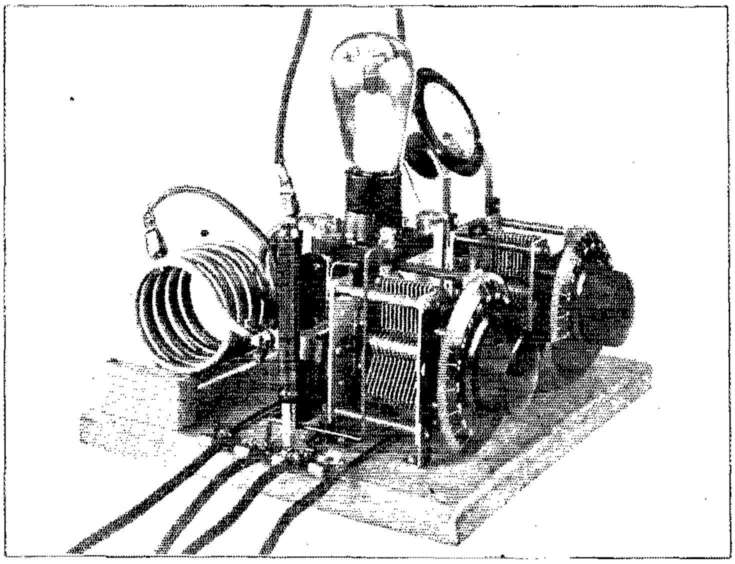
Overhauling the Transmitter for 1929

Some Modifications Which Permit Substantial Advances in Self-Excited Circuit Performance.

By Ross A. Hull*

Foreseeing the inevitable change in operating conditions in 1929 and appreciating the urgent need for modification and improvement of amateur equipment, the A.R.R.L. Board of Directors appropriated a sum from the League's surplus for the conduct of a program of investigation and development of amateur transmitters and receivers. This article embodies the conclusions resulting from the first phase of the program work—a study of self-excited transmitters. It is, we feel, one of the most important articles ever published for the radio amateur. Let every amateur study it most carefully, and apply its information, for it contains salvation for 1929.—Editor.

IN any undertaking, I suppose, half the battle, or at least an appreciable fraction of it, is in the determination of a method of attack—the drafting of a procedure and a policy. Anyway, in the instance of the A.R.R.L. Technical Development Program we found this to be true. There was, for example, the apparently simple question of whether the present-day self-excited circuits were worthy of any consideration. Of the several scores of possible fields of endeavor, we thought, there is at least one which we can delete. Hartleys, Colpitts and Tuned-grid tuned-plates have been in general use throughout the world for years, and amateurs, experimenters and scientists have sought constantly to improve them. And yet, we reflected, with all the developments and advances of recent times, if the world's crystal-controlled and oscillator-amplifier amateur transmitters could be taken off



A SIMPLE TRANSMITTER WITH A "1929 TYPE" PERFORMANCE

Incorporating a Hartley circuit and differing only in the arrangement of its plate "tank", this transmitter, when carefully tuned, is capable of producing signals that are up to any reasonable standard which could be set for next year. The use of a High-C plate circuit results in unusually heavy circulating currents and, in consequence, particularly heavy conductor must be used for the coil and its leads to the tuning condenser. Except for the filament lead and on the antenna coil (where the currents are relatively low) clips for connections are absolutely banned.

*Associate Technical Editor, QST. In charge A.R.R.L. Technical Development Program.

the air to-morrow there would be about five truly constant frequency and unmodulated signals left. Most certainly, we decided, the self-excited circuits are the bunk. They have had six or seven years in which to prove their worth and in all that time they have succeeded in making a variety of horrible noises; let's forget them and break into some brand new territory.

But, as we have said at the start, decisions on such matters comprise at least a fraction of the battle—and even fractions of battles cannot be dismissed so simply. It is true, we reflected on second thought, that by far the majority of present-day amateur transmitters are built around self-excited circuits; it is true that such circuits have been the very foundation of world-wide amateur radio communication; it is true that the scrapping of self-excited circuits would mean the scrapping of about 90% of existing amateur transmitters. Is not, then, the self-excited circuit perhaps one of the biggest things in amateur radio we mused. Is it not deserving of the most detailed study and investigation possible, in the attempt to preserve it, even though it has done its work in such a noisy fashion throughout the years?—And so was written into the program of activities, at the head of what is now an elaborate document, a Problem One—"The Study of Present Day Self-Excited Circuits—The Possibilities, if any, of Their Use in 1929".

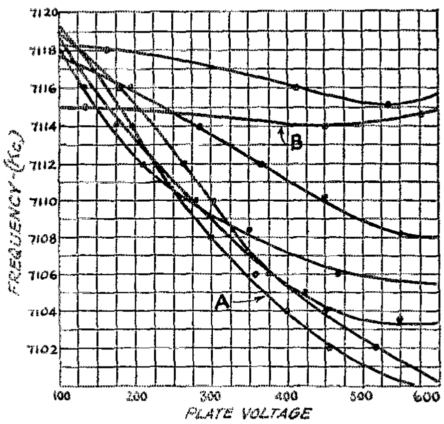


FIG. 1. SHOWING WHY AN UNRECTIFIED OR IMPERFECTLY FILTERED PLATE SUPPLY CAN CAUSE A TRANSMITTER TO MONOPOLIZE WIDE SECTIONS OF THE BAND

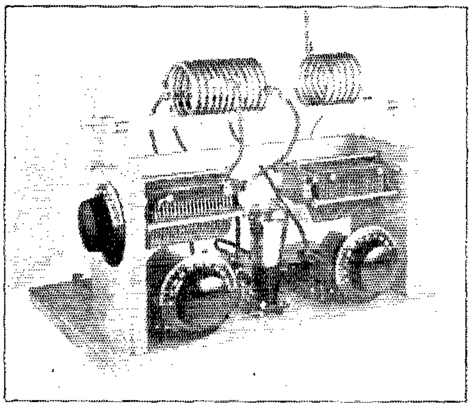
From Curve A it can be seen that in a typical 1928 transmitter, poorly adjusted, the frequency "flutter" due to a "ripple" of 100 volts in the plate supply can be as high as 4 Kc., under which conditions the note is "hash". From Curve B—the performance of the same transmitter adjusted correctly—the "flutter" with a similar plate supply is seen to be negligible. In this case the note would be a "musical d.c".

