MCMARTIN

a presentation by

Leonard Hedlund

Vice President and Director
of
Research and Development

before

the FM Clinic
Madison, Wisconsin

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TOMORROW'S FM MONITORS - TODAY

THEORY OF DESIGN

The new generation of FM monitors consists of a base band modulation monitor, the TBM-3500B, a baseband frequency and modulation monitor, the TBM-3700, a TBM-2200A stereo monitor, and the TBM-2000B SCA monitor. The TBM-3700 or TBM-3500B is used for the measurement of all the modulation parameters of the baseband RF carrier. The TBM-3700 also measures carrier center frequency deviation. The add-on TBM-2200A stereo monitor and TBM-2000B SCA monitor are driven from the wide band composite outputs of the TBM-3700, or the TBM-3500B.

The new generation monitors utilize plug-in cards rather than plug-in modules used in the previous generation. The advantage is easier servicing as all components are accessible on the plug-in cards. The plug-in cards can be removed from the rear of the monitor without the unit being removed from the rack. Tantalum rather than aluminum electrolytic interstage capacitors are used for coupling insuring longer, trouble-free operation.

Electronic equipment experiences losses due to aging of components, such as change in characteristics of coils and filters, loss in meter amplifier gain, diodes, etc. We have also experienced loss of modulation meter sensitivity after a period of time, evidently due to loss of flux density. The changes, though small, can easily add up to over 0.5 dB error. This error in broadcast audio equipment is negligible but is serious in a monitor. A 0.5 dB error is equal to a modulation error of 5 percent in the base band monitor. Errors can also accumulate in the stereo monitor section. Especially in the 19 kHz band pass filters that are used to measure the 19 kHz pilot level. These filters must have high selectivity to reject 15 kHz audio signals that are nine times greater in amplitude than the 19 kHz pilot carrier. This requires high Q circuits. All present day monitors use high grade core material with a slow aging rate for the inductors and temperature compensating capacitors in the tuned circuits for stable operation over a wide temperature range. However, they are still subjected to amplitude losses due to slight detuning etc. over a period of time and can lead to serious error in the measurement of pilot injection. The same holds true for the measurement of SCA injection.

All four of the new monitors have built-in calibration facilities which allow simple daily checks to insure that the monitors are operating correctly and giving accurate measurements of all transmission parameters. The built-in calibration feature also insures that if a plug-in card is replaced in the field, it can be adjusted to the internal standard for continued accuracy, without returning the unit to the factory. The TBM-3700 frequency and modulation monitor utilizes completely separate circuitry for modulation and frequency circuits without affecting the accuracy of the modulation measurements, and vice versa. The frequency meter discriminator is very stable and from many field reports seldom requires adjustment of the meter zero control.

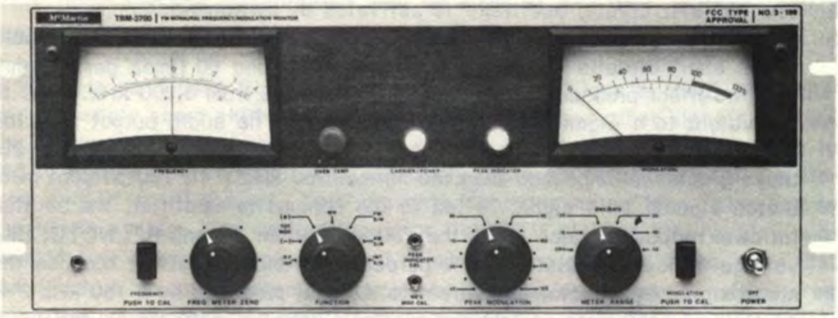
Another advantage separate circuitry gives is the ability to check the frequency meter zero calibration while the station is programming without interrupting monitor audio output. This can be important if you are using the monitor as a source of 'off air' house monitoring.

Although the FCC has relaxed the requirement for FM station frequency monitors, I personally feel that a frequency monitor is still necessary in monitoring the carrier frequency. Some may argue that you are simply comparing a crystal in the transmitter against a crystal in the monitor and the crystal in the transmitter may be as stable as in the monitor. True, this is very possible, but should a serious frequency error be indicated by the frequency monitor it will alert the station engineer to the fact that possibly the error may be in the transmitter. He can immediately take steps to insure that his station frequency is correct. Without any type of frequency monitoring, the engineer would be unaware if the transmitter frequency control system would suddenly malfunction and change frequency to another channel. I have known of several cases where this has happened involving transmitters using the phase lock technique of frequency control, where the exciter locked to a sub multiple of the divider chain. One station received calls from listeners saying they were receiving their station at another place on the dial. The station engineer said this was impossible as his exciter showed that it was in proper phase lock condition, however in further checking he found that the listeners were right and the unit had accidently locked to another frequency. This can occur if the exciter is severely overmodulated or subjected to a high DC transient.

