Stereo AM Radio Systems

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One of the changes brought about by the Broadcasting Bill will be a new Radio Authority. To make way for more services in the medium-wave band, notably the new community stations, the BBC has relinquished some of its m.w. allocations, concentrating its services in the v.h.f./f.m. and l.w. bands. One notable development will be the introduction of compatible stereo transmissions for the m.w. independent radio services. Motorola's CQUAM system has been adopted for this purpose.

Compatibility

Compatible stereo means that a conventional mono receiver using an envelope detector will be able to produce an undistorted mono output from the stereo transmission. While compatibility is a basic requirement, equally important from the broadcaster's point of view is that stereo operation should not significantly reduce a transmitter's service area. The success of commercial radio depends on the number of people it can reach. So the station must be "loud". One of the tricks used to give greater "punch" is over-modulation. The stereo system should therefore be tolerant of this practice.

The compatibility requirement means that amplitude modulation must be used, in conjuction with other techniques, for the new m.w. stereo services. The main problem with m.w. broadcasting stems from the very large number of transmissions within a band just over 1MHz wide. A 9kHz channel spacing permits an audio bandwidth of barely 5kHz to be used. So a stereo subcarrier is out of the question. There is also the problem that sky-wave propagation improves rapidly after dark, when the absorbent D layer vanishes to follow the sun. This results in the nightly cacophony of whistles and sideband splash.

AM Radio Limitations

The use by most self-contained transportable a.m. radio receivers of inadequate loudspeakers and small acoustic chambers to house them, also power output/battery economy considerations, further contribute to the inferior results obtained. It's only with in-car systems, for which people seem to be prepared to spend a lot of money, that acceptable l.f. audio performance is now commonplace. The ferrite-rod aerial is another limiting factor with transportable receivers. It has excellent directional properties, but often makes receiver siting a compromise. In addition the ferrite rod is affected by the harmonics of the higher frequencies in the audio circuits. This gives rise to audio distortion unless the receiver's h.f. performance is rolled off. The roll-off reduces the intensity of the night-time whistles, but further widens the performance gap between v.h.f./f.m. and m.w./a.m. systems. In-car receivers and those intended for incorporation in a domestic audio installation, using a long-wire aerial, avoid these latter drawbacks and can be expected to comprise the bulk of the target market for a.m.-stereo.

Amplitude modulation does have some advantages however. It's the most efficient method for narrow bandwidth use and is independent of noise. With an a.m. receiver the background noise remains the same whether or not modulation is present. With phase and frequency modulation systems however noise that isn't present with an unmodulated carrier arises when modulation is present.

Stereo AM Principles

Most of the work on compatible stereo-a.m. systems has been carried out in the USA. In addition to Motorola's CQUAM system, Belar, Harris, Hazeltine-Kahn and Magnavox have developed systems. All transmit L + R and L − R signals that are matrixed in the receiver to obtain the orginal L and R audio signals (for mono operation L + R is used, the L − R stereo-difference signal being ignored). The L + R signal amplitude modulates the carrier which is also phase or frequency modulated by the L − R signal. In addition some systems use quadrature modulation techniques. Most systems don't allow negative-going modulation peaks to go over 100 per cent (the condition when the modulation is equal to the amplitude of the unmodulated carrier) because momentary disappearance of the carrier stops the stereo decoding and produces bursts of noise. The problem here is that a lot of mean sideband power is lost when the modulation is held below 100 per cent, with the result that the transmitter's service area is reduced.

A further requirement is the right "tuning feel" with behaviour similar to an f.m. stereo receiver. This calls for a high-gain, critically damped a.g.c. system. The traditionally "loose" feel of a.m. tuning would result in stereo image shift as the user tunes through a transmission. Other factors that have to be taken into account are adjacent channel interference, differential fading and signal-to-noise ratio penalties.

