Federal's

HIGH POWER TRANSMITTER

built for

Columbia Broadcasting System

for

COLOR OR FINE LINE TELEVISION

FEDERAL TELEPHONE & RADIO FTR

Federal Telephone and Radio Corporation

Newark 1, New Jersey

An IT&T Associate

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FEDERAL TELEPHONE AND RADIO CORPORATION IS READY TO QUOTE ON I KW, 490 MEGACYCLE COLOR TELEVISION EQUIPMENT — COMPLETE FROM MOVIE FILM DISSECTOR, TELEVISION TRANSMITTER TO HIGH GAIN ANTENNA AND LINE.

INQUIRIES ARE INVITED

FEDERAL FTR TELEPHONE & RADIO

FIG. 1

Transmitter for color or fine line television, designed and built by Federal for the Columbia Broadcasting System. It has an output of 1 KW at 500 MC; uniform modulation from DC to 10 MC

INTRODUCTION

The transmission of color television imposes unusually strict limits on the performance of the transmitter, if the full potentialities of the system are to be realized. For this reason, when the Columbia Broadcasting System approached Federal Telecommunications Laboratories a year ago with a request to design a transmitter for them, the specifications defined a transmitter of greater bandwidth and power than had ever before been built. Careful calculation by Federal engineers indicated that a complete solution was possible, using tubes recently developed in our laboratories. With this assurance, the contract was awarded, and the development begun. Active work on the project began only after V-E day, and the full program could not be attempted until after V-J day. In spite of delays arising from the confused condition of radio parts suppliers, the transmitter was completed and delivered to its final location in the Chrysler Building by December 21, 1945, and was operating at rated power before the middle of January.

I. THE TRANSMITTER

Essentially, what was required was a wide-band transmitter operating on a carrier frequency of 490 megacycles with a power output of one kilowatt peak. The output can be modulated uniformly with all frequencies from direct current to ten megacycles. It is the most powerful transmitter yet installed of this carrier frequency and modulation bandwidth.

Complete with all power units and water cooling equipment, the transmitter occupies ten bays each 30 inches wide, and weighs approximately 12,000 pounds, exclusive of studio equipment or antenna installation. The appearance of the transmitter as installed is shown in figure I.

II. RADIO-FREQUENCY PROBLEMS

The radio-frequency portion of the transmitter consists of a conventional chain of amplifiers and frequency multipliers following a crystal oscillator. The oscillator stage uses a type 6V6/GT tube in a tri-tet circuit, with a crystal frequency of 6.805 megacycles. The oscillator stage is arranged to double the crystal frequency in the plate circuit, so the output of this stage is approximately 3 watts at 13.611 megacycles.

The following stage uses a type 815 tube in a push-pull frequency tripler circuit. This tube, which is a dual beam tetrode, delivers approximately ten watts at 40.833 megacycles. The following stage is another type 815 in a tripler circuit, delivering approximately ten watts at 122.5 megacycles.

This stage is followed by an amplifier stage using a type 4-125 power tetrode, operating without neutralization, but with the reactance of the screen lead series resonated to bring the screen to ground potential more effectively. This arrangement has proved entirely stable, and the stage delivers approximately 120 watts at 122.5 megacycles:

The remaining stages of the radio-frequency chain make use of the type 6C22 tube, designed by the Federal Telecommunication Laboratories. This tube, which is a triode of high mutual conductance and low plate resistance, uses the ring-seal technique to reduce the inductance of the leads to the electrodes, and to make the tube suitable for operation in the ultra-high frequency portion of the spectrum. The anode is a solid block of copper fitted with a water jacket for cooling. With a water flow of one gallon per minute the tube may be used for plate dissipations up to one kilowatt in radio-frequency service. In applications where no grid dissipation is encountered, as is common in video-frequency amplifiers, somewhat greater dissipation is permissible, and with a water flow of two gallons per minute, a dissipation of two kilowatts is reasonable.

The fifth stage of the radio-frequency chain consists of a type 6C22 tube in a coaxial circuit operating as a frequency doubler at high power level. With an input of 120 watts at 122.5 megacycles, the stage delivers 250 watts output at 245 megacycles. In this stage the cathode of the tube is by-passed to ground, and the grid circuit is excited with driving energy. The anode circuit of this stage is a quarter-wave line shorted at the end farthest from the tube. Tuning is by a movable piston.

The sixth stage of the radio-frequency chain also uses a type 6C22 tube in a frequency doubler circuit, but in this case it is no longer possible to ground the cathode, because of the cathode lead inductance. In this case the grid is grounded, and the drive energy fed into the cathode circuit. With 250 watts of drive, this stage delivers 300 watts output at the final carrier frequency of 490 megacycles.

