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MOSQUITO METROLOGY AND COMMUNICATIONS

By

WILLIAM H. OFFENHAUSER AND PETER WILLIAMS

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PROCEEDINGS OF THE RADIO CLUB OF AMERICA

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MOSQUITO METROLOGY AND COMMUNICATIONS*

By

WILLIAM H. OFFENHAUSER[1] AND PETER WILLIAMS[2]

Editor's Foreword. This paper summarizes a generation of work by a group of devoted scientists who have wedded biology and electronics to produce entirely new knowledge, available to neither kind of specialist working alone. That continued expansion of this kind of work will ultimately rid man of a perennial nuisance is more than merely predictable; it has already been shown that electronic simulation of the appropriate mosquito sounds can lure the mosquito to an apparatus of destruction, as does the cheese to a mousetrap, without also luring friendly and helpful to the interests of man.

1. Introduction

Two recent papers before the Radio Club of America illustrate the rise of new electronic technologies which can materially alter and improve the opportunities of biological-electronic research. Dr. Knowlton's paper on "Computer Produced Movies" showed how automatically produced microfilm plotted points and drew lines at rates many times faster than is attainable by the most skilled human draftsman. The vast volume of data which must be analyzed and reduced to useful graphic presentation require just such technology to make them useful to the bio-electronic scientist. Similarly, Dr. Eberhardt Rechtin, at the Club's 56th Anniversary Banquet, made an amazing presentation on space probe telemetry and computer implemented command and control, technologies which can be made to serve biological-electronic research, covering a wide range of sensors, temperature, pressure, humidity, radiation, etc., originating from remote locations. These are some of the many requirements of entomological research, in the study of sound and radiation against insects for which practical technologies and instrumentation have been recently developed.

With such methods and devices, not only can we refill our almost empty storage shelf of the facts of natural science, but we also should uncover new facts as rapidly as the need arises. With the reliability that our science has shown in space studies, we should be capable of solving new problems in apparatus-related technologies soon after they have been raised. If planned on a systems organization basis, many of the basic needs of natural science can be met, including some outlined for the International Biological Program from the proposals of the International Scientific Unions.

Biological phenomena, especially of lower order living things, are essentially statistical; they deal in large numbers and rely for their significance upon a large number of repetitive tests. For this the computer and automated basic research and development is eminently fitted.

2. Mosquitoes and Modern Science

If, as scientists, you look through the world's literature, you will find no answers to some very common questions, such as:

2.1 How many people have been bitten by mosquitoes?

2.2 How many have not been bitten?

2.3 How many have tried to swat a mosquito and missed?

2.4 How many have tried and succeeded?

2.5 Why success in one case and not in the other?

According to "Mosquito Control," Herms and Gray, p. 97, most observations are limited to a remark such as, "The mosquitoes are simply terrible." Science history is filled with situations like this; the basic data is needed and it has never been collected.

Entomology has become an experimental science rather than merely a descriptive one because of the need for species selectivity in insect counter-measures and of the insect's biological adaptations to the newly man-made efforts to effect species sanitation and/or control. Insect control will soon become a scientific strategy amenable to computer simulation and solution after the basic data will have been collected.

A most important application for mosquito metrology at this stage is the surveillance of insect populations of interest and the collecting of samples by electronic means, especially in areas where such work has been going on steadily by more primitive means. Such installations and activities provide the required opportunity to relate statistically the newer procedures of population surveys.

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[2] Wilton, Conn.

* Presented October 21, 1965

We need to re-awaken scientific curiosity and observation to obtain clues to the answers to further unanswered questions, such as:

1. How does the first mosquito that locates you and bites, find you? (Only females bite; males never do).

2. Why does she seem to come back to the same spot on the same victim after she was brushed off? How does she accomplish this feat?

3. After a single female has selected her victim, how does she code her signals with position and angle-of-attack information so that other females can 'home right in' unerringly with great precision?

If modern science cannot answer such simple questions in an age of science, something is amiss. Perhaps man is not curious although history seems to tell us otherwise. Perhaps man needs to improve his methods of observation with instruments.

Slapping a mosquito is not enough. It wastes far too much costly kinetic energy per insect destroyed. Chemicals usually destroy perhaps 1,000 times as many beneficial insects as harmful ones they seek to destroy. Species selectivity is very difficult with chemicals.

3. Observation

To examine the possibilities of observation, a reading of "Mosquito Control" by Herms and Gray, will be helpful. From this you will learn that there are over 1400 described species divided into four genera based upon anatomical structure. Since these classifications are descriptive, they take no account of stimulus-response characteristics, on which there is so very little data. Extensive experimental testing is required, relying upon automatic data collection and computer analysis, to classify the functional relations among genera and species. The same systems configurations may, of course, be used for the study of other insects.

If a female mosquito bites you in Florida, for example, she can produce thousands of biting progeny during her life span of only three weeks. She will produce male offspring on about a one-for-one basis with females. Male mosquitoes, like their human counterparts, do not live as long as females. Among certain species, males, after emerging from pupae, do not leave the swamp.

But the female requires a blood meal to produce living progeny after copulation. Consequently, she leaves the swamp, often flying two miles or more to obtain the blood meal from a horse, cow, dog, man, bird, rabbit and the like, from whatever convenient blood source can be found most easily.

When a female mates for the second time, she often returns to the swamp where the males are but does not appear to look hard for her first mate. However, she seems choosy and does not want any old male. She can select a single individual from a group, using sound as her communications medium. When she has indicated her choice, other males seemingly defer to her wishes. They do not try to push away the chosen male or interfere.

Statistically, the female finds no difficulty in finding another willing male after the first. But she is not as successful when she seeks a blood meal. Perhaps, like humans, the male takes care of the big problems while the female takes care of the victuals and the progeny.

The life cycle of the mosquito is complex. There are four stages of metamorphosis: 1. eggs; 2. larvae; 3. pupae; and 4. adults. Larvae, (wrigglers) and pupae need still water for their growth; deny them water and you eliminate them. Larvae come to the surface to breathe; deny them air or poison the water surface with oil, and their breathing tubes cannot function; they suffocate or die.

Hungry gold fish, frogs and toads love larvae for food. Cut the in-water vegetation of a pond where mosquitoes breed and the fish can catch the wrigglers. Certain toad songs are Lorelei sounds similar to those made by the mosquito the toad is trying to catch.

