SELECTION OF THE BASIC RADIO FREQUENCY CIRCUIT AND MODULATION SYSTEM FOR A HIGH POWER BROADCAST TRANSMITTER

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SELECTION OF THE BASIC RADIO FREQUENCY CIRCUIT AND MODULATION SYSTEM USED IN CONTINENTAL ELECTRONICS TRANSMITTERS

Before selecting the basic radio frequency circuit and modulation system, a review was made of various circuits which might be utilized in a very high power broadcast transmitter. The principal idea being a consideration of circuit innovations, tube or component developments which might be applicable in the design of a transmitter of this particular power rating. A summary of the review is stated briefly below.

1.1 THE CHIREIX OUTPHASING MODULATION SYSTEM

This system of modulation was described by Henry Chireix in the Proceedings of the Institute of Radio Engineers in 1935, and has recently been used in a standard band broadcast transmitter by an American company under the name "Ampliphase". The system was used in Europe for several stations, but has since been abandoned in those countries for various reasons. This system uses two radio frequency channels which are each complete frequency amplifying systems and are fed by a common frequency generator. In the low level stages the output phase of the two channels is set to a desired phase difference. Phase modulation has been applied to the two channels so that phase difference between them varies from 180° at the negative peak of modulation to perhaps 60° to 90° at the positive peaks of modulation, with the carrier level at a point of intermediate phase difference.

At the output of the two final power amplifier stages associated with each of the radio frequency channels, the radio frequency output is combined and amplitude modulation results from the algebraic addition of the two outputs with varying phase angles. The intended advantage is that the output stages of the two channels can be operated Class C with resulting higher efficiency. Intermediate stages of the two RF channels could be operated Class C, but the critical tuning required to maintain the correct phase angle throughout the amplifying system has led to the use of wide band amplifiers in the intermediate stages, which undoubtedly results in lower efficiency in these stages.

It is obvious with this system that in order to arrive at a 100% negative peak of modulation it is essential that the output from the two RF channels be exactly equal in amplitude and have exactly 180° phase difference. This equal amplitude and phase difference must be maintained through several stages of amplification in each RF channel. In this type of transmitter, tuning adjustments during program operation are not recommended.

With this system it is not possible as a practical matter to maintain sufficiently and accurately the critical adjustment to provide a 100% negative peak of modulation with suitable low distortion. For this reason and perhaps for other reasons, the transmitter offered in the Standard Broadcast Band at the present time utilizes grid bias modulation of the final amplifier stage from a low output level modulator in order to correct for distortion occurring during the negative peak of modulation. Thus, the complexity of two modulation methods is added to the circuit.

If the modulation in a negative direction exceeds 100%, then the phase vectors of the two radio frequency channels pass through 180° and the RF output amplitude starts rising again. If overall negative feedback is applied to such a transmitter and this over-modulation is allowed to occur, the negative feedback becomes positive and regeneration occurs with resulting sideband splatter and instability. Corrective measures are applied to avoid this situation and these corrective measures must be maintained in proper operating condition.

Fundamentally, the outphasing modulation system is not linear because of the fact that the phase vectors of the two RF channels follow a sinewave curve rather than a straight line. Predistortion is introduced to compensate for the non-linearity of the system.

Although the output amplifiers of the two RF channels of this system are operated as Class C amplifiers, the maximum efficiency of conventional Class C amplifiers is not achieved over the modulation cycle, since the output of one amplifier feeds a circuit where current is flowing with a phase which is advanced to the phase of its own output, while the other amplifier feeds its output into a circuit where current is flowing with a lagging phase to that of its own output. Therefore, the amplifiers do not see resistive loads, but reactive loads, one seeing a load with a capacitive reactance and the other a load with an inductive reactance.

Compensating circuits can be provided so that at one point during the modulation swing the load is resistive for both amplifiers. This point, for best efficiency, is not usually the carrier condition, and at all other points over the modulation cycle, a reactive component is seen in the load by the power amplifier tubes. The capability of such an output circuit to feed into various transmission lines with different standing wave ratios, and the ability to provide optimum conditions of loading for the tubes with fast frequency change, has not been a part of this study.

The loaded Q of the output circuit of the out-phasing modulation system varies over the modulation cycle, the Q being the lowest at positive peaks of modulation and extremely high at negative peaks of modulation. It appears that this would cause the modulation of harmonic frequencies to exceed the percentage of modulation of the fundamental.

In review, some of the objections of the Chireix Out-Phasing Modulation system are as follows:

a. The complication of two radio frequency channels is required.

b. Critical adjustment of the phase modulator and predistortion system is necessary. (In the standard band AM transmitter, two complete modulators are provided because readjustment of this portion of the system is presumed to be impossible during program operation.)

c. The modulation characteristic depends upon the critical adjustment of two radio frequency channels in order to maintain accurate phasing throughout the two channels. This phase adjustment should not be confused with the adjustment of the phasing networks in the high efficiency linear amplifier where a tolerance of plus or minus 10° has no effect on the circuit operation of distortion characteristics.

1.2 CLASS B LINEAR AMPLIFIER SYSTEM

The Class B Linear Amplifier system is well known and has been used in broadcast service for many years. Continental has developed several Linear High Power Amplifiers for single sideband transmission. However, the oridinary Class B and linear amplifier in AM broadcast service has a very low power efficiency and other systems have advantages over it.

1.3 HIGH LEVEL PLATE MODULATION SYSTEM

The High Level Plate Modulation System with a Class B or Class AB push pull modulator is manufactured by the largest number of different transmitter manufacturers. Continental Electronics has in the past designed, constructed and operated transmitters using this system in power output ranges up to 250 kilowatts.

The disadvantages of the High Level Plate Modulation System with a Class B or Class AB modulator become increasingly great with higher power. This is in direct contrast to the Continental Screen Grid/Impedance Modulation System which becomes more and more desirable as compared with other systems, the higher the power output required.

a. With high level plate modulation, the maximum voltage swing on the power amplifier tube (audio swing plus radio frequency swing) is nearly four times the DC anode voltage at carrier condition. In a typical instance, the peak voltage is about 52 kilovolts for 14 kilovolt DC anode voltage whereas in the Continental system, the maximum voltage swing is about 32 kilovolts. This means less hazardous operation for the tubes in the Continental system.

b. The Class B or Class AB push pull modulator requires a high power high voltage modulation transformer and modulation reactor. These components present increasingly difficult design problems as the power capability required is increased. Because of the high voltage swing, sometimes accompanied by undesired transients, there is the possibility of catastrophic failure of one or both these components, and this does in fact occasionally occur. This of course puts the transmitter completely out of commission until the component is replaced. Such components are not normally carried in stock by the manufacturer, and the replacement time can be a matter of months. To avoid the possibility of a sustained interruption, it is necessary to keep on hand at the station a replacement spare unit which is quite an expensive item.

c. In the High Level System of this type, the plate current is delivered to the anode of the power amplifier tubes through the modulation reactor. The stored energy in this reactor is proportional to the inductance multiplied by the square of the power amplifier plate current. This represents a large amount of stored energy which of course is larger the higher the power of the transmitter. In case of a sudden interruption of this current such as might occur with the loss of radio frequency drive to the power amplifier tubes, this stored energy causes a very high voltage transient across the modulation reactor which is applied to the plates of the power amplifier tubes. This voltage can easily reach a value 8 to 10 times the normal voltage applied. Such an occurrence will invariably cause an insulation breakdown or an arc somewhere to dissipate the energy. In many cases, the arc is inside one of the power amplifier tubes which can cause release of gas and additional problems. Protective gaps are usually used across the modulation reactor, but since these must be set wide enough to avoid arc-over with normal operation voltages under all conditions of humidity, temperature and dust, the protection provided by such a gap is marginal.

d. Overall, rectified radio frequency, feedback is highly effective in a broadcast transmitter for the purpose of reducing audio harmonic distortion and residual noise and for stabilizing the gain of the system. In high power transmitters, the higher power tubes with large filaments and high filament current have a higher inherent noise level from filament hum than smaller tubes. Therefore, the desirability of overall feedback becomes more important the higher the power of the transmitter. In the High Level Plate Modulated System, overall, rectified radio frequency, feedback is not possible because of the large audio phase shift introduced by the modulation transformer at some frequency slightly above the normal audio range. The application of overall audio feedback requires a wideband system with a gain reduction with frequency on a slope of not over 10 decibels per octave, which is of course impossible with a large modulation transformer. Therefore, the only feedback which can be used on the High Level Plate Modulated System is audio feedback which may be used to improve the distortion and noise characteristics of the high power audio channel. This does not include the power amplifier in the feedback loop.

1.4 THE DOHERTY HIGH EFFICIENCY LINEAR AMPLIFIER SYSTEM

The Doherty High Efficiency Linear Amplifier presents a very efficient and stable transmission system for high power broadcasting. The Continental Electronics Type 105C, 1,000,000 watt AM broadcast transmitter used this system and has been successfully used by the United States Voice of America operations. The advantages of a system of this kind increase rapidly with increase in power output rating of the transmitter.

The output power of an RF vacuum tube amplifier may be varied in several ways. One of the ways is by changing the value of the load resistance connected in its plate circuit.

Assuming a constant DC plate voltage, constant bias voltage, and a certain degree of saturation of the grid by the RF excitation voltage, the power output will be approximately inversely proportioned to the plate load resistance over a range of resistance that is suitable to the limits of the tube's capability.

For example, if a tube operating under the above conditions is delivering 100 kW into an 800 ohm plate load, it will deliver 200 kW if the plate load resistance is changed to 400 ohms.

When the load resistance is decreased to one-half its original value, the current will double provided the voltage remains constant. Ordinarily, we think of a 2 to 1 increase of current as meaning 4 times as much power in the load. However, in this case to obtain this increase in current, the value of the load was decreased to one-half of its original value. Therefore, the resulting power in the load is only 2 times its original value.

This principle is utilized in the operation of the "Carrier" tube in the Doherty amplifier. The output, or load circuit, of this carrier tube is made to vary over a range of 2 to 1 as the transmitter is modulated from 0 to 100% so that at 100% modulation peaks, the carrier tube delivers twice as much power to the antenna as it does at zero modulation. The circuit arrangement for accomplishing this change of load resistance of impedance is described in the following paragraphs.

This is a simplified description of the principles involved in the operation of this circuit.

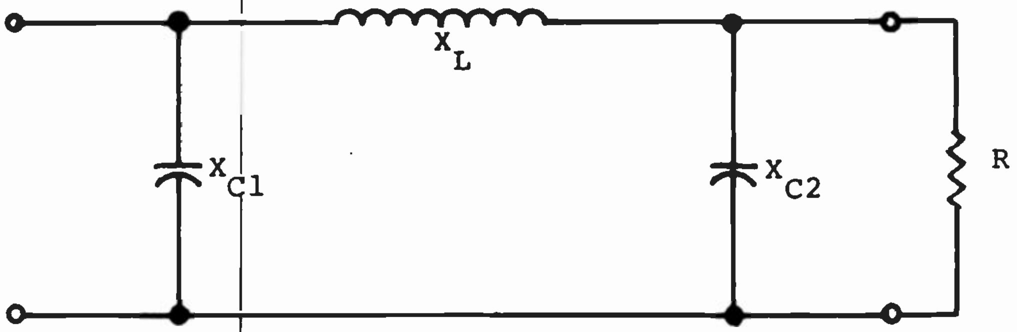

FIGURE 1.1 A NETWORK CHARACTERISTIC

This circuit shows a simple π network. If we choose some operating frequency and make the values of $-X_{C1}$, X_L, $-X_{C2}$ all equal, and equal in ohms to the value of R, then tne input impedance will be equal to that of R. (Incidentally, under these conditions a phase shift of -90° occurs through this network.

