Some Results of Radar Signal Detections by the Use of Compressive Receiver

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Abstract – **The paper presents some results of weak, pulsed and continuous radar signals detection by the use of compressive receiver.**

Keywords - **Signal spectrum, chirp transform, compressive receiver, signal detection.**

I. INTRODUCTION

Radar technology is considered as having the lowest probability of intercept capability. The noise radar techniques have a lot of potential if future radar systems and equipment design and high of low probability of intercept (LPI) factor [5]. It should be anticipated that the corresponding counter them systems will be designed. The basic element of such systems is receiver operating within high frequency bandwidth. It should be admitted that LPI factor causes the intercepted signal power be extremely low. The problem becomes extremely difficult when short pulsed radar signals are discussed. Facing that problem the paper presents a wideband signals compression principle using dispersive delay lines (DDL) to measure instantaneous spectrum of short pulsed radar signals and to detect weak radar signals existing at the receiver input. Basic theory of problem is described and experimental results are presented. Furthermore the detection of weak continuous radar signals has been performed.

II. BASIC THEORY OF COMPRESSIVE RECEIVER

The compressive receiver (CR) performance requires a short discussion of the fundamentals of chirp transform. The chirp transform is based on classical Fourier transform in which linear dependency between frequency and time [1-4] has been introduced.

$$F(\omega) = \int_{-\infty}^{+\infty} f(t) e^{-j\omega t} dt \quad \text{and} \quad \omega = 2\mu\tau \qquad (1)$$

where: *f(t)* - input signal, ω - frequency due to time τ, μ - frequency-to-time conversion factor. After substitution the equality $\omega=2\mu\tau$, and applying the identity $2\tau t=\tau^2+t^2-(\tau-t)^2$, and suitable factorization, the first equation is converted in a frequency-to-time scaling problem

$$S(\tau) = \left\{ \int_{-\infty}^{+\infty} s(t) e^{-j\mu t^2} e^{-j\mu(\tau-t)^2} dt \right\} e^{-j\mu\tau^2} \qquad (2)$$

where with comparison to the equation (1), $F(\omega)$ and $f(t)$ have been substituted by $S(\tau)$ and $s(t)$ respectively. The last expression describes the full chirp algorithm. It has electrical implementation, presented in Fig.1, which requires three operations. First, the input signal s(t) is multiplied by a chirp reference signal. Secondly, the resultant product is convolved in pulse compression filter with an equal but opposite frequency-to-time slope value μ. Thirdly, a multiplication by a second chirp, which removes the phase distortion introduced by the first chirp.

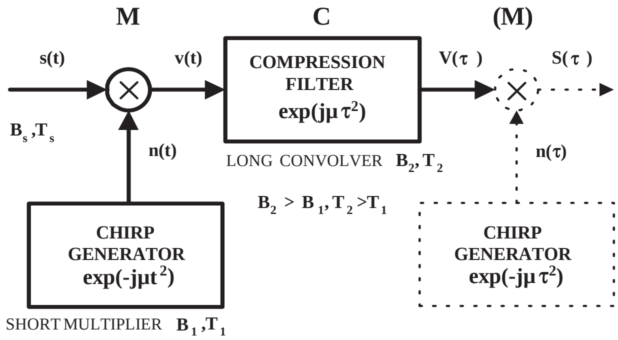

Fig. 1. Chirp algorithm arrangement

In spectral analysis application or signal detection, the second chirp multiplication is omitted since the desired information is the envelope of the Fourier transform. In such a case the chirp algorithm becomes the version which produce signal power only

$$V(\tau) = \int_{-\infty}^{+\infty} s(t) e^{-j\mu t^2} e^{-j\mu(\tau-t)^2} dt \qquad (3)$$

The chirp algorithm arrangement (3), referred to us as M-C (multiply-convolve) release has practical hardware implementation including chirp generator, mixer, compression filter, amplifier and envelope detector. The radio frequency (RF) signal is multiplied by the linear sweeping reference signal to produce of the linear sweeping intermediate frequency. This signal is applied to the pulse compression filter connected with the intermediate frequency (IF) amplifier. The compressed output signal envelope is reproduced by the detection circuit. Output video signal appears at time determined by the input signals frequency values. It reflects instantaneous spectrum of input signal. The M-C algorithm, is recommendable for detection of weak radar signals.

III. SIGNAL DETECTION

Compressive receiver output signal reflects instantaneous spectrum of the intercepted signal. It performs signal interception in particular time samples called as duty cycles. This results signal spectrum averaging over reference signal time and bandwidth. In other words, the CR output signal expresses signal energy being under analysis.

