HEWLETT-PACKARD
JOURNAL
TECHNICAL INFORMATION FROM THE HEWLETT-PACKARD LABORATORIES
VOL. 1 No. 12
PUBLISHED BY THE HEWLETT-PACKARD COMPANY, 395 PAGE MILL ROAD, PALO ALTO, CALIFORNIA AUGUST, 1950

A New Monitor for FM Communications Services

IN recent years the use of radio communications has grown enormously in fields such as land transportation, public safety, and public utilities. The consequent crowding of available spectrum has resulted in FCC adoption of tighter carrier frequency tolerances for these radio services. At present such services are, in general, required to maintain their carrier frequencies accurate within 0.01% when below 50 mc and within 0.005% when above 50 mc. In addition, periodic measurements must be made to determine that carrier frequencies are within FCC tolerances.

The new -hp- Model 337 FM monitor shown in Figure 1 directly measures and continuously indicates both the carrier frequency and modulation deviation of an FM transmitter operating in the range from 30 to 175 mc. Two models of the instrument are available. The Model 337A monitors the carrier frequency and modulation deviation of a single FM (or PM) transmission, while the Model 337B monitors up to four transmissions. The latter instrument is similar to the Model 337A except for a panel switch that connects any one of the four carrier frequencies to the monitoring circuits. All coil changes are performed automatically by the panel switch and no plug-in coils are used.

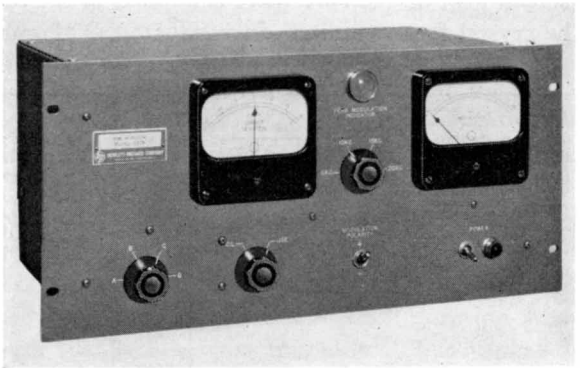


Figure 1. *-hp- Model 337B FM Monitor can be used with four channels in the 30-175 mc range.*

The heart of these new monitors is the pulse-counter type discriminator which was developed for the popular -hp- Model 335B FM broadcast service monitor[1]. This discriminator is extremely stable; in fact, no zeroing control is necessary or provided for the discriminator in the Model 337. The stability depends only on two small capacitors and four resistors, for which precision parts are used. The reliability of the circuit and the stability of its measurements have been proved thoroughly in the Model 335B and 337A-B monitors now in the field.

Besides their primary function of indicating carrier frequency and modulation deviation, the Model 337 monitors are valuable to the station for making audio measurements on the transmitter. With the use of a distortion meter such as the -hp- Model 330B, the audio frequency characteristics of the transmitter are easily measured. In addition, a monitoring amplifier can be driven from the monitors for aural monitoring purposes.

In production work the Model 337 moni-

[1]N. B. Schrock and D. Packard, *A Pulse Counter Type FM Station Monitor*, Proceedings of the National Electronics Conference, Vol. 3, 1947.

tors are being used to check the performance of fixed-frequency FM transmitters and to make rapid spot measurements of spurious FM generated within AM transmitters and signal generators.

OPERATIONAL CHARACTERISTICS

The sensitivity of the monitors has been made quite high, being better than 400 microvolts over the entire 30-175 mc range. This sensitivity value is the actual voltage required across the 50-ohm input connector for the instrument, and is high enough to permit convenient monitoring of semi-remote transmitters, as in cars and trucks. To monitor such transmitters, it is usually necessary only to connect a short wire to the Model 337 when the transmitter is within a few hundred feet of the monitor. By connecting the monitor to existing antenna lines, semi-remote transmissions can often be monitored under actual useage conditions. A special feature of the monitors is that the signal strength of the rf carrier being received can be read on a panel meter to ascertain that the received carrier is of an amplitude sufficient for proper operation.

