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Research Order #1
Phase I - Progress Report #4

7 April 1954

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OBJECTIVE:

To study and evaluate the factors and components involved in the design of a portable infrared communicator.

GENERAL DATA:

The work to be performed according to Bid Proposal #76-1, Phase I, may be summarized as follows:

A. Evaluation of sources and sensitive elements

B. Determination of beam width requirements and evaluation of "find-operate" systems

C. Study of modulation methods and attendant optical systems

D. Evaluation of power sources

E. Study of required circuit characteristics

The results of these studies will be used as the basis for recommending a system to be developed.

DETAILED DATA:

A. Evaluation of sources and sensitive elements

Investigation of sources has been centered about tungsten filaments and zirconium arcs with the following results:

First it should be pointed out that the transmitter can be analyzed in a manner identical to the analysis of searchlight systems; that is, since a luminous source is to be placed at the focal point of an optical system, and the resultant beam has small angular width, the net result (neglecting modulation) is no different from an automobile spotlight or a 60 inch searchlight

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insofar as illumination is concerned. The theory of searchlights has been well covered in the literature[1], but the important result for our application is that the illumination produced by a searchlight at a point on its axis is equal to that which would be produced by a source of the same size as the exit pupil (normally the searchlight reflector) and having the same brightness as the original source. The product of the area of the exit pupil and the brightness of the source is called the beam candle power, and the illumination produced is directly proportional to this value.

Since the illumination at the receiver determines the signal value, it is of prime importance to maximize the beam candle power of the transmitter. Extending the size of the source does not increase the beam candle power if its brightness is kept constant; it is of importance, however, in determining the angular width of the beam thru which the beam candle power is a maximum. Also, if mechanical modulation is used, problems involved are proportional to the source size.

Thus for our application it is of prime importance to consider the brightness of the source and the diameter of the optics. The focal length of the optics and the size of the source together will determine the beam width, according to the approximate formula $W \cong 57.2 \frac{s}{f}$ degrees. Conversely, if the beam width and focal length are given, the source size is immediately dictated.

Size considerations have restricted our thinking to a maximum diameter of 10 inches and a focal length in the range of 6 to 10 inches for the optics. The necessary beam width has not been derived, but we believe it will be in the neighborhood of one degree. The resulting source size then is from 0.100 to 0.180 inch.

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[1] JOLLEY, WALDRAM & WILSON: "The Theory & Design Of Illuminating Engineering Equipment", Wiley, 1931.
HARDY & PERRIN: "The Principles Of Optics", McGraw-Hill, 1932.
JENKINS & WHITE: "Fund.Of Optics", 2d ed., McGraw-Hill, 1950

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The characteristics of three zirconium arcs are given below:

Power	Size	Brightness	Life
2 watts	.003"	9,620 C/cm^2	175 hrs.
10 watts	.016	5,500 C/cm^2	700 hrs.
25 watts	.029	4,030 C/cm^2	800 hrs.

It is seen that even the largest of these falls far below the minimum tentative size requirement. It is possible to increase the effective size of the source by at least two schemes, but one of these decreases the net beam candle power, and the other imposes requirements on the optical system which are not feasible at such low focal ratios as we are considering. Such a lamp would be ideal for use once contact were established because the narrow beam greatly improves security.

The life indicated for these lamps is quite favorable as is the extraordinary brightness. The brightness of any of the lamps can be increased even further at the expense of life. Their small size makes them ideal for mechanical modulation.

In Volume 4 of the Summary Technical Report of Division 16, NDRC (1946) is listed a majority of the tungsten lamps used during World War II for infrared applications. Of the many listed one appears to have possibilities for our use. Its characteristics are:

Power:	30 W
Size:	1 mm x 7 mm (approx.)
Brightness:	2100 C/cm^2 *
Life:	30 hours

This size filament would form a beam of approximate dimensions $1/3^o$ x $2\text{-}1/2^o$ with 6" focal length optics when oriented perpendicular

* based on an approximate color temperature of $3,300^o$ K.

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to the optical axis. If the coil axis were made coincident with the optical axis, the beam would be symmetric and about 1/2° across.

