

RADIO TASTE RECEPTION*

By

ALFRED N. GOLDSMITH

(DIRECTOR, RESEARCH DEPARTMENT, RADIO CORPORATION OF AMERICA)

AND

EDWARD T. DICKEY

(ASSISTANT RESEARCH ENGINEER, RADIO CORPORATION OF AMERICA)

I. INTRODUCTION

Practically all reception of radio telegraphic signals of a practical nature which has been done up to the present time has been accomplished thru the sense of hearing of the operator. Some slight amount may have been done by using the operator's sense of sight, but this has never been found sufficiently satisfactory to warrant its use in practice. It was suggested by Mr. Arthur A. Isbell, that under certain operating conditions, for example, in places where there is great interference due to exterior noises, as in the case of the operator on an airplane, there might be a certain advantage in employing the operator's sense of taste rather than his sense of hearing in receiving signals. The object of this paper is to describe some tests made to determine the feasibility of reception of radio telegraphic signals by the sense of taste.

II. PRELIMINARY TESTS USING DIRECT CURRENT AND 60-CYCLE ALTERNATING CURRENT

1. TESTS USING DIRECT CURRENT

(A) APPARATUS

(a) ELECTRODES

The fact that a stinging taste sensation may be produced by placing the two wires of a low potential electric circuit on the tongue is well known. The first problem met with in investigating taste reception was to design a pair of electrodes which

*Received by the Editor, January 12, 1920. Presented before THE INSTITUTE OF RADIO ENGINEERS, New York, October 6, 1920.

could be kept in the operator's mouth for a considerable length of time. It was, of course, necessary to choose for the metal of these electrodes some material which would not form injurious salts of the metal in the mouth of the operator. This limited the available metals to gold, platinum, or silver. Because of the prohibitive cost of the first two, silver was selected for use in these tests.

Two electrodes were made of sheet silver about 0.016 inch (0.04 cm.) thick, 0.5 inch (1.27 cm.) wide, and 2 inches (5.08 cm.) long. They were separated by a piece of insulating material about 0.25 inch (0.63 cm.) thick. The construction is shown in Figure 1. It was intended that the tongue should be placed between the electrodes. Wires were brought from each electrode so that they might be connected to a source of potential.

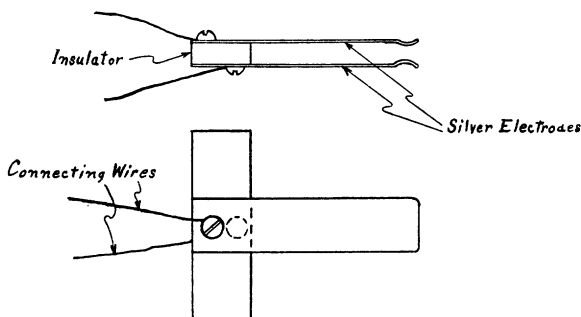


FIGURE 1

A few tests were made to determine the best position, pressure, and size of contact for the electrodes. It was found that placing the tongue between the electrodes as originally intended did not give the most satisfactory results. For the tests using direct current and 60-cycle alternating current, it was found better to have the electrodes slipped over the upper front teeth rather than the tongue. In this way one contact touched the inner part of the upper lip, while the other could be conveniently touched by the tip of the tongue. All the taste sensation was then confined to the tip of the tongue, which was found to be by far the most sensitive region in the mouth. The electrode touching the upper lip acted merely as a means for connecting that side of the circuit to the mouth.

In later tests made when using signals from a buzzer

source, and signals from an antenna, it was found that the arrangement of electrodes just described was apt to cause painful sensations in the operator's front teeth. In an effort to prevent this, another disposition of the electrodes was tried. This was to have the ends of both contacts touch the tip of the tongue. This arrangement was found to give very good results. It had been tried previously when using the direct current and 60-cycle alternating current sources of potential, but had been found unsatisfactory, probably because of the relatively higher current and lower potential values common to such sources.

