MULTIGIGABIT SATELLITE ON-BOARD SIGNAL PROCESSING*

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ABSTRACT

Satellite communications in the late 1980s and 1990s must provide reliable high-rate communications between very small inexpensive terminals with routing flexibilities approaching today's telephone system. The capabilities needed for successful competition with established and evolving terrestrial communications systems can be provided most efficiently using Satellite On-board Signal Processing.

The rapid improvement of high-speed digital technology makes it possible and cost-effective to demodulate, process, and remodulate individual data streams with rates approaching a gigabit. System processing capacity of several gigabits (ten in the example described) through a single satellite can be provided.

The satellite communications system described provides communications for very small and very large (trunking) users. Independent combinations of FDMA and TDMA are used in the uplink and downlink designs to minimize terminal costs. Signal routing for small users is accomplished by a digital store-and-forward technique which greatly simplified the terminal receiver, compared to satellite-switched TDMA. Different processing techniques are used for very high data rate users, but complete interconnectivity between all users is maintained. This avoids double-hop routing with excessive transmission delays.

On-board processing allows use of innovative responses to rain attentuation without requiring expensive, large signal-power margins. Terminal synchronization and timing is greatly simplified without a significant increase in satellite complexity, by integrating the synchronization loops with the downlink communication TDMA burst structure.

INTRODUCTION

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A NASA LeRC funded 20/30 GHz Mixed User Architecture study has resulted in a baseline system design for cost-effective communications in the years 1990 to 2000. Generation of a useful mixed user TDMA architecture has required a broad overview of system characteristics.

The TRW 20/30 GHz Baseline System consists of a synchronous orbit satellite, 18 large trunking terminals with 12 meter apertures and 10 km space diversity, 25 to 30 small trunking terminals with 6 meter apertures and 10 km space diversity, several thousand inexpensive direct-to-user (DTU) terminals, and a master control station with at least one alternate master control station.

The DTU terminal low-cost design offers the greatest challenge in the 20/30 GHz communication system. Since the number of DTU terminals is very large, the terminal direct cost is a large (perhaps the largest) element of system cost. The DTU terminal performance drives the satellite design, and hence determines a second major system cost element. Because the DTU system is able to avoid using terrestrial signal distribution and routing, and the charges associated with these functions, the DTU system also represents the largest economic value element of the system.

Because of these factors, the 20/30 GHz TDMA Mixed User Architecture design must start with definition of DTU user terminal characteristics. TDMA, control, and onboard processing architectures are designed to maximize system performance with minimal DTU user terminal requirements.

Trunking terminal design and the satellite trunking support components are less critical elements in determining system cost effectiveness. Trunking at 20/30 GHz provides direct cost benefits and prevents saturation of the lower frequency satellite communication bands. Integration of trunking and DTU systems provides the greatest economic benefit to the DTU system, however, by increasing the utility of a DTU terminal.

DTU terminals need the ability to integrate their communications channels with a trunking system. A large percentage, perhaps greater than half, of DTU point-to-point communication channels will have their other termination point located in a trunking area. By shifting signals from the DTU system to the trunking system in the satellite, the more expensive DTU system carries less total traffic. Signal routing is greatly simplified. Without this interconnectivity it might be necessary to provide DTU terminals at each trunking location to provide integration and avoid double-hop routing.

The baseline 20/30 GHz satellite communication system resulting from this study incorporates on-board satellite demoduation and routing of individual 65 Kbps digital voice-grade circuits. This level of routing flexibility is necessary to provide efficient communications to the very large number of DTU terminals projected. From an external point-of-view, the resulting system looks very much like a very large, distributed telephone switching system. The circuit interfacing hardware is distributed among all the DTU and trunking terminals. Control and routing computers are at master control station(s). And the switching circuitry which provides full interconnectivity between 30 to 45 thousand circuits is in the satellite.

