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The BC-221 Frequency Meter as a VFO

A Combination Crystal and Variable-Frequency Exciter for Transmitter Control

BY HOWARD W. JOHNSON,* W7NU

• In an earlier issue of *QST*[1] the use of surplus military frequency meters as frequency-control units in transmitters was suggested. This article shows how one of these meters may be made to serve as a calibrated highly-stable VFO exciter without impairing its use as a frequency meter. Not the least attractive feature of this unit is that the oscillator is sufficiently well-shielded so that it need not be keyed for break-in work, thereby minimizing the problem of good keying.

THE already crowded conditions on the amateur bands plus the rapid influx of new operators have made variable-frequency exciters a necessity rather than a luxury. The subject of spot-frequency operation has been well-enough covered recently so that no amateur has to be sold on its merit. It can almost be said that if two or more stations would use the same frequency during contacts, there would be twice as much effective space in the bands as there is now. This is not quite true, because many amateurs are following this practice at the present time. Obviously we can't zero-beat stations operating outside the American bands!

It is desirable that the VFO be variable only at the will of the operator; too many of those built without proper care have ideas of their own on the subject and seem to want to be constantly variable. Let's take a look at the desirable features which should be incorporated in a variable-frequency exciter for amateur use.

1) *Stability:* This is the primary consideration and should mean stability under vibration, temperature variation, and load variation.

2) *Calibration:* The combination of stability and accurate calibration are the two things which help to insure operation within the band limits.

3) *Keying:* The exciter should be capable of being keyed for break-in operation without being heard in the receiver with the key open, and should be free from transients or chirps.

4) *Output:* This will vary with transmitter requirements, but in general the output should be from two to five watts and preferably at low impedance to allow the exciter to be located at the operating position.

5) *Crystals:* It is desirable but not necessary to have one crystal on each band for use in band-edge operation.

Most of the commercially-available VFO exciters satisfy the first fairly well. As for the second, very few of them have calibration accurate enough for dependable operation adjacent to band edges. The third requirement is seldom met in commercial models, since it is necessary to key the oscillator for spot-frequency break-in work and this cannot be done without chirps or clicks to a greater or lesser degree.

The power output mentioned in the fourth consideration is more than ample in some of the models available. It is the opinion of the author

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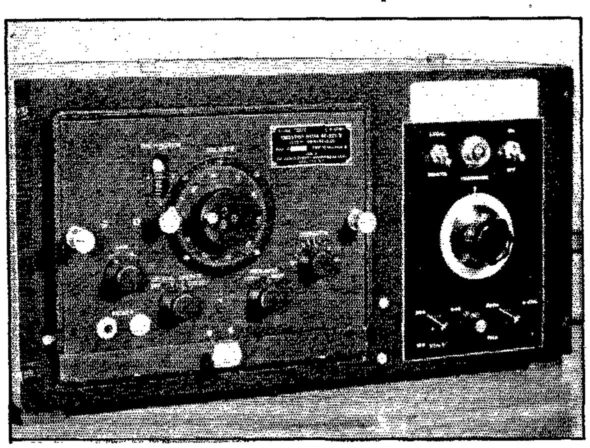
[1] Conklin, "Frequency Meters as Master Oscillators," *QST*, August, 1946, p. 34.



The BC-221 frequency meter mounted to serve as the VFO in a transmitter exciter. Controls to the right are for the added stages which boost the power output to about 3 watts. The entire assembly is mounted in a cabinet fitted with shock-absorbing rubber feet.

