

SATELLITE NAVIGATION IN R. V. GAVESHANI

P. E. Sankaranarayanan

National Institute of Oceanography, Dona Paula - 403 004, Goa

ABSTRACT

The paper describes in brief the Canadian Marconi Model CMA-722A, Satellite Navigation System, which will be installed in the research vessel "Gaveshani" of the National Institute of Oceanography, Goa. The system is fully automatic and locks on to the passing satellites, decodes the satellite messages and derives the doppler shift frequencies associated with these signals. These messages are processed directly in an online digital computer to determine the receiver position fix. The functioning of the system is also explained.

INTRODUCTION

The research vessel *Gaveshani* of the National Institute of Oceanography, Goa, will be installed with a Canadian Marconi Model CMA-722A, Satellite Navigation System. The system is a fully automatic data receiving and processing equipment and permits all-weather, world wide, precise position location through the use of signals from the U. S. Navy Navigation Satellite System. The System automatically acquires and locks-on to the signals from passing satellites, decodes the satellite messages, and derives the doppler shift frequency associated with these signals to produce digital outputs of orbital parameters and integrated doppler counts. The output data of the receiver is processed directly (on-line) by a digital computer to determine the exact position of the receiver-position fix.

BASIC CONFIGURATION OF THE SYSTEM

The CMA-722A on-line system, for R. V. *Gaveshani*, comprises the following units:

- (i) an antenna unit.
- (ii) a receiver/signal processor unit.
- (iii) a digital computer.
- (iv) a teletype as data terminal.
- (v) a high speed tape reader.
- (vi) a tape punch.

The simplified block diagram of CMA-772A, system is shown in Fig. 1.

The CMA-722A Satellite Navigation System primarily receives 400 MHz and 150 MHz signals from the passing satellites, processes these signals and yields the following outputs: (Wells, 1971 and Sankaranarayanan, 1975).

(a) *Doppler shift, associated with the received signal, in the form of integrated doppler counts* — The doppler shift is caused by the satellite motion relative to the receiving antenna. The doppler shift is positive as the satellite approaches the receiver and negative as the satellite moves away from the receiver. The magnitude of the doppler shift is a function of the relative speed and the angle between the satellite and the receiver.

(b) *Orbital and timing data from the satellite* — This data, which is extracted from the satellite signal, provides up-to-date orbital data and timing information in coded form.

(c) *Two-minute time marks between satellite passes* — To keep track of elapsed time between the satellite passes, the receiver generates a time mark every two minutes.

The major outputs described above are converted into suitable format for immediate processing by the digital computer and/or as an output to a teleprinter, and/or a paper-tape punch. The system acquires the satellite signal automatically with the option of manual intervention. When initiated by the operator, it performs the self test.

