Now...Power Savings of

—through Unique Circuit

NEW BTA-5T
5 KW AM TRANSMITTER

How It Works: The increase in efficiency in the BTA-5T Transmitter is achieved by reducing the modulated amplifier plate current pulse to reduce the power loss in the power amplifier tube during the conduction interval. A harmonic trap in the cathode circuit squares up the wave shape of the grid driving voltage, and another trap in the plate circuit further shapes the plate current pulse. Consequently, when the tube begins to conduct current, the power loss in the tube plate circuit is low and remains so throughout the cycle.

15,000 KW Hours per Yr.!

permitting 90% Plate Efficiency

NEW HIGH-PERFORMANCE 5 KW AM TRANSMITTER

This new transmitter incorporates the only significant development in Class "C" power amplifier design in 20 years. A new circuit provides a plate efficiency of 90%.

With continuous operation, savings of approximately 15,000 kilowatt hours per year are realized. Only 1 PA tube is needed.

Other improvements, including all silicon rectifiers and improved protective circuits, enhance performance and extend operating life.

Functional styling provides a choice of red or grey doors to suit station decor and add a harmonious note.

Some of the fine features of the New BTA-5T

1. **FEWER TUBES**—Fewer tubes—a total of twelve—save on replacement cost. Only one 7762 PA Tube for lower operating cost.

2. **QUIET-OPERATING BLOWER**—Very low plate dissipation in the output stages reduces heat within the transmitter, and also permits use of a slow-speed blower for quiet operation.

3. **SILICON RECTIFIERS**—All silicon hermetically sealed rectifiers of proven reliability are ideal for remote control.

4. **OVERLOAD PROTECTION**—Complete overload protection is provided for all circuits. All line breakers carry an instantaneous over-current protection, while main breakers retain instantaneous and thermal protection. Remaining circuits are protected by fast-acting overload relays with provision for external indication.

5. **REMOTE CONTROL PROVISION**—Built in provision is made for remote control and conversion to Combined, power cut-back and a carrier off monitor.

6. **FCC OK**—Meets all new FCC Spurious Emission requirements.

7. **SPACE SAVING**—New style cabinets offer excellent accessibility to all components and allow a great saving in floor space.

Your RCA Broadcast Representative will gladly provide further particulars about this new transmitter. Or write to RCA, Dept. BS-107, Building 15-1, Camden, N. J. In Canada: RCA VICTOR Company Limited, Montreal.

RADIO CORPORATION of AMERICA

BROADCAST AND TELEVISION EQUIPMENT • CAMDEN, N. J.

NEW HIGH-EFFICIENCY 5-KW AM TRANSMITTER

Unique Class C Amplifier Operates With 90 Percent Efficiency

by I. R. SEARER, *Broadcast Transmitter Engineering*

FIG. 1. Easy access to all tubes is made through two interlocked front doors of the BTA-5T Transmitter. The PA, modulator, and silicon rectifiers are in the cabinet on the right, and the exciter, driver and control equipment is on the left. The attractively styled cabinets are available with red or gray doors.

This new 5-kw AM transmitter, type BTA-5T, incorporates the only worthwhile development in class "C" power amplifier design in 20 years. The newly-designed PA circuit operates with a plate efficiency of 90 percent. This represents an improvement of 20 percent over normal class "C" operation. As a direct result power savings of approximately 11,000 kilowatt hours per year can be realized.

Basically, the new transmitter uses the design proved in the BTA-5R/10L.[1] However, using the recently-developed high-efficiency circuit, only one PA tube is needed. Other circuit innovations (such as silicon rectifiers and improved protection) have been made to improve performance and to extend operating life.

Principle of Operation

The high-efficiency plate-modulated power amplifier uses a single tube to deliver the nominal 5 kw with 5.5 kw power output capability at 90 to 92 percent plate power conversion. Referring to the simplified schematic (Fig. 3), the circuit arrangement is very similar to a conventional class "C" amplifier except for presence of two resonators L_1, C_1 and L_2, C_2. In fact, the new high-efficiency stage behaves so much like the conventional class "C" stage that with the resonator shorted, or mis-tuned, the PA tube returns from the high-efficiency to the conventional class "C" operation. This characteristic, as will be shown later, is very useful in the initial tune-up of the transmitter. For the moment it will be helpful in making a detailed comparison.