"Why, we might spend a month on the problem," said Perry Briggs, 1BGF (who was destined to do the study) "and then we might find that they always will mean swinging, chirping, rattles and mush!"

Little did we think at the time that it would be possible to make the statement that we now can make with complete confidence—*that all standard self excited circuits can produce signals that will comply with any reasonable standard set for 1929 if only they are built and operated intelligently.* But there is a lot hanging to those last four words. There is in fact this entire story.

TRANSMITTERS UNDER A MICROSCOPE

The first requirement in the study undertaken was, of course, a means of examining the performance of any type of transmitter in precise detail. It would not serve, we realized, to put the various transmitters on the air and ask QRK? QSB? QSSS? and then decide from the various FB's and QSA's received in reply that 1929 was a cinch. Instead, we had to provide for some electrical miscroscope through which we could examine and reduce to black and white the actual performance of any transmitter under any conceivable set of conditions. The most useful apparatus used in this work was an enlarged and modified version of the "Growler" (a shielded oscillator). Built within a large copper wash-boiler this oscillator was provided, in addition to the usual tuning control, with a vernier straight line frequency condenser giving a full scale tuning range



ONE OF THE "1928 TYPE" TRANSMITTERS RESPONSIBLE FOR SOME OF THE CURVES ON THESE PAGES

As an example of the use of long condenser leads and clips the arrangement is one to be avoided. The wide separation of the tube, the condensers and the coils does not permit the short stiff leads which are to play such an important part in obtaining a "1929" performance.

of about 28 Kc. The output of the oscillator was fed through a three-stage resistance-coupled audio-frequency amplifier to a loud speaker of high quality, so giving some hope of a reasonably flat audio frequency response curve. To provide for quantitative observation the oscillator was calibrated roughly on the major tuning dial and with a certain degree of precision on the vernier. The calibration curve for the latter control, incidentally, was obtained by

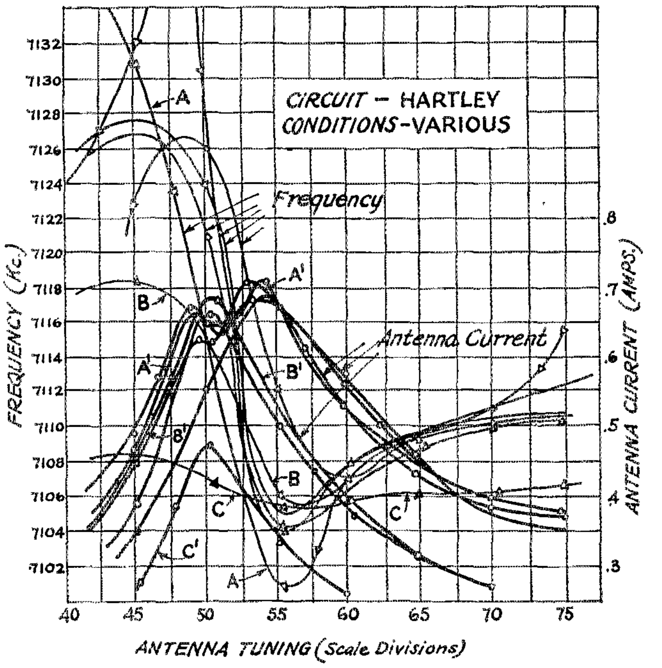


FIG. 2 A FAMILY OF ANTENNA TUNING-VS.-FREQUENCY CURVES OBTAINED WITH MISCELLANEOUS VALUES OF ANTENNA COUPLING IN A "1928 TYPE" TRANSMITTER

The splendid gain in frequency stability provided by loose antenna coupling can be seen by a comparison of Curves A, A1 and B, B1. The former were plotted with "two-inch" antenna coupling and the latter with "five-inch" coupling. The dark lines indicate the variation of antenna current as the antenna is tuned up to and past resonance while the light lines show the change in frequency resulting.

the rather unusual method of checking the beats produced by the oscillator against a second radio frequency oscillator, directly with a one thousand cycle, electrically driven tuning fork supplying energy of that frequency to one of a pair of head phones. After adjusting the two r.f. oscillators to zero beat (the output of one being in the second head-phone) the second r.f. oscillator was detuned until a one thousand cycle beat was obtained, first on one side and then on the other. At these two points, in turn, the oscillators were again set to zero beat and the detuning to one thousand cycles repeated, each point being automatically doubly checked as the work proceeded. A third and even a fourth check was made possible by detuning the oscillators to musical octaves (2000 and 3000 cycles) as well as by 1000 cycles. Possessed with a "musical ear" and considerable patience, we thought, the amateur could well calibrate his 1929 frequency meter in this manner from one known point on the scale!

The purpose in providing and calibrating a vernier of this type was to supply a means of observing the swing or drift in the frequency output of any transmitter due to prearranged variations in plate voltage, filament voltage or antenna constants, and to measure it down to about 100 cycles. Fortunately, the "Boiler" proved highly satisfactory for this work, and during some hundreds of comparisons of circuits, transmitters and constants, it was run almost continuously for several weeks.