3.1 Metrology - Method and Philosophy

We live in an energy world; we can measure energy. At absolute zero (-273C) there is so little energy that a mosquito will not bite and you will not slap. At 15C, your refrigerator temperature for keeping milk, a mosquito lives for six months but is so sluggish that you can slap her easily. At 27C in Ormond Beach, Florida, she lives only about three weeks but is so fast that you cannot slap her.

Where the human eye is inadequate to observe mosquitoes, we must use instruments. There are many possibilities: doppler-detection devices used with ultrasonic fields, radio proximity devices, photography, both still and motion, and many others. Measurement, counting and display devices abound. All give precise reproducible numerical results. The use of controlled radiation fields has seemingly never been attempted. Automatic digital readout of the number of mosquitoes responding to a test stimulus in a sample population is still unknown. It is still overdue.

With sound, it is now possible to obtain real-time on-line Fourier analysis of wave components. This has never been attempted for mosquito sounds.

Our recording systems are capable of remarkable frequency range and fidelity. They remain almost untried. In the space program, many remarkable and effective methods have been utilized to detect a very low energy signal in a large energy noise environment. Without them, it would have been impossible to obtain the photographs of the surface of the planet Mars. All these and more are available for use. None have been attempted.

Computers could quickly match sounds produced by certain mosquitoes with similar sounds made by other species and genera. With the basic data recorded on magnetic tape for computer analysis, readout could be as rapid as it would be useful. Computer matching would be useful to relate mosquito and predator. Computer simulation of mosquito-borne disease control problems could become a useful art quickly and economically. Our greatest need is for scientific imagination.

To be useful today, experimental entomology demands measurement. Measurement involves standards; the standards are explicit and have been formulated by a legal-technical procedure in every scientific nation of the world on a worldwide basis for matters of universal importance. Measurement methods not only involve numbers but they require a working knowledge of the precision of available standards and of the working standards used. Many are described in American Standards approved by the American Standards Association. Many Recommended Practices are described and have been approved by the International Standards Organization of Geneva.

3.2 Method

If we use sound as the energy form, it is reasonable to require that the sound be (1) recorded and (2) analyzed with procedures that have been standardized. Since all mosquito sounds are low in energy level, it is also necessary to collect substantially all the sound radiated and to exclude substantially all noise, with 60 DB S/N (signal-to-noise) ratio as the target objective for all recorded signals.

The system must be very stable electrically, very reproducible and quite free of microphonics and all extraneous noise, both airborne and transmitted through solid structures. Since preliminary measurements indicate a range of about 20 to 25 DB between the upper threshold for mosquito and the lower, a 60 DB S/N ratio is adequate to assure, based upon prior experiments, that no noise component is sufficiently high in energy level to act as a spurious stimulus.

A reference signal for system calibration (by substitution) is a sine wave 1 kcs audio oscillator of high stability and pure wave form, working with a microvolter and a standardizing coupler. These are reliable and inexpensive. Design the system to bring all signals up to a standardized bus level of +10 VU as read on an ASA Standard VU Meter, whether the signal comes from live pickup or from a recording. Measure the gain required and calibrate in terms of absolute energy level. Connect all auxiliary equipment as bridging loads that draw negligible power from the recording signal bus. Once data have been collected with sound as the basic energy form, other energy forms may be utilized. They should be similarly calibrated in terms of absolute energy level, so that the systems may be suitably compared.

3.3 System Calibration and Operation

Calibration by direct substitution is simplest, since, in the dimensional equations representative of events, similar terms appear in both numerator and denominators of the equation. These cancel out, leaving only the terms representative of the reference oscillator itself to be considered.

In such a system, it would be worth while to make the data recorded about the event amenable for computer input. This can save much time in data processing. Track #1 may record all the audio signals; #2, the gain and energy information; #3, the test conditions being examined; #4, the physical and other conditions under which the test is being made, such as temperature, pressure, humidity, time, radiation and everything else pertinent. If you try to substitute log sheets for some automatic data recording, be prepared to collect much paper, too much to store.

3.4 Energy Measurement

After you have done the foregoing, what can you do with it?

1. Calibrate your system for total energy at all other gain settings. Take some reference condition as an arbitrary base and state all inputs in terms of decibels above or below the reference.
2. Measure total energy radiated from each normal call of each normal female and normal male mosquito. Determine the variations in level among individuals for the same call and among calls for normal individuals. Measure differences in level and spectrum due to metabolism changes. Relate this to temperature between 15 and 30C. Measure the energy levels of responses compared with stimuli.
3. Compare an individual with another of the same genus, species and sex. Also, for different sexes for similar calls, for different calls.

4. Compare individuals of different species, but of the same genus.

5. Compare individuals of different genera but unrelated species.

6. Compare individuals of different genera but related species.

7. Seek to define the terms related and unrelated in view of the new data.

8. Compare the performance of groups (say, 100 insects) with that of individuals; compare different groups with each other.

9. Compare unknown insects with known insects. Compare insects with marked radiation (P_{32}) with reference insects not so marked. Compare wild insects with those raised in captivity. When I made such a test in 1949, I considered the insects so marked poisoned.

In all cases, it is essential to describe the absolute value of energy and to state it explicitly. We obtained in 1949 for a single female Anopheles albimanus for total sound radiated -10^{-13} watt. It has been reported that this signal can be detected by a male of the same species through the normal high noise background at a distance of 300 meters. A verification of this measurement with modern measurement technology would be highly valued.

We have guessed that the female antenna performs like a folded dipole, while the male antenna is like a 6 element Yagi. Verifications of these assumptions would suggest what frequencies in the centimeter bands could affect mosquitoes.

The basic thesis which I present is simple. With the Total Energy System of measurement, comparisons among different individuals of a species can be quickly made, as well as comparisons among species and even among biological orders.

In the case of mosquitoes, it is possible to measure the total energy input. Both male and female mosquitoes consume fruit nectars (simple sugars) which oxidize with air-breathing into heat, carbon dioxide and water vapor. Energy determinations can be made by measuring the heat liberated when such sugars are oxidized in an oxygen bomb calorimeter or the like.

