FM

by Federal

Technical Data

1KW and 3KW

FM Broadcasting Transmitters

Federal Telephone and Radio Corporation

Clifton, New Jersey

AN IT&T ASSOCIATE

TECHNICAL DATA

Federal's

1 KW and 3 KW

F M

BROADCAST TRANSMITTERS

The new Federal 1 KW FM Broadcast Transmitter which combines outstanding fidelity and mean carrier stability characteristics with simple circuits, economy and reliable performance.

Complete
FM Broadcasting Systems
by Federal

To conform with the high standards established for FM as a means for high-quality noise-free radio broadcasting, FEDERAL has designed a complete system from microphone to the antenna.

Combining the new Federal "FREQUEMATIC"* FM Modulator and center frequency control unit with advanced Federal power tubes, results in an FM radio Broadcast transmitter of superb quality and excellent stability.

New microphones and speech input equipment together with all required studio accessories, are made available as a complete Federal FM Broadcast System.

Multiple array, high-gain antennas, and low-loss transmission line, are a part of the Federal FM system.

Guyed and self-supporting steel antenna towers, as well as VHF studio to transmitter emergency radio links, are a part of the overall customer service.

WHEN YOU BUY AN FM BROADCAST STATION

You are buying more than a transmitter along with various associated items of equipment.

You are buying the right to disseminate programs over a given area — to have folks in that area look to you — in fact, depend upon you — for regular day in and day out uninterrupted service.

You have the right, therefore, to ask these questions:

Will my station represent the very latest in engineering technique?

Will it meet good engineering practice—plus high quality of materials and workmanship to insure more than minimum requirements of reliability?

Will the transmitter, speech input equipment, antenna and all other associated items be designed to work together as a single co-ordinated system?

Will the system be delivered to my doorstep and promptly forgotten, or will the manufacturer see me through until it is completely installed and I am on the air?

In short, is the manufacturer well known. Has he been tried and proved in the broadcast field. Above all, is he jealous of his reputation, will he back up his equipment—and me—if called upon to do so, far beyond normal expectations.

Federal answers YES to all of these questions.

*TRADEMARK

Features of
Federal's FM Broadcast Transmitters

1. A newly developed Federal "FREQUEMATIC" FM Modulator attains improved high-quality and noise-free transmission.

2. All-electronic, simple circuits maintain the center frequency stable to within 1000 cycles of its assigned frequency as compared with the present FCC requirement of ± 2000 cycles.

3. Linear modulation of all audio signals between 50 and 15,000 cycles is maintained even when the transmitter is overmodulated by as much as 200%.

4. Modulator emergency operation with center frequency control system inoperative.

5. Power stages are push pull throughout, with non-critical tuning.

6. Non-glare meters using fluorescent scales illuminated with ultraviolet light, greatly improve scale visibility.

Federal Telephone and Radio Corporation
"Frequematic" Frequency Modulation
Radio Broadcast Equipment
1000 Watts – 3000 Watts
Frequency Range 88 to 108 Megacycles

In developing a vastly improved type of modulator-oscillator unit—the "FREQUEMATIC" for application to its complete line of FM Broadcast Transmitters, the Federal Telephone and Radio Corporation makes available to the broadcast industry equipment that combines outstanding fidelity and mean carrier stability characteristics, with economy and highly dependable performance.

Culminating a full year of intensive research, the new Federal "FREQUEMATIC" FM Modulator far exceeds the exacting requirements of the FCC Standards of Good Engineering Practices on every technical point. Distortion and noise have been reduced to the minimum, and the mean carrier frequency is stable to within 0.001% of its assigned value.

This development carries with it the assurance that every voice, or tone or sound produced on a program will be faithfully reproduced and transmitted noise-free with all natural, fine quality. Even transient passages which overmodulate the transmitter by as much as 200% do not materially increase the low distortion and noise levels inherent with Federal's "FREQUEMATIC" FM Modulator.

This unit also solves one of the major problems in FM broadcast transmitters—stability of the mean carrier frequency—which Federal accomplishes through an all-electronic center frequency control system. As a result of the precision crystal control used, Federal FM Transmitters will maintain the mean carrier frequency of the broadcasting station to within 1000 cycles of its assigned channel compared with the 2000 cycles allowed by the FCC.

Further, this high-degree performance has not been obtained with intricate, specially componented, difficult-to-operate equipment. On the contrary, simple circuits and standard receiver tubes are utilized throughout, and the equipment depends mainly upon resistances and capacitances for critical and non-critical functions.

Another of its outstanding features—one that should be of special interest to all broadcasters—is the extreme ease of initial alignment and operational maintenance.

The unit can be completely tuned in a matter of minutes due to the fact that only two tuning operations are necessary. There are no tuned circuits in either the crystal oscillator or frequency divider networks. All tubes and components are readily accessible so that they can be easily checked or replaced.

Test measurements taken of Federal's "FREQUEMATIC" Modulator for FM Transmitters reveal the following outstanding characteristics: The audio distortion is not more than 0.5% for all frequencies between 50 and 15,000 cycles, while the noise level is —75 decibles below full carrier modulation or a signal to noise ratio of 562,000.

The full significance of these values is indicated by the fact that Federal, of necessity, had to design and build special test equipment in order to measure the low order of noise, distortion, and frequency shift, since no available commercial equipment could measure such small gradients.

Technical Description of Federal's "FREQUEMATIC" FM Modulator

I. INTRODUCTION:

The solution of one of the major problems in FM transmitters—stability of the mean frequency—as well as an improved method of direct frequency modulation has been accomplished by Federal Telephone and Radio Corporation, associate of International Telephone and Telegraph Corporation. Utilizing an all electronic system permitting performance well within limits established by the FCC Standards of Good Engineering Practice, this unit (Fig. 1 & 2) features simplicity and economy, for it employs standard receiver tubes and contains only three tuned circuits.

The mean carrier frequency is precisely controlled by means of a crystal via a method of frequency division. The frequency division is accomplished through multivibrator circuits which depend mainly on resistance and capacitance components for critical and non-critical functions thus enabling the equipment to have outstandingly stable and rugged mechanical as well as electrical characteristics. In addition it assures extreme ease of initial alignment and a minimum of operational maintenance.

II. THE FEDERAL MODULATOR:

The Federal modulator unit is of extremely simple design using only three tubes, a 12J5 oscillator, a 6AB7 modulator and a 6AB7 buffer. Modulation is effected by

