MINIATURIZED SATELLITE TRACKING RECEIVER

A compact receiver with sufficient sensitivity and accuracy to track the Navy's Navigational Satellites has recently been developed at the Applied Physics Laboratory. Commonly referred to as 'Miniceiver," this device also provides accurate time information derived from the satellites.

Its originators, E. E. Westerfield and J. R. Norton,* designed the Miniceiver as an item of test equipment for the Space Program at APL, but soon found it to have a very useful time-recovery capability. Completely self-contained, including its own antenna and power supply, the Miniceiver can provide time synchronization with a satellite to within a fraction of a second. If auxiliary equipment is used, and if the slant range of the satellite is known, synchronization can be provided to within a fraction of a millisecond. Particularly useful to a ship operating far from radio stations, the Miniceiver could provide accurate time information for navigational or other purposes.

The Miniceiver (Fig. 1) is designed to minimize both size and cost, while maintaining simple construction. The complete unit is mounted in a metal case 12 x 9 x 8 inches, and weighs only 14 pounds. It is powered by nickel-cadmium batteries and contains the circuitry required for charging the batteries when a source of alternating current is available. A meter is provided for determining the frequency being received, signal strength, and battery voltage as well as the charge and discharge current.

The Navy's Navigational Satellites transmit on the internationally assigned frequencies of 150 and 400 Mc/s. As part of the navigational information, these satellites transmit a time reference mark every two minutes, as a phase modulation of the R-F carrier. The Miniceiver was designed specifically to detect this modulation.

The Miniceiver contains a narrow-band, dual-conversion, phase-locked, coherent receiver capable of receiving the 150-Mc/s signal transmitted by the satellites. Mounted directly at the rear of the Miniceiver case, or placed at a remote location, a quarter-wave vertical whip is used as an antenna. As shown in Fig. 2, the signal from the satellite received by the antenna is fed into a 150-Mc/s R-F amplifier where it is amplified. The signal is mixed with a local oscillator signal, furnished by the voltage-controlled oscillator and multiplier, to provide a signal at the first I-F frequency of 10.7 Mc/s. The signal is amplified and fed to a second mixer where it is converted to 455 kc and fed to a second I-F amplifier which has a bandwidth of 3 kc. The signal is again amplified and fed to a phase comparator where its phase is compared with a 455-kc reference signal. The resultant signal, proportional to the phase error, is fed through a suitable network to the voltage-controlled oscillator. Because of the loop characteristics of the system, the frequency and phase of the signal produced by the oscillator accurately tracks the frequency and phase of the incoming signal. The intelligence transmitted as phase modulation of the R-F carrier is detected by picking off the error voltage from the phase comparator and feeding it through a suitable audio amplifier. By connecting a speaker to the output of the amplifier, the desired time information will be heard as a 400-cycle tone burst whose beginning occurs at the beginning of each even minute.

Fig. 1—APL Miniceiver.

The Miniceiver has special features to maximize its effectiveness in time recovery applications. The most important feature is an "alert" mode in

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* E.E. Westerfield is Supervisor of a Systems Development Project within the Space Development Department and J.R. Norton is a member of that Project.

which the Miniceiver sweeps the narrow band of frequencies in search of satellite signals, and, upon locating one, sounds an audible alarm. As a result, it is not necessary for the Miniceiver's user to have a schedule of satellite passes. This feature was engineered to use minimum current from the batteries so that the Miniceiver could operate in the alert mode for long periods of time without the necessity of recharging its batteries. Normally, the maximum search period required with the present satellite configuration would be four hours.

Another feature of the Miniceiver is its narrow band filter, tuned to the frequency on which the time signal is transmitted. This arrangement emphasizes the signal and thus provides more reliable operation under adverse conditions. The Miniceiver is also equipped with a small audio output amplifier and speaker so that no headphones or other external equipment is required for operation.

