Volume I Part 2

PROCEEDINGS
OF THE
INSTITUTE OF RADIO ENGINEERS

CONTENTS:

EDITED BY
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NEW YORK, APRIL, 1913

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RADIO OPERATION BY STEAMSHIP COMPANIES.*

By Robert H. Marriott

(*Vice-President and Past-President of the Institute*)

I believe that the INSTITUTE will show marked advancement during the year 1913. Papers are issued in the PROCEEDINGS, reports of the Standardization Committee are in preparation, and other Committees are actively engaged in valuable work. It is felt that the INSTITUTE OF RADIO ENGINEERS presents some features which are of use to every person engaged in the radio art.

There is a twofold reason why the membership of the INSTITUTE should and will increase. We must consider not only the benefit to the members resulting from the activity of the INSTITUTE but also the benefit to the art of radio communication, to the users of radio apparatus, and to the general public. Almost every portion of the present radio equipment and business routine will bear improvement. (Some parts are badly in need of it). The INSTITUTE should be a guide to the best possible radio service. We desire instantaneous communication in cases of distress, and adequate, rapid, and accurate communication at all times. The membership of the INSTITUTE can be a potent factor in the attaining of this state of affairs.

Misrepresentation concerning radio apparatus and radio companies has been, and unfortunately still is, a damper on the advancement of the radio science and art. One of the most commonly prevalent methods has been to provide an able press agent with a company owned or controlled publication, and with the privilege of inserting such statements as may suit his fancy in acquiescent newspapers. Many mysterious and hero-worshipping exaggerations have thus found their way into the press. Thus the public has been at times woefully misinformed. Such a misleading policy is directly opposed to the spirit of the INSTITUTE. What is wanted

* Lecture delivered before The Institute of Radio Engineers, January 8th, 1913, at Fayerweather Hall, Columbia University.

about radio apparatus and engineers is the simple truth.

This address was originally planned as a resumé of the progress in radio art during 1912, including that of our members, but one topic has become the main subject of the paper to the exclusion of the resumé. However, I wish to mention before proceeding with the main subject, that Dr. Lee de Forest has given us an excellent account of some notable long distance work and observations with an interesting theory which may help to explain and overcome radio absorption. This absorption of signals is one of our worst enemies, and we feel grateful to Dr. de Forest for the work he has done in attempting to find how it is brought about.

It was while writing of the work of Messrs. Davis and Parkhurst of the United Fruit Company that the main subject of this address was brought out. We frequently hear the statement that the United Fruit Company has practically the best radio service. If this is true, it may indicate that the steamship companies would obtain better radio service if they bought their apparatus outright and hired their own operators and engineers. Whether such a course is the best one is certainly a topic worthy of discussion. For such a discussion should assist in bringing about an improvement in radio communication whether the operating is done by the steamship companies or by general operating companies.

There are at least eighteen members of this INSTITUTE who are capable of designing and constructing far better apparatus than is commonly found on steamships to-day, and there are at least four companies in the United States that sell such apparatus.

In favor of the method of obtaining apparatus through competitive bids, the fact may be stated that the United States Army and Navy get superior apparatus by specifying to a certain extent what is wanted and then calling for bids. Their equipment is therefore obtained from more than one company.

Radio communication is valuable to the public in general. It is particularly valuable to the ocean-going public, steamship companies, marine underwriters, newspapers, shippers, armies, navies and weather bureaus. For all this service the public probably pays in the end, but the most apparent (or possibly it would be better to say the most painful) payment is that made by the steamship companies. They feel the financial burden most directly. The best radio service can be attained only when each person concerned sees clearly that he is receiving a just return for his investment. If, as may be the case, the steamship companies or any of the other users of radio service are not getting just returns in the way of apparatus, service or financial reimbursements, they should be shown how to get them.

The sinking of the Titanic brought out clearly some of the strong and weak points of the radio service at that time. Many of the weak points have not as yet been remedied. There is apparatus on many vessels, which is a disgrace to radio-communication. Much of it was out of date four to eight years ago. A possible explanation of this fact is found in the following considerations.

The government departments usually get the best available apparatus because they employ experts who understand the science and art. So that high class apparatus is usually specified and bought from the manufacturer who provides the desired apparatus at the most reasonable cost. Apparently the steamship companies know very little about radio apparatus. Some of their vessels are equipped with apparatus which would not have been accepted by the navy ten years ago.

In suggesting radio operation by the steamship companies, we should consider the matter of profit or greater profit.

Paying and boarding the operator is probably the main expense in all cases. But there should be more or less work which could be done by the operator while listening for calls. Let us assume that the variation of the receiving tune required for picking up signals be accomplished by a spring or electric motor. This is feasible, and the work may be done much more thoroly than the average operator does it by hand. Freeing the operator from this manual labor would leave him free to do clerical or similar work. It is said that some of the Pacific steamship companies now have operator freight clerks who earn good salaries.

Probably an investigation on the part of the steamship companies as to the requirements of the communication part of their business would show them new and profitable ways in which the radio service might be employed, and other functions for the operator. It may be mentioned that if the operators were shown how to educate the public in the valuable ways in which radio service may be used and were given a bonus on the business handled, undoubtedly the receipts would be materially increased. The handling of the business should involve no difficulties, for a steamship company has sufficient office force to handle the operators, and the salary and message accounts.

As to the maintenance of the steamship-owned apparatus, properly designed apparatus in the hands of first class operators should require very little repair. Such special repairs as would be needed occasionally might be provided for in the contract with the manufacturer.

At present, the radio operator on a steamship is a somewhat undefined position. He is paid by an operating company and carries on the business of that company; he signs with the steamship company; he takes his orders from the operating company; he is supposedly under the captain; he has charge of important work; and finally, he gets little, if any, more pay than an ordinary sailor. This confusing state of affairs should cease to exist if the steamship companies operated their own radio equipment.

Formerly more or less specious arguments were presented by the operating companies to prevent the steamship companies from purchasing and using radio apparatus. The operating companies claimed that they had a patent monopoly, and that their reason for merely renting apparatus was that it was in their power to prevent the use of apparatus not supplied by them. The fact that other companies continued to make and use such apparatus and that the government continued to obtain all the apparatus it desired without renting it showed that this claim was at best a weak one. A later claim made by the operating companies was that they controlled all the stations in their field, and that in consequence stations of any other system in that field would have nobody to work them. But laws have been passed which compel the exchange of messages regardless of the system used. Even if the operating companies closed their shore stations, there would still remain the naval stations. And it is quite possible that the newspapers or wire telegraph companies would erect stations as means for obtaining news or as feeders to the land lines. And finally, it was stated that radio operators were difficult to train and to hire. They probably are not very anxious for employment when they are offered only thirty or forty dollars a month.,

Let us contrast the conditions now existing with those which we might expect to exist if steamship operation of radio communication were generally adopted. Suppose at present the steamship companies are paying between one hundred and one hundred and fifty dollars per month for two unprofitably occupied operators, an inferior equipment, and inferior service. If now the steamship company were to buy a first class equipment (for which it would pay, say, three thousand five hundred dollars), and were to give two first class operators profitable work which would reimburse the company for their salaries and accomodations, the company should insure for itself and its passengers prompt and correct radio service under ordinary and distress conditions. It could secure a share of the message tolls received from the passengers, dividing the remainder of these tolls between the shore stations and the operators. It would place the operators in a definite relation to the remaining of the ship's crew. And it should be protected against patent suits by the manufacturer of the radio apparatus.

It seems to me that the latter arrangement is far more satisfactory and profitable. With the salaries of the operators eliminated from the expenses to be charged to the radio service, the former rental of one hundred to one hundred and fifty dollars per month certainly should be more than sufficient to cover interest and depreciation on the thirty-five hundred-dollar investment.

Probably twenty per cent of the members of the INSTITUTE are connected with operating companies, and five per cent with manufacturing companies, while the remainder have more or less impartial relations with both. So that I may hope for a fair and thorough discussion of these suggestions.

I wish to express my gratitude for the honor which, for four years, has been conferred on me: the presidency of the Wireless Institute and the presidency of THE INSTITUTE OF RADIO ENGINEERS.

It gives me great pleasure to pass the office of president of THE INSTITUTE OF RADIO ENGINEERS to a man whom I have known and appreciated for eleven years, a man famous throughout the radio world, Mr. Greenleaf W. Pickard.

DISCUSSION.

PHILIP FARNSWORTH: I shall undertake to start the discussion of Mr. Marriott's very able paper. The paper was brim full of timely suggestions. But I think that some of us may reach different conclusions from those presented. Concerning the methods of commercial management of radio communication, the interesting question is raised whether it is best to have a single operating company or to split up the operating company into separate smaller and competing companies. In my judgment, the natural laws of business will automatically regulate this.

