A Radical Approach to VFO Design

New Hope for an Old Problem

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• For some years the self-assured author of this article has been a controversial figure, and the publication of his articles has often precipitated a storm of protest and encomium from our better-informed and most erudite readers who take their radio more seriously than the average amateur. However, recognizing the inherent worth of his current interest, we have no alternative but to offer another example of Mr. Rapp's conceit.

The science of amateur radio has been brought to a high degree of perfection in practically every phase except one. There is little room left for improvement in receivers and r.f. power amplifiers. The modern two-wire feed version of the off-center fed antenna, with its standing-wave ratio of less than 0.5 on all bands, has neatly solved the antenna problem for all but a few, and even those few are beginning to have their doubts. However, there is still one field in which amateurs have not kept up with the times, and that is the field of frequency control.

Let us examine the record. Amateurs have vacillated from self-controlled oscillators of the worst possible sort (*circa* 1922) to crystal control (*circa* 1933) to the well-loved-but-inadequate "ECO" (electron-coupled oscillator, *circa* 1939). Listening to the signals on most of the bands, one gains the impression that all three types of oscillator are still in use. Unquestionably this is a disgusting blot on the glorious escutcheon of amateur radio! Simply changing the name from ECO to the more general "VFO" has effected little if any improvement. It is time something was done about it.

Something *can* be done about it! The author will present in this paper his latest findings on frequency control and stabilization, and it would be well for every amateur to study the following pages carefully unless he has something better to do. Even the manufacturers might learn plenty.

It was obvious from the beginning that the oscillator circuit must meet several stringent conditions. It should be completely insensitive to temperature and voltage changes, and it should be impervious to shock and vibration. However, the primary objective of good stability was never lost sight of.

As it developed, and as other workers have noted, the temperature and shock requirements could be met by good mechanical design and thermal compensation. The author's major contribution is in the field of voltage insensitivity. The clue was found in an old log book, where it was noted that most of the operators working the low edge of a band used the Hartley oscillator, while those at the high end used the Colpitts.

Basic Circuits

For those readers whose knowledge of oscillator circuits doesn't go further than the Clapp and the modified Pierce, a slight review is indicated. The basic Hartley circuit is shown in Fig. 1-A. It can be seen that the cathode connects to a tap on the inductance. The Colpitts, shown in Fig. 1-B, is somewhat similar, in that the cathode connects to a tap on the capacitance. In practice this was readily obtained through the use of two capacitors in series. The clue, mentioned above, was in recalling that all Hartley oscillators chirped one way (higher in frequency) and the Colpitts chirped in the opposite direction (lower in frequency). Obviously, the amateurs had been aware of this and used only the band edge that would permit them to chirp back inside. It occurred to the author that the two circuits might be combined to result in an oscillator that wouldn't chirp in either direction. (It should be pointed out that the chirp of any oscillator is a result of voltage changes during "make" and "break.") Combining the two circuits to form a Harpitts (or Coltley) circuit is a simple matter, resulting in the basic circuit of Fig. 2. It seems rather odd that this was never done in the past, but blind spots like this occasionally show up in our think-

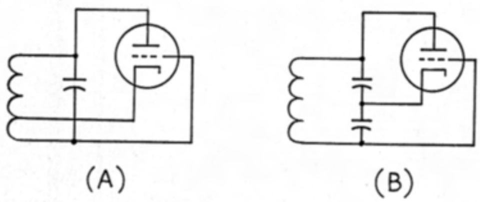

Fig. 1 — **(A) Basic Hartley oscillator circuit. (B) Basic Colpitts oscillator circuit.**

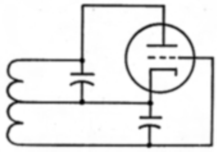

Fig. 2 — **Combining the two circuits of Fig. 1 results in a VFO circuit with amazing possibilities. The circuit shown here is not a practical one, since no provision has been included for applying power.**

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Readers who may have had doubts about the effectiveness on the air of Mr. Rapp's inventions can forget them in view of this evidence. The coveted "Helvetia XXII" award has been received by only four other Ws, all in the 2nd call area.

ing. A practical circuit based on Fig. 2 would include an adjustable grid leak to set the operating bias to a proper value. Since the chirp is dependent upon the amplification factor (μ) of the tube, adjustable bias and the use of a variable-μ tube are obvious necessities.

