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FR-3754

RESULTS OF FLIGHT TESTS ON COMPONENTS OF THE DATA RELAY NAVIGATION SYSTEM

NAVAL RESEARCH LABORATORY

WASHINGTON, D.C.

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ABSTRACT

A short history of the Data Relay Navigation System is given together with a description of the components. Photographs of the received picture in the aircraft while in flight are included and a generally favorable comparison is drawn between it and the transmitted picture. The antenna collector system used on the aircraft in conjunction with the 1000-Mc link ground transmitter is discussed from the standpoint of its limitations. Conclusions are drawn that the picture as received by an aircraft with such a system is technically satisfactory for possible short-range navigation, and recommendations are made for a higher-power, lower-frequency link transmitter to give more reliable reception in the aircraft.

PROBLEM STATUS

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

AUTHORIZATION

NRL Problem R04-42R
NR 504-420

[redacted]

[redacted] DECLASSIFIED

UNCLASSIFIED

RESULTS OF FLIGHT TESTS ON COMPONENTS OF THE DATA RELAY NAVIGATION SYSTEM

INTRODUCTION

The Data Relay Navigation System is part of the NRL implementation of the CNO Aviation Plan No. 73.[1,2] Specifically, the DARN system is planned as an experimental investigation of a portion of the over-all carrier all-weather flying program. The short-range navigation portion of the data relay system observes the position of aircraft within radar line-of-sight from the carrier by means of a search radar. The radar picture plus a video map containing wind and weather information is transmitted, via radio link, to the aircraft where a suitable receiving unit presents the data to a pilot or navigator on a CRT.

For the initial development, a Navy search radar (SP-1M) and an AEW receiver-decoder (P02M) were procured. A test video generator was modified to serve as a synchronizing center and added to the SP-1M equipment trailer. In addition a Block III link transmitter was installed in the SP-1M. Thus the SP-1M, plus added components, was capable of scanning the surrounding area and transmitting its gathered data by radio link to the P02M for display. One important item remained to be added. To supply map data and write-in information, a VE remote indicator was modified into a flying spot scanner using photographic negatives.

Once the SP-1M —P02M link had shown the feasibility of using the modified SP-1M as an information-gathering and -disseminating center, the next step was to build an airborne equivalent to the P02M. For the first model, a type AN/APS-15A radar receiver-indicator was modified to contain the Block III receiver and the decoder circuits. Test flights in February 1948 with this setup showed the feasibility of the system but cast grave doubts on the usability of the low-power link transmitter then in use. After considering the need for higher power and the possible transfer of the Block III band to other services, it was decided to change to a 1000-Mc link frequency.

After deciding on the 1000-Mc link frequency, work progressed along four main avenues.

1. A new airborne equipment was built resulting in the unit we now have.

2. A 1000-Mc, 70-watt link transmitter was designed and constructed.

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[1] Brodzinsky, A., Friedland, M. S., and Chitty, H. W., NRL Report R-3291, dated 1 June 1948

[2] Brodzinsky, A., "Recommended Research Program for Carrier All Weather Flying," NRL Report 3458 (Confidential), dated 27 April 1949

