COMMERCIAL RADIO

SEPTEMBER
1935

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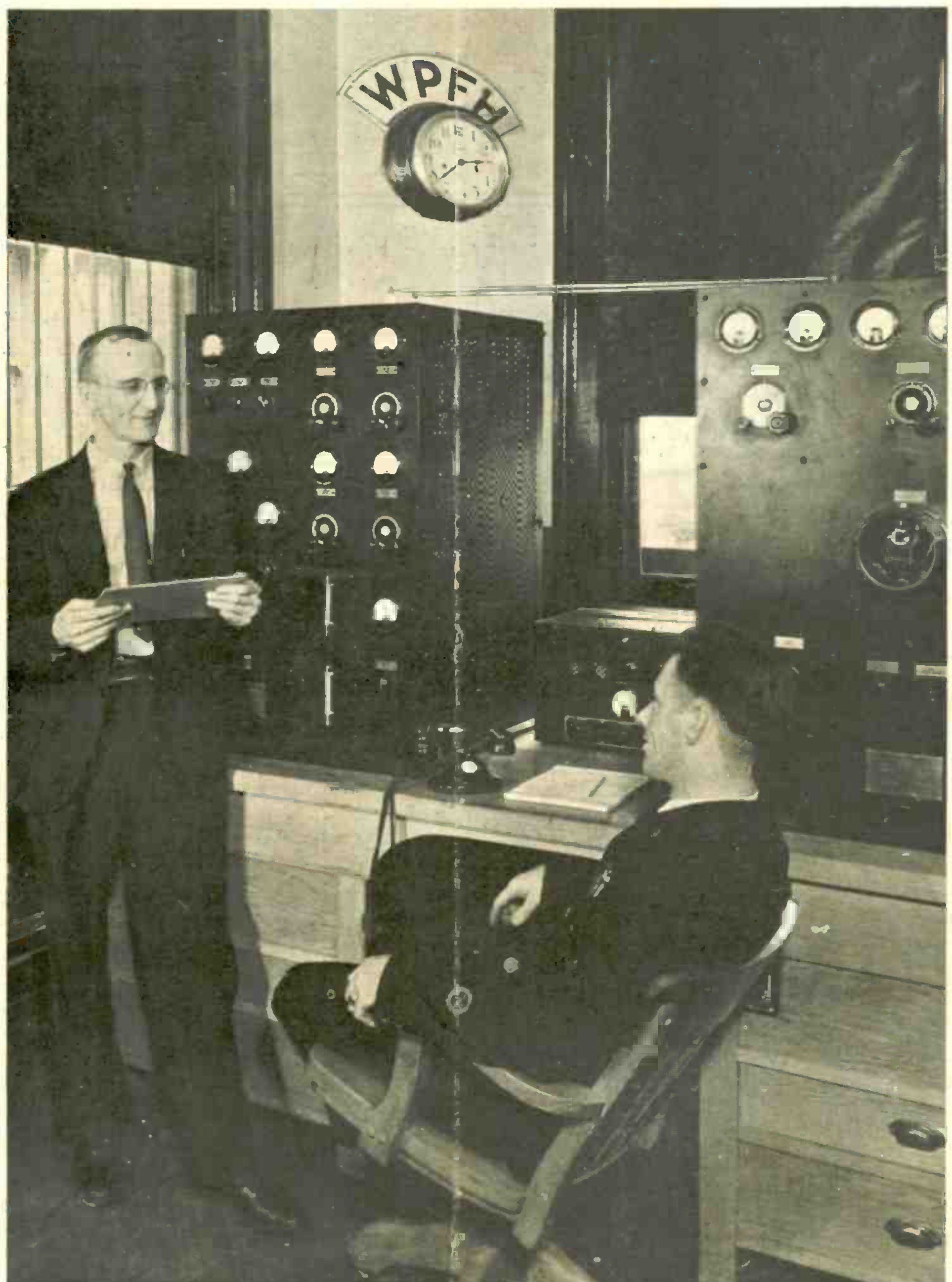

Communication
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Barkhausen
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Airway News

Assignments
News, Reviews
"Wrinkles"

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A MONTHLY JOURNAL DEVOTED TO THE COMMERCIAL RADIO & ALLIED FIELD

PUBLICATION OFFICE

NEW YORK

7 West 44th Street

Phone: VAnderbilt 3-9461

VOLUME IV NO. 10

THE "Red Herring" will not be downed. The first rumblings were the announced policy of "drilling from within." This means the policy of certain members of communistic leanings of joining as good members of units of The American Federation of Labor, with the vicious forethought of advancing such ideas and leaders in the organization.

The later voicings in Russia by the well known Pacific Coast shipping group leader Darey in Russia, followed by this government's protests to such actions in a friendly nation. The periodic official announcements through official channels of the A. F. of L. that they are familiar and fighting against communistic groups acting under their banner, require more than passing notice.

The radio man is organized. Under one group or another he has now taken his place. It is unfortunate that every action to gain ground is often branded communistic, but it is high time that every radio man look well about him. Especially should he be careful in picking, or voting for leaders. A careful attention to the working of any organization of which he is a member is a personal obligation. After all if an attempt by a minority to inject communism into an organization is tolerated by the lack of grouping of the majority, each individual member not holding such ideas is equally responsible for his share.

COMMERCIAL RADIO

(FORMERLY "C-Q")

The Only Magazine in America Devoted Entirely to the Commercial Radio Man

Contents for September, 1935

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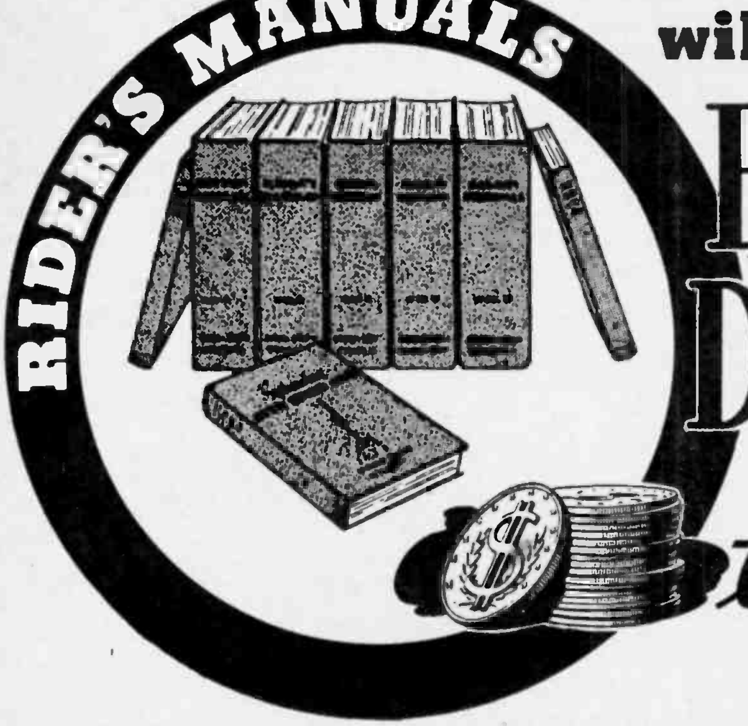

will help you HARVEST DOLLARS this FALL

LONG before the dew has vanished from the fields, the farmer is at work . . . the harness of his team creaking sharply in the dawn . . . the plow shearing through the earth . . . long furrows turning in a measured arch and fall of brown loam . . . unlocking the fields, opening the earth to the sun and the awakening rains of Spring—and Summer. . . . . The story of farming is as old as the Earth. But the present-day methods of farming are new—new as the Age of Science. Today farming is a business for profit. Harrowing, planting, cultivating, harvesting, marketing—each step is a matter of knowledge. No seed is sown without careful reference to experience and information in books.

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A New Development in Communication Engineering

IN WHICH A NEW DEVICE IS UTILIZED TO AFFORD THREE WAY DUPLEX OPERATION

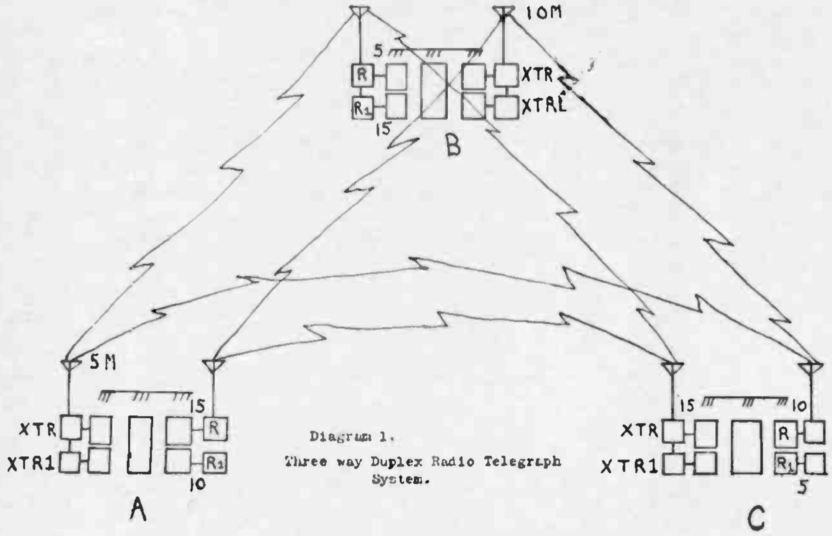


Diagram 1.
Three way Duplex Radio Telegraph System.

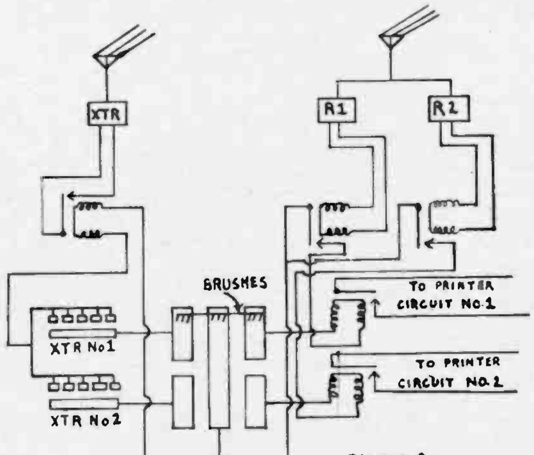


Diagram 2.
Schematic Diagram of one station in the Three Way Duplex.

A LEADING communication was faced with a major problem. Handling reports, from point to point, thru three key radio stations, they found their facilities overloaded by traffic. The annoying part was that the traffic really was not more than could be handled by steady transmission over the twenty-four hours each day, but due to the nature of the transmitted material such a schedule was impossible.

Handling communication is handling a highly perishable commodity. A paragraph scheduled to make the noon edition of a San Francisco paper is worthless if held up two hours because the Chicago transmitter is tied up handling important press to New York. Sports events, such as ball games, tie up transmission for hours on end and frequently are of only localized interest. If you have ever listened to the broadcast of a running report on a ball game you will realize that the time on the air actually used to convey pertinent information is only a small fraction of the total and that the same words, bereft of fill-in and given in continuity form at the end of the event, would t- up about one quarter of the tin. Of course, the news value would suffer proportionately.

The communications company felt that to stop transmission to New York in order to break in with material necessary for San Francisco was often not only impractical, but absolutely impossible. Too many times some receiving center had to get "the short 2nd," much to their disgust and dissatisfaction with the company's service. What was needed to solve the problem was either a complete additional set of transmitting and receiving channels, whose income would never justify the tremendous expense involved, or some means of splitting the present channels for simultaneous two communication. With wired channels this is feasible, with radio transmission it sounds impossible.

William A. Bruno, of the Bruno Laboratories, a transmission engineer, was called into consultation. His solution of the problem was simple and satisfactory, but before it can be set forth we must review briefly the method of handling press transmission for the benefit of those not acquainted with this branch of the art.

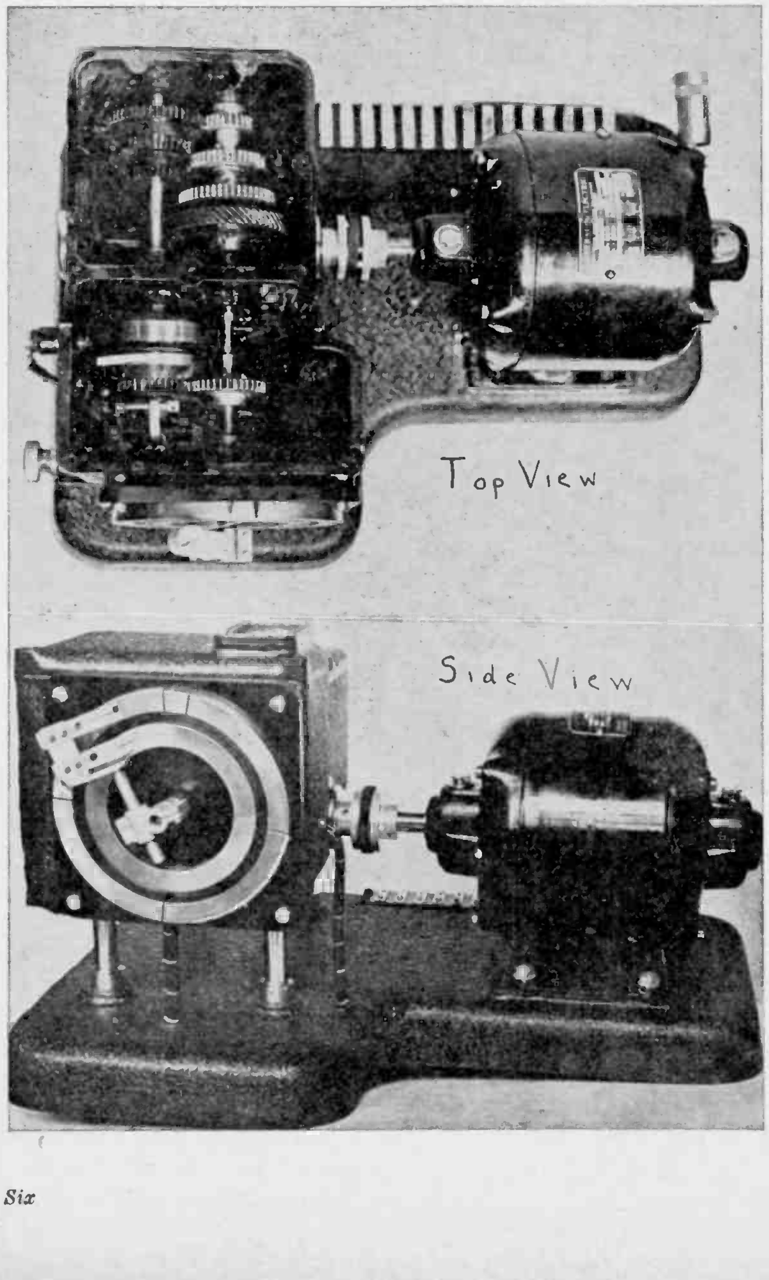
Material to be automatically transmitted is first "printed" by perforating a tape on a machine which looks something like a typewriter. This perforated tape is then fed into a sending machine which controls the "keying" of the transmitter. At the receiving end the signal is caused to perforate another tape which becomes a duplicate of the original. This second tape is fed into a decoding machine which translates it into a typewritten duplicate of the original message.

