THE GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE /GOES/ IMAGING COMMUNICATION SYSTEM

W.L. BAKER AND J. SAVIDES
Aeronutronic Ford Corporation
Palo Alto, California

Summary. The SMS/GOES Satellite obtains day and night weather information from synchronous geostationary orbit by means of (a) earth imaging, (b) collection of environmental data from ground based sensors, platforms, and (c) monitoring of the space environment.

SMS-1 and SMS-2 have been in orbit for 17 months and 8 months respectively and are presently taking full earth disc images in the visible and infrared every 30 minutes. SMS-1 is positioned to cover the eastern portion of the United States while SMS-2 is positioned to cover the western portion.

This paper provides a general overview of the imaging communication portions of the SMS/GOES, related to the image data encoding and transmission as well as the method of the data time multiplexing and the manner in which the scan line to line synchronization is achieved.

Introduction. The Geostationary Operational Environmental Satellite (GOES) is the operational version of the Synchronous Meteorlogical Satellite (SMS), and provides for improved weather prediction, environmental sensing and timely warning of hazardous environmental conditions.

This paper provides a general overview of the imaging communications portions of the GOES. Figure 1 shows the SMS/GOES. The first SMS (SMS-1) was launched on May 17, 1974 and the second SMS (SMS-2) was launched on February 6, 1975. At this time we have accumulated some 25 months of operational experience. After the initial checkout of these satellites by NASA the SMS satellites were turned over to the National Oceanographic and Atmospheric Administration (NOAA). SMS-1 was utilized to support the Global Atmospheric Research Program, Atlantic Tropical Experiment (GATE) during June 1974. Subsequent to the GATE SMS-1 was positioned at 75° west longitude. SMS-2 was positioned at 115° west longitude. Both SMS-1 and SMS-2 have been providing

---

This work was performed for NASA/GSFC under Contract NAS5-21575 and NAS5-20750

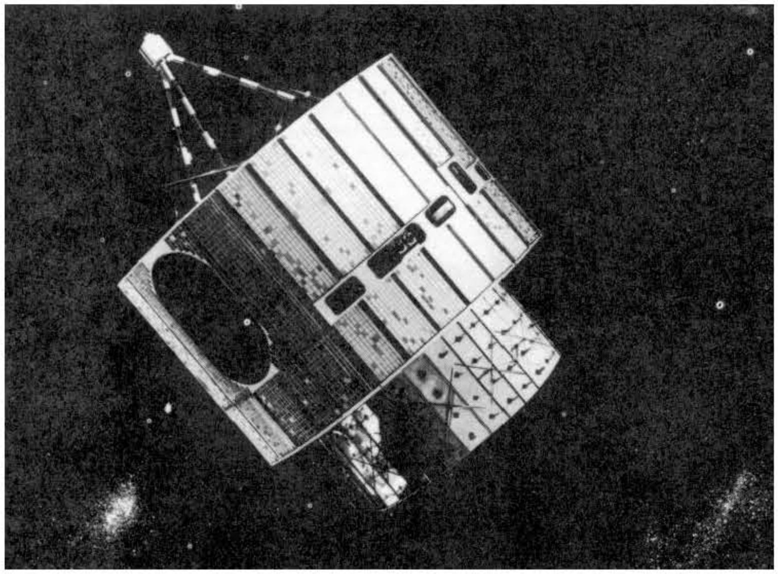


Figure 1 SMS/GOES

imaging data (full earth disc) every 30 minutes since operation has been turned over to NOAA.

SMS-C/GOES A will be launched in October 1975.

General System Description. The GOES is a spin stabilized satellite with nominal spin rate of 100 RPM (spin period = 600 milliseconds). This allows the use of a visible and infrared spin scan radiometer (VISSR) in which the west to east scanning is accomplished by the spinning of the satellite while the north-south scan is accomplished by stepping a mirror within the VISSR optics. This VISSR data is digitized, encoded and transmitted as shown in Figure 2 to the Control and Data Acquisition (CDA) station at Wallops Island, Virginia. At the CDA the VISSR data is buffered, stretched in time and anotated with gridding data and identification data and then retransmitted to the GOES for transponding to the National Environmental Satellite Services (NESS) at Suitland, Maryland and other users.

