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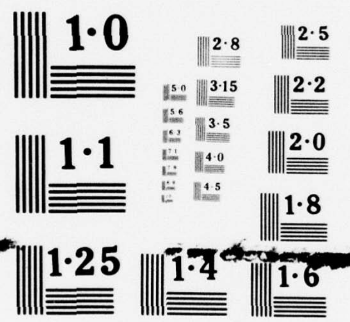

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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

SINGLE PULSE RADAR

by

T'ao Wang-ping

FOREIGN TECHNOLOGY DIVISION

EDITED TRANSLATION

FTD-ID(RS)T-0766-77 13 June 1977

MICROFICHE NR: FTD-77-C-000694

CSL76020810

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English pages: 13

Source: Hang K'ung Chih Shih, Peking, Number 11, 1975
pp. 13-15

Country of origin: China
Translated by: LINGUISTICS
F33657-76-D-0389
H. P. Lee
Requester: FTD/ETWR

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Single Pulse Radar

By

T'ao Wang-ping

Single pulse radar, in precision of detection, resistence to interference and data rate in detection, is better than any other type. At the beginning, it was only used to make single-target automatic precise tracking, and it is now emplyed to make multi-target scanning and searching.

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The single pulse radar made its debut in the early 1950's. Following the rapid development of aviation and rocket technology and the requirement for such space flying machines as guided missile and man-made satellite, in the 1960's, this kind of radar had opportunity to make a rapid development. The introduction, as well as the development, of single pulse radar is about ten years later than that of conic scanning radar. At its early stage, the single pulse radar was only used to make single-target automatic precise tracking, but it is now used as multi-target scanning radar, air-borne early warning radar, multi-function intercepting radar and ground object searching radar. In the automatic target searcher of guided missiles, it is used as well. The scope of its usefulness has been rapidly expanding. In the recent anti-intercontinental guided missile system, two sets of phase single pulse radar are often used to replace the past five or six sets of radar work.

Basic Working Principles

Single pulse radar can send back complete information of the angular position of the target by using only one echo wave. This is the source from which comes the technical term "single pusle direction detection". There are two basic methods of single pusle direction detection: the amplitude directional method and the phase directional method. It is the amplitude single pulse method which is used more than other methods at the present time. The antenna of this kind of radar can emit a bundle of four waves, up and down, left and right, which often pile one upon the other, as indicated in Figure I. It uses the amplitude of left-right wave bundle to detect azimuth angle, and the amplitude of up-down wave bundle to detect elevation angle. The principles allied to the detection of azimuth angle and elevation angle are completely the same. For brievity, the discussion that follows is limitted to the principles of detecting elevation angle only.

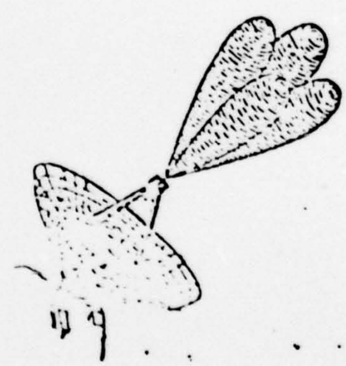

Figure I Four wave bundles emitted from amplitude single pulse radar and they pile one upon the other.

The amplitude single pulse radar, like conic scannning radar, uses the principle of comparing signal method to work. As illustrated in Figure 2, when the target deviates from antenna axis and inclines to the upper part of elevation angle, the echo wave received by wave bundle I is much stronger than that received by wave bundle II. After comparing the strength of those two signals, the deviation angle θ of the elevation angle can be determined. The difference between single pulse radar and conic scanning radar rests on that single pulse radar can at the same time emit two wave bundles and compare the elevation angle; while the conic scanning radar can emit only one wave bundle and it can not begin to compare the elevation angle until it receives echo wave from several times of conic scanning. Only because such difference, the single pulse radar can have the angular information by only one pulsation; the typical conic scanning radar must make a cycle of conic scanning, namely it must emit and receive several ten-times of pulsation in order to have the angular information of the target.