Mr. Bruno reasoned that as at many times the channel was tied up in transmission of material of a semi-continuous nature (that is, one having momentary pauses such as sports events previously referred to), advantage could be taken of these pauses to transmit news of other interest. He proposed a synchronous switching system to be operated at high speed and to be applied at both receiving and transmitting ends. The fundamentals are these: Suppose the Chicago transmitter to be in operation and sending two sets of material, one of interest to New York, the other to San Francisco. Two separate tape machines are feeding the transmitter. The operation of the tape transmitters is controlled by the synchronous switch which turns them on and off alternately many times per second.

In New York and San Francisco are located duplicate synchronous switches controlling the operation of the printing machines attached to their respective receivers. The New York synchronous switch allows its printer to operate only during that portion of the time that the sender handling New York material is feeding the Chicago transmitter. Similarly the San Francisco printer is only in operation during the time news intended for it is being transmitted. Switching takes place at the rate of 240 switches per minute. In this way two complete channels are available and a great percentage of "waste time" eliminated. Of course, any number of desired channels could be made available in the same manner.

The apparatus developed by the Bruno Laboratories to answer this purpose is illustrated in the photographs. It consists of a rotary switch arm which contacts a number of segments in turn. One segment for each desired channel plus one comparatively small segment used for synchronization. The switch controlling the transmitting type machines rotates continuously. Each time it passes the synchronizing segment it causes the transmitter to send a synchronizing pulse. At the receiving end, the switch is arranged to make one complete revolution and then stop on the synchronizing segment until released from this position by the incoming synchronizing pulse. In this way it is impossible for the two machines to get out of step as they are automatically re-synchronized at each revolution.

Diagrams 1 and 2 illustrate how a four segment synchronous switching system can be used to give two-way communication between any and all of three points. Diagram 2 shows the installation at the individual station. It is self explanatory when studied in conjunction with Diagram 1. The segments have been developed in order to facilitate interpretation of the schematic. The solid center bar representing the switch arm which in this instance is constructed in such a way as to make the contact with two segments at a time. It should be noted that there is no idle time, all transmitters and receivers working full time.



HERE AND THERE

SAN FRANCISCO, CAL.—The Maritime Federation composed of all marine groups on the West Coast was asked to vote on the British Columbia cargo plan recently as a basis of operation.

NEW YORK, N. Y.—A war against elimination of noise was declared. This will probably spread to other parts of the country. Sound measurement instruments on radio lines described in our last issue are utilized with the decibel as a measurement unit of sound.

CAMDEN, N. J.—Interest aroused by the three months ship yard strike of the employees of the New York Shipbuilding Corp. bring to mind the October 1, 1928, announcement of the American Brown Boveri Electric Corp. that from that time on a completely owned subsidiary under this name would take over all existing ship contracts of the American Brown Boveri. American Brown Boveri has since been taken over by Allis Chalmers. Work on seven naval vessels have been delayed on account of the strike.

DETROIT, MICH.—A radio device is used to transmit a musical note of definite pitch to a lightship in the harbor. The transmitted signal starts a generator on the lightship to supply the radio beacon, and an air compressor to keep the fog signal in operation. The Eleventh Lighthouse District developed the equipment, and no one is regularly on duty on the lightship. It is said other units will be so equipped if this one is successful.

LONDON, ENGLAND.— William Clive Bridgeman, better known as Viscount Bridgeman, head of the British Broadcasting Corporation, died in London, August 14th.

NEW YORK, N. Y.—Wired Radio, Inc., subsidiary of The North American Company, is again trying out radio over lighting wire circuits in Ohio, supplied to customers of their operating company there on a rental basis—no advertising announcement of any kind is allowed.

LOS ANGELES, CAL.—The RCA Communications, Inc. have opened up a Los Angeles office. This now gives them offices in Baltimore, Boston, Chicago, Detroit, Los Angeles, New Orleans, New York, Philadelphia, San Francisco, Seattle, and Washington, D. C.

WASHINGTON, D. C.—Another attempt is to be made to put through Congress at the next session a ship subsidy bill. The last session had little success in bringing the different interests concerned to an agreement. President Roosevelt is known to be for a subsidy, but has ideas of his own along what lines this should be.

Broadcast Station News

By WILLIAM D. KELLY

THE gigantic, stupendous, colossal Third Annual Outing of the I. R. C. was held Sunday, July 28th, at Solmson's-on-the-Severn. Members of the club and their friends met at the studios of WCAO. After a tour of the studios and transmitter there, provisions were made for those who did not have automobiles with those who did, and the caravan proceeded onward to the Severn River with the honking of horns, some of the boys sending code on auto horns like a farmer at sea sending with his left foot. This all happened in Baltimore, you must remember. The I. R. C. is a club of Baltimore radio men from all branches of radio—broadcast, telegraph, public address men—all of these being represented at the outing. I. R. C. is Institute of Radio Conferees.

At the shore there was plenty of beer and eats and a good time was had by all. There was a base ball game, mouse race, tug of war, etc., but the biggest event of the day was a husband calling contest for the ladies. Much credit goes to Lt. Wm. E. Taylor and Charles Ellert, the entertainment committee. Well, that covers that.

Joe Rubin, radio telegrapher on the SS Carolyn, was married July 7th. Bon voyage, feller. On the sea that isn't always smooth and calm.

Paul Ruckert of WFBR Control Room celebrated a birthday August 5th with a big cake 'n everything. Paul treated himself to a Scott All-Wave Imperial, too.

Bob Briel is back in town after working as vacation relief at WJEJ in Hagerstown.

Gus Lynch is with EAT in Savannah, so 'tis said.

Morris Blum took the job as relief operator on the SS Dorchester during August.

Summers T. Carter is down in Spartansburg, S. C., at WSPA.

Norman O'Hearn, WFBR's vacation relief man, is an automobile salesman in his spare time. Wanna buy a car?

James Shultz, WCAO's chief, is sporting a new Ford automobile. There's gonna be a lot of new things up WCAO way soon—new transmitter 'n everything.

Amateur radio shows seem to be the thing nowadays. In Baltimore, three stations, WFBR, WBAL and WCAO, are broadcasting the same amateur show from one of Baltimore's local theaters.

Speaking of amateur shows—WCBM had a show called Amateur Night in Harlem—the show being picked up from one of Baltimore's colored theaters.

Harry Boone just blew into town and is going to take a trip on the SS Beach Maru for a little while.

From down Norfolk way comes word that Robert L. Kennedy left in July. His place was filled by John Carl Morgan.

Down at WTAR, J. L. Grether is the chief engineer and John C. Peffer is the chief operator at the transmitter, with Wm. L. Davis as transmitter operator and Charles R. Pattee in control operator.

Myril Harrison left WTAR recently and when last heard of was in New York City.

George A. Boisseau is pounding brass on the SS Clare.

On the City of Havre we find: Roy Bartels, chief; Forest Flander, second; and Baker, third opr.

The Baltimore Mail Line is carrying three operators now, so I am told.

George Brewer is the chief engineer up at WJEJ, Hagerstown, Md. Willard Betts is the assistant.

Sam Canter is the Sparks on the SS Millinocket.

Edward McDowell is down at WIOD, Miami, Fla.

Eddie Stover took a "Postman's Vacation"—took in all the radio stations he could find on his vacation.

Harry A. Mills is new man at WCAO coming to Baltimore from Cumberland. Harry says that he is going to move his family and W8DSO to Baltimore about October 1. W8DSO will be known in Baltimore as W3UO and has a power of 1 kw.

Martin Jones of WCAO is also sporting a new Ford auto.

Porter Houston and his brother Sammy down at WCBM are in training for announcer. Both have had a shot at it on the air recently—it's a long story.

FOREIGN PRESS

Reviewing the March of World Progress

Linguistic Transmissions from Italy

ROME: The "Duce" not only believes in modernity but "ne plus ultra" for his subjects' radio transmissions; hence, Italian news goes forth to all points of the compass in twelve different languages: English, French, German, Spanish, Italian, Hungarian, Greek, Bulgarian, Esperanto (the universal language), Arabic, Roumanian and Albanian.

Transmitters are located in Rome, Milan, Florence, Turin, Bolzano, Trieste, and Bari. Latter station broadcasts lessons in Italian for the edification of the neighborly Greeks and Albanians

Progress in Radio Communication

LONDON: In a paper published by Col. A. S. Angwin, which appeared in the Journal of Electrical Engineers, February 1935, tells of the technical progress made during the last two years. Briefly, Mr. Angwin says: At the beginning of 1932, the number of licensed listeners in Europe was nearly 14 millions, and two years later it was nearly 20 millions (see next item). In 1929 the total power used in broadcasting was 420 kilowatts, whilst 5 years later it was more than ten times greater. Now the average high-powered station consumes more than 2 million watts yearly; it is, therefore, important to use transmitters of high efficiency. The extended use of short-wave telegraph working in ships has enabled the British Post Office stations to communicate regularly with whaling boats in the Antarctic and in Eastern waters. Directive antennas have been erected at these stations covering all the main shipping routes of the world, and this has greatly improved services. Additional radio-telephone services from Great Britain to South Africa, Egypt and India have been opened up, while services to Japan, Shanghai, Kenya and Iceland are projected. By extension to circuits already existing, radio communication is now possible with nearly all South American states. The outstanding feature in radio research has been the intensive study with the help of the cathode-ray oscillograph on the propagation of waves in the ionosphere. The methods now in use indicate that the reflected signal from a single pulse incident on the ionosphere consists frequently of a doublet, the components of which are separated by a small time interval. The reflected components are apparently electrically polarized waves of opposite rotational sense.—Extracted "*Nature*," No. 3424, Vol. 135

More than 21,000,000 Receivers in Europe

PARIS: Statistics issued by the International Union of Radio-diffusion, in Geneva, and published by the French technical press, indicate a 19 per cent increase in the number of European broadcast receivers. The report states that in 1933 there were over 17 million receivers, while today the figure is well over 21,000,000.

Below are tabulated comparative figures which indicate the number of receivers per 1000 inhabitants:

Denmark	160.00—1000
Gr. Britain	147.25—1000
Sweden	118.03—1000
Holland	108.96—1000
Switzerland	97.75—1000
Germany	94.22—1000
Iceland	90.00—1000
Austria	78.00—1000
Belgium	73.52—1000
Danzig	63.90—1000
Norway	54.85—1000
Czechoslovakia	47.10—1000
Luxembourg	45.83—1000
France	41.97—1000
Hungary	39.15—1000
Italy	10.08—1000
Spain	8.90—1000
Roumania	5.49—1000
Bulgaria	1.48—1000
Greece	.05—1000

On the continent, Great Britain has approximately 18 million receivers, Germany 6 million, and France 2 million. In the United States there are better than 20 million sets which barely eclipses the European total.

Television in Germany

BERLIN: During the last few months the German Post Office authorities have been giving public demonstrations of the progress made on television apparatus. Reports indicate that the German public is not yet ready to accept television as a commercial product. Two reasons are given for this reluctancy: first, the high cost of television receivers (200 to 1600 dollars); and second, loss of detail in reproduction. Of course, development continues, but until such times as price, incongruous distortions, fogging, optical lattice phenomena, and distortion are eliminated, television will remain as one of the scientific wonders of this electrical age.

An article in a German paper "*Elektrische Nachrichten Technik*" says: that Germany proposes national coverage by installing a group of 5:7 meter transmitters having output powers from 2 to 20 kilowatts. By selecting the best geographical sites for transmitters, a field strength of 1 millivolt per meter is planned. Transmissions will be of the 180 line type, 25 scannings per minute. Band width allocated will be 2,400 kilocycles, practically all stations will be synchronized. At the receiver a heterodyne oscillator will be employed for simultaneously receiving both frequencies.