FEDERAL CFS—MODULATOR UNIT

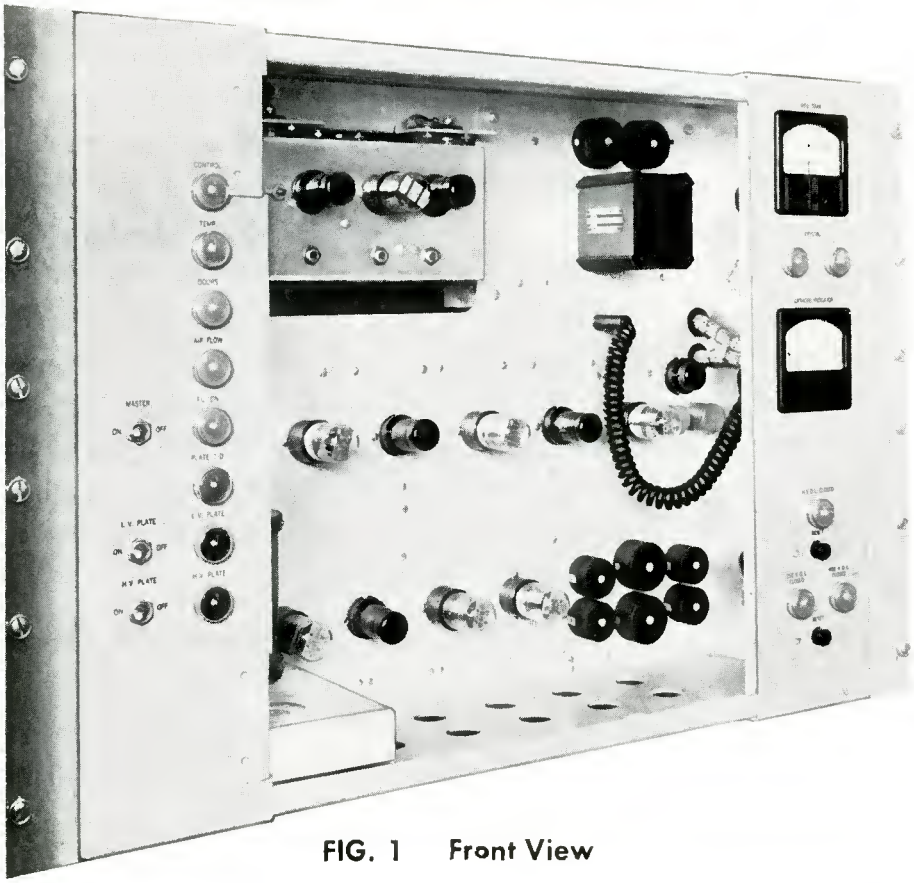


FIG. 1 Front View

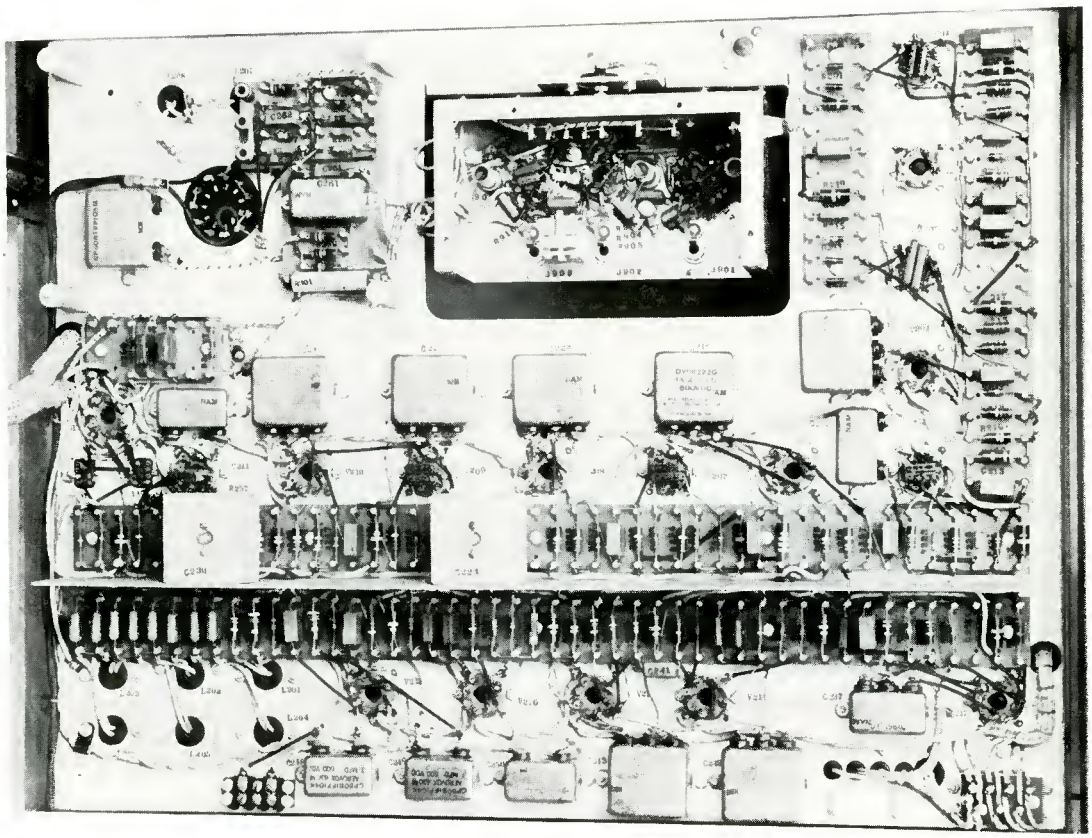


FIG. 2 Rear View

reflection of the effective capacitive variation of the modulator tube grid circuit across the master oscillator tank. This capacitive change is proportional to the total voltage on the 6AB7 modulator tube grid which is the sum of the program audio frequency input and the center frequency stabilization (CFS) phase detector output voltages. Thus the modulator not only converts the audio voltage into the desired frequency variations but acts in conjunction with the CFS system to accurately maintain the mean carrier frequency in exact coincidence with that of the temperature controlled precision crystal.

The linear relationship between the input capacitance and the transconductance of a vacuum tube amplifier is made use of in the Federal Modulator to swing the frequency of a Hartley oscillator. Operating the modulator in its region of linear transconductance and applying a modulating signal to its control grid, we obtain an input capacitance, applied to the oscillator, directly proportional to the amplitude of the modulating signal. (Fig. 3)

To a first approximation, and for a qualitative discussion of the mechanism of the action of the modulator, it can be shown that the input capacitance of the vacuum tube is given by:

$$C_{in} = C_{gp}\left(1 + g_m R_L\right)$$

where R_L is the load impedance at resonance. Since the frequency of oscillator is approximately $\omega_o = \frac{1}{\sqrt{LC}}$, we have the differential of frequency, for an increment of capacitance ΔC:

$$d\omega = \left(\frac{d\omega}{dc}\right)\Delta C = \frac{-1}{2\sqrt{L}\,C^{3/2}}\,\Delta C = -\frac{\omega_o}{2C}\,\Delta C$$

This shows that the frequency swing is directly proportional to the change in injected capacitance and inversely proportional to the fixed tank capacitance C. To obtain a fixed frequency swing for a given change in input capacitance, as the oscillator capacitance is changed to cover the frequency band, an adjustable capacitance C_C is used to couple the modulator to the oscillator. To reduce the R.F. signal on the modulator grid, the capacitance is injected across only a portion of the tank inductance.

III. THE FEDERAL CENTER FREQUENCY STABILIZATION SYSTEM:

The Federal Center Frequency Stabilization System (Fig. 4) is based upon the automatic synchronization of two oscillators—a crystal oscillator and a master frequency-modulated oscillator—to obtain mean center frequency control. The frequencies of the crystal oscillator and the master oscillator are each divided to a common frequency and are then combined in a balanced phase detector. The integrated rectified output is used to actuate the Federal modulator so as to pull-in and lock the master oscillator mean frequency to that of the crystal oscillator.