We know how to measure total sound energy output. Perhaps this can be used as the index of total energy output. To measure total sound energy, use a curve-tracing milliameter connected as a ballistic galvanometer across the sound recording bus and calibrate it. Total energy may be measured with a planimeter or in a number of ways well known to the engineer-mathematician.

3.41 Mosquito Duty Cycle - The Biological Clock

When the experimenter makes his first recordings, he will find that he must sit up around the clock for full twenty-four intervals to learn when the particular mosquitoes being observed are active and precisely how energetic. They seem to work in mathematically Gaussian manner for about one-half hour each day near sunrise and again near sunset. During the remaining twenty-three hours, there is no significant activity. With curves traced over full twenty-four hour intervals, you can integrate areas under the curves with a planimeter. Peak flight activity, measured as electrocutions per minute when lured by an appropriate recorded call matches the peak sound activity traced by the ballistic galvanometer; the shapes of the curves match.

With such curves and data, you can calculate duty cycles, load factors, form factors and all other factors common to electrical measurement. For whatever reason, mosquitoes either know their statistical mathematics thoroughly or they slavishly obey its laws. We have never observed deviation.

The biological clock phenomenon is still a mystery. It is not known what winds the clock, how long it runs on a winding and what regulates the balance wheel. Mosquitoes start making their sounds, are active and stop their sounds at regular intervals every day, with only a minute or two difference from one day to the next. Since light is a presumed stimulus, we dark-adapted a test group of Aedes aegypti in the laboratory for several days by covering up the glass panel of the sound chamber, excluding light. Even without the light as a cue, these mosquitoes turned their sound on and off regularly each day for several days as if they were actuated by a time clock. This phenomenon requires thorough examination. The tests reported here were limited in scope.

There are physical stimuli to which mosquitoes are responsive. One insect, for example, continued to yell when wetted with water for about twenty minutes with a sound like the wing sound shown in the spectrogram. When the sound stopped, the mosquito was dead. If jarred, they will react with short bursts of sound like wing sound. Such sounds seem to have no effect as stimuli upon other mosquitoes. Further sound spectrograph analyses should disclose additional facts about frequency and modulation characteristics as well as energy levels.

A word of caution to experimenters is in order. It is a waste of time to make tests when the stimulus response values are below 50%. The time interval between the 50% rise time and the 50% decay time is rarely more than a half hour. You cannot obtain responses representative of the wide-awake, normal active mosquitoes from those that are inactive and asleep. With Aedes taenioryhchus, for example, the response level is above 50% for only twenty minutes in Florida. Thus, a response test made in Florida upon Ae. t. at 1600 hours, for example, is just as fruitless as one in the blazing midday sun at 1200 hours.

The duty cycle may be obtained equally well from either the traces and data of the ballistic galvanometer or by counting the number of mosquitoes attracted by a suitable lure call. The curve shapes are the same and peaks occur at the same time. The ballistic galvanometer test is usually simpler to conduct. Responses of 90% ±10% are usually obtained to normal stimuli from the same species under normal physical conditions of temperature, humidity, light, time, pressure, etc. Such values apply to make responses to the female sex call or to female responses to the female blood call that alerts other females within communications range, whether directly or by mosquito relay.

If your test results are lower than the 90% value suggested, re-examine your experiment for errors. When the mosquito first emerges as an adult, it is not thoroughly dry and its sound emissions and receptions have not stabilized in frequency. One hour of sunny weather often corrects this condition. It is usually fully corrected within twenty-four hours after emergence. To err is human. Mosquitoes are not human. Do not forgive human errors by altering their responses from their normal.

Let us keep in mind the immortal thought of Lord Kelvin: "Until you have expressed your observations in numbers, you have not yet reached the first stage of science."

Energy, which is measurable, is the common denominator for all such living things and time is of the essence.

4. Biological Order

We should begin to re-examine the classifications established in the middle 1700's by Carl von Linne and still used, to bring to bear experimental stimulus-response data to determine how it harmonizes with the earlier descriptive morphology. We need more precise definitions of old terms, not only to describe the appearance of insects, but to relate present classifications to their behavior. It is difficult to describe insect movements and sounds precisely without photography and sound recording. A wide variety of excellent acoustical instruments is now available for measurement. Many have been designed and built only since the end of World War II, a twenty year span.

As will be seen by a comparison of the spectograms shown as Figures 1, 2 and 3, the Aedes

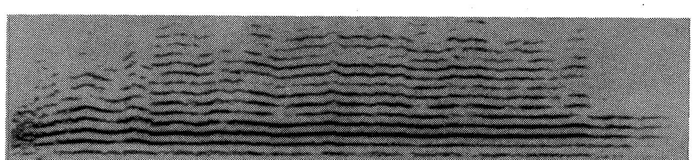

Fig. 1 - Aedes aegypti - Female

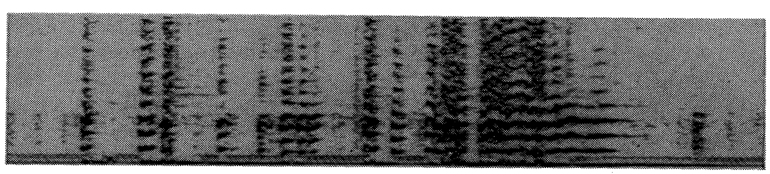

Fig. 2 - Aedes aegypti - Male

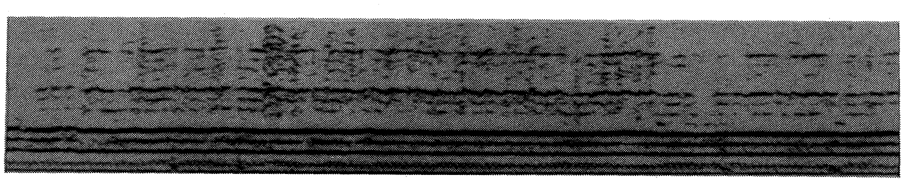

Fig. 3 - Aedes aegypti - Male - Wing Sound

SPECTROGRAMS OF MOSQUITO CALLS

aegypti wing sound is not only continuous for several seconds but also has the fourth, eighth and twelfth harmonics strongly emphasized, giving the tone a shrill whistle. In addition, there is but a single modulation frequency rather than the two found in the other spectrograms. It is of 35 cps, roughly intermediate between the other two, both in frequency and in modulation depth.

