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A DUAL-PRF, DUAL-PULSE-LENGTH SYNCHRONIZER FOR THE TWO-FREQUENCY RANDLE CLIFF RADAR

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13. ABSTRACT


A dual synchronizing system has been developed to provide synchronized timing of the transmitter and receiver functions in the two-frequency Randle Cliff Radar. Selected pulse repetition frequencies (prf's) in the range from 10 to 2000 pps and pulse lengths from 5 to 1000 μsec are supplied to the vhf radar in synchronism with prf's from 80 to 120 pps and a 100-μsec pulse length for the uhf radar.

When it is desired to operate the two radars at different prf's, the synchronizer generates a selected crystal-controlled high prf from which a selected submultiple prf is also generated. The high prf is used for one radar and the submultiple prf is used for the other. The pulses of the low-prf radar are therefore synchronized with the pulses of the high-prf radar. The pulse period at the high prf which immediately follows the low-prf pulse is called the coincident pulse period, whereas other periods following the high-prf pulse are designated intermediate pulse periods.

During the coincident pulse period, both radars and the range tracking unit of the synchronizer receive time-delayed triggers. The relative time delays depend on the selected vhf pulse length in such a way that alignment of pulse centers between the fixed-pulse-length uhf radar and the variable-pulse-length vhf radar is maintained. Pulse-centering alignment is also applied to the generation of range-tracking and box-car gates used in the receiver video outputs.


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During the intermediate pulse period, only the range tracker and either the vhf- or uhf-radar triggers are generated. The time delays to these triggers are shortened to use effectively a greater portion of the pulse period than during the coincident period, where the shorter-pulse generation was delayed to maintain a coincident pulse center with the longer-pulse radar. Thus, the synchronizer provides dual prf-pulse-length operation of the two radars, using a common range tracker.

Either the prf or the pulse length, or both, may be changed during operation without losing track or affecting range-measurement calibration. By designing the synchronizer into four partially independent modular units, radar operation is permitted with limited prf-pulse-length flexibility when one or more units are not in service. Expanded synchronizer functions can be incorporated as modifications to existing units or as separate units. The system will permit variable-prf and variable-pulse-length operation of the uhf radar if those capabilities are subsequently provided in the uhf transmitter.

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CONTENTS

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## PROBLEM STATUS

This is an interim report on one phase of the problem; work is continuing.

## AUTHORIZATION

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Project RF 05-151-402-4001

Manuscript submitted May 5, 1970.

# A DUAL-PRF, DUAL-PULSE-LENGTH SYNCHRONIZER FOR THE TWO-FREQUENCY RANDLE CLIFF RADAR

## INTRODUCTION

The Randle Cliff Radar (RCR) is used to investigate the effects of the atmosphere, particularly the ionosphere, on the propagation and detection of radar signals. A detailed description of the system has been given in a previous NRL report*, although some features of the system have been changed since that report was written.

The RCR currently uses two radar systems, one operating at vhf and the other at uhf. These two radars are often operated concurrently so that data can be obtained on a target simultaneously at two frequencies. To permit simultaneous operation of the radars at different pulse repetition frequencies (prf) and different pulse lengths, a common synchronized timing system is required. This timing system, termed the radar synchronizer, provides the radars with properly timed triggers and gates for a variety of functions. This report describes the design and operation of the synchronizer which has been built and tested. It was installed in the radar system in October 1969 and consists of four rack-mounted units using solid-state discrete component and integrated circuitry. Simultaneous operation of the radars at different prf's and pulse lengths is provided, with the prf's synchronized.

This type of system is necessary, for example, when one radar is operated with a short pulse length and high prf and the other radar is operated with a longer pulse length and a lower prf. This combination of operating conditions would provide the advantage of high data rate and range resolution with the first radar while the second radar would provide greater unambiguous range. When the radars are operated at different pulse lengths, alignment of the pulse centers for both transmitted pulses and for subsequent gating pulses for the receiver is maintained. A common range tracker is used in the synchronizing system. It is switched between the higher-prf and lower-prf radars when the radars are operating at different prf's and pulse lengths.

## OPERATIONAL MODES

The components of the synchronizer are a prf generator, a pulse-centering control unit, a pulse-length generator, and a range tracker, shown in Figs. 1 through 4, respectively. The latter three units function as controlled, interconnected time-delay trigger-pulse generators. Full dual-prf, dual-pulse-length operation requires interconnection of all of these units. However, limited operation is possible with one or more units removed from the system.

When the pulse centering control unit is switched out, combined vhf-uhf radar operation is limited to a common pulse length of 100 $\mu$sec and a common prf of 80 to 120 pps. This restriction is imposed by the uhf transmitter and is not a limitation of either the

*NRL Report 5801, "A VHF-UHF Missile- and Space-Research Radar With a 150-Foot Steerable Antenna," Aug. 1962.