South American 50KW Transmitter

RIO de JANIERO: The great South American newspaper "*Jornal de Brasil*," (Radio TUPY) will inaugurate amidst neo-Brazilian pomp and beautiful senoritas its new 50 Kilowatt transmitter, broadcasting on 325 meters. Preliminary tests made by installators of the new equipment, which is of American and British manufacture, indicate that the entire country will be amply served by the super-power station. The immensity of the signal coverage can be visualized by taking into account that the area of Brazil is very much greater than that of the United States. Unfortunately, more than 90 per cent of the inhabitants of Brazil are illiterates; hence, broadcasting in that country in a grandiose style requires a plenty of courage and initiative. Incidentally, there is a dearth of radio receivers outside of the country's five key cities; one is not surprised to find no sets of any description in some well-populated regions.—Scarcity of money, compatible with the low I. Q. are factors which prevent sales of receivers.

Laws and Restrictions in Cuba

HAVANA: An ultimatum has been issued by Nicholas G. de Mendoza, Radio Commissioner, that all transmitters located within urban areas having powers of 250 watts or over must either reduce power by August 31st or have their permits revoked. A report from an associate of the Secretary of Communications states that this new ruling will clear up present congested conditions on the air.

A new law which was signed on the 2nd of July, under the revised Cuban Radio Code, states: that no electrical transcriptions characterizing things Cuban, such as music, song or composition may be broadcast. All other types of recordings suffering no prohibition.

AUSTIN Y. TUEL DIES

Austin Y. Tuel, vice president and general manager of the Mackay Radio and Telegraph Company who had been in radio since 1909, when he was connected with the United Wireless Company, died in New York City on August 27th.

Mr. Tuel had been a telegraph operator, and early went into wireless. He was for a long time in charge of the Federal Telegraph Company's San Francisco station in the early days. During the war in his capacity of radio man he served as lieutenant with the navy. He later returned to Federal, and continued on with Mackay. Mr. Tuel was one of the pioneers who became a rapid sender of code and set a mark that was hard to get near, averaging close to fifty words a minute.

RANDOM NOTES

R. S. Polk is holding down his job of chief of the Santa Rita of the Grace Line.

George Fitzsimmons, on the S. S. George Washington, of the Old Dominion, is doing a nice job as chief.

Roy Hester Roberson (we put in the Hester so there will be no confusion of identity) is running on the Rosa Queen down off the South American Coast for the Grace Line.

Steve Kovacs is looking for a lift to dear old Budapest. "I must see it again," says Steve.

Alex Vadas is in Steve's heart's desire—summering in Hodmezovasarhaly, Hungary. Sometimes it's whistled and sometimes it's sung.

Richard Golden, up Boston way, is doing well these days. "Boston is a good spot for me," says Dick.

J. E. Brockway, well known old timer on the West Coast, is now in San Francisco, working on a Diesel Engine project. Say, J. E., when do you ship again?

Karl Baarslag, well known author of "S O S to the Rescue," is just taking it easy working twenty-five hours a day, but it won't be long so Karl says until we will have some nice reading matter from him for COMMERCIAL RADIO. In fact you can look forward to seeing it in the next issue.

Brother Delaney has taken out a boat for Mackay, and is looking much "cheer up" these days. Good luck, Jim, and may your boats always come in.

Forms for Making Applications

FCC FORM NO.:

301—Application for Radio Broadcast Station Construction Permit or Modification Thereof.

302—Application for Radio Broadcast Station License.

303—Application for Renewal of Radio Broadcast Station License.

304—Application for Modification of Radio Broadcast Station License.

305—Application for Authorization to Install Automatic Frequency Control.

306—Application to Determine Operating Power of Broadcasting Station by Direct Measurement of Antenna Power.

307—Application for Radio Broadcast Station Special Experimental Authorization or Extension Thereof.

308—Application for Permit to Locate, Maintain, or Use Studio or Apparatus for Production of Programs to be Transmitted or Delivered to Foreign Radio Stations.

401—Application for Radio Station Construction Permit (Other than Broadcasting).

402—Application for Modification of Radio Station Construction Permit (Other than Broadcasting).

403—Application for Radio Station License (Other than Broadcasting).

404—Application for (New) or (Modification of) Aircraft Radio Station License.

405—Application for Renewal of Radio Station License (Other than Broadcasting).

407—Application for Modification of Radio Station License (Other than Broadcasting).

410—Application for Experimental Broadcast Station Construction Permit or Modification Thereof (for the frequencies 1530, 1550, and 1570 kilocycles only).

411—Application for Experimental Broadcast Station License.

501—Application for Ship Radio Station License.

602—Application for Amateur Station License (under Special Provision of Rule 366).

610—Application for (New, Renewal, Modification, Duplicate, or Replacement) Amateur Radio Station and Operators License.

701—Application for Additional Time to Construct Radio Station.

702—Application for Consent to Assignment of Radio Station Construction Permit or License.

703—Application for Consent to Transfer of Control of Corporation Holding Construction Permit or Station License.

756—Application for Radio Operator's License.

MULTIVIBRATORS

by

BERNARD EPHRAIM, E.E.

Controlling the Multivibrator—Unsymmetrical Systems Phenomena of Frequency Demultiplication

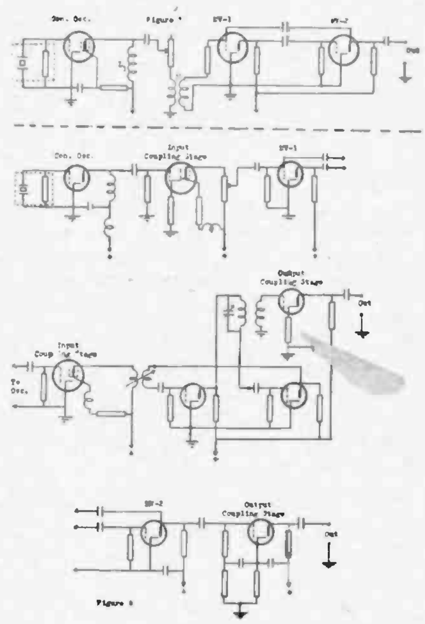
IN FOUR PARTS—PART 2

Controlling the System

IN reviewing the theory and circuital function of the multivibrator, it is obvious that no precautions have been taken into consideration to stabilize the systems against variations in plate, filament, or heater supply voltages, or changes in the circuit constants. If remedial measures are not taken to rectify the instrument against these transitional effects, small frequency excursions will occur in the system making the multivibrator of little use in measurements where stability of frequency is of prime importance. Fortunately, any spurious effects may be cancelled out by simply controlling the *time of relaxation* thru synchronization with energy supplied by an external frequency standard. Under such external influence, the stability of the multivibrators' oscillatory system depends upon the accuracy and operating parameters of the controlling agent, and not upon any other influence except those which tend to either impair the precision of the standard or alter the relaxation time or circuit constants of the device. A scheme by which the multivibrator is being controlled by an external frequency is shown in Figure 7.

Primary and Secondary Frequency-Control Standards

Oscillators used for controlling the multivibrator may be classed as either primary or secondary control-frequency standards. A primary standard, according to late engineering bulletins of the General Radio Company, is a standard known to keep its frequency accurate to better than one part in a million (0.0001 per cent). It is unquestionable that this is certainly high precision and implies a much higher degree of accuracy than is generally sought. A secondary standard, while not quite as accurate as a primary standard, may include any calibrated frequency-measuring device whose accuracy can be determined by direct or indirect comparison with a known accurate or better standard. It is common for secondary standards of the crystal-controlled type to continuously maintain a frequency accurate to within 20 parts in a million (0.002 per cent). Other types of frequency standards using stabilized oscillators ofttimes can maintain accuracies comparable to that of a primary standard for short periods of time. The period during which ordinary oscillators may remain stable depends principally upon the operating parameters of the circuits. Hence, for work requiring continuous use of a highly accurate frequency, a primary standard would be the instrument to use; where lesser accuracy can be tolerated, the secondary standard is the ideal instrument. On the other hand, if an ordinary oscillator is employed as a temporary standard, and has been carefully constructed to minimize frequency variations, it is possible to obtain frequencies of high precision for short periods of time. These frequencies will have sufficient stability to be satisfactory for practically all laboratory measurements.



There are numerous factors which enter into the design of an oscillator of high stability, that a discourse on this subject is outside the scope of this paper. It matters little, however, what type of oscillator is employed to control the multivibrator so long as it is *lightly loaded.*[8] It is paramount that the frequency be highly stable during frequency measurements, standardization, monitoring or calibration work. If attendant precautions are not taken into consideration, the oscillator frequency will deviate and the multivibrator frequency will change accordingly causing measurements taken at the time to be in error.

Coupling the Multivibrator to the Control Standard

In properly controlling the multivibrator, success lies in the type of coil used to couple the controlling frequency to the system. If the inductance of the coil is not of the proper value, oscillations generated in the multivibrator may react back and cause disturbances in the circuit of the control oscillator. The details entering into the design are given herewith:

The loading inductance designated in the circuit wiring diagrams as L-1 may be either a honey-comb, duo-lateral, or universal wound coil. It is essential that the coil have such an inductive reactance at the control frequency that the amplitude of the voltage in the coil is smaller than that of the oscillations generated in the main oscillatory circuit. In other words, the resonant frequency of the coil MUST be above the fundamental frequency and not equal to any harmonics produced in the circuit of the external oscillator. When this condition is obtained, no circuit interaction can exist between the natural frequency of L-1 and the main oscillatory circuit. The inductance of the coils shown in the various diagrams in these articles are of the optimum value for the frequencies given.

Input Coupling Methods

In coupling the multivibrator to the control oscillator, it is optional whether inductive or conductive coupling be employed. Whatever method is selected, it is very important that no load be imposed or reflected upon the oscillatory circuit of the controlling medium. This precaution must be closely observed in order to preclude the possibility of a frequency drift occurring in the system. The factors which may impair the stability of the controlling device are principally caused by changes in the multivibrators' load, coupling or circuit constants. These factors may be prevented from appreciably exerting their influence upon the controlling device by simply isolating the multivibrator from its source of control. This measure can be carried out by either electron-coupling the oscillator to the multivibrator, or by coupling through a shield-grid amplifier. Figure 8 shows some common methods of coupling.

Output Coupling Methods

The output of the multivibrator may be coupled by the same methods used in coupling to the input. Therefore, in the case of inductive coupling, a small coil of low inductance need only be inserted in *any* branch of the oscillatory system not forming a portion of the control circuit. By referring to Figure 8 will be seen diagrams of output coupling schemes. The output coil L-2 consists of a few turns of wire wound on any suitable form. If the inductance of the winding is made resonant to the fundamental or to an harmonic frequency of the system, and a variable condenser shunted

8 R. Gunn, "Stabilized oscillator systems," Proc. IRE, Vol. 18 No. 9, pg. 1560, 1930

in the circuit to assist tuning, the output signal strength can be multiplied several times. If purity of wave form is desired, a series tuned filter may be inserted into the output as a possible shunt for removing undesired frequencies.

It will be noted that an auxiliary amplifier stage has been added to the output as well as to the input stages of the multivibrator. These amplifier stages serve to isolate the multivibrator system from any external coupling influence which may tend to affect the frequency stability of the system. The amplifiers also augment the strength of the input-control and output frequencies.

Preface to the Unsymmetrical Multivibrator

To present a satisfactory explanation applicable to all types of unsymmetrical structures is a difficult problem. However, after an exhaustive search of engineering archives, three excellent explanations have been found. The first, by Messrs. L. M. Hull and J. K. Clapp[9] (US) deal with a multivibrator having only dissymmetrical plate resistors; one of these has a value 5 to 50 times greater than the other. Such an unsymmetrical relationship in the respective plate loads causes greater changes in plate current across the smaller resistor than across the larger. Thus, allowing the symmetrically loaded tube to function as a straight resistance-coupled amplifier, and the unsymmetrical tube to operate as an unstabilized amplifier over the complete tube characteristic from saturation to cut off. The Hull and Clapp system can be analyzed by practically the same methods used in studying the symmetrical multivibrator, except that it is necessary to consider the dissymmetry in the plate resistors, all other factors remaining substantially equal.

The second and third engineering papers of technical interest, written by F. Vecchiacchi (Italy) and R. N. Harmon[10] (US), respectively, describe a system in which the ratio of the condenser discharge time-constants are *not* equal, plate circuits, however, being symmetrical. A small difference exists between the Vecchiacchi and Harmon circuits, the latter containing a small inductance in the common plate lead. This inductance causes periodic interruptions to the relaxation frequency which stabilizes the operation of the system. Incidentally, this is one of the features of the Harmon patent. Upon a careful study of the aforementioned circuits, it has been found that both may be investigated by practically the same analyses. Fortunately, the technical material embodied in the Harmon patent contains a complete complement of analytical data freighted with such clarity that portions of this interesting paper have been abridged and appear below in the explanation.

Explanation of the Unsymmetrical Multivibrator

An unsymmetrical multivibrator circuit is shown in Figure 9. Attention is called to the time constants of the two condensers C_1, C_2 which are adjusted so that the ratio between them T_1/T_2 is, as nearly as possible, an integer. The adjustment merely consists of either making condenser C_1 considerably smaller than C_2 or by making resistors R_1 and R_1 considerably smaller than resistors R_3 and R_2, or both of these expedients.

