CAD model of a radar receiver, with typical radar scenarios, in combined ADS and Matlab environment

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Abstract

In the design of radar receiver systems a suitable simulation environment is useful. In this work a model of a radar receiver (with both analogue and digital parts in the same model) has been extended with typical radar scenarios. This makes it a complete model of a radar receiver where both the performance of the system and the parts of the radar receiver, i.e. RF parts, A/D converter and digital filters can be evaluated. The simulations are done in Agilents software Advanced Design System (ADS) with some parts of the model using ADS models and some parts as Matlab models implemented in ADS.

RADAR RECEIVER MODEL

The simulations are done in Agilents software Advance Design System (ADS). In the model the RF parts uses ADS component models and the models of the signal generator, A/D converter and digital filters are made in Matlab. The simulator has an ADS environment interface into which the user can add the Matlab models of some components of the receiver. This model of a radar receiver has originally been developed by FOI, LiU and Ericsson Microwave Systems [1]. In this work typical radar scenarios has been added to the model to make it useful for evaluation of the performance of different parts of the receiver and the complete receiver. Fig. 1 shows a schematic description of the model.

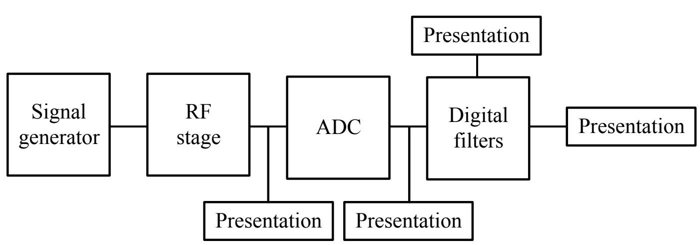

Fig. 1. Schematic description of the radar receiver model.

In order to evaluate the receiver model some input signals and different presentations made in Matlab have been implemented in the model. The signal form used for the simulations is a saw tooth FMCW signal with a carrier frequency of 10 GHz (X-band) and a sweep bandwidth of 75 MHz. The signal is multiplied with a reference signal so that as much of the sweep as possible is used and the incoming signal lies within the receiver bandwidth. The sweep bandwidth can be increased to get a better range resolution. The signal generator, based on Matlab, can be set to generate one or more targets at different ranges from the radar. Their speed and input power to the radar can be set individually. This makes it possible to test the radar model for e.g. resolving a weak target echo near a strong echo.

Linearity and Spurious Signals

With the ability to test the receiver for different target scenarios it is possible to measure the intermodulation (IM) products created when two nearby signals, equal in magnitude, are injected into the receiver and get a measure of the spurious free dynamic range, [2], of the receiver. For the IM product measurement two targets at distances yielding frequencies f1=2,34 MHz and f2=2,74 MHz above centre frequency were simulated. The input power was varied from –100 dBm to –10 dBm. The thermal noise level was –174 dBm/Hz and the components in the receiver were set to have good performance, such as a 3 dB noise figure of the first amplifier in the RF part and an ADC jitter of 0.5 ps [1]. Shown in Fig. 2 are the two output signals at f1 and f2, which should have a slope of 2 for small nonlinearities, versus input power. Also shown are the 3:rd order IM product 2f1+f2 and the output power of the interfering DC component, which originates from LO leakage in the mixer.

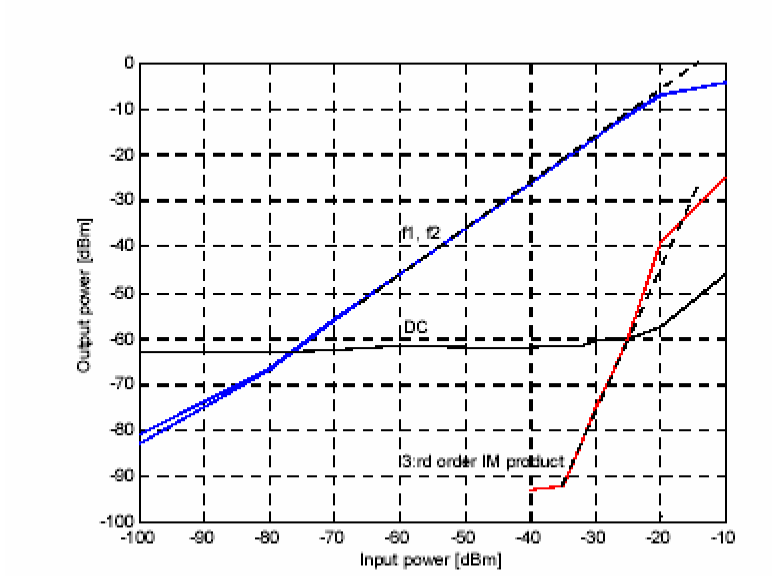

Fig. 2 Output signals at f=f1, f=f2, f=2f1+f2 and DC.

