Evolutionary synthesis of non-Barker sequences

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In the previous article, I made an unforgivable mistake. When proposing a method of transmission using a pseudo-noise signal, I should have proposed a sequence that would provide acceptable characteristics of the communication channel. The requirements for the sequence are standard: the correlation coefficient (normalized in our case) should be equal to +1 or -1 in case of synchronization of the input and received sequences. It must also be equal to zero (or an acceptable small value) at any other sliding time moments of the input signal relative to the prototype. This requirement is known to be fully satisfied by Barker sequences.

However, the proposed method of signal transmission requires solving a problem unsolvable both analytically and numerically: for a sequence of length 32 characters and 8-bit quantization of samples, the number of variants will be equal to N = 8160! Of course, any computer cannot handle such a factorial value in any reasonable amount of time.

Besides, there is no evidence that sequences suitable for the proposed communication channel exist at all. This leaves only the intuitive-experimental way of analyzing the problem.

Let us try to develop a software stand to search for sequences. We will use the transitions: -1,+1,-1,-1,+1,+1,-1,+1. In such a sequence of symbol changes all possible cases of formation of parasitic lobes of the correlation transformation will be taken into account. The level of the useful signal will be normalized to +/-1 at the moment of synchronization, and the rest of the samples will be represented in fractions of the found unit (this function is provided by the Pearson correlator).

Let us set a symmetric sequence with time and level inversion for the right and left halves. We will choose the best variant from randomly generated sequences.

The first results turned out to be the most unsuccessful, which is to be expected: the area of "good" sequences in a potentially huge data set is negligible, and the probability of getting into it tends to zero.

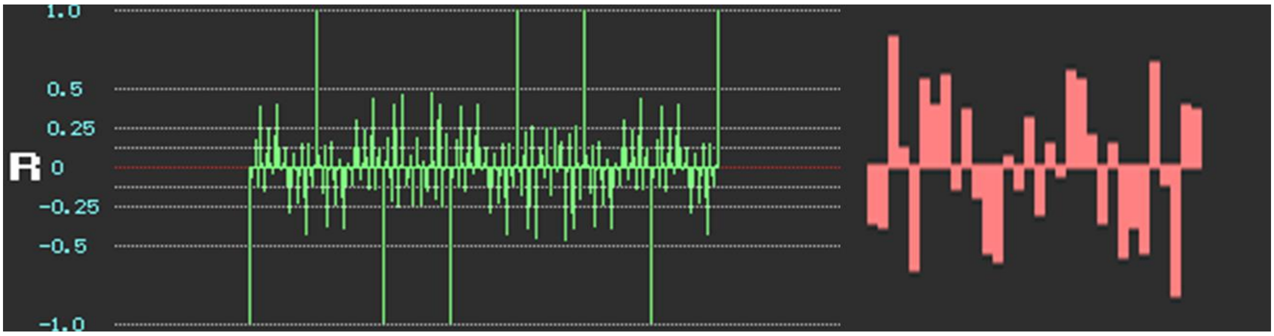

Fig.1. Experiment with random data: on the left the signal at the correlator output, on the right the image of the applied pseudo-random sequence. The result is only slightly better than 3 dB, and it cannot be recognized as acceptable.

Let's try to use the method used in the Miller-Yuri experiment: let's turn on the stand for a long time and wait for the sequences that give the best results. We will evaluate the quality of sequences in the form: K = U/R, where R is the maximum value of the unwanted lobe of the correlation transformation, and U is the value of the correlator signal at the moment of synchronization. The result of the experiment, in which "K" exceeded the previous value, will be displayed, and otherwise - ignored.

In the process of operation, we have a time-delayed rise of the graph, and the waiting time for a new "good" sequence becomes unacceptable. At the same time, the achieved coefficient does not provide the desired quality of the correlator operation.

