TT&C COMMUNICATIONS ARCHITECTURE FOR THE NEXT GENERATION OF MILSATCOM SYSTEMS

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Introduction

Military Satellite Communication (MILSATCOM) systems are developed and deployed to provide enduring communications for essential Department of Defense (DoD) missions (Reference 1-5). These missions must be completed under the direct influence of, and subsequent to, hostile electromagnetic and physical attacks. Additionally, mission and TT&C communications must be capable of propagating through a disturbed atmosphere (Ref 6). The classic tracking, telemetry and control (TT&C) functions provide critical support to all essential communications missions. Enduring TT&C is necessary for effective enduring MILSATCOM missions (Ref 7). The next generation of MILSATCOM systems includes many capabilities that can be shared by the mission traffic and TT&C communications to efficiently and effectively accomplish both objectives. This paper advocates an integration of TT&C into the communications channels for the next generation of MILSATCOM Systems.

TT&C Capabilities

Department of Defense satellites have traditionally employed the U.S. Air Force Control Facility Space Ground Link System (SGLS) TT&C activities. Typical satellites using SGLS are the Defense Satellite Communication Systems (DSCS) II and III (Ref 8-10), the Fleet Satellite Communications (FLTSATCOM) System (Ref 11) and several NATO communications satellites.

The generic DSCS II satellite architecture is illustrated in Figure 1. The X-band communications channel and the S-band TT&C channel are independent. This is similar to the architecture currently employed by commercial satellites. The commerical equivalent to the SGLS is the Unified S-band TT&C system (Ref 12), a forerunner of the SGLS.

