Your FAQ about coding

1. Why is the coding necessary in communication systems, if thus an average error probability actually increases during transmission, since it is needed to transmit for the same time additional control symbols of a code?

It is quite right. If for an example they take a code with **R**=1/2, the transmission energy for one code symbol will be at 3 dB (twice) less, than without coding, and an error probability will increase for each binary digit notably. But, nevertheless, if the code has a large enough code distance, for example, with **d**=11, the resultant probability of an error after successful decoding can be at some decimal exponent smaller, than the error probability in a channel.

Numerical example: let initial an error probability in each transmitted bit without coding of the transmitting sequence is equal to $\mathbf{p_1}$=0,01. Because of coding at twice decreasing symbol energy the symbol error probability in a Gaussian channel will be already $\mathbf{p_0}$~0,05. But since the lower precise enough estimation of an error probability, for example, after MTD or any of the optimum decoder (OD) for this code looks close to $\mathbf{P_b(e)}$~$462\mathbf{p_0}^{(d+1)/2}$, the large exponent at $\mathbf{p_0}$, equal 6, provides small total probability of an error of the decoder on bit $\mathbf{P_b(e)}$~10^{-5}. Comparing initial probability $\mathbf{p_1}$=10^{-2} and resultant - $\mathbf{P_b(e)}$~10^{-5} at the identical bit energy/noise density ratio, we see, that the coding has appeared rather useful, as the code gain (CG) for these code parameters will be more than 5dB (~3 times).

2. Why is it necessary to use codes in general? You see at their usage the signal spectrum is extended or the time of communication grows.

Yes, it is necessary to transmit additional symbols in any way too. It is considered, that just the bit power in most cases is a main parameter, which they need to minimize. Though spreading of spectrum is desirable to be minimal also. They usually do not try change time in considerations with respect to the case of transmission without coding. But just the economies of signal power bring a very large economic profit calculated in millions of dollars. The result of coding application can be reduction of the aerials sizes, increase of distance or transmission rate, and also many other advantages. It also determines value of coding for satellite communications systems.

3. How can we write the good Requirement specification (RS) for the coding system?

Below we suggest to your attention representative enough version considered by the customer and customer list of an coding system parameters, which ones they should agree in the process of RS consideration.

List

main specifications of code and decoders' parameters
for coding system development

1. Main specifications.

1.1. Block/convolutional codes.
1.2. Binary/binary code.
1.3. Code length **n** (number of code symbols).
1.4. Decision delay **L** (number of code symbols).
1.5. Code rate **R** (redundancy).
1.6. Code distance **d** (minimum or free).
1.7. Code gain (CG) **G**, dB.
1.8. Output decoder probability, bit error rate (BER) $P_b(e)$,
($\sim 10^{-5}$ or something else).
1.9. System of signals of modulation (binary, circular PSK, quadrature (flat system 4x4) etc.
1.10. Form of channel quality control.

2. Padding and interdependent with main coding parameters.

2.1. **K** - length of the encoding register.
2.2. $\mathbf{E_b/N_o}$ - channel bit energy to noise power density ratio.
2.3. $\mathbf{p_o}$ – an error probability at the input of the decoder (at the channel output).
2.4. $\mathbf{E_s/N_o}$ - channel character energy to noise power density ratio.
2.5. Kind of the modem: hard/soft.
2.6. Applicability or necessity of concatenating.

3. General characteristics of a communication system.

3.1. Block transmission delay, (ms).
3.2. Decision decoding delay, (ms).

3.3. Kinds and ways of interaction with clock equipments (branch, symbol, block, frame, …..).

3.4. Implementation: software/hardware.

3.5. Total characteristic of a channel.

3.6. Capabilities of multisequencing of functions in the decoder.

3.7. Decoding processing speed (bits/s).

3.8. Time of the project development.

3.9. Subject of researches in the process of development realization (vague moments of the project).

3.10. Complexity of development (scope of work, scheme complexity, indispensable development time, degree of homogeneity, ways of testing, kinds and volumes of testing, indispensable infrastructure for development, kinds of interaction with the modem).

3.11. Availability of instrumentation of testing (digital noise simulation etc.).

4. Management.

4.1. Order of financing.

4.2. Possible kinds of the agreements.

4.3. A subject of the agreement (what must be done).

4.4. Training of staff.

4.5. Form of tests, order.

4.6. Fulfillment of work stages.

4.7. Responsibility of the parties.

4.8. Using of intellectual actives.

1.1. Assistance to prolongation of scientific investigations

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4. How can they test possibly greater numbers of best known algorithms during a communications system designing?

It is desirable permanently to work in this composite and interesting area of system design of communication. It will allow to keep abreast of all main results in the field of coding engineering. The majority of the best algorithms should be modeled and continuously be compared one another. Besides it is necessary to keep track of by the published reviews in the field of coding.

We have decided to facilitate to the designers a problem of selection of a coding method and have created the digital satellite channel communication simulator, which one contains all main most effective coding methods.

Its description is at our web-site.

If necessary we shall include in a structure of the simulator additional software and those, probably, special coding/decoding methods, which ones are necessary for considering in your corporation.

Acquiring such a computer simulator with the best up-todate coding algorithms, you can watch and forecast an advance in technology of coding on many years forward.

As soon as possible we shall prepare the new version of the digital simulator, which one will allow to check up hardware versions of decoders work.

