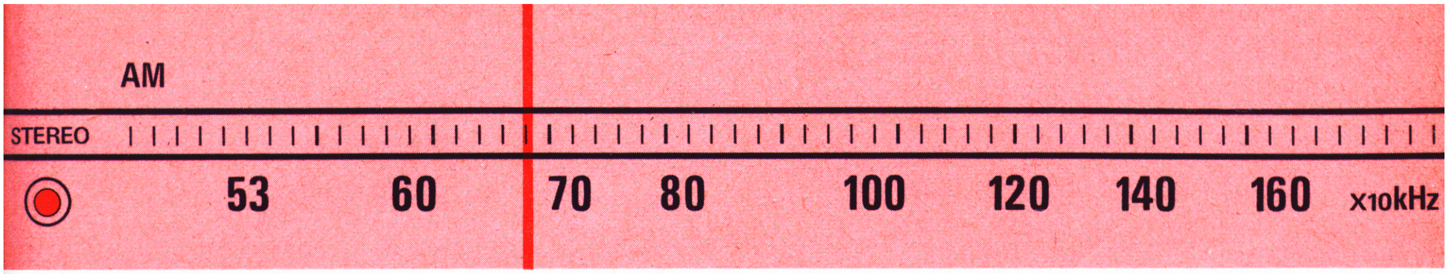


Broadcast Systems For AM Stereo

A number of different systems have been conceived in the years since AM stereo was first proposed. The FCC may soon select one as the standard

LEN FELDMAN
CONTRIBUTING HI-FI EDITOR

BY THE TIME YOU READ THIS, THE NATIONal AM Stereophonic Radio Committee (an audio industry group formed under the auspices of the Electronic Industries Association) will have completed its lab and field tests in Bethesda, MD. These tests are the culmination of a long series of events dating back to the 1950's, when the Federal Communications Commission was asked to make rules for stereophonic FM broadcasting. At that time, it was proposed that rules also be made for stereophonic AM broadcasting as well as for the stereophonic broadcasting of the audio portion of TV.

Rule making was initiated only for stereo FM broadcasts at that time, and in 1961, compatible stereo FM broadcasting began. It was felt that there was no real need for stereo sound on TV and that, in the case of stereo AM, owners of AM broadcast stations were doing quite well financially, whereas FM station owners were facing extreme economic hardships. To bolster the FM situation, action was first taken with regard to stereo FM to give those stations a clear advantage over their AM competition.

At present, FM broadcasting is an extremely healthy industry (some say it has surpassed the older AM in its economic success), and it is the AM broadcasters who have been crying for help! Apparently, if timetables hold, help is on the way. Before long, the FCC will be examining the massive amount of data submitted to it by the NAMSRC (*Na*tional *AM S*tereophonic *R*adio *C*ommittee) with an eye towards setting up new rules for stereo AM broadcasting.

When this committee began, at least five proponents offered stereo AM broadcast techniques for consideration. These were Leonard Kahn (whose stereo AM system has been successfully used in transmissions from Mexico for many years), RCA, Magnavox, Motorola and Sansui. In recent months (and in the field tests themselves), the number of systems has narrowed down to three: Magnavox, Motorola and the Belar Company (whose system is essentially that proposed originally by RCA). While the mathematics of each of the remaining systems is rather complex, we will review briefly how each system works and what changes must be made in transmitting and receiving equipment in order to handle each of the three remaining systems.

Magnavox system

The proposed Magnavox stereo AM broadcasting system is an AM/PM (*P*hase *M*odulation) system that places left-plus-right (L + R) information on a phase-modulated channel with a proposed phase deviation of one radian. In addition, a 5-Hz subaudible tone is frequency-modulated into the carrier with a deviation of approximately 100 Hz. This tone is for stereo identification (similar to the way a 19-kHz pilot carrier in stereo FM lights an indicator on the receiver) and is an attractive selling point.

A block diagram of the complete transmitter system is shown in Fig. 1. The transmitter uses nearly all of an existing monophonic AM transmitter with no modification. The channel oscillator is replaced with a phase-modulated signal generator and signal tone source. This signal generation method provides for on-frequency operation, eliminating the need for multiplying or mixing stages. The station carrier is generated on-frequency and modulated with a 5-Hz tone. This signal is then used as a reference for a wideband phase-locked-loop to generate a true phase-modulated (PM) signal on-frequency. The latter signal is then amplified and modulated by the L + R audio signal in the existing transmitter. The processing blocks shown at

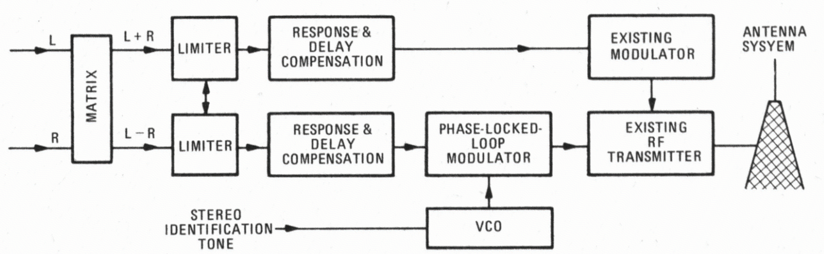


FIG. 1—TRANSMITTER FOR MAGNAVOX SYSTEM uses a phase-locked-loop to produce a phase modulated carrier. The audio signals are limited and compressed after matrixing.

the left of Fig. 1 limit and compress (as required) the audio signals *after* matrixing. This technique insures that the L + R loudness for the monophonic program listener will be maintained during reception of a stereo broadcast; and that, for the stereo listener, proper loudness tracking will be maintained between the L + R and L − R signals.

The receiver configuration shown in Fig. 2 is considered by Magnavox to be one of the main advantages of their system. It is a single IF system and uses a standard envelope detector for the AM channel. Since the carrier level is maintained for all program material, an automatic-gain control system capable of holding the L + R output nearly constant over a wide range of RF levels can be achieved. This allows for proper dematrixing of the L + R and L − R signals. The PM information is recovered by sampling the IF signal, limiting it and detecting it with a phase-locked-loop circuit.

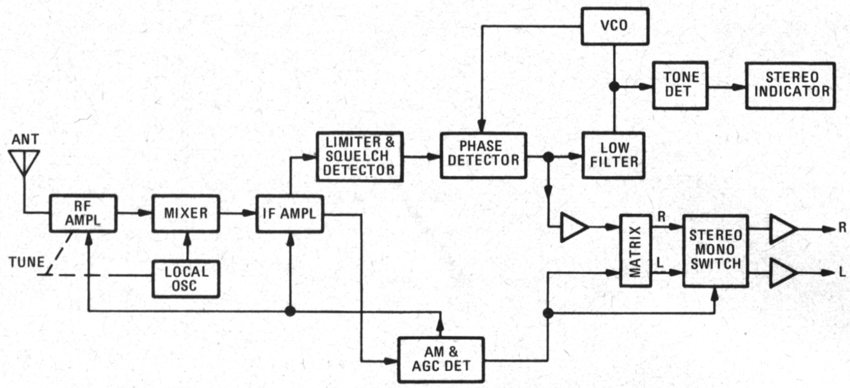


FIG. 2—RECEIVER FOR MAGNAVOX SYSTEM has single IF. A standard envelope detector recovers the AM channel. The phase-modulated information is recovered by a PLL.

The stereo identification tone is regenerated by recovering the audio tone that exists between the main voltage-controlled oscillator and the loop filter and passing it through a second phase-locked-loop circuit to drive an indicator. Left- and right-channel information is recovered from a standard matrix. In addition, an automatic mode switch that chooses between mono and stereo is driven by the presence or absence of the stereo signal.

Motorola system

The Motorola system basically involves transmitting two signals on one carrier by separately modulating two carriers at the same frequency and arranging them in phase quadrature with respect to each other. In color TV this method is used to transmit two separate color signals on a single subcarrier.

The phase of the existing broadcast carrier can be split into two separate components, angularly displaced by 90 degrees and each component can be separately modulated with one of the audio signals. The method provides a relatively simple modification of existing transmitters and stereo receivers that derive the left and right audio signals using simple product detectors, one for each channel. In its simplest form, the Motorola system can cause distortion in mono receivers when the left and right signals have significantly differing program content. This distortion is due to the use of current rectifiers or envelope detectors in a monophonic AM set.