The Model 337 monitors are basically fixed-frequency receivers which include circuits capable of measuring precisely the carrier frequency of the received transmission. The precision of measurement is affected by the stability of the discriminator, described above, and by the stability of the reference or heterodyning local oscillator in the receiver. Hence, the stability and accuracy of the local oscillator are matters of considerable importance in the design of the circuit. Typical stability curves are shown in Figure 2 where it can be seen that the oscillator is stable within a few parts per million over long periods of time.

To set up and use, the operator needs only to connect the monitor to a power source and to an antenna

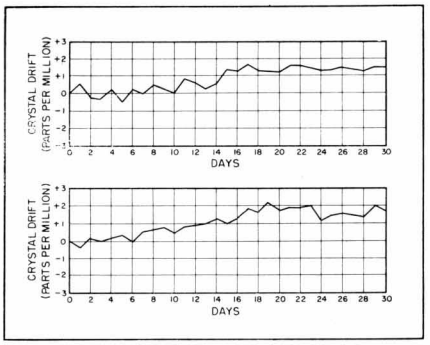


Figure 2. *Stability curves of reference oscillator in two Model 337 FM Monitors.*

line. Two panel controls select the polarity of the modulation to be monitored and the modulation deviation at which the over-modulation lamp flashes. In the four-channel Model 337B, a third control selects the channel to be monitored.

CIRCUIT DESCRIPTION

In Figure 3 the circuit is shown in block form. The FM or PM transmission to be monitored is applied across a tuned circuit to the mixer, where heterodyning with the output of the local oscillator occurs. The local oscillator frequency is controlled by a low temperature-coefficient crystal that has been aged and carefully monitored at regular intervals before use until stabilization is assured. A thermostatically - controlled oven operated at 65° C maintains a constant temperature for the crystal.

The oscillator uses an electron-coupled circuit with the tuned circuit connected to the screen grid of the oscillator tube. The crystal frequency is selected to lie within the 7.5-9 mc region, the exact frequency depending upon the frequency of the transmission to be monitored. To obtain the necessary multiplication of the oscillator frequency up into the 30-175 mc range of the transmitters, two stages of frequency multiplication are used. First, the plate circuit of the oscillator tube is tuned to a harmonic of the crystal frequency. Second, the harmonic voltage in the plate circuit is of sufficient amplitude to overdrive the mixer grid, generating additional harmonics which heterodyne with the incoming transmitter frequency. The crystal frequency is selected so that an intermediate frequency of 30 kc will be obtained at the output of the mixer tube. This

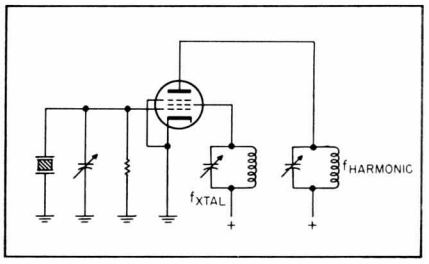


Figure 4. *Basic circuit of reference oscillator.*

30 kc I.F. is applied to a three-stage limiting amplifier. High frequency products of the mixing action are by-passed by distributed capacity at the input to the amplifier.

PULSE-COUNTER DISCRIMINATOR

The output of the limiting amplifier is a nominal 30 kc square wave whose average frequency depends upon the exact transmitter carrier frequency and which contains the complete modulation swings. This square wave is applied to the pulse-counter discriminator of Figure 5