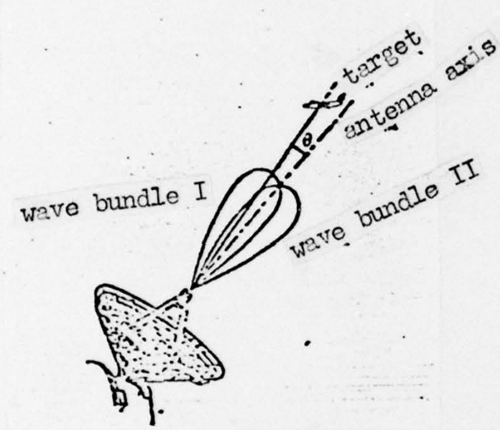

Figure 2 Making direction detection by comparing the echo signal of two wave bundles.

In an article of Conic Scanning Radar, we have introduced the fact that because of the complexity of the shape of their surface, the vibration in their flight and the rapid change of flying pattern, air planes, guided missiles and other flying bodies often produce a phenomenon of scintillation (i.e. the signal reflection follows the ups and downs of the flying body) to the reflection of radar waves. The typical conic scanning radar cannot begin to detect direction and to track target until it completes a cycle of conic scanning. Because of this, and because of the effect of scintillation, its precision in angle detection falls in between 1 and 2 mi-wei* (1密位=0.06°). The single pulse radar uses one pulse to detect direction and track target.It can avoid the effect of reflective scintillation, so its precision in direction detection can reach as high as about 0.1 mi-wei. This is a significant strong point of single pulse radar. Different single pulse radar systems which are used often will be introduced as follows.

Amplitude Single Pulse Radar

The compostion of amplitude single pulse radar is illustrated in Figure 3,but the mechanical device of emitter is not included in the Figure. The wave bundles, as illustrated in Figure 4, emitted from the emitter to detect elevation angle, because of the same phase position,are all marked with a sign "+". These two wave bundles will return after

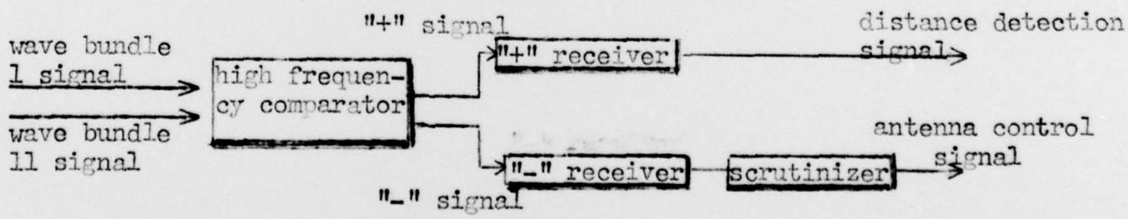

Figure 3 Diagram of working principles of amplitude single pulse radar.

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* The Chinese word "mi-wei" literally means "close position" or "unit (measurement) of closeness". Hereafter a transliteration of "mi-wei" is used in this article.— the translator.

encountering the target and will be received by the antenna. Through comparison performed by the high frequency comparator, they give signal "+" and signal "-". Signal "+" represents that the directions of two intersecting wave bundles (see Figure 4) are closed and added together to form a new direction as indicated in Figure 4 B. Signal "-" means that from the directions of wave bundle 1 wave bundle II was subtracted and the result becomes what is illustrated in Figure 4 C. Signal "+" and "-" each undergoes a course of amplifying and processing in a receiver, then they are compared in the scrutinizer and give signal to control movement of antenna. If signal "-" is zero, the control signal is also zero. This indicates that the antenna axis is exactly pointing the target. If signal "-" is not zero, there will appear a control signal. And by comparing the phase position of both signal "+" and signal "-" to determine to which direction the antenna axis should incline. Signal "+" is not only used as a regulating signal of phase position and can also be used as a distance detection signal. Because it is the sum of two signal bundles, its signal has double strength, so it is good to be used to detect distance.