The transponding of the stretched data via the GOES is performed in a time multiplex manner. As shown in Figure 3 the VISSR data is transmitted to the CDA at a 28 Mbps data rate, during the 30 ms that the VISSR views the earth. During this 30 ms earth in view period the GOES transponder is squelched off. In the remaining 570 ms of the GOES spin period the VISSR output is squelched and the transponder squelch is removed enabling the transponding of the stretched VISSR data in a serial format at a 1.75 Mbps data rate. The offset in time of visual and IR channels relative to the VISSR data transmission is due to the transport time to the CDA and return to the GOES. The stretched VISSR (SVISSR) data is then retransmitted to the NESS Central Facilities (World Weather Building) at

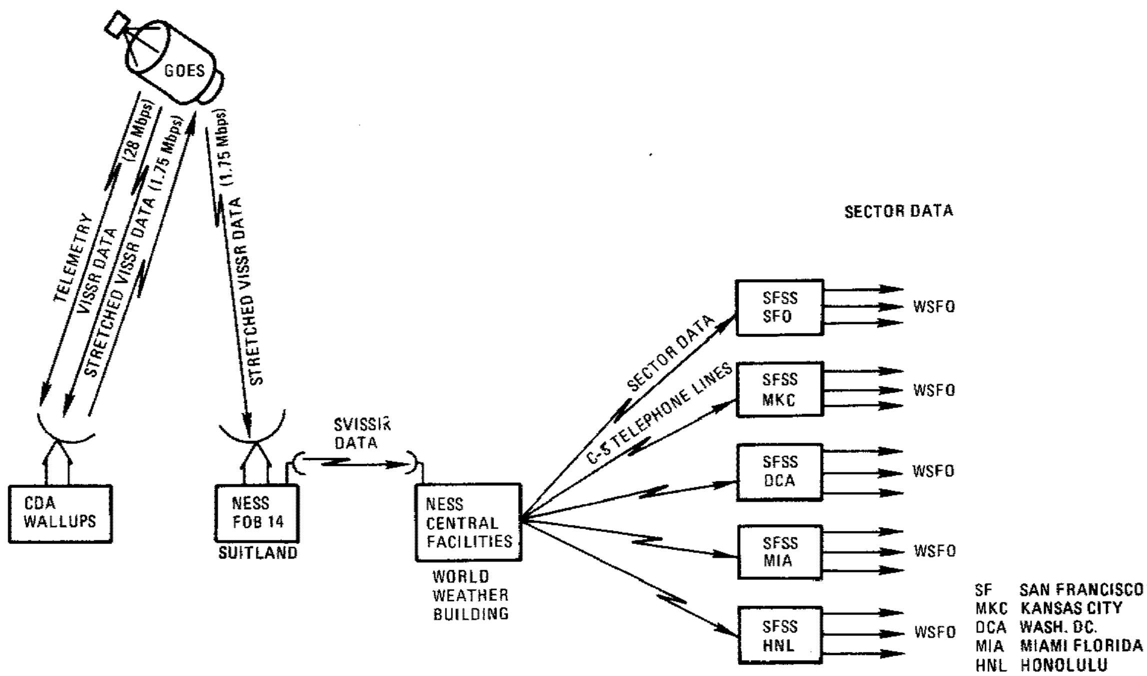


Figure 2 The GOES Imaging Communications System

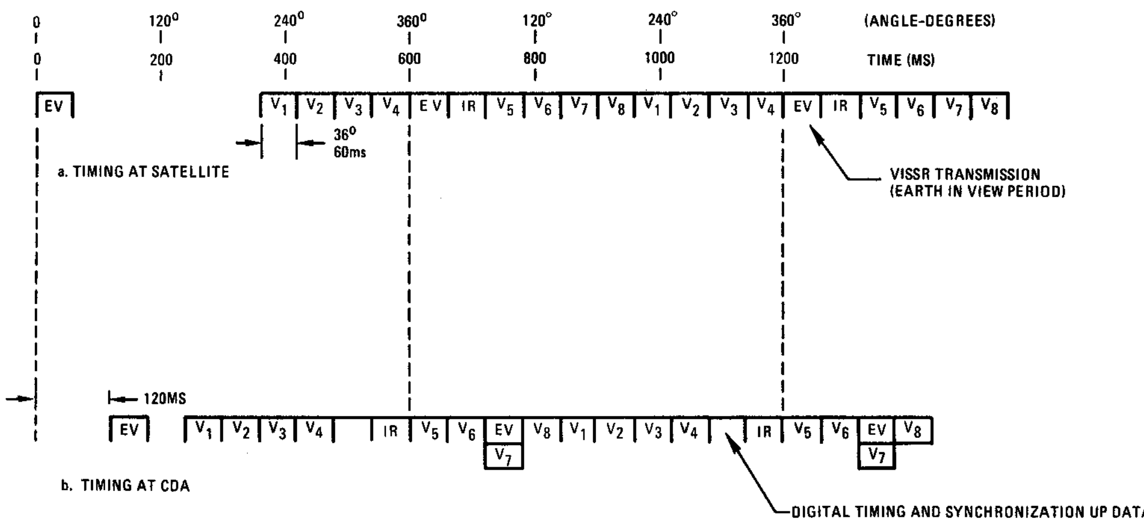


Figure 3 VISSR/SVISSR Transmission Timing

Camp Springs, Maryland. Within the World Weather Watch Building the imaging data is processed for analysis and wind derivation. In addition, the imaging data is "sectorized" into 13 sections of 0.5 nmi resolution which cover the contiguous 48 states, and the Caribbean area. This sectorized data is transmitted to the regional satellite field service stations (SFSS) which in turn provides analysis of the imaging data as well as relaying the sectorized data to the various local weather service forecast offices (WSFO) for their analysis and interpretation.

In addition to the imaging data, both a real time sun sync pulse and a digital sync word (with the VISSR data) are transmitted to the CDA for synchronization of the SVISSR transmission to the satellite spin rate and for the line to line synchronization of the visual and IR channels.

GOES Segment. Figure 4 shows the satellite imaging sensor configuration. There are 8 visual channels in the 0.55 micron to 0.75 micron spectrum and two redundant IR channels in the 10.5 micron to 12.6 micron spectrum. As shown in Figure 4 the west to east scanning is obtained by the spinning of the satellite and north-south is obtained by stepping the scan mirror in 0.192 mr steps after each earth in view time. 1821 scan mirror steps provides a 20 degrees north-south scan. The subsatellite resolution for the sensors are 0.5 nmi for the visual and 5 nmi for the IR.

