MILSATCOM Architecture

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Abstract—The Military Satellite Communications Systems Office (MSO) of the Defense Communications Agency has recently prepared an architectural framework for the evolution of military satellite communications systems through the end of this century. The realization of the goals of the architecture should provide significantly enhanced military utility to three functional classes of users. The strategic forces would be directed and managed through a two-way, highly survivable, jam-resistant Strategic Satellite System (SSS). The Tactical Satellite System (TACSATCOM II) offers a jam-resistant, low probability of detection, communications system for employment of ground mobile forces as well as tactical Naval and Air Forces. The future Defense Satellite Communications System (DSCS III U/IV) will provide the high data-rate users with increased jam resistance to perform their missions. These satellite systems will use higher frequency bands (EHF), on-board processing, and improved antenna techniques. To implement the EHF technology in a coherent fashion, the MSO has also prepared a Technology Development Program Plan which identifies and plans for the needed R&D efforts.

I. BACKGROUND

IN November 1978, the Military Satellite Communications Systems Office (MSO) published an architectural document "Framework for MILSATCOM Development" (FMD). The framework outlines plausible avenues for Department of Defense (DoD) satellite communications systems development with continuity and evolving capability. An excellent unclassified version of the framework is provided by Tuck [1].

Briefly, the FMD categorizes the disparate users of MILSATCOM systems into three broad groupings: wideband, tactical/mobile, and nuclear-capable, on the basis that each user group includes a sufficiently large mix of users with enough common characteristics to qualify for its own exclusive satellite communications system. By the mid-1980's the DoD will have a three-segment satellite communications capability which consists of FLTSAT/LEASAT, AFSAT (SDS/FLTSAT), and DSCS II/III satellites. These satellites will operate with an extensive inventory of earth terminals whose investment will have exceeded that of the space segment. As a result, the prospective terminal inventory will be a significant factor in determining the pace at which it is possible to transition to new satellite programs with improved capabilities. In view of this limitation, with the exception of DSCS III, no new communications satellite systems will be put into operational use in the near term (before 1985). However, critical deficiencies (e.g., sufficient capacity and jam-resistant service for wide-band data relay and tactical mobile users) still exist in some systems and must be alleviated. The intervening period in the early 1980's should be used for laying a sound technical

foundation for the next generation of MILSATCOM systems with distinctly improved military-unique properties.

The evolution of MILSATCOM systems through the early 1990's is illustrated in Fig. 1. The wide-band community comprise a diverse mix of fixed, transportable, shipboard, and airborne terminals. It is served by the DSCS system at SHF, using presently the DSCS-II satellites with planned transition to DSCS III satellites beginning in the early 1980's. The DSCS III satellites will provide significant improvements in jam-resistance, capacity, flexibility, in-orbit life, and system control. The FMD recommends an evolutionary block-change upgrade of DSCS III satellites in the late 1980's. DSCS III upgrade may include EHF transponders for providing the enhanced jam-resistance and high data rate capabilities to selected wide-band users.

The Tactical Mobile community consists of a large population of mobile platforms operating with small antenna terminals. Presently, these users are served at UHF by the GAFILLER and FLTSAT spacecrafts; these satellites will be gradually replaced by LEASAT's beginning in 1983. However, a UHF space-segment capability will probably be required well into the 1990's in view of the heavy DoD investment in UHF terminals. A new system, TACSATCOM II, is proposed for the far term (1990's) to alleviate the deficiencies of UHF systems in the areas of bandwidth and jam resistance. The TACSATCOM II will operate primarily in the EHF band, with on-board processing and most likely, antenna nulling for improved jam resistance.

The Nuclear-Capable Forces Community is presently served by the AFSATCOM system consisting of communication packages on a number of satellites in geostationary and elliptical orbits. In the near term the present AFSATCOM system will be supplemented by addition of single-channel transponders (SCT's) on DSCS III and other host satellites. A Strategic Satellite System (SSS) is, however, proposed for the mid-1980's with evolving capability in the far term (SSS-U). A transition to the SSS system with enhanced jam resistance and physical survivability in the mid-1980's is considered essential for the vital users of the system.

The SSS is a system designed to provide critical command and control communications from the national command authorities to the CINCS of the Unified and Specified Commands and to the nuclear capable forces. It will be designed to survive and endure through all phases of a protracted nuclear engagement as one component of a battle management system for the command and control of the strategic forces.

The progressive improvements proposed in the FMD for each of the three MILSATCOM systems require a vigorous research and development program to define, develop, and test advanced concepts and technology, preferably in a quasi-operational environment. To provide the foundation for such a

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Fig. 1. MILSATCOM evolution.

program, the MILSATCOM Systems Office published in December 1979 a "Technology Development Program Plan (TDPP)" for the development of the technology necessary to support the evolution of this MILSATCOM Architecture. A technology program that includes a developmental satellite payload and associated service-unique terminals for joint test and evaluation in the mid-1980's is proposed.

This paper briefly describes the study and technology R&D efforts recommended in the TDPP to support the evolution of FMD's three-system architecture. While there is some commonality and interdependence between the technology efforts for each of the communities, the MILSATCOM system serving a particular user community has user-unique features requiring that the supporting technology for each system be developed separately.