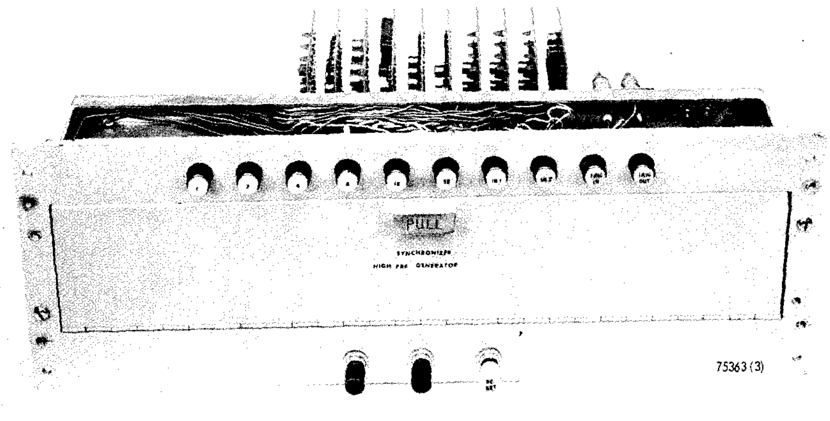



Fig. 1 - Prf generator

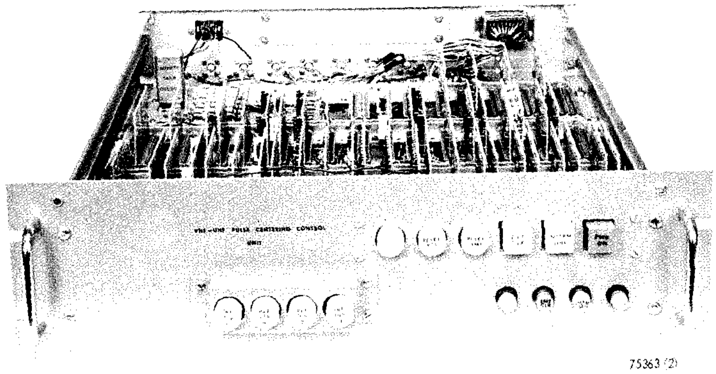



Fig. 2 - Pulse centering control unit

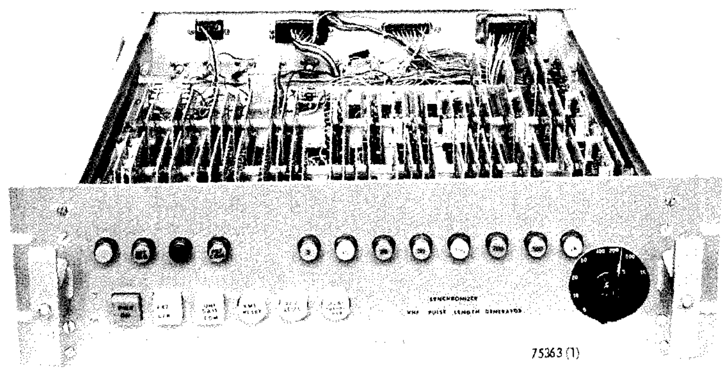



Fig. 3 - Pulse length generator

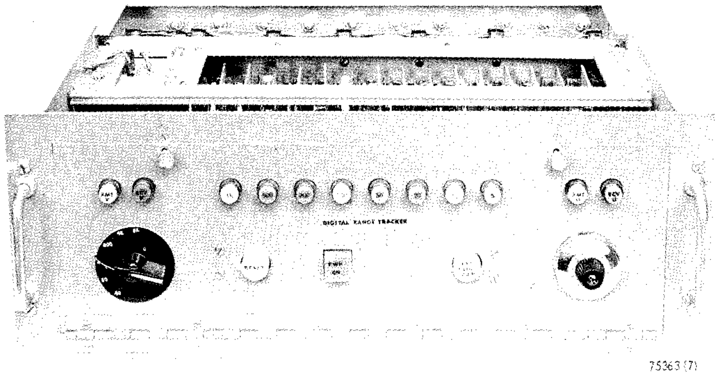


Fig. 4 - Range tracker

synchronizer or the receiver. However, with the vhf radar operating independently of the uhf system, any prf or pulse length can be selected within the 1% duty cycle limit of the transmitter.

Operating the pulse centering control with the other three components of the synchronizer permits full use of the vhf radar with selectable pulse lengths (5 to 1000 $\mu$sec) and prf's (10 to 2000 pps) in synchronism with the fixed-pulse-length (100 $\mu$sec) and limited-prf (80 to 100 pps) uhf radar. Synchronism in this context is defined as pulse-center alignment of the transmitted pulses and receiver-gating pulses, respectively.

Selectable operating modes of the pulse length generator and the pulse centering control are available to permit limited radar operation when only one of these units is operating. Also, the uhf radar may be operated at any of the prf's or pulse lengths available for the vhf radar when suitable transmitter modifications are made. The uhf receiver is already compatible for variable pulse lengths.

Five specific operating modes of the system are currently available. The first four are available with just the pulse centering control or the pulse length generator in conjunction with the prf generator and range tracker. They are as follows:

Pulse Length Generator Only

1. Variable prf and pulse length with vhf operating alone.

2. Single prf (80 to 120 pps) and single pulse length (100 $\mu$sec) with combined vhf-uhf operation.

Pulse Centering Control Only

3. Variable prf (10 to 1000 pps vhf or 80 to 120 pps uhf) and single pulse length (100 $\mu$sec) with either system operating alone.

4. Dual prf and single pulse length (100 $\mu$sec) with combined vhf-uhf operation.

Of course any of the above four modes may be selected with the full synchronizer configuration which includes the pulse length generator and the pulse centering control operating together.

The additional mode that the full synchronizer configuration makes possible is:

Dual Mode

5. Dual prf's of 10 to 2000 pps vhf and 80 to 120 pps uhf integrally related, with dual pulse lengths of 5 to 1000 μsec vhf and 100 μsec uhf.

If the uhf transmitter in the future is equipped with a full variable-pulse-length, variable-prf capability, the uhf radar could then operate with a prf of 10 to 2000 pps and a 5 to 1000 μsec pulse length, in conjunction with the same or different prf's and a 100-μsec pulse length for the vhf radar. Then the uhf triggers would be derived from the pulse length generator, whereas the vhf triggers would be supplied by the pulse centering control.

In the dual-prf, dual-pulse-length operation of the two radars, the time delays generated in the pulse centering control and pulse length generator operate partially in coincidence and partially in sequence. The same result could be achieved by a common time-delay generator of greater capacity instead of by the separate smaller-capacity time-delay generators in the two units. However, the separate-time-delay approach permits the partial system operation, noted above, using either the pulse length generator or the pulse centering control alone.

## SYSTEM CONFIGURATION

The synchronizer system is divided into four subsystems or units as shown in the system block diagram in Fig. 5. The units of the system are (a) prf generator, (b) pulse centering control, (c) pulse length generator, and (d) range tracker.

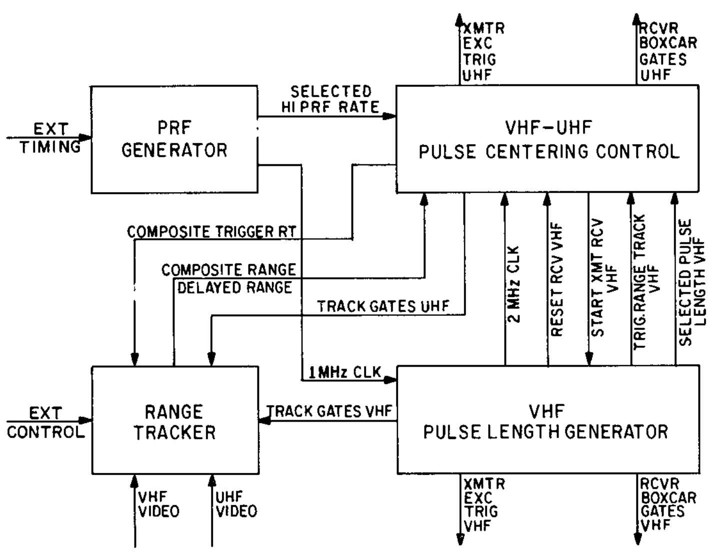



Fig. 5 - System block diagram for the dual-prf and dual-pulse-length synchronization of vhf and and uhf radar

The following description of the synchronizer operation will be in terms of the existing RCR system, which has a variable-pulse-length, variable-prf vhf transmitter and a fixed-pulse-length, limited-prf-variability uhf transmitter. To facilitate cross referencing between diagrams, in this description, numbers have been assigned to the various pulses that occur. Some of these numbers have the letter suffixes u or v, the former indicating that the pulse is for the uhf system, the latter that it is for the vhf.

## PRF Generator

The prf generator supplies a variable output trigger rate from an internal crystal oscillator or from an external source, as shown in Fig. 6. The internal oscillator operates at 1 MHz. It also serves as the master clock source for the other units of the synchronizer. The oscillator output is decade-divided down to trigger rates of 10,000, 1000, and 100 pps. One of these rates is selected as an input to an output rate divider, which provides a selected division by any integer between 1 and 63 to form the output trigger rate. The external timing signal can be inserted as an input to the output rate divider in place of the decade divider outputs. The output prf is selected by this division procedure to give a choice of about 120 discrete internally generated prf's within the range of 10 to 2000 pps. If dual-prf operation is desired, the higher of the two prf's is the one that must be selected in the prf generator. With the present RCR system, this means that the selected prf must be at least 80 pps, since that is the lowest prf of the uhf radar. The resultant prf is designated the high prf.