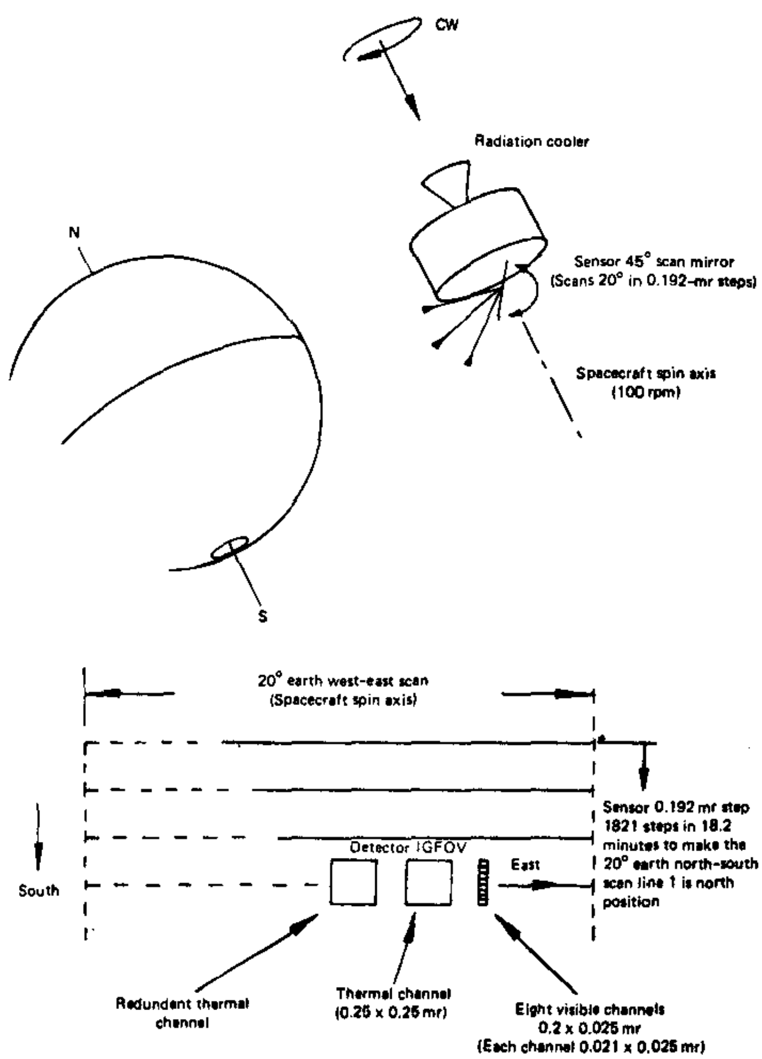


Figure 4 Imaging Sensor Configuration

Figure 5 shows a simplified functional block diagram of the GOES VISSR data transmission equipment. The 8 visual and 2 IR analog output signals of the VISSR (0 to 5v) are fed to the VISSR digital multiplexer (VDM). Each signal is then passed through pre-sampling filters, sampled and then converted to digital data. The visual and IR channels are sampled at a 500KHz and 125KHz rate respectively. A linear analog to digital (A/D) converter is used to convert the IR channel to 8 bit digital words.

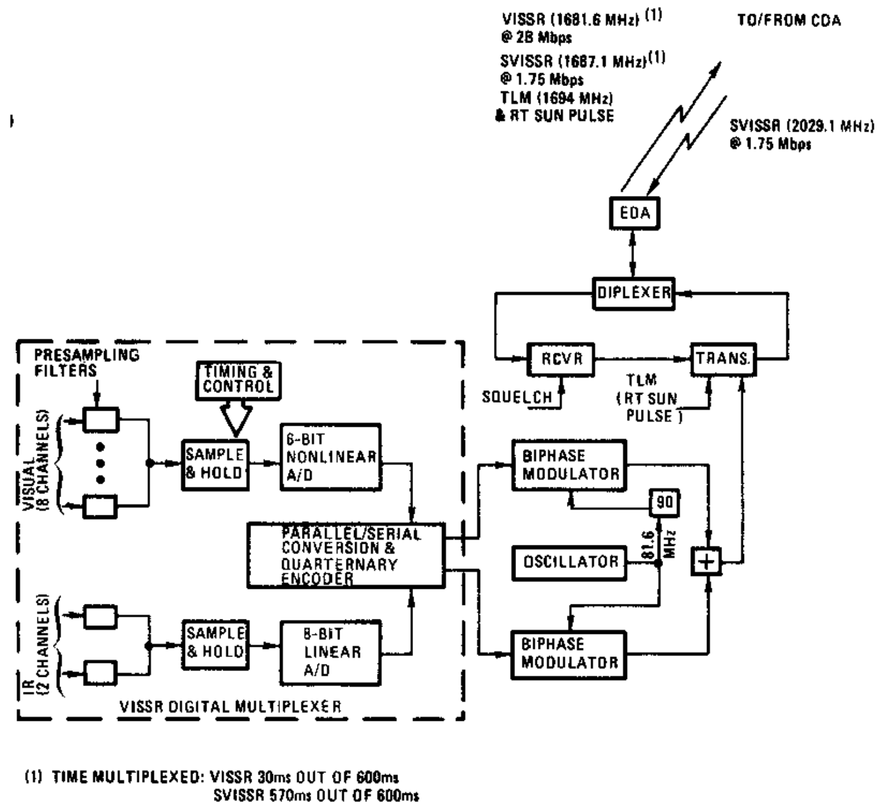


Figure 5 Simplified Functional Block Diagram of the GOES Segment

A linear A/D converter could have been utilized for the visual channels, however, this would have resulted in a 37.5 Mbps transmission rate. To reduce the transmission rate a 6 bit nonlinear A/D converter was utilized. The nonlinear transfer function was selected to match the noise characteristics of the photo multipliers used in the VISSR. The photo multipli output noise increases in proportion to the square of the output signal.[(1)]

