The UK system of digital two-channel sound with terrestrial television

S.R. Ely, Ph.D, C.Eng, M.I.E.E

Summary The UK Government has approved the joint BBC/IBA specification of a transmission standard for digital stereo sound with terrestrial television. This system, which was developed by BBC engineers during the past four years, conveys two high-quality, digitally-coded sound signals along with the picture and mono f.m sound signals of the UK television System I.

Extensive laboratory and over-air tests have proved the compatibility and ruggedness of this system, and optimized the choices of modulation system and baseband coding method.

Assistance has been given to broadcasters in the Nordic countries towards the adaptation of the UK system for use with television Systems B and G.

Introduction

For many years there has been a growing interest in stereophonic (stereo) and dual-language sound with television. Indeed, stereo sound with television is already available in the UK from pre-recorded video cassettes and discs, and there are possibilities for multi-channel sound in the systems proposed for direct broadcasting satellites and cable networks. Broadcast engineers in the UK were therefore faced with the challenge of devising a suitable method for radiating multi-channel sound along with the picture and normal mono sound of the existing UK System I terrestrial broadcasts.

In these circumstances, where it is proposed to add a new signal component to an existing service, the conflicting requirements of compatibility and ruggedness must be met: on the one hand, the new signals must not cause interference to reception of the picture and mono sound on existing receivers, which were not designed with the new signals in mind; on the other, the new service must be capable of being received reliably by the new sets designed to decode it, even at the limits of the service areas of the transmitters and in places where reception is already difficult. Furthermore, account has to be taken not only of the wanted broadcast signal, but also other broadcast signals sharing the same or adjacent channels.

The BBC commenced studies related to the possibility of multi-channel sound with terrestrial television in the late 1970s and intensive work on this topic started during 1981. This led to the joint BBC/IBA specification of a digital system which, in September 1986, was approved by the UK Government as the UK Standard for two-channel sound with television. This system conveys two high-quality digitally-coded sound signals along with the picture and mono sound signals of the UK television System I.

Although this work was naturally centred upon the development of a multi-channel sound system for use with the television System I used in the UK, there has been considerable international interest in the system. Broadcasters in the Nordic countries have adapted the UK system for use with the television Systems B and G used in those countries, and the European Broadcasting Union (EBU) is considering a recommendation that those members planning to introduce digital two-channel sound with terrestrial television should base their choice on this system.

Survey of multi-channel systems considered

Terrestrial television signals are broadcast according to a wide range of different standards throughout the world. There are various channel bandwidths, scanning standards, colour systems, sense of modulation, vestigial sideband widths, sound carrier frequency offset and sound-signal modulation systems. Furthermore, these different television systems

S. R. Ely

Bob Ely graduated from the University of Liverpool in 1972 with a degree in Electronics. He remained there to study towards a Ph.D which was granted in 1977 for a thesis on high-speed data communications. This work was undertaken in conjunction with the Daresbury Nuclear Physics Laboratory.

In 1975 Bob Ely joined BBC Research Department, Kingswood Warren. He had responsibility in the development of the Radio Data System, RDS, and was involved in the development of the Teleswitching System. Since 1983 he has had responsibility in the development of the UK System for Digital Two-Channel Sound with Television. Bob Ely is at present Head of Carrier Systems Section at BBC Research Department. His current research activities include modulation and coding systems for digital audio and television and conditional access television.

Table 1: Multi-channel terrestrial television sound systems considered

System	Description	Where used
Pilot-tone	A.M subcarrier system modulating existing mono f.m carrier. (as in v.h.f/f.m sound broadcasting).	Used in the USA (with noise reduction on the difference signal). BTSC/MTS system.
	F.M subcarrier modulating existing mono f.m carrier	Used in Japan since 1978
Two-carrier f.m	Additional f.m sound carrier	Used in W. Germany, Holland, and Australia
	F.D.M-additional sound carrier modulated by digitally encoded sound signals	Used in the UK digital system and its System B/G variants. The NICAM 728 system.
Digital systems	T.D.M -digitally encoded sound signals introduced in vertical blanking interval (as in teletext).	Not used — capacity already used for teletext.
	T.D.M -digitally encoded sound signals introduced in horizontal blanking interval. (as in Sound-in-Syncs).	Used in the BBC Sound-in Syncs system for point-to-point distribution of sound signals.

have different tolerances to co- and adjacent-channel interference which reflect in the planned levels of these interferences in different countries and across borders. All of these factors have some influence on the possibilities for adding additional sound signals[1].

Table 1 lists the alternative multi-channel sound systems which are already in use in other countries, and which were considered for the UK before the development of the UK digital system.

Pilot-tone system

The pilot-tone stereo system used for v.h.f/f.m radio broadcasting in the UK and other countries is capable of high quality and is simple to implement at the transmitters and in receivers. A first approach was therefore to investigate whether it might be feasible to adapt this system for television sound. The principal problem was found to be interference from the vision signal: intermodulation with components at line frequency and its harmonics can cause highly audible whistles in a pilot-tone television receiver. These effects are reduced by choosing line frequency rather than 19kHz as the pilot tone but it is found that the power spectral density of these vision-signal-related interferences increases sharply with increasing baseband frequency so the difference signal is very vulnerable.

One possible solution to such interference is to use a noise reduction system. However, to maintain compatibility with existing mono receivers this noise reduction system can be applied only to the new stereo difference signal and not to the sum signal as well. Under these circumstances, with noise reduction applied to the stereo difference signal alone, careful attention must be paid to the alignment of the encoder and decoders since small errors in the tracking of the decoders with the encoder will result in poor separation between the decoded left and right audio signals.

