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Ultra-High-Frequency Television Monitor

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ULTRA-HIGH-FREQUENCY TELEVISION MONITOR

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Abstract.—A monitor for ultra-high-frequency television stations has been developed to provide carrier-frequency monitoring of the video transmitter and both carrier-frequency and modulation monitoring of the fm sound transmitter. A feature of this new monitor is the use of the same reference crystal oscillator for monitoring both transmitters while still allowing independent monitoring of each transmitter. Use of a single precision reference crystal for both transmitter carrier frequencies materially reduces error in computing intercarrier separation frequency. A new harmonic generating circuit using germanium diodes has been developed for the uhf stage of the crystal-controlled multiplier chain. Separate diode mixers are used for the fm sound and am video monitors, and the multiplier chain is split into two legs to provide adequate isolation between the two input circuits to preserve the good signal-to-noise ratio of the fm monitor. The fm signal is heterodyned with a reference crystal harmonic, and the resultant if signal is used to operate a cycle-counter-type discriminator within a standard type fm frequency and modulation monitor. The video transmitter signal is also heterodyned with the same harmonic of the reference crystal. The resultant if signal in this case requires a second conversion before application to a cycle-counter-type frequency meter.

I. INTRODUCTION

The monitoring system described here is intended to provide continuous indications of carrier-frequency deviation or drift for the am visual transmitter and both carrier-frequency deviation and modulation for the fm sound transmitter of a standard television station. By suitable selection of tuning units, any channel from channel 2 to channel 83 may be monitored. Either transmitter may be monitored alone, and, of course, both may be monitored simultaneously. A view of the complete assemb[illegible] the Type 1183-T T-V Station Monitor, is shown in Fig. 1.

II. COMPARISON OF THIS MONITORING SYSTEM WITH PREVIOUS MONITORS

In order to make clear the revisions in monitoring technique represented by this new Type 1183-T T-V Station Monitor, it may be useful to review briefly the previously used monitoring system. Figure 2 shows a block diagram of the former system compared with the new one. The system shown in Fig. 2A comprises two separate monitors. Each monitor has its own reference crystal oscillator, the frequency of which is multiplied up to that of the proper channel minus the intermediate frequency of the metering circuits. The crystal oscillators used are completely independent, and each is operated on a frequency appropriate for the individual channel concerned. Comparing this system with that shown in Fig. 2B, note that one crystal reference oscillator is common to both monitors. This arrangement is adopted in order to provide improved stability by means of a more stable oscillator without the necessity of providing two separate highly stable crystal-controlled oscillators. The second crystal oscillator shown in the Type 1171-A Visual Transmitter Frequency Monitor is essentially an interpolating oscillator which always operates at approximately 4.35 mc, and hence contributes little to the total error in frequency measurement even though it may drift by a small percentage of its operating frequency. A second benefit is also derived from this new system since the frequency difference between the two carriers may now be established with great accuracy. With the previously used system of Fig. 2A, both oscillators could drift separately, each oscillator being allowed a