The satellite (Figure 1) must be fairly large to provide such a capability. The digital onboard processor will be complex and will represent a significant, but not dominant, portion of the satellite. By moving all the switching control logic to the master control station, and by taking advantage of a level of digital technology that is commercially available (but not yet space qualified) today, the digital on-board processor design risk is acceptably low.

PROCESSING SYSTEM REQUIREMENTS AND IMPLEMENTATION

The system network configuration required to support DTU terminals efficiently is shown in Figure 2. While terminals handling heavy trunking loads can continue to operate in a net-connected configuration, a star-connected configuration is required for small users to simplify the DTU terminal. Furthermore, the central node of the star must be located in the satellite to avoid additional transmission delays to and from a ground processing station.

The concept selected to provide the configuration of Figure 2 is shown in Figure 3. Separate multiple beam antennas (MBA) provide fixed-beam coverage of the high-density traffic regional and scanning-beam coverage of low-density traffic regions. The high-density region trunking users can be interconnected using SSTDMA technicaues similar to those developed for the Advanced WESTAR communication system.

DTU terminals require on-board satellite routing, and this is most economically provided by demodulation, digital routing, and remodulation. Analog routing techniques become difficult when several thousand channels must be independently routed.

DTU terminals need the ability to interconnect with trunking communication systems. This can be provided by locating a DTU terminal at each trunking terminal, or by integrating trunking and DTU signals on board the satellite. We have chosen the latter approach. This is shown by the trunk/DTU interfaces in Figure 3. Integration of DTU and trunking signals on board also solves the problem of serving thin-route trunking locations that cannot economically justify an independent satellite antenna beam in the fixed-beam MBA.

The satellite communication subsystem supporting the concept of Figure 3 is shown in Figure 4. An SSTDMA section at the top of the block diagram supports the eighteen fixed locations shown in Figure 5. An on-board processing section with demodulation and remoduation of each signal operates with scanning receive and transmit arrays to cover all other locations in the contiguous forty-eight states. (Hawaii and Alaska coverage is easily added).

The processing section has been sized for a 3 Gbps data throughput. While this seems very large, it could be mechanized with currently available but unqualified digital LSI circuits. The total system throughput is 10 Gbps. Of this eight Gbps is trunking data and two Gbps is DTU data. Seven Gbps is of trunking data passed by the SSTDMA switch without further processing. The two Gbps of DTU data, plus one Gbps of small trunking and trunking/DTU cross-system data must be processed.

The processing technique used is illustrated by Figures 6 and 7. The memory is loaded with all the data to be processed for one frame period. Routing is accomplished by then reading the memory during the next frame period in a different arbitrary order. The read-out order is defined by a system master control station and provides complete routing control of the data. Two memories are required since at any one time one memory is being loaded and one is being read.

SUMMARY

A system design has been completed which, by transferring system complexity to a satellite and master control station, provides economic communication capabilities with very expensive DTU terminals.

