A LOW COST, ACCURATE, TARGET DETECTING DEVICE FOR ALTIMETRY AND FUZING

Thomas O. Perkins III, James A. Teunas, Alfred J. Cann,
Martin R. Richmond, William J. Bradley

Sanders Associates, Inc.
Manchester, New Hampshire 03108-8500

ABSTRACT

An accurate, simple, reliable, low-cost target detecting device for radar altimetry and fuzing applications is reported. The system employs a single active microwave solid state device for both transmit and receive while requiring only one antenna.

INTRODUCTION

FM-CW altimeters are well-known and capable of working to nearly zero altitude, but fairly complex. A recent application which required only moderate altitude performance led us to re-examine an old idea (1,2) with modern components to meet the need for extremely small size, weight, and cost. The resulting altimeter uses a superregenerative oscillator as both transmitter and receiver. Highly efficient techniques minimize the complexity of the signal processor as well. We were naturally driven in this direction by the Company's expertise in superregenerative oscillators, developed on other programs.

This approach is easily adaptable to any microwave frequency. Modular options and common generic building blocks simplify adaptation to varying requirements at minimal design cost. Low electronic observability due to use of only one antenna is another significant aspect of this approach. The scheme can be implemented using a bipolar transistor, GaAs power FET, or IMPATT diode, depending on power and frequency requirements. Cost and weight are low because significantly fewer components are required when compared with conventional pulse or FM-CW altimeters.

OVERVIEW

Superregenerative pulsed altimeters are described in which the transmitting oscillator also serves as receiver. The altimeter will detect when a preset altitude is reached by using a fixed pulse spacing corresponding to the round trip time from the antenna to the ground and back.

This paper also discusses simple extensions of this scheme to permit continuous altitude measurement.

BASIC PRINCIPLES

The basic altimeter block diagram is shown in Figure 1. In the simplest system

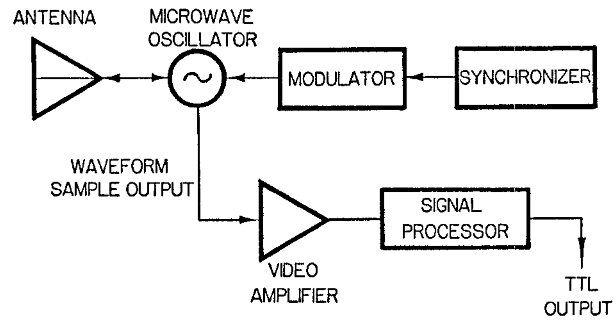

FIGURE 1. BASIC ALTIMETER BLOCK DIAGRAM

configuration a microwave oscillator is modulated with a preset pulse spacing. The first pulse is the transmit pulse. On the second pulse (though it is also emitted) the oscillator operates as a superregenerative detector (3). When the round trip delay of the ground echo equals the pulse interval, detection will occur as illustrated in Figure 2.

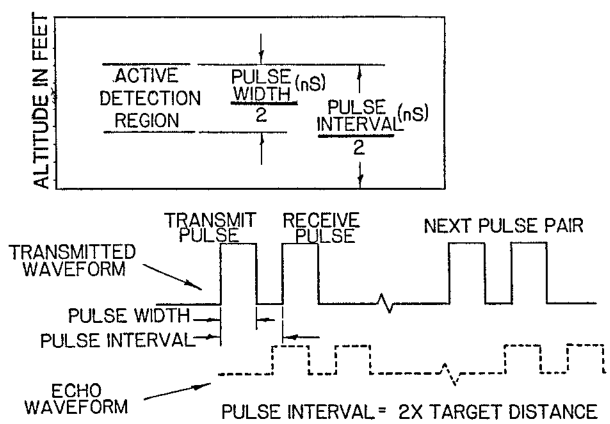

FIGURE 2. REPRESENTATIVE ALTIMETER WAVEFORMS

0149-645X/85/0000-0155 $01.00 © 1985 IEEE 1985 IEEE MTT-S Digest

The echo causes the rf oscillations to build up earlier in relation to the keying pulse. This change is sensed on the collector current waveform and amplified to TTL level. In the signal processor, this leading edge shift is converted to a voltage which is amplified and thresholded.

EXPANDED CAPABILITY

In a continuous readout system, the pulse spacing is swept periodically. The detection causes the sweep voltage to be sampled and held and also resets the sweep. This provides an analog voltage corresponding to altitude. Some commercial pulse altimeters operate this way (2).