In all cases the best pressure between tongue and electrodes was found to be a firm, but by no means heavy pressure.

The electrodes should be small and should be close together so as to confine the taste sensation to a small area of the tongue and thus concentrate it. Two pieces of number 16 silver wire¹ 0.5 inch (1.27 cm.) long, separated about 0.125 inch (0.31 cm.) and partially imbedded in some insulating material would make very satisfactory electrodes for actual signal reception. The taste sensation should be obtained with the tip of the tongue, for this organ becomes increasingly insensitive toward its posterior portion.

(b) DIRECT CURRENT CIRCUIT

The circuit and instruments used in the d.c. tests are shown in Figure 2. Storage cells were used as the source

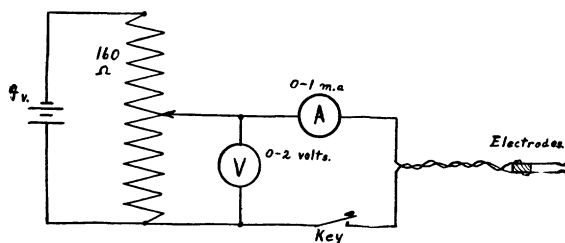


FIGURE 2

of potential. The potentiometer was a 160-ohm sliding contact resistance connected as a potentiometer. The voltmeter had a range of 0-2 volt, and the milliammeter had a range of 0-1 milliampere. The contacts of an omnigraph could be substituted for the key shown in the figure.

¹ Diameter of number 16 wire = 0.05 inch = 0.013 cm.

(B) OBSERVATIONS

The first test that was made was to determine the constant potential necessary to produce the least noticeable taste sensation. It is quite probable that this potential would vary with different individuals, and possibly with the same individual at different times. The value necessary for the observer was $V=0.4$ volt. For this potential, the current thru the tongue, as indicated by the milliammeter, was 0.01 milliampere. Tests were then made at higher potentials, the results obtained being as follows:

$V=0.75$ volt. The tests made indicated that signaling would be impossible at this potential. The element of fatigue was strongly noticeable at this voltage. It was found that if the key were kept depressed for 5 seconds, it was impossible to detect the opening and closing of the key immediately after the continuous current period. In fact, it was generally necessary to rest for about 10 seconds before the opening and closing of the key could be again clearly noted. The current at this potential was about 0.02 milliampere. On first closing the key it is probable that the current was of the order of 0.1 milliampere for a short time. It fell quickly, however, to the lower value. This effect was probably due to the polarization phenomena which will be described later.

$V=1.0$ volt. Using this potential it was found that the opening and closing of the key could be detected after an almost indefinite period of continuous current. It should be noted here that while it is stated that the opening and closing of the key could be noted, it was really only the closing that produced a noticeable sensation. With the potentials used up to this point, it was not possible to note the actual opening of the key by noticing the cessation of the taste sensation. The current at this potential was approximately 0.05 milliampere. On first closing the key it was probably about 0.2 milliampere.

$V=1.5$ volts. Using this potential it was just possible to note the time of opening the key after a period of continuous current due to the cessation of the taste sensation. The current at this potential was approximately 0.1 milliampere. On first closing the key it was probably 0.2 milliampere. It would be possible to transmit signals very slowly (about 2 words per minute) at this potential.

$V=2.0$ volts. The taste sensation obtained with this potential was considered sufficient for the practical transmission of signals. The probable speed of transmission would not be over

10 words per minute, and possibly no higher than 5 words per minute. The current at this potential was approximately 0.25 milliamperes, and slightly higher than this on first closing the key.

(C) NOTES ON TASTE SENSATIONS

It is proposed to give herein the physiological effect of this method of reception on the operator, and to discuss certain electro-chemical phenomena in connection with the mouth electrodes.

