DSCS III—Becoming an Operational System

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Abstract—This paper addresses the progress of the Defense Satellite Communications System, Phase III (DSCS III), related developmental efforts directed toward facilitating operational employment of the new generation spacecraft, and an overview is provided illustrating how some of the innovations of the DSCS III will be used in the operational environment. The major features of the DSCS III are reviewed and a status report is provided on the development of the spacecraft. Special emphasis is given to those areas judged to be significantly different from other satellite systems—dynamic control of the multibeam antenna (MBA) systems, and its ability to detect and reduce the impact of interfering signals. Support software to expedite and optimize responses to changing operational requirements, including jamming, is addressed.

BACKGROUND

The Defense Satellite Communications System (DSCS) III communications satellite is being developed as a replacement for the current DSCS II space segment. Key objectives of the DSCS III are: 1) improved life cycle costs by means of longer design life; 2) significant improvements over that provided by the DSCS II in its ability to withstand electronic warfare environments; and 3) increased flexibility to provide optimum service to an increasing and dissimilar set of user groups.

The most significant operational features of the DSCS III are in the areas of electronic counter-countermeasures (ECCM) and flexibility of operation and are made possible by means of the antennas on board the DSCS III spacecraft. The flexibility to contour coverage areas to match user locations and gain requirements are provided by the 61-element receive MBA and two 19 element transmit MBA's. The receive MBA provides dramatic mitigation against jammers by providing the capability for detecting, locating, and placing a null on jammers while leaving the gain on user terminals relatively undisturbed. Nulling is not constrained to simple beam turnoff but utilizes phase and amplitude control of all 61 feed horns to enhance its ability to discriminate against jammers. Fig. 1 shows the 61-element receive MBA and its associated BFN's. The receive BFN is composed of 121 variable power dividers (VPD's) and phase shifters which allow precise and incremental control of the signal combining from the individual feed horns.

Full attainment of the benefits of the flexibility of the MBA's, other antennas, and the multiple transponders of the DSCS III spacecraft are ensured by the development of a "real time adaptive control system (RTACS)." The RTACS will provide for computer assisted automation of status gathering, computation of user demands, and resource allocation on a priority basis; assistance in the collection and analysis of status information, analysis of changes in user requirements, and generation and optimization of alternative system configurations (see "Communications system control for the Defense Communications System" by R. Rosner elsewhere in this issue for more detail on control).

The predominant users of the DSCS are 1) Worldwide Military Command and Control System (WWMCCS), 2) ground mobile forces, 3) Navy ships, 4) wideband data relay, 5) Defense Communications System (AUTOVON, AUTODIN, etc.), 6) White House communications, 7) Diplomatic Telecommunications System, and 8) support to allied nations. When the DSCS III reaches full operational capability, it is expected to serve approximately 400 earth terminals. The current system is supporting over 130 earth terminals.

Support for these users is planned via a worldwide deployment of four operational satellites located at longitudes of 12°W, 135°W, 175°E, and 65°E. High availability will be ensured by maintaining two on-orbit spare satellites.

This paper addresses the DSCS III from an operational viewpoint reviewing current status of its development and outlining its salient features for completeness only. The major thrust is to look at the significant improvements provided by the DSCS III and to address how these features can be operationally exploited to serve user requirements. That some of the new features add operational complexity to the DSCS is granted; however, significant effort is underway to provide computational support to the operators of the DSCS III. This support will provide for more efficient use of the spacecraft resources, higher quality and more responsive service to the users and quick reaction capability for network adaption under a jamming attack.

STATUS OF DSCS III PROGRAM

Phase 1 of the DSCS III program commenced in February 1975 with two companies addressing the perceived high risk
areas associated with the development of the spacecraft prior to commitment to a full-scale development program. Satisfactory progress was achieved during Phase 1 of the program and led to Phase 2.

Phase 2 of the DSCS III program was initiated in February 1976 by awarding a contract to the General Electric Company with the objective of producing two Demonstration Flight Satellites (DFS's) which are expected to demonstrate that the goals of the DSCS III program are achievable prior to a full commitment to production satellites. The first DFS DSCS III (DFS-1) is now scheduled for launch around June 1981 aboard a Titan III-C launch vehicle. DFS-2 is expected to be launched in mid-1982.

