NEW CONCEPTS AND TRENDS IN SPACECRAFT
TELEMETRY, COMMAND AND CONTROL SYSTEMS

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This paper presents a new family of telemetry and command front-end products, as applied to spacecraft ground segment systems.

The general philosophy behind both check-out systems and command and control stations has recently evolved from large host computers to a more distributed architecture, where more processing for either recovering telemetry data or encoding commands is done at the front-end level. The overall reliability and safety of such systems have also called for communications oriented subsystems, complying with international standards (ETHERNET, IEEE 488, CCITT X25...). For the same reasons, satellite manufacturers and operators are now requesting more integrated front-end subsystems, which include in one unit subcarrier modulation (PSK or FSK) and baseband functions (Telemetry synchronisation or command encoding), as well as the corresponding built-in test capabilities.

The 3000 series family of products complies with all the criteria enumerated above. Furthermore, it offers a line of matching telemetry and command units, available in both overall check-out (O.C.O.E.) and Telemetry, Tracking and Command (T.T.&C.) versions, thus facilitating the complete integration of a spacecraft system from ground test to in-orbit operation. The choice of industry standards such as the VME bus, the host-based development of firmware in “C”, also ensure product modularity, allowing easy expansion or adjustments to the specific requirements of particular missions or programs. The 3000 series complies with the European Space Agency (E.S.A.) PSS-45 and PSS-46 standards, which are compatible with NASA/GSFC Aerospace Data Systems Standards and the NASCOM message format.

These concepts are illustrated in the application of the 3000 series products in the EUTELSAT II program. Architectures for both the ground check-out systems and the control stations are presented; technical choices for system set-up and control and communications in-between subsystems are discussed.

Future trends and new standards in spacecraft telemetry, command and control systems are presented, and particularly the implementation in the 3000 series products of the
recommendations from the Consultative Commitee on Space Data Systems (C.C.S.D.S) on “Packet’’ Telemetry and Telecommand, as well as channel coding (Viterbi and Reed-Solomon algo- rythms) using proprietary developments of VLSI circuits.

INTRODUCTION

There are two typical applications of baseband equipments:

Ground check out:

During the design, ground test and evaluation of the satellite, Telemetry and Command units are used as part of the Overall Check-Out Equipment (O.C.O.E). In this environment, they are associated with Specific Check-Out Equipment (S.C.O.E.) under the generic name of Electrical Ground Segment Equipment (E.G.S.F.). The S.C.O.E. may include dedicated instruments for testing the satellites payload or some of its subsystems.

In a conventional ground check-out architecture, the test equipment is under control from the master control computer which sends orders to the telecommand encoder for issuing stored telecommand (TC) messages and receives real time Telemetry (TM) data from the telemetry processor. It in turn dispatches test measurements to user’s workstations over a local area network.

In-orbit control:

During the operational - or “post-launch” - phase, Telemetry and Commands units are integrated in Telemetry, Tracking and Command (T.T. & Q stations where they perform, together with the ranging subsystems, the overall house-keeping of the satellite.

In this configuration, the equipment is controlled by the monitoring and control subsystem (M.C.S.) via either a local area network or a general purpose instrumentation bus (IEEE 488), while TC messages and TM data are exchanged with the operations and control center (O.C.C.) over a public packet switching data network (X25).

The current evolution follows two axis:

- Integration of the all the various parts of the telemetry or telecommand link like Intermediate Frequency or Video modems, primary and secondary synchronizers, and data extractor, formatter and display.
Adaptability of the baseband equipments to be suitable either during check-out before launch and in the operational mode.

TECHNOLOGY

Like other developments in the space industry, the main criterium in the choice of hardware components is the reliability since the life time must be equivalent to the spacecraft one except that the palliative maintenance is possible. Then comes the modularity and finally the wide use which guarantees that a lot of communication interface and that up-to-date processors are available.

All these criteria are matched by the VME bus which can also be extended using high data rate bus like VSB.

The choice of industry standards, such as the 68000 microprocessor family and the VME bus, for design makes a modular product, opened to future developments, while offering today high performances in a compact unit.

COMMUNICATION STANDARDS

The need of high data rate and standardisation becomes sensitive for spacecraft test and control. Nowadays, specific transmission protocols are not sufficient for the connection of heterogeneous systems like dedicated telemetry preprocessor or telecommand encoder and multi-purpose desktop computer allowing high level of command languages and results display.

