CONFIDENTIAL

NRL REPORT 3528

UNCLASSIFIED

THE MEMORY TUBE AS A STORAGE MEDIUM FOR MOVING TARGET INDICATION

DECLASSIFIED: By authority of
NRL Classification Change Notice
No. 21-61 Dated 2 May 61
Dreda Jean Lambert 2028
Entered by NRL Code

NAVAL RESEARCH LABORATORY

WASHINGTON, D.C.

CONFIDENTIAL

SECURITY

This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794. The transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

Reproduction of this document in any form by other than activities of the National Military Establishment and the Atomic Energy Commission is not authorized unless specifically approved by the Secretary of the Navy.

CONFIDENTIAL

NRL REPORT 3528

UNCLASSIFIED

THE MEMORY TUBE AS A STORAGE MEDIUM FOR MOVING TARGET INDICATION

E. E. Herman and I. C. Lantz

September 2, 1949

Mr. A. A. Varela, Head, Search Radar Branch
Mr. L. A. Gebhard, Superintendent, Radio Division II

NAVAL RESEARCH LABORATORY

CAPTAIN F. R. FURTH, USN, DIRECTOR

WASHINGTON, D.C.

CONFIDENTIAL

DISTRIBUTION

BuShips	
Attn: Code 916	5
Attn: Code 939	5
ONR	
Attn: Code 470	1
CNO	1
Attn: Code OP-413-B2	5
CO, ONR, Boston	1
Dir., USNEL	2
CDR, USNOTS	
Attn: Reports Unit	2
SNLO, USNELO	2
Supt., USNPGS	1
Ch. of Staff, USAF	
Attn: Office of the Air Comm. Officer	1
OCSigO	
Attn: Ch. Eng. & Tech. Div., SIGTM-S	1
CO, SCEL	
Attn: Dir. of Eng.	2
CG, AMC, Wright-Patterson AFB	
Attn: Eng. Div., Electronics Subdiv., MCREEO-2	1
BAGR, CD, Wright-Patterson AFB	
Attn: CADO-D1	1
CO, Watson Labs., AMC, Red Bank	
Attn: ENR	1
CO, Air Force Cambridge Res. Labs., Cambridge	
Attn: ERRS	1
RDB	
Attn: Library	2
Attn: Navy Secretary	1
Naval Res. Sec., Science Div.	
Attn: Mr. J. H. Heald	2

CONTENTS

ABSTRACT

Application studies have been made of the Haeff Memory Tube as a possible MTI storage medium. Storage tube requirements for MTI are set forth, and proposed modes of operation along with experimental results are described.

One mode of operation, "controlled leakage," yielded an MTI output which depends upon modulation period rather than direct pulse-to-pulse subtraction. Another mode of operation, "back-plate modulation," was also investigated. No experimental results were obtained under this mode because of internal resistance in the output electrode. Physical defects of the experimental tubes have hampered investigation of both modes.

Further studies of the adaptability of the Memory Tube to MTI will involve the latest type Memory Tube developed at the Naval Research Laboratory as well as other proposals for employing the original type.

PROBLEM STATUS

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

AUTHORIZATION

NRL Problem R02-24R (BuShips Problem No. S1055-C)
NE 051-412

THE MEMORY TUBE AS A STORAGE MEDIUM FOR MOVING TARGET INDICATION

INTRODUCTION

In radar detection the presence of a multiplicity of fixed targets and ground clutter at times inhibits the display of moving targets. Under such conditions "Moving Target Indication" (MTI) becomes expedient. Ideally, MTI accomplishes the suppression of all fixed target echoes while providing a display of all moving targets. Of several means of accomplishing MTI, the method of storage and subsequent comparison of video pulses on consecutive range scans has been most widely applied.

Sonic delay lines have generally served as the storage medium for attaining the video storage necessary for range scan-to-scan comparison. However, certain disadvantages have been present, particularly in the mercury delay-tank type. The most common disadvantages are weight, physical bulk, possible need for temperature compensation, and pulse-repetition-rate limitations.

In an attempt to circumvent the disadvantages of sonic-type storage mediums, the Haeff Memory Tube has been under investigation as a possible MTI storage medium.

