ROCKET-SPACE DEVICE ENGINEERING AND INFORMATION SYSTEMS
Vol. 3, Iss. 2, 2016, pp. 60–65

The Analysis of the Potential for Applying the CCSDS Recommendations with a View to Improve Technical Characteristics of the Domestic Space Radio Links Intended for Transmitting Telemetry from Objects of Different Purposes

V.L. Vorontsov

candidate of engineering science
A branch of Joint Stock Company "United Rocket and Space Corporation"–"Institute of Space De-vice Engineering" ("ORKK"-"NII KP"), Russia

e-mail: a762642@yandex.ru

Abstract. The paper presents the analysis of the opportunities to use the CCSDS recommendations for building the domestic radio links to transmit telemetry in the absence of the required domestic teleme-try standards. Advantages and problematic issues are highlighted related to applying the CCSDS rec-ommendations for the domestic practice. The most important features of the CCSDS recommendations in force are related to integrating operations with data (signals) and combining data (signals) with a view to implement certain functions ensuring significant advantages and employed for developing space radio links. Good prospects apperar to get these advantages when building domestic space radio links. However, consideration should be given to specific features of domestic space radio links (there are notable differences) and to the procedure for applying the CCSDS recommendations (particularly, using the patented technical solutions).

Keywords: space agency, CCSDS recommendations, space radio link, telemetry, modulation tech-niques, noiseless coding techniques

The significance of the CCSDS recommendations (technical solutions given in the CCSDS documents) when solving practical tasks of the domestic telemetry, in particular, the coarse (field) of SLS is increasing (CCSDS – Consultative Committee for Space Data Systems; SLS – Space Link Services). This tendency is caused by the substantial improvement of the space radio links opportunities during the realization of these recommendations. In addition, a problem of the valid choice of the reasonable technical solutions in the CCSDS recommendations becomes urgent due to the constant growth of the CCSDS recommendations number, their constant correction and absence of the necessary domestic telemetry standards.

The aim of the paper is to determine the general approaches to the choice of the reasonable technical solutions contained in the CCSDS documents related to the space radio links used for transmitting telemetry data from the objects of various purpose being telemetered.

Usually, in the CCSDS practice, initiating new technical solutions by the space agencies and formulating the CCSDS documents provisions corresponding to them are caused by the following reasons:

– new tasks of the space agencies-members of the (relevant recommendations are usually written in the Blue Books; surveys are written in the Green Books; explanations of the provisions are in the Blue Books; and best practices are in the Purple Books);

– "rigid" requirements, which significance is expected in future (they are written in the Orange Books, or Experimental Specifications);

– necessity in coordination (correction) of the separate provisions of the recommendations (for example, if some contradictions are revealed) can arise at any development stage of the existing recommendations.

Under such conditions, following approaches regarding solving organizational and technical issues exist:

– ensuring succession. For instance, using the modulations that provide carrier suppression is more profitable from the energy point of view than to use a residual carrier. However, since many space agencies employ ground stations operating with the residual frequency, where they invested great sums of money (rec. 2.3.1 [1], rec. means a recommendation), so, according to the CCSDS recommendations [1], the phase-locked loop (PLL) means of the receiver used for work with both residual and suppressed frequencies can be applied;

– complexing the methods of operations on the data (signals) and of the data (signals) with allowance for their mutual dependence and variety of space radio links, as well as changing conditions of applying radio links (for example, changings in time of the jamming situation, changing of the distance between the source of information and the recipient);

– coordination of the corrected CCSDS documents provision with space agencies-members of the CCSDS to provide mutual support.

However, at times, separate technical solutions or their combinations and restrictions (requirements) corresponding to them can be applied in solving other tasks (the tasks, not initiated for CCSDS). i.e., they turn out to be universal in some way. Moreover, there is a tendency to universality (diversification). It reveals itself in complexing the methods of operation on the data (signals) and of the data (signals) to fulfil certain functions used for solving the building tasks of a space radio link.

A confirmation of the complexing should be further examined.