Assume that the output terminals of the network are shorted. The input of the network sees an anti-reasonant or parallel resonant circuit consisting of $-X_{C1}$ paralleled by X_L, similar to the usual tank circuit used for radio frequency amplifiers.

The resistance seen at the input is infinite, or an open circuit (except for losses in the coil and condenser which will result in some very high finite value).

Assume that the short is removed from the output of the network and its terminals are left open. The input of the network sees a series resonant circuit consisting of X_L and $-X_{C2}$. A series resonant circuit is a short-circuit. (Except for the resistance in the coil and condenser.) Since the input terminals are connected to a short-circuit, X_{C1} is shorted and has no effect on this short-circuit resistance.

This type of network is said to have an "impedance inverting" characteristic.

Assume that a resistance R equal to X is connected to the output terminals of the network. Then the input terminals will see a resistance equal to R. If a resistance equal to 2R is connected at the output, the input terminals will see a resistance equal to 1/2R. Or if 1/2R is connected to the output, the input will see 2R, and so on.

Stated generally, the resistance seen by the input is inversely proportional to the resistance connected to the output.

The values of $-X_{C1}$, $-X_{C2}$, and X_L for a 90° characteristic are always equal and when unequal impedances are being matched, the values of these components can be determined from

$$X = \sqrt{(\text{input } R)\ (\text{output } R)}\ .$$

This characteristic of this network is used to control the output load resistance of the "Carrier" tube in a Doherty amplifier and thereby vary its power output when the transmitter is modulated.

The fact that this network also has the characteristic of introducing a 90 degree negative phase shift is of no importance to the operation but does provide a convenient way of tuning, as will be discussed later.

The Doherty circuit may be considered a system in which RF amplifiers are connected in a special arrangement of parallel operation. However, the two amplifiers do not operate during the same angle of time and are biased and driven differently and operate at different efficiencies. The "Carrier" tube is operated as a more or less conventional linear Class B amplifier and serves to furnish the carrier power at zero modulation conditions. The "Peak" tube is biased for Class C operation and only delivers power when its excitation voltage rises above carrier level, or in other words, when positive modulation takes place.

Actually, the "Carrier" tube is connected in parallel with the "Peak" tube but with inter-connecting circuitry necessary to enable both tubes to be driven with the same source and to feed into the same output load when operating under the above two modes of operation. This combination results in an overall efficiency that is about twice as high as that of the conventional linear RF amplifier.

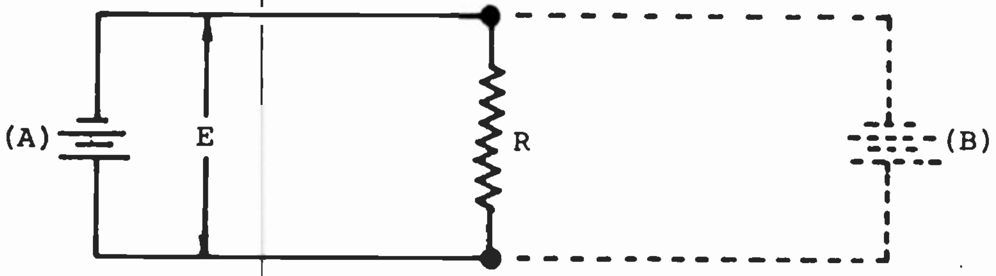

FIGURE 1.2 SIMPLE ANALOGY OF PARALLELED OPERATION

Consider a simple case of a voltage E impressed across a load resistor R. A current I, will flow and the resistance as seen by battery (A) can be expressed as:

$$R = E/_{I}$$

Now if a second battery (B) of the same voltage and polarity is connected to the resistor R, it will supply half of the current through the resistor. Then the resistance seen by each battery will be:

$$R = \frac{E}{I/_{2}} = 2E/_{I}$$

or apparently twice the original value.

The Carrier and Peak tubes in a Doherty amplifier may now be substituted in place of the batteries in Figure 1.2.

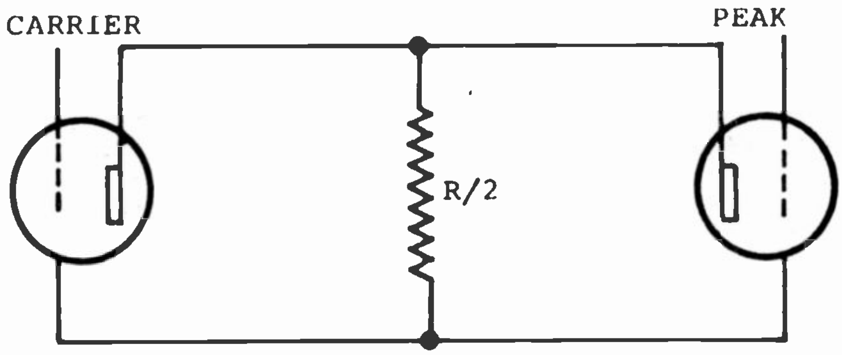

FIGURE 1.3 CARRIER AND PEAK TUBES IN A DOHERTY AMPLIFIER

The actual load should be R/2 and the resistor can be removed and replaced by one of half of the original value. The loads seen by the respective tubes will again be the correct, original value of R.

If the "Peak" tube is disconnected, then the "Carrier" tube will see a resistance value of R/2.

While the "Peak" tube is disconnected, suppose we insert the network described under Figure 1.1, between the Carrier tube and the load resistor R/2.

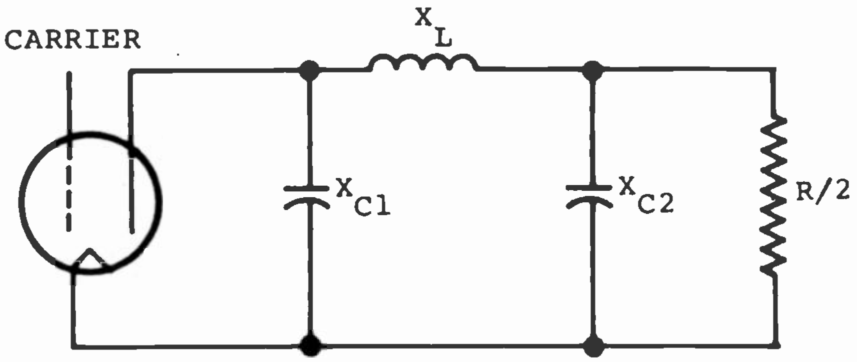

FIGURE 1.4 CARRIER TUBE WITH π-NETWORK BETWEEN TUBE AND LOAD RESISTOR

As mentioned above, the values of $-X_{C1}$, X_L and $-X_{C2}$ are all equal to R.

Due to the impedance inverting characteristic of the network, the impedance seen by the Carrier tube will be 2R when the load resistance to the network's termination is R/2. Now if the "Peak" tube is reconnected and is made to deliver the same amount of power to the circuit as the Carrier tube, the resistance seen by this tube will again be R. Since the network is again terminated by an effective resistance of R, this same resistance will appear at the input of the network or at the output of the "Carrier" tube.

Therefore, both tubes see the load resistance R as was originally set up.

The above represents the operating condition in the Doherty amplifier at the positive peak of 100% modulation.

If the value of R was selected as the optimum resistance for full power output from the particular tubes used, then they will be delivering maximum possible power under this condition.

Suppose now that, instead of disconnecting the "Peak" tube we increase its bias voltage to the point that its RF output is reduced. As power from the "Peak" tube into the load decreases, the effective load resistance of R becomes less and the resistance seen by the "Carrier" tube at the network input terminals increases (due to the inverting characteristic of the network). When the "Peak" tube is biased to the point of cutoff of the plate current, the value of the load resistance will be R/2 and the "Carrier" tube will be 2R because of the network.

As shown above, the "Carrier" will deliver one-half as much power into 2R as it did into R. This represents the operation of the Doherty amplifier at carrier only conditions - no power output from the "Peak" tube - the "Carrier" tube delivers all of the carrier power by itself and this power is only one-half of the total output capability of this tube.

> (At the positive peak of 100% modulation, as previously mentioned, each tube was working into a load value of R. Therefore, each tube was delivering twice the carrier power, making a total output of 4 times the carrier, which is the normal output at 100% modulation.)

The "Carrier" tube has approximately "cut off" bias so that with no grid excitation, practically no plate current will flow. At normal carrier condition, this excitation voltage should be sufficient to just swing the grid to "saturation".

As mentioned previously, the "Peak" amplifier is biased beyond cutoff so that at normal "Carrier only" conditions, this tube is inactive and has no output.

Ordinarily, a Doherty amplifier is driven by a modulated source of RF voltage.

When this voltage departs from the carrier level in the negative direction, (negative half cycle) the power output from the "Carrier" tube reduces until at the 100% negative peak. At the end of the negative half cycle its output will be back up to "carrier only" conditions.

During this negative half cycle, the "Carrier" tube operates as an ordinary Class B linear amplifier, except that the plate RF voltage swing, at carrier only condition, is the large swing required to deliver the carrier power into a load resistance of 2R. This is at least twice the voltage swing of an ordinary Class B amplifier at carrier condition, and this is why the Doherty amplifier has about twice the efficiency of an ordinary Class B amplifier.

It is obvious that the "Peak" tube is inactive during this negative half cycle because of its high bias which holds its output to zero at carrier only condition level.

As the modulated exciting voltage on the grids of both tubes starts to rise with the positive half of the modulation peak, the "Carrier" tube is soon driven into the "saturation" region and cannot respond with higher output voltage swing since it is already at maximum. At this point the "Peak" tube takes over.

The rise on the positive peak of the exciting wave drives the grid of the peak tube above the high bias placed on it and it delivers output to the load. As it does so, the load resistance of 1/2R seen by the output of the network becomes "effectively" higher until at the peak of positive modulation the network sees an effective load of R.

At this point the peak tube is delivering twice carrier power into the load which is now effectively R to this peak tube.

At this point also the "Carrier" tube sees a load of R instead of 2R because the input of the "inverting" network has changed from 2R to R with the change from 1/2R to R at its output, caused by the peak tube. So the carrier tube is also delivering twice carrier power.

It was stated that during the positive half cycle the carrier tube was driven into saturation and could not respond. However, it did respond with twice carrier power because of the change in its load resistance, as explained above. In order to do this, it actually required about 30 to 50% increase in its drive on the positive peak over its grid swing at carrier, which has to be held down to just "saturation" so this tube's output may linearly decrease as soon as the negative peak starts. The 30 to 50% increase on positive peaks is, of course, available from the modulated excitation voltage.

As stated above, the impedance inverting network between the "Carrier" tube and load R had an incidental characteristic of shifting the phase of the signal by 90°. This means that the output from the "Carrier" tube is delayed 90 degrees with reference to that of the "Peak" tube which is feeding into the same load.

In order to bring the output of the "Carrier" tube into phase with that of the "Peak" tube, the phase of the excitation voltage applied to the grid of the "Carrier" tube must be advanced by 90°.