GENERAL EXPLANATION: When the multivibrator is controlled by a voltage such as illustrated in Figure 10, curve "a", a voltage like that shown in curve "b" will be obtained in the output of tube VT-1 which gives rise, in the output transformer to a voltage represented by curve "c." It will be observed that curve "b" has a square wave-form

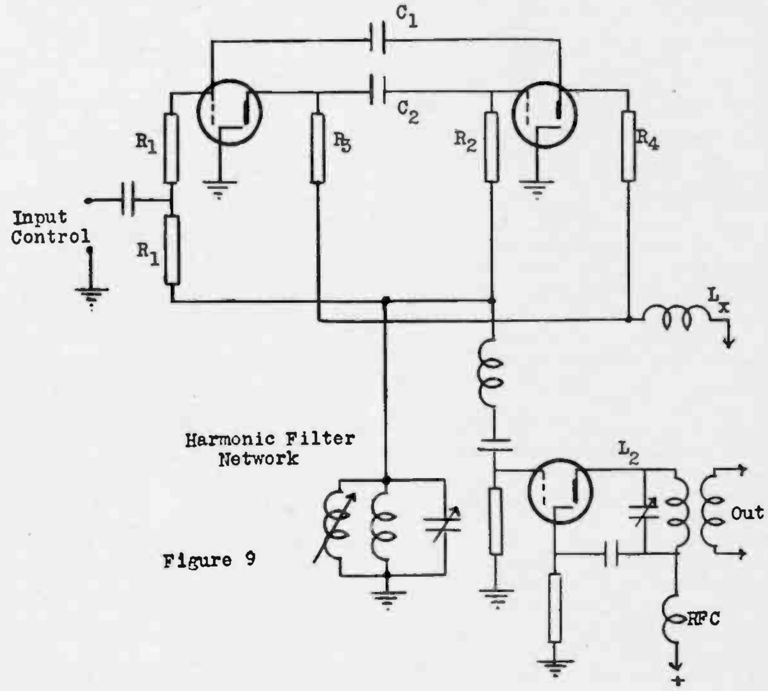


Figure 9

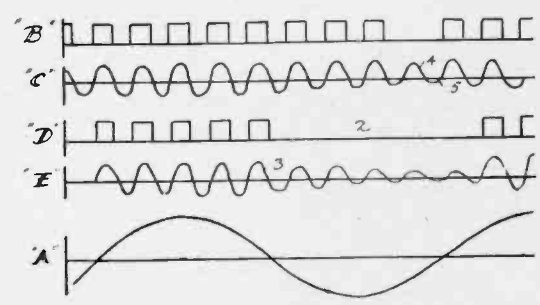


FIG. 10

of uniform character except that, at point 1, a single wave has been omitted.

The omission of a single cycle of the high-frequency, square-wave-form potential corresponds to the adjustment in which the time constant of condenser C_1 is nearly equal to the time constant of condenser C_2. If these constants are less nearly equal, the potential delivered by VT-1 will be similar to that shown in curve "d," and the period during which the square-wave-form pulses will not be delivered is greater, as illustrated at point 2. Curve "e" illustrates the potential which will be delivered by the output transformer under these circumstances. It will be observed that a decrement shown by curve "e" occurs, beginning at the beginning of the period represented at point 3 and continuing throughout this period. At the end of the period, the amplitude returns to its original value. A similar but much less conspicuous decrement is illustrated by curve "c" and may be observed by noticing the peak, see point 4, is not as high as its neighboring peaks and the trough, point 5, is not as deep as the neighboring troughs.

If a voltage is injected into the circuit corresponding to curve "c", the output wave-form will closely resemble curve "a." When this is done, the only readjustment of the constants of the apparatus required is in the output circuit which now must be changed to a low frequency.

The following results have been obtained experimentally: if the inductance of coil Lx is omitted from the circuit, a more critical adjustment of the condensers and resistors is required in order to produce the results described. The condition pending upon the multivibrator being under control. If the system is not controlled, and inductance Lx is omitted, the apparatus will give rise to a square-wave-form in the output of VT-1 which may be controlled, to some extent, by adjustment of the ratio between the time constants of the two condensers, but under these circumstances, the adjustment is exceedingly critical,

9 Hull & Clapp, Proc. IRE. Vol. 17, No. 2, pp 252, 1929

10 US. patent No. 1,936,789; assigned to the Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.

many harmonics will be present and the interruptions to high frequency, represented at points 1 and 2, will not occur.

When the controlling voltage and Lx is omitted, similar results may be obtained by inserting an inductor in the connection between resistor R_3 and the plate of VT-1 or between R_4 and the plate of VT-2. The results obtained are not very stable when the inductor is inserted at the points mentioned.

Analysis of Circuit Operations

The anaylsis about to be given here differs from that previously given on the symmetrical multivibrator, because the time constants of the condensers are unequal in the structure here proposed and are equal in the structure previously analyzed in these parts. There is a further difference which results from the presence of inductance.

Oscillographic observations show that tubes VT-1 and VT-2 are alternately conductive and non-conductive, because of the grid potential changing past the cut-off point. Curves which have been prepared from oscillographic observations are represented in Figure 11. Curve "f" represents the plate current through VT-2. Curve "g" represents the charge on condenser C_1. Curve "h" represents the potential on the grid of VT-1. Curve "i" represents the plate current through VT-1. Curve "j" represents the charge on condenser C_2. Curve "k" represents the grid potential in tube VT-2. Curve "L" represents the potential across Lx. The part of the curve above the zero axis represents the potentials directed upward in Lx. Curve "m" represents the control voltage.

Refer now to Figure 12. The moment at which the tube VT-2 changes from a conductive and approaches a non-conductive condition is represented by point 6 in curve "f" of Figure 11. As a consequence, although not all of the consequences, of the change of current thru VT-2, is that of the potential of the plate of the tube rises, because of the potential drop across R_4 which approaches zero. As the plate voltage on VT-2 increases, the condenser C_1 will receive a charge from battery 1 over the circuit 1, 2, 3, 4, 5, 6, 7 and return. The increase in the charge on C_1 is represented by the upward trend at point 7 of curve "g" of Figure 11. The charging current flows downward in R_1 as the diagram is drawn. Therefore the grid of VT-1 which is connected to the upper terminal of this resistor, is positive relative to the filament of the tube, which is connected to the lower end of said resistor. This is indicated by the fact that point 8 of curve "h" is above the line.

VT-1 becomes conductive because its grid is positive. At the same time, there is some current flow from the grid to the filament in this tube and, therefore, the charging circuit for C_1 includes the grid-filament path in VT-1 in parallel with R_1. The current drawn by the plate of VT-1 during this time is represented at point 9 of curve "i."

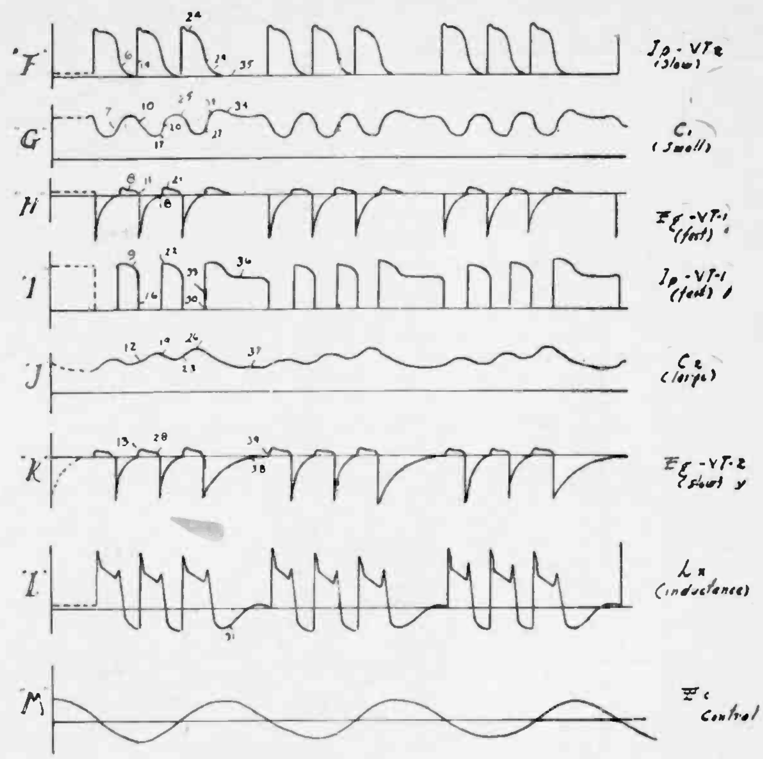
Condenser C_1 will continue to charge during the time fixed by its capacity and the resistance of the charging circuit. The conditions just described, namely, VT-2 non-conductive, VT-1 conductive, will continue until the charging of C_1 is completed.

When the condenser C_1 is completely charged, as indicated at point 10 of curve "g," no more current will flow in the charging circuit. The drop over R_1, therefore, becomes zero, and the potential of the grid of VT-1 will fall, as shown by point 11 of curve "h."

Even though the potential of the grid does not fall below the cut-off point for the tube, it falls enough to cause a diminution in current through VT-1. Diminution in this current causes an increase in the plate potential of VT-1. The increased potential is impressed upon condenser C_2 which begins to charge as shown at point 12 of curve "j."

That the condenser C_2 was, at this moment, either completely or partially discharged, is a consequence of the fact that VT-1 had been conductive during the period C_1 was charging. The discharge circuit for C_2 was thru VT-1 to ground and from the ground thru the elements 7, 6, and 8.

(Continued on Page 18)



After R. N. Harmon U.S. Pat # 1,936,789

FIG 11

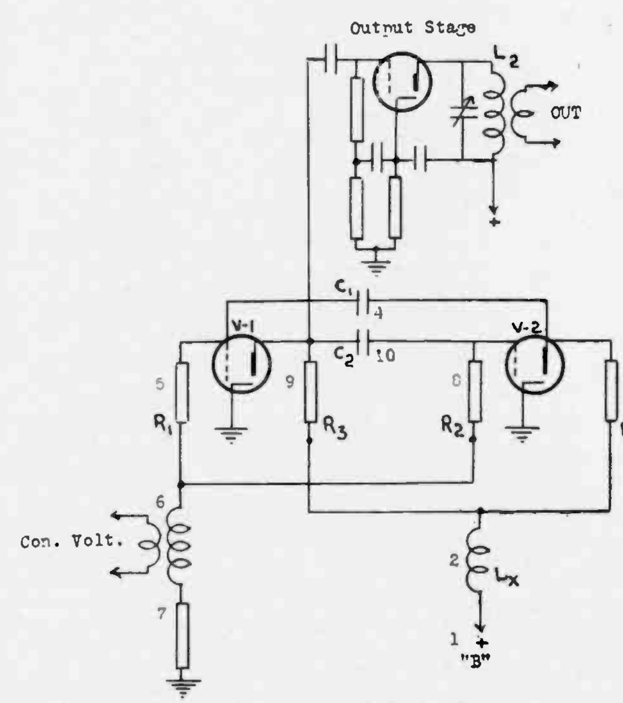


Figure 12—Unsymmetrical Structure of R. N. Harmon, U.S. Pat. 1,936,789 ***Constants of Parts:***

R_1—60,000 ohms
R_2—60,000 ohms
R_3—11,000 ohms
R_4—11,000 ohms
L_x—5 henries
C_1—.015 microfarads
C_2—.3 microfarads

DESIGNING THE MIDWEST ALL-WAVE 18

By WALTER SHIRK*

THE difficult designed problem encountered in developing the receiver having enormous range of 4½ meters to 2400 meters is without a doubt the oscillator. It is a very serious task to develop a circuit giving uniform oscillator voltage for the American broadcast band which covers only a tuning ratio of three to one frequency range. It is much more difficult to obtain a circuit that will cover the enormous range of 530 to 1. Both the oscillator and radio frequency circuits require special attention. In addition, the terrific losses encountered at sixty-five million cycles per second almost prevent even feeble oscillation. At these frequencies it is necessary to deliver very large amounts of energy to the grid of the mixer tube in order to produce proper heterodyne action.

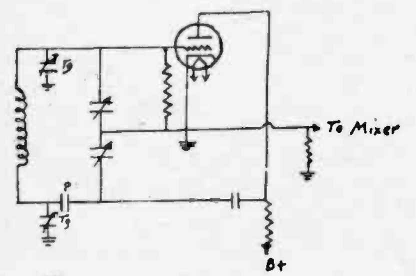


Fig. 1.

Colpitts Oscillator Circuit

The customary oscillator circuit containing a "tickler" coil in the plate circuit for feeding back energy to the grid circuit, fails to deliver sufficient feed-back to sustain oscillation unless the period of the plate circuit is very close to the period of the grid circuit; or unless the coupling is exceedingly tight. Both of these methods limit the tuning range of the grid circuit, either because of the exceedingly high distributed capacity introduced or because of the period of the primary, interfering with the tuning of the secondary.

A further difficulty encountered with the customary type oscillator circuit is the non-uniformity of the output thruout these higher frequency bands. It is noted that the output tends to decrease very rapidly at one end or the other regardless of what circuit is used. All of these difficulties can be solved by means of the "Colpitts" oscillator, provided that a two-gang condenser is used for tuning the coil, thus insuring uniformly increasing feed-back proportionate to the frequency. In this manner the losses are successfully overcome.

The "Colpitts" circuit is fundamentally a tapped condenser rather than a tapped coil as shown in Figure No. 1. The voltage generated across the coil is divided in inverse portion to the capacity of the condenser as shown.

In the event that one of these condensers is fixed the feed-back is not uniform, therefore, it is very desirable that the two condensers should be equal at all times, thus a two-gang condenser is re-

(Continued on Page 17)

*Midwest Radio Corp.

AIRWAY NEWS

HOW EASTERN HANDLES WEATHER REPORTS

AN octopus-like system of teletype lines and radio channels, tapping the 25 cities on the 3,755-mile Eastern Air Lines routes, is centered in the weather-operations office of the airline at Washington, D. C., comprising the elaborate new weather department which operates 24 hours of the day, out-guessing nature in all her angry moods.