The serial data stream is then differentially encoded into two 14 Mbps data streams each of which biphase modulates two carriers which are added in phase quadrature. The quadraphase (QPSK) modulated signal is then upconverted to 1681.6 MHz, amplified and transmitted to the CDA via the GOES electronically despun antenna (EDA). During the VISSR data transmission period, which is during the 30 ms earth in view period, the output of the receiver is squelched off to eliminate interference with the VISSR data. During the remaining portion of the spin period (570 ms) the VISSR Digital Multiplexer

(VDM) is powered off, the QPSK modulator output is squelched and the squelch is removed from the receiver allowing transponding of the SVISSR data.

Both housekeeping telemetry data and a real time (RT) sun pulse are transmitted to the CDA. The primary interest in telemetry is the transmission of the RT sun pulse which consists of a 70KHz stable oscillator whose output is gated "on" by a 100 microsecond sun sync pulse. The 70KHz sun sync pulse is phase modulated upon the telemetry carrier for transmission to the CDA for synchronization of the CDA timing.

Figure 6 shows the data format for the transmission of the VISSR data as well as the timing sequence for operation. At -19.6°, relative to the subsatellite earth center position, the VDM power is turned on. VDM turn on prior to data transmission allows time for gain stabilization of the VDM. At -11.5°, a 2 ms preamble, which consists of alternate ones and zeros, is transmitted to provide for carrier acquisition and bit sync of the CDA QPSK demodulator. At -9.8° a decom sync is provided to the VDM for the scan line start of the data transmission. The first 56 bits of each scan line consists of a 16 bit scan sync word, a 12 bit line scan identification (VISSR mirror position) and the 8 LSB's of a 23 bit digital sun pulse. The remaining 20 bits are transmitted as alternate ones and zeros. The visual and IR data is transmitted during the rest of the scan line transmission period as shown. At +9.8° the VDM power is turned off for the end of transmission. During the next earth in view period the cycle is repeated.

