Image Cover Sheet

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TITLE

EARS IF RECEIVERS SWITCHING CIRCUIT

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EARS IF RECEIVERS SWITCHING CIRCUIT

FINAL REPORT

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SUMMARY

This report presents the final test results for the IF receivers following the addition of switches to the input section of each of the sixteen IF receiver boards used in the Experimental Array Radar System (EARS). The EARS has two front end receiver arrays, a horizontal array and a vertical array. Each array has eight channels, with a 60 megahertz IF output from the mixers. Two similar IF receiver units are rack mounted in the EARS lab, one for each array.

The addition of fast RF switches to the IF receiver inputs allows the inputs to be disconnected from the front end. The purpose for adding these switches is to correct a possible oscillation problem in the IF receiver circuits. This oscillation has been observed when the IF receiver attenuators are set for any value from zero to eight decibels, inclusive. Attenuator settings above eight decibels do not cause oscillations.

The oscillations are caused by the initial saturation level radar return, known as the 'main bang'. It is the first signal received by the arrays following the application of the enable gate to the TWTA. Its amplitude is much greater than any returns from the targets of interest, at ranges from about 500 metres to twenty kilometres.

The switches are Daico model DS0699 GaAs SPST non-reflective RF switches. They use a small five pin TO-8 metal can package. They are mounted directly on each IF receiver board, beside the first input amplifier. The switches are controlled by a TTL input signal. This signal must be supplied by the Master Timing Unit (MTU) to blank the 'main bang'. The duration of the 'main bang' signal is about two microseconds. A single TTL line from the MTU controls all sixteen switches in parallel.

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LIST OF FIGURES

1.0 INTRODUCTION

This document is the Final Report for the intermediate frequency (IF) receivers modifications work. This task is covered under section 2.2 of the Statement of Work for the W7714-5-9868 contract.

There are two eight channel IF receivers in the EARS. They are functionally identical, with similar interconnections, although there are minor differences. The Side-Lobe Canceller (SLC), or horizontal array, IF receiver was designed and built first. The Vertical Array IF receiver was built about one year later. It has many minor design improvements over the SLC receiver. Whenever possible, these improvements were also implemented on the SLC IF receiver, therefore the electrical performance of each receiver is identical.

The first initial energy into the front end horns and receivers is caused by returns from the sidelobes of the transmitting antenna impinging the front end structure and building. This energy is known as the 'main bang' and has a typical duration of twice the transmitted pulse width. It is usually much larger in amplitude than any of the distant target returns. The main bang amplitude into the IF receiver is limited by the front end components, particularly the maximum saturated output of the mixers.

The main bang is not a problem when the IF receiver attenuators are set to about ten decibels or greater. This attenuates the level of the main bang enough so that it does not cause the receiver components to react abnormally. It was discovered that when the SLC IF receiver attenuators were set to eight decibels, or less, an oscillation problem occurred. It is not known which component is oscillating but it is after the attenuator. This oscillation has not been observed on the vertical array IF receiver. The oscillation begins during the main bang and continues for at least 50 microseconds, affecting the target returns during that period.

The best way to ensure that the IF receivers do not oscillate is to remove the main bang signal. This can be done by disconnecting the IF receiver inputs from the front end mixers during the main bang period. Fast RF switches are used to remove the inputs so the main bang is not seen by the receivers. Control of these switches is from the MTU.

A Design Specification Document (DSD) was written in May 1995 for this task. It contains the detailed design information for the addition of the switches. The information contained in the DSD will not be repeated here. This final report is in addition to the DSD. It has been written after all sixteen switches have been installed, tested and demonstrated. The reader should be familiar with the DSD and the IF receivers before reading this report. The switches were added and connected exactly as described in the DSD. There were no problems encountered.

2.0 MANUAL CONTROL MODIFICATIONS

Each receiver has an external manual control box. These boxes have many toggle switches on them to control the attenuators, IF test input switches, phase shifter sources and calibration switches. In addition, one of the manual control boxes can also control the phase shifters. This box has more switches on it than the other. It was built first and is the main box used when only one IF receiver is being tested. The control boxes are connected to the DB-25 connections at the rear of each IF receiver, using long cables. This is normally where the system controller and MTU would be connected to the receivers.

The main manual control box was modified so it could be used to test and control the switches. Two toggle switches were added in the upper right quadrant of the front of the box. An SMA connector was added to the rear panel, beside the DB-25 connector and directly below the two added switches. The connector is used to input the TTL level IF switch control signal from an external source. For testing, this source was a pulse generator, although it could be any TTL control source, such as the MTU.

The added toggle switch on the right controls the source of the TTL IF switch control signal. When this toggle switch is in the lower position the control is from the external source, using the SMA connector input. When it is in the upper position the control is from the second added toggle switch. The second toggle switch will hold all the IF switches open when it is in the lower position and will hold all the IF switches closed when it is in the upper position. The added toggle switches and connector have been labelled on the manual control box. The second manual control box was not modified. Therefore, only the IF switches on one array IF receiver can be tested at any one time. When there is no control input connected to the IF switches they will assume a closed position. The TTL drivers on the IF switches will float high, closing the switches, in the absence of a TTL control input signal.

There is a long cable connecting the manual control box to the IF receiver. It is made of straight single conductor wires and is not intended to carry high speed or high frequency signals. It is not the ideal setup to test high speed switches. The cable probably degrades the rise and fall times of the switch signal so these measurements are not applicable.

3.0 SWITCH TESTING

Testing was carried out in four phases. Each switch was individually tested on a breadboard before mounting on the IF receiver boards. These tests insured that each switch conformed to the manufacturer's specifications. After each switch was installed, they were individually tested on each receiver board. The connections and cables within each board were tested at this stage.

The final two test phases were done after all the switches were installed and the receivers were put back in the racks. A local test was done by injecting a 60 MHz continuous wave (CW) signal into each channel, one at a time. A pulse generator was used to control the switches. The final test used actual radar returns, monitored at the IF monitor points and from the offset video output connections.

The first two phases of switch testing went well, with all sixteen switches operating as expected. Each board was set up on the bench using the test jig cabling that was used for testing when the boards were built.