I shall endeavor to consider the matter entirely independently of the question of patents. Independently of the patent matter, it is a question whether it is not better to have a single operating company. It is really a question of good service, rather than of patents or of monopoly. The case may be considered to be similar to that of the Telephone Company. In that case, exclusive operation by a single company seems the best policy. Even some of the objectionable features of operation by a single radio company are not inherent faults of the single-company plan, and are remediable by the operation of natural laws of trade. And by placing the operation in the hands of one company a chaotic state of affairs is avoided which otherwise might occur.

The case of the radio work of the Government can hardly be fairly adduced as an argument for radio operation by the separate steamship companies themselves. The Government work is substantially under unitary control, and this tends to promote good service. If the individual steamship companies separately operated, that might tend the other way. If the policy of a single operating company is continued, it is obvious that such a company should co-operate with the Government and endeavor to provide a service at least as good as the Government's.

The work of the radio operator has always seemed to me rather responsible and difficult. I must confess that I cannot understand how it would be advisable to burden him with other duties as a steamship freight clerk. His close and continued attention to his work seems essential, but of course, it is possible that additional work might be permitted, under two-operator requirement.

ROBERT H. MARRIOTT.: The wire telephone is limited to available wire space, while the medium of radio communication, the ether, is apparently unlimited. For this and other reasons I consider the Telephone Company and general radio operation companies to be quite different types of organizations.

To protect the public, certain standards of apparatus and operation are required by law, and the steamship company is held liable in case of failure to obey the law. Therefore, it seems to me that the control of the apparatus and operators might better be in the hands of the steamship company, it being the responsible body.

Not only the case of the United States Government, but also that of the United Fruit Company indicates that it is thru open competition that the better apparatus is obtained.

As regards the time of the radio operator: in many cases he does not do much work. On the small boats, he probably averages under present conditions one message and three distance reports each day, so that, at the rate of twenty words per minute, it cannot take long for him to complete the actual manual labor. At present a large number of operators become tired and dissatisfied, because they have nothing to do.

PHILIP FARNSWORTH: I have the impression that the purpose of that clause in the law requiring two operators was that one would have the opportunity to sleep while the other worked; that is, one operator at least would be listening all the time, night and day. It seems to me that the duties of freight clerk might be inconsistent with those which the spirit of the law demands from the radio operator, but I confess I do not know as much about the matter as Mr. Marriott.

ROBERT H. MARRIOTT: The value of the services of a radio operator as an insurance against the loss of life and property is underestimated and not appreciated. The problem, as I see it, is to give the operator work which will bring him an income which is in proportion to the amount he is worth. The steamship company will increase his income only for a tangible reason.

As to the demands on his time by listening in, there is nothing to prevent him from wearing the telephone receivers while doing his freight clerk work, the tuning being done automatically by a spring or electric motor. Experience has shown that he will recognize his call or a distress signal even when deeply engrossed in other work.

CHARLES A. LE QUESNE, JR.: The receiving set might be normally adjusted to the distress tune, and only adjusted further when there was special need for it. In regard to radio operators doing other things than receiving messages, on the Pacific coast there are a number of operators who also act as assistant pursers. The operators do not like the double duties, however. Maybe this is because they get no increase in salary.

EDWARD GAGE: From my experience, I should not think that an operator could satisfactorily fill another position as well.

CHARLES A. LE QUESNE, JR.: In the case of automatic tuning, one might pass the wave length on which one was being called just during the space between two dots or dashes, and thus miss the signal.

ROBERT H. MARRIOTT: The tuning can be accomplished quite as slowly mechanically as by hand.

FRANK FAY: The operator can always hear things of interest to him even when he is not paying particular attention to them. In ordinary telegraphy, an operator recognizes his own call, no matter how inattentive he is.

EDWARD GAGE: The method proposed might suffice for isolated stations, but not for stations handling much business.

ROBERT H. MARRIOTT: The method of automatic tuning is primarily suggested for stations which do not get the opportunity to handle much radio business. If the station handles much business, the operator can earn a fair salary without doing other work.

LLOYD ESPENSCHIED: There appears to be two sides to the question, one of economic efficiency and the other of justice. Undoubtedly greater efficiency can be realized under one management, and, other things being equal, a single organization would therefore be the best. The case of the telephone company may be cited.

In radio work a tendency is manifest toward the concentration of power by patent monopoly. If a patent monopoly were realized, the government would be in the position of furnishing the mainstay (patents) for the trust and at the same time furnishing the market for its product by means of laws compelling the use of wireless. This would work an injustice to the wireless customer. It is only where monopoly is inherently necessary or is obtained and held through superiority of service that it is justified.

ROBERT H. MARRIOTT: It is unfortunate if a patent prevents the accomplishing of some object efficiently. But from the large number of makers of radio apparatus, one would conclude that after all the patents are weak.

Another advantage of superior apparatus would be that the operator would get louder signals and less interference from other stations and from the so-called "static."

LESTER ISRAEL: The telephone company is more efficient as a single concern, because in that case the most important part of the equipment is in the wire lines. But in the case of the radio station there is no cost for interconnection. The advantage of combination in the case of the telephone is that the needless duplication of long and expensive wire lines is avoided. Radio service differs so radically in this respect that no parallel conclusion can be drawn.

FRANK FAY: In the case of the telegraph companies, forty-three per cent. of the capitalization is in overhead lines, which, therefore, is not the main item of expense.

ALFRED N. GOLDSMITH: I should value the opinion of the members present as to the propriety of granting patents which constitute potential bases of monopoly in a developing art, such as that of radio-communication.

LLOYD ESPENSCHIED: The granting of patents in the form of *MONOPOLIES*, as in the present practise, is, I believe, morally and even economically wrong. There has been proposed a system which possesses merit — that of granting a bonus to investors. The matter of finding a better patent system is, of course, a subject ill adapted to hasty consideration.

JOHN L. HOGAN, JR.: The question is apparently one of good and bad trusts, and so broad a topic we cannot hope to discuss thoroly here.

To come back to the case of the United Fruit Company: This corporation is one having special powers, as it does a large telegraphic business from ship to ship and between its shore stations. It is able to maintain a system which cannot be maintained by a smaller company. A steamship company of the size of the Old Dominion Line, for example, would not be in the position to maintain such an operating and bookkeeping system. It would be unprofitable. What the steamship companies desire is good apparatus and service.

We have had during the evening various hints that misrepresentation of apparatus is practised occasionally. If the steamship companies were to purchase their apparatus and attempt to operate it themselves, they would be misled by the same rosy claims. Rather improve the operating companies and thus remove the objections against them.

PHILIP FARNSWORTH: I do not intend to say that radio "control" should be in any corporation. "Control," or perhaps a better term is "supervision," is very properly in the Government. But, as in the case of the telephone system, is it not a fact that the best service accompanies *operation* by a single company, because of the resulting economies in and efficiency of both the manufacture of apparatus and the operation of the telegraph service? Be assurred that in the case of persistent failure to supply suitable apparatus and good service, that very failure would have its natural result, as would also any attempt to enforce an unnatural or unfair monopoly.

But is there anything inconsistent between a single company and the best apparatus and service? And is there any reason why the single company cannot co-operate with both the Government and the steamship companies to secure the best apparatus and service for both the Government and the steamship companies? Is there any reason to suppose that a single company is not in the best position to effectuate improvements and standardization for apparatus and service common to both the Government service and that of the steamship companies?

It surely is not the natural function of either the steamship companies or the Government to develop and improve radio apparatus and service. And is not a single company in the best position to take and maintain the lead in the improvement of apparatus and service, for both Government and steamships? It would seem to be the best policy for a single company to provide even better apparatus and service than the law requires, and it is believed that both the Government and the steamship companies, stimulated by public opinion, would cheerfully pay adequately for such service. I heartily agree with Mr. Marriott's statements concerning the power of the will of the public. And to an enlightened management, the possibilities of successful competition as the effect of poor service supplied is a sufficient inducement to provide everything of the very best character.

It is true that a steamship company is a public service concern, and from this some persons might argue that it is logical that the public service of operating a radio telegraph company might be properly executed by the steamship companies. But each of the many steamship companies has its own management independently of the others; the operation of a radio service is not a natural function of a steamship company; and the radio service, including both the design and production of apparatus and its operation in the public service, requires specialists and a competent general management such as only a radio company can provide satisfactorily.

It is intimated that the service of some of the radio companies is not all that it should be. But even if that be true at present, the radio service is yet youthful and I am confident that the managements are doing everything in their power to make improvements. Even if the Government's service at present is better than the service on the merchant marine, we ought to remember that the Government has been paying more for its apparatus and service.