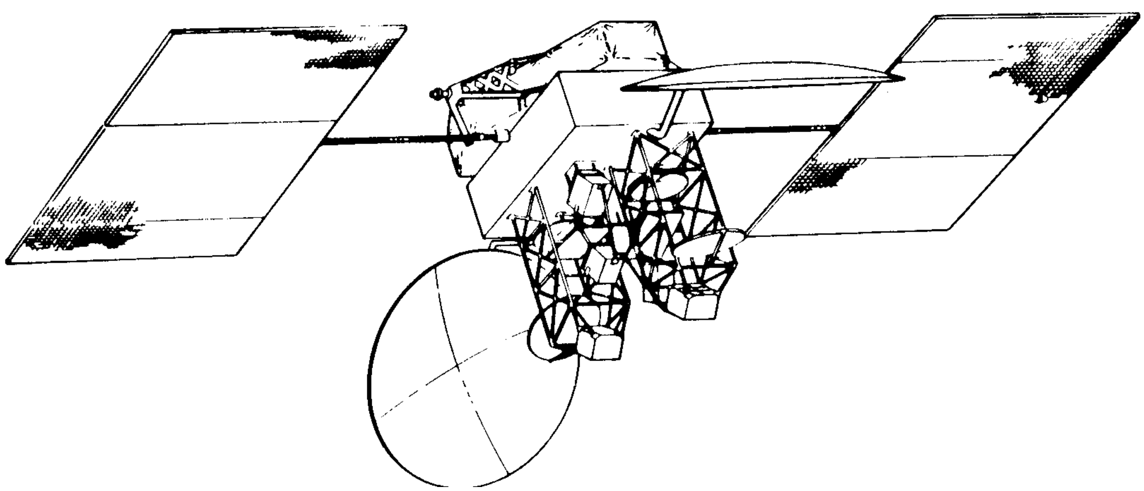

Figure 1. Preliminary Satellite Design

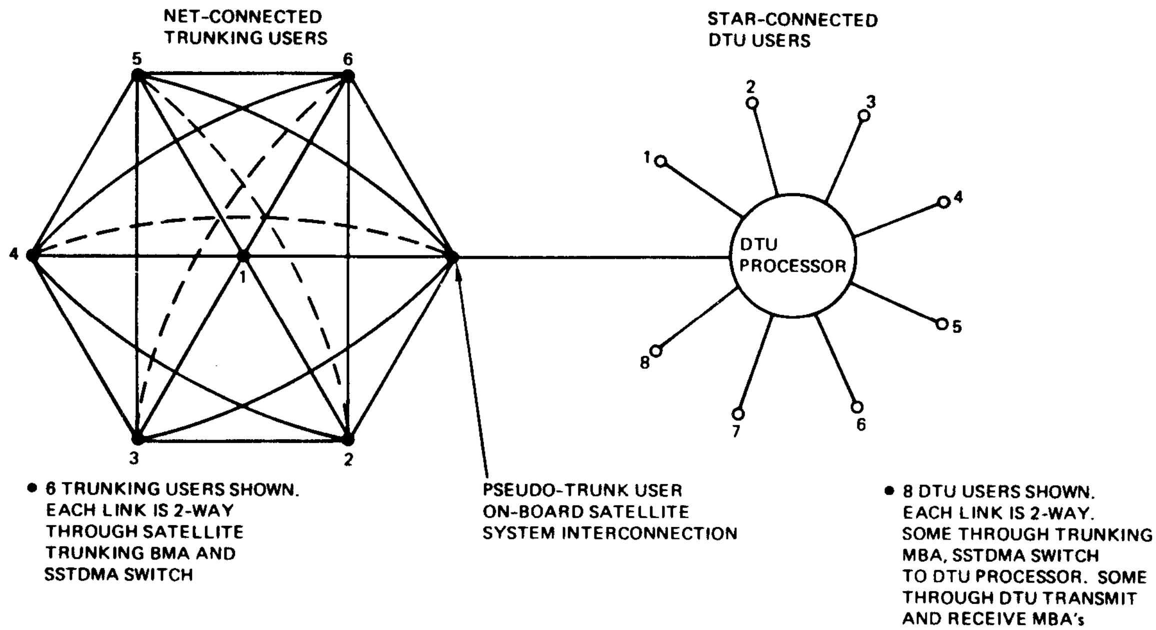