In case of carrier suppression, one of the following modulation method should be used (rec. 2.3.2A [1]):

– (filtered) BPSK,

– (filtered) QPSK,

– filtered OQPSK (rec. 2.4.17A and 2.4.17B [1]),

– GMSK (rec. 2.4.17A and 2.4.17B [1]),

when a system with a residual carrier surpasses the restrictions on power flux density (PFD) onto the Erath's surface providing the following values of the speed to transmit the symbols of the space-to-ground communication channels are not exceeded:

– 2 Msymb/s in the bands 2 and 8 GHz;

– 10 Msymb/s in the band 26 GHz;

– 20 Msymb/s in the band 32 GHz.

If the above-mentioned modulation methods are used (that provide carrier suppression), so data randomization should be used, as it is determined in rec. 2.3.2A [2].

It should be noted that at the symbol bit rate not more than 2 Msymb/s and frequency band 2200–2290 MHz, the BPSK methods with filtration, OQPSK with filtration and GMSK relate to the modulation methods ensuring carrier suppression. The OQPSK methods with filtration and GMSK therewith are the most preferred. At the symbol bit rate more than 2 Msymb/s and frequency band 2200–2290 MHz, the OQPSK methods with filtration and GMSK are also recommended.

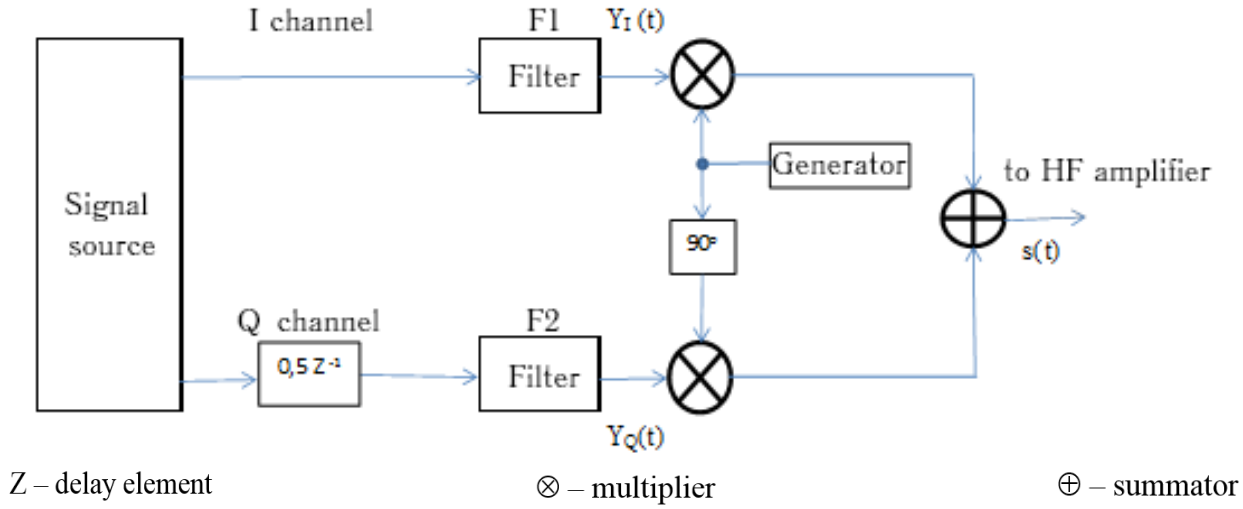

Fig. 1. A block diagram of the Q-I modulator with filtration of the main frequency band

In its turn, the OQPSK methods with filtration and GMSK are built according to the complexing principle [3]. As the OQPSK-modulator circuit (Fig. 1) [3] shows, that certain actions on the signals precede the carrier frequency modulation. Common-mode and quadrature signals are filtered by means of smoothing filters F1 и F2, and a signal delay in the Q channel is a half of the durability of the symbol interval T_s to create a phase shift between the I and Q channels. Signals of the I and Q channels on the output of the signal source are formed in the NRZ format.

VCM and ACM, presented in the DVB-S2 standard [4], aimed at increasing the resistance to jamming, are connected with complexing of the modulation methods and antinoise coding.

