# Detection and Classification of Objects from Their Radio Shadows of GPS Signals


**Chr. Kabakchiev[1], I. Garvanov [2], V. Behar [3], D. Kabakchieva [4], K. Kabakchiev [5], H. Rohling [6], K. Kulpa [7], A. Yarovoy [8]**

[1]Sofia University, Sofia, BULGARIA
ckabakchiev@fmi.sofia-uni.bg

[2]University of Library Studies and Information Technologies, Sofia, BULGARIA
i.garvanov@unibit.bg

[3]Institute of Information and Communication Technologies, Sofia, BULGARIA
behar@bas.bag

[4]University of World and National Economy, Sofia, BULGARIA
dkabakchieva@unwe.bg

[5]University of Birmingham, Birmingham, UK
kalin.kabakchiev@gmail.com

[6]Technical University of Hamburg-Harburg, Hamburg, GERMANY
rohlingr@tu-harburg.de

[7]Technical University, Warsaw, POLAND
kulpa@ise.pw.edu.pl

[8]Technical University, Delft, THE NETHERLAND
a.yarovoy@irctr.tudelft.nl



***Abstract:*** *The paper focuses on scientific issues related to new application of GPS in radar networks using the effect of Forward Scattering (FS) of electromagnetic waves to detect, locate and classify objects by their GPS radio shadows. The aim of the paper is to make experimental studies of GPS radio shadows of different objects irradiated by GPS signals and to develop methods and algorithms for automatic detection, estimation and classification of the shadows of these objects. The practical utility of the results obtained is to use a specific processing of the received signal in the GPS receiver, then to use the extracted information for positioning and classification of moving objects; for accurate assessment of the geographic location of fixed objects by method triangulation in systems for transport management, security of zones, subsequent identification of the detected objects from digital geographical maps.*


## 1. Introduction

The main idea is that radio shadows contain valuable information about the objects that can be used to improve the performance of systems with secondary application of wireless technologies. These technologies are FS passive bistatic positioning systems based on radio communication or radio navigation systems, in particular the GPS system. Normally in conditions of radio shadow of the subject these passive radio systems lose the object. When the object is close to the line between the transmitter and the receiver, the receiver loses the reradiated signal from the object (radio shadow). When the user of the GPS information moves in urban, he kept losing signal because of tall buildings or trees, bridges, etc..

Forward Scattering Radar operates in the narrow area of the forward scattering effect where the bistatic angle is close to $180^0$, and the target moves near the transmitter-receiver baseline (Fig.1) [1].

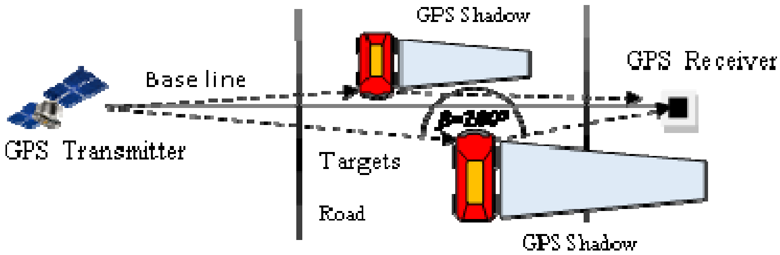


Figure 1: GPS FSR topology

Due to the forward scattering effect, the Radar Cross Section (RCS) of targets extremely increases (by 2-3 orders) and mainly depends on the target's physical cross section and is independent of the target's surface shape and the absorbing coating on the surface. The use of GPS signals as a passive radar system is becoming increasingly popular as an alternative to radar systems. The idea to apply a GPS L1 receiver to FSR for air target detection is discussed in [2]. Some experimental results of a GPS L1 receiver concerning the detection of air targets are shown and discussed in [3]. A possible algorithm for air target detection in a GPS L5-based FSR system is described in [4], and the detection probability characteristics are calculated in [5] in case of low-flying and poorly maneuverable air targets in the urban interference environment. GPS L1 FSR system is researched in [6, 7] for detection of FSR shadows from stationary ground objects. Target detection is indicated if the signal integrated from some satellites exceeds a predetermined threshold.

The main goal of this paper is to study, theoretically and experimentally, the dependence of target detectability on the distance between the GPS receiver and the target in the GPS based FSR system. A passive FSR system, in which GPS satellites are exploited as non-cooperative transmitters, is studied. The aim of this study is to verify the possibility to detect FSR shadow of moving ground targets when GPS satellites are located at small elevation angles. The experimental scenario includes a set of moving targets and a stationary-based FS-GPS system that registers FS shadows of targets.

## 2. FSR Experiment Description

The experimental scenario includes targets moving into two directions and a stationary FS-GPS system that registers FS shadow formed by ground moving targets (see figure 1). The GPS receiver is positioned at one side of the road. The purpose of the experiments is to verify that with a small and omnidirectional commercial GPS antenna is possible to register differences in GPS FS shadows of moving targets depending on their size and velocity, and also to verify whether the differences in the shadows allows classifying the objects (Fig.2).


