

Analysis of the Possibilities for of Secondary Applications of CDMA Cellular Systems

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Abstract – The paper deals a new promising application of the existing broadcasting and mobile communication systems - the secondary applications of the transmitted RF signals for radiolocation purposes. Particular emphasis is given on the CDMA technology. The properties of the different CDMA IS-95 standard signals are analyzed in order to define the best of them for this secondary application. Matlab simulations of the autocorrelation properties of the downlink pilot channel signal are given. The range resolution properties as well as the conditions for un-ambiguity distance measurements are discussed too.

Keywords – SAWT, radiolocation, CDMA, secondary applications, cellular applications, ICEST 2003.

I. Introduction

On the background of existing global communication and navigation networks appeared the concept of Secondary Application for Wireless Technology – (SAWT). The research in this area is connected with using radio communication and electromagnetic signals, which cover a large frequency band from KHz to tens GHz. The situations, which could be observed, are various. For instance many different powerful ground-located radio transmitters, satellite transmitters or wireless telecommunication networks can be used for bistatic radiolocation. There is a comparatively simple situation when the receiver receives signals that have a direct and a reflected component. Analyzing the angle of arrival (AOE) and time of arrival (TOA) appropriately a definite radiolocation scene could be composed, which could give us a concept of some of the target's parameters. Investigation of these problems could extend and develop the wireless services.

II. Short Analysis Examples and Results

The characteristic of the information, which radiolocation device receives, depends on the structure and the properties of the used signal. According to its purpose the signal has to allow optimum realization of:

- Sufficient signal energy.
- Maximum detection of distance and velocity
- High noise resistance /from artificial and natural sources/

In the contemporary communication networks signals correspond to some basic radiolocation requirements:

- The communication codes have good autocorrelation function (ACF). At its hand the good ACF ensures the correct recognition of the reflecting signal and is a precondition for good range detection.
- These codes have a good cross correlation function, which allows it low cross channel interference. On the other side thanks to the good division we can do radiolocation statistical analysis of the different data from different channels. This allows us to increase radiolocation measurements.
- Optimum frequencies that can provide necessary frequency band.

The analysis of the opportunity for secondary application of wireless signals is connected with the radiolocation evaluation of the signal. Various algorithms for detection of the signal are used. Also different methods to evaluate Angle of Arrival (AOA) and Time of Arrival (TOA) of the direct and reflected received signals are used [1]. Powerful means in the radiolocation analysis is the ambiguity function of radar signals. It describes the complex envelope curve on the entry of radio locator like a function of target range and velocity. It is completely defined with the Eq. (1)[2]:

$$\chi(\tau, \Phi) = \int_{-\infty}^{+\infty} u(t)u(t + \tau)e^{-j2\pi\Phi t} dt, \quad (1)$$

where $u(t)$ – complex modulating function; τ – time delay of the signal is connected with range \mathfrak{R} ; Φ – Doppler frequency difference connected with radial velocity V .

Let $\Phi = \text{const.}$, then we obtain an expression for the function of the ambiguity function by range.

$$\chi(\tau, \Phi) = \chi(\tau) = \int_{-\infty}^{+\infty} u(t)u(t + \tau) dt \quad (2)$$

In this situation, range ambiguity function coincides with Autocorrelation function (ACF) of radiolocation signal. If we express Eq. (2) with digital signals we will obtain the well-known formula – ACF of a digital signal: [3,4]

$$P(u(t)) = \sum_{i=1}^n P u_i(t) \delta(u - u_i(t)) \quad (3)$$

By synthesizing and analyzing the ambiguity function of contemporaneous digital signals we can to obtain notion of

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radiolocation properties of these signals. We can also estimate range and velocity with certain accuracy of the radiolocation measurements with conventional digital communication signals [4]. As the ACF has a determined period [3,5], we can also define a parameter – range of synonymous evaluation. This parameter is connected to the period of repetition of the ACF, which at eventual radiolocation range measurement will lead to ambiguity of distance detection at the moment of delay, which equals a period of ACF.

Consider the simple geometrical equation (Fig. 1) [4], which gives a classic situation of a bistatic radiolocation. At point A we have a source of radio waves, which is a part of radio communication network. At point B there is a target, which reflects a radio communication signal, and at point C there is a receiver. The receiver could evaluate with known

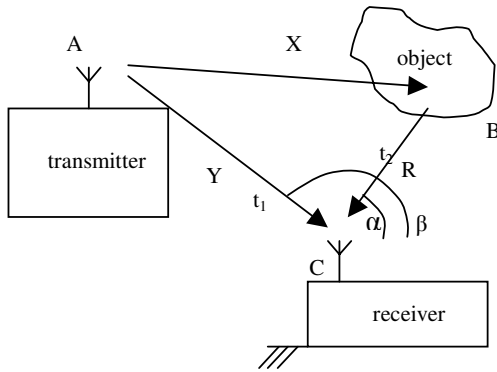


Fig. 1. Block diagram of wireless system

methods the time delay of both signals, which gives an idea of traversed distance, t_1 and t_2 respectively. We assume that the two angles (α and β) can be obtained quite exactly with the help of a course and bearing indicator, for example. The covered distance will be as follows:

$$AC = Y = \frac{c}{t_1} \quad (4)$$

$$d = ABC = X + R = \frac{c}{t_2}, \quad (5)$$

where $c = 3 \cdot 10^8$ m/s.

