ENHANCEMENT OF ENDURABILITY BY MODERN TECHNOLOGY IN TRANSPORTABLE MILITARY TT&C GROUND TERMINALS

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WWMCCS and Survivability of Satellite Links

WWMCCS is a Worldwide Military Command and Control System which uses command centers, warning and surveillance systems, communication systems and data processing or computers. One of the functions of WWMCCS is to use existing worldwide jam resistant satellite communications to link decision makers in the United States with commanders overseas as well as to support tactical mobile ground shipboard and airborne users and designated nuclear capable forces. It is intended for use by the National Command Authority for the dispatch of the most critical commands. It must operate successfully under severe enemy counteractions and during and after a nuclear exchange. It demands the ability to survive and the utmost in reliability and endurability. In addition, its function of providing a means to dispatch critical commands, WWMCCS also provides a common user Automatic Data Processing (ADP) which is used in normal day to day environment, and computer-to-computer connections through an intercomputer network (WIN) program. WIN is an ARPANET-like packet switching network interconnecting 20-25 Honeywell 6000/GCOS hosts located at sites across continental United States, Hawaii, Korea and Europe. At present WWMCCS is providing dialog communication lines between all major users and is studying alternatives for the development of an information system (WIS) to interlink not only computer networks but message handling centers, intelligent terminals, and command center display systems.

According to Lt. Gen. H. Dickinson, Organization of the Joint Chiefs of Staff, writing in SIGNAL, May/June 1981, “EHF radio and millimeter wave technology provide similar (to Fiber optics) promising improvements in bandwidth survivability and security. The widespread use of satellite terminals has been perhaps the single most important change that has influenced the way we operate in recent years.”

This paper will discuss the enhancement of the endurability of the WWMCCS satellite network by use of transportable TT&C earth terminals which can be proliferated and/or rapidly deployed to operate and/or maintain the status and health of satellites in the WWMCCS network. Such transportable earth terminals have the capability of being transported by truck, or by aircraft such as C-130, C-141, or C-5A, to be set up in any part of the world and to be able to assume many or even all of the TT&C functions of modern military TT&C earth terminals including telemetry data processing functions and some level of local command authority executed upon instructions from a remote command center or based on "canned" commands or with limited local autonomy, or with the transportable terminal implemented to operate as a mobile mission control center.

The Meaning of Endurability by TT&C Terminals

Endurability is defined by Webster as the "ability to survive and maintain". From the WWMCCS standpoint; this implies the ability to maintain various key functions during various levels of threat. In general, the satellite functions in the WWMCCS include communications, data gathering, networking, meteorology, navigation, etc. TT&C earth terminals must then provide tracking, telemetry analyses, and commands in order to provide endurability of satellite functions. This endurability by a TT&C earth terminal is then provided by the following:

- Functional transfer: In the event of the loss of one TT&C earth terminal, its functions could be transferred to another terminal.

- Proliferation/redundancy: This provides for backup, alternate, or alternative TT&C earth terminals to maintain satellite support.

- Mobility/Transportability: This provides for either movement of a TT&C earth terminal from one place to another to escape a threat or serve a scenario, or to rapidly deploy or move a TT&C earth terminal to a designated location,

- Hardening/CBR: This provides for protection or endurability of a TT&C earth terminal in the presence of an EMP threat or chemical or biological warfare.

- Satellite Autonomy: This provides TT&C earth terminal data processing of orbital data to provide update of semi-autonomous satellite orbital position

- Frequency diversity: This provides the ability to move to other TT&C frequency bands including Ku-band and EHF to serve various scenarios or endure various levels of threat.

- Data Processing Commonality: This provides the ability to process the TT&C data for a variety of different satellite system and missions.

- Earth Terminal Semi-Autonomy: This provides the capability to maintain communication and data links with remote command centers and to provide limited autonomous operation in various situations of threat.

The Technologies of Endurable TT&C Earth Terminal

TT&C terminals differ from communication terminals in that they must be capable of precision tracking of low and medium altitutde orbiting satellite in addition to geosynchronous satellites. They must be capable of determining satellite position and range and of detecting telemetry downlink signals and producing uplink command signals.

