

of locations is optimal in the sense that it yields an optimal combination of gains, matched 3-dB widths, low cross-polarization, and low side-lobe levels. The elliptical shape of the scanning mirror was cho-

sen, from among a number of superquadric shapes, as the one that results in the lowest overall side-lobe levels.

*This work was done by Ziad A. Hussein of Caltech and Ken Green of Microwave Engi-*

*neering Corp. for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-30506*

## Eight-Channel Continuous Timer

**This timer measures every cycle of every input clock signal.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A custom laboratory electronic timer circuit measures the durations of successive cycles of nominally highly stable input clock signals in as many as eight channels, for the purpose of statistically quantifying the small instabilities of these signals. The measurement data generated by this timer are sent to a personal computer running software that integrates the measurements to form a phase residual for each channel and uses the phase residuals to compute Allan variances for each channel. (The Allan variance is a standard statistical measure of instability of a clock signal.) Like other laboratory clock-cycle-measuring circuits, this timer utilizes an externally generated reference clock signal having a known frequency (100 MHz) much higher than the frequencies of the input clock signals (between 100 and 120 Hz). It counts the number of reference-clock cycles that occur between successive rising edges

of each input clock signal of interest, thereby affording a measurement of the input clock-signal period to within the duration (10 ns) of one reference clock cycle. Unlike typical prior laboratory clock-cycle-measuring circuits, this timer does not skip some cycles of the input clock signals. The non-cycle-skipping feature is an important advantage because in applications that involve integration of measurements over long times for characterizing nominally highly stable clock signals, skipping cycles can degrade accuracy.

The timer includes a field-programmable gate array that functions as a 20-bit counter running at the reference clock rate of 100 MHz. The timer also includes eight 20-bit latching circuits — one for each channel — at the output terminals of the counter. Each transition of an input signal from low to high causes the corresponding latching circuit to latch

the count at that instant. Each such transition also sets a status flip-flop circuit to indicate the presence of the latched count. A microcontroller reads the values of all eight status flip-flops and then reads the latched count for each channel for which the flip-flop indicates the presence of a count. Reading the count for each channel automatically causes the flip-flop of that channel to be reset. The microcontroller places the counts in time order, identifies the channel number for each count, and transmits these data to the personal computer.

*This work was done by Steven Cole of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*The software used in this innovation is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-40233.*

## Reduction of Phase Ambiguity in an Offset-QPSK Receiver

**Ambiguity would be reduced to twofold at no cost in power efficiency.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Proposed modifications of an offset-quadrature-phase-shift keying (offset-QPSK) transmitter and receiver would reduce the amount of signal processing that must be done in the receiver to resolve the QPSK fourfold phase ambiguity. Resolution of the phase ambiguity is necessary in order to synchronize with the received carrier signal, the signal generated by a local oscillator in a carrier-tracking loop in the receiver. Without resolution of the fourfold phase ambiguity, the loop could lock to any of four possible phase points, only one of which has the proper phase relationship with the carrier.

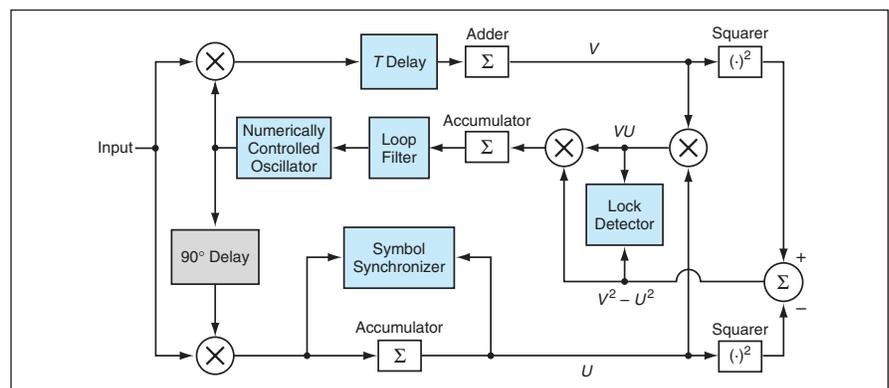


Figure 1. This **Carrier-Tracking Loop** of an offset-QPSK receiver differs from a maximum a posteriori (MAP) carrier-tracking loop of a non-offset-QPSK receiver by incorporating a unit that imposes a delay of one symbol period ( $T$ ).

The proposal applies, more specifically, to an offset-QPSK receiver that contains a carrier-tracking loop like that shown in Figure 1. This carrier-tracking loop does not resolve or reduce the phase ambiguity. A carrier-

tracking loop of a different design optimized for the reception of offset QPSK could reduce the phase ambiguity from fourfold to twofold, but would be more complex. Alternatively, one could resolve the fourfold phase ambiguity by

use of differential coding in the transmitter, at a cost of reduced power efficiency. The proposed modifications would make it possible to reduce the fourfold phase ambiguity to twofold, with no loss in power efficiency and only relatively simple additional signal-processing steps in the transmitter and receiver. The twofold phase ambiguity would then be resolved by use of a unique synchronization word, as is commonly done in binary phase-shift keying (BPSK).