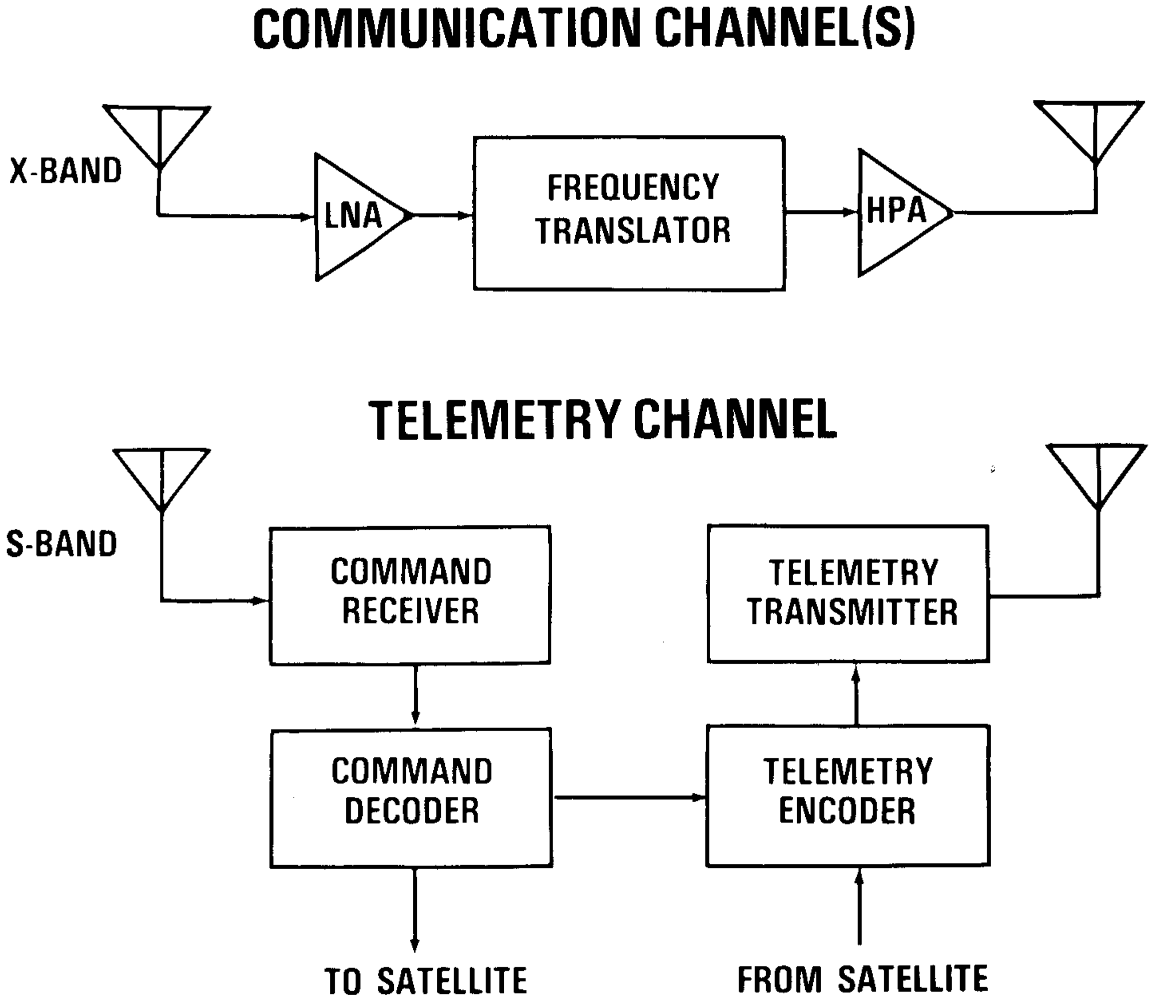

FIGURE 1, GENERIC COMSAT ARCHITECTURE

The distinguishing characteristic of a military communications system is that it must be able to support essential missions throughout various threat environments. To defeat one portion of the threat, cryptography is employed to prohibit unauthorized insertion of commands into the uplinks and to prohibit unauthorized extraction of telemetry information from the downlinks; specific examples are: to prevent an adversary from assuming command of a satellite, to shut the satellite off, move it, tumble it, or derive information about the satellite by listening to the telemetry downlink. For these reasons, MILSATCOM Control Systems are now secured. Jamming is another facet of the threat that must be defeated to prevent an adversary from saturating the command receiver with noise to prohibit the successful reception of a valid command and therefore, prevent the accomplishment of an essential mission.

The S-band SGLS offers many desirable features for MILSATCOMs. The SGLS is designed to support all MILSATCOM mission phases, from launch and orbital insertion through operations to shutdown. It is compatible with the Air Force's existing capability of ranging, receiving telemetry, and commanding satellites. It has been implemented with near omni-directional satellite antennas. This is desirable because it provides the capability to communicate with satellites which have attitude errors, including tumbling spacecraft.

The SGLS should be retained on the next generation MILSATCOM Systems to capitalize upon these attributes. However, as will be presented, this capability should be considered as a backup to a more threat resistant solution.

The more recent DoD programs, e.g., DSCS III and FLTSATCOM, incorporate a more robust approach to the command uplink by providing TT&C capabilities at X-band in addition to the S-band. Spread spectrum modulation is used on the X-band link. The resulting processing gain, coupled with additional antenna gain achievable at X-band, provides significant improvements in the ability of the satellite to successfully receive a valid command while being jammed. Additionally, X-band provides reduced susceptibility over S-band to the effects of a nuclear disturbed atmosphere.

Communications Capabilities

As MILSATCOM has matured and missions have become more complex and more important, the perceived threats to MILSATCOM Systems performance have increased. Among these threats are jamming, against both the up- and downlinks, nuclear weapons effects disturbing the propagation media, and signal intelligence. The currently evolving joint MILSATCOM architecture includes many techniques and features to ensure the successful completion of MILSATCOM missions in spite of these threats. The next generation of MILSATCOM spacecraft is being planned to have multiple uplink frequencies (UHF, SHF, and EHF) and, in general, multiple channels having varying degrees of onboard signal processing. The EHF channels are of specific interest (Ref 13). Two types of EHF systems are proposed for the next generation of MILSATCOM systems. The first is being planned to serve tactical, strategic and mobile users with relatively low data rates. This system will include a fast hopping uplink signal format. Fast hopping means the hopping rate is greater than the symbol rate. The second type of system is intended to provide service to users with higher data rate requirements. This will be a slow-hop system; that is, the hopping rate is less than the symbol rate.

