Radar Signal Generation for Multi Emitter Environments for Meaningful Receiver Tests

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Abstract: *This paper proposes a new and innovative solution for radar signal generation in multi emitter environments. Traditionally, people use regular RF and microwave signal generators to stimulate radar warning receivers in order to measure the analog RF performance. Many different test cases allow to validate every single parameter. Yet, once test cases with more realistic signals become necessary for operational testing towards the end of the development cycle, it is quite a complex task to generate meaningful signals to stimulate the receiver in order to fully evaluate its performance. Dedicated test systems are available on the market and are traditionally used for these tasks, but they suffer from several technical drawbacks beyond the cost factor. These systems cannot generate continuous signals together with pulsed signals simultaneously as they normally use a fast hopping synthesizer concept. This paper introduces a novel solution which allows to generate complex RF signals for real world simulation scenarios based on commercially available PC software and vector signal generator hardware.*

1. Introduction

During the development cycle of electronic support measures e.g. radar warning receivers on board of ships or airplanes, different level of tests have to be performed. In the beginning of a development and verification cycle, all the well-known analog RF parameters like frequency response, linearity, matching etc. have to be tested with state-of-the art signal generators. Once it comes further to operational testing more real life signals are necessary in order to present challenging signals to the receiver and evaluate its capabilities under more demanding circumstances. In real world environments these receivers need to capture radar signals which are produced by multiple radar transmitters. The receiver scans the electro-magnetic spectrum and extracts the individual signals in order to determine its origin and threat level. In this case not only injection of a single waveform into the receiver under test is required but complex scenarios which include receive signals originating from multiple emitters. Emitters normally produce signals whose amplitude is also shaped by the emitter antenna diagram and antenna scan. In addition emitters apply mode changes according to the operational task which they have to perform. In total the generation of these environments becomes very complex and a multitude of waveforms including different emitter characteristics have to be produced and injected in the receiver. As there are no general standards for these kind of tests, engineering staff are responsible to define meaningful signals. This is an extremely time consuming task and occupies quite a lot of resources. Traditionally, there are dedicated solutions on the market which are uniquely designed to produce complex multi emitter signals. Yet, as they are especially designed for that task only, additional equipment for the initial measurement tasks for the analog RF performance is needed. With budgets for development going more and more down it would be desirable to maximize the use of commercial-of-the shelf test and measurement equipment by enhancing it with the capability to easily generate also multi emitter signals. In this paper a solution is presented for producing very clean and accurate microwave radar signals with vector signal generators up to 40 GHz. The required radar

waveforms are calculated with a commercially available PC software from Rohde & Schwarz (R&S®Pulse Sequencer software). With this PC software it is possible to calculate real life signals for multi emitter environments and generate the calculated signal(s) with vector signal generators from Rohde & Schwarz.

2. Generation of multi emitter environments for operational receiver testing

If complex signals are needed real world effects have to be considered. The PC software as mentioned above together with vector signal generators allows to create real world radar signals. In this software, the following features are included:

- Definition of complex pulses with modulation on pulse
- Support of all traditional modulation types
- Plug-in interface for proprietary modulation content
- Import of waveforms based on I/Q samples, e.g. telecom waveforms
- Availability to generate bursted and nested signals
- Antenna diagrams and antenna scans with motion for emitter and receiver
- Receive signal calculation based on emitter and receiver definition and locations with consideration of free space loss

All the before mentioned features can be used and combined into a simulated emitter. Emitters can be defined having multiple modes as they often occur in radar systems. The various modes can be predefined and called one after another for the simulation. Also multiple emitters can be configured e.g. surveillance radar emitters, multi-mode radar emitters or navigation radar emitters. In order to make scenarios more realistic the defined emitters can be placed on a 2D map together with a receiver in a graphical user interface of the R&S®Pulse Sequencer software by drag and drop. With this simulation environment the software allows to calculate the resulting signal as it would be produced in a real world scenario at the antenna output of a receiver. These signals then include the waveform and also the effects of antenna diagrams, antenna scans and free space attenuation. In addition the attitude of the emitters and receivers can be considered together with the height above ground of the individual emitter or the receiver. Figure 1 shows one example, where the radar receiver is located in the origin of the Cartesian plot. The receiver will collect all the transmitted radar transmit signals and the signal from interferers (e.g. a GSM base station).

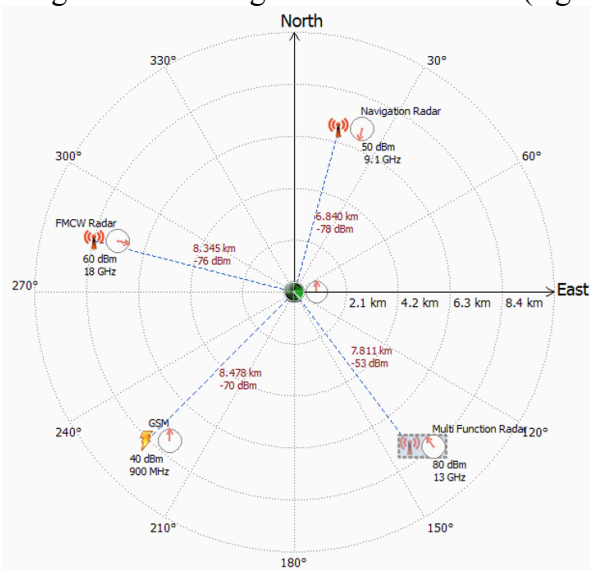

Figure 1. Simulation environment for 2D scenario simulation for 3 radar transmitters and one interferer and one receiver in the middle of the coordinate system.