GENERAL REQUIREMENTS

A storage tube which serves as a storage medium for MTI should be capable of recording, in the form of an electrical charge pattern, a series of video pulses. Further, it must be capable of rescanning this stored charge pattern while simultaneously modifying those charges that do not exactly conform with newly supplied video information. Simultaneously, an electrical output is required which corresponds only to the instantaneous change in charge produced on any element.

If a fixed target is present, the video information is identical on two successive scans, and no output will result on the second scan, since the charges are established on the first scan and no modification occurred on the second. If a moving target is present at some point on the second scan, the video information will not exactly conform. The charge pattern will be modified at this point and an electrical output will result corresponding to the moving target. It should be noted that the charge pattern at the end of the second scan should directly correspond with the video information contained in the second scan. Hence, the third scan will be compared with recorded video information of the second scan.

TUBE CONSTRUCTION AND PRINCIPLES

Because the Haeff Memory Tube[1] is a relatively new development, the physical construction and principles of operation will be described. The tube in its present form comprises two or more electron guns, the number depending upon the specific application intended. All guns are directed toward a common storage surface in the front of the tube envelope. The tube used in this investigation was of a three-gun type with all three beams independently focused and electrostatically deflected.

The storage surface (mosaic) consists of a plate-glass sheet sprayed with P-5 phosphor (calcium tungstate). Mounted approximately 0.005" in front of the mosaic is a stainless steel mesh (230 wires/inch), which serves as a decelerator and as a signal output electrode (Figure 1). As in typical cathode-ray tubes, an aquadag coating on the tube wall serves as a post-deflection accelerator and final collector.

The principle of charge recording on the mosaic involves the effects produced by bombarding the mosaic with an electron beam. The phenomenon of secondary emission is utilized in the charge-laying process in the following manner. When an insulating surface (mosaic) is bombarded with an electron beam, the potential of the point under bombardment depends upon the secondary emission ratio of the material and the net beam velocity. The latter is generally expressed in terms of net acceleration voltage existing between the electron source and the point under bombardment. Figure 2 shows a typical secondary-emission-ratio curve for a metal. For purposes of discussion, the characteristics of an insulator will be considered similar to those of a metal. From the curve it can be seen that if a point is bombarded with a beam of over 100 volts net velocity, the secondary electrons emitted from the mosaic are greater in number than the incoming primaries. Hence the potential of the point under bombardment will rise until the secondaries are no longer drawn away in greater numbers than primaries arrive. The ratio of the number of secondary electrons permanently escaping the area under bombardment to the number of incoming primaries will be referred to as the secondary escape ratio, as distinguished from the secondary emission ratio. As a point approaches collector potential, the emission ratio remains greater than unity but the secondary escape ratio drops to unity. The excess secondaries are returned to the point under bombardment.

In the Haeff tube, the wire mesh serves to control the escape of secondaries from the mosaic. Hence, any point under bombardment by a high-velocity beam will rapidly rise to approximately mesh potential, since secondary escape would be completely suppressed if it rose appreciably higher. Thus an equilibrium point exists which will be referred to as the positive equilibrium point. If any point on the mosaic is bombarded with a beam of less than 100 volts net velocity, the emission ratio being less than unity, the point under bombardment will become negatively charged to cathode potential, whereupon the primaries will be turned back. Thus another equilibrium exists at cathode potential, since, if the point starts to drift positive because of leakage current on the phosphor surface, a few primary electrons will be absorbed, thereby driving the point back to cathode potential. This will be referred to as the cathode, or negative, equilibrium point.