SWEEP PARAMETERS

To cover an altitude range of 50 to 10K ft, for example, requires a pulse repetition interval (PRI) of 0.1 to 20 microsec. By sweeping the PRI from high to low and stopping when a detection is made, one avoids the problem of false alarms due to multiple-time-around echoes. (These can occur whenever the echo delay is a multiple of the PRI).

TRACKING MODE

A refinement that provides a higher data rate operates in two phases, search and track. When first enabled, the altimeter is in search mode as described above. It sweeps until the ground is detected, then enters track mode. In track mode, the sweep is not reset all the way to maximum altitude when the ground is detected but is set back only a small amount. Thus, in track mode, the altimeter is still sweeping continually but with very short sweeps. This provides a high data rate (see Figure 3).

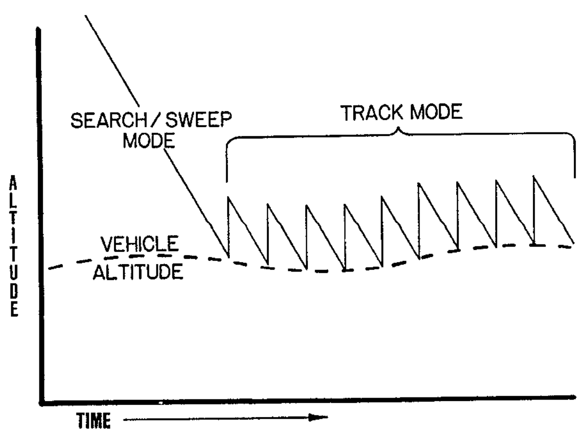

FIGURE 3. SEARCH AND TRACK MODE

A classical range tracker using split gates obviously would provide the highest possible data rate. But the approach described herein is far lower in cost, size, weight, and complexity and it can provide data rates adequate for most applications. For example, a 50Hz sampling rate would provide about a 20Hz data bandwidth. The sweep duration in the tracking mode would be 20ms. Assume the altitude can change, at most, 5000 ft. per second. This is 100 ft. in 20ms, thus the sweep amplitude (setback) need be only 100 ft. and the sweep rate required would be 5 ft/ms. If one uses an integration time of 3ms, for example, this would provide a range resolution of 15 ft. Range accuracy could then easily be on the order of 3 to 5 ft.

SIGNAL DESIGN

For the basic altimeter first described, one would use a pulse pair whose spacing (leading edge to leading edge) equals the round trip delay for the preset altitude. For example, 200 ns for 100 ft. The width of the first pulse provides a detection window. Continuing the example, if the width were 80 ns, detections would occur for any altitude between 160 and 200 ft.

A continuous readout system with a wide range of altitudes is slightly more complex. A very narrow pulse is needed for operation at low altitudes to provide some recovery time between pulses. If the same pulse width were used at high altitudes, very little of the available echoing area on the ground would be used and a very high peak power would be needed. Instead, we vary the pulse width to maintain approximately a constant duty factor. Then the echoing area is determined only by the antenna pattern and the angular variation of terrain reflectivity. For a given terrain type, then, the signal strength varies only as the inverse square of the altitude and much less peak power is required.

EXPERIMENTAL RESULTS

A demonstration altimeter for fuzing applications was designed and fabricated. A 100 mW, 4.3 GHz, common-base, bipolar oscillator was used for the microwave source as shown in Figure 4.

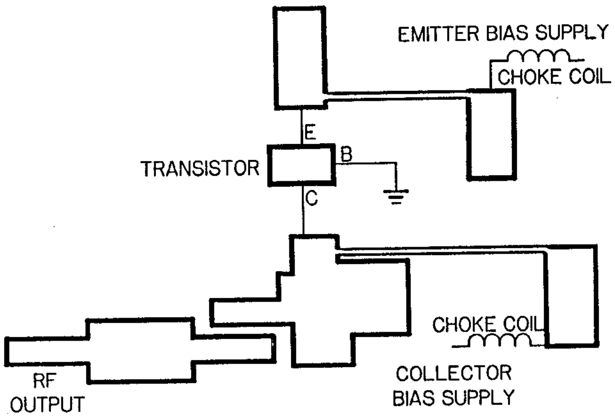

FIGURE 4. MICROWAVE OSCILLATOR

Figure 5 is a multiple exposure of the detected RF pulse's leading edge, illustrating the shift with increasing injected signal level. A measurement of this leading edge shift is plotted in Figure 6.