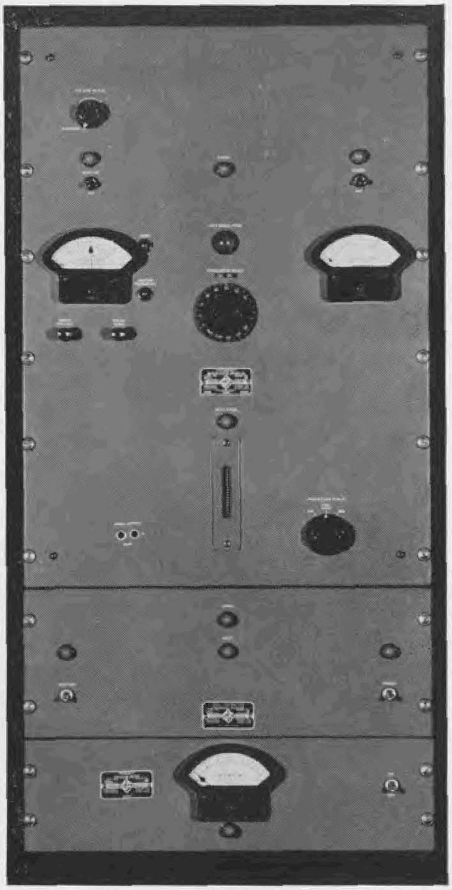
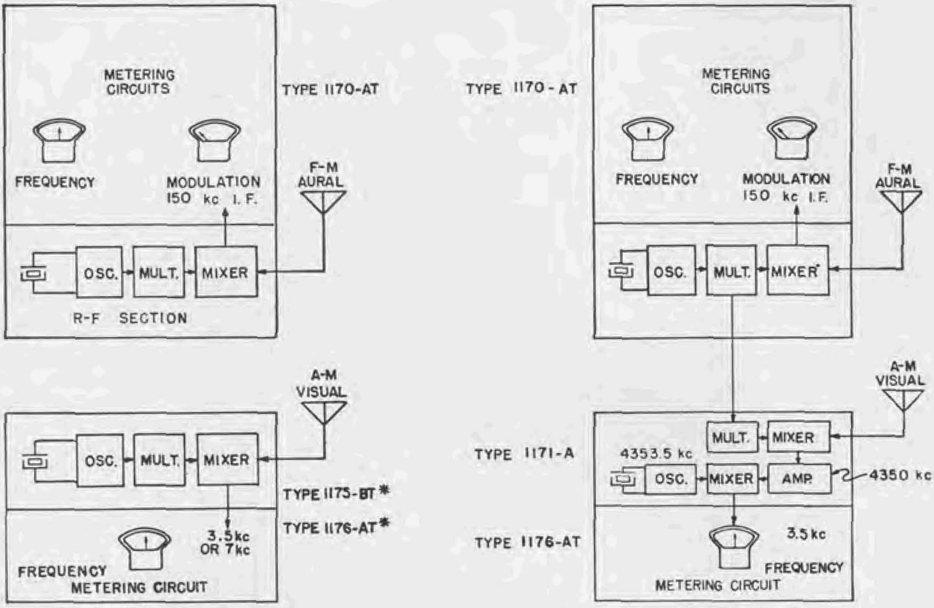


Fig. 1—Panel view of Type 1183-T T-V Station Monitor.

maximum drift of slightly less than $\pm 0.001\%$ or approximately half the transmitter tolerance figure. Thus, if both oscillators should drift in opposite directions from the proper frequency, the net difference between them could approach 0.002% of the carrier frequency. At 900 mc, this could reach a frequency difference of 18 kc in the intercarrier separation, enough to cause trouble in intercarrier-sound receivers. The new system eliminates this possibility while retaining the ability to monitor either carrier separately for adjustment purposes without the other being turned on.

III. STABILITY CONSIDERATIONS

The Federal Communications Commission has signified its intention to make frequency assignments of co-channel stations on an "offset-carrier" basis, one station being assigned the exact channel frequency, another a frequency 10 kc above this frequency and perhaps another 10 kc below. This is to be done to reduce interference between stations. The tolerance with which these assignments must be maintained is ± 1000 cycles. The master reference oscillator of the new monitoring system incorporates a plated-electrode hermetically sealed quartz crystal meeting Western Electric specifications for Type 20 crystals. This crystal unit in an oven maintained



*TYPE 1175-BT + TYPE 1176-AT DESIGNATED AS TYPE 1182-T FREQUENCY MONITOR

A. PREVIOUSLY USED SYSTEM FOR ±0.002% TOLERANCE OF CARRIER FREQUENCIES

THIS ENTIRE ASSEMBLY DESIGNATED AS TYPE 1183-T T-V STATION MONITOR

B. PRESENTLY USED SYSTEM FOR ±0.0005% TOLERANCE OF CARRIER FREQUENCIES

Fig. 2—Block diagram of former monitoring system compared with present system.

at 60°C ±0.1° provides the necessary ±300-cycle oscillator stability in the vhf band when used in the oscillator circuit which we normally use in General Radio frequency monitors. This oscillator circuit, which is somewhat similar to a Colpitts circuit, uses capacitors in series with the crystal, shunting the grid-cathode and cathode-ground capacitances of the oscillator tube, thus effectively swamping out any changes in tube capacitances.

