Stabilizing Superheterodyne Performance

Electron-Coupled Oscillators Using Heater-Type Tubes

By James J. Lamb, Technical Editor

ALTHOUGH it is common to associate frequency stability almost exclusively with transmission and frequency measurement, and to consider lightly, if at all, the problem of frequency stabilization in such oscillators as may be involved in receivers, a current Hq. attack on c.w. receiver selectivity has shown strikingly the absolute need of a high order of oscillator frequency stability in a receiver that can make any pretense to the kind of selectivity we have in view. It has shown even more strikingly the utter inadequacy of the kind of oscillators that we had come to take for granted. From the present point of view it is something of a paradox that we should have been so worshipful of oscillator stability for transmitters and, at the same time, so completely disrespectful of oscillator stability for the receivers in which well-nigh perfect signals were to be heterodyned. We now see in this lack of coördination between transmitter and receiver stability the explanation of a number of things. There isn't as much transmitter frequency "creeping" as was thought, for instance — a great deal of it is in the receivers; there aren't so many non crystal-controlled transmitters that actually merit "CCDC" reports — a really stable and highly selective receiver shows up even minute defects in less-than-perfect signals. But the rest of that must wait for a future issue of *QST*. The oscillator that satisfied the demand constitutes this story. Although the use specified for it here is in the superhet receiver, it is just as applicable to frequency meters, beat-frequency oscillators and general laboratory apparatus requiring a highly stable tuned oscillator that can furnish a little power to a load circuit without jumping off the reservation.

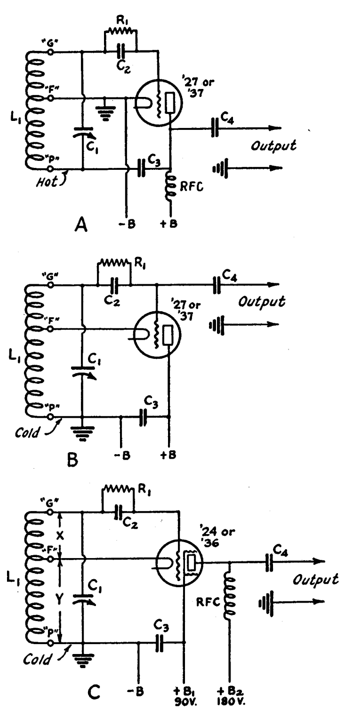

FIG. 1 — THE EVOLUTION OF THE HARTLEY TYPE ELECTRON-COUPLED OSCILLATOR CIRCUIT FROM ITS TRIODE PARENT

Just one of the several problems peculiar to superheterodyne receivers, and a particularly touchy one in the case of the high-frequency superhet, is that of obtaining an oscillator-first detector combination in which the oscillator not only has a high order of frequency stability *per se* but also is capable of maintaining its intended frequency unaffected by the first detector circuit with which it is associated. It is not enough that it have only the kind of frequency stability that is relatively impervious to changes in supply voltages; it also must be practically impervious to rather drastic variations in its load circuit, for it is required to furnish power, small though that power may be, to the first detector circuit. The oscillator load conditions are not constant. The first detector must be tuned. The degree of "pulling" of oscillator frequency with tuning of the first detector circuit seems to be, unfortunately, a matter of percentages and not one of a fixed number of kilocycles at all points in the frequency spectrum. Therefore an oscillator-first detector combination that may be entirely satisfactory in the broadcast range below 1500 kc. becomes completely hopeless as we go up through the high-frequency amateur bands. The superhet, with its dependence on a fixed arithmetical difference between signal and oscillator frequency to give its required intermediate frequency, is an intolerant thing in that respect.

Of the systems in vogue, using conventional oscillator circuits, those in which the oscillator output is coupled to some element of the first detector circuit not directly associated with its tuned input have been found by critical comparison to be least liable to this pulling effect. Of these the screen-grid modulation system shown by Howard Chinn[1] seems better than the others while various schemes utilizing coupling to the detector cathode circuit appear less favorably. Perhaps the most

[1] Chinn, "A High-Frequency Converter with Single-Dial Control," *QST*, June, 1931.

effective arrangement is one in which a buffer or coupling tube is interposed between the oscillator output and the grid circuit of the first detector, a feature of the receivers used to pick up foreign broadcasts at Rocky Point.[2] This provides a degree of oscillator independence impossible with the simpler systems but is robbed of some of its appeal by the necessity for the extra tube and necessary coupling gadgets, especially of its appeal to one who finds the superhet already complicated enough and who is looking for simplification rather than complication of the animal. But the buffer is attractive — in fact doubly attractive because it provides not only the isolation we want but also because it can serve as an effective harmonic generator. Doubling, tripling and quadrupling the oscillator output frequency, one oscillator tuning range can be used for several ham bands; and, what is more, oscillator independence becomes truly complete when its harmonics, and not its fundamental, are used to heterodyne the signals in the first detector. Eliminate the coupling tube and, at the same time, improve oscillator stability — that would be something!