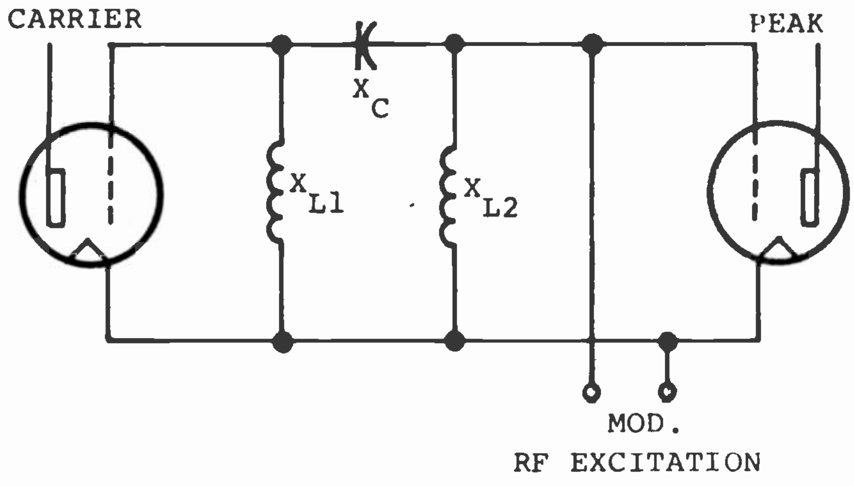

FIGURE 1.5 A SUITABLE CIRCUIT FOR ACCOMPLISHING THIS PHASE ADVANCE

In this network $X_C = -X_{L1} = -X_{L2}$. This network will advance the phase 90° when terminated with the proper load resistor so the RF excitation voltage applied to the "Carrier" tube grid will be 90° in advance of that applied to the grid of the carrier. Although the main purpose of this network is to correct the phase relations of the output of the "Carrier" tube, it can also be used quite conveniently to adjust the relative amounts of excitation voltage applied to the two grids of the amplifier tubes, since it, too, has the characteristic of being an inverting network.

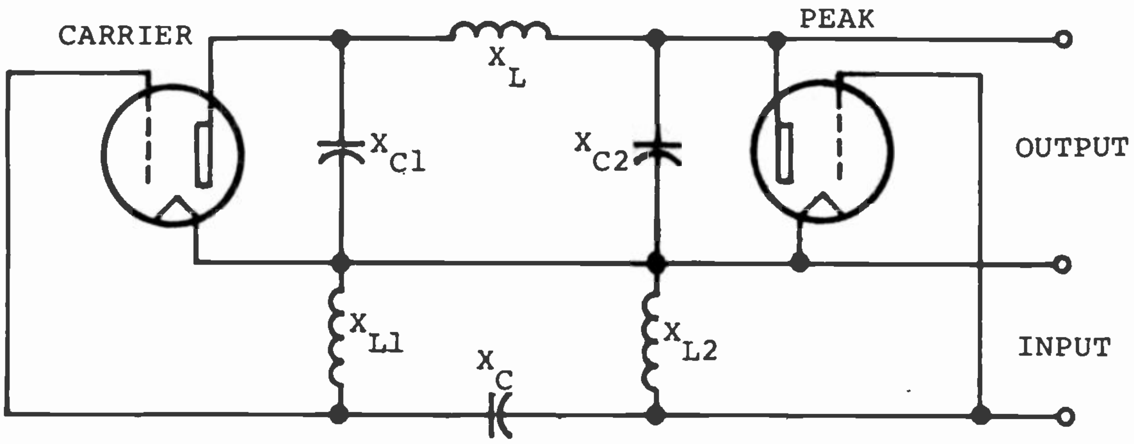

FIGURE 1.6 THE COMPLETE AMPLIFIER

The circuit above illustrates the essential fundamental radio frequency circuit of the complete Doherty amplifier.

The modulated RF excitation voltage is applied directly to the grid of the "Peak" tube and through the 90° advance network to the grid of the carrier tube. The output of the "Peak" tube is applied directly to the load and that of the "Carrier" tube passes through an inverting network that introduces a 90° phase lag. Consequently, the outputs of both tubes reach the load in phase.

The expansion of this circuit to practical application includes the addition of various other components and arrangements necessary for tuning, loading, regulation of RF excitation, isolation of bias, etc. A tank circuit of fairly high KVA/KW ratio is used at the output of the "Peak" amplifier and the same type of tank circuit is used at the grid of the "Carrier" amplifier. For convenience of tuning and adjustment, tank circuits are also included at the output of the "Carrier" tube and at the grid of the "Peak" tube.

The grid tanks should have KVA/KW ratios of at least 3 or more to provide a low impedance driving source and particuarly in the case of the "Carrier" tube this grid tank should be loaded quite heavily to provide good regulation.

Tuning of these circuits, originally, can best be done by means of an RF bridge and good quality RF oscillator. For routine check and adjustment, a cathode ray oscillograph provided with a switch or jacks connected to various points in the circuit, will enable one operator to maintain an accurate adjustment of the amplifier.

With the deflection plates of the oscillograph connected between the grids of the two tubes, a circular pattern will be obtained if the phase relation is 90°, and if the voltages applied to the oscillograph are equal. The same pattern will be obtained when the oscillograph is connected to the plates of the two tubes under the same conditions. Ordinarily, the voltages applied to the oscillograph are made to be unequal in order to obtain an ellipse rather than circle. The correct orientation of an elliptical pattern can be observed much more accurately than that of a circle.

The pattern obtained on the oscillograph when its plates are connected to the plate and grid of either tube will be a straight line oriented at 45° if the voltages are equal and have a phase relation of 180°.

The Doherty High Efficiency Linear Amplifier provides:

a. Greater reliability,

b. Higher fidelity,

c. Greater simplicity,

d. Greater operating economy, and

e. Lower initial cost.

The Doherty amplifier is relatively free from the surge conditions associated with large amounts of stored energy and does not require protection against excessive modulation peaks or transients; in fact, the transmitters of this type can be heavily overmodulated with interrupted or continuous tone at any audio frequency, low or high, for long periods without damage.

The adaptability of the system to large amounts of feedback derived from the final output envelope permits attainment of extremely low noise, harmonic distortion and intermodulation over wide variations in tube characteristics and circuit adjustment. The negligible carrier shift assures full utilization of the assigned carrier power of the station.

The circuits used in the Doherty amplifier are no more complicated than the ordinary coupling network used to match an antenna to its transmission lines. A radio frequency bridge is commonly employed to adjust such a coupling network and to adjust the matching network or phasing equipment at the input end of the line, if such networks are used. This procedure may be carried into the plate circuits of the transmitter with particular advantage in the case of any high power equipment, regardless of the system used. It provides a quicker and more accurate means of knowing that when the plate voltage is applied, the tubes will be working into a resonated tank circuit offering the proper load impedance. The bridge method of tuning high power equipment is therefore recommended for all high power work. The advantages of its use in the Doherty amplifier over others relates mainly to the fact that there is one more circuit in the amplifier which may be adjusted conveniently by this method.

In a Doherty amplifier a sample of the output carrier is rectified and fed into the audio system at 180° phase difference from the impressed audio signal voltage. Thus the use of overall feedback is made to perform automatic compensation for the side band clipping tendency of the sharply tuned antenna system. This compensation is not possible in the high level transmitter.

The negative feedback principle is now employed in all high fidelity broadcast transmitters. In transmitters employing high-level plate modulation, the feedback loop is usually arranged to include only the audio system so as to avoid oscillation difficulties due to phase shift in the modulation transformer. As a result, distortion and noise arising in the modulated Class C amplifier are not removed. With the Continental Electronics transmitters, on the other hand, since there is no modulation transformer, feedback is obtained by rectifying a sample of the final r-f envelope and the resulting correction is effective for noise and distortion arising from all sources.

The method of controlling harmonic radiation is also straightforward in the Continental Electronics single-ended output circuit. Attenuation of harmonics is determined by the type of output circuit and networks used and components selected for use therein.

1.5 THE WELDON GROUNDED GRID HIGH EFFICIENCY LINEAR AMPLIFIER SYSTEM

A simplified schematic of the Doherty high-efficiency linear RF amplifier is shown below. In its conventional form, a phase advance network is connected between the RF excitation source and the grid of the carrier tube. This network serves to correct for the phase lag that occurs in the plate circuit impedance inverting network.

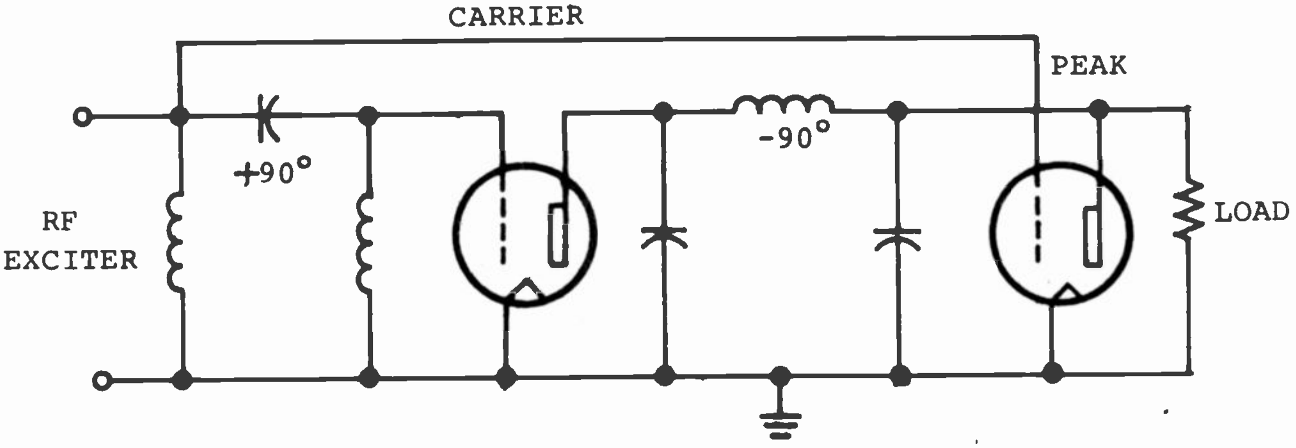

FIGURE 1.7

The Weldon grounded-grid high efficiency linear amplifier modifies the Doherty system above and improves the circuit in several respects. In order to realize a number of basic advantages in RF amplifier design, the power amplifier circuit in the Type 317B transmitter has been modified to incorporate a grounded-grid arrangement of the Carrier tube. This is illustrated in the simplified circuit diagram below.

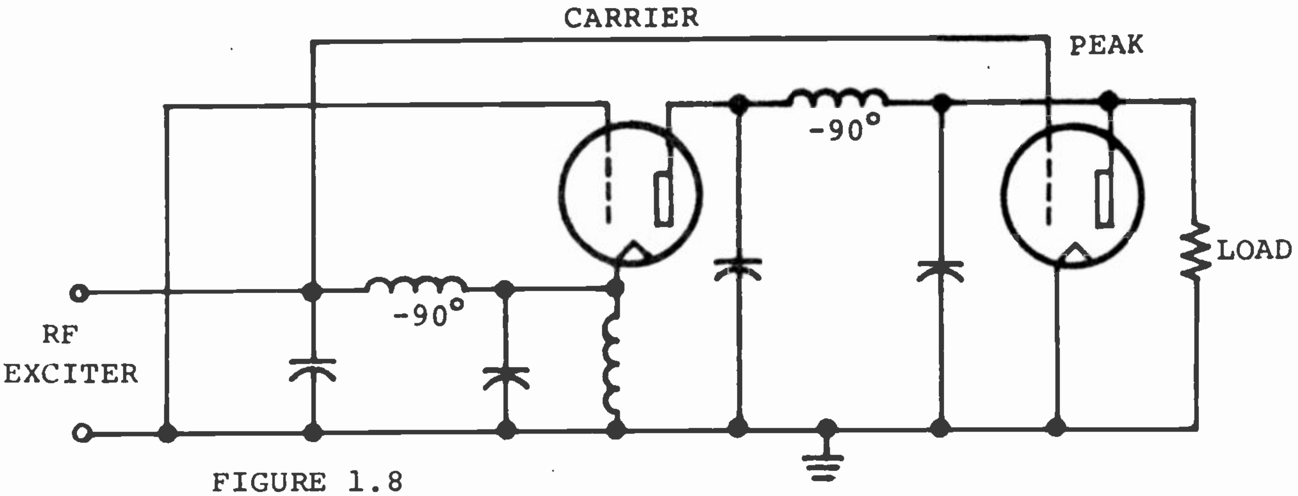

FIGURE 1.8

In the Weldon amplifier, the grid of the carrier tube is operated at ground potential insofar as signal is concerned. The cathode of this tube is operated "above ground" and is connected to the excitation source through a phase lag correction network, rather than a phase advance network, to enable the output of this tube to have the right phase relation to the load circuit.

