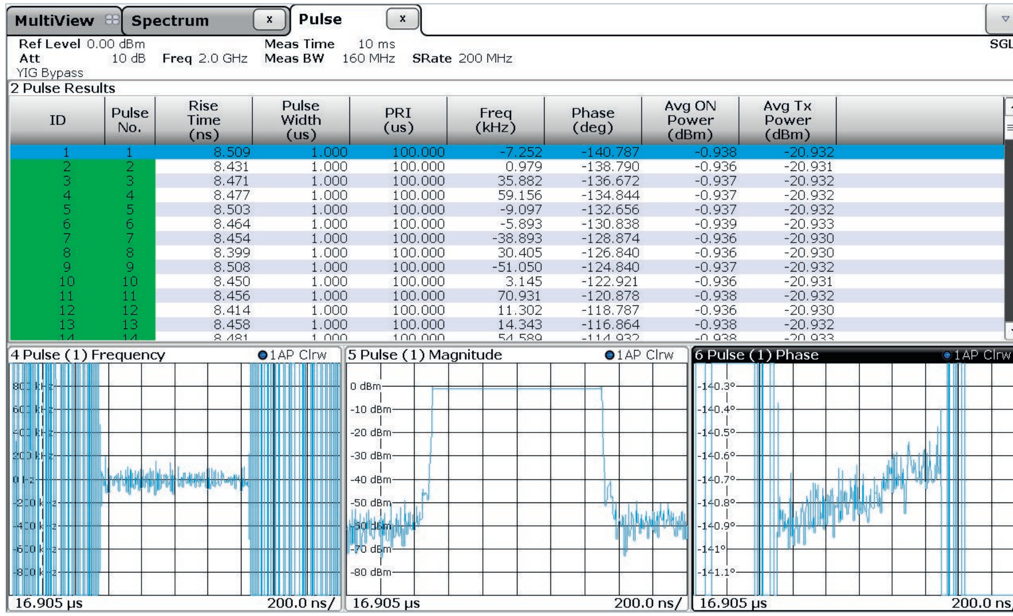
Spectrum analyzers are excellent tools for analyzing radar signals. They have a wider frequency range than oscilloscopes and allow detailed measurements of phase and frequency within a pulse. This is not possible with simple pulse analyzers. Spectrum analyzers have made great strides over the last few years with regard to analysis bandwidth. The R&S®FSW signal and spectrum analyzer (shown on page 30), for example, now offers an analysis bandwidth up to 2 GHz and a frequency range up to 85 GHz. This makes it possible to analyze even very short pulses, with the result that spectrum analyzers have replaced oscilloscopes. In addition, features such as rapid identification of spurious emissions, low phase noise and extensive pulse analysis functions running as software directly on the analyzer make the R&S®FSW an indispensable tool for the production and development of radar equipment.

Fig. 1 shows the result of the analysis of radar pulses using the R&S®FSW equipped with the R&S®FSW-K6 pulse measurements option. Pulses with a length of 1 µs and a pulse repetition interval of 100 µs were recorded at a 200 MHz sample rate. The table shows the most important parameters such as rise time, pulse width, PRI and frequency. The graphs below the table display frequency, magnitude and phase vs. time for an individually selected pulse (highlighted in blue in the table). The software allows further detailed analyses of pulse parameters such as rise and fall times, dwell time, settling time, overshoot and undershoot.

Segmented capture saves memory space and increases the analysis period

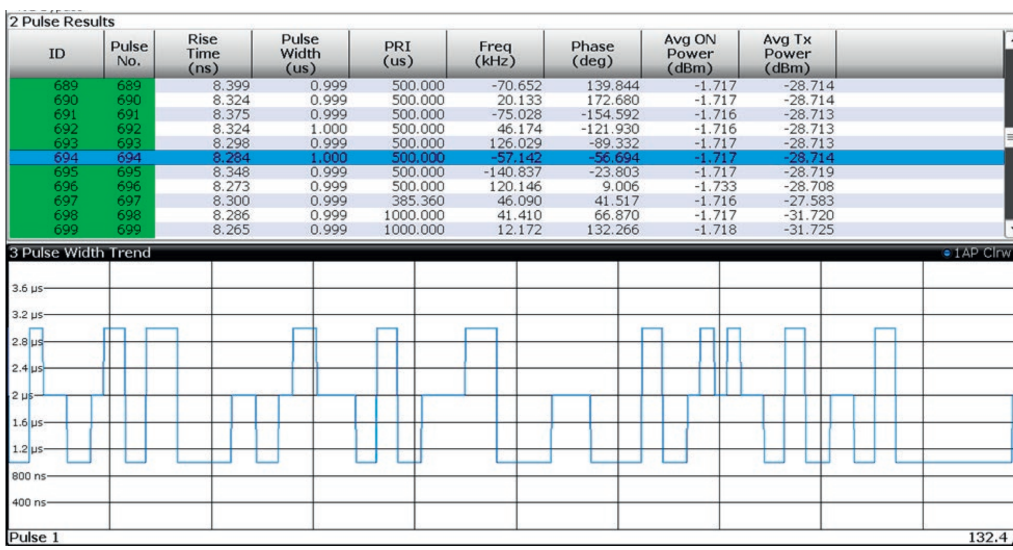
The high sample rates required and the limited memory space restrict the continuous recording and analysis period. The pulse analyzer software has been equipped with efficient signal segmentation and memory management so that pulse parameter trends can be analyzed by the R&S®FSW over a long period. The principle: superfluous data is omitted. The nature of pulsed signals is that only noise is recorded during the pauses. Omitting the noise while recording saves memory space and makes a longer recording time available.