The technologies which are required to assure the survivability/endurability of TT&C earth terminals include new antenna designs for fast erection time and minimum size/ weight packaging onto aircraft, and the associated use modular shelters which are also especially designed for transportability. Equipment technology for endurability includes new LNA and solid state power amplifier technology with particular emphasis on reliability through soft failure modes; new digital antenna control instrumentation; the use of modern integrated circuits including LSI and employment of new equipment packaging techniques to reduce size and weight; modern data handling and processing systems including computer and peripherals; microprocessor control and monitoring systems including the use of the IEEE-488 bus, the use of fiber optics for EMI-free data interconnectivity; and the use of antenna sidelobe control to reduce susceptibility to jammer interference.

The TT&C Military Earth Terminal

Figure 1 illustrates the use of a TT&C military earth terminal (or ground terminal) in a typical user scenario. Here the TT&C terminal, consisting of a tracking antenna, an RF system, a baseband system, and a TT&C data processing system, communicates satellite tracking and telemetry information, obtained from a DSCS II satellite at S-band, back to a DSCS ground station via the same (or another DSCS II) satellite at X-band using a portable or local DSCS X-band portable terminal. This data return could also have been accomplished by a Telco or microwave radio system.

The TT&C terminal is made up of the subsystems shown in Figure 2. The antenna is a tracking antenna and can be either a full motion antenna (horizon to horizon) or a limited motion antenna limited to a restricted portion of the sky. It should have all the electronics and movements required to track a specified satellite and to determine the satellite position, and to demodulate and process the telemetry and range data using both baseband and data processing subsystems. It should be also capable of receiving command data from a command station and transmitting these commands to the satellite.

A TT&C terminal for typical military satellites such as DSCS-II, NATO III, DSP, DMSP, SCF, NASA, and GPS must not be confused with the fairly simple terminals used to provide voice and data communications at, say X-band via DSCS-II. It is a very sophisticated and complex terminal capable of not only tracking and establishing up and down links for telemetry and command data and for range and range rate functions, but also, as shown in Figure 2, to provide the complete range of telemetry, command and ranging baseband functions required, and to locally process this data to an extent determined by a distant master terminal. In the present era of computer technology, the range of data processing capability of a military TT&C earth terminal is not limited by the equipment and hardware used, but by the extent of available software and the availability of a personnel complement capable of providing not only the data processing and terminal operation, but also direction and in cases of certain threat levels, actual mission management and control.

The Technologies Relating of Transportability and Deployment

If a military TT&C terminal is to be transported, it must conform to the pacing size and weight requirements of the available transporting vehicles. Consider the use of the C-130 aircraft as the candidate vehicle for transporting a military TT&C terminal. A C-130 can carry a load weighing 32000 pounds in a space roughly 8 X 8 X 40 feet.

The pacing weights of a military TT&C terminal are provided by the antenna subsystem, the HPA, and the shelters and equipment. The antenna weight can vary from 5000 to 25,000 pounds (30-foot full motion). Shelter weights are 5000 to 6000 pounds for 20 X 8 X 8 foot enclosures. The HPA weighs about 3200 pounds for each 2 KW of power. In addition, about 10,000 pounds of baseband equipment (8 to 10 racks) and consoles and 5000 pounds of TT&C equipment. A hypothetical TT&C terminal with a 20-foot full-motion antenna disassembled in a package 20 foot in length, and three subsystem shelters each 20 ft. long would weigh about 50,000 pounds. Since a C-130 can only carry 32,000 pounds, two C-130s or one C-141 will be required, to meet the weight requirement.

The size of T/MGS is of particular concern for transport by aircraft such as the C-310, which has a cargo size capacity of 8 X 8 X 40 feet. Standard ISO shelters come in the 8 X 8 X 10, 8 X 8 X 20 or 8 X 8 X 36 foot size. A hypothetical TT&C terminal with a 20-foot full-motion antenna packaged into a space 20 X 8 X 8 feet in size, and three shelters (RF, BB, TT&C), would fit in two C-130 aircraft. A 30-foot, disassembled, full-motion antenna will consist of a package 36 feet long and 8 X 8 feet in cross section. Hence two C-130s would be required to carry the antena alone.