THE "BEST" CIRCUIT

A detailed study of the data obtained revealed in all its brilliance the fact (which we had so long thought true) *that all standard self-excited circuits, irrespective of how carefully designed and built they may be, are equally and any time capable of producing truly wretched signals. And, conversely, that all such circuits, when correctly arranged and tuned, can be made to produce signals that are veritably above criticism.* Along with this we can insist with limitless assurance that the performance of the various standard circuits actually is equivalent — that the Tuned-grid tuned-plate cannot be said to be "better" than the Hartley or the Hartley "better" than the Colpitts unless detailed qualifications be included in the statement. Which is, after all, merely a reiteration of *QST's* claim of all the years—that "that circuit is best with which you are most familiar."

THIS TUNING BUSINESS

And now, in all humility, let us ask to be pardoned if we appear excessively frank in the statement of some further deductions resulting from the study. We are convinced, for instance, that if all amateur operators of the world, without any changes in their equipment, were to be displaced by a new generation of amateurs having a clear understanding of transmitter tuning,

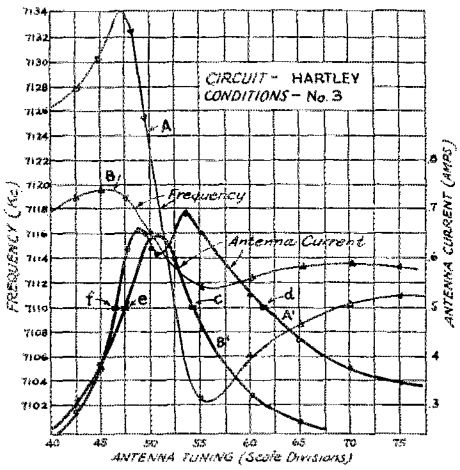


FIG. 3. INDICATING THE FREQUENCY CHANGES RESULTING FROM ANTENNA DETUNING IN A TYPICAL HARTLEY CIRCUIT

A change from "two-inch" to "four-inch" coupling in this case shows an avoidance of the "double resonance hump", with an insignificant sacrifice of antenna current, and a vast improvement in the frequency change. The necessity of detuning the antenna in one particular direction is shown clearly in these curves.

and the desire to put their knowledge into effect, completely satisfactory operation in the 1929 amateur bands would be inevitable. In short, and more abruptly, the chief ailments of present day amateur radio are the men pushing the keys. They have built their power supplies with one thing in mind—voltage; they have tuned their transmitters with just a single thought—antenna current—they have pounded out their CQ's for but one purpose—DX; and the signal, the very foundation of the whole game, has been left to splutter, wobble, creep and rattle across great slices of the bands because of some dizzy FB's and QSA's given, in most cases, with about as much sincerity as the pleasantries passed across the counter by a grocer's clerk to his customers. Whew!

Of course, there is not the slightest question that the condition has been a natural one. The amateur bands have been wide and it was not a tragedy if one station did swamp a couple of hundred kilocycles. The off-wave operation has been a relatively minor offense, for the fields beyond the fence were almost vacant. Further, a creepy-wobbly signal has been readable because it usually could wobble a long way before it ran into another station. It is not surprising that amateurs have been careful of everything except their signal; that with certain obvious exceptions the correct tuning of a transmitter was the result of accident rather than design. In 1929, as we have already suggested, it will not be essential for all transmitters to be rebuilt. It will, however, without the slightest doubt, be absolutely necessary for all amateurs to make it their business to learn the finer points of transmitter tuning; to learn exactly how to make their signals conform with the high standard to be required in 1929 and to *provide the means of checking, within the station, the character of the signal being transmitted.* For the success or failure of amateur radio in the future is to depend chiefly upon the personal element—the men behind the keys.

THE "1929" SIGNAL

At this stage it would be well perhaps to outline the specification of what is now considered to be the desirable 1929 signal, drawn up after close study of the requirements and since checked by experiment to determine its complete practicability. It should be understood that this specification does not cover the most desirable signal but rather that signal, attainable with even the most modest equipment that will permit its owner to identify himself as a sincere dyed-in-the-wool radio amateur.

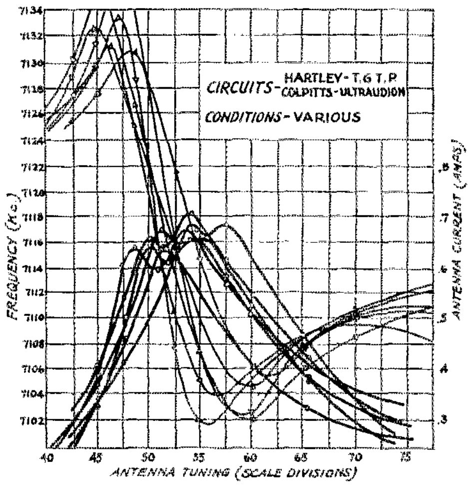


FIG. 4. SOME SIMILARLY POOR PERFORMANCES OBTAINED WITH FOUR DIFFERENT CIRCUITS

Selected average curves obtained with poorly adjusted Tuned-grid tuned-plate Hartley, Colpitts and Ultraudion circuits are shown.

The 1929 signal, in the first place, must be entirely within the limits of the band. Then, its frequency "flutter" due to irregularities of plate supply must not exceed about 1/30 of 1% (approximately 250 cycles at 40 meters). *We'll say more on that later.* In addition, the frequency of the signal must be relatively constant. The signal must not "shimmy" as the antenna vibrates, it should not "chirp" as it is keyed, nor can it "creep" appreciably as the line voltage fluctuates or the tube heats. In short, the frequency of the first dot transmitted should be within 1/10 of 1% (about 750 cycles at 40 meters) of the hundredth dot, even if the plate has reddened or the line voltage drifted in the meantime. And at the end of a few hours of operation the frequency should not have strayed much farther.