Some of the more obvious advantages of this arrangement are as follows:

a. No neutralization of the carrier tube is required.

b. The power output of the driver is coupled through to the antenna load, thereby reducing the output requirement of the power amplifier by about 10%.

c. Since the antenna load circuit is reflected back to the driver, it serves as grid loading and eliminates the necessity of the conventional "swamping" resistors. Less driver power is required and greater efficiency results.

d. Use of lag networks (low pass filters) in both drive and output of carrier amplifier reduces harmonic content of power fed to the load circuit.

The Weldon grounded-grid high efficiency linear amplifier is simple to adjust initially, highly stable, and requires no special adjustments over long periods of operation as measured in terms of weeks or months. The Continental Electronics Type 317B 50 kW AM broadcast transmitter has but two non critical controls that provide necessary adjustment of:

a. Power amplifier output tuning, and

b. Power amplifier output loading.

The only other control requiring occasional adjustment is the grid circuit drive control which controls a potentiometer on the 5 kW driver unit to effect increase or decrease in drive power to the 50 kW amplifier. Thus, in general, there are fewer controls to be adjusted on the Continental Electronics Type 317B 50 kW transmitter than on any other 50 kW AM broadcast transmitter presently available.

Some of the information provided above is well worth repeating in more detail, in order to achieve a complete understanding of the simplicity of the Weldon circuit principles.

The "Carrier" tube is operated with its grid at ground potential insofar as signal is concerned. This principle is well known and its inherent advantages have been recognized in the design of high frequency transmitters. In this arrangement, the excitation or driving voltage is applied to the cathode of the tube. The cathode (filament) is operated above ground by means of a special reactor through which the filament power is fed, and the grid of the tube is completely by-passed to ground by means of capacitors.

It is immediately obvious that the "Carrier" tube does not require neutralization since its grid acts as a grounded shield between cathode and plate.

In the conventional type of RF linear amplifier that must handle a modulated signal, it is necessary to employ rather heavy loading on the drive source in order to "stiffen" or improve the regulation of the excitation voltage. This "swamping" resistor loading quite often consumes much more power than is utilized in the form of grid current of the driver stage. In the Weldon cathode driven arrangement, the cathode reactance is effectively in series with the output plate load circuit. Consequently, the driving power applied to the cathode of the tube is also delivered to the load circuit. This results in the driver being effectively "swamped" by the resistance of the antenna or load circuit; therefore, the necessity for the conventional "swamping" resistor is eliminated. This means that no driver power, other than the small amount in the grid circuit current, is lost or dissipated and that excellent "swamping" is accomplished in an efficient manner.

Since the output power of the 5 kW driver is utilized in the antenna circuit, less power is required from the 50 kW power amplifier; actually, this has been determined to be somewhere in the vicinity of 45 kW for a nominal 50 kW output from the transmitter.

An advance network is normally used in the "Carrier" tube grid circuit of the conventional Doherty System to correct for the phase lag incurred in the operation of the impedance inverting network used in the plate circuit of this tube. The combination of these two networks converts the phase relationship of the "Carrier" output to the same as is present in the output of the "Peak" tube which is driven directly by the excitation source and which is directly connected to the load. Obviously this arrangement was necessarily modified in the Type 317B transmitter where the grid of the "Carrier" tube is grounded and where the cathode of the tube is driven and operated above ground. In order to obtain "in phase" relations of the two tubes in the load circuit, the phase advance network in the grid circuit has been supplanted by a lag network connected between the driver and the cathode of the carrier as illustrated above. This phase lag network is in the form of a Pi section constructed of variable components and is usually adjusted for a 90° shift.

Since a Pi network of this type has a characteristic of a "low pass" filter, an added advantage of its use is realized in that additional harmonic suppression occurs between the driver source and the cathode of the "Carrier" amplifier.

The Type 317B transmitter utilizes two Type ML-6697 power tubes in the output stage. One of these is the "Carrier" amplifier and one is in the "Peak" amplifier. The ML-6697 is a coaxial-terminal, thoriated filament triode capable of 50 kW output up to 30 MHz.

It is important to note that the advantages of the Weldon grounded grid high efficiency linear amplifier system for RF amplification in high power radio transmitters have been further extended to utilize the latest techniques in tube types and RF circuitry. As a result, an inherently stable and efficiency system of amplification has been improved not only from a performance standpoint, but also from that of the number of components required.

It may be said that the Weldon grounded-grid, high efficiency, linear amplifier may be considered the system in which two RF amplifier tubes are connected in a special arrangement of parallel operation. However, the two amplifier tubes do not operate during the same angle of time and are, consequently, biased and driven differently and operate with different efficiencies. One tube, the "Carrier" amplifier, is operated more or less as a conventional Class B linear amplifier and serves to furnish the transmitter output carrier power at zero modulation condition. The other tube, designated as the "Peak" amplifier, is biased for Class C operation and delivers power only when its excitation voltage rises above the carrier level, or in other words, when positive modulation takes place.

Actually, the "Carrier" tube is connected in parallel with the "Peak" tube, but with inter-connecting circuitry which enables both tubes to be driven from the same source and to feed into the same output load when operating under the above two modes. Since the "Carrier" tube is not required to furnish linear voltage amplification in the region of positive modulation, its output RF voltage swing remains substantially constant during this portion of the modulation cycle. Consequently, it may be driven and loaded, to utilize its maximum output RF voltage at all times. This combination results in an overall efficiency that is more than twice as high as that of the conventional linear RF amplifier.

The output of the "Peak" amplifier is connected directly to the load through a conventional type circuit. However, the output of the "Carrier" amplifier is connected to a so-called impedance inverting network before it reaches this tank and load circuit. This impedance inverting network is in the form of a Pi section adjusted for an impedance ratio of approximately 4 to 1.

In other words, during "carrier only" conditions the 'Carrier" amplifier supplies the full carrier power through the 2 to 1 voltage step down ratio of this network, and the "Peak" tube is substantially idle. When modulation is applied the "Peak" tube then supplies power to the load circuit. Although the load circuit is a fixed resistance (the antenna), the current being fed into it by the "Peak" tube increases the voltage across it and insofar as the "Carrier" tube is concerned, this load resistance has increased. Since this tube sees the load resistance through the inverting network, it appears to have decreased insofar as the load presented to the "Carrier" tube is concerned. Since this tube supplies a constant RF voltage, the RF plate current will then increase and the power output of the "Carrier" tube will increase. When 100% modulation is accomplished the RF plate current of the "Carrier" tube will have doubled at the peak of modulation. Since the tube load impedance at this point is one-half of its original value, the "Carrier" tube will be delivering twice its original output. At this point of 100%

modulation, the "Peak" tube will also be delivering an equal amount of power to the load circuit and the total power output at the instant of 100% modulation will be four times the level for "carrier only" condition.

1.6 THE PULSE DURATION MODULATION SYSTEM
(Referred to as "PDM")

a. As in high level plate modulation, with PDM the maximum voltage swing on the Power Amplifier tube is nearly four times the DC anode voltage at carrier condition (about 52 kV for 14 kV DC anode voltage) whereas in the Continental system, the maximum voltage swing is about 32 kV. (Less hazardous operation for the tubes.)

b. In PDM, the modulator is in series with the power amplifier. The DC rectifier voltage must be two times the Power Amplifier anode voltage plus about two thousand volts. This doubles the DC insulation problems in the rectifier components such as plate transformer, filter choke and capacitor, etc., and requires rectifier diodes of twice the inverse voltage capability needed for the Continental Electronics system.

c. PDM is Series Modulation. The negative terminals of both the Modulator and Rectifier are at ground potential. Therefore, the power amplifier tube, its filament and bias supplies, and its mounting must all be insulated above ground for the full modulator voltage swing; i.e., the rectifier DC voltage of about 30,000 volts. The output circuit requires a high voltage DC blocking capacitor in both the plate and filament RF output terminals.

In addition, an enclosure for the entire RF amplifier-driver channel must be insulated for the same voltage above ground, since all of these circuits operate at the modulator output voltage swing. This whole high voltage area has been referred to as an "Isolated RF Enclosure".

Anyone familiar with the operation of equipment at high potential above ground in an air stream will immediately visualize the serious dust collection problem of these "floating" components and the insulators supporting them. It is also obvious that a serious voltage breakdown hazard continuously exists, and an abnormal number of high voltage isolating components are necessary, increasing vulnerability to breakdown.

d. With the RF circuitry "floating" at high DC voltage above ground, there is a difficult metering problem for displaying the necessary operating currents and voltages for the tubes in these circuits. Many of the meters will have their movements and cases at high voltage and for personnel safety, must be mounted behind the protective glass panels. The high potential will cause a continuous dust collection problem on the meter faces which will have to be cleaned by gaining access through the protective cover to the high voltage area.

e. The description of PDM shows modulation impressed only on the Power Amplifier anode. With a triode Power Amplifier, most such systems modulate the driver to obtain good fidelity. With a series system, this presents greater difficulties.

f. In PDM, the 70 kilohertz pulses in the modulator provide only 7 pulses per cycle for a 10 kilohertz audio signal. A low pass filter to integrate this will need to cut off above 10 kilohertz at a slope of about 20 dB per octave. This will make it impossible to make use of overall inverse feedback for improved stability and reduction of noise and distortion.

g. The modulator is operated in full voltage swing continuously since 70 kilohertz square waves at 50% duty cycle are applied. With no modulation, the voltage on the anode of the modulator is twice the DC voltage across the power amplifier for one-half of the total time. For the other half of the time, it is swung to minimum voltage which may be about two thousand volts. At 100% tone modulation, the value of this voltage remains the same; that is, full rectifier DC voltage for 50% of the time although the width of the applied pulses varies with the modulation index. Since the plate current is drawn during the time that the anode voltage is at its minimum, modulator anode dissipation is no problem. However, the continuous application of saturation grid pulsing on a 50% duty cycle basis represents a much more severe duty for the tube than in the ordinary Class AB modulator where the voltage swing is zero during periods of zero modulation and reaches maximum only at the sinewave peaks of 100% modulation.

h. In PDM all of the current delivered to the power amplifier flows through the modulator tube. Since the modulator tube is pulsed on a 50% duty cycle, the peak current demand of the modulator is two times the DC current to the power amplifier. The tube selection for the modulator will determine how near this peak current requirement approaches the emission limit of the tube. If the emission limit for the established drive conditions (which are constant) approaches this peak current demand, the modulator tube will become useless. This peak current demand is approximately 1.5 times the peak current demand per tube in a two-tube push pull Class AB modulator.

i. With PDM, a diode clamp is required to prevent the maximum voltage on the modulator from swinging above the output voltage of the anode supply rectifier. Usually a vacuum tube is used for this diode clamp. An internal arc or short circuit in this diode clamp will place the output voltage of the rectifier continuously on the modulator anode until protective circuits operate. If the diode clamp should open (filament or diode burn out), a worse condition may result from the rise of voltage across the 70 kilohertz filter coils and modulator. Depending on the filter characteristic, the transient voltage might exceed 100,000 volts.

j. In the case of an arc-over in the modulator, the cathode of the power amplifier will be grounded and the full rectifier voltage will be continuously applied across the power amplifier tube. This is twice the normal anode voltage for the tube. This overload condition will exist until circuit breakers can remove the rectifier voltage.