Well, we have it. Improved performance without complication and with actually better all-around frequency stability than the oscillator-buffer can deliver has been realized with modifications of the electron-coupled type of oscillator described recently by Lieutenant Dow.[3] In this family of circuits a screen-grid tube is used with the cathode, control grid and screen grid forming the elements of the frequency-generating circuit while the plate is in the output circuit, shielded from the oscillator circuit proper by the screen grid. The coupling to the load circuit is electronic rather than capacitive or inductive, thereby greatly reducing effects of load circuit conditions transferred into the frequency generating circuit, in much the same way that they are reduced by the usual separate buffer amplifier. To effect this it is necessary that the screen-grid or inner anode be at "ground" r.f. potential which, in turn, makes it necessary to have the cathode "up in the air." With tubes having directly heated cathodes (the usual "filament" types) it is requisite that the filament leads be brought to the tube either through the tank inductance or that the filament be fed through r.f. chokes, an inconvenience in either case. With tubes having indirectly heated cathodes, however, it has been found completely satisfactory to operate the heater at "ground" r.f. potential and connect the cathode to its proper position in the frequency generating tank circuit. The inner-anode (screen-grid) end of the latter is grounded and connected to the negative side of the plate supply. Contrary to expectations, the r.f. potential difference between the heater and cathode does not seem to have any ill effect nor does the small heater-cathode capacity seem to be injurious. On the contrary, there is evidence that the variation in this capacity with temperature changes tends to compensate for other capacity-temperature effects, with the result that the frequency creep during warming-up is less than is usual with the same tubes in more conventional circuits. Coupled with the inherent dynamic self-stabilization that is characteristic of this type of oscillator, these properties make it fitted not only to the jobs offered in the superhet receiver, and in transmitters, but also, we believe, to a number of other jobs that beg for such stability.

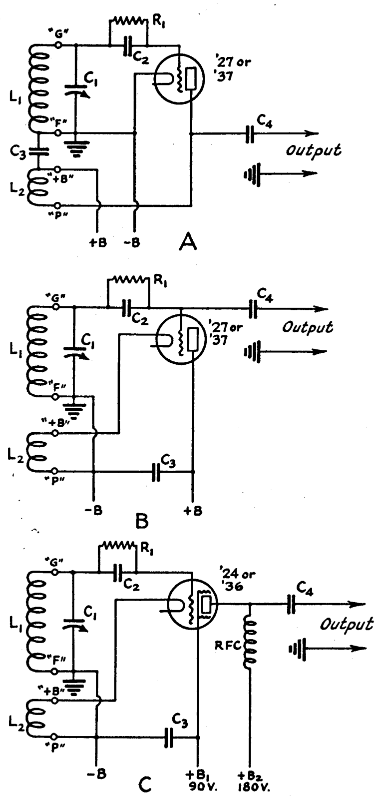

FIG. 2 — TRACING THE TUNED-GRID AND TICKLER VERSION FROM THE FAMILIAR REGENERATIVE TRIODE CIRCUIT

TESTED CIRCUITS

Illustrating that there is nothing mysterious about the relationship between the Hartley of the electron-coupled type and the more familiar triode oscillator of the same family, Fig. 1 shows the evolution of the former from the latter. At "A" we have an old friend, the "conventional Hartley" (how many times have we read that in "Station Descriptions"?) with its cathode grounded and with shunt plate feed. Both ends of the tank are "hot" with r.f., as all who have burned their fingers on dial set-screws need not be reminded. At "B" we see a less familiar version of the same circuit, one that has been used

[2] Peterson, Beverage and Moore, "Diversity Telephone Receiving System," *Proc. I. R. E.*, April, 1931.