Although the mathematical and signal-processing principles underlying the modifications are too complex to explain in detail here, the modifications themselves would be relatively simple and are best described with the help of simple block diagrams (see Figure 2). In the transmitter, one would add a unit that would periodically invert bits going into the QPSK modulator; in the receiver, one would add a unit that would effect different but corresponding inversions of bits coming out of the QPSK demodulator. The net effect of all the inversions would be that depending on which lock point the carrier-tracking loop had selected, all the output bits would be either inverted or non-inverted together; hence, the ambiguity would be reduced from fourfold to twofold, as desired.

*This work was done by Jeff Berner and Peter Kinman of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-30384*

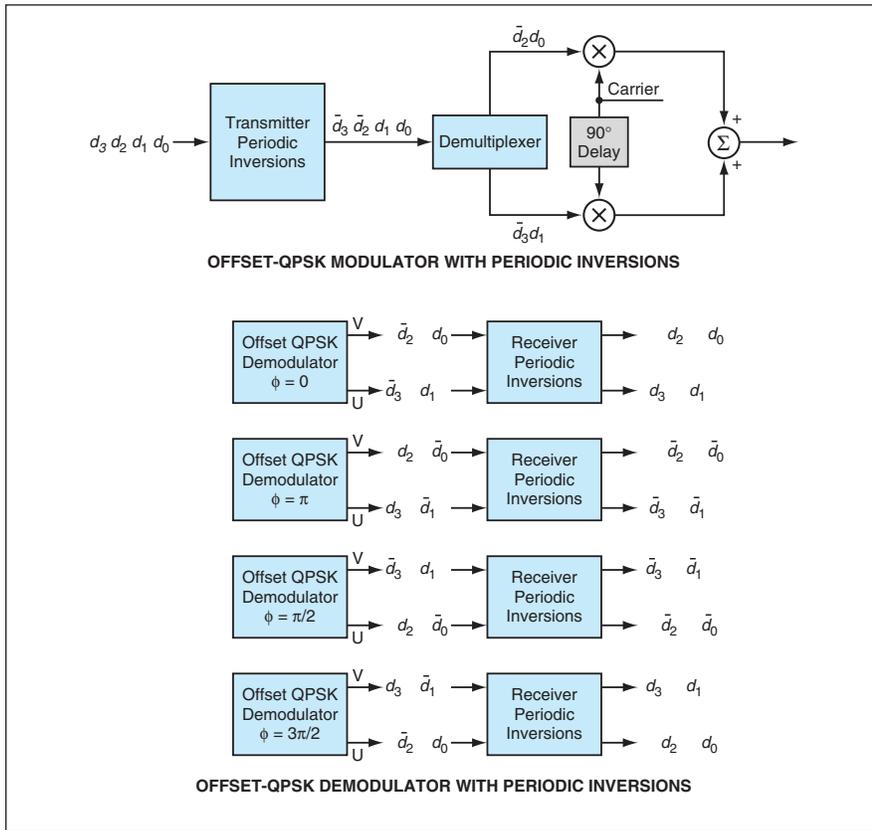


Figure 2. Inversions of Bits in cycles of four bits ( $d_0 d_1 d_2 d_3$ ) would cause all the output bits to be either inverted or noninverted together, depending on the phase difference ( $\phi$ ) between the received carrier and the local-oscillator signal in the carrier-tracking loop. The loop could lock at any of four points ( $\phi = 0, \pi/2, \pi, \text{ or } 3\pi/2$  radians).

## Ambient-Light-Canceling Camera Using Subtraction of Frames

Ambient light would be suppressed more effectively than by optical filtering alone.

NASA's Jet Propulsion Laboratory, Pasadena, California

The ambient-light-canceling camera (ALCC) is a proposed near-infrared electronic camera that would utilize a combination of (1) synchronized illumination during alternate frame periods and (2) subtraction of readouts from consecutive frames to obtain images without a background component of ambient light. The ALCC is intended especially for use in tracking the motion of an eye by the pupil center corneal reflection (PCCR) method. Eye tracking by the PCCR method has shown potential for application in human-computer interaction for people with and without disabilities, and

for noninvasive monitoring, detection, and even diagnosis of physiological and neurological deficiencies.

In the PCCR method, an eye is illuminated by near-infrared light from a light-emitting diode (LED). Some of the infrared light is reflected from the surface of the cornea. Some of the infrared light enters the eye through the pupil and is reflected from back of the eye out through the pupil — a phenomenon commonly observed as the “red-eye” effect in flash photography. An electronic camera is oriented to image the user's eye. The output of the camera is digitized and processed by algorithms that

locate the two reflections. Then from the locations of the centers of the two reflections, the direction of gaze is computed. As described thus far, the PCCR method is susceptible to errors caused by reflections of ambient light. Although a near-infrared band-pass optical filter can be used to discriminate against ambient light, some sources of ambient light have enough in-band power to compete with the LED signal.

The mode of operation of the ALCC would complement or supplant spectral filtering by providing more nearly complete cancellation of the effect of ambient light. In the operation of the ALCC,