It was noted that the taste sensation was more pronounced on first closing the key than after the key had been held down for some length of time. This was probably due to fatigue of the taste nerves on continuous excitation, and also to a partial polarization of the cell formed in the mouth. This latter effect would cause a decrease in the current, and thus a weaker sensation of taste. The fact, noted before, that the current was apparently higher on first closing the key seems to indicate that polarization was the deciding factor in this phenomena. This leads to the suggestion that alternating current might give better results than direct current as the source of potential, as the former would be free from polarization effects. It was found that the positive mouth electrode became blackened by a coating of oxide where the tongue made contact with it. As the other electrode did not become blackened at all, the nature of the polarization is clearly shown.

It will be remembered that in these preliminary tests one electrode made contact with the upper lip and the other was touched with the tongue. In the tests made so far, the latter had been connected to the positive pole of the battery. To determine whether the polarity of the tongue electrode would make any difference in the characteristics of the taste sensation, the polarity of the source of potential was reversed. It was found that the sensations were slightly less distinct when the negative pole was connected to the tongue electrode.

After this test the polarity of the electrodes was changed back to the original arrangement, and it was found that a much larger current now flowed in the mouth electrode circuit than had been obtained previously, using 2.0 volts potential. The current now obtained was 0.4 milliamperes instead of the 0.25 milliamperes previously recorded. On keeping the current on continuously it was found that the meter indicated a slow fall in the value of the current until the former value was approached. From this we conclude that the polarity of the electrodes

had been reversed until the polarization of the cell in the mouth was such that it assisted the flow of current. After the current had flowed for a time, however, the polarity of the mouth cell became again reversed, and by opposing the battery potential, caused the value of the current to fall.

In connection with the increase in current just described, a peculiar effect on the sight of the operator was observed. On closing the key the operator noticed an effect which, at first, made him think that the lights in the room were flickering. On further investigation, however, it was noted that the apparent flicker of the lights occurred only when the key was closed. As nearly as could be determined, the effect of this relatively large current passing thru the mouth was to cause the iris of the operator's eyes to contract momentarily, thus giving the effect of a flickering of the lights in the room. A slight effect of a similar nature was noted on opening the key.

In connection with the reading of signals by taste, it was noted that the greatest difficulty was experienced in reading dots which were immediately preceded by dashes. The letter "c" (—.—) was especially difficult to receive for this reason.

2. TESTS USING 60-CYCLE ALTERNATING CURRENT

(A) APPARATUS

The source of potential used was a 110-volt, 60-cycle generator. The circuit used is shown in Figure 3. The potential was impressed across the 160-ohm non-inductive resistance shown as R' in the figure. As the potentials needed in these tests were of the order of 1 or 2 volts, a second resistance, R'' ,

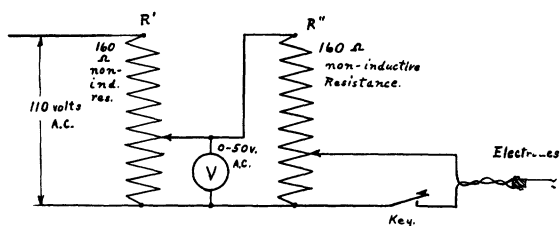


FIGURE 3

was shunted around a portion of R' . As there was no a. c. voltmeter available for this work, which could be used to measure 1 or 2 volts, the potential impressed across R'' was measured

by an a. c. voltmeter having a range of 0-50 volts, and the potential impressed on the mouth electrodes was calculated. As R'' was just 15 inches (38 cm.) long (actual resistance wire winding), a potential of 15 volts was impressed across it. Thus there was a potential drop of one volt per inch of length along the winding. R'' was wound non-inductively like R' . As the amount of current taken by the mouth electrode circuit was small (not more than 0.5 milliampere) and as great accuracy as to the value of the potential was not essential, this method gave a value which was sufficiently exact for our purpose. No attempt was made to measure the current in the mouth electrode circuit.

(B) OBSERVATIONS

Tests were first made to determine the lowest alternating potential with which it was possible to obtain a taste sensation. This was found to be with approximately $V=0.5$ volt.