Even though the FCC does not require a frequency monitor, it is still the responsibility of the licensee to maintain the station frequency within the specified limits at all times.

For those stations who wish to rely on the inherent frequency stability of their transmitter, or those who have accurate frequency counters available to them as a separate instrument, McMartin has developed the TBM-3500B which monitors modulation percentage only. The basic circuitry of the TBM-3500B is similar to that used in the modulation monitoring portion of the TBM-3700. A very important improvement has been incorporated into the TBM-3500B design. This is the ability to increase the input sensitivity to 350 microvolts by insertion of an optional plug-in card, the LL-35B. Where adequate field intensity exists this makes it practical to drive the TBM-3500B from antenna-derived 'off air' signals. When practical caution is exercised in the antenna installation to eliminate external noise and interference and maintain phase linearity, the off-air performance of the TBM-3500B is identical to its performance when fed directly from a transmitter output.

TBM-3700
FREQUENCY MODULATION MONITOR



I have a block diagram of the TBM-3700, Figure 1, and will explain the method used to produce the internal calibration voltage for calibration of the modulation measuring circuits.

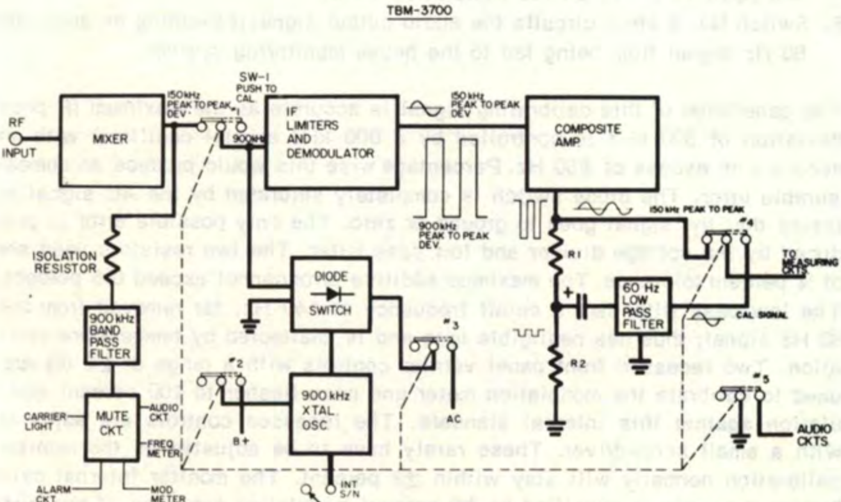


Figure 1

The local crystal control oscillator operates 900 kHz above the incoming RF signal producing a 900 kHz IF frequency. In normal operation the 900 kHz signal is deviated ±75 kHz which is equivalent to 150 kHz P-P for 100 percent modulation. This signal is fed to the IF limiters and demodulator.

When the 'Mod Push to Cal' switch on the TBM-3700 is depressed, the following 5 events occur simultaneously: (Note: the 5 sections of the switch shown in Figure 1 are in the 'depressed' position.)

1. The signal from the mixer is removed by switch No. 1.
2. The 900 kHz crystal oscillator is activated by switch No. 2.
3. Switch No. 3 feeds an AC signal to a diode switch (note diode block) which short circuits the 900 kHz signal to ground 60 times per second. This in effect produces an IF frequency deviated from 0-900 kHz. This is equivalent to a signal deviated 900 kHz P-P. The audio output from the demodulator under this condition consists of a signal which is now six times greater in amplitude than the normal 150 kHz P-P, 100 percent modulated signal. This signal is fed to the composite amplifier, the emitter follower output of which feeds the voltage divider R1 and R2. NOTE: this voltage divider, consisting of ¼ percent tolerance resistors, reduces the audio signal by a factor equivalent to a signal produced by a 150 kHz P-P deviation or 100 percent modulation. This signal is a 60 Hz square wave signal and is fed to a 60 Hz low pass filter which removes all harmonics and restores the 60 Hz signal to a pure sine wave with distortion of less than 0.1 percent. We now have an accurate internal signal for calibrating the rest of the measuring circuits.
4. This low distortion 60 Hz signal is fed through switch No. 4 to the phase splitter and measuring circuitry. This signal is ideal as a signal with negligible distortion as required for accurately adjusting equal negative and positive peaks on the modulation meter.
5. Switch No. 5 short circuits the audio output signal preventing an annoying 60 Hz signal from being fed to the house monitoring system.