Such a pilot-tone system with a proprietary noise-reduction system on the difference signal is used in the USA. This is the BTSC* multi-channel television sound (MTS) system [2]. In addition to stereo, the BTSC system provides (on supplementary subcarriers above the difference signal) a second audio programme (SAP) channel and a data channel known as the non-public channel (NPC). The BTSC system, which was still emergent whilst the UK system was being developed, did not, however, seem to meet fully the objectives of improved quality and excellent audio channel separation (for dual-language use) which were sought for a UK system.

F.M/F.M system

The f.m/f.m system[3,4] is similar to the pilot-tone system except that frequency modulation of the subcarrier is used instead of amplitude modulation. This yields some advantages but also some disadvantages, notably increased distortion compared with an a.m subcarrier system[5].

This system has been used for stereo and dual-language in Japan since late 1978. Its use was considered by several European broadcasters in the early 1970s but it was found[3] that the two-carrier system described below gave better performance under multipath reception conditions or when co-channel interference is present.

Two-carrier f.m system

A two-carrier f.m sound system was developed in the Federal Republic of Germany (W. Germany) and has been introduced into service there and in several other countries including Holland and Australia[3,6]. The additional sound carrier is used to carry either the additional information needed for stereo or a second language.

In television Systems B and G used in W. Germany and much of the rest of Europe the main (mono) sound carrier is spaced at 5.5MHz above the vision carrier. In the two-carrier f.m system the additional sound carrier is set at 242kHz above the main (mono) sound carrier, i.e, 5.742MHz above the vision carrier.

In the television System I used in the UK, the vision signal has a greater bandwidth and the main (mono) sound carrier is set at 6.0MHz above the vision carrier. To adapt the two-carrier f.m system for use in the UK it would therefore have been necessary to choose a new

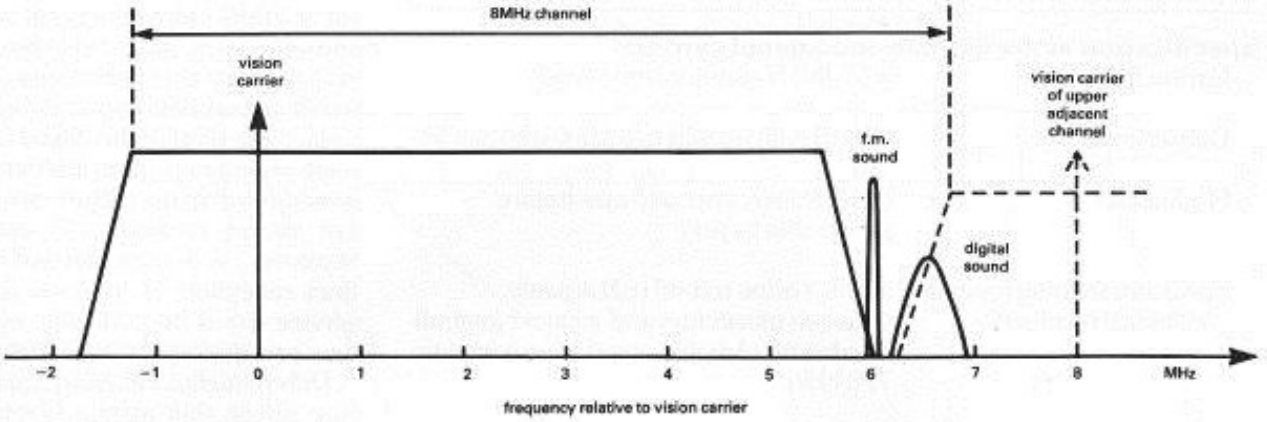


Fig. 1 Spectrum of System I television signal with digital two-channel sound-signal (vertical axis not to scale)

intercarrier spacing for the second sound carrier. Tests conducted by the BBC during 1982 indicated that an intercarrier spacing of about 6.304MHz would be preferred for a System I version of the two-carrier f.m system.[7] These tests revealed that with this adapted system the available margins of compatibility and ruggedness were uncomfortably small. If the second f.m sound carrier were set at a level just sufficient to allow reliable detection on new receivers, then to prevent intermodulation products appearing on some existing receivers it would have been necessary to reduce the level of the main (mono) sound carrier to a point at which buzz-on-sound would have become a problem on others.

Digital systems

While these investigations of analogue systems were taking place, compact disc made its debut, heralding the introduction of low-cost digital sound systems into the home. Proposals for direct broadcasting satellite (d.b.s) and cable systems based on the MAC/packet family of systems[8] offered the prospect of digital multichannel sound with television via those routes. So it seemed appropriate to examine the feasibility of broadcasting terrestrially the necessary extra information for stereo or dual language in digitally encoded rather than analogue form.

A digital system offers a number of important advantages over an analogue system:

a) improved signal-to-noise ratio and low distortion,

b) theoretically unlimited separation between the decoded sound signals,

c) uniform performance throughout the service areas of the transmitters; noise and distortion are not cumulative throughout the transmission system,

d) additional capacity is available to provide a low-rate data channel, e.g, to carry encryption control data in a pay-tv system. When not needed to carry stereo or dual-language sound signals, the main digital channels may be used to convey data.

There are several ways in which digitally encoded sound signals can be introduced into a television channel:

a) frequency division multiplexing (f.d.m),

b) time division multiplexing (t.d.m) at baseband,

c) time division multiplexing at radio frequency (r.f t.d.m).