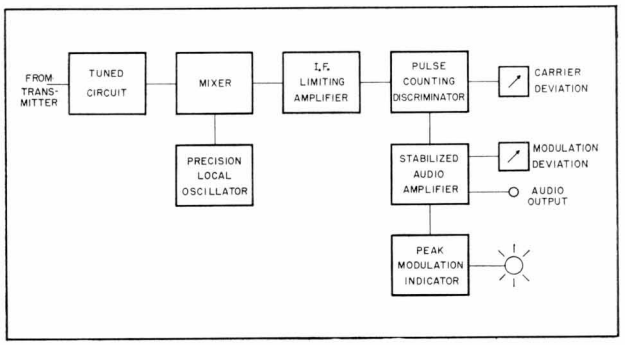


Figure 3. *Block diagram of Model 337 monitor circuit.*

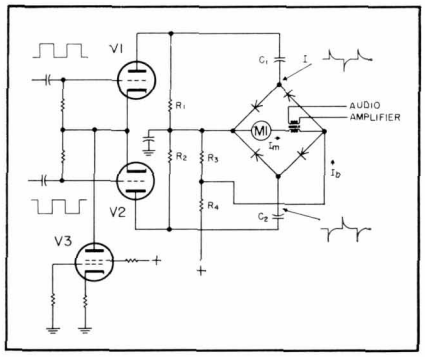


Figure 5. *Diagram of basic pulse-counter circuit.*

and is of sufficient amplitude to drive the grids of the discriminator tubes beyond cut-off.

Tubes VI and V2 in Figure 5 obtain their space current from a constant-current source V3 to assure uniformity of plate currents. Alternate half cycles of the square wave from the limiting amplifier operate V1, producing a current pulse through C1 like that shown. Similar current pulses flow through C2 on the remaining half cycles when V2 is conducting. The bridge rectifier applies these current pulses unidirectionally to the dc meter M1.

The charge in each of the current pulses is determined by the values of C1 and R1. These values are selected so that at the highest frequency to be counted capacity C1 will be fully charged before the expiration of the half-cycle. Thus, a fixed charge is always passed to the meter for each half-cycle of the I.F. and the meter reading is proportional to the number of charges per unit time or to the frequency of the I.F. In turn, the I.F. is related to the transmitter frequency.

If no special arrangement is used, the circuit will indicate a change in carrier frequency by a change in some high-scale meter reading. However, greater readability can be obtained by balancing out the meter current that results from the 30 kc I.F. and using a zero-center meter to indicate only the changes in transmitter frequency. To acomplish this, an opposing current equal to that resulting from the 30 kc I.F. is applied to the meter, giving a center indication when the transmitter is on frequency and either negative or positive indications when the carrier frequency changes. The balancing current is obtained from a precision divider R3 and R4 located in the plate supply of V1 and V2. Thus, any plate current variations that tend to cause a change in the current pulses applied to the meter are automatically compensated by corresponding changes in the opposing current.

The instantaneous I.F. varies around the 30 kc point in accordance with the modulation on the transmitter carrier. These same modulation deviations are present in the instantaneous pulse frequency applied to the meter, although no variations occur in the meter reading because the pulses are integrated by the ballistic characteristics of the meter and by a meter by-pass capacitor. Thus, the meter indicates only the average carrier frequency.

However, the modulation can be recovered or detected by inserting an audio transformer in series with the meter as shown. By suitable filtering, a demodulated signal is obtained and is applied to a feedback-stabilized audio amplifier which operates the modulation meter. In addition to being a frequency meter, then, the counting circuit also operates as a demodulator and for this function has extremely good linearity and stability.

MODULATION METER

The modulation meter is calibrated in kilocycles of deviation from 0 to 20 kc. The meter is fast-acting and indicates the deviation of a modulation burst of only 130 milliseconds duration with less than 5% error. The response of the meter is constant within $\frac{1}{2}$ db over the range from 300 cps to 3 kc. Either positive or negative modulation swings can be observed by means of a panel switch.

A peak modulation lamp is included in the modulation meter circuit and can be adjusted by means of a panel control to flash on any deviation from 5 to 20 kc. The lamp is faster acting than the meter and is useful to indicate modulation bursts that exceed the 15 kc deviation maximum authorized by the FCC.

AUDIO OUTPUT CHARACTERISTICS

On modulation swings of 15 kc, five volts of audio output are provided—ample for driving aural monitoring amplifiers or for operating measuring equipment. Less than 1% distortion is contributed by the monitor circuits. The response of the audio system is constant within $\frac{1}{2}$ db from 300 cps to 3 kc when no de-emphasis is used.