$V=1.0$ volt. Using this potential it was found possible to note the time of opening the key after a period of continuous current, by the cessation of the taste sensation. It would be possible to transmit signals very slowly at this potential. The definiteness of the signal in this case was about the same as that obtained using 1.5 volts d. c. It is hard to compare the two directly, for as will be described later, the nature of the taste is rather dissimilar for the two types of current.

$V=1.5$ volts. The taste sensation obtained using this potential was considered sufficient for practical transmission at a rate of 5 words per minute.

Higher speeds than this (10 words per minute) might possibly be obtained by using higher potentials. It is probable, however, that this increase in speed would be due to the operator's ability to read by muscular reaction instead of the sense of taste. As will be described later, this phenomenon of muscular reaction was quite noticeable at the higher potentials.

(C) NOTES ON TASTE SENSATIONS

The taste sensation accompanying the use of an alternating current source of potential differed from that obtained using direct current in the following ways:

- 1.—The element of fatigue did not seem to be so noticeable when using a. c. This may have been due to a slight variation of the taste with the alternations.

- 2.—The taste sensations did not appear to be any stronger than those obtained using the same potential d. c. However,

it is probable that at the peak of each wave a larger current flowed than was the case with the d. c. The lack of any polarization phenomena with a. c. would lead to the belief that a somewhat larger current would be passed. The taste sensation was more continuous in its intensity when using a. c. than when using d. c.

3.—Combined with the taste sensation was the natural muscular reflex common to a. c., which was felt as a trembling in the tongue. At the higher voltages this was more noticeable than at the lower voltages. At 0.5 volt it was almost unnoticeable. It is probable that this muscular reaction was the principal reason for the taste sensations seeming to be more constant in intensity with a. c. than with d. c.

The more constant character of the taste sensation, combined with the slight muscular reaction obtained with a. c., made it possible to read signals, using a lower potential than was required with the d. c.

At higher potentials (2.0 to 3.0 volts) the same effect on the operator's eyes was noted that has been mentioned under the section on d. c. tests. As in the former case, the phenomenon was due to large values of current thru the mouth electrode circuit. In the a. c. tests a slight difference in the effect was noted. The operator not only noted a quivering of the eyes on first closing the key, but also a constant quivering as long as the key was held down. It was also noted that, for the same potential, the effect on first closing the key was not so marked as with d. c.

(D) REMARKS ON SIGNALS RECEIVED USING 60-CYCLE ALTERNATING CURRENT

The highest speed which the operator found it possible to receive by taste reception was 5 words per minute, and in order to do this it was necessary to become accustomed to this method of receiving, for it is quite dissimilar to audio-reception. It is possible that with sufficient practice an operator might be able to receive at a rate of 10 words per minute by taste reception. It is doubtful, however, if the speed could be increased much above that. The reason for this is what might be called the "lag" of the taste nerves. It has not been possible to determine whether this is due to an actual sluggishness in the nerves, or a mechanical inertia of the liquids in the mouth. It should be noted that a certain time is required for the chemicals which cause the taste sensation to form between the electrode and the tongue, and then that a further small period of time is necessary for them

to be dissipated after the forming current has ceased. Regardless of the exact nature of the phenomenon, however, the fact is easily demonstrable that a fraction of a second elapses between the time the circuit is closed and the moment when the sensation of taste is first noted. Furthermore, a similar period may be noted after the current has ceased, when the taste sensation still persists. As nearly as could be ascertained, this time lag is from 0.25 to 0.5 a second. The effect of this is to slow down the permissible speed of signal transmission. It also necessitates a special type of sending. The dots and dashes must be of greater length than in ordinary transmission, and the spaces between the dots and dashes of a single letter must be longer than usual. As a consequence, of course, the spaces between letters and words must be correspondingly increased. All of these requirements limit the possible speed of reception.

3. CALCULATIONS TO DETERMINE THE PRACTICABILITY OF TASTE RECEPTION FROM AN ENERGY STANDPOINT

To determine whether it would be possible to use the taste receiver for the reception of actual radio signals, calculations were made on the basis of the data obtained in the d. c. and a. c. tests, to ascertain if the amount of energy ordinarily available in a small receiving antenna could be sufficiently amplified to be used for taste reception.