DECLASSIFIED

Figure 1 - SP-1M radar ground station

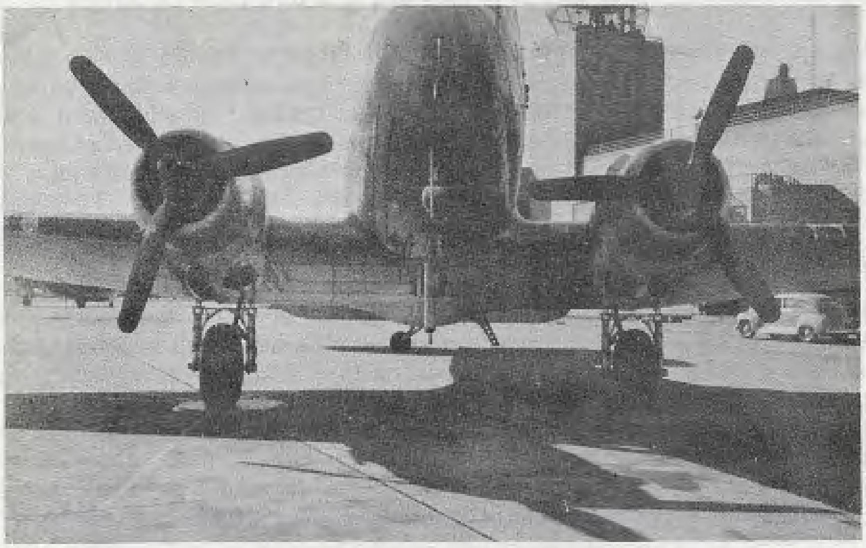

Figure 2 - DARN-equipped plane

3. The flying spot scanner underwent several modifications, using various tubes. The present video mapping scanner uses a specially built cathode-ray tube with a P11 phosphor.

4. Aircraft identification was provided by using an S-band beacon. Several beacons were tried with some success. We are at present using an APN-29 beacon.

DESIGN AND DEVELOPMENT

Essential Components of the Ground Equipment

The video generator, which is a Navy test equipment manufactured to provide a check of the over-all performance of the shipborne AEW System in the absence of an AEW plane, provides the initial rotational data. Its output consists of four sync pulses giving azimuth and timing information. A block diagram of the ground equipment is shown in Figure 3.

The output (as shown in Figure 4) consists of:

1. A basic pulse, establishing the start of each repetition cycle.
2. A sine pulse, so-called because the time interval between it and the basic pulse is a function of the sine of the azimuth angle of the radar beam from an arbitrary reference.
3. A cosine pulse, so-called because the time interval between it and the sine pulse is a function of the cosine of the azimuth angle.
4. A "transmitter" pulse--a timing pulse for the indicator sweeps.

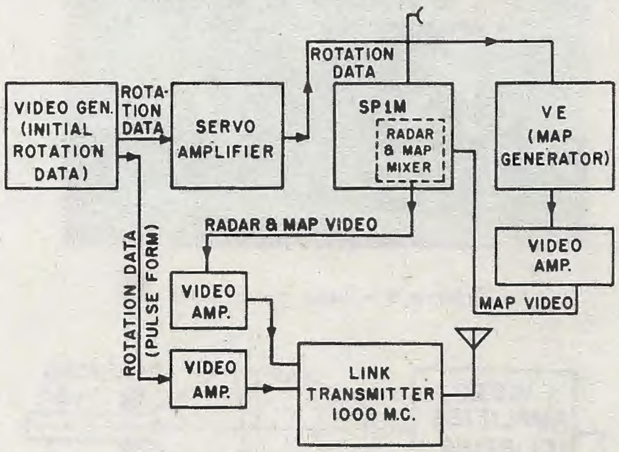

Figure 3 - Block diagram of the ground equipment

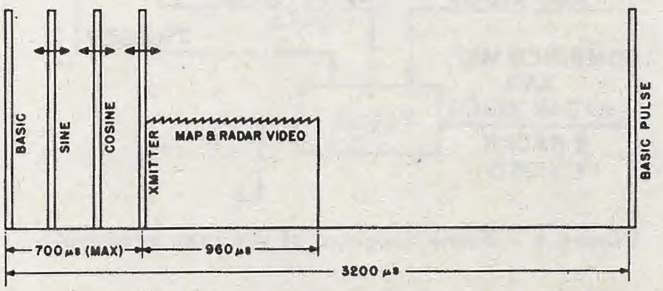

Figure 4 - Time block

The main modification made in the video generator for use in the DARN system was the addition of a sync generator geared to the sine potentiometer to generate rotational data for the SP-1M and map generator in synchronism with the pulse rotation data sent to the link transmitter.