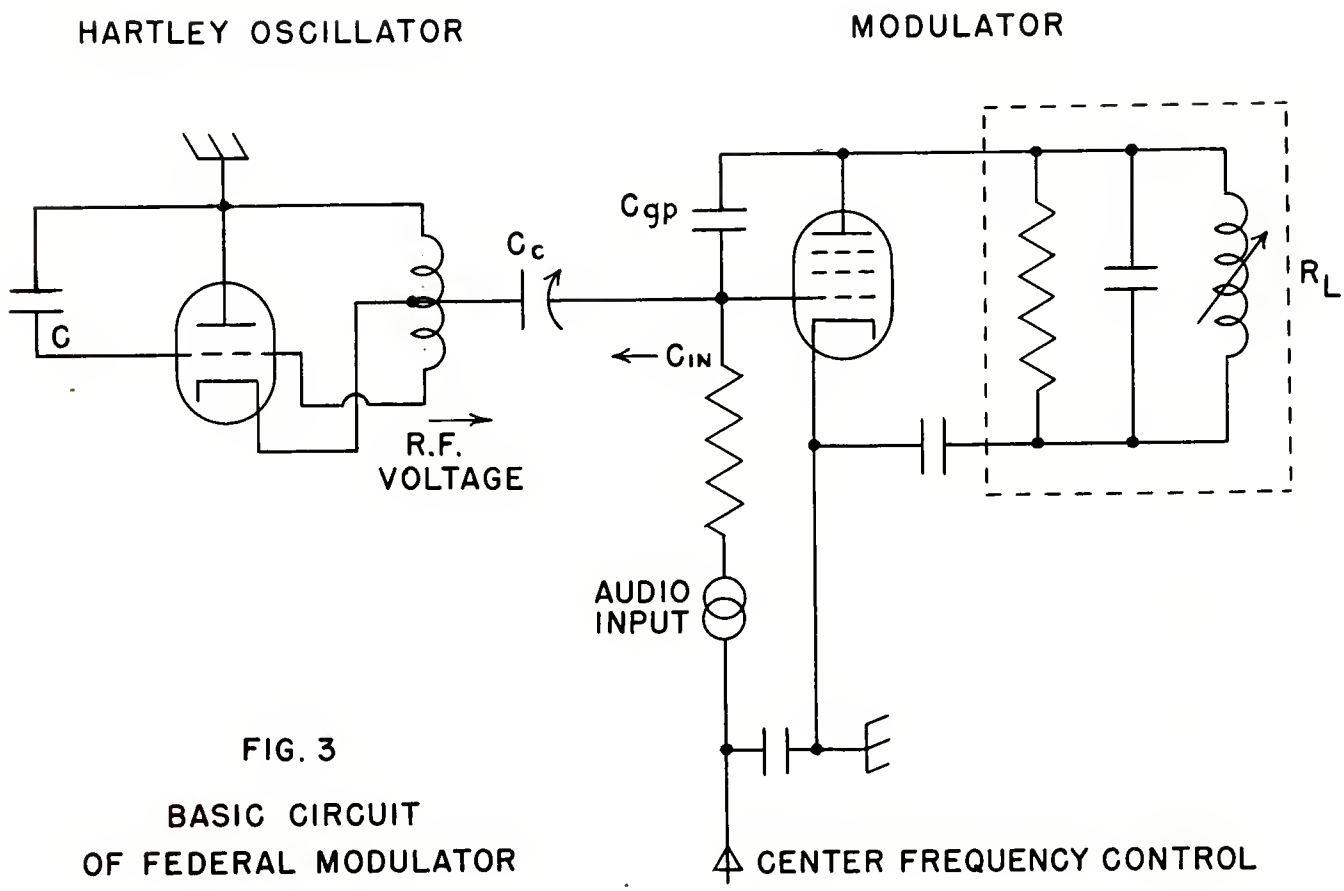


FIG. 3

BASIC CIRCUIT
OF FEDERAL MODULATOR

To effect the frequency division the frequency modulated master oscillator is fed through a total of six multi-vibrator frequency divider circuits to reduce the original 3.7 to 4.5 Mc. carrier frequency 256 times to 14.3 - 17.6 Kc. In a similar manner the crystal frequency of 114.5 Kc - 140.7 Kc is divided by a factor of 8 in two multi-vibrator circuits to the common 14.3 - 17.6 Kc value. All multivibrators are of the well known Abraham-Bloch type, which accurately divides the applied frequency by means of extremely simple and reliable circuits. As additional insurance that precision control of the frequency is effected, a special Federal Telecommunication Laboratory power supply is used which delivers a stable regulated voltage with only a slight ripple.

The carrier is controlled by a crystal mounted in a Bliley type TC-93 oven holder. The frequency of this crystal is 1/768 of that of the carrier.

SPECIAL FEATURES

A. *Operational Features:*

1) Precision lock-in of carrier to crystal frequency by frequency division and phase comparison.
2) High performance with simple single-ended modulator circuits:
   AF Distortion 0.5%
   FM Noise ..... 75 db. below 100% modulation
   AM Noise ..... 60 db. below carrier level
3) All-electronic action.
4) Correct modulator emergency operation with center frequency control system inoperative.
5) Wide-range frequency hold-in (2000 cycles at 4 Mc.)

B. *Circuit Features:*

1) No tuned circuits in crystal oscillator.
2) Minimum number tuned circuits (only three).
3) Untuned-type frequency dividers.
4) DC operation of filaments.
5) Single crystal used with spare crystal provision.
6) Maximum accessibility to tubes and all circuit components for check or replacement.
7) Standard tubes throughout.

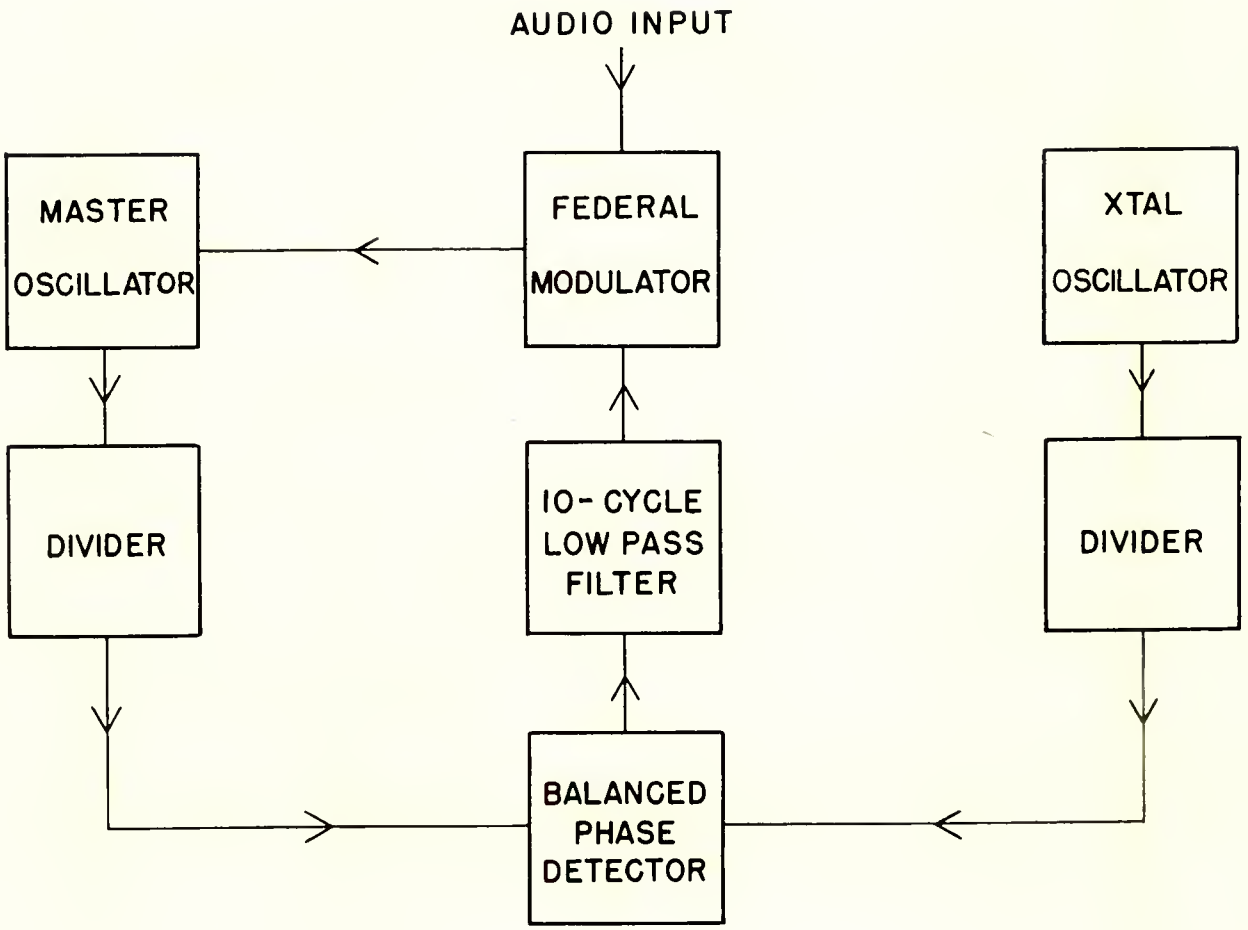
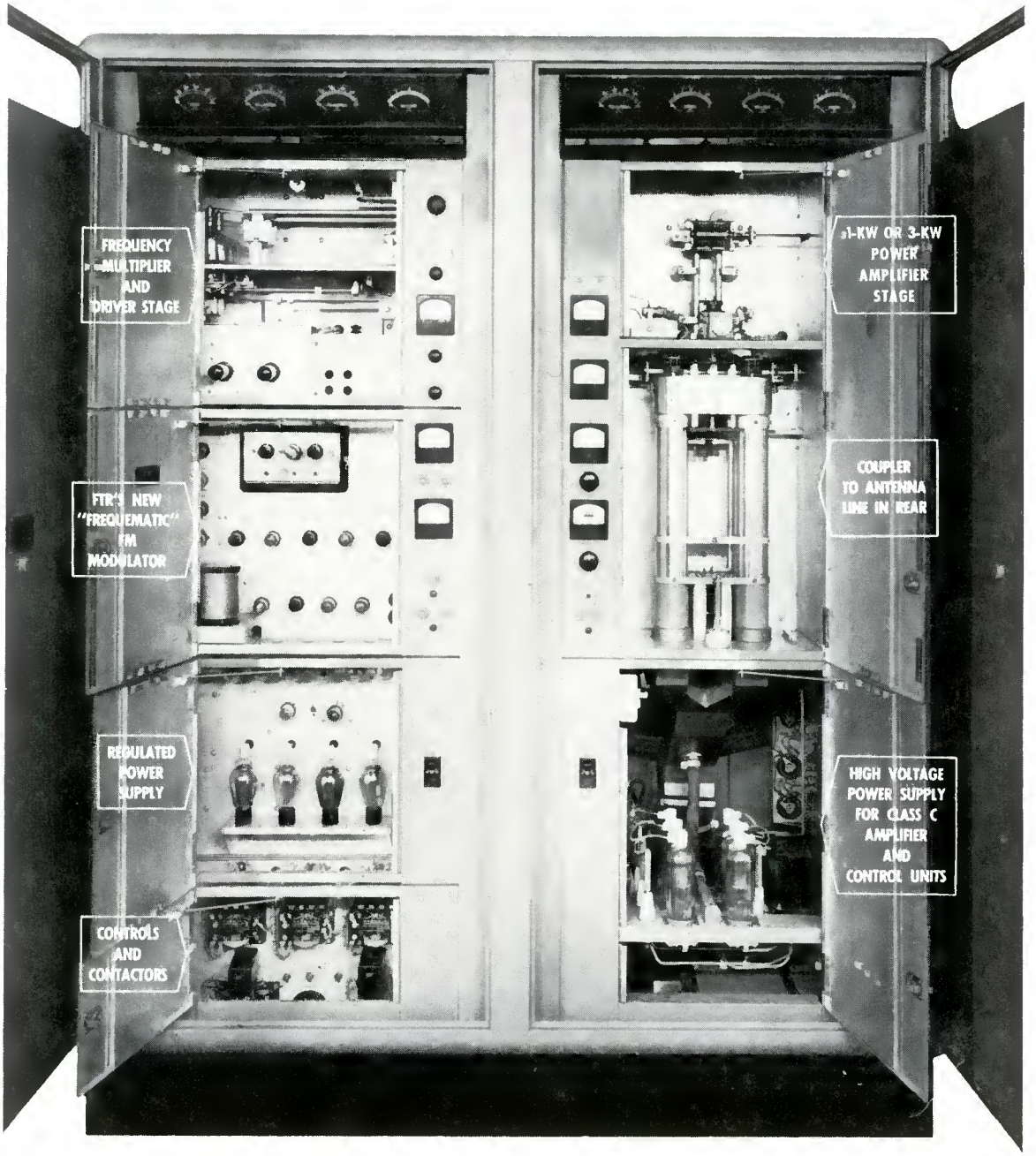