The final version of the Motorola proposal slightly modified the radiated quadrature signal. The result is that distortion normally appearing in the mono receiver is transferred to the stereo receiver, where it is corrected to restore the original quadrature signal. The quadrature signal is then decoded by a pair of product multipliers to derive the left and right audio signals directly.

Figure 3 is a block diagram of a transmitter modified to produce a compatible quadrature signal. The transmitter uses the carrier-frequency oscillator to supply a signal to the modified exciter. The exciter splits the carrier into two components in quadrature phase. The first component is modulated by L + R, and part of the oscillator signal bypasses the balanced modulator to provide a residual carrier of the L + R phase. The second component is modulated with L − R to provide a suppressed carrier signal in quadrature with the first. The two signals are added and limited to create an output signal that drives the high-power transmitter stages, which are phase-modulated with the same phase information contained in the composite of the two modulated signals in quadrature.

The transmitter modulator is supplied with L + R to provide a compatible envelope signal for detection by a signal current or envelope detector.

Figure 4 is a block diagram of a receiver for the Motorola system. The receiver is similar to one used for the reception of two signals in quadrature, except that the carrier-level modulator restores the received signal to its original quadrature carrier form where the left and right signals can be taken directly from two product detectors. The in-phase detector can be used for squelch or auxiliary controls in addition to controlling gain.

Motorola cites several advantages for their system:

1. A minimum of monophonic coverage loss due to sky-wave sideband distortion of low-frequency audio signals.
2. The power spectrum at the transmitter signal closely resembles monophonic for the most stable compatible performance on monophonic receivers.
3. Left and right signals can be directly recovered from the demodulators without matrixing sum and difference signals.
4. Compatibility with monophonic receivers using envelope detection or synchronous detection.

Belar system

The Belar system is essentially the one originally proposed by RCA. The RCA Corporation is not an active proponent in the present stereo AM considerations.

This system uses a pre-emphasized

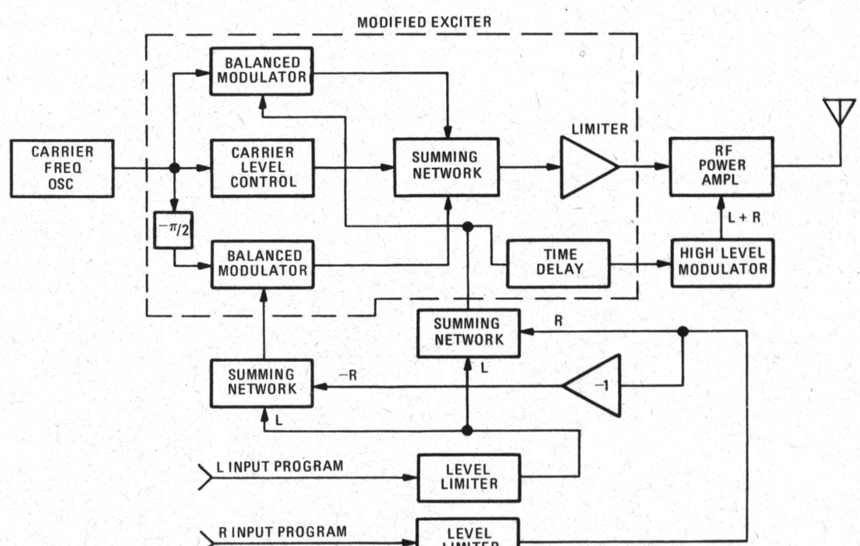


FIG. 3—TRANSMITTER FOR MOTOROLA SYSTEM modulates two carriers in phase quadrature. The modified exciter splits the carrier into two components in quadrature phase.

L − R signal to frequency-modulate the carrier. The resulting signal is amplitude-modulated with the monophonic sum signal, L + R. A transmitter block diagram for this AM/FM system is shown in Fig. 5. The FM exciter, carrying the L − R modulation, replaces the ordinary fixed-frequency crystal exciter that would be used in ordinary monophonic AM transmission.

Figure 6 shows a receiver that would be suitable for use with this AM/FM system. The output of the common IF amplifier is fed to circuits that provide amplitude-insensitive FM detection. A form of dynamic limiter (preceding the discriminator) is shown. Because the diodes are self-biasing, the output is proportional to the mean level of the IF signal and no tracking circuitry is required.

A variation of this system, known as an AM/FM/AM system, in which the FM modulating signal is modified to (L − R)/(1 + L + R), was also investigated by RCA. A definitive paper on this modified system was published in the September 1960 issue of *The RCA Review*. In this modified system, the output of a balanced discriminator would be independent of the AM modulation and equal to (L + R), provided the carrier frequency is at the discriminator null. However, this system is highly subject to AM-to-FM crosstalk if the receiver is detuned and therefore requires some form of AFC circuitry to insure perfect tuning.

When will stereo AM begin?

No one can predict when or even if the FCC will decide upon one of the systems described here. If past history is any indication, in the case of stereo FM, the field tests were completed in early 1960 and a final report was submitted to the FCC shortly thereafter. The report and order approving the currently used stereo FM system were issued by the FCC in April, 1961. By the summer of that year, the first stations began transmitting stereophonically.

There are some indications that the FCC may move more rapidly in the case of stereo AM. For one thing, there are fewer system results to be analyzed (there were five proponents of stereo FM, all competing for acceptance). Also, pressure from the public and AM stations (all very much accustomed to stereo records, tapes and FM broadcasts) may cause the FCC to move more rapidly this time. In any event, when and if a system is approved, you can be sure that manufacturers will scurry to be out there with suitable stereo AM tuners and receivers as quickly as possible.

One final word regarding stereo AM is, perhaps, in order. As most readers are aware, AM as broadcast and received in this country can hardly be considered a "high-fidelity" broadcast medium. Not that it could never be! There are many AM stations in this country that take pride in broadcasting audio signals having a frequency response right out to 15,000 Hz, just like FM. However, most AM receivers and tuners are unable to reproduce much above 4 or 5 kHz, and many AM broadcast stations use standard telephone lines to pipe their signals from studios to transmitters, and these lines have about the same high-frequency response limitations.

So, unless you own one of the few wideband AM receivers, and unless stations start using high-fidelity lines when stereo AM is finally approved, you will not hear Hi-Fi over AM just because you can receive separate left and right channels. The musical instrument and vocal sounds may move to their proper stage locations—and that will certainly lend some excitement to AM reception—but the fidelity of those instruments and voices will still be as low as you are accustomed to hearing over AM. **R-E**

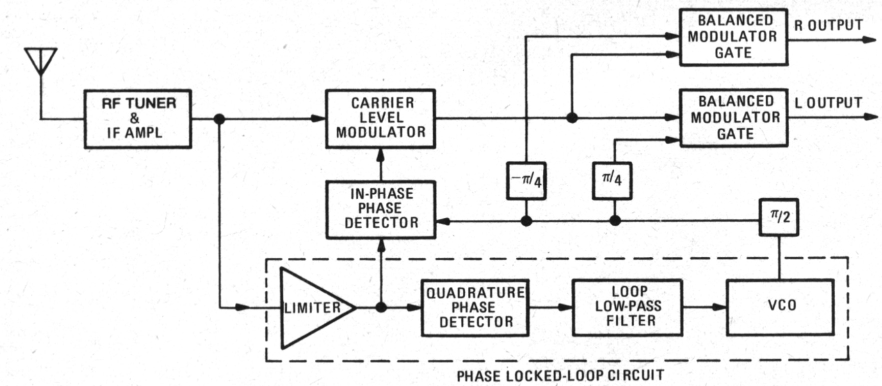


FIG. 4—RECEIVER FOR MOTOROLA SYSTEM. Phase-locked-loop and balanced modulators recover the R and L signals.