II. WIDE-BAND USERS/SYSTEMS

Enhanced antijam protection for the high data rate users is of major importance in the far-term evolution of the DSCS system. To accomplish this objective, the FMD recommends moving the high data rate users into the higher 30/20 GHz band. A gradual time-phased transition into the 30/20 GHz band can be achieved initially through addition of simply straight-through transponders on DSCS III satellites in the late 1980's, and more complex processing transponders on later satellite designs (DSCS IV). The 8/7 GHz band, however, will continue to remain the primary band for DSCS operation even in the DSCS IV era.

An interservice coordinated R&D program in the 30/20 GHz band is necessary for the development of system operation concepts and the space and ground segment technologies. With regard to the satellite multiple-access technique, TDMA appears to be the preferred approach with the DSCS III-U satellites, since it would provide a higher throughput than FDMA while avoiding the transponder intermodulation and uplink power control problems associated with FDMA. Use of more advanced multiple-access techniques, such as satellite-switched TDMA (SS-TDMA), TDMA with time-hopped beams, etc., are candidates for application with the DSCS IV satellites. Under benign conditions, an efficient multiple-access scheme can increase the satellite's data handling capacity substantially, and provide more flexibility for accommodating users with differing data rates and connectivity needs.

The DSCS III-U satellite will use narrow-beam antennas for 30/20 GHz operation. For better jam resistance, the feasibility of a 30 GHz receive nulling antenna, such as an MBA or a phased array on DSCS III-U, should be considered. In the long term (DSCS IV), antenna discrimination from the satellite will be essential for high data-throughput under strong uplink jamming. Antenna nulling techniques and their hardware implementation be investigated for operation with SS-TDMA and time-hopped beams for potential DSCS IV application.

In the 30/20 GHz band, 1.5 GHz of bandwidth is allocated internationally for fixed and mobile satellite service. In the United States, however, the upper 1 GHz of the exclusive band is assigned to the DoD. Since it would be difficult to spread pseudonoise waveforms over 1 GHz, conventional frequency-hopping, frequency-hopped TDMA, and hybrid (frequency hopping in combination with pseudonoise) schemes may be explored for users requiring antijam (AJ) protection. The selected AJ technique will be used in conjunction with antenna nulling [DSCS III-U], and on-board AJ processing in the far term with DSCS IV satellites.

If the decision is made that the DSCS IV satellite should use SS-TDMA or something similar, it would be necessary to provide the capability of beam switching (appropriate interconnection of uplink and downlink satellite antennas) in the satellite. The switching can be done either at RF or at baseband. Baseband switching, although more complex (since it requires complete demodulation of the uplink signals in the satellite) would provide greater dynamic flexibility for interconnecting users distributed over a wide geographical area.

The need for satellite on-board AJ processing at 30/20 GHz will depend largely on the characteristics of the potential user communities and their terminal capabilities. For example, earth terminals with large antennas (e.g., 40 ft paraboloid) can operate effectively even under heavy uplink jamming, with conventional straight-through transponders. A processing transponder will improve their AJ performance only by 6 dB, which probably would not justify the additional hardware processor complexity on the spacecraft. On the other hand, for small-antenna mobile/transportable terminals, on-board processing will be essential for supporting even 2400 bits/s under strong uplink jamming. The issue of on-board-AJ processing will be deferred till a determination of 30/20 GHz users and their terminal characteristics is established.

Research and development efforts should be initiated to develop the necessary technology for the 30/20 GHz spacecraft and user terminal hardware components. Primary emphasis will be placed, in the near term, on the development of DSCS III-U spacecraft components and the associated user terminals.

III. TACTICAL MOBILE USERS/SYSTEM

The next generation tactical satellite communications system TACSATCOM II will operate in the EHF frequency band with satellite on-board processing and (perhaps) antenna nulling for maximum jam resistance and LPI. The MILSATCOM Architectural Working Group [2] has recommended the use of the 45 GHz band for the uplink; the associated downlink still

remains to be determined. While the 40, 20, and 7 GHz bands are all candidates for the downlink, the 20 GHz appears to be the best compromise, on the basis of simpler frequency/orbit coordination than 7 GHz, less rain attenuation than at 40 GHz and adequate jam resistance against downlink jamming.

For most of the tactical users' introduction of TACSATCOM II will require a transition from present operation at UHF to operation at EHF. Reequipping tactical platforms with new terminals is both a long-term and expensive proposition. In many cases users may have to operate simultaneously at both UHF and EHF during the transition phase. Timing of the transition from the LEASAT to TACSATCOM II will depend largely on the availability of EHF terminals. In planning for this transition, it must be determined whether the TACSATCOM II payload design must also support the entire existing UHF communication requirements prior to UHF/EHF transition, or whether LEASAT-like assets would be maintained for separate UHF communications beyond the presently programmed schedule.

