Available online at www.sciencedirect.com

ScienceDirect

Procedia Technology 17 (2014) 99 – 106

Procedia Technology

Conference on Electronics, Telecommunications and Computers – CETC 2013

Application of communication signals for remote sensing

Krzysztof Kulpa[a], Mateusz Malanowski[b], Piotr Samczyński[c], Piotr Krysik[d], Stanisław Rzewuski[e], Edward Sliwa[f]*

Institute of Electronic Systems, Warsaw University of Technology, ul. Nowowiejska 15/19, 00-665 Warsaw, Poland

Abstract

The paper presents the concept of applying different communication signals as illuminating signals in a remote sensing application. Classical remote sensing in radio frequency and microwave regions is based on active radar technology. When specially designed, in most cases a pulse signal is sent by the radar to illuminate the sensing scene and the return echo is analyzed. As more and more communication signals are freely available in the surveillance space, microwave sensing without its own illumination has been the focus of increasing interest. In the paper detailed discussion of the properties of different signals for remote sensing is presented, together with experimental results carried out at the Warsaw University of Technology, Poland.

Peer-review under responsibility of ISEL – Instituto Superior de Engenharia de Lisboa, Lisbon, PORTUGAL.

Keywords: Passive radar; Multistatic radar; Remote sensing; GSM; WiFi; FM; DVB-T.

[a] Krzysztof Kulpa. Tel.: +48-22-234-7478; fax: +48-22-825-2300.
*E-mail address:*K.Kulpa@elka.pw.edu.pl
[b]Mateusz Malanowski. Tel.: +48-22-234-5588; fax: +48-22-825-2300.
*E-mail address:*M.Malanowski@elka.pw.edu.pl
[c]Piotr Samczynski. Tel.: +48-22-234-5588; fax: +48-22-825-2300.
*E-mail address:*M.Malanowski@elka.pw.edu.pl
[d]Piotr Krysik. Tel.: +48-22-234-7740; fax: +48-22-825-2300.
*E-mail address:*P.Krysik@elka.pw.edu.pl
[e]Stanisław Rzewuski. Tel.: +48-22-234-5007; fax: +48-22-825-2300.
E-mail address: S.Rzewuski@elka.pw.edu.pl
[f] Edward Sliwa. Tel.: +48-22-234-5212; fax: +48-22-825-2300.
E-mail address: E.Sliwa@elka.pw.edu.pl

Peer-review under responsibility of ISEL – Instituto Superior de Engenharia de Lisboa, Lisbon, PORTUGAL.
doi:10.1016/j.protcy.2014.10.196

1. Introduction

Classical remote techniques can be divided into two major classes – passive and active. Active techniques use their own illumination of the sensing area. To this class belong active radars (including SAR -Synthetic Aperture Radars), laser scanners, LIDARs, and time of flight cameras among others.

The passive sensors exploit either the target's own emissions (like infrared cameras) or external illumination (usually originating from the sun) in visual light or nearby IR or UV regions.

This paper is focused on microwave sensors. Up to now two main microwave sensors have been in use: radars and radiometers. The monostatic active radar illuminates the scene using electromagnetic radiation in the radio and microwave region, and detects the echo returns coming from the observed targets. Dedicated signal processing is used to improve both signal to noise ratio and spatial resolution. For illumination high powered transmitters are used, which require a high power supply. The radiometer works in the passive mode, collecting the thermal emissions of the targets in the microwave region. In this case coherent signal processing can also be applied to improve sensor resolution. At present the application of radiometry is becoming more and more difficult, as it is hard to find a frequency band free of human emissions. Such emissions are usually much more powerful than the thermal emissions of the target, giving rise to the possibility of them being completely masked.

While more and more emissions in different bands are present in the surveillance space they can be used as illumination sources, as the sun is used for optical illumination. Using optical sensing, it is possible to achieve high spatial resolution of the sensor when the wavelength is very short in comparison to lens aperture. In the microwave region the spatial resolution of antenna systems is much lower, so additional signal processing is required. Moreover, attenuation in fog and rain is much higher in the optical frequency bands, which significantly limits applications of optical sensors in bad weather conditions. The possibility of day/night and all weather conditions operation is the main advantage of the microwave sensor in contrast to optical sensors.

2. Passive radar idea

The active radar illuminates the sensing area, sending pulse or continuous microwave emissions with known modulation. Matched filtering is applied to the received signal to increase range resolution. In the case of relative motion between the target and radar, additional cross-range compression (SAR or ISAR processing) is applied to increase spatial resolution, which is well beyond the true (physical) antenna resolution, which in many cases is in the order of a few degrees.

Passive radar does not emit any radiation but collects the radiation available in the surveillance area. It should be equipped with a multi-beam antenna system. One of the available beams should be directed towards a selected transmitter, while the other to the observed scene. The beam directed towards the transmitter receives a copy of the illumination signal, while the surveillance beams directed towards the scene receive the echo signals. Fig. 1. presents a typical scenario of remote sensing using a single transmitter of opportunity.

In the passive optical system, a lens frontend separates the echo signals from direct (e.g. the sun) illumination.

In the microwave region, separation between the direct and surveillance signals (in the surveillance channel) is usually small (10-30 dB) and thus adaptive filtering of the direct signal has to be applied in order to remove it almost completely (well below the echo signal). The removal processing based on a lattice filter is described in [1, 2, 3, 4]. In a passive radar, range compression can not be performed using a matched filter when the illumination signal is not known in advance. Correlation processing is used instead. The received (surveillance) signal, after the direct signal and clutter cancellation, is correlated with the modified reference (illumination) signal [1]. The modification is done based on the predicted target motion. In the case of target radial motion the Doppler shift of the reference signal is applied to compensate the echo Doppler shift. If the Doppler shift is unknown (as in most cases when a non-cooperative target has to be detected) it is necessary to apply a bank of all possible Doppler filters. This leads to the calculation of a cross-ambiguity function described by the following formula:

$$y(r,v) = \int_0^{t_i} X_R(t) \cdot X_T^*\left(t - \frac{r(t)}{c}\right) \cdot e^{2\pi j \frac{F_t(r(t)-r)}{c}} dt, \tag{1}$$