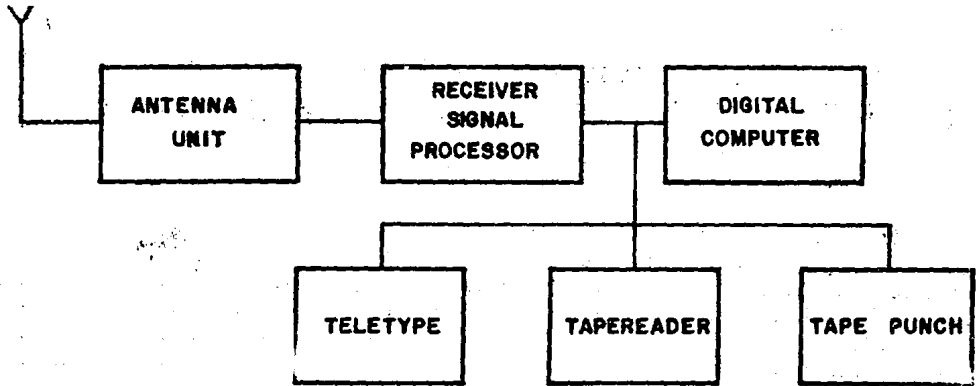


Fig. 1. Simplified block of CMA-722A system

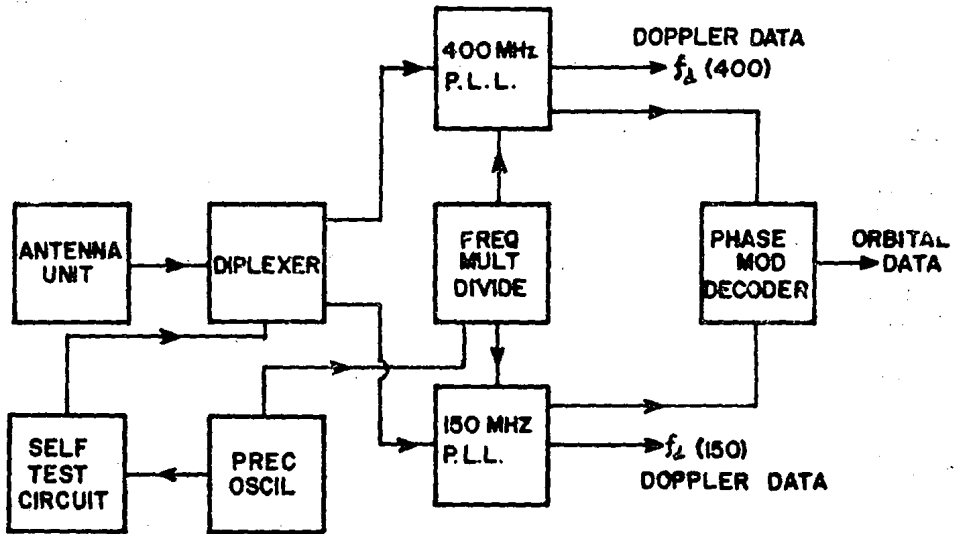


Fig. 2. Schematic of the receiver

FUNCTIONAL DESCRIPTION

The functions of each unit could be briefly described as follows:

The antenna unit

The shipborne antenna is a flange-mounted unit enclosed in a sealed epoxy-fibreglass cylindrical radome. The antenna provides full hemispheric coverage at 150 MHz and 400 MHz. The gain of the antenna unit is about 3 dBI and the vertical half-power beam-width is 150 degrees at both 150 MHz and 400 MHz.

The antenna signals are amplified in a low-noise filter preamplifier assembly, as shown in Fig. 2. This provides front end selectivity and sufficient gain to prevent the deterioration of the overall receiver sensitivity due to antenna cable losses and to the noise of the input stages in the receiver/signal processor. The antenna receives the two satellite signals of $150 \text{ MHz} \pm f_d$ and $400 \text{ MHz} \pm f_d$. A coaxial cable is used to interconnect the antenna/preamplifier assembly with the receiver/signal processor.