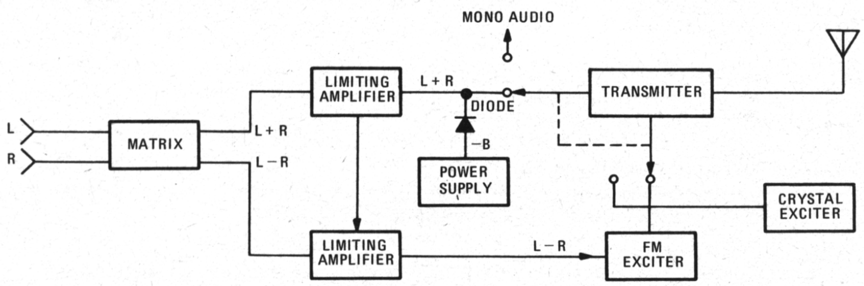


FIG. 5—TRANSMITTER FOR BELAR SYSTEM. The carrier is frequency modulated by the difference signal and amplitude modulated by the sum signal.

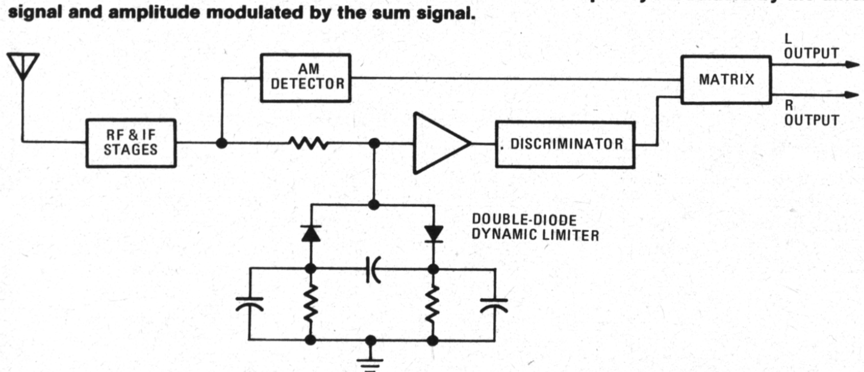


FIG. 6—RECEIVER FOR BELAR SYSTEM uses a dynamic limiter circuit to provide AM-insensitive FM detection.

AM STEREO
SOON ON THE AIR?

BY JOE DEANGELO

Five proposals for AM stereo systems are being considered by the FCC. One may be on the air in 1979, revitalizing AM broadcasting

AM-BROADCAST stations are about to undergo a massive change. During the summer of 1979, assuming the FCC comes to a final decision by then, many AM stations in your area will begin broadcasting in stereo.

AM stereo is not new. In 1925, WPAY (New Haven, CT) made the first wireless stereo transmissions by broadcasting from two separate AM transmitters on two different frequencies. In the mid-1950s, a small number of stations expressed renewed interest in AM stereo by experimenting with AM and FM simulcasting. Historically, then, two separate receivers were needed to obtain stereo audio. With the new systems proposed to the FCC and detailed here, a single AM-stereo transmitter and a single AM-stereo receiver are needed. The transmitted AM-stereo signal is also mono-compatible.

The Contenders. There are five AM-stereo system designs presently before the FCC, proposed by Belar Laboratories, Harris Corp., Kahn Communications, Magnavox, and Motorola. Each system has its own unique method for generating stereo signals.

The *Belar* system amplitude modulates the carrier with L + R information and frequency modulates the carrier with L − R information, using 320-Hz frequency deviation and 400-µs preemphasis. The *Harris* system employs quadrature modulation with a reduced L − R component, which is equivalent to L and R modulation of two carriers separated in phase by 30°. The *Khan* system uses independent-sideband (ISB) modulation to force the modulated envelope to carry L and R informaton. *Magnavox's* system utilizes simple L + R amplitude modulation with L − R phase modulation of the carrier with 57° phase deviation. Finally, *Motorola's* system, like the Harris system, employs quadrature modulation, but it predistorts the entire signal, not just the L + R sidebands, to force the modulated envelope to carry the L + R information.

Each of the proposed AM-stereo systems is compatible with the mono receivers currently in use. Compatibility with present-day mono envelope detectors and good stereo performance have been the major hurdle for the proponents of AM stereo. The challenge has been met with some success.

Some common features and methods appear in each of the proposed AM-stereo systems. All process the audio

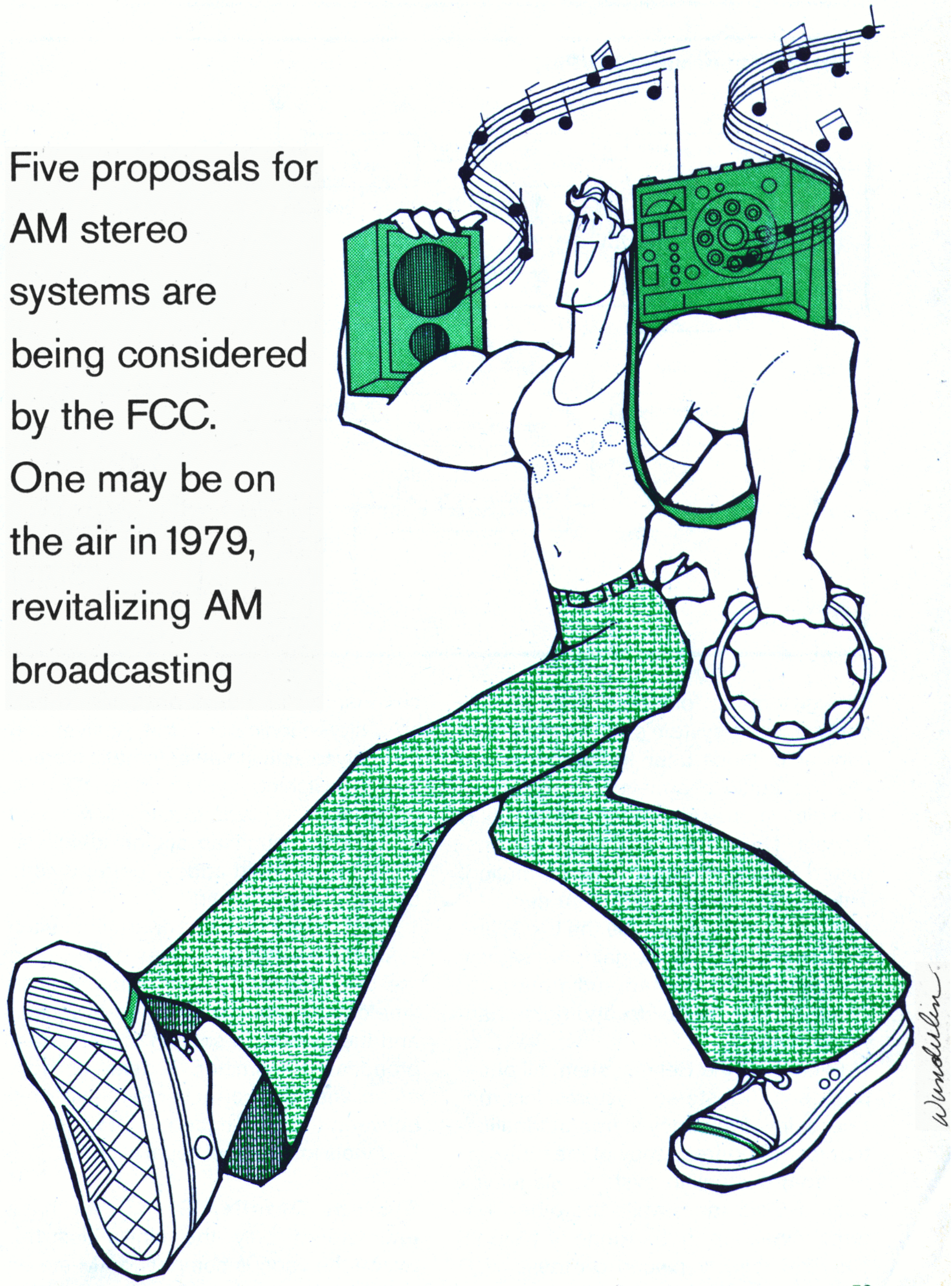


Fig. 1. Belar (AM/FM)