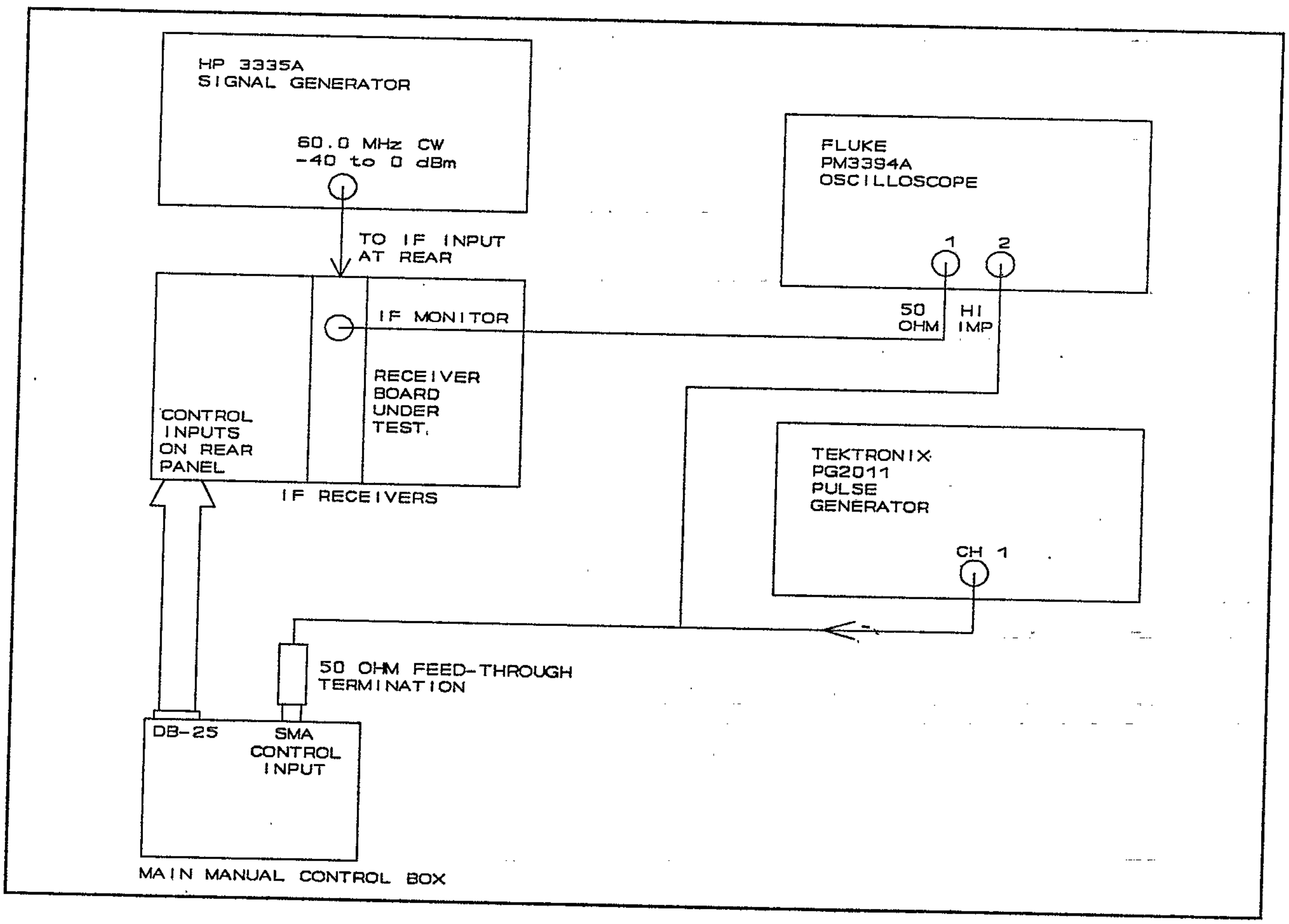

Figure One
Phase Three Test Setup of IF Switch Operation

3.1 Phase Three Switch Test Setup

The phase three IF switch test used the test setup shown in figure one. The IF receivers had been mounted back in the EARS lab racks and were powered by their normal power supply. The eight IF inputs on the rear of each receiver were disconnected from the front end. The 65.0 megahertz IF reference was also disconnected.

The HP3335A signal generator was used as the source of the continuous wave (CW) 60.00 megahertz IF input signal. It was connected to one of the eight IF receiver rear panel IF inputs. The signal level was varied from -40 dBm to 0 dBm, to test the switch action over a range of input levels. The Tektronix PG2011 two channel pulse generator was used as the source of the IF switch TTL control. It was set to produce the TTL switch control pulse using a variety of pulse widths from 200 nanoseconds to several microseconds. The PG2011 output is fifty ohms, therefore it was terminated at the manual control box SMA input with a fifty ohm feed-through termination. A BNC tee was used to allow this control signal to be input to the oscilloscope.

The Fluke PM3394A Combiscope was used to view and record the traces for the IF monitor outputs and the control pulses. The PM3394A can be operated as a traditional analogue oscilloscope or as a digital sampling oscilloscope (DSO). Each IF receiver channel was tested individually, in turn. Only the front panel IF monitor points were observed, not the rear panel offset video outputs. It would have required a second phase locked source for the IF receiver reference, to generate the offset video signals.

3.2 Phase Four Switch Test Setup

This final test setup is shown in figure two. The eight IF inputs from the front end mixers were connected to the rear panel. The IF reference from the exciter was connected to the rear panel input. These are the connections for normal IF receiver operation in the EARS. The modified manual control box was used to control the attenuators and to allow the input of the TTL switch control pulses. The manual control box was connected to the DB-25 connector at the rear of the IF receivers. A fifty ohm feed-through termination was used on the SMA control input since the PG2011 has a fifty ohm output impedance. A BNC tee in the PG2011 output line allowed the connection of the switch control pulse signal to channel three of the oscilloscope.

The front panel IF monitor output was connected to channel one of the oscilloscope, which was set for fifty ohms. The oscilloscope channel two input was from the offset video output at the rear of the IF receivers. This is the signal that normally goes to the analogue to digital converters and requires a fifty ohm termination.