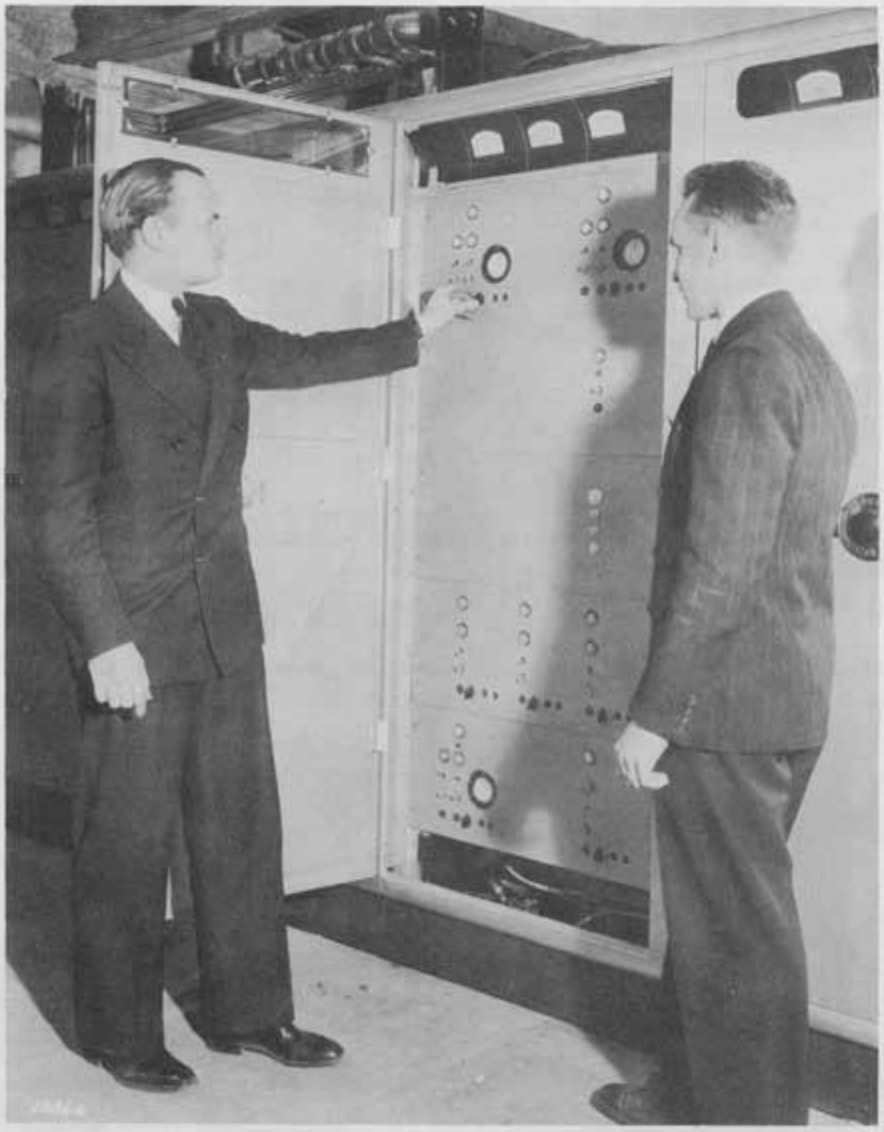
The seventh stage is a neutralized amplifier, using the type 6C22 in a grounded-grid circuit. With 300 watts of drive it delivers approximately 700 watts output at 490 megacycles. This is considerably more than is required to drive the final stage of the transmitter to its rated output of one kilowatt peak, but the excess power is dissipated in a damping resistor attached to the coupling line between the driver stage and the modulated amplifier stage. The load imposed by this resistor acts to maintain constant output voltage from the driver stage in spite of changing load imposed by the output stage as its bias is varied through the modulation cycle. This improves the linearity of the modulation characteristic, and somewhat reduces the voltage required from the modulator stage.

The eighth stage of the radio frequency chain is the final, or modulated amplifier stage. This stage also uses a type 6C22 tube in a neutralized, grounded-grid circuit. With a drive of 350 watts from the preceding stage it will deliver any output from zero to one kilowatt depending on the grid bias at the time. (For dissipation reasons it is not possible to deliver one kilowatt continuously; one kilowatt peak, or 600 watts average, is the rated output of the stage.)