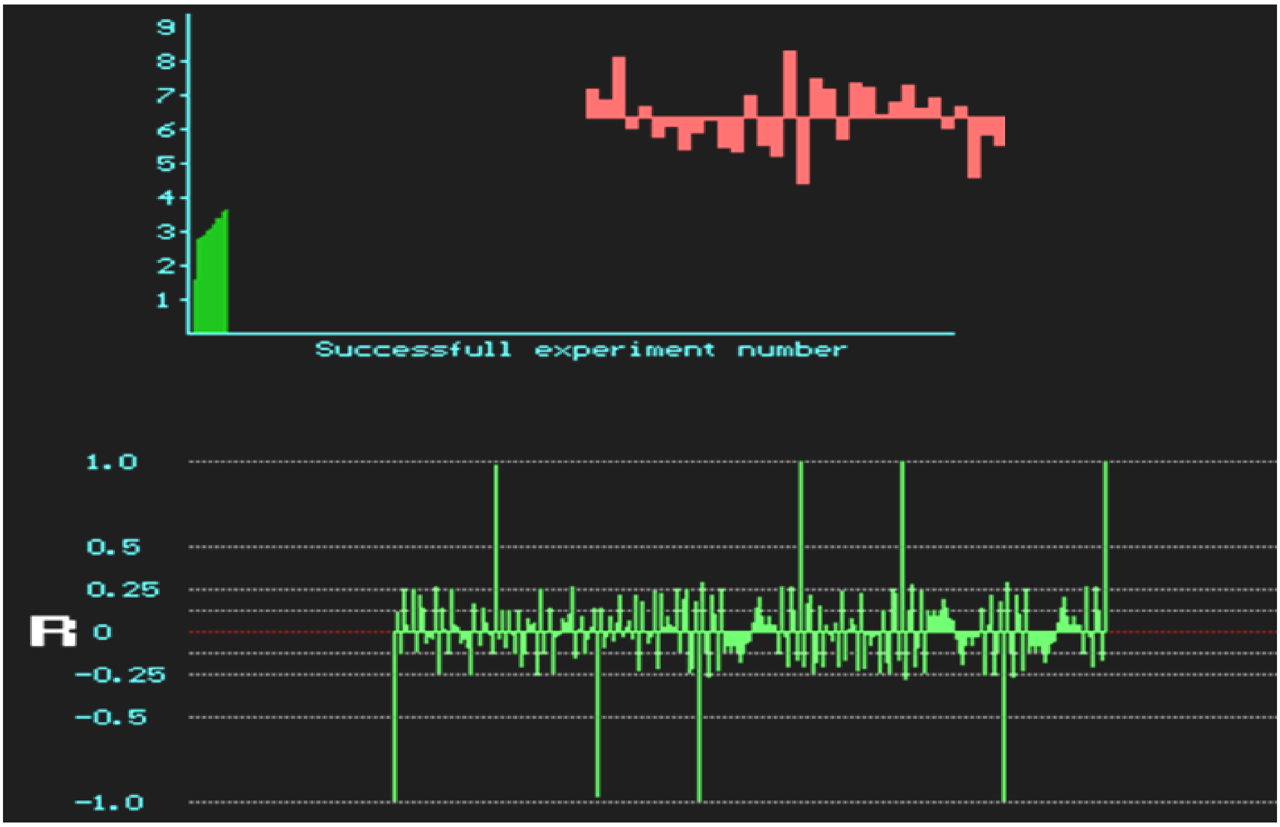

Fig.2. The result of random sequences enumeration. After 24 hours of continuous operation "K" less than 6 dB was obtained, its graph (shown on the upper left) stopped, and the increasing time of waiting for new successful sequences made the continuation of the experiment pointless.

So, we can consider that there is a deadlock, or, better to say, a barrier, and the function of increasing required search time is described by the graph of increasing values of the factorial. Let us call it the first barrier and take into account that in the experiments on spontaneous synthesis of amino acids the process stopped in the same way. The only way out of this situation can be assumed to be the inclusion of evolutionary mechanisms.

Let the sequence that has been found not yet very "good" has acquired the ability to replicate itself, and the replication occurs with errors, i.e., with inclusions of noise components whose contribution is significantly less than the absolute values of the symbols of the initial set.

As an analogy: such a jump must have inevitably occurred at the early stages of formation of biological life. Without this stage, any further development of self-copying systems is hardly possible - the barrier must be overcome.Let us conduct an experiment of primitive reproduction and selection on the criterion of the quality of self-reproducing sequences - whether chemical as in the beginning of biological history, or just computer models. Some general laws of early evolution must be the same for both the first randomly assembled molecular structures and pseudo-noise sequences. Therefore, the criterion for suitability for "life" would be suitability for survival in the environment in one case, and suitability for operation in radio systems in the other.