It has been found that the current in a 25-ohm antenna, necessary to produce unit audibility in the telephones, using a crystal detector, is 5 microamperes. As a basis for calculation, a signal giving an audibility of 1,000 was selected. The current in the antenna system for such a signal would be approximately 30 times that necessary for unit audibility, or 150×10^{-6} amperes.

In order to determine the voltage and energy amplification required to permit such a signal to be tasted, it was now necessary to ascertain the potential and energy available in the secondary or detector circuit.

Calculation showed that such a signal corresponded to an energy in the secondary circuit of approximately two-tenths of a micro-watt.

In the tests using direct current and 60-cycle alternating current it was found that about 2.0 volts potential was necessary for workable taste signals. The measurements made with d. c. indicated that this potential produced a current of about 0.25 milliampere in the mouth electrode circuit. In other words,

the energy necessary for readable taste signals was about 500 micro-watts.

Comparing these values with those of the actual signal as found above, it is seen that the necessary voltage amplification is 50 times, and that the energy amplification is 2,500 times. As it is possible in practice to obtain voltage and energy amplifications of this order, there was justification for further investigation of the taste receiver, using actual signals as the source.

III. TESTS MADE WITH RADIO FREQUENCY SIGNALS

1. USING SIGNALS FROM A BUZZER SOURCE

(A) APPARATUS

(a) CIRCUITS

It was decided to try signals from a buzzer source first, as these could be easily obtained and controlled. Accordingly, the circuit shown in Figure 4 was set up.

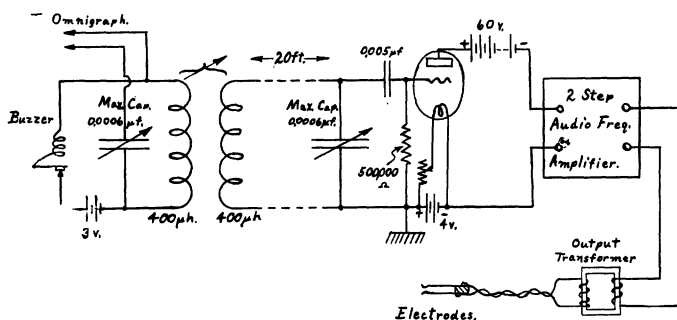


FIGURE 4

The circuits were tuned to a wave length of approximately 600 meters. The detector used was a vacuum tube. The plate potential employed was 60 volts. The capacity of the grid condenser was 0.005 μ f., and the leak resistance between the grid and the plus side of the filament battery was 500,000 ohms. The amplifier used was a two-stage transformer-coupled amplifier giving a total voltage amplification of 150 times. The transformer between the amplifier and the mouth electrodes will be described later. An omnigraph was used in the usual way in the buzzer circuit to produce signals.

It was found necessary to ground the plus terminal of the

filament battery to prevent the amplifier from howling. The amplifier bulbs were lit from the same battery as the detector bulbs. Separate plate batteries were used, however.

It was necessary to place the buzzer circuit across the room from the detector and amplifier circuits, because when placed nearby, the buzzer induced strong audio frequency currents in the amplifier circuits. The inductance coil of the receiving circuit was coupled to the buzzer inductance, and twisted leads were run across to the receiver circuit.

In these tests, the electrodes were placed about 0.125 inch (0.3 cm.) apart and touched to the operator's tongue. This was found to give better results for the reception of radio frequency signals than the method employed in connection with the d. c. and a. c. tests.

(b) OUTPUT TRANSFORMER

It was of course, impossible to connect the taste electrodes across the output terminals of the amplifier as the d. c. plate current of the last amplifier bulb would then pass thru the operator's tongue. It was, therefore, necessary to find a suitable transformer so that only the audio frequency a. c. would be obtained in the taste electrode circuit.

The following transformers were tried after consideration of the requirements:

Century Telephone Company, Air Core Transformer, number CAC 1013A.