At the present writing, the F.C.C. has not announced plans for offset-carrier operation in the uhf tv band. If tolerances are narrowed in the future as a result of the offset-carrier method of operation, an increase in the stability of the master reference oscillator of the monitoring system will be sufficient to handle this requirement, since the rest of the circuits are already stable enough for this application. The fm monitor metering circuits have a maximum error of less than ±200 cycles, and the visual transmitter monitor has less than ±100 cycles error in the metering circuits.

IV. FREQUENCY MULTIPLIER SYSTEM

In Fig. 2B it will be seen that the master reference crystal oscillator in the Type 1170-AT F-M Monitor is followed by a frequency multiplier chain with two branches. Both of these branches multiply up to the same harmonic of the crystal frequency, one branch feeding the mixer of the fm sound monitor and the other the mixer for the am visual monitor. By this branching of the frequency multiplier chain, two worthwhile results are achieved: first, the fm sound monitor input is isolated from the am visual transmitter which is heavily modulated by the synchronizing pulses, and, second, the frequency multiplier chain branches are called on each to produce only as much output power as is needed for one mixer.

V. FM METERING CIRCUITS

The metering circuits of the fm sound monitor are unchanged from the former design shown in the block diagram of Fig. 3. The mixer feeds a signal at an intermediate frequency of 150 kc to an amplifier and limiter which produces a square-wave output. This square wave is applied to a pulse-counter type discriminator, the d-c output of which is used to indicate carrier center frequency. The a-c component or envelope of the discriminator output is used to measure modulation deviation, and after suitable de-emphasis to provide an audio output signal for aural monitoring and another for noise and distortion checks. The de-emphasis and re-emphasis shown on the diagram for the modulation metering circuit is used because of certain circuit simplifications it makes possible.

Remote meter indication of center frequency deviation and modulation percentage are provided. A flashing-lamp-type modulation peak indicator is incorporated, and this indicator is also provided with an external connection if desired.

The ultimate signal-to-noise ratio of this fm monitor is a function of the fm noise and hum in the reference oscillator and frequency multiplier system, combined with the mixer noise and hum pick-up and the noise and hum added in the amplifier-limiter system. The residual fm noise level of this monitor in the vhf band is approximately 72 db below 25 kc swing, and in the uhf band it is probably less than 3 or 4 db worse. We have already measured one figure of −68 db below 25 kc swing, and the actual noise level may prove to be less than this.