[3] Dow, "Electron-Coupled Oscillator Circuits." *QST* Jan., 1932.

little but which could be put to work nevertheless. One end of the tank circuit is now "cold," and the rotor of the tuning condenser can be grounded. The cathode is above ground as far as r.f. is concerned and the plate is brought to ground r.f. potential through the by-pass condenser C_3. No r.f. choke in the plate feed is necessary. Coupling to the output circuit is shown from the grid, through C_4, but could be taken off just

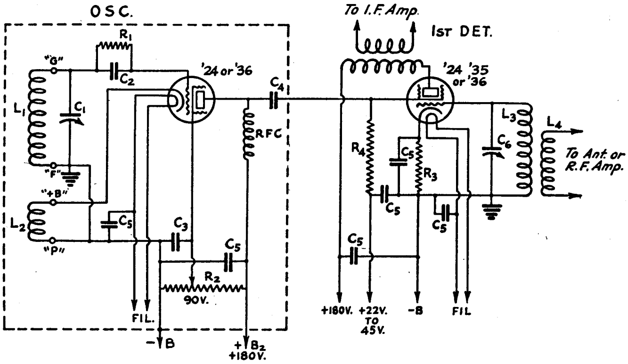

FIG. 3 — A TICKLER FEED-BACK E.-C. OSCILLATOR AND FIRST-DETECTOR COMBINATION THAT CAN BE ADAPTED TO EXISTING RECEIVERS AND HIGH-FREQUENCY CONVERTERS

L_1, L_2, L_3, L_4 — *Usual for frequency range covered. See* "The Radio Amateur's Handbook."
C_1 — *Band-spread tuning condenser (Cardwell, General Radio, National or R.E.L.).*
C_2 — *Grid condenser, 100- to 250-μμfd. mica type.*
C_3 — *Inner anode by-pass condenser, 0.01-μfd.*
C_4 — *Plate coupling condenser, 100-μμfd. mica fixed or midget variable.*
C_5 — *By-pass condensers, 0.01-μfd. or larger.*
C_6 — *Usual grid tuning condenser, 100-μμfd. or smaller.*
R_1 — *100,000-ohm grid-leak.*
R_2 — *Voltage divider, two 10,000-ohm 2-watt carbon- type in series.*
R_3 — *Detector cathode (bias) resistor, 5000-ohm 1-watt carbon type.*
R_4 — *Screen-grid coupling resistor, 50,000-ohm 1-watt carbon type.*
RFC — *Radio-frequency choke for oscillator frequency range.*
Filament supply for '24 and '35 tubes, 2.5-volt a.c. with filament center-tap connected to "—B"; for '36 tubes, 6 volts d.c. with no filament center-tap. The same filament and plate supply can be used for both oscillator and first detector. Oscillator filament by-pass condenser C_5 should be connected directly to one filament (heater) socket terminal and must not be omitted.

as well, and perhaps to better advantage, at the cathode. The coupling condenser could be omitted, by the way, for direct coupling to the grid of an amplifier. Bias for the latter could be provided by a resistor between "$-$B" and its cathode. After "B" there isn't much of the mysterious about "C," the electron-coupled Hartley circuit. The screen-grid becomes the inner anode, taking the place of the triode's plate, and the load is coupled to the tetrode's plate. Although it does not look that way on the diagram, the best ratio of turns between cathode-grid and cathode-anode is about 2 to 1; that is, "*X*" should comprise approximately two-thirds of the total inductance and "*Y*" one-third. The tank circuit, L_1C_1, preferably should be rather high$-C$ — for instance like that of the dynatron frequency meters that have been described in *QST* and in *The Radio Amateur's Handbook.* The use of a band-spread condenser utilizing a fixed minimum capacity in parallel with a tuning section works out very well. With battery "B" supply the voltages indicated on the diagram can be used, but with power-pack supply it is advisable to incorporate a voltage divider in the circuit, as shown in Fig. 3. The component specifications for both Figs. 1 and 2 are the same as those of corresponding designations in Fig. 3.

Fig. 2 shows the evolution of the electron-coupled tuned-grid and tickler circuit from its triode parent. There is nothing mysterious about it, either, even though it appears like a misprint to have both the grid and plate connected to the "grid" circuit, the cathode connected to the tickler, and one side of the latter grounded. But it works in great style and does so with coils intended for a regenerative receiver. In fact it is used regularly, in our work, with an Aero automatic tuner [4] "as is," covering the bands from 3500 to 14,000 kc. with band-spreading all the way. This arrangement is immediately adaptable to existing superhets and high-frequency converters that use tuned-grid coils, plug-in or otherwise, in the oscillator. The coil-terminal designations correspond to those for a triode tube and are given to make changing over less confusing.