As to patent monopolies, I would have you consider the interests of the inventor and patentee. The object of the grant of a patent is to promote and develop an art. It offers an inducement to inventors. What we all want is to have the art developed and better servive provided. The term of a patent is only seventeen years, and in return for the exclusive use of the invention during that time, the inventor discloses it to the public by way of the patent, so that everyone may use it after the seventeen years are up. The term is really a very short one, in view of the fact that usually no profits are realized until the patent is several years old. Of course, if a large company exists, which can pay the inventor a fair price and put the invention into use, that is advantageous to everybody. But the term of seventeen years is none too long in any case.

Of course, the broader a patent is, the harder it is to devise non-infringements, but this also helps the art by compelling more new inventions. The fact is that the real inventor of an improvement to-day stands little enough chance of enforcing his limited monopoly and obtaining adequate compensation for his contribution to the art. But it may be that a law can be devised which will improve these conditions while also preventing abuse by corporations of the privileges of patents.

There seems to be no difficulty in the patent situation if one radio telegraph company were in control of the field. If inventors outside the company produce useful improvements, the company must buy such improvements or compete with them. The more strongly the patent laws support the inventor, the greater is the price the company has to pay and the less its chance of successful piracy. On the other hand, if the company's employees produce the improvements, the company is entitled to its economic reward in the form of a monopoly lasting for a very limited term.

In short, let us, in considering the status of a patent and possibility of a single radio company, follow the "rule of reason."

LLOYD ESPENSCHIED: The inventor can be given sufficient reward without being given a monopoly. There is a movement on foot to secure a revision of the patent laws in the direction of broadening the circle of those who may manufacture under a patent, even without the inventor's consent.

Apropos of the discussion regarding patents which has arisen, I would suggest that the subject be more actively pursued by the INSTITUTE, especially in view of the agitation now being carried on by engineering and scientific bodies for a thorough revision of our patent system.

THE PRESIDENTIAL INAUGURAL ADDRESS: ENGINEERING ETHICS.

By Greenleaf Whittier Pickard
(*President of the Institute*)

Members of the INSTITUTE OF RADIO ENGINEERS:

I sincerely thank you for the confidence you have shown in me by your votes. While our membership represents many still opposing interests in the commercial field, I am certain that during the coming year we will work harmoniously together for the advancement of the art of radio-communication.

Fortunately our Constitution does not require a *formal* address of the incoming President. After my predecessor's able address, I fear that any extended talk on my part would be an anti-climax. I believe, however, that there are several important lines along which our energies for the coming year may be well directed, and of these I will speak briefly.

The work of our Committee on Standardization is admittedly of first importance. Our art has grown so rapidly that many of us have, perforce, made our own and sadly variant technical vocabularies. To progress, we must standardize; we must all speak and understand the same language. Much work has already been done, and well done, by this committee, and, I can safely say, much remains to be done during the present year. Standardization, in such a branch of the electrical art as ours, may never be complete. Rather, it must be a living, growing structure, added to and revised to keep pace with the changes and development of the art.

Our membership should be increased. The influence, we as a body may exert, depends both on our size, and the character of our members. I believe that there are many active workers in this field, at least qualified for associate membership, who would join us if they appreciated the value of association with our INSTITUTE. And I am certain that there are a number of men, both in this country and abroad, eligible for full membership, who would make useful, active members of this INSTITUTE. We need these men, and they will join us, if our work and our aims are made known to them. Our standing Committee on Publicity is our present link with the outside public and technical world. I am not sure but that a special Committee on Increase of Membership might well supplement, in this particular direction, the work of the Publicity Committee.

This mention of our Committee on Publicity and my predecessor's discussion of misrepresentation of apparatus and achievements reminde me of our connection with and our duty to the public. Men in any technical pursuit are apt to forget, in the absorption of their work, how intimately they are linked with the general public. It may be somewhat early to even mention a code of ethics for our profession, and I certainly do not wish to suggest the appointment of a committee for this purpose. Yet, perhaps, we are in greater need of such a code than our brethren in any other branch of engineering. In the past, and even at the present time, much of the commercial development of this art has been assisted financially by the public. We owe a duty to this public, and our individual part therein is perhaps best expressed by a quotation from a report presented by the Committee on a Code of Ethics at the 24th Annual Convention of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, in 1907.

"In both his professional and his business relations the electrical engineer should follow strictly the same ethical principles that are recognized in the social relations of everyday life. He should consider himself personally responsible for the character of the enterprises with which he is associated professionally.

"Before he enters into professional relations, it is his duty to satisfy himself that the enterprises with which he connects himself are of a legitimate character. If, after becoming associated, he finds them to be of a questionable nature he should sever his connection as soon as possible. It should not be considered an excuse that his connection extends only to legitimate engineering work.

"By permitting the use of his name in any enterprise or exploitation he becomes morally responsible for its character. He should therefore not allow the use of his name in connection with anything upon which he is not qualified by training and experience to exercise competent judgment.

"He should endeavor to assist the public to a fair and correct general understanding of electrical matters, spread the general knowledge of electrical engineering, and discourage wrong or exaggerated statements on engineering subjects published in the press or otherwise, especially if these statements are made for the purpose of, or may lead to, inducing the public to participating in unworthy schemes."

Many feel that ethical codes are best followed when unwritten. I believe, however, that something may often be gained by the repetition of even truisms, and I am sure that it is not Utopian to consider the above quotation as applying strictly to ourselves.

I cannot close without a word of appreciation for the work of our past President, Mr. Robert H. Marriott. He has given unsparingly of his time and energy in the formation, building up and directing the activities of this INSTITUTE. He has initiated, and guided to a strong development many important lines of work. I am reconciled to my present office only by your wise action in electing him our Vice-President. If we can carry forward the work he has so ably started, in such a manner as will insure its soundness, I shall feel my administration a success.

THE EFFECTS OF DISTRIBUTED CAPACITY OF COILS USED IN RADIO-TELEGRAPHIC CIRCUITS.

By Frederick A. Kolster
(*United States Bureau of Standards*)

During the past eight or ten years much more attention has apparently been given to the development of the transmitting apparatus in radio-telegraphy than to the receiving apparatus.

Consequently the same sort of apparatus used five years ago or more to receive highly damped multi-frequency waves is still in use to receive the more persistent waves of single frequency which result from the improved transmitters of to-day.

It is, of course, apparent that the more nearly undamped are the transmitted waves, the more care must be taken in the design of the receiving apparatus.

Among the many things to consider in the design of circuits in which persistent radio frequency currents exist, are the effects of distributed capacity in the coils of the circuit.

It is the purpose of this paper to give the results of some preliminary experiments which were conducted with the view of determining how important are the effects of the distributed capacity of coils used in radio frequency circuits. At first thought, these effects would seem to be of minor importance, and this is generally true if proper precautions are taken in the design of the circuits and the construction of the coils.

In much of the apparatus in practical use, however, those precautions have apparently not been taken, with the result that peculiar phenomena are often observed. In laboratory apparatus for calibration and measuring purposes consideration of distributed capacity effects is of extreme importance.

It is not unusual in practise to find that coils used in wave meters and receiving apparatus have distinct natural periods or frequencies in the range of frequencies for which the circuit may be adjusted.

If the inductance of such a coil is measured at various frequencies, it will be found that this inductance apparently changes with the frequency as shown by the curve of Figure 1. The crosses on the curve indicate experimentally observed values. The natural wave length of the coil tested is about 260 meters and its inductance approximately 1.5 milli-henrys when measured at very low frequencies.

If it is assumed that a coil having distributed capacity may be, for all practical purposes, artificially represented by a loop circuit containing inductance and capacity in parallel as shown in the diagram of Figure 1, then we may write for the apparent inductance of the coil, if resistance is neglected,

$$L^1 = \frac{L}{1 - L\,C^1\,\omega^2}$$

where L is the true inductance of the coil, C its effective capacity, and ω equals 2π times the frequency.

If this assumption is good, it should be possible to determine the values of L and C of an equivalent loop circuit such as to make its apparent inductance equal to that of the coil under test for the range of wave lengths desired.