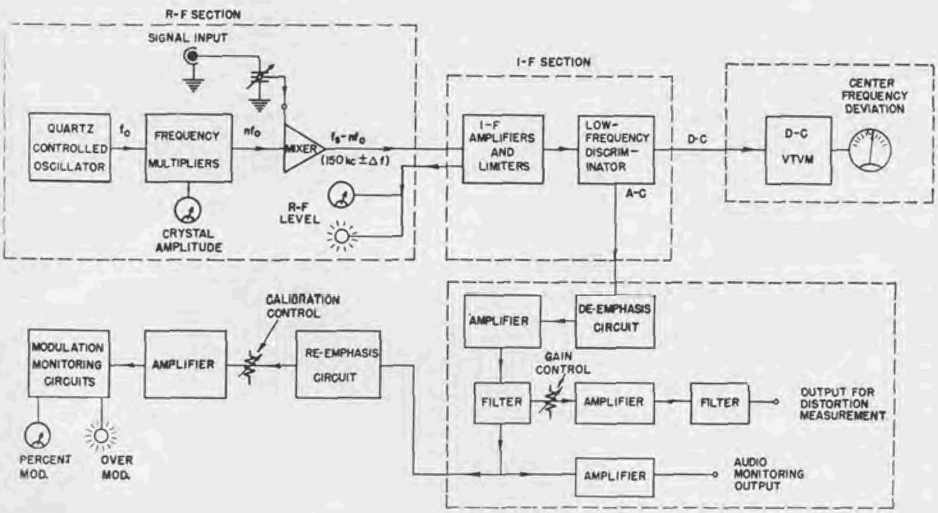


Fig. 3—Block diagram of fm sound monitor.

VI. UHF TUNING UNIT

The principal changes required for ultra-high-frequency use, aside from the revision of the monitoring system as discussed above, are found in the frequency multiplier chain and the mixer circuit. Figure 4 shows the replaceable uhf tuning unit for the fm monitor compared with the unit for channels 7-13 installed in the rf section of the monitor. The vhf unit includes only three tubes, two pentode frequency multipliers and one pentagrid mixer. The uhf unit incorporates three frequency multiplier tubes, two crystal-diodes in a frequency multiplier stage, one acorn diode mixer, and a pentode beat amplifier. A bottom view of this tuning unit is shown in Fig. 5. A simplified circuit diagram of the uhf tuning unit is shown in Fig. 6. The output of the second frequency multiplier stage in the permanently mounted rf section of the monitor is fed into the replaceable tuning units at a frequency between 37.5 and 60 mc. The first type 6AG5 multiplier in the uhf tuning unit is used as a doubler, driving the second 6AG5 as a buffer amplifier and phase inverter. The 6J6 is used as a push-pull tripler, supplying the driving power for the Type 1N34-A germanium diode frequency multipliers. These diodes are connected in push-push for doubling and push-pull for tripling to the final output frequency. The output of this stage is coupled to the

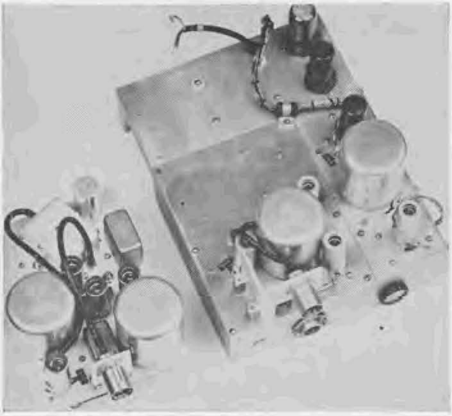


Fig. 4—View showing uhf tuning unit (at left) and vhf tuning unit (installed in rf section) of fm monitor.

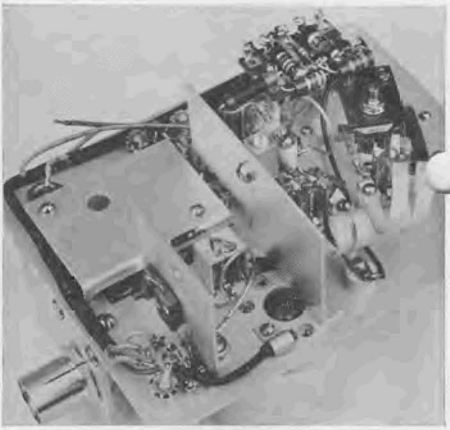


Fig. 5—Bottom view of uhf tuning unit for fm monitor.