Fig. 3 shows the circuit of an oscillator-first detector combination that originally was equipped with a triode oscillator. The only changes necessary were in the oscillator circuit. If the first detector coil-former happens to be equipped with a tickler winding it is suggested that the oscillator coupling condenser C_4 be attached to one end of it instead of to the screen-grid of the detector tube and that the other end of the tickler winding be grounded. This provides inductive coupling from the oscillator to the first detector grid circuit and is more effective than the screen-grid connection. Slight pulling of the oscillator frequency with tuning of the detector is probable at frequencies in the 7-mc. band and higher but this can be eliminated by using the second harmonic of the oscillator. With this coupling scheme the screen grid of the detector is connected directly to the "+22 V" tap and the resistor R_4 is omitted.

Shielding of the oscillator, indicated by the dash-line box in Fig. 3, is recommended — is necessary, rather, if the full capabilities of the

[4] Hoffman and Mix, "Revolutionizing High-Frequency Tuner Design," *QST*, Feb., 1930.

system are to be realized. Any kind of an oscillator in any kind of a superhet should be screened off by itself, we have learned from experience, because unscreened it not only gets into crazy coupling entanglements with the detector circuit but also it may try to pick up and detect signals on its own, may operate as a secondary autodyne feeding the i.f. amplifier with troublesome beats and generally complicate things no end. That this oscillator can be adapted to the various *QST* converters and to the one described in *The Handbook* goes without saying. But when the change is made it is suggested that the above suggestions regarding shielding be adopted also.

The rest of the story — about receiver frequency stability and "single-signal" c.w. selectivity? It's on the fire. But no questions answered before it breaks in *QST*. So let's talk about tourmaline crystal control and meet the mailman at the corner for the next month or so.

STRAYS

The Bloomfield Radio Club of Northern New Jersey has been one of the most active backers of 56-mc. communication. Recently D. A. Griffin, ardent member of this club, took his pair of '12 tubes to a hilltop two miles from home. Between the hours of 2 and 5:30 p.m. he worked a total of 12 stations ranging in distance up to 25 miles. Lack of breath was the reason for closing down.

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Our Frankenstein Stray of last month can get some close competition. One fellow built an Unorthodox Receiver. In all sincerity he explains that he used d.c. instead of a.c. tubes, left off the untuned stage, did away with the screen-grid detector, eliminated the band spreading, avoided the ganging of tuning condensers and reverted to transformer coupling. Strangely, the set didn't work, and it was "built according to *QST*"!!!

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Testing tubes can be carried too far. W9UZ, purchasing four of these newfangled photoflash lamps for taking flashlight photographs, asked the man behind the counter if he would "test" them, and waited to see what would happen. Believe it or not, the clerk blew up two of them before the proprietor came along and blew up also. W9UZ escaped and is still at large.

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"FS" opines that these transmitting tests of Handy's ought to end the depression in the power industry.

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BOARD MEETING SOON

The Board of Directors of A.R.R.L. holds its annual meeting in middle May. Now is the time to convey to your director the suggestions you have for bettering amateur radio. His name and address are on page 6 of any *QST*.

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Miss Josephine Rohas, whose picture appears in this neighborhood, is possibly the youngest duly qualified and licensed YL ham in the world. With six months of solid amateur activity behind her, Josephine still looks forwards to her fourteenth birthday in June. At brother Rod's station W8EKM she wields a fine fist almost nightly. Her other activities include planning stations for the Girl Scout troop headquarters, where she spends a deal of time, and for the local High

School, in which Josephine is a freshman. Schedules with other YL's (and with OM's for that matter) are requested.

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There is another handy gadget manufactured locally which should be of interest to hams needing the necessary delay before applying voltage to their '66s. A double wall-type switch from all appearances, but one of the switches has a delay of 15 seconds before closing, is what we have run across, and is one of a list of dozens of variations all selling under the name of Mark-Time switches, made by M. H. Rhodes Company, Hartford, Conn.

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A last resort to filter a refractory "B" supply when no additional filter apparatus is available is to hook a "B" battery, any size, any degree of defunctness, in series with the positive lead. The combined resistance and polarity effect completely eliminate supply hum.

— *W1CBD*