The New KFI

Reproduced from the February 1932 issue of *Radio News*

"KFI is now in the super-power class, having recently increased power to 50 Kilowatts—the first station west of Texas to use this power. This article provides a detailed description of the new transmitter."

By I. R. Baker

NEW and improved radio service is available to listeners along the Pacific Coast and DX fans in other parts of the country have a new mark to shoot at with the opening of KFI's new 50 kw transmitter near Los Angeles, California. KFI, which is owned and operated by Earle C. Anthony, Inc., has operated for many years, and until recently had a power output of 5000 watts. With the installation of the new equipment, it is expected that listeners will be able to hear this station over a much wider range.

The transmitter is located on a thirty-acre tract near Buena Park, Los Angeles County, approximately twenty miles from the city of Los Angeles. The location was selected after extensive field strength tests by engineers of the RCA-Victor Company, who furnished and installed the transmitter. The location, of course, was chosen so that a very nearly "circular pattern" was obtained, assuring equal radiation in all directions.

Station Design

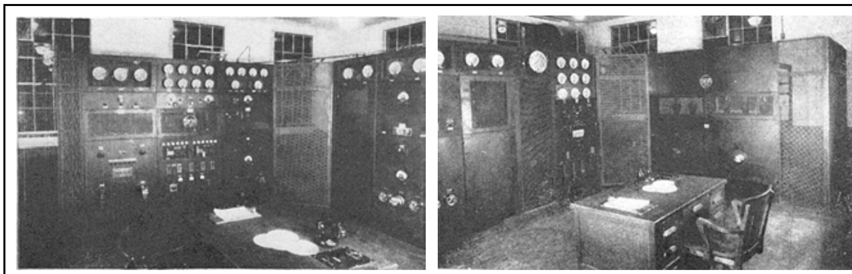
The new station is housed in a brick, steel and concrete building of two-story construction. The lower floor houses the power plant and the upper story contains the transmitter proper. The equipment is so arranged that an operator can readily observe the entire operation from one point.

The towers are 400 feet high, located 700 feet apart, and so placed that they form, with the building, almost an equilateral triangle—the building being 475 feet from the middle point between the towers.

The transmitter is one of the standard RCA 50-B units. Figure 2 shows the block diagram of the r.f. and power circuits. Figure 1 shows the schematic of the transmitter.

For the purpose of description, the transmitter can be divided as follows:

- (a) Low-power rectifiers and control panel
- (b) Exciter modulator unit
- (c) 5 kw amplifier
- (d) 50 kw amplifier



The RF Portion of the Transmitter Equipment

The three panels at the left contain, respectively, the low-voltage rectifier and automatic controls, the exciter and modulator equipment, and the 5 kw intermediate amplifier. To the right of the gate are two of the panels on which the 50 kw amplifer equipment is mounted.

(e) Main control panel
(f) Main rectifier
(g) Basement apparatus
(h) Antenna tuning equipment

One of the illustrations shows the entire radio-frequency unit. On the extreme left is the low-power rectifier and automatic control unit. This panel contains three individual mercury vapor rectifiers, various contactors and relays associated with the control circuits, and condensers and reactors associated with the oscillator-modulator amplifier panel. There are a total of ten UX-866's in this panel which supply power to the various radio-frequency stages located in the first three panels.

The Modulator Unit

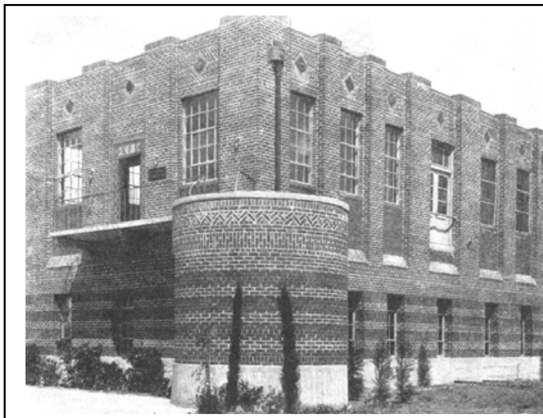
The next panel shown in the same illustration is the exciter modulator unit. This panel performs the following functions: (1) produces a constant frequency by means of a crystal control oscillator, (2) amplifies the carrier frequency to a power level to excite the succeeding 5 kw amplifier, and (3) receives low-level audio energy from the incom-ing audio line and amplifies this to the level sufficient to modulate the radio-frequency system 100%.

The two complete crystal oscillator units are mounted side by side in this unit behind glass-front doors. The connec-tions are so arranged that either of the crystal units can be used at will, depending upon the position of the crystal unit transfer switch.