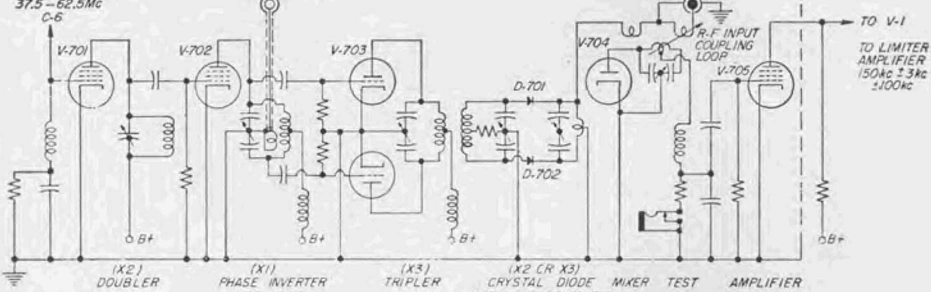


Fig. 6—Elementary schematic diagram of uhf tuning unit for fm monitor.

mixer by means of a coaxial line and coupling loop. A type 9005 acorn diode is used as a mixer, and a 6AG5 functions as a beat amplifier over the range of 50 to 250 kc. The output of this stage returns to the permanently installed monitor intermediate frequency amplifier used normally to amplify the output of the pentagrid mixer used at lower carrier frequencies.

The mixer circuit shown in Fig. 6 may appear at first glance to be something unusual although it is actually a conventional circuit born of necessity. The necessity arises from the determination not to use coaxial lines or other distributed circuits, even at 890 mc. The small butterfly-type variable condensers used throughout the uhf tuner were found to have low enough self-inductance to be satisfactory as tuning elements. However, in order to use a heater-cathode type of diode it was desirable to ground the cathode to minimize a-c hum. Hence the circuit shown is used with the condenser rotor grounded and the diode connected across one side of the condenser. Transmitter input and local oscillator are coupled in by loops, the transmitter loop being adjustable for proper input. At this point it may be in order to mention that a thermionic diode was used in order to withstand accidental overloads due to accidental maladjustment of the transmitter coupling system. It was felt that available crystal mixers were not as well suited for this application as the type 9005 diode because of this possibility of accidental burn-out.

VII. CRYSTAL-DIODE FREQUENCY MULTIPLIER STAGE

In the course of development of this uhf tuning unit, some difficulty was experienced in obtaining a frequency multiplier with appreciable output up to 900 mc. The 6J6 operated as a push-pull or push-push multiplier seemed to lose its punch above about 400 mc with some small output at higher frequencies but considerable tendency to oscillate and a general tendency to obscure the harmonic energy available by large quantities of fundamental output. The use of a non-linear circuit element as a harmonic generator was then tried with successful results. In fact, the results were so satisfactory that no further work was done on other types of frequency multipliers for the last multiplying stage. Germanium crystal diodes offered the required non-linear element.

The circuits used are shown in Fig. 7. Circuit A shows the connection for doubling with the diodes connected in push-push. Circuit B shows the push-pull connection for tripling. Since the diodes are effectively in series across the input tuned circuit, they add only one half of the individual diode's capacitance in parallel with the tuning condenser. It is imperative in using this circuit to choose diodes with relatively low shunt capacitance since even a relatively small capacitance added to such a circuit in this frequency range can restrict the tuning range drastically and sometimes even drop the top frequency below the required value. Also, the capacitance of the diode shunts the non-linear resistance element. A relatively high shunt capacitance could even require use of a different circuit operating at a lower impedance level. Fortunately, crystal diodes are much better in this respect than most pin-base type miniature vacuum tubes.

After some preliminary work had shown that this method of harmonic generation was practical, power output measurements were made which gave surprisingly good results. As representative maximum results obtained, Circuit A, Fig. 7, gave 63 milliwatts out at 534 mc as a doubler, and Circuit B gave 28.5 milliwatts out at 777 mc as a tripler. Circuit C gives comparable outputs but also gives considerably higher leakage of fundamental frequency power. Since this would be a possible spurious signal in a monitoring system, it was decided to use the Circuits A and B. After a number of measurements of harmonic output power from various types of germanium diodes, we decided to use type 1N34A's since they have high and uniform output and are widely available for use in manufacturing and for replacement. A photograph of the multiplier as used in the monitor is shown in Fig. 8.