Figure 2. System Network Concept

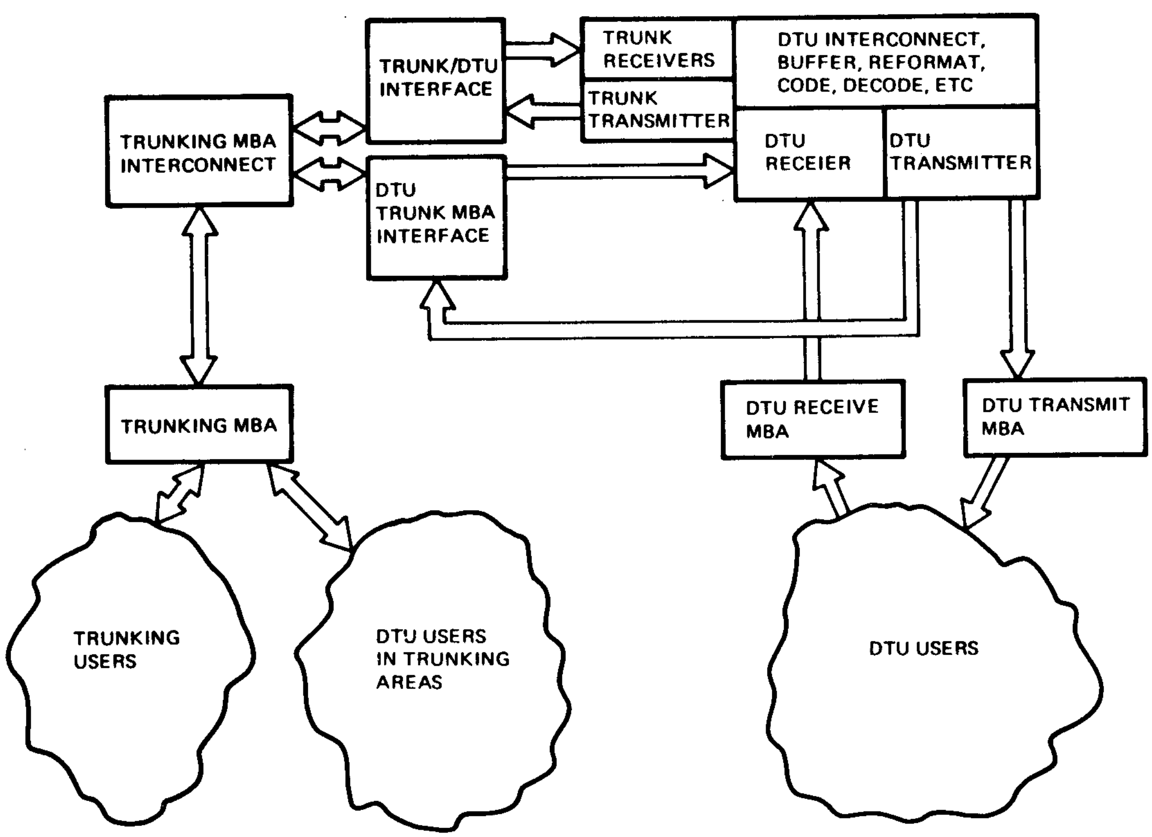

Figure 3. 20120 GHz Mixed User