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Present and Future Trends in Military Satellite Communication Systems

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ABSTRACT

Recent years have seen a phenomenal growth in the field of satellite communications. Satcom systems offer many advantages for military applications which include wide area coverage, rapid deployment, flexible networking and long range service to moving platforms like ships, aircraft and vehicles. This paper gives an overview of the special features and future trends in military satcom systems. A brief account of various countermeasures against threats, use of EHF, spread-spectrum techniques and on board processing has also been given. Major technological advances are anticipated in near future to realise high capacity, secure and survivable satcom systems for Defence applications.

1. INTRODUCTION

Satellite communications offer several advantages for military applications.These include: wide area coverage with distance—insensitive cost, communication to remote areas, rapid extension to new locations; highly flexible networking, large capacity; reliable long range service to moving platforms like ships, aircraft, vehicles; and transmission of command and control information in a combat area. Military satellite communications are influenced by many needs not generally considered for commercial networks. Foremost among them is the ability to survive while facing the enemy threats which may include jamming, interception, spoofing of communication channels/satellite control links, physical destruction of space or ground systems, and several other effects resulting from nuclear weapons. The systems should also have the following desirable characteristics :

(a) Flexibility to provide efficient service under a wide range of scenarios and network configuration;

(b) Ability to serve a variety of users with diverse capacities and terminal sizes;

(c) Facility to accommodate a large number of low-duty-cycle mobile users;

(d) Compatibility with other network/communication media;

(e) Inter-operability among satcom terminals under different jurisdictions; and

(f) Cost effectiveness and improved spectrum utilisation.

Because the potential of this unique transmission medium has become widely recognised, the demand for satellite service has increased dramatically in recent years and a number of diverse applications of satcom systems in military are emerging day-by-day.

2. GROWTH OF TACTICAL SATELLITE COMMUNICATIONS

Until recently, the development of military satcom systems was mainly confined to fixed terminals to carry wideband traffic at high data rates using large antennas. The needs of tactical military communications have given rise to the development of small road and air transportable terminals which can be quickly shifted to a new location and deployed within a short time under field conditions to provide secure and reliable communication between the moving units. Examples of such terminals include the road/air transportable satcom

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Figure 1. '3M' road transportable satcom terminal.

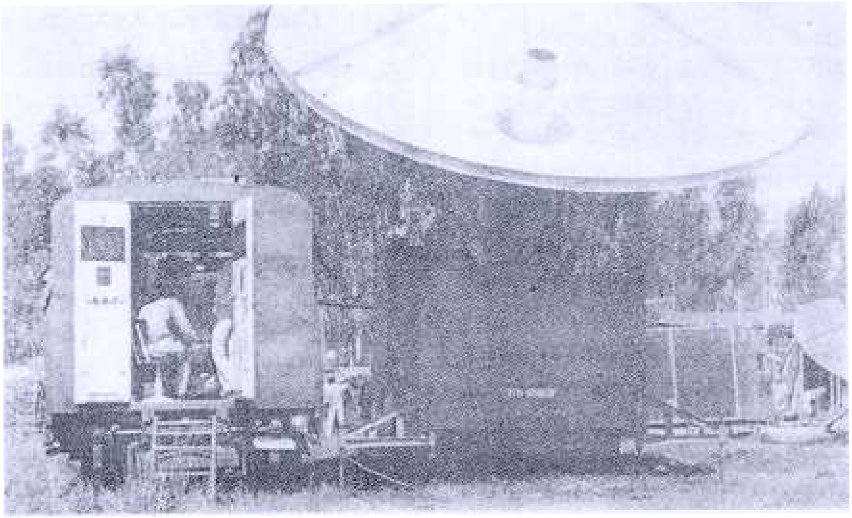

Figure 2. '6M' road transportable terminal.

terminals developed by Defence Electronics Applications Laboratory, Dehradun, shown in Figs 1 to 4. These terminals can be transported to remote areas along with the moving forces and communication can be established in a short time under hostile environment and adverse climatic conditions.