FIG. 4

BASIC BLOCK DIAGRAM
OF FEDERAL C.F.S. MODULATOR SYSTEM

Federal

1 KW — 3 KW
FM BROADCAST TRANSMITTER



Description of Federal's FM Transmitters

CIRCUIT ARRANGEMENT

The standards which have been set up for FM broadcasting systems are extremely rigid. Therefore, in the design of transmitter circuits the utmost care must be exercised to provide extremely low distortion and residual noise level. The phase shifting capabilities of the conventional phase shift modulator are so limited that it is necessary to accomplish modulation at a very low initial frequency. This limitation presents a very severe problem since random phase shifts caused by power supply hum and microphonics will be multiplied many times and infinite care must therefore be taken to prevent objectionable final phase shift modulation, known as residual FM noise level.

In Federal's "FREQUEMATIC" FM Modulator frequency modulation, rather than phase modulation is employed, and a much higher initial frequency of approximately 4 megacycles is used, thereby eliminating to a large extent the difficulty encountered by excessive multiplication of minor modulations produced by power supply ripple or microphonics. The modulating capabilities of the FTR frequency modulator are such that a frequency excursion many times that set up by the FCC as representing 100% modulation can be obtained with very low distortion.

Four pentode stages, three of them being doublers, one a tripler, all extremely simple in design, follow the modulated oscillator in the equipments.

Two push-pull pentode stages, at the final output frequency, increase the power to approximately 250 watts, followed by a pair of push-pull triodes to either 1000 watts or 3000 watts.

PLATE VOLTAGE

The 1 KW power amplifier is identical to the 3 KW power amplifier, excepting that the former uses a plate voltage of 2000 volts, while the latter uses 3000 volts.

In line with R.M.A. recommendations, the primary power of the 1 KW transmitter is obtained from a single-phase, 230-volt power source, while the 3KW unit operating at higher power, requires a 3-phase, 230-volt source.

POWER TUBES

New power tubes developed by Federal are employed in the power amplifier stages of all FM transmitters. These air-cooled, high efficiency vacuum tubes assure long life, stable operation at 100 megacycles and low noise level. Typical of the improved

type power tube developed by Federal is the FTR 7C26 triode, the characteristics of which are:

Data on 7C26

Filament Type	Thoriated Tungsten
Filament Voltage	9.0 volts
Filament Current	28.5 amperes
Available Peak Emission	8.5 amperes
Amplification Factor	17
Mutual Conductance	20,000 umhos
Type of Cooling	Forced-Air 75 CFM
Maximum Overall Dimension	
Length	4 1/4 inches
Diameter	2 1/2 inches
Approximate Direct Inter-Electrode Capacitances	
Plate to Grid	12 uuf
Grid to Filament	12 uuf
Plate to Filament	1.0 uuf

Maximum Ratings and Typical Operation for Maximum Frequency of 150 Megacycles

Class C Power Amplifier and Oscillator

Key-down conditions without amplitude modulation

Maximum Ratings

DC Plate Voltage	3000 volts
DC Plate Current	1.0 ampere
Plate Input	3000 watts
Plate Dissipation	1000 watts
DC Grid Current	0.1 ampere
DC Grid Voltage	–800 volts

Typical Operation

DC Plate Voltage	3000 volts
DC Plate Current	1.0 ampere
Power Output	2350 watts
Plate Efficiency	79%

Class C High Level Amplitude Modulated Amplifier

For use with a Maximum Modulation Factor of 1.0

Maximum Ratings

DC Plate Voltage	2500 volts
DC Plate Current	.815 ampere

Plate Input	2000 watts
Plate Dissipation	660 watts
DC Grid Current	0.1 ampere
DC Grid Voltage	−800 volts

Typical Operation

DC Plate Voltage	2500 volts
DC Plate Current	0.815 ampere
Power Output	1580 watts
Plate Efficiency	78%

Two of these tubes are being used in the Federal 1KW and 3KW FM transmitters in grounded filament circuits.

Expansion to Higher Powers

Unit construction is employed in all transmitters so designed that equipments may be increased to higher powers with a minimum of labor. The 3KW unit will drive the 10KW amplifier and this in turn will drive either the 25KW or 50KW power amplifier. Sectional units can be added at any later date to increase power.

Mechanical Arrangement and Characteristics

In the mechanical design of the FTR FM radio transmitter simplicity of control has been emphasized, together with arrangements for complete accessibility of component parts.

Electrical components are so assembled on vertically mounted aluminum chassis that they are entirely accessible from both front and rear. Appreciating the necessity for quick removal and replacement of components, these transmitters were designed with this feature in mind. It is also possible to service any one of the components without interfering with others.

The operating controls are arranged on vertical front panels, one on the right and one on the left. Switches and controls are an integral part of the main chassis, and the individual controls are mechanically adjusted at the factory.

Controls

Indicating lights are also located on the two vertical side panels, one right, and the other on the left, and are arranged in operating sequence. The controls are located

at a convenient height for operating personnel. A round knob with an easy grip feature is used to facilitate operation.

Cabinet

The FTR FM broadcast equipment is housed in a cabinet of modern design which presents a highly attractive appearance and enables convenient access to all components as well as insuring protection to the operator. The cabinet is finished in beige which very successfully blends with the remainder of the equipment. This color is optional, however, and can be altered to suit the customer's requirements.

Complete access to all the apparatus locked in the rear side of the vertical chassis is possible through the full length doors located in the rear. Complete personnel protective circuits are used in conjunction with these doors which are electrically integrated with the control circuits so that all high voltage is cut off when the door is open. Included in this protective system is a switch which automatically shorts out the rectifier bus when the door is opened.

Two full-length front doors cover the operating front of the transmitter proper. These doors are opened by a centrally located knob which operates a 3-point catch. Upon opening the front doors, the operating front of the transmitter is exposed. Accessibility into the fronts of the vertical chassis is accomplished by opening small access doors which cover the various units in the transmitter. Each door giving access to high voltage is interlocked with the high-voltage power supplies to insure operating personnel safety. The cabinet is constructed entirely of aluminum for several reasons: (1) to minimize weight, (2) to minimize corrosion.