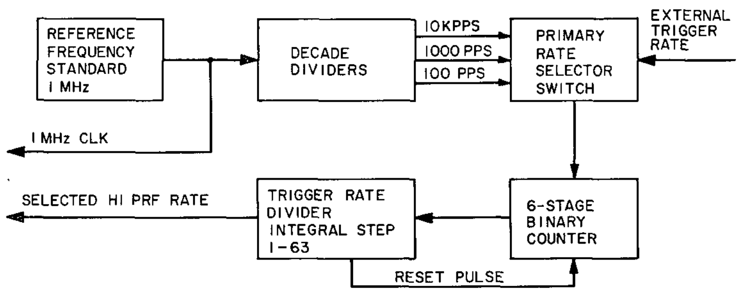



Fig. 6 - Block diagram of prf generator

## Pulse Centering Control

In the pulse centering control unit, Fig. 7, a low prf is generated as an integral submultiple of the input high prf by the sync mode control circuit. The two prf pulse trains are then separated in this circuit into coincident pulses for controlling the triggering sequence for the two radars and intermediate pulses for triggering the radar selected for high prf. Pulse periods following the coincident pulses are designated either coincident-short-pulse when the vhf radar has the shorter pulse or coincident-long-pulse when the vhf radar has a pulse equal to or longer than the uhf pulse. This triggering sequence during the coincident period is determined by the vhf selected pulse-length signal from the pulse length generator to the sync mode control circuit. Pulse periods following the intermediate pulses are designated either intermediate vhf or intermediate uhf. The radar so designated then operates at the high prf, whereas the other radar operates at the low prf.

During the coincident period when both vhf and uhf radars are triggered, the time delay generator of the pulse centering control generates delayed triggers to maintain alignment of the transmitter- and receiver-gating pulse centers between the two radars. The amount of delay between basic triggers during the coincident pulse period of the two radars is controlled by the difference of their pulse lengths as defined by the delayed selected pulse-length signal from the sync mode control circuit.

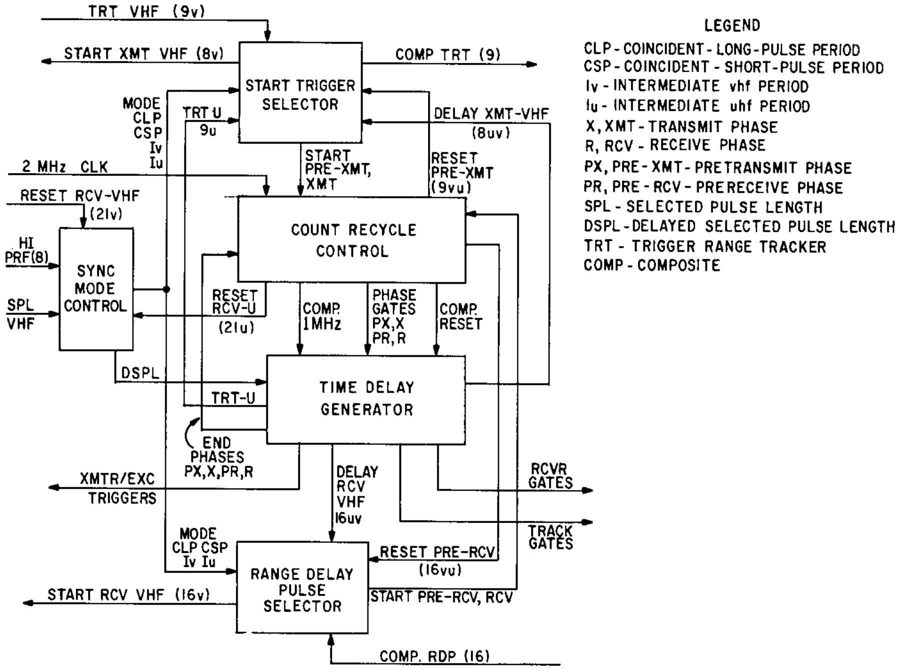



Fig. 7 - Block diagram of pulse centering control unit

Each pulse period is divided into transmit and receive phases. The start trigger selector of the pulse centering control provides the switching of the initial prf trigger (pulse 8) so that the transmit phase of the longer-pulse radar is triggered first during the coincident period. Then delayed triggers are generated and separately switched by the start trigger selector to start the transmit phase of the shorter-pulse radar and also to trigger the range tracker (pulse 9). The range-delayed pulse from the tracker (pulse 16) is then switched by the range-delay pulse selector to start the receive phase of the longer-pulse radar. During this initial receive phase, a delayed pulse is generated to start the receive phase of the shorter-pulse radar.

The initial triggers of the intermediate pulse periods are switched by the start trigger selector to start the transmit phase of the higher prf radar. A delayed trigger is then generated and multiplexed onto the composite trigger line to the range tracker. The composite range-delayed pulse (16) from the tracker is then demultiplexed by the range-delay pulse selector to start the intermediate receive phase of the higher-prf radar.

The pulse centering control thus provides the distribution of internally or externally generated initial and delayed triggers to: (a) start vhf transmit phase, (b) start uhf transmit phase, (c) trigger range tracker, (d) start vhf receive phase, and (e) start uhf receive phase. The various trigger pulses for coincident and intermediate pulse periods are multiplexed on separate control lines to initiate these five functions. It is important to note that only the transmit and receive phases for the fixed-pulse-length radar (uhf) are generated in the pulse centering control. The transmit and receive phases for the variable-pulse-length radar (vhf) are generated in the pulse length generator from input triggers shown as start-transmit-receive-vhf in Fig. 5 and as pulse 8v and pulse 16v in Fig. 7. The reset-receive-phase triggers for uhf and vhf pulses 21u and 21v on Fig. 7, generated in the pulse centering control and pulse length generator, respectively, are used to terminate the coincident and intermediate prf period gates. These gates serve as control elements of the five trigger switching functions in the pulse centering control.

During the uhf transmit phase, the time-delay generator of the pulse centering control supplies trigger to the uhf transmitter and rf exciter. A range-tracker trigger pulse is also generated and is switched onto the composite range-tracker trigger line during coincident periods when the uhf radar is operating with the longer-pulse length or during intermediate periods when the uhf radar is operating with the higher prf. During the uhf receive phase, narrow and wide receiver boxcar gates are generated as well as the early and late range-tracking gates. Compatible time delays for transmit and receive phases are insured by the delay of all pulse-length changes by the sync mode control until the uhf receive phase is completed.

The count-recycle control circuit supplies the timing pulses and gates for operating the time-delay generator through four separate phases of pretransmit, transmit, prereceive, and receive. Indicators are activated by the phase gates for operator monitoring. The time-delay generator is reset after each phase by the count-recycle control by combining end-of-phase pulses on to a composite reset line. The elements of the time-delay generator are identical to those used in the pulse length generator and shown in greater detail in Fig. 8.

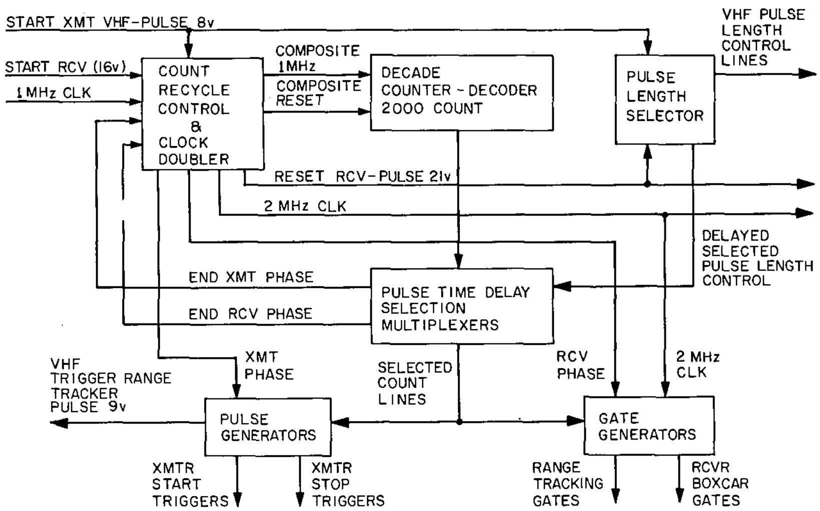



Fig. 8 - Block diagram of pulse length generator

## Pulse Length Generator

The pulse length generator in Fig. 8 has an operating cycle which consists of a transmit phase and a receive phase separately triggered by the pulse centering control unit for each pulse period of the vhf radar. These phase triggers are derived initially from the prf generator and the range tracker, respectively, and are designated as pulses 8v and 16v on the block diagram of Fig. 8. Time delays may be switched in these trigger lines to the pulse length generator by the pulse centering control during coincident-short-pulse periods.