The crystal oscillator stage employs one UX-210 tube, connected in the circuit with a quartz crystal accurately ground to a frequency of 640 kc at a specified temperature. In order to insure the highest degree of frequency stability, the crystal is mounted in a specially-designed holder and is kept in place by quartz spacers. These spacers are ground from the same block as the crystal and therefore have the same temperature coefficient, thus keeping the air gap constant with changes in temperature. The crystal holder is mounted inside a specially designed heated compart-ment with thermostatic control so that the constant temperature is maintained at the crystal. The heater unit is known as an attenuated heater.

Crystal Temperature Control

A sensitive thermostat is located in the vicinity of the source of heat so that it operates on a very small temperature change of the heater element itself. Due to the great thermal capacity of the conducting layer, the resultant change in temperature around the crystal is but a small fraction of the change in temperature which causes the thermostat to operate. In this manner the frequency variations of the temperature changes are kept within very narrow limits. In order to



The Transmitter Building

maintain accurate temperature at the crystal itself, a thermometer projects from the oven and accurately indicates any changes which may take place therein.

The power required for the heater is obtained from the 110-volt station lighting circuit instead of from the control circuit used in other parts of the transmitter. Thus the unit can be kept at the proper temperature whether the transmitter or the crystal unit is in regular service or not.

The crystal stage is followed by two buffer amplifier stages, all located in the same cabinet. As stated before, the cabinet is in duplicate, including power supply. The two buffer amplifier stages have identical circuits and use UX-865 screen-grid tubes. The screen-grid feature, of course, eliminates the need of neutralizing. Any reactions from the tuning and buffer amplifier stage are not reflected back to the crystal oscillator. Individual shielding is used to further reduce induction between stages. Each stage has its individual plate current meter; the plate voltage on the amplifier and oscillator is measured by means of a voltmeter.

There is still a third unit in the spare parts kit of the transmitter which can be pressed into service in the event one of these two units in the transmitter should be removed, thus always giving a large factor of safety in operation.

Referring again to the block diagram, it will be noted that following the crystal control units is the first r.f. amplifier, which utilizes another screen-grid tube, type UX-860, of 75 watts capacity. This is the third buffer amplifier stage between the crystal and modulated stage. It can be readily seen that so many stages are not necessary for providing the necessary power to excite the modulated stage. It is generally conceded, however, to be good engineering practice to have as many buffer amplifier stages as economics will permit between the modulated stage and the crystal stage to prevent any reaction which might occur due to modulation. It also allows the crystal stage to be operated at very low power output which, in itself, makes for better stability.

Following the UX-860 stage is the modulated amplifier consisting of one UV-849 tube. This stage is modulated by two of the same type tubes. The power for this stage and the driving stage is furnished by six UX-866 tubes located in the first panel from the left and arranged in a three-phase, full-wave circuit. The output of this stage is a modulated radio-frequency with peak power of approximately 800 watts delivered to the grids of the succeeding 5 kw amplifier stage.

The *5* kw. amplifier stage is the third panel from the left. This stage utilizes two of the UV-863 high-power tubes connected in a push-pull circuit. This stage is operated Class B and is used to amplify the modulated carrier from the preceding stage. The UV-863's utilize water cooling on the plates. Filament power for this stage is secured from a filament motor generator set which is used to supply both this stage and the final power amplifier stage. Plate voltage is secured from the high-power rectifier in the same manner by means of a voltage reducer unit.