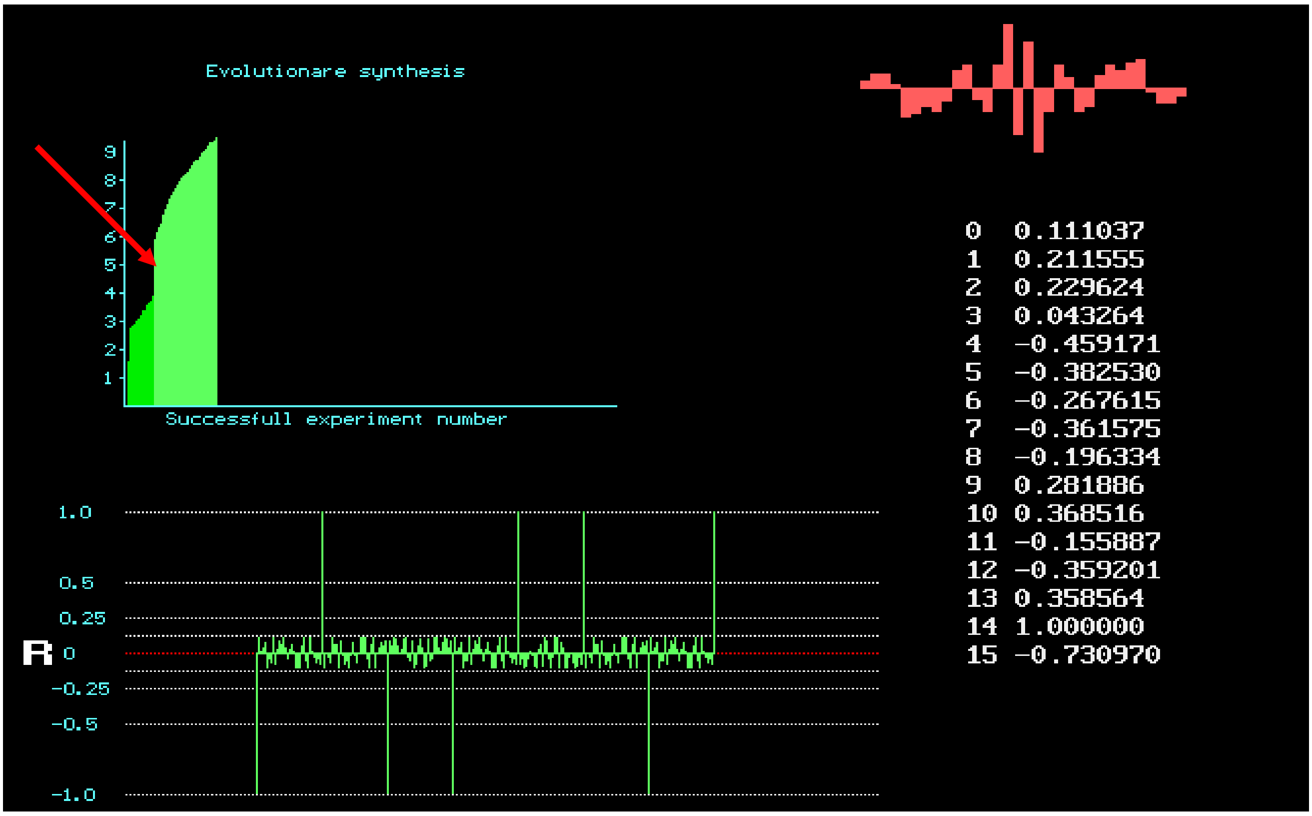

Figure 3. At the moment shown by the red arrow, a mechanism is switched on when the sequence values are not replaced completely, but the original sequence is supplemented with random data, and the contribution of the noise component is two orders of magnitude less than the original signal level. The selection of "qualitative" sequences is based on the "K" value. The new mode of operation is highlighted in bright green color. Values in fractions of one unit are shown on the right, they can be used (the right part is inverted by U and t).

The obtained result can be considered satisfactory: 20 dB is quite sufficient for operation of the threshold system at the output of the correlator, because in real radio technical conditions there are always air interference and own hardware noise.