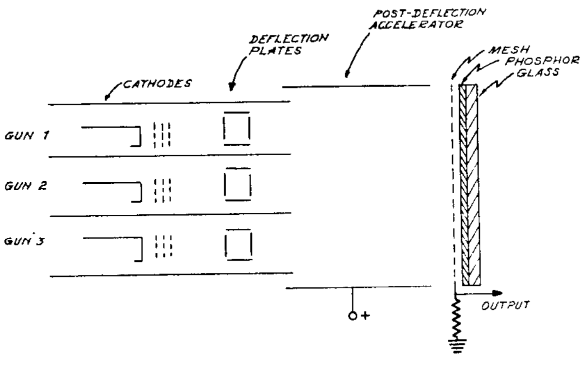


Figure 1 - Diagram of Haeff Memory Tube

---

[1] *Haeff, Andrew V., "A Memory Tube," Electronics, vol 20, No. 9, 80-83, September 1947*

Several proposals for MTI systems utilizing the storage properties of the Haeff Memory Tube have been under study. Those which involve video storage and play-back to external comparison circuits have not yet been investigated since the tube resolution is not adequate to provide recording and play-back without pulse distortion. In general, it seems desirable that the scan-to-scan comparison (cancellation) take place within the tube, so that resolution distortion is identically introduced on all pulses under comparison.

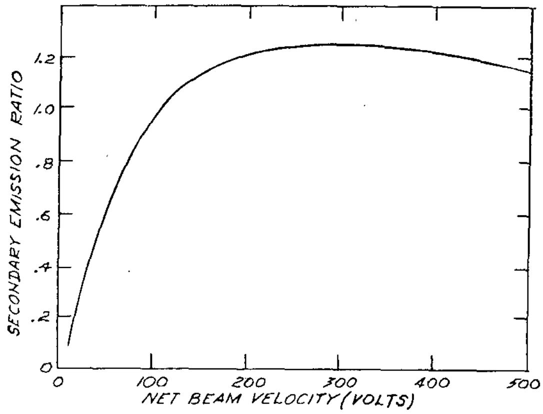


Figure 2 - Typical secondary emission characteristics for a metal

CONTROLLED-LEAKAGE MTI USING DEFLECTION MODULATION

In the mode of operation involving controlled-leakage MTI using deflection modulation, only two electron guns were employed. One beam was operated at high velocity (600 volts to 800 volts net), focused, and used to control the charge pattern and to produce an electrical output. This beam was deflected horizontally with a linear "range" scan, while being vertically deflected by the incoming video information, as in type "A" radar display.

The other gun was operated at low velocity (approximately 70 volts net). This gun was defocused and served to spray all mosaic elements traversed by the high-velocity beam. Since the low-velocity spray was operating below unity secondary-emission ratio, it served as a means of controlling the leakage of the mosaic elements since it tended to cause all points to drift more negative in potential. However the spray-beam density (intensity) was kept low so that any point on the mosaic which was brought near mesh potential by the high-velocity beam, would require the time of several range scans to drop completely to the spray cathode potential.

The theory of operation is assumed to be as follows. As the high-velocity beam progresses across the mosaic, repetitive video information (fixed targets) causes the beam to traverse exactly the same mosaic elements on each scan. The average potential of these mosaic elements is only a few volts negative with respect to the mesh since they are restored by the high-velocity beam on every scan. At points corresponding to nonrepetitive video information (moving targets), the mosaic elements are not restored positively on every scan; thus they were allowed to leak further toward cathode potential. This results in a more negative average potential for these nonrepetitive elements. It is assumed that under operating conditions the high-velocity beam does not restore any element completely to mesh potential.

The phenomena involved in producing the electrical output are complicated by several effects. However, by deduction from experimental results the following explanation is advanced: The wire mesh (signal electrode) is subject to electron bombardment directly from the electron gun as well as by electrons arriving from the mosaic. The secondary-emission characteristics of the mesh (Figure 2) differ from those of an insulator in that all points on the metal surface are equi-potential due to conduction.

The bombardment of the mesh due to intercepted electrons directly from the electron guns represents a constant and need not be considered.

As the high-velocity beam scans the mosaic elements, the secondary emission from the mosaic is primarily collected by the mesh. These electrons from the mosaic strike the mesh and in turn knock out the secondary electrons from the mesh. (The post-deflection accelerator serves as a final electron collector.) The secondary-emission ratio of the mesh is determined by the potential difference between the mesh and the mosaic element originating the bombarding electrons.