5. Why are the lower estimations of error probability of the MTD decoding (decode BER) even at rather low values of a code distance d to be a very small? Are they weak estimations?

No, they aren't. If the characteristics of decoding algorithms correspond to the optimal decoder (OD) capabilities or are close to them, then, really, the probabilities of decoding error even at a code distance of used codes **d~7** appear to be small enough. But the OD characteristics should be reached even in any ways! MTD can do it in many cases. And about other algorithms it cannot be asserted. It is necessary to consider everything accurately.

6. Why do the optimum decoders (OD) usually create the decisions with packets of errors? If it is effect of decoding error propagation, then is it possible to reject it? Do other decoders make errors grouping too? And how do MTD behaves itself in this case?

It is a lot of questions, but all of them are actually about the same relevant subject.

The optimum decoders are characterized by that they will realize in this or that form an exhaustive solutions search and then will chose best of them. But for them it is necessary to select best, densely packaged codes with the greatest possible values of a code distance **d** also. And in such codes there are a lot of code words of weight **d**. But then in such a code there will be always words of minimum weight with many "ones" in informational positions. It is well-known and for a long time parsed situation. In the case of OD they are reconciled with errors grouping, because errors decrease seldom enough thanking just to large values of code distance **d** of codes used for OD.

And if the decoder is not optimum, decoding errors grouping may be property of the decoding algorithm too. In this case it is possible to speak about an error propagation effect (EP) of decoding. Thus, the errors grouping always depends both on algorithm, and on kind of a used code. It is necessary to allow it also by selection of such algorithms, specially if they are intended to be used in concatenated circuits of coding. It is possible to make a EP very small by exact selection of codes in MTD.

7. Why does the coding demand very large solution delays ?

Actually it is not always so. If the requirements for code to work at a very large noise level are absent, it is always possible to find algorithms with enough moderate delay. And when working near Shannon channel capacity C it is really necessary to apply only lengthy codes. This important property is illustrated by diagrams of spherical packaging bounds, which ones are in our presentations on this web-site both in Russian, and in English versions.

8. It is a lot of different channels, in which there are no errors practically at all. Why must they apply coding in general, if it is possible simply to increase transmission energy?

When they have connected two computers on one desktop by a cable and rewrite the data from one disk to another, there are no errors in a cable usually and it is no necessity to apply codes in this case.

But if in a satellite channel you do not have errors even without code application, it means only, that you have spent very large money for its creation and you use only 1% (1 percent) of the channel capacity **C** or even less. If your system is commercial, you will be guaranteed bankrupt, because in other channels of the same type your competitors transmit in hundred (and may be even in 1000!) times more information namely due to coding application.

Remark, that indisputable true at a solution of communications system exact designing problem in Gaussian (and many others) channels is extremely paradoxical (only for the start view!) phrase: in the correctly designed satellite channel there should be a large enough mean error probability per bit. And we hope, that it is understandable for you, that from here also follows that in such a channel the modem contains a very effective decoder, at many decimal exponents lowering total error probability after corresponding processing. It guarantees, that in such a communications system the fundamental ratio **R<C** (code rate less than channel capacity) will be true, and the attitude **C/R**, in turn will not be too large. It is possible to consider as a quite good result, if it will appear, that **R~0,8C**. However for very expensive communication systems already now channel utilization index (in our example – it is 0,8) already at state of the art of coding engineering can be increased up to 0,9 and even more higher values.

9. Give, please, example of bad comprehension and usage of coding methods.

We would like to say very much, that we do not know such cases. But, unfortunately, everything is quite the contrary. They avoid coding under the most fancy excuses in different cases. It is a pity specially, when codes are applied abnormally and as a result they discredit the extremely relevant and useful methods and ideas.

Here is a recent very sad example. It was supposed to use in a customary binary channel (BSC) with PSK-2 Read-Solomon (RS) codes and there was a condition to achieve higher decoding characteristics, than in the case of Viterbi algorithm (VA) application. "The strong" argument was that the RS code with parameters **(n,k,d)** = (64,32,33) has length in bits, equal, apparently, **L**=64*6=384. It is clear, that this **L** is much more large, than for a standard code for VA with **K**=7. And for VA **d**=10, that is much less too, than for a RS code. So in general, a new coding "revolution" approached again. And really, the specialists for a long time work with decoders for RS codes even with length 256. So "no any problems at all"!

But the everything has ended in such a way. If they will orient to the binary transmission, it is necessary to transmit 6 bits for each character of a code RS reception. The VA effectively works in Gaussian channel at R=1/2 and error probability at the input of the decoder $\mathbf{p_0}$~0,05, reducing bit error probability at the VA output to the standard values ~$\mathbf{10^{-5}}$. So all 6 bits (and **q**-ary character itself) will be received correctly with probability only $\mathbf{(1-p_0)^6=(1-0,05)^6\sim 1-6*0,05\sim 0,7}$, i.e. error probability of each transmitted character (because of the poor correspondence of RS code with a binary channel) is close to 0,3. And as it is necessary to transmit 64 characters of the RS code block, the average number of errors in the block will be **N**=64*0,3=19. But this code can correct only 16 errors in the block! Where do they win over VA!? All blocks of RS code after customary decoding algorithms will be erratic.

And that's all!

By the way, some of such "specialists" have post-graduate students on coding. Be careful!

So come to us to study codes.

And the effective simple decoders creation for non-binary codes - it is a good task for us too.

Following portion of questions on coding
we shall consider approximately in one month.