MEASURING PERFORMANCE

An examination of these requirements showed clearly that we could, in our Laboratory, even with the limited facilities, determine just when a transmitter came

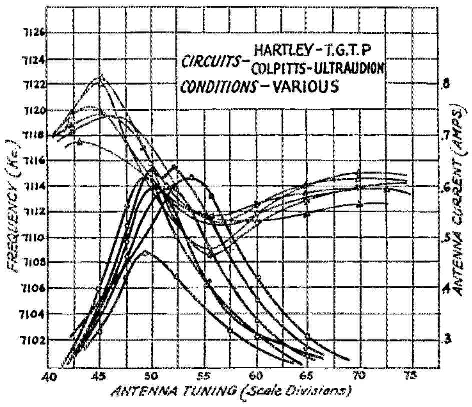
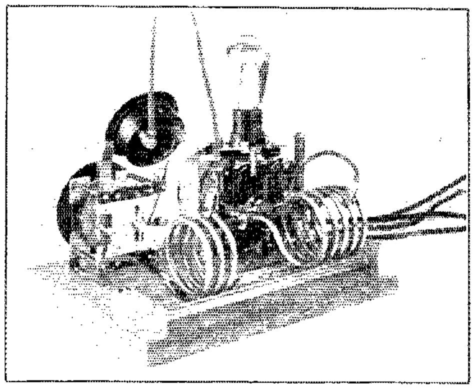


FIG. 5. CURVES TAKEN WITH THE SAME CIRCUITS RESPONSIBLE FOR FIG. 4 ADJUSTED TO GIVE THEIR BEST PERFORMANCE

Being representative of the capabilities of average present day self-excited transmitters, these and other similar curves are proving of great value to use in comparisons with those obtained with transmitters of modified or more advanced type.

up to the specification, and, if it did not, by just how much it failed. And so, at the outset, we built a transmitter with the closest possible electrical resemblance to the average low-powered amateur transmitter of the present day in order that we could plot in black and white the exact amounts by which it missed the mark under a variety of conditions.

Right here we must delve into a discussion of notes with the hope of clearing up some of the widespread misunderstanding which exists. First let us state that there are three distinct groups into which all notes can be divided. They are (a) the "pure d.c." produced by a transmitter emitting a single frequency (which incidentally is an extremely uncommon and rather undesirable note). (b) The "musical" note, resulting from a signal which is modulated by plate supply ripple in amplitude only (good crystal control transmitters with rippled plate supplies give them). And (c) the "mush" note, which is the outcome of a signal both "fluttered" in frequency



A REAR VIEW OF THE "1929 TYPE" LOW-POWERED HARTLEY

The tube socket being mounted on top of the plate tuning condenser, its plate and grid terminals are particularly convenient to the leads between the condenser and the coil on to which they are connected through the plate and grid condensers. And the left is the antenna tuning unit, consisting of a coil—which is moved along the glass rods for variation of antenna coupling—a condenser, and a thermocouple ammeter. The meter, though mounted on the condenser, must be insulated from it. The plate choke can be seen between the two variable condensers. Aside from their use in supporting the antenna coil, the glass rods also serve to prevent the plate coil from vibrating.

and modulated in amplitude by the plate supply.

The important point is that note "a"—the "pure d.c", occupies the least possible amount of territory, with note "b" coming next and occupying slightly more territory on account of the side-bands resulting from the modulation. Note "c", however, though obtained from the same plate supply that gave note "b", can well occupy ten times the territory, *for the output "frequency" of the transmitter is buzzing across a whole band of frequencies.*

Our first interest, therefore, was an actual measurement of the frequency change due to changes in plate voltage—that undesirable characteristic of self-excited transmitters which causes the *frequency* to "flutter" with any "ripple" in the plate supply.

Considerable difficulty was experienced in plotting the curves shown in Figure 1 for the reason that they were planned to represent only the frequency changes caused by variation of plate voltage and not the further changes due to resulting plate temperature variations. Though a high degree of accuracy was not found possible, the curves nevertheless were sufficiently representative of average performance to be of great value. From Figure 1 it can be seen that the average transmitter, tuned in the average manner, and operated on the 7,000-7,300 Kc. ("40-meter") band, can have its output varied by at least 18 Kc. with a change in plate voltage from 100 to 500. In the "self-rectified" or "raw a.c. supplied" transmitter this means that during each half cycle, as the voltage climbs to maximum and drops to zero, the frequency swishes back and forth across a band of more than 18 Kc! Is it any wonder that so many signals are just splutters, blotting out wide sections of the band? Among the curves are some representing the performance of all the standard circuits and from this and other families of similar curves it has been shown definitely that similarly horrible performance can be obtained from all the circuits without difficulty. What is more interesting, however, is that the enormous improvement indicated by a comparison of curves "A" and "B" can be attained in any of the circuits *merely by careful tuning*— a

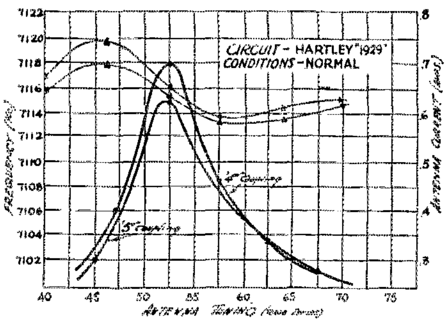


FIG. 6. IN WHICH IS SHOWN THE IMPROVEMENT RESULTING FROM THE USE OF A HIGH-C PLATE CIRCUIT

The antenna-tuning-vs.-frequency curves of the simple "1929-type" Hartley taken within two values of antenna coupling. Aside from their value in indicating the probable frequency response to antenna swaying, these and similar curves in Figs. 2, 3, 4 and 5 were found to be splendidly representative of the merit, in most other respects, of the circuits giving them. They were taken in large numbers and given detailed consideration for this reason.

reduction of the frequency "flutter" from 18,000 cycles to 600 cycles! With each curve the constants of the circuit were noted and from study of the conditions and the resulting curves a tuning procedure was evolved. But more of that anon.