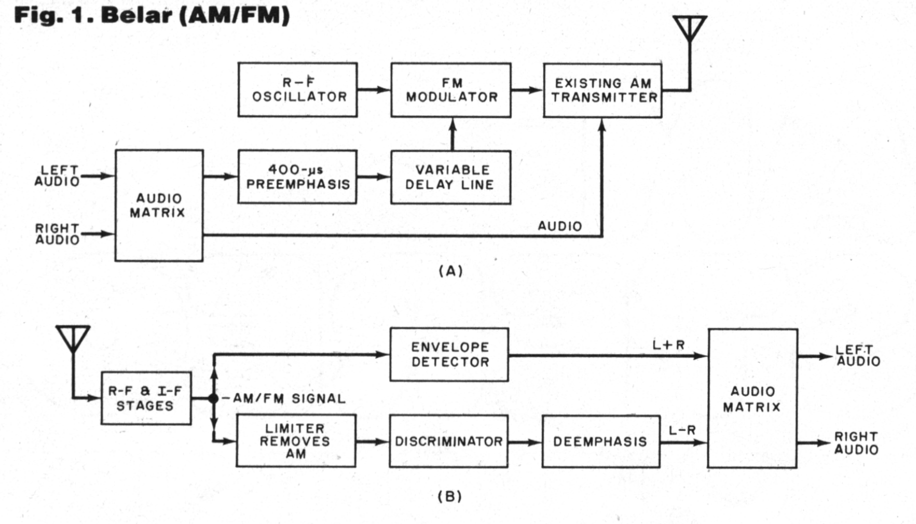
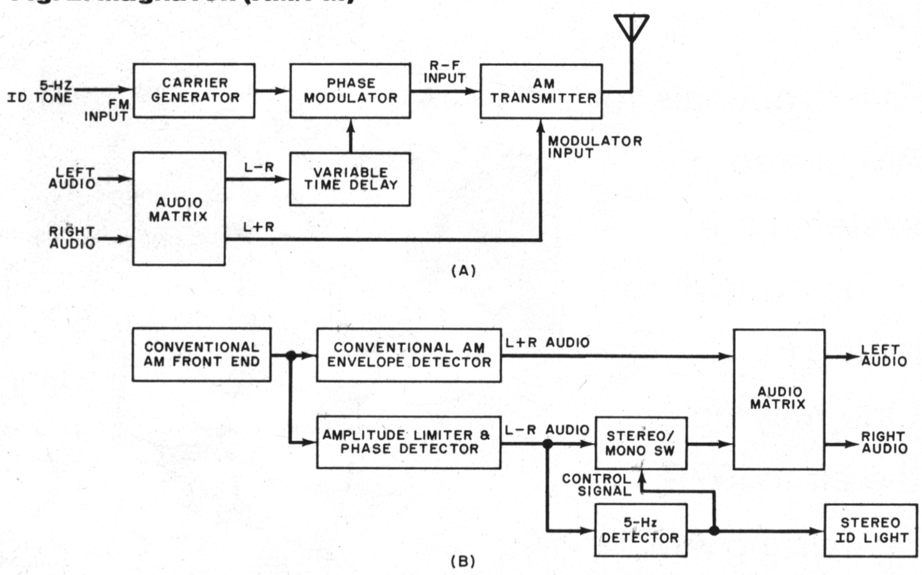


Fig. 2. Magnavox (AM/PM)



through a matrix for transmission and reception. Each system's stereo generator (similar to those used in FM) combines the two audio channels to give L + R and also subtracts them to obtain L − R signals. The stereo information is transmitted as L + R and L − R information. The AM-stereo receivers then demodulate the carrier and derive the L + R and L − R signals. Once again, the signals are passed through an audio matrix to obtain independent left- and right-channel signals.

Except for the Belar system, all of the proposed AM-stereo systems incorporate a low-frequency stereo-indentification tone. The frequency of the tone varies from system to system. Magnavox uses a 5-Hz tone, while the other systems' tones are in the range of 15 to 25 Hz. The tone is placed on the L − R channel signal and is designed to turn on a stereo indicator in the receiver and possibly to activate an automatic stereo/mono switching system. The ID tone could also be used to carry low-speed digital data, such as station identifications, which could appear on a numeric display in the receiver.

To preserve audio separation, each system employs time-delay networks in the L + R or/and L − R paths. A finite time delay exists between the r-f section and the modulator section of a standard broadcast transmitter. A delay network establishes the correct time relationship between the transmitted L + R and L − R signals for channel separation.

System Details. So far, we have enumerated only the similarities between the various competing AM-stereo systems. Now let us look at the individual systems in brief detail.

Belar (AM/FM). This system uses AM/FM techniques for modulation. The L + R audio component is applied to the modulator stage of the transmitter and amplitude modulates an FM carrier (Fig. 1A). This allows current mono receivers to detect L + R audio and makes the Belar system mono-compatible.

To generate the stereo part of the signal, the L − R information from an audio matrix is applied to a 400-μs preemphasis network and a time-delay network that, in turn, frequency modulates the carrier. Peak deviation of the carrier is ± 320 Hz. The FM carrier is then amplitude modulated.

Reception of the Belar signal is perhaps the easiest for the five systems. The i-f output of the receiver (Fig. 1B) is split into two paths. One path goes to an envelope detector that recovers L + R information and the other goes to a hard limiter that strips away all AM components. The limited i-f signal then passes through a frequency discriminator that recovers L − R information. The L − R audio must then be deemphasized to cancel out the preemphasis applied at the transmitter. The detected L + R and L − R audio components are then applied to an audio matrix, where discrete left- and right-channel signals are obtained.

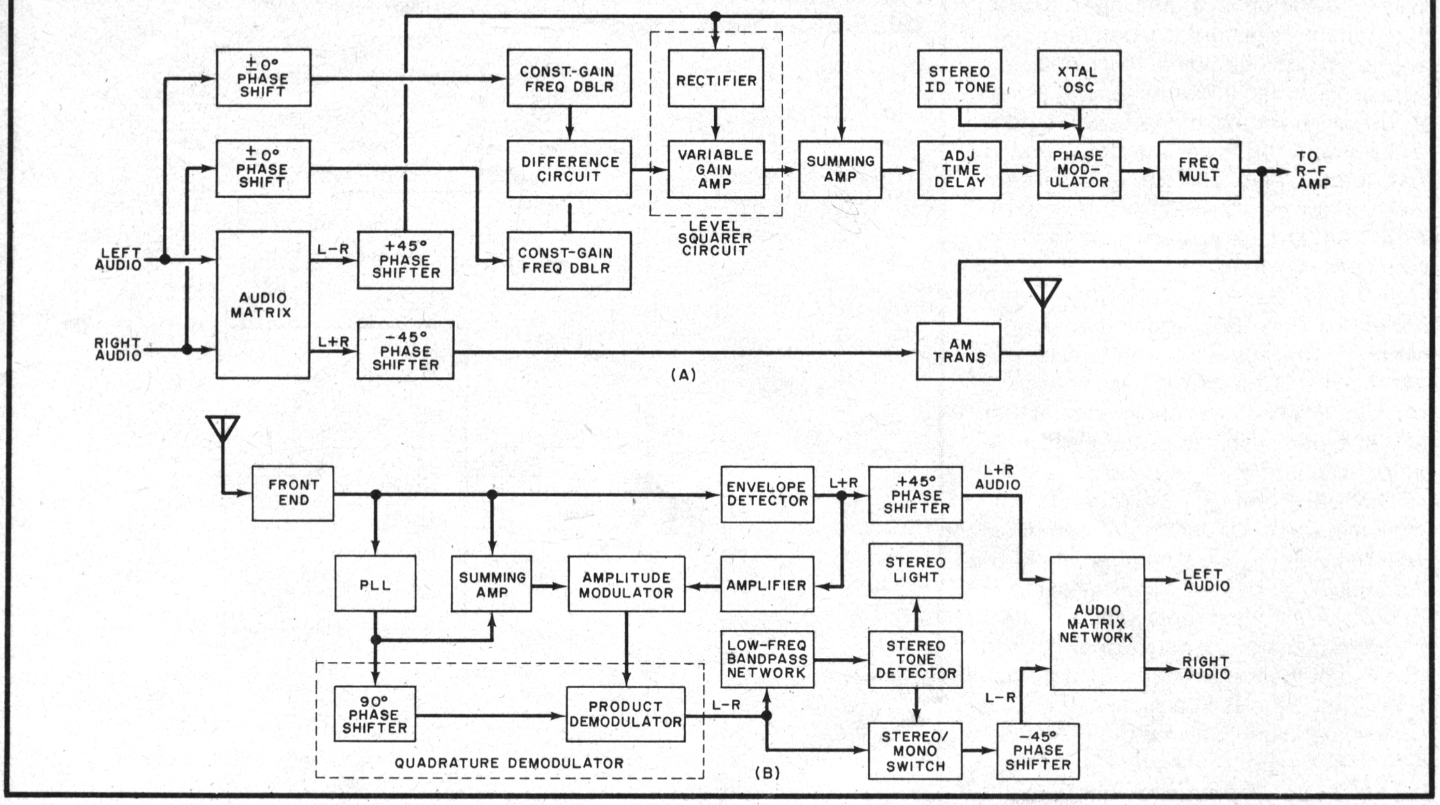
Magnavox (AM/PM). Somewhat similar to that of Belar, in this system, the L + R information amplitude modulates the carrier and the L − R information phase modulates the carrier (Fig. 2A). The phase variation of the carrier is held to a peak of 57°. The FM carrier is then amplitude modulated.