The generation of this calibrating signal is accurate as the maximum IF peak deviation of 900 kHz is controlled by a 900 kHz crystal oscillator with an accuracy in excess of ±50 Hz. Percentage wise this would produce an unmeasurable error. The diode switch is completely saturated by the AC signal to insure that the signal goes to ground or zero. The only possible error is produced by the voltage divider and low pass filter. The two resistors used are of ¼ percent tolerance. The maximum additive error cannot exceed 0.5 percent. The low pass filter has a cutoff frequency of 140 Hz, far removed from the 60 Hz signal, thus has negligible loss and is unaffected by temperature variation. Two recessed front panel vernier controls with a range of ±2 dB are used to calibrate the modulation meter and peak flasher to 100 percent modulation against this internal standard. The recessed controls are adjusted with a small screwdriver. These rarely have to be adjusted as the monitor calibration normally will stay within ±2 percent. The monitor internal calibration accuracy is specified as ±2 percent modulation accuracy. If the modulation meter or peak flasher cannot be calibrated to 100 percent with the recessed front panel control, a malfunction has occurred and immediate servicing should be done.

When doing the annual proof of performance, the question frequently arises as to whether the monitor or the transmitter equipment is at fault if an FM S/N reading of 60 dB cannot be met. The TBM-3700 has provision for verifying the inherent noise characteristics of the monitor. By switching the function switch to the 'Int-S/N Noise' position, the signal from the transmitter is activated by Switch No. 6 (Figure 1) and fed to the mixer input. This will verify the inherent FM noise of the monitor which should be in excess of -70 dB below 100 percent modulation when the unit is performing properly. This internal noise measurement may be made at any time, with or without modulation.

A 900 kHz band pass filter with a bandwidth of 90 kHz at the 3 dB points and extremely sharp skirts that will reject adjacent and other signals outside the assigned channel frequency of the monitor is incorporated. This signal is fed to a mute circuit which will positively mute all functions when the station carrier is off the air. This prevents annoying noise from being fed to the house system. The carrier indicator light will also go off. A relay contact closure occurs and may be used to activate an external alarm. Note that the filter is completely isolated from the modulation measuring circuits as this filter would otherwise create serious modulation errors due to disturbance of the sidebands produced by modulation. Severe overmodulation will also mute the monitor.

Optional remote monitoring facilities are available for frequency and modulation measurement as well as peak flasher operation.

TBM-3500B
MODULATION MONITOR

A recent addition to the McMartin monitor line is the new FCC type approved TBM-3500B base-band monitor. The TBM-3500B is used for the measurement of all the wide band modulation parameters of the RF carrier. Two composite outputs feature flat frequency response beyond 100 kHz with accurate duplication of the original modulation signal. As with the TBM-3700, the TBM-3500B may be used for stereo and/or SCA monitoring when used with the TBM-2200A and TBM-2000B.

The TBM-3500B also features an optional A1-A plug in, low level card to allow operation of the monitor with RF input signal level as low as 350 microvolts obtained from an antenna, with minimal degradation of composite signals and frequency response extending to 100 kHz. The standard A-1 RF card requires operation directly from the transmitter pickup with an input level of .01 to 1 watt. The RF attenuator is located on the front panel for setting the RF level to the correct value.

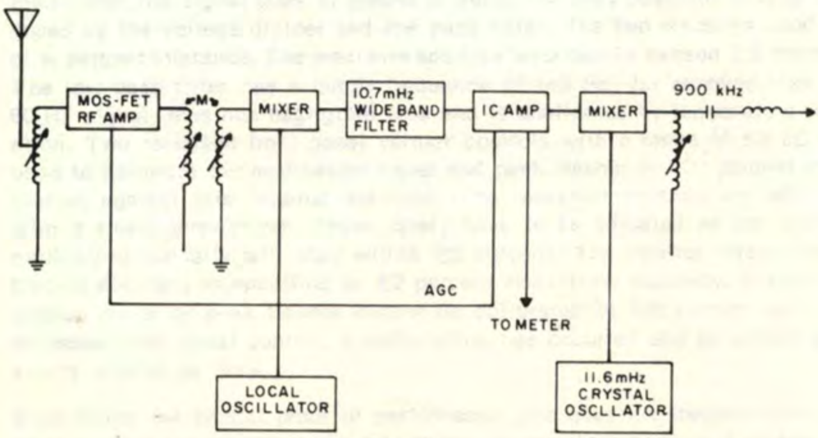


Figure 2

I have a block diagram of the low level A1-A card, figure 2.