Map Generator

This component of the ground equipment (with the possible exception of the 1000-Mc link transmitter) presented the most difficult problem, chiefly because of the high resolution requirements.[3]

Figure 5 and Figure 6 show a picture of the VE indicator modified for mapping and an operational block diagram respectively.

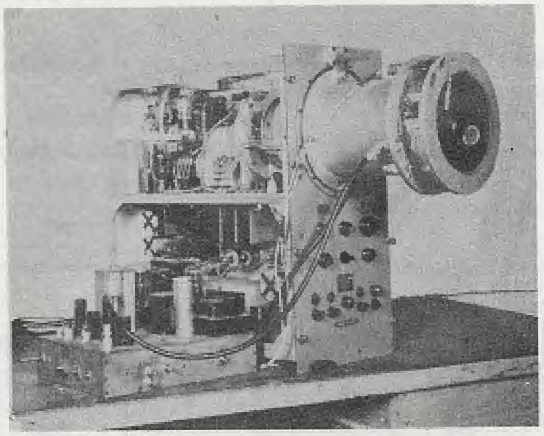

Figure 5 - Map generator

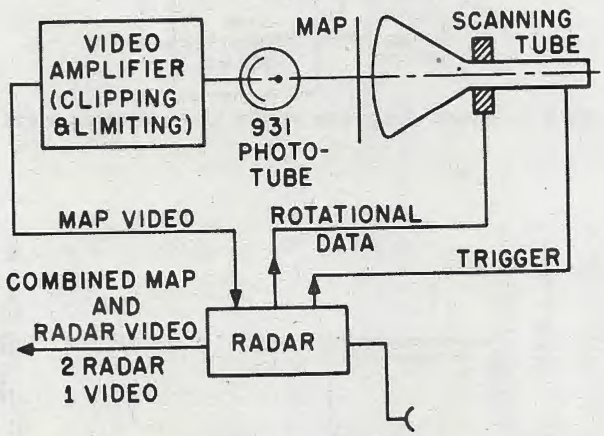

Figure 6 - Block diagram of the map generator

3 Winick, A. B., and Saffitz, I. M., "Video Mapping for the Data Relay Navigation System," NRL Report R-3317 (Confidential), 14 July 1948

The video mapping device consists of:

1. A scanning CR tube in a standard Navy VE indicator,
2. A map negative placed in front of the tube face,
3. A phototube to pick up the variations in light output, and
4. An amplifier to raise the level of the phototube output.

The flying spot of the CR tube completely scans the map placed in front of it. The map data, consisting of transparent lines on an opaque background, cause a variation in the light reaching the phototube which corresponds to the map lines. The phototube converts these fluctuations into video pulses, and the accompanying video amplifier shapes them into rectangular pulses of greater amplitude.

The scanning beam is triggered by the transmitter pulse of the radar, and the deflection coil is rotated in synchronism with the radar antenna. The sweep length of the beam of the scanning tube is made to correspond to the scale of the map being used. Consequently, when map and radar data are superimposed, radar targets will be in the correct azimuth and range relationship to the map. This map video is then mixed with the output of the radar receiver and the combined output modulates a link transmitter. The signals are received in the aircraft, and the composite picture is reproduced on the airborne indicator. The plane also receives transmitted rotational data, so that the airborne indicator is in synchronism with the radar antenna.

Besides the standard 50- and 80-mile map, provision has been made for easily inserting write-in-forms into the map holder. The forms are made of plexiglas on which is placed a coating of Durol black dye mixed with tallow. The coating does not harden, and a blunt stylus can be used as the writing instrument. Another method of obtaining written messages is to use a stencil-cutting machine. The ease of message construction allows a wide variety of written information to be sent up to the pilot, and such data as wind and weather information can be transmitted and appear visually before the pilot.