Figure 2: Experimental equipment

The paper describes an experimental scenario where a moving targets move on a road and a stationary-based FS-GPS system that records FS shadows formed by moving targets (see Fig.1 and Fig.4). It is assumed that during the experiment, the conditions for the occurrence of the FS-GPS effect are guaranteed. During the experiment the GPS receiver is positioned from the one side of the road and records the signal from GPS satellites. Only such visible satellites, which are located at low elevation angles and form a baseline (between satellite and receiver) perpendicular to the road are selected and there signals are recorded because in that case the FS effect is formed. Moving objects passing on the road have different dimensions (cars, peaple, cycler and etc.). The purpose of these experiments is to check whether the type of the registered FS shadows depends not only on the type of objects, but also their speed. The dependence of the type of FS shadows on the size and speed of the marine targets using coastal FSR radars is established in [1].

## 3. Signal Processing

The general block-scheme of a possible algorithm for FSR shadow detection is shown in Fig 3 [1, 8]. According to this block-scheme, several visible GPS satellites are acquired and tracked over the complete duration of recorded signals. We consider the case when the acquisition and tracking algorithms of a GPS receiver are implemented in MATLAB. The absolute values of the *Ip* component at the output of the Code&Carrier tracking block are then integrated during *N* milliseconds. Target detection is indicated if the integrated signal exceeds a predetermined threshold *H*.

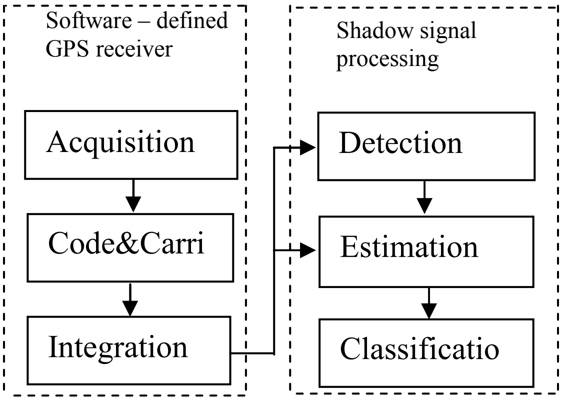


Figure 3: The general block-sheme of signal processing for target detection, parameter estimation and classification used in a passive GPS based FSR system

## 4. Experimental Results

GPS receiver is located on one side of the road at a height of one meter from the ground (Fig.4).


Figure 4: Experiment topology:

The street has four lanes with a width 3 m, two in one direction. On the west of the receiver is a high building, so the GPS receiver only receives signals from the GPS satellites on the east. During the experiment, several cars travel at velocity about 30 - 40 km/h in relative to the GPS receiver. The position of the visible satellites and the intensity of the incoming signals from them are shown in Fig. 5 and Fig. 6.

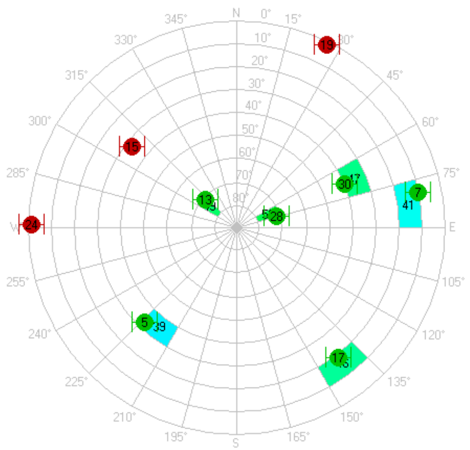


Figure 5: Satellite constellation

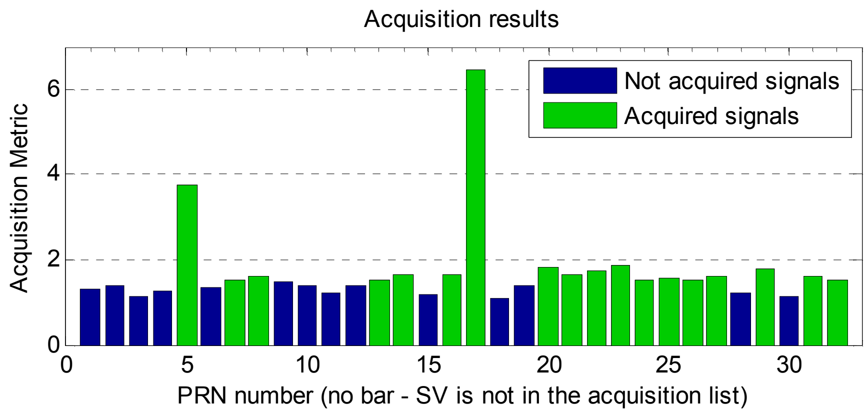


Figure 6: Acquisition results

It can be seen that during this experiment six satellites are visible, one of which with number 17 create the best conditions for the occurrence of the FS effect. It is the most low on the horizon and the car crosses the baseline "satellite - receiver" at the angle of about 90 degrees.