The input signal is fed through a preselector coil to a low noise MOS FET RF amplifier. This is followed by two high Q coils feeding an integrated circuit (IC) mixer operating in a differential mode. The local oscillator operates at 10.7 MHz below the carrier frequency thus producing an IF frequency of 10.7 MHz. The 10.7 MHz signal is fed to a special 10.7 MHz bandpass filter with a bandwidth of 530 kHz at the 3 dB points and extremely sharp skirts with a 50 dB bandwidth of only 850 kHz. Thus giving good rejection to alternate channels.

The linearity is such that minimal degradation occurs and excellent distortion exists at frequencies up to 100 kHz measured with a wide band distortion meter.

The signal from the filter is fed to an IC amplifier with a gain of at least 70 dB and exceptionally hard limiting. This hard limited signal is fed to a second bipolar mixer. An 11.6 MHz crystal oscillator is mixed with the 10.7 MHz signal producing a 900 kHz IF signal which is fed into the 900 kHz amplifier, limiter, and demodulator identical to the demodulator card used in the TBM-3700. Thus, the same internal calibration scheme is used in the TBM-3500B as in the TBM-3700.

The integrated circuit used following the wideband 10.7 MHz filter has provision for supplying AGC voltage to the RF amplifier providing excellent RF gain control and allowing operation of the monitor with signals as high as one volt without creating phase error in the recovered composite signal.

The integrated circuit also supplies a squelch signal. The squelch point is purposely set at 350 microvolts as signals below this level are subject to noise which can cause erroneous modulation readings due to the wide band width of the composite signal.

The modulation meter will indicate the RF level when the function switch is in the RF level position. Any signal over 85 percent indicates adequate RF input for proper operation of the low level card.

The circuitry following the demodulator is identical to the modulation portion of the TBM-3700.

TBM-2200A
STEREO MONITOR

The new TBM-2200A stereo monitor has the capability of measuring the frequency deviation of the 19 kHz pilot carrier within ±2 Hz, in increments of 0.1 Hz, as well as all other parameters of the stereo signal. Two modulation meters are used. The left meter indicates pilot injection, left channel modulation, L+R modulation and 38 kHz carrier suppression. The right meter indicates right channel modulation and L-R modulation.

Figure 3 on the following page explains the operation of the internal calibration facilities for measuring the 19 kHz pilot injection level of the TBM-2200A stereo monitor.

The proper operating level is determined by the 60 Hz internal calibration signal from the TBM-3700.

With the 'Push to Cal' switch depressed on the TBM-3700/TBM-3500B base band unit, the internal 60 Hz calibrate signal is fed via a coaxial interconnecting cable to the input of the stereo monitor. The front panel recessed 'level set' control A of the TBM-2200A is adjusted to give a reading of exactly 100 percent on the left meter with the function switch in the 'Cal' position. This sets the operating level with a signal equal to 100 percent modulation.

Tracing the signal in Figure 3, note that the 60 Hz signal from the 'level set' control is fed through the No. 1 section of the 'Push to Cal' switch SW-1. This signal then continues to the 'Calibrate' position of the function switch and is routed through a meter amplifier (not shown) to the left modulation meter.

When the 'Push to Cal' switch on the TBM-2200A is depressed, the following events occur simultaneously: NOTE: The 3 sections of the switch are now in the 'C' position.

A 190 kHz crystal oscillator and ÷10 circuitry is activated by switch No. 3. The stable 190 kHz oscillator frequency error is divided by 10 producing a very accurate 19 kHz square wave signal which is fed through a 19 kHz low pass filter. This removes all harmonics, resulting in a very low distorted 19 kHz signal fed to the recessed 'Internal Cal': Control B. The 19 kHz signal from this control is fed through the center arm of switch No. 1 directly to the function switch 'Cal Position' through a meter amplifier (not shown) to the left modulation meter. The 'Internal Cal' control B is adjusted for a reading of 100 percent on the left meter. This adjusts the 19 kHz signal to a level equal to 100 percent modulation. Voltage divider R-1 and R-2 divide this 19 kHz signal to a level of exactly 10 percent modulation. This signal is fed through the center arm of switch No. 2 to the selective 19 kHz amplifier feeding the recessed 'Inj. Cal. Control C.'