In order to meet the demands of command and control of highly mobile units/moving platforms such as the ships and aircrafts with modest bandwidth requirements, satellite systems built around lower frequencies (UHF) evolved to fill the critical need of tactical communications. UHF systems, utilising smaller antennas with wider beamwidths do not require high accuracy beam pointing mechanisms and can easily be accommodated on mobile platforms. Although, UHF terminals can be made small and relatively inexpensive, the available bandwidth and the degree of protection from interfering sources is limited. The desire to improve satcom service to both the strategic and tactical users has led to the use of higher frequency bands. With the growing operational deployment of satcom systems,

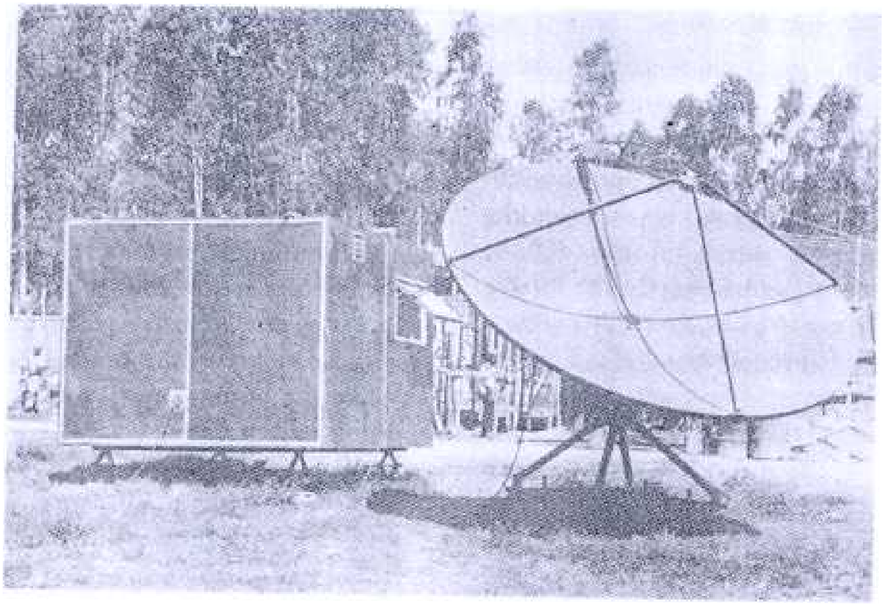

Figure 3. '3M' air transportable terminal.

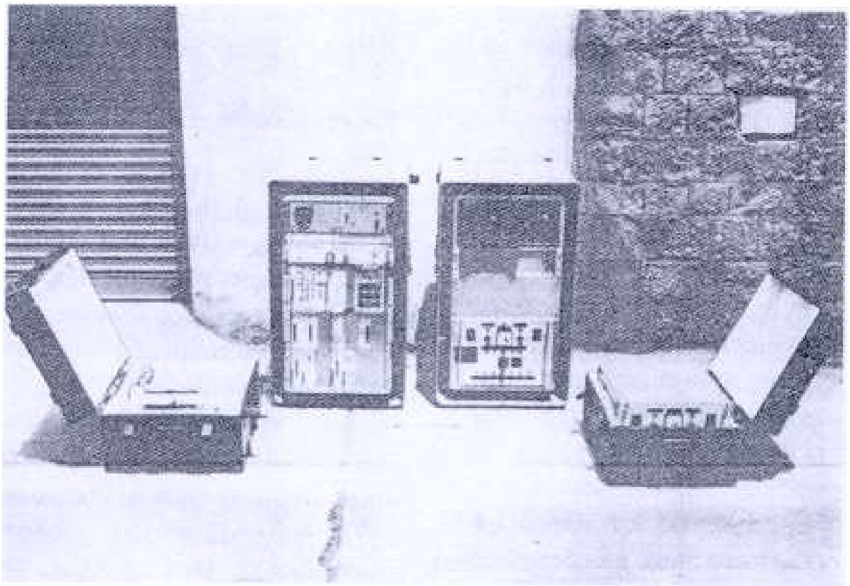

Figure 4. Electronic equipment of '3M' air transportable terminal.

several new requirements are influencing the future developments to realise more robust and flexible systems for military applications.