Reception of the AM/PM signal is illustrated in Fig. 2B. The i-f signal is split into two paths, one of which goes to an envelope detector to recover the L + R information and the other goes to a limiter to eliminate AM components. A phase detector is then used to recover the L − R audio. The recovered L + R and L − R signals are combined in an audio matrix to yield independent left- and right-channel stereo signals.

Kahn (ISB). In this independent-sideband (ISB) modulation system, the left-channel information appears on the lower sideband and the right-channel information appears on the upper sideband. This system predistorts the entire signal to force the envelope to carry L + R signals for mono compatibility.

As shown in Fig. 3A, the left and right audio channels are applied to a matrix.

Fig. 3. Kahn (ISB)



The L + R signal goes to a −45° phase-shift network and is applied to the audio inputs of a standard transmitter. The L − R information passes through a +45° phase-shift network. At this point, the L + R and L − R signals are 90° out-of-phase with each other. The L − R component feeds a summation network and controls an agc circuit. A variable time-delay network is inserted in the output of the summation amplifier to equalize the delays between the L − R and L + R signal paths.

The output of an oscillator that operates at a submultiple of the standard broadcast transmitter's frequency is applied to a phase modulator. The L − R audio signal from the time-delay network is then applied. The PM signal is brought up to the carrier frequency by a frequency multiplier. The PM carrier is then routed to the transmitter.

Kahn discovered that a further improvement in channel separation was possible by adding a second-harmonic phase-modulated component. Independent left and right audio signals are routed through differential phase networks with zero relative phase. The second-harmonic component is obtained from constant-amplitude frequency doublers, the outputs of which are applied to a difference network, followed by a level squarer.

The level squarer is essentially an agc amplifier whose gain is controlled by a sample of the L − R signal. The agc amplifier supplies the proper amount of second-harmonic component to optimize separation. When the audio signals are equal and in-phase, the L − R commponent is zero and correspondingly reduces the agc's gain to zero. (This would be the case with mono audio.) When both channels are present and in-phase but not equal, the agc amplifier's gain is only partially reduced.

Kahn developed the ISB system with the objective that two ordinary mono AM receivers could be used to receive stereo. One receiver could be used to tune the lower sideband for the left channel and the other to tune the upper sideband for the right channel. Single AM receivers would need only be tuned on-carrier for mono L + R reception.

The ISB signal can also be recovered with a single receiver. Kahn has outlined various ways in which this can be accomplished. One reception scheme incorporates independent i-f stages. Another scheme employs a single i-f section, as shown in Fig. 3B.

Kahn Communications developed one of the first AM-stereo systems. Leonard Kahn petitioned the FCC for adoption of AM stereo as early as 1959. Since then, he has field tested his AM-stereo on WFBR (Baltimore, MD) and XETRA (Tijuana, Mexico).

Motorola (C-QUAM). Motorola has developed yet another technique for transmitting and receiving AM stereo. Its C-QUAM (Compatible Quadrature Modulation) system is perhaps the most convenient means for transmitting two signals on one carrier. Quadrature modulation is perhaps best known for its application to color television, where two separate color signals are transmitted on a redundant single subcarrier.

To best understand the C-QUAM system, let us first look at an AM-stereo system that uses basic quadrature modulation. (This basic discussion on quadrature modulation also applies to the Harris AM-stereo system, which uses modified quadrature modulation.)

A system for transmitting two signals in quadrature is shown in Fig. 4A. Here, two separate transmitters are fed from a single carrier oscillator, with the phase of one carrier leading the other by 90°. One AM transmitter is modulated with left- and the other with right-channel information. The respective outputs are combined and broadcast by a common antenna. The use of two independent transmitters for generation of quadrature modulation is not necessary for practical applications. At the receiver (Fig. 4B), each carrier is detected to derive the left and right audio channels.

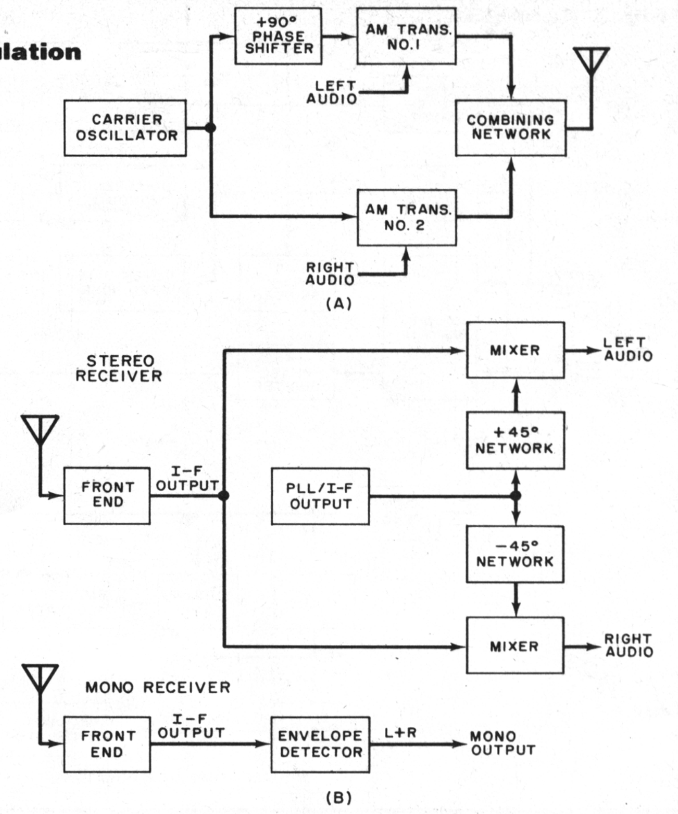
AM-stereo quadrature modulation presents a problem in compatibility with today's envelope detectors. An envelope detector is a nonlinear device that generates distortion when the quadrature signal contains a significant amount of stereo information. The signal recovered from the mono envelope detector is not the linear sum of L and R and it can also contain a significant amount of distortion (28% maximum). The C-QUAM system attempts to overcome this problem.

In the proposed C-Quam AM-stereo generator (Fig. 5A), the left and right channels are applied to the familiar audio matrix. One carrier is amplitude modulated with L + R audio and another carrier is phase shifted by 90° and amplitude modulated by L − R audio.

The L + R and L − R sidebands from the balanced modulators are combined with the carrier in a summing amplifier. The output of this amplifier is limited to remove AM components. The resultant phase-modulated carrier signal is used in place of the transmitter's crystal oscillator. The L + R information from the matrix is applied to a time-delay network and then to the transmitter.

