

# Development of an Ultra-Wideband Radar System for Vehicle Detection at Railway Crossings

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**Abstract** – This paper describes an ultra-wideband (UWB) radar system designed to detect motor vehicles such as cars and trucks when they are present in a railway crossing. Once fully developed, the detection performance of the system is to be compared against a video detection system in a test at a crossing in Maywood, Illinois. If the test is successful this system may be further developed and installed at a four-quadrant gate crossing to sense vehicles trapped in the crossing island (i.e. the area bounded by the gate arms). This paper describes the problem at hand and gives details of the radar system development to date. With the current prototype, a pulse width of 3 ns has been achieved, which yields adequate range resolution for this application.

## I. INTRODUCTION

According to statistics compiled during 1994 by the Federal Railroad Administration, 610 people were killed and 1,923 injured in 4,921 highway rail-crossing collisions.[1] More than 50 percent of those crashes occurred at public crossings where active warning devices such as gates, lights and bells were present and functioning properly. In many cases, these crashes occur when drivers ignore the warning devices. The result can be deadly, as motorists are 30 times more likely to die in an accident involving a train than in a collision with another motor vehicle.

One particular problem is when motorists drive around the crossing gates while they are down. These motorists may believe that the warning system is malfunctioning or that they can beat the train. One method being studied by the railroad industry to stop these drive-arounds is to use gates that span all lanes of traffic on both sides of the tracks. This arrangement, known as four-quadrant gates, effectively blocks cars from entering the crossing island, or the rectangular area where the road and the rails intersect.

The use of four-quadrant gates, however, also prevents vehicles from conveniently exiting the island if they happen to be in the island area when the gates start coming

down. A sensing system that can detect the presence of a vehicle in the crossing island and raise the gates to provide the vehicle an easy exit path offers a solution to the problem. A number of potential technologies can be used, but ultra-wideband, impulse radar has the potential to provide an all-weather, inexpensive, and fail-safe solution.

Other sensors that could be used in this application include buried inductive loops, video cameras, and traditional radar. Buried inductive loop are loops of wire that are buried under the pavement. When magnetic materials, such as steel, come near the loop the impedance changes and this change is sensed. Most railways companies prefer not to use buried loops because of the need to tear up roadways and perform maintenance in cooperation with highway departments. Another possibility is video cameras, which can be mounted on railway cantilevers. The problem with video is that the cost is high and video solutions are not all-weather capable. Traditional radar is all-weather capable, but costs more than ultra-wideband radar.

In this paper an ultra-wideband radar system is described that will be installed in the Chicago area and tested to see how well it performs as a motor vehicle detector. Section II covers issues associated with the engineering of the system, Section III describes the system, and Section IV describes the planned experiment, and Section V concludes the paper.

## II. SYSTEM ENGINEERING

Figure 1 shows the railway crossing in Maywood, Illinois where the system is to be installed and tested. This intersection features four lanes for vehicular traffic, two railroad tracks, and a full compliment of active warning devices including flashers, flashers on cantilevers, and gate arms.

The problem at hand is illustrated in Figure 2, which shows vehicles in the crossing island. This figure depicts three vehicles. One in the crossing island, one not in the island, and one partially in the island. The job of the

This work was supported in part by LaBarge, Inc.



Fig. 1. Railway crossing in Maywood, Illinois.

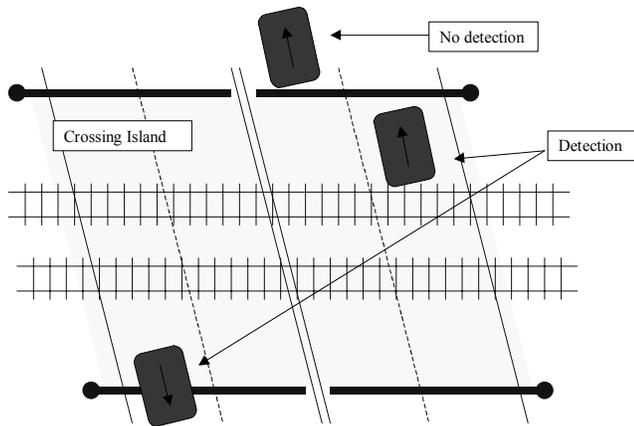


Fig. 2. Detection of vehicles in crossing island.

sensor system is to detect vehicles that are either wholly or partially in the crossing island and raise the exit gates if vehicles are detected.