The Air Mass Analysis System of weather forecasting, proved practical for airline operation only a few years ago on the Pacific Coast, has been instituted by Joseph George, chief meteorologist of Eastern Air Lines. In 1932 he collaborated with scientists of the California Institute of Technology in testing the method over a western airline.

The communications tentacles of the company weather bureau follow the three great air routes of Eastern Air Lines; New York to Miami, New York to New Orleans, and Chicago to Miami. Weather information is not only received by teletype and radio from the 15 states served by the airline, but two general and 46 trip forecasts are issued from the "octopus-like brain" during the 24 hours, or practically one every one-half hour.

In the general forecasts sent to every station at 9:30 a.m. and 9:30 p.m., the Eastern Air Lines Air Mass forecasts advise what trips will complete or cancel and where delays will occur before the weather clears. The special trip-forecasts are sent to pilots and dispatchers an hour before scheduled departures at the six major terminals so that a study can be made before any particular flight takes off.

Supplementing hourly reports from various eastern points, the United States Weather Bureau also supplies the Eastern Air Lines Weather Bureau with two general weather reports from the 250 major weather bureau stations as far north as Point Barrow, Alaska, Canadian stations, and 10 ships at sea in the Atlantic Ocean. These reports are received at 8:25 a.m. and 8:25 p.m.

The information received by the airline and also that disseminated, gives ceilings of clouds, visibility of stations and the airway, general conditions, such as rain, snow, haze, fog and type of cloud formations, temperature, dewpoint, wind direction and velocity and barometric pressure.

In connection with the new weather department, Eastern Air Lines has inaugurated scientific treatment of each of the 24 flights made during the 24 hours over its vast system. After collecting information on winds aloft, their speed, and general weather conditions, the weather department determines mathematically the correct altitude, course, and cruising speed for the pilot to use to reach his destination in the fastest time with the greatest comfort to passengers.

Monteagle, Tenn., Station

THE Monteagle Airway Station is on top of Cumberland Mountain, the highest point on the Chicago-Miami run, and is the midpoint between Chattanooga and Nashville. Since being commissioned in November 1930, the station has been in operation twenty-four hours a day. There are three operators or keepers assigned to this post and in addition to operating and maintaining the radio and teletype equipment and weather observing, they are required to keep up the grounds and station building and equipment in general.

The station has a marker type radio range transmitter that is used when ceiling and visibility are low and for answering calls from passing ships. Two radio receivers are used for ground to plane communication and for monitoring the Nashville Radio Range Transmitter. There is a tape teletypewriter on the Nashville-Atlanta line which is used for dispatches and to gather weather data to and from all stations on the line to be used by weather forecasters at the larger airports.

The three keepers are William A. Coleman, Dentis Milam and G. E. Knight. Mr. Coleman came to Monteagle in 1932 and is the keeper in charge. Mr. Milam came to Monteagle in the same year and Mr. Knight was transferred from Adairsville, Ga., about four months ago.

Monteagle is a summer colony popular with people from Nashville, Chattanooga and Atlanta. The elevation is 2000 feet and one sleeps under a blanket even in July. The station is in a beautiful location and can be seen to the left of the Chattanooga-Nashville highway just before starting the descent on the north side of the mountain.

NEW RADIO STATION IN SECOND DISTRICT

THE Second Air Navigation Division District of the Bureau of Air Commerce is opening or about to open eight new stations. These are located in the southeastern part of the United States in the following places: Vero Beach, West Palm Beach and Daytona Beach in Florida, Savannah and Brunswick in Georgia, Warrentown, North Carolina, and Lane and Beaufort, South Carolina.

Beaufort, Lane and Warrenton will be weather observing and teletype stations in all probability, and there will be a keeper and three assistants at each of these places. It is expected that the other stations will be larger and equipped with radio facilities and that an assistant radio operator and three juniors will be assigned to each of these radio stations.

There is some talk of a radio station for Florence, South Carolina, but the Office has not announced what the personnel would be for Florence.

The Barkhausen Oscillator

By F. B. LLEWELLYN

Member of Technical Staff; Bell Telephone Labs.

THE Barkhausen oscillator for ultra-high frequencies has been the subject of many complicated analyses. As with other developments, the history of its theory has gone through three stages starting with a simple but incomplete concept advancing through a more and more involved mathematical analysis, and finally yielding the important properties in simple enough form to be stated in everyday language.

The elementary concept upon which the explanation of the Barkhausen oscillator was originally based was that of an electron or group of electrons which danced back and forth through the opening, in a positively polarized grid. Among other things this concept did not show why the number of electrons going in opposite directions through the grid was not always the same. The mathematics which followed led in many cases into strange paths, but finally was placed on a sound basis. When this had been done it was found that the explanation could be made in a perfectly straightforward way, and that the original concept of the dancing electron contained only enough truth to delay and complicate the process of arriving at the correct answer.

Physically the Barkhausen oscillator consists of a filamentary cathode surrounded by a cylindrical grid and plate, as shown in Figure 1. The grid is operated at a positive potential, the plate is biased to a slightly negative potential, and a tuned circuited LC is usually connected between them.

Electrons starting out from the cathode are attracted by the positive grid, and move with increasing velocity in that direction. Many of the electrons hit the grid, and become of no further concern. Many others, however, pass between the grid wires without hitting them and move toward the plate with decreasing velocity, coming to rest just before reaching the negative plate and then starting back toward the grid again. As before, a given electron may hit the grid or may miss it again and continue on toward the cathode, when the cycle is repeated.

If the tube were not oscillating, the story would now be complete. A convenient way of seeing what causes the oscillations in the tube is to investigate what happens when a transient oscillation is produced in the LC circuit by some external means. If the forces produced on the moving electrons by this transient deliver energy to the electrons, the transient will die out; but if the electrons, having acquired kinetic energy from the grid battery, can oppose the forces set up by the transient and thus deliver energy to the circuit, the transient will persist or build up as a continuous oscillation instead of dying out.

In the absence of the transient, an electron starting from the filament moves in the direction of the force from the positive grid, and so draws energy from the grid battery. After passing through the grid wires, the electron moves against the force from the grid, thus returning energy to the grid battery. When it comes to rest in the grid-plate space, the entire amount of energy picked up in the cathode-grid space has been restored to the battery. During the return trip, the same sequence again occurs: the energy which was abstracted in moving toward the grid is restored in moving away from it. The net result is that energy is neither absorbed from nor delivered to the external circuit and batteries by such an electron. This fact is made graphically evident in Figure 2, where the force from the batteries which acts on the electron is plotted as ordinate while the distance the electron has moved from the cathode is taken as abscissa. The area under the curve consequently measures the work done on the electron during its trip across the tube: the positive work done between cathode and grid is just equal to the negative work done between the grid and the plate.

When the transient is introduced into the LC circuit, conditions are considerably changed. Superposed on the force diagrammed in Figure 2 is the force set up by the alternating grid potential. Since the latter force alternates the resultant forces acting on electrons which start out from the cathode at different times in the alternating-current cycle will be quite different. For purposes of illustration, it is sufficient to trace the history of two electrons only. One of these starts out just at the time when the alternating force begins acting in the same direction as the constant force of Figure 2. The other starts out a half cycle later, when the alternating force begins to oppose the constant force.

In the first case, the alternating force increases in intensity as the electron moves along, then decreases to zero, then reverses and opposes the motion, and finally completes the cycle by becoming positive again. If the electron passes through the grid mesh just before the alternating force returns to its first zero value, the action of the force upon it is as shown in Figure 3. At the instant the electron passes through the grid, of course, the direction of the force acting on the electron reverses, not because of any abrupt change in the grid potential, but because the grid is now located behind the electron instead of ahead of it. As the electron moves on toward the plate, however, the alternating force decreases to zero and then reverses. Thus during both halves of the cycle the force acts in the same direction as the electron is moving, and delivers energy to it, as can be checked by reference to the area under the curve in Figure 3. In other words, the transient in the external circuit has done work on this particular electron, and the electron, by taking energy away from the circuit, has produced a tendency for the transient to die out.

There is nothing in this behavior that gives encouragement to the maintenance of oscillations. The only consolation comes from noting that the electron is

Fig. 1—This general arrangement of tube elements and circuit is used in the production of Barkhausen oscillations

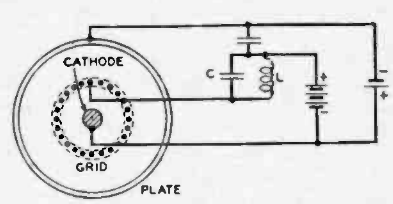
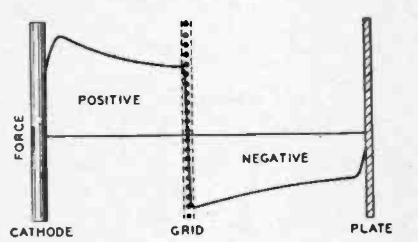


Fig. 2—When a constant is applied to the grid of a vacuum tube constructed as shown in Figure 1, the force exerted on the electron at various points in its trip across the tube is as shown by the curve. The work done on the electron is therefore measured by the area under the curve



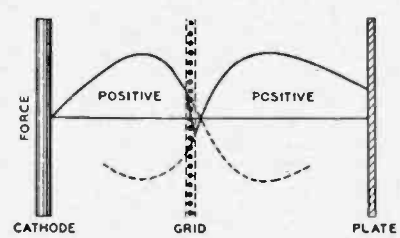


Fig. 3—Because the work done on an electron of the useless type by an alternating force is positive, the electron abstracts energy from the alternating-current transient

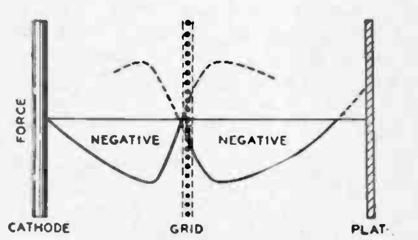


Fig. 4—With an alternating force, an electron of the useful type delivers energy to the transient, at the expense of the battery producing the constant force

(Continued on Page 17)

WITH THE TECHNICAL EDITOR

Contributions to these columns are invited from readers. They should be concise and may deal with technical articles published in previous issues, or other subjects of some general interest and professional importance. Statements made by writers do not necessarily carry the endorsement of this publication. Address all communications to the Technical Editor.

Upon the Propagation of Micro-Waves

Here is an interesting question excerpted from an article appearing in an Italian radio journal: How can ultra-short waves that were not reflected by the ionosphere be carried beyond the optical horizon?

The author of the above article, Mr. I. Gianfranceschi, answers this perplexing question by saying: "Transmission occurs by defraction and refraction; of the latter, the curvature of the upper atmosphere deflects the trajectory of the rays—similar to that of optical phenomena."—*E. Scientiarum Nuncio Radiophonico*, No. 24, July 27, 1933. (See also COMMERCIAL RADIO, W. Goodall, "The Ionosphere," Vol. IV, No. 6, pg. 9, 1935.

* * *

Note on Designing Noise Controls

The noise control which masquerades under the so-called name of "tone control" functions only to by-pass such frequencies that are not desirable in the output. Usually, noise frequencies are in the upper end of the spectrum and, their attenuation *sometimes* helps in clearing up QRM; more often the use of the device distorts all definitive qualities of reproduction. However, those wishing to properly design a noise control will find the following data of inestimable value.

A formula to represent the attenuation of any frequency above a standard auricular frequency of 16 cycles for use in designing a noise control is given below:

$$DB = 5 \text{ Log } \frac{(6.28\,CR)^2 + .0039}{(6.28\,CR)^2 + \frac{1}{f^2}}$$

Symbols: C, farads; R, resistance in ohms; f, loss frequency

If, for example, an optimum value of 150,000 ohms was given to R, and .01 microfarad to C, noise frequencies in the upper end of the spectrum would be greatly (not completely) attenuated; and conversely, if R had a low value, say 50,000 ohms, and C, 1 microfarad, noise frequencies from 5000 down to 3000 cycles would be completely suppressed. The response below 3000 cycles being augmented to a certain degree.—(See also COMMERCIAL RADIO, "Factors Affecting Sound Reproduction," Vol. III, No. 21, pg. 5, 1934.)

* * *

Release of Gas During Storage Battery Charging

(J. Lester Woodbridge, The Electric Storage Battery Co., Phila., Penn.) The conversion of lead sulphate ($PbSO_4$) into lead peroxide (PbO_2) in the positive plate and lead in the negative plate is not the only reaction occurring while charging current is passing. These are the preferential reactions and take place so long as there is sufficient sulphated active material accessible to absorb the current, and diffusion can take place at a rate which will prevent excessive acid concentration in the pores of the plates. Whenever the charging current exceeds this value, the excess which cannot be used for charging the active material causes decomposition of the water of the electrolyte into hydrogen and oxygen which are released as gas bubbles—the hydrogen at the negative plate and oxygen at the positive. A higher voltage is required to release gas than to charge the active material so the beginning of the active gassing is indicated by a comparatively rapid rise of voltage at the cell terminals.—According to Faradays law a given amount of current passing through an electrolytic cell can produce only a definite amount of electro-chemical reaction. Hence, that part of the current which produces gas by decomposing the water in the electrolyte cannot have any effect in charging the active material. This applies separately to the positives and to the negatives that is, the same current which produces gas (oxygen) at the positive plate after the plate is fully charged may still be charging the active material of the negative plate, if the plate is not fully charged; but any part of the charging current which produces gas at both plates is absolutely wasted as far as charging the active material is concerned.—*Electrical Engineering*, Vol. 54, No. 5, 1935

* * *

Amplitude and Frequency Modulation Defined

(J. G. Chaffee, Bell Tel. Lab., N. Y.) One of the fundamental differences between the two systems of modulation is the following:

In amplitude modulation the variations in the energy associated with the high-frequency wave which occur during modulation are primarily supplied by the source which energizes the transmitter.