The qualification model DSCS III satellite is undergoing testing at the General Electric Valley Force facility and is meeting all key performance specifications. Two of the critical elements of the DSCS III program are: 1) the multibeam antennas (MBA's) which provide flexible and efficient antenna coverage for widely varying user locations, and 2) the Satellite Configuration Control Element (SCCE) which provides spacecraft command and telemetry processing functions via specially equipped DSCS earth terminals. The multibeam antennas and their associated beam forming networks (considered by some to be a high-risk element at the beginning of the program) are meeting or exceeding all of their performance specifications. The SCCE for the DFS-1 satellite has been completed, has met all specifications, and is ready for installation at the DSCS Earth Terminal Complex at Sunnyvale, CA.

The early completion of the SCCE has allowed engineers from the Defense Communications Engineering Center (DCEC) to run test configurations and simulated MBA patterns for anticipated terminal deployments for the mid-1980 time frame (features of the SCCE are described in more detail later in this paper). These sample configurations include up to 25 separate earth terminal locations with several postulated jamming attacks. The results of these simulations illustrated not only that the DSCS III could be configured to provide significant support to users in the face of difficult scenarios but that the operational control of the "complex" MBA could be accomplished by operators having only a brief period of instruction.

The tests conducted by the engineers incorporated procedures identical to the procedures to be used operationally in commanding the DSCS III spacecraft, except that the commands generated were not executed. High confidence is held in the resulting antenna patterns since comparisons have shown them to have excellent correlation with those obtained on the antenna range. (Note: The SCCE database contains detailed range pattern data on each of the 61 (or 19) individual beam (or singlet) patterns. The SCCE then synthesizes the composite antenna pattern or null from these data.)

The capability to synthesize antenna patterns from stored singlet patterns will allow operators to become highly proficient in reacting to various potential jamming attacks and to fine tune and store nulling configurations that have a high probability of success against likely jamming scenarios. By means of remote access terminals, the engineers at the DCEC can derive optimum antenna coverage patterns for routine and contingency communications needs in support of current operational support as well as support of anticipated communications requirements and deployments 5 to 10 years in the future. A sample plot of one such scenario is shown in Fig. 2. In this scenario, each of the earth terminals in this deployment received antenna gain equal to or greater than that required for full support of the postulated requirements.

The contour lines of Fig. 2 are equal gain contours. Each contour level is operator selectable which allows the operator to explore trends or variations in developing candidate antenna patterns. The desired and resultant gain for each earth terminal (or jammer) is also printed out numerically to allow quick evaluation of the success of the run and/or to allow the values to be automatically entered into resource allocation algorithms to determine appropriate earth terminal responses.

SUMMARY OF KEY DSCS III FEATURES

The DSCS III design provides a flexible configuration to allow optimization of the transponder transfer characteristics for each major grouping of users. Likewise, the antenna coverage of four of the transponders may be contoured to concentrate power and $G/T$ only to those areas of interest. This not only enhances the antenna gain but excludes areas of no interest, greatly reducing interference potential to and from other users. Table I lists the salient features of the DSCS III. These features allow the tailoring of the spacecraft configuration to best meet the users' requirements within the constraints of a given scenario. Figs. 3 and 4 show the frequency plan and transponder block diagrams, respectively. The frequency plan of Fig. 3 was developed in 1974 and constrained by the International Telecommunications Union regulations of that period. Notable in this design is the dual frequency translation which is required if: 1) the fixed satellite "exclusive" band (no sharing of frequency allocations with terrestrial services) is to map on both uplink and downlink frequencies, and 2) full use of the 500 MHz allocation is desired. This dual translation was required since the ITU "exclusive" allocations had a 725 MHz offset, whereas the full frequency band offset is 650 MHz.