From the known cosine theorem we can obtain an arithmetical expression of range R :

$$X^2 = R^2 + Y^2 - 2YR \cos(\beta - \alpha) \quad (6)$$

from Eq. (5)

$$X = d - R \quad (7)$$

replace in Eq. (6)

$$(d - R)^2 = R^2 + Y^2 - 2Y(d - R) \cos(\beta - \alpha) \quad (8)$$

After a suitable transformation we can obtain the final expression for estimating the unknown distance to the target:

$$R = \frac{d^2 - Y^2}{2d - 2 \cos(\beta - \alpha)} \quad (9)$$

Consider the well-known communication cell system based on the CDMA principals – IS-95A[6]. The planned

structure of the network is made with the purpose of assuring maximal coverage of a defined area, which on the other side guarantees reliable receiving in the whole range of the communication network. The structure of the network is mapped in the Fig. 2[6].

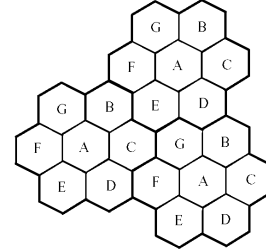


Fig. 2. Cellular structure

The question is could the situation from the Fig. 1 be obtained on the structure of communication network from Fig. 2[6]. We reduced the analysis of the problem to evaluation of the ambiguity function of a communication signal in this network. We attempt to explain this signal as a radiolocation signal in the bistatic radar system. The standard IS-95A is based on the spread spectrum signals (SSS)[3]. It was found that these signals could be used as radiolocation signals, because they are synthesized with a low cross correlation function with the purpose of low influence between particular channels [6]. On the other hand signals used for spreading of informational signals (PN code) are m-sequence [6], which guaranteed very good ACF. If this signal can be used for radiolocation observing, it has to correspond to certain conditions.

- Uninterruptedness of the radio transmission
- Easily detectable
- According to bistatic reflecting surface of the target the signal has to have enough energy to cover some measurement range

On this base we have to exclude the signals for Uplink, because they are low powered and are of chance character. For this reason we have to exclude Traffic and Paging channels from Downlink channel. We concentrate on the Pilot signal. It is uninterrupted and consists of simple signals. It is used primarily as a coherent phase reference for demodulation the other channels. For this reason, IS-95 requires that the chip timing and carrier phase of each Downlink channel be in very close agreement. The pilot signal are constant logical 0, it is modulated at Walsh chip rate of 1.2288 Mcps by H_0 , the 0-th row of the 64x64 Hadamart matrix, which is the Walsh sequence consisting of 64 zeros-thus, in effect, it is not modulated at all. The two distinct short PN codes – I and Q (Eq. (10) and Eq. (11)) are maximal length sequence generated by 15-stage shift registers and lengthened by the insertion of one chip per period in a specific location in the PN sequence. Thus, these PN codes have periods equal to the normal sequence length of $2^{15}-1 = 32767$ plus one chip,

or 32768 chips [6]. The first channel architecture is shown in Fig. 3 [6]. The PN-code spreading is followed by classic QPSK modulation of the radio frequency carrier. This signal is perfect for secondary radiolocation because it is more powerful signal than the others. This is the reason for the easy detection and also it has a short period of repetition, which allows fast synchronization.

$$f_1(x) = 1 + x^2 + x^6 + x^7 + x^8 + x^{10} + x^{15} \quad (10)$$

$$f_2(x) = 1 + x^3 + x^4 + x^5 + x^9 + x^{10} + x^{11} + x^{12} + x^{15} \quad (11)$$

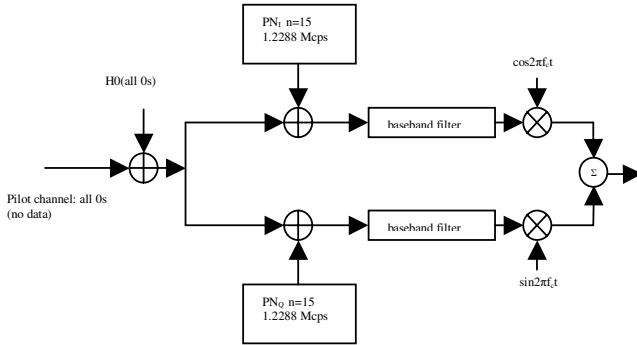


Fig. 3. Pilot channel modulation

With the assistance of MATLAB [8] we did visualization of ACF of the two PN sequences (Fig. 4). From the figure we could see that both functions have small side lobes (Fig. 6) which level is $1/N$ (N is the length of the m -sequence). Consider the range of range of un-ambiguity (Fig. 4), which can be achieved by using such a signal for bistatic radiolocation. The period of repetition of both functions could be evaluated with:

$$P = \frac{N}{C_r}, \quad (12)$$

where N is the size of the PN code ($N=2^n-1$, n -power of the equation of the PN code) and C_r – chip rates (chip/s) [6]. It turns out that the period of repetition is 26.66 ms, which at its hand defines the range of un-ambiguity:

$$S = t * c = 26,66 * 10^{-3} * 3 * 10^8 \approx 7980km, \quad (13)$$

where $c=3.10^8$ m/s.