By no stretch of the imagination could the Aedes aegypti female and the male mating sounds, also shown, be confused with the wing sound when all three are compared by the human ear; the differences among them are too pronounced. The wing sound spectrogram shown is recommended for study by nomenclature bodies. It defines the wing sound of the Aedes aegypti male mosquito precisely in physical terms using numbers. There is no need to relate the hearing sensation produced with the mode of production of the sound. In fact, the mechanism for production of the sound is as yet unknown.

5.0 The Mosquito Status Quo - Physical Tests

A review of technical books and literature turns up remarkably little information on how mosquitoes react to physical stimuli and environment and a far smaller quantity of quantitative data of any kind. In "Sound Against Insects," (New Scientists, London, June 1965) Prof. and Mabel Frings urge that physical methods of insect control should be examined in depth. "Ultrasonic waves might be successfully used to repel insects or to jam their signals so that breeding is inhibited - even to kill them outright - if more were known of their signaling and hearing mechanism." They mention electricity, light, heat, radio frequency, ionizing radiation, pressure, sound and ultrasound as examples of stimuli to be examined.

Although comparatively few papers have been published on mosquito sounds and their analysis, the two decades have not been without some progress. S. Young White, a radio pioneer well known to the Radio Club of America membership, brought his ultrasonic generator, known as the Hartman whistle, to Cornel Medical College Laboratories, at the invitation of W. H. Offenhauser. With its full output of $3\frac{1}{2}$ watts and 40 kilocycles per second, it produced no visible effect upon live mosquitoes. But when its output was frequency modulated with wide modulation bands, mosquitoes were killed with no visible external physical damage. The Hartman whistle is described in Audio Engineering, March 1949 by its inventor under the title of "Experimental Ultrasonics."

5.1 Mosquito Killing by Electrocution and Ultrasonics

Virtually nothing is known about the physiology of insect electrocution. After luring mosquitoes to a trap with recordings, we soon learned that the current-limited neon sign lighting transformer furnished by the fly screen manufacturer would kill flies but failed to kill mosquitoes. But using a three-quarter kilowatt high voltage transformer with a 750 watt incandescent lamp in series as a current limiter and with the leakage inductance resonated to obtain a high voltage peak, a mosquito was killed with certainty every time one approached. The insect did not actually have to touch the wires; he had only to approach them to end his or her life. Examination showd that only the tops of the antennae and the bottoms of the hind feet were burned. The remainder of the body was intact and undamaged. This is, of course, a fact of great value in furthering the science of insect electrocution.

The following are the characteristics of S. Young White's ultrasonic Generator:

Frequency range	15-80 kcs.
Test frequency used	40 kcs
Power at 40 kcs	3.5 watts
Air pressure gage	40 lb/in.^{2}
Motor rating	$\frac{1}{3}$ HP
Cavity diameter	0.062 in.
Orifice size	0.044 in.
Adjustment range, resonating column	0.20 - 0.160 in.
Best adjustment	1.25 D, where D=0.062 in.

Considerable further research is needed, before ultrasonics can be used to replace electrocution of mosquitoes for reseanch purposes, particularly at modest energy levels.

5.2 Mosquito Communications and Behavior

As we have already discussed in considerable detail, mosquitoes respond to sound stimuli selectively; the female sex call causes sound response by the male and is disregarded by females. The female blood call alerts other females, but the males are unaffected. Neither males or females are attracted by wing sound of their own species. Much work remains to be done to determine whether these observed reactions apply to all species. Certainly there is promise in the possibility that appropriate recorded insect communication signals will ultimately be used to control their behavior.

5.21 Early History of Mosquito Sound

In 1878, Hudson Maxim observed large quantities of dead mosquitoes near the early electric generator he had installed at the Grand Union Hotel in Saratoga Springs, N.Y. The finding was valid and could have paved the way to progress. But the editor of an English scientific journal returned Hudson Maxim's submission on the subject as "too stupid to publish."

Reviewing the period from 1878 to the present, despite constantly improving acoustical apparatus, very little interest in using it for entomoligical study can be found. But it is now reasonable to hope that, as a result of modern developments in electronics, computers and telemetering, a new era is approaching and that the present empty scientific cupboard will again be refilled with facts for the benefit of mankind.

5.22 Later History of Mosquito Sound

In 1945, Kahn and Offenhauser reported the first sound recordings of mosquitoes in Science, made with high quality recording equipment. To complete the record, Offenhauser and Marrison are publishing a paper, "Sound Spectrograms of Mosquito Call," in Acoustica, 1966. The analysis of Offenhauser's recordings were made by Dr. Marrison at the Bell Telephone Laboratories. Figures 1, 2 and 3 show the male, female and wing sound analyses included in this paper. The findings are summarized as follows:

1. Mosquito sounds are distinctive; no two species are alike and their sounds are different also to the human ear. Most are so low in energy level, that their normal environmental noise would make it impossible to hear them with the unaided human ear.
2. All mosquito sounds are composed of a well-defined fundamental in the center of the audio range, together with overtones, even in the case of sounds that are sensed as clicks. In some spectrograms as many as 15 distinctive frequency bands are recognizable.
3. All mosquito sounds have vibrato effects. Some tones show a single warble rate; others show double warble modulation. A common rate for the lower warble is 2 to 15 cps; the higher rate, when present, is often some 5 times lower. The magnitude of the lower rate may be some five to 10 percent; the higher rate is about one-fifth to one-tenth the lower.
4. Male sounds are usually more broken than the female. In most cases, the apparent pitch of the male is higher than the female of the same species despite only a small difference in their fundamentals. Mosquito sounds often show a change in pitch with time. Some increase as much as 25% in as little as 0.05 second.
5. The intensity is modulated in all sounds. In some cases modulation is a complete interruption of an entire band or bands; in other cases, harmonics are varied only, leaving the remainder unaffected.
6. Mosquito sounds are low in energy level. The total sound power output of a single female Anopheles albimanus is circa 10^{-13} watts.