Beam interruption and zone detection are two methods for detecting objects using radar. With beam interruption, a beam is directed toward a reflector and if the beam is interrupted the received power will be reduced indicating an object in the beam. With zone detection a radar with range resolving capability is used to detect objects at different ranges. In this case the objects to be detected must have stronger returns than the background. For this installation, zone detection using two radars was selected. Figure 3 shows the layout of how the radars will be installed. Two radars are required to cover the necessary area both having a beamwidth of  $50^\circ$  in the horizontal plane. If one radar were to be used, the beamwidth would need to be widened reducing the gain and lowering the sensitivity at more distant ranges. Placement of the radar would also be difficult since constant range arcs make determining the presence of a vehicle within a rectangular crossing island difficult as can be seen in the figure.

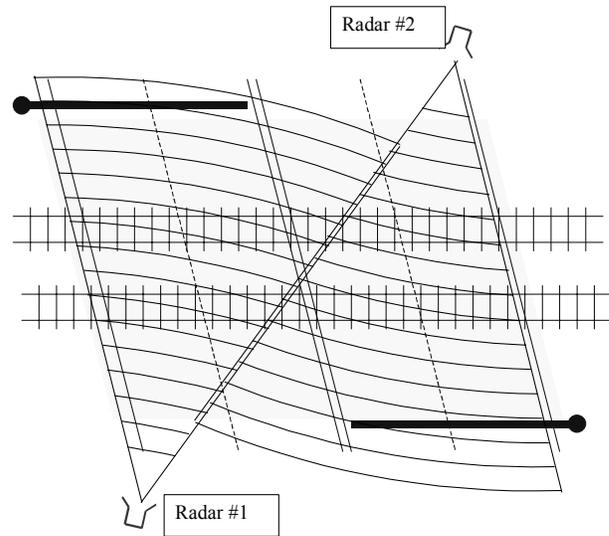


Fig. 3. Layout of radars in crossing island showing arcs of constant range.

One advantage of a radar sensor over a sensor operating at optical wavelengths is the ability to operate in all weather conditions. There are two effects that weather can have on electromagnetic waves in a radar application. First, the weather particulates can attenuate the signal as it passes through the medium, reducing the power with increasing distance, which decreases the sensitivity of the sensor. At the short ranges involved in this application, attenuation due to rain, snow, fog, and dust is negligible. Second, weather particulates can scatter energy back towards the radar. If the backscattered return from the particulates is larger than the backscattered return from the desired targets than this return will mask the desired targets. Table 1 lists the expected radar cross section of the desired targets[2] and the weather (or clutter) targets[3]. Since the clutter RCSs are normalized to remove the effects of resolution volume and wavelength and expressed in units of dBZ, additional denormalizing calculations were performed to facilitate comparison. For our radar a reduction of 90 dB is required. As can be seen from the table, the clutter targets will not have sufficient radar cross sections to mask the returns from the desired targets.

### III. SYSTEM DESCRIPTION

The heart of the system is the pulse generator, which generates a carrier-free short pulse of moderately high voltage. Figure 4 shows the pulse generation board, and Figure 5 shows the waveform generated by the circuit. The pulse has a rise time of 655 ps, a fall time of 2.16 ns for an approximate pulse width of 3 ns yielding a range resolution of 45 cm. The bandwidth of the pulse was measured on a spectrum analyzer to be 1.77 GHz.

TABLE I  
RADAR CROSS SECTIONS OF DESIRED VS. CLUTTER TARGETS.