III. THE VIDEO FREQUENCY MODULATOR

The modulator system consists of a five-stage video frequency amplifier having uniform response from DC to ten megacycles. The method of high-frequency compensation is quite conventional, being based on principles of design arrived at from filter theory, using both two terminal and four terminal networks. One unusual feature of the amplifier system is the absence of any system of DC restoration. Since the DC component of the signal is retained throughout the chain, restoration is not required.

The method of low-frequency coupling is shown in Fig. 2. (No high-frequency compensation is shown in this figure, but, of course, any type desired may be used without affecting the principles discussed.) A condenser (C_1) is connected from the plate of the first stage to the grid of the second. From each side of this condenser isolating resistors (R_1) are connected to the terminals of a regulated power supply, referred to as a coupling pack. No other path from the grid of the second stage to ground is provided. The cathode of the second stage is directly grounded. The isolating resistors are made very much larger than the first stage load resistor (R_1) so that the capacitance of the coupling pack to ground will not impose a shunt on the first stage at high frequencies, but for such frequencies the coupling condenser carries the signal without any appreciable change in the potential to ground of either terminal of the coupling pack. For very slow changes in potential of the plate of the first stage it will be apparent that both terminals of the cou-



NORMAN H. YOUNG, F.T.L. ENGINEER, AND
ORVILLE J. SATHER, CBS ENGINEER,
INSPECTING MODULATOR UNIT

pling pack are raised or lowered in potential by the same amount as the plate of the first stage, thus transferring the signal to the second stage through a path consisting of the isolating resistors and the pack itself. When the coupling condenser greatly exceeds the capacitance to ground of the coupling pack the region of transfer of signal from one path

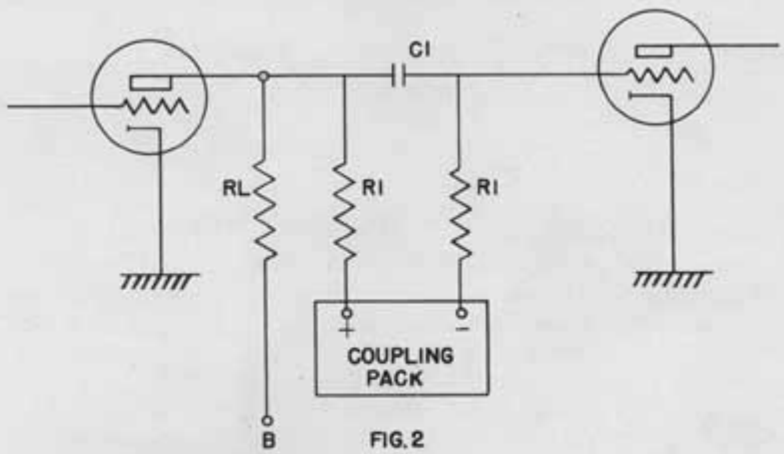


FIG. 2

to the other is gradual and smooth, and the response of the amplifier is uniform from a moderate frequency which passes through the condenser, to DC, which is transferred through the pack.

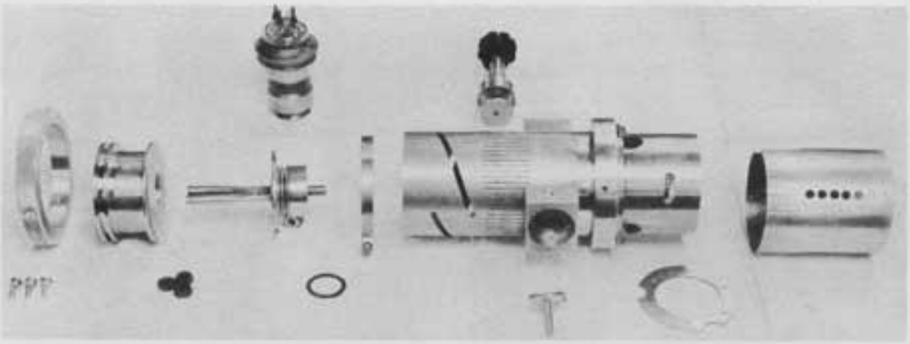
This system of coupling is used throughout the video-frequency system to retain the DC component of the signal and to insure good response at the very low frequencies. In spite of the possibility of a small instability in one of the early stages being magnified to cause "bounce" or flicker in the output, no such troubles have been encountered, principally due to thorough attention to the proper regulation of the coupling packs in the low-level stages of the system.

The first stage of the modulator system uses a type 6AG7 tube. Normal input for the stage is approximately 2 volts peak-to-peak. (All signal voltages discussed in the video frequency portion of the system will be referred to in terms of their peak-to-peak amplitude). The stage gain is 7, giving an output of 14 volts.