It is interesting to speculate how these complex and distinctive sounds are produced and are sensed and what the equivalent filters may be that make it possible to filter out all the tremendous noise interference of the surrounding natural world when they fly unerringly toward their targets. The filters and sonic location mechanism appear truly remarkable in terms of our own art in the same frequency bands. Mosquitoes have miniaturized their audio apparatus far better than we, and their power supplies which energize it.

The mosquito has no brain to interfere with normal response to a normal stimulus. It has no intelligence at all. This provides, we believe, a golden opportunity to learn quickly some of nature's best-kept secrets.

E. J. QUINBY FEATURED IN SHORT CIRCUIT BULLETIN

The December issue of the Short Circuit Bulletin, published by the Texas Division of the Electric Railroaders' Association, features member E. J. Quinby's "Best Trolley Ride by a Damsite," a high-speed trolley interurban run, installed on the tracks used to ship supplies during the building of the Skagit hydro-electric project in Oregon. Quinby, a long time Radio Club member, once an interurban motorman himself, trolley and side-wheeler steamboat fan and Chairman of the Board of the Greene Line Steamers, operators of the Delta Queen Cincinatti side wheeler run, described his 75 mile run through Skagit Gorge with the feelings of a veteran of high speed trolleys.

Quinby can still be seen from time to time running a high speed trolley at Branford, Conn., where the last remaining such trolley in the East runs over a few miles of track during the summer. Your editor remembers the New England trolleys with a bit of nostalgia too because they provided his daily trip to and from school in Greenwich, Conn., on their New Rochelle to Stamford run. We almost managed to spare the space to run a narrative poem by E. Jay Quinby on the North Jersey Rapid Transit run to Suffern, but it was a bit too long for a non-radio item. The last run to be given up in the East, in the late 1940's, was the Washington to Baltimore run. But its equivalent is no doubt coming back in an improved version to solve metropolitan area transportation problems, just as the now vanished crystal detector of high-speed trolley days has come back in transister format.

DR. HENRY K. PUHARICH DISCUSSES AUDITORY STIMULATION BY MODULATED RF

At a technical meeting of the Radio Club of America at the Carnegie International Center on February 24th, Dr. Henry K. Puharich, President of the Intelectron Corporation, presented an interesting and informative paper on the use of modulated RF carrier through appropriate electrodes in the treatment of persons defined clinically as totally deaf.

Dr. Puharich pointed out that the term "hearing radio waves," is perhaps misleading because it implies that radio waves may be heard without the aid of a transducing medium. There have been many stories published about persons who claimed to hear radio waves directly in the presence of high power radio transmitters. Other published items have described children wired up for orthodontic treatment who heard the modulation of radio frequency radiation, possibly resulting from rectification by two dissimilar metals in contact in the teeth. Although such reports have been given a great deal of study, they are far from convincing.

The work considered in Dr. Puharich's paper deals with experiments made upon people described clinically as totally deaf. This is not the equivalent of total lack of ability to hear. The medical profession considers total loss of hearing on the basis of capability to distinguish words, phrases and sounds, a definition which may leave considerable capacity to hear and to recognize certain sounds.

Demodulation By Skin Tissue

If a subject stands close to an operating radio transmitter and places the end of a piece of bus wire between his teeth or in contact with soft tissue of his head, he will be able to hear the modulation provided he strokes the wire with a gentle motion of his fingers. The whole process is dependent upon "skin stroking," as we call the bowing motion necessary to observe this phenomenon. Naturally, we have a great interest in what takes place at the interface between the wire and the skin which has the effect of demodulating the signal. Although six years of experiment devoted to this work has subjected the phenomenon to continued scientific observation, we are by no means sure of what takes place.

A somewhat simpler technique than holding the wire between the teeth has been devised which avoids the problems resulting from working within the field of a 30 watt transmitter. The equipment used in most of our experiments consists of a power amplifier which feeds a modulated radio frequency signal through a tuned inductance to electrodes applied to the head of the person being experimented upon.

Using a 50 kilocycle central frequency, the potential measured at the electrodes is 4 to 6 volts, peak to peak, and the current in the order of 1 to 3 milliamperes. The series inductance has to be carefully tuned to suit the individual requirements. If the contact with the tissues is moved across the skin, the subject will hear the modulation and will be able to distinguish words.

Brain Acts As Sound Path

The radio frequency wave is beamed through the head in a quite narrow beam, only about 8 degrees in width. The sound signal is generated at the point of contact with the tissue and is apparently fed through the elastic substance of the brain. The problem of proving this theory is complex because of the difficulties of simulating the substance of the brain.

When using a pick up wire to respond to the radio frequency signal from a radio transmitter field, changing the angle of the wire with respect to the head changes the angle at which it goes through the head to the other side.

The sound of the modulation is segregated from the radio frequency carrier by stroking the skin tissue with the applying electrode and it can be detected on the opposite side of the brain by means of a stethoscope. The use of the stethoscope instead of microphones and amplifiers eliminates a great many of the problems arising from the presence of strong radiating energy in any electronic monitoring equipment.

The sound introduced by stroking the electrodes can also be monitored by an oscilloscope. When the input electrode is at rest, the scope will show the radio frequency carrier. But when the input electrode is stroked, half wave rectification is seen to take place on the scope. The positive side of the wave is always clipped and the negative side of the wave passes through.

Best Sound Detection Areas

Different parts of the head are better or worse rectifiers. The supermastoid areas, down the neck, below the ear and along the jawbone, and an area slightly anterior to the tragus seem to offer the best detection characteristics. Other areas of the head are not nearly as good detectors for the radio frequency energy. By the use of high voltages, 1,000 or more, applied in quadrature, broad signal bands can be introduced, as long as the stroking process is maintained.

Dr. Puharich outlined a progressive course of treatment for subjects who are deaf by the medical standards already described. Using substantial power levels, such as 4 watts, 50 or 50 cycle carrier, and modulation ranges over 200 to 2,000 cycles, at two minute intervals for half hour daily sessions, the subject will become conscious of these varying tones after a few days. Continuing this for several weeks, there will be a 5 to 30 DB improvement in response, particularly at the lowest frequencies. The response band is gradually increased to reach as high as 8 kilocycles. By the application of a steady low frequency bias, such as 250 kilocycles, the response will gradually improve at the higher frequencies, from 1 to 3 kilocycles. The improvement effected by the rf stimulation at first may last for only about 24 hours but it can be gradually extended to last several months. The improvement in word recognition as a result of long treatment is quite dramatic. The present capabilities of prolonged treatment indicate that substantial improvement in hearing is attainable as a result of stimulated modulated rf impulses even in the most extreme cases.