Choice of multiple-access and antijam modulation waveform at EHF for the mobile users is an important architectural consideration. In the interest of providing interoperability between tactical users, and to reduce the design complexity of the satellite on-board processor as well as users modems, it would be desirable to select a common transmission waveform format. The MSO is presently conducting a comprehensive investigation of candidate multiple-access and antijam schemes for EHF tactical applications, taking into account such factors as: EHF propagation effects, characteristics of the users, including their AJ, LPI, and data rate requirements, threat scenarios, satellite processor, and modem technology state-of-the-art. The selection of the waveform will be based on providing the best compromise between multiple-access efficiency, jam resistance, LPI, and other important system attributes.

Satellite on-board processing may include: despreading, demodulation, decoding, and demultiplexing of the uplinks; correspondingly coding, modulation, and spectrum-spreading on the downlink. The extent of on-board processing, however, needs to be carefully balanced with respect to incremental improvement in performance, system operational complexity, and processor technology.

Inclusion of EHF antenna nulling capability on the TACSATCOM II will substantially improve jam resistance and LPI performance of the mobile users. Therefore, antenna nulling schemes (MBA, phased-array, etc.) should be investigated for later TACSATCOM II satellites in the mid-1990's time frame.

A strong-technology development program over the next several years is recommended to provide a sound technical foundation for the TACSATCOM II system consistent with current projections of user requirements, EHF technology, and electronic threat. Immediate R&D efforts shall be initiated to develop the necessary EHF space and ground segment components, such as: antennas, high-power amplifiers (HPA's) and low-noise amplifiers (LNA's), satellite on-board processors, and spread spectrum modems, etc.

IV. NUCLEAR CAPABLE USERS/SYSTEMS

General characteristics and needs of this community are similar to that of the tactical/mobile users. The nuclear capable users, however, require maximum physical and electronic survivability under extreme conditions for command and control of the forces. The Strategic Satellite System (SSS) serving this community will evolve from its present capability (AFSATCOM) through a more jam resistance configuration with better physical survivability (SSS) in the mid-1980's, to an SSS-U system with substantial jam resistance and physical survivability in the 1990's.

One possible candidate for the SSS system in the mid 1980's is a set of dedicated satellites in inclined circular orbits at five-times synchronous altitude, together with single-channel transponders (SCT's) on a number of host satellites in both geostationary and elliptical orbits. Because of sunk cost in UHF force terminals, the uplinks from small mobile platforms probably will continue to be at UHF. Selected users may be provided with SHF and/or EHF uplinks. The downlink from the satellite will be at UHF and SHF. Another SSS candidate being studied includes a number of proliferated satellites.

Significant technology development effort for the SSS does not appear to be necessary. Technology maturity has been achieved through the comprehensive RDT&E program, leading to the operational test and evaluation of the LES 8/9 satellites with prototypical R&D terminals. These demonstration tests validated critical design concepts such as crosslinks, advanced jam-resistance modulation techniques, and the use of EHF frequencies. A sound technical base is extant to support the evolution of the SSS system through the 1980's.

In the far term, the SSS-U should achieve even better jam resistance and physical survivability features. With regard to electronic survivability (jam resistance and LPI), the MILSATCOM Architectural Working Group [2] has recommended the use of EHF frequencies (45 GHz up, 20 and/or 40 GHz down) for both the tactical-mobile and the nuclear-capable users. The FDM proposed the use of a common modulation waveform to achieve interoperability between the SSS and TACSATCOM II systems serving the two user communities. The selection of the common EHF modulation waveform is an important architectural consideration for both systems and is presently under investigation by the MSO. Technology development efforts for the SSS-U are similar to the TACSATCOM II discussed earlier.

Projection of the physical threat may necessitate increased physical survivability for the SSS-U. A comprehensive trade-off investigation of different approaches against estimate of physical threat shall be conducted to determine the most viable approach for the SSS-U system.

V. SUMMARY AND CONCLUSION

By the mid-1980's, the DoD will have substantial UHF and SHF satellite communications capability consisting of three satellite systems (FLTSAT/LEASAT, AFSAT packages on hosts, and DSCS II/III satellites) and a large inventory of airborne, shipboard, fixed, and mobile ground terminals. How-

ever, increasing demand for more bandwidth to meet high data-rate and antijam communications needs will require a gradual transition of some military users into the higher EHF band. The use of the EHF band, therefore, should be emphasized in the planning of next generation MILSATCOM systems. The 30/20 GHz band appears to be a good choice for the users from the wide-band community with high data-rate and high link-availability requirements. The 45 GHz on the uplink is more suitable for the tactical/mobile and nuclear-capable users needing high antijam and LPI protection.

Since, with the exception of DSCS III, no new satellite systems will be put into operational use in the near term, the next few years should be used to build a technical and preoperational foundation for the next generation of the satellite communications system with distinct military-unique properties. Progressive improvement in the three systems requires a vigorous R&D program beginning in FY 80 to define, develop, and test advanced concepts and equipments, both in space and on the ground. The MSO has prepared a Technology Development Program Plan (TDPP) which reflects the MSO Architectural Framework issued in November 1978. The TDPP is designed to highlight needed technology for realizing this architecture. If approved, it should assist the Services in preparing their technology development plans and programs.

REFERENCES

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