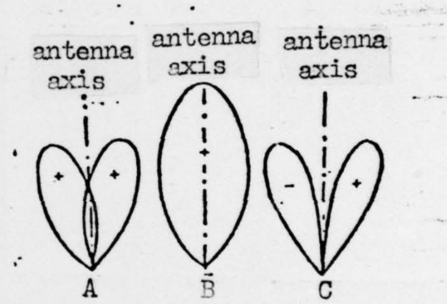

Figure 4 A: the direction of two intersecting wave bundles.
B: direction of two bundles.
C: direction of the difference of two wave bundles.

What has been discussed above is only regarding to the detection of elevation angle. If the azimuth angle is detected at the same time, the operation should begin with the left-right two wave bundles. After passing through the high frequency comparator, the "+" receiver and azimuth "-" receiver begin to work. Then they pass through the scrutinizer and produce an azimuth control signal. In fact, single pulse radar works only by amploying one "+" receiver and two "-" receivers. When it works, the up-down and left-right four wave bundles on "+" side are added together. The elevation angle "-" wave bundle is formed by adding up-left to up-right and down-left to down-right ,then comparing them. The azimuth angle "-" wave bundle is formed by adding left-up to left-down and right-up to right down,then comparing them.

Phase Single Pulse Radar

Phase single pulse radar uses phase difference of the receiving wave bundle signal to detect target direction, and the amplitude of the received signal is often irrelevant to target direction. The four wave bundles emitted from antenna are always parallel (see Figure 5). The real antenna structure, as illustrated in Figure 5, is that an antenna

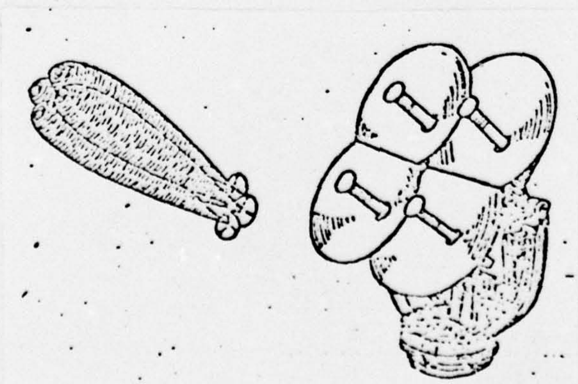

Figure 5 Diagram of four parallel wave bundles emitted from the antenna of phase single pulse radar (left) and their structure (right).

which comprises four wave bundles is single and separate.

The principles of using phase single pulse radar to detect direction are presented in a diagram in Figure 6. Because the antenna is arranged in a straight line, the radiative wave bundles are parallel, and the iso-signal direction (direction of antenna axis) is exactly in front of the antenna radiator. When target is far away from the antenna, the direction of target reflecting signals are nearly parallel and the amplitudes are equal, but the phase positions are not. As indicated in Figure 6, the signal in the lower part has to travel an a-b distance but not the signal in the upper part. However, the a-b distance is not long and it has no significant effect on the transmission of the strength of signals, but it can affect the phase position greatly. As radar is a kind of microwave work, the wave length is usually of several cm. If a-b distance is of the same length as a wave length, it will be 360° when phase position is short by one wave length. If a-b distance is one half of a wave length, it will be 180° when phase position is short by half wave length. The length of a-b distance, as indicated in Figure 6, is related to the target declination angle θ. Thus, by detecting the phase position of wireless current, the direction of the target deviating away from the antenna axis can be detected. The structure of phase single pulse radar and that of amplitude single pulse radar are of great analogy and small

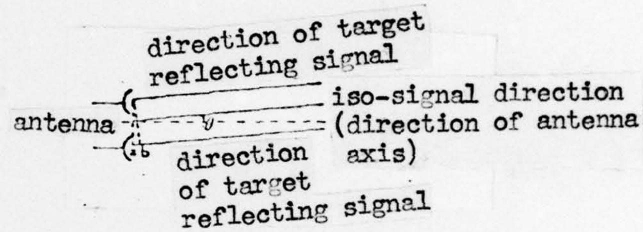

Figure 6 Diagram of principles phase direction detecting.

difference, and the difference is only in the appearance of antenna and scrutinizer. At the present time, most of the single pulse radar use amplitude type to work, and only a small number uses phase type to work.

