The Space Congress® Proceedings

1981 (18th) The Year of the Shuttle

Apr 1st, 8:00 AM

SBS System Description

W. H. Curry
System Definition and Control, Satellite Business Systems

SBS SYSTEM DESCRIPTION

W. H. Curry, Jr., Manager
System Definition and Control
Satellite Business Systems
McLean, Virginia

ABSTRACT

Satellite Business Systems (SBS) recently initiated customer services, consisting of private, switched networks for integrated voice, digital and image transmission using satellite links among earth stations located on customer premises (Customer Network Service type A (CNS-A)). Later, SBS plans to evolve system operation to allow the introduction of shared services for customers with more modest transmission needs.

The paper relates the essential engineering features of the SBS system to the resulting operational capabilities. The system description includes the satellite, earth station, TT&C and control configuration, as well as the Time Division Multiple Access (TDMA) burst architecture.

SYSTEM AND SERVICE OVERVIEW

SBS offers large capacity telecommunication services to business and government organizations through the use of communication satellites providing connectivity throughout the contiguous 48 states. The basic offering to customers is private-line, switched communications service for integrated voice, data and image transmission among dispersed customer locations. In addition, advanced services, such as video teleconferencing and high data rate transmission are economically supported through earth stations located on customer premises. SBS identifies this as Communications Network Service, Type A, or CNS-A.

The dedicated transmission capacity of each customer's network is allocated among network earth stations as needed. Optional transmission capacity can be provided on demand to a network during peak traffic periods. Other CNS-A features, such as voice activity compression, further improve transmission efficiency and thereby reduce the cost of service.

The SBS earth stations will interconnect with customer provided PBXs, data terminals and other communications terminal equipment as well as other common carrier communication services and facilities. Customer equipment co-located with an SBS earth station can be interconnected with conventional on-premises facilities. Customer terminal locations remote from the earth station can be interconnected by communications facilities or services acquired by the customer, or by SBS on the customer's behalf, from other common carriers. Complete interconnectivity of all services specified by the customer is provided by the network switching equipment.

The principal operating features of CNS-A and the technical features which make them possible are presented in Table 1.

There is no "typical" CNS-A network, because of the wide range of alternatives and the great flexibility offered by the SBS design. A network can be as few as three or as many as 100 earth stations each serving as a switching node for as many as 365 voice circuits or the equivalent capacity in data transmission, to an aggregate of about 12 Mbps per earth station. The aggregate network throughput capacity is more than 40 Mbps using a 48 Mbps transmission burst rate.

Users of the service perceive no significant difference from the service and procedures they have come to expect from their local public telephone companies and private networks. For example, call dialing procedures, call processing signals heard (dial tone, ringing, busy), and the speed of completing connections are similar.

An advantage of CNS-A is that it extends these reliable, user-proven services to high rate data and image transmission. Moreover, network transmission capacity may be used interchangeably for voice or data and dynamically assigned among network nodes as needed.

SBS plans to introduce additional services early in 1982 to economically serve customers with smaller traffic volume by sharing network resources. Communications Network Service Type B (CNS-B) will permit two or more private networks to share an earth station. Message Service TYPE I (MS-I) will permit low-cost, long distance telephone service.

Access to MS-I earth stations will be via dedicated lines furnished by SBS. Later, SBS plans to introduce Message Service Type II, which will connect users to earth stations via the public telephone system.

The SBS design features which allow the flexible evolution of services described above include stored program controlled switching and processing at earth stations, and time division multiple access of the satellite transponder. The details of that design are addressed in the sections that follow.

MAJOR SYSTEM COMPONENTS

The major system components are the ground segment, space segment, and control segment. Their interrelationship is depicted in Figure 1. The Telemetry, Tracking and Command (TT&C) system and the Network Control Center (NCC) provide satellite and network control for all customer networks. Individual customer networks consist of three or more earth stations communicating through a single transponder.

One earth station in each transponder provides the TDMA timing reference and dynamic capacity allocation for all networks operating in the transponder. This station is called the Reference Station.

GROUND SEGMENT

As indicated in Figure 1, the main components of an earth station are the Port Adapter System (PAS), the Satellite Communications Controller (SCC), the Burst Modem (BM), the Radio-Frequency Terminal (RFT), and the Monitor and Command System (M&C System). The functions of these components are summarized in Table 2.

