A Survey of Periodic Binary Nearly Perfect Signals with Lengths N≡0mod4

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Introduction

In the paper the results of our survey of periodic binary nearly perfect signals with lengths $N \equiv 0 \bmod 4$ are presented. These signals possess autocorrelation functions, which have both the possibly smallest quantity and magnitude of side lobes and, due to this reason, they are named nearly perfect. A very important positive feature of the periodic binary nearly perfect signals is the possibility to be processed by the so-called side lobes suppression filters with very small losses in the signal-to-noise ratio. The results, obtained in the paper, could be useful in development of different types of radar sensors and radio-synchronization devices.

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The signal families with good (or optimal) correlation properties have great importance for the radio-communication systems (RCSs) in general, because the signal processing in RCS receivers begins with evaluation of autocorrelation functions (ACFs) or periodic ACFs (PACFs) of the detected signals as this procedure maximizes the signal-to-noise ratio (SNR). Despite of all taken efforts, at the moment only few classes of perfect signals are discovered. This situation can be explained by the fact that this problem may be extremely hard from theoretical point of view.

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The universal computer program, developed for our survey, uses several restrictions, which exclude all repeating information or simplify the computational procedures.

R 1) *Focusing the search on the BNPSs with length* N≡0mod4. R1 accounts the fact, that the Periodic Binary Nearly Perfect Signals (BNPSs) with length N≡0mod4 may have PACFs with large zones with zero-level side-lobes. As a result, the masking the main-lobes of the PACFs of the weaker signals by the side-lobes of the PACFs of the more powerful signals can occur very seldom.

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R 2) *Precise determination of the quantities of samples-1 and +1 of the synthesized BNPSs.*

R 3) *Excluding equivalent signals from the survey.*

This restriction accounts the fact that every phase modulated (PM) signal can be transformed in several ways in other PM signals with equivalent auto-correlation properties. From all known equivalent transformations, the following five can be exploited in the synthesis of BNPSs.

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ET 1) All the cyclically shifted versions of the PM signal have cyclically shifted PAFCs (the positions of the main-lobes of PACFs coincide).

ET 2) The PM signal and its negative version have equivalent AFCs and PACFs.

ET 3) The PM signal and its reverse version have equivalent ACFs and PACFs.

ET 4) The alternate version of the PM signal has alternate ACF and alternate PACF.

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ET 5) The decimated version of the PM signal has decimated PACF.

The usage of restrictions R1, R2 and R3 allows the volume V_{BNPS} of the BNPSs space to be reduced:

$$V_{BNPS} = 2C_{N/4}^{N_{0-}} C_{N/4}^{N_{1-}} C_{N/4}^{N_{2-}} C_{N/4}^{N_{3-}} \ll V_{BS} = 2^N \quad (47)$$

In (47) N_{0-}, N_{1-}, N_{2-}, N_{3-} are the quantities of samples $\varsigma(k) = -1$ in sums

$S(l) = \varsigma(0 + l) + \varsigma(4 + l) + \cdots + \varsigma(N - 4 + l), l = 0, 1, 2, 3$ (16),

and $V_{BS} = 2^N$ is the volume of the binary signals space.

Main Results of Conducted Survey of Periodic Binary Nearly Perfect Signals with Lengths N≡0mod4

Examples of the found BNPSs with lengths $N \equiv 0mod4, 4 \leq N \leq 100$, which have the smallest losses in the SNR, are presented in Table 1. In it, the characteristic sets of the BNPSs, comprising only the positions of the samples -1, are presented in the third column. Besides, $\gamma, \gamma \geq 1$ denotes the coefficient of losses in the SNR, when the respective BNPS is processed by its side-lobe suppression filter (SLSF).

A part of Table 1 is shown below.

№	N	The characteristic set of the binary nearly perfect signal	γ
17	68	{1 2 3 4 5 8 11 15 16 19 21 23 24 25 28 32 33 34 37 39 40 42 43 44 46 49 57 59 65}	1,0765
18	72	{5 6 8 9 14 15 16 21 22 23 24 25 26 28 29 34 35 38 39 43 46 47 49 50 52 54 57 59 61 65 71}	1,1516
19	76	{1 2 3 6 7 8 11 12 16 19 20 21 23 24 25 26 27 34 38 41 48 49 51 55 57 58 60 61 63 67 69 71 72 76}	1,0873
20	80	{1 2 5 8 10 13 16 17 18 21 22 24 26 28 30 33 34 35 36 39 40 41 42 43 48 57 58 62 67 68 69 71 72 78 79}	1,1488
21	84	{1 4 5 6 7 8 9 10 11 14 16 17 23 24 26 27 30 31 32 36 37 41 44 48 51 53 55 56 59 60 62 64 65 67 73 75 77 79}	1,2784
22	88	{1 5 7 8 9 11 12 13 14 15 21 23 24 25 27 28 30 31 32 36 37 40 49 51 55 58 60 61 62 66 69 70 72 75 77 80 82 83 87 88}	1,1760
23	92	{1 2 3 7 9 12 17 18 19 22 24 35 37 38 43 44 46 47 48 50 51 55 56 59 60 64 65 67 70 71 74 76 77 78 79 81 85 87 89 91 92}	1,1153
24	96	{8 9 10 11 13 14 17 20 21 23 26 27 28 29 30 34 35 39 42 43 44 46 53 55 57 61 65 70 71 76 77 79 81 82 84 85 86 87 89 92 93 94 96}	1,1273
25	100	{4 5 7 10 14 17 20 21 26 27 28 29 31 36 38 41 47 49 51 53 54 55 56 57 59 61 63 64 65 66 68 69 70 74 77 81 82 83 85 86 88 89 94 99 100}	1,2477

Conclusion

In the paper several restrictions, which diminish the computational load in the exploring the BNPSs with lengths N≡0mod4, are substantiated. These restrictions have been implemented in a computer program, which has been used for an exhaustive research of these signals. As a result several unknown up to now periodic binary nearly perfect signals with lengths $N \equiv 0 mod 4, 40 < N \leq 100$ have been found.

The results, obtained in the paper, could be useful in the process of development of radar sensor and time-synchronization networks.