This has been achieved with a simple yet effective algorithm. It ensures that the I/Q samples together with the time at which they were recorded are not saved to memory unless the power level has exceeded a specific threshold. Samples can also be saved before the trigger event. All additional samples up to the next trigger event are rejected. With typical duty cycles of 1 %, the maximum observation period can be increased by a factor of 100. If you take into account 50 % pre- and post-trigger values, i.e. a recording time of double the pulse length per pulse, then this still results in a factor of 50. Accordingly, a higher duty cycle increases the maximum recording time. The segmented recording of I/Q signals can be initiated by an external trigger and the internal power trigger.



ID	Pulse No.	Rise Time (ns)	Pulse Width (us)	PRI (us)	Freq (kHz)	Phase (deg)	Avg ON Power (dBm)	Avg Tx Power (dBm)
1	1	8.509	1.000	100.000	-7.252	-140.787	-0.938	-20.932
2	2	8.431	1.000	100.000	0.979	-138.790	-0.936	-20.931
3	3	8.471	1.000	100.000	35.882	-136.672	-0.937	-20.932
4	4	8.477	1.000	100.000	59.156	-134.844	-0.937	-20.932
5	5	8.503	1.000	100.000	-9.097	-132.656	-0.937	-20.932
6	6	8.464	1.000	100.000	-5.893	-130.838	-0.939	-20.933
7	7	8.454	1.000	100.000	-38.893	-128.874	-0.936	-20.930
8	8	8.399	1.000	100.000	30.405	-126.840	-0.936	-20.930
9	9	8.508	1.000	100.000	-51.050	-124.840	-0.937	-20.932
10	10	8.450	1.000	100.000	3.145	-122.921	-0.936	-20.931
11	11	8.456	1.000	100.000	70.931	-120.878	-0.938	-20.932
12	12	8.414	1.000	100.000	11.302	-118.787	-0.936	-20.930
13	13	8.458	1.000	100.000	14.343	-116.864	-0.938	-20.932
14	14	8.481	1.000	100.000	54.589	-114.932	-0.938	-20.933

Fig. 1: Result table of the R&S®FSW-K6 pulse measurements option. It shows the most important parameters of each pulse, such as rise time, pulse width and repetition interval, as well as frequency.



ID	Pulse No.	Rise Time (ns)	Pulse Width (us)	PRI (us)	Freq (kHz)	Phase (deg)	Avg ON Power (dBm)	Avg Tx Power (dBm)
689	689	8.399	0.999	500.000	-70.652	139.844	-1.717	-28.714
690	690	8.324	0.999	500.000	20.133	172.680	-1.717	-28.714
691	691	8.375	0.999	500.000	-75.028	-154.592	-1.716	-28.713
692	692	8.324	1.000	500.000	46.174	-121.930	-1.716	-28.713
693	693	8.298	0.999	500.000	126.029	-89.332	-1.717	-28.713
694	694	8.284	1.000	500.000	-57.142	-56.694	-1.717	-28.714
695	695	8.348	0.999	500.000	-140.837	-23.803	-1.717	-28.719
696	696	8.273	0.999	500.000	120.146	9.006	-1.733	-28.708
697	697	8.300	0.999	385.360	46.090	41.517	-1.716	-27.583
698	698	8.286	0.999	1000.000	41.410	66.870	-1.717	-31.720
699	699	8.265	0.999	1000.000	12.172	132.266	-1.718	-31.725

Fig. 2: Display of a 20 s recording time, showing that the radar system being analyzed operates in three different modes.

Evaluation of trends

Fig. 2 shows the pulse width vs. the pulse number over a recording time of 20 s. You can see that the radar device operates in three different modes (1 µs, 2 µs and 3 µs pulse width) which appear in random order. Without segmented recording, the maximum recording time would only be 2.3 s at a 200 MHz sample rate, which is not enough to see the pattern of the different modes.

Segmented recording expands the analysis period, allowing a series of many consecutive pulses to be recorded. This makes it possible to detect and analyze parameter trends and to track changes from pulse to pulse. Effects such as changing modes, for example, do not remain hidden.

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