The Link Transmitter

In keeping with the program as originally proposed for the Data Relay Navigation System, namely, that it was to be developed from existing components readily available to the Navy, it seemed logical than an existing transmitter be taken and modified for the specific purpose. An available Block III transmitter was modified so that it could be plate-modulated with sync pulses and grid-modulated with map and radar video. This type of modulation was necessary so that we could maintain a two-to-one ratio of sync to video which was necessary for proper operation of the airborne decoders. This transmitter was used to feed a slot antenna of the "split can" type with some gain, so that the effective radiated power was in the neighborhood of twenty-five watts at 300 Mc.

After extensive flight tests it was obvious that a transmitter with higher power output would be necessary in order to have a greater signal strength at the plane so that consistently good PPI presentations could be displayed in the cockpit.

In view of the fact that the Block III frequencies would not always be available for this type of work, it was decided that our efforts should be directed toward the development of an entirely new transmitter with greater power output and at some available frequency in the uhf band. It was suggested that the logical frequency should be 1000 Mc.

The new transmitter consists of a coaxial-line oscillator, a coaxial-line amplifier, and the modulator power supplies.[4] Separate sync pulse and video inputs were employed to simplify the problem of maintaining a two-to-one ratio of sync to video. The sync pulses were used to drive a blocking oscillator and the video was used to drive a video amplifier. 807-type tubes were used in both of these stages and their outputs were combined to drive four 6AS7 modulator tubes.

Figures 7 and 8 are photographs of the 1000-Mc link transmitter.

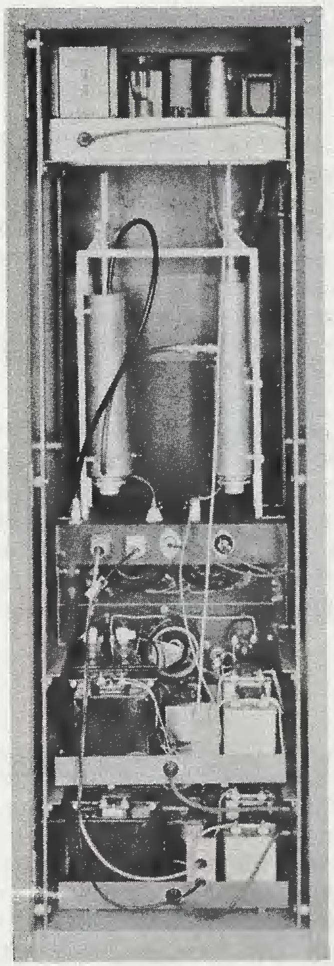

Figure 7

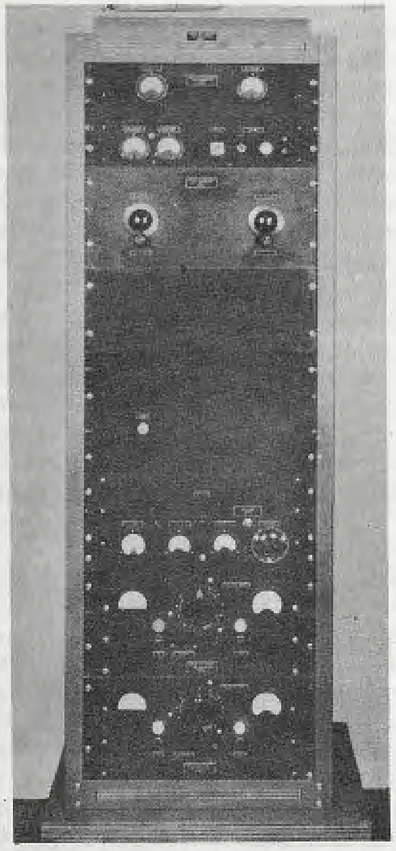

Figure 8

The 1000-mc link transmitter

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[4] Huntley, K. L., Heinmiller, D. R., "Experimental Video Link Transmitter at 1000 Mc for the Data Relay Navigation System," NRL Report 3551 (Confidential), 6 October 1949

Airborne Equipment

The antenna as now used is a 1000-Mc stub mounted on the end of a radome which is suspended from the under side of the fuselage in a forward position just below the pilot compartment. Figures 2 and 10 show the antenna mounted on the R4D used in the flight tests.