In both systems the angle of the tube current conduction is restricted to that portion of the cycle wherein the instantaneous plate current is high and the instantaneous plate voltage low, corresponding to a low anode dissipation at a relatively high-power output. In the class "C" operation, however, the waveform is sinusoidal and is rub-

[1] "New 5000-Watt AM Transmitter", by J. North and I. R. Searer, *Broadcast News*, Vol. 105, March, 1958.

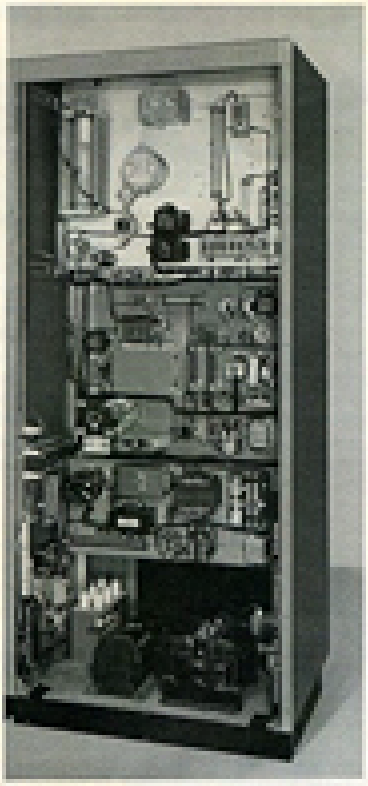

FIG. 1. This is the rear of the BTA-1B. Complete access to all components is easily made through the removable interlocked panels.

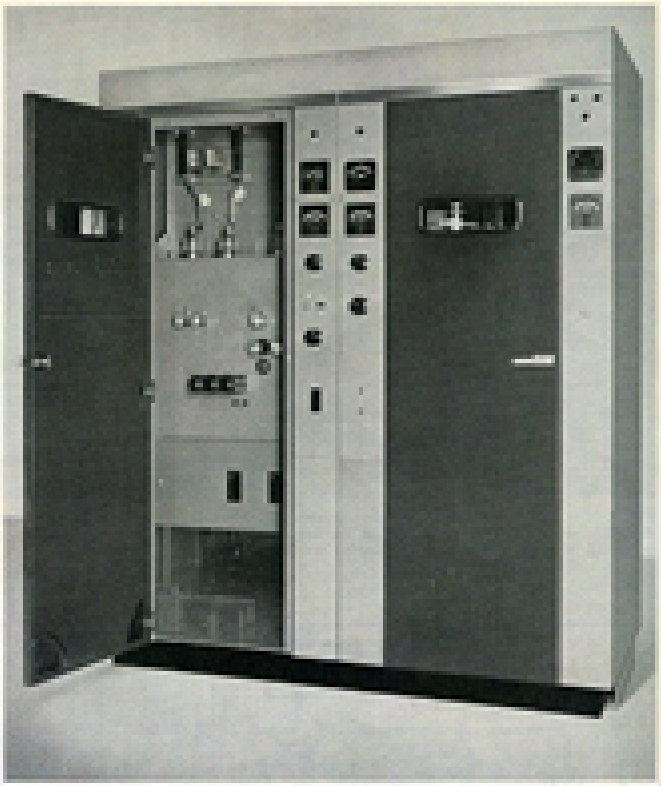

FIG. 2. The exciter and BTA stages are shown here. Note the three crystal sockets on the exciter chassis, and the easy to reach tubes.

stantially rounded off. Therefore, a large portion of the power is lost in the anode, resulting in an average efficiency of about 70 percent. The new system provides corrective means for maintaining a flat waveform near the peak, resulting in 90 percent average plate efficiency.

The waveshaping is done by two LC parallel resonant circuits, one located in the plate and the other in the cathode circuit of the power amplifier tube. Both resonators are adjusted to resonate at the third harmonic of the carrier frequency.