DONG W. LEW DESCRIBES COMPUTER TYPESETTING

Predicting that automatic photo typesetting will displace the use of hard type, Dong Lew, Manager of System Planning of the Harris Intertype Corporation, described currently available computer equalized typesetting systems at the January 20th meeting of the Radio Club of America.

Although automatic typesetting systems are built up to suit particular requirements, such as newspaper typesetting, display advertising, book composition and other forms of printed matter, the basic elements of systems are generally similar. They consist of (1) a tape perforator, which may be operated manually or equipped with an optical reader, serving as the input to the system; (2) an input and output switching and control console; (3) a typesetter computing and processing center, which automatically justifies the right column by controlling spacing and hyphenating automatically when necessary or else balances display type, line by line, about the center of the column and (4) either a photographic typesetting unit for producing photo-offset copy or else a linecasting machine producing justified galleys of hard type.

The Farrington optical reader "reads" typewritten copy with an electric eye and converts it automatically into punched tape. This in turn operates the electronic photo-setter without the intervention of a single finger operated keyboard.

Speed of Automatic Copy Setting

The Intertype system, as currently available, sets high quality composition on photographic film or paper for offset reproduction at the rate of twenty characters per second. This compares with the 150 to 200 characters per minute set manually by a linotype operator or somewhat more than ten times the speed of manual methods. The associated photographic unit will produce 22 lines per minute of newspaper type or more than 20,000 ems per hour of book composition. It can process the day's output of several keyboard consoles. The computer, which is used to convert unjustified perforated tape into tape containing needed data to produce justified and properly hyphenated composition, also accomplishes most of the human labor now spent in layout and composition of type matter.

Plasma-jet Light Source

The key to the speed and quality attained by the system is the unique high intensity plasma-jet light source which permits character exposures in only one-millionth of a second, thus making possible the high disc speeds upon which the exposure of the individual letters depend. The photo-electronic system produces mixed tabular and block composition in 40 faces ranging from 5 to 72 points in a wide variety of type faces to meet every typesetting requirement.

Instead of automatic reading of typewritten copy, the tape may be punched manually by an operator, then fed to the computer, which accomplishes arrangement in appropriate columns or balances display copy and then perforates a new tape ready to feed photographic copy or galleys of type for printing purposes. This variety of optional inputs permits progressive application of automated processes in existing facilities.
The computer memory unit, which accomplishes hyphenation, stores specific rules for hyphenation, plus a stored memory of more than 10,000 exceptional words. Depending on the type of equipment used, virtually perfect hyphenation of

The Farrington Optical Reader is at the left, switching and control center in the foreground, equalizing computer, left rear wall, and Fototronic print-out unit at right rear. This Harris-Intertype system produces finished copy for offset printing directly from typewritten manuscript automatically.

the 50,000 most frequently used words of the English language is attainable.

Automated Layout

Copy may be set up in a solid block, with normal spacing and paragraph indentation or, by appropriate symbols, be arranged in desired column or tabular form. And, in response to other symbols, each line may be centered in the column, so as to make possible automatic setting of display advertising.

Type face changes, column width alterations, such as indentation of quoted material or for tabulations, sequential or selective switching of inputs according to priorities, when several different internal or remote sources of input actuate the typesetting or photo copy output equipment, all are accomplished automatically by the switching and computing unit.

Phototypesetting or hard type linecasting at rates of 12,000 characters per hour, of which these systems are capable, will greatly increase the efficiency of the facilities used for publication and can speed up production over manually operated newspaper publication establishments, tending to counteract the present high cost of newspaper production.

Flexibility in Type Faces

The computers can produce output from an input tape to set justified copy for a hardboard book and later accomplish typesetting in a different type face and a different type size and column width for a paperback edition, all from the same original perforated tape. Author's alterations can be handled automatically.

The discs from which photo copy is produced rotate at 2,400 revolutions per minute. Each disc has 240 characters. The automatic photocopy production machine can hold two discs. Thus 480 characters are continuously available. Furthermore, discs may be changed in 45 seconds. The intensity of the light source is varied, depending on the type size being used. Type size is varied optically, thus providing all facilities necessary to produce body copy, subheads and headlines, encountered in normal book or newspaper production.

The photographic unit is equipped with a dark booth which permits an operator to remove exposed film without interrupting the unit's operation. The photographic unit may be connected directly to the dark room. The film carriage holds 100 foot rolls of film or paper in any of four available widths. Exposed material is automatically cut off on signal which is punched into the tape, facilitating make-up as photocopysetting progresses.

MEASUREMENTS'
"FAMOUS FIRSTS"

1939 MODEL 54 STANDARD SIGNAL GENERATOR—Frequency range of 100 Kc. to 20 Mc. The first commercial signal generator with built-in tuning motor.

MODEL 65-B STANDARD SIGNAL GENERATOR—This instrument replaced the Model 54 and incorporated many new features including an extended frequency range of 75 Kc. to 30 Mc.

1940 MODEL 58 UHF RADIO NOISE AND FIELD STRENGTH METER—With a frequency coverage from 15 Mc. to 150 Mc. This instrument filled a long wanted need for a field strength meter usable above 20 Mc.

MODEL 79-B PULSE GENERATOR—The first commercially-built pulse generator.

1941 MODEL 75 STANDARD SIGNAL GENERATOR—The first generator to meet the need for an instrument covering the I.F. and carrier ranges of high frequency receivers. Frequency range, 50 Mc. to 400 Mc.

1942 SPECIALIZED TEST EQUIPMENT FOR THE ARMED FORCES. WORLD WAR II.

1943 MODEL 84 STANDARD SIGNAL GENERATOR—A precision instrument in the frequency range from 300 Mc. to 1000 Mc. The first UHF signal generator to include a self-contained pulse modulator.

1944 MODEL 80 STANDARD SIGNAL GENERATOR—With an output metering system that was an innovation in the field of measuring equipment. This signal generator, with a frequency range of 2 Mc. to 400 Mc. replaced the Model 75 and has become a standard test instrument for many manufacturers of electronic equipment.