The C-QUAM system overcomes the mono envelope-detector distortion problems associated with conventional quadrature modulation. The C-QUAM system inherently generates distortion products when it amplitude modulates the PM carrier. These distortion products cancel quadrature distortion in an envelope detector if they are received in the same relative phase and amplitude relationships. This design philosophy has two shortcomings. First, it places critical phase and amplitude requirements on the receiver's i-f section. Secondly, the generated distortion products that cancel the mono envelope detector's distortion appear in the stereo receiver. These distortion terms must be

Fig. 4. Basic Quadrature Modulation



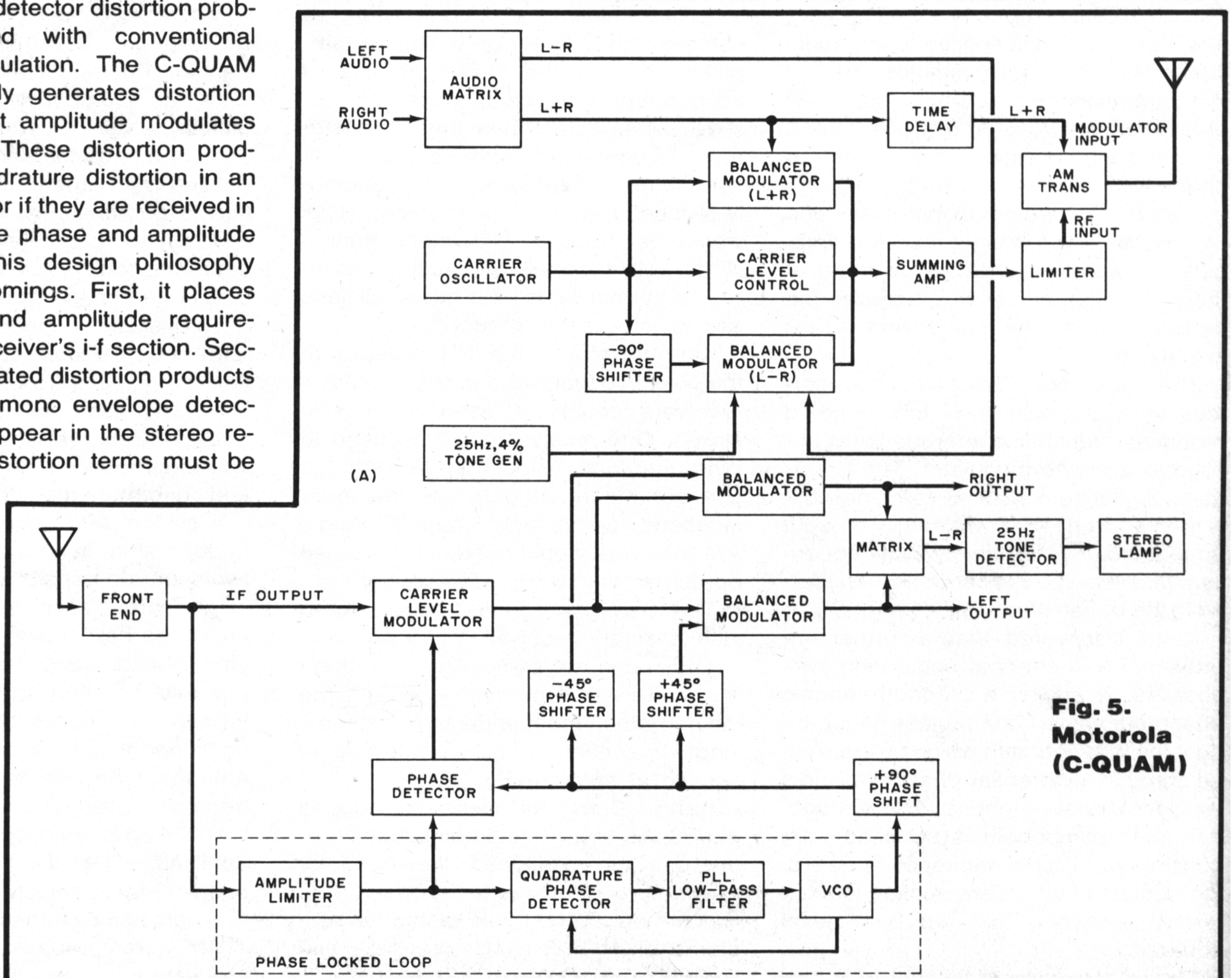


Fig. 5. Motorola (C-QUAM)

corrected, for which processing circuits are required in every C-QUAM receiver.

The C-QUAM AM-stereo signal can be received by using synchronous detectors, as shown in Fig. 5B. The receiver's i-f is applied to a carrier level modulator and an amplitude limiter. A voltage-controlled oscillator (vco) is locked in-phase with the i-f carrier. The outputs of the vco and limiter provide input signals for the phase-detector circuit. The phase detector and the necessary low-pass filter keep the vco locked in phase quadrature with the i-f carrier signal.

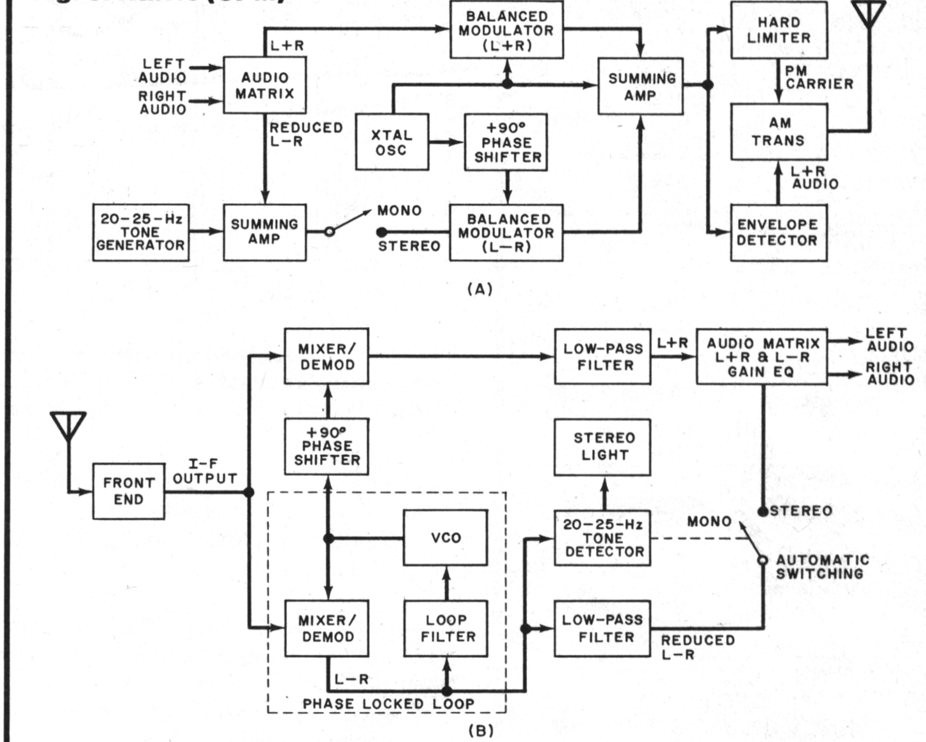
The vco's output is shifted 90° to provide a signal that is in-phase with the receiver's i-f signal. The phase-shifted vco signal is used with a signal from the amplitude limiter to feed the phase detector, which, in turn, drives the carrier level modulator. The carrier level modulator is simply a multiplier that converts the C-QUAM i-f signal to a quadrature i-f signal. The left and right signals can be recovered by synchronous detectors. The synchronous detectors (balanced modulators) are supplied with the quadrature i-f signal and i-f carrier generated by the vco and shifted by ±45°.

The left and right outputs of the balanced modulators can be routed to the audio amplifier. To recover the stereo identification signal, sample left and right signals are matrixed together. The matrixed L − R signal feeds a 25-Hz tone detector. The stereo ID tone then turns on a stereo indicator in the receiver and would possibly operate a stereo/mono switch in the input to the audio amplifiers.

Harris (CPM). The Harris Compatible Phase Multiplex (CPM) system is a linear-additive quadrature modulation scheme. The CPM system amplitude modulates two carrier signals separated in phase by 30°. The left-channel signal amplitude modulates a carrier that lags the transmitted resultant by 15°, and the right-channel signal modulates a carrier that leads by 15°. These two signals are linearly combined (added) to form the CPM signal. This makes Harris' the only proposed linear system.

One method of generating the CPM signal is illustrated in Fig. 6A. An audio matrix produces L + R and reduced L − R components. A low-level, low-frequency stereo ID tone is inserted in the L − R component in a summation amplifier. The 20-to-25-Hz tone is used only for AM stereo signaling purposes. The tone is not heard in mono receivers because it is in the L − R channel only. It will not be heard with stereo receivers because it appears out-of-phase on the two channels and cancels out in the listening environment. Hence, little or no filtering is required in stereo receivers.