If the modulator is keyed off or stops passing current, then the entire isolated RF enclosure and all components thereon will rise to the full voltage of the plate rectifier and remain there until the plate circuit breaker opens, after which the filter bank will still be charged until grounded.

k. In PDM, the audio current to the power amplifier is drawn at an audio frequency rate from the high voltage power supply rectifier the same as it is in the Continental system. This means that the high voltage power supply in PDM must have a filter capacitor with sufficient storage capacity to deliver the lowest audio frequency without offering a serious reactive impedance. In other words, a large filter capacitor is required across a very high voltage power supply (twice the normal voltage for an ordinary high level modulated transmitter and 60 or 70% higher than that used in Continental transmitters). Since the stored energy in this capacitor is proportional to the square of the voltage across it, the energy delivered into a fault will be four times as great as would be delivered by the rectifier in a conventional high level plate modulated transmitter and at least three times as great as that which would be delivered by the power supply on Continental transmitters.

l. Both PDM and the Continental system have the advantage of elimination of the modulation transformer and modulation choke. This obvious advantage has always been available in Continental high power transmitters.

It is not necessary to accept the additional hazards of the PDM circuit to accomplish the elimination of the modulation transformer and reactor.

m. It is not necessary to accept the operational hazard of the Pulse Duration Modulation System to obtain high overall transmitter efficiency since the patented reliable screen/ impedance modulation system offered by Continental provides equal efficiency.

1.7 THE CONTINENTAL HIGH EFFICIENCY SCREEN MODULATED AMPLIFIER TECHNICAL DESCRIPTION

The development of tetrode tubes having plate dissipation in excess of ten kilowatts has made possible the design of a high power modulated amplifier which combines the advantages of screen grid modulation with the high efficiency amplifier. The result is a transmitter having very high overall efficiency.

The following is a description of the circuit as used in the design of the 50 kilowatt broadcast transmitter manufactured by Continental Electronics and designated as Type 317C.

This description typifies the principle of operation which is the same for transmitters of any power.

The final, or modulated amplifier, consists of two Type 4CX35000C ceramic tetrodes in a high efficiency amplifier configuration. Rather than operating as a linear amplifier for a modulated wave, both tubes are simultaneously screen grid modulated with a low power modulator. As formerly envisioned, the Doherty amplifier, being a linear amplifier of modulated waves required that the carrier tube be operated Class B in order to preserve the linearity of negative peaks. In the new circuit, since the linearity of negative peaks is dependent mainly on screen grid linearity and not on control grid operating conditions, then the carrier tube can be operated as a Class C amplifier with resulting high plate efficiency.

Further, since the plate voltage swing does not increase with positive modulation, then DC plate voltage much higher than normally used for plate modulated transmitters can be used. At 16 kVDC, plate efficiency of 80% has been achieved.

Since screen grid modulation isolates the modulation source from the RF driving source, there is no need to swamp the grid drive to maintain linearity and the driving power required for the two final amplifier tetrode tubes is quite small. A 4-400A tetrode is used to drive Continental's 317C 50 kW output amplifier.

Since the peak tube also operates as a Class C amplifier at high plate efficiency, then all of the RF stages are Class C and because the RF drive and modulator requirements are very slight, the overall transmitter efficiency is very high. Another factor that contributes to high efficiency is the greatly reduced cooling requirement since there is so little heat to be removed. Where 8 to 10 horsepower for cooling was formerly required, the new design with only about 5 horsepower has more than adequate cooling.

Referring to Figure 1.9, which is a simplified schematic diagram of the amplifier, let us first consider the operation of the carrier tube V2. This tube is a conventional grounded cathode Class C amplifier that supplies the full 50 kilowatt carrier power when no modulation is applied. As such, it will be characterized by high plate efficiency and can be tuned by noting a dip in plate current as the plate tank is resonated. The screen voltage is maintained at +700 VDC by a separate low voltage supply.

The plate voltage is 16 kV and the RF grid excitation is sufficient to maintain a peak plate swing of 15 kV even with the increased loading encountered on positive modulation peaks when the plate load impedance is one-half the carrier only value.

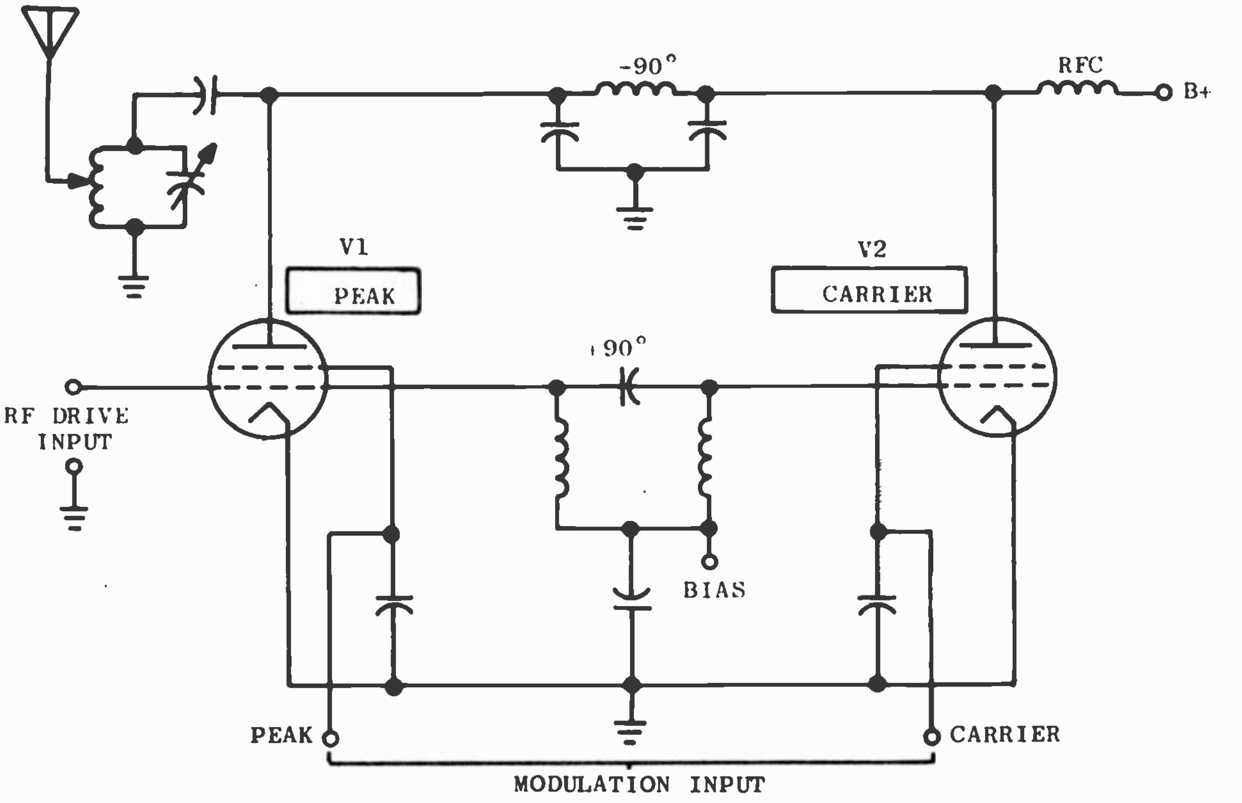

FIGURE 1.9. AMPLIFIER SIMPLIFIED SCHEMATIC

Operated in this manner, the tube cannot be screen modulated in a positive direction since the plate swing cannot be increased with an increase in screen voltage. But a decrease in screen voltage will be accompanied by a linear decrease in plate swing. In other words, the stage can be screen modulated in a negative direction in much the same manner as the visual carrier of a television transmitter. Because of the high grid drive used, the screen voltage has to be modulated past zero volts, or cathode potential. Carrier cutoff, or 100% negative modulation occurs at about -300 volts screen voltage. Thus, a negative going half sinewave of 1000 volts peak amplitude is all that is required to modulate the carrier tube. The novel requirement of a half sinewave modulating signal has lead to a unique modulator design which will be shown later.

The peak tube has the same DC plate voltage and RF grid excitation as the carrier tube but delivers no power at carrier condition because its plate current is cut off due to the -300 volts screen voltage. As a positive going voltage is applied to the peak tube screen, the tube delivers power into the load until at crest condition; that is, when the instantaneous screen voltage is equal to the carrier tube screen voltage, the peak tube plate swing doubles the voltage across the load which for the 50 kilowatt transmitter is 500 ohms. This would make it appear that the 500 ohm load has increased to 1000 ohms.

This apparent increase in load impedance at the end of the impedance inverting network to 1000 ohms causes a decrease in load impedance at the carrier tube from 2000 to 1000 ohms. Therefore, at crest condition, both tubes are operating under identical instantaneous conditions; that is, equal plate swing, load impedance, screen voltage and grid drive. Since the carrier tube load impedance is half what it was at carrier level and the plate swing is the same, then the carrier tube power output is doubled to 100 kilowatts. Since the peak tube is operating under identical conditions, then it is also putting out 100 kilowatts. The combined output is therefore 200 kilowatts on positive peaks, which is what is required for 100% modulation. Since the peak tube is cut off at carrier level, there is no need to modulate its screen with a negative going wave. Only a positive going half sinewave having a peak amplitude equal to the negative half sinewave required for the carrier tube will be necessary.

Since the voltage contributed by the carrier tube undergoes a 90° phase lag by the time it appears across the load, then it is necessary to introduce a 90° phase advance in the carrier tube grid driving voltage in order that the power output of both tubes will combine in the proper phase. This is accomplished by the leading 90° grid network shown in Figure 1.9. This circuit has a 1:1 transformation ratio, so that both tubes receive equal grid drive.

While on the subject of the 90° grid and plate networks, it would be appropriate to dispel the myth about this type of amplifier being critical as to phase adjustment of these circuits. It has been shown in practice and can be proven in theory that misadjustment of these circuits resulting in phase differences as great as 20° makes only a barely discernible deterioration in performance. This is because we are adding the cosine of the phase deviation angle. For instance, misadjustment resulting in 10° phase difference at the load will result in only a 1.5% reduction of the positive peak, or a deviation as great as 20° will yield only a 6% reduction. Overall envelope feedback will automatically compensate partially for this. There is no effect at all on the negative peak since from carrier level down to trough condition, the peak tube is cut off and therefore there is no combining action.

It has been shown that the peak and carrier tubes need only to be screen modulated with alternate half sinewaves, positive halves for the peak tube and negative halves for the carrier tube. Because of this unique requirement, it was possible to design a modulator similar to a push-pull Class B modulator, but without a combining transformer.

Referring to Figure 1.10, separate tubes, V2 and V3, are used to modulate the screen grids of the peak and carrier tubes. Tube V1 is a conventional resistance coupled driver stage. The modulators, V2 and V3, are cathode followers because of the variable load resistance presented to them by the change in average screen current during modulation. Because of the unsymmetrical nature of the half sinewave outputs of the modulator tubes, direct coupling to the modulated amplifier screens must be used, since half of each of the half sinewaves would be lost with condenser coupling.