For certain operations it is desirable that time be obtained with a considerably higher accuracy than can be done auricularly. This can be accomplished by feeding the output of the Miniceiver's phase comparator to a decoder unit that processes the signal transmitted from the satellite and recovers the required time information electrically. This device would not be part of the Miniceiver.

In addition to its use for recovering time, the basic design principle of the Miniceiver could be used for other functions. A typical function would be for the reception of phase-modulated or narrow band frequency-modulated telemetry information. Within the present Miniceiver case size, a small discriminator could be readily built that would be capable of driving a small recorder. The Miniceiver could also be used for any other function that required the decoding of a phase-modulated signal that is transmitted on a frequency within the Miniceiver's tuning range.

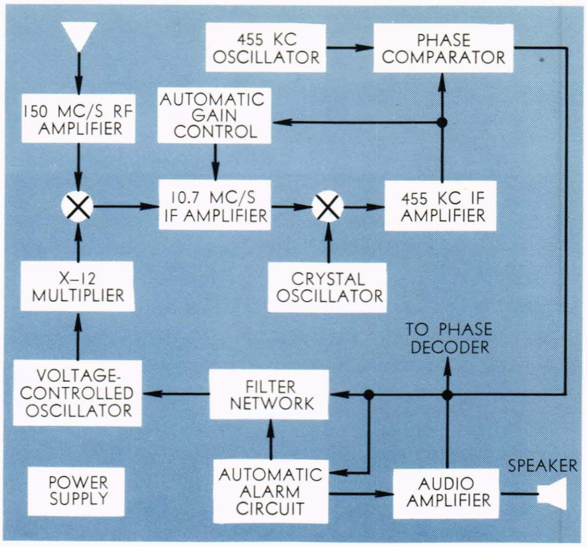

Fig. 2—Block diagram of Miniceiver.

To date, the Miniceiver has shown an unusual ability to operate under a variety of conditions. Its designers are optimistic about other applications, including the possibility of integrating the unit with additional equipment to form a complete satellite tracking station.

ADDRESSES

The listing below comprises the principal recent addresses made by APL staff members to groups and organizations outside the Laboratory.

F. T. McClure presented a series of lectures at *Trinity College,* Washington, D.C., during February-March 1966: "Particles and Quantum Concepts" (Feb. 17); "Bohr Atom and Atomic Structure" (Mar. 3); "Gas Kinetics and Thermodynamics" (Mar. 10); and "The Impact of Physics on Modern Society" (Mar. 15).

R. M. Fristrom, "Fundamental Research in Fire Extinguishment," *Fourth Annual OCD Fire Research Contractor's Conference,* Pacific Grove, Calif., Mar. 10, 1966.

V. G. Sigillito, "Pointwise Bounds for Solutions of Parabolic Equations," *Mathematics Colloquium,* University of Notre Dame, Indiana, Mar. 11, 1966.

J. A. Schetz and S. Favin, "The Ignition of Slot-Injected Gaseous Hydrogen in a Supersonic Air Stream," *Conference on Aerospace Engineering,* University of Maryland, College Park, Md., Mar. 15, 1966.

F. K. Hill, "Chemical Non-Equilibrium Effects on High-Speed Flow," *Conference on Aerospace Engineering,* University of Maryland, College Park, Md., Mar. 15, 1966.

PUBLICATIONS

The following list is a compilation of recently published technical articles written by APL staff members.

R. P. Rich, "Information Handling," *Methods of Information in Medicine,* **IV**, No. 4, Dec. 1965, 159-163.

I. Katz, "Wavelength Dependence of the Radar Reflectivity of the Earth and the Moon," *J. Geophys. Res.,* **71**, No. 2, Jan. 15, 1966, 361-366.

V. O'Brien and F. E. Logan, "Velocity Overshoot within the Boundary Layer in Laminar Pulsating Flow," *Phys. Fluids,* **9**, No. 1, Jan. 1966, 214-215.

L. S. Glover, "Approximate Re-Entry Velocity and Heating Equations," *J. Spacecraft and Rockets,* **3**, No. 1, Jan. 1966, 156-158.