In a system employing frequency modulation the energy in the high-frequency wave remains constant during modulation, and the energy which is associated with the useful output of the detector is supplied by the source which energizes the receiver.—*Proc. I. R. E.*, Vol. 23, No. 5, 1935.)

* * *

Conduit Microphone Developed

(P. W. Williams, Muirhead & Co. Ltd., London) A conduit microphone designed by P. W. Williams, and exhibited at Kings College, London, represents a marked departure from existing practice. The basic idea is effective removal of the microphone from the sound field by attachment to its input side of a long conduit. The standing waves set up between the microphone and the open end of the conduit are damped out by means of an acoustic resistance, which consists of a second conduit fill will wool "beyond" the microphone. The microphone assembly, which consists of a fine aluminum ribbon suspended between pole pieces (velocity microphone), is so designed that no reflection of sound waves takes place at the strip, with the result that the vibrations of the strip are substantially proportional to the vibrations of air at the mouth of the conduit. One advantage of the conduit microphone is that it has the quality of "acoustic smallness," and thus gives rise to less distortion of the sound waves without the disadvantage of insensitivity and fragility which must necessarily be present in the use of microphones which are intrinsically small. — *Electrician*, Vol. CXIV, No. 2954, 1935

* * *

Push-Pull vs. Parallel Operation

(J. N. A. Hawkins, Eng., Pac. Bldg., San Francisco, Cal.) The recent development of low C tubes makes it easy to practically eliminate former difficulties encountered from parasitics and instability which accompany parallel operation of vacuum tubes. Parasitics are largely caused by stray inductance and capacity in the tubes themselves, as well as in the connecting leads between the tubes and the associated grid and plate tank circuits. Parasitics are not confined to tubes in parallel, but are in fact nearly as common in push-pull circuits because the inductance of the leads when connected through the tank tuning condensers can form an ultra-high frequency tuned-grid tuned-plate oscillator. This causes oscillation at a frequency other than that desired, with consequent low efficiency and reduced power output, as well as resulting in a poor note.

Parallel operation has many advantages over push-pull operation, even at the higher frequencies, provided low C tubes are used. The plate tuning condenser can be one of a cheaper variety for a given tuning capacity and one neutralizing condenser is eliminated for parallel operation. The tubes are usually easier to drive to a given output when used in parallel, due to the higher transconductance of the two tubes in parallel. The amplification factor is the same for two tubes in parallel as it is for one tube, whereas the plate resistance is cut in half.

High C tubes, such as the 45, 2A3, 10, 211, 203A and 204A should generally be used in push-pull below 40 meters because the high capacity shunted across the plate tank when high C tubes are used in parallel makes the use of a low C, low loss tank circuit impossible.

Another advantage of parallel operation is that it permits the use of the simplified PI antenna coupler system for effective reduction of illegal radiation of harmonics. This system also gives continuously variable antenna coupling.

When three tubes are used in parallel there is less tendency for parasitics than when two tubes are paralleled. This is because the addition of the third tube unbalances the TPTG ultra-high frequency oscillator effect which sometimes results from the inductance of the leads when two tubes are used in parallel.—"*Radio*," Vol. 17, No. 7, Pg. 26, 1935

NEW APPARATUS

GRINDER USED IN SOUND EFFECT

MANY successful sound effects have been created using the DeLuxe Hand-ee Grinder as the motor power. Doubtless in your connection with the radio broadcasting field you are familiar with the reluctance sound effect men have in divulging details of their profession. To our personal knowledge at least three effects were created and the DeLuxe Hand-ee used, together with the

foot speed control, replacing larger and heavier equipment formerly used for the same effect.

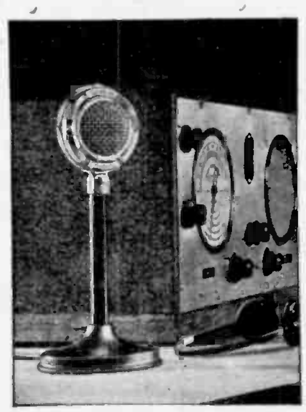
The foot speed control is a rheostat device we have developed for controlling the speed anywhere within a range of 300 to 25,000 r.p.m. Of course in the sound effects created velocity plus speed of the tool was used to give that particular sound created only by high speed. In one case the rise of an elevator in a large building was imitated, the speed of the tool being varied by using foot speed control to designate the progress of the passenger car upwards. This effect was as a background to dialogue which was carried on during the radio sketch.

The unit has been successfully used in a barber shop scene of a rather prominent sketch which recently was heard over one of the large networks. In this case the set screw on the chuck was loosened when the tool was revolved, the clicking served as a perfect imitation of barber's clippers. The dialogue called for the man in the chair to fall asleep and the barber to increase his speed of conversation as he progressed with the haircut. As the conversation was increased the motor was also increased in speed by the foot speed control and the effect created was most realistic.

In addition to the foregoing many sound effects have been created with the Grinder, details of which we are unable to divulge. In addition, the service engineers have found use for the tools in polishing jacks, removing pit marks from relays to secure a smooth contact.

NEW CRYSTAL MICROPHONE

A new diaphragm-type crystal microphone, especially designed for highly-effective communications service in airways, police, commercial and amateur radiophone systems, has recently been announced by Shure Brothers Company,



"Microphone Headquarters," 215 West Huron Street, Chicago. The new model is known as the 70S, and is furnished with a convenient desk mount and two conductor shielded cable.

The 70S has been designed to produce a higher effective percentage modulation on "intelligibility" speech frequencies than can be obtained with the ordinary speech-input system. It is well known that low-frequency speech components, with their high peak amplitudes, establish the overload level of the speech-input and modulator, yet they contribute very little to the intelligibility of the signal. This limiting factor has been largely eliminated. The response increases linearly a total of 20 db in progressing from 60 to 2,000 cycles, is substantially uniform from 2,000 to above 4,000 cycles, followed by gradual cut-off. The response curve is entirely free from sharp peaks which tend to produce "harsh" reproduction. The rising characteristic attenuates the low "overload" frequencies and results in clear speech with effective side-band power double or more than usually obtained from the transmitter. From a communications standpoint, this is equivalent to doubling the carrier power with its attendant increase in signal-to-noise ratio. In addition, there is a real improvement in the output signal quality from highly selective receivers.

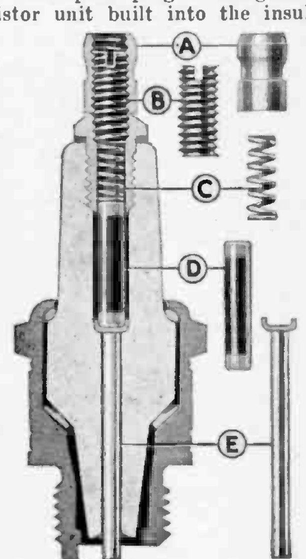
Candler Moves to Asheville

Walter H. Candler, President of the Candler System Company, announces that he has moved his school to Asheville, N. Car. Mr. Candler, although born in the vicinity of Asheville, has been a resident of Chicago for twenty years or more, during which time he has been teaching his original method of high-speed telegraphing to thousands of radio and American Morse operators.

SPECIAL SPARK PLUG FOR RADIO CARS

A new type spark plug for cars equipped with radio, has been developed by engineers of the AC Spark Plug Co. The new development makes possible better radio reception along with good engine performance, AC engineers declare.

The new spark plug is designed with a resistor unit built into the insulator.



To replace resistor, remove terminal (A), take out screw (B), and shake out the spring (C), and resistance unit (D). Clean both ends of spring with emery cloth. (E) indicates the center electrode

The resistor unit can be removed and replaced when it becomes ineffective without replacing the entire spark plug. Because the resistor unit is close to the point where the actual spark takes place in the cylinder, noise or click from the radio receiver is reduced to a minimum.

Press Wireless to Ethiopia

AUTHORITY was granted to Press Wireless, Inc. on July 19th to include Addis Ababa, Ethiopia, as a point of communication. Press Wireless was thoroughly explained in our October 1934 issue, as rendering a service to certain member newspapers.

Complete news from the Ethiopian front is expected to come over this new radio link first hand to those papers served by Press Wireless, Inc.

Airway News

George Shuman, at the Airway Radio Station, Shushan Airport, New Orleans, is a hustling chap. Stands his watch, then goes to his shop and turns out cracker-jack keys for telegraph work. George, to you old timers, is the same who used to work the United Fruit line.

If present plans work out, the same system of blind approach landing now in operation at Newark, will be in use at Washington Hoover Airport, Washington, D. C., Atlanta, Buffalo, Cheyenne, Indianapolis, Los Angeles and St. Louis.

Actions of The Federal Communications Commission

CALL SIGNALS ASSIGNED

Name of Station	Call Signal	Owner and/or Licensee
	Commercial Ship	
"Princeton"	WOFT	Board of National Missions Presbyterian Church
Unda Maris	WOFS	Edward K. Hause
Elco 48	WOFU	Electric Boat Co. of N. Y.
Kinkajou	WOFV	Dwight H. Baldwin of Maui, T. H.
Gallant Lady	WOFW	Mendle C. Riggs
F. B. Squire	WOFY	Buckeye S. S. Company
Seminole	WOFZ	Federal Emergency Relief Adm.
Varian	WOGA	F. B. Woodworth
Naugatuck	KJSJ	Radiomarine Corporation of America
	Government Ship	
Brown Bear	WWFZ	Dept. of Agriculture
	Municipal Police	
Clearwater, Fla.	WQFK	City of Clearwater Police Dept
Oak Park, Ill.	WQFL	Village of Oak Park
Green Bay, Wis.	KNHB	City of Green Bay
Wilkes-Barre, Pa.	WQFM	City of Wilkes-Barre
Winter Haven, Fla.	WQFN	City of Winter Haven
Ada, Oklahoma	KNHC	City of Ada Police Dept.
Lafayette, Indiana	WQFQ	City of Lafayette Police Dept.
	State Police	
Springfield, Ill.	WQFP	State of Illinois, Dept. of Public Works and Bldgs.
Redwood Falls, Minn.	KNHD	Bureau of Criminal Apprehension, State of Minnesota
Portable	WQFR	State of New York, Division of State Police
	Point to Point Telegraph	
Aniak, Alaska	KIOQ	Lee S. Gardner
Hyder, Alaska (changed from KDF)	KIOP	Hyder Radio & Telephone Co.
Destrehan, La.	WOEU	RCA Communications, Inc.
Kasilof, Alaska	KIOY	Territory of Alaska
Deering, Alaska	KIOW	Territory of Alaska
Portable	KIOV	Alaska Empire Gold Min. Co.
Deering, Alaska	KIOX	Territory of Alaska
Hawk Inlet Camp Alaska (Portable)	KIOR	Alaska Empire Gold Min. Co.
Kasilof, Alaska	KIOZ	Territory of Alaska
	Aeronautical and Aeronautical Point to Point	
Summit, Ill.	WEEO	Aeronautical Radio, Inc.
Casper, Wyo.	KNCK	Aeronautical Radio, Inc.
Cheyenne, Wyo.	KNCL	Aeronautical Radio, Inc.
Billings, Mont.	KNCM	Aeronautical Radio, Inc.
Sheridan, Wyo.	KNCN	Aeronautical Radio, Inc.
Denver, Colo.	KNCO	Aeronautical Radio, Inc.
Motor launch "Midway"	KNCP	Pan Amer. Airways, Inc.
Motor launch "Wake"	KNCQ	Pan Amer. Airways, Inc.
Portable-mobile	KNCR	Pan Amer. Airways, Inc.
West Yellowstone, Mont.	KNCS	Aeronautical Radio, Inc.
	Commercial Aircraft	
NC-876M	KHAFK	C. P. Hoafey
NR-10239	KHAFL	Thor Solberg Aviation Corp.
NC-13464	KHAFM	Reginald H. Jackson, Jr.
NC-14924	KHAFN	American Airlines, Inc.
NC-14925	KHAFO	American Airlines, Inc.
NC-14566	KHAFP	Westchester Airplane Sales Co.
NC-6V	KHAFQ	S. C. Johnson Son, Inc.
NC-11176	KHAFR	Delta Air Corporation
NC-11177	KHAFS	Delta Air Corporation
NC-11174	KHAFT	Delta Air Corporation
NC-14599	KHAFV	Delta Air Corporation
NC-10846	KHAFW	Delta Air Corporation
NC-14598	KHAFX	Delta Air Corporation
NC-15061	KHAFY	Inter-Island Airways, Ltd.
NC-15062	KHAFZ	Inter-Island Airways, Ltd.
NC-14945	KHAGA	Max C. Fleischmann
NC-15551	KHAGB	Pan Amer. Airways, Inc.
	Aviation Obstruction Marker Beacon	
Mason, O. (near)	WOEW	The Crosley Radio Corp.
	Commercial Broadcast	
Rockville, Md.	WRMD	The Monocacy Broad. Co.
Brady, Tex.	KNEL	G. L. Burns
Del Monte, Calif. (changed from KFUH)	KDON	Richard Field Lewis
Boston, Mass. (changed from WMFH)	WCOP	Joseph M. Kirby
Hilo, T. of Hawaii	KHBC	Honolulu Broadcast. Co., Ltd.
	Broadcast Pickup	
Portable	WOEB	Agricultural Broadcasting Co.
Portable	KNEC	Puget Sound Broad. Co., Inc.
Portable-Mobile	KNED	Carter Publications, Inc.
Portable-Mobile	KNEF	Radio Service Corp. of Utah
	General Experimental	
Hull, Mass.	W1XEE	Town of Hull, Fire Dept.
Portable-Mobile	W9XHA	Donald A. Burton
Woodbridge, N. J.	W2XIC	Township of Woodbridge
Portable-Mobile	W2XID	Bell Telephone Laboratories
Portable-Mobile	W2XIE	Borough of Deal, N. J.
Portable-Mobile	W4XAS	Aeronautical Radio, Inc.
Portable-Mobile	W4XAT	Aeronautical Radio, Inc.
Portable-Mobile	W1XEF	East Providence Police Dept.
Alpena, Mich.	W8XEN	City of Alpena
Portable-Mobile	W9XHB	Anderson Broadcasting Corp.
Portable-Mobile	W9XHC	Kansas State College of Agriculture & Applied Science
Portable-Mobile	W9XHD	Agricultural Broadcasting Co.
Portable-Mobile	W9XHE	Agricultural Broadcasting Co.
Portable-Mobile	W9XHF	Agricultural Broadcasting Co.
Storrs (College Campus), Conn.	W1XEG	Connecticut State College
Portable	W7XBK	Puget Sound Broadcasting Co.
Portable-Mobile	W10XFQ	National Broadcast. Co., Inc.
Portable-Mobile	W10XFR	National Broadcast. Co., Inc.
Belmar, N. J.	W2XIF	Borough of Belmar
Mobile	W2XIG	Borough of Belmar
Portable-Mobile	W1XEI	Westinghouse Elec. & Mfg. Co.
Terre Haute, Ind.	W9XHG	City of Terre Haute
Mobile	W9XHH	City of Terre Haute
Mobile	W9XHI	City of Terre Haute
Portable-Mobile	W9XHJ	The Pulitzer Publisher Co.
St. Cloud, Minn.	W9XHK	Frank O. Knoll & Julian F. McCutchan
Burlingame, Calif.	W6XJK	City of Burlingame, Calif.
Mobile	W6XJL	City of Burlingame, Calif.
Mobile	W6XJM	City of Burlingame, Calif.
	Special Experimental	
Portable (Pacific Islands)	K6XJI	Dr. Dana Coman
Portable (Pacific Islands)	K6XJJ	Dr. Dana Coman
Avon, Conn.	W1XEH	Travelers Broadcasting Service Corp.
	Geophysical	
Portable-Mobile	WAAY	Sun Pipe Line Co.
Portable-Mobile	WAAZ	Sun Pipe Line Co.

