

PAPER • OPEN ACCESS

The study on the possibility of forming quadrature components based on Barker codes

To cite this article: K A Osipov *et al* 2020 *J. Phys.: Conf. Ser.* **1691** 012046

View the [article online](#) for updates and enhancements.

You may also like

- [Modelling and Control of Robot Manipulators](#)
L Sciavicco and B Siciliano
- [Characteristics of manipulative in mathematics laboratory](#)
A Istiandaru, V Istihapsari, R C I Prahmana et al.
- [On-chip light scattering imaging of the guanine platelet](#)
Masakazu Iwasaka



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

The study on the possibility of forming quadrature components based on Barker codes

K A Osipov², L V Prosviriakova¹ and A A Dmitriev¹

¹ Department of Radioelectronics and Telecommunication Systems, Irkutsk National Research Technical University, st. Lermontov, 83, Irkutsk, 664074, Russia

² Institute of High Technologies, Irkutsk National Research Technical University, st. Lermontov, 83, Irkutsk, 664074, Russia

E-mail: osipov_k_a@outlook.com

Abstract. The formative stages of the minimum frequency manipulation with a continuous phase with a modified algorithm of formation of quadrature components and Barker code encoding are discussed in this article. The results of modelling the digital sequences scheme using this method are presented. The method of minimum frequency manipulation with continuous phase with changed algorithm of quadrature components formation and Barker code encoding has been described earlier. The minimal spreading of frequencies for minimum frequency manipulation by which the orthogonality of opposite signals is still maintained, it is implemented when the manipulation index is $m = 0.5$ and constitutes the value that is inversely proportional to the doubled duration of the elementary pulse transmitted by the sequence, $2\Delta f = 1/2\tau$.

For many years now, radio communication has been an essential part of our lives and each generation discovers new ways to improve it, and in particular to provide more protected and less power-intensive connection by upgrading the transmission and reception methods. The formation of quadrature with considering the approximate similarity of zeros and ones, which are extracted from the information stream and the use of coding by means of Barker code, leads to the better interference protection at the receiving end due to the autocorrelation function of Barker codes.

The complex signals are encoded with special sequences that have strongly correlated characteristics. One type of such sequences are Barker codes, which have the best autocorrelation functions. The correlators or coordinated filters with pre-defined parameters corresponding to the received signal are the part of the noise-like receivers, which are Barker codes, it allows you to maintain confidentiality of information. There is a known way to transmit binary information by complex signals with intra-pulse minimum frequency manipulation, where the encoded information sequence is received to the inputs of the quadrature modulator. [1]

In the article we present the results of the study on the formation of digital order by a new method of modulation to increase the noise immunity of the radio channel.

For the transmission of information by signals with minimum frequency modulation, including the minimum frequency modulation of the carrier frequency, the analysis of the sequence is carried out to determine the order of the even and odd unit bits of information, the order of distribution zero bits of information following the odd bits of units, determine the even and odd timing periods in the information sequence, resulting from the analysis the manipulation sequences of in-phase and



quadrature channels are formed, then the resulting sequence is converted into a bipolar code and modulated by the phase of sine and cosine harmonic vibrations of the carrier frequency, the period of which is equal to a quadruple duration of the elementary parcel of the transmitted information sequence, then the modulated phase of the oscillations are fed to the quadrature modulator of the carrier frequency.

The Universal Quadrature Modulator multiplies the phase component of the C_n carrier frequency, located in the positive frequency region, and the phase component of the complex envelope C_n , whose speed is directly proportional to the frequency deviation, and the direction of rotation depends on the value transmitted bit information. Since $f_n \gg f_d$, the direction of rotation is the same as that of the phase component in a carrier frequency, only the absolute value of the angular velocity of rotation changes, when the directions of rotation of both phase components match, it will be equal to the sum $f_1 = f_n + f_d$ or the difference in frequency $f_0 = f_n - f_d$, when they are rotated in different directions. [2]

The signal that is modulated in frequency by the minimal frequency modulation of the digital sequence a_k , presented in the form of a bipolar code, can be expressed as.

$$s(t) = \cos\left(\omega_n t + \frac{\pi a_k}{2T_b} t\right) = \cos(\omega_n t + a_k \Omega_d t) \quad (1)$$

Assuming that (1) is the complex signal actual (real) part, adding the real part of an imaginary component in the form of a Hilbert transform from the real part, then the expression for the complex signal, presented (2) in trigonometric and exponential form [2] is obtained.