R.F t.d.m could not be introduced compatibly on existing terrestrial broadcasts; baseband t.d.m. was, however, a possibility, using data inserted into television lines in the field blanking time or into the line blanking time of the video signals. Teletext systems, however, already occupy many of the available lines in the field blanking of UK broadcasts. And although Sound-in-Syncs (SIS) has been successfully used for many years to convey sound signals digitally in the BBC's point-to-point distribution circuits, data introduced into the line-blanking interval was found to be incompatible with some existing domestic receivers especially under conditions of multipath interference (when the data signal becomes visible as crawling dots).

The suggestion of using an f.d.m. system with an additional digitally modulated carrier to convey sound or data signals with System I television signals was made in 1978[9]. During 1983, a preliminary experimental system based on this proposal was built, and laboratory and field-tests begun.

The UK digital system

Summary of the specification

The outline characteristics of the UK system for providing two additional sound channels with System I television are given in Table 2. Figure 1 gives the idealized spectrum of the System I picture and sound signal components and shows the position at which it was decided to place the new, digitally modulated carrier. A preliminary estimate of the likely effects of interference to and from signals in the upper adjacent channel led to the conclusion that with the new digitally modulated carrier frequency set at about 6.55MHz above the frequency of the transmitted vision carrier, a bandwidth of around 700kHz would be availa-

* So designated after the Broadcast Television Sound Systems Committee of the Electronic Industries Association (EIA) of the USA who proposed it as a USA standard.

Table 2: Summary of the characteristics of the UK standard for digital stereo sound with System I television

Specification of the digitally modulated carrier:	
Carrier frequency	6.552MHz above vision carrier
Carrier level	–20dB with respect to peak vision carrier
Modulation	Differentially encoded quadrature phase-shift keying
Spectrum shaping (overall with ideal receiver)	100% cosine roll-off split equally between transmitter and receiver (overall bandwidth of digital signal approximately 728 kHz)
Level of primary f.m sound carrier	–10dB with respect to peak vision carrier
Overall bit-rate	728 kbit/s
Sounding coding characteristics:	
Pre-emphasis	CCITT Recommendation J.17 (6.5 dB attenuation at 800 Hz)
Sampling frequency	32 kHz
Initial resolution	14 bits/sample
Companding Characteristics	near-instanteous with compression to 10 bits/sample in 32-sample (1ms) blocks
Coding for compressed samples	2's complement
Number of coding ranges	5 } signalled by 3-bit scale factor
Number of protection ranges	7 }
Error protection	One parity bit added to each 10-bit sample to check the six most significant bits (parity modified for scale-factor signalling)
Scale-factor signalling 3 bits per sound coding block (two blocks per frame)	By modification of 9 parity bits per scale factor bit, detected by majority decision logic.
Bit Interleaving	44 × 66 (frame alignment word not interleaved)
Energy dispersal scrambling	By addition, modulo-two of a pseudo-random sequence of length $2^9 - 1$ bits, synchronously with the multiplex frame. Frame alignment word not scrambled.
Frame format	728 bits frame length (in 1ms) with 8-bit frame alignment word.

ble for the digital signal.

The level of the digital signal was set at 20dB below the peak vision carrier level by the need to balance very carefully the conflicting requirements of compatibility and ruggedness: if the level of the digital signal were set too high, then interference would result to the picture or mono f.m sound received on existing receivers; if it were set too low, then reception of the new digital service woud be unreliable on the new sets designed to decode it.

Differentially encoded quadrature phase shift keying (d.q.p.s.k) modulation was selected as offering the best overall compromise between efficient use of the available spectrum space and the need for reliable reception with inexpensive receivers. This modulation system allowed an overall bit-rate of around 700kbit/s to be accommodated.

The audio sampling-frequency of 32kHz was selected because of its existing international use in point-to-point distribution circuits and in the MAC/packet family of systems. Previous BBC work on point-to-point digital sound transmission systems had led to the development of a high-quality near-instantaneous companding system which needed, after allowing for overheads such as framing, error protection and ancillary data, a little over 10 bits per sample[10]. This system required an overall bit-rate which could be fitted comfortably in the capacity available.

In preliminary tests, an early version of the BBC NICAM digital sound companding and multiplexing system was used at a bit-rate of 704kbit/s. Later tests used BBC NICAM-3 equipment which is used for point-to-point transmission and has an overall bit-rate of 676kbit/s. Although this NICAM-3 equipment was found to work well in this new application, UK receiver manufacturers had indicated a strong desire for maximum commonality with one of the digital sound coding options specified in the agreed MAC/packet family of systems[8]. Accordingly, a new baseband coding structure was defined in which the data are formed into 728-bit frames each of 1 ms duration, giving an overall bit-rate of 728kbit/s. In each 728-bit frame (figure 2), the