The decoder, or console, went through several designs.[5] The first model used an APS-15 chassis with the receiver and decoding circuits as the only addition. Operation and flight tests were fair but intermittent action of sweeps occurred due to loss of sine or cosine voltages from the decoder because of insufficient signal strength. It was decided to build a new unit with improved circuit design and more compact arrangements. Figure 9 shows the airborne equipment exclusive of the beacon.

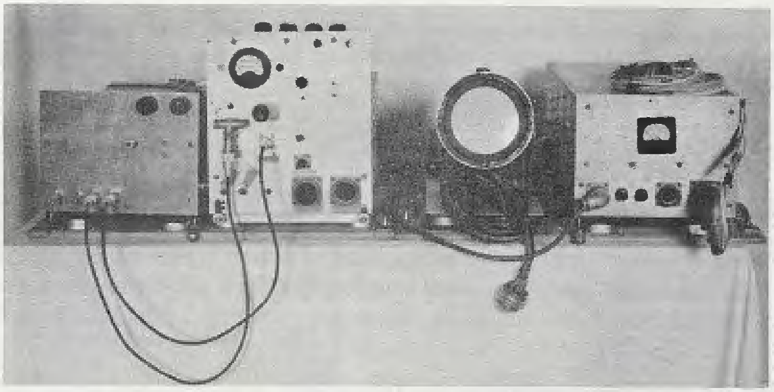

Figure 9 - Airborne equipment

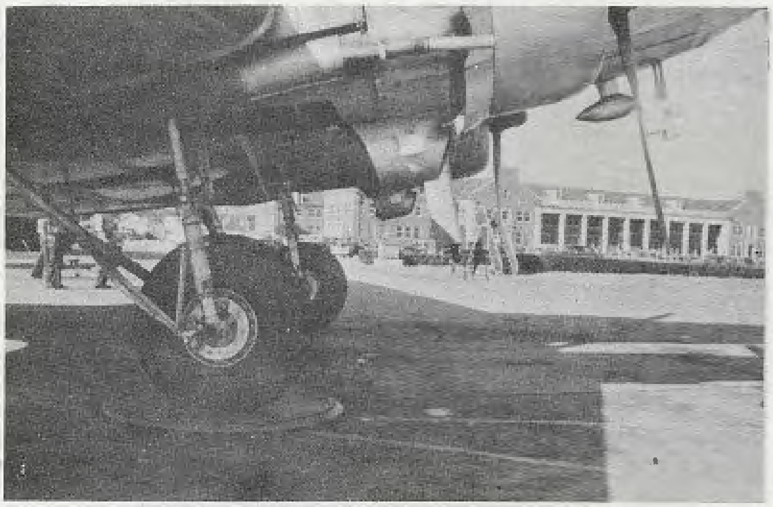

Figure 10 - Airborne equipment antenna

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[5] Pending NRL Report on Airborne Components of the Data Relay Navigation System

Some time was spent on the decoder units before obtaining satisfactory results since the circuits seemed to be very critical to slight variation of components and line voltages.

A beacon is used for purpose of plane identification so that each plane so equipped can place itself in relation to other planes in the air. An AN/APN-29 S-band beacon is used for the purpose. Ultimately a beacon should be designed to be incorporated into the system's console so that weight and bulk are reduced.

RESULTS OF TESTS

Range of the System

In our experimental system the maximum usable range was slightly over 30 miles. With further development this range could probably be increased by three methods which are given below.

Transmitted Power

At the present time the 5588 triode which is used in the link transmitting is being operated at its limit, indicating that the first approach to more power output involves the procurement of a new type of tube or combination of tubes. Increased activity in the vicinity of 1000 Mc for other purposes indicates that there may be new tubes available in the near future. This method seems to be the most positive approach to longer range.