When the amplifier tube is driven, the harmonic component of the grid input power sets up and maintains circulating current within each resonator. Since the resonator is designed to store high K.V.A. the total voltage supply at the plate is composed of the usual d-c plate supply and the superimposed oscillatory potential equal to the voltage build-up across the resonator. This oscillatory voltage, being at the third harmonic, vectorially adds twice to, and

TABLE I — EFFICIENCY COMPARISONS

		Conventional Class C BTA-1B	High Efficiency Class C BTA-1F
Power Amplifier (Carrier)			
Power Output	kw	5.0	5.0
Number of Tubes (RCA 5762)		2	1
Inst. Plate Current (calculated)*	Amps.	3.6	3.5
Inst. Grid Current (calculated)	Amps.	2.7	1.8
Peak Cathode Emission	Amps.	8.5	5.3
Plate Dissipation	kw	1.5	.37
Filament Power	kw	.74	.37
Plate Efficiency	%	76	90
Modulator & Power Ampl. (100% Mod.)			
PA Plate Dissipation	kw	2.25	.85
Modulator Plate Dissipation	kw	2.0	1.7
Overall Input	kw	13.5	11.2
Overall Efficiency	%	56.4	67
Transmitter Power Input (.95 P.F.)			
Carrier	kw	11.6	10.0
Average Program	kw	12.7	11.0
Input Power/Yr. Saving	kwh	—	15000

* The high efficiency calculation is based on a rectangular waveform, where the peak efficiency is equal to the average efficiency, i.e., V_p/E_p. The average power value is proportional to the angle of tube conduction, or the plate input, plate output, and the grid dissipation is: $I_p E_p \theta$; $I_p V_p \theta$ and $I_c (V_c - E_c) \theta$ respectively (where θ is the duty cycle or Ys for 180 degrees of tube conduction). The actual value given in Table I takes into account the correction factor determined experimentally.

FIG. 4. The author is shown adjusting the new PA stage. Only one 1762 tube is used for high efficiency operation. The coil, shown on the right, is the third harmonic coil used in the plate circuit of the PA to increase efficiency by shaping the plate waveform

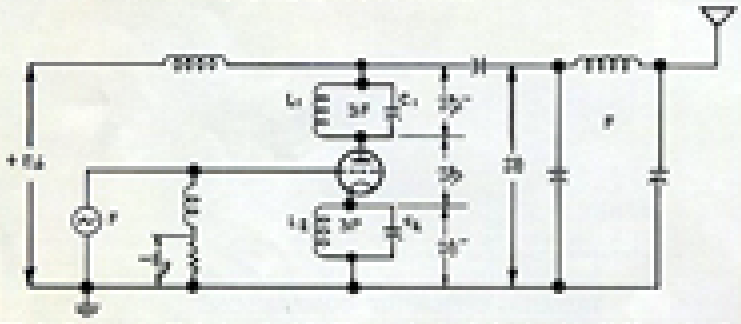

FIG. 5. This is a simplified schematic of the PA stage showing the location of the third harmonic coils.

subtracts once from the fundamental, thus producing a flat top waveform (see Fig. 1A). When the cathode resonator is adjusted to resonate at the third harmonic, the instantaneous grid-to-cathode potential modifies the cathode emission to approximate a rectangular pulse (see Fig. 1B).

Improved Efficiency

In the BTA-5T transmitter, adjustment of the plate resonator improves the efficiency by 6 to 8 percent. Subsequent adjustment of the cathode resonator improves the efficiency by an average total of 20 percent above conventional class "C" operation.

Improved Tube Performance

The energy stored within the resonator modifies the instantaneous current voltage waveform of the conventional class "C" amplifier to reduce its amplitude and broaden the top. For the same power output, this means not only reduction in the plate dissipation, but also considerable reduction in peak-plate to plate-peak grid current and operation at a much lower cathode emission (see Table I). As the result of the high-efficiency operation, the BTA-5T transmitter employs only one PA tube, an RCA type 1762. It is worthy to note that plate dissipation in the new system is comparable to the filament power consumption of the old.

Improved Stability and Tuning

The third important feature in favor of the new transmitter is: simplicity of the initial tune-up and stability of operation. Upon mistuning the harmonic resonator, the PA tube returns from the high-efficiency to the conventional class "C" operation. Except for the loss in the efficiency of the PA, the circuit neutralization, tank tuning, the stage loading remains the same for both types of operation.