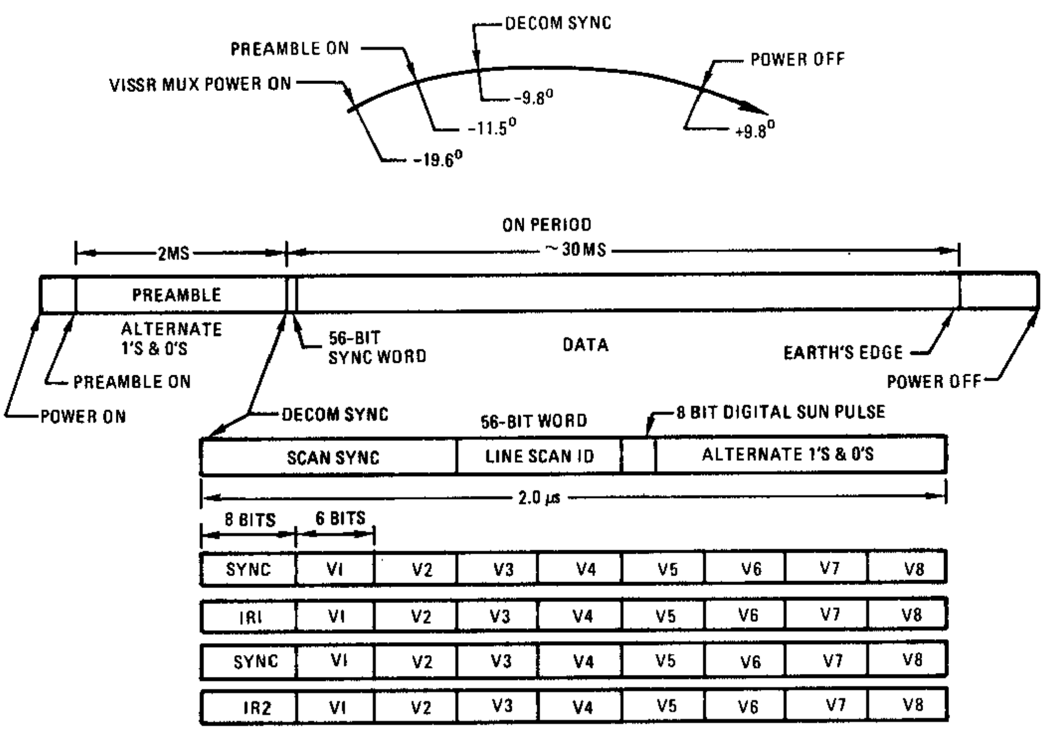


Figure 6 Data Format for VISSR Transmission

The GOES Control and Data Acquisition (CDA) Segment. Figure 7 shows a simplified block diagram of the CDA. The 28 Mbps VISSR data and the telemetry data is received via a 60 foot parabolic antenna and then down converted to a 70 MHz intermediate frequency. The QPSK VISSR data is demodulated and demultiplexed to provide an 8 bit parallel transfer of each IR word or 6 bit parallel transfer of each visual word to the buffer storage of the synchronizer/data buffer (SD/B). In addition, a scan sync timing pulse, bit clock, IR data strobe and a visual data strobe is also provided to the S/DB. The telemetry is demodulated with the real time sun pulse also being provided to the SD/B.

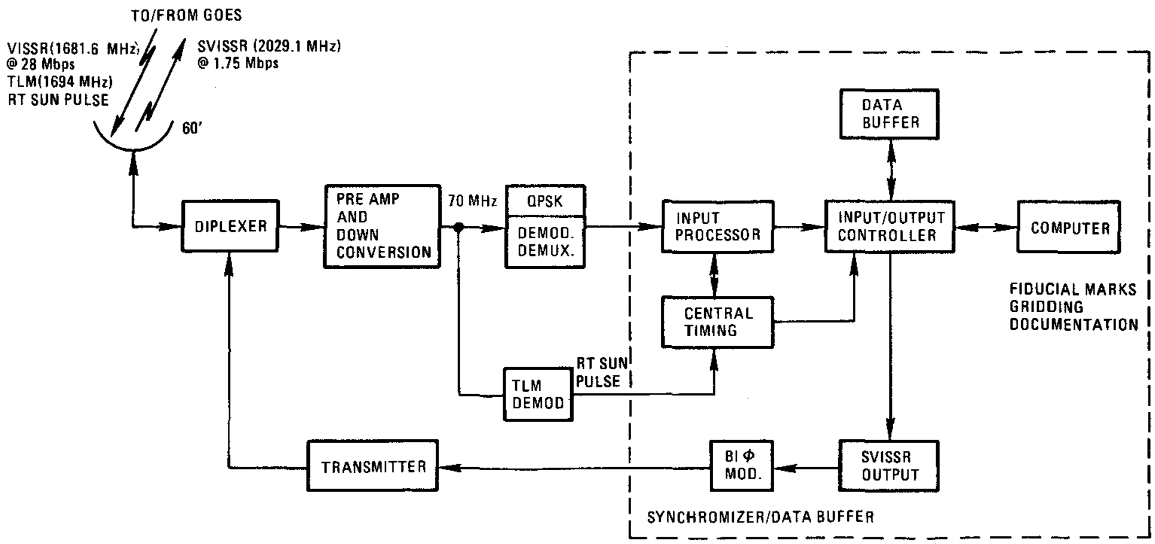


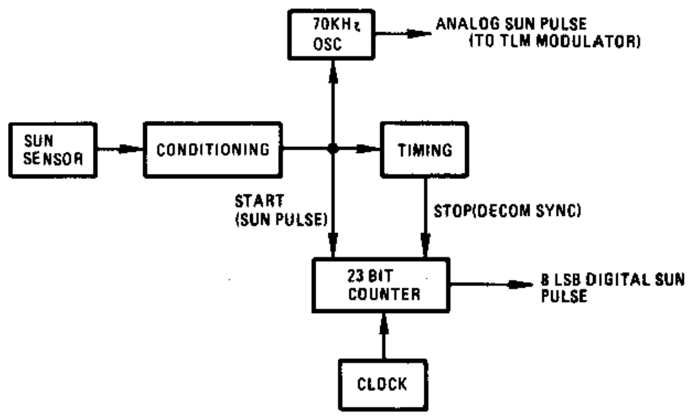
Figure 7 Simplified Block Diagram of CDA Segment