Fig. 6. Harris (CPM)



The L − R component is applied to a balanced modulator along with a +90° phase-shifted carrier. The L + R information is also applied to a balanced modulator along with a normal carrier. The outputs are summed with the proper amount of carrier to produce the CPM signal. The low-level CPM signal could be transmitted as if it were followd by a linear amplifier. However, the interface requirements with current AM transmitter prohibits this.

To interface with current AM transmitters, the CPM signal is separated into envelope and phase-modulated components. An envelope detector derives L + R information from the CPM signal that is applied to the audio input of the transmitter. The CPM signal is also processed through a hard limiter to remove the AM component and yields a PM carrier signal that is used in place of the crystal oscillator in the transmitter.

The reduction in gain in the L − R quadrature channel is the key to providing compatibility with mono receivers and envelope detectors. When the CPM stereo signal is received on a mono receiver using an envelope detector, some distortion (typically 0.5%) results due to the presence of quadrature sidebands. If the L − R quadrature component were not reduced in transmission, the distortion would be about 11%.

Stereo receivers for the Harris CPM system will use synchronous detectors, rather than envelope detectors, to obviate any distortion in the stereo and mono modes. Such a stereo receiver is detailed in Fig. 6B, which illustrates one of the several ways to recover the CPM signal. Unlike the case for the four other receivers, the CPM receiver does not require the more costly front ends with equal amplitude and phase characteristics to receive low-distortion stereo.

The receiver's i-f signal is first applied to a synchronous detector. The detector serves two purposes. First, it works as a phase detector for the phase-locked loop made up of the loop filter and vco. The vco is locked to the i-f and oscillates 90° out-of-phase with the incoming i-f signal. Secondly, the balanced modulator directly demodulates the quadrature L − R part of the signal. The vco's output signal is shifted 90° and used to demodulate the in-phase L + R component of the signal. Low-pass filters remove all carrier frequency components from the output of the detectors. The L + R and L − R signals are combined in a simple audio matrix to recover independent left and right channels. Amplitude equalization of the reduced L − R component also occurs in the matrix.

The stereo ID tone can easily be re-

Popular Electronics
AUGUST 1980

AM STEREO WINS FCC APPROVAL

The Magnavox amplitude/ phase-modulation system, selected as the U.S. AM stereo transmission standard, is described

BY STAN PRENTISS

STEREOPHONIC transmission on the standard AM broadcast band, under test and evaluation by the Federal Communications Commission, Electronic Industries Association's Stereophonic Radio Committee and other organizations since September 1978, has finally been approved by the FCC. The nod of acceptance was given to the system proposed by Magnavox Consumer Electronics Company.

In competition with other systems offered by Motorola, Belar, Harris, and Kahn, the Magnavox system that combines amplitude and phase modulation was selected by a vote of five commissioners to two. Broadcast transmitters can be fitted for it fairly simply, with the greatest cost expected to be in studio equipment. Consoles and playback equipment will have to be converted to stereo, and directional antennas will have to be very carefully phased. Signal losses compared with monophonic are not expected to exceed 3 or 4 dB in daytime operation.

The Broadcast Bureau Report and Order, following the Magnavox selection by some 60 days, was published in the Federal Register. However, a formal final vote has not been taken at this writing and rival stereo developers are challenging the decision in an effort to have the Federal Communications Commission modify or reconsider its preliminary ruling.

Meanwhile, the EIA and Institute of High Fidelity (IHF) have recommended that the FCC authorize a nine-month delay in service startup from the time that the final reports and orders are made so that AM-radio inventories can be cleared from dealer shelves and AM stations can install equipment to begin broadcasting. At this writing, Magna-

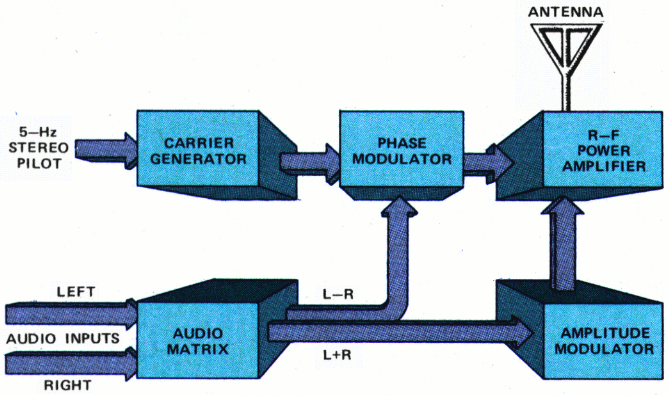


Fig. 1. Block diagram of the stereo transmitter. A 5-Hz stereo identification tone frequency modulates the carrier generator. The L + R signal amplitude modulates the carrier while, the L − R signal phase modulates it.

vox has announced that it will not assert its patent rights against broadcasters or broadcast-equipment manufacturers, but it is willing to enter into licensing agreements with manufacturers of receiving equipment.

How the System Works. Amplitude modulation and phase modulation are the equivalents of FM stereo's baseband main and subcarrier modulation. Left plus right (L + R) channel information is transmitted as standard AM, while the carrier phase is modulated with L − R information so that 100% modulation corresponds to a peak deviation of 1 radian (57°). Negative amplitude modulation is limited to 95%, leaving the phase of the remaining 5% detectable at all times. There is also a 5-Hz signal transmitted to alert the receiver that AM-stereo intelligence is being broadcast. Although this signal could conceivably be used to transmit low-speed digital data such as time, weather, etc., in addition to station identification, there are no plans for such use at this time.

A block diagram of the stereo transmitter is shown in Fig. 1. The 5-Hz stereo identification tone frequency modulates the carrier generator (nominally 20-Hz deviation), with the resultant phase modulation being a 4-radian deviation. (Phase deviation = $\Delta f/f_{mod}$ = 20 Hz/5 Hz = 4 radians, where Δf is nominal carrier deviation and f_{mod} is ID-tone modulation frequency.) This signal then combines in the phase modulator with L − R from the audio matrix as the stereo portion and continues into the final r-f amplifier. Similarly, L + R information is developed through the audio matrix and feeds the amplitude modulator. Finally the carrier, angle-modulated with an ID tone and L − R information and amplitude-modulated with L + R, is fed to the transmitting antenna. Since the L + R and L − R signals may undergo unequal delays in the above process, delay lines are used to reestablish correct time relations.

A simplified block diagram of the receiver Magnavox actually used in all field tests prior to FCC system approval is shown in Fig. 2. The receiver has a conventional r-f/i-f front end, followed by an envelope detector for amplitude modulation. Thereafter, however, circuits become less familiar, since phase variations representing the stereo ID tone and the L − R information must be demodulated and processed.

As a first step, envelope variations are stripped by a limiter. Then a phase-locked loop (PLL) system—consisting of a loop filter/amplifier, voltage-controlled oscillator (VCO), and phase detector—simultaneously recovers phase and stereo indicator signals. L + R and L − R signals are then added and subtracted in the matrix to form the 2L and 2R (left and right, respective) signals. The succeeding stereo—mono switch is activated by the 5-Hz detected impulses, and separated left/right audio flows to respective speakers. (A 10-kHz filter eliminates annoying whistles.)