SPACE SEGMENT

The SBS Space Segment includes the Satellite, the Telemetry, Tracking and Command (TT&C) earth stations and the Satellite Control Facility (SCF).

SATELLITES

Each satellite carries ten active and six redundant Travelling Wave Tube (TWT) amplifiers, each of nominal 43 MHz bandwidth, plus one active and three redundant receivers. One receiver serves all TWT amplifiers. A receiver/TWT combination is referred to as a transponder. The satellite communications subsystems are shown schematically in Figure 2.

The satellite orbit is precisely maintained to minimize satellite drift and thereby eliminates the cost of accurate earth station antenna tracking which would otherwise be necessary. The satellite antenna coverage specification, shown in Figure 3, has been shaped to provide weighted coverage of the contiguous U.S., favoring the areas of high earth station density.

CONTROL SEGMENT

The support components of the SBS System are those which are not directly in the customer traffic signal path. In the description below, support components apply to the space segment or ground segment, shown in Figure 1, as follows:

Space Segment

- o Telemetry, Tracking and Command (TT&C) earth stations
  - Beacon Station (Denver, CO)
  - Control Station (Clarksburg, MD)
- o Satellite Control Facility (SCF) (part of control station)
- o RF System Monitor (Clarksburg, MD)

Ground Segment

- o Network Control Center (NCC) (McLean, VA)
- o Operations and Maintenance Facilities (locations TBD)

SPACE SEGMENT SUPPORT

Space segment operational support is provided by a complex consisting of a Beacon Station, a Control Station, and a Satellite Control Facility (SCF). For a spacecraft launch, additional tracking and command facilities to provide worldwide coverage are leased.

TELEMETRY, TRACKING AND COMMAND EARTH STATIONS

SBS will use two geographically separated TT&C stations for receiving telemetry from the satellites, for tracking to determine the orbital parameters, and for issuing commands to the satellite. Each station will be equipped with antenna and associated equipment that will enable simultaneous processing of TT&C signals for two satellites. One TT&C earth station is located at Castle Rock, Colorado, and is referred to as the Beacon Station. The second TT&C station is combined with the Satellite Control Facility at Clarksburg, Maryland, and is referred to as the Control Station.

BEACON STATION

The Beacon Station consists of one (1) fully steerable antenna/RF Terminal (RFT) and two (2) limited motion RFTs along with tracking, telemetry, and command processing facilities. The Beacon Station provides the following functions for the SBS System:

- Tracking Beacon for satellite antenna pointing
- Primary Satellite Commanding (modulating the tracking beacon)
- In-Orbit Testing
- Drift Orbit Monitoring
- Secondary Telemetry Processing
- Tone Ranging

Each of the limited motion RFTs is dedicated to a specific geostationary satellite and provides beacon and command capability and secondary telemetry. The fully steerable RFT performs the in-orbit testing and ranging, as required, and provides backup to the limited motion RFTs.

CONTROL STATION

The Control Station consists of two (2) limited motion RFTs and the associated telemetry, tracking and command processing facilities. It serves the following functions in the SBS System:

- Primary Telemetry
- Secondary Spacecraft Commanding
- RF System Monitoring
- Tone Ranging

SATELLITE CONTROL FACILITY (SCF)

The SCF is the nerve center of the TT&C system and is responsible for control of satellite operation. Satellite commands are formulated in the SCF and forwarded to the proper TT&C earth station for further processing and transmission. Specific functions performed by the SCF, in addition to general monitoring of the satellite status, are:

- Generate, validate and transmit commands
- Evaluate telemetry responses
- Relay attitude and ranging data to the orbit determination computer at COMSAT
- Receive attitude and orbit correction parameters from COMSAT computers and generate proper correction commands
- Evaluate inputs from the RF System Monitor
- Exchange appropriate information with the SMF

RF SYSTEM MONITOR

The purpose of the RF System Monitor (RFSM) is to receive transmissions from all SBS satellite transponders and analyze their RF characteristics. The RFSM has RF equipment that is tunable over the entire satellite downlink frequency band. The RFSM is co-located with and shares an RFT with the SCF.