Considering now the curve in Figure 1, we may write for any two wave length or their corresponding values of ω,

$$L_1^1 = \frac{L}{1 - L C\,\omega_1^2} \quad \text{and} \quad L_2^1 = \frac{L}{1 - L C\,\omega_2^2}$$

By elimination we get

$$L = \frac{L_1^1\ L_2^1\ (\omega_1^2 - \omega_2^2)}{L_1^1\,\omega_1^2 - L_2^1\,\omega_2^2}$$

or in terms of wave lengths, since $\omega = \frac{2\pi v}{\lambda}$

$$C = \frac{L_1^1\,L_2^1\ \ (\lambda_2^2 - \lambda_1^2)}{L_1^1\,\lambda_2^2 - L_2^1\,\lambda_1^2}$$

Averaging the results obtained by taking several pairs of points on the curve in Figure 1, a value of 1.50 millihenrys is obtained for the true inductance of the coil measured.

The value of the effective capacity of the coil may be

Fig 1

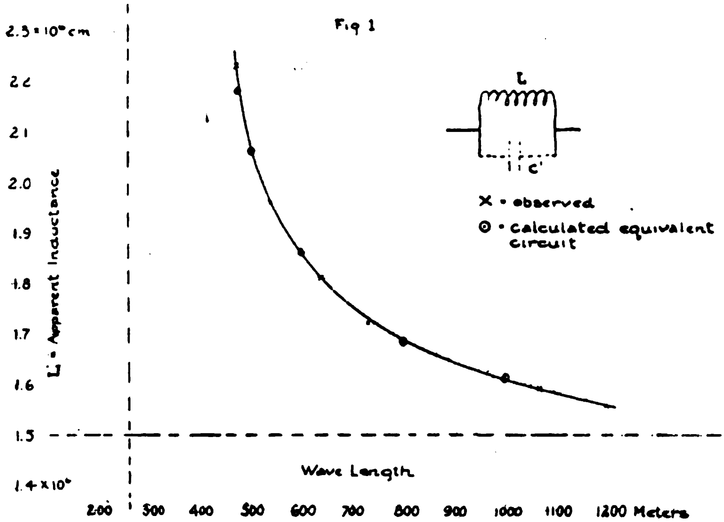
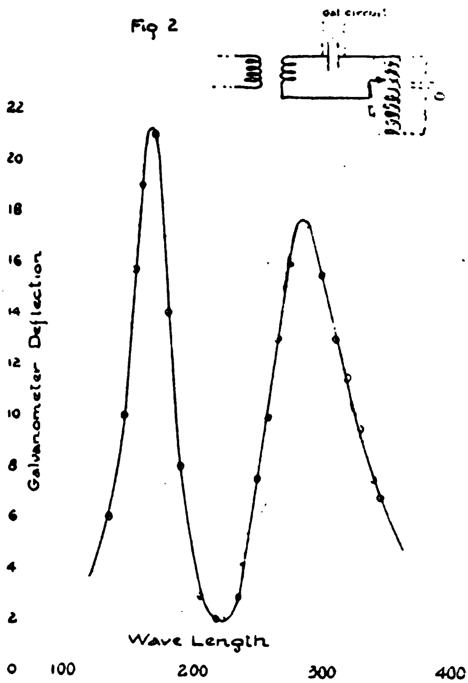

2.3 × 10⁶ cm
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4 × 10⁶
L' = Apparent Inductance
L
C'
X = observed
O = calculated equivalent circuit
Wave Length
200
300
400
500
600
700
800
900
1000
1100
1200 Meters

Fig 2


Gal circuit
22
20
18
16
14
12
10
8
6
4
2
0
Galvanometer Deflection
Wave Length
100
200
300
400

expressed as

$$C = \frac{1 - \frac{L}{L^1}}{L\,\omega^2}$$

or, in terms of the wave lengths as

$$C = \frac{\lambda^2}{4\,\pi^2\,v^2}\left(\frac{1}{L} - \frac{1}{L^1}\right)$$

Averaging the results obtained for various wave lengths we get for this capacity, 0.000013 micro-farads.

The coil in question may, therefore, be represented by an equivalent loop circuit having a condenser of 0.000013 micro-farad in parallel with a coil of 1.50 millihenry. The circles on the curve in Figure 1 indicate the calculated apparent inductance of this equivalent circuit for the ranges of wave lengths indicated, showing that the assumption made is good for all practical purposes.

The diagram shown in Figure 2 represents a common form of circuit used in receiving apparatus and in some forms of wave meters. The loading coil L of considerable inductance and distributed capacity is divided into sections one or more of which may be connected in circuit to allow adjustment for various ranges of wave lengths. The imaginary condenser in parallel with this coil represents the effective capacity of the coil. For short wave lengths only part of the coil is in circuit, the unused sections being, however, inductively related to the part in circuit. It will be seen that this arrangement is really a case of two closely coupled circuits which should undoubtedly respond to two distinct frequencies or wave lengths. This fact is shown to be true by the experimentally obtained curve in Figure 2.

A brief theoretical consideration of a circuit of two degrees of freedom as shown in Figure 2 is of interest. This circuit may be diagrammatically represented by the circuit in Figure 3.

The reactance of the loop circuit 1 l^1 c^1, if resistance be neglected, may be written,

$$X = \frac{l\omega\,(l^1\,C^1\,\omega^2 - 1)}{(l^1 + l)\,C^1\,\omega^2 - 1}$$

The curve (a) in Figure 3 shows the variation of the reactance of such a loop circuit for various values of ω. Curve

Fig 3

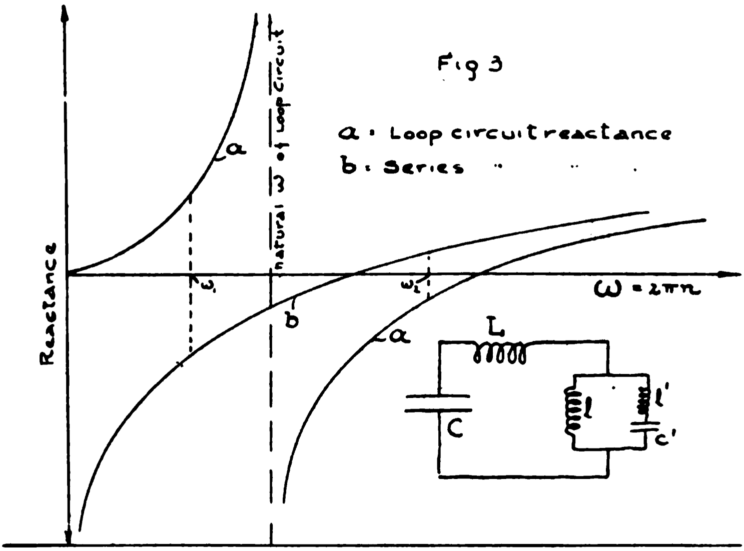
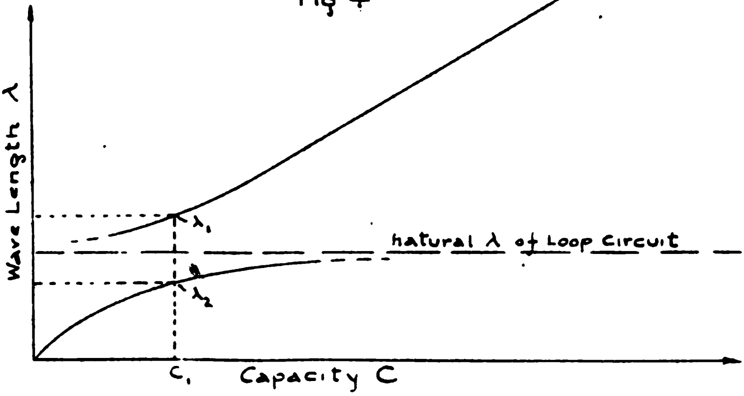

a : Loop circuit reactance
b : Series "   "
natural λ of Loop Circuit
Reactance
$\omega = 2\pi n$
ω_1
ω_2
a
b
a
L
C
l
l'
c'

Fig 4


Wave Length λ
λ_1
λ_2
natural λ of Loop Circuit
C_1
Capacity C

(b) gives the reactance of the series circuit L,C for various values of ω.

The total reactance of the system for various values of ω is therefore the sum of these two curves, and it is seen that zero reactance is obtained for two values of ω, showing that for any particular setting of the condenser C, the system will respond to two distinct wave lengths.

For various settings of the condenser C, a calibration curve as shown in Figure 4 is obtained. Such cases as this actually occur in practice, the cause being entirely due to the effects of distributed capacity in coils.

The radio-frequency resistance of coils with appreciable distributed capacity is found in practice to be higher for some frequencies than that calculated from the well-known formulae. This may be at least partly explained if we again assume that such coils may be represented by equivalent loop circuits.