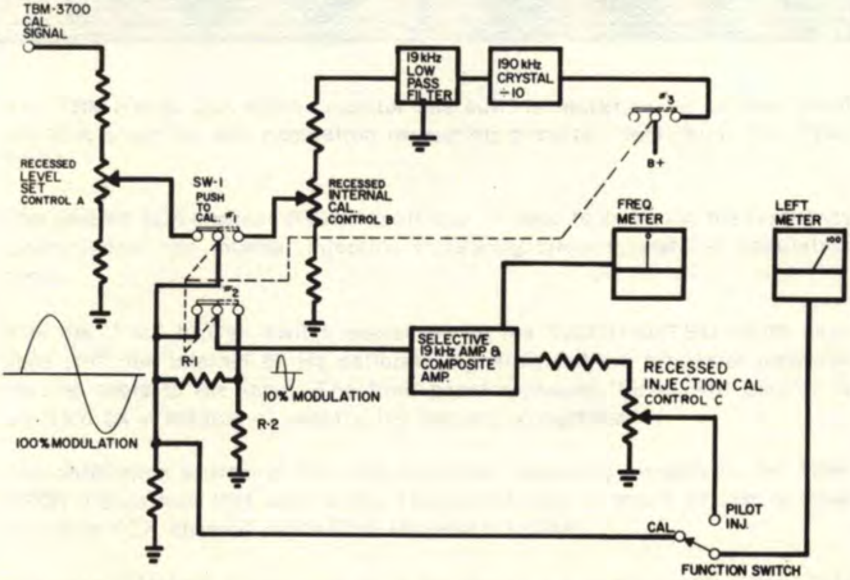


Figure 3

With the function switch in the 'Inj. Position' and with the 'Push to Cal' switch SW-1 depressed, the 10 percent calibrate voltage is now routed through the highly selective 19 kHz measuring circuits and through the function switch to the meter amplifier and left meter. The recessed 'Inj. Cal' control C is adjusted for a reading of 10 percent Injection on the meter. The pilot injection accuracy is specified as ± 0.2 percent error.

The 'Push to Cal' switch serves an additional function, that of calibrating the zero center of the 19 kHz frequency meter.

Another method of calibrating the zero center of the frequency is incorporated. This is accomplished by depressing the 'Freq. Push to Cal' switch located on the right side of the monitor. This operation allows checking the frequency meter zero calibrate at any time without interrupting any other function or program material.

Simultaneous monitoring of the total left and right channel modulation is possible with the TBM-3700/TBM-3500B and TBM-2200A combination. Complete remote monitoring facilities of the left and right modulation and pilot frequency are available.

TBM-2000B
SCA MONITOR

The TBM-2000B SCA add-on monitor has built-in facilities for calibration of the SCA injection and modulation measuring circuits, identical to the TBM-2200A.

The desired SCA channel crystal oscillator is used to calibrate the frequency discriminator, the internal injection measuring circuits, and the modulation meter.

With the 'Push to Cal' switch depressed on the TBM-3700/TBM-3500B base band unit, the internal 60 Hz calibrate signal is fed via a coaxial interconnecting cable to the input. The front panel recessed 'Level Set' control is adjusted for a reading of exactly 100 percent modulation.

The calibration system of the SCA injection measuring circuits in the TBM-2000B differs from that used in the TBM-2200A only in that a 67 kHz or other specified SCA channel calibration frequency is used.

One special feature of this monitor is the use of a dual bandwidth filter. This filter compares a narrow band section that is used to accurately measure the injection level of subcarriers separated by only 5 kHz. The second section is a wide band, phase linear filter used for audio recovery of the FM modulated signal. it also permits accurate monitoring of injection level at any time with full SCA modulation. The narrow band filter is useful only in measuring an unmodulated carrier as the injection level will vary considerably when modulation sidebands are produced which extend beyond the restricted bandwidth characteristic of the filter.

A crystal reference oscillator and circuitry similar to the TBM-3700/TBM-3500B are used for establishing 100 percent modulation. 100 percent modulation, equivalent to ±6 kHz or ±4 kHz frequency deviation, is switch selectable by the operator.

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The 67 kHz reference oscillator is gated to produce a P-P deviation of 67 kHz. This deviation is divided down to a P-P deviation of either 12 or 8 kHz for internal reference level.

The TBM-2000B, like the TBM-3700 or TBM-3500B, has provision for verifying the inherent noise characteristics of the monitor. An internal crystal oscillator is substituted for the incoming signal. Typically the noise level is greater than 70 dB below 100 percent modulation, reference from ±6 kHz deviation.

The TBM-2000B has remote monitoring facilities of the frequency, modulation, and peak flasher.

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