During the transmit phase the pulse length generator supplies: (a) a range-tracker trigger pulse (9v), which also serves as a delayed trigger for uhf transmit in coincident-long-pulse mode, and (b) a sequence of six pulses which control the pulse lengths of the transmitter and rf exciter. The available vhf pulse lengths are 5, 10, 20, 50, 100, 200, 500, and 1000 μsec. The selected vhf pulse length controls all time-delay generation in the pulse length generator and in the pulse centering control. Pulse lengths from 5 to 50 μsec are designated short pulse, whereas pulse lengths from 100 to 1000 μsec are designated long pulse.

During the receive phase, generated after a selected range delay, the pulse length generator supplies (a) variable-width pulses proportional to the selected pulse length for automatic range tracking and (b) fixed and proportional-width pulses for gating the high- and low-level receiver boxcar channels. Also, an internally generated reset-vhf-receive-phase pulse, designated pulse 21v on Figs. 7 and 8, is sent to the pulse centering control to signify the end of the used portion of the pulse period.

The pulse length generator consists basically of a two-phase count-recycle control section, a pulse-length selector, and a time-delay generator. Composite 1-MHz timing pulses enter the counter-decoder portion of the time delay generator during the transmit and receive phases of each vhf prf period. The required pulse time delays are selected for each pulse length by multiplexers at the decoder outputs. The multiplexers drive the output pulse and gate generators which are activated by the required transmit or receive phase signal. Reset pulses are generated by the count-recycle control after the end of each phase and are sent to the counter-decoder over the composite reset line. The pulse length generator also contains a rate doubler circuit to convert the crystal-controlled 1-MHz clock signal from the prf generator to a 2-MHz clock for timing the gate generators in the count-recycle control and the time-delay generator. The 2-MHz clock is also sent to the pulse centering control for controlling similar functions. However, both the pulse length generator and pulse centering control have internal clock sources for independent or emergency operation. As shown in Fig. 8, the multiplexers are controlled by delayed selected pulse-length-control lines from the pulse-length selector. Hence, all pulse-length changes take effect only after the end of the receive phase of the current pulse period.

## Range Tracker

The digital range tracker, Fig. 9, is activated by the composite trigger from the pulse centering control and generates controlled time delays for triggering the synchronizer initial receive phase. The tracker operates at any prf or pulse length, and control is switched between the higher-prf trigger during the intermediate period and the longer-pulse-length trigger during the coincident period as designated by the pulse centering control. The higher-prf and longer-pulse-length triggers may be for the same or different radars.

The time delay generated by the tracker can be programmed locally by the operator or by external control signals. A ten-to-one vernier range control is available within six overlapping range scales from 4 to 8000 naut mi. The vernier range control varies the output frequency of a voltage-controlled oscillator from 100 kHz to 1 MHz. This oscillator drives a 14-stage counter as shown in Fig. 9. One of six discrete counts is selected by counter output gates, which are activated by the selected range-scale signal. Both the range vernier and scale-control signals can be generated internally or supplied from an external source.

Monitor lights are provided on the tracker to indicate the selected vhf pulse length and the generation of the transmit and receive phases of the synchronizer cycle for both vhf and uhf radars. If the receive-phase indicators are not activated, it is indicated to the operator that the selected range delay may be too large for the selected prf interpulse period. Proper operation would be restored by switching to local control and then switching to a lower range scale.

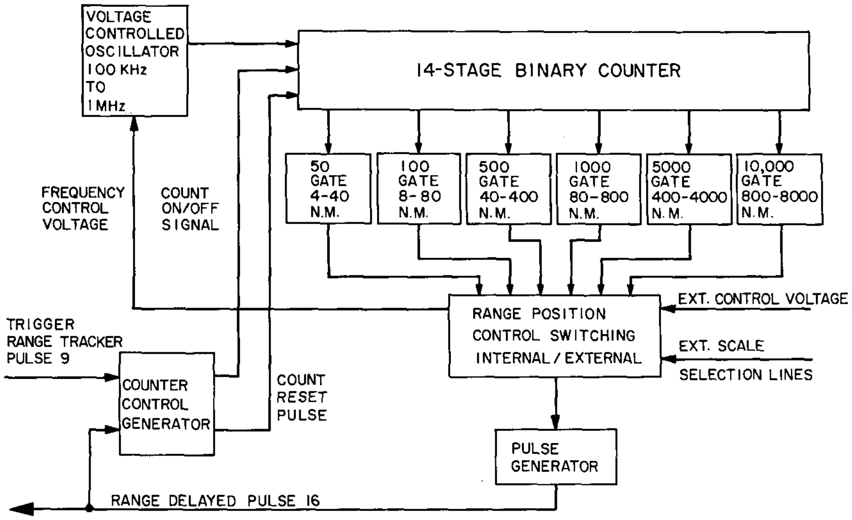



Fig. 9 - Block diagram of range tracker

The present range tracker configuration shown in Fig. 9 does not have automatic tracking capability, although in Fig. 5 the dual vhf-uhf early and late tracking gates from the pulse length generator and pulse centering control are shown supplied to the unit. The addition of a bidirectional range follow up counter and a parallel fixed-frequency counter-register is planned to provide dual automatic tracking. Dual tracking control provides switching such that the longer-pulse tracking gates take effect during the coincident period, whereas the high-prf tracking gates take effect during the intermediate period. Thus, the tracking gates for vhf are supplied to the tracker only during the pulse period in which the vhf range-tracker trigger is supplied to the composite trigger-range-tracker line. The same criterion holds for the transmission of the uhf tracking gates only during the period in which the uhf range-tracker trigger is supplied.

## TRIGGER SWITCHING

The following two sections provide a functional representation of the start-trigger and range-delay pulse selector circuits of the pulse centering control. These circuits perform the five trigger-switching functions previously discussed, which initiate the transmit and receive phases and trigger the range tracker. Additionally, pretransmit and prereceive phases are generated to serialize time delays supplied by the pulse length generator with those of the pulse centering control. This procedure is used to produce the long time delays required in the coincident-long-pulse triggering mode.

### Start Trigger

A functional diagram of the synchronizer start-trigger switching is given in Fig. 10. The input signals are (a) the coincident and intermediate pulses, (b) the vhf and uhf trigger for the range tracker, and (c) the vhf pulse-length control signals. The switch has three poles and four positions to supply the three required output triggers in four possible modes of prf and pulse-length operation. In two of the modes, time delays are inserted between the input signal and the switch positions. The output triggers are (a) the start-vhf-transmit-phase trigger, (b) the start-uhf-transmit-phase trigger, and (c) the composite trigger to the range tracker, which are labeled 8v, 8u and 9, respectively.