SUMMARY OF APPLICATIONS FOR NEW TRANSMITTERS GRANTED

(Telegraph Division)

Aeronautical		
Aeronautical Radio, Inc.	Tulsa, Okla.	30 watts
Police		
City of Wilkes-Barre, Pa.	2442 Kc	50 watts
City of Winter Haven, Fla.	2442 Kc	50 watts
State of Illinois, Dept. of Public Works and Bldgs., Springfield, Ill.	1610 Kc	1 KW.
City of Green Bay, Wisc.	2382 Kc.	50 watts
City of Ada, Okla.	2450 Kc.	25 watts
Bur. of Criminal Apprehension, State of Minn., Redwood Falls, Minn.	1658 Kc.	500 watts
Village of Hibbing, Minn.	2382 Kc.	50 watts
City of Lafayette, Ind.	2412 Kc	50 watts
Point-to-Point		
Northern Commercial Co. Hamilton, Alaska	3092.5 Kc.	2 watts
General Experimental		
City of Alpena, Mich.		25 watts
Borough of Belmar, N. J.		25 watts
City of Terre Haute, Ind.		25 watts

Loftfield & Mathison, Terminal Island, Calif.	50 watts
Rockland Co., New City, N. Y.	150 watts
Special Experimental	
New England Tel. & Tel. Co. Motor vessel Fauci	10 watts
New England Tel. & Tel. Co. Motor vessel Whalen	10 watts
New England Tel. & Tel. Co. S. S. Hekla	10 watts
RCA Mfg. Co., New York City	100 watts
Unusual	

Pioneer Sea Foods Co., Cordova, Alaska. Granted temporary authority to W. Lewis and Harold Tvest to operate radio equipment aboard tenders "Cora B" and "Taku" for 90 days, provided these men qualify for proper class licenses within that time.

SUMMARY OF APPLICATIONS RECEIVED FOR NEW INSTALLATIONS

(Telegraph Division)

Aeronautical	
Aeronautical Radio, Inc. Summit, Ill.	1000 watts
Aeronautical Radio, Inc. Miles City, Mont.	50 watts
Aeronautical Radio, Inc. St. Louis, Mo.	125 watts
Peoria Air Associates, Inc. Peoria County, Ill.	15 watts
Police	
City of Prescott, Prescott, Ariz. 2430 Kc.	10 watts
City of Fort Smith, Fort Smith, Ark. 2406 Kc.	50 watts
City of Augusta, Augusta, Ga. 2414 Kc.	250 watts
Point-to-Point	
Koyukuk Community Radio Serv., Wiseman, Alaska 252 Kc.	50 watts
Elwin P. Dell, Hooper Bay, Alaska 3092.5 Kc.	25 watts
General Experimental	
Huntington Police Dept., Huntington, Ind.	15 watts
City of Hamilton, Hamilton, O.	150 watts
City of Burlingham, Burlingham, Cal.	50 watts
City of Petaluma, Petaluma, Cal.	10 watts
Wayne Miller, Des Moines, Ia.	50 watts
Star Chronicle Pub. Co.. St. Louis, Mo.	100 watts
Special Experimental	
Press Wireless, Inc., Hicksville, N. Y.	1.2 watts
Press Wireless, Inc., nr. Daly City, Cal.	1.5 watts

The Barkhausen Oscillator

(Continued from Page 13)

moving faster when it approaches the plate than it would if no alternating forces had acted on it, and consequently it will hit the plate even though the latter be at a slightly negative potential. Thus this useless, and in fact harmful, electron is at least prevented from doing still further harm by being removed through the plate from the scene of action.

Fortunately the other electron, that leaves a half cycle later than the worthless one just dismissed, is more useful. From the very start the alternating force opposes the motion of the new electron, but cannot stop it because the alternating force is never larger than the constant force of Figure 2. The electron is therefore doing work against the alternating force, delivering energy to the transient in the external circuit. As the electron progresses, the phase of the force changes as shown in Figure 4. Unlike Figure 3, the reversal in direction occurs before the electron has reached the grid, because the force opposing the motion has decreased the speed. When passage through the grid mesh again reverses the direction of the force, the agreeable electron continues to deliver energy to the circuit transient, as it approaches the plate. Having lost much of its velocity in transferring its energy to the circuit, the electron comes to rest before hitting the plate, and then, urged by the constant force of Figure 2, starts on its return journey toward the grid. At about the same time, the phase of the alternating force again reverses and again opposes the motion, so that the hapless electron must give up still more of its energy to the growing transient.

Another passage through the grid follows, accompanied by another reversal in the phase of the alternating force, and the tormented electron must again yield energy acquired from the constant force to the hungry transient. The energy loss brings the electron to a halt before it reaches the cathode, the phases again reverse, and the cycle starts over again.

In its round trip, the useful electron of Figure 4 supplies to the transient nearly twice as much energy as the useless one in Figure 3 abstracted in its one-way trip. Moreover, the useful electron reaches the cathode again at just the right time to join with other electrons of the useful type and augment their relative number. The action is consequently progressive, building up more and more useful electrons.

In practice, operating conditions modify somewhat the mechanism described. For example, space charge near the cathode produces more harmful electrons than useful ones and is to be avoided. Space charge near the plate causes a shift between the phase of the grid voltage and the force acting on the electrons, which in general tends to raise the frequency of oscillation. On the other hand, space charge in general makes the electrons move slower. Since the slower motion tends to decrease the frequency, the net result of space charge near the plate is only a small decrease in frequency. The tuning of the external circuit can also modify the frequency by about thirty per cent, but for fixed values of plate, grid, and filament battery voltage, there is a particular tuning adjustment which gives maximum output.

There is a simple approximate expression for determining the proper grid voltage and size of vacuum tube to produce oscillations of a given wavelength. For example, a tube with a plate diameter of one centimeter, and with 100 volts applied to the grid, will produce oscillations with a wavelength somewhere between 100 and 50 centimeters, corresponding to a frequency between 300 and 600 megacycles, depending on the circuit adjustments.

It is interesting to note that the same kind of analysis here used to illustrate the workings of the Barkhausen oscillator can be applied to the well-known feedback oscillators operating with negative grid and positive plate, and shows that the two are not very different from each other after all. The Barkhausen oscillator will probably prove very useful in the fields of ultra-short-wave transmission, which are rapidly coming into commercial application.

Designing the Midwest All-Wave 18

(Continued from Page 12)

quired for tuning the oscillator circuit alone.

In a commercial receiver it is desirable that each variable condenser should have a trimmer as indicated at Tg and Tp for making the minimum capacities uniform for high speed production. Likewise in order that the oscillator circuit may tract with the other condenser required to tune the R. F. coils, the padder is inserted as indicated at P. Thus, the entire circuit becomes complicated.

In addition there are by-pass condensers and isolating condensers required to prevent the B+ voltage from being applied across the tuning condenser.

With such an oscillator it is found that the output is entirely satisfactory to less than four (4) meters with conventional equipment. If all dielectrics are limited to isolantite the frequencies may be still further increased.

Design of radio frequency circuits to handle signals to sixty-million cycles per second demands very careful design to prevent losses which can easily be so great as to cause attenuation of the signal rather than amplification of it. Ceramics, materials which have the lowest losses of any materials known, must be used exclusive of any other coil form or trimmer condenser insulating material.

All parts must be so designed and located that even very short leads which would radiate much energy are unnecessary. The parts themselves must be used as leads.

The coils must be so wound, spaced and designed that both the inductance and capacitive coupling are aiding. This is imperative as tight coupling must be used at high frequencies to obtain sufficient amplification.

A double ratio tuning knob (fast and slow) is necessary in order that one may reduce the apparent selectivity of the receiver sufficiently to tune in ultra-short wave stations.

A careful choice of the type direction and location of the antenna is of especial importance at sixty million cycles per second.

Multivibrators

(Continued from Page 11)

The charging circuit for C_2 is from battery 1 thru elements 2, 9, 10, 8, 6, 7 and return. The direction of the charging current for C_2 is downward thru R_2 and, therefore, the grid becomes positive with respect to the filament, as soon as the charging of C_2 begins. This is represented at point 13 of curve "k." This results in VT-2 drawing current as shown at point 14, curve "f."

VT-2 being conductive opens a discharge path for C_1. The discharge current flows thru VT-2 to ground, thence thru elements 7, 6, 5 and to the condenser. Since the discharge current is upward thru R_1 the grid of VT-1 becomes negative with respect to the filament and VT-1 becomes non-conductive. Moreover as there is substantially no inductance in the discharge path, the change in the potential of the grid of VT-1 is abrupt, as shown at point 15 of curve "h."

It should be noted that the consequence of the small decrease in current thru VT-1 which resulted from the cessation of charging current for C_1 causes an abrupt termination of all current thru VT-1 as shown at point 16 of curve "i."

The condition, VT-2 conductive and VT-1 non-conductive, will continue until C_1 discharges. During this time, C_2 is receiving a charge. (NOTE: UP TO THIS POINT THE DISCUSSION IS SIMILAR TO THAT OF THE SYMMETRICAL SYSTEM, FROM HERE ON, THE DIFFERENCES SHOULD BE CAREFULLY OBSERVED.) This will be added to the charge which remained in C_2 at the moment of change in conditions, represented at point 12 of curve "j." The condenser C_2 will not have been completely discharged because its time constant is slower than the time constant of C_1. The change from discharging to charging was brought about by the completion of point 10 of the charge upon C_1, which happened before the discharge of C_2 was completed.

The period now under consideration will continue until C_1 has completed its discharge, as indicated at point 17 of curve "g." When this discharge is completed, discharge current will cease to flow over R_1. The potential of the grid of VT-1 will, therefore, rise from a negative value to zero, as indicated at point 18 of curve "h," and the tube again will become conductive. As soon as this happens, C_2 will begin to discharge thru VT-1, as indicated at point 19 of curve "j." VT-2 will, thereupon, become non-conductive, the plate potential across the tube will rise, and C_1 will begin to charge, as indicated at point 20 of curve "g." When C_1 begins to charge, the grid of VT-1 will become positive, as indicated at point 21 of curve "h," and the tube will become even *more* conductive. All the changes just noted are abrupt because no inductance is involved in any of them. The current thru VT-1, therefore, rises abruptly from zero to maximum value, as indicated at point 22 of curve "i."

Conditions are now as they were at the beginning of this analysis except that the charge upon C_2 is somewhat greater than at first. Operations will repeat themselves in this way until the charge on C_2 has increased sufficiently to require less time for the completion of the change than is required for the discharge of C_1.

The analysis that has so far been given to the unsymmetrical multivibrators applies equally well to both Vecchiacchi and Harmon circuits. The remainder of this discussion will deal exclusively with the function of inductance Lx, a feature of the Harmon invention.

Consider the moment when C_2 begins to receive charging current after the charge which has been accumulated therein is nearly sufficient to fill it, as indicated at point 23 of curve "j." At that moment, VT-2 is conductive, as indicated at point 24 of curve "f," and the condenser C_1 is discharging, as indicated at point 25 of curve "g," but C_2 completes its charge, as indicated at point 26 of curve "j," before C_1 has completed its discharge, as indicated at point 27 of curve "g." When this happens, the charging current thru R_2 falls to zero. The potential in the grid of VT-2, therefore, becomes zero, as indicated at point 28 of curve "k," and the tube, while still conducting draws less current than before, as indicated at point 29 of curve "f." VT-1 is, at this moment, in a non-conducting condition, as indicated at point 30 of curve "i." The total current drawn thru inductance Lx, therefore, diminishes.