A loop circuit having an inductance L with calculated radio-frequency resistance R, in parallel with a condenser C as shown in the diagram of Figure 7 will have an apparent resistance

$$R^1 = \frac{R}{R^2 C^2 \omega^2 + (L C \omega^2 - 1)^2}$$

Curve (a) in Figure 7 gives the calculated radio-frequency resistance of a particular coil for various wave lengths. Curve (b) gives the apparent radio frequency resistance of this coil for this range of wave lengths, taking into consideration the distributed capacity and treating it as a loop circuit.

Distributed capacity effects in the coils of the so-called untuned or aperiodic detector circuits are in many cases very striking, the result being that the circuit is not at all aperiodic but responds much more violently at a particular frequency depending upon the natural period of the coil.

The so-called untuned detector circuit is shown in the diagram of Figure 5. The curve in this figure shows experimentally observed galvanometer deflections when the circuit is excited at various wave lengths. A comparatively sharp resonance curve is obtained showing that the circuit is distinctively not aperiodic.

An extremely interesting and ingenious method for determining the value of the effective capacity of a coil is described

Fig 7

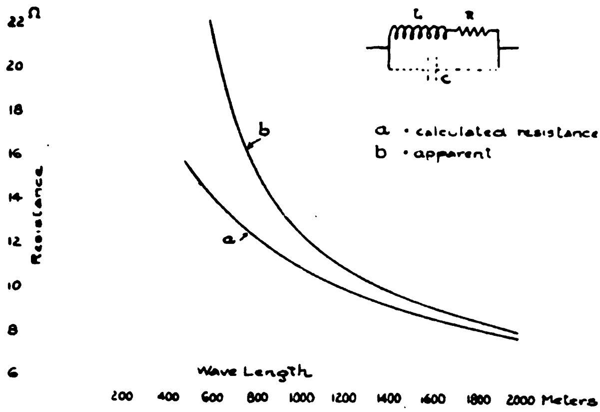


Fig 6

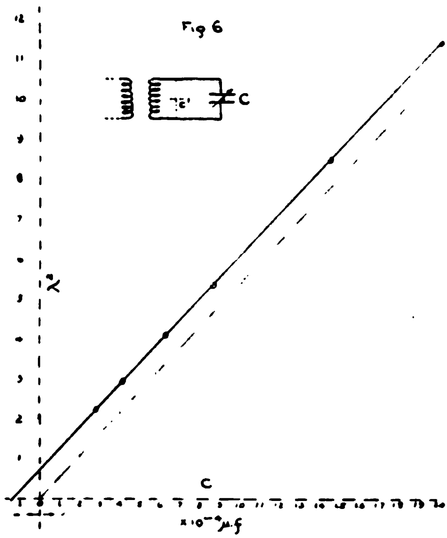
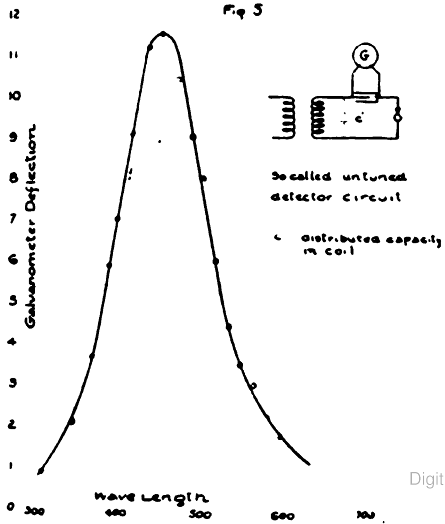


Fig 5



in an article written by Professor G. W. O. Howe in the Proceedings of the Physical Society of London.

A variable condenser of known capacity is connected to the coil under observation and the circuit is excited at various frequencies. A curve as shown in Figure 6 is plotted with values of condenser capacity as abscissae and the squares of the wave lengths as ordinates. A straight line is obtained which, instead of striking the horizontal axis at zero, which would be the case if no distributed capacity existed in the coil, gives the negative value of C corresponding to a value zero for the square of the wave length. This negative value is the effective capacity of the coil.

The true value of the inductance of the coil may also be determined from the broken line shown in Figure 6, drawn parallel to the observed line, through C equal to zero. Taking value of λ^2 as determined by this broken line for various values of C, and averaging the results from the usual formulae

$$L = \frac{\lambda^2}{4\pi^2 v^2 C}$$

the value of the true inductance is obtained.

The curve in Figure 6 was obtained for the same coil as in Figure 1, and the values for the effective capacity and true inductance of this coil as determined by these two methods agree almost exactly.

The results of these experiments show the importance of taking into consideration the capacity effects in coils of circuits designed for calibration and standardizing purposes, and in particular in circuits of large inductance and small capacity.

Inductance coils for radio-frequency circuits should be designed to have minimum capacity as well as minimum resistance. It is unfortunate that the best design for one of these requirements is generally not the best design for the other.

Coils with "dead-ended" turns should not be used, even though the turns not in use are metallically disconnected from the circuit. They should be entirely out of the field of the active turns.

Coils in so-called untuned detector circuits should be particularly designed to have minimum capacity or else for each short range of wave lengths a separate coil should be used having a natural period best adapted to this range.

SUMMARY: It is shown experimentally that an induc-

tance having distributed capacity may be practically replaced by an inductance (called its "true inductance") in parallel with a capacity, (called its "effective capacity"). Methods of calculating each from observations are given and it is shown how strong response to one or more frequencies in wave meter and so-called untuned detector circuits is caused by distributed capacity inductances, particularly those with dead-ends. Practical conclusions are drawn.

DISCUSSION.

ALFRED N. GOLDSMITH: The assumption made by Mr. Kolster that an inductance having distributed capacity may be for electrical purposes replaced by a definite inductance in parallel with a definite capacity can be true only when the inductance is reasonably localized and the capacity not extremely great. It certainly cannot hold in unmodified form for radiative antennae. By experiment it has been shown to be a valid assumption (within the errors of measurement) for practically non-radiative coils of moderate dimensions.

An interesting fact concerning an open or radiative circuit, that is, one containing large distributed capacity, is that the frequencies of the alternating currents produced in such a circuit when it is coupled to a closed oscillating circuit cannot be correctly calculated from the equations holding for closed coupled circuits, and that the frequencies of the overtones produced in the open circuit are not integral multiples of the fundamental frequency. (See L. Cohen, Bulletin Bureau of Standards, Vol. VI, No. 2, 1909).

GREENLEAF W. PICKARD: Distributed capacity effects in inductances are important radio apparatus, and are usually detrimental. While it is obvious that such capacity cannot be entirely eliminated, it may be minimized in various ways. Multiple layer coils of ordinary construction have excessive distributed capacity, and many more or less successful attempts have been made to decrease this. Certain early patents in this art show multiple layer coils, wound in a peculiar manner, each section of the coil having its layers pyramided, so to speak. Such a construction is indeed a partial solution of the problem, and it is interesting to note that although these patents are now some fourteen years old, a similar method of winding is now being introduced as a novelty.

Occasionally the distributed capacity of a coil may be made to serve some more or less useful purpose. An example of this is the early Slaby wave-meter, consisting merely of an "open" coil, with no capacity other than that of the winding.

EMIL J. SIMON: Will Mr. Kolster describe the various methods of partially avoiding distributed capacity, for example, the use of banked turns?

FREDERICK A. KOLSTER: I did not propose to go into that matter in detail in the present paper. Banking or interweaving of the turns is of value. The reason therefor seems to be that the potential differences between adjacent turns of wire are reduced by this method of winding.

In wave meter circuits, coils having distributed capacity should not be partly inside and partly outside the instrument. They should be connected directly and entirely to the variable condenser, for then the main effect of the distributed capacity will be merely a small addition to the capacity of the variable condenser.

ROY A. WEAGANT: In the experiments, what was the source of oscillations?

FREDERICK A. KOLSTER: Buzzers or quenched gap exciters were employed.

ROY A. WEAGANT: Were any experiments made at various decrements to determine if the effects were altered?

FREDERICK A. KOLSTER: It was found that the smaller the decrement of the transmitter, the more pronounced the results became. The decrement of the exciting circuit containing the quenched gap was 0.008.

ROY A. WEAGANT: There was a case when the closed oscillating circuit showed apparently infinite impedance?

FREDERICK A. KOLSTER: There was such a case. In the arrangement shown in Figure 8, where L_2 is coupled to the exciting circuit, A is the current indicator, and L_3 the coil having distributed capacity, the apparent resistance of the

Figure 8

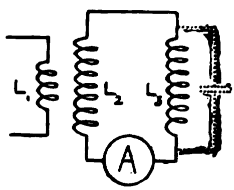


Figure 9

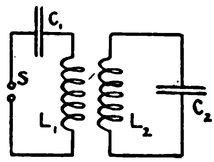


Figure 10.