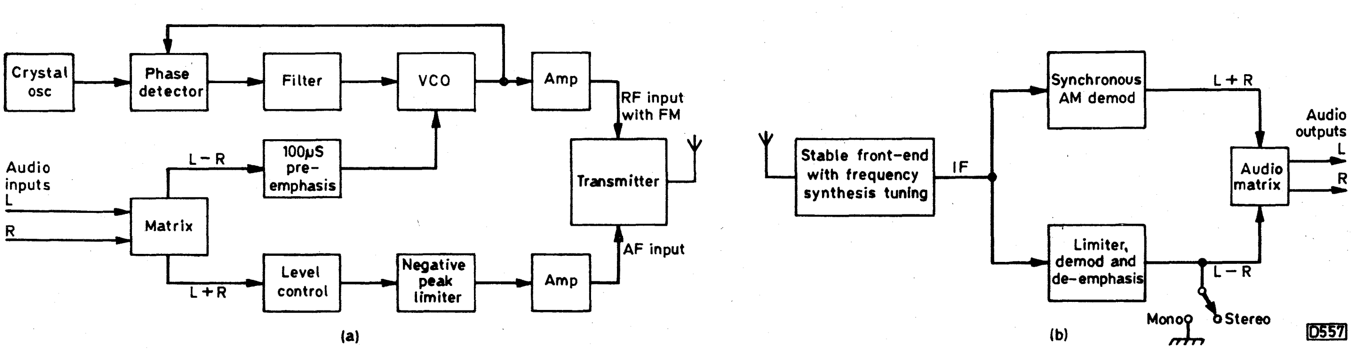

Fig. 1: The Belar system. (a) Block diagram of the transmitter. (b) Block diagram of the receiver.

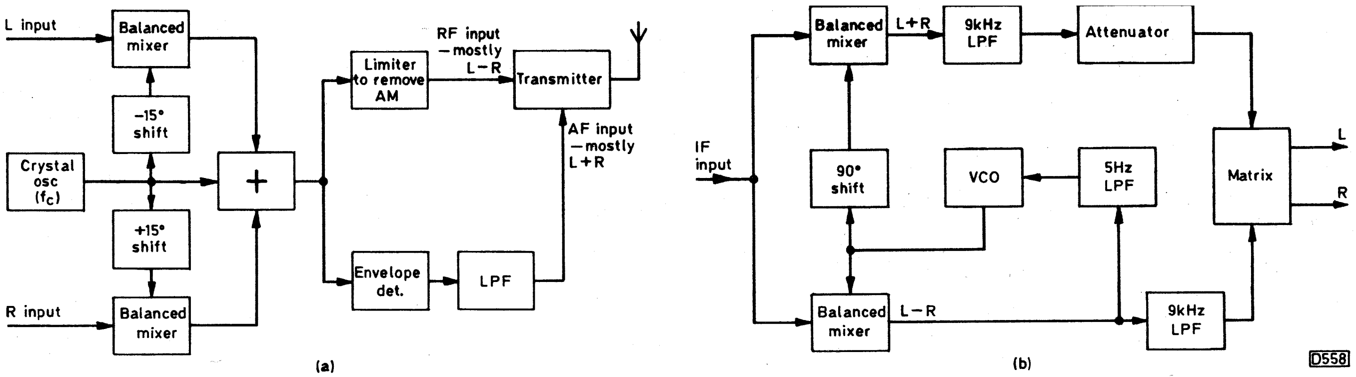

Fig. 2: The Harris CPM system. (a) Block diagram of the transmitter. (b) Stereo decoder block diagram.

Out of interest we'll take a brief look at the alternative systems proposed before dealing with the Motorola CQUAM system in greater detail.

Belar System

The Belar system serves as a simple introduction. Fig. 1(a) shows the arrangement used at the transmitter. The left and right audio inputs are first matrixed to obtain L + R and L − R signals. Compatibility is ensured by using the L + R signal to amplitude modulate the carrier. The same carrier is frequency modulated by the L− R signal, which is subjected to 100μsec pre-emphasis and used to provide a peak deviation of ±1·25kHz. Negative-going audio peaks are limited to prevent the modulation depth exceeding 90-95 per cent: positive peaks are not limited, permitting the carrier to reach maximum output so that the compatible system can compete in audibility terms with its mono neighbours.

Unless it's poorly aligned, a receiver's envelope detector will ignore the frequency modulation and will demodulate the a.m. signal component in the normal way. As shown in Fig. 1(b) the receiver has two i.f. systems, one for the a.m. and the other for the f.m. component of the received signal. A matrix is used to recover the original L and R signals.

Harris CPM System

In the Harris compatible phase multiplex (CPM) system the left and right audio signals amplitude modulate two carriers at the same frequency but with a phase difference of 30°, see Fig. 2(a). The carriers are then added to produce a mono signal with sidebands that contain, at a much lower level because of the 30° phase difference, the L − R signal. This is known as a modified quadrature system which in some respects resembles the technique used in NTSC and PAL TV receivers for the two transmitted colour-difference signals. Phase modulation is carried out by the two balanced mixers, with carrier insertion at the following adder. The adder's output follows two paths. In one it's limited to remove all a.m. The limiter's output forms the transmitter's carrier, with phase modulation that consists mainly of the L − R information. The other path is via an evelope detector and a low-pass filter whose output, mostly L + R, amplitude modulates the carrier.