SYSTEM OPERATION

The SBS system supports private customer networks providing both advanced and conventional communication services. The advanced services involve high transmission rates and connectivity not otherwise available. The conventional services are those that customers have come to accept as standard from other common carriers, but which can be flexibly integrated with more advanced customer requirements in Communications Network Service Types A and B. CNS-A has fully dedicated facilities, whereas CNS-B consists of private networks sharing resources.

CNS FEATURES

A CNS-A network consists of all the earth stations serving a particular customer, the access lines, and a satellite transponder. The Customer premises earth stations (CPES) communicate among one another by TDMA bursts in the transponder. More than one network may operate in any given transponder.

One earth station in each transponder is designated by SBS as the Reference Station. The Reference Station provides the network reference timing and controls the allocation of network capacity.

A CNS-B network is similar except that some customers may share the resources of specific earth stations. The resulting CNS features are described in the following sections.

FULL CONNECTIVITY

All earth stations in a network have the ability to communicate directly with all other earth stations in the same network. Likewise, any switched station on a customer's network (e.g., telephone, data terminal and so forth), can be connected on a dial-up basis to any other compatible station.

DYNAMIC NETWORK CAPACITY ALLOCATION

The TDMA feature of CNS allows flexible and efficient assignment of network and satellite transponder capacity to meet dynamically changing customer traffic requirements, in contrast to networks using fixed-capacity trunk routes. This is made possible by the allocation of transmission capacity to CNS nodes by time division.

There are six levels of capacity allocation control, some optional and some standard, operating in conjunction to provide demand assignment (DA) of network capacity. These are:

- o Assignment of full-time Transmission Units (FTUs) to the network for basic services (tariffed feature).
- o Assignment of Demand Transmission Units (DTUs) to/from a network dynamically as network loading changes (optional tariffed feature).
- o Fully Variable/Demand Assignment (FV/DA), a standard evolutionary CNS feature.
- o Variable destination/Demand Assignment (VD/DA), a standard CNS feature.
- o Port Activity Compression (voice-VAC, Digital-DAC), a standard CNS feature.
- o Capacity Transfer Control (CTC), a standard evolutionary CNS feature.

These DA features are described in the following paragraphs.

FULL-TIME TRANSMISSION UNITS (FTUs)

An FTU is a full-time assignment of 224 Kbps of simplex transmission capacity leased to a CNS network. The minimum tariffed CNS network configuration is one FTU per earth station and three earth stations per network (minimum of three FTUs per network). Since the number of FTUs required to support a network is a function of the network configuration, changes to the FTUs employed in a specific network would normally be made commensurate with major network reconfigurations.

The FTUs are assigned to a network, as opposed to individual earth stations. The Transponder Reference Station can automatically allocate capacity to specific earth stations on demand within the network capacity boundaries established by the number of network FTUs (and DTUs) authorized by the customer.

DEMAND TRANSMISSION UNITS (DTUs)

A portion of each transponder's capacity (time assignment) is reserved by SBS in a pool for assignment on demand to customer networks which have selected this tariffed option. A DTU is 224 Kbps of transponder capacity assigned to a customer's network from a common pool subject to availability. The Reference Station increments or decrements network capacity from/to the DTU pool on request in minimum increments of 224 Kbps, not to exceed the sum of active digital baseband traffic present in the network. The maximum augmentation available to a network is limited to the number of DTUs authorized by the customer. DTU capacity changes are implemented over TDMA superframe burst boundaries, which occur several times per second.

FULLY VARIABLE/DEMAND ASSIGNMENT (FV/DA)

The Reference Station normally allocates available network capacity by assigning the burst length (capacity) of each network earth station as limited by the total network leased capacity (FTUs and DTUs). This capacity allocation is determined from the current traffic as reported by each SCC to the reference station several times per second. Total network capacity is thereby efficiently reallocated among network nodes (earth stations) as nodal capacity requirements change.

VARIABLE DESTINATION/DEMAND ASSIGNMENT (VD/DA)

To enable a call at an originating earth station to be directed to a specific address served by a destination earth station, the TDMA frame structure provides a destination address for each traffic channel in an earth station transmission burst. Therefore, the transmit SCC can flexibly load its assigned burst capacity with traffic without regard for the traffic destination. Further, the reference station need not be concerned with the assignment of receive capacity to individual earth stations, since the destination SCC can screen the aggregate network traffic as received and strip off for processing and delivery those traffic channels with local addresses. VD/DA thereby simplifies the process of adding new calls and deleting old calls from the burst traffic channels at each earth station and facilitates efficient utilization of transmission burst capacity. VD/DA is a standard feature of CNS TDMA.