Federal Telegraph and Telephone Company, Type 226W Transformer.

Western Electric Company, number 5 Induction Coil.

Western Electric Company, number 26A Repeating Coil.

In testing these transformers the following facts were noted:

A step-down ratio of transformation was necessary from the last step of the amplifier to the taste electrodes.

In the detector circuit, or with only one stage of amplification, a 1-to-1 ratio was best. As would be expected, the higher the amplification, the greater the necessary lowering of the voltage for proper reception.

The requirements of the taste receiver seemed to necessitate the use of a power transformer, that is, one capable of handling considerable energy while acting as a potential transformer.

The following figures give the relative strength of the taste sensation obtained, using the four transformers mentioned above,

taking the intensity given by the Federal Company's transformer as 5:

Western Electric Company, number 5 Induction Coil (reversed).....	0
Century Telephone Company, number CAC 1013A (step-down).....	1
Western Electric Company, number 26A Repeating Coil (step-down 3-to-1).....	4
Federal Telegraph and Telephone Company, Type 226W (step-down).....	5

As the Type 226 W Transformer of the Federal Company gave the most satisfactory results, it was used in the tests which are described below.

(B) OBSERVATIONS

The coupling between the buzzer circuit and receiving circuit inductances was increased until a taste sensation was obtained which was of the proper strength for signaling. Measurements were then made of the audibility of the signal in the detector circuit by the usual shunted telephone method. In making the measurements a pair of Western Electric Company Type P-11 telephone receivers were used. These telephones have an impedance of 22,000 ohms at 500 cycles. A decade resistance box was used to shunt the telephones. It was found that the signal of the proper intensity after two stages of amplification to permit of reception by taste, had an audibility of 500 in the detector circuit.

It was thought that a possible increase in the intensity of the taste sensation might be brought about by tuning the mouth electrode circuit to the audio-frequency tone of the buzzer. Values of capacity from 0.05 μ f. to 4.0 μ f., were tried in series with the transformer winding and mouth electrodes. With a condenser of 1.0 μ f. capacity in series, the taste sensation was of the same intensity as when no capacity was in the circuit. With all other values, however, the insertion of the condenser decreased the intensity.

2. USING SIGNALS FROM AN ANTENNA

(A) APPARATUS

For the purpose of receiving outside signals, an ordinary inductively coupled vacuum tube receiver was employed. The antenna used was a single wire, 150 feet (45.8 m.) high and 180 feet (54.9 m.) long. It was found necessary to use four

stages of audio-frequency amplification in order to get taste sensations of the proper intensity. Two sets of two-stage transformer-coupled amplifiers were connected in cascade. By separating them about ten feet (3 m.), it was possible to get rid of the howling tendency sufficiently for the purpose of taste reception, provided the operator, who was connected to one amplifier, did not go too near the other. The reason for needing a greater amplification in this test than in the tests using buzzer signals was probably that the antenna used had a very high resistance, and thus altho the voltage amplification obtained with a two-stage amplifier would have been sufficient, the actual energy available at the end of the second step was not sufficient for taste reception.

(B) OBSERVATIONS

With four stages of amplification it was possible to get taste sensations from all signals, the audibility of which in the detector circuit was 500 or more. The higher the audibility of the signal, the stronger was the taste sensation produced. The strongest signal received had an audibility of 5,000 in the detector circuit. The taste sensations resulting from this signal were not strong enough to cause discomfort for the operator. Whether or not a signal might be obtained of sufficient intensity to cause discomfort to the operator, would depend on the amount of energy which the last stage of the amplifier could handle.

As the signals received were commercial messages, their speed prevented them from being read by taste reception, but the intensity was sufficient to permit of their having been read had the sending been slower. It was found possible to tune in a station by noting when the intensity of the taste sensation was greatest. It was also noted that a slight difference existed between the taste sensation produced by a 240-cycle spark transmitter and a 500-cycle spark transmitter. The difference was not sufficient to permit of one being received thru the other, as could be done with audio-reception. It would be impossible to read thru interference with the taste receiver unless one signal was quite strong and the other almost unnoticeable. Strong strays would probably cause signals to become unreadable.