The i.f. amplifier in a stereo receiver feeds two balanced mixers – see Fig. 2(b) – which are also supplied with an unmodulated carrier. This carrier is obtained from a PLL that uses the incoming i.f. as a reference signal – the 5Hz low-pass filter effectively removes any modulation. The VCO's output is 90° out of phase with the incoming i.f. signal and can be used for demodulation of the L − R signal directly: for demodulation of the L + R signal the VCO's output is passed through a 90° phase shifter. Audio matrixing is then carried out, an attenuator in one feed to the matrix providing gain equalisation.

Hazeltine-Kahn ISB System

The Hazeltine-Kahn independent sideband (ISB) system generates a lower sideband that contains the left stereo information and an upper sideband that contains the right information. A mono receiver tuned to the carrier centre will demodulate L + R. At the transmitter the L and R signals are matrixed to produce L + R and L − R signals which are then fed through phase shifters, −45° in the case of the L + R signal and +45° in the case of the L − R signal. The L + R signal amplitude modulates the carrier while the L − R signal is used to phase modulate the carrier. Right channel components add in the upper sidebands produced by the system and cancel in the lower: similarly the left channel information cancels in the upper sidebands and adds in the lower sidebands. Because of the system's limited stereo separation, a separation enhancement system is used at the transmitter.

Two separate receivers can be used for stereo reception, with the left one tuned slightly below the carrier centre frequency and the right one tuned slighly above. A stereo receiver designed for optimum use of the system uses an envelope detector to demodulate the L + R signal with a more complex channel including a PLL, an amplitude modulator and a product detector to provide an L − R output. Phase shifting (±45°) is required before the L − R and L − R signals are matrixed to yield L and R.

Magnavox System

The Magnavox system again uses a.m. for the L + R signal and phase modulation for L − R. The transmitter uses a frequency synthesiser that's phase modulated by the L − R signal. The output from this, see Fig. 3, is fed to a mixer whose other input is obtained from a crystal oscillator. A low-pass filter is included in the mixer's output, which consists of a carrier containing the L − R information in the form of phase modulation. This carrier is amplitude modulated by the L + R signal. The receiver employs a full envelope detector for L + R and a limiter and PLL-controlled phase detector for L − R. A 16µsec delay is required in the L + R channel.

Motorola CQUAM System

In the Motorola CQUAM system the L + R and L − R signals amplitude modulate two carriers in quadrature, i.e. with a 90° phase difference between them. This is the same basic technique that's used for the B − Y and R − Y colour-difference signals in the NTSC and PAL systems. Fig. 4 shows the arrangement used at the transmitter. The L + R and L − R outputs from the L/R matrix are fed to a pair of balanced modulators. One receives an in-phase (I) carrier input from the master oscillator and the other a 90° shifted (Q − quadrature) carrier input. Double-sideband, suppressed-carrier outputs are obtained from the modulators. These are added, together with an in-phase carrier, the result being a perfect a.m. quadrature signal. This is heavily limited to remove all a.m., the output from the limiter being a carrier that contains the L + R and L − R information in the form of phase modulation. To provide a compatible signal the carrier is, as in the other systems, amplitude modulated by the L + R signal.

The use of quadrature amplitude modulation allows a second carrier to be added without a noise penalty. Because both carriers have the same frequency and carry f.m., the two components of the signal suffer identical attenuation and distortion under difficult reception conditions. As in an NTSC or PAL colour receiver, two synchronous demodulators using reference signals with a 90° phase difference can be used to detect the L + R and L − R signals separately.

Decoding CQUAM

In a practical CQUAM receiver decoder an envelope detector is used to demodulate the L + R signal while synchronous detection is used to extract the L − R information. Fig. 5 shows a basic arrangement. The incoming i.f. signal is fed to an evelope detector and, via a

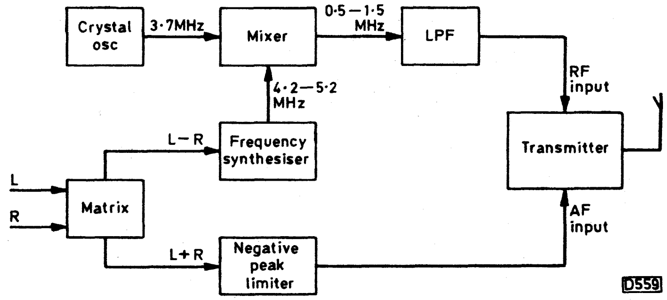

Fig. 3: Block diagram of the transmitter arrangement with the Magnavox system.

