August, 1920 20 Cents

The WIRELESS AGE

Volume 7 Number 11

W. Harold Warren and Guests Receiving Signals from Stations 200 Miles Distant in a Radio Roller Chair on the Asbury Park Boardwalk

THE NEW YORK RADIO CENTRAL STATION

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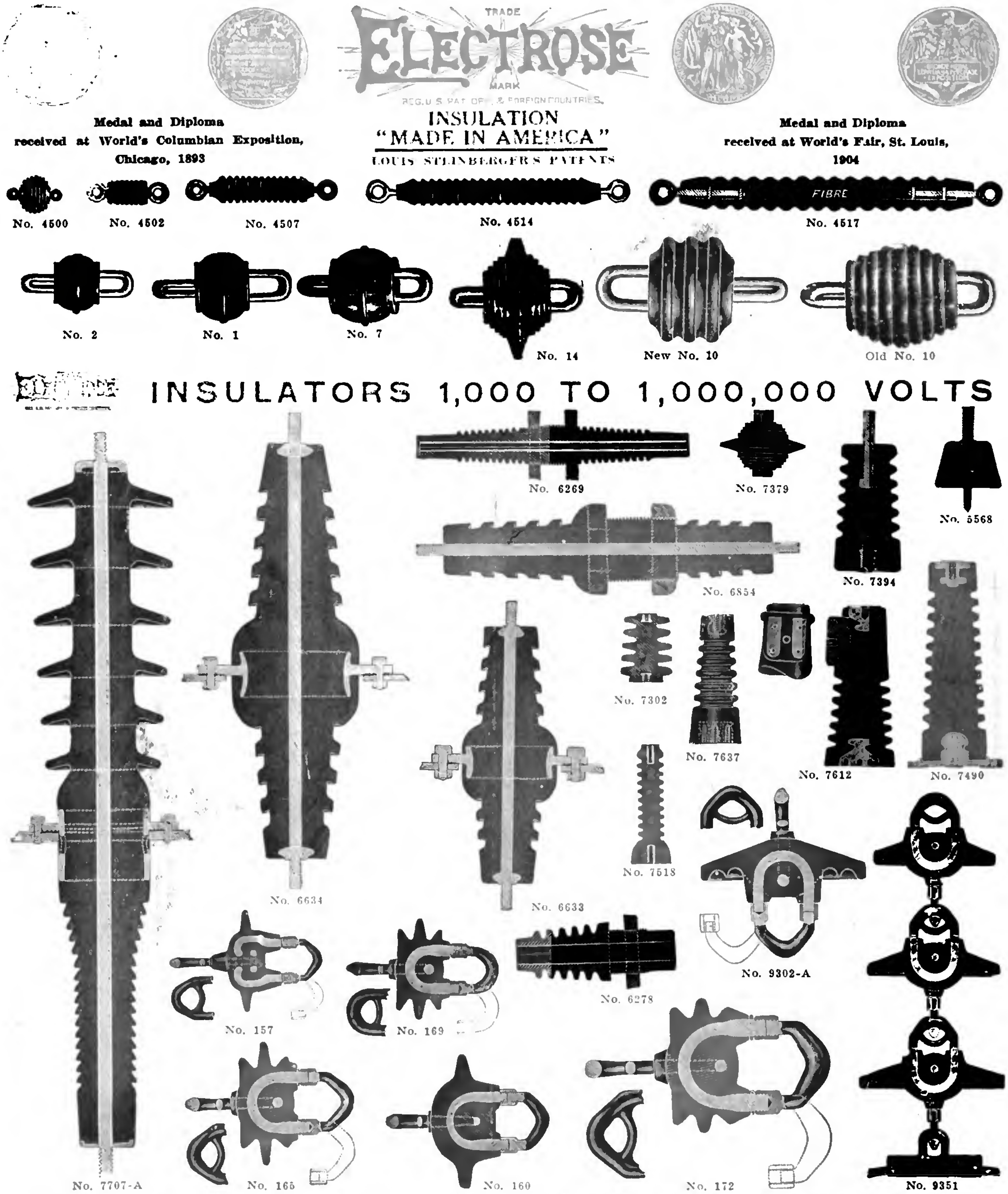

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Vol. 7 Contents of **The Wireless Age** for Aug. 1920 No. 11

Edited by J. ANDREW WHITE

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GREAT BRITAIN, 12-13 Henrietta St., London

AUSTRALIA, 97 Clarence St., Sydney, N. S. W.

Yearly Subscriptions in U. S., $2.00

Outside U. S., $2.48; Single Copies, 20 cents

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A
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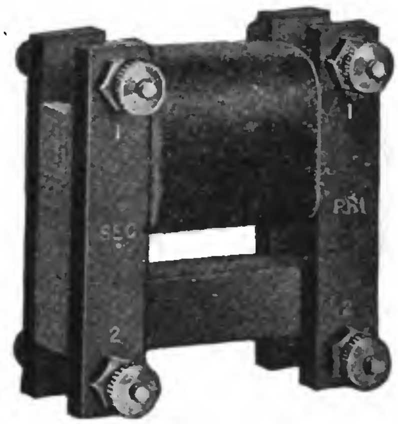

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Radio Engineers and Manufacturers

47A West Street **New York, U. S. A.**

If this page is cut out and appended to the same page cut from the editions to follow, a complete file of very interesting information will soon be available. (No. 8)

Vol. 7. No. 11. August, 1920

THE WIRELESS AGE

WORLD WIDE WIRELESS

Television, a New Radio Development

FROM England comes announcement of two developments in wireless transmission, both picturesque, one indeed bordering upon the realm of the fantastic and marvellous. H. Grinnell Matthews, an English experimenter, avers that he has made encouraging progress with a "television" device which will make it possible to witness, almost instantaneously, events that are actually happening far away.

He also announces that he has successfully photographed sound waves and reproduced them from the photographs with the aid of electricity. This would make possible a practical "talking movie."

However, the television announcement was skeptically received by some American wireless experts. Dr. Alfred N. Goldsmith, secretary of the Institute of Radio Engineers, doubts whether this wonder is to come to pass.

"If an entirely new principle of sound and light transmission has been discovered," said Dr. Goldsmith, "it is possible that the scheme will be successful; but from the data at hand I should judge that these discoveries are not much more than the annual rediscoveries which are so common in radio work.

"Every little while some amateur 'discovers' something strange and marvellous in radio work—only to find that he has 'discovered' a fact already familiar to research workers. Therefore, unless something revolutionary in science has been unearthed in England, there probably is nothing new in these devices."

Dr. Goldsmith added that the transmission of images over long distances was not only possible, but that fairly successful experiments had been made with the process. The basis of image transmission is selenium, an element not unlike sulphur. Selenium, in the dark, is an insulator; but when light is thrown on it, it permits an electric current to pass through.

Radio Does Double Duty in Sky Piloting

SERMONS are being sent through the sky in Kansas now. Dr. Clayton B. Wells, a minister at Wichita, Kan., has his sermons sent broadcast every evening by a member of his congregation who has an amateur station at his home.

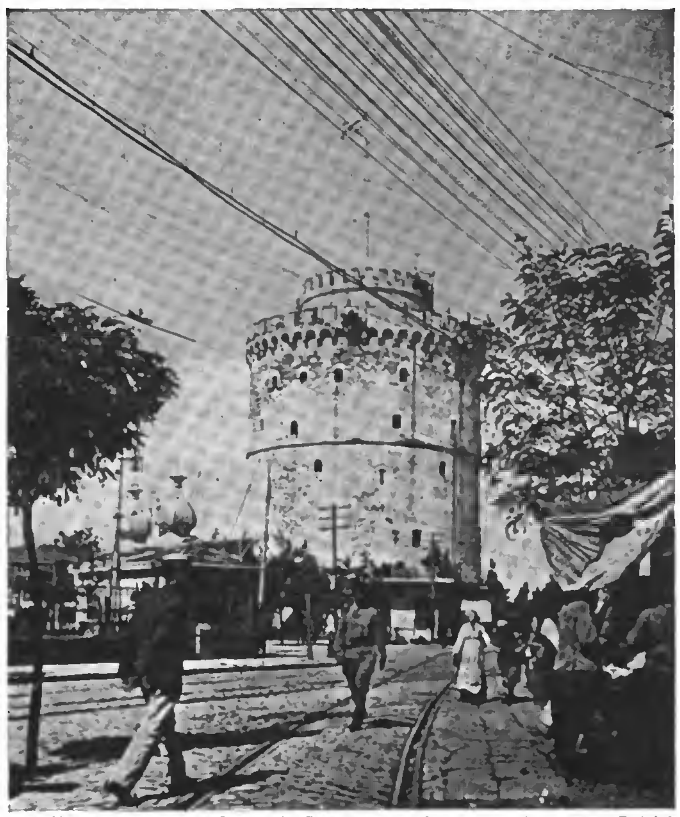
The idea occurred to C. A. Stanley, of Wichita, after sending out a "QST" one Sunday night as to how many station operators had attended church service that day. Of the 300 in his territory very few attended. He wirelessed them, inquiring if they would care to take the sermon every Sunday night.

From the cow country of the Texas Panhandle, the mountains of Colorado and the rural sections of Iowa came back a request to shoot out the sermons. Stanley proceeded to shoot and he has been sending out the sermons for several weeks. He attends the morning service and takes note of the sermon. The sermons are wire-

Argentina Plans Elaborate Commercial Radio Service

RADIO service in Argentina is soon to be augmented and devoted to commercial uses, it is announced. The installations at present in use are employed mostly for Government despatches.

Radio stations are to be set up at the Patagonian ports of Gayman, Rawson and Puerto Gallegos and one at Buenos Aires. It is intended later to supplement them with others at Corrientes, Bahia Blanca, Comodoro, Rivadavia and Ushuaia. Stations already existing will be increased in power.



"La Tour Blanche" of Saloniki, Greece, one of the most important British wireless stations during the war. (See description on page 8)

Night Landing of Mail Plane by Means of Radio

WIRELESS calls for aid sent out by a government mail airplane which faced a descent in the dark, enabled the plane to make a safe landing. Delayed an hour by a wind storm on the last lap of a journey from New York to Chicago, the radio operator on the plane sent out calls while approaching Chicago to light the landing field and prepare for the machine's descent.

The message was picked up by the wireless operator at Great Lakes Naval Training Station and on several amateur wireless outfits and relayed to the landing field by telephone. The plane, which carried three passengers

Radio Messages Sent From Old Tower That Once Served as Prison of Torture

ON the top of the "Tour Blanche"—the notorious "Bloody Tower" of Saloniki, Greece—the British erected a wireless station that enabled them to keep in touch with their ships in the Mediterranean and Aegean Seas. This was one of the most important of Allied "talking-points," which were spread over the earth's surface, and its messages, relayed to all posts of the Western World, played an important part in the final victory of the Allies.

This tower of stone has lived through a long and colorful history. Centuries ago it was built by the Turks, and it is said that it was used as a house of torture and execution for political prisoners. Under the Turkish régime in the Near East many Christians of European countries are supposed to have perished in this tower.

Saloniki, situated at the head of the gulf of the same name, is second only to Constantinople as a seaport. It has a spacious harbor—opened in 1901—where the imports for Macedonia, Albania and Serbia are received. Exports from this port consisted chiefly of grain, flour, chrome, manganese, hides and tobacco. In recent years these countries have been so depleted of men and prod-

Underwood
Members of the New York University reserve officers training corps operating a field wireless set

ucts that they have not been able to supply their own industrial wants, to say nothing of exportation.

Prior to the Turkish Revolution of 1908, Saloniki was the headquarters for the Young Turks. The city surrendered to the Greeks in the Balkan War, November, 1912, and is now a part of Greater Greece. Its present population, mainly Jews, is estimated at 174,000.

The strategic importance of Saloniki cannot be overestimated, and was one reason for the location of the British Wireless Station at this point. During normal times, it possesses railway connections with Constantinople, Vienna, and Paris, besides Nish, Uskub, and Monastir, in Serbia.

Given a strong wireless station to supplement its shipping and harbor facilities, it became a port of real naval value. From their keys in the old stone tower overlooking the waters of the Aegean, these British wireless operators could talk to their commanders and comrades all over the Near East. Strong radio stations were maintained by the British on the Island of Modros, at the entrance of the Dardanelles, on Lemnos, at Suda Bay in Crete, and on Malta. From these wireless posts, many instructions were issued to the British submarines, which had their base at Mitylene.

During the Allied occupation of the city, the old Turkish citadel became the headquarters for the press and censorship bureaus and the base headquarters for the American Red Cross. Many tons of food, clothes, and medicines were unloaded from the ships anchored at its docks, and transported by slow train, motor car, and pack-mule to the remote districts, whose people were hungry, sick and naked. The work of Red Cross doctors and nurses has improved the conditions of sanitation and health throughout the Balkans, and saved many lives.

French Scientist Predicts Synchronized "Voice-Movies" by Means of Radio

OUT of the void into every moving picture theatre, synchronized with all the movements shown on the film, will come in the near future the voices of the actors as they play their parts. Such is the dream of Professor Edouard Branly, expert on wireless telephony.

The success of the concert given by Mme. Melba at Chelmsford, England, to all the wireless telephone listeners in London, Paris, Berlin, Rome and Christiania, is his text. Soon, he declares, everyone will be able to stay at home and hear any concert he wishes, and for all the movies one orchestra will be sufficient.

He even goes further. Groups of motion picture theatres, he declares, will throw the same film on the screen at the same instant, while the actors will speak their parts into wireless telephone instruments thus securing the synchronization which is impossible with the talking machine, and in the days to come the movies will become the serious rivals of the theatre.

The only difficulty foreseen seems to be the breaking of the film while the voices go on without action.

Sweden Adopts Radiophone to Aid Fishing Industry

WIRELESS telephone receivers are being placed by the Swedish Government on fishing craft, so the fishers may be warned of bad weather and informed where good catches of herring may be expected. As no transmitters will be placed on the boats the fishers will not be able to communicate with other vessels nor with wireless stations on shore.

Marconi's Wireless Telegraph Company of London Declares Dividend

THE Radio Corporation of America, which recently succeeded the Marconi Wireless Telegraph Company, has received information from London that the Marconi Wireless Telegraph Company, Limited, the British company, had earned a profit of £1,220,000 in 1919, including £590,000 damages from the British Government. Directors of the British Company have declared a final dividend of 15 per cent. on ordinary and preference shares, together with a bonus of 5 shillings per share. New shares issued last December to former stockholders do not participate in the dividend and bonus. The statement showed that £955,000 was carried forward to surplus.

French Conducting Radio Research in the Pacific

VALUABLE experiments in wireless telegraphy are being conducted by the French war sloop Aldebaran, which has been cruising in the Pacific near the Chatham and Bounty Islands. Lieutenant Guierre, wireless expert, will probably submit the result of his experiments to the international wireless conference in Washington shortly. He states that the wireless "reception" in New Zealand from French instruments is of special interest to continental experts, as New Zealand is practically the antipode of France. It is claimed that the Aldebaran is carrying out for the first time a truly comprehensive system of measuring the strength of "receptions."

Submarine Wireless Perfected

THE last annual report of the Bureau of Standards states that members of the bureau's staff have developed very successful methods of communicating with submerged submarines by radio-telegraphy. With a single-turn coil or loop attached to the outside of the submarine, signals can be received as well when the vessel is submerged as when it is at the surface. It is also possible to transmit from a submerged submarine a distance of twelve miles. Thus it becomes possible for a ship and a submarine to exchange recognition signals.

A coil aerial is a satisfactory direction finder when submerged and readily receives signals transmitted thousands of miles, just the same as when used in the air. The navy has equipped its larger submarines with this apparatus.

Mother of Marconi Dies

MRS Marconi, mother of Guglielmo Marconi, the inventor, died June 15. She was an Irish woman and the widow of Giuseppe Marconi, of Bologna.

France Plans Extensive Wireless Service

THE success of the French Government's wireless service between the Continent and Algiers is assured. The Ministry of Telegraphs is preparing a scheme for the extension of the wireless service which will involve the erection of several stations and the inauguration of commercial as well as official wireless service between France and America, Germany, Italy and Constantinople. It is proposed also to erect stations in important French cities, thereby relieving the pressure of the land wires, and if the Government provides for it in the budget the French colonies and island possessions are to be linked up by wireless next year.

The first wireless extension to be attempted was communication with the United States, messages being sent from a station near Lyons and received by United States naval stations, where they are transferred to the telegraph lines. This service has been used for the last few months by several American newspapers.

Radio Banking Service on the High Seas

WIRELESS banking is a success aboard the ex-German liner Imperator. The Cunarder has established the first sea bank with a safe large enough to carry a huge amount of ready cash. Drafts on shore banks are honored and money transferred by radio.

Results of Marconi's Recent Radio Cruise

SIGNOR MARCONI, the wireless expert, has improved the wireless compass, according to the London Daily Mail, which will emit wireless warnings in a fog and by the aid of it he can tell which is on the port and which is on the starboard side of a vessel. The Mail's correspondent at Rome quotes him as follows with reference to his recent cruise in the Electra in search of new data to be used in the development of wireless:

"We steered the yacht the whole way," he said, "by the use of a wireless direction finder and kept away from the rocks off Cape Finisterre, northwest Spain, exclusively by its use. Most of the time we were able to locate our position by magnetic intersections on land stations.

"We made one fairly important discovery. I have evolved an improved wireless compass by which I can tell which is the port (left) and which is the starboard (right) side of a ship. It will emit wireless warnings instead of fogblasts." Senator Marconi went on:

"I kept in touch with England for a time by wireless telephone, our instrument having a radius of 450 miles. I also conducted business by the same means between Seville and Lisbon.

"We had great fun on the way out, having musical evenings with Chelmsford, Essex. They put on the latest tunes on the gramophone at Chelmsford and we heard them plainly. We applauded and they thanked us.

"The wireless telephone worked splendidly throughout and was clearer than a land telephone.

"My cruise is only half finished. The yacht is at Spezia and I intend to return to England in her in about a fortnight. The voyage should result in several improvements and new inventions being patented."

Senator Marconi naturally is inclined to be reticent on this subject, but he gave the impression that he will shortly announce the perfecting of the existing wireless direction-finding gear, enabling ships to steer clear of one another by this means alone in thick weather. Also that, although the day when ships may dispense with the use of lighthouses is not yet, vessels may soon be able by simple wireless means to avoid rocks as Senator Marconi did. Senator Marconi is also probing the origin of atmospheric or electric storms and how to combat them. He encountered one when he was off Algiers.

Underwood
Firemen operating a wireless telephone installed on rear of fire tender

Manitoba to Use Radiophone

EXPERIMENTS conducted at the request of the Manitoba government with wireless telephone apparatus between Winnipeg and Portage la Prairie, 80 miles away, have been successfully concluded and a second step in the experiments is about to be taken, when conversations will be attempted between Winnipeg and Ft. William, a distance of nearly 400 miles. The experiments are being taken with a view to testing out a proposed system of wireless to be installed in northern Manitoba.

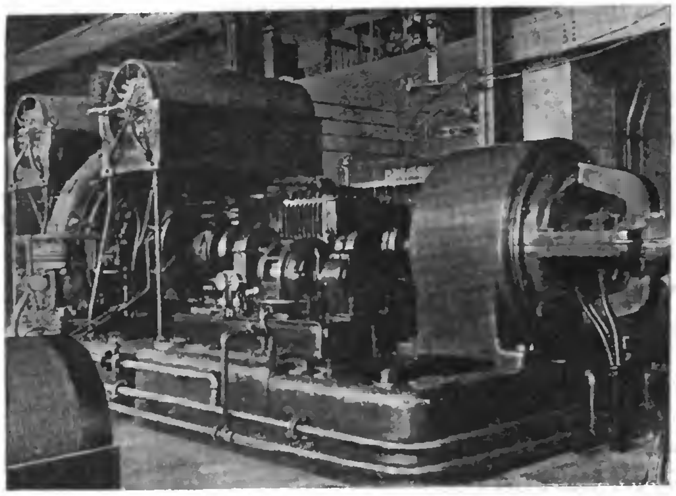
Mining districts and fur marketing centers are far scattered and sparsely settled. Land wires are costly to install and to maintain owing to falling trees in the bush country. It is proposed to establish some dozen stations at central points in as many districts of the northland. and these will in turn be given communication with the outside by a station of larger power at The Pas, which will work with another similar station at Swan River, 250 miles south of the former place, and in the well settled portion of the Province.

Should wireless telephony prove successful it is probable that the Manitoba government will assume control over this form of communication, just as it has the telephones, and that the wireless will be incorporated in the government telephone system. In this way the government may be able to give service to many isolated points, notably in mining sections east of Lake Winnipeg which cannot now be reached by land wires.

New York Radio Central Station

Details of a Super-powered Radio Station to be Erected Near New York for Communication with Five Nations

FOR more than two decades the wonders of wireless have so unceasingly intrigued the public imagination that it would appear little remained to be accomplished in developments of revolutionary character. Yet, once again, it is disclosed that a startling conception in wireless communication has been quietly brought to a point of realization. On the north shore of Long Island, near New York, the Radio Corporation of America is about to begin construction of a super-powered radio station that will simultaneously send to and receive messages from five great nations of other continents.



200-Kilowatt Alexanderson Alternator, which is part of the equipment of the Station

The bare announcement presages a new era in commercial radio communication. It is one conceived in the convention-defying spirit which, coupled with engineering skill, has brought about the expansion of wireless to its present status as a world-wide public utility. Instantly obvious is the fact that the plan will result in the contribution of an important means of breaking down America's isolation from the peoples of certain other continents and open up visions of communication possibilities which, through inherent limitations, could never be realized by the undersea cables.