The diminution produces an electromotive force downward in Lx, as represented in the diagram at point 31 of curve "L." The increase in plate potential across VT-2, which result from

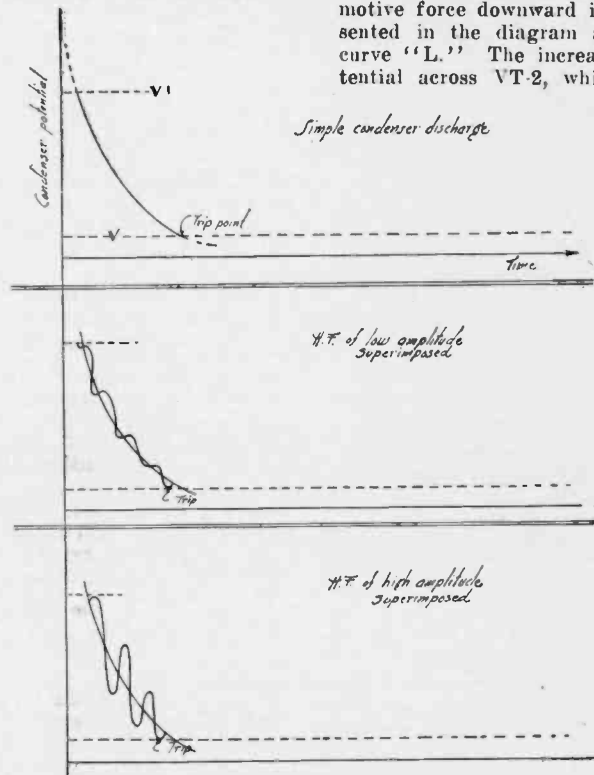


FIG. 13

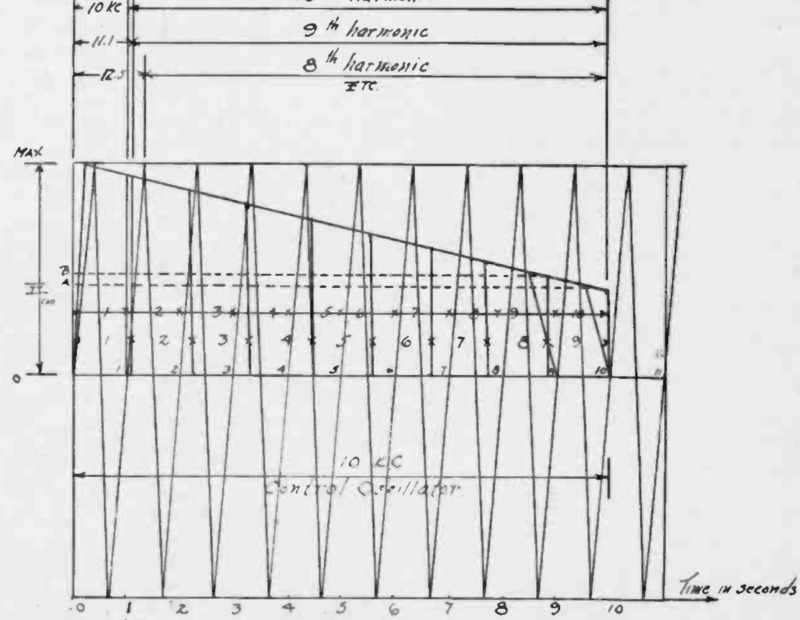


FIG 14

Graph showing relation between control voltage and harmonic dimultiplication the diminution in the drop thru R_1, is added to the EMF from Lx, and the increase in plate potential across VT-2 is, therefore, greater than heretofore. The charging effect upon C_1 is, therefore, greater. The condenser charges, not only to a higher potential, but more rapidly, as indicated at point 32 of curve "g." VT-1, therefore, becomes conductive, as indicated at point 33 of curve "i," and, if anything, more abruptly than before.

The extra rise in plate potential upon VT-2 was temporary. The effect of Lx disappears and the higher potential to which C_1 has been charged soon exceeds the potential impressed upon the plate of VT-2. Condenser C_1 will, therefore, discharge, but not thru VT-2. It will discharge over the path from 9, 3, 2, 1, 7, 6, and 5 until the potential on C_1 falls to the potential impressed by battery 1 as indicated at point 34 of curve "g."

Since C_1 discharges over a path including battery 1, the potential producing the discharge current is only the difference between the battery potential and the potential to which C_1 is charged. This difference is small. Consequently, the rate of discharge is slow. The current thru R_1 is therefore small, and the grid of VT-1, although it becomes negative, does not become sufficiently negative to render the tube non-conductive.

Since the time during which C_1 is discharging is brief, as may be seen by observing point 34 of curve "g" that the portion of the curve which slopes downward is short, the slightly negative potential of the grid was not caught by the oscillograph, which is the reason why it is not exhibited by curve "h."

When the potential of C_1 has fallen to that impressed by the battery, it will not continue to discharge over the path last traced, because of the opposing potential of the battery. It will not discharge over the path thru VT-2, because this tube is, at this time, non-conductive (see point 35 of curve "f"). The charge of C_1 will, therefore, remain steady, and there will be zero current thru resistor R_1. Consequently, VT-1 will be somewhat conductive (see point 36 of curve "i") and C_2 will discharge (see point 37 of curve "j"), thereby maintaining the grid of VT-2 negative (point 38 of curve "k") and VT-2 non-conducting until C_2 is completely discharged.

When C_2 is completely discharged, the potential of the grid of VT-2 becomes zero (point 39 of curve "k"). This tube begins to conduct. The condenser C_1 can, therefore, discharge, and the cycle of operations repeat.

It will appear upon the study of the aforegoing analysis that one really significant action of Lx is to bring to pass that, during a short time, condensers C_1 and C_2 are both discharging, (compare point 34 of curve "g" with point 40 of curve "j"). This changes the control from the fast condenser to the slow condenser, and the high-frequency impulses will not appear until the slow condenser has discharged.

There are many peculiarities of the electromotive force across Lx as shown by curve "L" beside the one just mentioned, but this one alone produces significant results. For this reason, the other peculiarities are not described in detail. The several sharp peaks correspond to the moments when the total of the current in tubes VT-1 and VT-2 is increasing. The portions of curve "L" which fall below the zero line correspond to times when the total is decreasing.

Tubes continue to be conductive after their grid potential has become negative. It is not until the grid has become several volts negative that the current is cut off entirely. This is the explanation of the fact that curve "f" slopes downward at point 20 at the same time curve "i" slopes downward at point 22, and this accounts for the negative portion of the curve "L" vertically in alignment with points 20 and 22.

The portion of the curve immediately to the left of point 31 is explained in the same way but, considering the points on curves "L" and "i" vertically in alignment with 31, it will be seen that the portion of the curve "f" between points 29 and 35 slopes downward, while the portion of the curve "i" at point 36 is horizontal. The decrease in total current is, therefore, very small, and the portion of curve "L" to the right of point 31 will rise rapidly towards the zero line.

The time constants of the two condensers are so adjusted that the ratio between them is, as nearly as possible, an integer. If this adjustment is inexact, condenser C_2 may complete the last step in its charging action somewhat too soon, but the inductance Lx will produce the effect described. Consequently, the presence of the inductance in the common plate lead makes the adjustment of the resistors and condensers non-critical.

In conclusion, the advantages of the Harmon circuit over other unsymmetrical schemes wherein the discharge times are unequal are: (1) circuit adjustments are not critical; (2) means for obtaining any selected harmonic without the use of multitubes which have heretofore been required for this purpose.

Factors Govering Frequency at Time of Control

The most popularly used unsymmetrical multivibrator is the Hull and Clapp type, wherein the condenser discharge time-constants are equal and the plate circuit unsymmetrical. This type of multivibrator structure will form the basis of the following discussions.

It is generally understood that an uncontrolled multivibrator is controlled by its fundamental frequency or by an harmonic of this fundamental. This is a mistaken idea, as it is practically impossible to control these frequencies by synchronization. Moreover, control can only occur when the controlling voltage has been sufficiently raised to supply enough real energy[11] to the multivibrator to accelerate the normal relaxation time up to such a frequency that the relaxation time itself greatly depends upon the value of the voltage injected. (Control voltage is seldom over 3 volts.) To properly control the multivibrator, the uncontrolled frequency (real fundamental) must be raised to such a value that when the system is under control of the governing agent, either the fundamental or harmonic of the new frequency assumes a definite phase relationship to the controlling frequency. To make the control effective, the constant of the multivibrator must be adjusted so that the uncontrolled frequency is slightly below the frequency of control.

Relation Between Control Voltage and Harmonic Demultiplication

When the control voltage is carried beyond the region necessary to maintain control at the fundamental or synchronizing frequency, the relaxation time will suddenly change to a new value. The transition occurs without actual changes in the circuit constants. In general, when the control-voltage is increased beyond the value necessary to maintain control, the multivibrator will produce a still higher frequency. On the other hand, if the control voltage is at a frequency which is a harmonic of the multivibrator fundamental, then increases in the control of voltage will produce control at lower and lower harmonics. At this juncture, it should be borne in mind that any factor which tends to accelerate or retard the multivibrator condenser discharge times makes the system act as though the CR product has been either raised or lowered, whichever the case may be.

The relationship existing between the control voltage and the production of higher harmonics, called harmonic demultiplication[12], is explained as follows:

Suppose that a 10 kilocycle control oscillator was controlling a 1 kilocycle multivibrator, necessitating, of course, that the 10th harmonic of the multivibrator be in phase with the controlling device. Curves representing the wave components, not to scale, of the apparatus are shown in Figure 14. Here, the 1KC multivibrator and its 10th harmonic are superimposed upon the 10 KC oscillator sinusoid. Now, if the control voltage E_c, shown at the left of the illustration, is slowly raised from "a" to "b," more voltage will be injected into the multivibrator which will accelerate the condenser discharge time and so *tend* to raise the fundamental frequency of the system. Here, the word "tend" is used advisedly, because the fundamental will remain at a fixed frequency (1KC), irrespective of the forced acceleration, until the voltage gas reached such a magnitude "b" to cause the fundamental to SUDDENLY JUMP to a higher frequency (1.11KC). The value of this jump depends upon the ratio of the control frequency to multivibrator frequency. If this ratio is 1 to 10, the first increase in the multivibrator fundamental will be equal to 1/9th that of the control oscillator. In other words, the frequency of the multivibrator will increase in steps at a rate of one-ninth, one-eighth, one-seventh, and so on, in ratio to the frequency of the controlling device. For a 1KC multivibrator, the progression of the control order may be followed by referring to the tabulations shown below.

11 J. Groszkowski, "Frequency division," Proc. IRE. Vol. 18, No. 11, Nov. 1930

12 B. van der Pol and J. van der Mark, "Frequency demultiplication," Nature (England) Vol. 120, pp. 363, 1927

Control Table Showing Harmonic Demultiplication Frequencies for 1 or 10KC Multivibrator Synchronized with a 10KC Oscillator

10	9	8	7	6	5	4	3	2
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.000	1.111	1.250	1.429	1.667	0.000	0.000	0.000	0.000
3.000	2.222	2.500	2.858	0.000	2.000	2.500	0.000	0.000
4.000	3.333	3.750	0.000	3.334	0.000	0.000	3.333	0.000
5.000	4.441	0.000	4.287	0.000	4.000	0.000	0.000	0.000
6.000	5.555	5.000	5.716	5.000	0.000	5.000	0.000	5.000
7.000	6.667	6.250	0.000	6.667	6.000	0.000	6.667	0.000
8.000	7.778	7.770	0.000	0.000	0.000	7.500	0.000	0.000
9.000	8.889	8.750	8.574	8.834	8.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Decimal values only approximate

Explanation of the Frequency "Jump"

What caused the frequency to "jump" when the control voltage is raised, is a question seldom answered. Here appears an explanation clarifying what might be conceived as a complex phenomenon.

In a communication to the writer, says Mr. W. F. Curtis, Naval Research Laboratory, "that the multivibrator works between two critical voltages, say v and v¹. The time taken for a condenser to discharge from potential v¹ to potential v is RC log v¹/V. (The so-called time-constant RC is simply the time in which the potential falls to zero 1/e times its initial value.) Now by superimposing a higher frequency potential upon the condenser potential, it will be found that the lower critical voltage is reached sooner than it otherwise would be; that is, the higher frequency *trips* the device. It can be readily seen that as the amplitude of the high frequency potential is slowly increased, see Figure 13, that the phase of the tripping point will correspondingly advance, but the order of division (and hence frequency) will remain fixed until the amplitude has reached such a value that the next earlier cycle will trip the device; whereupon there will be a sudden and discrete change in frequency"

In other words the frequency jump occurred because the cross-synchronizing current supplied by the control oscillator is insufficient to maintain proper phase relationship with the condenser charge and discharge voltages at the frequency in question. The instant the synchronizing current can no longer supply enough power to maintain synchronism, the multivibrator mometarily "falls out of step," but is immediately pulled back "in step" at the next lowest harmonic. The system is actually pulled into synchronism through extra power supplied to the multivibrator by the synchonizing current. This current transmits energy to accelerate the condenser discharges up to such a frequency that an harmonic of the fundamental coincides in PHASE with the controlling frequency.

(To be Continued)

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