Collector System on the Aircraft

It is very probable that an increase in range can be realized if a better airborne collector system can be obtained. The most reliable to date has been a $\lambda/4$ stub. It seems quite possible that with proper design a $\lambda/2$ antenna could be used which would effectively increase the range due to increase in the effective height. The dipole would be the simplest approach. However, other antenna systems should be investigated which would possibly increase the range by a greater factor than the dipole.

Decoder

It is possible that some improvement over the present receiver sensitivity of 100 microvolts required for the decoder can be attained, but it is expected that the improvement in this regard would be small.

The above suggestions are made in the event that the link frequency is to remain at 1000 Mc. It may be advantageous, however, to investigate the use of lower frequencies for the link, including the use of some of the recently developed data compression systems at vhf and uhf.

Figures 11 and 12 show photographs of the ~~antenna~~ airborne indicator with beacon responses at two different distances from the transmitter.

Reliability of the Presentation

Straight Flights on a Radial Line from the Transmitter

Although our maximum range was 30 miles, the picture was not continuously available from this point in to the transmitter. The presence and absence of the pictures with range was caused by the radiation pattern of the transmitting antenna as sketched in Figure 13. This pattern was verified by many flight tests, which gave consistent results with regard to the null points.

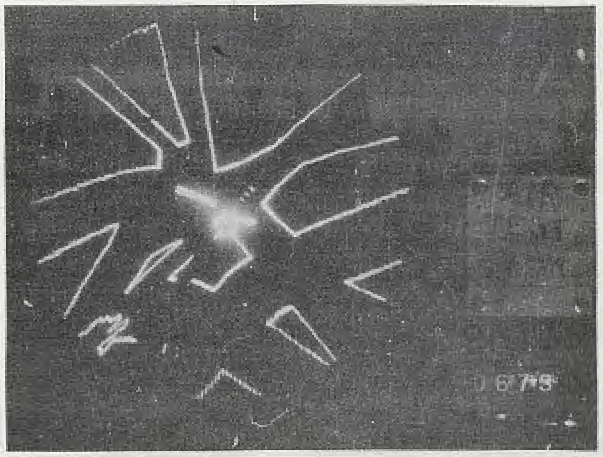

Figure 11 - Picture on airborne indicator.
Plane about 10 miles out.

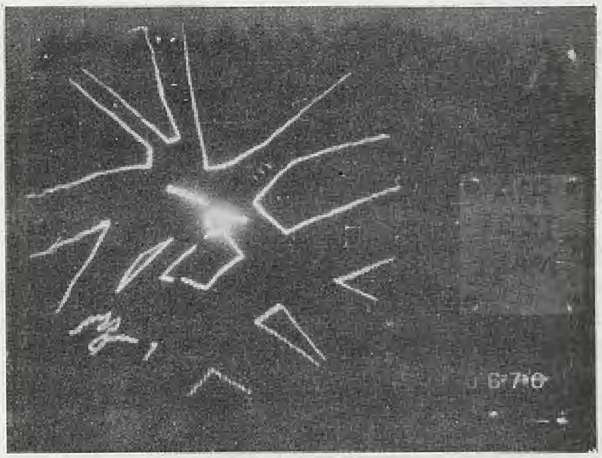

Figure 12 - Picture on airborne indicator.
Plane about 20 miles out.

The received picture was satisfactory from about 30 miles to about 15 miles. Inside the 15-mile range the picture was not continuously available. However, the picture, when available inside the 15-mile range, was of good quality.

<u>Reliability of Presentation with the Aircraft Maneuvering</u>

Several antenna reception systems were tested while maneuvering in the aircraft.