$$C = \cos(\omega_n t + a_k \Omega_d t) + j \sin(\omega_n t + a_k \Omega_d t) = \exp j(\omega_n t + a_k \Omega_d t) \quad (2)$$

The phase component C , represented as an exhibitor, with an argument in the form of the sum of the two sums can be represented as a product of the phase component in the modulating process S_m and the carrier frequency C_n .

$$C = \exp j(\omega_n t + a_k \Omega_d t) = \exp j(a_k \Omega_d t) \exp j(\omega_n t) \quad (3)$$

$C_n = \exp(j\omega_n t)$ describes the phase change of the carrier frequency rotating with angular velocity ω_n . (3) The value of the carrier frequency is determined by external factors, depends on the requirements for the radio system. The carrier frequency rating f_n can be selected by any frequency value lying within the range from VHF to VHF bands and above.

Multiplier $C_m = \exp j(a_k \Omega_d t)$ is the phase component of the complex envelope modulating signal. The speed of the envelope phase is many times less than the carrier frequency phase speed, $\omega_n \gg \Omega_d$. The deviation frequency, which determines the angular velocity of the low-frequency phase component, are in the video frequency area, located in the vicinity of zero frequency. This part carries information about the amplitude, in this case it is constant and accepted equal to one, phase and, consequently, the frequency of a complex envelope modulating signal.

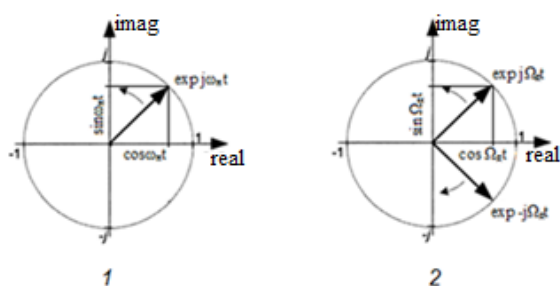


Figure 1. The phase component of the carrier frequency, C_n .

For the viewed signal with the minimum frequency modulation without breaking the phase amplitude of the signal is taken constant, equal to one, and $m = 0.5$, using the minimum possible frequency difference equal to $2\Omega_d$, which still maintains the orthogonality of the oscillations of the opposite bits on a symbolic interval. The a_k presence in the phase of the signal leads to an inversion of the phase

addition sign at the time when the bit changes to the opposite, resulting in a deviation frequency in the process of modulation, Ω_d , can take a positive or negative value.[3]

To maintain phase continuity, the modulating signal must be time-related to the code sequence.

In order to prove the above statements, a number of experiments were carried out to form a minimum frequency manipulated digital sequences with the Barker code using the electronic simulator PROTEUS. The results of the experiment are presented below.

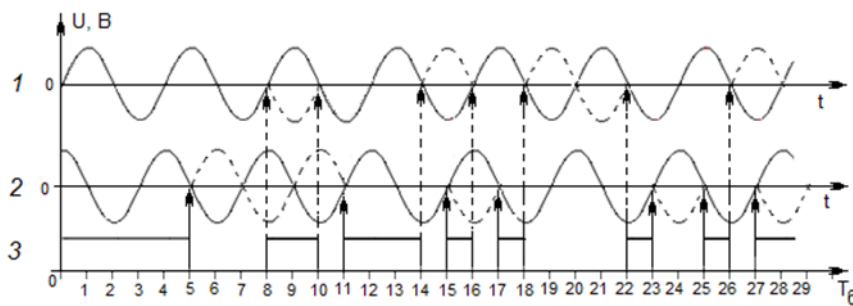


Figure 2. Correlation between the phase reversal requirement moments and favorable conditions for its implementation.

Image 2 presents the graphs explaining the transformation of the quadrature and in-phase component of the phasor to the quadrature component of the complex envelope modulating process relative to the modulating sequence. The graphs clearly illustrate the fact that the phase continuity is achieved.

Binary sequence of the modulation code is converted to BVN code. A signal manipulated by frequency in accordance with the minimum frequency manipulation of the digital sequence a_k can be expressed as:

$$S(t) = \cos\left(\omega_n t + \frac{\pi a_k}{2\tau} t\right) \quad (4)$$

where $\omega_n = 2\pi f_n$ - the carrier frequency, $a_k = \pm 1$ - a sequence of information symbols to be transmitted, expressed in the code of BVN. The next step is to select a sequence corresponding to the single bits of the previous code, the pulse duration is equal to half the duration of the bits of the code. Further, the sequence is passed through the frequency divider by two and the output is a sequence containing odd bits and zero bits.