The Technologies Relating to Deployment

The time-to-erect a disassembled antenna in the 10 - 30 ft diameter range is a critical parameter in getting a TT&C terminal "on the air" after it has been transported to a key site. Antenna technology for transportable TT&C operation has now matured to the point where the structural weight sequence to maintain the ridigity and strength required for accurate tracking and for tracking in high winds has been reduced by the use of innovative mechanical structures and self erecting pedestals. It is now possible to erect a 20 foot full motion on a 30 foot limited motion antenna in a time element from 8 hours to 24 hours depending on the type and location of the site, and the personnel available. Modern transportable/erectable antennas no longer require cranes or complex erection tools but utilize portions of the structure itself to aid in the erection.

Other aspects of deployment, including interconnecting the various equipment shelters and the antenna and the HPA are not significant problems, and indeed can be aided by the use of the fiber optic links between the baseband system and the data processing TT&C subsystem whose shelter may be located some distance from the baseband subsystem.

The Technology of Sensitivity and EIRP (LNA and HPA)

Two key parameters which are required to operate a military TT&C terminal with a given satellite — the earth terminal sensitivity figure of merit G/T and the earth terminal EIRP or up-link radiated power. These two parameters involve three major earth terminal systems and related interconnection systems. These major parameters include:

- Antenna gain G which is a function of antenna diameter and efficiency.

- Low noise amplifier whose noise temperature with antenna gain and noise temperature establishes G/T.

- HPA (high power amplifier) power output which with the antenna gain determines the earth terminal effective isotropic radiated power EIRP.

We have determined that at the SGLS frequencies of 1.7 GHZ uplink and 2.2 GHZ downlink, an antenna with a 30 ft. diameter, using a LNA with a 60°K noise temperature and an HPA with 4 KW of RF power will support TT&C links, including ranging, of existing geosynchronous spacecraft and that antenna diameters in the 14 to 21 foot diameter range, operating with the same LNA and HPA will support the TT&C links of low and medium altitude satellites.

Both the LNA and the HPA have undergone recent technological changes which significantly enhance the endurability of military satellites support WWMCCS links. The parametric amplifier LNA of the 1960's and 1970's has been replaced by the low noise field effect transistor (FET) amplifier using gallium arsenide MESFET's. These devices, now used worldwide in military and non-military satellite communications have an outstanding history of reliability where a very rare failure occurs gradually (soft failure) as compared to the rapid failures once characteristic of parametric amplifiers.

The high power amplifier is also the beneficiary of rapid advances in the development of microwave power transistors. The classical klystron (which must be tuned) and the TWT (which requires a heavy and very large HPA system) is now being challenged by the solid state power amplifier (SSPA) which produces output power at 1.76 GHz in 1, 2, 4 etc. KW increments as a result of the repeated combining of 20 watt transistors. Such HPA's are now being evaluated at Pt. Mugu and by FACC's DTF and have the advantages of only drawing dc power when an RF signal is passing through the HPA, and being inherently reliable with soft failure characteristics - a point failure of a transistor (operated in pairs) will have neglible-impact on power output (less than 40 watts).

<u>The Technology of Tracking Systems</u>

Antenna tecking has reliazed significant technological advancement during the last decade. The classical monopulse tracking systems requiring moveable feeds or multiple hours, has given way to steptrack for limited motion antennas or single channel monopulse systems for full motion antennas. Modern tracking system technology now benefits of FET LNA advancements, modern digital tracking receivers, and microprocessor control of receivers in association with solid state memory storage of obrital and ephemeris information.

<u>The Status of Baseband Equipment Technology</u>

SGLS baseband equipment was first built by MOTOROLA during the 1960's. Since that time relatively small numbers of procurements of the demodulators, bit synchronizes, range/rate units, command formatters, and other equipments have virtually stalled any significant advances in baseband equipment development. Some developments in packaging have taken place and the introduction of microprocessor control and adaptability to the IEEE-488 bus control and monitor system have resulted in some improvements in both equipment size and reliability.