When the data from one scan line (30 ms) is stored, the output controller will commence clocking out line by line at a slower rate; the total time to transmit the data being approximately 540 ms (60 ms available for each visual and one IR line). Of the 60 ms available for each line, the first 7.5 ms is utilized for line, bit and word synchronization as well as providing documentation information such as time of day, day, year, operating mode, resolution, etc., while the remaining 52.5 ms is devoted to the imaging data. Thus each line will be stretched by a factor of 52.5/30 = 1.75 which reduces the SVISSR transmission rate to 1.75 Mbps maximum (500ksps/l.75) x 6 bits/s. The SVISSR data is bi-phase modulated upon a 2029. 1 MHz carrier and transmitted to the GOES for transponding to the NESS.

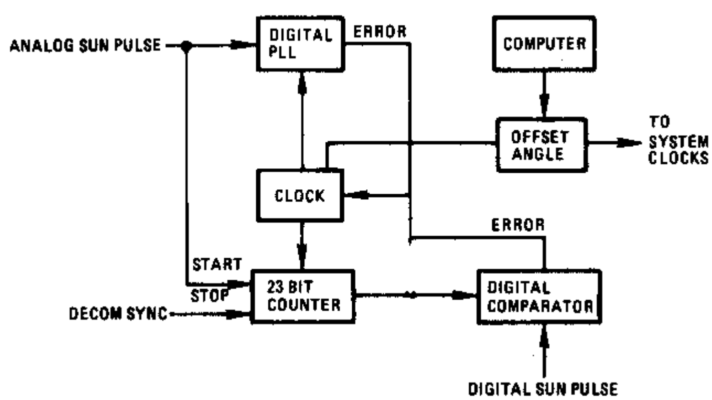
Spin Rate and Line to Line Synchronization. The primary requirement for timing is to provide for line to line synchronization within about 1/10 of a picture element. A picture element is 25,μRAD (0.5 nmi) at geosynchronous altitudes. The line to line synchronization requirement is then about 0.25 microseconds for a satellite spin period of 600 ms. To achieve this synchronization, the GOES utilizes both an analog and a digital timing system related to the satellite/sun position.

The analog timing is achieved by gating the output of 70 KHz crystal oscillator “on” during the sun pulse period. This analog sun pulse is transmitted to the CDA and utilized in a digital phase lock loop to obtain course timing. Satellite spin rate variations are tracked out utilizing the analog sun pulse tracking. The timing jitter for the course synchronization is on the order of 2 to 3 sec for typical on-orbit operation.

Fine synchronization is obtained by the utilizing the digital timing data. From Figure 8 it is seen that the GOES utilizes a 23 bit counter to provide a count between the sun pulse and the decom sync (start of data transmission). The 23 bit counter provides a 1.5,μrad (6% of picture element) timing resolution. The 8 LSB are inserted into the VISSR data stream and transmitted to the CDA.



a. GOES SEGMENT



b. CDA SEGMENT

Figure 8 Timing and Synchronization System

The S/DB generates a digital sun pulse in the same manner as the satellite. That is, a 23 bit counter is started by the analog sun pulse received from the satellite and stopped by the decom sync decoded from the VISSR data. The 8 LSB are compared with the decoded digital sun pulse and the associated error is computed and utilized to fine adjust the CDA clock. This approach minimizes the effect of long term drift of the satellite oscillator.

The timing is now synchronized to less than 1/10 of a picture element relative to the satellite/sun position. In as much as the satellite/sun position changes as a function of time, an offset angle is computed from the known sun/earth/satellite geometry, each satellite rotation. This offset angle is utilized to correct for the start of scan line.

The SMS imaging system has been performing for some 25 months with overall bit rate performance of better than one error per one million bits.

Acknowledgements. The development of the SMS/GOES Imaging Communication System was made possible by the efforts of many people at NASA/GSFC, Aeronutronic Ford Corporation (Satellite and Ground Demodulator/Demultiplexer) and Westinghouse Electric Corporation, Baltimore (S/DB).

References. (1) R. S. Davies, "Transmission of Radiometer Data From the Synchronous Meteorlogical Satellite" International Telemeterial Conference, October, 1973, Washington, D.C.