To provide flexible service, the next generation of MILSATCOM systems will have crossbanding and some degree of onboard traffic routing. To facilitate this service, the satellite will have multiple antennas on both uplink and downlink. Figure 2 shows such a generic satellite architecture. One chain, consisting of a receive antenna input processor, signal processor, output processor, and transmit antenna could represent either of the two types of EHF systems. In either case, certain features would be provided. First, the use of EHF to provide increased jam resistance and increased immunity to propagation effects caused by nuclear weapons, as compared to either X-band, L-band, S-band, or UHF. The

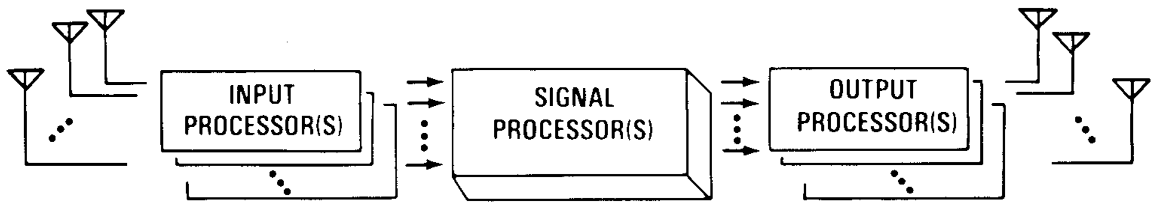

FIGURE 2, GENERIC FUTURE MILSATCOM SATELLITE ARCHITECTURE

second feature of either of these systems would be onboard signal processing to provide, as a minimum, despreading of the uplink and limited spreading of the downlink. This feature provides significant additional amounts of antijam capability. Complementing these is a third feature, a processing antenna on the uplink to provide null steering capability to suppress potential interference or jamming. The combined effects of the EHF, the signal processing, and the antenna null steering capability can provide enduring communications in the face of credible jamming attacks. Thus, to adequately support the communications missions under postulated threat conditions, a highly sophisticated spacecraft is planned.

Options

The endurance of essential mission communications is dependent upon the status and configuration (health and welfare) of the spacecraft. There are two extremes to insuring the continued health of the spacecraft. One is completely autonomuous spacecraft operation and the second is an enduring TT&C capability. The trade-offs between these approaches have been studied (Ref 7, 14). Autonomous operation is highly desirable. In fact, some degree of partial autonomy is a necessary ingredient for the next generation of MILSATCOM spacecrafts to be able to provide enduring mission effectiveness. The technical direction of spacecraft autonomy has been, historically, aimed toward preserving the spacecraft often at the expense of the mission. Thus, a spacecraft which loses its control communications may autonomously shut down its mission and remain inactive until the control communications are reestablished and it is commanded to an active mode. This approach has served well during the early growth of satellite communications and, moreover, was within the fiscal and technical constraints accompanying that period. Now, however, satellite communications are a proven DoD asset and operational commanders are ready to place increased reliance on them provided the mission capability will endure through hostilities. To provide the necessary assurance, the next generation satellites must not shut themselves off when adverse conditions occur. Instead they must martial the technical capabilities at their disposal and remain mission capable as long as they survive. Ideally, to do so, satellites would be completely autonomous. They would be capable of station-keeping, attitude control, fault detection, component switching, channel reassignment, power management, jamming sensing, and antenna null steering, - all the capabilities required to maintain operationally useful satellite functions in a stressed environment. Moreover, the extent and nature of the condition of the stressed environment are not known apriori.