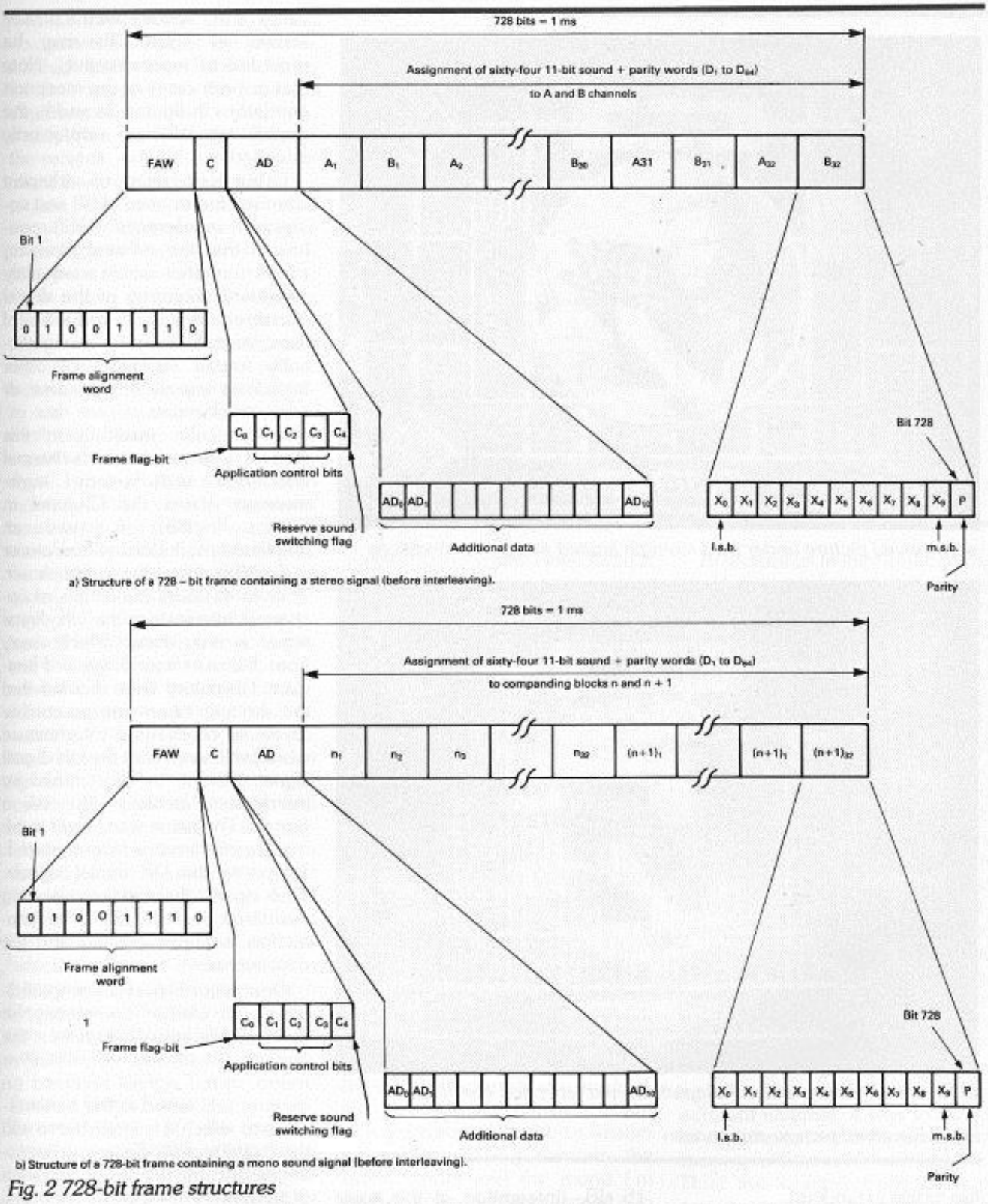


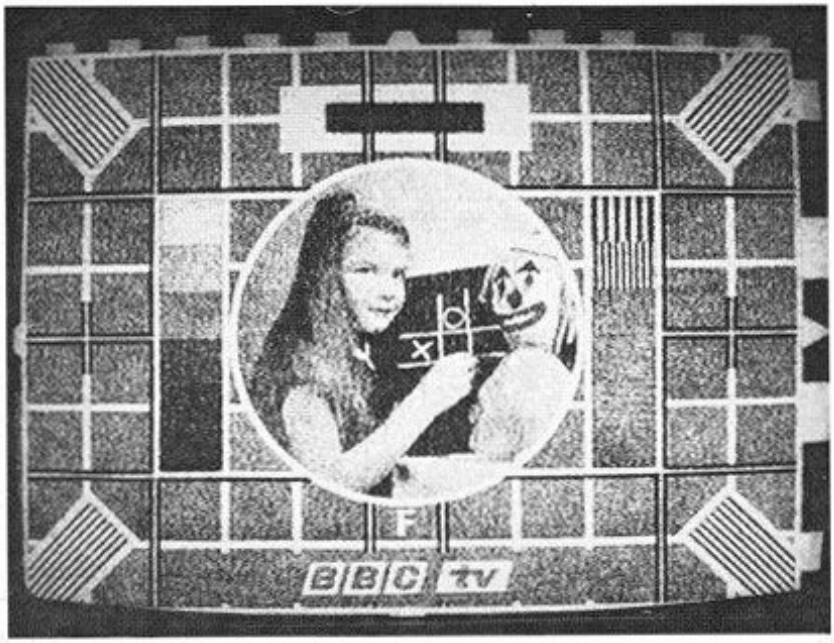
Fig. 2 728-bit frame structures

first eight bits comprise a frame-alignment word which is needed to enable the receiver/decoder to identify the boundaries of the frames in the received data stream.