Target	RCS (dB)	Reflectivity (dBZ)
Truck	23	
Car	20	
Bicycle	3	
Person	0	
Heavy Rain	-40	50
Light Rain	-70	20
Snow/Drizzle	-85	5
Drizzle	-85	5
Fog	< -85	< 5
Dust	< -85	< 5

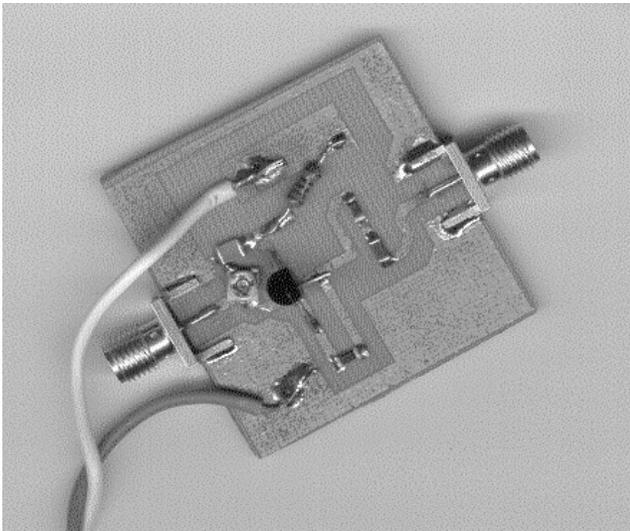


Fig. 4. Pulse generation circuit.

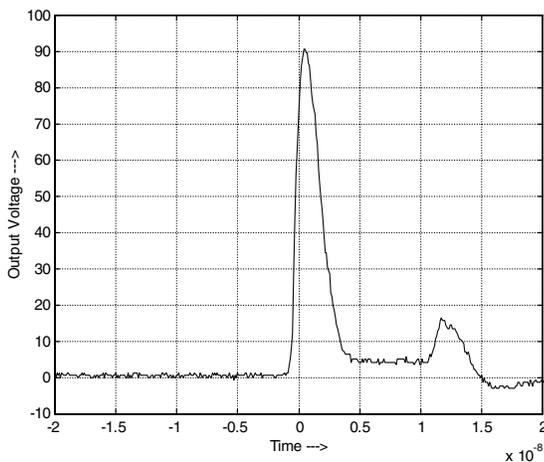


Fig. 5. Pulse generation waveform.

The pulse is triggered at a random time within the pulse repetition period. The actual delay is generated by a pseudo-random number generator feeding a digital delay chip. This

allows the two radars to operate simultaneously and not interfere with one another[4].

The transmit and receive antennas are WiNRADiO AX-31B printed log-periodic antennas that operate from 400-1400 MHz. Log-periodic antennas are dispersive by nature, but for this application a degradation in range resolution due to dispersion is acceptable.

Pulses are received by a matched-filter, correlation receiver consisting of a broadband Mini-Circuits receiver that uses a delayed and attenuated copy of the transmit pulse as its local oscillator (LO) input. This feeds an analog op-amp integrator that performs coherent integration.

#### IV. DESCRIPTION OF EXPERIMENT

The system is to be installed at the railway crossing shown in Figure 1. It is to be operated in parallel with a video sensing system. The detections from the video system are to be compared with the vehicle detections sensed with the UWB radar system to determine whether the performance of the UWB system is comparable to the video system. If so, then the UWB system may be deployed at a four quadrant gate installation.

#### V. CONCLUSIONS

This paper describes a UWB radar system design to detect vehicles such as cars and trucks when they are present in the crossing island. It is not designed to detect the presence of trains, but they could certainly be sensed if desired, since their radar cross sections would be larger than those of motor vehicles. To date the system components have been tested on the bench top, and integration of the components into a fieldable system is in progress. Once integration has been completed the system will be installed and tested at a railroad crossing in Maywood, Illinois to determine how the system performs compared to a video detection system.

#### REFERENCES

- [1] *Highway-Rail Crossing Accident/Incident and Inventory Bulletin, No. 17, Calendar Year 1994*, U.S. Department of Transportation, Federal Railroad Administration, Office of Safety.
- [2] M. I. Skolnik, *Introduction to Radar Systems*, 3<sup>rd</sup> Ed., McGraw-Hill, 2001, p. 64.
- [3] F. T. Ulaby, R. K. Moore, A. K. Fung, *Microwave Remote Sensing: Volume 1*, Addison-Wesley, 1981.
- [4] R. A. Scholtz, "Multiple access with time-hopping impulse modulation," *IEEE MILCOM '93*, Boston, MA, Oct. 11-14, 1993.