1945 MODEL 78-FM STANDARD SIGNAL GENERATOR—The first instrument to meet the demand for a moderately priced frequency modulated signal generator to cover the range of 86 Mc. to 108 Mc.

1946 MODEL 67 PEAK VOLTMETER—The first electronic peak voltmeter to be produced commercially. This new voltmeter overcame the limitations of copper oxide meters and electronic voltmeters of the r.m.s. type.

1947 MODEL 90 TELEVISION SIGNAL GENERATOR—The first commercial wide-band, wide-range standard signal generator ever developed to meet the most exacting standards required for high definition television use.

1948 MODEL 59 MEGACYCLE METER—The familiar grid-dip meter, but its new design, wide frequency coverage of 2.2 Mc. to 420 Mc. and many other important features make it the first commercial instrument of its type to be suitable for laboratory use.

1949 MODEL 82 STANDARD SIGNAL GENERATOR—Providing the extremely wide frequency coverage of 20 cycles to 50 megacycles. An improved mutual inductance type attenuator used in conjunction with the 80 Kc. to 50 Mc. oscillator is one of the many new features.

1950 MODEL 111 CRYSTAL CALIBRATOR—A calibrator that not only provides a test signal of crystal-controlled frequency but also has a self-contained receiver of 2 microwatts sensitivity.

1951 MODEL 31 INTERMODULATION METER—With completely self-contained test signal generator, analyzer, voltmeter and power supply. Model 31 aids in obtaining peak performance from audio systems, AM and FM receivers and transmitters.

1952 MODEL 84 TV STANDARD SIGNAL GENERATOR—With a frequency range of 300-1000 Mc., this versatile new instrument is the first of its kind designed for the UHF television field.

1953 MODEL 59-UHF MEGACYCLE METER—With a frequency range of 420 to 940 megacycles, the first grid-dip meter to cover this range in a single band and to provide laboratory instrument performance.

1954 FM STANDARD SIGNAL GENERATOR. Designed originally for Military service. The commercial Model 95 is engineered to meet the rigid test requirements imposed on modern high quality electronic instruments. It provides frequency coverage between 50 Mc. and 400 Mc.

1955 RADIO INTERFERENCE MEASURING SET. An aperiodic noise meter useful to 1000 Mc.

1956 MODEL 505 STANDARD TEST SET FOR TRANSISTORS. A versatile transistor test set which facilitates the measurement of static and dynamic transistor parameters.

1957 RADIO FIELD STRENGTH AND INTERFERENCE MEASURING SET. A tuned radio interference and field strength set covering the frequency range of 150 Mc. to 1000 Mc.

1958 MODEL 560-FM STANDARD SIGNAL GENERATOR—First successful FM Signal Generator using solid state modulator.

1959 MODEL 700 FREQUENCY METER—A completely new concept of frequency measurement. An instrument capable of direct and continuous reading to one cycle in 25-1000 Mc range.

1960 MODEL 139 TEST OSCILLATOR—A compact, versatile, and portable instrument for rapid and accurate alignment of I.F. circuits in all types of radio receivers.

1961 MODEL 760 STANDARD FREQUENCY METER—An accurate, simple to operate, direct read-out, portable instrument designed for servicing two-way mobile radio equipment.

MEASUREMENTS
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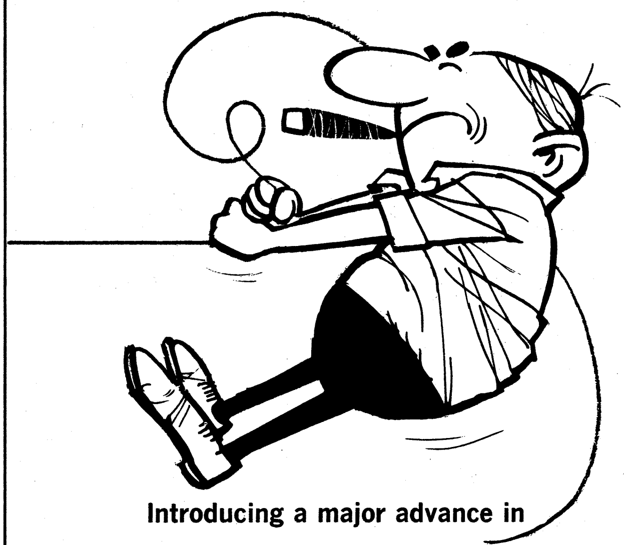

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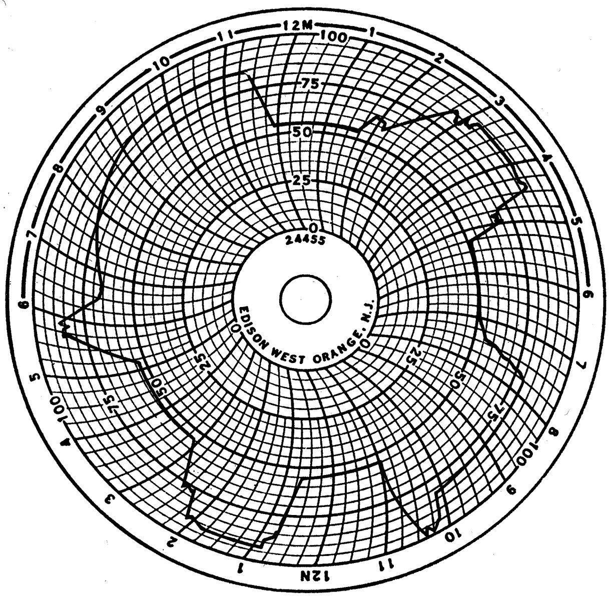

- **INEXPENSIVE**
- **RECORDS ANY VARIABLE**
- **REPLACES METERS OR INDICATORS**
- **PANEL OR BULKHEAD MOUNTED**
- **BUILT-IN VARIABLE CHART SPEED**
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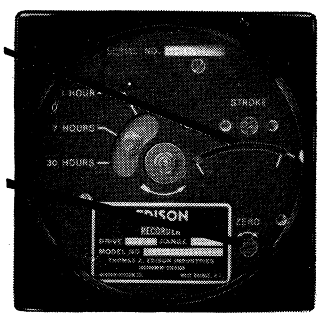
Now you can take advantage of a new, economical means of recording any variable that can be converted to an electrical signal. Thanks to Omnicorder, you need no longer rely on meters or indicators, even where cost factors or space restrictions would ordinarily dictate the use of these instruments.