Applying the above procedure in reverse, the initial tune-up consists of the resonator adjustment to obtain the maximum power output as indicated by the line or the antenna current ammeter. The plate resonator chiefly contributes toward the power output, while the cathode resonator in addition to increasing power output to some extent increases the power input.

With the system properly in operation, tuning of the output tank is similar to tuning of the conventional class "C" amplifier, except the tuning is broader. On either side of the tuning-dip the plate current rise is more gradual, the power output slightly rising on one side and falling on the other side. This self-adjusting property would provide additional stability in the case of accidental mistuning or mistuning due to a reactive load.

Overall Performance

Both the conventional and the high efficiency system were compared using essentially the same transmitter circuit with identical components. Each offered similar performance insofar as modulation capability, audio distortion, carrier shift and noise level are concerned (see Fig. 8). Tests were carried out over the broadcast frequency range, using a number of tubes of different socket life. Therefore, the high-efficiency class "C" operation data listed in Table I may be considered as typical for this power level and frequency of operation.[1]

Longer Tube Life

In order to determine what effects the high efficiency circuit would have upon 1762 tube life, tubes with known expectancy life characteristics were obtained and placed for service in a transmitter operating at maximum conditions with greater than average modulation applied for extended periods of time. The tubes were then retested, opened, the parts measured, and examined for evidence of deterioration. It was found that the life expectancy of all the tubes examined to be as good or greater than the expected life of tubes operating under conventional class "C" service.

Compact and Convenient

The entire transmitter, except the plate transformer, is housed in two attractively styled cabinets (see Fig. 1). All meters, indicators, control switches and tuning controls are located on the front panels. Vertical center chassis are fastened between the

[1] Data on operation at other power levels is given by V. J. Tyler, *Marconi Review*, No. 116, Vol. XII.

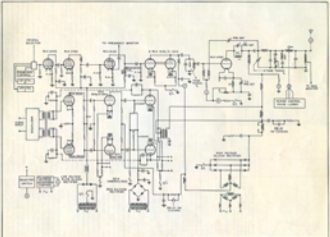

FIG. 6. The overall schematic of the [illegible] is shown here. The rear RF circuit resembles a conventional class "C" stage except for the addition of the plate and cathode L-C circuits for high efficiency operation. The silicon rectifiers are also shown.

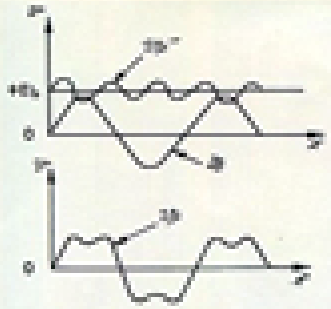

FIG. 7A. This is the harmonic addition of the plate voltage and the oscillatory voltage from the third harmonic L-C circuit. The resultant plate voltage waveform, below, resembles a square wave, and it is obvious the average level of plate voltage is higher.

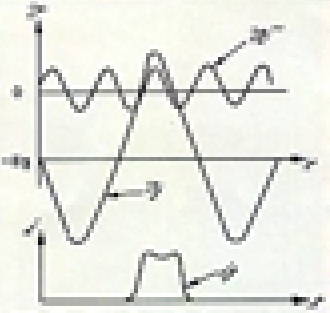

FIG. 7B. With the cathode resonator operating at the third harmonic the grid to cathode voltage modifies the cathode emission to produce a rectangular pulse of grid current. Again the higher average level of the signal has been increased, and this results in higher operating efficiency.

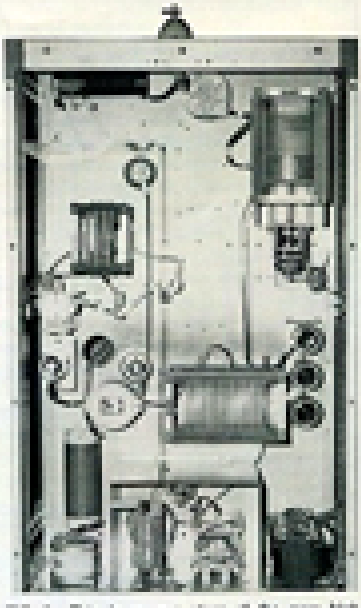

FIG. 8. This is a rear view of the new high efficiency PA and modulator stages. Removal of the rear panel provides complete access to all circuit components for ease of maintenance.