PORT ACTIVITY COMPRESSION

Voice Activity Compression (VAC) is a standard feature of CNS TDMA which reduces channel loading by recognizing temporarily inactive voice ports and excluding their data from traffic channels in the TDMA burst. VAC is made possible by the fact that typical periods of port inactivity substantially exceed the earth station burst repetition interval of one burst every 15 milliseconds, or 66 2/3 bursts per second.

VAC is implemented by sampling the content of voiceband transmit buffers and filling assigned burst capacity according to a priority system which excludes data from ports which are inactive. Since telephone conversations are marked by frequent pauses and listening periods which substantially exceed the fifteen milliseconds transmission burst repetition rate, there is frequently no need to assign a traffic channel in every burst to every port carrying a conversation in progress. Destination receive buffers insert normal idle channel "noise" to the talkers receive circuit if no new data is received so that a normal telephone conversation ensues.

CAPACITY TRANSFER CONTROL (CTC)

CTC is a standard evolutionary feature planned as an adjunct to high data rate conferencing. This feature allows a central control operator to assign (switch) a single high data rate broadcast allocation among conference participants in a network.

The combined network capacity assignment features discussed in the previous paragraphs (FTUs, DTUs, FV/DA, VD/DA, VAC, and CTC) represent a significant cost saving to CNS customers. The aggregate effect is to significantly reduce the transmission capacity that would otherwise be necessary to support a given function and network.

TIME DIVISION MULTIPLE ACCESS (TDMA) ARCHITECTURE

Many of the CNS advanced features are possible because transmission capacity is allocated to earth stations by time division. This process is called Time Division Multiple Access (TDMA). The SBS TDMA burst architecture is designed to allocate transmission (transponder) capacity among earth stations of a network according to total network activity. This is achieved by assigning each earth station in the network an exclusive periodic time period during which only signals from that SCC appear in the transponder. The duration of this exclusive time assignment is dynamically varied (shortened or lengthened) in response to changes in traffic activity among the SCCs of a network. Specific SCC transmit burst time boundaries (capacity) are assigned by the transponder Reference Station as a result of periodic capacity status messages from each SCC operating in the transponder. Changes to SCC capacity assignments can be implemented within a matter of seconds.

Figure 4 is a diagram of the SBS TDMA architecture, showing the FRAME, the control field, the traffic field, and a traffic channel. The FRAME is 15 msec in duration, including the unassigned portion.

A SUPERFRAME is 300 ms in duration, and consists of four groups of five frames, or twenty frames in all. The primary significance of the superframe lies in the fact that it represents a complete SCC status reporting and capacity assignment cycle for a transponder. Changes in the capacity allocation among the transponder SCCs can occur only at superframe boundaries.

The FRAME (Figure 4A) is the basic repetitive unit of the TDMA structure. Each frame has a fixed duration of precisely 15 milliseconds, controlled by a primary frequency standard (atomic clock) at the Reference Station with an accuracy of one part in 10^9 or better. (This basic repetition rate is subdivided as necessary to drive all of the clock circuits in the SCC, including the digital data port clocks).

The CONTROL FIELD (Figure 4B) is identified by a synchronizing burst from the Reference Station SCC, and marks the beginning of each frame. The control field has a duration of 10 1/2 channels. (A CHANNEL, consisting of 512 bits, is the basic capacity measure of the TDMA burst hierarchy). The control field is used by the Reference Station to transmit burst time boundaries (capacity assignments) and other control information such as any deviation from the nominal satellite range (propagation delay).

The control field also contains the Transmit Reference Burst (XRB) sent by each SCC in the network once per superframe. The XRB is used to report traffic activity and earth station status and alarms, and to confirm the accuracy of the transmitting station's synchronization with the reference station.

The TRAFFIC FIELD (Figure 4C) contains the individual traffic bursts from each SCC utilizing the transponder. Each SCC's traffic burst is separated from the previous SCC's burst by several symbol periods of guard time, followed by the synchronization preamble identifying the next SCC traffic burst. The preamble is then followed by the number of active TRAFFIC CHANNELS at the SCC, as constrained by the current SCC burst length assignment by the Reference Station.