SIGNALS WRECKED BY ANTENNA TUNING

Early in this work it became evident that one of the chief factors was antenna coupling and tuning. It was found that the performance changed radically as the antenna was tuned to resonance and beyond it, and that there were certain adjustments on one side of resonance or the other at which the desirable conditions were obtained. This check on previous observations[1] led to a most detailed study on the influence of antenna coupling and tuning —a study which provided a most magnificent check on all our previous deductions. In a series of some scores of curves the antenna tuning was varied and plotted against the output frequency. At the same time antenna current was noted at each adjustment of antenna tuning and the resonance curve so obtained plotted on the same sheet. The process was then repeated at several values of antenna coupling to pro-

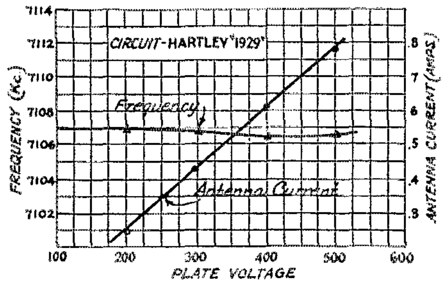


FIG. 7. DEMONSTRATING WHY "D.C." NOTES ARE NOT DIFFICULT TO OBTAIN WITH A HIGH-C PLATE CIRCUIT AND CORRECT TUNING

The "1929-type" transmitter under these particular conditions changed its frequency only 400 cycles when the plate supply was dropped 400 volts. Frequency "flutter" due to plate supply ripple was therefore extremely slight and a "d.c." note was obtained readily.

vide at least reasonably complete data for every circuit and transmitter under every practical combination of constants. Several typical curves obtained in this manner with a standard Hartley transmitter are shown in Figure 2. The values of antenna coupling are indicated in inches but it should be pointed out that, except under the particular conditions represented, these values are entirely meaningless. For us to say that your couping should be 2 inches would be as futile as for us to suggest that you should use 30 degrees of a condenser when we did not know its maximum capacity. The precise measure of coupling (the "coefficient of coupling") involves considerations of the inductance of the two circuits and their mutual inductance and it was merely the impracticality of using this measure

1. "Some Light on Transmitter Tuning", *QST*, July, 1927.

that led us to employ inches for comparative work.

THE EFFECT OF COUPLING

The important though elementary fact to be found illustrated in these curves is that as the coupling is reduced the frequency change due to variations in antenna tuning is steadily lowered. Two extreme examples indicated by curves "A" and "B" show that a reduction in coupling from 2" to 5", *though only resulting in a 5% drop in antenna current provided at least a 57% improvement in frequency stability.* Carried to a still greater extreme, and at the expense of about half the antenna current, a condition could be obtained (Curves "C") where an improvement of about 92% resulted. It may seem strange that these and succeeding similar curves are taken so seriously and given so much consideration and for this reason it might be explained that aside from indicating the responsiveness of the circuit to movements of the antenna they were found to be surprisingly representative of the merit of the particular transmitter from all other aspects. Without a single exception the adjustments and constants which provided the best antenna-tuning-vs.-frequency-change curve also provided the best plate-voltage-vs.-frequency curve and the best performance in general. And a more recent detailed theoretical study has shown that this should have been the case.

A point of considerable interest and of the greatest importance is illustrated on the curves of Figure 3 representing the performance of a Hartley at two less extreme values of antenna coupling. Curves "A" in this case represent those of a typical amateur transmitter in which the antenna coupling is excessive. Two points of maximum antenna current are found and relatively serious frequency change is indicated. Curves "B" represent the conditions with a desirable value of coupling, showing a single point of maximum antenna current (not appreciably lower than that of "A") and a much improved frequency characteristic. The important point, however, is that resonance occurs right at the steepest point of the frequency curve and that at this point the frequency stability under operating conditions probably will be at its lowest value. Further, it can be seen that whereas detuning of the antenna to a higher wavelength than the oscillator will mean operation on a flatter portion of the frequency curve, detuning in the opposite direction could result in operation right at a sharp peak of the frequency curve (the upper peak of curve "A" for instance) and the possibility of a stable frequency so be made equally remote. In actual practice it was found that not only was the stability much improved when the antenna was tuned to a higher wavelength (in this particular case) than the oscillator but also the note was vastly better. The latter condition resulting, of course, from an improved plate voltage vs. frequency curve. When the antenna *was tuned to the points "c" and "d", under these conditions, the note was a pure "d.c."* When it was tuned to points "e" or "f" (the antenna current being the same in each case) the note was heavily modulated and worthy only of the term "rac". At certain

