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AM STEREOFÓNNY SYSTÉM S PRENOSOM DOPLNKOVÝCH ÚDAJOV

AN AM STEREO SYSTEM WITH ADDITIONAL DATA TRANSMISSION

Skôr vyvinuté AM stereofónne systémy už boli popísané. V príspevku je popísaný nový kompatibilný AM stereofónny systém. Nový systém umožňuje zavedenie stereofónneho vysielania so šírkou pásma zvukových kanálov od 50 Hz do 4,5 KHz (alebo viac) a prenos dát s prenosovou rýchlosťou 25 bit/s.

Previously proposed systems for AM stereo are discussed. The new compatible AM stereo system is described. The new system makes it possible to implement a stereo transmission with a bandwidth in the sound channels from 50 Hz to 4.5 (or more) kHz and a data transmission with a modulation rate of 25 bit/sec.

Introduction

Due to increasing interest in stereophonic music reproduction in the 1950s, techniques for stereo transmission on AM stations were investigated. Work on the AM stereo system has been in progress ever since. Several solutions have been developed.

All the proposed systems transmit a sum signal, usually $L + R$, and a difference signal, usually $L - R$. The modulation of the carrier with the $L - R$ signal is generally phase or frequency modulation. The main purpose is to ensure that satisfactory reception of stereo can be obtained without unduly impairing the reception of the sum (monophonic) signal on conventional AM receivers. The spectrum of the composite radiated signal must be contained within the normal passband and the difference signal components must be chosen with care if they are not to cause envelope distortion. Thus, the specification must be somewhat of a compromise. Some proposals use quadrature amplitude modulation of the carrier to carry the stereo difference components.

Table I. gives a summary of the main characteristics of five systems under consideration (in 1984) by the American FCC.

The phase deviations of the proposed quadrature systems are much smaller than those of the PM and FM systems. Thus, the monophonic receivers with envelope detectors can work with little distortion, but the coverage area of the stereo reception is significantly smaller than that of the monophonic reception.

The PM and FM systems do not have this shortcoming. They work without any distortion if all bandpass filters in the

transmitter, antenna system and receiver have a flat amplitude and linear phase response. (A distortion-free monophonic reception with envelope demodulation requires the same conditions.) The coverage area can approach that of the monophonic reception.

During the development work on AM stereo, successful experiments on systems with additional data transmission were also carried out on long wave and medium wave AM transmitters.

The author of this article has worked with AM stereo and the admittional data transmission for several years. The experimental works in the laboratories of the Szechenyi Istvan College have confirmed the idea that it is possible to combine the AM stereo with a low rate data transmission.

System considerations

Both methods, the AM stereo and the LF radio data, need similar techniques in the transmission of the necessary additional signals. If the additional signals are transmitted by phase modulation of the carrier, we can regain them from the phase demodulator of the receiver. It is easy to separate the two signals if their bands do not overlap one another. That means that the spectrum of the data signal must be limited. The limit is the lowest frequency in the sound transmission which is about 30 ... 40 Hz.

The signalling for the stereo transmission can be solved by means of the data signal as well. A signalling system alerts the listener that a stereo broadcast is being received and can automatically switch the receiver between its mono and stereo modes.

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Table I.

Company	Harris	Haseltine/Kahn	Motorola	Magnavox	Belar
System	PM	ISB	C-QUAM	AM/PM	AM/FM
(L + R) signal modulation	AM	AM	AM	AM	AM
(L - R) signal	modulation	Quadrature	Quadrature	PM	FM
	frequency or phase deviation	AM	MA	MA	
	additional features	$\pm 15^\circ$	-	$\pm 45^\circ$	± 1 radian
		(L - R) predistortion to compensate for subsequent envelope distortion 90° phase shift between sum and difference	(L - R) predistortion to compensate for subsequent envelope distortion	-	-
Additional signals (stereo)	20 - 25 Hz added to (L - R)	15 Hz	25 Hz 4 % added to (L - R)	5 Hz 4 radians added to (L - R)	-
Preferred method of stereo detection	L and R synchronous detectors each operating at 90° to the unwanted signal, with phase locked loops	Modulation with (L + R) to remove distortion, then synchronous (L - R) detection, 90° before sum/difference	Envelope distortion introduced prior to L and R synchronous detector	Limiter and phase detector provides (L - R)	Limiter and frequency demodulation provides (L - R)

If it is a requirement that the stereo transmission has to achieve the coverage area of the monophonic transmission, S/N in the L - R channel must equal S/N in the L + R channel which can be fulfilled only by use of FM or PM. The latter is more advantageous because of its implementation simplicity. The S/N of the L + R channel equals that of the L - R channel if the demodulation gains are the same. At an AM - PM system it means:

$$m_p^2 = \frac{2m_a^2}{2 + m_a^2}$$

where m_p and m_a are the modulation indices.

Channel noise can be particularly perceived if the modulation indices are small. In this case

$$m_p \approx m_a$$

and the channel noise is merely 3 dB higher in the L and R channel than that in the L + R channel. (The S/N depends also on the signal distribution between the L and R channel. The extreme values are 3 dB higher or 3 dB lower than S/N is in the L + R (monophonic) channel.)

