Design and Implementation of an Automatic Cruise Control Radar for Smart Vehicle

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Abstract

Smart vehicles are evolving for collision avoidance after the success stories of airborne SAR for air traffic detection and control. Efforts for the development of such vehicular radar using spread spectrum waveform are attempted by authors. Model based design and simulation of the radar system along with target modeling and ISAR imaging are successfully completed. Baseband and IF portion of the radar model are realized by uploaded and downloaded to Arbitrary waveform generator and Vector signal generator respectively. The total radar system with ISAR Imaging are successfully tested at the open range of the authors premises with multiple standard targets.

1. Introduction

AWACS (Airborne Warning and Control System) is a Synthetic Aperture Radar system that are used extensively in surveillance purposes to detect and track airborne targets. Also SAR provides high resolution maps of remote terrain and other targets. Now with the tremendous growth of VLSI, vehicles are now commercially available with multiple collision avoidance radars having both Short Range Radar(SRR) and Long Range Radar (LRR) versions [1][2]. Vehicles on road having such types of radars detect nearby vehicles and invoke ACC (Adaptive Cruise Control). With a motivation to realize an ACC radar in modern vehicles, efforts are imparted by the authors to implement one such radar with spread spectrum waveform[3]. CAWAS (Collision Avoidance and WArning System) model is popular and is effectively the modified version of AWACS model.

2.The Theory of Spread Spectrum Radar Operation: The Barker Code for Radar Operation

Barker code for the spread spectrum radar is the choice of waveform for Author's work. Lots of performance benefits is expected as compared to its analog LFM counterpart. Criterion for the selection of a good 'random' phase coded waveform is that its auto correlation function should have equal time side lobes. Barker codes, which are subsets of PN sequences, are commonly used in digital communication systems and digital radar.

Autocorrelation is one of the major tools to be used for better rejection of clutter. The mathematical expression of the corresponding Autocorrelation Function is as below:

$$R_c(\tau) = \frac{1}{T_b}\int_{-T_b/2}^{T_b/2} c(t)c(t-\tau)\,dt$$

Where, $R_c(\tau)$ is the Autocorrelation Function. The $R_c(\tau)$ & τ will be measured at the receiver to evaluate the RCS and Range of the target respectively.

3.The Simulation of the Spread Spectrum Radar

3.1 The Simulation of the Radar Model with a Single Target

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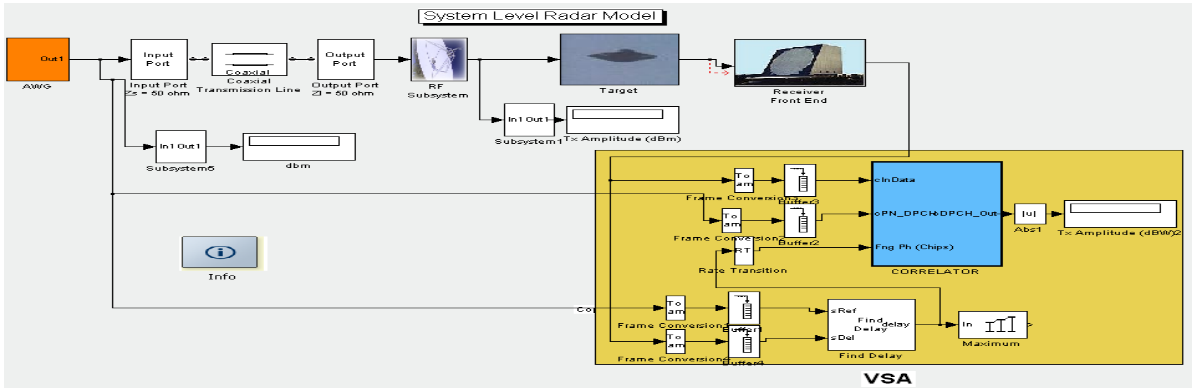

Fig. 1: The END-TO-END Simulation of the spread spectrum radar

Fig. 1 shows the total radar which is modeled using model based Simulink software. AWG(Arbitrary Waveform Generator) is utilized as part of baseband and IF section of the transmitter. Each sections are discussed in details below.

Baseband part of the Transmitter Section mainly consists of pulse generation and its modulation (BPSK). Here continuous Barker Code (13 bit) is first being converted to pulsed Barker code by multiplying it with a pulse having 6% duty cycle. An offset of 1 is then provided to the pulsed Barker code so as to shift the level and make it compatible for Modulation. After the offset, BPSK Modulation is being done and the modulated signal is fed to the next stage.