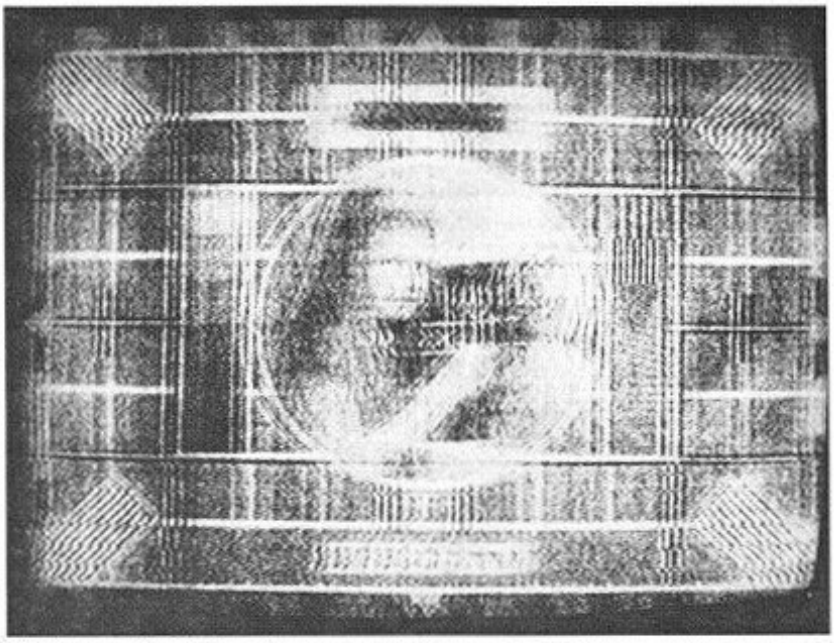
The 720 bits which follow the frame-alignment word form a structure common with that of the first-level protected, companded sound-signal blocks in the MAC/packet systems.

Laboratory and field tests

In the autumn of 1983, over-air field tests of the modulation and r.f aspects of the then experimental digital system were performed using a BBC transmitter at Wenvoe in South Wales.[11] The main purpose of these tests was to investigate the reliability of reception of the system under a variety of propagation conditions. The Wenvoe transmitter was chosen because it serves a mountainous area in which the effects of multipath are a particular problem. Furthermore, because of this topography, large numbers of rebroadcast relay stations (transposers) are used to serve the surrounding area, and it was of interest to investigate whether the signal would travel satisfactorily through long chains of transposers



a) Received picture under field-strength limited reception conditions



b) Received picture under multipath limited reception conditions

Fig. 3 Received picture comparison

(up to five in tandem).

These tests gave very satisfactory results, indicating that the system was acceptably rugged against impaired reception due to low field-strength and/or multipath propagation. Figure 3a show an example of the picture received under field-strength limited reception conditions; the input e.m.f to the receiver antenna input was about 30μV (75Ω source) and the picture-signal-to-r.m.s. unweighted noise ratio about 18 dB. (Integration of the noise during the exposure time of the photograph has given an improvement in the picture quality shown in figure 3a compared with that seen on the screen). Figure 3b shows the picture quality under multipath limited reception conditions; multiple echoes of 30% or more were present at delays ranging up to 10 μs. (The effect of multipath on the digital system is critically dependent upon the precise delay of the echoes but the picture shown in figure 3b may be regarded as representative). Note that in both cases of the reception conditions in figures 3a and b, the digital signal was satisfactorily decoded.

Laboratory tests of adjacent channel interference (ACI) and co-channel interference (CCI) confirmed that the existing planning protection ratios would adequately safeguard reception of the digital signals and that the introduction of these signals would not significantly impair reception of other broadcast signals in the same or adjacent channels.

A particular question in this respect was potential co-channel interference with System L transmissions across the Channel in France. System L uses an amplitude-modulated sound carrier at 6.5MHz above the vision carrier. Therefore, under conditions of co-channel interference the UK digital signal is only about 50kHz away from this a.m sound signal. However, laboratory tests showed that the limiting factor for acceptable levels of co-channel interference would still, even with the UK digital signal present, be determined by interference between the vision signals. The same was found to be true for interference from System L signals to the UK digital signals. Thus again, the existing planning standards provide adequate protection for both existing and the new services.

One major aspect of compatibility which cannot completely be evaluated in laboratory tests is the impairment, if any, of picture or mono sound signals received on existing sets tuned to the transmissions to which it is intended to add the digital signals. Factors influencing this include the design and state of adjustment of individual receivers, and local propagation conditions. Such factors can be assessed only in a full-scale over-air compatiblity test.

This was done in the spring of 1984, using one of the main BBC transmitters in London together with its associated relay stations. Various levels of the main (mono f.m) and digital sound signals were used, bracketing the levels proposed. These tests took place outside

normal programme hours and comprised a series of still pictures and high-quality speech (both chosen for their sensitivity to the expected impairments). Invited observers, mainly from the BBC, the IBA and the receiver industry were asked to assess these tests for patterning on the picture, buzz on sound or other impairments. Examples were given of these expected impairments to sensitize the observers to them.

The results showed little evidence of impairment to reception of the picture or mono f.m sound signals when the digital signals were added. Indeed, this good level of compatibility with existing receivers has been confirmed during the continuous experimental broadcasts of the UK digital system which have been radiated during normal programme hours since July 1986. Two factors contribute towards this good result: the digitally modulated signal can be added at a lower level than an analogue f.m signal for reliable reception at the fringes of the service areas; and the digital signal is much more noise-like than an analogue f.m signal, so any intermodulation products resulting from the digital signal are less annoying than those from an f.m signal.

After this preliminary work had been done, further work was undertaken towards confirming the detailed choices of modulation system and development of the 728kbit/s digital multiplex described above. These later laboratory and over-air tests helped to optimize these choices in the specification of the system which has now been adopted as the UK system for digital two-channel sound with terrestrial television.[12]

Tests in Hong Kong

Demonstrations of the system aroused considerable international interest. In 1984 the BBC was approached by broadcasters from Hong Kong who were interested in performing their own tests with the system. Hong Kong uses the same System I television standard in the u.h.f bands as the UK, and has a need for dual-language broadcasts. The digital system, with its very good channel separation, would be well suited to such use. Tests have therefore been carried out by TVB using equipment loaned to them by the BBC and with help from BBC engineers who visited Hong Kong at the start of the tests.