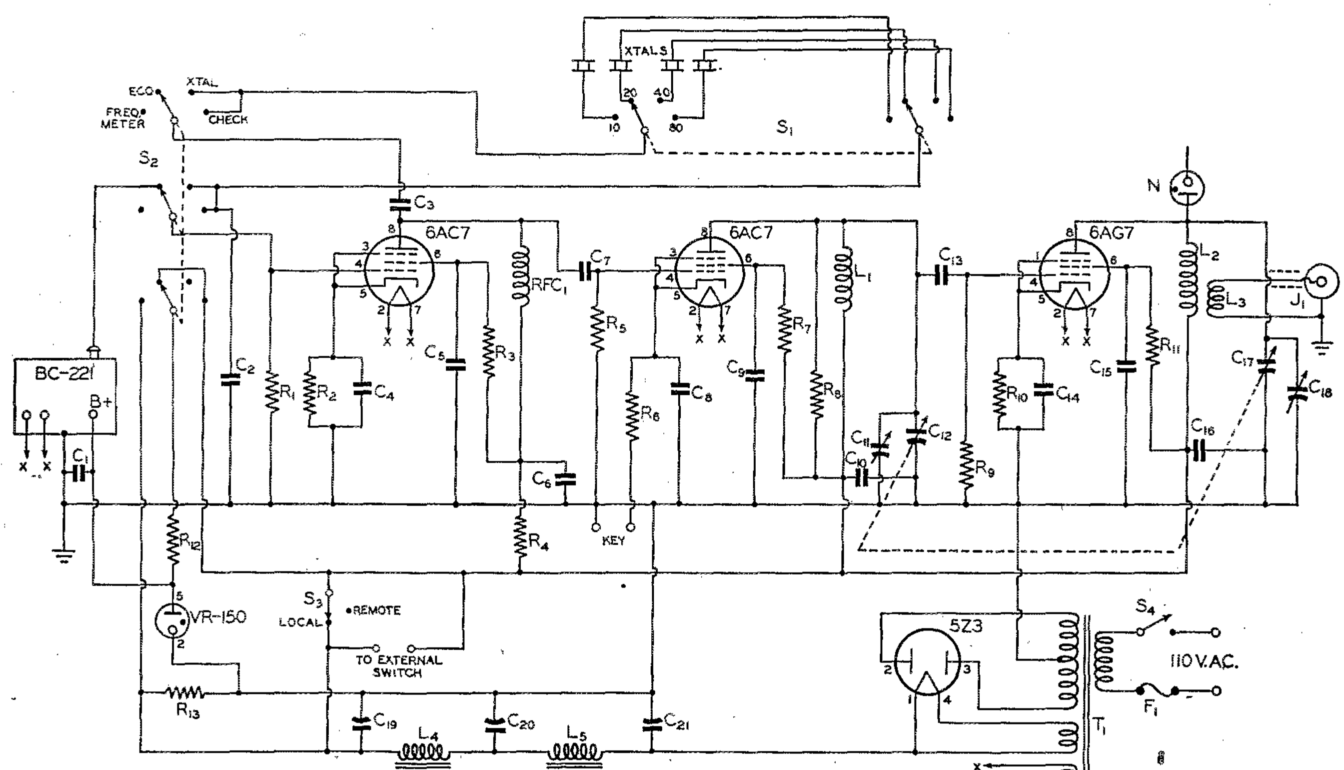


Fig. 1 — Circuit diagram of the BC-221 VFO unit.

C1, C8, C4, C5, C6, C8, C9, C10, C14, C15, C16 — 0.006-μfd. mica.
C2, C7, C13 — 100-μμfd. mica.
C11, C18 — 50-μμfd. variable.
C12, C17 — 75-μμfd. variable.
C19, C20, C21 — 8-μfd. 450-volt electrolytic.
R1, R5 — 0.47 megohm, 1 watt.
R2, R6 — 150 ohms, 1 watt.
R3, R7 — 68,000 ohms, 1 watt.
R4 — 4700 ohms, 2 watts.
R8, R11 — 22,000 ohms, 1 watt.
R9 — 0.22 megohm, 1 watt.
R10 — 220 ohms, 1 watt.
R12 — 5000 ohms, 10 watts.
R13 — 20,000 ohms, 10 watts.
L1, L2 — 30 turns No. 18, 1½ inches diameter, 2 inches long, 20 μh.
L3 — 2 turns coupled to cold end of *L2*.
L4, L5 — 30-hy. 85-ma. filter choke.
F1 — 1-amp. panel fuse.
J1 — Coax-cable connector.
N — ¼-watt neon bulb.
RFC1 — 2.5-mh. r.f. choke.
S1 — 2-pole 4-position rotary switch.
S2 — 3-pole 4-position rotary switch.
S3, S4 — S.p.s.t. toggle switch.
T1 — Power transformer: 700 volts c.t., 85 ma.; 5 volts, 3 amp.; 6.3 volts, 3 amp.

that therein lies perhaps the greatest weakness of these units. It is impossible to achieve real stability and still develop seven to ten watts in only two stages. The control oscillator should not be a power-generating device. Stability is dependent on circuit-merit factor, and high Q cannot be obtained with heavy power demand.