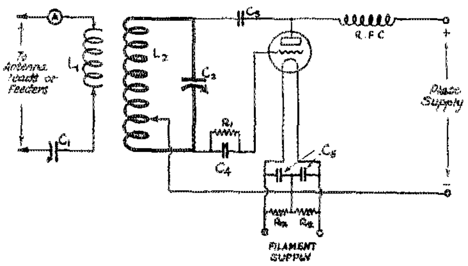


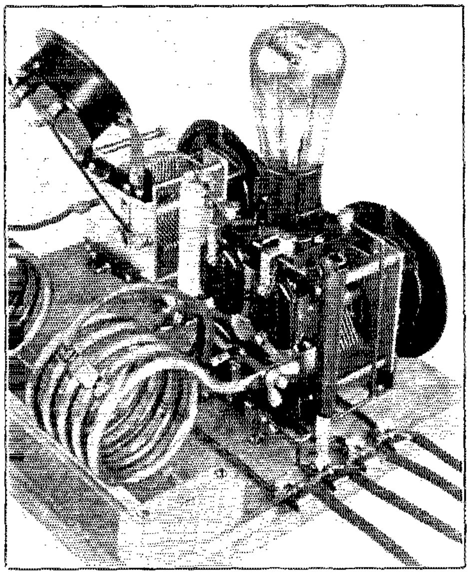
FIG. 8. THE SIMPLIFIED HARTLEY CIRCUIT OF THE "1929 TYPE" TRANSMITTER

A—Thermocouple ammeter 0-1 amps.
C1—500 μμfd. receiver type variable condenser.
C2—500 μμfd. receiver type variable condenser of good quality.
C3—500 μμfd. fixed condensers.
C4—250 μμfd. fixed condenser.
C5—2000 fd. fixed condensers.
R1—10,000 ohm. gridleak.
R2—50, 100 or 200 ohms fixed resistors or Christmas-Tree Lamps.
RRC—160 turns of No. 30 gauge D.C.C. wire on ¾" diameter wooden rod.
L1 and L2 for the various bands are described under the photograph of them.

values of antenna coupling this effect became much less marked, and at other values the "d.c." note was obtained on the reverse side of resonance. In quite the majority of runs, however, *it was found essential to detune on one particular side of resonance in order to obtain the best note and the maximum frequency stability.*

A COMPARISON OF CIRCUITS

Having made some preliminary studies of different circuits in regard to the variations of frequency caused by changes in plate voltage, and having been impressed by the similarity of their performance, a detailed comparison was undertaken at this stage. The various circuits were set up and in turn they were adjusted carefully to give their best performance. Then by tuning everything to resonance and by providing excessive grid excitation and antenna coupling they were each adjusted to give a series of poor performances. Scores of curves drawn from the data so obtained proved conclusively that the Hartley, Tuned-grid tuned-plate, Colpitts and Ultraudion all were capable of producing equally poor frequency stability and note, and on the other hand, when they were adjusted correctly, that their maximum performance was definitely of the same order. In Figure 4 is reproduced a family of typically poor curves for the standard circuits. In all cases they represent similar input power and, as can be seen from the resonance curves, similar antenna current. Figure 5 is a selection of the best curves obtained with each circuit, input and output powers being held to the same value in each case. The latter curves, aside from their interest as proof that standard circuits are similar in their performance, were of great value to us in providing a statement of the best possible results that could be expected from present day self-excited amateur transmitters. With these curves we could make accurate comparisons of the improved performance resulting from modifications and refinements and so determine rapidly and definitely the relative merits of the various arrangements. The curves representing the performance of the "Transmitter With a 1929 Performance" are reproduced in Figures 6 & 7 to provide just such a comparison. From these curves it will be seen that the simple—in fact crude—rig illustrated in the photographs is capable of performing quite creditably. It has a frequency change when correctly tuned of but 6 Kc. as the antenna circuit is passed entirely through resonance. It will encounter a sudden 400-volt change of plate voltage and swing its frequency approximately 400 cycles. In consequence when operated from rectified and reasonably well filtered a.c. the "flutter" will be negligible and the output in consequence "musical". In fact, even when supplied from the unfiltered product of a motor-generator it is capable of turning out a note that can hardly be described as other than "d.c." *Always providing, of course, that it is tuned with extreme care in the manner to be outlined.*



A "CLOSE-UP" SHOWING THE HEAVY "TANK" LEADS AND SOLID CONSTRUCTION

The plate and grid fixed condensers are mounted immediately under the tube socket. Below them are the two filament by-pass condensers and the center-tapped filament resistor. On the far side of the tube socket is the plate choke supported from the plate terminal. On the near side is the grid leak pushed over a wooden peg in the base-board. Heavy flexible wire is used for the filament lead to the inductance, a clip being permissible in this case on account of the low current to be passed by it. Relatively enormous currents flow in the coil-condenser circuit and in this case connections between the two must be made with wing nuts, or some similar device, in order to avoid serious losses.

And the circuit of this transmitter, disappointing though it may be, is nothing more than a simplified Hartley! Through all the work we had looked forward to the possibility of being able to insist that 1929 will not necessarily mean more complex or more expensive apparatus and even if we do anticipate some "raspberries" over the crudity of our sample transmitter we cannot disguise our pleasure at being able to state just that.

HIGH-C CIRCUITS

The feature of the transmitter which is directly responsible for its rather unusual performance is the plate oscillatory circuit, which is so proportioned as to have a preponderous of capacity. Such a circuit, having a low inductance-capacity ratio (to be described as a High-C circuit) has characteristics which make its use in the self-excited transmitter very desirable. A change from the inductance-capacity ratios in general present use to those indicated in Figure 8, for instance, resulted in a splendid improvement in the Antenna Tuning vs. Frequency curve (compare Figures 5 and 6); a distinct advance in the Plate Voltage vs. Frequency characteristic (compare Figures 1 and 7); and a corresponding improvement in the note. Of course, some minor disadvantages are involved.

In such High-C circuits, as the inductance is reduced and the capacity correspondingly increased, the circulating current mounts rapidly. Even with the UX-210 in the circuit of Figure 8, the radio-frequency current flowing through the plate coil and its condenser is of the order of 5 amperes, while with the larger tubes, and similarly High-C plate circuits, currents as high as 16 or 18 amperes are to be expected. High currents such as these enormously exaggerate the weaknesses in the tuned circuits and for this reason, if self-excited circuits are to be operated successfully next year, the arrangement of *the plate "tank" and the apparatus used in it will be matters of the greatest possible importance.* If a typical wire or small strip inductance of the present day is used, the losses in it will mean a drastic reduction of power. If a poor condenser is asked to do duty it will introduce still further losses or, if the inductance is good enough to give it a chance, will end its useful life by burning up its insulation.