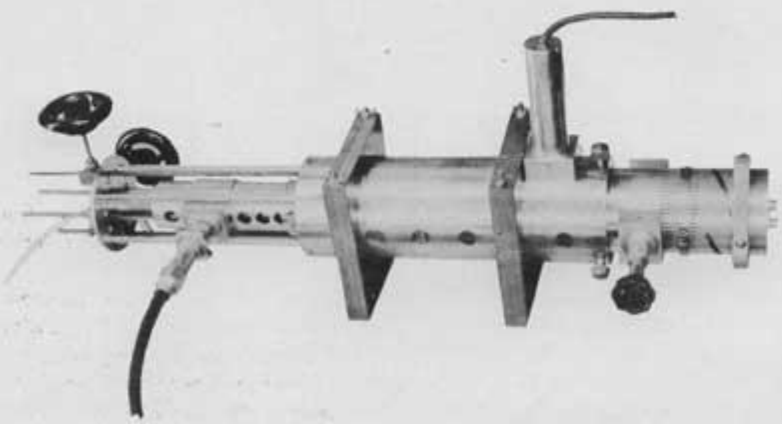
The following stage uses a type 807 tube, giving a gain of 2.8 and an output of 40 volts.

The third stage uses three type 807 tubes in parallel. This is necessitated by the relatively large input capacity of the following stage. The stage gain is 4.5 and the normal output 180 volts.

The fourth stage uses a type 6C22 tube as a conventional triode amplifier. Although the tube interelectrode capacitances are not large, the Miller effect increases the appar-



"EXPLODED" VIEW OF COAXIAL AMPLIFIER USING
6C22 TUBE AT 500 MEGACYCLES



COAXIAL AMPLIFIER AT 500 MEGACYCLES USING
FEDERAL 6C22 TUBE

ent input capacity of the stage to a considerable degree. With a suitable driver stage no other detrimental effects are found. The gain of this stage is 3.5 and its output is 700 volts.

The fifth stage is a cathode-follower using two type 6C22 tubes. The principal purpose of this stage is to supply a driving signal from a source of sufficiently low impedance that the effects of the changing load imposed by the output stage grid circuit will be negligible. In the region they are operated in this service the mutual conductance of each tube is approximately 10,000 microhms, so that the source impedance of this stage may be considered as 50 ohms. In addition, the high current capabilities of this stage and the negative feedback present in the cathode follower connection enable the preserving of a flat frequency response in spite of the shunt capacitance of the radio-frequency amplifier load. The stage gain is 0.8 and the output voltage 550 volts.

IV. POWER SUPPLIES AND CONTROL EQUIPMENT

The video-frequency amplifier and modulator uses a relatively large number of power units, since a separate coupling pack is required for each stage, and in addition, separate regulated supplies are used for the 6AG7 and the two 807 stages. The two stages using 6C22 tubes are fed from a common anode supply. This produces a desirable effect, since the current drawn by the cathode follower stage is increasing when that drawn by the amplifier stage is decreasing, and vice versa. This effect reduces the magnitude of current change in the pack load, and improves the low-frequency response.