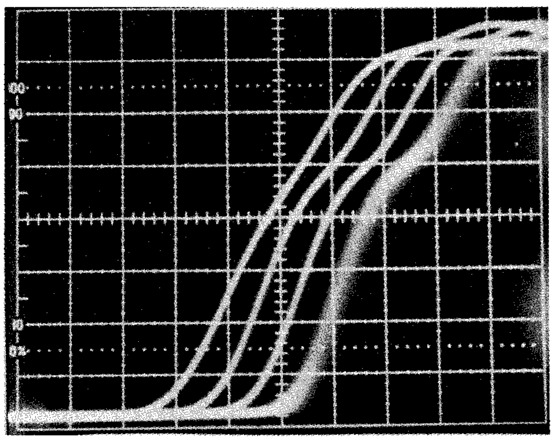

FIGURE 5. DETECTED LEADING EDGE PULSE SHIFT WITH INCREASING SIGNAL LEVEL

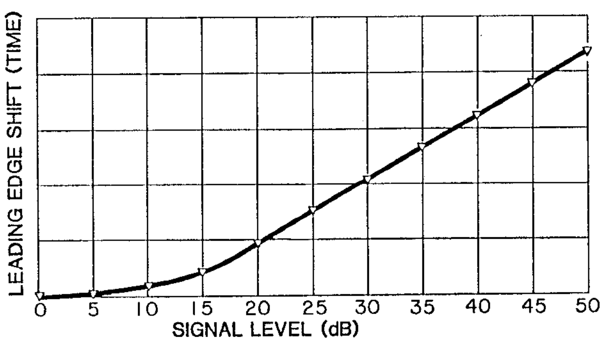

FIGURE 6. LEADING EDGE OF RF PULSE AS FUNCTION OF INJECTED SIGNAL LEVEL

The altimeter was tested in free space over a horizontal path. It was found necessary to use a radar absorber fence to eliminate ground lobing. The experimental conditions were as shown in Figure 7.

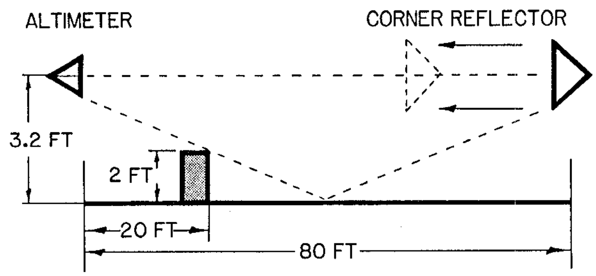

FIGURE 7. FREE SPACE HORIZONTAL TEST CONDITION

The target was a corner reflector whose right-angle sides measured 18 inches. Its radar cross section was calculated to be 25dB above one square foot at 4 GHz or approximately 300 square feet. The altimeter was set for 75 feet. The corner reflector was moved to different spacings and the output of the signal processor was monitored with the results plotted in Figure 8.

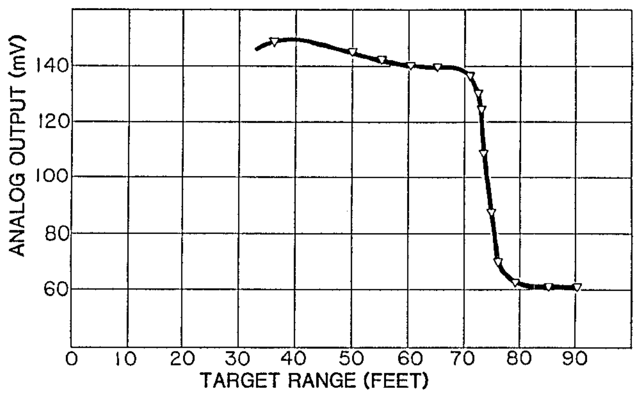

FIGURE 8. SYSTEM FREE SPACE EXPERIMENTAL RESULTS

Another altimeter design using the same oscillator was successfully flight tested on a rocket-launched test platform, demonstrating a 300 foot height of function.

CONCLUSION

A proven receiver technique is exploited using modern solid state microwave devices and very simple signal processing for altimetry and fuzing. Examples of potential applications are chaff decoys, cargo parachutes, smart weapons, and missile and aircraft guidance.

REFERENCES

(1) R. W. Bogle, "Echo Altimeter for a Low Level Guidance System", U.S. Patent No. 3, 088, 112:April 30, 1963

(2) Bonzer Corporation, now owned by Terra Corporation

(3) S. N. Van Voorhis, "Microwave Receivers", Radiation Laboratory Series, Volume 23, McGraw-Hill Book Company, Inc., New York: 1948