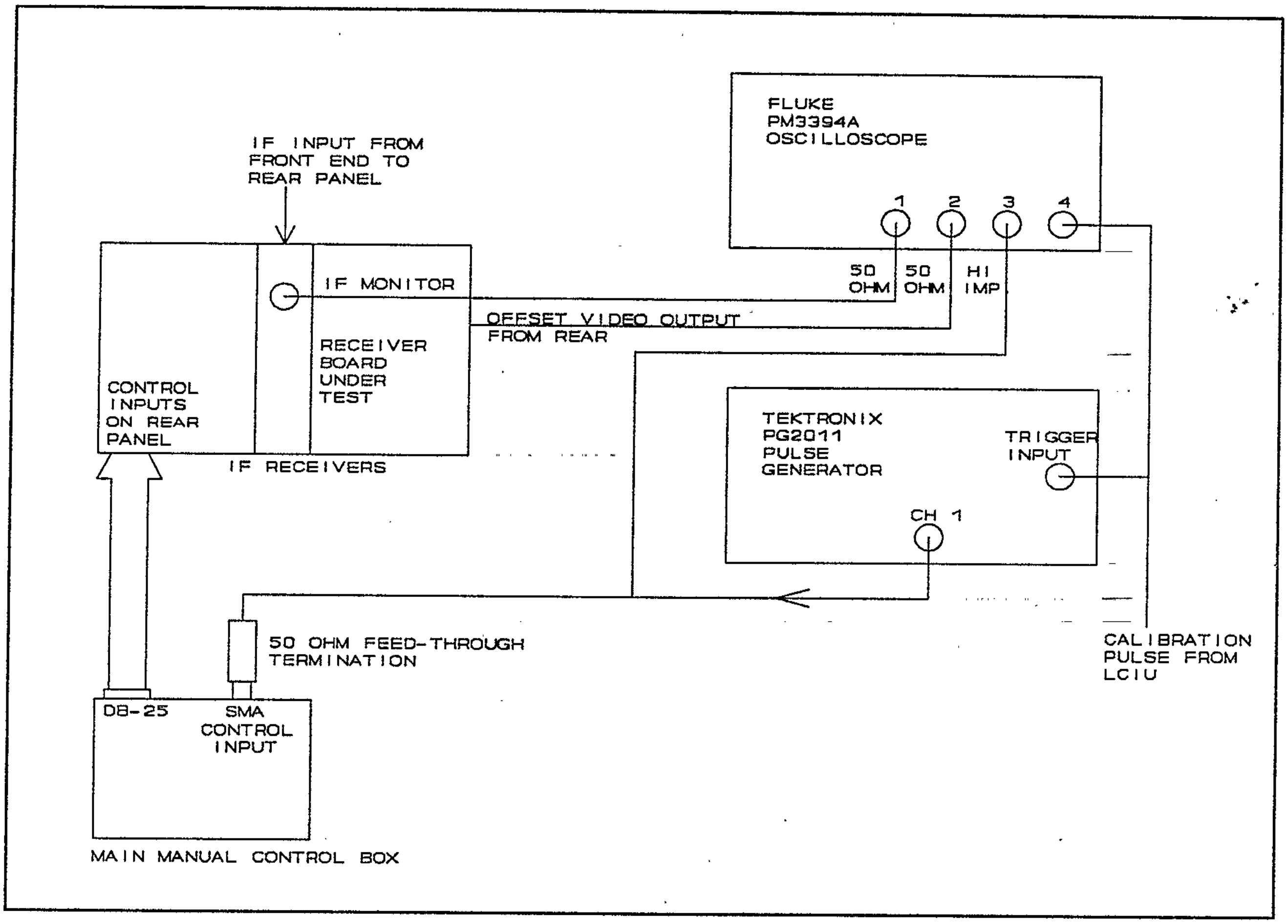

Figure Two
Phase Four Test Setup of IF Switch Operation

The Local Control Interface Unit (LCIU) is located on the front end rack. It was operated in local mode, therefore the MTU and system controller were not necessary. The LCIU has a calibration pulse output. This fifty ohm impedance signal is one microsecond wide. It is delayed from the exciter gate by about 97.5 microseconds and is normally used for testing the front end operation. The falling edge of the calibration pulse was connected to the trigger input of the PG2011. The delay was set in the PG2011 to about 904 microseconds. After this time the PG2011 output went high, turning on the IF switches. This switch control signal went low when the next LCIU calibration pulse went high. The PG2011 delay was increased or decreased by several microseconds to change the closing time of the switches. The switch control signal was input to channel three of the oscilloscope. Figure three is a timing diagram showing the relationships between the exciter gate, calibration pulse, switch control and radar return signals. The main bang was just under two microseconds in duration, since the transmit pulse width is fixed at one microsecond when using the LCIU under local control.

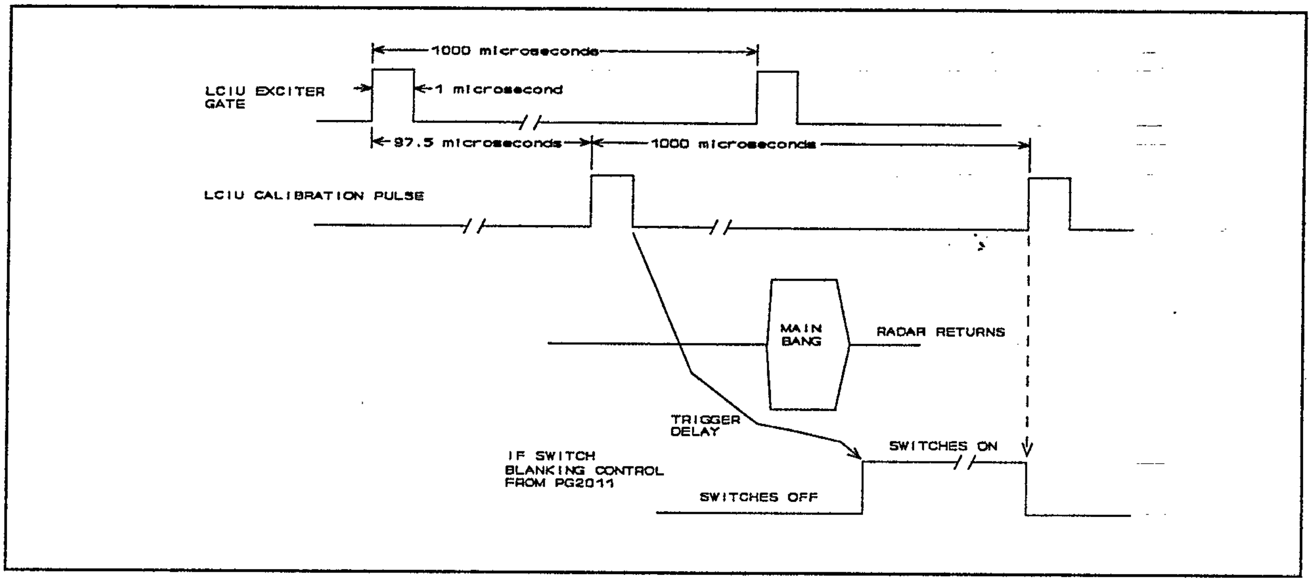

Figure Three
Phase Four Test Timing Diagram (Not to scale)

4.0 IF SWITCH TEST RESULTS

The switch for each channel of each receiver was tested and they all operated similarly. Channel five of the SLC IF receiver was chosen as a typical channel for the detailed phase four measurements and observations.

Figure four is the oscilloscope plot recorded for the phase three testing. It shows the IF monitor output of SLC channel eight. The upper trace is the IF switch control and the lower trace is the switched CW 60 MHz IF signal. The figure shows the timing relationship of the switch with respect to the control input. The IF receiver input was set to 0 dBm and the attenuators were set to 56 decibels. The TTL switch control pulse is 300 nanoseconds wide. The time base on the 'scope plot is 50 nS per division. Measurements were made with the cursors on the 'scope. The turn-on delay from the rising edge of the control pulse to the start of the rising edge of the IF signal is about 100 nS. The turn-off delay, from falling edge to falling edge, is also 100 nS. The rise and fall times of the IF signal are both about 50 nS. These times are specific to this test setup and may change slightly with different channels, input levels and cables. The long cable from the control box to the rear of the IF receivers has a significant degrading influence on the timing measurements.