COIL AND CONDENSER VALUES

Of equal importance to the coil and condenser are the connections between them. Spindly leads between the coil and condenser with clips on them for adjustment of turns can cause a heavy loss of output power, even in a 7.5-watt transmitter, and usually will result in a greater loss of stability than the High-C circuit could hope to give. In the higher-powered transmitter the resistance of such leads and clips can well cause the circuit to be entirely inoperative. A successful High-C plate circuit will require the use of ¼" copper tubing (or strip of similar surface area) for the coils of the transmitter of 50 watts or less, and at least ⅜" tubing or its equivalent for the higher powers. Then it will be necessary to determine the correct number of turns experimentally in order that the end turns may be screwed directly to the condenser terminals or to connecting strips. One satisfactory arrangement is that shown in the "close-up" of the transmitter. In this case "wing nuts" were fitted to the machine screws holding the inductance in order to facilitate changes from one band to another. In the case of the filament lead and other leads in the transmitter the currents are no higher than in the usual transmitter and consequently it is necessary to exercise only the ordinary care. The one redeeming feature of the "tank" condenser problem is that the voltages developed across a High-C circuit are much lower than in the circuits of the usual constants. For this reason good receiver-type condensers are satisfactory for transmitters operating with plate voltages of 1000 or less, while nothing more than "double spacing" should be necessary for transmitters employing the UX-852 or UV-204-A. It might be explained at this point that much higher capacities than those indicated in Figure 8 can be used if only heavy enough inductances and good enough condensers are used. Experiment with inductance-capacity ratios involving capacities as high as 1000 μμfds. at 7100 and 14000 Kc. has indicated, however, that with the usual equipment available readily at the present time the losses involved with ratios higher

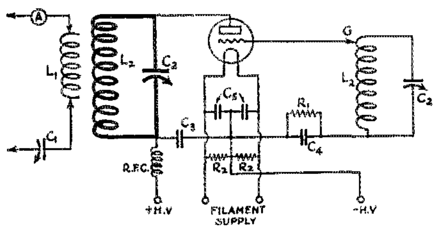


FIG. 9. SHOWING SIMILAR MODIFICATION OF THE TUNED-GRID TUNED-PLATE CIRCUITS

The grid clip "G" is provided to permit effective adjustment of grid excitation. The letters correspond to those of Fig. 8.

than that used in the transmitter illustrated are out of proportion to the increase in frequency stability afforded by them.

REBUILDING THE PLATE CIRCUIT

The modification of any present-day self-excited transmitter for operation with a High-C plate circuit is not a matter which should mean either appreciable expense or difficulty. In the transmitter used for work on all or several wave bands, a condenser of 500 μμfds. is suggested. For a transmitter which is to be operated exclusively on the 14,000-14,400 Kc. ("20-meter") and the 28,000-30,000 Kc. (10 meter) bands, a maximum capacity of 350 μμfds. should serve effectively. In the transmitter employing 1000 plate volts or less, a *good* receiver-type condenser should be satisfactory but it is suggested that it should not be considered above suspicion if trouble develops. In one of the experimental transmitters, fitted with a condenser of splendid reputation and operating with a single UX-210, a few hours of steady operation resulted in an invisible insulation breakdown which had the effect of reducing the output by about 50% and which caused the note to become a complete "hash". Under these conditions, obviously, all the careful tuning possible was of no avail. Another condenser of the same type, operated under similar conditions for several hours as a check, disappointed us by performing perfectly.

For the higher powered transmitters the use of two good transmitting condensers in parallel to give the suggested capacity values would serve but experimental work in progress at the moment (to be detailed in a future article) would seem to indicate the desirability of using an air-dielectric fixed condenser for the plate circuit, a small vernier being fitted for tuning. When variable condensers are used, it must be remembered that the mere inclusion of a 500 μμfd. size condenser in the set does not result in a High-C circuit unless the coils are so proportioned as to give the necessary frequency at the *upper end* of the condenser scale. For the 28,000-Kc. band the coil should be of such a size that about 200 μμfds. of the condenser are used; for the 14,000-Kc. band about 300 μμfds; for the 7,000-Kc. band about 400 μμfds; for the 3,500-Kc. band 450 μμfds., while for the 1715-Kc. band (on which frequency stability is not nearly so difficult to obtain) the same order of capacity is completely satisfactory. The coils shown in the photograph operate with just such capacities on the various bands in the particular transmitter for which they were wound. In the Tuned-grid tuned-plate or Colpitts circuit similar plate circuit constants are suitable.

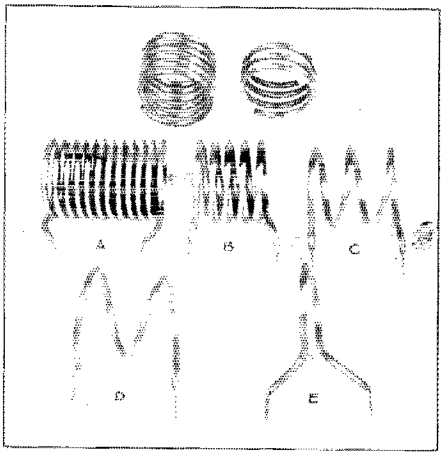


PLATE AND ANTENNA COILS FOR FIVE BANDS

Coils A. B. C, D and E are used for the 3,500-4,000 Kc. (80 meter), 7,000-7,300 Kc. ("40 meter"), 14,000-14,400 Kc. ("20 meter"), 28,000-30,000 Kc. (10 meter) and 56,000-60,000 Kc. (5 meter) bands, respectively. They have an inside diameter of 2⅝" and were made by winding the ¼" soft copper tubing over a length of 2⅝" outside diameter iron water pipe by hand. To facilitate the winding process holes were first drilled in the pipe and the tubing, one end of the copper tubing being secured to the iron pipe with a machine screw before the winding was started. The ends of the coils are hammered flat and drilled to fit under the wing nuts which hold them to the condenser leads. Two antenna coils—to be seen above the plate coils—serve for use with coils A, B, C and D. Their size will be determined to some extent by the type and constants of the antenna.