The mosaic elements which are repetitively scanned, and which have a potential average only a few volts negative, produce escaping electrons which result in low secondary emission from the mesh. The net electron current flow to ground through the mesh load resistor is proportional to the difference between the incoming primaries and the escaping secondary electrons.

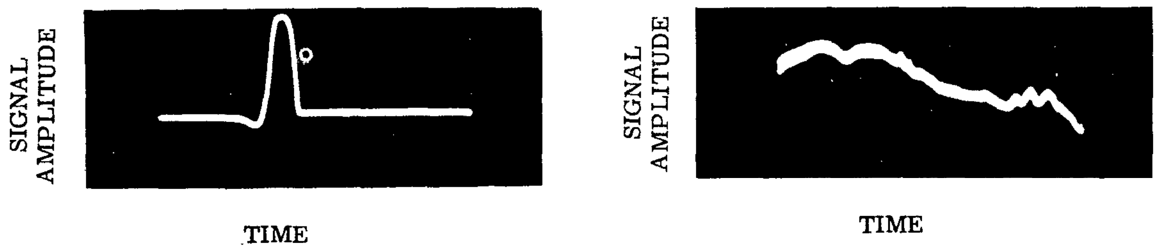
For mosaic elements not repetitively scanned, their more negative potential instantaneously results in greater mesh secondary emission when scanned by the high-velocity beam. Due to this increase in mesh secondary emission, the net electron current flowing in the mesh load resistor is decreased, thereby resulting in a positive output.

Experimental results produced a pulse output of approximately 1000 microvolts under the following conditions of test:

Impedance level of output circuit	3300 ohms (resistive)
Writing speed (minimum)	0.43 mm/μsec
Range scan duration	117 μsecs
Repetition rate	3000/sec
Pulse width (fixed target)	13 μsecs
Pulse width (moving target)	13 μsecs
Writing-beam net velocity	800 volts
Spray-beam net velocity	70 volts
Echo modulation rate	600 cps
Writing beam current (approx.)	6.0 μ amps
Spray beam current (approx.)	1 μamp
Output polarity	positive
Output magnitude (fixed target)	negligible
Output magnitude (moving target)	1000 μvolts

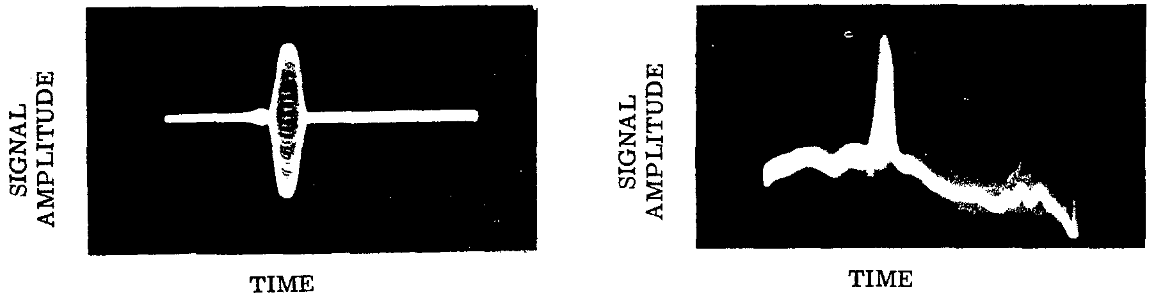
Figure 3 shows the input and corresponding electrical output of the Memory Tube with a signal present which represents a fixed target. The irregularities in output are attributed to nonuniformity of mesh secondary-emission characteristic.[2]

[2] *Later findings revealed the presence of extraneous foreign material on the mesh surface.*



(a) Input *(b) Output*

Figure 3 - Oscillograms of simulated fixed-target input and output of Memory Tube



(a) Input *(b) Output*

Figure 4 - Oscillograms of simulated moving-target input and output of Memory Tube

Figure 4 shows the electrical input and the corresponding electrical output of the Memory Tube, with a signal present representing a moving target.