However, the technical capabilities to do so have been more realizable in principle, than in practice. It is, therefore, reasoned that a limited, but necessarily enduring TT&C capability is a requirement for the next generation of MILSATCOM Systems.

Integration

The necessary background has now been established to discuss the principal question of this paper - how to provide an enduring TT&C function in the next generation MILSATCOM systems. The uplink command and downlink telemetry can effectively be accomplished through the already developed enduring mission communication channels and hardware. The aggregate data rate for the mission functions dwarfs that required for all but the most demanding TT&C concepts. Therefore, burdening the already existing communications mission hardware to perform the TT&C communications functions and signal processing functions would be small and almost inconsequential. But, more importantly, it would eliminate extensive spacecraft subsystem duplication. The tracking, or ranging, portion of TT&C is already provided because it is an integral requirement for mission communications (Ref 15). To complete the tracking function of the TT&C, the tracking earth terminal need only be afforded the same satellite functions also offered to other mission communications terminals. This is reasonable for most military applications; however, care must be exercised to insure excessive timing information is not destroyed in the processing satellite.

Figure 3 illustrates a generic implementation and shows how this can be achieved. Note that it is merely a small augmentation of the capability shown in Figure 2. This integration of TT&C into the communication channels has been demonstrated on the LE5 8/9 program (Ref 16). All of the threat protection provided the mission communications is afforded the TT&C communications. Although the TT&C communications function may complicate the operation of selected communications terminals chosen to effect enduring satellite control, it will, indeed, distribute that operation to the benefit of endurance.

In fact, TT&C communications may achieve even better threat resistance than mission communication due to the inherently low data rate. Moreover, integrating TT&C into the communications functions for the next generation of MILSATCOM systems provides enhanced SIGINT protection and permits spacecraft simplicity and reliability. SIGINT protection is provided because the TT&C signature is identical to a mission signature, both of which are protected by cryptography on the uplink and downlink and have a common, indistinguishable waveform. Spacecraft simplicity is achieved by integrating the TT&C into the communications mission channels to eliminate duplication. Reliability is achieved

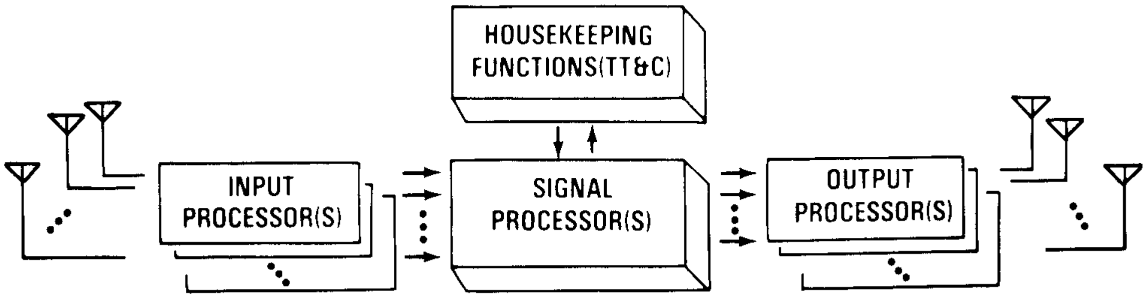

FIGURE 3, GENERIC FUTURE MILSATCOM SATELLITE ARCHITECTURE WITH HOUSEKEEPING FUNCTIONS

by providing redundant capability to achieve the integrated functions rather than duplicative capabilities - one to perform mission communications and one to perform TT&C.

Conclusion

The next generation of MILSATCOM satellites will require enduring TT&C capabilities and onboard communication signal processing capabilities. S-band TT&C capabilities should be retained on this generation of satellites. Additionally, to achieve endurance, jam resistance, robustness, and other advantages, the TT&C functions should be integrated with the mission communications and capitalize on the commonality of onboard signal processing capabilities.

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