This lamp is the type 1045 and was used in the production model snooperscope and sniperscope. It represents about the maximum brightness that can be obtained consistent with reasonable life and power. However, by over running the lamp, the brightness can be increased approximately 20% for every 50% reduction in life. Thus, for a rated 15 hour life the brightness of this filament might be increased to 2,500 C/cm^2.

From an optical standpoint, the zirconium arc has everything in its favor but its size. Its brightness exceeds twice that of the tungsten filament, and its life is twenty times greater. Overall size of the lamps is nearly the same in either case, although the tungsten lamp is slightly smaller and more adaptable to reflective optics.

The main disadvantage of the zirconium arc is that it requires an initial starting pulse of at least 1,000 volts and a ballasted operating power supply of at least 50 volts for stability. Tungsten filament on the other hand, of course, can be designed to operate at practically any combination of current and voltage, and the coil can ordinarily be wound to a desirable size.

When a coiled filament is used as the source in a system however, the illumination across the generated beam is very non-uniform, the effect being caused by the space between adjacent filaments. This condition does not exist in the zirconium arc, since the source here is a spot of high brightness across its entire face.

In spite of its superior optical characteristics, the electrical difficulties of the zirconium arc plus its small source size will probably preclude its use in our design.

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B. Determination of beam width requirements and evaluation of "find-operate" systems

The darkroom is presently in use for beam width studies. Apparatus was set up in the last few days of this period and is now being debugged. Decade amplifiers may have to be used with the gear to improve signal response.

C. Study of modulation methods and attendant optical systems

Further study has been made of the problems involved in mechanical modulation systems. In general there must be a compromise between great optical magnification of the motion of the modulated surface and a compact, rugged construction necessary to maintain linearity and modulation percentage under field conditions. As explained in section "E" (below) a system of non-linear modulation is being considered. This system would require 100% modulation on all frequencies, and the difficulties in achieving this might more than overcome those involved in maintaining good linearity in a system using a variable modulation percentage.

The general limits on the size and displacement of the modulated surface are being set on the basis of theoretical studies. When these are completed, a transducer capable of supplying the motion will be chosen, and an appropriate optical system built up for tests.

D. Evaluation of power sources

An order has been placed with Motoresearch Company, of Racine, Wisconsin, for two alternators to the following specifications:

1. Mechanical input: 100 watts at 12,000 rpm
2. Electrical output: 6.3 v, 9 amp., and 220 v, 100 ma at 800 cps
3. Voltage regulation: 5%

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4. Wave form: 10% total harmonic distortion
5. Rotor to withstand: 15,000 rpm rotation
6. Size: 12 cu. in. maximum volume
   1.5 lbs. maximum weight

While this specification was set up primarily for a system using a tungsten source and mechanical modulation, the alternator frame could be adapted to voltages required by other sources and modulation methods. The cost of two units will be $2,235, and delivery is expected by July 1.

[redacted] has completed delivery of the four engines ordered for test. A preliminary check of the silenced engine (which consists of a special silencer to which a standard engine is fitted) indicates that, while the reduction of exhaust noise is great, a further reduction will be required for our application. Complete tests will be made when a suitable test stand has been fabricated. 25X1

E. Study of required circuit characteristics

A study is being made of the system of non-linear speech transmission reported in the "Proceedings of the Symposium On The Application Of Transistors To Military Electronic Equipment, at Yale, September 1953." This system is based on the observation that most of the intelligence is contained in the time relationships of the zero-crossings of the speech wave form. The speech signal is differentiated, and the resultant used to trigger a flip-flop. The pulse output (which amounts to "infinite clipping" of the input signal) is transmitted through whatever band pass would normally be used. At the receiving end integration restores a fairly normal sound.

It is claimed that this system gives intelligibility at signal-to-noise ratios of 1 or less. When applied to a mechanical modulation system, it would make it unnecessary to maintain linearity of modulation, which is normally quite difficult to achieve over reasonable dynamic range. The disadvantage, as pointed

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out above (C), is that the non-linear system calls for a capability of 100% modulation over the pass band.

Equipment necessary to test the system has been ordered or is already on hand. Tests will be coordinated with the modulator studies.

PROGRAM FOR NEXT INTERVAL:

Beam width tests will continue. Theoretical studies will be pushed far enough to make possible some tests of electro-mechanical transducers for use as modulators.

Report prepared by

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