Several side-effects were noted which substantiate the proposed theory of operation. For a given spray-beam density with an MTI input, it was found that as the writing-beam density was increased from zero level, no output resulted until a certain density threshold was reached. For a certain range of writing density, MTI output resulted. As the writing density was raised still further, the MTI output disappeared until either the spray density was raised or the writing density was decreased. This indicates that the elements are not completely restored to mesh potential by the writing beam. Otherwise, excess writing-beam density would not be detrimental to the MTI output. The minimum writing density is apparently that required to insure that the repetitive elements do not drop to cathode potential.

It was noted that if the spray beam were suddenly cut off, the MTI output would still appear for two or three range scans. This further substantiates the fact that the writing beam was not completely restoring the mosaic elements to mesh potential on every scan. Apparently with no spray beam present, two or three writing scans were necessary to bring the mosaic elements up to mesh potential. In spite of these two limitations on beam densities, the intensity and net beam velocity settings were not particularly critical. Changes in repetition (scan) rate and sweep speed necessitated the resetting of beam intensities.

Another condition of operation was predicted. This differs from the above mode only in that the high-velocity-beam density was made sufficiently high to insure complete restoration of mosaic elements to mesh potential on every scan. This condition was also expected to result in a positive output polarity. However, as mentioned earlier, excess writing-beam densities prevented MTI output. Apparently if the repetitively scanned mosaic elements operate too near mesh potential, fewer electrons are attracted to the mesh thus providing a reduction in mesh electron current, and thereby counteracting the MTI output.

Several defects are apparent in this system of MTI. Deflection modulation inherently results in an increase in writing speed at the leading and trailing edges of all pulses. This increased writing speed produces a lower average potential on the corresponding mosaic elements. Unless rounded pulses are used, the electrical output shows small spikes, in addition to the true MTI pulses, at the leading and trailing edges of all fixed targets. While it is true that intensity compensation of the writing beam would minimize this effect, it is nevertheless a rather critical compensation to adjust. Deflection modulation also results in a more basic criticism when used with controlled leakage; namely, the MTI output was found to be dependent upon how infrequently a mosaic element was traversed. Ideally, the MTI output should be proportional to the difference in pulse amplitudes on successive scans, and not primarily dependent upon the time interval between pulse coincidences.

It was hoped that this defect could be rendered less objectionable by reducing the modulating deflection amplitude. However, when this was attempted the desired output decreased in level until it was masked by the extraneous output due to foreign material on the mesh.

A possible variation of this mode of operation for future consideration is the use of a high-frequency vertical deflection component to defocus effectively the beam in one direction. By this means two successive pulses, differing only slightly in amplitude, would occupy a great deal of area in common. The result would be a correspondingly small output. In this manner it may be possible to produce a characteristic more nearly proportional to pulse-to-pulse amplitude differences.

Further study of this mode must be postponed until a tube uncontaminated by foreign material is available.

BACK-PLATE MODULATION

The mode of operation involving back-plate modulation was experimentally investigated using a special three-gun Haeff Memory Tube. This tube was equipped with a "Nesa" (transparent conductor) film deposited on the mosaic plate (Figure 5). This coating serves as a modulating electrode and is made transparent solely for convenience in viewing the storage phosphor.

Only one gun was utilized and this was operated at high velocity (approximately 1000 volts net beam-acceleration voltage). The electron beam was deflected horizontally with a linear range scan. Video information was fed to the Nesa back plate while the wire mesh served as a signal output electrode.[3] Due to the fact that all incoming video information

---

[3] *The mode of operation involving back-plate modulation has been successfully employed on the "STE" storage tube developed by RCA. However, electrical output was taken from the final collector rather than from the mesh. See A.S. Jensen, et al., "Barrier Grid Storage tube and its Operation," RCA Review, 112-135, March 1948.*

would directly appear in the output by capacity coupling between the front plate and the mesh, the electrical output was isolated from the input by employing what is called "carrier read-off." In this system the electron beam was intensity-modulated with an r-f signal of 30 Mc (the exact frequency being unimportant). Instead of a resistor load in the mesh output circuit, a parallel-tuned circuit adjusted to 30 Mc was used. The 30-Mc output amplifier was of typical i-f amplifier design with a bandwidth of approximately 4 Mc, and following this, was a detector and a video amplifier. Since the tuned-circuit load and amplifier prevented the capacitively coupled video from being amplified, the electrical output was isolated from the incoming video.