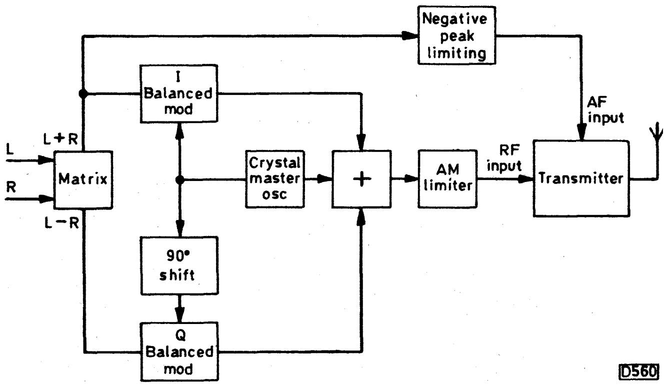

Fig. 4: Block diagram of the transmitter arrangement with the Motorola CQUAM system.

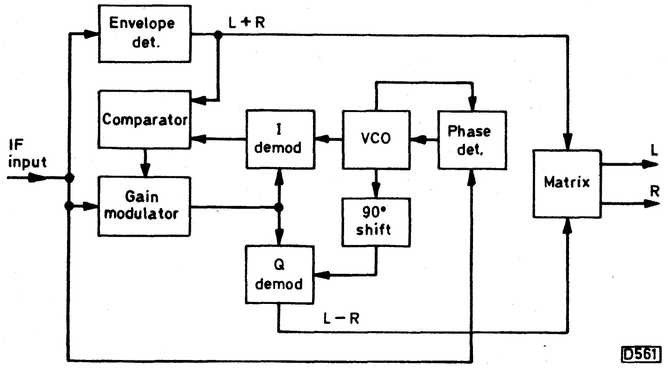

Fig. 5: Block diagram of a stereo decoder for the Motorola CQUAM system.

gain modulator that acts as a kind of fast a.g.c. system, to the two synchronous demodulators I and Q. With a mono signal the a.m. and I signals are identical and there is no output from the comparator. Normal envelope detection produces an L + R output. In the presence of a stereo signal the a.m. and I signals differ and the comparator develops an output that controls the gain modulator. The action of the gain modulator ensures that a perfect quadrature signal is applied to the I and Q demodulators so that the output from the Q demodulator is an accurate L − R stereo-difference signal. L + R from the envelope detector and L − R from the Q demodulator are then matrixed in the usual way to obtain the L and R audio signals. The VCO is incorporated in a PLL.

Heavy modulation of the carrier is necessary to obtain maximum output from a stereo-a.m. transmitter. This can result in small bursts of noise from the stereo information part of the system. An advantage of the CQUAM system is that when the carrier level is momentarily reduced to a very small value by the modulation the output from the envelope detector similarly falls to a very low level. This produces an error voltage from the comparator. Thus the comparator and gain modulator reduce the i.f. input to the I and Q demodulators so that their outputs are also very low, drastically reducing the effect of the noise bursts.

CQUAM Receivers

The remainder of the receiver is conventional apart from the fact that the i.f. bandwidth is increased to around 6kHz and screening of the audio power sections has to be improved to prevent coupling into the ferrite-rod or slab aerial. These measures improve the receiver's audio performance but reception may suffer in the usual way after sunset. Inclusion of a 9kHz rejector to eliminate adjacent channel whistle is virtually mandatory – note that stereo a.m. receivers made for the American market will have a 10kHz filter, making them unsuitable for use here without modification.

With CQUAM the burden of good audio quality is placed firmly on the receiver. When a.m. stereo models begin to appear on the market the old adage "you get what you pay for" will be true. The nature of the CQUAM Q signal is such that a variety of methods can be used to decode it, giving various levels of performance. Stereo separation, signal-to-noise ratio and tolerance to overmodulation are the key factors. Without radical l.w. and m.w. broadcasting practice changes that would render existing receivers obsolete we are left with a.m. for the foreseeable future. What stereo a.m. means in terms of extras in the receiver will probably amount to just one chip and a few associated components.