Let us assume that the technical problem in the first approximation is solved: such sequences can be generated many and different. I.e. additional opportunities to increase the bandwidth of the communication channel are obvious. Note also that when using different sequences to transmit identical symbols, illegal synchronization (and decryption of data by Eve, provided that Bob and Alice have sufficient computing power of transceivers) will be difficult.

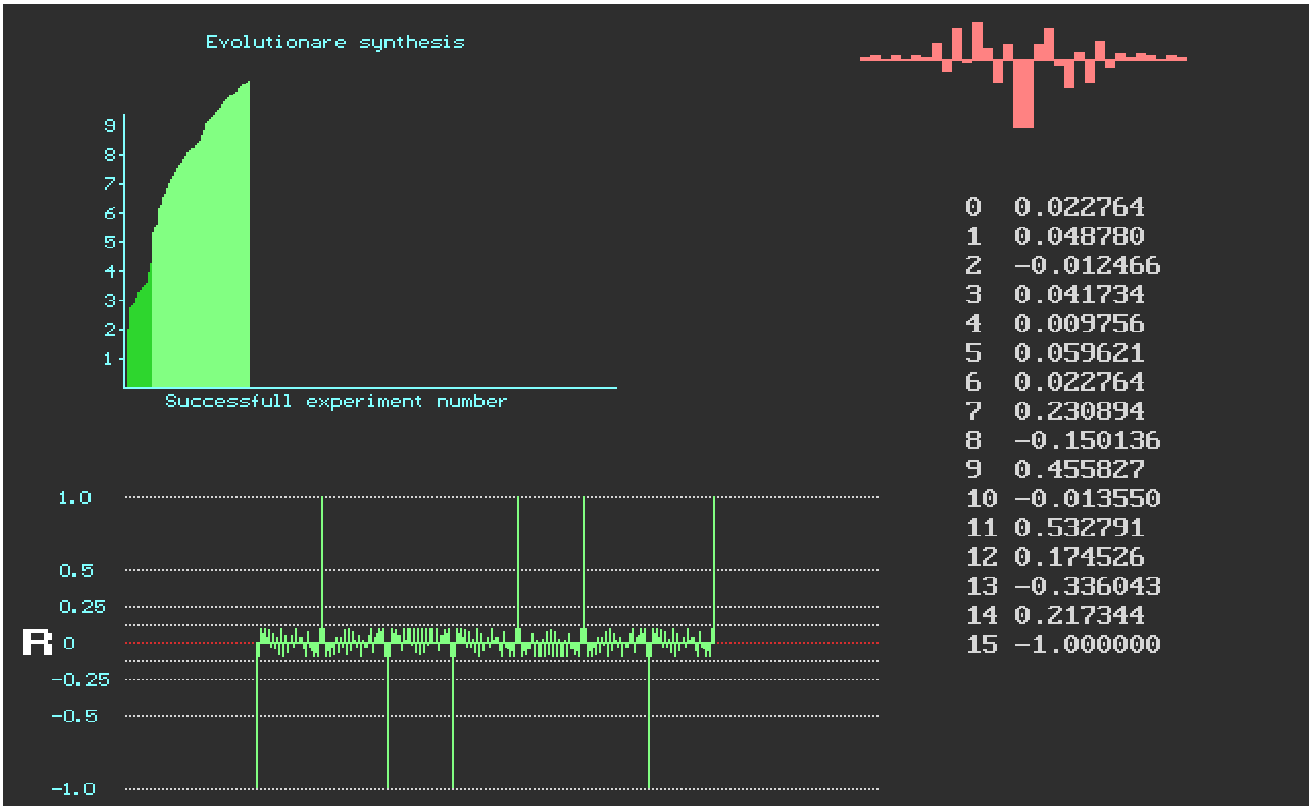

Figure 4. Another not fully symmetric sequence: in this case the coefficient is more than 22 dB.

Further "evolutionary" experiments, it should be assumed, have no practical sense. But there are so many interesting mechanisms in nature that it is hard to resist the temptation to try them. First of all it would be logical to check whether plasmid transfer of information works, and what the simplest crossingover will give.

Even the first experiments with the exchange of information (in the presence of noise) from two "parents" gave unexpected results: the hypothesis that a usable sequence must be symmetric and have zero mathematical expectation turned out to be untenable. Some asymmetric "children", as it turned out, have quite a "right to life".

At the same time, the hypothesis that some "descendants" will exceed both "parents" in quality was fully confirmed.