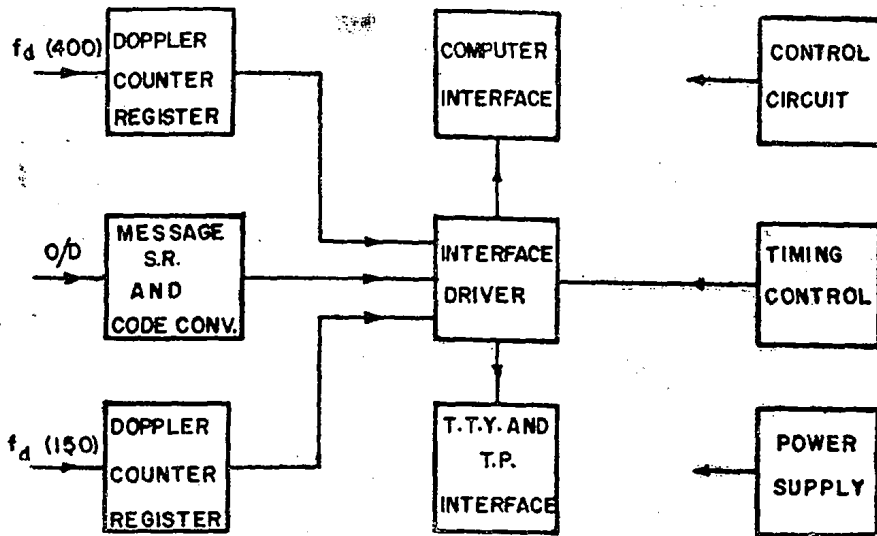


Fig. 3. Schematic of the signal processor

The receiver/signal processing unit

The receiver/signal processor unit processes the signals received from the low-noise, preamplifier in the antenna, to produce digital outputs of integer Doppler counts and orbital data, for application to the computer, teleprinter and/or paper-tape punch. The receiver/signal processor unit comprises a precision oscillator, self test circuitry, signal processor, control circuits, and power supplies. Functions are briefly described in the following paragraphs with reference to Figs. 2 and 3.

Precision oscillator — This is an extremely accurate crystal oscillator (Fig. 2) and generates a 4 MHz signal. This signal is used as the reference throughout the receiving system. In the worst case, the ageing rate will be 5 parts in 10^{-10} per day, and the short-term stability (less than 10 seconds) in 2 parts in 10^{-11} .

Self test circuitry — The self-test circuitry (Fig. 2) generates 150 MHz and 400 MHz self test signals which are applied to the receiver/signal processor. These signals are processed, in the same manner as a satellite signal and the receiver produces an output which is indicative of the condition of the system.

The receiver — The receiver (Fig. 2) comprises a diplexer, a 400 MHz phase locked loop, a 150 MHz phase locked loop, frequency multiplier and divider, and phase modulation decoder.

The receiver separates the 150 MHz and 400 MHz signals received from the antenna, tracks and converts these signals, in separate channels to generate the following major outputs.

- Doppler data signals, f_d 150 and f_d 400.
- Phase modulation decoder signal from which orbital data is derived.

With reference to Fig. 2, the combined 150 MHz and 400 MHz signals received from the antenna are separated by the diplexer. The frequency multiplier and divider synthesizes the local oscillator signals required for the two phase locked loops from the 4 MHz reference signal from the precision oscillator.

The 400 MHz and 150 MHz phase locked loop trackers track and demodulate the satellite signal and derive the doppler data phase modulated data and lock indication signal. The phase modulated data contain the binary information derived from the satellite carrier frequencies. These are applied to the phase modulation decoder.

The phase modulation decoder synchronously demodulates the phase modulated output derived from the two phase locked loops. The output of this synchronous detector comprises the binary formatted signal used by the message shift register and code converter circuit to produce satellite orbital data.

The synchronization process and the demodulation of the satellite message starts on the channel which is first locked to a satellite as determined by the lock indication signal. When both channels are locked, the signal from the 400 MHz channel is used.

Signal processor — The signal processor (Fig. 3) comprises a message shift register and code converter, two Doppler counters and registers, interface driver, TTY and TP interface, computer interface and timing control.

The signal processor converts the orbital and Doppler data signals from the receiver, and generates the synchronization and timing control.

The signal processor converts the orbital and Doppler data signals from the receiver, and generates the synchronization and timing signals required for proper formatting of the data, for the computer or peripheral equipment.

The signals coming out from the phase modulation decoder, are accumulated in the message shift register. This data are converted from BCDXS-3 code to 4-wire BCD code in the code converter for further processing in the interface driver.

Two Doppler counters and registers are used in the signal processor, one for the 150 MHz channel, and the other for the 400 MHz channel and in these the respective doppler data are stored temporarily. The counters are read out at the end of every line into the registers. The 4-wire BCD output of the registers is applied to the interface driver.

The 4 MHz reference frequency from the precision oscillator is used for the timing control. The timing control, generates word rate, line rate and two minute time signals.

The interface driver receives information data from three sources:

1. Orbital data; demodulated satellite message from the message register and code converter.
2. Doppler 150 data; Doppler count accumulated in the 150 Doppler counter and register.
3. Doppler 400 data; Doppler count accumulated in the 400 Doppler counter and register.

The interface driver controls the sequence of presentation of the orbital data, the Doppler 150 data, and the Doppler 400 data shifted out to the TTY and TP interface and the computer interface assemblies. The interface driver gets the command from the timing control.