So it is important to be compliant with the Open System Interconnection standard of ISO (International Standard Organisation). This standard is now well-known and has two actions on the baseband designer. The first one is a quality criterium: the systems must be architecteded using the seven level model. But the second one is a big advantage: it is quite simple to add a new kind of interface to a system without any expensive development. So we are able to propose our baseband equipment with connections on X25, ETHERNET and any other link which hardware interface is available on the VME bus.

SOFTWARE

A fully portable and high-level software language is used: C-language, which have proved its high degree of performance for real-time software and which is a structured language. A wide set of software tools are used for the development of C-Language programs in an host computer (VAX-VMS) to assure the software quality.
EUTELSAT II EXAMPLE

These concepts are illustrated in the application of the 3000 series products in the EUTELSAT II program.

The operational control of the satellite is done by two TT&C stations, one in FRANCE and the other in PORTUGAL. These stations are fully automatic and the only man action is maintenance. So the supervision of the sub-systems is done by the Monitoring and Control System, also called MCS, which is based on a single computer. Several IEEE 488 busses are used to support the supervision data exchanges within the station. The operational data, like telemetry and telecommand messages, are transmitted by an X25 network.

The main cases of misfunction are forecasted and some specific and new functions are included within the baseband equipments. The best example of this is the IBC function created to answer to the following question: what use can have a fully automatic station when its central and unique control computer is in failure?

In this case, the Satellite Control Center or SSC Must be able to check the state of the station sub-systems and also be able to do a new configuration of one telecommand chain in order to send messages to any satellite. The IBC function (or Instrumentation Bus Control) is designed to include a gateway between the X25 network and the IEEE 488 busses in the telemetry and telecommand units. When the SCC detects the failure of the MCS, it creates an IBC session by opening an X25 virtual circuit with one telemetry or telecommand equipment for each IEEE 488 bus. As these equipments become bus controllers, the SSC can get the status message or send a set-up command to any of the baseband sub-system. After MCS recovery, the closing of the IBC virtual channel releases the control of the IEEE 488 busses allowing the MCS to do again the supervision.

But before any operational control, an important phase is the check of satellite system before launch. After the traditional checks of the satellite, of the Control Center and of the TT&C station separately, a global system test can be done under the satellite designer responsibility. The test is done in the most realistic mode, i.e., the Control Center sends telecommands to the satellite and receives back the telemetry using in the two modes the baseband equipments and the X25 network.

The satellite designer used some specific baseband equipments. The difference between them and the TT&C version is that they are often used in manual mode. So the operator interface is more powerful and no X25 link is needed.
In order to allow the global test, these equipments are modified to include the same X25 interface but keep the operator interface to give to the satellite designer the capacity of test supervision and emergency stop in case of abnormal telecommands sent by SSC which may be dangerous for the satellite in its current configuration.

Only the application of the new concepts explained before, allows the implementation of this kind of function in baseband equipment (particularly, hardware versatility and software modularity).

**FUTURE TRENDS**

The current evolution will continue to allow the integration of the telemetry and telecommand chains. The most important change of characteristics will be done around the bit rates and the availability of data.

The transmission speed is increasing and will go up to several Mbps. During the same time, the data will be more confident as result of the use of convolutional encoders and decoders (Viterbi and Reed-Solomon) and more easy to use by application of the recommendations from the Consultative Committee on Space Data Systems (CCSDS) on “Packet” Telemetry and Telecommand.

Our Viterbi decoder is built around one VLSI only. It takes in serial or parallel data from bit synchronizers operating in hard or 3 bits soft-decision. It performs self-synchronization and provides information on synchronization status and quality.

Our Reed-Solomon decoder incorporates one to five VLSI chips, depending on the required interleaving depth, with data rates ranging up to 20 Mbps. It provides status information on: error detection, block correction as well as the number of errors corrected in a given block.

These two decoders are available on VME boards and uses CMOS 1.5 Microns VLSI with more than 45,000 gates integrated on a single 130 mm2 chip.

One of the more currently studied characteristic of the new CCSDS recommendation is the Virtual Channel. This concept is useful in case on share of the same physical link by a multi-experiment spacecraft. The data flow received from the telemetry link is splitted into different ground media and transmitted towards each user. Priorities can be affected to each channel in order to give preference to the critical tests. This can be compared with the commonly used timesharing in computers where each user may think that all the hardware ressources are affected to its own work.
CONCLUSIONS

A baseband equipment is no more a sophisticated PSK modem, but must be able to include some high level functions like the multi-standard communications, self-check software and any automatism needed by a specific system architecture.

The maximum level of integration is requested not only for price reduction but also for the simplification of the user’s procedures in operational mode and during maintenance. We are working to give to the user a single box to communicate with his spacecraft and to let him forget what is a signal to noise ratio.