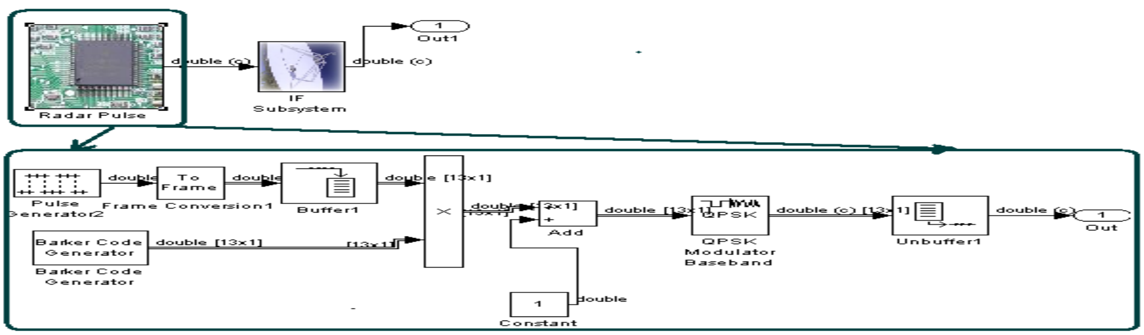

Fig. 2: Realization of the blocks in AWG through downloading

The output of BPSK modulated baseband signal is up-converted to the intermediate frequency of 70MHz with the help of an up-converter mixer. Here we introduced a GAIN block so as to attain the power level of 17 dBm (as per the specification of the AWG the output power level of the signal is of 17 dBm). Thus at the output of the AWG we have 70 MHz up-converted pulsed barker code with output power of 17dBm.

In RF Subsystem, the signal is again up-converted to RF level of 2.1 GHz using RF mixer. The RF signal is then band limited using band pass-pi filter. The band limited signal is then amplified using TWT amplifier and transmitted using Antenna. The RF section is modeled as in Fig. 3.

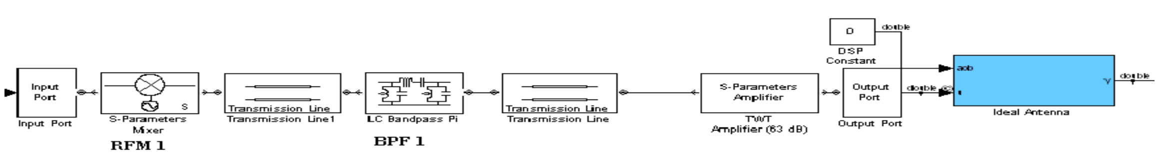

Fig. 3: Block Diagram of RF Section of Transmitter

The target is modeled as in Fig. 4 using the basic radar equation and there is the provision of changing target cross section, target distance. The target can be placed up to a maximum distance of 2000m away from the transmitter.

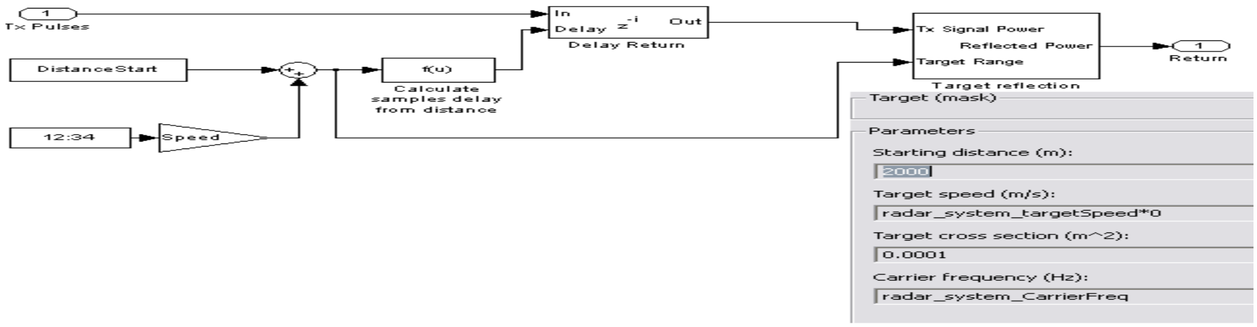

Fig. 4: Single Target Model

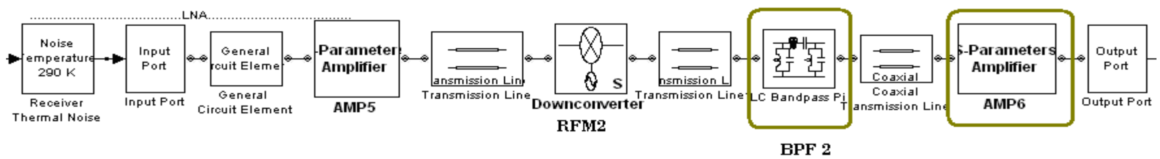

Fig. 5: Block Diagram of RF Section of the radar receiver

At the receiver front end, the received signal is first feed to a LNA(Low Noise Amplifier) and down converted to the IF level (i.e. 70 MHz) after amplifying by 45 dB amplifier. IF signal is again band limited using 70MHz band pass-pi filter and once again amplified by an amplifier having a gain of 37dB.

Autocorrelation is the one of the vital part of the system that provides uniqueness to this Radar system. The first operation of autocorrelation block is bit by bit synchronism of the Received and Transmitted IF and then bit by bit multiplied, integrated and dumped. This auto correlated value represents the presence of target and the delay represents the target distance from the transmitter antenna.