Very few if any commercially-built exciters have the band-edge crystals mentioned in (5) above but supplementary units are available which serve the purpose very nicely.

The above comments on commercially-built units may seem to be too critical. The fact is that all of these units are good and unless you are prepared to put some real time and care into the construction of a VFO, then by all means buy one, or stick by crystals.

Features

The exciter described here is built around the BC-221 frequency meter which is now available at most parts houses or through surplus dealers. This unit is admirably adaptable to use as the oscillator unit of a VFO exciter for ham transmitters. The oscillator tube in the unit is a 6SJ7-Y (special nonmicrophonic type) which is operated at very low input. The shielding of the unit is excellent, so that the leakage with the oscillator running continuously is below the noise level of a good receiver. Therefore oscillator keying is not necessary for break-in work and advantage may be taken of the superiority of amplifier keying.

The frequency stability of the oscillator is exceptional. The circuit is electron-coupled and the grid of the tube is connected to the tuned circuit through a resistor which limits the feedback to the minimum required to maintain oscillation. The unit is provided with a calibrated dial which may be read accurately to 50 cycles over the range of 2000 to 4000 kc. There is no mechanical back-lash and return to logged settings is dependable.

Extremely good isolation at the output terminal is achieved so that connecting a capacitive or inductive load or even short-circuiting it to ground causes no noticeable frequency deviation. Because load conditions do not affect the frequency, keying is as clean as with any crystal — cleaner than many. The rugged construction satisfies the requirements of stability under vibration. Striking the unit with the fist during operation causes practically no instantaneous frequency change and absolutely no permanent change.

The FCC requires that some means other than the dial reading of the frequency-control oscillator shall be provided for frequency checking. The crystal calibration which is an integral part of the unit should satisfy this condition. It is a separate oscillator and may be set on WWV. The crystal frequency is 1 megacycle.

Circuit

The modification to adapt the unit to VFO use consists of adding amplifier stages and a power supply to bring the output level up to 3 watts or so. The circuit diagram appears in Fig. 1. The output of the BC-221 is capacitance-coupled to an untuned stage in which a 6AC7 is used. This stage operates as a Class A amplifier, since it draws no grid current. Another 6AC7 is used in the following stage which is tuned. A 6AG7 is used in the output stage, and its tuning condenser is ganged with that of the preceding stage and the low-impedance output is fed through a link to a coaxial-cable outlet connector.

Some eyebrows may be raised at the use of resistor R_8 across the plate coil of the second 6AC7, but because of the extremely high-gain characteristics of the 6AG7 it showed some tendency to operate as a t.g.t.p. oscillator under key-up conditions in spite of careful shielding. More output was obtained by loading the tuned circuit than by running the second stage untuned, undoubtedly because this stage operates Class B or BC. The value of this resistor may have to be altered slightly depending upon output loading and other factors.

The untuned 6AC7 doubles in brass as a Pierce oscillator when the switch, S_2, is in the "xtal" position. Four crystals are provided for band-edge operation on 10, 20, 40 and 80 meters. S_3 is the "on-off" switch. A pair of terminals is connected in parallel with S_3 for remote control when desired.

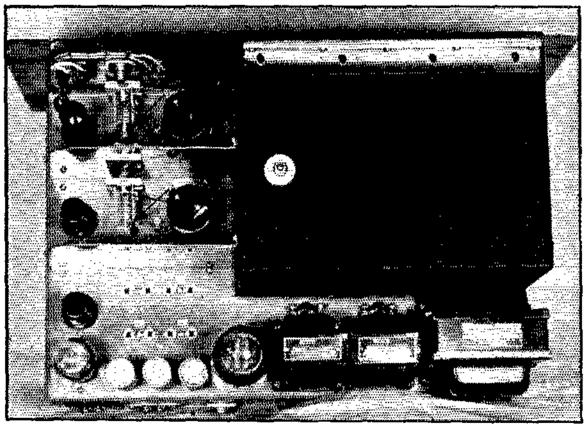
High values of grid-leak resistance are used in the first two stages to compensate for the difference in drive between crystal and ECO operation. The first stage operates strictly Class A on ECO but as a Pierce oscillator a high bias is developed which keeps the output low and improves stability. The high-resistance grid leak in the second stage (R_5) performs a like function and the output is substantially the same with either crystal or ECO. The output 6AG7 stage has extremely-high power gain and runs well into the Class C range. The cathode bias is approximately 6 volts and a grid bias of about 8 volts is developed for a total of approximately 14.