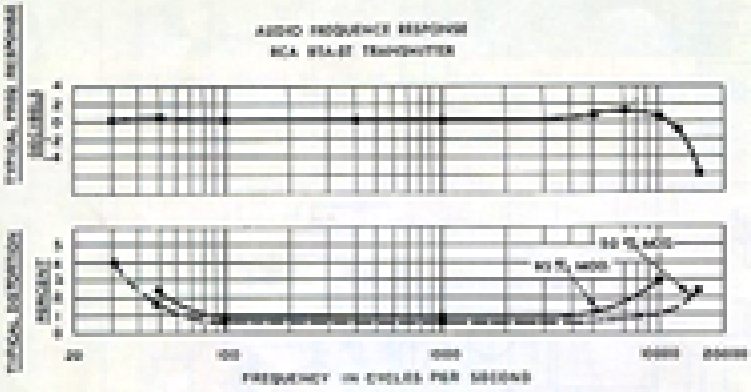

FIG. 9. Typical response and distortion curves for the BTA-1T. The high efficiency PA stage actually helps to improve the overall performance of the transmitter.

end panels to form a basic "H" cross section. The front doors give immediate access to tubes, feedback ladders and overload relays, which are mounted on the vertical chassis (see Fig. 2). Remaining components are mounted on the rear of these chassis, behind removable rear panels, while the large power components are mounted on the base of the cabinet. This type of construction offers excellent accessibility, while retaining the compactness of the transmitter (see Fig. 9).

Proved Design

A simplified schematic of the BTA-1T transmitter is shown in Fig. 6. The exciter unit, the PA modulator driver stages and the high-level linear modulator remain essentially the same as in BTA-1R/1R1 transmitter. The power supplies are silicon rectifier type. New instantaneous circuit breakers are employed in the control circuits. The plate-modulated power amplifier is of course improved by virtue of the new high-efficiency technique and the resultant power and tube savings.

Only Two Tuning Controls

The BTA-1T transmitter has only two front panel tuning controls with one local-remote power control. The driver stage is tuned by means of a slug-tuned coil, and the PA by means of a variable vacuum capacitor. Remaining circuit adjustments, necessary only at installation, consist of tap changing in accordance with the calibration chart. The PA plate resonator is adjusted by means of a front panel screwdriver slot actuating a variable vacuum capacitor. Capacitor of the cathode resonator is adjusted in similar manner. Both capacitors are adjusted for peak of the line ammeter. The variable vacuum PA neutralizing capacitor, employed in conjunction with a broadband neutralizing transformer is also preset at the initial installation.

Semiconductor Power Supply

The BTA-1T uses silicon-type rectifiers throughout. This type of rectifier offers excellent reliability in normal operation and even more so in a remote-control application. The transmitter will operate within ambient temperatures from —20 to +40 degrees and up to 7500 feet above sea level.

The proven reliability high-voltage rectifier (see Fig. 10) is arc-back protected for trouble free operation, requiring neither warm-up time nor thermostatic cooling control. It carries an over-current safety factor of 200 percent, or in other words, it is capable of continuous short circuit operation. The peak inverse voltage rating is 140 percent, allowing 30 percent above the starting transient and the silicon peak inverse voltage safety factor.

The bias and low-voltage rectifiers are sealed silicon units permitting a more reliable operation.