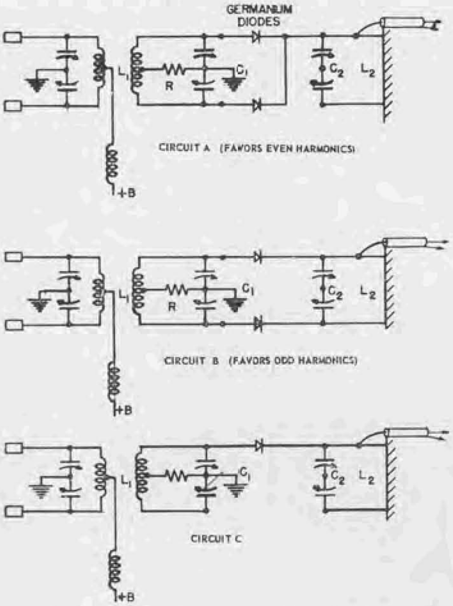


Fig. 7 — Crystal-diode frequency multiplier circuits.

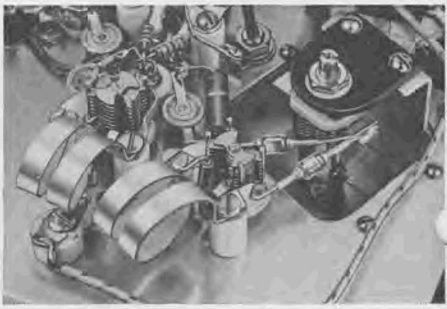


Fig. 8 — Photograph of crystal-diode frequency multiplier.

VIII. VISUAL TRANSMITTER FREQUENCY MONITOR

The rf tuning units for the Type 1171-AT Visual Transmitter Frequency Monitor are substantially the same as the replaceable portions of the rf section of the fm monitor, except for the omission of the unused low frequency stages of the multiplier chain, and a certain amount of simplification allowed by the freedom from signal-to-noise ratio problems. Since the visual transmitter monitor does not monitor modulation percentage, it is not critical with regard to signal-to-noise ratio.

The remainder of the circuit of the visual transmitter frequency monitor shown in Fig. 9 is fairly conventional. A plated-electrode quartz crystal similar to the one used as a master reference oscillator is used to control the frequency of the heterodyning oscillator at 4353.5 kc for the non-offset case. This crystal is in a small oven with only moderate temperature stability which is quite satisfactory for this application. The if input from the mixer is supplied to a double-tuned input transformer where a small attempt is made to match the mixer impedance. The diode uhf mixer is connected across a fixed capacitor of approximately 100 $\mu\mu$f, while the pentagrid mixer used for vhf is connected across the smaller air trimmer giving a somewhat higher input impedance. The low side of the grid circuit is grounded directly to eliminate any incidental pulse modulation of the grid. A high impedance plate load for the