System Architecture

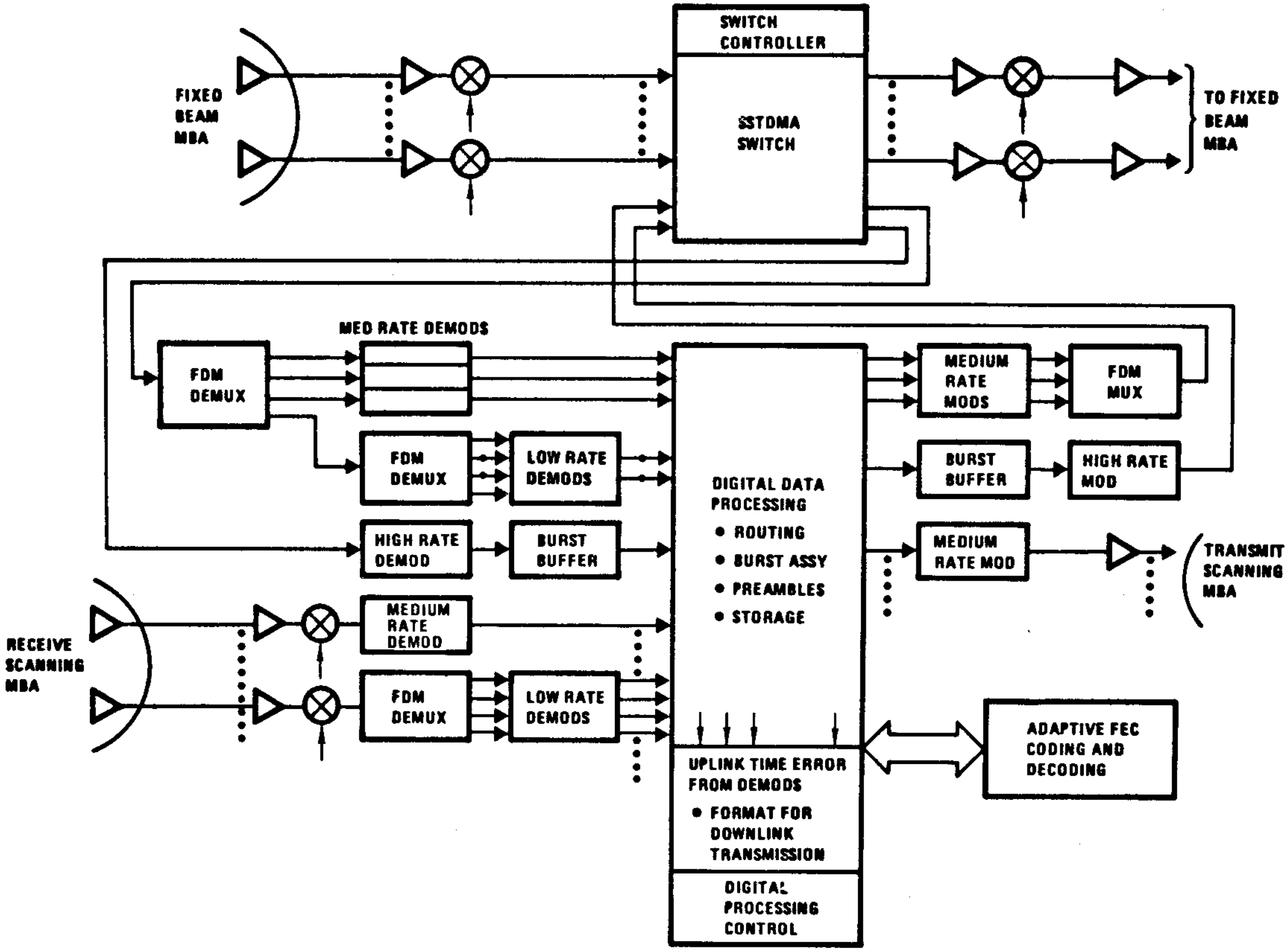

Figure 4. Satellite Communication Subsystem Block Diagram