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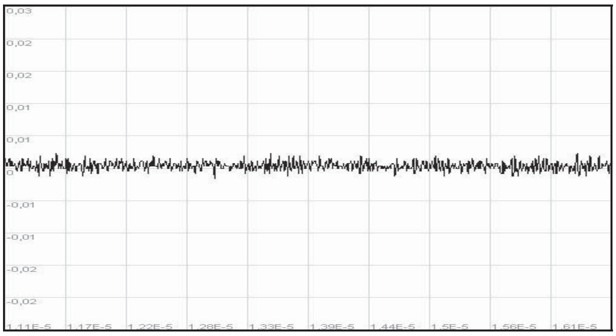

Fig. 2. CW signal, 30MHz, amplitude - 9 dBm, 1us/div (single duty cycle of compressive receiver)

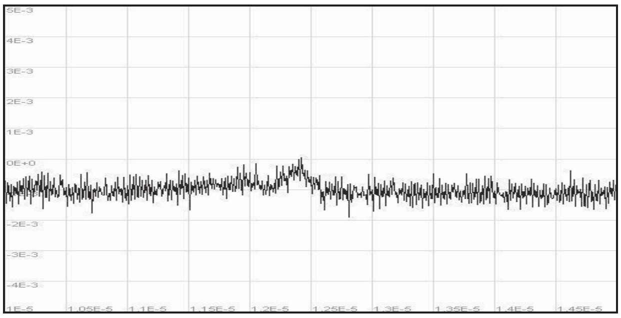

Fig. 3. CW signal, 30MHz, amplitude - 9 dBm, 1us/div (after averaging)

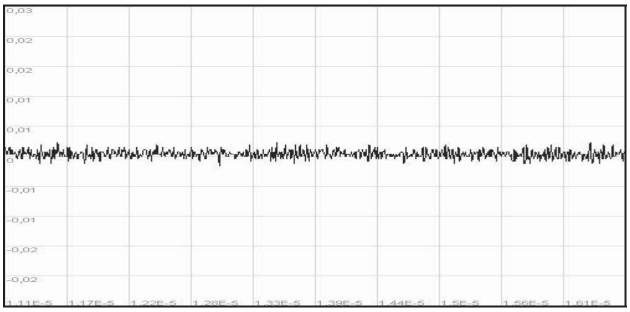

Fig. 4. Linear frequency modulated signal, 30MHz, FM 4MHz, PRI - 1,003ms, PW - 4us i amplitude - 10 dBm 1us/div (single duty cycle of compressive receiver).

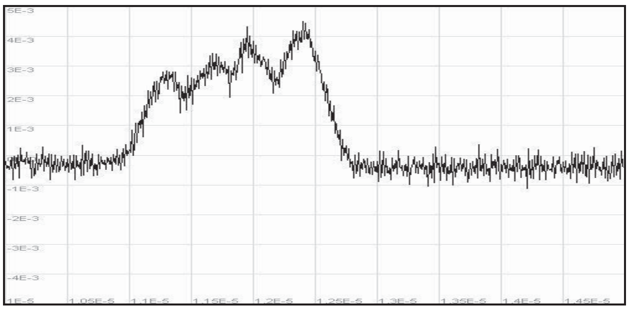

Fig. 5: Linear frequency modulated signal, 30MHz, FM 4MHz, PRI - 1,003ms, PW - 4us i amplituda - 10 dBm 1us/div (after averaging)

Thus, with respect to the time-frequency distribution terms, to collect a total signal energy it is necessary to gather signals existing in several duty cycles of the CR. Therefore these feature may be used for signal interception and detection especially when weak signals are considered. Results of signal detection are presented on Fig.2-5.

IV. CONCLUSIONS [1]

The compressive receiver is a very efficient tool for the time-frequency signal analysis. It's important advantage is high speed of performance, so it may be applied in radar signal environment, for signal interception and measuring frequency parameters. It is especially important when short-time narrowband and wideband linear frequency modulated signals are considered. The CR requires effective software for signal processing to provide its practical usefulness. Because the CR output signal represents the instantaneous spectrum of the input signal only, the pulse time of arrival measurements are strongly required. The measurements should be completed for each duty cycle of the CR to evaluate real time-frequency structure of a signal. It should be noted that processed output signals are extremely short and their time of appearance at the output has stochastic nature implied by random temporal relations between the reference and input signals. Finally, as far as the CR concept is discussed, one can admit that it may be implemented to the analysis of instantaneous frequency structure of the signal. Furthermore as it results from the examination compressive receiver offers possibility to detect signals having power below noise floor of interception system. The main conclusion is that the compressive receiver is high speed Fourier transformer, that aided by task oriented software realizing functions of the virtual measurement instrument provides effective possibility to measure frequency parameters of radar signals and to detect radar signals. Thus it could be recommended to design "hard to get threats" systems. The CR most significant o feature is ability to analyse signals that are simultaneously present at the CR input. This recommends it to use in dense signal environment typical for ELINT/ESM systems for signal detection and analysis.

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[1] The financed is supported from sources for science in the years 2007-2010 in a frame of ordered scientific project PBZ-MNiSW-DBO-04/I/2007.