The essence of the Adaptive Coding and Modulation (ACM) is in well-timed change of the modulation type and (or) the speed of the antinoise code dependently on the jamming situation state evaluated on the recipient's side according to signal-to-noise ratio. In such conditions, parameters combinations of the modulation and antinoise coding, structure and meaning of the commands formed on the recipient's side for correct adjustment of the modulator and coder are determined a priori. The data formed on the information source's side for further sending to the recipient incorporate reference data on setting of the modulator and coder that enables one automatically change the adjustment of the modulator and decoder on the recipient's side. Change in the modulator and coder settings (as well as demodulator and decoder respectively) is carried out without loss of information.

In case of Variable Coding and Modulation (VCM), well-timed change of the modulation type and (or) the speed of the antinoise code is performed by the program.

Methods of the antinoise coding and conditions for their fulfilment are also connected to complexing (Fig. 2) [2].

Apart from showing the nature of the above-mentioned complexing, the results given (despite the fact that there are not many examples) show quite full that substantiation of the operation methods selection over the data (signals) and features of the data (signals) when building a certain space radio link is connected not to the obvious choice of the relevant CCSDS recommendations (providing the stated radio link correspond to the CCSDS requirements).

There are other aspects as well, regarding building a space radio link, connected to the necessity to fulfill specific CCSDS requirements.

In particular, there are the requirements of the electromagnetic capability (EMC) through limitation of the spurious emission level.

Following the CCSDS recommendation (rec 2.4.16 [1]), total power of any spurious emission should not exceed -60 dBc (dBc is measured relatively to the total power of the unmodulated carrier).

One of the methods to meet this requirement is to eliminate a symbol asymmetry of the digital signals in the modulator input. The essence of the CCSDS recommendation (rec. 2.4.8 [1]) is such: the symbol asymmetry should not exceed 0.2% (the recommendation gives the description of the parameter essences "Symbol asymmetry", i.e., a methodology to evaluate the asymmetry evaluation is given).

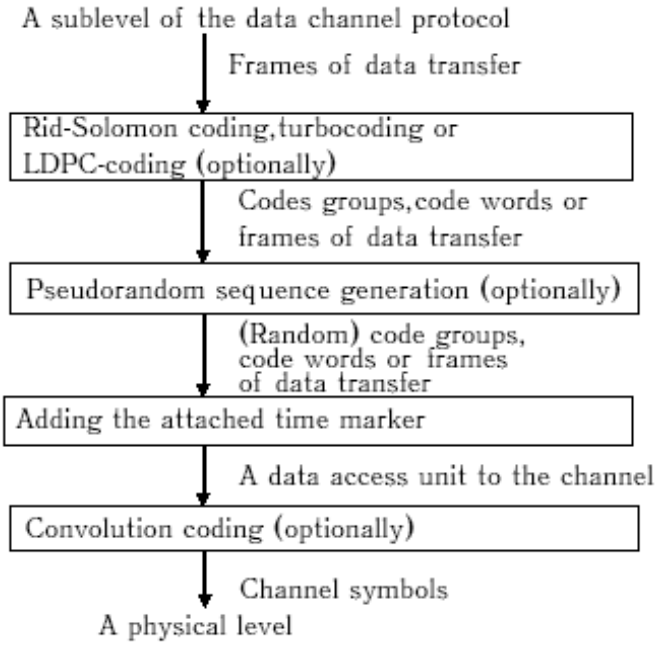

Fig. 2. An internal arrangement of the sublevel for synchronization and coding channels of the information source

Another way is to eliminate phase and amplitude instability. In the CCSDS recommendation (rec. 2.4.12A [1]; the BPSK/(O)QPSK/GMSK modulators, suppressed carrier, space-to-ground channels, category A) it is written the following: for the quadrature modulation when speed and power for data transfer for (I) channels and quadrature (Q) channels are the same, phase and amplitude instability are caused by mutual interference of channels due to impossibility to support interchannel orthogonality or because of imperfect tracking of the carrier. This unfavorably affects the system performance. Its essence is the following: instability of the modulator phase should not exceed 5 degrees, and amplitude instability should not exceed 0.5 dB between the constellation points.