The PLL detects signal phase and supplies some filtering between the stereo component and 5-Hz identification signal. A low-pass filter then passes the 5-Hz information to its detector and from there on to the control logic. Following the phase detector, L − R information is gain-equalized and passed through a between-channel muting switch. From there, it goes to the L − R/L + R matrix. Muting is controlled by the output of the high-pass noise detector that continually monitors the loop filter/amplifier for the excessive high-frequency noise that is generated when

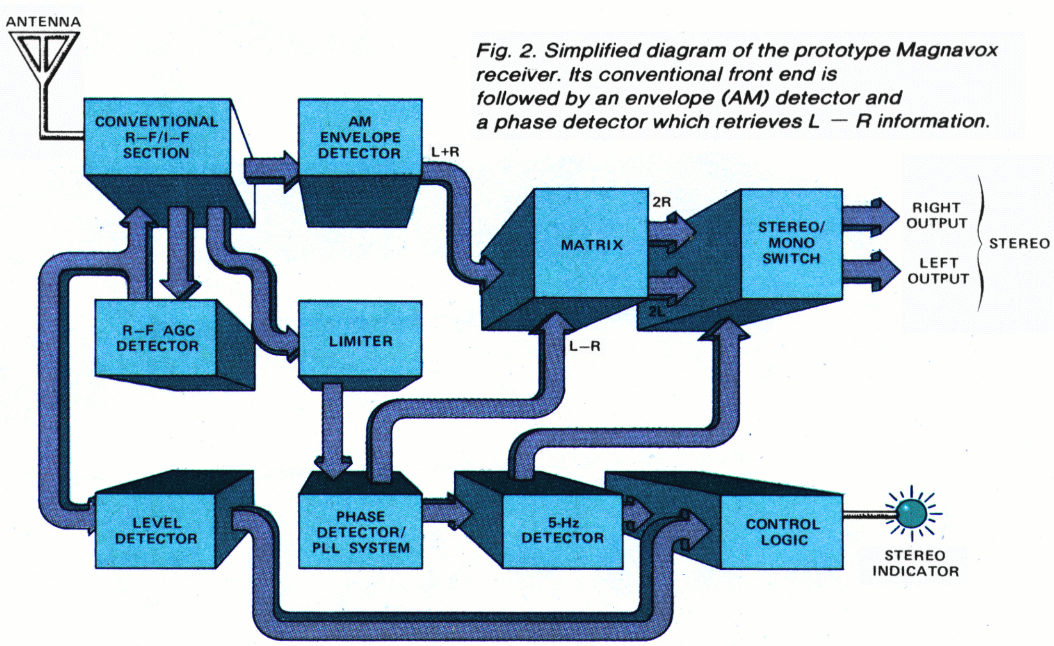


Fig. 2. Simplified diagram of the prototype Magnavox receiver. Its conventional front end is followed by an envelope (AM) detector and a phase detector which retrieves L − R information.

the receiver is not tuned to a specific broadcast. The output of the L + R full-wave detector is delayed 16 μs. Then L + R and L − R are matrixed into 2L and 2R outputs for amplifiers driving the left and right speakers.

Other Proposed Systems. Among the other AM-stereo systems considered and rejected by the FCC was Motorola's C-Quam (Compatible Quadrature Amplitude Modulation). In this system two separate carriers of the same frequency in phase-quadrature are modulated with separate left and right signals, and the outputs of the transmitters are combined and applied to a common antenna load. The two carriers and their intelligence are demodulated in the receiver by two synchronous detectors that derive the stereo information directly.

Belar Electronics proposed an AM/FM system, with some differences, originally tested by RCA as early as 1959. Matrixed right and left audio signals in the Belar system generate L + R and L − R signals, and the L − R portion is preemphasized and frequency modulates the r-f transmitter. The L + R signal is handled in routine fashion. Envelope detection (L + R) and frequency discrimination (L − R) is applied to recover these signals, which are then processed in an audio matrix to produce left and right outputs. Harris's system advocated carrier phase modulation, and Kahn's proposed a method employing independent sidebands.

In Closing. Does all this mean that electronic companies will immediately jump on the AM-stereo manufacturing bandwagon? It's a little early to tell, but at this writing there is some indication they will. For example, Pioneer has demonstrated at the NAB conference both home and auto AM-stereo sets using the Magnavox AM/PM system. Semiconductor manufacturers, too, are ready with products—Motorola with an integrated decoder design already breadboarded, Sprague/Signetics will reportedly announce an IC version in the Fall, and National Semiconductor with an announced decoder product available about now. Japanese manufacturers are eagerly awaiting the day when they too can introduce AM-stereo products to the U.S. market.

Industry sources tell us that Harris, Collins, and RCA are almost certain to offer broadcast transmitters in the near future. Furthermore, once studio links and other gear have been installed, the L-R exciter can be connected into the rest of the system in one evening.

Our sources also say that General Motors, Ford, and Chrysler are laying plans to offer AM-stereo options in their new vehicle models. ◇

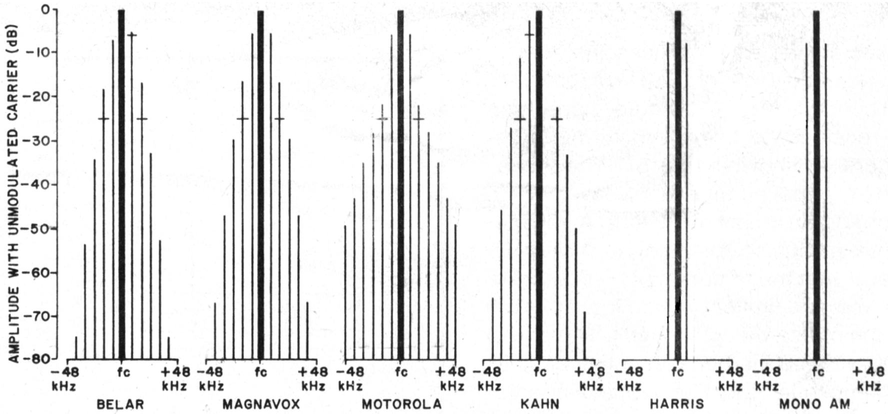


Fig. 7. Transmitted spectra of proposed AM stereo systems. Bar through spectral line indicates point that exceeds existing FCC limits for radiated sideband power.

covered. An L − R sample is applied to a 20-to-25-Hz detector, which turns on a stereo indicator and can activate a stereo/mono mode switch.

Now and the Future. The five AM-stereo systems described here have all been field tested. Each system has its own advantages and disadvantages. In its technical evaluation, the FCC will consider a number of performance factors. Paramount among these will be the amount of increase in occupied channel bandwidth; mono and stereo receiver distortion under skywave, selective fading, narrow bandwidth, and mistuning conditions; and stereo separation, frequency response, and noise under various receiving conditions.

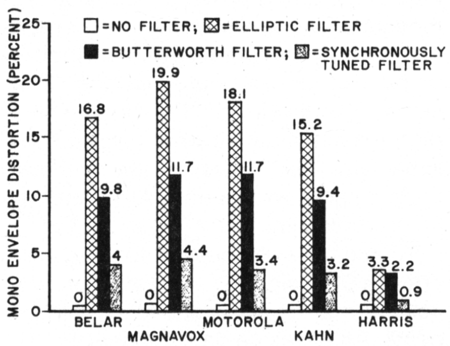


Fig. 8. Monophonic envelope detector distortion through various i-f filters.

Other conditions that are certain to come under the FCC's scrutiny include: amount of reduction in mono service area; system implementation into current and future AM receiver designs; and the use of a stereo pilot for indicator lights and/or stereo/mono switching.

System comparison charts and graphs are given in Figs. 7 and 8. Final adoption and approval of an AM-stereo system based on these and other criteria could occur as early as the spring of 1979.

While the five contenders have been active in designing, testing, and promoting their systems, receiver manufacturers have not been idle. Several receiver manufacturers, including Pioneer and Sansui, have already recommended to the FCC adoption of the Harris AM-stereo system because of its technical advantages. Most receiver manufacturers, however, are taking few chances and have breadboarded most of the competing systems. The major semiconductor manufacturers are also gearing up for this new market by designing single-chip AM-stereo detector ICs.

AM stereo will do more than just bring to the public a new two-channel sound medium. It will also usher in higher quality of sound than was heretofore generally available with AM, and greater realism through two-dimensional sound reproduction. The new receivers may have a virtually flat audio response out to 10,000 Hz, compared with current AM receivers whose response is often down 20 dB at 5000 Hz.

The automotive market presents the greatest potential for AM-stereo receivers since AM signals now cover areas where FM does not penetrate.

Receiver manufacturers plan to have AM-stereo receivers on the market two to three months after final FCC approval. AM-stereo receiver marketing estimates go as high as $20-billion to supplement the 425-million mono AM receivers already in use today.

The FCC's decision to adopt AM stereo will undoubtedly have an enormous impact on the radio-listening public. The repercussions are expected to be similar to those at the time the FCC approved color television. ◇