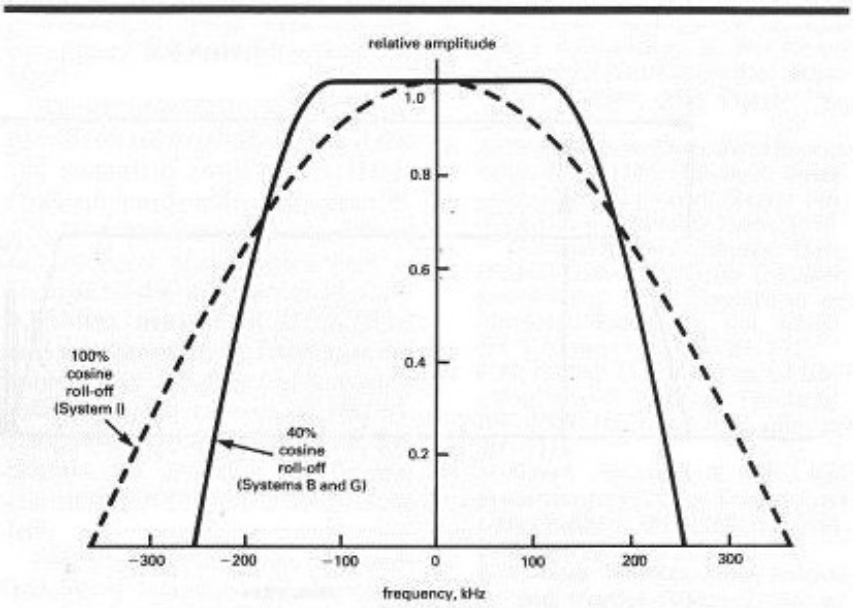


Fig. 4 Spectrum shaping for System I and System B/G

Despite the adverse propagation conditions, mainly due to mountains and tall buildings, these tests gave encouraging results, and have given further confidence in the ruggedness and compatibility of the UK system.

Application to other television systems

Most of the rest of Europe uses television Systems B and G rather than System I. System B exists in 7MHz v.h.f channels rather than the 8MHz u.h.f channels of System I. There was therefore some question as to whether it would be possible to use a digital system in these narrower channels. However, the spectral gap available for the digital signal is the same in System B as it is in System I because the narrower channels are compensated by a smaller intercarrier spacing between the vision carrier and the mono f.m sound carrier (5.5MHz instead of 6 MHz) and a narrower vestigial sideband for the picture signal.

Broadcasters in the Nordic countries had started independent tests with a 512kbit/s digital system in 1984. This lower bit-rate allowed the frequency of the digital carrier to be set at only 350kHz above the f.m sound signal, i.e, 5.85MHz above the vision carrier. Although encouraging results were obtained with this 512kbit/s system, the reduced bit-rate caused some loss of quality compared with the 728 kbit/s system. Also the advantages of commonality with the UK system (and the MAC/packet family) were recognized by the Nordic broadcasters and the receiver industry. Consequently, towards the end of last year, the Nordic broadcasters, with some help from the BBC, made strong efforts to adapt the 728kbit/s UK system for use in Systems B and G.

To avoid interference to receivers tuned to the signal in the upper adjacent channel, it was found to be essential to restrict the intercarrier spacing in System B to 5.85MHz. Thus the spacing from the f.m sound signal was only about 63% of that in System I. This was inadequate to accommodate the

Table 3: Modulation characteristics for digital two-channel sound with television

	System B and G	System I
Carrier frequency	5.85 MHz above vision carrier frequency	6.552 MHz above vision carrier frequency
Spectrum shaping	40% cosine roll-off overall	100% cosine roll-off overall