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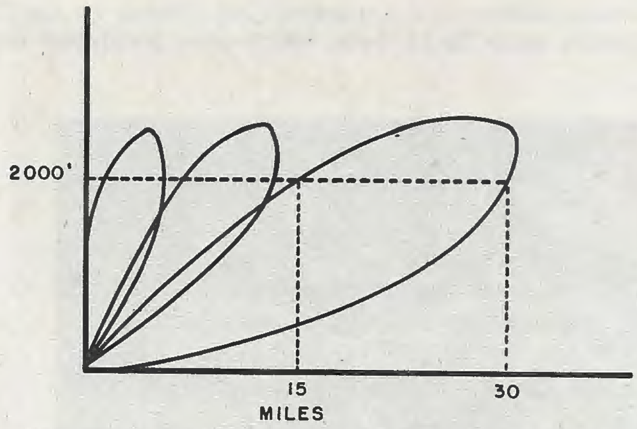

Figure 13 - Antenna pattern, 1000-Mc transmitter

1. A single λ /4 antenna on an 18-inch extension mounted on the belly of the plane midway between the wings and the tail. Results were fair in level flight but poor with any type of turn.

2. A λ /4 antenna on the bottom of each wing tip. Data was taken on antenna voltage for each antenna while turning. Performance was fair, with one of the two antennas providing a usable signal at all points on the turn, but sensitivity was decreased due to the long leads between the antenna and receiver. Another drawback to the system is the necessity of providing an electronic selector to cut in only one antenna at a time.

3. The final antenna tried was the same antenna mounted on a 5-ft radome on the belly of the plant at the front edge of the wing. Results were fair and the map stayed in at all points on a 360° turn with a bank of 10°.

The desired requirements of the system with respect to constant picture with the aircraft maneuvering have never been defined. This is a problem, however, which has had many parallels in electronic systems in aircraft. A study of the literature on the subject might provide the best answer. Once again increased power output of the transmitter may improve this condition.

Written Messages

The messages which were transmitted and received were of two different types as explained previously. The first type was a Plexiglas form coated with black dye mixed with tallow. The coating does not harden and the message can be written with a blunt stylus (Figure 14). The second type of message was a form of opaque stencil paper with the message stamped out with the stencil machine (Figure 15).

Possibly the final system would be a stencil machine similar to a typewriter, but equipped with special characters using opaque paper circles about the size of the map and 1/4- or 3/8-inch letters. With such equipment messages could be typed out and transmitted as needed with little time delay. Figures 14 and 15 show actual photographs of airborne indicators illustrating various types of written messages. The curved character of the lines is due to nonlinearity of the sweeps in the indicator.

[redacted]

 [redacted]

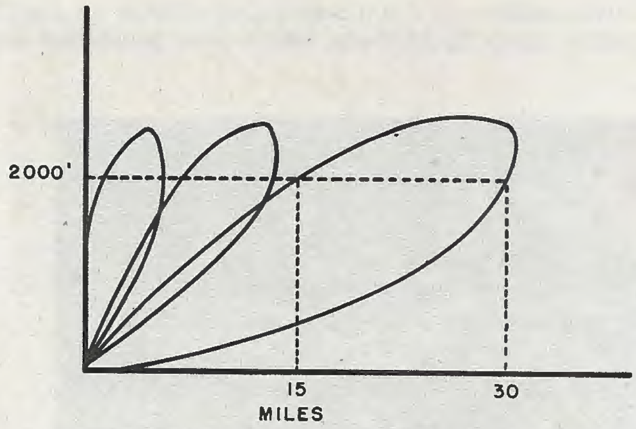

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Figure 14 - Transmitted written message

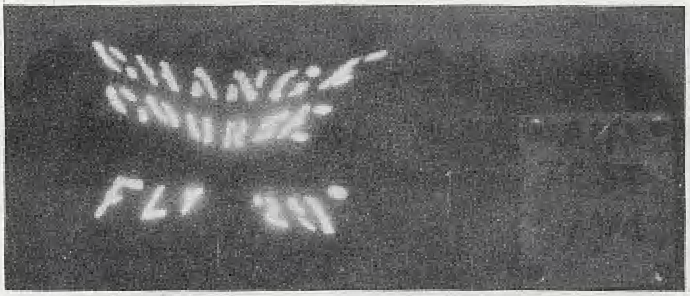

Figure 15 - Transmitted stencil machine message

Another variation in message transmission would be as shown in Figure 16. With this particular variation the transmitted picture would not be removed when the message is transmitted. The message covers only a portion of the map and a radial line points to the particular aircraft being directed.