The new and great medium of far-reaching economic and political influence will bear the name New York Radio Central Station, the steel towers of which will arise on a 6,400-acre tract, comprising nearly ten square miles of land lying east of Port Jefferson, with a long frontage on Long Island Sound. The preliminary engineering studies have been completed, contracts for all the construction materials are being let, and a force of radio experts, after months of preparation, will immediately take the big job in hand.

A definite idea of the ultra-modern character of this radio plant may be gained from the observations of Edward J. Nally, president of the Radio Corporation of America, under whose direction the world wide wireless system has emerged from an idea into a reality. "Everyone at all familiar with wireless," said Mr. Nally, "knows that at Nauen, Germany, and Bordeaux, France, are two of the largest stations in the world. Up to now they have been viewed with admiration; consider, then, the tremendous advance represented in this latest step; the New York Radio Central Station, in the aggregate, will be five times more powerful than either of these!"

He explained that there will be five complete transmitters, each one a duplex unit with a corresponding receiving station located nearby. All five transmitters and the five receivers will operate simultaneously and will transmit and receive messages over thousands of miles continuously during day and night.

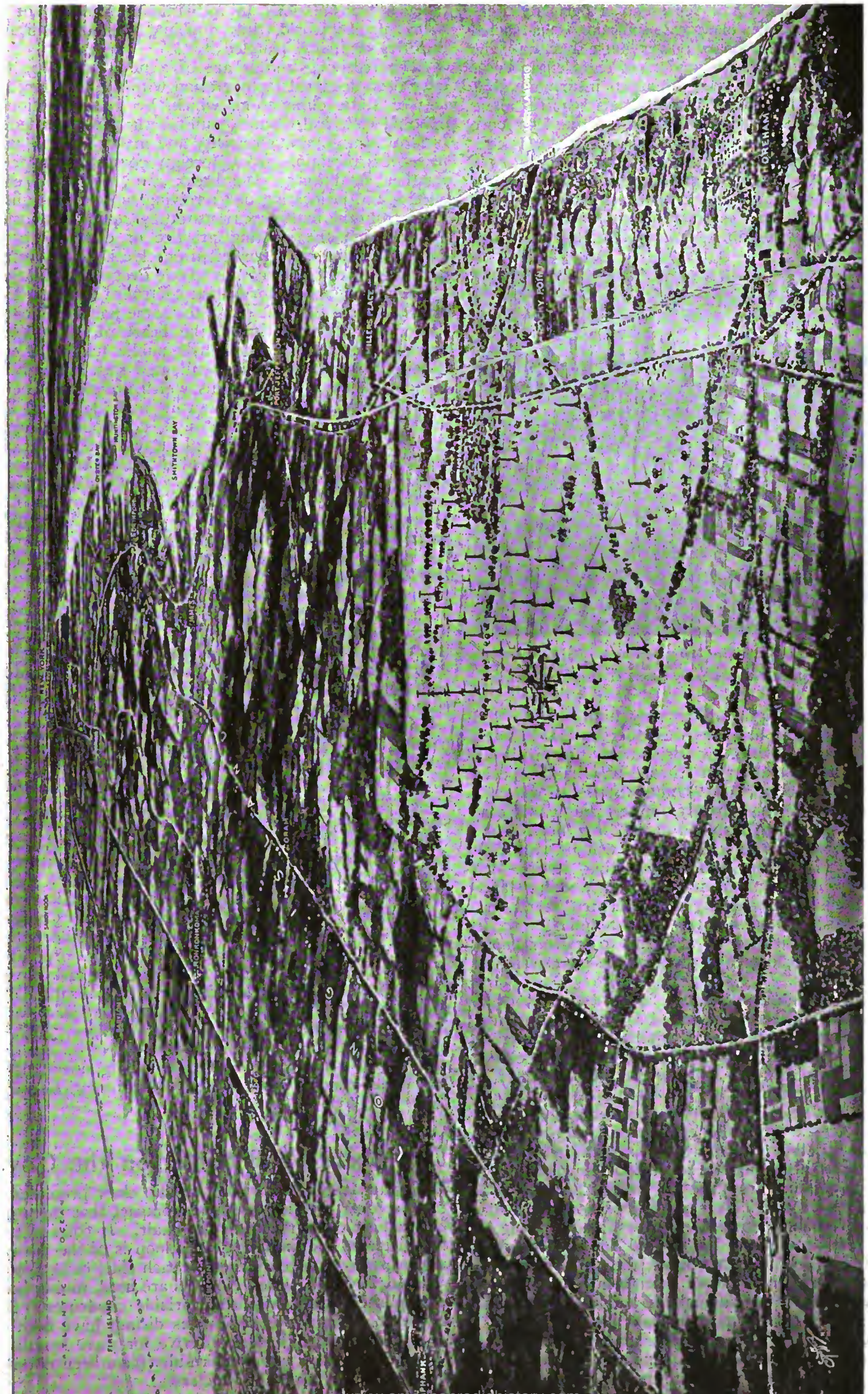
"New York will be the direct focal point of world's intelligence in an entirely new sense under this communication scheme," he continued. "As soon as the station is completed immediate message service will be established with France and Germany to supplement the existing commercial circuits; ultimately, radio from this station will connect up Buenos Aires and other points in South America, and ether-wave messages will be flashing to and from Poland, Sweden, Denmark and other European countries. Like the ripples that race in circles over a pond when a stone is dropped in the water, the electro-magnetic waves from this station will soon encompass practically the whole of the civilized globe. It is a plant that dwarfs all existing wireless stations into insignificance; a single unit will have power and range the equivalent of the largest wireless stations in the world today.

"The form of aerial construction, too, is wholly a new departure. From the central power house six spans of aerial wire will radiate out in a star pattern to a distance of more than one mile from the center. The wires of this huge antenna will be supported on self-supporting steel towers, each 400 feet in height, with the wires suspended at the top between 150-foot cross arms. Each of the six antennae will have twelve towers, forming so to speak, the spokes of a giant wheel fashioned out of seventy-two miniature replicas of the famous Eiffel Tower in France. Five of these antennae spokes will be used for regular service while the sixth is reserved for emergency operation.

"Far more impressive than physical appearance, however, will be the things the eye cannot encompass," Mr. Nally explained. "Appreciate," he said, "that in the wires forming each spoke of the gigantic wheel there will be generated a power equal to the greatest of present day trans-oceanic wireless stations; then comprehend, if you can, the fact that all five of these powers can if desired, be combined into one, for signaling. A telegraphic signal created out of such tremendous electromagnetic energy could encircle the entire globe!

"But that is not all. The apparatus and system which will be installed for each of the five units will be the same as that at present in our New Brunswick (N. J.) station from which the voice of Secretary of the Navy Daniels was carried to President Wilson when he was at sea aboard the U. S. S. 'George Washington.' In a number of experimental tests the voice has been carried by this radio telephone over distances of 2,500 miles with complete success. This leads us to state very definitely that before long a direct wireless telephone service will be established with foreign countries."

Every exacting requirement of commercial radio message service will be satisfied fully in the apparatus and system of circuits with which the great station will be equipped. The generation of the energy required to span thousands of miles will be effected by Alexanderson alternators, powerful machines constructed by the General Electric Company, which have made it possible to carry the radio signals through space by continuous wave trains, instead of by the interrupted or discontinuous waves, generated by systems using the old-time "spark discharge" apparatus. Taken by itself, the Alexanderson alternator is an achievement rivaling the design of the new world-wide station. This machine is the concrete expression of an ideal which electrical engineers have



View showing the location and tremendous size of the New York Radio Central Station—It will cover 6,400 acres of land east of Port Jefferson, Long Island, with a long frontage on Long Island Sound. This most powerful station will have five complete transmitters, each one a duplex unit with a corresponding **receiving station located nearby** held for many years, for it represents a perfected generator of high frequency electrical oscillations constructed along the lines of the ordinary power house dynamo. The problems solved by Mr. Alexanderson, chief engineer of the Radio Corporation, were thought insurmountable. Because the transmission of radio signals requires alternating currents of frequencies a thousand times or more in excess of those used in power engineering, it was considered beyond the range of practicability to obtain such currents from a dynamo. In the Alexanderson alternator equipment, the new station will have a source of energy proven as reliable as the power dynamo, yet creating a steady stream of electromagnetic oscillations, which will

The office in New York City, where Marconigrams for England, Norway, Hawaii and Japan are handled daily, will also handle the New York Radio Central Station's business by means of distant control

permit telegraphic signaling at very high speeds. So efficient and reliable has the Alexanderson 200-kilowatt alternator installed at New Brunswick proven itself, that leading radio experts of Europe have made special trips of investigation to the United States to view its performance; now this already famous single machine is to be duplicated and installed in the New York Radio Central Station; but this time there will be two 200-kilowatt machines for each transmitting station—ten in all. The achievement, from a radio engineering standpoint has nothing approaching a parallel: ten alternators, 2000 kilowatts, 3000 horsepower—an astounding force to concentrate in realization of a dream to transmit messages over the world to all points of the compass from a single source!

Mr. Nally emphasized another forward step in engineering which will be incorporated in the super-station. "We will utilize what is termed a multiple tuned antenna, which," he explained, "materially reduces the wasteful electrical resistance of the long, low, flat-top aerials formerly used. A great saving in power is thus effected; in fact for the same power input formerly used for a single station, six times the effectiveness at a distance is obtained. In other words, we obtain with this antenna the same effect at a distance with 200 kilowatts input, as would be obtained from the old type of antenna with 1200 kilowatts input. This new type of antenna is the equivalent of six independent radiators, all operating in unison at the same wave length and for the complete station with its five antennae units, the power required will be less than 20 per cent of that formerly necessary. The project, however, contemplates additional possibilities. To illustrate: We may, in many cases, utilize but one-half of a single spoke of the antenna system for communication service to a certain point. On this basis, the Long Island Station will ultimately permit simultaneous transmissions to a maximum number of ten points in the world, thus doubling the communication facilities originally planned.

"The receiving aerials are of a new type, too; they have been designed for operation with the Weagant system of static elimination, which, by a combination of opposed electrical circuits, nullifies the long-dreaded effects of atmospheric electricity and makes possible uninterrupted reception from foreign countries under all weather conditions. We break away from precedent once again, in locating our receiving units only eighteen miles from the multiplex transmitting equipment, instead of following the existing practice of establishing one transmitter and one receiver in one locality and restricting the service of the circuit to one oversea destination."

The arrangements for distant control of the New York Radio Central Station follow the same policy of concentration. In Broad Street, the heart of New York's financial district, the company's public telegraph office is being re-equipped to handle the new station's messages along with the Marconigrams which are now received for England, Norway, Hawaii and Japan. Thus messages for any of the five additional countries reached by the new station will be received in the New York City office and dispatched direct from a series of operators' keys and relays which will operate the powerful transmitting circuits located miles away out on Long Island. Messages from over the ocean will ultimately be received in the same manner, receipt and delivery of the actual messages being effected by the customary messenger boy service direct to the home or office of the user of the trans-oceanic wireless.

It is expected eventually to install apparatus for high speed transmission and reception, which will be under the supervision of a trained staff of operators, along with which there will be the usual staff of expert Morse operators, who will work those circuits over which high speed transmission is not taking place.

Countless details of great technical interest and engineering importance are embraced in the specifications for the station, prepared by combining the personnel of the Radio Corporation and the General Electric Company, an arrangement made possible by the recent merger effected by these interests and the absorption of the Marconi Wireless Telegraph Company of America. Even to the uninitiated in technical matters this gives assurance of perfection of detail in design; equally certain results will follow in the manufacture of the apparatus which has been delegated to the General Electric Company, while the construction of the station will be under direction of the engineering staff of the Radio Corporation. As Mr. Nally expressed it: "The great task is well begun and will progress steadily to a realization of a new conception of the conquest of the barriers Nature has erected between the brotherhood of races. With the speed, accuracy and lower cost of wireless, the new station will give to the world something novel, useful and epoch-making in the field of international communication."

The Board-Walk Chair on the Cover

THE apparatus comprising a radio chair presented on the cover of this issue is so compact that three persons can sit comfortably in the chair. It consists of a loop, detector and amplifier. The loop is of the flat type and measures eighteen inches on each side, being wound with No. 26 S.C.C. wire. No coils are used, tuning being accomplished solely with the variable condenser. Signals from stations over 200 miles distant have been received, and the set is most effective for wave lengths of 300 to 500 meters, but good results have been obtained at wave lengths up to 800 meters.

The Alexanderson System

Its Performance and Operation at the New Brunswick Station

By Elmer E. Bucher

Commercial Dept., Radio Corporation of America

(Continued from the July Issue)

THE antennae commonly used at high-power radio stations may be broadly classified into two types, viz., the long horizontal aerials which are suspended on comparatively low towers, and the vertical, fan or umbrella aerials which are generally supported at great heights. The flat-top antenna was adopted for long distance transmission because it was believed to have marked directional properties and would therefore provide maximum radiation in the direction desired and lesser degrees of signal intensity in all other directions.

Experiment has indicated, however, that this directional effect disappears at distances beyond 300 miles or so from the transmitter and thus the benefits of directional radiation are realized only in a limited area. Beyond this the flat-top antenna has been found to have comparatively high resistance. This may be said to be due to the long path through which part of the ground current has to pass to the far end of the antenna, which is a path of relatively high resistance. This resistance cannot be materially decreased by laying wires in the ground, for because of the inductive impedance of such long wires (at radio frequencies) a large percentage of the ground current will still pass through the earth. It is therefore evident that if the length of the ground path in a radiating system could be reduced, a considerable saving of power would be effected.

At any given wave length the radiation from an antenna has been found to be proportional to the square of the effective height and the square of the antennae current. The exact relation is $W = \frac{1{,}600.\ h^2 i^2.}{\lambda^2}$ This points to the desirability of a high antenna, but since the cost of building such a radiating system increases very rapidly with its height, the factor of economy requires that the money expended on a station be apportioned between the cost of the antenna, power apparatus, and maintenance in order to arrive at the lowest total cost for transmission over a given distance. It is obvious that if, by any means the wasteful resistance of the long, low, flat-top antenna, that is, conductive losses, leakage through insulation, etc., could be reduced, and if its radiation properties still could be maintained, then assuming equal power inputs into the two systems, a station using a long, low and relatively cheap antenna could produce the same signal strength as that from a high and costly antenna.

The multiple tuned antenna devised by Alexanderson brings about a marked decrease in the ground resistance of a flat-top aerial. His antenna can be compared to a station using a number of small antennae connected in parallel, the height of each of which is great compared with their horizontal dimensions. It follows from simple electrical principles that several antennae in parallel will possess a lower joint resistance than a long antenna of the same radiating capacity. The same result may be obtained from the Marconi flat antenna by bringing down leads from the flat-top, at regular intervals, to the ground through appropriate tuning inductances. With this construction it will be seen that the antenna charging current has a much shorter path through the down leads than it had with the former design.

The improved efficiency of the multiple tuned antenna has been amply demonstrated at the New Brunswick station where the resistance of the Marconi flat-top has been reduced from 3.7 ohms to 0.5 ohm with the consequent saving of power.

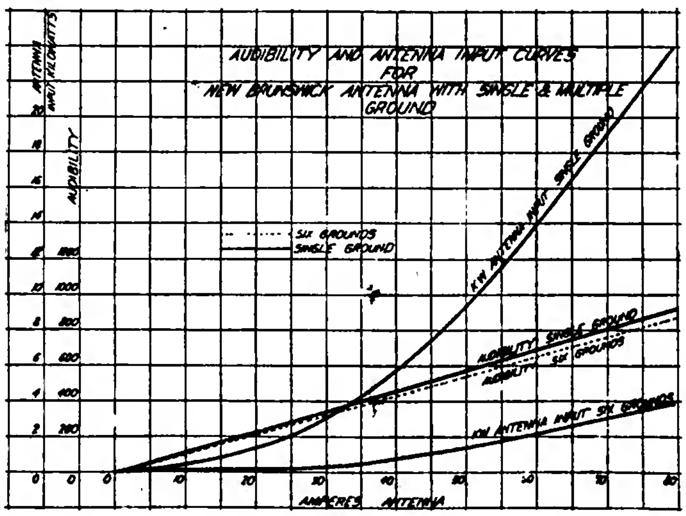


Figure 22—Curves showing comparative signal audibilities obtained from the Alexanderson multiple tuned antenna and the open-ended flat-top antenna

The curves of figure 22 show the results of a series of experiments conducted between New Brunswick, N. J., and Schenectady, N. Y., with the object of comparing the relative signal audibilities ampere for ampere in the old antenna with a single ground and the Alexanderson antenna with multiple grounds. The results show quite conclusively that with the same current in a flat-top antenna and in a multiple tuned antenna, substantially equal audibilities are obtained at the receiving station. However, the power required by the plain antenna for a given number of amperes is very much in excess of that fed to the multiple tuned antenna for the same total current. Thus as the curve shows, to put a total of 70 amperes in the branchces of the multiple tuned antenna with six grounds, requires but 3 kw., whereas with the flat-top antenna and a single ground, 18½ kw. are required. This is of course a very small proportion of the total output available at New Brunswick. The values shown in the curve should not be taken as indicative of those used in daily operation.

The points of distinction between the two types of antennae may become evident from the following comparative analysis. Thus the flat-top antenna with single ground is shown in figure 23. The equivalent circuit resolved into lumped or concentrated values of inductance and capacitance is shown in figure 24. The schematic circuit of the Alexanderson antenna is that of figure 25 where L_1, L_2, L_3, L_4, L_5, L_6 are current paths between the flat-top and the earth. The inductance of each down lead is made six times the capacitive reactance of the flat-top at the frequency of operation selected. The capacitive reactance of the flat-top is thus neutralized at six places. The circuit is therefore the equivalent of six independent radiators operating in parallel.

The equivalent circuit of figure 25 is that of figure 26, which is an artificial circuit comprising a number of parallel resonance circuits adjusted to the frequency of the alternator N. The branches L_1 C_1, L_2 C_2, L_3 C_3, etc., which are in shunt to one another are fed by the alternator. When each branch is tuned to the frequency of the alternator it will follow the well-known laws for parallel resonance. A large current will flow back and forth between the inductance and the condenser, and the alternator will simply supply power to compensate the resistance losses of the circuits. These large currents are directly due to the high voltages maintained across the inductance and the capacity, when the circuit is tuned for resonance. These voltages may be calculated when the value of inductance or capacitance and the current flowing therein are known.

If a parallel resonance circuit had no resistance, the conditions for parallel resonance would be strictly the same as for series resonance. These conditions are, however, very closely realized in the parallel circuit. In series resonance the e. m. f. on the condenser is equal and opposite to that of the coil and thus there is a large flow of current between the condenser and coil. There is also a large current flowing between the condenser and the coil in parallel resonance, but viewed from the standpoint of the feed or power supply circuit, the feed current is simply the difference of the currents in the condenser and the coil.

The resistance of a parallel-resonance circuit, in radio, is often treated as a negligible quantity. This resistance, however, assumes considerable importance in the multiple antenna as it determines the power taken from the alternator. Thus if the wasteful resistance of each branch in a multiple tuned antenna of six branches is 2.7 ohms, their joint resistance is $2.7/6 = 0.45$ ohm (assuming equality) and it is this resistance plus the radiation resistance of the entire antenna system through which the alternator works.

It is obvious that the alternator can be connected as in figures 27, 28 and 29 with the same effect as shown in figure 26. Thus in figure 27 the alternator terminals are connected in shunt to the parallel resonance circuits. In figure 28 the alternator output is fed to the antenna through the inductive transformer P S. In figure 29 an auto-transformer connection is employed.

In order to obtain resonance between the alternator and the several radiators of the multiple antennae of figures 25 to 29, the joint reactance or impedance of the down leads L_1, L_2, L_3, L_4, L_5, L_6, must be chosen to equal the capacitive reactance of the flat-top at some particular frequency. Hence with multiple tuning at six points the reactance of each down lead, for a given wave length (or frequency), must be six times the capacitive reactance of the whole antenna.

The method of computing the inductance in the down leads for a given wave length is as follows: We may take as a representative example the capacitance of the New Brunswick flat-top antenna, which is a long low aerial of the Marconi type. Its capacitance as measured is 0.066 mfd. Assume that operation is desired at 15,000 meters.