Weight

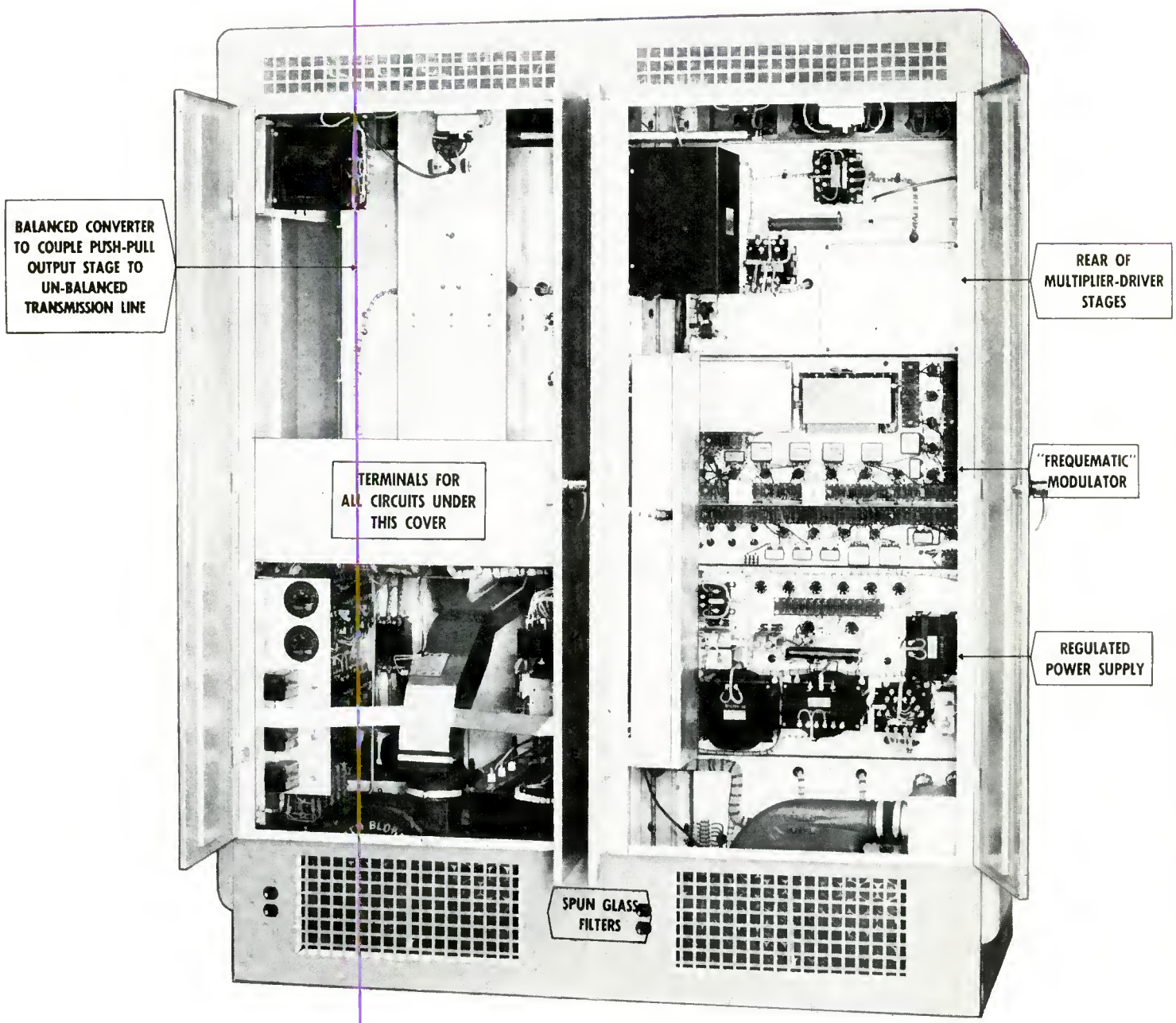
The 1 KW unit weighs approximately 1500 pounds.
The 3 KW unit weighs approximately 2000 pounds.

Dimensions

1 KW and 3 KW units: $66\frac{1}{2}$" wide, $39\frac{1}{2}$" deep, 83" high

Ventilating and Air Filtering

One blower provides forced air cooling for the 250 watt transmitter while two blowers are used for the 1 KW and 3 KW transmitters. These are mounted on rubber-cushioned mounting cradles. Filters in the rear of the transmitter prevent entrance of dust when the blowers are in operation, and the air outlet at the top of the cabinet is covered by copper screening to prevent the entry of foreign substances.



Rear View

FTR 1 KW FM Transmitter

Warning of excess temperature, such as might be caused by failure of the blower or by clogging of the air-intake filter, is given by thermostat, buzzer, and an indicating light on the front panel.

Arrangement of Component Units

The FM transmitter consists of two individual sections made integral by means of unified cabinet design. The left section, known as the "exciter unit" consists of a meter panel, intermediate power amplifier, multiplier, a modulator, a regulated power supply, and a control unit.

The right section consists of a meter panel, a power amplifier, and a power supply and control unit.

Electrical Characteristics

Frequency Range

88 to 108 Megacycles.

The carrier frequency in the band 88 to 108 megacycles should be specified.

Modulation

Linear modulation of all audio signals between 50 and 15,000 cycles is maintained even when the transmitter is overmodulated by as much as 200%. The modulator circuits are independent of the center frequency control system and will operate correctly even if the CFS unit is removed.

Speech Input Level

Program level about O vu for full modulation of ± 75 KC per second. Single frequency level of +10 dbm for same excursion.

Frequency Response

Flat for all audio signals between 50 and 15,000 cycles to within ± 1 db.

Noise Level

The FM noise present in the transmitted wave measured under normal broadcast conditions is —65 db below full carrier modulation.

Pre-emphasis of Audio Frequencies

Pre-emphasis circuits, in accordance with RMA standards, have been provided at the audio input. The use of this circuit is optional and can be cut out if so desired.

Frequency Stability

The mean frequency of the master oscillator is synchronized to that of a temperature controlled quartz crystal, thus maintaining the center frequency to within 0.001% of its assigned value.

Primary Power

250 watt exciter operates from a 220 volt, single phase, 60 cycle power source, and requires an input of 3¾ KVA for full power output.

1 KW transmitter operates from a 230-volt, single phase, 60 cycle power source, and requires an input of 5 KVA for full power output.

3 KW transmitter operates from a 230-volt, three phase, 60 cycle power source, and requires an input of 8½ KVA for full power output.

Control System

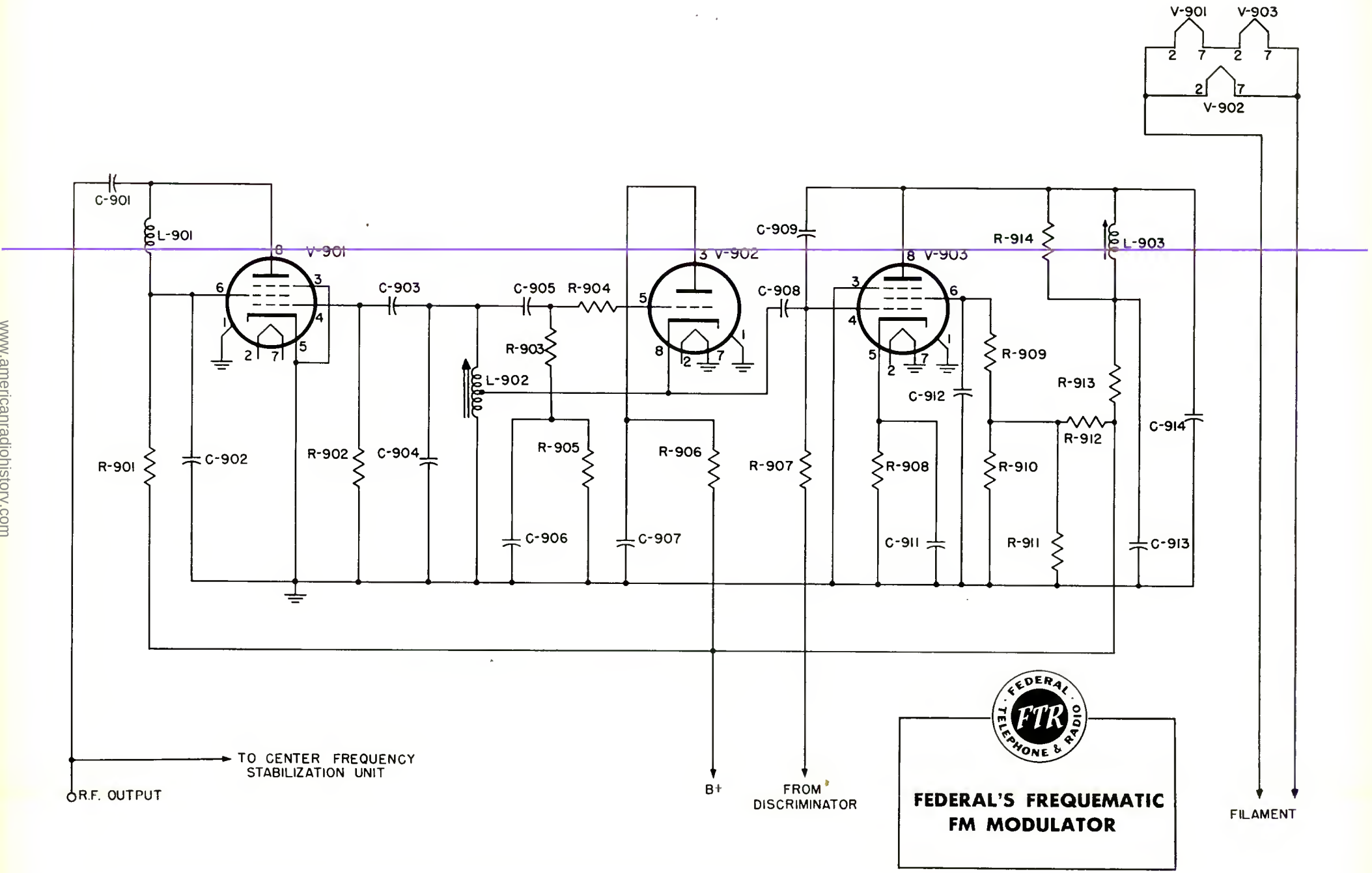
Toggle and push button switches control the application of power to the transmitter. For normal on-off control a single master switch is used with sequencing and time delay cycling entirely automatic. Individual plate and bias switches are provided for maintenance and checking purposes. Automatic time delay equipment for filament preheating is a standard feature of this unit.