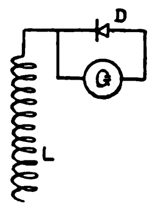


Figure 11

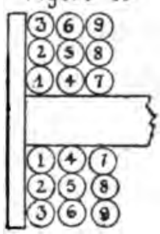


Figure 12

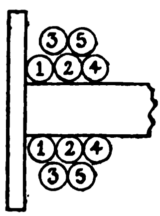


Figure 13

Figure 14

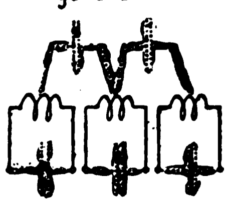


Figure 15

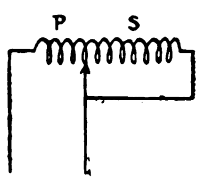
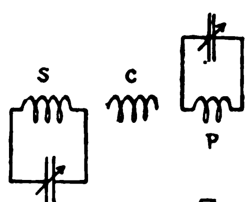


Figure 16



loop circuit at certain frequencies as indicated by the current readings, was in the megohms.

BENJAMIN LIEBOWITZ: How were the capacity and true inductance of the coils measured?

FREDERICK A. KOLSTER: Professor Howe found the free period of the coils he used by exciting the coil and attaching a vacuum tube to one of its terminals. A method which I have employed is shown in Figure 10. L is the coil, the natural period of which is to be determined, G a galvanometer connected to a rectifier D. When the maximum deflection is obtained in the galvanometer, the periods of the coil L and the exciting circuit are equal (for very loose coupling). If the inductance of the coil, measured at a very low frequency, say 100 cycles, is known, then having measured its natural period, its capacity may be calculated. However, it is best to use Professor Howe's method, as described in the proceedings of the Royal Society, or else to determine the equivalent loop circuit, as I have shown in my paper.

H. E. HALLBORG: Can you excite the coil with a buzzer and measure the wave length with a wave meter?

FREDERICK A. KOLSTER: That method is dangerously unreliable.

ROY A. WEAGANT: In obtaining the resonance curve in the aperiodic circuit containing a detector, were the resonant effects obtained certainly due to distributed capacity, as you have stated, or might they not be due to a gradual change of decrement in the exciting circuit?

FREDERICK A. KOLSTER: The observations were too marked to be due to decrement changes. The measurements were quantitative, a thermo-couple and galvanometer being used for the indicators.

ROY A. WEAGANT: It seems to me that with the coupling values fixed, there would be a change of indication (a gradual increase) as the wave length was altered because of change of coupling.

FREDERICK A. KOLSTER: The effect was not that of a gradual increase. It was a distinct peaked curve in a limited range of wave lengths.

EMIL J. SIMON: There are a number of ways of reducing distributed capacity through the banking of turns. Two are shown in Figures 11 and 12. The numbered circles represent the cross sections of consecutive turns, wound in the order indicated. Each of these methods of winding is somewhat difficult to construct mechanically, but the second method is preferable in that regard.

GUY HILL: Have you tested transmitting apparatus for these effects?

FREDERICK A. KOLSTER: Yes, and the effects found were similar.

H. E. HALLBORG: If we have the arrangement shown in Figure 13, did you find that the distributed capacities add when the coils are connected in series?

FREDERICK A. KOLSTER: The arrangement shown is probably equivalent to that represented diagrammatically in Figure 14. There the distributed capacity of the coils are shown connected directly across the coil terminals, and the "mutual capacities" of the individual coils are shown connected from coil to coil.

ALFRED N. GOLDSMITH: Such systems as that shown in Figure 13, if the distributed capacities are large, have a great number of degrees of freedom and will respond more or less powerfully to many frequencies. In practice, this may lead to flat tuning.

H. E. HALLBORG: The distributed capacity in the secondary of an ordinary high tension transformer may be a direct cause of breakdown if the transformer is feeding a circuit in which there are radio frequency currents of certain definite periods. At Brant Rock there was employed at one time a 100 kilowat 12,500/25,000 volt transformer, tested by the manuturer to three times the rated voltage. At a wave length of 1,500 meters, it was impossible to operate this transformer without breakdown of the internal secondary coils unless a large choke coil was connected in series. At 3,700 meters no choke coil was necessary, although one was used. I attributed the phenomenon to internal resonance at a frequency corresponding to the 1,500 meter wave length. The coils had large distributed capacity, being step wound. Break-down always occurred in the same coils and at the same wave length. A choke coil in series reduced the period to a point where no resonance occurred through the range of wave lengths used and therefore made operation safe for these frequencies.

GREENLEAF W. PICKARD: I should like to ask Mr.

Kolster's opinion of the relative merits of the methods shown in Figures 13 and 15, for avoiding the "dead-end" effect of the unused portion of an inductance coil. In Figure 13, the inductance is sub-divided into a number of small sections, which are successively connected together and to the circuit; while in Figure 16, the required amount of inductance is placed in the circuit, and the remainder of the coil, or a considerable portion thereof, is short-circuited.

FREDERICK A. KOLSTER: The inductance made up of many small sections disconnected from the rest is better. Short-circuiting is perhaps a good thing if it is necessary to have the unused portions of the coil inductively linked to the active turns.

ROY A. WEAGANT: Does not the short-circuiting method give rise to large damping?

FREDERICK A. KOLSTER: It may well do so. Still, I should prefer to short-circuit unused portions of the circuits which could not be bodily removed.

GUY HILL: I tried the short-circuiting method and found no marked losses.

CHARLES A. LE QUESNE, JR.: As a matter of fact, in receiving, short-circuiting a number of turns sometimes helps.

ROY A. WEAGANT: The improvement in strength of signals which is thus obtained can always be surpassed by a direct change of inductance, capacity and coupling in the circuits. The short-circuiting method is not a desirable way of tuning. In some cases I found that a single short-circuited turn caused a 10 to 50 per cent. diminution in the strength of the signals.

GREENLEAF W. PICKARD: If the resistance of the coil is small, the effect of short-circuiting a section is small. If an active portion of the coil is short-circuited, the effect will be greater.

ROY A. WEAGANT: If as much as 25 per cent. of the coil is in use, I found that only a few turns need be short-circuited to completely spoil the signals.

FREDERICK A. KOLSTER: After short-circuiting the additional turns, Mr. Weagant, did you retune the circuit?

ROY A. WEAGANT: I did. I always made a series of adjustments with and without short-circuiting.

ALFRED N. GOLDSMITH: It will be noted that Figure 15 represents an auto transformer, of which P is the primary and the entire coil the secondary. Short-circuiting a portion of the secondary according to the well-known theory the transformer, increases the apparent resistance of the primary and diminishes the apparent inductance of the primary by calculable amounts. The result in our case is that both the damping and period of the primary circuit are altered, and retuning and variation of coupling are necessary if a fair comparison is to be made between the methods shown in Figures 13 and 15.

But, á priori, the general theory of the conservation of energy indicates that the short-circuiting method is the less desirable one.

ROY A. WEAGANT: The effects actually observed were always as Dr. Goldsmith has stated.

FREDERICK A. KOLSTER: As an example of a coil intended for work in ranges of frequencies to which it was actually resonant, I may mention one of 100 turns wound 32 to the inch, on a threaded rubber spool 4 inches in diameter. The unused turns were wound up and short-circuited on a metal spool. The fundamental wave length of this coil was 300 meters! This was due to the neighboring metal cylinder.

GREENLEAF W. PICKARD: It may be of interest in this connection to describe a method of measuring the natural period of a coil, which does not involve any attachment to the coil. In many cases, the capacity of the coil is so small, that the addition of even a few inches of wire to one terminal will have a marked effect on the natural period. I have shown this method in Figure 16, where the coil C, under test, is placed between an exciting circuit C and a receiving circuit S, the distance between coils being, in some cases, several feet.

When circuits P and S come into resonance with coil C, this coil either acted as an absorbing screen, diminishing the current in S, or, with certain forms of coil and relative positions of the three circuits, a marked increase of current in S occurred at the resonant point. In either case, the resonant point was so sharply marked that an excellent determination of the natural frequency of the coil C could be made.

This reversal of effect is probably due to the combination of electrostatic and magnetic coupling between C and S. The energy in S was measured by detector and galvanometer in the usual manner.

LESTER ISRAEL: If the resonance point is determined by maximum deflection when the electrostatic coupling is predominant, and by a minimum when the magnetic coupling is predominant, will there not be some position where no indication of resonance can be obtained?

GREENLEAF W. PICKARD: Experiments for determining this were not tried. It might readily be investigated by rotating or otherwise moving C, so that the electrostatic and magnetic couplings were differently varied.