3. COUNTERMEASURES AGAINST THREATS

The requirement to provide survivability of communication under different types of threats distinguishes military satcom systems from the commercial systems. Satellite communications have an intrinsic vulnerability to jamming and unauthorised interception. Jamming of satellite transponders can be a serious threat. Downlink jamming from an aircraft or similar platform is also possible. Various techniques are used on-board the satellite and/or ground terminals to counter these threats. The measures which are most commonly employed are the spread-spectrum techniques and the use of antenna nulling to exclude the possible jammer from having visibility to the satellite. Techniques for ensuring low probability of interception (LPI) and complex enciphering methods are also employed for military satcom systems.

3.1 Spread-Spectrum Techniques

Spread-spectrum is an anti-jam technique which relies on the user, spreading his signal with a spreading function which cannot be replicated by the enemy. The receiver performs the inverse de-spreading operation. The advantage given to the wanted signal over the interference is called the 'processing gain' and is defined broadly as the ratio of the spread-bandwidth to the signal-bandwidth. There are two basic spread-spectrum techniques, viz. direct sequence (also called pseudo-noise) and frequency hopping. Both the techniques have their own advantages and sometimes are used together to obtain high anti-jam margins when the available spread-bandwidth is sufficiently large. Conventional straight through satellite repeaters do not provide adequate anti-jam capability to support communications between small terminals under jamming. When the jammer is much stronger than the user, almost all the satellite EIRP is captured by the jammer. With spread-spectrum (pseudo-noise or frequency hopping) modulation, the tolerable jammer-to-signal power ratio (JSR) depends upon the processing gain and other parameters like limiter suppression and required *Eb/No*, etc. Increasing the spread-bandwidth to improve the anti-jam performance is beneficial only as long as the downlink SNR is not too small.

In order to provide significant enhancement in anti-jam capability, there is substantial merit in separating the uplink signals from uplink jamming within the repeater. This is possible if the uplink signal is first de-hopped and demodulated in the satellite and then re-hopped and remodulated for downlink transmission to protect against downlink jamming.

3.2 Antenna Nulling

Anti-jam performance can be further enhanced by the receive antenna nulling technique on-board the satellite, i.e., by providing spatial discrimination between the user and the possible jammer location. If the satellite receive antenna produces high gain in the direction of the user and low gain towards the jammer then the tolerable JSR will increase by the difference in gain between the two directions. If one uses EHF, then this difference in gain can be between 20 to 30 dB depending upon the frequency and the type of antenna used. The concept may be extended further by providing an array of spot beam antennas with proper selection of appropriate coverage region. This can be integrated as a multiple beam antenna which employs a number of feeds sharing a common dish reflector or else a waveguide-lens structure.

3.3 Nuclear Threat and Radiation Hardening

Radiation, EMP and atmospheric ionisation/scintillation are the other nuclear threats apart from the threat by direct blast. Appropriate shielding and choice of components are the key factors for nuclear hardening. While the primary EMP may be insignificant at great distance, significant secondary EMP can be introduced by the initial incident pulse. Nuclear detonation can ionise the upper atmosphere, seriously affecting the space to earth propagation. Initial period is followed by nuclear scintillation so that signal fades rapidly. This affects the UHF communication for many hours, SHF for a few hours, but EHF momentarily. This requirement is also a driving force towards the use of EHF in Milstar programme of USA.

3.4 Physical Survivability of Space Segment

Emerging satellite communications beyond the timeframe of the present systems will need physical survivability against anti-satellite (ASAT) threat. Two basic concepts for achieving survivability of the space segment have been considered. First one is to put a number of satellites in geosynchronous and higher altitudes. Second approach is to arrange large number of small satellites in lower or medium orbits so that substantial number of them have to be eliminated to cause major reduction in communication capability.

In the Milstar programme, the first approach has been adopted. Four geosynchronous satellites and three inclined orbit satellites are interconnected by cross-links. Depending on the scenario, one user may be interconnected to another by different methods. Required connectivity takes place in stressed, jamming or nuclear environment very quickly by the network management including the inter-satellite and intra-satellite links.

4. FUTURE DEVELOPMENTS IN MILSATCOM SYSTEMS

Development efforts to realise future Milsatcom systems are directed on technologies in EHF band, more sophisticated on-board signal processing, and the adaptive antennas to make the satellites more adaptable to changing tactical scenarios, to provide flexible coverage, improve resistance to jamming, ability to reconfigure the networking for survivability, more efficient demand assignment techniques and protection against nuclear effects/physical attack.