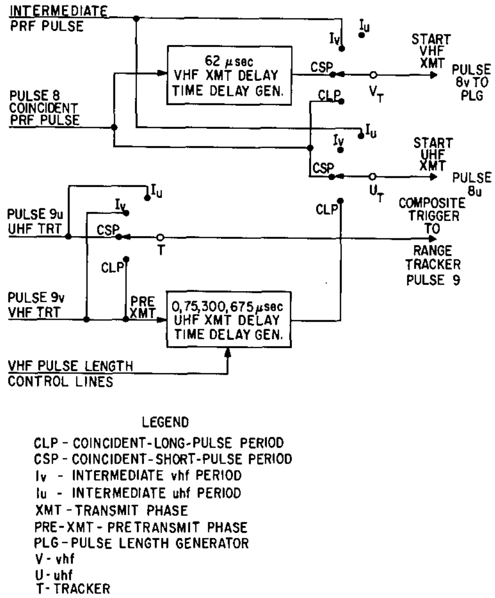



Fig. 10 - Functional diagram of start trigger switching for transmit phase and range-tracker initiation

The intermediate pulse is sent to two mutually exclusive terminals of the switch designated Iv and Iu, so that the intermediate pulse is used to trigger either the start-vhf-transmit phase or start-uhf-transmit phase. The radar system designated to receive the intermediate pulse will then be operating at the high prf.

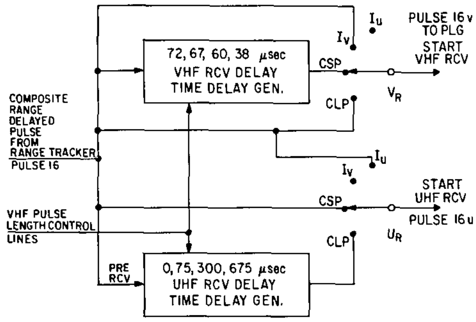
The coincident pulse is fed directly to the coincident-short-pulse terminal of the start-uhf-transmit Ut section of the switch. Coincident pulse 8 is also fed to the vhf-transmit delay where it is delayed 62 μsec and sent to the coincident-short-pulse terminal of the start-vhf-transmit Vt section of the switch. This delayed pulse is designated as pulse 8uv on the pulse centering control diagram, Fig. 7. Hence, the uhf-transmit phase is started 62 μsec ahead of the vhf-transmit phase of the synchronizing cycle in the coincident-short-pulse mode. Additional delays are inserted after the start of the vhf and uhf transmit phases so that the actual transmitted pulses are centered.

Note that coincident pulse 8 also feeds the coincident-long-pulse terminal of the Vt section of the switch so that the start-vhf-transmit phase is triggered immediately in this mode. During the vhf-transmit phase, the vhf range-tracker trigger pulse 9v is generated and is fed to the uhf-transmit delay. Depending on the selected vhf pulse length, a delay of 0, 75, 300, or 675 μsec is inserted, and the delayed output pulse is fed to the coincident-long-pulse terminal of the U section of the switch. The above delays, generated in the pretransmit phase of the pulse centering control, become additive to the internal pulse-length-dependent delays of the vhf range-tracker trigger supplied by the pulse length generator to give the total delay between start-vhf-transmit and start-uhf-transmit triggers.

The range-tracker trigger pulses, supplied by the pulse centering control and pulse length generator (pulses 9u and 9v), are fed to the coincident-short-pulse intermediate uhf and the coincident-long-pulse intermediate vhf terminals, respectively, of the mode selector switch section T. In the coincident-short-pulse mode, the uhf range-tracker trigger is generated prior to the vhf range-tracker trigger, whereas in the coincident-long-pulse mode the vhf range-tracker trigger is generated first. The switch always picks up the range-tracker trigger from the longer-pulse radar during the coincident period, and then switches to the higher-prf radar for the range-tracker trigger during the intermediate period. The switch output then becomes the composite trigger to the range tracker.

## Range-Delayed Pulse

The composite delayed output pulse from the range tracker at the selected range is switched through the mode selector to form the start-vhf-receive and start-uhf-receive triggers. These triggers are supplied from the Vr and Ur sections of the switch as shown in Fig. 11.




LEGEND
CLP - COINCIDENT-LONG-PULSE PERIOD
CSP - COINCIDENT-SHORT-PULSE PERIOD
Iv - INTERMEDIATE vhf PERIOD
Iu - INTERMEDIATE uhf PERIOD
RCV - RECEIVE PHASE
PRE-RCV - PRERECEIVE PHASE
PLG - PULSE LENGTH GENERATOR
VR - vhf RECEIVE
UR - uhf RECEIVE

Fig. 11 - Functional diagram of range-delayed-output pulse switching for receive-phase initiation

The composite range-delayed pulse is fed directly to either the intermediate vhf (Iv) or intermediate uhf (Iu) terminal of the switch to start the vhf or the uhf receive phase. The switch positions of Vr and Ur are in synchronism with those shown on the start-trigger-switching diagram, Fig. 10, so that if the switch is in Iv at the start-transmit time, it will remain in the Iv position for the duration of the pulse period. The range-delayed pulse also is connected directly to either the coincident long pulse of the Vr section or to the coincident short pulse of the Ur section to start either vhf or uhf receive phase immediately during the coincident period.

The coincident-short-pulse terminal of Vr and the coincident-long-pulse terminals of Ur are fed from the delay circuits labeled vhf-receive delay and uhf-receive delay, respectively. These delay circuits are triggered by the composite range-delayed pulse and are selected by the vhf pulse-length-control lines. The vhf-receive delays are 72, 67, 60, and 38 μsec for vhf pulse lengths of 5, 10, 20, and 50 μsec, respectively. The vhf-receive delays change with pulse length to compensate for the delay in generation of the vhf range-tracker trigger from the start-vhf-transmit trigger. The vhf-receive-delay pulse is designated pulse 16uv in Fig. 7. The uhf-receive delays are 0, 75, 300, and 675 μsec for vhf pulse lengths of 100, 200, 500, and 1000 μsec. The uhf-receive delays generated during the prereceive phase are the same as the delays used prior to the uhf-transmit phase, since the transmit delays are triggered by the vhf range-tracker trigger. The uhf-receive-delay pulse is designated as the reset prereceive pulse 16vu on Fig. 7.

## SYNCHRONIZER TIMING SEQUENCE

The sequence of pulses generated during a complete synchronizer cycle varies to some extent according to the operating mode of the pulse period. Hence, a general case of dual-prf operation is shown in Fig. 12 spanning several pulse periods. Then more detailed views of sequential intermediate and coincident pulse periods are shown in Figs. 13 and 14. Finally, the pulses generated during the transmit and receive phases of the coincident period are shown for two different pulse lengths.

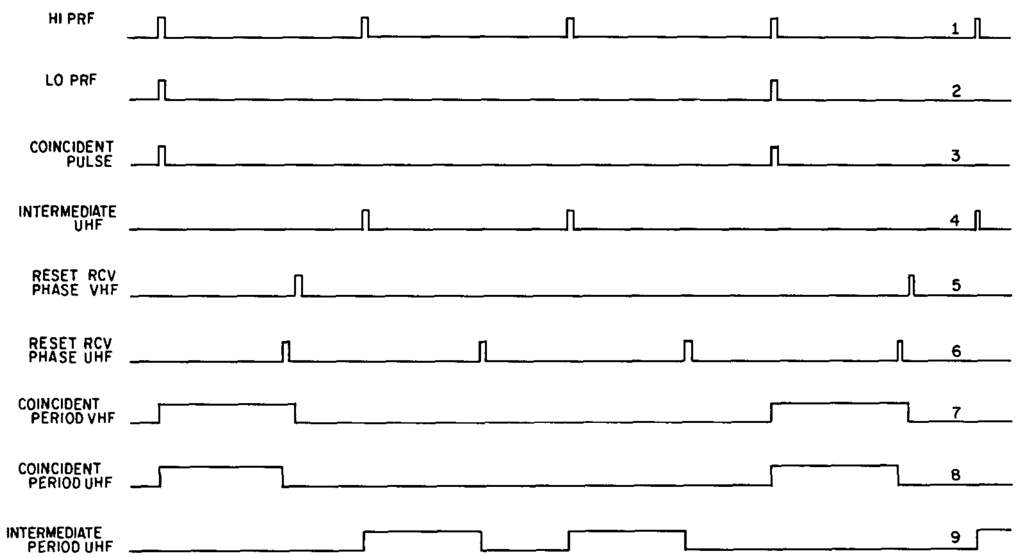



Fig. 12 - Timing diagram for dual-prf operation in which the uhf radar is designated for the higher prf