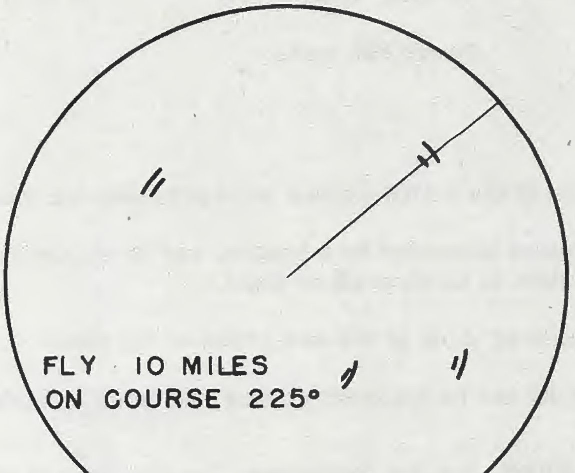

Figure 16 - Map with written message superimposed

[redacted]

This type of message has not been transmitted and would require an additional phototube scanning system, the output of which would be mixed with the output of the map generator. It seems probable that with this additional equipment integrated with the present equipment the desired message form could be obtained.

Saturation Point of the System

We have used only one (multipulse beacon-equipped) plane in our tests. It is evident that as more planes are added to the display, overlapping of the beacons' responses and saturation of the display will result. However, if the beacons are restricted to a single pulse, and self-identification provided by a lubber line, this saturation point would be higher. In addition, altitude separation as was proposed in the Teleran system will also raise the saturation point.[6,7] This second proposal will require additional equipment.

Weight, Volume, and Power Requirements of the Airborne Components

The weight, volume, and power requirements of the present system are as follows:

Weight, 80 pounds

Volume, 5 cubic feet

Power, 800 watts

Since the system tested was the first of its type, with workability the primary consideration, it is possible that the following should be attainable:

Weight, 50 pounds

Volume, 3 cubic feet

Power, 600 watts.

CONCLUSIONS

The evaluation flights of the DARN system have provided the following conclusions:

1. A map, with the plane identified by a beacon, can be successfully displayed with acceptable resolution in an aircraft in flight.

2. This presentation is of value in the navigation of the plane.

3. Written instructions can be transmitted and presented as above with good readability.

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[6] RCA Report on TELERAN for Air Navigation, Traffic Control and Instrument Approach dated 20 January 1946

[7] "The Teleran System of Air Navigation," Watson Laboratories, AMC, Red Bank, N. J., technical report number 46 (Restricted), 30 November 1949

4. The simplicity of the presentation is good, and the information may be utilized with little or no technical instruction or ability.

5. Uses of this system for other than aircraft navigation seem apparent. For example:

   (a) To provide small harbor craft (tugs, pilot boats, etc.) with an all-weather picture of the harbor and ships inside the harbor. The cost, weight, bulk, and power requirements of the shipboard equipment should be much less than that of supplying a radar system for each small craft.

   (b) To provide each ship of a convoy with a picture from a central ship.

   (c) Direction of helicopters for sonar dunking.

RECOMMENDATIONS

Based on the investigation carried out, the following steps are recommended:

1. Development of a more powerful link transmitter (not necessarily at 1000 Mc).

2. Development of a better transmitting antenna.

3. Investigation of antenna receiving systems in aircraft with regard to continuous receipt of signal by aircraft while at various altitudes.

4. Investigation of use of the system for navigational purposes.

5. Evaluation of the system in actual navigation flights after improvements are effected.

6. Investigation of narrow-band techniques (at a lower link frequency) for the system.

* * *

NAVY-DPPO PRNC. WASH., D.C.