The oscillation frequency,

$$N = \frac{300{,}000{,}000}{15{,}000} = 20{,}000 \text{ cycles}$$

The capacitative reactance of 0.066 mfd. at 20,000 cycles

$$= \frac{1}{2\pi N C}$$

$$= \frac{1}{6.2832 \times 20{,}000 \times 0.000{,}000{,}066}$$

$$= 120.5 \text{ ohms.}$$

The inductance required to neutralize the capacitive reactance is found from the relation

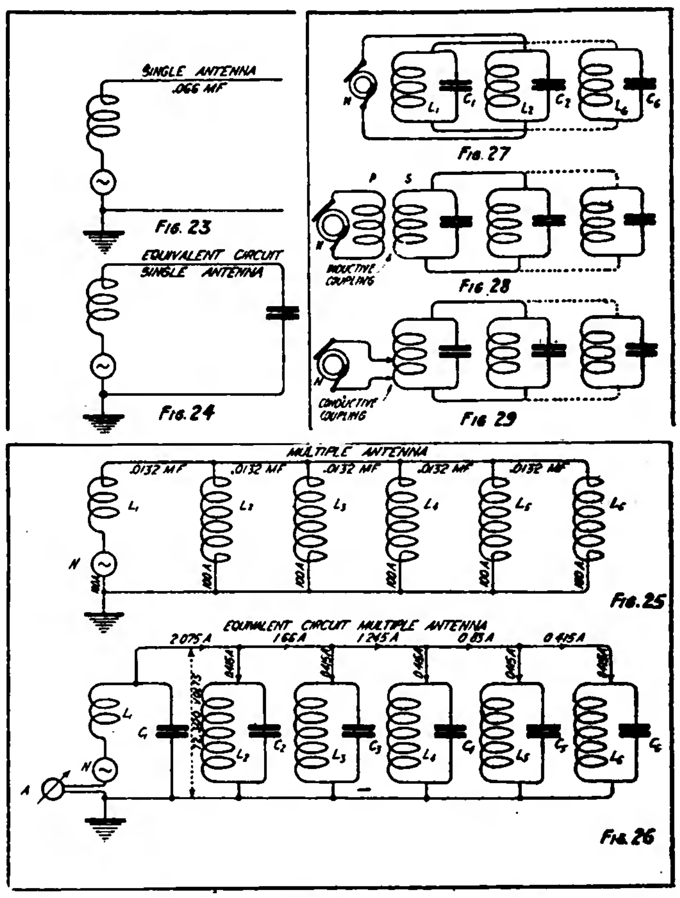
$$L = \frac{X}{2\pi N}$$

$$= \frac{120.5}{6.2832 \times 20{,}000}$$

$$= 0.000{,}958 = 0.958 \text{ millihenry}$$

The total inductance of each down lead should then be 6 x 0.958 = 5.74 millihenry; and the reactance of each down lead, 6 x 120.5 = 723 ohms.

Curves may be prepared to give the values of inductance required to tune the multiple antenna with various number of grounds at different wave lengths. If then the line coils be calibrated for different numbers of turns at different frequencies, it is a relatively simple



Figures 23 to 29—Fundamental and equivalent circuits of flat-top antenna and Alexanderson multiple tuned antenna

matter to set these inductances to the correct value for any wave length. A series of curves showing the inductance required to operate the New Brunswick antenna at various wave lengths are given in figure 30. These are cited merely as illustrative examples.

The term "feed ratio," for convenience, has been applied to express the ratio of the total current in the six radiators of the multiple antenna to that flowing in the down lead of the branch to which the alternator is coupled. Assume that equal inductances are inserted in each down lead. With all other conditions equal, the same current will flow in each of the six circuits when supplied with energy at the frequency which produces resonance.

Thus if the ammeter A, when connected in series with the station down lead, figure 26, indicates 100 amperes (at resonance), and the same current is obtained in each branch, the total antenna current is 6 x 100 = 600 amperes.

The feed ratio is then equal to

$$\frac{\text{Total Current}}{\text{Current in the station down lead}}$$

which in this case $= \frac{600}{100} = 6:1$

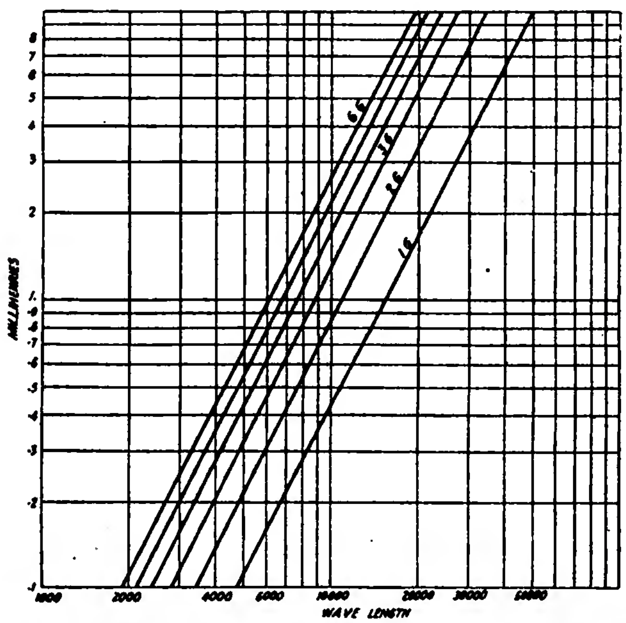


Figure 30—Graphs showing inductance required to tune the multiple tuned antenna at New Brunswick to different wave lengths

It is of interest to note that this feed ratio is only maintained when the inductance in all the down leads is equal. Assume, for example, that the inductive reactance in the branch through which the energy is supplied is decreased and the frequency of the alternator is raised for resonance. Assume also that the feed ratio previous to this change is 6:1, the wave length 15,000 meters, the frequency 20,000 cycles, and the inductive reactance at each down lead 723 ohms. If now the wave length is reduced to 14,500 meters, the frequency increases to 20,700 cycles. This represents an increase of 700 cycles, which is 3½% of the original frequency of 20,000. It may be shown that 1% change in frequency requires a 2% change of inductance for resonance. Hence the inductive reactance in the circuit for 20,700 cycles is 100%—7% or 93% of the value at 20,000 cycles; that is, 93% x 723 = 672 ohms.

Now if the five line coils to earth are left unchanged and since each has an impedance of 723 ohms at 20,000 cycles, or multiple impedance of 723/5 = 144.6 ohms, the impedance at 20,700 cycles obviously is 20,700/20,000 x 144.6 = 149.6 ohms. The new feed ratio is evidently proportional to the two impedances or 672/149.6=4.49:1.

The value of this determination lies in the fact that upon changing the wave length by tuning at the station down lead only, the new feed ratio can be computed, thus enabling the operator to ascertain the correct feed current necessary to maintain a given total value of antenna current.

After viewing the physical aspects of the antenna layout in figure 24 it might appear that a disturbing phase angle would exist between the currents in the radiating circuit embracing the alternator, and those in the radiators placed at increasing distances from the power source. It can be shown, however, that for all practical purposes the currents in all the down leads are substantially in phase. Thus in figure 31, the branch L_6 C_6, since it is a tuned circuit, operates at unity power factor and therefore may be treated as a non-inductive resistance of a value equal to

$$\frac{L}{CR}\left(\text{or } \frac{1}{R\ (2\pi N^2)\ C^2}\right)$$

If (at λ = 15,000 m.) C_6 = 0.011 mfd., L_6 = 0.00574 henry and R_6 = 2.71 ohms, then the impedance of any single branch to the e. m. f. impressed thereon is equal to

$$\frac{0.00574}{0.000{,}000{,}011 \times 2.71} \doteq 192{,}500 \text{ ohms approximately.}$$

Since the circuit L_6 C_6 R_6 is in resonance with the e. m. f. impressed at T_1 T_2, the current in it is also in phase with the impressed e. m. f., which may be considered to operate through a non-inductive resistance of approximately 192,500 ohms.

Let the inductance of the flat-top between the fifth and sixth branches be represented by L. The value of L is one-fifth of the total flat-top inductance without loading and in the case of the New Brunswick antenna is approximately 0.00013 henry. We then have in the last branch (L_6 C_6) a current which lags behind the current flowing in L_5 C_5 by the angle θ where

$$\tan\ \theta = \frac{2\ \pi\ N\ L}{R}$$

$$= \frac{6.2632 \times 20.000 \times 0.00013}{192.500}$$

$$= \frac{1}{11{,}780} \text{ (which is negligibly small)}$$

The phase difference between the sixth and fifth radiator is thus negligible. The phase difference between the currents in branch L_1 C_1 and branch L_6 C_6 is five times as great, but it is still of negligible importance. The currents in the six radiators are therefore in substantial phase, the effect of the inductance between branches is negligible, and the charging currents which are measured currents in the down leads can be considered to be in phase. Since the length of the antenna is but a fraction of the wave length employed and the phase difference is slight compared with the wave length, no appreciable directive effects will be obtained.

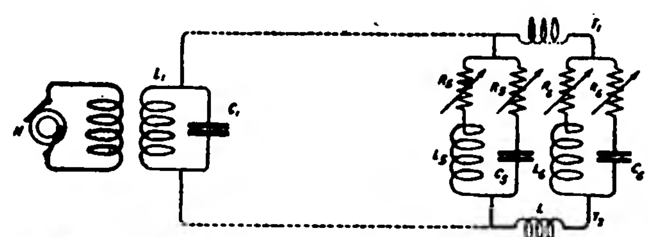


Figure 31—Equivalent circuit of multiple tuned antenna for computation of phase difference

The antenna voltage may be computed when the equivalent capacitance of one section and the current in the station down lead, or the total antenna capacitance and total antenna current are known. This is obtained from the relation, $E = \frac{1}{2\ \pi\ N\ C}$ or $E = \frac{1}{X}$ where X is the capacitive reactance of the antenna at some frequency.

Using these values, assume that I as measured by an ammeter in the station down lead is 100 amperes. Then since the capacity reactance to be neutralized by the down lead is one-sixth of the whole capacity or 0.011 mfd., then

$$E = \frac{100}{6.2832 \times 20{,}000 \times 0.000{,}000{,}011}$$

$$= 72{,}300 \text{ volts}$$

A current of 100 amperes performs the same functions in each of the remaining branches, so that the whole antenna is maintained at a voltage of 72,300 volts by six separate currents, all in phase, of 100 amperes each. Since the multiple impedance of the six branches has been shown to be 120.5 ohms, the total antenna current is 72,300/120.5 = 600 amperes. This is merely a further proof of the assumption made at the outset.

As previously cited, the branches of the multiple antenna follow (except in one respect explained later)

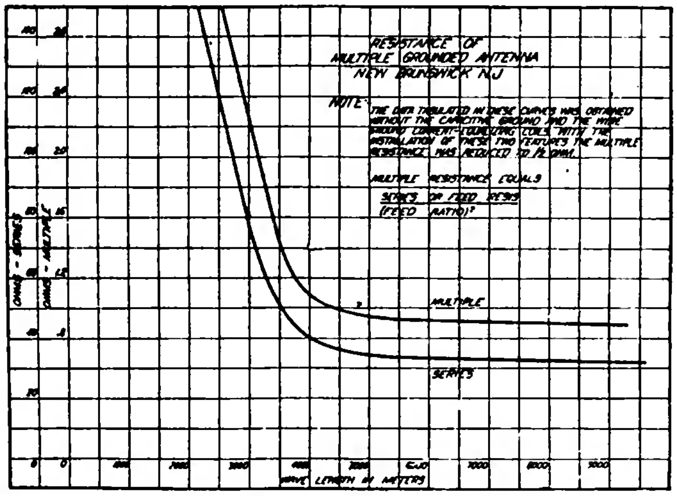


Figure 32—Comparison of multiple and "series" resistance of Alexanderson multiple tuned antenna

the laws of parallel resonance circuits with lumped inductance and capacitance, and the current supplied to any branch by the main or power supply circuit is at any instant the algebraic sum of the currents in the capacity and the inductance. If there were no resistance in the branch antenna it would have infinite impedance to the power supply at resonance, and no current would flow in the feed circuit after the initial e. m. f. has been applied. In the actual circuit there must, however, be some resistance and the energy for heating this resistance must be supplied by the alternator, that is, the alternator makes good this loss of energy.

The branch circuit of figure 30 at N = 20,000 cycles, C = 0.011 mfd., L = 0.00574 henry and R= 2.71 ohms, was shown to have an impedance of approximately 192,500 ohms. The antenna charging voltage at 100 amperes is approximately 72,300 volts. The energy current supplied by the power source to one branch is therefore 72,300/192,500 = 0.375 ampere. The power supplied to each branch is 72,300 × 0.375 = 27.1 kilowatts and to the six branches (assuming equality throughout) 6 × 27.1 = 162.6 kilowatts.

The foregoing method of computation while correct for parallel resonance circuits with lumped inductance and capacitance from which no radiation takes place, requires some modification when the phenomena of radiation from the multiple antenna is considered. Thus, in the multiple antenna, the radiation resistance, whatever its value, may be said to be common to all six antennae, whereas the ground and coil resistances belong to the different antennae individually. The combined circuit of the multiple antenna can therefore be represented by a radiation resistance common to all antennae which is in series with a group of six wasteful resistances connected in multiple.

Thus assume now that the radiation resistance of the individual radiators in the multiple antenna (at λ = 15,000 meters) is 0.06 ohm and the ground and coil resistance of each antenna individually, 2.63 ohms. A current of 600 amperes works through 0.06 ohm radiation resistance, while 100 amperes flow through each of the 2.65 ohm resistances. The consumption of power in radiation is $600^2 \times 0.06 = 21.6$ kw., and in each branch $100^2 \times 2.65 = 26.5$ kw., or $6 \times 26.5 = 159$ kw., in the six branches. The total consumption is therefore 180.6 kw.

The point to be brought out is, that if the radiation resistance of 0.06 ohm was added to the wasteful resistance in each radiator, and the energy consumption computed therefrom, the result would be too small. Thus assuming that the total resistance of each antenna was taken as 2.65 + 0.06 or 2.71 ohms, the power in each radiator would be 27.1 kw. and in the six branches, 162 kw., but, as just shown, the correct value, when the radiation resistance is treated properly, is 180.6 kw.

The multiple antenna may be treated in another way. With a total power consumption of 180 kw., the power supplied to each antenna is 30 kw. and the energy current consumed by each oscillating circuit at 72,300 volts is 0.415 ampere. Thus while the total oscillating current is 600 amperes the energy current which flows horizontally from the power source is 2.075 amperes. This distribution is shown by the arrows in figure 26. In other words the energy fed to the system by the first tuning coil in the form of 100 amperes at say 1800 volts is transformed in the first oscillating circuit to 72,300 volts (in the case of the particular problem cited) and distributed as in a transmission line from which 0.415 ampere at 72,300 volts is drawn at five places.

When the inductance in each of the down leads has been adjusted to provide resonance with the alternator and the feed ratio has been determined, the multiple resistance of the Alexanderson antenna can be computed from simple measurements taken within the station house.

The process is as follows: Measure the current in the station down lead at resonance and then measure the

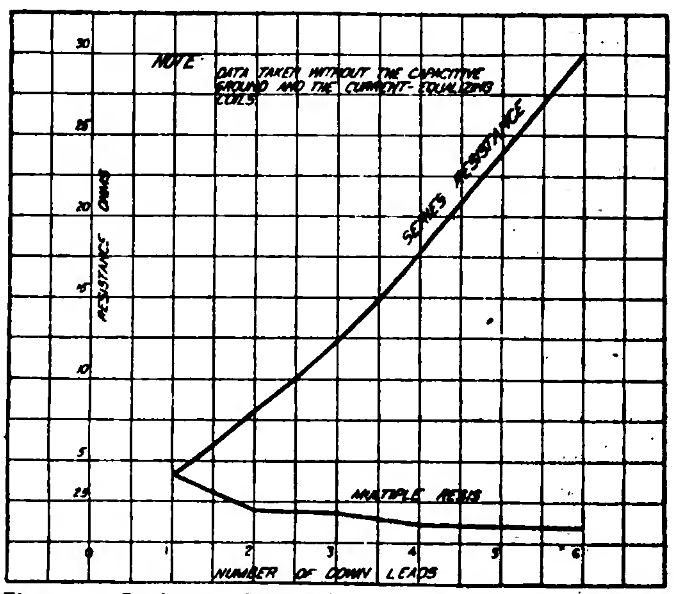


Figure 33—Graphs showing "series" and multiple resistance, New Brunswick antenna with different numbers of down leads

open circuit voltage of the alternator (at the transformer secondary). The voltage divided by the current gives the "series" resistance of the antenna from the standpoint of a load on the alternator. This resistance is evidently the combined resistance of the alternator and the "series" resistance of the antenna system. The resistance of the alternator must be obtained from a separate measurement and subtracted from this value to give the "series" or load resistance of the antenna system.

Thus if the open circuit voltage of the alternator transformer is 2000 and the current in the down lead is 100 amperes, the resistance of the alternator plus the "series" antenna resistance is obtained from R = E/1 or R = 2000/100 = 20 ohms.

Assume that the alternator resistance (from the standpoint of the transformer secondary) as obtained from previous measurements is 2 ohms; then the series antenna resistance (considered as a load on the alternator) is $20 - 2 = 18$ ohms. The multiple resistance of the antenna is then equal to

$$\frac{\text{Series Resistance}}{\text{Square of the Feed Ratio}}$$

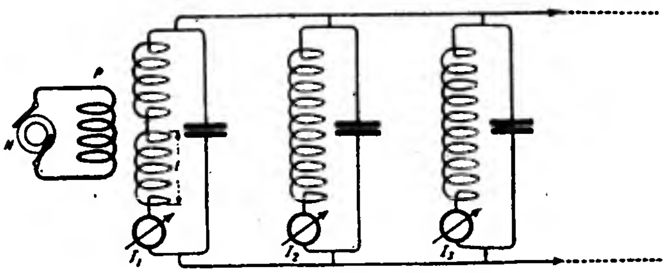


Figure 34—Fundamental circuit of multiple tuned antenna for determining the distinction between "series" and multiple antenna resistance

which in the problem above $= \frac{18}{6^2} = 0.5$ ohm. Proof of this formula is given below.

A set of curves showing the comparative values of these two resistances at the New Brunswick station for wave lengths between 2500 and 9000 meters are shown in figure 32. Thus at $\lambda = 8600$ meters, the series resistance is 32.5 ohms and the multiple resistance 0.9 ohm. It is the latter value that must be used to compare the multiple tuned antenna with the common antenna with single ground. Curves showing the decrease of multiple resistance at New Brunswick with increase of the number of tuning points are given in figure 33. It is to be noted that the data for these curves and also that of figure 32 was taken without the capacitive ground and the current equalizers already described.

In making measurements as above, the transformer must be regarded in all respects as a part of the alternator, that is, the open circuit voltage of the transformer secondary, and the resistance of the alternator from the standpoint of the transformer secondary must be treated as the voltage and the resistance respectively of the alternator.

A proof of the formula Multiple Resistance

$$= \frac{\text{Antenna Series Resistance}}{(\text{Feed Ratio})^2}$$

may be had from the following simple analysis. Reference should be made to the equivalent circuit figure 34, which is assumed to be made up of a number of radiating systems in parallel, all tuned to resonance with the alternator N.

Let E = open circuit voltage of transformer secondary.

Let I = current in the station down lead at resonance.

Let Ra = the effective alternator resistance from the standpoint of the secondary.

Let r = the "series" resistance of the external or antenna circuit considered as a load on the alternator.

Then $E = I\,(Ra + r)$

from which $r = \frac{E}{I} - Ra$

(Ra is obtained from a separate measurement.)

The power consumed in the "series" or load circuit external to the alternator is then,

$$W = I^2 r.$$

Consider now the resistance of the complete antenna from the standpoint of several radiators in parallel:—

Let F = feed ratio.

Then FI = total antenna current in the several radiators.

Also let Ra = multiple resistance of the several radiators in parallel.

Then, the total energy in the several radiators is equal to the product of the multiple antenna resistance and the square of the total antenna current, or,

$$W = (F\,I)^2\,Rm.$$

This energy obviously is the same as that consumed in the circuit external to the alternator, which as shown before, $= I^2 r$.

$$\text{Hence } (FI)^2\,Rm = I^2 r$$

$$\text{from which } Rm = \frac{r}{F^2}$$

That is, the antenna multiple resistance is equal to the "series" or "alternator load" resistance divided by the square of the feed ratio. Expressed in terms of all the factors involved.

$$Ra = \frac{\frac{E}{I} - Ra}{F^2}$$

It is thus possible to compute the multiple resistance of the Alexanderson antenna from a few measurements made within the station with instruments used in ordinary power work.

Accurate measurement of the current in each down lead is essential, prior to making the above measurements, as equal divisions of current, due to physical factors surrounding the station, cannot always be obtained. Only in this way can the true feed ratio be determined.

The multiple antenna can, under some conditions, be used to advantage with unequal currents through the down leads although, in general, equality of currents gives the lowest resistance. This is apparent from the fact that with unequal division some of the current has a longer path to travel than with equal division, making that particular branch of higher resistance. This also is obvious from the fact that if a given amount of current is to be passed through parallel conductors their joint resistance will be less if the division of current is in inverse proportion to each path.

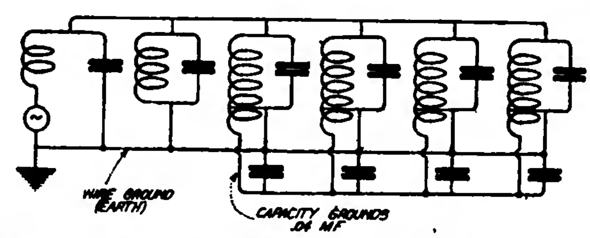


Figure 35—Equivalent circuit multiple tuned antenna, New Brunswick Transoceanic Radio Station

Unequal division of current is an advantage under two conditions. First the "series" or "load" resistance of the antenna can be adapted to the voltage of the alternator, if the alternator voltage cannot be adapted to the antenna resistance. Second, by allowing unequal division of current the wave length of the system can be changed in a much simpler manner than when equal division is maintained. Each change of wave length clearly requires a change in the inductance of all the down leads to maintain equal current division. If the inductance in all down leads is not the same, the current will divide itself in inverse proportion to the inductance of each path.

Further consideration will reveal that for wide changes of wave length it may be advisable to disconnect some of the down leads.