Since in the basis of the recommended CCSDS modulation methods (in particular, the above-mentioned BPSK, QPSK, OQPSK, GMSK methods) there are phase manipulations methods, so corresponding specific requirements are aimed at eliminating a phase ambiguity of signals either through synchromarker or through the modulation insensitive to polarity (rec. 2.4.11 [1]).

Necessity to perform the above-mentioned (and other) specific requirements evaluating according to the accepted CCSDS techniques (type of the technique for evaluating the symbol asymmetry) makes certain limitations concerning the choice of the rational technical solutions from the CCSDS recommendations when building a space radio link.

At the same time, several CCSDS recommendations have descriptions of the limitations that significantly increase the opportunities of their structuring, create favourable conditions for their further consideration (or ignoring) at the early stages of the analysis. Such limitations are the following:

– altitude from the Earth where the tasks are solved (less than 2.0×10^6 km relate to the A category and not less than 2.0×10^6 km relate to the B category);

– data transfer direction (signals) (space-to-ground and ground-to-space);

– entities of the sematic composition of the signals (data) of the radio link [only telemetry data, telemetry data and telecommands; telemetry data and signals to measure the range (as described in [5], [6] or [7]); radiometry; etc.];

– separate software and hardware tools (SHT) that are the parts of the radio link [onboard means of spacecraft (SHT of an object being telemetered), ground station, transponder and so on];

– etc.

Several restrictions (additional to the listed above) are connected with the peculiarities of the development of the domestic telemetry. Thus, a usually typical radio line for the domestic practice is to be applied only for telemetry data transfer. Under such circumstances [in particular, for launchers], its combining with telecommands or signals transfer to measure the range (as described in [5] or [6]) is not carried out. All things considered, in the nearest future an autonomous flight control of a carrier-rocket will exist. Moreover, determination of its movement parameters by means of the customer navigation equipment (CNE) will exist as well. With such an approach, necessity in realization of the corresponding technical solutions described in the CCSDS recommendations does not arises [1] and completely in [5] and [6].

It should be noted that the CCSDS recommendations being in force should not be obligatory met. In the foreign practice, the provisions of the corresponding practice is the guide to action. They are formed not only based on the CCSDS recommendations, but also taking into

consideration other documents, in particular, the ITU radio link regulations, SFCG frequencies distributions (ITU – International Telecommunications Union, SFCG – Space Frequency Coordination Group). That is why, for example, the ECSS-E-ST-50-05C recommendations of the ESA [8], regarding radio frequencies and modulation, is not a copy of the CCSDS recommendations [1].

There are no necessary domestic telemetry standards (see appendixes on the development of the standardization process of the domestic telemetry concerning rocket and space and rocket engineering [9]). If there are no any, it is possible to use CCSDS recommendations when developing SOW (Statement of Work) for building a space radio link. One should take into account the following condition peculiarities of the CCSDS practice for the domestic practice:

– mutual support (in case of joint projects with other space agencies, for example, with NASA and ESA);

– considerable benefits from using technical solutions given in the provisions of the CCSDS documents (for instance, significant improvement of the data); the following aggravating circumstances therewith appear:

a) the CCSDS requirements recommendations badly agree with the existing domestic practice (see the analysis given above regarding the entities of the CCSDS recommendations);

b) necessity in getting the right to lawful fulfillment of separate technical solutions, in particular:

1) a number of technical solutions given in the CCSDS recommendations being in force is patented, and one needs to get a license (see, for example, Sections 1.7, B3.1 and B3.2 of Appendix B [2] on turbocoding and coding by means of low density codes with control to evenness; Section 1.8 and Appendix B [4] on the DVB-S2 technology, as well as Section 3.4.1.7 [10] with the set approach to the patented technologies);

2) necessity in getting a right to the usage of the PN codes. There is a SNIP agreement between three agencies-members of the CCSDS (NASA, ESA and JAXA), which use the PN codes named "a family of SNIP codes" (SNIP stands for Space Network Interoperability Panel). Moreover, a new set of codes has been developed that named as "a set of PN codes of the CCSDS" [5];