Each traffic channel consists of an address portion (16 bits plus 16 bits more for Forward Error Control of the address portion), followed by 480 bits of traffic data. A channel represents 480 bits transmitted each 15 ms, or 32 thousand bits per second (32 Kbps), which is the equivalent voice delta modulation bit rate. A channel of 480 data bits is therefore often referred to as a Voice Equivalent Channel (VEQ) even though the 480 bits may not be voice information.

In the case of data transmission, the channel represents the next 480 data bits. For data rates of less than 32 Kbps data accumulates at a rate less than one channel per 15 ms and therefore need not be included in each burst. On the other hand, for data rates exceeding 32 Kbps, the data accumulates at a rate greater than one channel per 15 ms and therefore multiple channels per burst must be allocated. The SCC stored program generates the proper channel transmission patterns to efficiently load each SCC burst. For example, the burst pattern for a data port operating at 9.6 Kbps is three channels per ten bursts. The pattern for a data port operating at 224 Kbps is seven channels per burst.

If the capacity allocated to an SCC exceeds the number of active channels during a frame, the SCC fills out its burst with null channels. Should traffic activity exceed the assigned capacity, then one or more ports (usually a voice port) will not be allocated a channel in the next burst. This condition is referred to as "freezeout." Due to the redundant nature of speech, an occasional 15 ms freezeout of a voice port will not impair a conversation in progress.

Assuming that the full 15 ms frame capacity is not fully subscribed by the (one or more) customer networks operating within a transponder, the unsubscribed capacity is assigned by the Reference Station to itself, in order that the entire frame be filled. This unsubscribed capacity represents a pool of transmission capacity that is available to be assigned to one of the customer networks as Demand Transmission Units (DTUs).

SYSTEM EVOLUTION

SBS is interested in continuing to incorporate advanced system features which will extend the range of services which can be competitively offered. Therefore, SBS is actively pursuing the following evolutionary features:

- o Extended network connectivity and capacity by allowing network operation across two or more transponders
- o Greater flexibility in high rate switched digital and image transmission for local area connectivity
- o Extension of economical services to smaller traffic volume users.

For the immediate future, the engineering emphasis will be placed on realizing stable operation of the advanced features already provided by the initial service. But SBS plans to continue to provide system engineering leadership in new satellite communications applications to business needs for the years to come.

ACKNOWLEDGEMENTS

Many SBS employees have contributed material or made valuable constructive suggestions to the material presented in this manuscript. Among them, the author would like to recognize A. Blagrove, C. Kittiver, G. Pendleton, and W. Schmidt. M. Schnell expertly typed the many revision.

Table 1

SBS Service/Technical Features

CNS-A Features:	Made Possible By:
• Integrated voice, data, image transmission • Private networks • Bulk transmission encryption* (optional) • Unattended earth stations* • Centralized network management • Dynamic allocation of network capacity* • Port activity compression for increased transmission efficiency • Temporary assignment or demand of pooled transmission capacity* (optional)	• TDMA of satellite capacity • All digital transmission • RF operation at 12/14 GHz • 5/7 meter (nominal) diameter Customer Premises Earth Stations