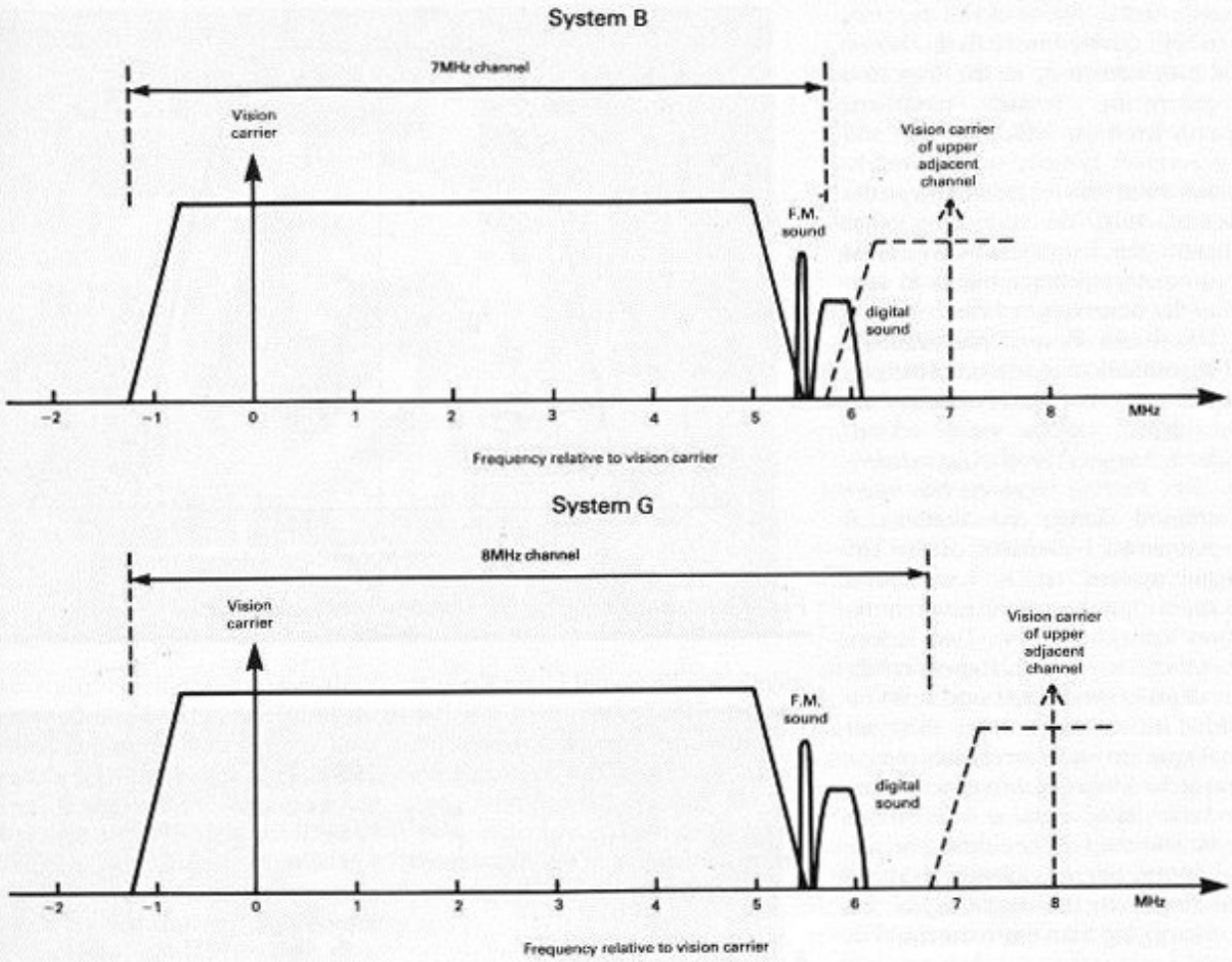


Fig. 5 Spectra of digital two-channel sound with television in Systems B and G (vertical axis not to scale)

spectrum of the specified digital signal which, for the UK system, is 700kHz wide. However, by using narrower bandwidth data-shaping filtering, (figure 4) (40% cosine roll-off overall instead of 100%) the 728kbit/s signal can be accommodated in System B with 5.85MHz intercarrier spacing (figure 5a). The same parameter values can also be used in System G where, with 8 MHz wide u.h.f channels, there is plenty of space for the digital signal (figure 5b).

Following successful tests with this adaptation, the Nordic broadcasters have adopted the UK 728kbit/s system. Furthermore, the European Broadcasting Union (EBU) is considering a recommendation that those members planning to introduce digital two-channel sound with television should base their choice on this system.

The differences between the System B/G and System I versions are shown in Table 3. These may be seen to comprise only the different intercarrier spacing and data-shaping filtering needed because of the existing differences between these television systems.

The successful application of this system to Systems B and G indicates that the System would also work in other television systems. The BBC has made limited laboratory tests which indicate that it would work in the television System L used in France. Furthermore, with suitable choice of intercarrier spacing, the system seems likely to work in television System D used in China and in System M used in the USA. Tests of compatibility with existing receivers, ruggedness, and co- and adjacent-channel interference would, however, be needed in the countries concerned to establish this.

Further work

Although neither the BBC nor any of the ITV companies have yet announced firm plans to provide a full stereo sound service, the BBC, at least, is taking the first steps towards making the programme distribution and transmitter network capable of conveying digital stereo sound signals. This will include provision of a dual-channel SIS system for point-to-point distribution of stereo signals. Within the next eighteen months, the majority of BBC TV main production studios will be equipped for stereo productions. Since July 1986, several of the programmes broadcast each week from the BBC-2 transmitter at Crystal Palace in London have included experimental digital stereo sound and from April 1987 these experimental transmissions have been extended to include broadcasts from the BBC-1 transmitter at Crystal Place.

Detailed discussions have been held with receiver manufacturers concerning implementation of receivers for the digital system, and several manufacturers are well advanced in the development of receivers.

Conclusions

A digital system (now known as the

NICAM 728 System) to convey two high-quality digitally coded sound signals with the existing terrestrial u.h.f television System I has been developed and the joint specification prepared by the BBC and IBA has been approved by the UK Government. Although primarily intended for stereo sound, this system is also capable of conveying two separate digitally coded sound signals or data signals in addition to, and separately from, the mono f.m sound signal. This feature could be used for multi-language sound broadcasts.

Laboratory and over-air tests have been successfully undertaken to prove the compatibility and ruggedness of the UK system, and to help determine the optimum choices for the modulation and baseband coding systems. These tests have confirmed that the specified system, using differentially encoded d.q.p.s.k. modulation and a system of Near Instantaneous (NI) Companding digital sound coding with an overall bit-rate of 728kbit/s, yields excellent results. There is good commonality between the sound coding of the NICAM 728 system and one of the sound coding options contained in the agreed European MAC/packet family of systems.

Considerable international interest has been aroused in the UK system. Broadcasters in Hong Kong, where, as in the UK, System I television is transmitted, have undertaken successful laboratory and over-air tests of the UK system and its predecessors using experimental equipment loaned to them by the BBC.