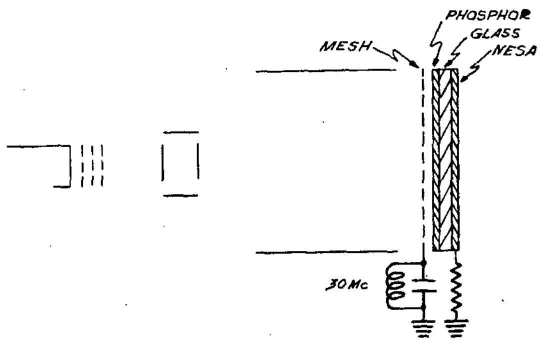


Figure 5 - Nesa-coated mosaic used in back-plate modulation experiments

The theory of operation is based upon the following principles. Each element of the mosaic can be considered as an individual capacitor which can be independently charged. As the electron beam progresses across the mosaic, it serves to maintain the surface of all elements along its path at approximately mesh potential (positive equilibrium point). Simultaneously, video information impressed upon the back plate alters the potential on the opposite side of the mosaic elements due to capacity coupling. Those elements under the beam at the time of a video pulse are restored toward mesh potential, since the beam action tends to return all element surfaces to the positive equilibrium point. This results in a change in charge on each elemental capacity, the charge magnitude depending upon the incoming video information.

On the next successive range scan, repetitive video information (fixed targets) will not alter the element charges since the charge magnitude already conforms with the video information. Nonrepetitive video information (moving targets) results in a change in the corresponding element charge to conform with the new information. This instantaneous change in charge is accompanied by a change in the number of secondary electrons escaping from the mosaic, which in turn alters the net electron current flowing in the mesh tuned circuit. The change in electron current serves to amplitude-modulate the 30-Mc carrier, thus producing an MTI output.

An incidental difficulty arose as a direct result of carrier read-off. It was found extremely difficult to prevent the 30-Mc carrier from capacitively coupling into the output. Shielding was only partially effective due to the tube construction. In future applications involving carrier read-off it is proposed to intensity-modulate at one-half the output amplifier frequency. Assuming a pure sine-wave input, the capacitively coupled r-f will not be amplified. By driving the intensity grid into nonlinear operation, the tube can serve to generate second harmonics which can be amplified to produce the desired output.

Another practical difficulty arose in the experimental trials. Nesa was found to be far from a perfect conductor. When an attempt was made to tune the high capacity existing between the mesh and the Nesa back plate, the resulting "Q" and circuit impedance were so low that no electrical output could be detected. This system was thereupon abandoned until a tube could be obtained with a low-resistance back plate.

CONCLUSIONS

The mode of operation involving controlled leakage produces an MTI output. However, the output is proportional to the time lapse between exact pulse coincidences rather than to the result of a pulse-to-pulse amplitude comparison. Tube contamination by foreign material nullified further attempts to minimize this defect. Undesirable spiking of the output occurs due to writing speed variations as the electron beam is deflection modulated.

Back-plate modulation tests are as yet inconclusive since the experimental tube is not directly adaptable for this mode of operation. Further tests will be conducted when a suitable tube becomes available.

The investigation has been seriously handicapped by physical defects of the experimental tubes. Every tube has developed an ion spot during operation. A short circuit developed in one tube, another was low in cathode emission, and still another was found to be contaminated with foreign material on the mesh. In view of these tube defects, continued tube development is a requisite for further application investigation.

FUTURE DEVELOPMENT PROSPECTS

Since the beginning of this study, continued development of the Haeff Memory Tube at the Naval Research Laboratory produced a tube which no longer employs a wire mesh as a means of controlling the mosaic potential. The new tube appears to simplify the read-off phenomena and has already demonstrated better resolution capabilities. Further investigation will be directed toward possible application of this new tube as well as the original type. Among several proposals yet to be studied is a charge recording and comparison process which involves switching the writing-beam net velocity between successive scans.

* * *

NAVY-DPPO-PRNC-WASH D C [illegible]