The power supply is standard. With condenser input it delivers about 300 volts under load. The high voltage to the BC-221 is regulated by a VR-150; the voltage to the external stages is not regulated.

Construction

The illustrations and the schematic contain most of the necessary constructional information and moderate deviation should not affect the operation of the finished unit.

The lower battery compartment of the BC-221 was sawed off on a contour saw and the face of the cabinet was cut off flush with the panel of the



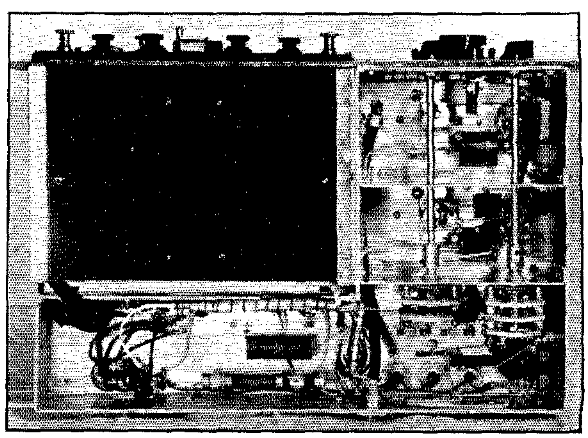
Top view of the BC-221 exciter designed to drive a crystal stage. The chassis is fitted around the BC-221 cabinet with the power supply at the rear and the additional r.f. amplifiers at the left.

oscillator unit. After smoothing with a file, the unit was refinished and mounted through a cut-out in a 9½ × 19-inch panel. This is not a standard panel width but it fits the only cabinet we had. It is fastened to the panel with aluminum angle strips. The cut-out in the panel is made large enough to accommodate the calibration book underneath the oscillator. The book holder is provided with a knob and slides in and out like a drawer on two runners of aluminum angle. The chassis is made of ⅛-inch aluminum with welded corners and is built to fit around the BC-221 cabinet. It is 3 inches deep and 17 inches long at the rear. The depth will be determined by the amount of space required behind the frequency meter for the power transformer.

In the top-view photograph, the power supply components are lined up along the rear edge of the chassis with the additional r.f. stages to the left. The first untuned 6AC7 stage is to the rear with the second 6AC7 stage in the middle and the 6AG7 output stage toward the front. Baffle shields between stages are provided both above and below the chassis. Four crystal sockets are provided although there is space for additional sockets if they are found desirable. The two padder condensers, C_{11} and C_{18}, are mounted vertically beneath the chassis with their shafts protruding above so that they may be adjusted with a screwdriver. The resonance-indicator neon bulb is mounted on the front panel with a single lead connecting its center terminal with the top end of L_2.

In the underneath view, the crystal switch, S_1, is to the left and the function switch, S_2, to the right near the rear. They are fitted with shafts extending to the front panel. R.f. ground returns in each stage are tied to a common point within the stage.

The output lead from the frequency meter is run down inside the inside corner of the cabinet from the underside of the binding post and through a feed-through insulator at the bottom of the cabinet to the wafer switch. This keeps it shielded from the output stage and prevents any tendency for feed-back. Some of the BC-221 meters have the antenna post on the other side of the cabinet, and in this case it might be well to mount the unit on the right side of the panel to shorten this important lead. No attempt has been



Bottom view of the VFO unit built around the BC-221 frequency meter. The amplifier stages are shielded both above and below the chassis.

made to specify manufacturers' names on transformers or other components, since it is the experience of the author that the average ham usually comes up with a pretty good substitute out of the junk box. If desired, an equivalent arrangement can be made up by combining a 3 × 4 × 17-inch chassis across the back and a 7 × 7-inch chassis to the left.