All signals, propagation losses, beams, antenna diagrams and antenna scans are taken into account when calculating the receive signal at receiver.

The calculated signal(s) can then be used and injected into the RF input of a real receiver. The R&S SMW200 vector signal generator enhanced by additional RF paths (by adding a SGS100A signal generator combined with a SGU100A up-converter) provides the required hardware solution for putting the pre-calculated waveforms into the RF domain as shown in Figure 2. The SMW200A provides all the baseband signals for its own RF paths and also for the additional RF sources. With this software and hardware solution, it is now possible to stress the receiver and help to test the receiver's capability to detect the relevant signal(s) out of the multitude of received signals.

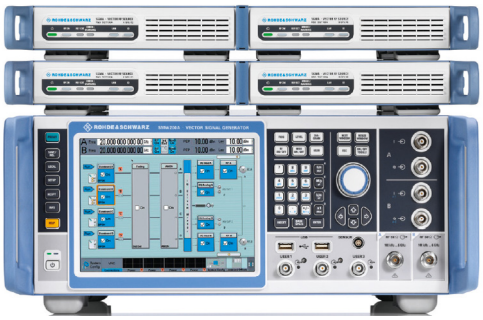

Figure 2: Hardware solution to produce 4 independent emitters up to 20 GHz with SMW200A vector signal generator enhanced by SGS100A vector signal generator and SGU100A up-converter

If general purpose vector signal generators are used to generate the RF signals, also emitters transmitting communications signals, CW or FMCW signals can be added to the simulation scenario together with emitters transmitting pulsed signals. By using vector modulators, limitations coming from fast hopping synthesizer concepts can be overcome. Fast hopping synthesizers cannot generate continuous signals together with pulsed signals due to the hopping among carrier frequencies of various emitters. So fast hopping synthesizers can either produce only one CW signal or only the pulsed signals with a certain dropout rate of the pulses.

Combining the signal generator hardware with the R&S®Pulse Sequencer software provides a compact, space-saving solution for multi-emitter target simulation that brings reality into the lab, significantly simplifying the testing of radar hardware with real-world radar signal profiles. With such a test environment in place built with vector signal generators, the receiver test cases can be built up from simple and basic pulsed signals all the way up to system level tests which include all the relevant contributions from realistic radar systems together with all relevant interferer coming from standard telecommunication signals for example. [1]

3. Phase Coherence

In order to identify the direction where a signal is coming from, multiple receive antennas and receiver chains are used. Testing the direction finding performance of these multi-channel receivers can be quite complex as real word scenarios need to be created in order to simulate signals originating from different directions. By evaluating the phase differences among the different receive antennas, the origin of the signal can be identified. These tests can be simplified by using phase coherent multi-channel vector signal generators. They allow to vary the phase from channel to channel deliberately in order to generate signals with a defined

phase difference. The following figures show the simulation scenario and the test set-up with the signal generators SMW200A, SGS100A and SGU100A in a phase coherent configuration. In this set-up, four RF signals are created in a phase coherent manner. Now, phase offsets can be applied in the digital basebands of the signals generators in order to create the different receive signals as they would occur at the output of the four receiving antennas.
More details on phase coherent set-ups and the long term performance of phase coherent signals is given in [2].

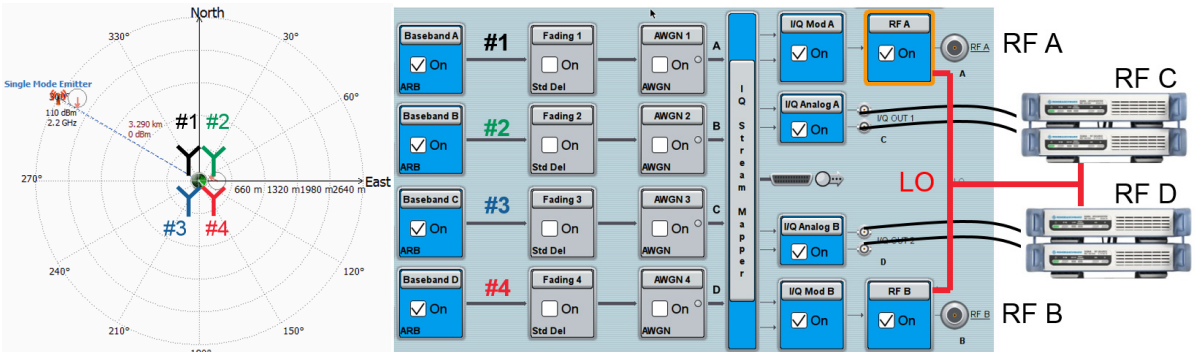

Figure 3: Simulation Scenario for a four channel receiver and one emitter (left) and a corresponding test set-up with a dual channel SMW200A enhanced by additional SGS100A and SGU100A signal generators to provide four phase coherent signals (right).

4. Conclusion

In this paper a novel solution to generate multi emitter environments with commercial of the shelf signal generator hardware and software is presented. This solution allows to use the measurement equipment not only for early stage verification but also later in the operational evaluation and verification phase. The R&S®Pulse Sequencer software offers a predefined tool box out of which all the complex signals can be created from a top-down or bottom-up approach. Together with the tailor made vector signal generator hardware, an off-the-shelf solution is available to produce realistic multi emitter scenarios for receiver testing.

References:

[1] Simplify pulse and emitter generation for radar testing, Application Card 01.00, Rohde&Schwarz GmbH & Co. KG, 2015
[2] Multichannel coherent signal generation, Application Card 01.00, Rohde&Schwarz GmbH & Co. KG, 2015