To detect radio shadows of moving targets the averaging algorithm is used with an interval of integration 200 ms. Figure 7 shows the GPS radio shadows of three moving targets (car, pedestrian and bus). For classification of these objectives, it is necessary to evaluate their parameters in the time/frequency domain.

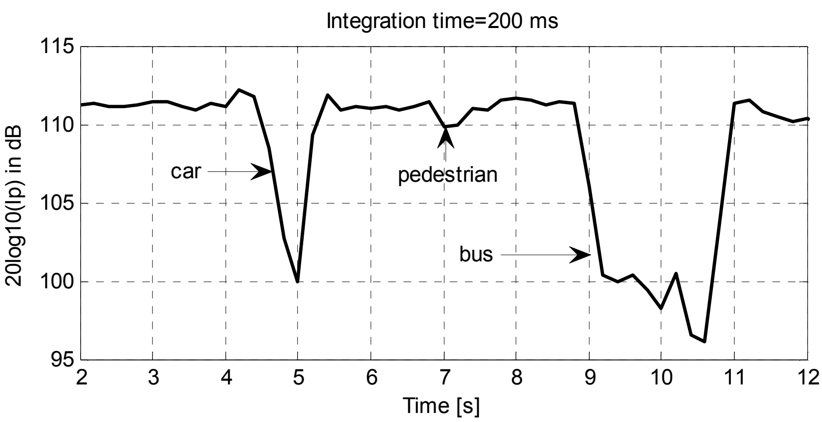


Figure 7: GPS radio shadows from car, pedestrian and bus

The spectra of three types of objectives (pedestrian, car and bus) are studied using the signal from satellite 17. Depending on the size of the target, its speed and the distance to the antenna, the radio shadow has specific characteristics. Figure 8 shows the bits of the navigation message of the satellite 17 for three types of targets. The power spectrum of the three targets is obtained after averaging four power spectra of the same targets. The power spectra of these targets are shown in Fig.9.

The same three spectra are plotted in Fig. 10 where it is seen that the three spectra are very close, although they may be used for classification of the target. For the higher target, the spectrum expands to a greater frequency range. At -40 dB level of the spectrum can be seen that the spectrum of the human is concentrated to 15 Hz as opposed to the car and a bus, where the spectrum is up to 30-35 Hz.

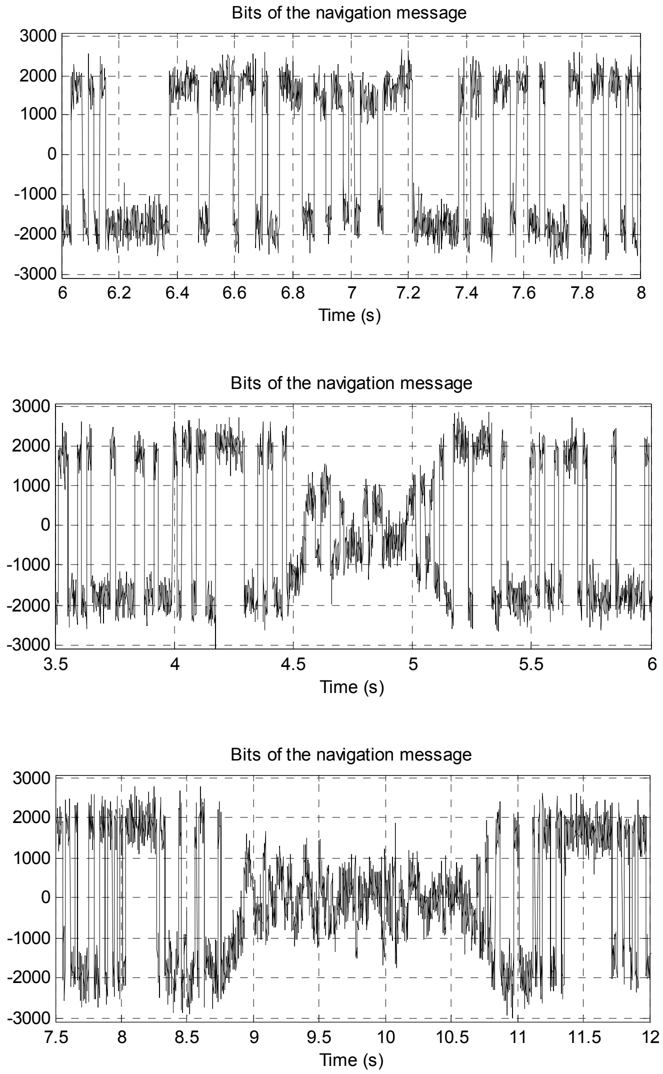


Figure 8: Bits of the navigation message (pedestrian, car and bus)