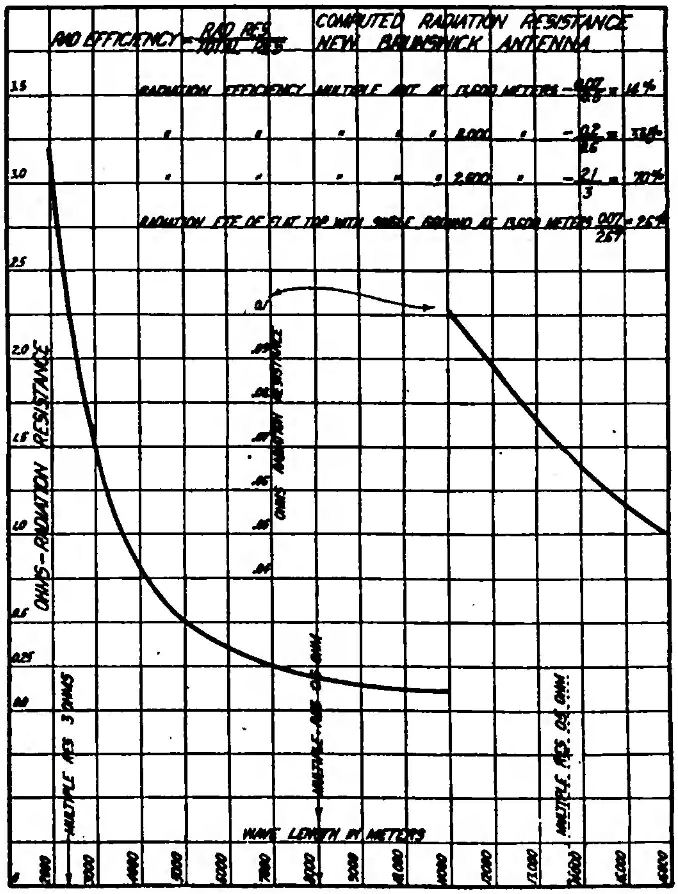


Figure 36—Computed radiation resistance multiple tuned antenna, New Brunswick Transoceanic Radio Station

In order to compute the amount of inductance that is necessary in each down lead at some given wave length, the capacity of the antenna must be measured by the ordinary processes and its capacitive impedance, calculated. This of course, must be computed for each wave length. The capacitive impedance for any other wave length can be obtained from this value, since impedance is directly proportional to wave length. The inductive impedance of each down lead should then be adjusted, previous to tuning of the alternator, to a value six times the capacitive impedance of the antenna, if six tuning points are used. The inductance of the down leads to the tuning coils can be estimated roughly and the value allowed for when placing the tap on the ground coil.

The inductance of the tuning coils should be computed for different numbers of turns at different wave lengths and plotted in a series of graphs as in figure 30. This will simplify the operation of obtaining the correct inductance for any wave length. In case there are no means at hand of calibrating the tuning coils, the required number of turns may be selected by trial. The supposed number of turns required can be estimated roughly and connected in all six down leads, but an allowance must be made in the case of the station down lead for the inductance of the alternator (or for the inductance of the secondary coil of the transformer). The speed of the alternator may then be varied until resonance is found. If the number of turns selected tune at too long a wave length too much inductance has been inserted in the down leads, and if it tunes at too short a wave length not enough inductance has been added.

A general description of the earthing system at the New Brunswick station has been given. In the early experiments it was found that when connection was made from the tap on the down lead inductance to the wire ground, the inner wires carried the greater proportion of current, due to the fact that they offered less impedance than the outer wires. A more equal current distribution was obtained by inserting the equalizing coils between the line inductances and the earth wires as shown in detail figure 15. These coils are in inductive relation and are connected to pairs of the buried wires as there shown. The effect was to increase the impedance of the wires nearest the center and therefore to force practically the same amount of current in the outside wires as in the center wires. This lowered the antenna resistance from 0.9 to 0.7 ohm.

A still better distribution of the earth currents was obtained by installing the counterpoise already shown in figure 16. As is shown schematically in detail A, figure 16a, the section of the coil above the ground connection may, for purposes of illustration, be considered as positive with respect to the ground and the section below the point at which the ground is connected may be considered as negative with respect to the ground. The capacitive ground may therefore be considered as a combination of a forced and a tuned oscillation circuit. It

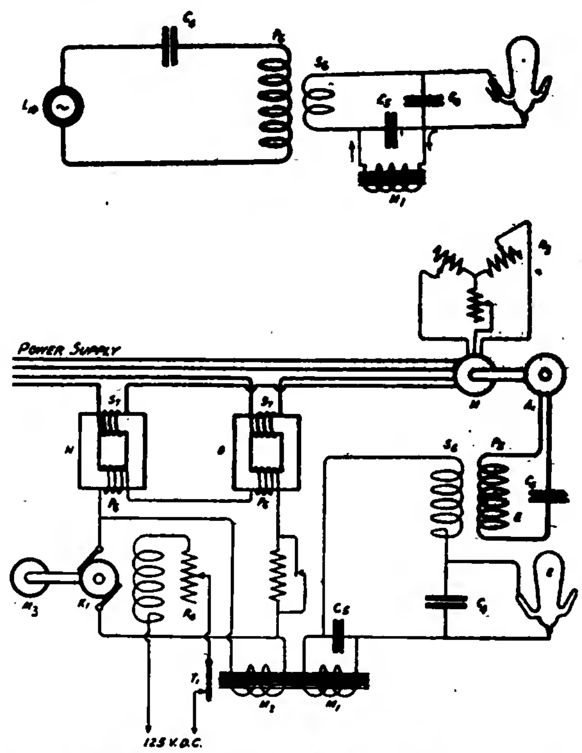


Figure 37—Fundamental circuits of speed regulator of the Alexanderson radio frequency alternator system

has the effect of drawing the current from the ground more uniformly, than with the wires lying on the ground or buried beneath the surface. The addition of the counterpoise in the case of the New Brunswick station reduced the antenna resistance from 0.7 to 0.5 ohm.

By suitable tuning, the total current through the down leads may be distributed between the capacitive ground and the wire ground in any desired ratio. If the wire ground is disconnected and the capacitive ground is tuned to take all the antenna current, the capacitive ground then takes on the characteristics of a tuned circuit. In this case the wire ground may be connected to the zero potential point on the coil (which may be found by experiment), under which condition it forms a path to earth for the lightning discharges with no other appreciable effect upon the system. An efficient ratio of current in the wire and capacitive ground is half of total in each. The capacitive ground may be installed in separate units at each tuning point, or may be connected together as a single unit as shown in figure 16.

Taking into consideration the counterpoise and buried wire ground, the equivalent circuit becomes that of figure 35.

It may be well to point out here that the design and construction of the grounding system for the multiple antenna may undergo considerable modifications in future high-power installations. It is probable that the system can be considerably simplified and yet provide a lower

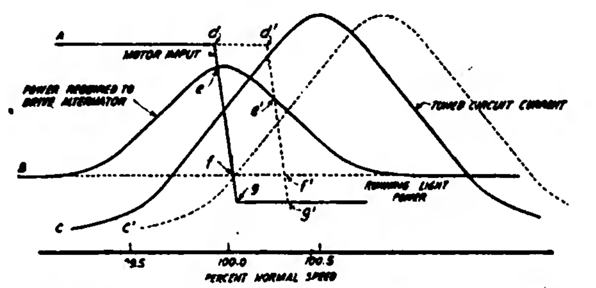


Figure 38—Graphs of Alexanderson speed control system

antenna resistance than that obtained at the New Brunswick station.

An antenna with a single ground and effective height equal to that of the New Brunswick aerial, can be assigned at the wave length of 15,000 meters a radiation resistance of 0.06 ohm and a total resistance of 2.71 ohms. This is, in fact, about the values that would be obtained in practice. The radiation efficiency is therefore 0.06/2.71 or 2.21%.

As a multiple tuned antenna the resistance of the New Brunswick aerial is slightly under 0.5 ohm, and the radiation efficiency is 0.06/0.5 or 12%. The radiation efficiency of the multiple antenna at this wave length is therefore 12% against 2.21% in the individual antennae.

The radiation efficiency of the multiple antenna is very much higher at the wave length of 8,000 meters which has been found the most suitable for radio telephony. Thus the radiation resistance of the New Brunswick antenna at 8,000 meters is 0.2 ohm and the multiple resistance 0.6 ohm. The radiation efficiency is 0.2/0.6 or 33%.

It is important to note that the New Brunswick antenna may be operated at the wave length of 2,500 meters, although its natural wave length as a flat-top antenna is 8,000 meters. Operation at such short wave lengths obviously would not be possible with the antenna in its old form. The multiple resistance of the New Brunswick antenna at 2,500 meters is 3 ohms, and the radiation resistance is 2.1 ohms. The radiation efficeincy is therefore 2.1/3 or 70% whereas with a single ground antenna the resistance at the same wave length would be about 5.4 ohms, and the radiation efficiency, 2.1/5.4 or 40%.

A curve showing the computed values of the radiation resistance of the New Brunswick antenna, at various wave lengths, is given in figure 36. The multiple resistance as actually measured at the wave lengths of 2,500, 8,000 and 13,600 meters is pointed out. The radiation efficiency at these three wave lengths should be noted, and also the comparative efficiencies of the common antenna with the single ground and the Alexanderson antenna with multiple grounds, at the wave length of 13,600 meters.

Although the radiation efficiency of all types of antenna decreases with increases of wave length the smaller absorption obtained at the longer wave lengths offsets this decrease. Efficient wave lengths for trans-oceanic communication have been found to lie between 10,000 and 20,000 meters.

As pointed out in the July Wireless Age, in order to secure a constant output at the alternator and to prevent a diminution of the received current at the receiving station, the speed variation of the radio frequency alternator, when signaling, must be maintained within one-tenth of one per cent. It is evident that the governing mechanism to maintain such constant speeds must come into such a critical state, at the motor speed to be maintained, as to cause a high percentage of change in itself for a low percentage change in speed.

The circuits of the Alexanderson speed regulator have been shown in the fundamental station circuit, figure 19. They are shown separately in figure 37. L_{10} is an armature coil which supplies a constant voltage at the frequency of the alternator. C_4 and P_5 are a capacity and an inductance which are tuned to a frequency slightly above that at which the alternator is to be worked. The coil S_6 is coupled closely to P_5, but not so closely as to affect appreciably the tuning of the resonant circuit. E is a rectifier (of the G. E. Tungar or Mercury Arc type) which is shunted by a condenser C_4 of 0.16 mfd. capacity.

M_1 is an auxiliary control coil of the voltage regulator. The latter through the contacts T_1 acts to control the voltage of a generator K_1. C_5 is a condenser of 1 mfd. shunting the coil M_1. Care is taken that the circuit S_6, C_4, C_5, is considerably off resonance with the frequency of the circuit L_{10}, C_4, P_5, in order that the speed held by the regulator may be changed with the greatest simplicity.

N and O are variable impedances connected in the two phases of the power supply lines. They contain the D. C. control coils P_6 and the variable impedance coils S_7. R_3 is a liquid rheostat connected in the circuits of the rotor.

The generator K_1, which is driven by the motor M_3, is provided with field current from a D. C. source of constant voltage which is varied by the rheostat R_4.

In regard to the functions of the impedances N and O, it may be said, in general, that with zero current in the control coils P_6, their impedance becomes a maximum. If on the other hand the current through P_6 is such as to saturate the cores, their impedance becomes a minimum. Any intermediate value of D. C. control current will vary the A. C. impedance of the coils S_7 accordingly.

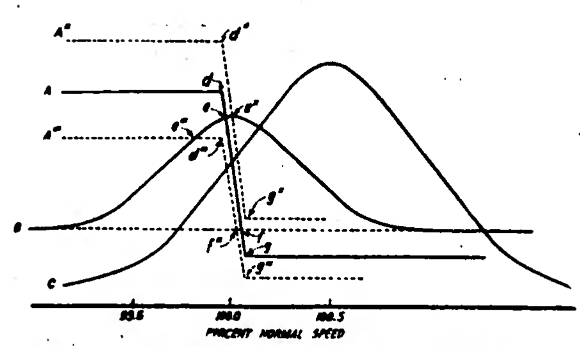


Figure 39—Additional graphs showing certain characteristics of the Alexanderson speed control system

It will now be shown how the motor input may be varied inversely as the current fed into the coil M_1 from the resonance circuit brought from a coil in the armature. Since the circuit L_{10}, C_4, P_5, is resonant to a frequency slightly above that of the alternator, it will develop an increased current as the motor M speeds up. This will send a D. C. component through the coil M_1 which assists that flowing in coil M_2; this causes the voltage regulator proper to maintain a lower voltage at generator K_1. This in turn decreases the current through the coils P_6 and therefore increases the impedance in the power supply circuit, tending to decrease the speed of the motor. When the speed falls slightly the rectified component through the coil M_1 decreases, thus causing the voltage regulator to maintain a higher voltage on the generator K_1 and therefore increase the control current through P_6, and thus again decrease the impedance in the power supply circuit. A given mean current is thus maintained through the control coils P_6, the value of which is determined by the value of the current through M_1. The speed of the driving motor is thus held constant.

A series of graphs showing the phenomena involved in the action of the speed regulator are shown in figure 38 and figure 39.

In curve A, figure 38, the "motor input" is plotted

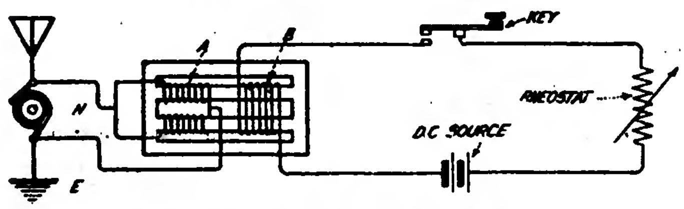


Figure 40—Magnetic amplifier in simplified form

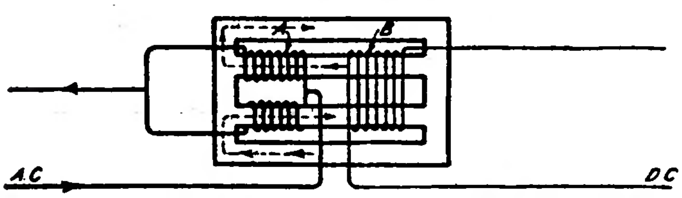


Figure 41—Showing inductive action of amplifier windings upon the control winding

against "percent variation of normal speed" with the normal line voltage and frequency and with the resistance R_3 (in the rotor circuit of the motor) properly adjusted to provide the required power. The flat part of the curve to d, indicates the motor input with maximum field on generator K_1, figure 37, which is the result obtained with zero current in the coil M_1 of the voltage regulator. It should be noted that the motor input with the speed less than 99.95% normal is well above that required to drive the alternator with the sending key closed. The motor will therefore increase its speed up to point d, where the speed regulator takes hold. From here the motor input drops off rapidly because of the increasing current in coil M_1 (of the voltage regulator) until its curve intersects curve B which represents the power required to drive the alternator at point e. Here the motor input and the power required to drive the alternator are equal and the speed will remain constant.

When the key is opened, the power required to drive the alternator drops off to that indicated by the dotted line and the surplus of power supplied to the motor speeds up the alternator until the motor input has dropped off to a value equal to that required to run the alternator light. This condition is represented at the intersection f at 100.05% normal speed.

Point g represents the point at which the speed regulator has decreased the motor input the maximum amount possible, with minimum field on generator K_1; and for any small increase in speed above this point, the input will be the same as at g. Since here the power required to drive the alternator is greater than that supplied to the motor, the motor will slow down until equality is obtained as at point f with the key open, or as at point e with the key closed. With the speed at point f when the key is closed, the speed will decrease to point e, and when the key is opened again, it will increase again to that represented by f. This speed variation being less than 0.1%, no inconvenience is suffered.

If, however, the characteristics of the speed regulator are such that it lags in action, the speed may fall below e, before the regulator can effectively increase the power input. This will cause a greater variation of speed than would otherwise obtain. "Hunting" may then take place and result in a speed variation greatly in excess of the allowable variation for constant alternator output. This is prevented by properly designing the whole set

The speed held by the regulator at a given alternator frequency may be changed to some other value by retuning the circuit L_{10}, C_4, P_5 through variation of its capacity or inductance. This will change curve A figure 38 which will then maintain the same relation to the curve C, thus providing a different speed at which the power required to drive the alternator will equal the motor input These conditions are represented in dotted lines in figure 38, e' and f' representing the speeds held with the key closed and open respectively, and d' the point at which the speed regulator takes hold.

To obtain proper regulation the speed regulator must be adjusted so the point e will be on the left or lower side of curve B, for on that side of the curve an increase in speed will incur an increase in load (as resonance in the alternator antenna circuit is approached) which automatically will tend to keep the speed down. On the other hand if the point e lies on the high side of the curve B an increase in speed will decrease the load which will tend to cause still further increases of speed. This is prevented only by the fact that the speed regulator causes the motor input to fall off faster than the load falls off Because of the fact that better regulation is secured on the low side of the curve, it is called the stable side, and the high side the unstable side.

If the power supplied to the driving motor is increased, such as by an increase in line voltage or frequency, or by a change in the setting of the motor circuits (such as a decrease in the rotor resistance of an induction motor) the curve for motor input will rise as to A", figure 39. If the power supplied to the motor is decreased the curve of motor input will fall as to A"'.

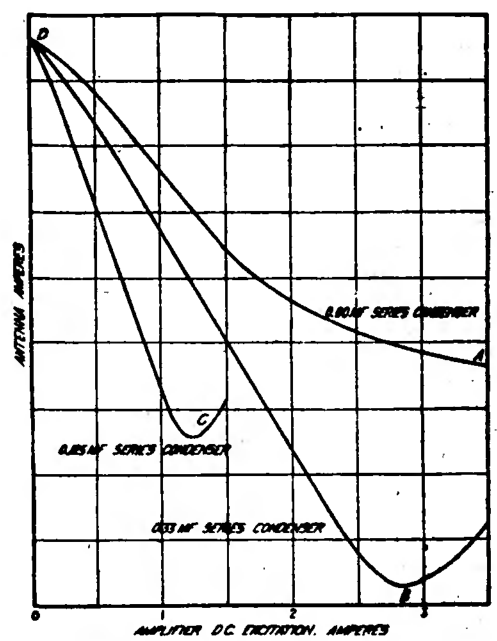


Figure 42—Control characteristics of the magnetic amplifier

The motor adjustment must be maintained so that point g on the motor input curve will be kept well below the power required to run the machine light (as shown by the dotted lines) and also point d must be kept well above the power required to drive the alternator at maximum tune of the antennae. In case point g is not well below the power required to run the machine light a surge in line voltage or frequency might increase it to g" where it would be greater and thus cause the alternator to run away when the sending key is left open a short interval. Also if point d is not well above the power

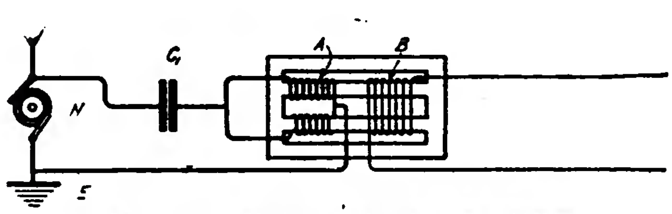


Figure 43—Magnetic amplifier with series condenser

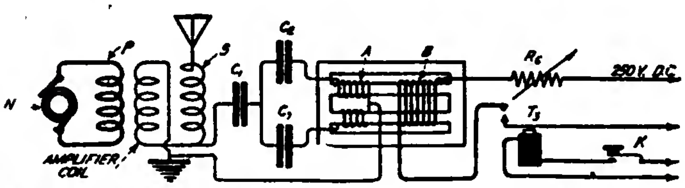


Figure 44—Magnetic amplifier with series and short-circuiting condensers

required to drive the alternator at maximum tune a slump in line voltage or frequency might decrease it to d''' and thus cause the machine to slow down to e''' when the key is closed, with a consequent falling off in signal strength and a swing in the pitch of the received note.

If adjustments are made so that the conditions outlined above are realized, no difficulties are encountered in maintaining a uniform speed at any desired alternator frequency.

This device already has been described as a variable impedance connected across the terminals of the radio frequency alternator for the purpose of controlling the power input to the antenna circuit. Its characteristics are

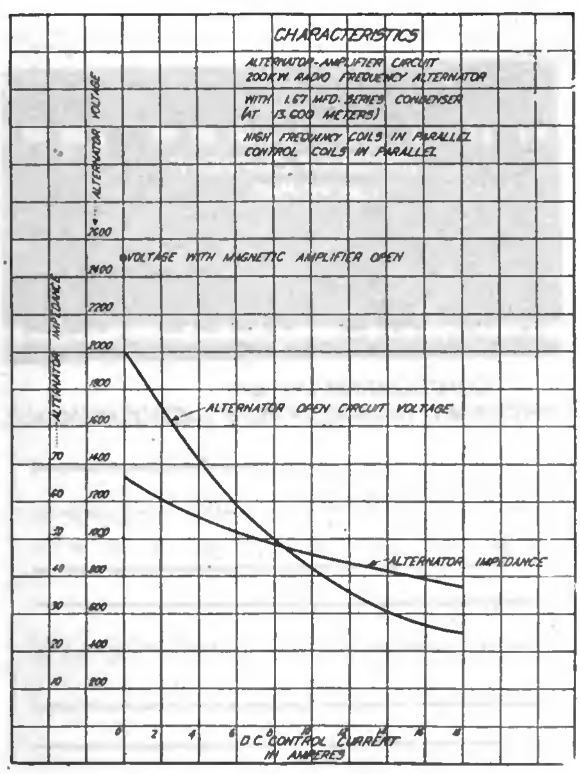


Figure 46—Characteristic of alternator-amplifier circuits, 200-kilowatt Alexanderson radio frequency alternator

such that a relatively small current in an excitation winding is enabled to control many hundreds of amperes in the antenna system. The amplifier performs two functions: When the sending key proper is open the alternator is placed on short circuit and the antenna system detuned. The joint effect of these two phenomena is a reduction in antenna current to 9% of its normal value. When the sending key is closed, the alternator assumes substantially its normal voltage, the antenna system returns to a state of resonance and the alternator output flows into the antenna system.