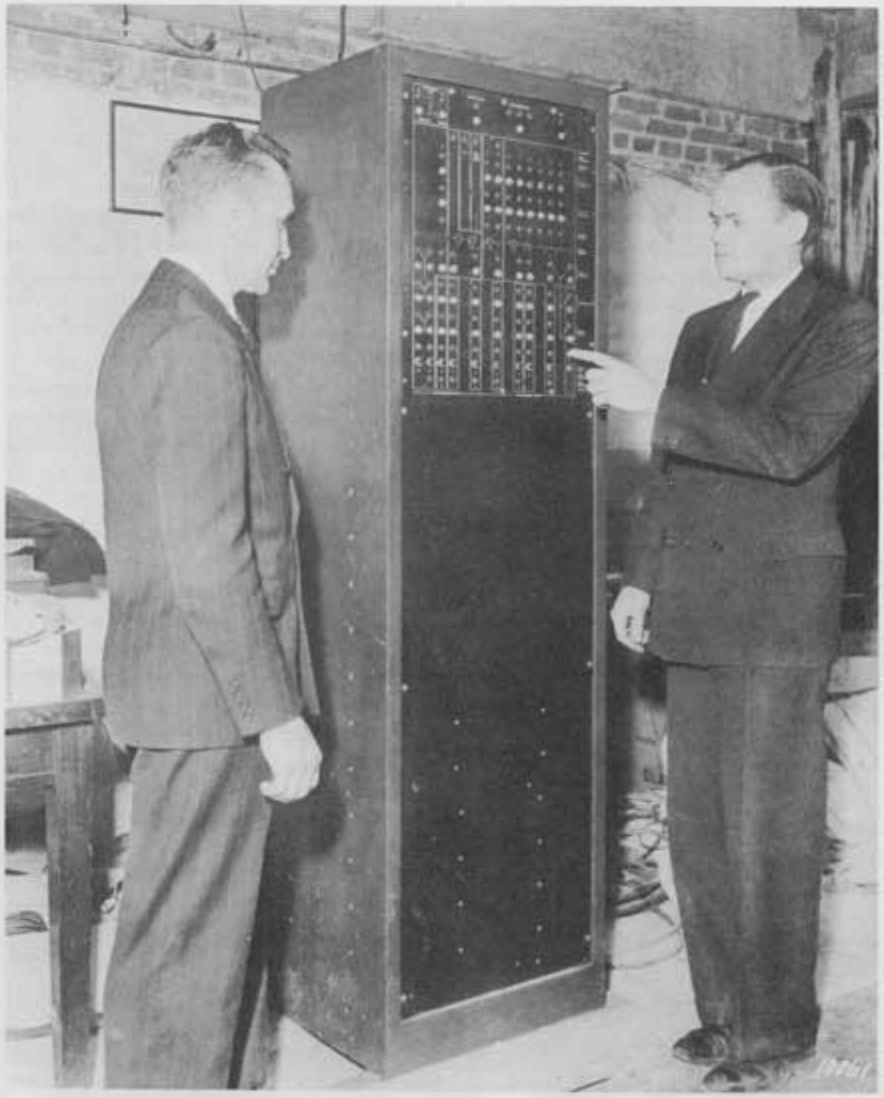
The radio-frequency system also uses a number of supplies, not only because a variety of voltages are required, but also to permit easy control and tune-up, and to prevent interaction between the modulated amplifier and the stages feeding it. Separate supplies are provided for the low-voltage stages of the exciter, for the two doublers, for the driver stage, and for the final amplifier.

Control of all power units, the water circulating pump, the main power circuit breaker, and all other necessary functions of the transmitter control are centralized in a console. From this point the transmitter may be completely started and stopped, or any portion of the unit turned on, as desired. Whenever it is desired to isolate any portion of the equipment, or whenever the opening of a door interlock switch or other protective device necessitates the interruption of any circuit, all other circuits dependent on that for proper functioning are automatically cut off. That is, complete interlocking for protection of personnel and equipment is included in the design of the control circuit. Pilot lights check the operation of each power circuit to speed the location of trouble in the system.

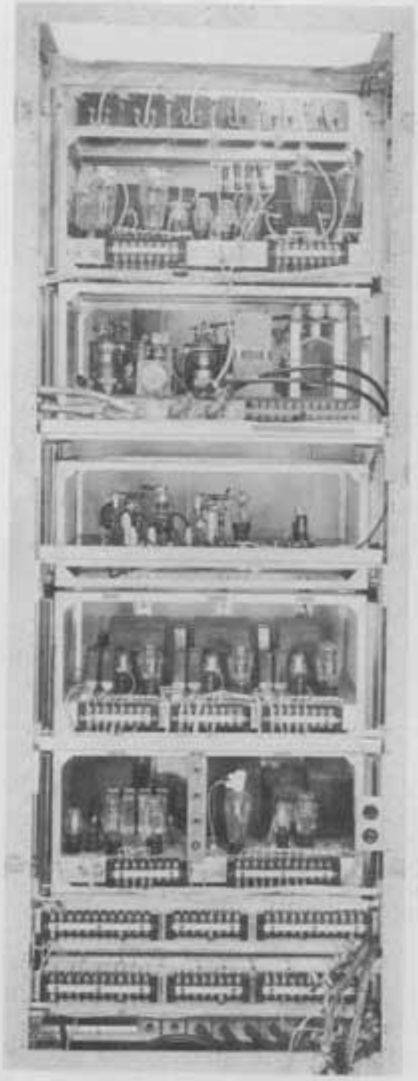
The console also contains cathode ray monitors for picture signals. Two image tubes are provided, one of which is continually on the radio picture actually radiated, while the other may be connected either to the incoming signal for comparison, or to any one of a number of monitoring points throughout the video and radio system for trouble shooting and servicing. An oscilloscope is normally associated with each of these image monitors, to check the synchronizing waveform at the monitored points.