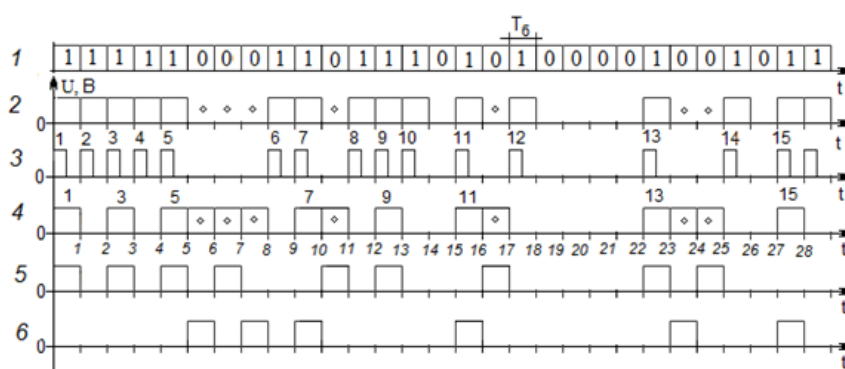


Figure 3. Time diagrams of control code formation stages.

Figure 3 shows graphs, that illustrate the forming of control codes: 1 - digital information sequence, 2 - displaying bits of the digital sequence by unipolar binary code, (rhombs denote zero bits following the odd single bits), 3 - numbered sequence of single bits, selected from the input sequence. 4 - A sequence of bits that is obtained at the output frequency halver of unit bits (the time axis is marked with the numbers of clock intervals; rhombs denote the unit bits obtained by transforming the zero bits following after the odd units in the input sequence), 5 - unit bits following on the odd clock intervals, 6 - unit bits following on the even clock intervals.[4]

Let us study the operation principle of the device for generating modulation codes on the example of the 111100010 sequence. In the sequence of the sinus channel we include the modulation code of the quadrature component of the complex signal, Q , relative to the signal coming from the block formation of quadrature channels. Thus, we obtain single (1st, 3rd and 8th units) or the following zero bits of information (9th and 10th zeros after 8th unit), or inverse modulation code quadrature component of the complex signal, relative to the inverse signal coming from the block formation of quadrature channels, it is (2nd and 4th) single, or the following zero bits of information (5th, 6th and 4th zeros after 4th zero).

In the sequence of cosine channels we include the modulation code of the in-phase component of the complex signal, I , relative to the signal product coming from the block of formation of quadrature channels and the information sequence signal (1st, 3rd and 8th) single or zero bits (5th, 6th and 7th), or inverse modulation code of the in-phase component of the complex signal, with respect to the product of the inverse signal from the block of formation of quadrature channels and the inverse information sequence signal (2nd, 4th and 8th) of single, or zero bits (9th). Then we replace the quadrature modulation codes, that are on the even clock intervals of the sinus channel, with the in-phase modulation codes of the even clock intervals of the cosine channel and vice versa.

The formation results of code marks in sinus and cosine channels for this sequence are presented in table 1.

Table 1. The formation result of modulation codes in the quadrature channels.

Input sequence.	1-odd	2-even	3- odd	4- even	5- odd	6- even	7- odd	8- even	9- odd
	1	1	1	1	0	0	0	1	0
Stage 1 of sine channel modulation sequence formation	Q 11110	$\bar{Q} \downarrow$ 00001	Q 11110	$\bar{Q} \downarrow$ 00001	$\bar{Q}$ 00001	$\bar{Q} \downarrow$ 00001	$\bar{Q}$ 00001	$Q \downarrow$ 11110	Q 11110
Stage 1 of cosine channel modulation sequence formation	I 11100	$\uparrow \bar{I}$ 00011	I 11100	$\uparrow \bar{I}$ 00011	I 11100	$\uparrow I$ 11100	I 11100	$\uparrow I$ 11100	$\bar{I}$ 00011
Modulation sequence of the sine channel after changing the codes at even intervals	Q 11110	$\bar{I}$ 00011	Q 11110	$\bar{I}$ 00011	$\bar{Q}$ 00001	I 11100	$\bar{Q}$ 00001	I 00011	Q 00001
Modulation sequence of the cosine channel after changing the codes at even intervals	I 11100	$\bar{Q}$ 00001	I 11100	$\bar{Q}$ 00001	I 11100	$\bar{Q}$ 00001	I 11100	Q 00001	$\bar{I}$ 11100
Modulation sequence of sine channel in bipolar code	+Q ++++-	-I ----+	+Q ++++-	-I ----+	-Q -----	+I ++++-	-Q ----+	+I ++++-	+Q ++++-
Modulation sequence of cosine channel in bipolar code	+I ++++-	-Q ----+	+I ++++-	-Q ----+	+I ++++-	-Q ----+	+I ++++-	+Q ++++-	-I ----+
(IQ)	+++++	+++++	+++++	+++++	----+	----+	----+	+++++	----+