The TTY and TP interface transforms the format of the data received from the interface driver to a format acceptable to the teleprinter and tape punch units. In addition, provision is made to print 2-minute time marks when no satellite is received. The 4-wire BCD input received from the interface driver is converted to an 8-bit ASCII parallel formatted signal and made available to the tape punch unit. For use in the teleprinter, the 8-bit ASCII parallel format is converted to 11-bit ASCII serial format. While tracking a satellite, the information received is printed or punched out line by line, and after every 25th line (2-minute period), a blank line (CR, LF) is inserted thus separating the 2-minute data packages. These operations are controlled by the interface driver.

The timing control also provides 2-minute time marks consisting of CR, LF and asterisk. An asterisk is printed out every two minutes while no satellite is being tracked thus allowing for computation of elapsed time between satellite passes.

The computer interface converts 4-wire BCD input from interface driver to 16 bit data words for processing by the computer.

Control circuitry — The main functions of the control circuitry are to initiate the acquisition or reacquisition of satellite signals by slowing the V. C. O's of the

400 MHz and 150 MHz phase lock loops, to provide rate aid while tracking satellite signal and during short loss of lock to help acquisition and to provide visual and audible display of the operating status of the system. In addition to slowing the V.C.O.'s, it monitors the fd 400 signal to determine whether the loss of lock is due to the end of the pass and from this to establish the new search. It also compares the two doppler frequencies (fd 150 and fd 400) and if the frequency difference exceeds a certain set limit, (42 Hz) sets the doppler counter and register for the unlocked channel to zero.

Power supply — The power supply, as usual, is a regulated one derived from the mains. This generates various voltages required to operate the receiver system. Stand by batteries are provided to keep the precision oscillator operational when the mains power is discontinued from the equipment.

Digital computer

The Hewlett-Packard Model 2100A digital computer processes the data for giving the position fix. In addition, it will compute, with the output of the Gyro, and log available, the dead reckoning position.

The computer has 16 K words magnetic core memory, each word comprising 16 bits. In addition to this memory and the arithmetic unit, the computer has six 16 bit working registers, two one-bit registers and one 16 bit display register on the operator panel. This display is in the octal notation. There are totally 13 interface slots available. But we use only four interface cards, *viz.*, Gyro-Speed-real time interface (slot 10), Receiver interface (11), teletype interface (12) and tape reader interface (13).

Teleprinter

The teleprinter (Model ASR-33) provides the means of communicating with the computer, and combined with the tape punch and tape reader combination, fulfills all the input/output functional requirements of the system. As an input device, the teleprinter gives commands and answer initializing questions. As an output device, the teleprinter prints out initializing questions and/or other pertinent data which have been previously processed by the computer.

Tape reader

The Hewlett-Packard 2748B binary tape reader (tape reader) provides a means of transferring information at high speed from a perforated paper photoelectrically detects coded data characters punched on perforated tape. A unidirectional mechanical drive mechanism advances the tape through the read head where phototransistors are used to detect the data. The tape reader accepts 8-track, 1-inch tape. Reading rate is up to 500 characters per second.

Tape punch

The tape punch is used to perforate one-inch paper or mylar tape to record, for later evaluation, raw data from receiver/signal processor or, when desired, processed data from the computer. The tape punch operates at a rate of up to 75 characters per second.

CONCLUSIONS

In the above paragraphs, the basic principle of operation of the CMA-722A on line Sat-Nav System has been briefly explained. This system will be soon installed on R. V. Gaveshani, for position fixing as well as for dead reckoning purposes.

REFERENCES

- Instruction Manual, CMA-722A Satellite Navigation System, Canadian Marconi Company, Montreal, Canada, 1974.
- SANKARANARAYANAN, P. E. 1975. "The Satellite Navigation System — Theory and Operation", Internal report No. INST-75-1, N. I. O., Dona Paula.
- WELLS, D. E. 1971. "Orbital information from the U. S. Navy navigation satellite system", UNB, Fredericton, Canada, Lecture notes No. 19 (Dept. of Surveying Engineering).