V. CONCLUSION:

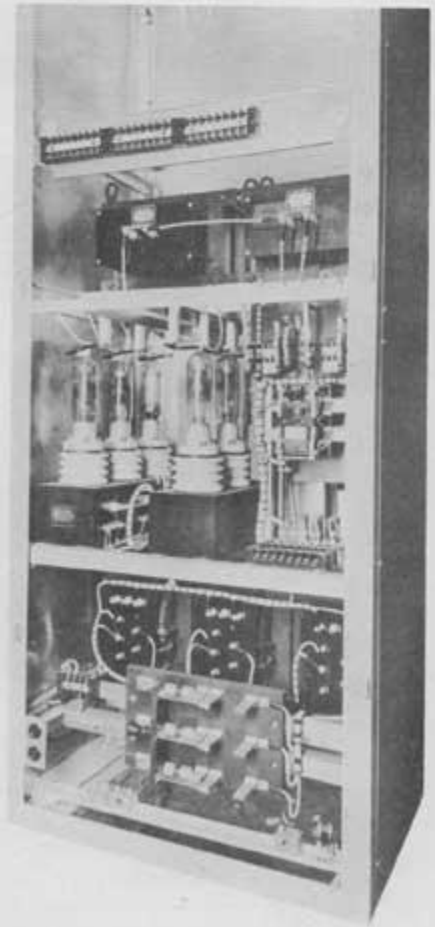
The completion of the transmitter and its installation and successful test shows clearly that the fundamental principles involved in the design are sound, and how that despite the strict performance requirements of color television, a transmitter can be designed to meet them using tubes and circuits now available. The problems encountered required for their solution the closest possible cooperation between the circuit engineers and the designers of the vacuum tubes used. The success of the project was due in large degree to the intimate cooperation between the tube laboratories and the television engineers working on the transmitter.