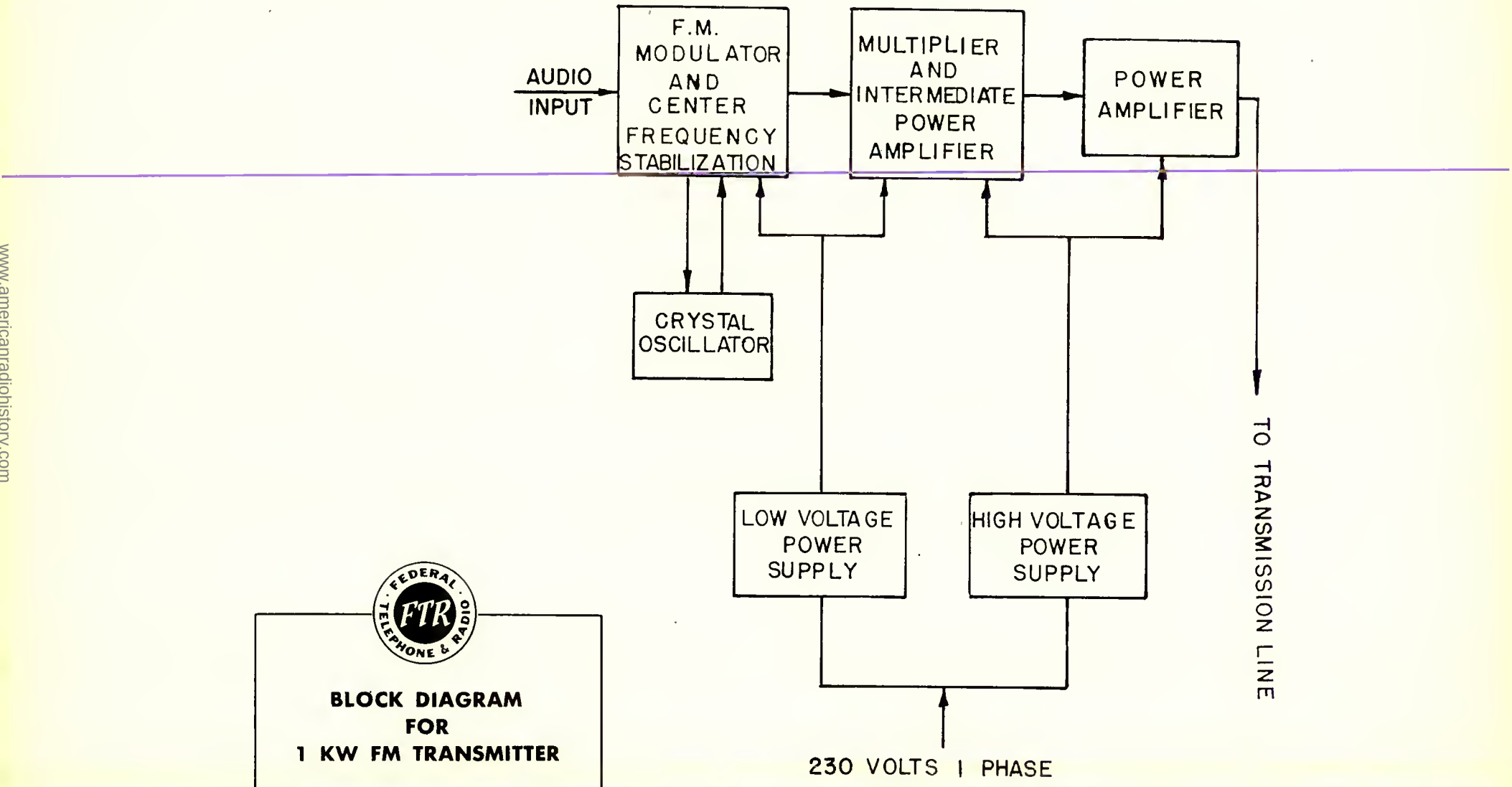
FEDERAL'S RESPONSIBILITY

Federal accepts full responsibility for its equipment. Each Federal FM broadcast transmitter meets every existing requirement of the FCC Standards of Good Engineering Practice.

Federal accepts full responsibility for supervision of the installation of its equipment.

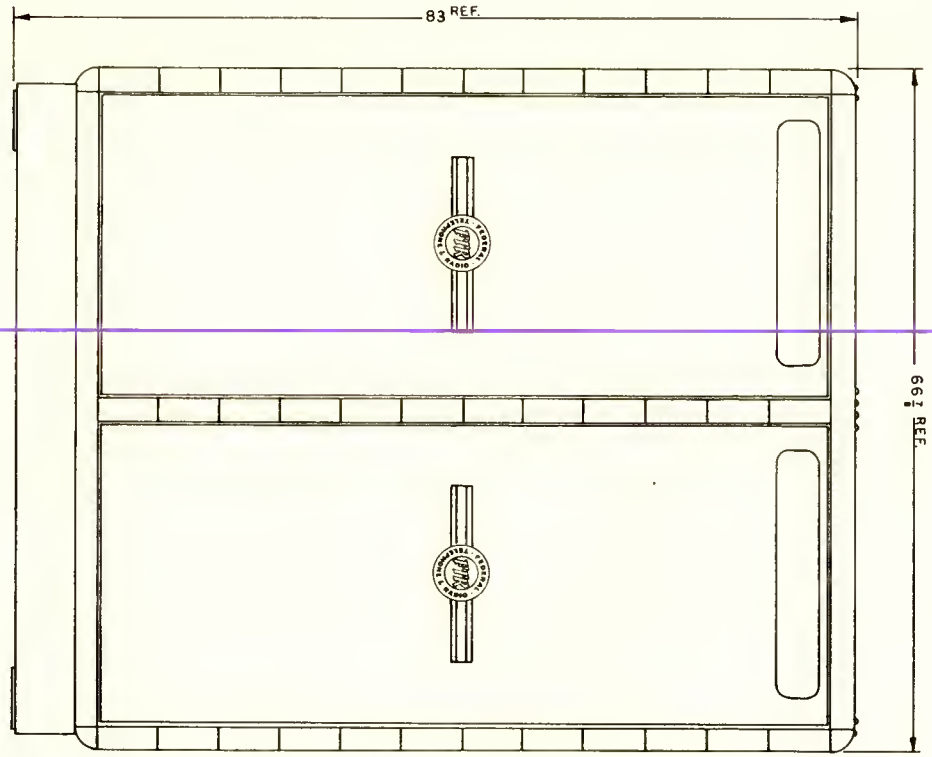
Federal, with its corps of competent, factory-trained engineers, stands ready to render every reasonable service, both prior to purchase and following installation, excepting where such is normally considered the function of recognized engineering services.