The monitors can be provided either with or without de-emphasis. When de-emphasis is used, the audio output follows the proposed RMA slope of 6 db per octave from 300 cps to 3 kc, resulting in about 2.5 volts output at low audio frequencies on modulation swings of 15 kc.

—J. E. Stiles

SPECIFICATIONS
MODELS 337A-B FM MONITORS

CARRIER FREQUENCY RANGE: Model 337A: for use on any one frequency in range from 30 to 175 mc. Model 337B: for use on any four frequencies in range from 30 to 175 mc (circuits adjusted at factory).

SENSITIVITY: Approximately 400 microvolts.

CARRIER METER DEVIATION RANGE: −15 kc to +15 kc.

CARRIER METER ACCURACY: Within 0.005% from 30 to 50 mc; within 0.002% above 50 mc.

MODULATION METER RANGE: 0 to 20 kc.

MODULATION METER ACCURACY: Within 5% of full scale.

MODULATION METER FREQUENCY RESPONSE: Within ½ db from 300 cps to 3 kc.

PEAK MODULATION INDICATOR RANGE: 5 to 20 kc (adjustable).

AUDIO OUTPUT: Without de-emphasis, 5 volts into 20,000 ohms on 15 kc modulation swings; de-emphasis decreases output.

DE-EMPHASIS: Supplied optionally.

POWER: Operates from nominal 115-volt, 50/60 cycle supply. Draws approximately 100 watts.

DIMENSIONS: 8¾" high, 19" wide, 10" deep.

MOUNTING: For relay rack mounting.

WEIGHT: Approx. 25 lbs. Shipping weight, 43 lbs.

PRICE: Model 337A: $300.00 less crystal and oven. Model 337B: $350.00 less crystals and oven. Crystal and oven: $27.50 per frequency. All prices f.o.b. Palo Alto, Calif.

Data subject to change without notice

New Aural and Video Monitors for TV Stations

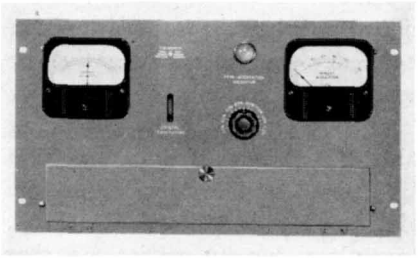
Monitors have been developed for both the aural and video transmissions of television stations. Both types of these new monitors are based on the circuitry used in the Model 335B FM broadcast monitor—the most widely used of all monitors in the standard FM broadcast field.

MODEL 335C-D AURAL MONITOR

This monitor is basically similar to the -hp- Model 335B broadcast monitor, except that the oscillator and multiplier stages have been redesigned to be suitable for the particular frequency channels used for television. In addition, the pulse counting circuits have been designed to be suitable for the 25 kc modulation swings used in television. Two models of the instrument are available, the Model 335C for use with any of channels 2 to 6 and the Model 335D for use with channels 7 to 13. Both instruments continuously indicate carrier frequency as well as percentage modulation.

The carrier frequency readings are accurate within 0.001%. To achieve this high accuracy, the monitor uses a pulse-counter type discriminator and a reference oscillator that is designed for very high stability. The crystal for the oscillator is housed in a double-chamber oven that regulates within approximately one-tenth of a degree Centigrade. The crystal itself has a low temperature coefficient of approximately one part per million per degree Centigrade.

The audio system in the monitor is of a quality that conforms to the high quality systems used in FM aural transmitters. The audio output voltage follows the standard de-emphasis curve within $\frac{1}{2}$ db over the range from 20 cps upward. Distortion is less than 0.25% at 100% modulation over the entire range from 50 cps to 20 kc, while residual noise



-hp- Model 335 Television Aural Monitor

is less than 0.03% or 70 db below 100% modulation.

Altogether, four important measurements can be made on the transmitter by means of the monitor: carrier frequency and percentage modulation are indicated directly, while distortion and frequency response can be measured with the -hp- Model 330B Distortion Meter.