The peak tube modulator V2 must put out a half sinewave having a peak amplitude of 1000 volts starting at -300 volts and going positive to +700 volts. For this reason, the cathode is connected to a -300 volt source and the bias is adjusted so that the plate current is cut off which puts the peak tube screen at -300 volts since there is no drop across the modulator cathode resistor.

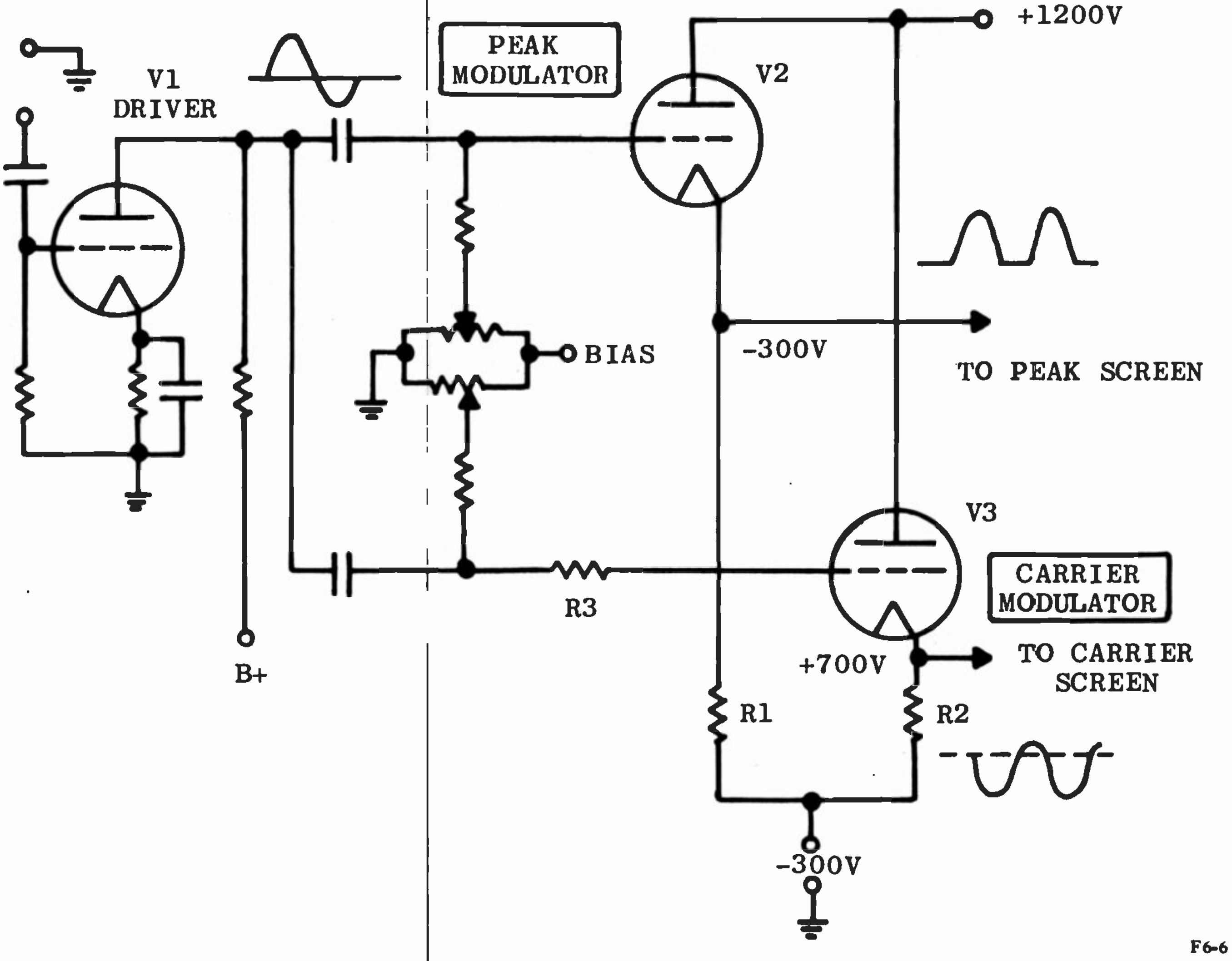

FIGURE 1.10. SIMULATING CLASS B PUSH PULL MODULATOR

The carrier tube modulator V3 must also deliver a half sinewave of 1000 volts peak amplitude but in a negative going direction. It must start at +700 volts and swing down to -300 volts. The cathode is connected to the same -300 volt supply and the bias adjusted so that the plate current causes a 1000 volt drop across the cathode resistor. This places the modulator cathode and the carrier tube screen at +700 volts.

Under these conditions the modulator static dissipation is quite low because the peak modulator tube is cut off while the carrier modulator, although not cut off, has only 500 volts plate to cathode voltage. This helps maintain high overall transmitter efficiency.

Both modulator tubes are driven in parallel from a common driver stage. The peak modulator will conduct only on the positive half cycle of the driving wave since it is biased to cut-off. This will result in a positive going half cycle output from the cathode. The carrier modulator will be linear only for the negative going half cycle since it has only 500 volts plate to cathode voltage. The negative going driving wave will cause the cathode voltage to go from +700 volts to -300 volts which is cutoff. Since the tube will be driven into grid current on the positive half cycle because of the low plate voltage a resistor R3 is placed in series with the grid to prevent excessive loading of the driver stage on positive peaks. The output of the carrier modulator will therefore be essentially a negative going half sinewave with a very rounded positive peak.

Since the modulators are cathode followers, they have a gain of about .8 and will therefore require a driving voltage of about 1250 volts peak or 2500 volts peak-to-peak to put out the 1000 volt peak half sinewaves. This is easily supplied by the driver tube V1.

Because of the half sinewave pulses of plate current similar to a Class B push pull stage, the modulator efficiency is quite high. Further, since the half cycles are recombined by the action of the high efficiency screen modulated amplifier, no audio transformer is required.

Although this modulator circuit has the advantage of high efficiency, it was deemed rather complex for use in a transmitter as small as 50 kilowatts where very little audio power is required. For that reason it was decided to use a conventional impedance coupled cathode follower modulator for the Type 317C 50 kW transmitter. With this circuit (Figure 1.11), the peak and carrier screens are connected through modulation reactors to their -300 and +700 volt power supplies. The cathode follower modulator stage drives both tubes simultaneously with a full sinewave. For transmitters of 250 kilowatts and higher, the high efficiency modulator appears to be attractive, however.

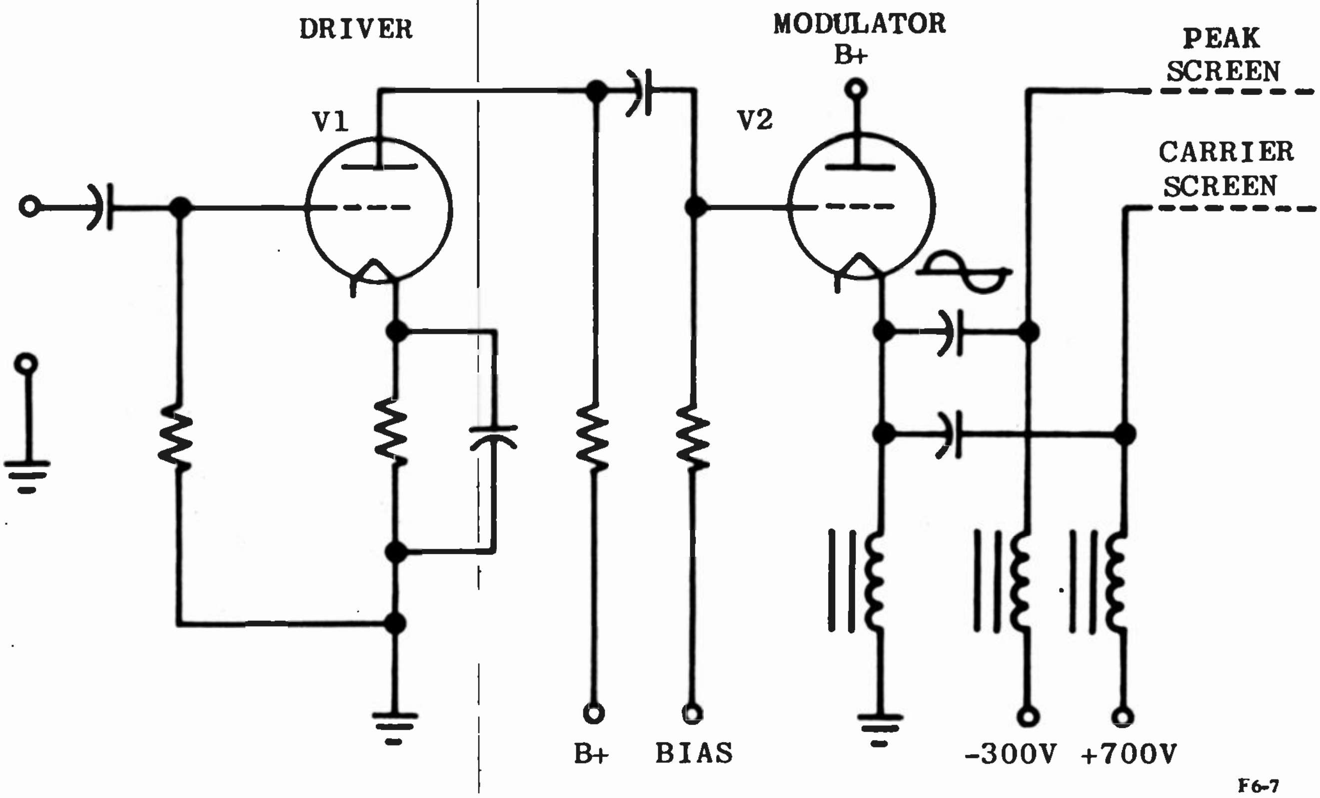

FIGURE 1.11. IMPEDANCE COUPLED CATHODE FOLLOWER MODULATOR

The successful application of large amounts of overall envelope feedback has been limited in previous designs of linear or high efficiency linear high power transmitters due to envelope delay or phase shift caused by the great number of tuned RF circuits between the low level modulated stage and the output of the final amplifier. This envelope delay made it very difficult to control precisely the phase and frequency response fall-off necessary for the application of inverse feedback. Since only the plate circuit of the high efficiency screen modulated amplifier handles the modulation envelope, then the envelope shift is greatly reduced and since there are no audio transformers in the system, the use of overall feedback greatly improves the audio performance of the transmitter.

Table 1.1 is a comparison chart showing the power input requirement for the various types of 50 kilowatt transmitters available today. Although 50 kilowatt transmitters are most always rated and run at 53 kW output, only one manufacturer stated power input required for 53 kW output. The figures shown for the plate modulated transmitter are the averages of figures stated by four American manufacturers including Continental Electronics for our 50 kW plate modulated shortwave transmitter. The reason for averaging these figures is because of the rather wide variation in the figures stated on sales brochures. The 110 and 140 kW figures for the phase to amplitude transmitter at 30 and 100% modulation are the result of an estimate gleaned from figures in sales literature since there is some conflict in the figures stated in the brochures. All of the manufacturers stated power input in kilowatts and all showed about 90% power factor. It can be seen that the Continental Type 317C offers a considerable improvement over the other two systems, especially at 100% sinewave modulation which although not as significant as the average or 30% modulation figure, is taking on new importance because average modulation seems to be climbing up toward 100% nowadays, due to the high limiting and the possibility of speech clipping in broadcast transmitters.