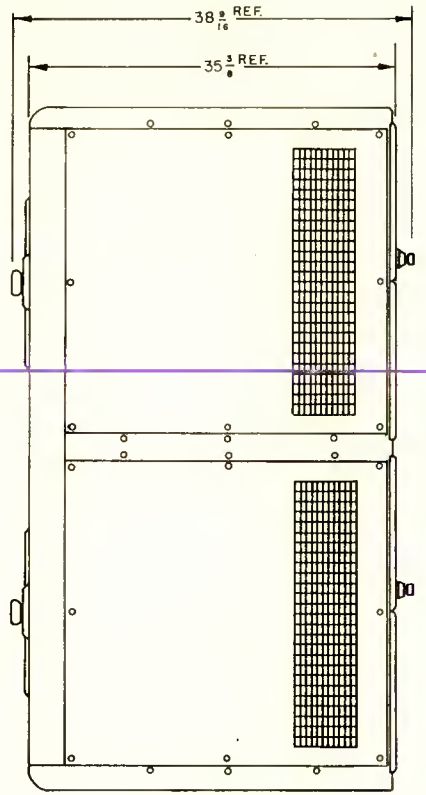


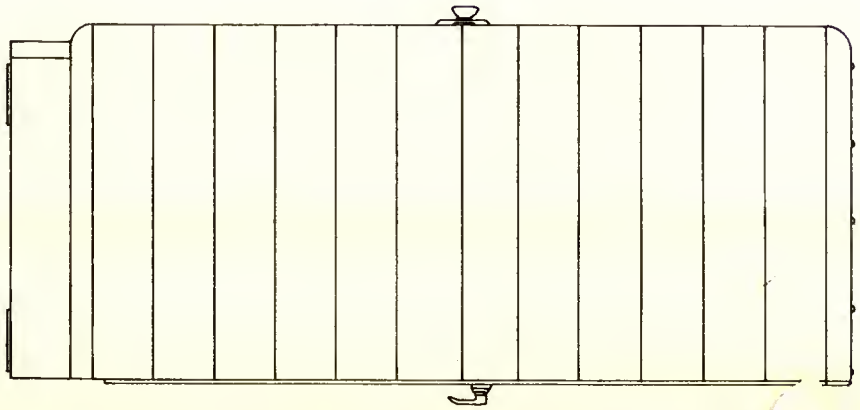


FEDERAL TELEPHONE & RADIO — FTR

BLOCK DIAGRAM FOR 1 KW FM TRANSMITTER

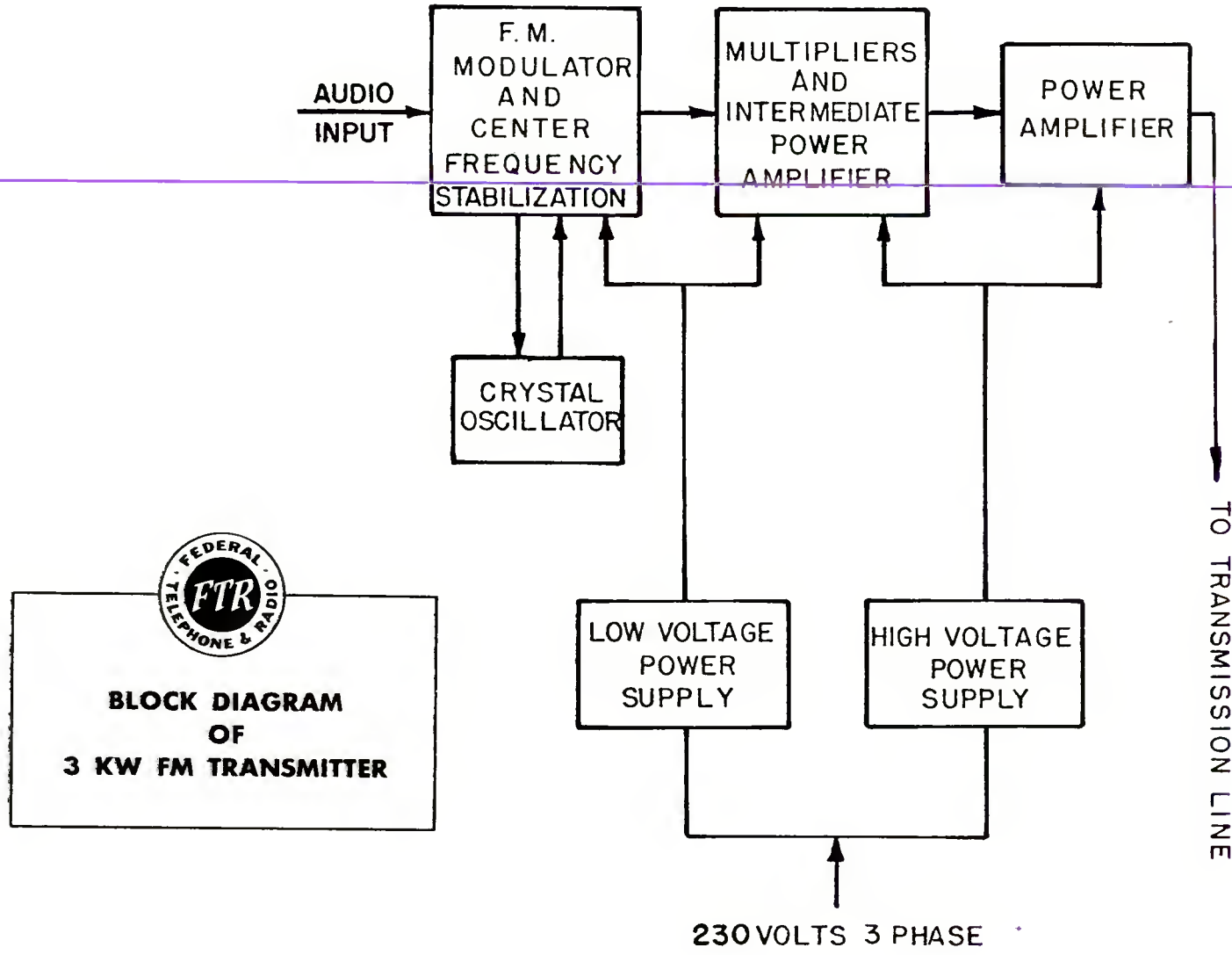






FEDERAL TELEPHONE & RADIO

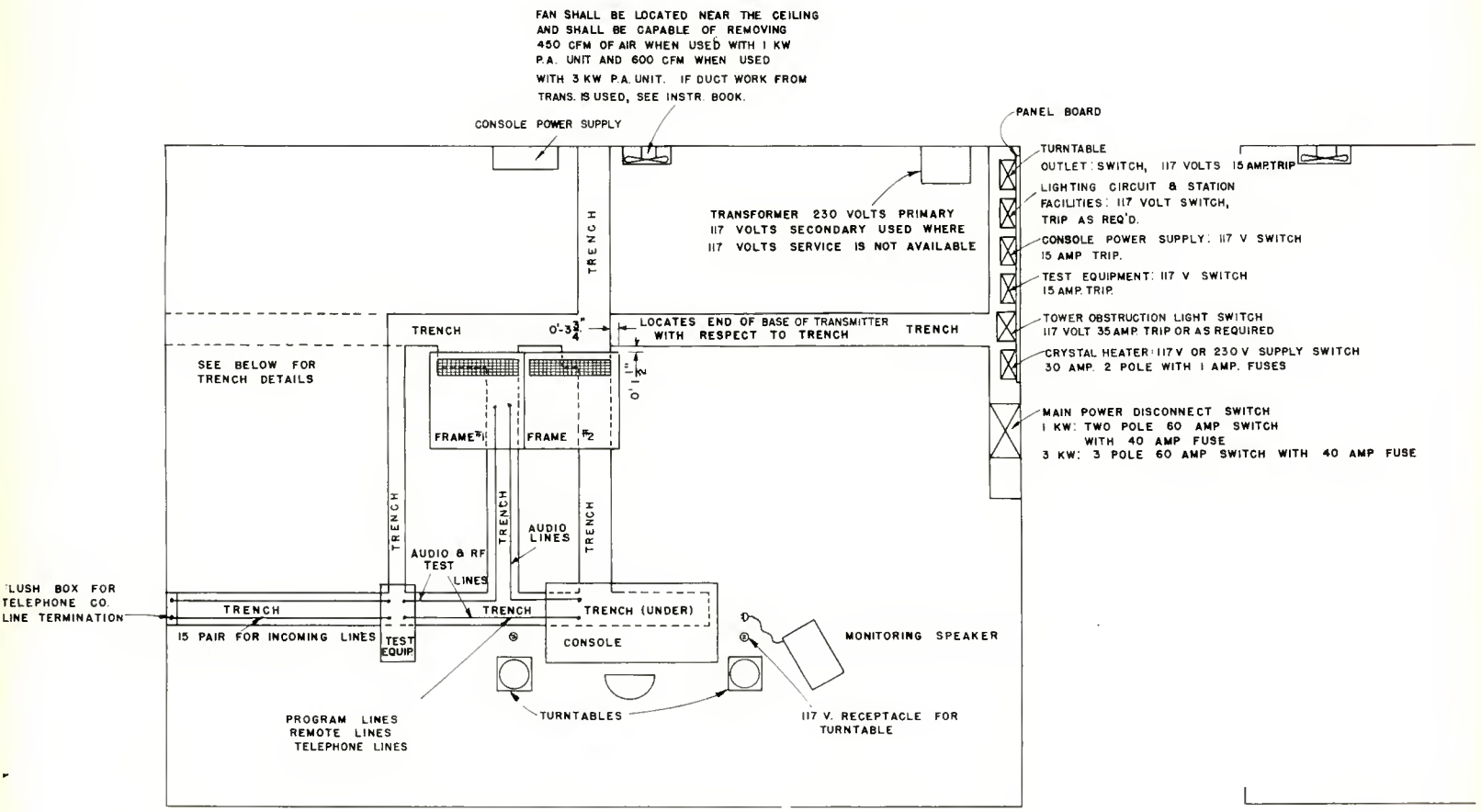
OUTLINE DRAWING FOR 1 KW AND 3 KW FM TRANSMITTER

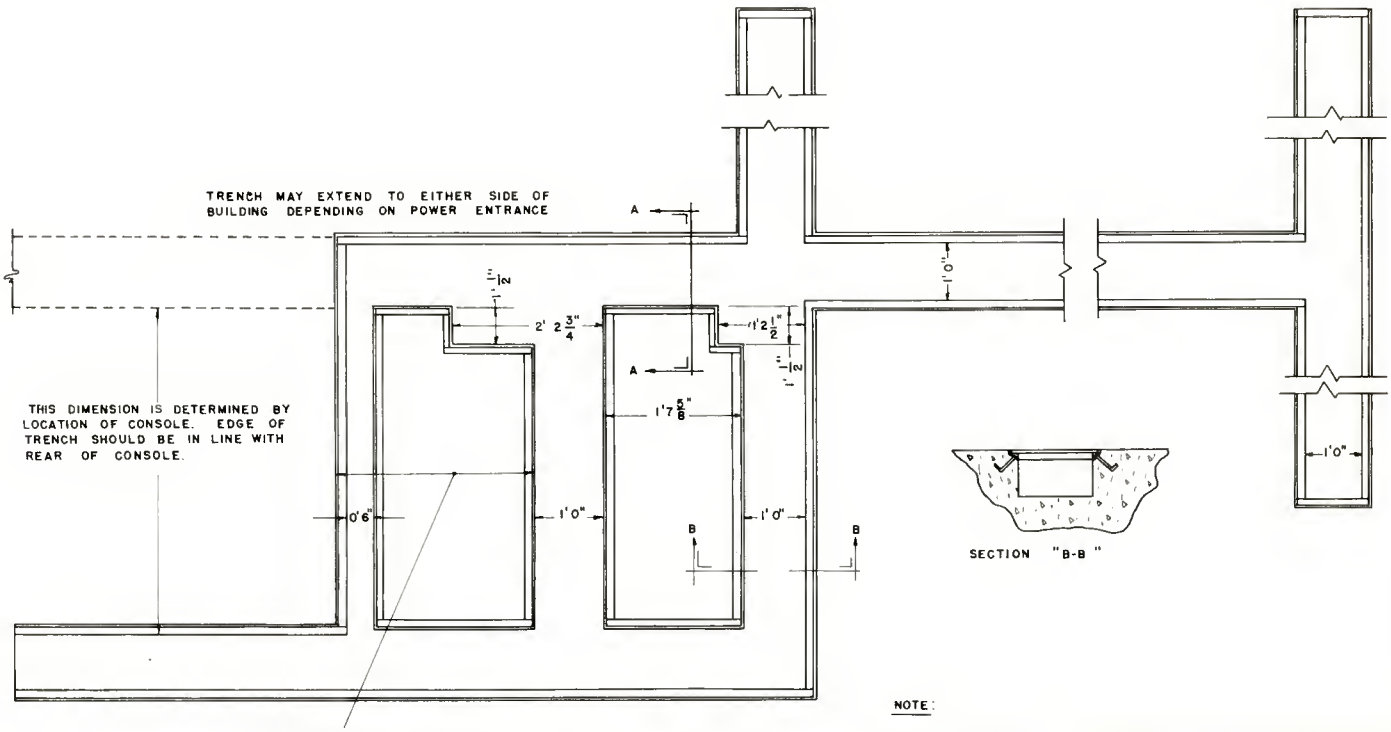


FEDERAL TELEPHONE & RADIO — FTR

BLOCK DIAGRAM
OF
3 KW FM TRANSMITTER

STATION LAYOUT
FOR
1 KW AND 3 KW FM TRANSMITTERS



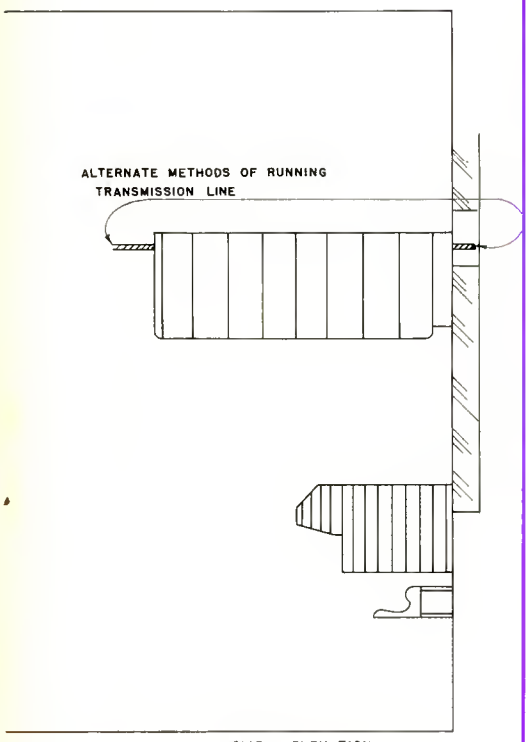


TRENCH DETAILS