The great advantage of the amplifier over other methods of modulation is that it gives a non-arcing control of the large currents required in high-power radio transmission and therefore permits rapid telegraph signaling. In fact the amplifier has been operated experimentally at speeds in excess of 500 words per minute with perfect success.

An idea of the fundamental actions of the amplifier can be gained from the circuit, figure 40 where the two windings designated by A and B are wound on a common iron core. The windings A are connected in parallel and shunted across the radio frequency alternator N. The coil B is an excitation winding which includes both the positive and the negative branches of the flux produced in the windings A, and hence, no voltages are induced in B by the radio frequency currents flowing in A. This is illustrated by the reference arrows in figure 41, which show the direction of flux in the amplifier coil at a particular half-cycle of the impressed current. It is clear that the tendency to induce an e. m. f. in one side of the control coil by one branch of A is counteracted by an opposing e. m. f. in the other branch.

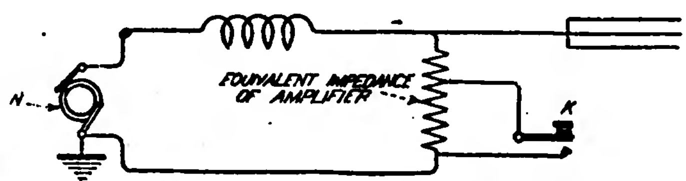


Figure 45—Equivalent circuit of Figure 44

It is apparent that should the flux produced in the core by the coil B be sufficient to saturate it fully, the impedance of windings A would become that of a coil without an iron core. On the other hand, with zero current in the winding B, the core will be magnetized by the windings A, and the impedance of A will thus become a maximum. In general, in order to obtain large flux variations in the windings A, the opposing ampere-turns in B must be approximately equal to those in A. Utilizing the alternator control circuit to figure 40, the problem is to obtain a minimum impedance in the windings A when the circuit to the excitation or control winding is closed and thus short circuit the alternator; and to obtain a maximum impedance when the control circuit is open, so that the alternator may assume within reasonable limitations its normal voltage. In this way the necessary variation of the antenna current for telegraphic signaling is secured.

The characteristics of a magnetic amplifier operated in a given instance as in figure 40, are shown in the curve A figure 42, where antenna amperes are plotted against different currents in the excitation or control coil. The curve A shows incomplete modulation of the antenna current, but it should be mentioned that with this circuit it is possible to secure more complete modulation with stronger currents in the control winding.

A more sensitive control of the alternator output to the antenna system can be secured by the series condenser C_1 of figure 43, for by the use of this condenser a much smaller control current is required to effect a given variation in antenna current. If the capacitance of C_1 is chosen to neutralize the inductance of the windings A for some definite value of excitation current in the control coil B, the impedance of the circuit C_1, A, becomes a minimum. The impedance at any lower excitation is determined by the difference between the inductive

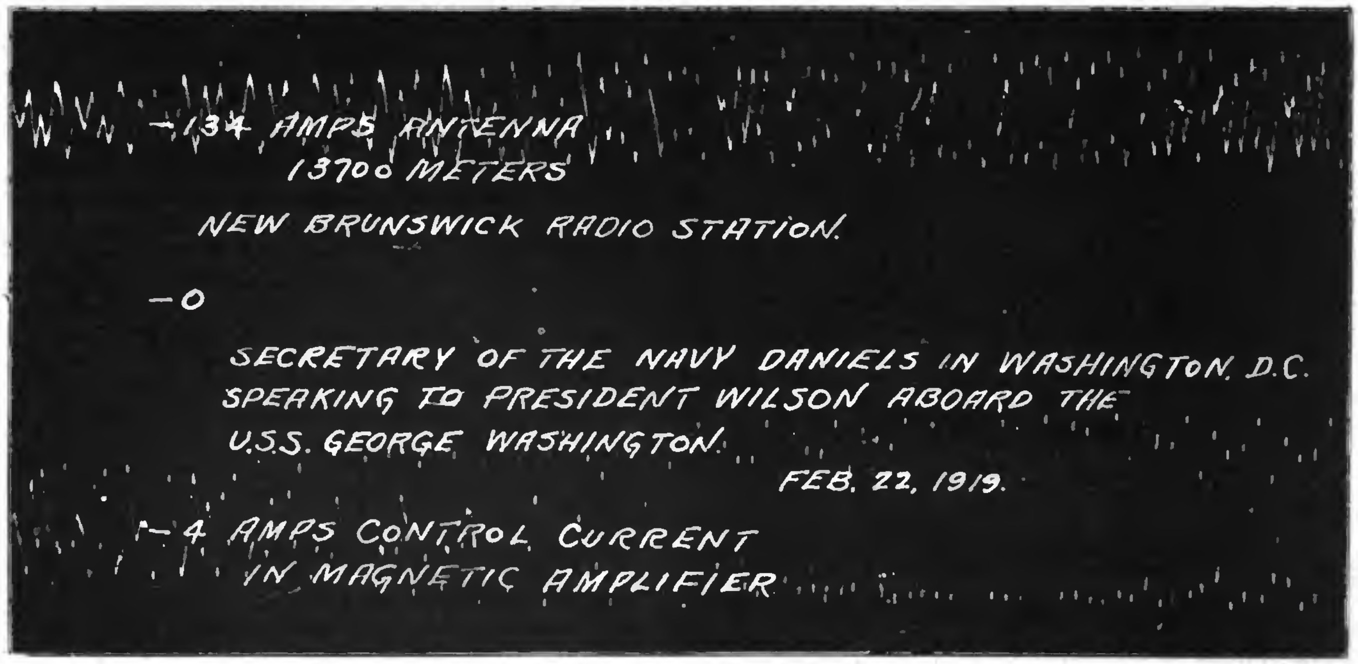


Figure 47—Oscillograms of control and antenna currents using a 200-kilowatt Alexanderson alternator set for oversea radio telephony

reactance of the amplifier coil and the capacitive reactance of the series condenser. However, the smaller this difference the lower will be amplifier excitation which gives minimum impedance and therefore minimum alternator voltage.

The increase in sensitiveness obtained from the series condenser is well shown by the curves B and C of figure 42. The curve A, as already mentioned, shows the antenna currents for different control currents, without the series condenser C_1. The curve B shows the control obtained with a series condenser of 0.33 mfd. and the curve C with 0.125 mfd. The curve B shows almost complete modulation of the antenna current. Although it is a matter of principal importance in radio telephony it is pointed out here that the curve B indicates a linear proportionality between control and antenna currents almost throughout its range. This is an essential requirement for satisfactory speech reproduction in telephony. The excessive control indicated at the right of point B with the larger values of control current is a condition easily avoided in practice.

In the final form of the magnetic amplifier, the condensers C_2 and C_3 are inserted in the amplifier windings A, as shown in figure 44. Their function is as follows: If telegraphic currents were introduced into the control coil B with the condenser C_2 and C_3 absent, a short circuit current would flow between the branches of A without producing any flux variations to the radio frequency current. This, however, is prevented by choosing values of C_2 and C_3 to have a low reactance to the radio frequency currents and a high reactance to the audio frequency currents. These condensers have no appreciable effect upon the tuning of the amplifier circuit.

In the commercial set the constants of C_1 are selected for the particular frequency at which operation is to take place, and it is therefore only necessary to vary the control current in the coil B until the most complete modulation of the antenna current is obtained. In the event that the alternator is worked at some frequency different from that originally contemplated, a value of C_1 can be found for some definite value of control current in B, at which a minimum impedance in the amplifier coils is obtained.

In summary of the foregoing the equivalent circuit of figure 44 will be seen to be that of figure 45 where the telegraphic key K when closed reduces the impedance of the amplifier and therefore the impedance of the amplifier-alternator circuit. This simultaneously detunes the antenna circuit and reduces the alternator voltage.

Characteristic curves showing the variation of alternator voltage, and change of alternator-amplifier impedance with different values of current in the excitation winding (for the standard 200 kw. set), are presented in figure 46. Thus with zero current in the control circuit the alternator open circuit voltage is 2,000, and approxi-

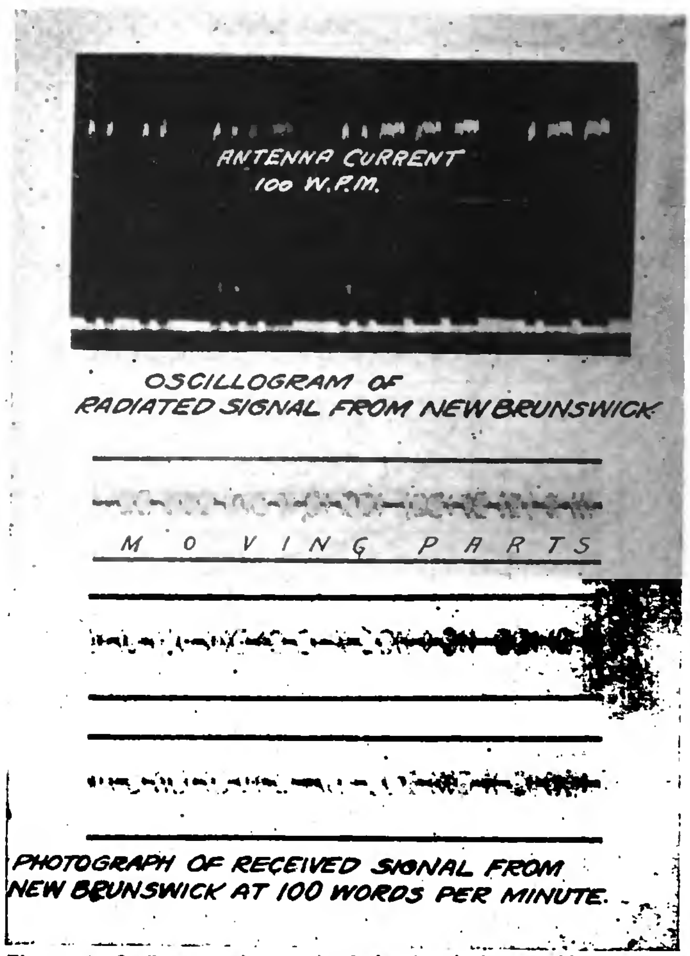


Figure 48—Oscillogram of transmitted signal and photographic record of received signal from New Brunswick Station at 100 words per minute

mately 500 volts with 18 amperes in the control coil. Similarly with zero current in the control coil the alternator impedance is 67 ohms and it drops to 37 ohms with 18 amperes in the control coil. Theoretical considerations of the circuits involved and actual test show that this drop in alternator impedance reduces the alternator voltage and detunes the antenna system to the extent that no more than 9% of the total normal current flows in the antenna system (when the current in the control winding is zero).

In explanation of the control current of 18 amperes (fed by a 250-volt source) in the case of a 200 kw. installation, it may be said that the same variation of alternator output might be obtained with much smaller values of control current. The larger value is purposely used to permit rapid signaling, that is, it permits the magnetic amplifier to function without lag.

Since the magnetic amplifier provides a linear control of the antenna current and functions with small values of control current, it is applicable as a modulation device in radio telephony. When telephonic currents of suitable amplitude are passed through the control coil B, figure 44, similar variations of the antenna current will be obtained, provided the amplifier characteristics are selected to give linear proportionality; otherwise inaccurate speech reproduction will result. It has been amply demonstrated in practice that such characteristics are readily obtained from the amplifier. Thus the curves B and C, figure 42, both show the desired linear proportionality between control currents and antenna currents, but the curve B shows the most complete modulation of the antenna input.

The perfection of control provided by the magnetic amplifier has been well demonstrated in a series of tests made on the 50 kw. Alexanderson alternator. With a telephonic control current varying in amplitude by 0.2 ampere, the antenna current was changed from 5.8 to 42.7 kw., a variation of almost 37 kilowatts.

Figure 47 is an oscillographic record taken on the 200 kw. set at New Brunswick, N. J., with Secretary Daniels, of the U. S. Navy Department, at Washington, D. C., speaking to President Wilson aboard the U. S. S. George Washington at sea. The satisfactory operation provided by the amplifier is here again well demonstrated.

When the Alexanderson System is used in radio telephony, the control circuit of the amplifier is placed in the output circuit of a bank of vacuum valve amplifiers. The input circuits of the amplifier bank are controlled by three preceding steps of vacuum tube amplifiers, which in turn are actuated by the microphone.

In a number of experimental tests made with the telephone set at New Brunswick, the voice was projected to European stations. At distances up to 2,500 miles very satisfactory results were obtained.

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By O. C. Roos
FELLOW I. R. E.

(*Continued from July* Wireless Age)

It is intended in each instalment to "overlap" slightly in regard to the reiteration of basic lattice winding principles involved in order to save the reader the trouble of referring in detail to the previous instalment where these fundamental laws of lattice winding are introduced. As these laws have hitherto been unpublished it is believed that a good educational purpose will be served.—*Editor.*

Resumé of First Instalment

Unsystematic practices in vogue in naming various universal wound coils noted.

Classification of universal, and lattice coils.

Methods of hand-winding.

Typical winding chart for a step-lattice coil.

General shape factors indicated.

Multi-lattice coils with one or several wires, and use in wavemeters or direction-finder loops.

Laws of lattice pattern-formation.

General approximate inductance formula.

High frequency lattice transformers with ferro-dust dielectric cores.

Synopsis of Second Instalment

Development of lattice layer on a plane, to show true value of "swing-angle," G.

Simple analysis of relations thus exhibited.

First working formulas shown, giving, K the "cross-step" or simply "step" and swing-angle, G and their general connection with tuning efficiency, P of the coil,

where $P = \frac{1}{R}\sqrt{\frac{L}{C}}$

Change of swing-angle with diameter illustrated.

Effect of same on properties of lattice "cells."

Distribution of L, C and R as effected at different layers, by this factor.

Suggestions for conditions of tests to secure better average checks on coil constants.

Effect of wire thickness on properties of coil.

Cross-spiral (or simply "spiral") lattices and their general relations to cross-step lattices.

Peculiarities of lattice coils in relation to derivation of design formulas.

Effect of swing-angle G on lattice-coil tuning efficiency, qualitatively considered.

Method of converting single wire uni-lattice into single wire multi-lattice coils.

General method of designing multi-lattice coils approached.

There is a certain angle, the "swing angle," made by the winding "cross-step" with either circumference of the cylinder faces. It directs the winding zig-zag and experience indicates should not be more than 30°. In figure 15 this is discussed in detail.

To the left in figure 15 we have a coil frame, with a wire "swinging" or "stepping" from O at the "right" of the frame to S at the "left." Let the plane XOY be tangent to the cylindrical frame along the element NO. If we draw OY in this plane at right angles to NO, it will be tangent to the circular face OVB. Let the line OR in the plane XOY represent the wire at a "swing angle" equal to G. Then if the wire OR and the plane is allowed to roll on to the cylinder clockwise, with the line OY always touching OVB, the winding OR will lay on the helical line OS, and will have a "swing angle" of G degrees.

To make the matter still clearer, look at it from another point of view. Suppose that the cylinder NOVB were turned with its ends reversed and then rolled clockwise along the line BO^1Y^1 to the right. If we "inked in" the lines on the plane XOY they would all print themselves on the plane $X^1O^1Y^1$, in their exact relations at the left and we would see why the angle G of the "swing" is the same from point O to point S on the winding. Of course X^1O^1 and Y^1O^1 are perpendicular. NS is the "angular" swing, NO is the width W, and O^1S^1 may be called the "cross-step" instead of "linear swing," for accuracy and brevity.

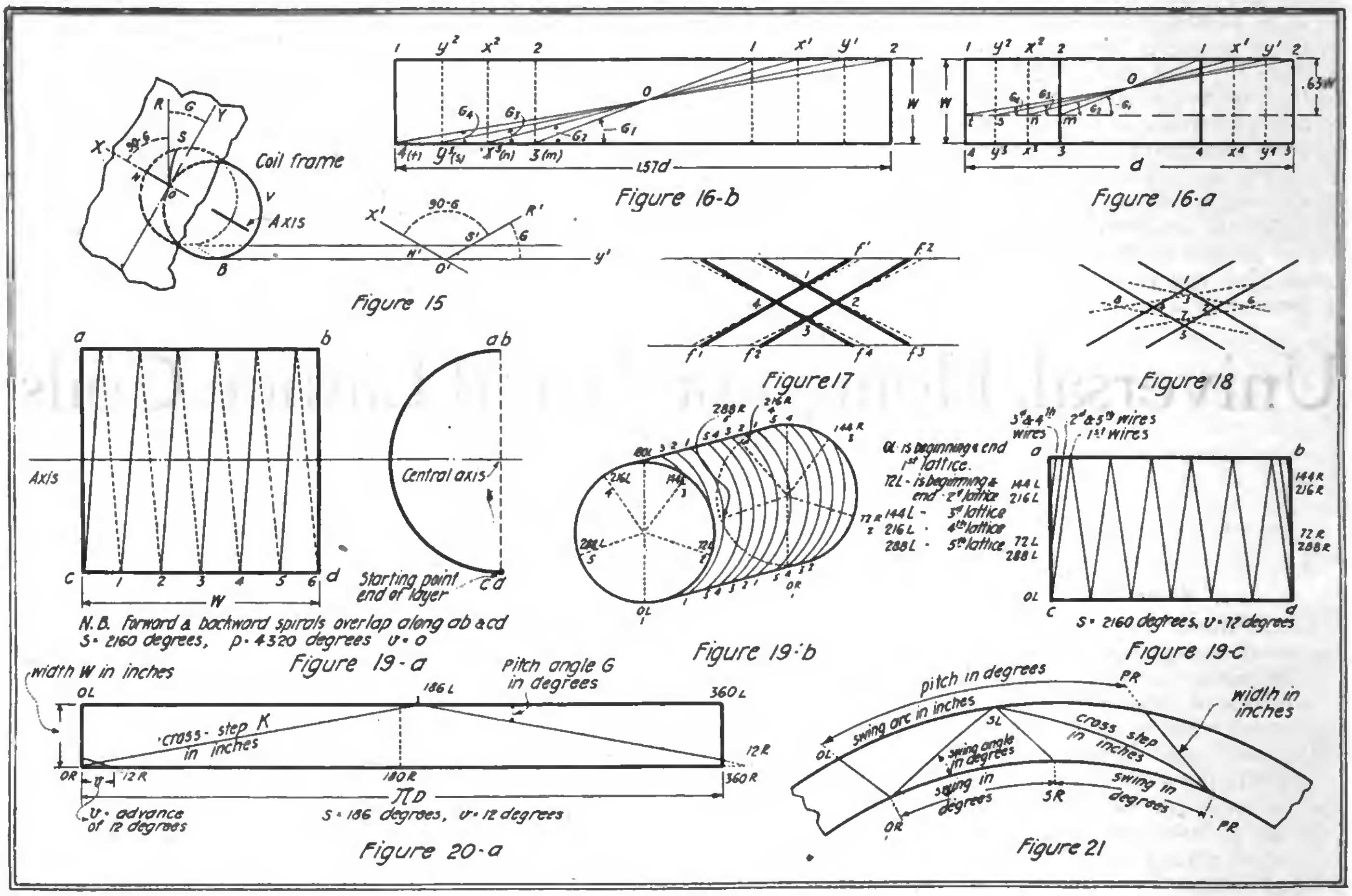
The actual "helical" or "screw" pitch in linear measure is the axial distance along the cylinder traveled during one turn of the winding, like that of any helix, but cannot be greater than W the width of the coil, hence the latter is assumed given and the swing angle calculated from the following two simple relations.

First: $K = \frac{Rds}{360}$

Where K = length of swing—O^1S^1 in figure 15—and therefore equals the "cross-step" or "step" "K."

s = angular swing, in degrees.

d = diameter of winding at a given layer. (N.B. We do not say "diameter of frame.")



Figures 15 to 21—Diagrammatic details of coils showing dimensions, method of winding, angle of pitch and general design principles

Second: $G = \sin^{-1}\frac{W}{K}$ which means that "G in the angle whose sine is $\frac{W}{K}$" and any book of trigonometric tables gives us G as soon as we know W and K. G must be less than 30 degrees. You ask—"why?"

First—It saves wire.

Second—It raises the selective power or tuning efficiency P of the coil, thus cutting down the damping; since

$$P = \frac{1}{R}\sqrt{\frac{L}{C}}$$

From purely manufacturing considerations it is not common practice to build a "step-lattice" coil with the "swing" much greater than 180 degrees.

The sine of $60° = \frac{1}{2}$, hence $\frac{W}{K}$ must be generally less than $\frac{1}{2}$ or W is less than $\frac{K}{2}$. In the best lattice coils its average value is less than $\frac{K}{6}$. This is shown in figure 16a, where cross-steps K, of constant angle (S) but varying length, are laid out.

Figure 16a is a plane section of a lattice coil. The diameters of four "layers" are indicated by pairs of lines, at left and right. The exact properties of lattice "layers" will be given later. The four lines at the left are 2-3, X_2-X_3, Y_2-Y_3 and 1-4. The winding cross-section at right and left is 1234. If we take .63—the ratio of the diameter of any layer to its semi-circumference—of the width W, and lay out the swing-angles G_1, G_2, G_3 and G_4 by joining m, n, s and t at the left to 1, X_1, Y_1 and 2 at the right, we will find these angles are accurate. Figure 16b proves this; as it is nothing more than figure 16a with the various layers rolled out or "developed" on a plane. The lettering is kept similar to that of figure 16a. The "similar" angles G_1, G_2, etc., in both sketches are exactly equal.