Some words about the range resolution. Having in mind the structure of spreading PN code and theory for these sequences could be build on the following scene Fig. 5. In this figure are shown the main peak (main lobe) of the function of the autocorrelation of both codes.

The base width equals to $2T$ (T -the period of repetition of the code) [3]:

$$T_r = \frac{1}{C_r} = \frac{1}{1.2288 * 10^6} \approx 0.8\mu s \quad (14)$$

As seen from the figure, range resolution is different depending on the level of ACF it works on. The closer to the top the higher the accuracy of the range estimation. Factors that can influence the level are phase jitter and thermal noise. This is a problem that impedes the conventional usage of the

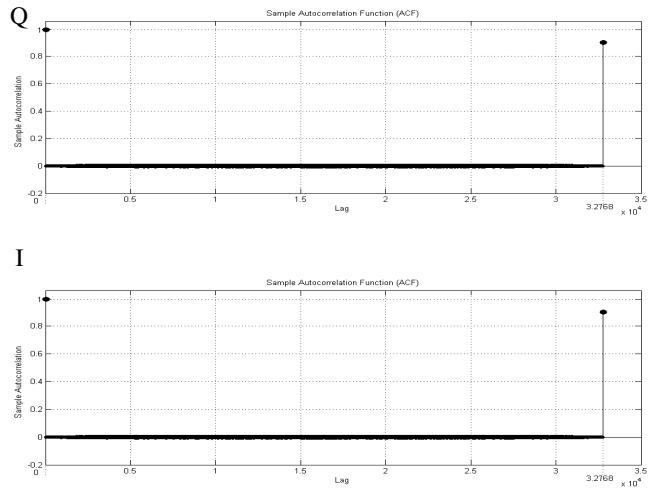


Fig. 4. ACF of the I and Q PN codes

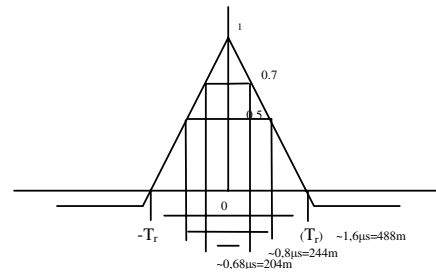


Fig. 5. Estimation of range resolution of the PN I and Q codes

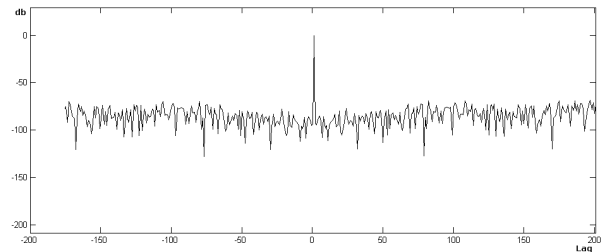


Fig. 6. Main lobe of the ACF of the PN I and Q codes

mobile network – it affects the synchronization of the receivers, so that it is being fought effectively. In Fig. 6 are shown the real situation of the main lobe of the ACF. From figure could be seen that the side lobes have very low level (less than 50 dB). That concludes good signal/noise (S/N) ratio and small probability of un-ambiguous range.

This consideration is presented in using the PN signal in the base band situation. There are possibilities to evaluation of the signal in the radio frequency range. In those situations observing of the phase shifting and the Doppler frequency could give us information about the target velocity.

III. Conclusion

The Secondary Applications of Wireless Technology is an promising aspect of using of wireless communications. The adoption of modern high quality digital radio communication systems and Spread Spectrum Signals will make these scientific researches fascinating.

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References

- [1] J. Caffery, G. StÜber, *Overview of Radiolocation in CD-MA Cellular Systems*, Georgia Institute of Technology, IEEE Communication Magazine, April 1998.
- [2] М. Сколник, *Введение в технику радиолокационных систем*, Мир, М. 1965.
- [3] G. Cooper, C. Mc Gillom, *Modern Communications and Spread Spectrum*, McGraw-Hill Book Co., 1996.
- [4] M. Cherniakov, K. Kubik, *Secondary applications of wireless technology (SAWT)*,
- [5] 2000 European Conference on Wireless Technology – Paris 2000.
- [6] S. Haykin, *Communication systems*, McMaster university, John Wiley & Sons, Inc. Book, 1994.
- [7] J. Lee, L. Miller, *CDMA Systems Engineering Handbook*, Artech House, Hardcover, November 1998.
- [8] D. Masters, P. Axelrad, *University of Colorado, Boulder Zavorotny V., NOAA Environmental Technology Laboratory Katzberg S.J., NASA Langley Research Center Lalezari F., Ball Aerospace Corporation* “A Passive GPS Bistatic Radar Altimeter for Aircraft Navigation” Presented at ION GPS 2001, Salt Lake City.
- [9] The MathWorks, Inc., <http://www.mathworks.com/>