H. E. HALLBORG: (By Letter). Since the delivery of Mr. Kolster's paper, I have found by measurement that the distributed capacity of two similar coils is half that of one, obeying the same law as condensers in series; and when connected in parallel, double. The exact value varies with the degree of electrostatic and magnetic coupling between the coils under consideration, as Mr. Kolster has stated. Hence, with a straight coil of considerable length, the distributed capacity of the coil as a whole falls off in a definite proportion to the increase in coil length or number of turns.

As regards the method which I mentioned for directly determining the frequency of a coil by exciting it with a buzzer, the reverse method yields surprisingly good results. The wave meter was excited by a buzzer, and reception was accomplished by a crystal hanging at one end of the coil under test. By adding a condenser of known capacity in parallel with the coil and taking a second reading, we can separate the distributed capacity and the true inductance of the coil.

(Editor's Note: The method employed for finding the free period of a coil in the Radio Engineering course at the College of the City of New York is by exciting the coil under examination from an APERIODIC buzzer circuit loosely coupled to it. This is, in effect, simply impulse excitation, and the results obtained have been highly satisfactory both in manipulation and accuracy. The unreliability of buzzer excitation is thus completely removed.

THE RELATION BETWEEN EFFECTIVE RESISTANCE AND FREQUENCY IN RADIO TELEGRAPHIC CONDENSERS.

By Louis W. Austin, Ph.D.

(*Head of the United States Naval Radiotelegraphic Laboratory.*)

In a former article (1) I described some experiments on the effective resistance of certain condensers used in radiotelegraphy. In these condensers two types of energy loss appeared, one of which, the brushing loss, increased as the square of the voltage; while the second the dielectric loss, was independent of the voltage between the limits of 4,000 to 20,000 volts No attempt was made in these experiments to determine the effect of changing the frequency, the only wave length used being approximately 1,000 meters.

It is, of course, well known that the dielectric conductivity of condensers at commercial and telephone frequencies, 60 to 5,000 per second, increases nearly in proportion to the frequency (2). So far as I am aware, however, no attempt has been made to examine this point in the range of radiotelegraphic frequencies.

During some experiments a few months ago on the effective resistance of glass plate condensers immersed in oil some anomalies were observed which led to observations being made on the effect of wave length on the resistance. It was at once found that the effect was very marked, and further observation showed that the resistance at a given wave length was the same whether the measurements were made at sevral thousand volts or at the low voltages produced by a buzzer circuit.

As the buzzer method of excitation for experimental purposes is far more convenient than that involving spark apparatus, the following measurements were carried out by this method. The arrangement of the apparatus is shown in Fig-

(1) Bulletin, Bureau of Standards, IX, Page 73, 1912.

(2) J. A. Fleming, Journal of the Inst. of Elec. Engineers, London, 49, page 323, 1912.

ure 1. Here A is the buzzer circuit, and B the experimental circuit, consisting of an inductance L, a low resistance thermo-element Th, with its sensitive galvanometer; and a double switch s-s by means of which either a variable air condenser C, or the condenser under test X can be thrown into the circuit. In series with air condenser C are mercury cups by means of which fine wire resistance units R can be thrown into circuit.

The method of observation consists merely of tuning the circuit B to A for the wave length desired with the switch thrown so as to connect the unknown condenser X. The deflection of the galvanometer is noted, after which the condenser X is replaced by the air condenser C and resistance inserted at R until the galvanometer deflection becomes the same as that first observed with the condenser X in circuit. As the air condenser may be considered free from resistance, R represents the "effective or dissipative resistance" of X.

Table 1 gives the observed resistance of a copper-coated glass plate condenser of 0.00196 mf. capacity with a copper coating of an area of 30.8 cm. by 30.9 cm., while the thickness of the glass dielectric is 0.296 cm.

TABLE I.

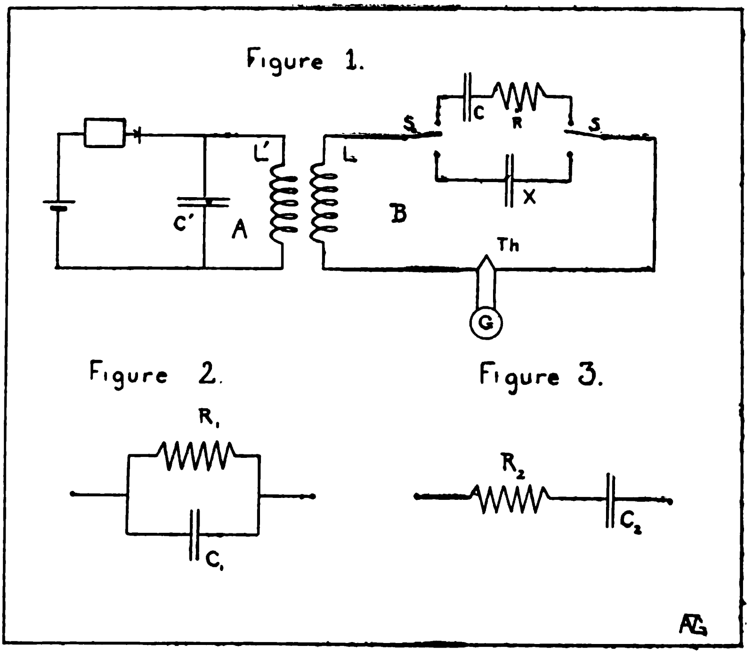
WAVE LENGTH	FREQUENCY	RESISTANCE	S (OBSERVED)	S (CALCULATED)
385 meters.	779,000	0.7 ohms	1.4	1.16
650	461,500	1.3	0.77	0.69
910	329,000	2.0	0.50	0.49
1325	226,000	3.0	0.33	0.34
1905	157,200	4.8	0.21	0.23
2360	127,000	5.4	0.18	0.19
3100	96,770	7.5	0.13	0.143

If we let S represent the conductivity, the reciprocal of the resistance, then, according to the results of Fleming, the dielectric conductivity can be represented by a formula of the form

$$S = A + B\,n$$

where A and B are constants and n the frequency. For good dielectrics, A in general is small and with such high frequencies its exact value would be difficult to obtain. Assuming that A is equal to zero, the value of B for our observations would be $1.49(10)^{-6}$ and our results would be represented by

$$S = 1.49(10)^{-5}\,n.$$



According to this formula, the resistance of this condenser at 60 cycles would be approximately 12,000 ohms. A similar condenser of practically the same dimensions and quality of glass was measured at the Bureau of Standards and found to have a resistance of 53,000 ohms. While this numerically differs considerably from the value indicated by our formula, it is still of the same order of magnitude, and it seems that the agreement is remarkable considering that the range of frequency in the two experiments varied between 60 cycles and 779,000 cycles.

TABLE II.

WAVE LENGTH	FREQUENCY	RESISTENCE	S (OBSERVED)	S (CALCULATED)
910 meters.	329,000	0.5 ohms	2.0	1.81
1325	226,000	0.9	1.1	1.24
1905	157,200	1.1	0.91	0.87
2360	127,000	1.4	0.71	0.70
3100	96,770	2.0	0.50	0.53

Observations were also made on a copper-coated Leyden jar of 0.00176 mf. capacity. (Table II). The coatings have a height of 25 cm. The diameter of the jar is 12.05 cm. and its thickness 0.292 cm. The conductivity of this par can be represented by

$$S = 5.5(10)^{-6}\, n.$$

TABLE III.

WAVE LENGTH	FREQUENCY	RESISTANCE	S (OBSERVED)	S (CALCULATED)
650 meters.	461,500	2.5 ohms	0.40	0.59
910	329,000	3.0	0.33	0.42
1325	226,000	3.6	0.28	0.29
1905	157,200	4.3	0.23	0.21
2360	127,000	4.8	0.21	0.16
3100	96,770	6.5	0.15	0.13

In Table III are given the resistances of an old Murdock condenser which has seen much service. Here the conductivities do not seem to follow the same relationship as exactly as in the case of the glass condensers of the same type measured a year ago, [1]. The resistance is much greater than was found in new condensers.

Additional observations were made on the dissipative dielectric resistance of glass plates in series and in parallel. As was to be expected, it was found that condensers in series show a total resistance equal to the sum of the individual resistances, while in parallel, the total resistance is equal to the single resistance divided by the number of plates, exactly as would be the case in metallic resistances. This differs from the case of the brushing resistance, which was found proportional to the number of plates, [1]. This shows that if condensers be arranged in series parallel, for the same capacity the dielectric resistance will remain the same as for a single condenser.

(1) Bulletin, Bureau of Standards, IX, Page 73, 1912.