These two figures show that the cell walls of lattice coils slowly change direction as the coil grows in diameter, somewhat like the pitch of a propeller blade. This means that there is a slight mechanical loss of rigidity in lattice "cells" whose linear dimensions are large and flattened as in figure 17a, especially when used with a small diameter of wire.

The wire f_1f_1 is called the "cross-step," and the swing angle G which it makes with the face of the coil, changes as shown in figures 16a and 16b, so that the cell-walls do not receive the support of the "steps" except at a fraction of their length. The dotted lines show the next outer set of "steps." This is shown, greatly exaggerated, in figure 18, where 1, 2, 3, 4 is a cell in one layer and 5, 6, 7, 8 is a cell on the next outer layer. Here is the real "secret" of the lattice coil. The greater the difference between the swing angles of successive layers, the smaller the distributed capacity of the coil, and the more economical it is of wire; since when G is small the time-constant is good. This change is slower near the outer layers, where, however, the effective radial capacity per unit length of coil is also smaller, for electrical reasons.

Since G becomes smaller as the coil diameter increases the inner layers are relatively inefficient in producing a good time-constant. Therefore it is not a fair test to use the whole coil to get the selectivity or tuning power P, which is measured by $\frac{1}{Ro}\sqrt{\frac{Lo}{Co}}$ where Ro, Co and Lo are the radio frequency resistance, capacity and inductances respectively. The whole coil shows up too well!

If the winding were stopped at half the total "layers" to be wound, or else a "tap" taken there, a test for Lo, Co and Ro to represent the uncompleted coil would give a more just average result. The former method is preferable on account of capacity dead-end effects present in the latter method.

It is important to remember that, the thicker the wire, the greater the change of swing-angle with a given change in number of circuits of winding and the less the distributed capacity always provided the spacing between "cell-walls" centers is kept equal to a constant multiple, say 3, of the diameter of wire. Otherwise, these wires of increased diameter in themselves have greater capacity and will neutralize a large part of the above advantage.

Spiral Lattices

It has been stated that for mechanical reasons "swings" or "steps" of more than 186° as given in figure 8 are usually avoided, except when the coil has a ratio of $\frac{d}{W}$ like figure 13 or else is small in diameter.

In these circumstances we may save wire and utilize the rapid change swing-angle G for small diameters—figures 17 and 18—by making the swing angle so small that many turns will be completed before the winding makes one swing. In this case we have a "cross-spiral"—instead of a "cross-step"—when the winding returns with 720° pitch, i.e. two turns or more to the starting point, or just beyond it, making a uni-lattice pattern if the pitch is exactly two turns, i.e. the winding starts a second layer at the original starting point. See figure 19a.

Now if the advance is an exact submultiple of 360° we have, a bi-lattice spiral for an advance of 180°, a tri-lattice spiral for 120° advance and an N-fold lattice spiral if the advance is $\frac{360}{N}$.

A penta-lattice spiral is shown in figure 19b with advance v equal to 72°. We could wind this as a five-wire uni-lattice spiral by starting separate wires at 0°, 72°, 144°, 216° and 288°. By choosing the turns in each lattice we can design an excellent unit for replacing five separate wavemeter coils.

In figure 19b we have the conditions in figure 19a modified to show five separate windings, giving as many lattices, each lattice formed from a cross-spiral. Colloquially we abbreviate "cross-step" and "cross-spiral" into "step" and "spiral" respectively. This spiral lattice or rather "five-spiral lattice" is shown in the forward swing of its first "layer," but for simplicity it is drawn in isometric projection and as though its wires each has only two instead of six complete turns or 2160° to a swing. The left face, nearest the reader, is lettered OL-72L etc., to show the starting points of the first to the fifth wires, as indicated on the top and bottom cylindrical elements 180L-180R,-OL,OR, by the series of numbers 321,54321,54, and 1543215432 respectively.

In figure 19c we get a side view of figure 19b showing, however, the twelve turns made by the first wire on the pitch of 4320°, the forward and backward spirals crossing at the starting element and 180° away. A five-wire spiral-lattice with 10 terminals is the result, although only the beginning and ending of the second, third, fourth and fifth spirals are here indicated.

We have to note, in figure 19a, that $\frac{d}{W} = 1.00$ and the angle G is too small here, to exhibit much change as the new layers are added. The layout of figure 19a is satisfactory, provided the "axial" or "helical" pitch 1-2, 2-3 etc., is at least thrice the diameter of the wire used.

The winding starts at OL—calling OL, OR the zero or starting element—and ends on OR. It immediately returns on the back swing of six turns (not shown) with a total "angular pitch" of 4320°, or twelve turns, to its starting point OL, and therefore, has no spiral "advance," or "step-advance," as shown in figure 1 or in winding-chart figure 8. The layers simply repeat from OL; as no "advance" of any kind is necessary for such a coil, which is therefore of the uni-lattice spiral type.

There is nothing to prevent efficient multiple-wound spiral lattices being used for couplers or wavemeters, etc.

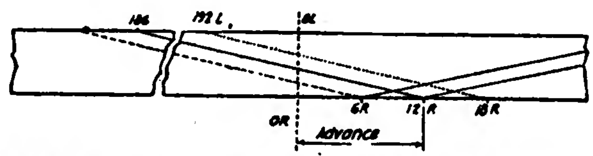


Figure 20b—A uni-lattice coil with swing 186° and advance 12°

There is a positive advantage in it, up to four separate lattices, as the change in G for separate layers of the same lattice is greater, making the cell shape more efficient. These corresponding "layers" for any particular lattice would really be four layers apart radially, and would have their distributed capacity correspondingly reduced, without reducing the inductance too much.

It is perfectly practicable to have these "intermediate" wire layers—in this case, 3 layers—replaced by an insulating lattice of moisture-proof hard cord. Such insulating lattices have been used in the past for different purposes. In regard to the mechanics of the thing, it is a fact that in one case, a coil of about four feet diameter was successfully wound out of small diameter rope. Furthermore, the use of large multi-lattice coils of bare and insulated wire for direction-finder loops is today being looked into, as a promising variation both mechanically and electrically.

Winding Peculiarities of Lattices, in Relation to Derivation of Formulas

There are several unobtrusive points about lattice coils which must be constantly kept in mind.

First: There is no "bedding" of wires at one level in the hollow or trough formed by the two adjacent wires underneath on the lower level. This is shown in the first diagram of this article.

Second: The question "what is a lattice winding level?" is answerable only by accepting a convention. The position of the wires in a "level" is only the same at certain repeated elements of the cylinder constituting the winding. The positions of wires in each level in a "layer" alternate from side to side and the levels themselves have their wires transposed radially in a peculiar way as one mentally passes a plane through the axis and rotates it while examining the winding.

Third: There are small or large projecting bands to be allowed for in calculations of length. These do not occur noticeably in form-wound coils, but lattice coils are not only form-wound, but when constructed of coarse wire with large diameter and few turns, they may be with advantage wound by hand and may purposely have as much as 2.5 per cent of wire added to aid in "tapping" the coil at the wire "bends"—say at a two-inch length of arc projecting from the face of the coil.

Fourth: The length of the wire in a lattice coil is based on the turns per "double level" or "layer," which is the design-unit. It is not convenient to use the "turns per level." This will be shown as being due to the alternate changing of upper to lower levels and vice versa which is illustrated graphically further on in this article.

Turning back to figure 20a we have the elements of the above peculiarities simplified. The perfectly practical winding-plan of figure 8 is given in sketch form. The symbols of figure 1 are applied, with a swing (s) of 186 degrees and an advance (v) of 12 degrees. The development shown in principle in figure 15 is used in figure 20a and the length, say, OL-360L represents the length of the circumference. The swing angle (G) depends, of course, with given cross-step K, on the width of the coil in a "step lattice" winding. In a spiral lattice winding it also depends on the axial width, or rather in this case, the axial length of the coil frame, provided the "cross-spiral" is constant in length. The term "cross-step" or simply "step" for ordinary use, is so much more convenient than the descriptive term "linear swing" (ls) that no excuse is needed for dropping the latter, except as a purely descriptive term. The length of a series of steps is that of a helix of the same angular development. This is obvious if we imagine all the odd or even steps, turned symmetrically to themselves and fitted to the other set, arranged as parts of a broken helix on the coil cylinder considered as extended. The result is a perfect helix, which we treat under the popular generic name of "spiral."

Since the advance v, travels forward by its own length during a certain number of applications of the pitch to the circumference, it must itself be contained in the pitch an exact number of times. Therefore, when the pitch is traveled over once by the advance we have a pattern or a complete lattice "layer." By "slipping" back the starting point when the "pitch" has gone beyond 360° as shown in figure 20b, we form a bi-lattice.

A uni-lattice coil with swing 186° (therefore pitch 372°) and advance 12 degrees, is shown in figure 20b in the full lines. If the swing 186L-12R is "slipped" back to 6R, losing 6 degrees or half the advance, it will come around again, arriving at, say, the swing, 192L-18R, if continued, giving the beginning of a bi-lattice pattern. To continue this bi-lattice, however, this again is slipped back 6 degrees to 12R and the next "circuit," which is defined as a revolution of the winding around the coil frame, starts at 12R, as it would have done originally, with a uni-lattice winding. Here we have the single wire bi-lattice winding. If we started a separate duplicate uni-lattice winding at 6R, and kept it separate, we would have a double or two-wire bi-lattice coil.

In figure 21 we have a value of s of about 30°. We are purposely showing the coil as wide enough to give a swing angle of 35°—an excessive amount. About 10° is good practice for coils about five inches external diameter. This figure also shows the winding surface more in detail than does figure 1.

SYNOPSIS OF THIRD INSTALMENT—SEPTEMBER

1 Laws governing width of coils in terms of "pitch" and "advance," Charts for layout of two types, "odd" and "even" lattices. 2—General relations involving "levels" and "layers" in lattice coils. 3—General properties of lattices in regards to shifting and transposition of wires. 4—Studies in "radial" and "axial" transposition with resultant "banking" of wires and "levels." 5—Detailed graphical analysis of above. 6—Handwinding and tapping of lattices with allowances for same. 7—Changes of swing-angle as related to diameter of wire. 8—Classification of results in preparation for examination of design-factors and formulas. 9—Tabulation of symbols, design-factors and formulas. 10—Selection of 12 coil-problems for mechanical design and comparison of windings. 11—Discussion of same. 12—Solutions of problems. 13—Lines of design development indicated for cross-step lattice coils. 14—Comparison of "cross-step" and "cross-spiral" design factors in lattice coils. 15—Conclusion of analysis and illustration of flexibility of lattice coil nomenclature suggested in this article. 16—Concluding remarks on etymology of nomenclature vs. practical utility in description and specification.

An Impedance Curio

WE ARE all prepared to find an increase of impedance when a condenser shunts a coil. This has been solved for the rejector circuit consisting of a pure capacity and a resistive inductance, about 1892. There are still, however, some very interesting properties of such circuits which have not been published, especially for the case where the capacity has leakage. In all these cases, however, we are prepared to see a sudden change in the reactance of the rejector circuit from condenser to inductor characteristics.

There is another, and a simpler but far stranger experiment on reactive shunts which is shown in figure 1. It seems to contradict the laws of Kirchoff until mathematically investigated. It has been correctly solved by A. Russell and discussed by Howe, Campbell and Still. The writer's work has been done independently of these investigators. In figure 1, x is a pure reactance, S is a pure variable resistance in shunt to x, r is a pure resistance in series with x.

If we apply an alternating sinusoidal potential of amount V to x at C and B and read the current in G and then shunt x by S and repeat the experiment the second reading will of course be greater.

You will probably say this must of course occur in all circumstances! Don't be too sure! Let us restore the series resistance by reconnecting the potential source through Y to A again and then repeat the experiment varying the resistance S from O to infinity.

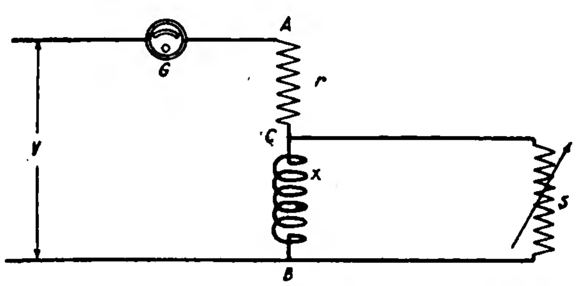


Figure 1—Circuit of the reactive shunt under discussion

Before we do this let us take some actual values. Let $x = 10$ reactive ohms; let $r = 5$ resistive ohms. Then the impedance with S open, figures out as 11.18 ohms. For convenience we will assume V equals 111.8 volts, giving a current in G of 10 amperes.

Now reduce S to zero and "short" x with it. The current in G is 22.36 amperes. Increase S and the current in G decreases as would be expected. If we observe care-

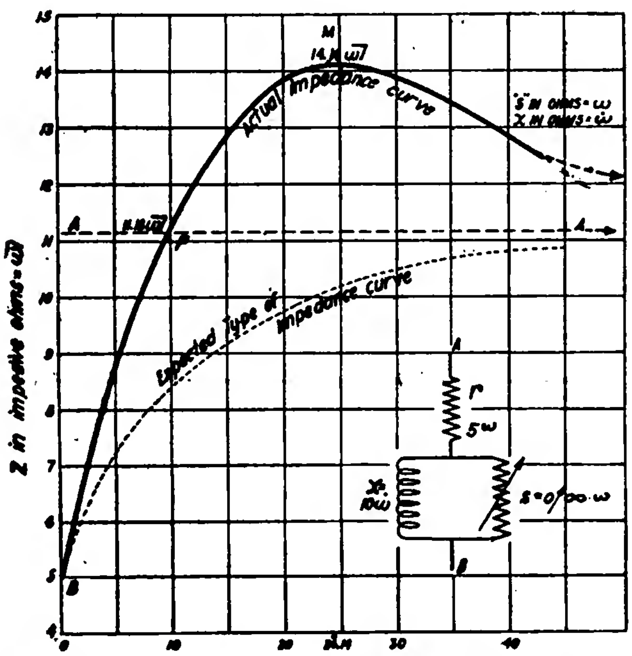


Figure 2—Graph showing actual and expected impedance curves

fully we will note that this decrease is unusually rapid. The majority of even experienced engineers would say that we could never reach as small a current as 10 amperes in G unless S became infinite. This is incorrect, however paradoxical the statement may seem!

The obvious proof is, first, that of experiment. Let us increase S to 10 ohms—i.e. to $\frac{x^2}{2r}$ ohms—G now shows 10 amperes! In other words, S makes no difference by its presence, except to change the current phase!

Stranger things follow when S is still further increased; for G shows still less current! S has actually raised the impedance to a value such that the effective value of r has been doubled while the reactance, however, has not been changed, i.e., $Z=2r+jx$ at its maximum. This value for S giving a maximum value of $Z^2=4r^2+x^2$

$$\text{is } S = \frac{x^2}{2r} + \frac{x}{2r}(x^2 + 4r^2)^{1/2}$$

$\therefore S = 24.14$ ohms when Z or Z^2 is a maximum

and $Z^2=100+100$

$\therefore Z = 14.14$ ohms

The current in G is now 7.86 amperes.

After this the circuit behaves normally, i.e. when S is gradually increased from 24.14 ohms to ∞ the current in G gradually increases to 10 amperes; since Z equals $r + jx$ when S equals $\frac{x^2}{2r}$ or infinity.

It is possible to solve the problem graphically, but it is advisable, at this point, to plot the graph of the impedance between A and B in figure 1 with S as independent variable.

The graph is shown as the curve BFMR. The interesting points are, first—the impedance at F, or the "final" value of 11.18 ohms which the circuit has when S is opened and second, at M, when S equals 24.14 ohms and shows the maximum impedance always greater than the final value, in this case by 2.96 ohms. The curve is, of course, asymptotic to the line AFA.

The clearest method of showing the relation of the elements which go into the formation of the impedance curve shown in figure 2 is to consider this impedance curve resolved into its two components, R and X, which are the equivalent resistance and reactance respectively.

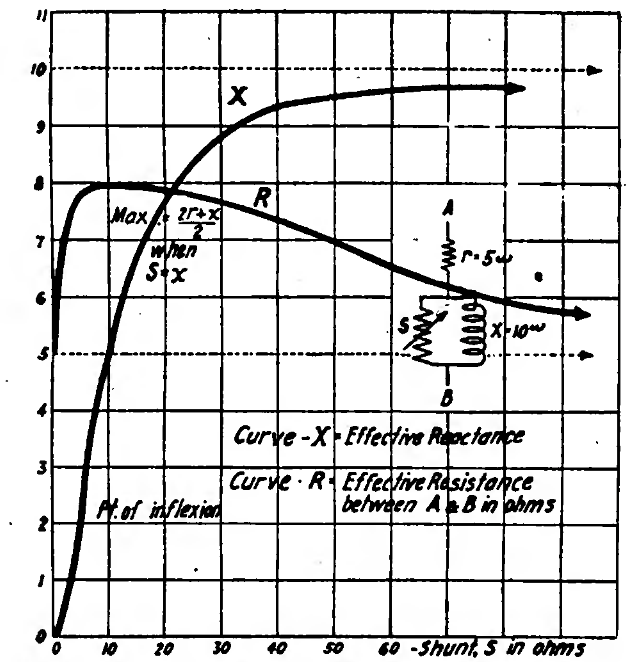


Figure 3a—Graph showing effective reactance and resistance curves

Their values are:

$$R = \frac{r S^2 + x^2 (r + S)}{S^2 + x^2} \text{ and}$$

$$X = \frac{S^2 x}{S^2 + x^2}$$

They are plotted as curves R and X in figure 3a in terms of varying shunt resistance, S.

R has a maximum value when $S = x$.

In this case $R = \frac{2r + x}{2}$

Now the relation $\frac{R}{\sqrt{R^2 + x^2}}$ gives the P. F. (power-factor) between the points A and B of figure 2 and similar figures. The special points F and M noted in figure 2 have been also noted in the P. F. curve shown in figure 3b, plotted in terms of the shunt resistance, S.

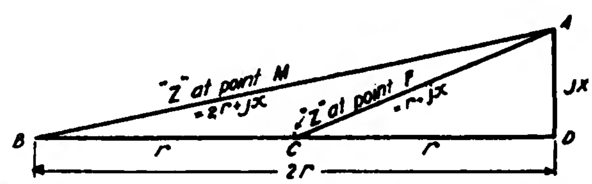


Figure 4—Values of impedance at points F and M in Figure 2

It is easily shown that the P. F. is always 100 per cent. at $S = 0$ and that there is a point of inflexion at about 8.43 ohms for S.

It is worthy of note that the series resistance r is the important element in producing this maximum. The larger r, the greater the difference between the points F and M as can be seen by an examination of figure 4, where OC gives the impedance shown at point F on the graph in figure 2 and AC gives the maximum impedance shown at point M.

On the other hand, the increasing value of the maximum takes place at decreasing values of S. This makes a sharper and higher maximum.

By examination of figure 4 we find that in figure 2 the maximum impedance ordinate OM is related to the "final" impedance ordinate OF by the equation

$$(OM)^2 = (OF)^2 + 3r^2$$

This shows clearly the greater difference between OM and OF as r gets larger.

Of course, when r is small, we approach the problem of the impedance of a resistance and reactance in multiple,

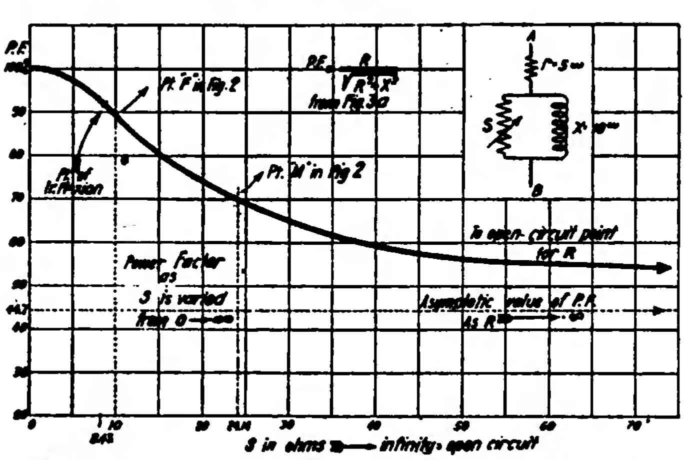


Figure 3b—Graphic curve plotted in terms of the shunt resistance

which exhibits nothing abnormal. Its graphical solution is important in order to solve the circuit of figure 1 graphically and will now be taken up. Before going into details, however, the ground will be prepared for the a.c. graphics by first solving for d.c. multiple resistances, graphically.