TABLE 1.1 POWER INPUT REQUIREMENT FOR VARIOUS 50 kW TRANSMITTERS

	CONTINENTAL TYPE 317C	PHASE-AMPLITUDE	PLATE MODULATED*
0% MOD.	82KW	94KW	93KW
AVG (30%) MOD.	92KW	110KW	108KW
100% MOD.	120KW	140KW	140KW

* FIGURES FOR PLATE MODULATED ARE AVERAGES FOR FOUR AMERICAN MANUFACTURERS.
FIGURES SHOWN ARE FOR 50KW OUTPUT WITHOUT 3RD HARMONIC WAVE SHAPING CIRCUITS.

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Although the figures shown for a 50 kW transmitter indicate a good reduction in operation cost, the importance of high transmitter power efficiency becomes quite a significant when considering the operating cost of a super power 500 or 1000 kilowatt transmitter. The inclusion of third harmonic resonators into the drive and plate circuits of the carrier tube will further reduce the transmitter input required.

It is important at this point to recognize the universal acceptance which this Continental Electronics patented circuit has received from the broadcast industry throughout the world.

It will be noted that the Patent was applied for in 1964 and issued in 1967. The first transmitter using this circuit was a 50 kilowatt transmitter delivered to a broadcasting station in Tijuana, Mexico on 15 January 1965.

The operating schedule of this transmitter is 24 hours per day and the first set of power amplifier tubes delivered with the transmitter were in service for a total of 48,000 hours per tube.

An important feature of this transmitter is the low duty requirement of the tubes and the resulting extensive tube life which has been experienced.

Continental Electronics has built medium wave transmitters using this system in power output ratings of 50 kilowatts, 100 kilowatts, 250 kilowatts and 500 kilowatts. These transmitters have been combined in pairs for operation up to as high as one megawatt and designs are in existence and available for production in single unit powers with the same type circuit up to 1 megawatt and for combined use up to 2 megawatts. All of the above are for the medium frequency range. A 2 megawatt unit using 2 1000 kW transmitters combined will be delivered in 1975.

Also, Continental has produced a shortwave transmitter design using this circuit with an output carrier power of 250 kilowatts, a frequency operating range from 3.9 to 26.5 megahertz with automatic tuning which allowed frequency change from maximum to minimum frequency and vice-versa in less than one minute.

The circuitry used has been made possible by the advanced development of tetrode tubes in the United States. These tubes have proved in service to have extremely long life. The present day processing of power tubes in the United States with higher pump out temperatures and better seals made possible by new types of ceramic envelopes contributes to this longer life.

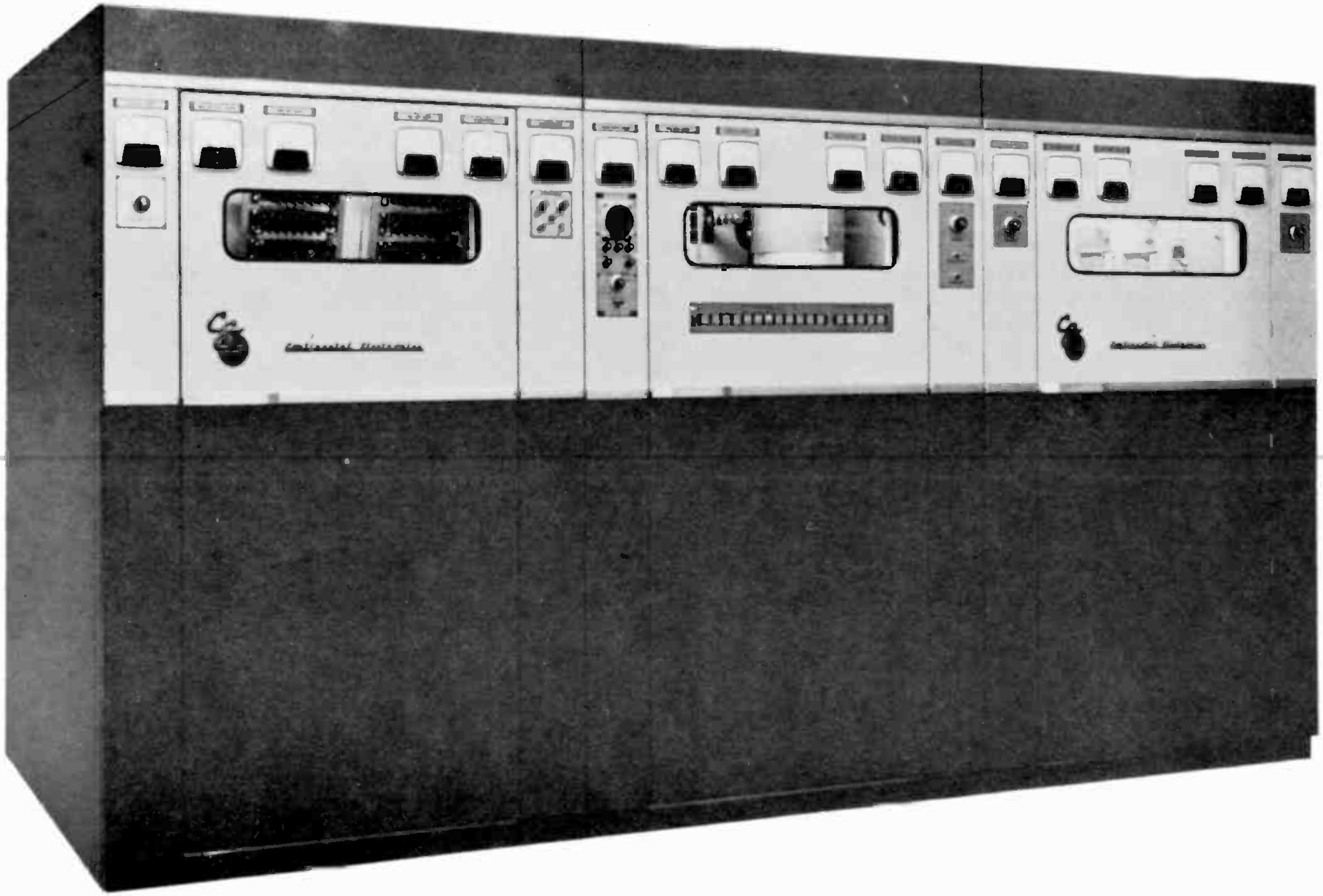
Since the first sale of the 50 kilowatt transmitter using the new Continental Electronics patented circuit, a total of 70 such 50 kilowatt transmitters (Continental Type 317C) have been sold. This was over a period of 9 1/2 years.

These sales have been based entirely on the universally enthusiastic acceptance of the technical superiority of this circuit design. During this same period the total number of 50 kilowatt transmitters sold by all other American manufacturers offering various other types of circuit design has been less than Continental's sales.

Fifty kilowatts output power is the maximum allowed in the United States by the Federal Communications Commission. This is also true in Canada. For this reason, our transmitter sales in powers above 50 kilowatts are in smaller quantities. However, Continental has sold a number of 100, 250, 500 and 1000 kilowatt transmitters using this particular circuit design. These are Continental's standard Types 318A, 319A, 320D and 323A.

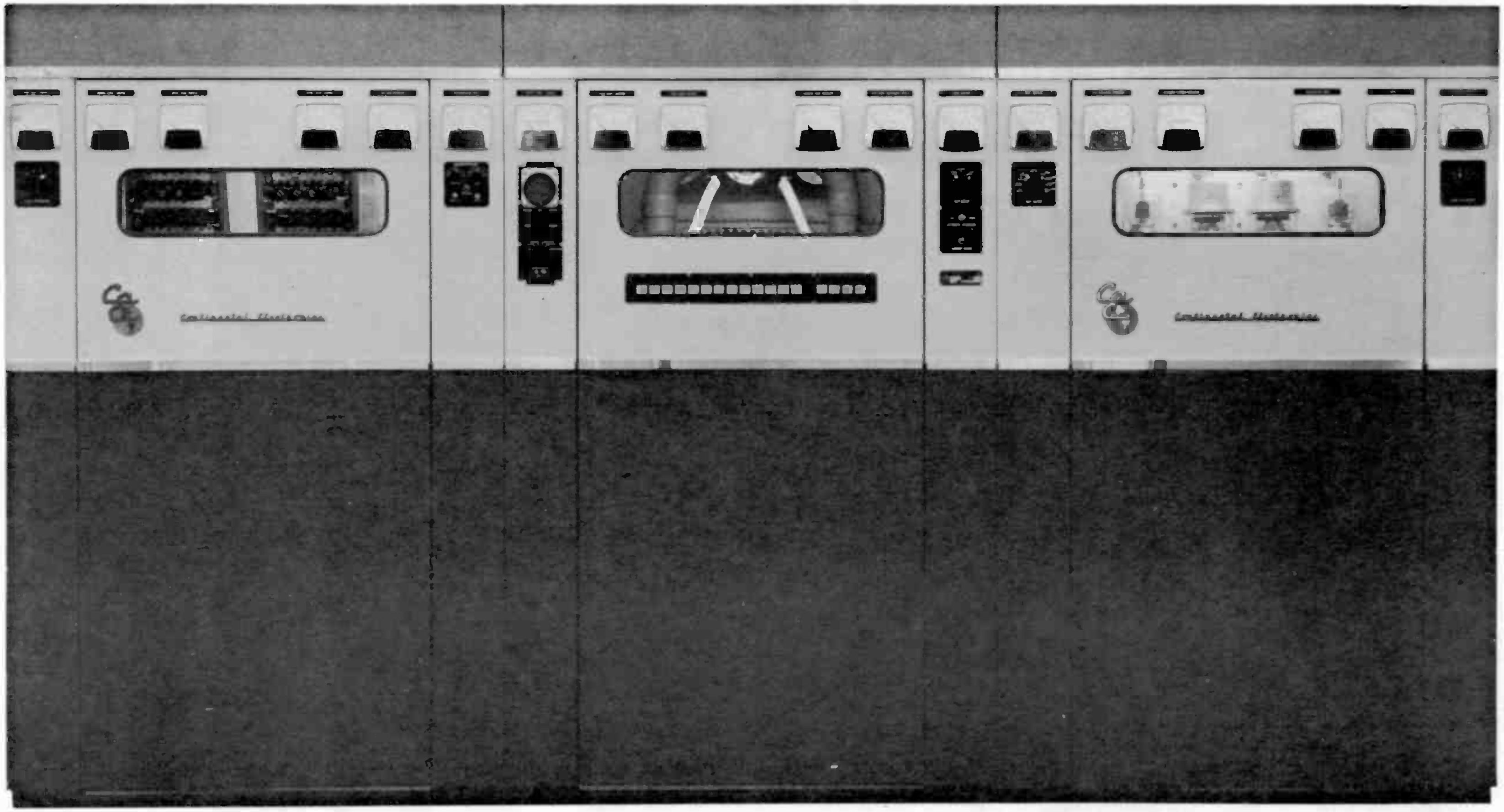
After reading the comparison of this Continental Electronics circuit with other systems offered by other manufacturers, it will become obvious that the advantages of the Continental system are excellent performance, greater reliability, easier maintainability and greater operating economy resulting from longer tube life and high power conversion efficiency.

The new high efficiency circuit is a step forward in the progress of transmitting equipment which has seen in recent years the development of such component parts as the high reliability silicon rectifiers, ceramic envelope power tubes and vacuum capacitors and many new materials which have made possible smaller and more reliable equipment.



