Approaches for Implementation of Golay's Complementary signals and Welti's Quaternary Signals in Radio-Communication Systems

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Introduction

The Golay's complementary signals (GCSs) and Welti's quaternary signals (WQSs) possess ideal correlation properties, which allow very effective exploitation of the electromagnetic spectrum. Due to these reasons, GCSs and WQSs have been intensively researched during the past sixty years, but up to now the relations between these signals are not systematically explored. Accounting this situation in the paper a rigorous proof of the GCSs and WQSs equivalency from the point of view of their implementation in the radio-communication systems is substantiated.

General Mathematical Model of Complex Radio Signals

In this paper the classic methodology for autocorrelation function (ACF) evaluation, using multiplication of polynomials of one variable, is elaborated as follows:

$$\sum_{l=-(N-1)}^{N-1} P_{ss}(l)x^l = \left(\sum_{l=0}^{N-1} s(i)x^i\right) * \left(\sum_{k=0}^{N-1} s(k)x^k\right) \quad (5)$$

Here the symbol

$$s(i) = V_{pi}U_{mi}\cos(2\pi f_i t + \psi_i)\,,\ i = 0, 1, \ldots, N-1 \quad (4)$$

contains simultaneously all information about the polarization (vertical V_{vi} or horizontal V_{hi}), the amplitude U_{mi}, the carrier frequency f_i and the initial phase ψ_i of the i-th signal's chip.

General Mathematical Model of Complex Radio Signals

Here it should be underlined the following facts.

First, in (5) $P_{ss}(l), l \in \{\pm 1, \pm 2, \dots, \pm(N-1)\}$ and $P_{ss}(0)$ are the side-lobes and the main-lobe of the ACF respectively.

Second, in (5) the symbol "*" denotes the multiplication of symbols (4), performed by the receiver, which is a filter, matched to the signal. This multiplication has a more complex nature, than the ordinary mathematical multiplication, as it depends on the types of modulation, applied over the chips.

Analysis of Approaches for Implementation of the Golay's Complementary Signals and the Welti's Quaternary Signals

From the analyses, performed in the previous section and in this section of the paper, the following conclusions can be made.

C 1) Both Golay's complementary signals and the Welti's quaternary signals can be realized as equivalent pairs of two ternary complementary signals, which have the following properties: all their chips are 0, -1 or +1; the sum of the ACFs of the signals, forming a pair, resembles the Dirac delta – pulse.

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C 2) The elements of the signal alphabet, exploited in the WQCs, can be realized physically by the following approaches.

AW 1) Application of two different types of polarization and binary phase manipulation (binary phase shift-keying – BPSK).

AW 2) Usage of four-level phase manipulation (quaternary phase shift-keying – QPSK).

AW 3) Usage of different carrier frequencies and BPSK.

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C 3) The binary complementary pairs of the GCCs, can be realized physically by the following approaches.

AC 1) The signals of the complementary pair differ in the polarization and their chips are generated by BPSK.

AC2) Usage of four-level phase manipulation (quaternary phase shift-keying – QPSK).

AC 3) Usage of different carrier frequencies and BPSK.

AC 4) Usage of time-interleaving of the complementary signals and BPSK.

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C 4) The above analyzed approaches for implementation of the WQSs and the GCSs are truly analogous with only one exception – the approach AC 4. Anyway, if a WQS is presented as sum of two ternary complementary signals, then this WQS can also be realized physically by the approach AC 4.

C 5) The technically simplest approaches for implementation of the WQSs and the GCSs in RCSs are AW 1, AW 2, AC 1 and AC 2.

Conclusion

In the paper a general mathematical model of the complex radio-signals is suggested. On its base a rigorous proof of the GCSs and WQSs equivalency from the point of view of their mathematical representation as radio signals is substantiated. Besides, all the approaches for implementation of GCSs and WQSs in RCSs are systematized and analyzed.

The results, obtained in the paper, could be useful in the process of modernization of existing RCSs or in development of new RCSs.