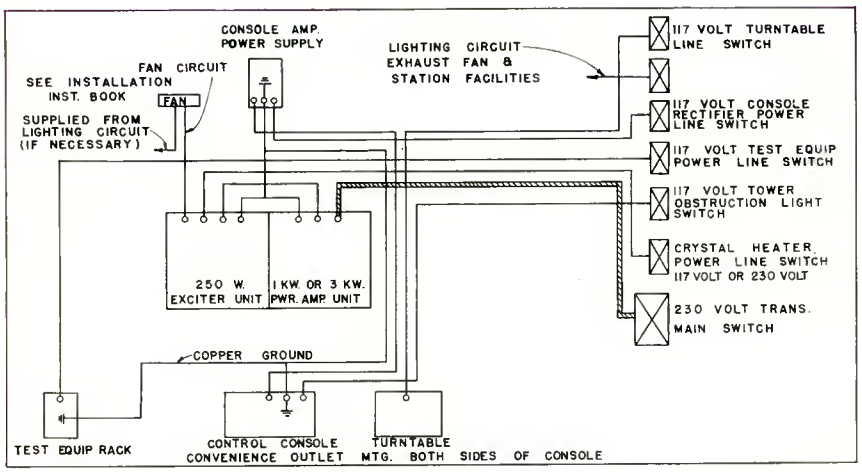
NOTE:

TRENCH CONSTRUCTION IS RECOMMENDED WHEN TRANSMITTER IS TO BE HOUSED IN A NEW BUILDING CONSTRUCTED EXPRESSLY FOR THAT PURPOSE.

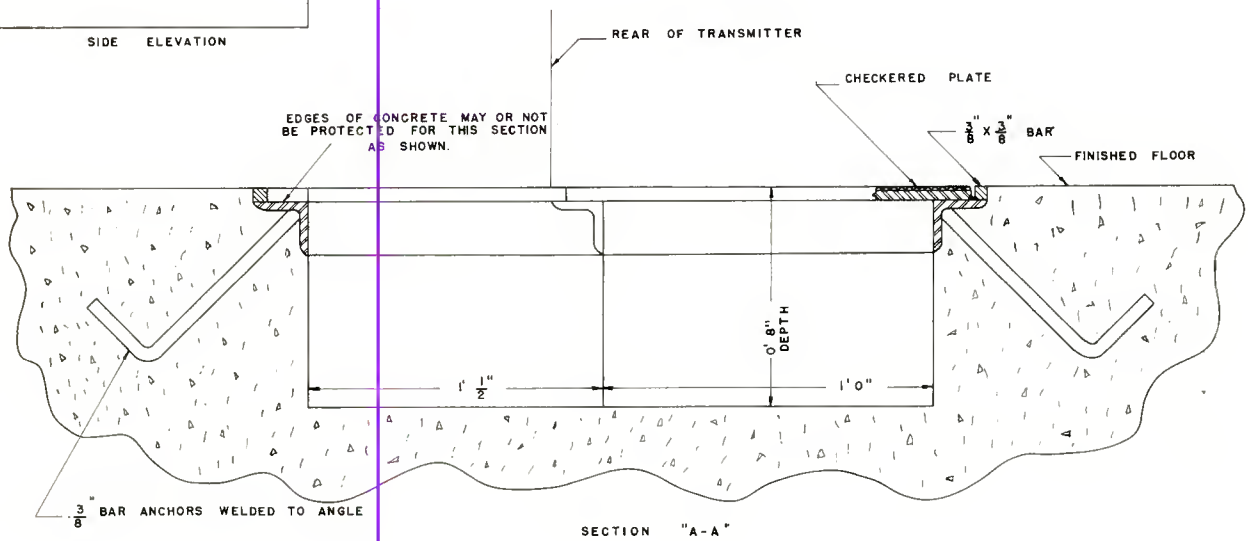
INSTALLATIONS TO BE MADE IN EXISTING BUILDINGS WILL REQUIRE THE INSTALLATION OF DUCT WORK UNDER THE FLOOR OR ON THE CEILING OF THE ROOM BELOW.



SIDE ELEVATION



PROPOSED BLOCK DIAGRAM



SECTION "A-A"

FEDERAL TELEPHONE & RADIO — FTR

STATION LAYOUT FOR 1 KW AND 3 KW FM TRANSMITTERS

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