When there is only a small non-linearity the 3:rd order IM product has a slope of 3 but the slope increases when compression of the fundamental signal starts at about –25 dBm (compare with the dashed lines). The spurious free dynamic range is just above 65 dB. Similar results are shown for the other 3:rd order IM products. From input powers of –10 dBm and above the higher order IM products will also interfere significantly in the output spectrum.

Gain and phase imbalance

Since the model uses digital filters to split the signal into its in-phase (I) and quadrature (Q) components there are no gain or phase imbalances induced between the I and Q channel. But in a radar receiver using an analogue I/Q demodulator there can be imbalances leading to degradation in dynamic range and creation of false targets. The receiver model includes the parameters gain and phase imbalance and they were set to 4 dB and 9 degrees respectively for the simulation. Fig. 3 shows two targets at equal range but moving at different speeds. The imbalances cause peaks at the image frequencies to appear in the output spectrum. It can be seen in Fig. 3 that these image frequencies create false targets in the plot.

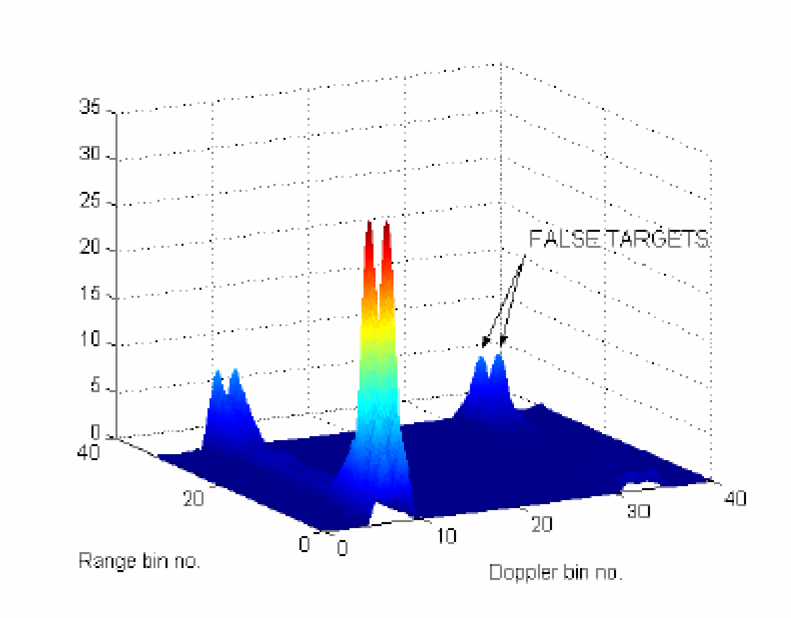

Fig. 3 Range-doppler plot showing the false targets that are due to gain and phase imbalances.

Cell-averaging CFAR

A cell-averaging threshold has been implemented, [3]. This can be set to a specific level depending on the amount of noise to keep the false alarm rate down. An example is shown in Fig. 4.

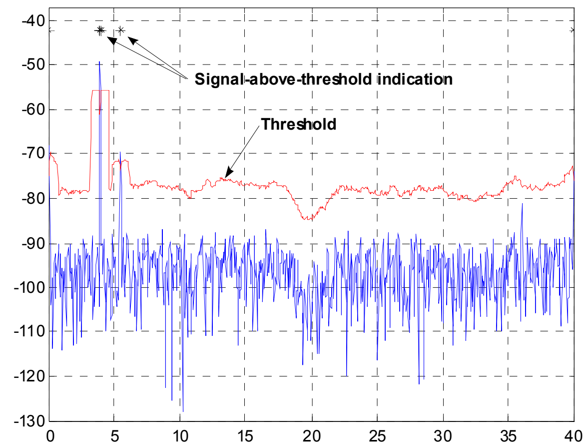

Fig. 4. Signal spectra and threshold level. y-axis in dBm,
x-axis in MHz above centre frequency after conversion into baseband.

CONCLUSION

An integrated simulation environment of a radar receiver has been extended to make it possible to simulate different target scenarios and show effects on detectability of targets when component parameters are changed. That makes it possible to evaluate different parts of the radar receiver and the complete system. The model is then a suitable CAD model of a radar receiver with typical radar scenarios included. Simulations show that, for example, the receiver model produces intermodulation products making it possible to do simulations similar to measurements on real hardware.

REFERENCES

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