MODEL 336C-D VIDEO CARRIER MONITOR

The Model 336C-D monitors are designed to indicate the carrier frequency of the video transmission of television stations. The Model 336C operates with any of channels 2 to 6 and is calibrated in 100-cycle divisions for carrier deviations from −3 kc to +3 kc ,while the Model 336D operates with any of channels 7 to 13 and is calibrated in 200-cycle divisions for carrier deviations from −6 kc to +6 kc. The carrier frequency readings are accurate within 0.001%.

APPROVAL STATUS

As of this writing, the FCC is not granting approvals for television monitors. However, engineering and test data required for approval for the Model 335C-D and 336C-D monitors have been compiled. Until such time as approvals are granted, the monitors are offered with the provision that approval is guaranteed when the "freeze" is removed.

VISIT THE -hp- BOOTH AT THE I.R.E.-W.C.E.M.A. MEETING IN LONG BEACH AND THE NEC MEETING IN CHICAGO

SPECIFICATIONS
MODELS 335C-D
TELEVISION AURAL CHANNEL MONITOR

CARRIER FREQUENCY RANGE: Model 335C: for use on any one of channels 2 to 6. Model 335D: for use on any one of channels 7 to 13.

CARRIER METER DEVIATION RANGE: Model 335C: −3 kc to +3 kc. Model 335D: −6 kc to +6 kc.

CARRIER METER ACCURACY: Within 0.001%.

R.F. POWER REQUIRED: 2 watts nominal. Operates satisfactorily over range from 0.3 to 3 watts.

MODULATION METER RANGE: 0 to 33.3 kc. Scale calibrated to 100% at 25 kc swing, 133% at 33.3 kc swing.

MODULATION METER ACCURACY: Within 5%.

MODULATION METER CHARACTERISTICS: Damped in accordance with FCC requirements. Reads peak value of modulation peak of duration from 40 to 90 milli-seconds. Pointer returns to 10% of full value within 500 to 800 milliseconds.

MODULATION METER RESPONSE: Constant within ½ db from 50 cps to 15 kc.

EXTERNAL MODULATION METER: Provision made for use with remote 400 microampere meter. Extra meters can be supplied.

PEAK MODULATION INDICATOR: Adjustable from 50% to 120% modulation. Provision made for use with external peak indicator.

AUDIO OUTPUT RESPONSE: Constant within ½ db from 20 cps to 20 kc. Equipped with standard 75 microsecond de-emphasis.

AUDIO OUTPUT VOLTAGE: At low frequency 100% modulation, 10 volts across 20,000 ohms.

MONITORING OUTPUT VOLTAGE: At low frequency 100% modulation, 4 mw into 600 ohms; balanced.

DISTORTION: Less than 0.25% at 100% modulation for frequencies from 50 cps to 20 kc.

NOISE: 70 db below output level corresponding to 100% modulation.

POWER: Operates from nominal 115-volt, 50/60 cycle supply. Draws approximately 150 watts.

DIMENSIONS: 10½" high, 19" wide, 13" deep.

MOUNTING: Cabinet or relay rack. Add "R" to model number for rack mounting (335CR or 335DR).

SHIPPING WEIGHT: Approx. 95 lbs.

PRICE: $935.00 f.o.b. Palo Alto, Calif.

Data subject to change without notice

SPECIFICATIONS
MODELS 336C-D
VIDEO CARRIER FREQUENCY MONITORS

FREQUENCY RANGE: Model 336C: For use on any one of channels 2 to 6. Model 336D: For use on any one of channels 7 to 13.

DEVIATION RANGE: Model 336C: −3 kc to +3 kc. Model 336D: −6 kc to +6 kc.

ACCURACY: Within 0.001%.

R.F. POWER REQUIRED: 2 watts nominal. Operates satisfactorily over range from 0.4 to 4 watts.

POWER: Operates from nominal 115-volt, 50/60 cycle supply. Draws approximately 60 watts.

DIMENSIONS: 8¾" high, 19" wide, 10" deep.

MOUNTING: Cabinet or relay rack. Add "R" to model number for relay rack (336CR or 336DR).

SHIPPING WEIGHT: Approx. 45 lbs.

PRICE: $400.00 f.o.b. Palo Alto, Calif.

Data subject to change without notice