3.2 Simulation Result

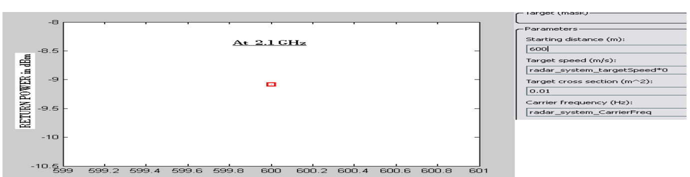

Fig 6: Identification Of Target (-20dBsm) at 600 meter distance

Fig 6 shows the target at different position. In the figure X-axis represents the target distance in meter where as Y-axis represents the received signal power. Here distance of the target is calculated by calculating the relative time delay between the received signal and transmitted signal. The above simulation model is updated towards Range-Doppler imaging. Data acquisition involves a range and Doppler extraction from the model with 181X 21 matrix which is then processed through ISAR processing and 2D matched filtering. One such range Doppler image is similar to the hardware experimental results of Fig. 9.

4. The Hardware Realization

4.2 Experimental Results

4.2.1 Measurement of Target Range

In the Laboratory, instead of vehicles, standard metal surfaces like two Flat Plates of dimension (0.68m x 0.91m) and (1m x 1m) are placed in front of the radar to measure the range between the two. The range and range resolution are tested and is shown in Fig.7. Thus, the targets are well resolved using spread spectrum radar.

4.2.2 Clutter Rejection Through Auto-correlation

Autocorrelation process is applied in the measured target data as discussed earlier. Careful observation of Fig.7 reveals that the unwanted peaks are vanished from the plot. It is clearly visible that around the Target Zone,. This implicates that the Ground clutters are rejected significantly over the Target Zone. [4]

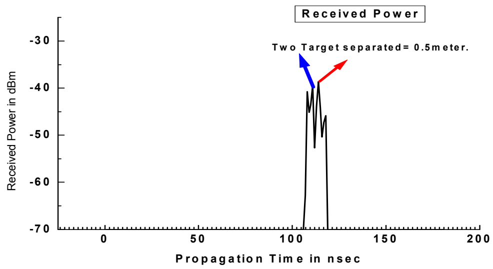

Fig.7: Range estimation for double targets
(R_1= 16.55m, R_2= 17.1m).

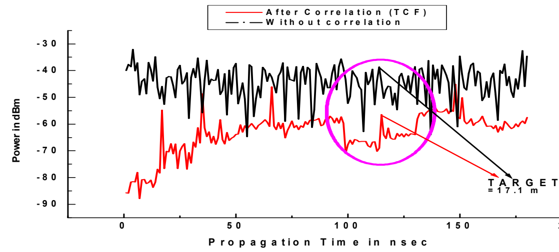

Fig. 8: Clutter rejection using Auto-correlation with
Transmitted barker Code

4.2.3 Target Cross_Range Estimation and Target Imaging

We have taken data for total 21 angular orientations (θ =23.5° to 29.5°; step = 0.3°) and 181 data points along range dimension. Thus we have collected the [181 x 21] matrix data which will be processed following Fig. 9 to form the image [5].

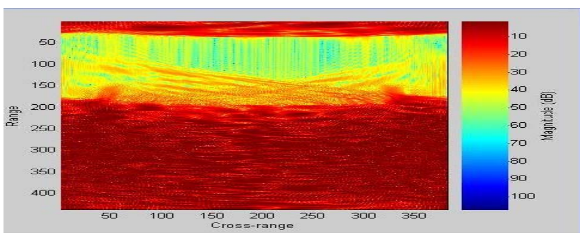

Fig.9(a): Before Interpolation

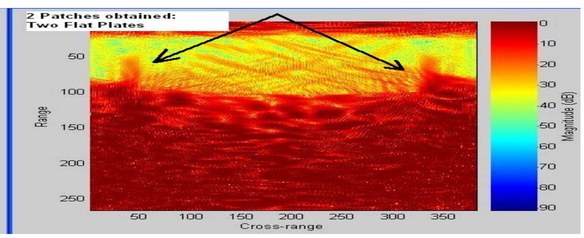

Fig.9(b): After Interpolation

Two Patches are obtained as in Fig. 9(b) for two Flat Plates which are resolved along the Cross Range as well as Down Range.

5. Conclusion

The Simulations are complete end to end simulation including radar transmitter, target model, radar receiver, radar DSP and ISAR imaging. Based on those complete simulation, relevant instruments, components and items are purchased to built the complete radar. Even some of the blocks of simulations are uploaded and downloaded to AWG and VSA for the realization of baseband and IF waveforms. The RF portion of the radar are realized using discrete components. The total radar performance are tested and range cross range imaging using ISAR technique are tried at the authors premises using standard target. The system is now ready for field trial. In summary, it is a successful attempts using spread spectrum waveform which has lots of benefits in radar operation like interesting clutter rejection and others. The 76 GHz is standardized for ACC radar operation. So, one of the major limitation of our system is that we have attempted the radar development at 2-3 GHZ RF band where advantages of 76 GHz RF millimeter wave was absent. So, in further attempts, the same radar will be testM. ed at 76 GHz exploring a bandwidth of 100 MHz.

6. References

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