Type 317C 50 KW Medium Frequency Broadcast Transmitter

Continental Electronics
DALLAS TEXAS



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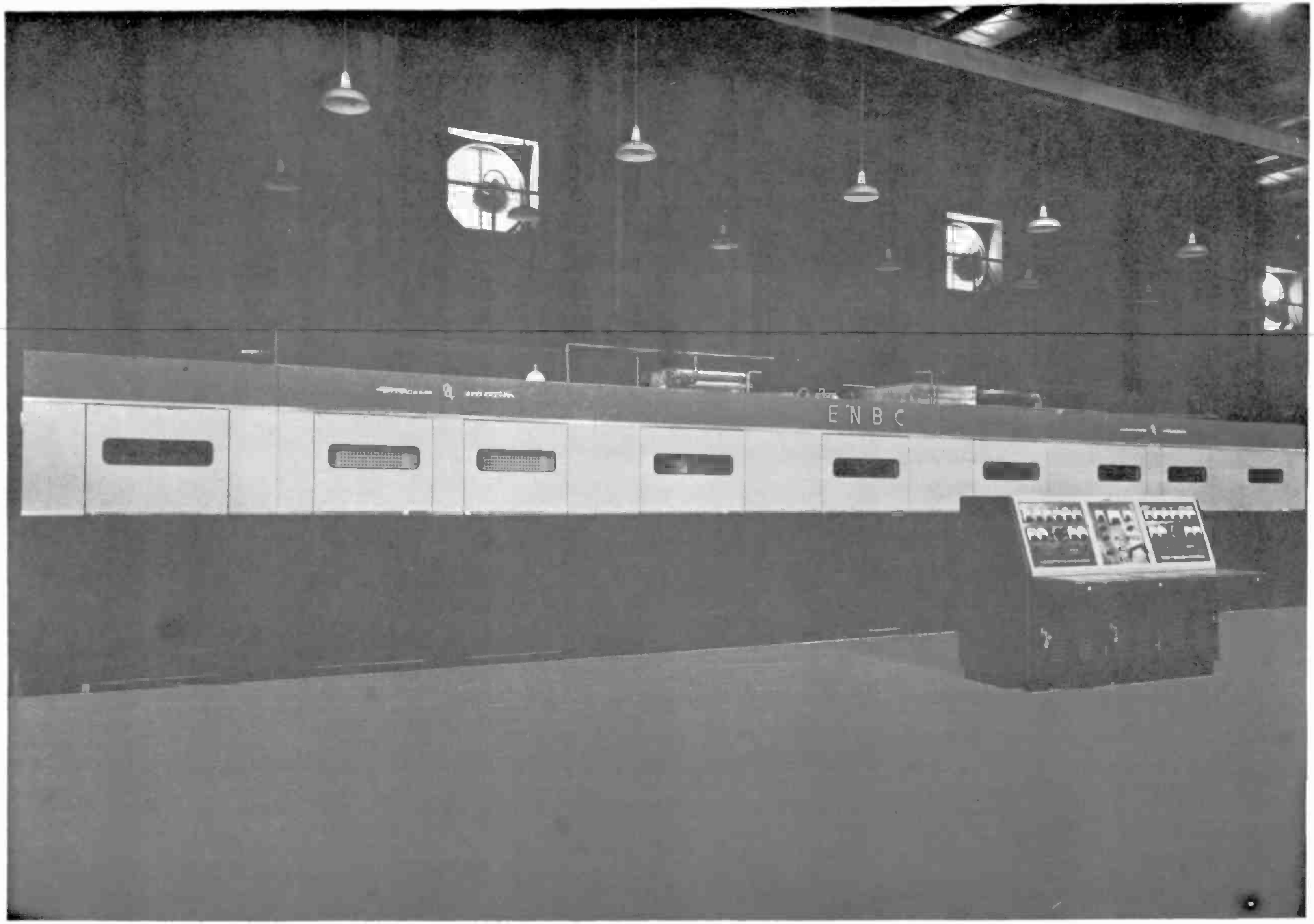
Type 318A 100 kW AM Broadcast Transmitter



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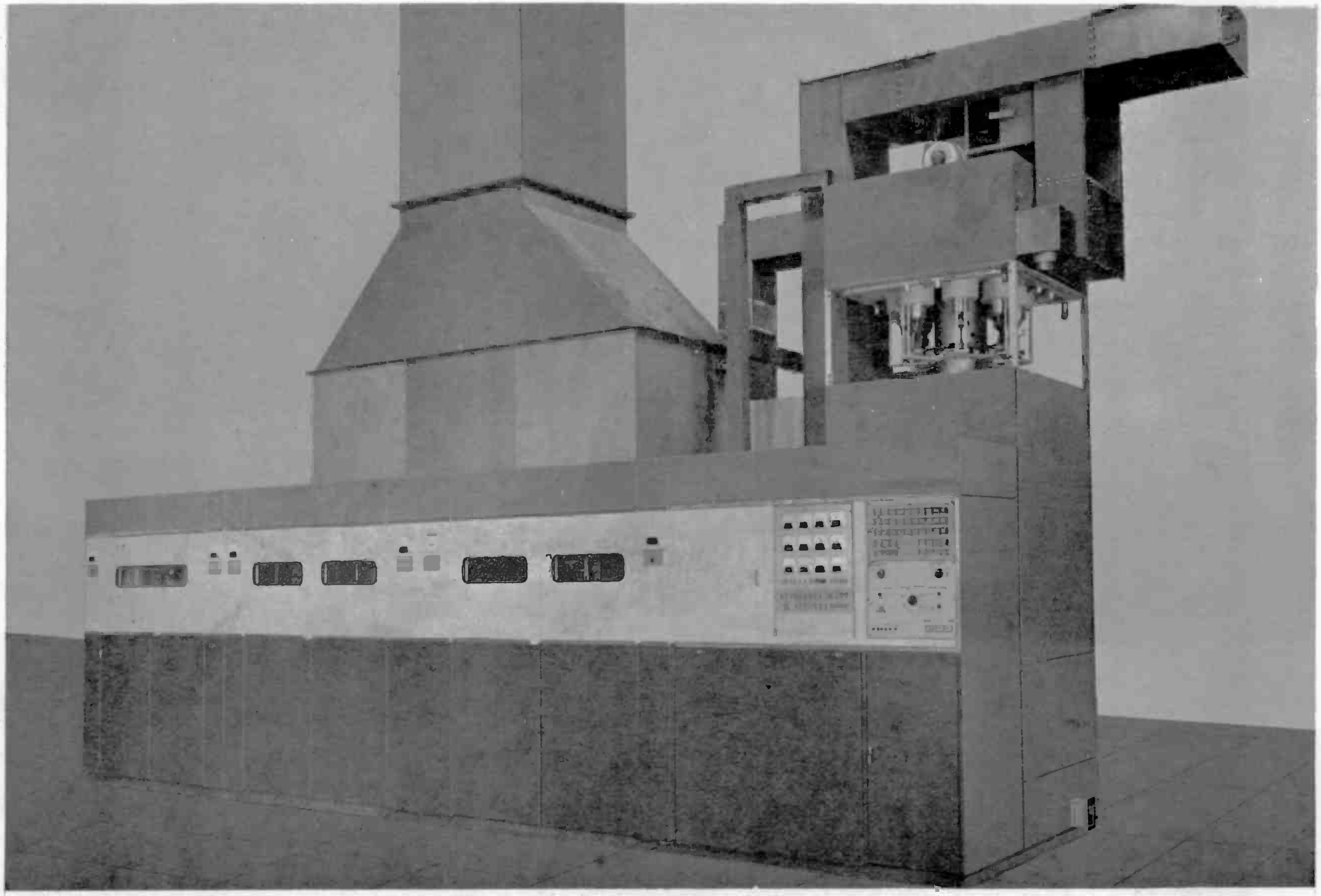
Type D319A Dual 250 kW MF AM Broadcast Transmitter

Continental Electronics
DALLAS, TEXAS



Type 419E HF 250 kW AM Broadcast Transmitter

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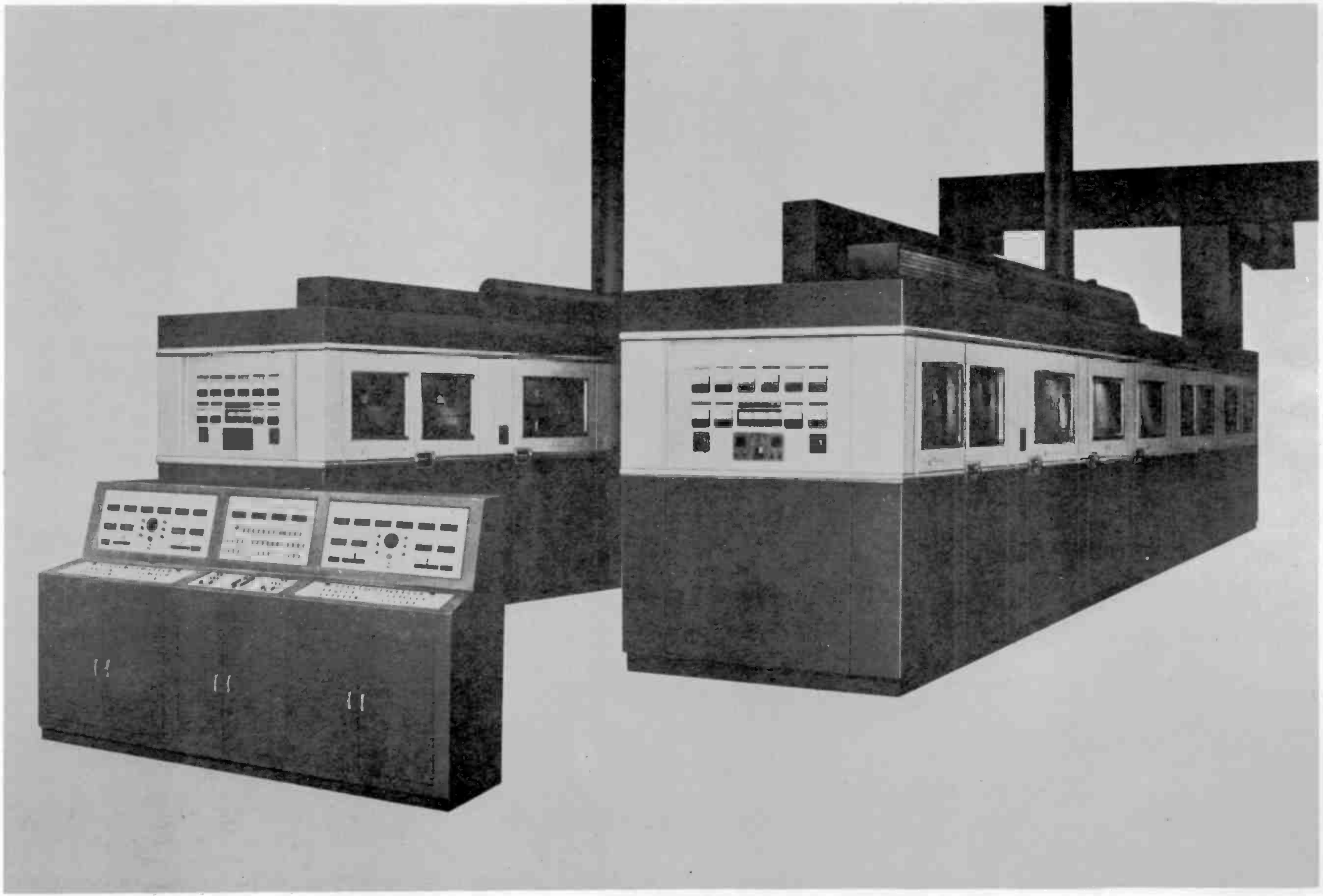
500 kW MF Transmitter Type 320D

Continental Electronics
DALLAS, TEXAS



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Type D320D MF 1000KW AM Broadcast Transmitter