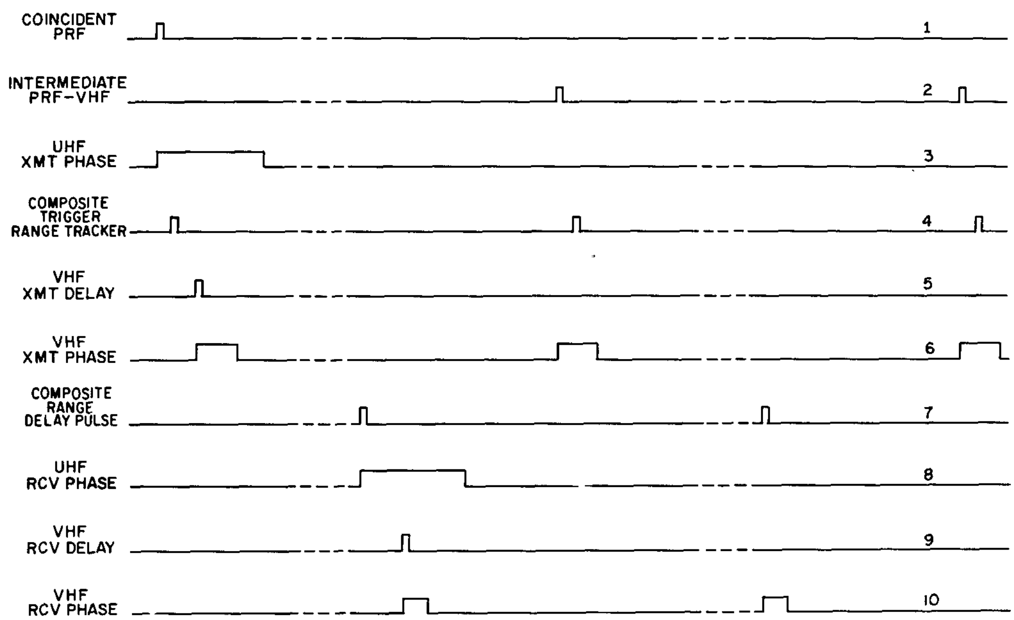



Fig. 13 - Timing diagram for dual-prf and dual-pulse-length operation in which the vhf radar is designated for the higher prf and shorter pulse length

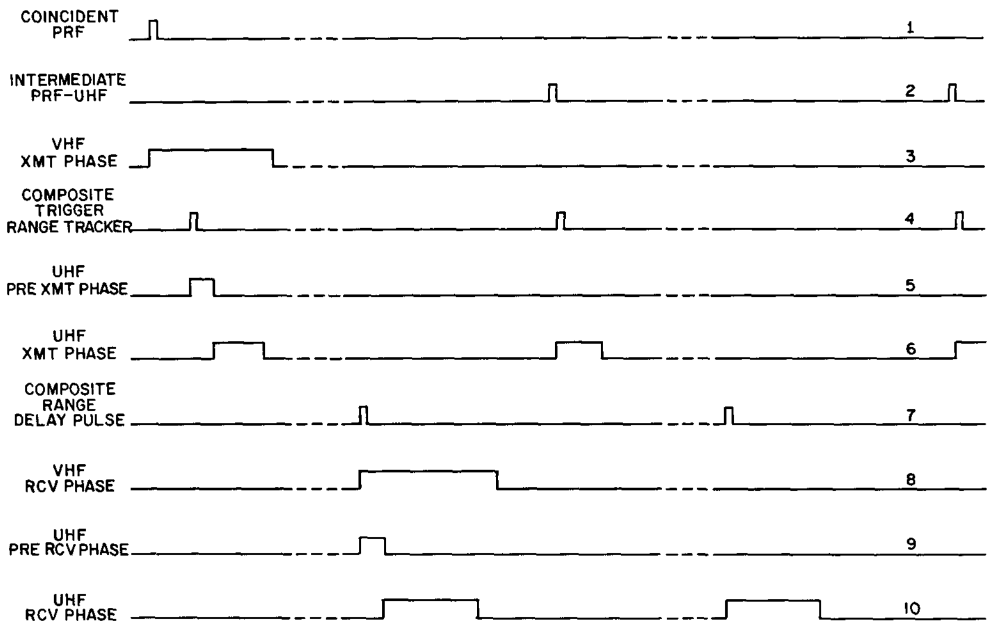



Fig. 14 - Timing diagram for dual-prf and dual-pulse-length operation in which the vhf radar is designated for the lower prf and longer pulse length

Dual-PRF, Dual-Pulse-Length Operation

The dual-prf timing diagram, Fig. 12, shows the initial high prf and a derived low prf (line 2) of one-third the high prf. The coincident pulses (line 3) are generated when the high-prf and low-prf pulses coincide in time, whereas the intermediate pulses are generated by anticoincidence of the high- and low-prf pulses. For the case shown the intermediate period has been designated for uhf (line 4).

The fifth line shows the reset-receive pulse for vhf occurring at the same rate as the coincident pulse but prior to the adjacent intermediate pulse (line 4). The reset-receive-vhf trigger terminates the coincident-pulse-period vhf gate shown on line 7.

However, the reset-receive-phase trigger for uhf (line 6) occurs at the high rate, since it is effectively generated from both the coincident and intermediate pulses. This pulse is used to terminate both the coincident-pulse-period and the intermediate-pulse-period uhf gates shown on lines 8 and 9, respectively.

An expanded view of the dual-prf, dual-pulse-length operation is shown in Fig. 13 for the short-pulse-vhf mode. In this case, the high-prf vhf mode is also represented. No absolute time scale is shown although the pulse positions are in proper relationship for the modes represented.

The coincident pulse (line 1) triggers the uhf-transmit phase shown in line 3. During this phase a uhf range-tracker trigger is generated and placed on the composite range-tracker trigger (line 4). Subsequently, a vhf-transmit delay is generated (line 5), which triggers the vhf-transmit phase (line 6). All these events occur during the uhf-transmit phase (line 3).

An intermediate pulse (line 2) triggers the vhf-transmit phase (line 6), directly during the intermediate period, however. Thus, the vhf effectively operates at a staggered high prf, receiving a delayed trigger during the coincident period which is then multiplexed with the direct undelayed trigger during the intermediate period. A vhf range-tracker trigger is generated during this period and then multiplexed onto the composite range-tracker trigger (line 4). The range tracker also effectively receives a staggered triggering rate by this procedure. Triggers for the third pulse period are shown on the right side of the figure.

The composite range-delay pulse (line 7) initiates the uhf-receive phase (line 8) during the coincident period and the vhf-receive phase (line 10) during the intermediate period. A delayed trigger is generated during the uhf-receive phase and is designated vhf-receive delay (line 9). This pulse triggers the vhf-receive phase (line 10) during the coincident period.

The dual-prf, long-pulse-mode timing relationships, shown in Fig. 14, are similar to those described above except that the functions of the prf triggers are interchanged between vhf and uhf. Also the uhf transmit and receive phases are delayed during the coincident period by the generation of pretransmit and prereceive phases, respectively.