Complete Overload Protection

To increase reliability, improvements were made in the control and protective circuitry of the BTA-1T transmitter. Primary lines are protected by circuit breakers with instantaneous and thermal overload trip protection. The 3-phase blower motor

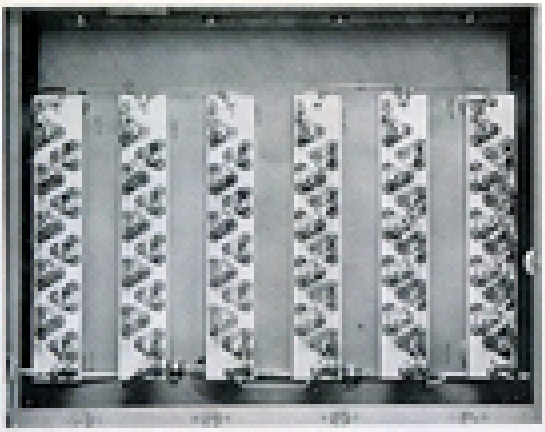

FIG. 10. The silicon high voltage rectifiers, shown here, consist of two legs each containing 20 diode units. This rectifier unit was designed with a 500 percent safety factor for increased reliability.

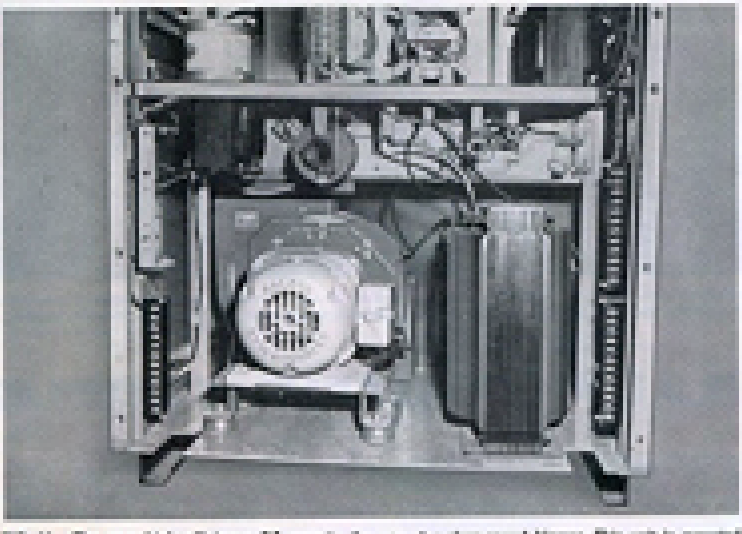

FIG. 11. The new high efficiency PA permits the use of a slow speed blower. This unit is mounted on rubber shock mounts in the base of the PA cubicle.

is protected by a contactor with the thermal cutoff in each phase; the relay switching is sequential so that the filament will not come on unless the blower is operating. Starting surges in the plate transformer, high-voltage reactor, and the filter capacitor are eliminated by the use of step-start and damping circuit.

Protected Cooling System

In keeping with modern trends, the transmitter is air cooled. Added refinements such as a delay relay have been built-in, to keep the blower system in operation for one minute after the transmitter has been shut down. This continues the supply of air to extend tube life. As the result of the high efficiency, the air pressure has been reduced, permitting use of a slow-speed blower unit, resulting in quiet operation (see Fig. 11).

Functional and Economical

Many years of design experience are reflected throughout. Functional styling predominates affording convenience of operation, furthermore, the user has a choice of red, or gray doors to enhance the station decor.

Emphasis, however, has been placed on the reliability and the dependable performance of the transmitter. This will result in many years of trouble-free operation. Power savings achieved by the new high-efficiency circuits provide for economical operation without sacrifice of performance.

DISTINCTIVE FEATURES OF THE BTA-5T

1. High efficiency circuits in the new transmitter offers an average power input saving of 15,000 kilowatt hours/year at a continuous program operation.

2. Very low plate dissipation in the output stages reduces the heat dissipation within the transmitter, and also permits use of a quiet slow-speed blower.

3. Expensive power amplifier tubes reduced from 2 to 1. Fewer tubes throughout—a total of twelve—which also saves on tube replacement cost.

4. All semiconductor type, hermetically sealed silicon rectifiers are of proven reliability.

5. Complete overload protection is provided for all circuits. All line breakers carry an instantaneous over-current protection, while main breakers retain the instantaneous and thermal protection combined. The remaining circuits are protected by fast acting overload relays with provision for external indication.

6. Built-in provision for the remote control, conversion to Combined, power cutback and a carrier off monitor is retained with improvements.

7. Meets new FCC Spurious Emission requirements.

8. The new style cabinets offer excellent accessibility to all components and allows a great saving in the floor space.