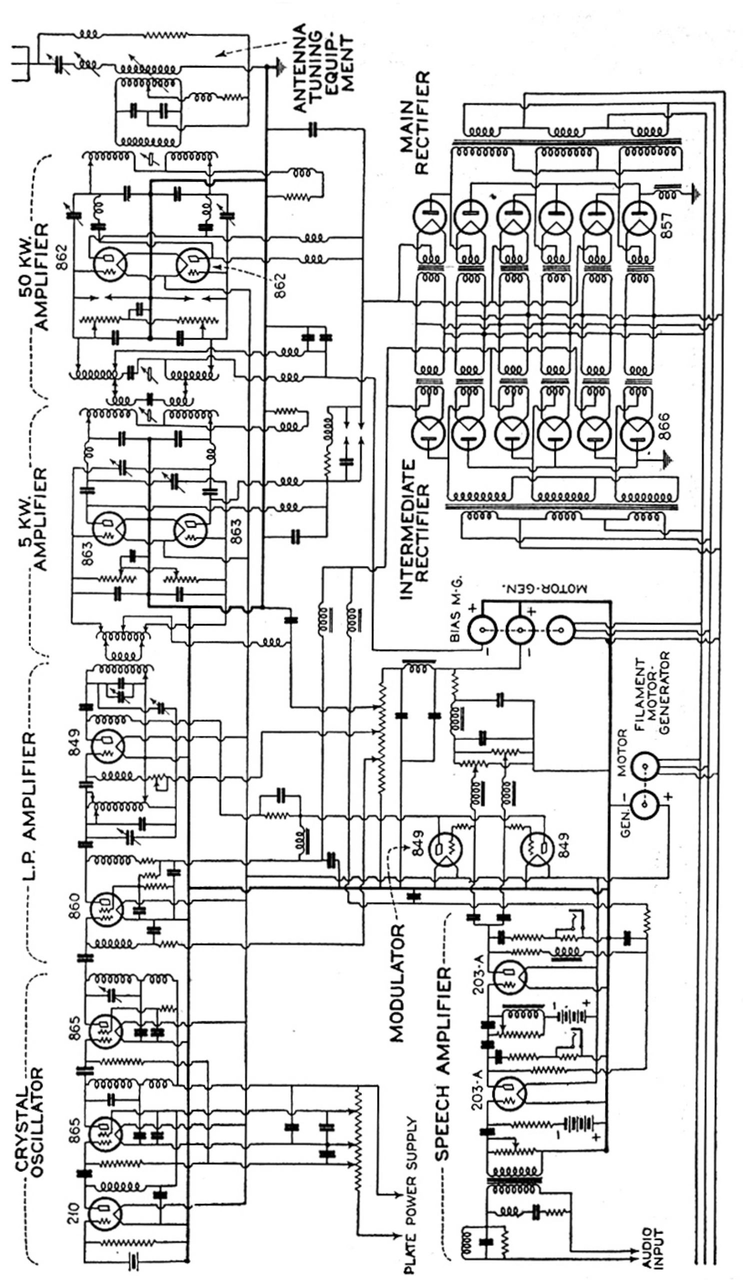


Figure 1. The Schematic Wiring Diagram of the KFI Transmitter

The next grouping of panels contains the final power amplifier unit which utilizes two UV-682, 100 kw Radiotrons arranged in a linear balanced power amplifier circuit.

The 100-kilowatt tube was developed specifically for use in 50-kilowatt transmitters since it was desirable, in the opinion of engineers, to avoid a paralleling of tubes in Class B operation. The adjustment of a Class B amplifier is very critical and unless extreme care is taken in the design and adjustment of the circuit, the amplifier will be unstable. This instability manifests itself in poor quality, short tube life, interruptions of service and flashovers. The final power amplifier was virtually designed around the 100-kilowatt tube. A great amount of time and money was spent in the development of the circuit for this tube and this work has resulted in a very stable and highly efficient circuit.

A Class B or linear amplifier, by definition, is one that operates in such a manner that the power output is proportionate to the square of the grid voltage. This is accomplished by operating the tube with a grid bias of such value that it substantially cuts off the plate current without excitation. When grid voltage is supplying excitation to the tube, essential half sign waves of plate current are produced in the least negative half cycle of the grid voltage. The distinguishing characteristic of Class B operation is a medium efficiency of, say, around 33% and a relatively low ratio of power amplification.

The essential condition for a balanced linear amplifier stage, such as the 5kw. unit and 50 kw final power amplifier unit, is such that both tubes must be worked under identical conditions. Both tubes must receive equal excitation voltage, equal bias, and must have equal characteristics. Since there has been very little written on the linear power-amplifier circuit