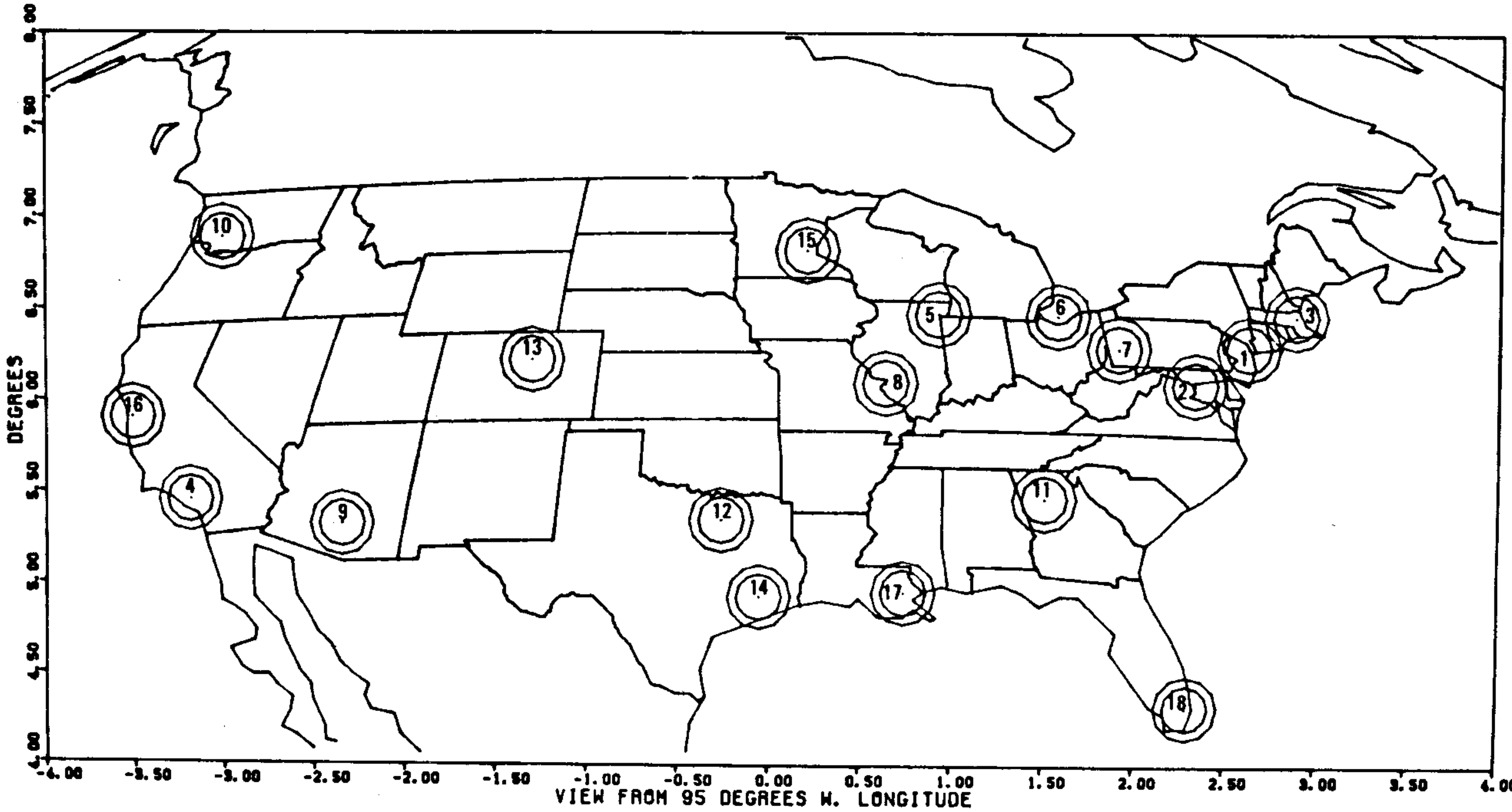

Figure 5. Trunking Station Plot

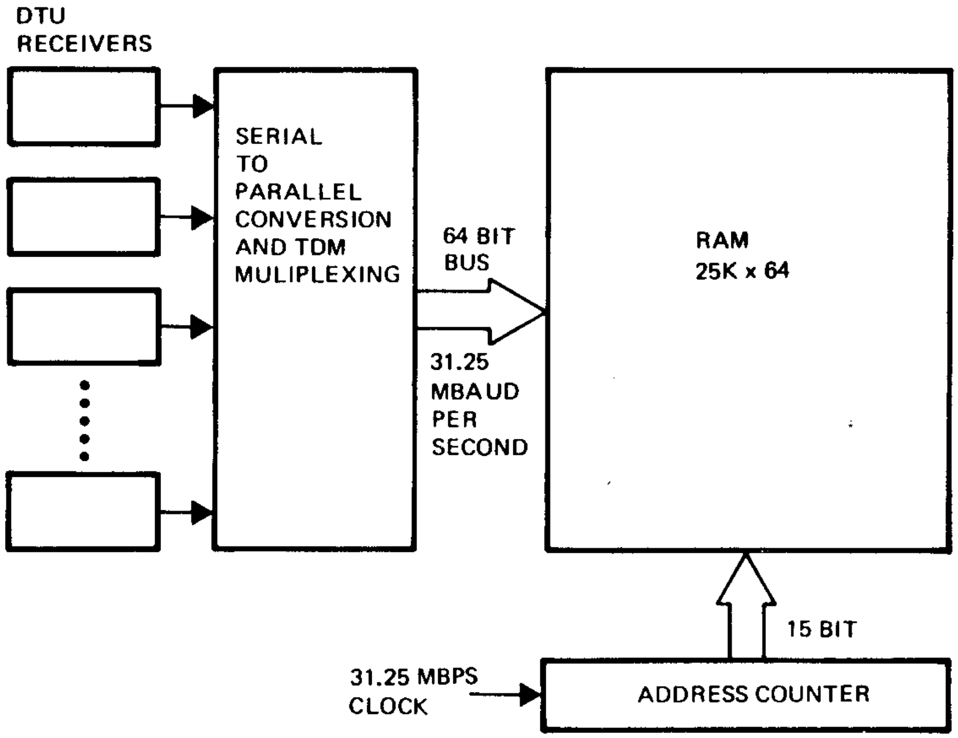