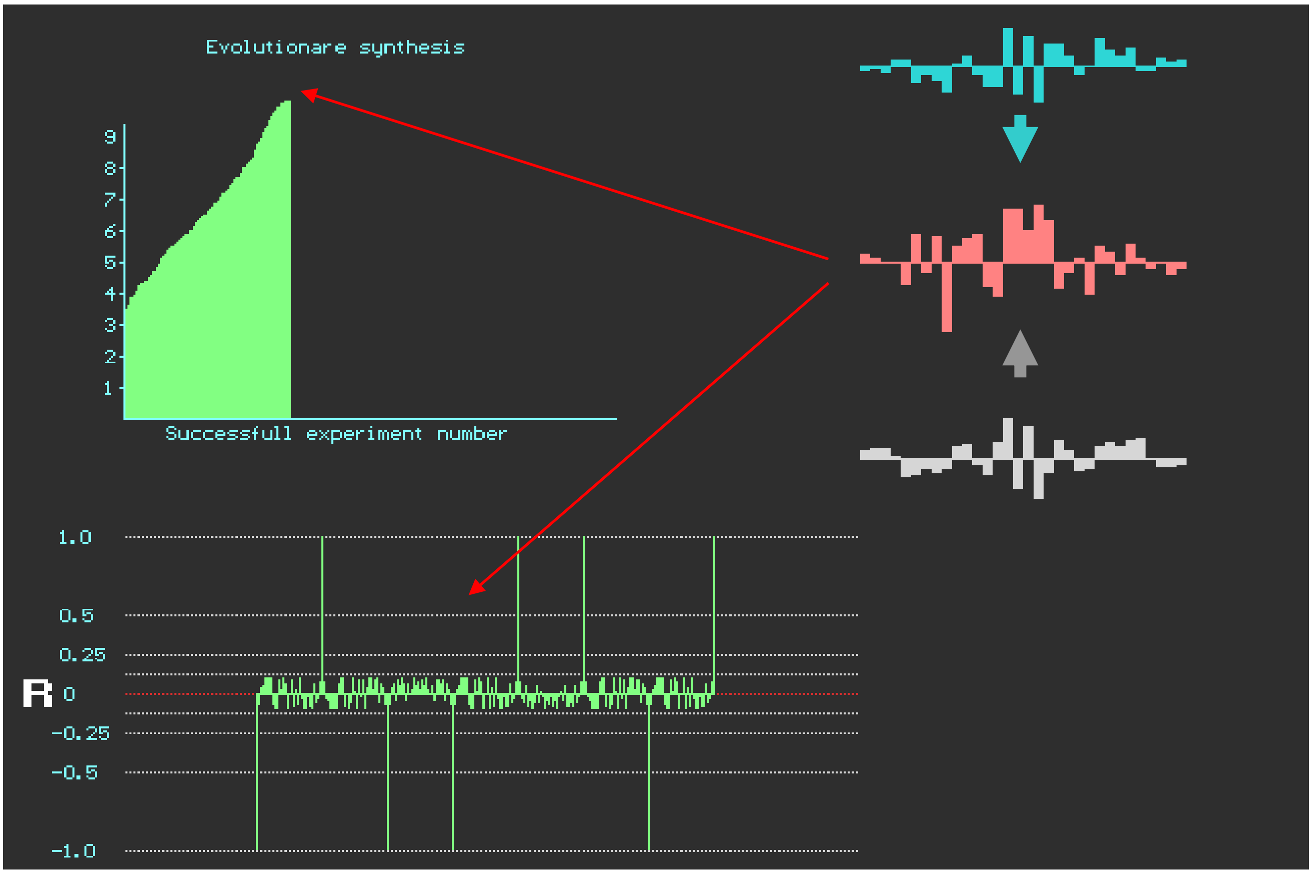

Figure 5. Evolution of the result of "crossingover" of gray and blue sequences. The quality of the red sequence is much higher, despite its unsightly appearance.

Conclusions:

1. Mathematically strictly the problem is not solved, but the proposed method of sequence synthesis can meet the technical requirements of pseudo-noise communication channels.
2. It will not be possible to obtain the optimal sequence with "Barker" characteristics, but any close approximation to it is possible.
3. Perhaps, the proposed method of problem solving will be useful in the analysis of biological evolutionary processes.