Thus, at the maximum modulation

$$m_p = m_a = 1,$$

That is the maximum phase deviation must be at least 1 radian. But at the final specification of the phase deviation, the properties of the demodulator, the value of the synchronous PM modulation of an AM transmitter and the bandwidth of the modulated carrier must be taken into consideration. The synchronous PM modulation and the phase noise of transmitters are very different. It is a very good value if the phase deviation of the synchronous PM modulation is smaller than 6° (at 1000 Hz and $m_a = 1$). The phase deviation from the L - R signal must be at least 10 times larger, that is 60°, so that we can achieve a good separation of the channels and a low distortion. (The synchronous PM modulation is in general largely distorted.) But too large phase deviations cannot be processed by certain PM demodulators. If the joint phase deviation coming from the data signal and the L - R signal are limited at 90°, most PM demodulators can be used in AM stereo receivers.

The bandwidth of a PM signal depends on the frequency of the modulating-signal and the phase deviation. At the phase deviation of 60° there are 2 ... 3 significant side frequencies in the spectrum. Fortunately the high-frequency components of the sound signal are of a small level. Thus, the phase deviation is small as well, and the spectrum can be kept within the specified bandwidth.

We can see that the phase deviation of 60° is an appropriate compromise. It makes possible a good S/N and channel separation with a low distortion. The spectrum spread of the transmitter is negligible. The lab experiments have proved that the stereo transmission is not disturbed by the data signal if the phase

deviation for the data transmission is smaller than 22.5° at a modulation rate of 25 Bd. (The highpass filters at the input of the L - R and L + R channel in the receiver were first-order with a cut-off frequency of 50 Hz.) The data-shapping filter in the transmitter had an amplitude response:

$$H_T(f) = \begin{cases} \cos \frac{\pi f t_d}{4} ; & 0 < f < 2/t_d \\ 0 & ; f > t_d \end{cases}$$

and here $t_d = 1/12.5$ second. (The logic 1 at the filter input was $\delta(t)$, the logic 0 was 0.)

If the sound transmission is monophonic, the phase deviation for the data channel can be enlarged up to 45° or even more. The receiver can automatically switch on its stereo mode if the phase deviation for the data transmission is between 22.5° and 45° .

The coverage is monophonic at a phase deviation higher than 45° or smaller than 22.5° . The 22.5° phase deviation is satisfactory for a secure data transmission.

Thus, the time function of the stereo signal is:

$$U(t) = [1 + (L + R)] \cos[\omega_c t + 1.047(L - R) + 0.393d(t)]$$

$d(t)$ is the data signal, for example, a shaped and biphas coded data waveform. All signals L + R, L - R and $d(t)$ have relative values and vary between -1 and 1.

Implementation

The AM demodulator of the AM - PM stereo system is the envelope detector. It is absolutely insensitive to the phase noise and synchronous PM modulation of the transmitter, which is very useful for the system. This type of the demodulator is traditional for the AM broadcasting and most receiver ICs incorporate it.

An effective AGC is an indispensable part of AM - PM stereo systems. The ICs designed for AM stereo reception contain this stage, and the level of the L + R signal is practically independent of the level of the input RF signal.

The receiver has to be exactly tuned in to ensure an excellent stereo reception. This is why electronically tuned receivers are advantageous for AM stereo.

After having reviewed the most important aspects we shall now see what the extra functions required for AM stereo are.

1. Removing the amplitude modulation from the phase - modulated carrier.
2. Demodulating the stereo difference signal (L - R).
3. Matrixing the L - R and the L + R signal.

4. Detecting and indicating the stereo identification (signalling system).
5. Soft blending of AM -stereo depending on receiving conditions.

For demodulating the phase modulated signal containing the L - R stereo information and the data signal, the so called quadrature demodulator of FM receivers can be used especially in an extended AM stereo - FM stereo receiver. In this case the demodulated L - R signal has to be corrected to transform the FM demodulation response with an integrator into a corresponding phase demodulation response.

If the receiver has a data stage, the filtered data signal can be used for the stereo identification (or signalling). After rectification and filtering of the received data signal we have a DC level depending on the phase deviation of the data transmission. By means of an appropriate comparator the signalling can be solved.

Measured system characteristics

The following data was achieved in a receiver incorporating an IF stage with two parallel resonant circuits. In stereo mode the L - R signal was regained by means of a quadrature FM demodulator.

Channel separation (40 Hz.....4.5 kHz)	(cross talk)	30 dB
Distortion ($m_a = 0.8$, $f = 1000$ Hz)	stereo mode	2 %
	monophonic mode	1 %

The channel noise in the L and R channels is at stereo reception 4 dB higher than that at monophonic reception.

If the transmission of the AM transmitter was switched in stereo mode the cross talk in the adjacent mono channel increased by 2 ... 4 dB depending on the modulation depth of the stereo transmitter and the field strength of the received mono signal. The channel distance was 9 kHz at this measurement.

Conclusion

The measurements on the experimental system have proved that the AM stereo and AM radio data can be combined advantageously. The two systems do not disturb each other if the data rate is low, moreover the signalling of the stereo transmission can be fulfilled by means of the data signal.

With a phase deviation of 22.5° in the data channel and of 60° in the L - R channel both, the data and the sound transmission have a good quality.

The implementation simplicity is an important feature of this system as well. The data signal and the L - R signal can be demodulated by the same phase demodulator.

Reviewed by: S. Marchevsky, J. Dúha

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