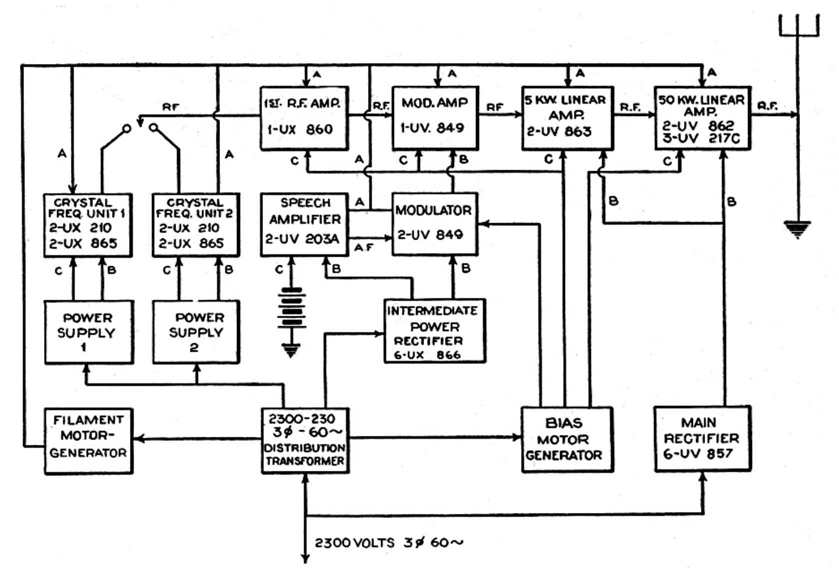


Figure 2. Block Diagram of the KFI Transmitter (in 1932)

as used in the last two stages of this transmitter, it might be well to explain briefly the operation of a Class B circuit.

The operation of a Class B push-pull amplifier can best be shown by a very simple diagram shows the dynamic characteristic of two tubes in a Class B circuit. The dynamic characteristic curve of one side is inverted in respect to the characteristic curve on the opposite side. It can be seen from this diagram that it is necessary to have the straight portions of the curve exactly in line, otherwise a distorted output wave will result. When the adjustment is properly made, the plate current for each tube forms a continuous wave of current which excites the plate tank circuit. When the tube is biased exactly to cut-off, each tube utilizes only one-half the grid voltage wave.

It can be noted that the output increases as the excitation is increased and that there will be required a tube capacity of four times the normal carrier in order to provide available power when the excitation swings the output up and down the dynamic characteristic curve. The two UV-862 tubes provide more than the 200 kw capacity on peaks. The limit of the curve that can be used is the point where the curve begins to bend over. If the tube is swung above this output, harmonics will be introduced into the output. The tubes, however, are of great enough capacity to readily supply 50 kw of power modulated 100%, which means that on modulation peaks of 100% there is an instantaneous power produced of 200 kw.

The single panel following the final power amplifier stage is the main power control panel. This panel contains controls for the entire transmitter, including the 2300-volt primary circuit-breakers and special controls for the power circuits of the 5 kw and 50 kw amplifiers and power rectifier, indicating and graphic metering equipment, filament and plate voltage regulator, and protective devices.

The various devices used for safety of operating personnel and protection of the apparatus include the following:

Water flow relays that prevent injury due to water failure.

Water temperature indicating thermometers.

Filament no-voltage protection on both dc and ac tube filaments.

Bias no-voltage relays.

Timed filament voltage build-up.

Step starting for the power rectifier.

Overload release on circuit breakers for both branches of power circuit.

Power rectifier surge overload relay with automatic reset. Power rectifier sustained overload trip.

Intermediate rectifier overload trip.

Sequence interlocks that protect each successive operation in either starting or stopping.

Thermal overload relays in each motor starter circuit.

Fuses in all branch circuits.

Disconnect switches in high-voltage circuits.

Filament burn-out relay on the 5-kilowatt amplifier that removes plate power when circuit unbalance is caused by tube failure; and removes filament voltage where both tubes take their filament current through a resistance.

Switches on all doors that remove bias and plate voltages, thus protecting the personnel from accidental contact with high voltages.

Timed water flow after removal of power tubes to assure complete cooling.

Automatic drain of cooling- water to prevent freezing in cold weather.

Visual indicators as a guide to all important circuit conditions.

The panel to the extreme right shows the rectifier unit which contains the tubes and filter condensers, filament transformers etc The high power rectifier which is used to supply the final stage and the 5 kw exciter stage, Utilizes 6 UV-857 tubes in a three-phase, full-wave circuit. The output from this rectifier is amply filtered by means of inductive reactors and banks of high-voltage condensers. The reactor is placed on the negative side of the high-voltage delivery circuit.

The transmitter can be thrown on and off by means of a single switch. This switch is provided in duplicate with one control located on the operator's desk.

The final stage contains a rectifier circuit utilizing a UV-217C for rectifying the r.f. and providing a source of power for the monitoring, speaker and the oscillograph. The oscillograph enables accurate check on percentage modulation, distortion and improper adjustments. The frequency characteristic of the KFI transmitter is substantially flat from 30 to 10,000 cycles. This insures high-quality transmission.

The primary power source for the KFI transmitter is a 2300-volt, 3-phase, 50-cycle supply. This supply is converted -by means of a frequency converter to 60 cycles. By using a converter the installation of a standard 60-cycle transmitter unit was made possible. It is interesting to note that this is the only 50 kw installation in the United States operating from a 5O-cycle power source.