IV. CONCLUSIONS

1 ELECTRICAL ASPECTS

From the point of view of electrical operation, taste reception is possible. It is possible to amplify sufficiently a signal having

an audibility of 500 in the detector circuit, to cause it to produce taste sensations. It is possible to read signals by the sense of taste if they are sent at a slow speed (about 5 to 10 words per minute).

2 MECHANICAL ASPECTS

At best, the mechanism of taste reception is unpleasant for the operator. A pair of head telephones which may be adjusted snugly to the ears are greatly superior in point of physical comfort to a pair of electrodes which must be held in the mouth, pressed against the tip of the tongue. There is also the disadvantage of the slow speed of transmission necessary for taste reception.

3 PHYSIOLOGICAL ASPECTS

The nerves of taste become fatigued by continued stimulations, and this will necessitate an increasingly higher amplification of energy if the operator is to be on duty for any considerable length of time. The effect on the operator's eyes of contracting the iris when very strong signals are received would be very disadvantageous, especially in airplanes. The taste sensation is a sour stinging taste which is far from pleasant. With high amplification and strong signals or strays, the taste sensations might be so strong as to be distinctly objectionable.

4 PSYCHOLOGICAL ASPECTS

Since the time when the progenitors of the human race began to communicate with each other by different sorts of sounds, the natural mode of communication between individuals has been by means of sounds. Thus the ear has become the organ which is developed from babyhood for the especial purpose of receiving intelligence. It is only natural, therefore, that this sense should be easily adaptable to the receiving of telegraphic signals. Its highly developed power of selectivity enables it to read only one of a number of signals or noises which may be heard at the same time.

The other sense by means of which intelligence is communicated, that is, sight, is valuable particularly because of its development in reading. In this way it often may be used to partially take the place of the sense of hearing, as in the case of lip reading employed by deaf persons. For the purpose of mechanical signaling it is useful in its ability to read from a tape record, and possibly also from the flashing of a light.

The sense of taste is naturally unfitted, because of lack of

previous training along such lines, for the task of associating impulses sent to it with the necessary accurate motor responses required for the copying of transmitted intelligence. In making the tests which have been described, it was noted that great concentration of thought, upon the sense in question, was required in order that the nature of the received impulses might be noted. This indicates that the association is a difficult and unnatural one. Furthermore, it should be noted that if great concentration is necessary in order to receive by this method, it certainly would be impracticable in an airplane where the noise would effectively prevent concentration.

With the amplifications and signal intensities used in the tests on taste reception, it would be possible to read signals by audio-reception in spite of any strength of interfering noise which the ear of man could endure.

In conclusion we wish to thank Mr. Carl Dreher of this Laboratory for his assistance in making the signal speed tests.

Research Department,
Radio Corporation of America,
December 31, 1919.

SUMMARY: The purpose of this research was to determine the feasibility of reception of radio telegraphic signals by the sense of taste.

Electrodes were made which could be placed against the tongue in such a way as to cause a taste sensation when a source of potential was connected to them. Tests were made, using low potential direct current and 60-cycle alternating current to ascertain the amount of energy and potential necessary for taste reception.

Tests were then made, using signals from a buzzer source. By employing a two-stage transformer-coupled audio-frequency amplifier it was possible to obtain taste sensations from a signal having an audibility of 500 in the detector circuit. The possible speed of transmission appeared to be limited to a maximum of about 10 words per minute because of the characteristics of the taste organs.

Finally, the reception of actual signals from an antenna was tried. It was found possible by using four stages of amplification to obtain taste sensations from all signals the audibility of which was greater than 500 in the detector circuit.

The results obtained thus indicate that from an electrical standpoint it is possible to receive radio telegraphic signals by the sense of taste. When compared to the sense of hearing or even of sight, however, the sense of taste is much inferior as a means for receiving intelligence.