After the formation of modulation sequences in the in-phase and quadrature channels, the signals are multiplied with the carrier, which is a sinusoidal and cosine weighting of symbols. As a result, the signals arrive at the quadrature modulator input, where the signal is formed with minimal frequency manipulation. [5]

In order to experimentally confirm the theory, we carried out a number of experiments on schematic implementation which was mentioned above using FPGA, the program was written in the Quartus II development environment in the Verilog electronic hardware description language. A model of the scheme for forming quadrature components was created and the code was written. The results are presented in figures 4 and 5.

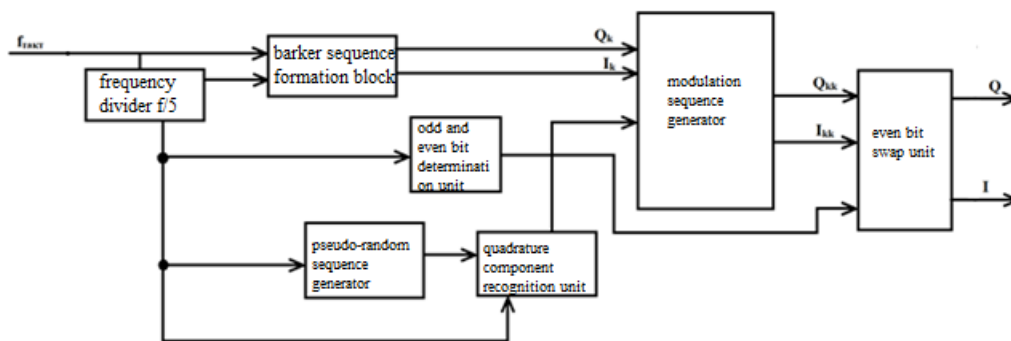


Figure 4. The structural scheme of forming the quadrature components.

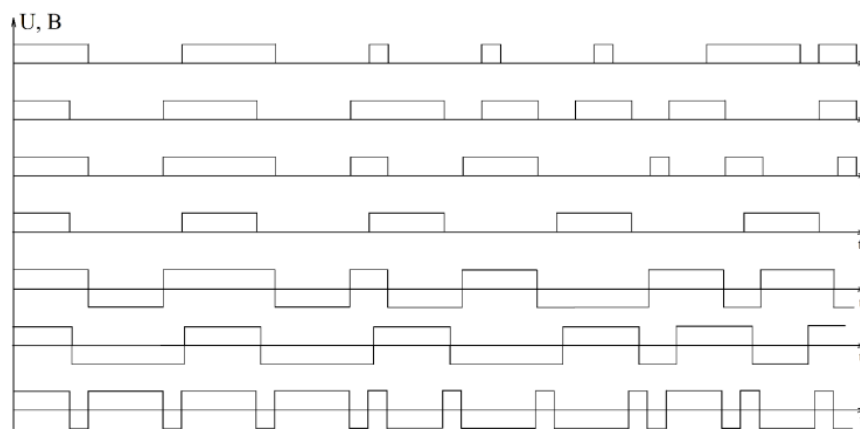


Figure 5. Time diagrams of the quadrature component shaper.

The results of the experiment show that the time diagrams match the theoretical representation. The considered principle of formation of the quadrature and in-phase channels code sequence is realized and it works, stages of changing and forming the carrier frequency phase that are graphically and mathematically described match with the practical ones. The results prove the reliability of the method and allow us to continue research to obtain a device to implement the above modulation method.

References

- [1] Galkin V A 2007 *Digital mobile radio communication: training manual for universities* (Moscow: Hot Line – Telecom)
- [2] Lyons R 2006 *Digital Signal Processing: Second edition* (English: Binom-Press)
- [3] Zasenkov V E, Prosviriakova L V and Shevchenko V E 2012 Pat. of the Russian Federation

- 2475936** appl. 16.03.2012, publ. 20.02.2013
- [4] Zasenko V E and Prosviriakova LV 2006 *Features of methods for generating digital signals with minimum frequency modulation with continuous phase 2* 161-4
- [5] Zasenko V E and Prosviriakova LV 2004 Pat. application **2231924** RU
- [6] Zasenko V E and Prosviriakova LV 2016 Pat. application **2358404** RU