While the resistance of the single condenser may be considerable at the longer wave lengths, in practice this is not disturbing, since the high power sets employed for long wave work would require so great a capacity that the resulting resistance would be practically negligible.

U. S. Naval Radiotelegraphic Laboratory.

Washington, March, 1913.

DISCUSSION.

(BY LETTER)

PROFESSOR A. E. KENNELLY: The excellent paper of Dr. Austin indicates, among other things, that a simple buzzer may serve as a valuable source of electric waves, of adjustable frequency, for testing purposes.

The results obtained for the losses in the condensers seem to indicate that it is simpler to conceive of these losses as due to an equivalent leakage conductance, in **MHOS** rather than to an equivalent series resistance in **OHMS**. Moreover, the Fleming constants, A and B, of this equivalent leakage conductance, can then be readily expressed, and tabulated or compared. The constant A would be a pure conductance in mhos, and theoretically might be found at zero frequency, or as a direct current leak. The constant B would be expressible as mhos-per-cycle-per-second. In the case of the first condenser examined in the paper, A would be negligible, and B would be 1.49 micromhos-per-cycle-per-second; whereas in the last case given, B would be 5.5 micromhos-per-cycle-per-second. For an air condenser, B would be nearly zero.

In this way, the leakiness of a condenser to high frequency currents would become saliently expressed. If two such condensers were in parallel, their B constants would add together; but if they were in series, the reciprocal of their sum of reciprocals would be taken. With "brushing" resistances present, the conditions would be more complex, as Dr. Austin indicates.

This paper might properly be referred to the Committee on Standardization of THE INSTITUTE OF RADIO ENGINEERS for suitable recognition and action.

LLOYD ESPENSCHEID: In interpreting the results of these measurements it is of advantage to bear in mind the physical significance of the quantities involved. The conductance expression.

$$S = A + B n$$

indicates that there are two components to the dielectric dissipation factor. One (represented by A) is due to the direct conductance through the dielectric material, and the other (represented by B) to the dielectric hysteresis, or molecular friction. In terms of resistance these components correspond respectively to the $R_{d.c.}$ and the $\Delta R_{a.c.}$ of an inductance coil.

The impedance of a condenser having energy losses may be represented by an equivalent impedance having the components R and C connected either in parallel or in series.

Starting with the parallel arrangement (shown in Figure 2) the admittance of the condenser is

$$2 \pi n C_1 = \omega C_1$$

and the conductance of the resistance is

$$S_1 = \frac{1}{R_1}$$

so that the impedance of the combination may be written in terms of conductance and admittance, thus—

$$Z = \frac{1}{S_1 + j \omega C_1} = \frac{S_1 - j \omega C_1}{S_1^2 + (\omega C_1)^2}$$

In the case of the series arrangement, (as shown in Figure 3) which applies to the form in which Dr. Austin's measurements are given, we have

$$Z = R_2 - j \frac{1}{\omega C_2} = \frac{S_1}{S_1^2 + (\omega C_1)^2} - j \frac{\omega C_1}{S_1^2 + (\omega C_1)^2}$$

which give us the expressions connecting the series and parallel circuits.

Considering the effective resistance components, namely

$$R_2 = \frac{S_1}{S_1^2 + (\omega C_1)^2}$$

since the numerator (S_1) varies only directly with the frequency, and the denominator varies as the frequency squared, R_2 goes down as the frequency goes up. This is in agreement with Dr. Austin's results.

We may express the series resistance R_2 in terms of the parallel resistance and capacity, instead of parallel conductance and capacity, thus:

$$R_2 = \frac{R_1}{1 + (R_1 \ \omega \ C_1)^2}$$

Since R_1 varies inversely with the frequency, the factor $(R_1 \ \omega \ C_1)^2$ remains constant and therefore R_2 varies inversely with the frequency.

Looking at it in another way, in the range of radio frequencies we should expect the impedance angle of the condenser to remain practically constant, and since the capacity reactance varies inversely with the frequency, the resistance should vary likewise.

At constant voltage the energy loss (I^2 R) increases with the frequency because the current squared increases more rapidly than the resistance decreases. At constant current, the loss (I^2 R) decreases with increase of frequency because the resistance decreases.

Messrs. **LESTER ISRAEL** and **ALFRED KUHN** contributed (independently) the following discussion:

The dielectric resistance of a condenser can be found from the effective dissipative resistance of that condenser as follows:

The current in the secondary of two very loosely coupled circuits is given by Bjerknes as

$$I^2_{\text{eff.}} = N \frac{E^2}{16 \, n^3 \, L_2^2} \cdot \frac{1}{d_1 \, d_2 \, (d_1 + d_2)}$$

where N is the number of times the condenser is charged per second,

E is the voltage applied to the secondary,

L_2 is the inductance of the secondary,

d_1, d_2 are the decrements of primary and secondary, respectively,

n is the frequency.

Since none of the other factors is changed, d_2 must be equal in the cases shown in Figures 2 and 3, assuming equality of current in the secondary in these cases. That is, when the air condenser and resistance in series are substituted for the Leyden jar (which is in effect a capacity in parallel with a resistance), the damping of the circuit is unchanged.

The differential equation holding for the circuit of Figure 3 is

$$L\frac{d^2 i}{dt^2} + R_2\frac{d i}{d t} + \frac{i}{C_2} = 0$$

the solution of which leads to the following values for the frequency n_2 and the decrement d_2 in this case:

$$n_2 = \sqrt{\frac{1}{L C_2} - \frac{R_2^2}{4 L^2}} \qquad \text{..................(1)}$$

$$d_2 = \frac{R_2}{2 L n_2} \qquad \text{............ .....(2)}$$

By considering that in the case shown in Figure 2 the sum of the currents in the branches R_1 and C_1 is equal to the current thru the outside inductance, the following differential equation for this circuit is obtained:

$$L\frac{d^2 i}{d t^2} + \frac{L}{R_1 C_1}\frac{d i}{d t} + \frac{i}{C_1} = 0$$

the solution of which leads to the following values of the frequency n_1 and d_1 for this case:

$$n_1 = \sqrt{\frac{1}{L C_1} - \frac{1}{4 R_1^2 C_1^2}} \qquad \text{................ (3)}$$

$$d_1 = \frac{1}{2 R_1 C_1 n_1} \qquad \text{..................(4)}$$

Equating the decrements and assuming, as experimentally arranged, that the frequencies n_1 and n_2 are equal, we have

$$\frac{R_2}{2 L n_2} = \frac{1}{2 R_1 C_1 n_1}$$

or

$$R_1 = \frac{L}{C_1}\cdot\frac{1}{R_2} \qquad \text{..................(5)}$$

Taking Dr. Austin's results as given in TABLE I and calculating R_1 from equation (5), we get the following table:

WAVE LENGTH λ	INDUCTANCE L_2	R_1 (OHMS	R_1/λ
385 m.	21,400 cm.	15,600	40.2
650	60,900	23,900	36.3
910	119,500	35,000	33.4
1325	252,000	43,000	32.2
1905	543,000	57,800	29.0
2360	802,000	75,800	31.9
3100	1,390,000	91,000	30.2

By plotting R_1 against λ, or by examination of the last column of the above table, it will be seen dielectric resistance of a condenser increases with the wave length, that is, the dielectric resistance is inversely proportional to the frequency.

(Editor's Note: Mr. Alfred Kuhn also showed that a relation between R_1 and R_2 identical with that given above is obtained by equating either the frequencies of the circuits from equations (1) and (3) and neglecting terms which are extremely small under the conditions of these tests, or by equating the energy consumption in the two cases shown in Figures 2 and 3.)

ALFRED N. GOLDSMITH: The following are some of the possible sources of error in an experiment of this kind and the methods of eliminating them:

1. Losses due to eddy currents in the plates and connectors of the standard condenser, C_2, which will result in an apparent value of R_1 smaller than the true value. The importance of these losses can be gauged by substituting for the standard condenser one whose plates are of a different and preferably much more resistant metal, but which is otherwise identical.

2. Large inductance in the leads and plates of the standard condenser cause the apparent value of R_1, to be larger than the true value. This effect may be minimized by properly arranging the connections and by employing a compact condenser, that is, one with (circular) plates at small separation.

3. The curve of current (i. e., the current wave form) may not be the same in the two cases because of the fact that the dielectric resistance is not a pure ohmic resistance but may vary during the current cycle. Detailed investigation of this effect using, for example, a Braun tube oscillograph is desirable.

And finally, an interesting method of verifying Dr. Austin's valuable results quantitatively would be by calorimetric measurements. The immersion of the condenser under test in an oil bath and the measurement of the temperature rise under known current and other physical conditions would enable the direct calculation of R_1.