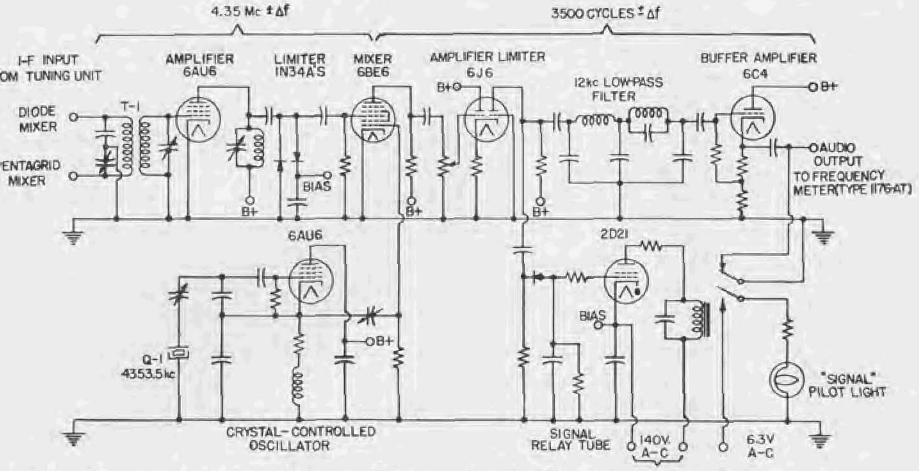


Fig. 9—Elementary schematic diagram of Type 1171-AT Visual Transmitter Frequency Monitor.

amplifier is provided by the tuned circuit feeding the germanium diode shunt limiter. The output of this limiter is essentially the intermediate frequency signal stripped to a large degree of its amplitude modulation components. This signal is mixed with the crystal oscillator signal to produce a 3500-cycle beat note which will shift in frequency exactly as the carrier frequency shifts. This signal is fed through a low-pass filter for reduction of any remaining 15,750-cycle line frequency components to a buffer amplifier. This buffer protects the output termination of the filter from changes due to long leads which may be used to connect to the frequency deviation meter.

The frequency deviation meter is a simple cycle-counter type with 3.5 kc at the center of the meter scale. An electrical suppression of the meter zero is used to provide a point at the mechanical zero which is really +500 cycles electrically. Hence the meter scale reads ±3000 cycles from the center zero, and the meter scale is so calibrated. The mechanical zero is at the left of the meter, and the meter rests there when the instrument is turned off, the bucking current being applied from the regulated power supply.

IX. ACCURACY OF VISUAL TRANSMITTER MONITOR

The anticipated drift of the 4353.5 kc crystal oscillator is less than ±10 cycles and the error of the frequency meter is less than ±90 cycles. Hence the net error in indication of carrier frequency for the video transmitter is less than ±100 cycles added to the error contributed by the master reference crystal oscillator located in the Type 1170-AT F-M Monitor.

X. INSTALLATION AND SERVICING

Some points of the design of this monitoring assembly deserve comment. The Type 1170-AT F-M Monitor is a large heavy instrument which is made large mainly to provide its excellent signal-to-noise ratio and freedom from drift, and to provide remote metering facilities. A two-piece shield box has been developed for this monitor which provides for the shield being bolted into the rack and the monitor being installed by slipping it into the shield. Once the shield is installed, it is relatively simple to slip the monitor out for servicing. The back of the shield box is removable for inspection from the rear.

The smaller instruments, the Type 1171-AT Visual Transmitter Frequency Monitor and the Type 1176-AT Frequency Deviation Meter, are more or less conventional in design using familiar chassis and panel construction. The shield of the visual monitor does, however, resemble the shield of the large fm monitor unit since it is mounted permanently in the rack, and the monitor slides out for inspection.

The power, rf input, audio output, and remote metering connections are all at the rear. Test jacks are provided at various strategic points in the monitoring circuits to aid in locating any improperly functioning or dead sections of the system. It is possible to operate the monitors in the rack while making checks on the circuit if enough slack is provided in the cables, or if extension cords are added to enable the monitors to be slid partially out of their shielding boxes.

XI. CONCLUSIONS

In summary, the problem of providing a monitoring system for the tv broadcasting station has been solved for all channels including the highest frequency in the uhf band. A single stable quartz-crystal-controlled oscillator is used to provide the reference frequency against which both aural and visual transmitter components are monitored. This oscillator uses a stable circuit and a plated-electrode hermetically sealed quartz crystal in an oven with good temperature stabilization. An interpolating crystal-controlled oscillator is used to provide the additional reference frequency required for monitoring the second transmitter. The carrier frequency range covered by th monitoring system has been extended to the top of the uhf band by the use of crystal-diode harmonic generators as frequency multipliers. These diodes have long life and are easy to use in this application, thus meeting the requirements for reliability posed by broadcasting equipment.