Figure 6. Processor Memory Loading

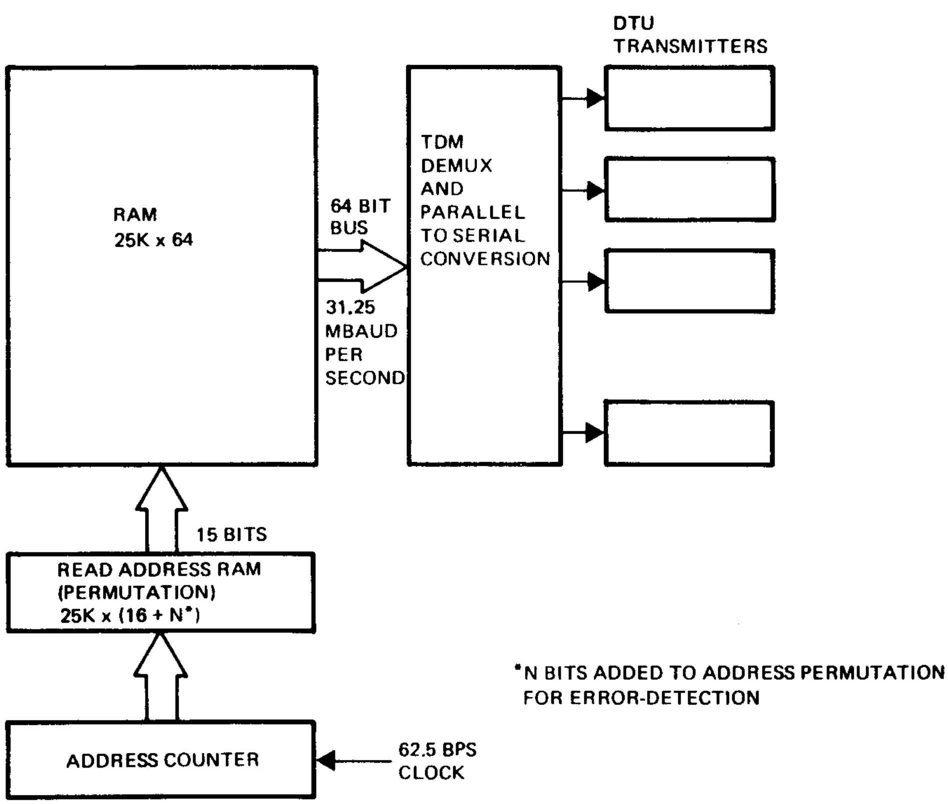

Figure 7. Processor Memory Output