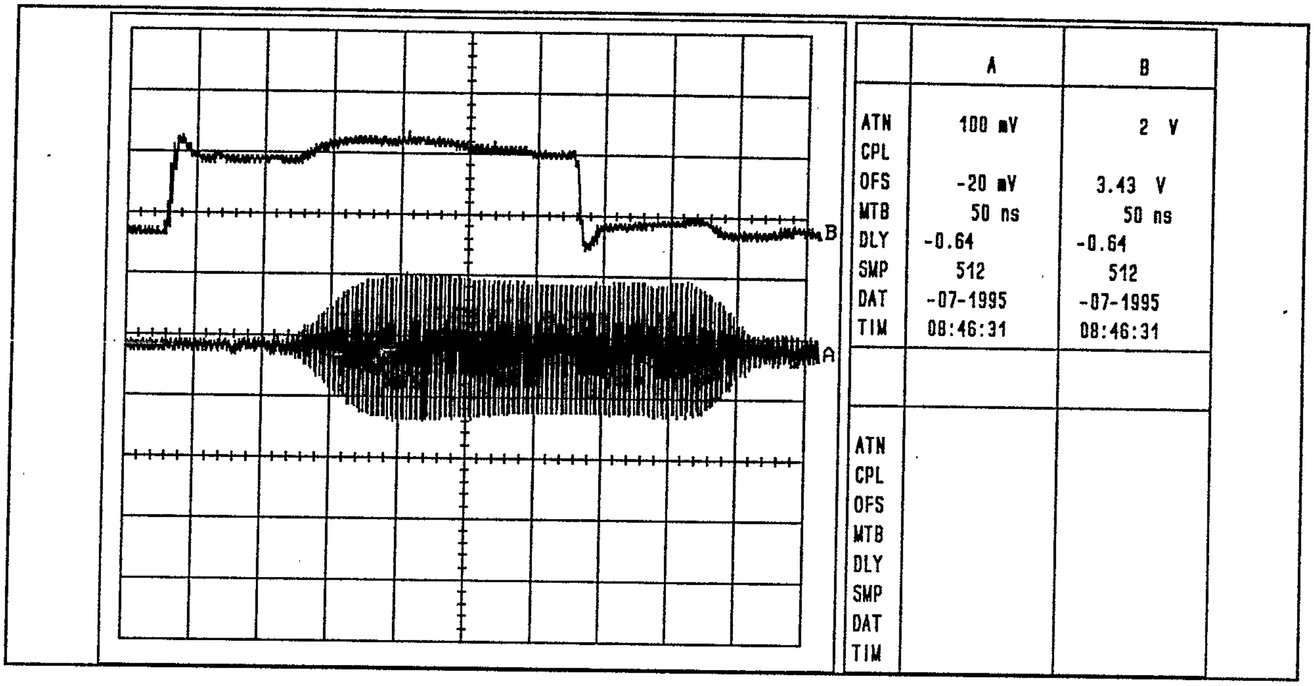

Figure Four
Phase Three Test Oscilloscope Plot

Figures five to twelve are oscilloscope plots showing various aspects of the phase four testing. They are all of SLC channel five with the radar pointed toward the silo. Each is described in turn. The upper trace is always the switch control signal and the lower trace is the radar returns, either at the 60 MHz IF or at the five megahertz offset video frequency. The oscilloscope time base is always one microsecond per division.

Figure Five

Shows the five megahertz offset video output with the switch on during the main bang. The main bang is not attenuated. The time base is one microsecond per division and the amplitude for the main bang trace is 0.5 volts per division. The IF receiver attenuators are set to eight decibels, a typical setting for a small distant target. The ADC input range is approximately +/- one volt, or about four divisions on the 'scope plot.

Figure Six

Similar to figure five, except the switch comes on 2.24 μS after the start of the main bang. The main bang has been attenuated to the approximate level of the first return at about 4 μS, or 600 meters.

Figure Seven

Shows the offset video output with the switch on during the main bang. The IF receiver attenuators are set to zero decibels.

Figure Eight

Compare with figure seven. Similar to figure seven, except the switch turns on about two microseconds after the start of the main bang. This shows the worst case main bang amplitude, with the attenuators set to zero. There were no oscillations observed on any of the IF receiver channels.

Figure Nine

Shows the 60 MHz IF signal from the front panel monitor with the main bang unaffected. The switch turns on about one microsecond before the start of the main bang. The attenuators are set to zero decibels.

Figure Ten

Similar to figure nine except the switch turns on 2.0 microseconds after the start of the main bang. With the attenuators set to zero, this is the worst case main bang amplitude. The peaks at the start of the main bang are just outside the normal range. The main bang quickly falls to a comparable level with the first return.

Figure Eleven

Similar to figure nine except the attenuators are set to eight decibels. The level of the unattenuated main bang is similar to figure nine. The first radar target returns have been significantly attenuated, along with the background noise.

Figure Twelve

Similar to figure ten except the attenuators are set to eight decibels. The main bang has been attenuated to within the linear range of the IF receiver and within the ADC range.