Measuring just 3¾″ x 3¾″ x 3″, Edison's Omnicorder, a unique circular chart recorder, is so compact that nine units occupy just one square foot of space. Thoroughly legible, yet requiring no ink, pen or ribbon, Omnicorder is equipped with a simple three-speed adjustment which regulates chart rotation, thereby providing time sequences to meet varied needs. A flick of the switch gives users a choice of these sequences: one hour, seven hours and thirty hours per revolution — or one day, seven days and thirty days per revolution.

Stylus operates through this slot. The measuring system is sealed off from any careless tampering.

Zero Set Screw: Adjustment is made when measuring system is not printing and when the circuit to be recorded is disconnected.



Omnicorder's simple, inexpensive construction assures dependable operation and a long, maintenance-free life. Four types of meter movements are available to measure a wide range of AC and DC electrical quantities, ranging from thermocouple outputs to currents as high as 100 amperes. No amplification is ever required, even for signals as low as 10 microamps.

For complete information on this rugged, maintenance-free Omnicorder, write for Catalog 3057.

Thomas A. Edison Industries

INSTRUMENT DIVISION

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TROPO

CANADA

Province of British Columbia, Canada — focal point of a pioneering tropo scatter communications system connecting Alaska, British Columbia, and the Continental United States.

In creating this system, prime contractor Lenkurt Electric Company of Canada, Ltd., a GT&E subsidiary, selected internationally-proven tropo scatter radio relay equipment by REL.

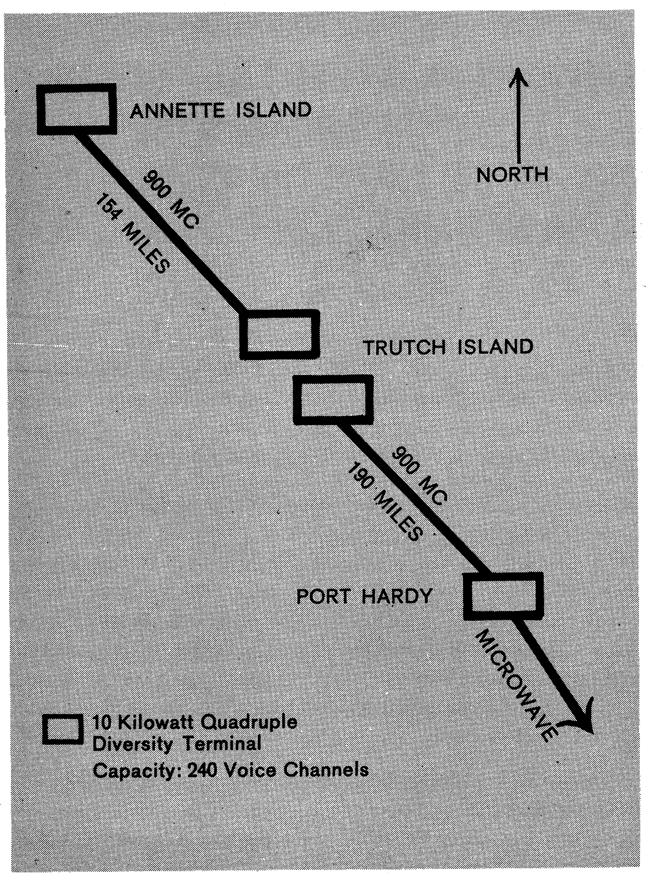
Operated by the British Columbia Telephone Company and the Alaska Telephone Corporation, also GT&E subsidiaries, the privately financed system spans 344 miles in two giant leaps to provide a totally integrated commercial telecommunications network.

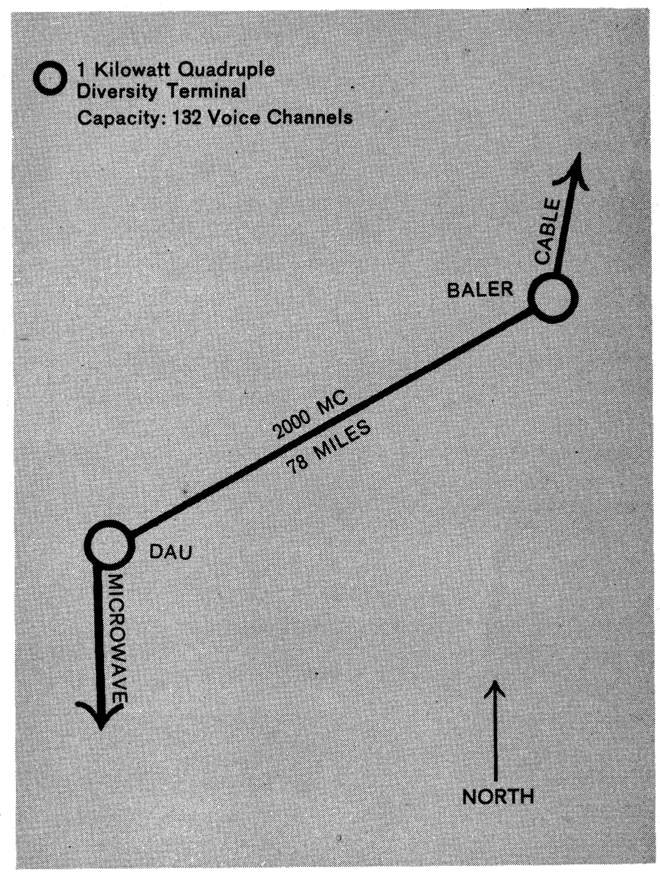
PHILIPPINES

Island of Luzon, Philippines — focal point of a tropospheric scatter system that provides a vital link in telecommunications between the Island Republic of the Philippines and the Continental United States.

Here again GT&E, through its Lenkurt International Division, selected radio relay equipment from REL — world leader in tropo scatter.

Operated by the Philippines Long Distance Telephone Company, the 132-channel system spans undeveloped mountain terrain to provide an economical and reliable communications link with international submarine cables to the United States.





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