The graphics of two parallel resistances r and R, with direct current is simply the geometrical interpretation of the expression for their combined resistance $\frac{rR}{r+R}$

Figure 5 gives the well-known solution for this. Take

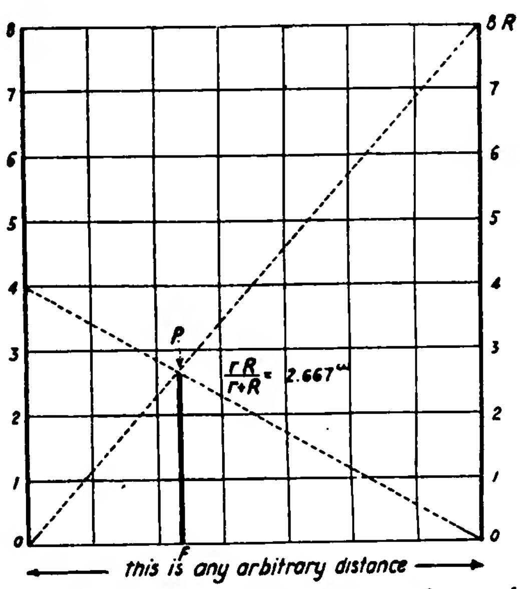


Figure 5—Chart giving the value of the multiple resistance of the two branches

any desired horizontal distance on the axis of abscissas and erect two ordinates at its ends. On these are laid off the values of r and R respectively. Join the points, say, 4 and 8 ohms to the opposite bases of ordinates, by the lines RO and rO. Their intersection marks a point P whose distance from the axis of abscissas gives the value

$$\frac{rR}{r+R}$$

or the multiple resistance of the two branches. It clearly and instantly demonstrates why such a multiple resistance is always less than the smaller resistance. This value, given by the line FP in figure 5 can itself in turn be used with a third parallel resistance laid off either on OR, Or or any other vertical line, as before, etc. Hence the graphic law corresponds to the most general case possible.

If OR and Or were similar reactive ohms, i.e. from

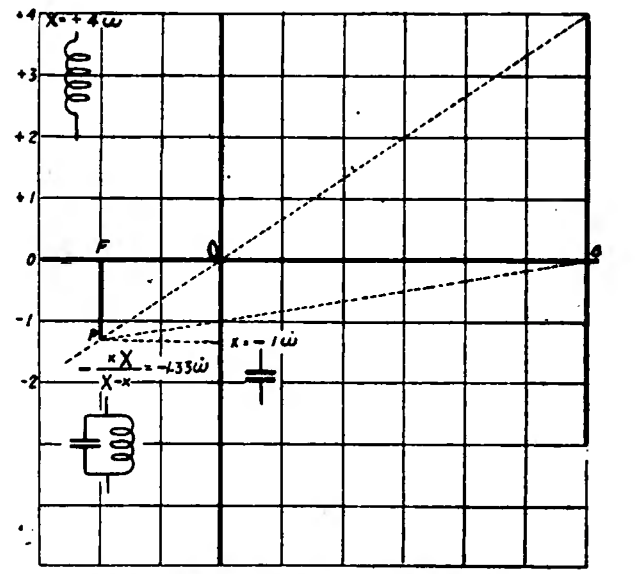
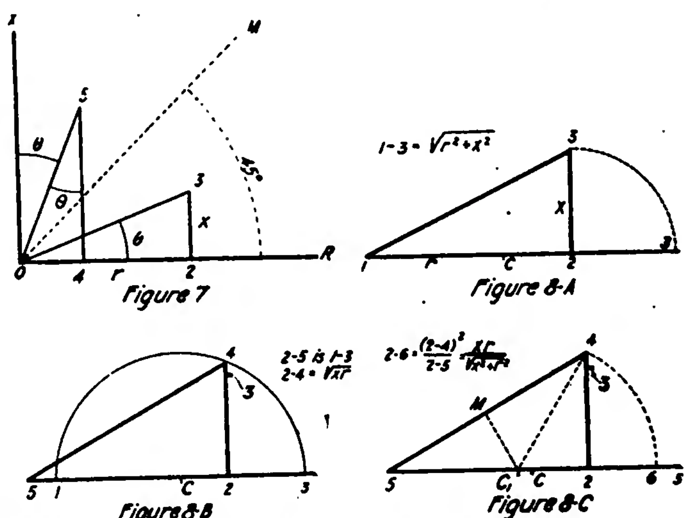


Figure 6—Diagram showing the value of the equivalent capacitive (or negative) reactance

either condensers or inductors, the same laws would apply in figure 5.

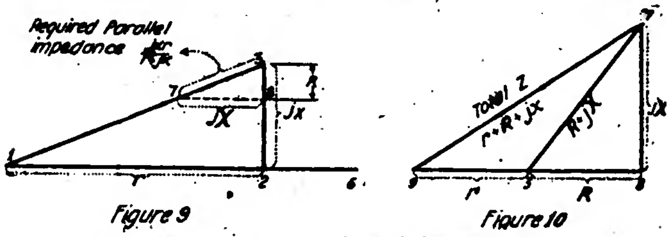
As a matter of fact, the general graphical law holds true, with all combinations of condensers and inductors using the extended diagram with either Or or OR negative in the above construction, but it is mechanically inconvenient to apply, as can be seen by inspecting figure 6 where it is used. Here the process is exactly the same. Lay off OX the inductive reactance and ox, the capacitive react-



Figures 7 to 8 c—The two impedance triangles and graphical solution of the mixed reactances in multiple

ance on opposite sides of the axis of abscissas O-o. Prolong the lines drawn through OX and ox till they meet at, say, P. The negative ordinate FP now represents the equivalent capacitive (or negative) reactance $\frac{Xx}{X-x}$. It is easy to see why FP grows enormously when ox approaches OX in value, i.e. when we approach the undamped resonant frequency of a branch resonant circuit. The values of FP go clear off any drawing-board to the left; as OF enlarges proportionately to FP, and suddenly as ox and OX pass through parallelism, come back again as enormous positive values or inductive reactances to the extreme right of OX.

We are now ready to find the graphical solution of mixed reactances in multiple but cannot use either figures



Figures 9-10—Graphical solutions of the impedance curio

5 or 6. Let the combined impedance of a reactance x and a resistance r in parallel be Z.

$$Z = \frac{r^2x^2}{r^2+x^2} + j\frac{r^2x}{r^2+x^2}$$

where the equivalent resistance $R = \frac{rx^2}{r^2+x^2}$ and the equivalent reactance $X = \frac{r^2x}{r^2+x^2}$

The impedance triangles of r and x in series and in parallel are worthy of comparison; as their phases bear a simple and easily remembered relation to each other.

In figure 7 we have the two impedance triangles for comparison. The triangle 023 is the series impedance triangle and—omitting a constant factor for the moment—045 is the parallel impedance triangle. It has the same shape as 023, but displaced through the angle 305. It is evident that the parallel circuit behaves as if the resistance and reactance changed places; since, for this case

$$Z = \frac{xr}{x^2+r^2}(x+jr)$$

instead of $Z = (r + jx)$

The graphical problem is to get the geometrical value of

$$Z = \frac{xr}{\sqrt{x^2+r^2}}$$

The solution is given in figures 8a, 8b and 8c: In figure 8a we lay off r equals 1–2 and x equals 2–3. Then swing 2–3 around as a prolongation of 1–2. The line 1–3 is of course $= \sqrt{r^2+x^2}$. Figure 8b is the same as 8a but with c as the midpoint of 1—3 as a diameter we describe a semicircle and prolong the line 2–3 until it intersects this semicircle at 4. The line 2–4 is a mean proportional between 1–2 and 2–3 or between r and x. Hence we now have $2\text{–}4 = \sqrt{xr}$. In figure 8c we now combine 1–3 and 2–4 so as to get $2\text{–}6 = \frac{xr}{\sqrt{x^2+r^2}}$ which is our answer—by proceeding as follows:

Lay off 2–5 equal to 1–3 and join 5 to 4. Erect a perpendicular at the midpoint M of 3–1 and let it cut the line 2–5 at C. With C′ as a center and radius equal to C′–4 describe an arc cutting 2–5, prolonged, at 6. The line 2–6 is the required geometrical measure of the combined impedance. This is surely different from the methods used in figures 4 and 5! It is far easier to do than to talk about, however!

In figure 9 we have the promised final graphical solution of the impedance between A and B in figure 1 by the application of figure 8a to an impedance triangle x + jr corresponding to the triangle 045 in figure 7.

In figure 9 we use the distance 2–6 found in figure 8c and lay it off as 3–7 along the line 3–1 in figure 8a, where 3–1 represents $\sqrt{r^2+x^2}$. Hence 3–7 equ...

The ratio of $\frac{2\text{–}6}{3\text{–}1} = \frac{xr}{x^2+r^2}$ and when applied to x + jr, gives the parallel impedance triangle, if we remember

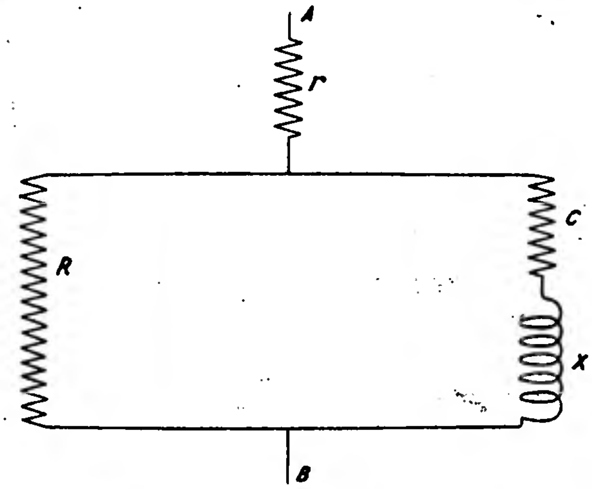


Figure 11—Circuit used in Campbell's solution

that the combined resistance R and reactance X are interchanged in phase relation, as shown in figure 7, when compared to the series impedance triangle 023.

So we take the portion 3–8 from 2–3 or x and call it R and similarly take the portion 7–8 parallel to 1–2 or r and call it j X. Thus the "parallel Z" = R + j X and in figure 10 by adding the series resistance r to the impedance triangle 387 we have solved our problem completely by graphical methods.

Now we are ready to take these results on the general resistance, r, and reactance, x, in series or parallel and apply them to figure 10 which is to be considered as representing the arrangements shown in figure 2.

It is the line 7–9 in figure 10 whose paradoxical behaviour we have been examining in figure 2. The greater the value of r the greater the departure from the usual behaviour of parallel impedances.

In closing this article I wish to call attention to a serious error on the part of Mr. A. Campbell who gave in the London Electrician for May 6, 1910, p. 157 a solution of the circuit shown in figure 11. He gives between A and B the impedance for a resistive inductance CX shunted by a pure resistance R and in series with a pure resistance r. It is in my notation given as

$$Z^2 = \frac{[r(R+C)+RC]^2 + (R+C)^2X^2}{(R+C)^2+X^2}$$

On inspecting this formula it looked unsound, and I became certain of its incorrectness when C is put equal to zero, when we have the case we have just investigated.

According to Campbell, for this case

$$Z^2 = \frac{r^2R^2 + R^2X^2}{R^2+X^2}$$

whereas the correct formula is

$$Z^2 = \frac{(RX^2 + R^2r + rX^2)^2 + R^4X^2}{(R^2+X^2)^2}$$

The absurdity of the previous formula is evident if we let r equal 0, in which case we get a true result

$$Z^2 = \frac{R^2X^2}{R^2+X^2}$$

but by adding r in series to this true result we do not get Campbell's shorter formula! The correct general formula for figure 11 is

$$Z = \frac{(R+C)CR + RX^2 + (R+C)^2r + yX^2 + jR^2X}{(C+R)^2+X^2}$$

and solution for the critical points of this equation is

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EXPERIMENTERS' WORLD

Views of readers on subjects and specific problems they would like to have discussed in this department will be appreciated by the Editor

Operating Suggestions for the Radio Amateur

By J. H. Tolley

FIRST PRIZE, $10.00

THIS prize contest which THE WIRELESS AGE announces on "Operating Suggestions for the Radio Amateur" is timely and should result in a benefit to all stations if even only a few of the suggestions brought forth are tried out by station owners. As pointed out in the contest announcement, a great percentage of the amateurs operating stations either have given the interference problem little thought or are indifferent to the interference and inconvenience they may be causing to brother amateurs or professionals by unprofessional methods of operating.

Enough has been said of the necessity of proper tuning of the transmitter and we will confine our remarks to the handling of it after the proper adjustments have been made. In the first place before attempting to do any telegraphing the student should know the code thoroughly, the practice work should be done on a buzzer set and continued until there is no hesitation in making any character desired. The spacing between letters and between words is very important. If the student will bear in mind that he is in fact writing when he telegraphs and strives to make his characters spaced exactly as they would appear in writing or in print, it will result in fewer twenty-eight letter words at the receiving station. The study of the proper spacing is as important to the beginner in telegraphy as is the study of tempo to the beginner in music. Until the student is able to take a newspaper and send a hundred or two hundred words without hesitation or stumbling and with uniform spacing between words he should not attempt to turn loose his skill upon the much abused ether. I have been chuckling lately when I see articles in the newspapers and magazines referring to strange signals undecipherable being heard and the possibility of their being signals from Mars. Confidentially, I feel sure that they are caused by some of the new crop of amateurs who reverse the process and learn the code last. Even after learning the code it is an excellent plan to do but little sending and much listening. This is the best way, too, in which to attain efficiency in receiving. Pick out some station which operates in a short business-like way and avoids saying or repeating the same thing over and over. Study his style of handling messages or conversation and note how he gets over the ground in comparison with the operator who insults your ability to receive by repeating numerous times.

Telegraphing is the same thing as carrying on a conversation by word of mouth providing always that the static or interference is not breaking it up, and numerous repetitions or lengthy explanations are as unnecessary there as in conversation by word of mouth. The international abbreviations used in handling traffic should be committed to memory, at least the ones in most common use, so that the meaning of each will be recognized immediately upon hearing it. A copy of this list should be posted in a convenient place also, so that a glance will be sufficient to read any abbreviation heard and not recognized. If this plan is followed out, it will be but a short time before the entire list is committed to memory.

It is not necessary that you do some transmitting every time you sit down to the apparatus either. Make it a practice to listen for at least five minutes after sitting in before you do any sending. This will give you an idea of what the conditions are like, and if the air is already crowded there is little use in getting in yourself and adding to the confusion. Just what idea underlies the practice of some stations calling others frantically and insistently only to say "Good evening, how do you get me," when they receive an answer, I am unable to say, but note that it is common practice. It would seem that if there is nothing more important to transmit it would not justify the interference and hard feeling caused. If the need of practice is felt, why not do it upon the buzzer set instead of turning it loose upon the heads of those engaged in trying to get through legitimate information.

When sending messages, use the regulation form. This will help the operator on the receiving end, as he is probably expecting that you will do this, and the use of Bohemian methods will probably decide him that he will see less of you until you learn something about the game. The old timers especially dislike to work with revolutionary newcomers and if you wish to stand in with them and become one of the gang with a standing, copy their style and graduate from the ranks of those responsible for the invention of the sandwich and the stove cover.

Avoid the long call. A half dozen times is as good as a million if the other fellow is not getting you, and if he is getting you, one is sufficient. In signing your own station-call the same advice applies. If he is getting you, once or twice is enough. If he is not getting you a million repetitions do no good. Above all do not be one of the expert alibi artists. If you fail to get what is sent you ask for repetition and stop there. An explanation comprising two hundred words of why you did not get the twenty-five words sent you is uncalled for and of no interest to the operator at the other end. The only thing of interest to him is the fact that you wish him to repeat. This last applies not only to amateurs but to a great many operators earning their livelihood as such. They waste their own time and others by going into lengthy explanations as to why they are asking for repetition, sending seventy or eighty words of this useless stuff when the message missed is possibly of only twelve or fifteen words and could be sent over a half dozen times while they are establishing an alibi.

If you know that your speed in receiving is limited to about fifteen words per minute, you invite trouble by sending to another station at a rate of twenty-five words per minute for the reason that in all probability he will answer you at the same rate of speed and you will then be called upon to exercise your ingenuity in establishing an alibi, which an incredulous and contemptuous operator at the other end clearly sees through. Try always to make good copy, and follow the professional form of writing messages; that is, place the message number, operator's signs, check, date, address, etc., on the sheet in the same manner as is done in professional work. It is bad practice also to write too close behind the sender for the

(*Continued on page* 41)

Operating Suggestions for the Radio Amateur by "Sparks"

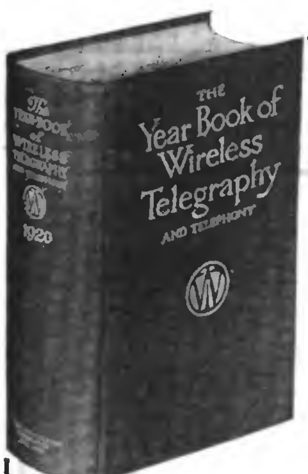
By H. S. Pyle

SECOND PRIZE, $5.00

WITH the present rapid growth of amateur radio telegraph stations, there being hundreds now where there were scores before the wartime closing, the time is fast approaching when the interference problem will grow to such a state that the handling of traffic at any distance on two hundred meters, will be absolutely impossible, whereas it is merely difficult now. The only method of side tracking such a condition of affairs, lies in efficient control of traffic and operators in such a way as to reduce interference to the minimum, and such regulation had much better come from the amateurs themselves, rather than from a disinterested government committee. Control *must* be had, and it is the purpose of the writer to endeavor to point out a few ways in which such control may be had, from experience gleaned from eleven years of amateur, commercial and government radio-telegraphy operating.

The chief cause of interference with long distance work on two hundred meters, seems to be from what is known as "local" interference; that is, interference within a few miles of the station attempting the distance work. Generally the cause is the use of too much power, by the interfering stations, for local work. The law distinctly states that—"the least amount of power necessary to effect reliable communication shall be used—" and amateurs are *not* exempt from existing laws. As a rule this use of surplus power is merely thoughtless, or the station may not be equipped with any method of reducing power. This should by all means be done, either by the use of impedance coils, or what is a far more satisfactory method, the use of a low power transmitting unit, designed only for short range local work. Several excellent articles describing such a set have appeared in recent issues of the WIRELESS AGE and any of these, if operated on a shorter wave than two hundred meters, will make an ideal local transmitter, with non-interfering characteristics. The use of a shorter wave length than two hundred meters, has not been as fully emphasized as it should be in the amateur world.

It is of great advantage to commercial and naval stations to be provided with a means of changing their wave length and no up-to-date installation will be found without some such wave-changing device. If it is desirable to use an antenna of 160 or 180 meters natural wave length, the use of a shorter wave cannot be effected efficiently, but in local work, efficiency need not be the prime consideration as distance is not the object in view. In such cases, then, the series condenser is wholly feasible, and it is suggested that the amateur operator, particularly in cities where a large number of good stations are located, read up on series condensers and their proper usage, in one of the many excellent handbooks obtainable from the Wireless Press. A wave as low as one hundred meters will be very satisfactory for all communication with other stations in the same city, or even nearby neighboring cities. The Canadian amateur before the war, was restricted to fifty meters, yet their stations, while hanging up no real distance records, did good work on this wave. Use a wave at least twenty-five meters below two hundred, and as little power as necessary to "get across" and if you are sharply



tuned, as you should be, not nearly so many complaints of interference will be logged against you. It is a simple matter, should you want to talk over a fishing trip with your friend a few blocks away, to call him on two hundred meters, where he is very likely listening, and tell him to come down to a hundred and fifty and listen for you.

Leaving the question of wavelength and power, much can be done with the actual handling of the key—or rather not handling. First, be certain of what you are about to say, before you attempt to make it on the key. Don't just "ramble along" using a great deal of unnecessary words to say some simple thing. In this connection it cannot be too strongly urged, that the amateur operator become familiar with a large part of the Phillips code, which greatly simplifies and shortens transmission. Calling a station, seems for some operators, to be almost a rite. A common occurrence is the use of the attention sign three or four times before commencing a call, and following that with a long winded call for the station, "DE" several times and a long string composed of your own call letters—usually a couple of "AR'S," "K's" and anything else which may catch the operator's eye while his glance wanders over the code chart follows.

It is surprising how few amateurs, comparatively, know the correct forms for calling, acknowledging, answering and sending a message. This is a great cause of unnecessary interference. The conventional methods for each of these transmissions take into consideration the least number of parts necessary to intelligently communicate, eliminating all unnecessary signaling.

A further cut in the conventional call, which specifies three times for each group of call letters (station called and calling station, preceded by attention sign and separated by "DE") may be made by shortening the repetition of call letters, for nearby stations, putting in a short snappy call and then quitting. If the station called is there and not otherwise occupied he will answer such a call as readily as a long drawn one, which causes all listening operators to sit back in disgust and think of you as a "ham." It used to be possible to learn efficient methods of operating by listening to the old commercial and naval men handle business, but the commercials are no more and the navy has found it necessary or seen fit, to make almost all of their stations student training stations and nothing can be learned from them. In fact it is advisable not to pattern your transmission after that which you hear today, but by far the best method is to obtain a copy of the regulations now in force governing radio communication, which may be obtained from the Superintendent of Documents, Washington, D. C. These contain all the forms authorized for use and practice of them on a buzzer with actual message forms as reproduced in the book is the best possible training to carry into your actual operating.

One rule of the utmost importance is perhaps the most generally disregarded of them all. I refer to the provision for listening in before transmission. It is obvious that if a station is engaged with another, he cannot handle your message at the same time, and it should be the amateur's "religion" to listen a few moments before calling a station. He may be copying a station whom you cannot hear—wait long enough to make certain that he is free, then put in a short call. Remember, too, that local men may be copying long distance stuff unknown to you and you may break them up with some inquiry of a totally superfluous nature. If you are asked to stop sending in such a case, don't become grouchy—give the other man a chance. Try to get through with your local chatter by nine P. M. Almost every one can do this, and it is becoming generally recognized that the hours after that are for long distance work. Any amateur who persists in "chewing the rag" needlessly long after nine o'clock may soon find himself held in much scorn by other amateurs, which may result in more stringent action from a local club.