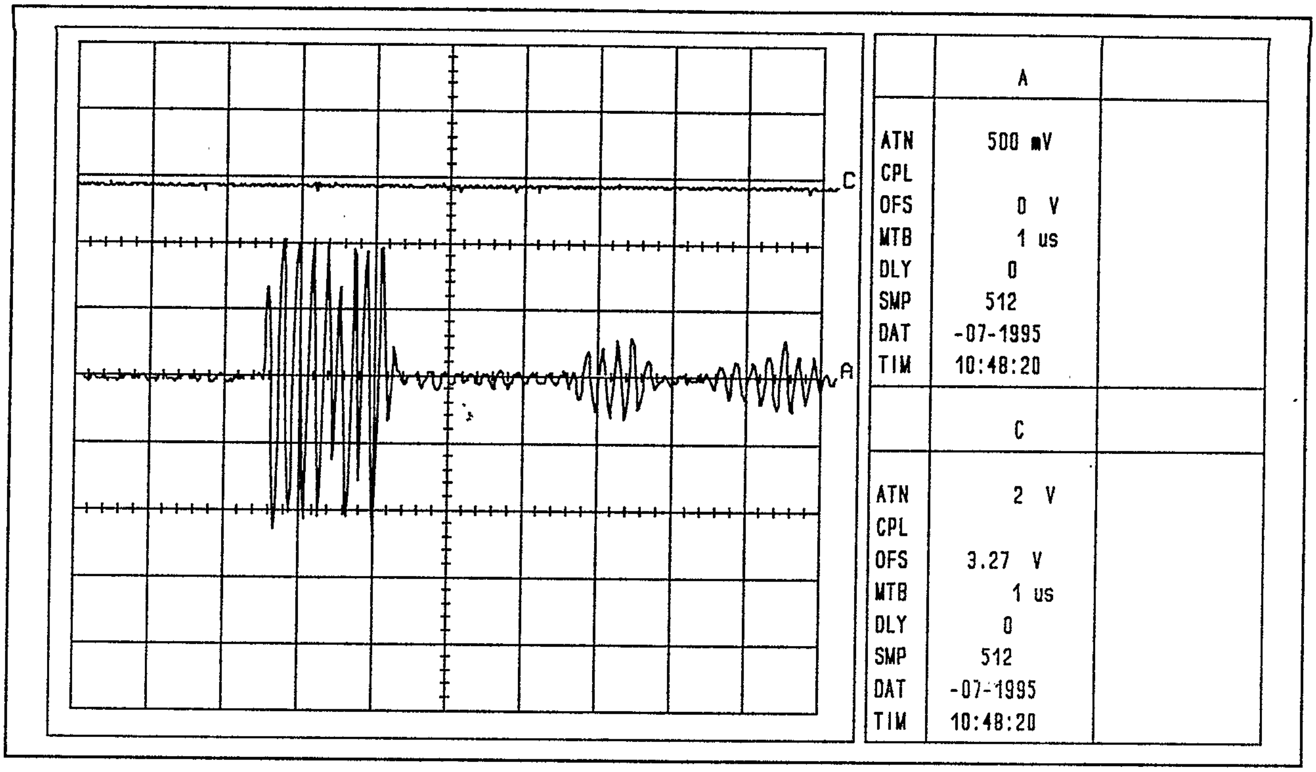

Figure Five
Offset Video Main Bang Not Attenuated

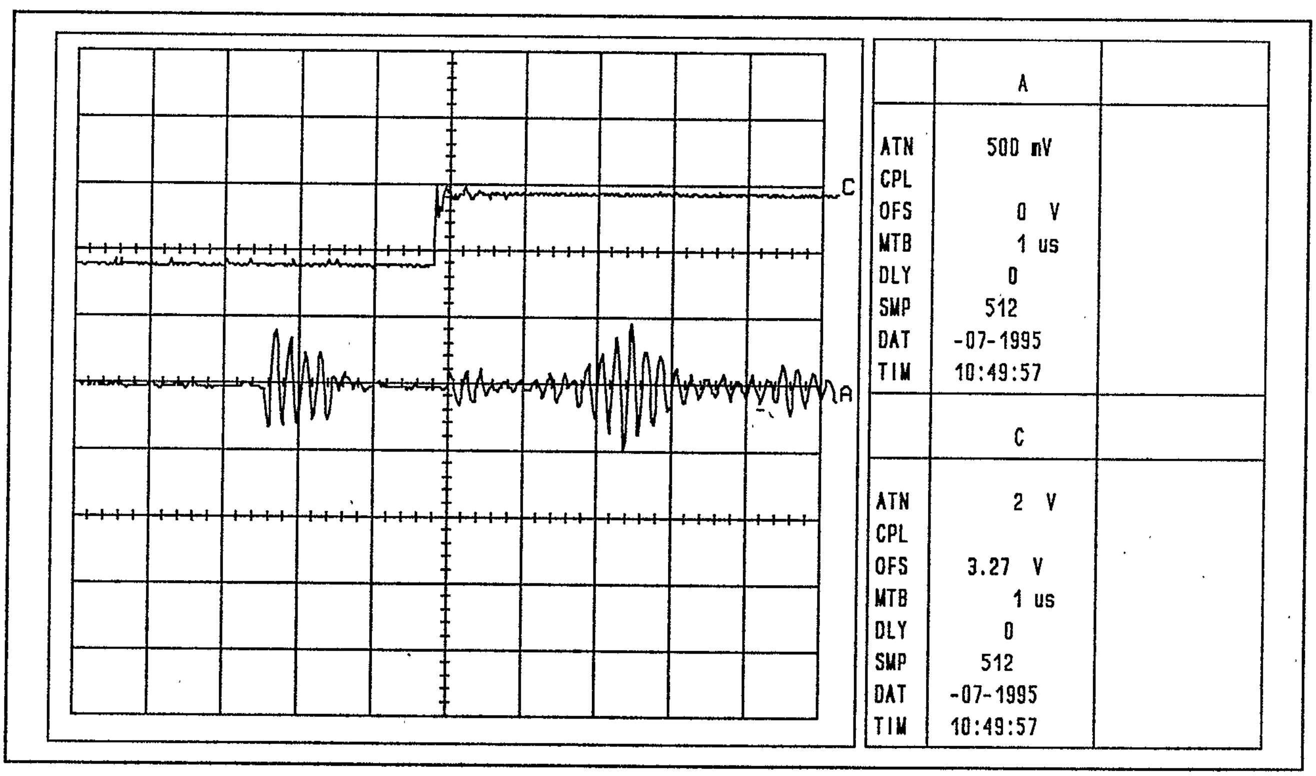

Figure Six
Offset Video Main Bang Switched Off

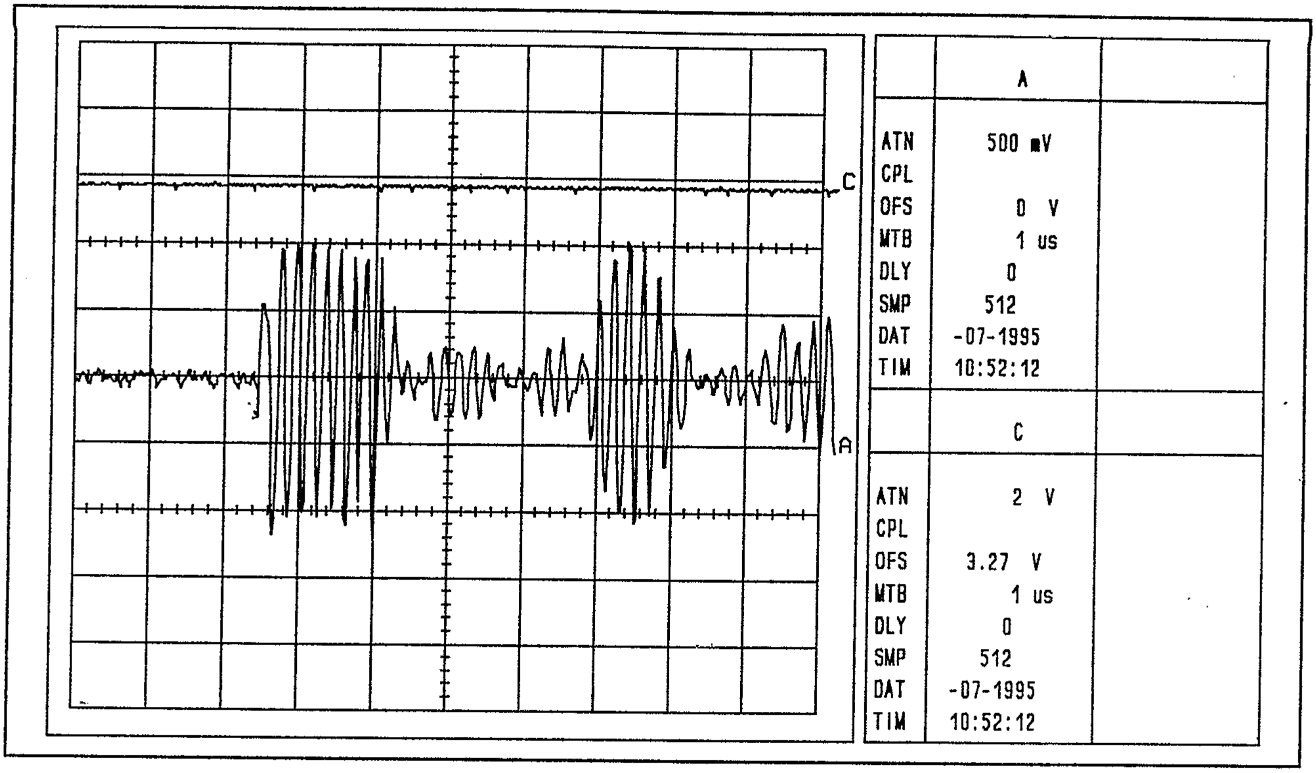

Figure Seven
Offset Video Main Bang Not Attenuated

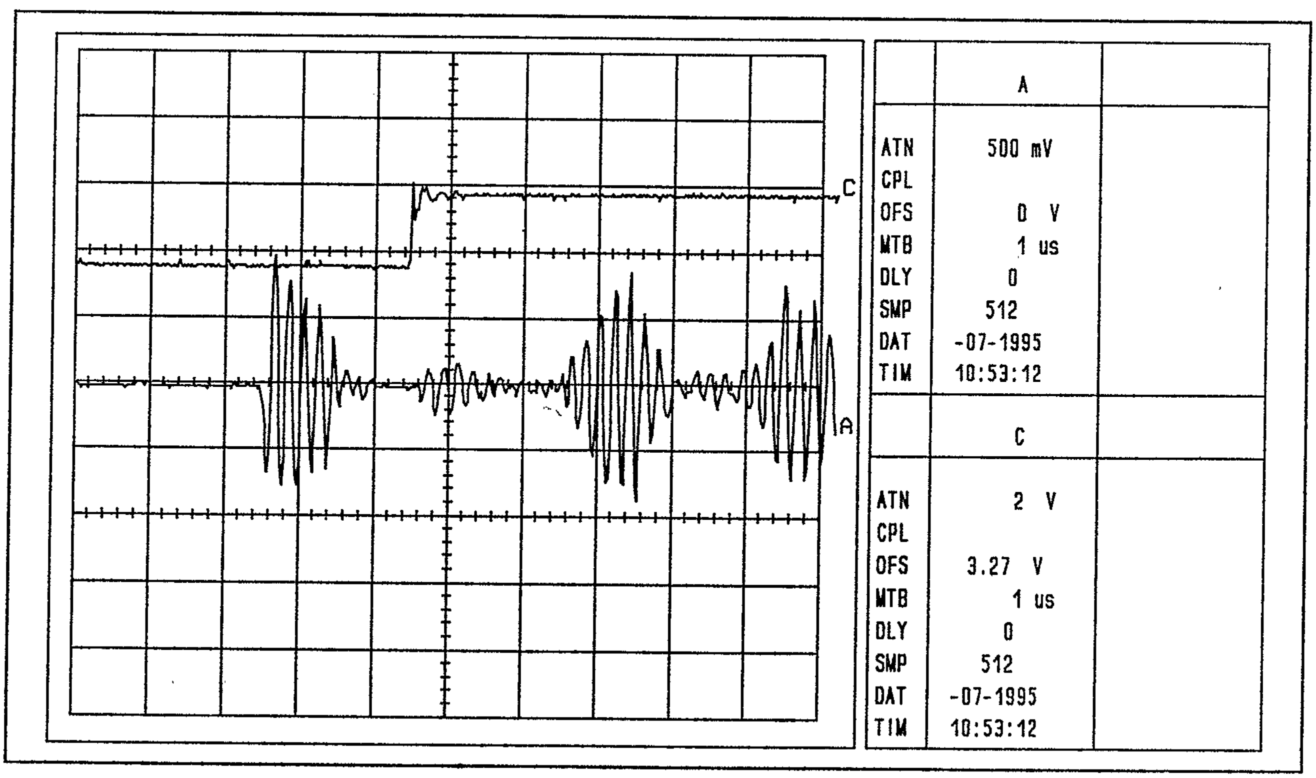

Figure Eight
Offset Video Main Bang Attenuated

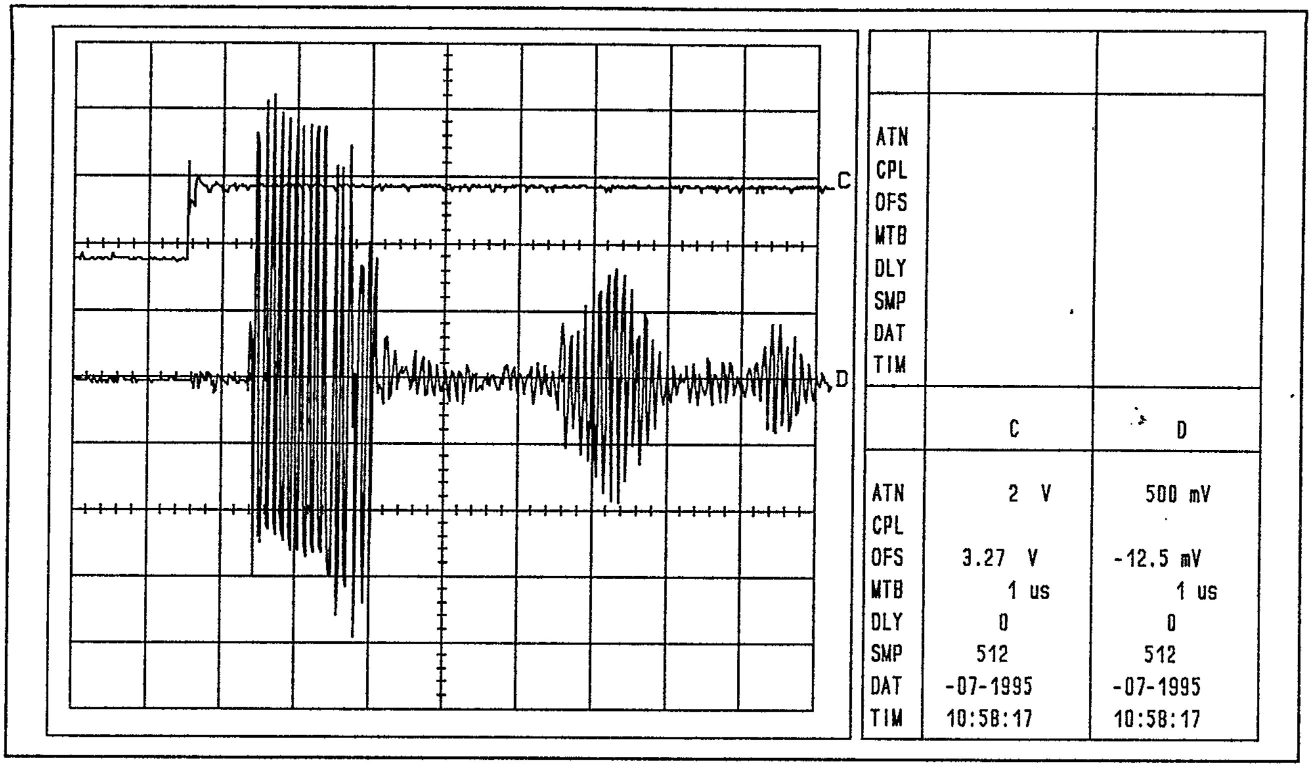

Figure 9
60 MHz Main Bang Not Attenuated

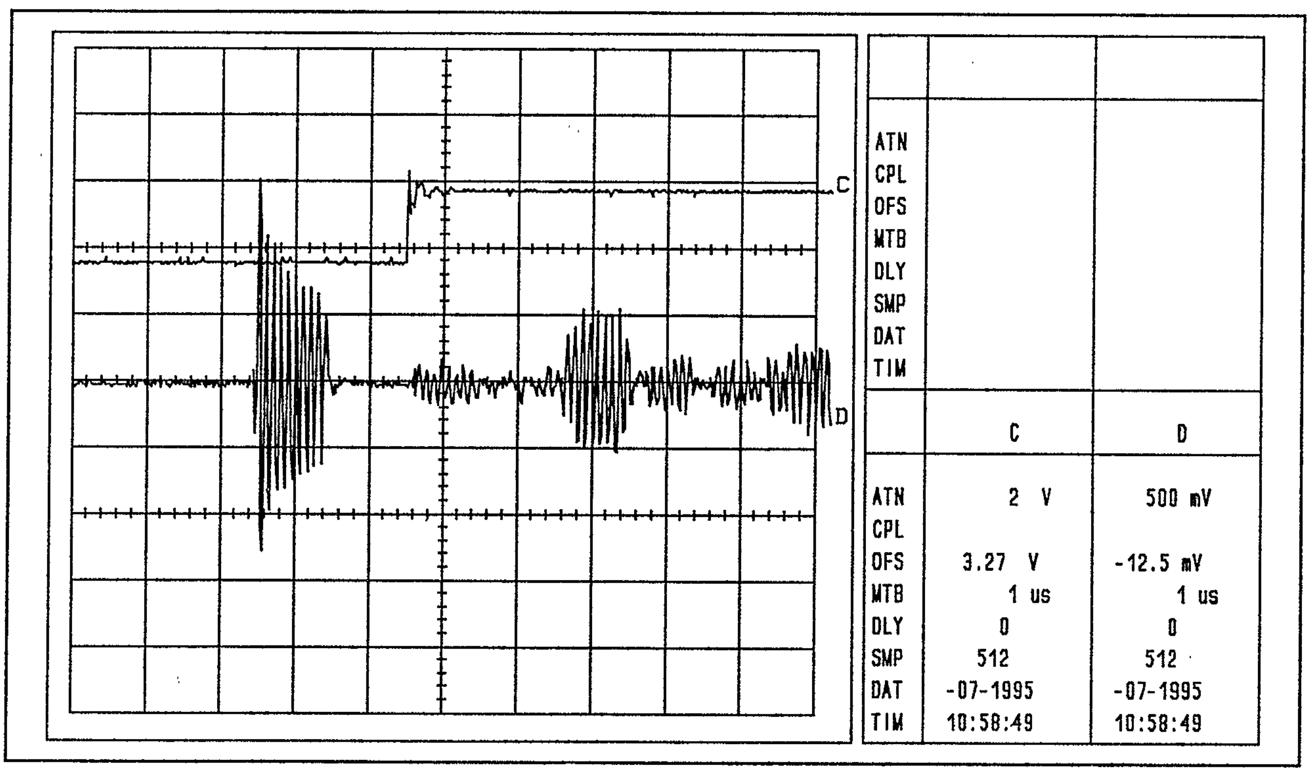

Figure 10
60 MHz, Switch On 2.0 μS After Main Bang Start

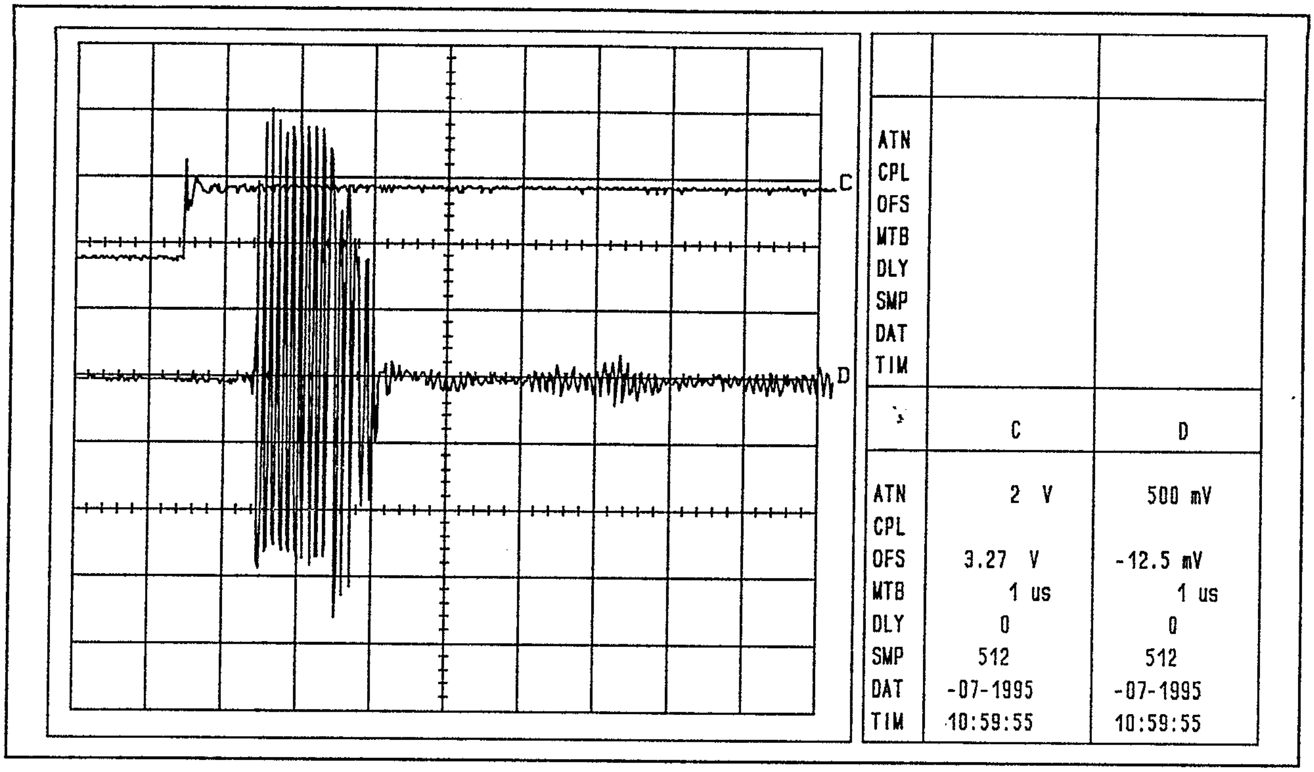

Figure 11
60 MHz Main Bang Not Attenuated

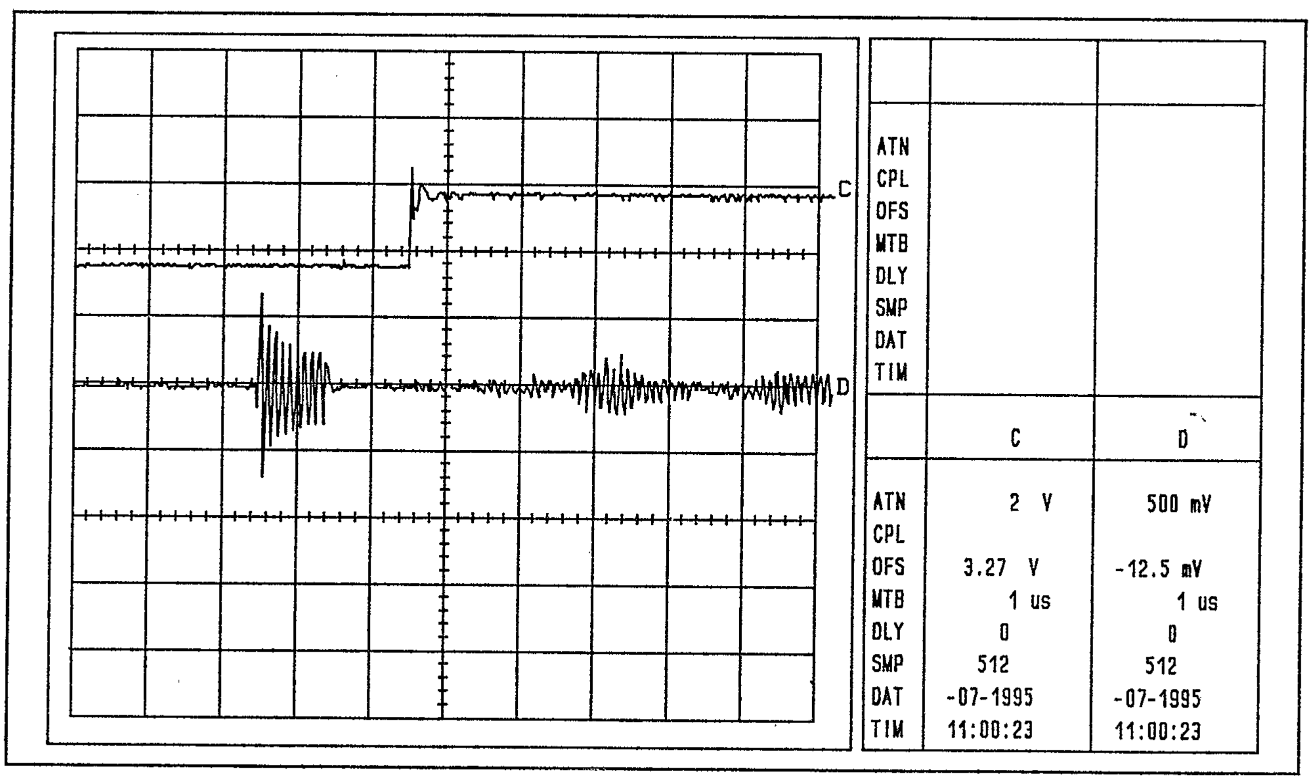

Figure 12
60 MHz, Switch On 2.0 μS After Main Bang Start

5.0 CONCLUSIONS

The switches work well and are able to reduce the level of the main bang to a tolerable level, even when the attenuators are set to zero decibels. It was not expected that the main bang would be entirely eliminated since it is such a strong signal. For typical attenuations used during radar trials, which are in the ten to 40 decibel range, the main bang is reduced to a very low level.

The switches can be used to effectively eliminate any unwanted returns, not just the main bang. They can be opened to detach the receivers from the front end to help measure the noise floor of the receivers. They