ORVILLE J. SATHER, CBS ENGINEER, AND
N. H. YOUNG, F.T.L. ENGINEER, AT
TRANSMITTER CONTROL PANEL



MODULATOR UNIT — REAR VIEW



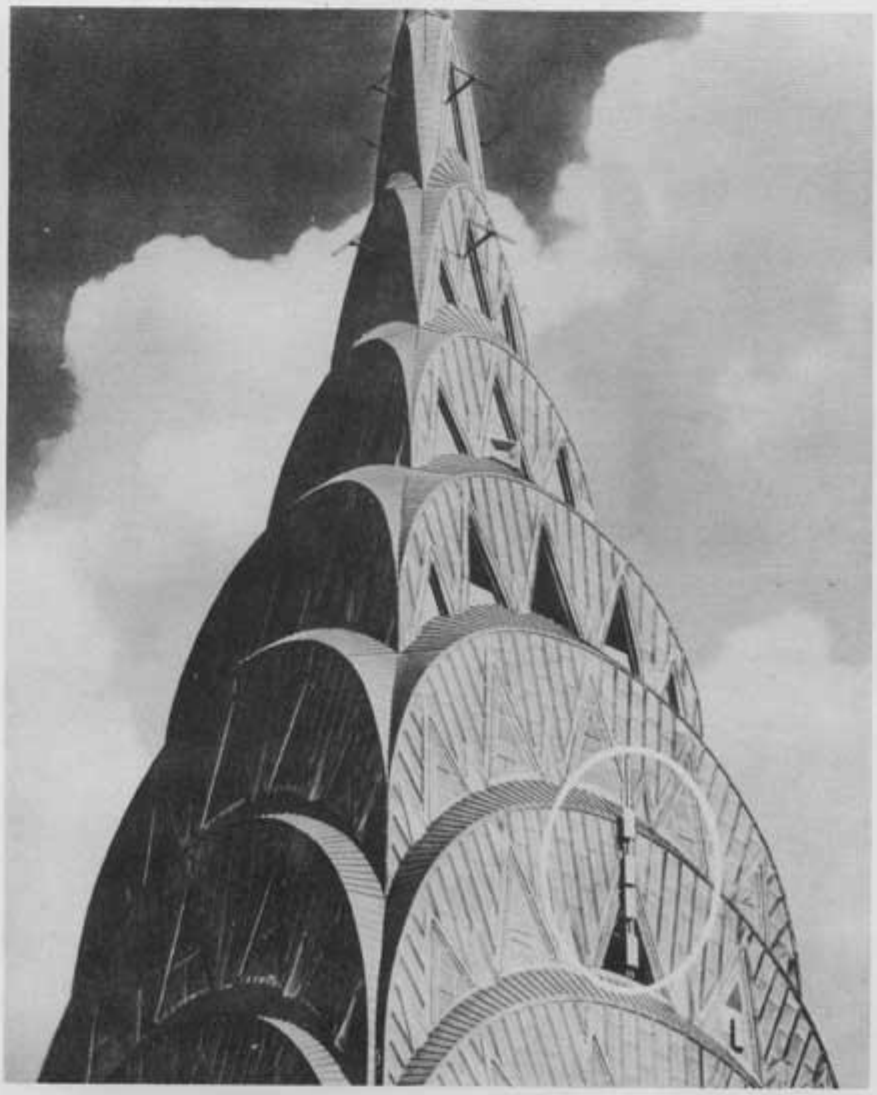
MODULATOR POWER SUPPLY

Columbia Broadcasting System Ultra High Frequency, Full Color Television Receiver

PROJECTION MODEL — Projection enlarges the pictures seen on this Columbia Broadcasting System high-definition, full color television receiver to a width of 22 inches. With the exception of this feature, operation of the receiver is the same as for the smaller, direct-view model. Ultra-high frequency television pictures are totally free of "ghosts" or unwanted reflections.

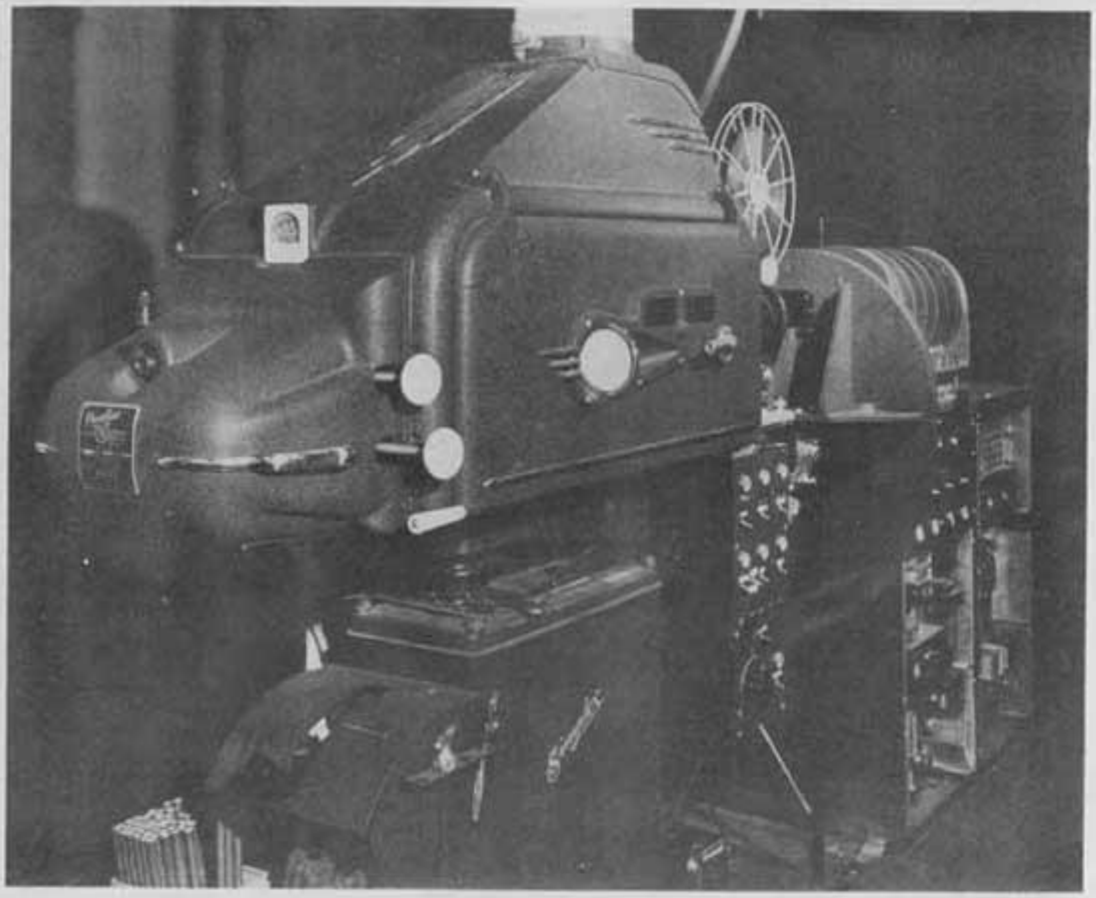
Columbia Broadcasting System Ultra High Frequency, Full Color Television Receiver

DIRECT VIEW MODEL — Designed and built by Columbia Broadcasting System engineers for operation on the ultra-high frequencies, this high-definition, full color television receiver has a 10-inch tube, magnified through curvature of a glass pane to approximately the size of a 12-inch tube. The set is much more compact than pre-war receivers, and is as easy to operate as standard black-and-white models.