THE PLATE SUPPLY

It is not possible to make a detailed discussion of the self-excited circuit performance without in some way considering the problem of plate supply. At the same time, in view of the hundreds of thousands of words which have been written on the subject in *QST* and the Handbook, it is not thought necessary to give circuits or constructional details. If the transmitter is to be given any chance to perform in 1929 fashion, it is needless to say that the supply, if not generator or battery d.c. must be rectified and in some way filtered a.c. Further, the battery, generator, transformers, rectifiers and chokes must be capable of supplying or handling much greater currents than they will be asked to pass in actual operation, for if this is not so, the handicap of poor regulation will surely make the attainment of a 1929 signal more difficult.

There is also the same old problem of keying. Key clicks and sparking contacts will continue to be important, even if the transmitter is re-arranged and correctly tuned. In this case also, the incorporation of methods and the observation of precautions described in many *QST* articles and the Handbook will be necessary. A matter which will be of even greater importance with the 1929 self-excited transmitter is the elimination of antenna swaying and the vibration of the set or any of its radio frequency wiring. The modified arrangement and correct tuning admittedly will reduce the effect of these variations on the frequency but at the same time the character of the note will be so improved that these variations will be much more noticeable. With a 1928 transmitter in which the plate supply ripple "flutters" its frequency over a band of 15 or 20 Kcs., the effect of a swinging antenna or a vibrating lead is to a considerable extent lost in the mess. With an otherwise steady and "pure d.c." signal, however, any such weakness will protrude in all its infamy.

THE ESSENTIALS OF TUNING

And now, since the highlights of transmitter tuning have been so broadly scattered throughout this rambly screed, let us collect them in a simple statement of good procedure.

When the transmitter has been assembled, or re-assembled; when the antenna and its leads or feeders have been tightened or in some other way prevented from swaying; when it has been found that all leads or coils, and the transmitter itself, cannot vibrate; when the coils have been adjusted to give the desired frequency with the necessary value of capacity—then, and not until then, should the grid excitation be adjusted to give a plate current of about half the rated value with the antenna coil removed. In the Hartley this will mean adjustment of the filament clip in steps of about half an inch at a time, keeping mind, for a rough guide, that the ratio of turns between the grid and filament clip and the turns between the plate and filament clip will be somewhere between 1 to 4 or 5. In the Tuned-grid tuned plate it will mean tuning of the grid circuit and the plate circuit and adjustment of the grid clip shown in Figure 9.

At this stage, when it is known definitely that the frequency is within the band, the antenna coil can be connected and coupled loosely to the plate coil. And loose coupling for the particular coils used in the Hartley transmitter illustrated is obtained with a spacing of *not less than five or six inches.* When the antenna has been tuned and the coupling increased to give the maximum antenna current, the value of that current should be noted mentally as something to avoid as one would the plague. Without delay the antenna coupling should be backed off until a point is reached at which the maximum current is about 85% of the previous value. And this reading should be recorded as something to be avoided with equivalent enthusiasm. At this stage the use of a "growler" (a shielded oscillator fitted with 'phones) or a receiver tuned to a weak harmonic becomes essential, for only by listening to the signal within the station is it practical to decide on which side of resonance the antenna is to be tuned to give the best note. Under practically all conditions, the correct adjustment will be obtained when the antenna is tuned to a lower frequency (a higher wavelength) than the oscillator but a comparison of the signal obtained in this way with that obtained on the other side of resonance will immediately indicate the desirable side. All that then remains is to detune the antenna on that side in order to give an antenna current of about 75% of the 85% peak value. *And this is the antenna current which should never be exceeded if the transmitter is to perform in the true 1929 manner.*

After a final check of the frequency, CQ's may now be pounded out in limited quantities and a QRK may be asked with a certain amount of confidence. If the reader has followed this story and put its suggestions into effect, he can expect a favorable report. It is conceivable, in fact, that the signal will inspire the answer "You have a 1929 signal, O.M." And, if he has previously listened to it himself in his own "Growler", he will know that he is entitled to believe it.

[As an extension of the subject of self-excited transmitters, the constructional considerations involved in the modification of higher-powered transmitters will be discussed in the September *QST*.—Editor.]

Editorials

(Continued from Page 8)

more, because more of us are going to be knowing what we are doing than ever before! If we may throw in a free advertisement for the old mag, don't miss *QST*—we're going to have lots of hot stuff.

And so, taking things by and large, we feel a lot better. Everything looks pretty. In fact we insist upon being optimistic as anything. And in winding up this screed for the month we want to point out that a great deal of the activity around the world in the way of readjustment attests a recognition of the established position of amateur radio which is based upon the strength we have secured by virtue of being written into the international treaty as one of the classes of stations that always shall be provided for. Believe us, that is good! It looks to us like it may turn out that, having developed our technique to where we may operate happily in our limited facilities, it was really a blessing to us that this international conference came along and resulted in our international status being so definitely established. All we want to say is that any ham who wants to sell his station because "this is the last year of amateur radio" is just plumb foolish!

K. B. W.

Strays

The Radio Corp. station WIK, a useful marker in the vicinity of our "20-meter" band, was changed in frequency on June 24th to a new assignment at 13930 kc. (approximately 21.54 meters). A new R.C.A. station, WOP, is approaching completion and will be heard soon on 13900 kc.

9DPL, having read the recent newspaper report that Congress had changed the postal rate to permit other than government postal cards to be mailed with one cent postage, claims that this should surely result in QSLL activity returning to normal.

The Headquarters Office of the Ninth District, Department of Commerce Radio Division, recently moved from the Federal Building to new quarters. Communications to the Supervisor of Radio in that district should now be addressed to 2022 The Engineering Building, Chicago, Ill.