can act as protection devices to eliminate damaging signals that might be accidently introduced into the receivers during testing or system operation. By opening and closing the switches at known selected times, visual target identification on the oscilloscope can be made easier. For example, if the target of interest is surrounded by background clutter or nearby targets, then the switches could be turned on only during the time the selected target is being received. This would make the target stand out on the oscilloscope or in the recorded data.

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GLOSSARY

array

A series of front end receiver channels, arranged with the receiver horns in a straight line. There are two arrays in the EARS, each with eight receiver channels. One has the receiver horns arranged in a straight horizontal line. It is known as the horizontal array, or SLC array. The other array is called the vertical array since its eight receiver horns are arranged in a straight vertical line.

attenuators

Components in the IF receivers that can be programmed to attenuate the 60 MHz IF signals in precise steps. They are digital attenuators, with a step size of two decibels and a range from zero to 62 decibels.

exciter

The front end device which is the source of the CW signals necessary for the radar operation. These include the transmitted X-band signal, the front end RF mixer reference signal and the IF receiver reference signal.

front end

Refers to the RF devices of the radar system including the transmitter, receiver horns, RF mixers, RF amplifiers, RF sources, etc. The outputs of the RF mixers are at the 60 megahertz intermediate frequency and are input to the IF receivers

local control interface unit

A device located in the front end equipment rack. It serves as an interconnection junction box for most of the timing and control signals between the front end devices and the units in the EARS lab. It also has circuits to supply the timing and control signals for local testing of the front end. The MTU is the normal source for the timing signals.

main bang

The first signal received following the transmission of the high power RF pulse from the front end transmitter through the transmitter antenna. Caused by reflections from the structure around the transmitting antenna.

master timing unit

A printed circuit board located in the VME crate in the EARS lab. It is the source of all the timing signals required in the EARS and uses the exciter 10 MHz master clock, doubled to 20 MHz, as its base clock.

offset video

The final output signal from the IF receivers. It is input to the analogue to digital conversion sub-system. It is at the second IF frequency of five megahertz and is the down-converted radar returns from the front end receivers.