Broadcasters in the Nordic countries have successfully adapted the UK system to work in the 7MHz channel bandwidth of System B. The changes from the UK system are minimal and involve only a change to the intercarrier spacing 5.85MHz instead of 6.552MHz) and the data-shaping filtering at the source and receiver (40% cosine roll-off overall instead of 100%). Following successful tests of this System B version, the Nordic countries have adopted the UK system.

Discussions have been held with interested receiver manufacturers concerning the implementation of receivers for the UK system. Several receiver manufacturers are well advanced in the development of prototype receivers for the UK digital sound-with-television system and the System B/G variant of it.

Acknowlegements

The author would like to acknowledge the contributions made to this work by his colleagues at Research Department and elsewhere within the Corporation. The author is also grateful to the Director of Engineering of the BBC for permission to publish this article.

References

1. S.M. Edwardson: 'Stereophonic and two-channel sound in terrestrial television broadcasting', IBC 1982, IEE Conf. Publ. 222, pp 276-281.
2. R. Hoffner: 'Multichannel television sound broadcasting in the United States', AES 82nd Convention, (March 1987), London, AES Preprint No. 2435 (C-4).
3. CCIR, Recommendations and Reports of the CCIR, 1978. Volume X, Broadcasting Service (Sound), Report 795. XIVth Plenary Assembly, Kyoto, 1978.
4. Y. Numaguchi and S. Harada: 'Multichannel Sound System for Television Broadcasting', IEEE Transactions on Consumer Electronics, Vol. CE-27, No. 3, (August 1981), pp 366-371.
5. E.M. Tingley: 'U.S. Multichannel Television Sound Technical Standards', IBC 1984, IEE Conf. Publ. 240, pp 308-311.
6. S. Dinsel: 'Stereophonic sound and two languages in TV, the double-sound carrier method', IBC 1980, IEE Conf. Publ. 191, pp 207-211.
7. A.H. Jones: 'The two-carrier method for dual channel TV sound: over-air tests in the UK', IEE Colloquium on Dual Channel TV Sound Terrestrial Broadcasting and Reception, (April 1983), IEE Digest No. 1983/39, pp 2/1 -2/4.
8. EBU, 'Specification of the systems of the MAC/packet family', Doc. Tech. 3258-E, EBU Technical Centre, Brussels.
9. J.L. Eaton and R.V. Harvey: 'A two-channel sound system for television', IBC 1980, IEE Conf. Publ. No. 191, pp 212-215.
10. C.R. Cain, A.R. English and J.W.H. O'Clarey: 'NICAM-3: Near-instantaneously companded digital transmission system for high-quality sound programmes', The Radio and Electronic Engineer, Vol. 51, No. 10, (October 1980), pp 519-530.
11. S.R. Ely: 'Experimental digital stereo sound with terrestrial television: field-tests from Wenvoe, October 1983;' BBC Research Department Report No. 1983/19.
12. A.H. Jones: 'Digital two-channel sound with terrestrial television', Electronics and Power (November/December 1986) pp 801-803.

ZUSAMMENFASSUNG

Die britische Regierung hat eine gemeinsame Spezifikation der Rundfunkgesellschaften BBC und IBA über Sendenormen für Digital-Stereoton bei erdegebundenem Fernsehen genehmigt. Dieses, über die letzten vier Jahre von BBC-Technikern entwickelte System überträgt digital kodierte Tonsignale hoher Qualität zusammen mit den Bild- und den Mono-FM-Signalen des britischen Fernsehsystems I.

Ausgedehnte Tests im Labor und über Funkstrecken haben sowohl Verträglichkeit wie auch Robustheit dieses Systems bewiesen und die Wahl des Modulationssystems sowie der Basisband-Kodiermethode optimiert.

Funktechnikern in den nordischen Ländern wurde bei der Anpassung des britischen Systems an die Fernsehsysteme B und G entsprechende Hilfestellung geleistet.

RÉSUMÉ

Le gouvernement britannique a approuvé la spécification commune BBC/IBA concernant une norme de transmission pour un son stéréophonique numérique avec une télévision terrestre. Ce système, qui fut mis au point par des ingénieurs de la BBC au cours des quatre dernières années, achemine deux signaux sonores de haute qualité, codés numériquement, avec l'image et des signaux sonores mono MF du Système I de la télévision britannique.

Des essais approfondis en laboratoire et sur les ondes ont démontré la compatibilité et la robustesse de ce système, et ils ont permis d'optimiser les choix du système de modulation et de la méthode de codage de la bande de base.

Une aide a été prêtée aux organismes de radiodiffusion des pays nordiques en vue de l'adaptation du système britannique pour l'utiliser avec les systèmes B et G de télévision.

RESUMEN

El Gobierno británico ha aprobado la especificación conjunta de BBC/IBA para una transmisión standard de sonido estéreo digital con la televisión terrestre. Este sistema, que han desarrollado los ingenieros de la BBC durante los últimos cuatro años, transmite dos señales de sonido de alta calidad y con código digital junto con las señales de imagen y sonido f.m. mono del Sistema I de televisión del Reino Unido.

Las amplias pruebas realizadas en el laboratorio y en el aire han demostrado la compatibilidad el este sistema, su resistencia, y han optimizado las posibilidades para elegir el sistema de modulación y el método de codificación de la banda base.

Se ha prestado asistencia a las compañías dedicadas a transmisiones en los países nórdicos par que adapten el sistema británico par uso con los Sistemas B y G.