Authorization of satellite communications to and from mobile platforms has been granted over the lower 125 MHz of the uplink and downlink frequencies, a 650 MHz offset, which overlaps the exclusive band. This presents a conflict between aligning the mobile authorization and the alignment of the exclusive band. Additional actions at WARC-79 reduced the protection of the exclusive band from a table entry to a footnote status, providing protection to satellite services only within those nations listed in the footnote. Design changes to the DSCS III in response to the revision in allocations will be analyzed for possible inclusion in the second block of production satellites. Other changes to the DSCS III are being considered on a product improvement basis as component technology is improved. One area under current investigation is that of substituting solid-state amplifiers (SSA's) for the current TWTA power output devices, with the goal of a significant improvement in reliability. Any changeover to SSA's would be on an incremental basis rather than a total changeover to SSA's.
Fig. 2. Sample antenna pattern.

TABLE I
MAJOR FEATURES OF THE DSCS III

- Six Independent Transponders
  - Each with its own Traveling Wave Tube Amplifier (TWTA)
    - Two 40 Watt TWTA's
    - Four 10 Watt TWTA's
- 61 Element Receive Multi-Beam Antenna and Beam Forming Network Which
  Allow:
  - Selective Coverage
  - Jammer Detection and Location
  - Multiple Jammer Nulling
- Two 19 Element Transmit Antennas Which Allow:
  - Selective Coverage for Ch. 1 and 3

- Selective Coverage for Ch. 2 and 4
- A Gimbaled Dish Antenna Which:
  - Provides High EIRP on an Area Coverage Basis
  - May be Connected to Transponders 1, 2, or 4; or 1 and 4; or 2 and 4
- Earth Coverage Receive Horns for Transponders 5 and 6 on a fulltime
  basis and Transponders 1 through 4 Selectively
- Earth Coverage Transmit Horns for Transponders 5 and 6 on a fulltime
  basis and Transponders 3 and 4 Selectively
- X-Band TEC with Protection Against Jamming
- Single Channel Transponder--Provides AJ Protected Uplink at SHF and
  UHF with UHF Downlink
Careful analysis of Figs. 3 and 4 will reveal that 16 different receive antenna configurations are possible and 24 potential transmit antenna configurations. A typical configuration will utilize the receive MBA on transponders 1 through 4 and earth coverage receive antennas on 5 and 6. A corresponding transmit connectivity may utilize transmit MBA No. 1 on transponders 1 and 3, the gimballed dish antenna (GDA) on transponder 2, EC horns on transponders 5 and 6, leaving transmit MBA No. 2 to be configured according to the needs of the users of transponder 4.

While the multiple transponders and flexible antenna connectivity allow for tailoring the spacecraft communications package to meet the changing user requirements and demands of four orbital locations, this same flexibility and the selective tailoring of the MBA receive and transmit antenna patterns pose a significant challenge to achieving optimum allocation of the spacecraft resources on a dynamic basis. This is especially true in responding to attacks by jammers. The following section will review several programs underway to facilitate adaption and optimum resource allocation, including some of the features of the SCCE which is a part of the DSCS III acquisition.

OPERATIONAL CONTROL AND RESOURCE ALLOCATION

During “operational exercises” and system loading for planning purposes, engineers at the Defense Communications Engineering Center (DCEC) developed several computer programs to assist in achieving more optimum allocation of the satellite and earth terminal resources of the DSCS. The need for computer assistance became quickly obvious while trying to balance, on a system basis, the composite network link equations. These equations, although more difficult to solve as a result of the variability of the satellite EIRP, G/T; and antenna connectivity, if properly manipulated, will result in a spacecraft configuration which is highly responsive to the users' requirements under varying defense postures and threat scenarios. Two fundamental computer programs necessary for resource allocation were anticipated early in the DSCS III program. They were the nulling and selective coverage algorithms of the Communications Configuration Program (CCP) being developed by the spacecraft developer, the General Electric Company; and an Interim Performance Analysis Software (IPAS) package being developed by DCEC.
The CCP, a part of the SCCE, provides the capability to configure the satellite MBA gains according to constraints entered by the SCCE operator including nulling responses to jammer attacks. In the operational environment, the controller enters user locations and required antenna gains into the CCP. The output of the CCP provides an antenna pattern display that best meets the requirements within the capabilities of the MBA's (this approach was used in obtaining the pattern of Fig. 2). If the antenna pattern is found to be satisfactory, the controller can implement it by pressing the execute button, thus sending the corresponding spacecraft commands already generated by the SCCE. If, while operating under this or other routine configurations, interference was encountered, sensors on board the spacecraft would signal an alarm at the controller's console, the location of the interference would be provided, a nulling response generated, and, if desired, a plot of the resulting antenna pattern including the nulling response would be displayed identical to that which would result if the implementing command were to be sent. Prior to implementing the null, the controller could choose to iterate the response while varying constraints on the algorithm in an attempt to obtain more optimum gain distribution in response to the priorities at that time. Optimum redistribution of user service resulting from changing priorities under jamming might necessitate an iterative process with the IPAS algorithms.