X-band

The designated RF band in which the EARS operates. The X-band is from 8.0 to 12.0 gigahertz. The EARS operates over a small section of this band, from 8.90 GHz to 9.40 GHz.

LIST OF ABBREVIATIONS

ADC	Analogue to Digital Converter
BNC	Bayonet (Navy) Mount RF/IF coaxial Connector
CW	Continuous Wave
dBm	Decibels with respect to one milliwatt into 50 ohms
DSD	Design Specification Document
EARS	Experimental Array Radar System
IF	Intermediate Frequency (60 MHz in the EARS)
LCIU	Local Control Interface Unit
MHz	megahertz = 10^6 hertz
MTU	Master Timing Unit
nS	Nanosecond = 10^{-9} seconds
RF	Radio Frequency (8.9 to 9.4 GHz in the EARS)
SLC	Side-Lobe Canceller
SMA	Sub-Miniature type A threaded RF coaxial connector
SPST	Single Pole Single Throw
TTL	Transistor Transistor Logic
TWTA	Travelling Wave Tube Amplifier
μS	Microsecond = 10^{-6} seconds

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FINAL REPORT

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EARS
Local Control Interface Unit
Main Bang
X-band
Radio Frequency
Travelling Wave Tube Amplifier
SPST
Array
Master Timing Unit
Exciter
Offset Video
Intermediate Frequency
Side-Lobe Canceller
Vertical Array
Attenuator

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