When in regular operation there is approximately 100 kilowatts of power from the tubes which must be dissipated. This power is dissipated by means of a water circulating system. Since there is a very high voltage on plates of the tubes, it- is necessary to use distilled water so that the mineral content and conductivity will be low. A long column of water flowing through a rubber hose on a reel is used to insulate the high voltage from the metal pipes. The cooling system consists, essentially, of the following: A water storage tank, centrifugal water pump, radiator and blower. The water storage tank is provided, since the system is a closed one. The pump, of course, circulates the water and has a capacity of approximately 55 gallons per minute against an 80-foot bead. A by-pass system is provided around the pump with the control valve for pressure control. The pump forces the water through the radiator, where the water is diffused through a bank of radiating fins. The radiator is equipped with a centrifugal blower driven by a totally enclosed 7-1/2-horsepower motor. The radiating system, as a whole, is designed to dissipate a much greater amount of power than is ordinarily required of it.

All power equipment, exclusive of that mentioned, is located on the basement floor. This consists of high-voltage transformers, filament motor generators, bias and motor generators, reactors and condensers and voltage regulator for the high-voltage plate supply.

The voltage rectifier is so designed that when voltage is thrown on the tubes it is only at 10,000 volts. The regulator automatically runs the voltage up to the normal voltage of 18,000 volts in a very short time. This gives added protection to the tubes. When the transmitter is thrown off, the voltage regulator drops immediately to 10,000 and the transmitter is ready to go into operation at low-value plate voltage. The regulator, of course, can be operated separately and by a raise-lower button.

The rectifier is of three-phase, full-wave system, employing a recently developed low-loss mercury vapor rectifier tube. The resistance of these tubes is so low that the IR drop is only 14 volts. The I^2R loss is consequently very low; so low, in fact, that water cooling is not used. This tube makes possible a great power saving over the older type of water-cooled power rectifiers. This UV-857 tube is rated, as will, be noted in the description of tubes used in the transmitter., at 18,000 volts and 20 amperes.

The output of the 50 kw amplifier is coupled to the antenna unit by a two-wire transmission line. This enables the antenna to be placed at a distance from the transmitter. The transmission line, properly terminated, has an efficiency of very nearly 100%; the only loss is that of the I^2R loss in the conductors, which is negligible. The antenna-coupling and tuning apparatus is housed in a separate building located directly under the antenna. The transmission line is terminated in an impedance equal to its own surge impedance. This condition being strictly met, all the power delivered to the transmission line is transmitted to the antenna. If the transmission line should not be properly balanced and terminated. the energy which would not be transmitted to the antenna, would surge back and forth from end to end (commonly called reflections) until it was dissipated in the line itself.

Editor's note: The Radio News article also had a number of graphs and charts detailing various features of the new equipment. Interestingly, one of these showed the audio frequency response to be almost flat from 30 to 10,000 cycles. True HiFi, even today.

Tubes Used in the KFJ Transmitter

4	UX-210	2	UV-863
4	UX-865	2	UV-862
1	UX860	6	UV-857
3	UV-849	3	UV-217-C
2	UV-203-A	10	UX-866

	4	UX-210	2 UV-863		
	4	‘UX-865	*2* UV-862		
	1	UX-860	6 UV-857		
	3	UV-849	3 UV-217-C		
	2	UV-203-A	10 UX-866		
		Ratings as Used in	*in 50-B Transmitter*		
Type	*Plate Current*	*Plate Voltage*	*Bias Voltage*	*Filament Voltage*	*Filament Current*
210	30ma.	350	minus 50V.	7.5	*1.25* a.
865	60 ma	500	75 (Cl. C)	7.5	*2*
860	.1 a.	2,000	“ 150	10	3.25
849	.1 a.	3,000	“ 132	11	5
203-A	50 ma.	1,000	“ 20 (audio)	10	3.25
863	.5 a.	12,000	340	*22*	52
~62	4.2 a.	17,500	380	33	207
217-C	.15 a. with 3000 .v. RMS applied			10	3.25
866				2.5	5

Peak plate current = 0.6-A

On 3-phase, full-wave connection, the inverse voltage is equal to 1.045 times the average d.c. output.

In the single-phase, full-wave rectifier using two tubes, the inverse peak voltage equals 3.14 times the average d.c. plate voltage.

Fil. voltage, — 5. Fil. current, — 60 a. — maximum peak inverse 20 KV.

Maximum peak plate current 20 amps.

The remarks given in regard to the 3-phase, full-wave 866 rectifier apply here with equal force