IPAS must solve the SATCOM link equations including earth terminal EIRP, G/T, modem processing gain, and benefits of satellite nulling. IPAS includes a simplified model of the MBA to simulate the MBA antenna characteristics.

The IPAS algorithms were developed by engineers and are very engineering oriented and, as a result, require iterative engineering judgement since the programs are operated independently. This mode of operation is adequate for engineering planning and for the establishment of a few adaptation states which could be implemented on a coordinated basis. However, looking forward to an operational system utilizing the DSCS III satellite, and with the introduction of the new SSMA equipment (AN/USC-28) which is now in production along with the new digital communications subsystem (DCSS), the need for a more integrated operator-oriented support system was anticipated.

To achieve this operational capability, the elements of the resource allocation problem (illustrated in Fig. 5) are being brought together into a single package called DSCS III Operations Support System (DOSS). The DOSS will also provide for proper interface of the Resource Allocation Software (RAS) with the Satellite Configuration Control Element. The first phase of this effort will utilize major elements of the IPAS package to ensure availability of this capability prior to the launch of the first Demonstration Flight Satellite. The second phase of this effort will incorporate improved allocation algorithms now under development within the Resource Allocation Software effort sponsored by DCA. The DOSS systems will be located at Sunnyvale, CA, and Fort Detrick, MD, Network Control Facilities which are being constructed for operational control of the two DSCS III Demonstration Flight Sat-
ellites. These satellites are planned to be located in the East Pacific and Atlantic regions. Each DOSS installation can be operated by local control or by remote terminals located at DCA operation and engineering centers. Configuration control of each spacecraft and the associated communications networks will normally be exercised by the network controller under the direction of the Defense Communications Operations Center (DCAOC); however, the Area Communications Operations Center (ACOC) will serve as an alternate to the DCAOC. Initial operation configuration of DFS-1 will be as shown in Fig. 6. During the initial test and evaluation period, the ACOC remote console will reside at the DCEC. Prior to the launch of DFS-2, the DOSS will be installed at Fort Detrick as shown in Fig. 7 and the DCEC remote will be utilized primarily for off-line engineering support and planning activities. As can be seen from the configurations in the above figures, the DOSS is primarily oriented for interaction with the space segment via the SCCE while providing manual interface via orderwires to the earth terminals with no direct control or earth terminal status assessment capabilities. Current planning is for the DOSS to provide operational support for the DSCS III system until the Real-Time Adaptive Control System (RTACS) is fielded around 1985.

The RTAC system is being engineered to extend the operational control to the DSCS earth terminals and to provide an enhanced space segment control and resource allocation capability that will improve resource utilization (which will result in an increase in capacity), simplify and expedite operational reconfgurations in response to changing requirements or anomalies, and improve the quality of communications provided by the DSCS. Experience gained on the DOSS system should prove to be valuable in the development of RTACS.

SUMMARY

The DSCS III is meeting all of the major objectives of the program as originally set forth, is exhibiting the configuration flexibility necessary to adapt to the variations in requirements due to system expansion/contraction and changes in defense postures and is expected to allow the DSCS to achieve a significant step forward in providing critical command and control communications under a wide range of stressed and benign environments.

The first DSCS III DFS planned launch date is June 1981 followed by the launch of the second DFS during the following year. With a favorable decision at DSARC, DSCS III production satellites will be launched two per year commencing in 1984 to establish a six satellite (four operational and two spares) constellation of DSCS III satellites. Subsequent launches will be scheduled to maintain this complement. These satellites are planned to provide service to the DSCS well into the 1990's.

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