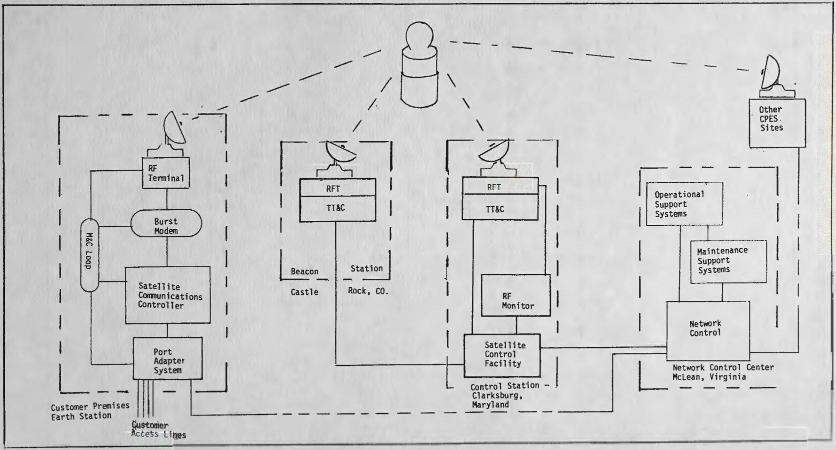
*Evolutionary

Table 2

Functions of Earth Station Major Components

Component	Functions
Port Adapter System (PAS)	Provides: Signal level conversion Supervisory signalling 48 VDC signalling power
Satellite Communications Controller (SCC)	Performs: Call processing (port-to-port), analog/digital conversions (voice/data), error control (FEC), activity compression, time division multiplexing/de-multiplexing of data streams, synchronization of transmit/receive bursts. Controls: Burst modem, M&C system Provides: Traffic activity status to the reference station. Call Records to the NCC. System health information to the NCC.
Monitor and Command System (M&C)	Collects and reports status and alarms from all major earth station components.
Burst Modem (BM)	XMT: Modulates the two channels (I&Q) of data from the SCC into a QPSK IF signal and provides it to the RFT in bursts. RCV: Demodulates the QPSK IF data stream from the RFT and provides it in two I&Q channels to the SCC.
Radio Frequency Terminal (RFT)	XMT: Translates the 70 MHz IF burst provided by the BM to 14 GHz, amplifies and transmits it to the satellite transponder. RCV: Receives the satellite transponder data stream (including own station) at 12 GHz, amplifies and translates it to 70 MHz IF for demodulation by the BM.

Figure 1   Major System Components



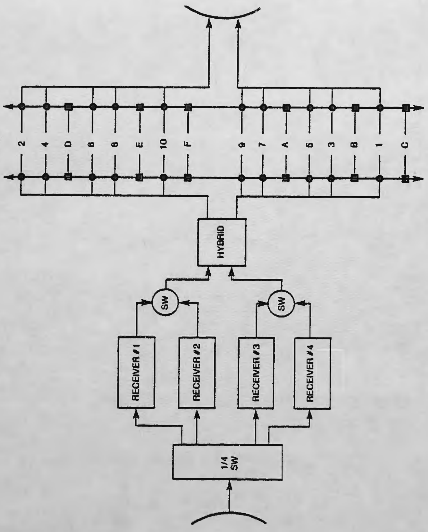
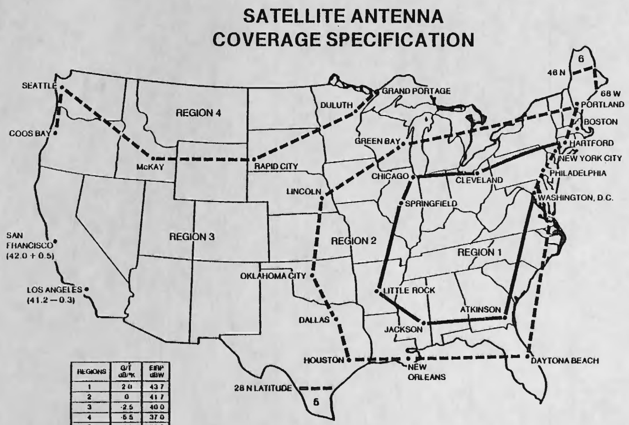


Figure 2. Simplified Satellite Communication Subsystem Configuration



REGIONS	G/T dB/°K	EIRP dBW
1	2.0	43.7
2	0	41.7
3	-2.5	40.0
4	-6.5	37.0
5	-4.5	38.0
6	-5.5	39.0

Figure 3. Satellite Antenna Coverage Specification

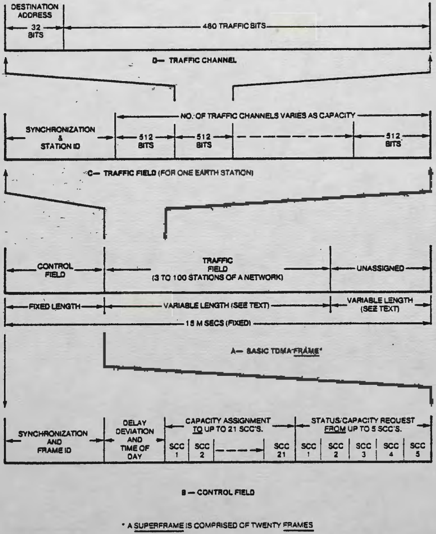


Figure 4. SBS TDMA Frame Structure