Operation

The switch S_2 performs four functions. In the "Freq. meter" position plate voltage is applied to the BC-221 directly from the power supply without the necessity for closing the "local-remote" switch. The frequency meter then performs in the normal manner and the amplifiers are inoperative. The antenna post may be used for coupling to receivers, oscillators, etc. In the "ECO" position the output of the BC-221 is connected to the grid of the first 6AC7 and, when the "local" switch is thrown to the "on" position, plate voltage is applied to the oscillator and the amplifiers. The tuning control for the two tuned amplifiers may be rotated until the neon light indicates maximum output. With the switch in the "ECO" position the trimmer condensers, C_{11} and C_{18}, may be set so that maximum output occurs when the output tuning control is at mid-scale and the frequency meter is set at 3750 kc. The range from 3500 kc. to 4000 kc. is used since this range covers all of the amateur bands in use at the present time. The output is always in the 80-meter band and any frequency multiplying should take place in stages external to the unit. Quick frequency readings of received signals may also be taken in this position by logging the dial setting being used for transmitting and then zero-beating the received signal for a check, after which the dial is returned to the former setting.

In the "xtal" position the first amplifier functions as a Pierce oscillator and plate voltage is removed from the BC-221. In the "check" position the crystal oscillator functions and plate voltage also is applied to the frequency meter so that the crystal frequency may be checked. This makes a convenient method for a quick check on any crystal by simply plugging it into one of the crystal sockets.

A small calibration chart is mounted on the front panel which contains the following information for each band:

1) Upper and lower settings for total band
2) Upper and lower settings for 'phone band
3) Check-point for either range

This makes it unnecessary to refer to the book for anything but exact frequency checks.

If the coaxial cable between the exciter and the transmitter exceeds 6 or 8 feet it should be terminated at approximately its surge impedance or reflections will cause detuning of the output stage. In most cases a 75- or 100-ohm resistor across the line will still give ample voltage to drive a former crystal-oscillator stage nicely. If more drive is required a small tuned circuit with a link will give good voltage step-up and serve to terminate the line. The transmitter at W7NU is remotely controlled from the floor above and the coaxial line is about 30 feet long.

Let us have more variable-frequency oscillators, but let us have good ones. *But,* of course, the best VFO in the world will be no better than the nut on the dial.

About the Author

● **Howard W. Johnson, W7NU since 1927, was first licensed in 1923 as 7JJ. This long-time two-letterer is currently handling radiotelephone, teletype and carrier-shift equipment for the Army Signal Corps. He is in charge of the construction and maintenance shops of the SCs Alaska Communication System. The Seattle Radio Club named W7NU its president in 1940.**

Strays

Brooklyn's Metropolitan Amateur Radio Society is holding its first postwar hamfest on March 13th at the Livingston, 301 Schermerhorn Street. Prizes, dancing and refreshments are scheduled. Admission: OMs $1.50; YLs and YFs, 75 cents.

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United Airlines is now using spun-glass lacing cord instead of the familiar linen type in applications affected by heat and humidity.

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"Lecturing at N.Y.U. the other night, one of our radio advertising professors — no doubt a fugitive from Radio City's gilded halls — gave us this one. He claims that on the b.c. band, stations on the 550-kc. end get out better than those on the high end. The reason: The ground waves vibrating at 550,000 c.p.s. are not so quickly exhausted of energy as those vibrating at 1,600,000 c.p.s. or so. Well, now I know why my 144-Mc. sigs get so tired going from the Bronx to Brooklyn!" — *W2QPQ.*

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"New Electronic Terms" Department:

Evening Tribune, Lawrence, Mass., via L. G. Wilde: ". . . a live wire carrying 110 *colts.*"

Boston Record, tnx to W1ATJ: ". . . amplifier . . . maintains two watts of *undisturbed* output."

The C-D Capacitor for September, courtesy W3DRH: "R-1 is 500 *kilowatts* or higher in value."

Radio News for November, spotted by W6ITH: "This set designed for . . . locating grounds, shorts, crosses, split *pears.*"

(Italics ours.)