– using common efforts in smb's interests – as it is accepted in the CCSDS practice – initiating by the Russian side the technical solutions (technologies) for the CCSDS-community (an example of such initiating: CCSDS-community is given a domestic technology for improvement the data reliability based on a more wide usage of the opportunities of the diverse reception [11]). In this case they should be approved by other space agencies (except Roscosmos). Hence, the following problematic issues arise:

a) necessity (expediency) of the joint tasks fulfilment corresponding to these technical solutions should be proved. Otherwise, approval is impossible (approval of the project by the space agency means undertaking the obligations for its funding);

b) to control the chosen technical solutions (to correct corresponding provisions of the certain CCSDS documents), it is necessary to agree specific interests of the Russian part with the technical CCSDS policy, which is very problematic (joint projects are necessary for this, otherwise there is nothing to do but conform);

c) strengths and means to work in the CCSDS to support and develop the relevant provisions of the CCSDS documents in the interests of the Russian part (in the interests of the domestic enterprises of the rocket and space field);

d) a problem of know-how associated with technical solutions, a problem of data confidentiality (for instance, in the military field) is possible. In these cases, the CCSDS-compatibility can turned out to be extremely undesirable.

It should be also noted that technical solutions important for building domestic space radio lines are possible out of the CCSDS recommendations (the developments of the Russian specialists described in the Russian sources can be among them).

Taking everything into account, in the existing conditions when there is a lack of necessary domestic telemetry standards, an essential condition of significance of the CCSDS recommendations when building domestic space radio lines used for telemetry data transfer is improvement of their technical characteristics. When justifying the CCSDS technical solutions (the CCSDS recommendations corresponding to them), it is expediently to take into consideration the peculiarities of the Russian practice for creating space radio links and the set CCSDS procedures for using the CCSDS recommendations.

References

1. Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft, Recommendation for Space Data System Standards CCSDS 401.0-B-23, Issue 23, Blue Book, Consultative Committee for Space Data Systems, December 2013.

2. TM Synchronization and Channel Coding, Recommended Standard CCSDS 131.0-B-2, Issue 2, Blue Book, Consultative Committee for Space Data Systems, August 2011.

3. Bandwidth-Efficient Modulations: Summary of Definition, Implementation, and Performance, Informational Report CCSDS 413.0-G-2, Issue 2, Green Book, Consultative Committee for Space Data Systems, October 2009.

4. CCSDS Space Link Protocols over ETSI DVB-S2 Standard, Recommendation for Space Data System Standards CCSDS 131.3-B-1, Issue 1, Blue Book, Consultative Committee for Space Data Systems, March 2013.

5. Data Transmission and PN Ranging for 2 GHz CDMA Link via Data Relay Satellite, Recommended Standard CCSDS 415.1-B-1, Issue 1, Blue Book, Consultative Committee for Space Data Systems, September 2011.

6. Pseudo-Noise (PN) Ranging Systems, Recommended Standard CCSDS 414.1-B-1, Issue 1, Blue Book, Consultative Committee for Space Data Systems, March 2009.

7. Pseudo-Noise (PN) Ranging Systems, Informational Report CCSDS 414.0-G-1, Issue 1, Green Book, Consultative Committee for Space Data Systems, March 2010.

8. European cooperation for space standardization. ECSS-E-ST-50-05C – Space engineering – Radio frequency and modulation, July 2008.

9. Artem'ev V.Yu., Vorontsov V.L. O standartizatsii, effektivnosti, tselyakh i stimulakh, kasayushchikhsya razvitiya otechestvennoy telemetrii, otnosyashcheysya k raketno-kosmicheskoy i raketnoy tekhnike [On standartization, effectiveness, aims, and stimuli regarding development of domestic telemetry concerning rocket and space rocket engineering]. *«Trudy MAI»* [Trudy MAI]. 2011, No. 44, pp. 1–15. (in Russian)

10. CCSDS Publications Manual, CCSDS Record, A20.0-Y-3, Issue 3, Yellow Book, Consultative Committee for Space Data Systems, December 2011.

11. Correlated Data Generation, Research and Development for Space Data System Standards CCSDS 551.1-O-1, Issue 1, Orange Book, Consultative Committee for Space Data Systems, July 2015.