Pseudo-single Pusle Radar

As single pulse radar needs three-route receiver to work, its structure is relatively complicated. For this reason, a new radar system called pseudo-single pulse radar has developed. It combines one "+" signal and two "-" signals together and uses a one-route receiver to work. When two "-" signals are combined together, on the one hand, they enable the amplitude of single pulse signal to have a modulation similar to that the conic scanning radar has, and, on the other hand, they produce a regulating signal also similar to what the conic scanning radar has. Thus the two "-" signals can separate after the receiver is amplified. This kind of pseudo-single pulse radar is also called a hidden conic scanning radar, because when it emits, it is just like a single pulsed and when it receives, it is like a conic scanning one. Compared with conic scanning radar, the pseudo-single pulse radar has an outstanding quality that it is not easily attacked by anti-radar guided missile, nor is it easily interfered by the inverted phase countermoving interference. But like conic scanning radar, it can be affected by the scintillation of the target reflecting signals, so its precision in angular detection is hard to improve, and its precision is generally a little more than one mi-wei. In addition to combining three-route receiver into one route, there are still some other methods, and sometimes the three routes can be combined into two to work. Because its structure is simple, the pseudo-single pulse radar is, at the present time, used rather widely.

The Application of Single Pusle Radar

The typical single pulse radar employed to track intercontinental guided missiles and man-made satellites is illustrated in Figure 7. The diameter of its antenna is 3.6 m., the energy rate of emission is about one trillion watts, the precision of angular detection reaches 0.1 mi-wei, error in distance detection is 4.6 m., and the distance from a target satellite is several hundred-miles.

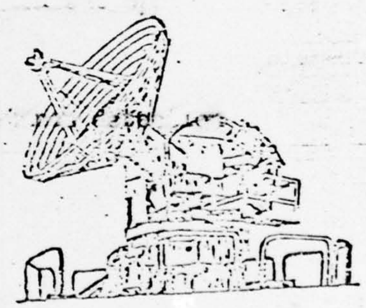

Figure 7 Precise detection single pulse radar used for tracking man-made earth satellites.

There are two different kinds of communication satellite: the static communication satellite and the moving communication satellite. Of a moving communication satellite, the requirements for installation of ground station are very strict and high. But the ground station of a static communication satellite needs only one antenna constructed by the principle of single pulse to connect the communication. There is one kind of ground guide station of moving communication satellite, which requires three sets of single pulse radar to work, as illustarted in Figure 8. An unsophisticated guide station is one set of phase single pulse radar and its antenna comprises four parallel screw-type antennae. In addition to making simple and sketchy detection of the position of communication satellite in space, it can also be used to receive the high frquency distance detection signal emitted back from the satellite. A sophisticated guide station is one set of amplitude single pulse radar. On the right side of Figure 8, there is a set of automatic tracking radar, and it is also an amplitude single pulse radar. Its antenna is a paraboloid reflector of radiative conic trumpet shape. The focal distance of the paraboloid is 18.2 m. and its open-mouth diameter is 20.6 m.. The whole antenna is covered by an air-filled cover, of which the diameter is 65 m.. The communication signals are transmitted through this antenna.