4.1 Enhanced Processing On-Board

There will be FH uplinks from small terminals and having multiple access in FDMA mode. This will be possible as wide bandwidth at EHF will be available. Therefore, protection against jamming for large number of tactical terminals is anticipated. Other features of on-board processing such as the demodulation to baseband and data routing on-board is also envisaged.

Antenna technology will be critical to future developments. In addition to downlink antenna developments including the electronically steered multibeam antennas, sophisticated antenna arrays will be required for uplink reception. These may provide jammer rejection together with high gain and perhaps frequency re-use on-board. Adaptive algorithms will discriminate against jamming or interference and wanted signals may need to be distinguished by secure spread-spectrum format. Developments may be anticipated in phased array antennas for spacecraft.

4.2 EHF Technology

The bulk of military satcom systems presently operate at SHF (7/8 GHz). Major exploitation of EHF band is envisaged in future Milsatcom systems. The use of EHF offers many advantages to military users. The Milsatcom frequency band is allocated as uplinks 43.5 to 45.5 GHz and downlinks 20.2 to 21.2 GHz. The 2 GHz uplink bandwidth will give increasing processing gain which may be further enhanced because of on-board de-spreading. For ECCM purpose, EHF will have further advantage as EIRP of small terminals increases with frequency while for the large terminals (jammer) tends to reach practical limits. The wider bandwidth at EHF will also allow higher traffic capacity and relative freedom from constraints on orbital spacing of satellites. Even small tactical antennas will be capable of narrow beamwidths. The smaller size and weight of hardware will encourage the use of more sophisticated on-board adaptive antennas. The cost of development of the advance technology in EHF is expected to fall as and when few countries start operating EHF satellite communication within next few years.

4.3 Optical Communication by Satellite

While optical satcom is particularly appropriate for inter-satellite links (where performance would seem to be comparable to EHF system), there is also scope for space-to-ground communications subject to the obvious problems of cloud and rain. Such a system might operate around 1.3 micron wavelength most likely with *Nd:YAG* sources and use pulse position modulation. Current technology is largely based on the direct detection methods. Coherent detection systems, where the optical signal is heterodyned down to RF, offer considerable potential.

Use of the blue-green lasers may permit communication with submarines below the sea surface. This might involve a one-way broadcast from a low orbiting satellite using modulated scanning spot beam, an optical wavelength appropriate to transmission in sea water, and a very narrow receiver optical filter to reject background noise.

4.4 Inter-Satellite Links

Inter-satellite links (or cross-links) may be used to extend the coverage area of a geostationary system, eliminating the need for intermediate anchor stations or as links between low orbiting and geostationary or supersynchronous satellites. Communication could be either by EHF at 60 GHz or optically. Calculations suggest that excessive powers are not required, and the main problems lie in the antenna/aperture acquisition and tracking.

4.5 Survivable Satellite Networks

The military satellite communication networks of future will be more flexible, more cost-effective and most importantly capable of functioning under any scenario from peace through protracted nuclear war. This goal will be achieved by ensuring inter-operability of links handling communications, mission data, or satellite tracking, telemetry and command for different types of future Defence satellite communication systems. The design of inter-operable and survivable networks for different types of Defence satellite communication systems is a highly complex task. Satellite data link standards will have to be evolved and common transmission formats, protocols and compatible software/hardware will be used for different classes of users to have survivable data links. Future network architectures will have to take into consideration not only the satellite links but terrestrial nodes as well and sufficient redundancy in space and ground links will have to be built to ensure alternate links for improved connectivity.

5. CONCLUSION

Present and future Milsatcom systems upto 2000 AD will use the frequency bands of UHF, SHF and EHF to support communications to a large number of small terminals. SHF systems which are being used by most of the nations at present will continue as primary systems for long haul high volume communications. Commercial C- and Ku-band systems and terrestrial/fibreoptic systems will continue to supplement for high data rates for use in peace time. EHF systems will be stabilised by 1995 which will have full anti-jam capability through spread-spectrum and antenna nulling. Major technological advances are anticipated in on-board processing techniques.

There is no accepted approach for physical survivability of the satellites as yet. However, Milsatcom systems may be perfected before the end of this century.