However, SCLS baseband equipments have been the last to see any impact by the LSI "explosion" of the 1970's and equipment complements to perform SGLS and DSIS functions still require almost the same number of equipment racks and only slight improvement in equipment weight over the original equipments of the 1960's.

It is hoped that development technology will be eventually be applied to baseband equipment functions for SCLS telemetry during the 1980's to produce significant reduction in equipment size and contribute a major enhancement of TT&C terminal size and transportability.

The Technology of the TT&C Data Processing System

In the 1960's and into the 1970's, a typical Air Force remote tracking station (RTS) used a redundant UNIVAC RMF 1230 and CDC disk memories. Such installations were massive and heavy and fixed plant installations of this type - including all displays, peripherals, control consoles, and associated equipments - were not candidates for transportability or remote shelter operation - as is now demanded of modern TT&C earth terminals such as those being designed by Ford for the GSLS system.

The explosive growth of data processing technology now makes possibles a TT&C data and control system whose equipments can be installed in a small 8 X 8 X 20 ft. shelter and which are limited only by software and by proximity to mission control to perform virtually the entire range of functions produced in the fixed plant equipments of the 1960's.

Modern military computers now provide up to megabyte of processing capability. Both Rolm and Norden provide full mil-spec ruggedized computers occupying only a few cubic feet of space and capable of extremely short mean-time-to-repair cycles. These modern computers are joined by mil-spec reggedized disk memories, mil-spec ruggedized plasma displays, and for that matter, a whole host of candidate peripherals from the commerical computer and data processing. Only applicable decommutation equipments have not seen the advent of data processing equpment and display development.

As mentioned above, software is the key to the range of data processing capability of a modern TT&C earth terminal and the extent of hardware vs. software development for an earth terminal directed toward a single mission or multiple missions is the final key to survivability and endurability when applied to a WWMCCS satellite link,

Other Applicable Technologies

Other applicable technologies which can contribute to the endurability of a military TT&C earth terminal in the WWMCCS system are listed as follows:

- Use of radiation hardening to resist or survive during a nuclear attack.

- Use of shelter design and equipments designed to protect personnel and equipment during chemical and biological warfare.

- Use of sidelobe cancellers with the antenna system to reduce the susceptibility to jamming by a terrestrial or airborne jammer.

- Use of spread spectrum techniques and security systems to reduce the possibility of jamming the operation of the TT&C terminal.

- Use of a mobile mission control center complex in a shelter interconnected to one or more data processing subsystems of a group of locally situated military TT&C earth terminals.

- Use of fiber optic connections to interconnect all digital equipments - both within and outside of the shelters.

- Use of additional X-band and EHF equipments which are capable of providing up and down links to the TT&C functions of DSCS III and to future EHF satellites now being studied and proposed by Dr. P. Jain of DCA.

- Development of extremely portable X-band low data rate terminals similar to the Ford Aerospace SCT-8 to provide communications with a WWMCCS satellite to assure communications back to a control center based on equipment which is transported and assembled along with the military TT&C earth terminal.