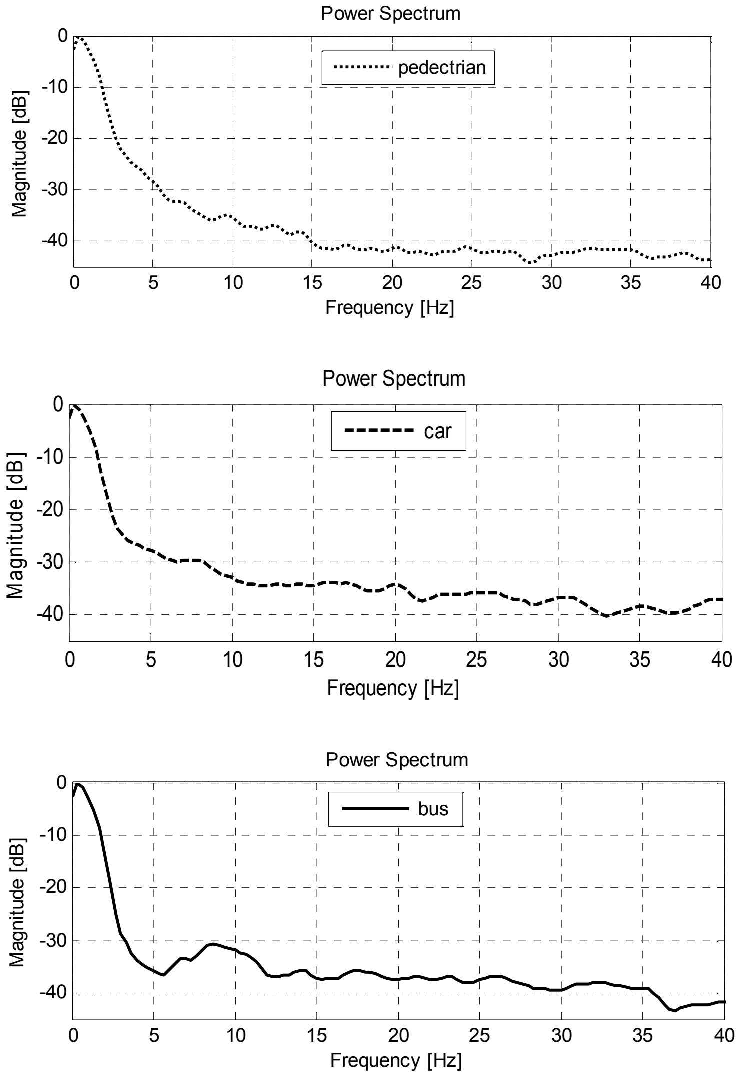


Figure 9: Power spectrum of pedestrian, car and bus

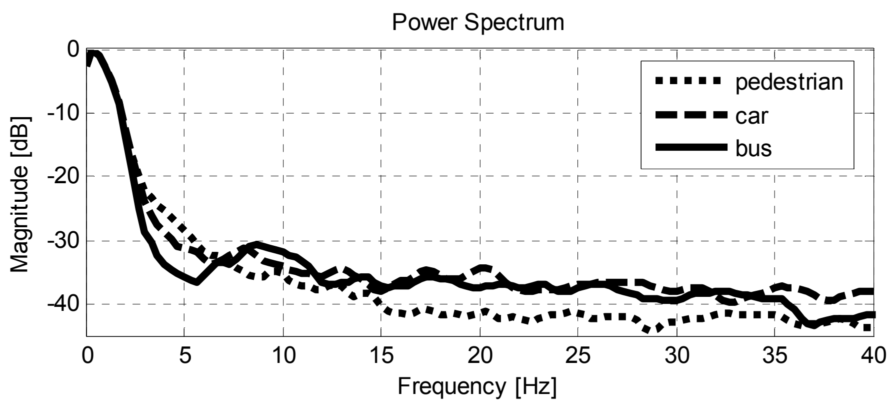


Figure 10: Power spectrum of pedestrian, car and bus

## 5. Conclusions

Using a small commercial GPS antenna and GPS receiver it is made a number of experiments with moving and stationary objects and moving and stationary receiver. Topology of the experiment suggests the presence of the conditions of occurrence of FS effect. This means that the satellite receiver and a transmitter are located on the same line, which crosses the object. Experiments have shown that different moving objects and a stationary GPS receiver can register the occurrence of the FS radio shadow. Experiments have shown that the FS shadow can provide information about the parameters of the object, from the width, shape and length of the received FS shadow.


## Acknowledgment

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