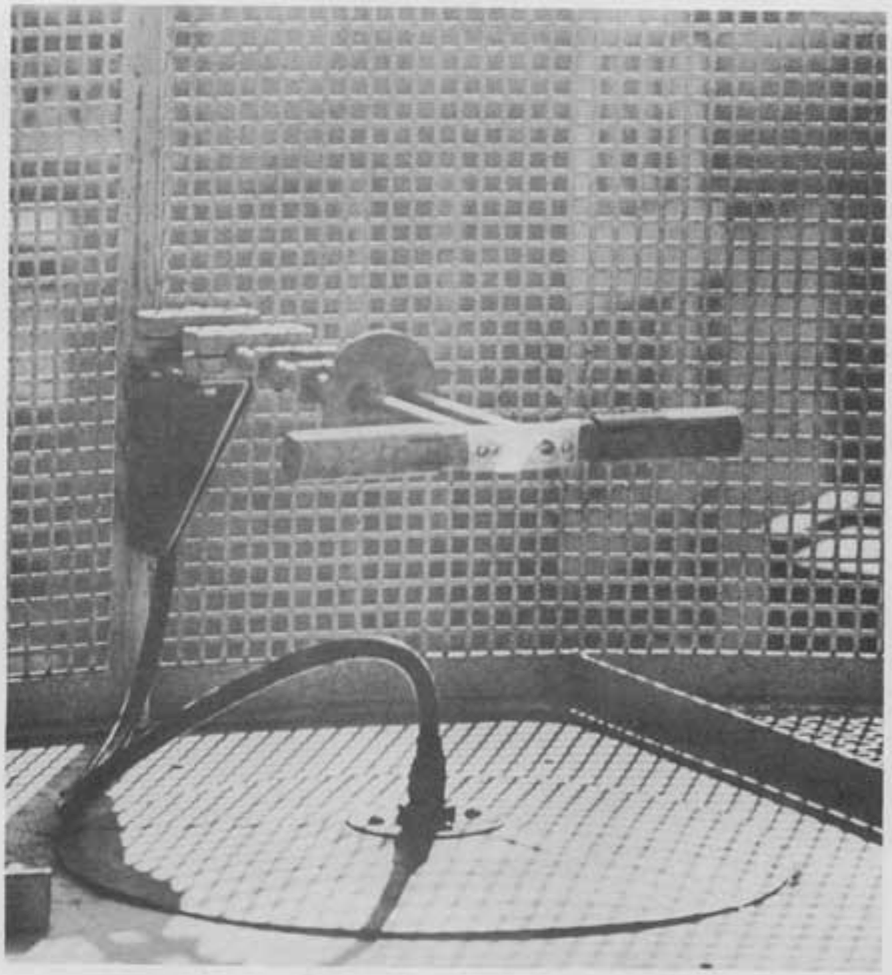
Columbia Broadcasting System Ultra High Frequency Full-Color Television Transmitting Antennas

Installation of New Transmitting Antennas has increased four-fold the effective power of the Columbia Broadcasting System's ultra-high frequency full-color television transmitter on New York's Chrysler Building tower. With its new transmitter, W2XCS (Columbia Broadcasting System Color Television Station) has an effective power four times greater than any television station now operating in the New York area. The two new antennas—one on the tower's south side (circled above) and the other on the north side—transmit both pictures and sound and perform the work of the eight low frequency antennas (some of which may be seen above them) required for operation of Columbia's black-and-white television station, WCBW.



Columbia Broadcasting System Ultra High Frequency Color Television Film Scanner

Columbia's demonstrations of ultra-high frequency, high definition full color television originate with this new film pick-up equipment. In the foreground, is the arc lamp with its control mechanism. The center section contains the scanning mechanism, while directly behind the film reel is the cylindrical unit that houses the electronic dissector tube.



Columbia Broadcasting System Ultra High Frequency Full-Color Television Receiving Antenna

The ten-inch horizontal bar of the receiving antenna with a section of its Parabolic reflector in the background, is an important factor in Columbia Broadcasting System system of ultra-high frequency, full-color television. It is here that all "ghosts" or unwanted reflections are stopped, a condition made possible only through the short wave-length of ultra-high frequencies.

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