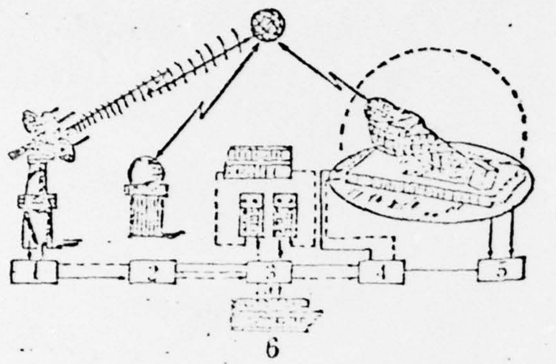

Figure 8 Diagram of principles for setting up a moving communication satellite ground guide station. 1: an unsophisticated guide station, 2: a sophisticated guide station, 3:computer, 4: automatic (two words blurre in xerox) transmission, 5: installation of communication and automatic tracking system, 6: control tower.

In the late 1960's, in the early warning system of ànti-intercontinental ballistic missile, two kinds of phase control single pulse began to be used. One kind of the radar can function at a distance of more than 4000 miles from the guided missile and the tracking distance can reach 1600 miles. The other kind is guided missile control radar, and it is mainly used to make precise tracking of the attacking guided missile and to control the air defence guided missile. The searching distance of this radar is more than 1000 miles and the distance of precise tracking is several hundreds of miles.

Because of its high precision in tracking and good capability of interference resistance, single pulse radar has also been widely used as air-borne radar. There is one kind of air-borne multi-function single pulse interception radar, for example, which can be used not only to control the ground-to-air firing power system and also carry out air-to-ground distance detection, topographical survey, ground object searching and ground tracking. If a plane is equipped with such kind of radar, it can fly with high speed and very close to the ground (or sea) level. It can break down the ground vigilance radar zone of the enemy side and it has no danger of pumping on the projecting object on the ground.

Strong Points and Weak Points of Single Pulse Radar and The Trend of Its Development

Compared with conic scanning radar, the single pulse radar has the following strong points: good capability of interference resistance; not affected by inverted phase countermoving interference; not easy to be attacked by anti-radar guided missile; high precision of detection; not affected by the scintillation made by target amplitude; and error in direction detection is 0.1 mi-wei. Its antenna is very good. It can use the largest amplitude direction of "+" wave bundle to take aim at the target. Its functional distance can therefore be increased to achieve a high data rate. When single pulse radar emits one pulse, it can obtain complete information of the target position; while the conic scanning radar must emit four to ten pulses for the same purpose (the so-called data rate is the count-down of time required for one collection of information from the target in a given air space). Furthermore, the noise control has improved, the single pulse radar has no mechanical structure of the conic scanning radar, which is always one source of noise.

Single pulse radar has the following weak points: the feedback line of the antenna and high frequency comparator is relatively complicated; the design and manufacturing, the production and adjustment of the receiver are all relatively complicated and the cost is high.

So far as the development of single pulse technology is concerned, this kind of angular track technology, like moving-target indicator, pulse compression and pulse Doppler technology, will be regarded as a radar technology and applied to other radar system. Of the single pulse radar, which is now being studied and manufactured, the precision in angular detection has reached 0.05 mi-wei. It is estimated that by the late 1970's, the precision will be further improved. At the present time, in addition to the improvement of precision in angular detection, single pulse radar has further solved the problem of detecting multi-target of high moveability, especially the detection of the separate guiding the re-entry of multi-warheads into guided missile. It also solved the problem of the interference of the ground object when the target is in low altitude. For the former, the solution is that single pulse system combines with phase control technology, and for the latter, the solution is that the single pulse system combines with pulse Doppler technology. To sum up, single pulse radar in modern radar technology is a new system, which is of important significance and in rapid development.

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1. REPORT NUMBER FTD-ID(RS)T-0766-77	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (*and Subtitle*) SINGLE PULSE RADAR		5. TYPE OF REPORT & PERIOD COVERED TRANSLATION
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(*s*) T'ao Wang-ping		8. CONTRACT OR GRANT NUMBER(*s*)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Foreign Technology Division Air Force Systems Command United States Air Force		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 1975
		13. NUMBER OF PAGES 13
14. MONITORING AGENCY NAME & ADDRESS(*if different from Controlling Office*)		15. SECURITY CLASS. (*of this report*) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

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