In closing, the whole "sermon" may be summed up in the well worn, but nevertheless suitable phrase: "Give the other fellow a chance."

Radio Amateur's Ten Commandments

By H. P. Roberts

THIRD PRIZE, $3.00

YE SHALL reap what ye sow.

2. Ye shall at all times "Listen In" before using that transmitting set of thine.

3. Transmit not for the purpose of hearing thy spark, unless thou connect not thine antenna.

4. A "Ham" will not enter into the kingdom of oscillation heaven, therefore be ye not a "Ham."

5. Write ye first upon a manuscript that which thou wish to transmit.

6. Ye shall keep a systematic record conscientiously, which shall be known as ye "Log."

7. Ye shall pound with thy fist clearly and distinctly without undue haste.

8. Ye shall at all times be courteous, remembering that some of the weaker sex, which God hath given us, do likewise understand that which thou sayeth.

9. Ye shall have thy transmitting set ready to instantly answer when thou art called, neither shalt thou depend upon thy memory, for it be mortal and subject to mistakes, wherefor shalt thou copy all messages of length.

10. Thou shalt transmit with proper form, waves and power prescribed by thy government.

Our text for today, brethren, is upon the ten commandments and is as follows:

Concerning commandment 1: If you wish consideration and lack of QRM, when you want to work long distances, give the same consideration to the other fellow when he wants it. If you continually "99" some other fellow, and think you own the air, you will be regarded as a ham-bug, and be treated so by others.

Concerning commandment 2: If you call a number on the telephone and the operator tells you the line is busy, you hang up and wait. When the radio circuit is "busy," just "hang up and wait" for your turn. You will in the long run get your message off quicker, for when the other fellow is through, he won't interfere with you.

Commandment 3 states that this "other fellow" is not at all interested in hearing your spark squeal test signals; he really is not in the least concerned with how clear your spark sounds, so why not just take off your antenna clip, when you want to "fuss" with it.

Commandment 4 warns you not to be a "ham," and you know you don't want to be one. If you can't copy 20 words a minute, and John Jones is always in the habit of sending at that rate, don't try to talk to John Jones; talk to Jack Smith, who can only send ten words himself, or get busy and practice your speed tests on a buzzer. Don't use the poor overworked ether, to learn the code on.

If you will heed commandment 5, and write on a blank, first, what you want to say, and how you want to say it, you will save much time in transmitting it, and also have a permanent record of what you did say to Jack Smith on the night of December 1, 1919, when "8XYZ" in Bingville, writes to you later, saying he heard your signals on that night, and wants a verification.

Commandment 6 tells you to try and operate your station as nearly as possible like a commercial station. Commercial operators must be efficient, and if the amateur will try to follow in their footsteps, they will be much better operators, and accomplish a good deal more.

Commandment 7 simply tells you to use "horse sense"; to take time enough to send each letter, each dot and dash, distinctly, and *not* to send so quickly and so haphazardly as to require repetition of your whole message, and loss of time. Again, follow in the footsteps of the commercial man, and listen to how he sends. He was once an amateur and he has simply had more practice and experience than you. For instance, watch how he sends his C's. Do you notice how he holds on to the first dash much longer than the second; That is not merely the operator's "fist," but it is his attempt at clearness, to make a distinction between the letter C, and two N's sent right together. He has many other little tricks which it will pay you to learn. Listen to them next time you hear him.

Commandment 8 advises you against losing your temper. We are all of us trying to coach the beginner along, and when he does get on the circuit, and is doing his best, and necessarily taking more time than you or I, just when you or I want to do some work ourselves, be a little patient. You and I were as bad or worse than he, at one time. *Be courteous—always.* You'll find it will get you much farther. Besides it may be some good looking young lady, trying to master the code, and then think how you'd feel if she looked you up in "Hoyle."

Commandment 9 gives us good advice. When you are ready to answer someone, and the "line" is OK, just remember that every other fellow also knows at that moment that the "line" is not busy, and he is liable to be getting ready to send, so don't throw your switch, and then start your rotary gap, and make other little adjustments before sending; while you're doing all this, some other fellow may have started sending, without your knowledge, for your switch is on "transmitting" side. Don't throw your antenna switch, unless you are all ready to hit the key, the instant it is thrown.

Commandment 10 is one we must follow. It is not optional. Uncle Sam requires us amateurs to use *not more than 200 meters.* Don't use 205. He requires us who are within five miles of a Government station to use not more than ½ kw. Don't use 17/32. He requires the rest of us to use not more than 1 kw. Don't use 1 1/10. Obey the law. Don't give the radio amateur a bad reputation. It reflects on us all, and when we want the Government to help us, we want to show that we have treated the Government square. Do you know that your government is giving you privileges far beyond the hopes of amateurs in other countries? *Be on the level!*

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Prize Contest Announcement

The subject for the new prize contest of our year-round series is:

"A FEW CAREFULLY THOUGHT OUT SUGGESTIONS CONCERNING THE DISTRIBUTION OF WAVE LENGTHS AND USE OF POWER FOR LOCAL, INTER-CITY AND LONG DISTANCE TRANSMISSION AND POSSIBLE METHODS OF ACCOMPLISHMENT."

Closing date, September 1, 1920.

Contestants are requested to submit articles at the earliest practicable date.

Prize Winning Articles Will Appear in the November Issue.

As a result of a long series of more or less formal inter-allied radio conferences and, more directly, as the result of the deliberations of a Wave Length Regulation Committee appointed by the Secretary of Commerce, it is very likely that ere long a new radio law will come into existence which fixes the range of wave lengths for amateur stations between 175 and 250 meters. It is to be noted that, generally, all spark stations will be held between 175 and 220 meters and that 220 meters to 250 meters is to be used strictly for undamped wave transmission and modulated undamped wave transmission.

Due to lack of appropriation, it has never been possible for our Department of Commerce to exercise strict control over amateur installations. As a result amateurs have, in the past, had a band of wave lengths equal or superior to that which is to be offered by the proposed law. Should this law be passed, it is very likely that it will be very much more rigidly enforced. Spark stations would then fall in a very much narrower band of wave lengths than has been the case. Interference, even with the present "free for all" arrangement has become a very difficult problem and will soon become a very much more difficult one. This has been apparent to a great many amateurs for a long time, and it is gratifying to note the keen interest which has been taken by amateurs everywhere in recent WIRELESS AGE *prize contests, which have directed amateur thought toward the limiting of interference by self regulation, self control and practice of a little unselfishness.*

PRIZE CONTEST CONDITIONS—Manuscripts on the subject announced above are judged by the Editors of THE WIRELESS AGE from the viewpoint of the ingeniousness of the idea presented, its practicability and general utility, originality, and clearness in the description. Literary ability is not needed, but neatness in manuscript and drawing is taken into account. Finished drawings are not required, sketches will do. The contest is open to everybody. The closing date is given in the above announcement. THE WIRELESS AGE will award the following prizes: First Prize, $10.00; Second Prize, $5.00; Third Prize, $3.00, *in addition to the regular space rates paid for technical articles.*

All manuscripts should be addressed to the Contest Editor of THE WIRELESS AGE

New License Tests

CHIEF Radio Inspector L. R. Krumm announces that after July 1st, applicants examined in his office for commercial radio operator's license will be tested in their transmitting ability in sending Continental Code.

Applicants for Commercial First Grade Operator's licenses will be required to send 100 satisfactory code characters in succession in a five-minute test at a 20-word-per-minute speed.

Applicants for Commercial Second Grade Operator's license will be required to send 60 satisfactory code characters in succession in a five-minute test at 12 words per minute speed.

The transmissions by the applicant will be received by the examiner and will also be graphically recorded on a tape recorder as a check against transmissions in case of doubt.

Radio schools training men who expect to take these examinations are requested to prepare their students for this transmitting test and include a test therein before they give the student the usual letter certifying that they have satisfactorily passed the course, and for which the applicant is allowed a 10% experience mark in this office. The transmitting test given the applicants will include characters, numbers and signals of all kinds used in the usual transmission. The conditions under which the applicant is tested are made as nearly similar to actual conditions as possible, the applicant hearing his own note in his receivers and otherwise working under no unusual conditions.

After July 1st, examinations for Commercial operator's licenses will be given on Mondays, Wednesdays and Fridays only, except on holidays. The examination is given at 9 A. M. in Room 603, Custom House, New York, and applicants should appear promptly with whatever documentary evidence they may have indicating their radio experience and training. Reservations for places should be made in advance as the facilities are limited and it is expected will be completely utilized on each day.

The Radio Club of Hartford, at its monthly meeting, decided that the first annual radio convention of southern New England would be held in Hartford. A committee was appointed by Vice President Edward L. Belknap, presiding, to decide upon the date of the convention and make all necessary arrangements. The committee, consisting of Hiram P. Maxim, chairman, Louis W. Batchelder, Walter B. Spencer, K. B. Warner and J. L. Belknap, will report at the next meeting.

David Moore of Farmington, a charter member of the club, was present at the meeting and told of his experiences as a ship's radio operator during a trip around the world, from which he has just returned. He left New York last October, going through the Panama canal and then to Japan,

the Philippines, Singapore, Java, Sumatra and the Cerebres Islands. He returned by the way of the Suez Canal, visiting Malta and Gibraltar.

At the recent meeting of the Lynn, Mass., section of the Essex County Radio Association, the following officers were elected: President, Roger Osborn; vice president, Harry L. Sawyer; treasurer, Herbert Young; secretary, Herbert I. Stickney; advisory board, Roger Osborn and Kendall Redfield.

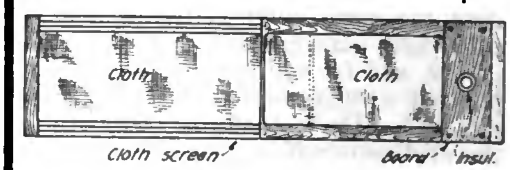
Plans were made to hold a dance soon, using music from a wireless receiver and loud speaking telephone to be demonstrated also at the coming General Electric field day.

F. Clifford Estey outlined the plans for the coming season and requested that all Lynners interested in radio work get in touch with the secretary. Mr. Estey is president of the Essex County Association and urged amateurs to send wireless messages of interest to newspapers and magazines to the secretary by wireless and also to keep in touch with members by wireless.

A Simple Lead-In

By Emil Otto

ALL amateurs living in the city have experienced the difficulty of constructing a suitable lead-in. The erection of the antenna seems to have been a simple problem when compared to the trouble of bringing the wire lead-in into the room. Landlords balk at having their walls and sashes drilled full of large holes and think they have gone far enough to allow the amateur to erect an antenna. Drilling window panes is a further task, as anyone will find if he tries.



After working some time with the problem, I came upon this solution: Upon a narrow screen such as is used for ventilation with a cloth netting instead of the usual wire, fasten a small board at one end with wood screws and drill a large hole for your entrance insulation. For insulation use a medium electrose tube for transmitters and a porcelain tube for reception. Hammer a small nail under the screen after it is in the window and it will not fall when the sash is lowered.

This screen has many advantages. It is cheap, portable, adjustable to any window, can cause no comment from the landlord, and above all, functions as it was intended and gives the operating room draughtless ventilation which is perhaps more important than the lead-in itself.

Operating Suggestions for the Radio Amateur

(*Continued from page* 32)

reason that if a mistake is made in sending it is written down and must then be erased. Writing a word or two behind the sender will result in better looking copy.

Avoid joining the ranks of the "QRA'S." They are already overcrowded. I refer to the operator who whenever he hears a strange call must open up and inquire "QRA O M." He is probably not O M to you anyway, being a stranger. Up to date call lists are to be had at a very low cost and reference to one of these is to be preferred to the QRA method.

Don't copy the style of the operator who affects a swing in his sending. It is odd of course, and attracts attention, but so do the guests at Mattewan and many other things which most people are shy of. *The best method of finding out what to avoid is to take note of what causes you to froth at the mouth when you are trying to get through something and are prevented by other stations interfering. Take careful note of what might have been eliminated by them and avoid just that yourself in the future.*

A word of warning in conclusion. The Government regulations are not strict and interference is bad. If conditions continue to grow worse, it is an unavoidable conclusion that the Government will take steps to improve matters and whatever form such legislation may take, it will surely place further restrictions upon amateur transmission. So, in justice to yourself and the many amateur station owners who strive to improve matters, get behind offending stations when you locate them, and if you cannot induce them to mend their ways by argument, apply a little pressure. Exclude them from your clubs and meetings; refuse to work with them, and if necessary explain matters to the government inspector and ask him to get behind the unmanageable one. In doing this, you will be doing it as much for yourself as anyone else. If you do nothing about it but let the newcomers play as they will, you also will be partly to blame, when stricter laws take from you some of the privileges now allowed.

Close Your Ground Switch

Radio amateurs should never fail to close the ground switch when leaving their apparatus. For an aerial attracts lightning and a thunder storm may come up when the operator is absent. If it does, and the lightning is led into the house, the amateur will find all his apparatus out of business, wrecked beyond repair, to say nothing of the responsibility of the house being set on fire.

Queries Answered

Answers will be given in this department to questions of subscribers, covering the full range of wireless subjects, but only those which relate to the technical phases of the art and which are of general interest to readers will be published here. The subscriber's name and address must be given in all letters and only one side of the paper written on; where diagrams are necessary they must be on a separate sheet and drawn with India ink. Not more than five questions of one reader can be answered in the same issue. To receive attention these rules must be rigidly observed.
Positively no questions answered by mail.

H. S., Brooklyn, N. Y.

You should be able to secure transil oil for use in your oil condenser from the Service Department of your electric lighting company.

* * *

F. P. B., Portland, Oregon.

Wiring diagram of a double rectifier and filter enabling the use of alternating current for plate supply of vacuum tubes, as well as dimensions of units used in this filter, has been printed in recent issues of this magazine. We hope to be able to publish in the near future an article giving constructional data to cover a step-up transformer 110 to 500 volts.

The current capacity of any rectifier tube is limited. If your rectifier tube will supply, say, 20 watts at 500 volts and your audion takes only 10 watts in the plate circuit, it will be possible for you to use two audions with one pair of rectifier tubes. If you use 4 audions you will need 4 rectifier tubes; 6 audions, 6 rectifier tubes, etc.

The more tubes used, the greater will the range be. Usually it is not the practice to use more than six tubes in multiple. Where tubes are connected in multiple, all grids are connected together, all plates together, and with the commercial type of vacuum tube, all filaments to the same lighting member with a separate rheostat for each filament.

Copper wire is best for an amateur aerial. Amateurs generally seem to use phosphor bronze. Phosphor bronze wire was originally used in wireless installation because of its great tensile strength—it being required that once an antenna had been erected, it would maintain its position permanently, regardless of heavy weather. The conductivity of phosphor bronze wire, however, is at best only about 75 per cent. of that of copper. In-as-much as the amateur is not particularly concerned about the continuity of operation of his outfit and in-as-much as his spans are usually short ones, copper wire is entirely satisfactory. For 200-meter work a "T" antenna is good, if you are so located that it is possible for you to tenna for general amateur use is the inverted L type, although it will usually be found that greater range is to be had with a vertical wire antenna, than with either of the above. For a given fundamental wavelength the vertical wire gives the greatest effective height.

* * *

R. D. McC., East Palestine, Ohio.

You may obtain condensers suitable for use in the super-heterodyne receiver as described in the February Wireless Age from the Adams Morgan Co., Montclair, N. J. Condensers supplied by this concern have a capacity of .01 mf. and an insulation resistance upward of 25,000,000 ohms.

You may use any type of detector tube as the detector in the above mentioned outfit. This also applies to the oscillator, but considerable care will need to be taken in the selection of the tubes for the amplifier for a noisy tube in the first stages of the amplifier will cause considerable trouble, due to the amplification of the noise as it passes from stage to stage.

* * *

M. M., Toronto, Canada.

N S N are the call letters of the U. S. S. Conner. W B F is the call of the Tropical Radio Company's station at Boston, Mass. We are unable to locate stations "P T A" and "V A V."

* * *

C. R. T., Scranton, Pennsylvania.

We presume that if you are going to build a lose coupler to operate on wave lengths between 1,000 and 25,000 meters, you expect to use a regenerative receiver of some type. The design of a receiving transformer for use with a straight detector is usually somewhat different both mechanically and electrically. If you will let us know just what type of outfit it is you have in mind, we will be glad to make suggestions as to its construction.

* * *

W. A. Clutier, Iowa.

If you intend to use the 250-ft. antenna for receiving only, the Radio Inspector will have no objections to make. If you should desire to do transmitting, it will be necessary for you to put up an antenna which is slightly under 100 feet in length.

* * *

Captain A. G. B., Edinburgh, Scotland.

With reference to the article by Mr. Charles R. Leutz in the January Issue which describes a detector and four-stage resistance coupled amplifier, we regret to say that the diagram, as well as our correction became somewhat mixed. The alteration as suggested in the April issue would short the "B" battery, as you have stated. It was Mr. Leutz's intention to use the same system of obtaining reaction as he described in his long wave receiver article printed in the September issue. As you have stated, and to use your words, the connection should be as follows:

"Delete connection of negative terminal of "B" battery direct to positive terminal of filament battery and substitute for it a connection from negative terminal of "B" battery to the terminal marked "wing."

The condenser referred to at top of page 26 of the January issue as C2 is that one which is placed in shunt to the plate resistance of the detector tube and therefore, as stated by Mr. Leutz, allows the high frequency oscillations to pass around the resistance, but, being generally of such small value as to force the audio frequency pulses through the resistance itself. We would be glad to learn of work which you are no doubt doing with circuits of this type.

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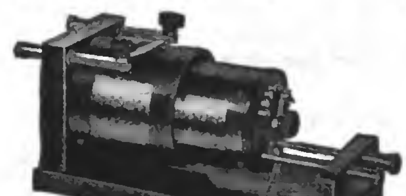

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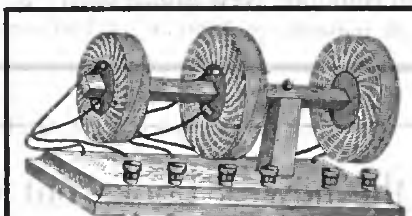

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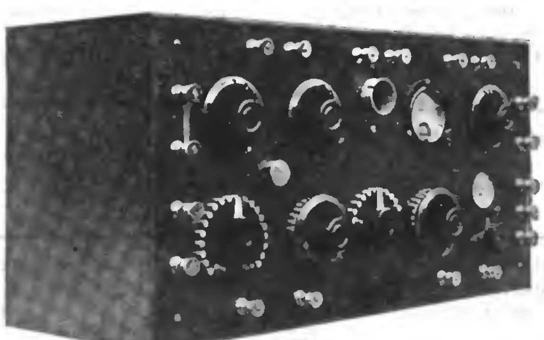

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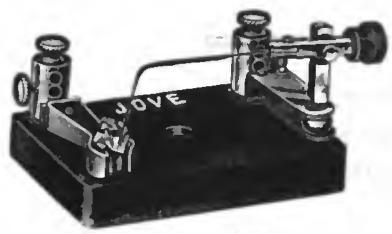

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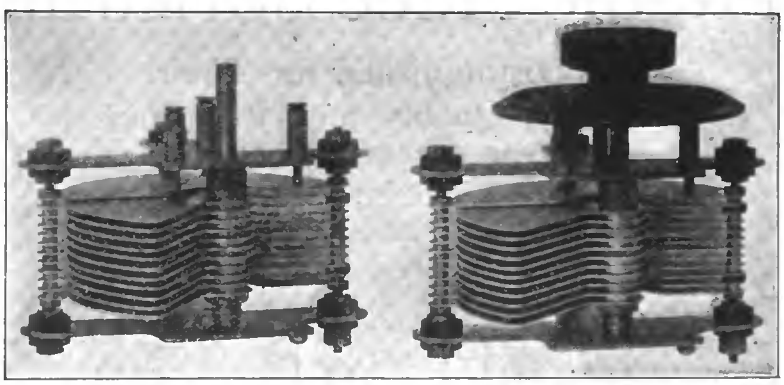

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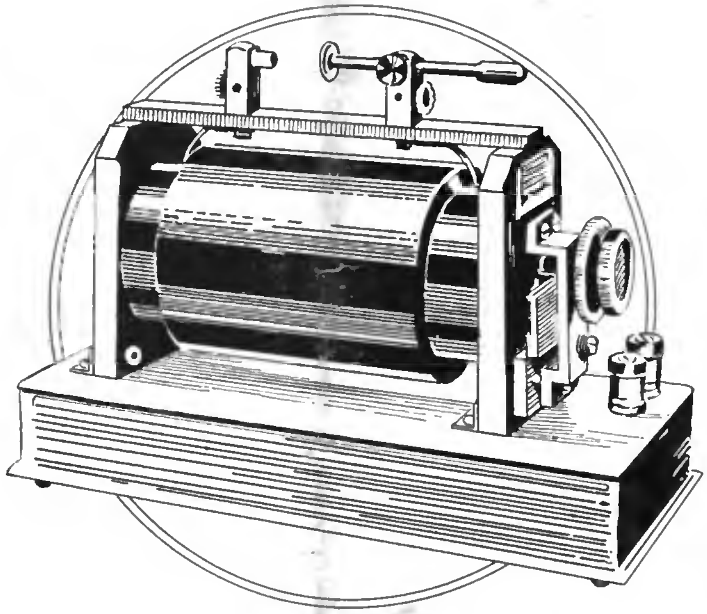

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