### Transmit-Receive Phase

The diagrams of the next series show the alignment of pulses generated during the transmit and receive phases. Pulse numbers shown at the left of these figures may be used to cross reference the pulses generated correspondingly for vhf and uhf and to previous block and switching diagrams. Time delays are shown at the right of each line.

Pulses supplied by the pulse-length generator are shown for a vhf pulse length of 10 μsec in Fig. 15. The transmit phase is triggered by pulse 8, which is the initial or delayed pulse from the pulse centering control and is used to trigger a monitor pulse generator (not shown). For a 10-μsec pulse length, pulse 9 follows the transmitter-start pretrigger pulse 10. Pulses 11 and 12, which turn on the exciter and modulator sequentially, follow pulse 10 by 5 and 10 μsec, respectively. The transmitter-stop trigger sequence consists of pulses 12, 14, and 15. The time separation between pulses 12 and 14, which are the on and off triggers to the modulator, at times 23 and 33, determines the actual transmitted pulse length. Pulse 15, which turns off the rf exciter, also serves as an end-of-transmit-phase signal at time 38.

Pulses 16 through 21 are generated during the receive phase when triggered by pulse 16. Note that pulse 16 is shown as coincident in time with pulse 9, which is the vhf trigger for the range tracker. This condition represents a zero-range delay, for illustrative purposes, to show the alignment of the tracking gates (pulses 16 to 19 and 19 to 21) with the transmitted pulse 12 to 14. Other receive-phase pulses are shown on the right side of the diagram together with a receiver output pulse which is equivalent in width to the transmitted pulse 12 to 14 and shown from time 8 to 18. The early track gate (pulse 16 to 19) starts 5 μsec after the receive-phase trigger pulse 16 at all pulse lengths. Pulse 19, which is the end of the early gate and the start of the late gate, represents the pulse center. The low-level receiver boxcar gate (pulse 17 to 20) is always equal to one-half the pulse length, whereas the high-level boxcar gate (pulse 18) is always equal to 5 μsec. Both boxcar gates are centered over pulse 19 at time 13 on the receive scale.

The time scale on the vhf-transmit-receive timing diagram, Fig. 15, described above uses the transmit- and receive-phase start triggers as the zero-time reference points separately for each phase. The cumulative time delay for pulse times during the receive phase is the sum of the delay to pulse 9 and the differential delay of the pulses 16 to 19 shown on the right side of the diagram.

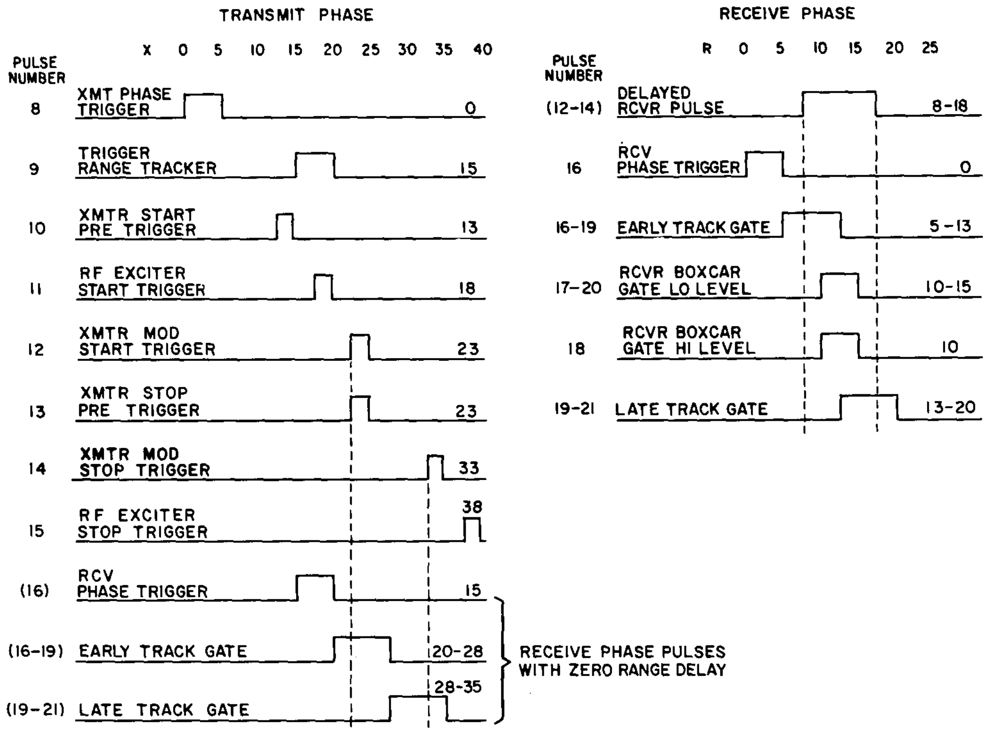



Fig. 15 - Timing diagram for transmit and receive phases for a 10-μsec vhf pulse length

The vhf-uhf pulse timing for a coincident pulse period is shown in Figs. 16 and 17 for two vhf pulse lengths. Corresponding pulse numbers for vhf and uhf carry a v or a u designation for cross referencing to the previously discussed vhf transmit-receive timing diagram. However, only selected pulse numbers are shown, sufficient to reflect the alignment of pulse centers. The time delays for each pulse are also shown on the right side of the diagrams.

For a vhf pulse length of 10 μsec on Fig. 16, the transmit-phase trigger for uhf (8u) starts first at zero time. The uhf range-delayed pulse (9u) is generated next, and the uhf transmitted pulse is generated from 40 to 140 μsec to have its pulse center at 90 μsec. The vhf-transmit group starts 62 μsec late so that the vhf transmitted pulse occurs from 85 to 95 to have a common pulse center with the uhf pulse.

The receive-phase timing pulses are initiated by pulse 16u, at time 10, which is shown coincident in time with the uhf range-tracker trigger pulse 9u. The center of the boxcar gate pulses 17 to 20u and 18u coincide with the start of the late tracking gates 19 to 21u at time 90, which is the pulse center. Pulse 16uv, generated 67 μsec after pulse 16u, a total delay of 77 μsec, is the delayed trigger which starts the vhf-receive phase. The time delays from the vhf-receive-phase trigger to the pulse numbers 17 to 20v, 18v, and 19 to 21v are the same as those shown on the vhf transmit-receive diagram in Fig. 15 for these same pulses. The pulse center, at time 90 in this case, occurs 13 μsec after the start of the receive phase.

For a vhf pulse length of 500 μsec, shown in Fig. 17, pulse 8v starts the vhf-transmit phase at zero time and the transmitted pulse is generated from time 390 to 890. Pulse 9vu is the equivalent uhf start-transmit-phase trigger which is generated by the pretransmit