A Super Solution

Most experimenters would have been satisfied with this solution, but the objective here was Perfection (with a capital "p"). Old hands at this radio game will recall that there is much to be said for push-pull operation of vacuum tubes. It is a matter of record that at one time in amateur radio practically everything was push-pull: transmitters,[1] receivers,[2] and even antennas.[3] For some reason that escapes the author, the widespread use of push-pull has fallen by the wayside, although suggestions of it may still be found in power supplies, some audio amplifiers, and primitive u.h.f. work. Having decided to utilize the advantages of push-pull in the Harpitts (or Coltley) circuit, it became obvious that push-push frequency multiplication would add still further improvements. As is well known, push-push frequency multiplication uses push-pull excitation and parallel output to obtain highly-efficient even-harmonic multiplication.[4] No well-designed VFO should operate on the same frequency as the radiated output, so frequency multiplication must be used somewhere, and what better spot than the oscillator?

The practical circuit is shown in Fig. 3, and it must be confessed that the results with it exceeded all expectations. After the cathodes had been permitted to come to temperature, plate and screen voltages were applied and the oscillator worked immediately. Tuning the plate circuit to the second harmonic peaked the output. When the frequency was changed by turning the control for C_1, it was observed that the frequency didn't change immediately. At first it was thought that this might be caused by a mechanical deficiency in the rubber tubing that was being used as a shaft coupling (as indeed some of it was), but it was finally established (after removing the rubber

(*Continued on page 118*)

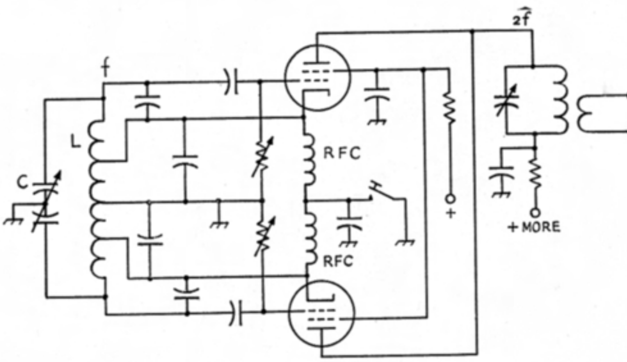
[1] Lamb, "Push-Pull Transmitters," *QST*, December, 1928.

[2] McCord, "A Receiver with Push-Pull R.F. and Detector," *QST*, September, 1930.

[3] W9CRD, "Push-Pull Antennas," *QST*, December, 1929, page 45.

[4] *The Radio Amateur's Handbook*, 12th edition, 1935, published by The American Radio Relay League, West Hartford, Conn., page 106.

Fig. 3 — The practical VFO circuit in its push-pull push-push variation. The use of variable-μ tubes is mandatory, as explained in the text.



Mr. Rapp

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tubing) that there was some "electronic backlash" to this circuit. Reference to the literature disclosed no discussion or report of the effect, and at first it was attributed to the inherent stability of the oscillator. This turned out to be the case but not the explanation; however, it is obvious that an oscillator that doesn't change frequency immediately even when detuned is indeed a very stable oscillator. A further analysis of the circuit disclosed that each tube was acting as a "Q Multiplier" during the half of the r.f. cycle when it wasn't oscillating, and consequently the effective Q of the circuit was higher than had ever been achieved before, even with special components. The author takes no credit for having anticipated this effect, merely for the explanation, but it should be apparent that the circuitry described saves two extra tubes. Since the effect of Q has been likened to inertia, or a "flywheel" action, the advantages of Q multiplication in an oscillator circuit are obvious. Everyone knows that once a flywheel is spinning at a given speed it cannot be made instantaneously to spin at another speed. In practice the slight time lag in changing frequency with tuning (only a few seconds) is no real operating hardship for anyone except perhaps a top contest operator. It affords a good measure of the effectiveness of the circuit, since if you can't observe the effect with the oscillator you build it should be apparent that you haven't constructed a true "push-pull push-push Q-multiplying Harpitts (or Coltley)." But don't settle for anything less!

One final advantage of this circuit should be pointed out, and then you can get busy with your soldering iron. It was observed that any kind of shaping filter or vacuum-type keyer connected in the keying circuit had absolutely no effect! This insensitivity to environment was accepted as another indication of the remarkable stability of the circuit. Eventually the key, with its associated shaping circuits, was placed in a later stage in the transmitter, and the fondest hopes of amateur radio were realized. No chirp or clicks!

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