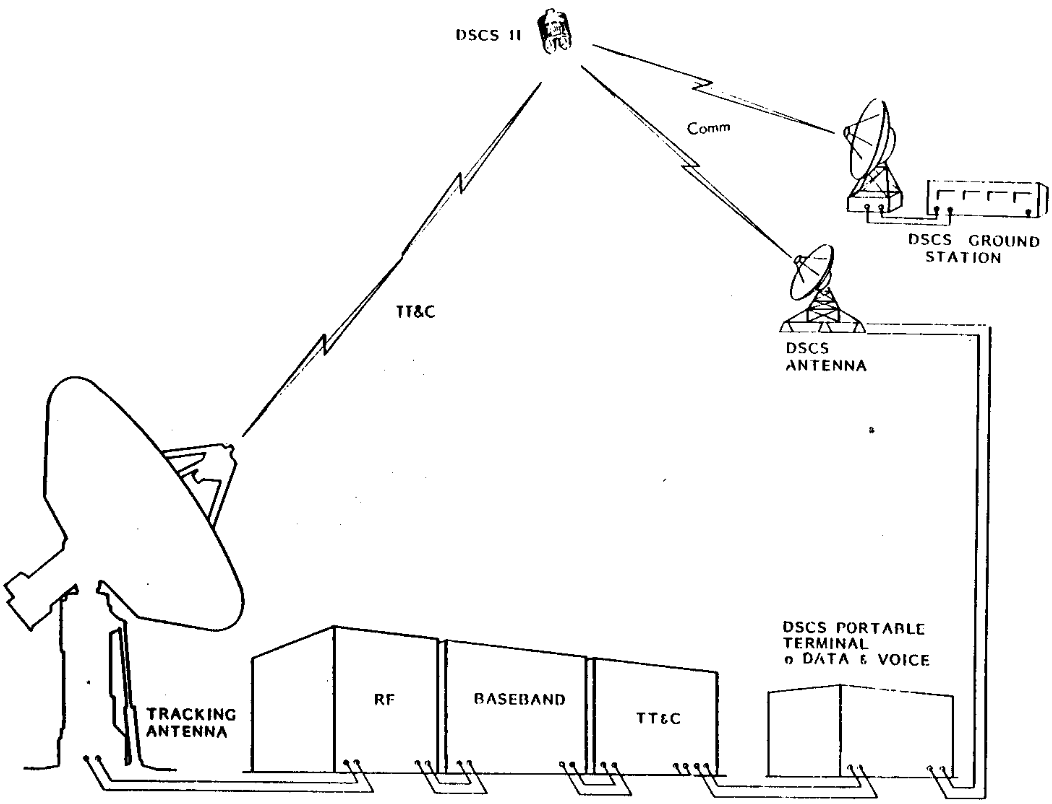

FIGURE 1 MILITARY TT&C EARTH TERMINAL IN A TYPICAL SCENARIO INVOLVING A DSCS II SATELLLITE

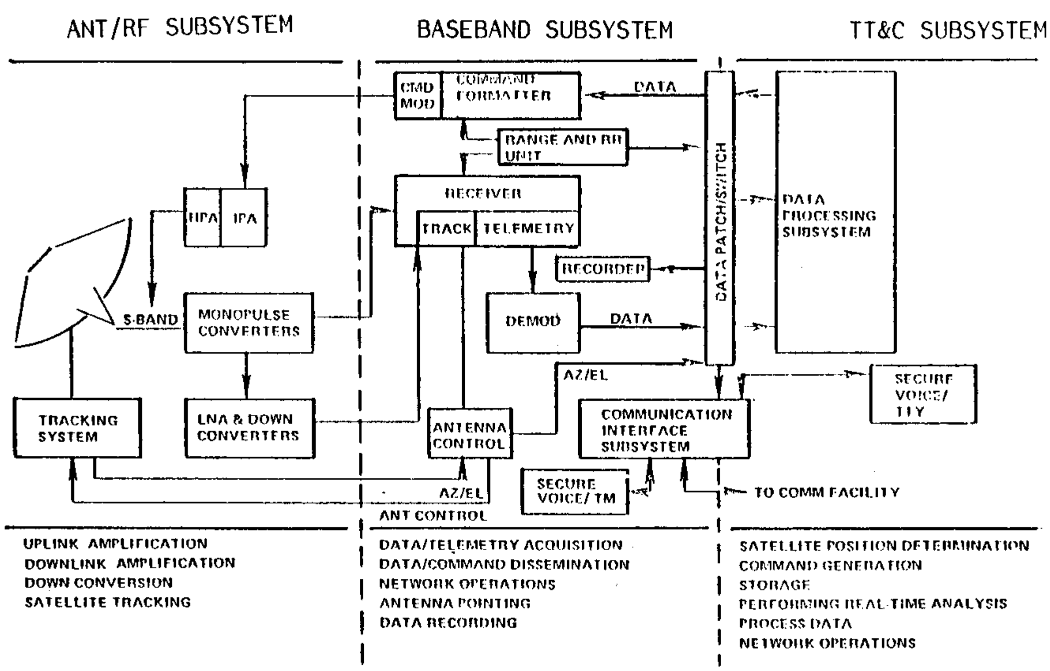

FIGURE 2 SUBSYSTEMS OF A MODERN MILITARY TT&C EARTH TERMINAL