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Design and Analysis of a New Class of Signals for Radar Applications

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Modern radar include more and more multiple functions and multiple channels; in this context sophisticated waveforms and related processing (pulse compression, extraction of information) are an hot research and development topic. A simple multifunction radar concept includes the detection of air targets (target channel) and the analysis of atmospheric phenomena (weather channel) [1]. In a target channel a low Peak Sidelobe Ratio (PSR) is needed in addition to low degradation in main lobe (low Signal-to-Noise Ratio, SNR, loss) and low sensitivity to the Doppler velocity [2]. A very common radar waveform to realize pulse compression is the Linear FM (LFM) chirp signal for its fairly ready generation and easy processing by a Matched Filter in time or in frequency domains. However the autocorrelation of the LFM chirp exhibits a $sinc(x)$ function shape with high PSR (≅ -13 dB). The reduction of the sidelobes is typically accomplished by amplitude weighting. This additional filtering perturbs the Matched Filter introducing a mismatching that causes losses in SNR (about 2 dB depending on the weighting function used). It is well-known that Non-Linear FM (NLFM) chirp modulation can advantageously shape the *"rectangular"* energy spectrum of LFM chirp, such that the autocorrelation function exhibits substantially reduced sidelobes. Consequently, no additional filtering is required and maximum SNR performance is preserved [2].

In a weather channel the design of the waveforms requires a low Integrated Sidelobe Ratio (ISR ≤ -30 dB in some cases) [3]. Such very low ISR values are generally not attained by the well known polyphase codes (Frank, P1, P3, Barker, ...) [3]. Many attempts have been made in the past [3]-[6], including the implementation of (very long) inverse filters [4] with the disadvantage of high complexity, specially in the pulse compression and in the related processing. As a matter of fact, the effectiveness of the sidelobe suppression filters is more and more affected by the Doppler shift, and to achieve (at zero Doppler) a very large ISR, e.g. –30 dB, filters as long as six times the code (that in practice means two or three hundreds of coefficients) are needed. But a filter of this length is very much affected even by a moderate Doppler velocity, e.g. a few m/s at S band, creating the need for a bank of many (e.g. 16 or 32) Doppler filters upstream the pulse compression.

In this paper we present a new approach that exploits the complementary properties of Golay codes (p, q), [7], to implement pulse compression in a multifunction, multichannel radar. This approach requires that the encoded pulses (p, q) have to be transmitted simultaneously and at the same carrier frequency. To separate them in reception, their sub-pulses can be further encoded by two orthogonal codes c_1 and c_2 respectively (*"nested" orthogonal codes into complementary codes*). The sidelobes, after the coherent combination of the two channels (*p-channel* and *q-channel*), assuming a Doppler effect absent or negligible, are substantially the ones of c_1 and c_2 by adding of the cross terms. Therefore, the codes (c_1, c_2) to be used must possess appropriate properties of cross-correlation.

This work aims to analyze the theoretical limit, in term of PSR and ISR, due to the cross contributions when a pair of complex orthogonal codes are used. Particularly we suppose the use of orthogonal codes *"up"* and *"down" chirp*: $c_{1/2}(t) = exp\{\pm i \cdot \phi(t)\}$. A mathematical model for the peak and for the integrated sidelobes energy is developed for a general pair of orthogonal codes. Moreover, numerical results are obtained for *"chirp"* up-down codes and final comparison are presented.

References

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