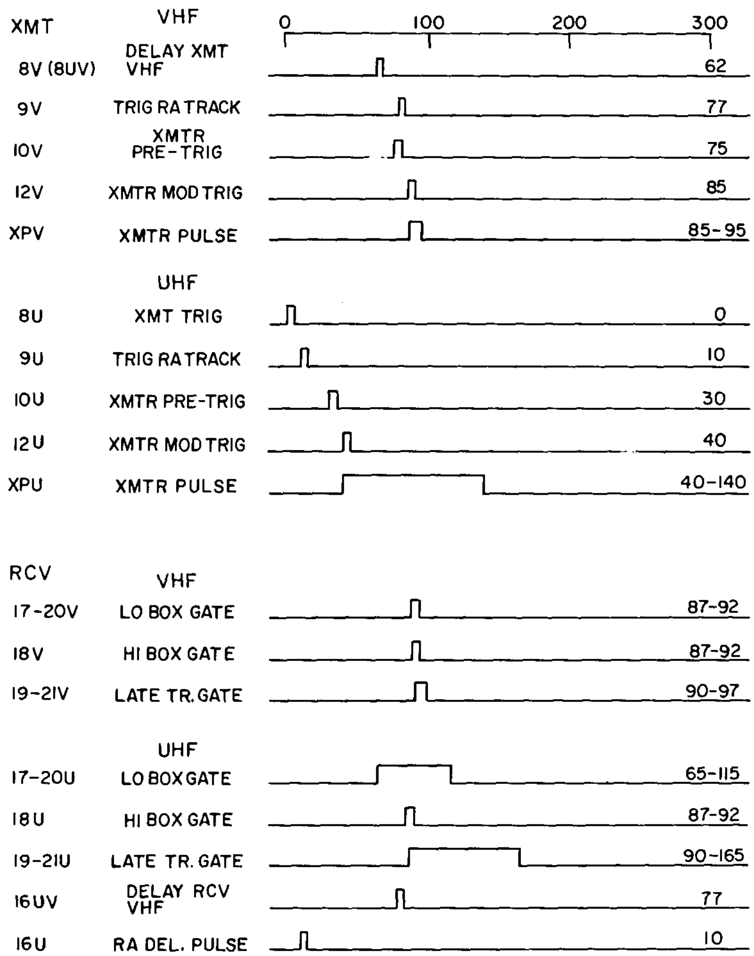



Fig. 16 - Timing diagram for the coincident-short-pulse period with a vhf pulse length of 10 $\mu$sec

phase delay 300 $\mu$sec from the vhf range-tracker trigger pulse 9v. The resultant uhf transmitted pulse is then generated from 590 to 690. The common pulse center occurs at time 640.

Pulse 16v, shown as time coincident with 9v, starts the receive phase in this case with the resultant boxcar gates 17 to 20v and 18v centered over the start of 19 to 21v at the pulse center. Pulse 16vu is generated by the prereceive phase 300 $\mu$sec after 16v and starts the uhf-receive phase. The uhf boxcar and tracking gates are shown as pulses 17 to 20u, 18u, 19 to 21u, and 16 to 19u with the pulse center at 640 as was the case for vhf.

In relating the above diagrams to the dual-prf, dual-pulse-length timing diagrams, the transmit phase covers the time from pulse 8 to 15, whereas the receive phase covers the time from pulse 16 to 21. Also, the constant-range reference point for all pulse lengths is the transmitted pulse center and the tracking gates' common point 19. The time difference between these two points is equal to the range delay generated between pulse 9 and pulse 16 and does not change as the pulse length is switched. Therefore, the range tracking is not altered in passing from a vhf long or short pulse width to the constant-width uhf pulse on successive pulse periods or when the vhf pulse length is changed. Also

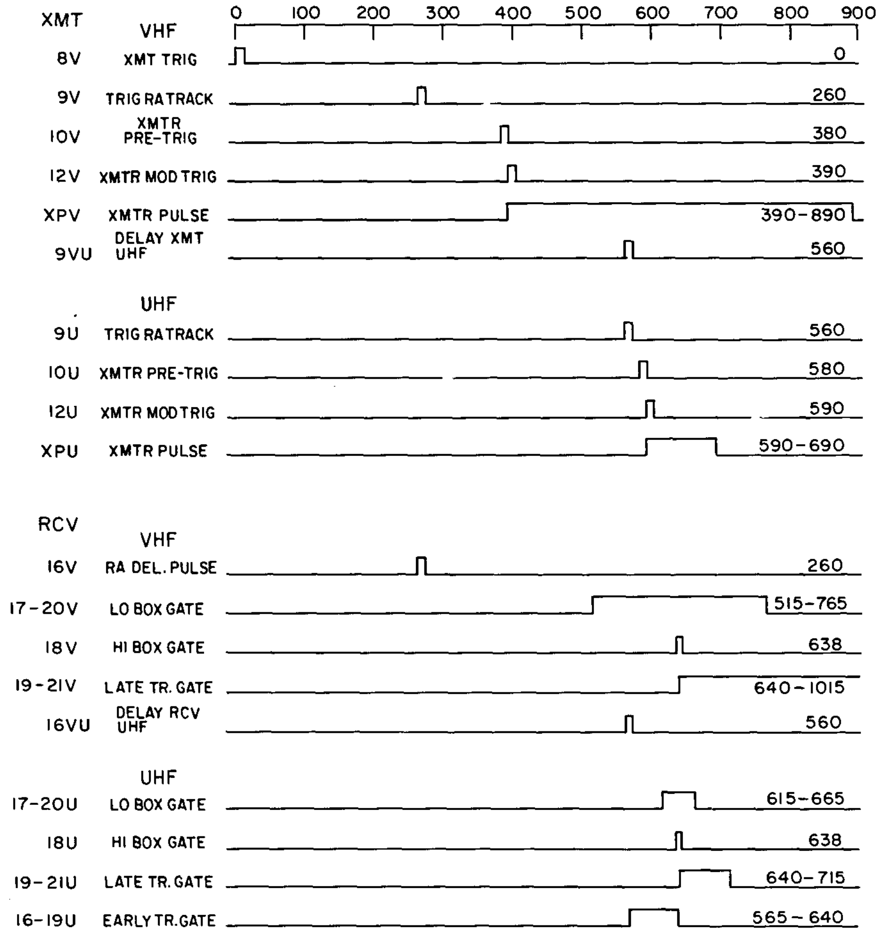



Fig. 17 - Timing diagram for the coincident-long-pulse period with a vhf pulse length of 500 $\mu$sec

the composite range-tracker trigger and range-delayed pulses are used for oscilloscope monitoring, range measurement, and data-acquisition triggering.

## FUTURE PLANS

Improvements to or modifications of the dual-prf, dual-pulse-length synchronizing system will depend on working experience with the synchronizer in the radar system and on whether they are required by new research applications. As has been noted, changes can be incorporated into various units of the system while still maintaining partial synchronizer operation. It is expected that the following additions will be made within the next 18 months in the order listed.

1. The range tracker will be equipped with automatic-tracking capability by installing a range-input counter-register in parallel with a bidirectional range-correction counter. Operation will be such that if the early and late tracking gates are centered around the video signal, the input and correction counters will read the same and no correction in range-delay pulse position is made. If the early and late gates are off-centered with respect to the radar video, a different range value is generated by the

correction counter which, when inserted in the input counter register, will cause a repositioning of the range-delay pulse in the next pulse period. This automatic tracking change will permit rapid pulse-to-pulse range comparisons between the two radars operating at different pulse lengths. In the dual-prf, dual-pulse-length mode, tracking control switches between the long-pulse radar to the short-pulse radar from coincident period to intermediate period.

2. Monitor timing phase circuitry will be installed in the pulse length generator and pulse centering control. This change will provide timing pulses for generating and sampling system-performance monitor pulses on a pulse-to-pulse basis at both vhf and uhf. The monitor phase will follow the receive phase and will terminate prior to the range-tracker trigger pulse of the transmit phase in the next pulse period. The monitor pulses will be generated with the same pulse lengths as the transmitter pulse for the two radars.

3. Variable-pulse-length selector circuitry will be installed in the pulse centering control unit. This change will permit expansion of the dual-pulse-length capability of the system such that pulse lengths other than 100 $\mu$sec can be used in conjunction with the eight pulse lengths from 5 to 1000 $\mu$sec supplied by the pulse length generator.

The above functions can be incorporated into the synchronizer system as additional separate units rather than as modifications to existing units. This approach costs more in hardware but results in greater operational availability of the full capabilities of the present system.