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THE IMPORTANCE OF PICTURE REPETITION RATE IN TELEVISION

NONE OF THE FACTS AND IDEAS DISCUSSED in this article is in any way new; very new is the impact on our imaginations of the success of the communication satellite, Telstar, which has already successfully transmitted colour television pictures across the Atlantic. The fact that the American pictures, after their 17,000-mile journey via space, could only be viewed on a few American receivers in Great Britain, and that the pictures from Britain had to be generated on American standards to make them of use in the U.S.A, is an ironic comment on the existence of differing scanning standards in a world which will soon be able to communicate by television from any one country to any other. Although, as we shall see, the world is dividing into two almost equal-sized groups of countries each using a different scanning standard, it is not too late to reverse this movement towards division. Fortunately, in a world where agreement is difficult to reach unless immediate benefits for individual countries arise therefrom, an important element of self-interest is involved. The two standards do not offer equal performance; the American standard of 525 lines/60 fields meets the needs of domestic reception better than the 625 lines/50 fields system. (For the purpose of this article, we shall call this standard the European Standard.) This should not be taken to mean that the parameters used in American broadcasting are superior in all respects; in particular the European system employs a wider bandwidth which, with advantage, could also be used for the American system if it was adopted in Europe.

DEFINITION OF TERMS

The technical terms concerned with scanning standards will now be defined. Although we shall be considering only interlaced systems of scanning, reference will be made to sequential systems. An interlaced system is one in which two *fields*, each consisting of one-half of the total number of lines forming a complete picture, are produced in sequence in time. Thus, two adjacent lines in the complete picture do not follow each other in the time taken to scan one line of the picture, say 60 μsec, but are spaced apart by a time corresponding to the field rate, i.e. 20 m sec for the 625 lines system and 17 m sec approximately for the 525 lines system. The phenomenon of retentivity of an image for a period of time by the human eye is called upon to achieve the impression of a complete picture. Because of the fine pitch of the scanning lines, the two fields can differ only in small details, so that the amount of light emitted by the whole area of the image is substantially the same in two successive fields. Since, at normal viewing distance, the observer's impression of flicker of the image as a whole is dependent on the total amount of light reaching his eyes, flicker, as normally understood, is determined by the field rate. The rate at which complete pictures occur is alternatively referred to as the "picture rate" or "frame rate"; we shall use the term "picture rate".

The European system uses 625 lines in the complete picture; the time of duration of one line is 64 μsec corresponding to a line frequency of 15,625 c/s, the field rate is 50 per second and the picture rate 25 per second.

The 525 lines system has 525 lines in the complete picture; the time of duration of one line is 63·5 μsec corresponding to a line frequency of 15,750 c/s, the field rate is 60 per second and the picture rate is 30 per second.

A sequential system is one in which the scanning lines of the complete picture are produced one after the other, separated in time by the duration of one line. For all practical purposes, this time, a few tens of microseconds, is so short that adjacent lines can be said to exist simultaneously so far as the viewer's eye

is concerned. The sequential system has no field rate, only a picture rate which must be high enough to avoid flicker. Thus, a 625 lines/50 pictures per second sequential system would give the same impression of overall picture flicker as a 625 lines/50 fields interlaced system. The time of duration of one line of such a system would be 32 μsec corresponding to a line frequency of 31,250 c/s, and the picture rate is 50 per second. Such a system would require twice the bandwidth of the interlaced system described above, which is why it is not used. The interlaced system is an attempt to use the characteristics of the eye to produce the same effect as the sequential picture and save half the bandwidth. As we shall see, like most attempts to get something for nothing, it is not wholly successful.

THE PRESENT POSITION OF SCANNING STANDARDS

There are at least four scanning standards in substantial use in various countries, but all countries not using the American 525 lines standard will either use the 625 lines European standard as they do now, or have announced their intention of so doing in the future. In the future, therefore, there will be two scanning standards in use throughout the world, the American and the European. So far as broadcasting is concerned, it seems not unreasonable to believe that the wider bandwidth needed for systems of more lines will prevent their use for a very long time, even if we wished to adopt them.

TECHNICAL CONSIDERATION OF THE TWO SCANNING SYSTEMS

The two scanning systems have virtually the same line scanning frequency, so that in any given bandwidth they are capable of resolving the same fineness of detail along the scanning line, a feature usually described as horizontal resolution. Apparently, having more lines in the height of the picture, the 625 lines system should have more vertical resolution than the 525 lines system, in the ratio of six to five. This, however, ignores the effects of interlacing and field repetition rate to which we shall return later. The most obvious difference in the two systems is the relative brightness of picture which each can produce without noticeable flicker because of their differing field rates.

Although the designers of the two systems were well aware of the implications of their choice of field rate, the decision to use 50 fields for European and some other countries and 60 fields for America was more or less inevitable because of the quite fortuitous fact that the frequency of the power supply in these two areas was 50 c/s and 60 c/s respectively; difficulties were encountered in the studio and particularly in the domestic receiver with the beat frequency which arose when the field rate and the power supply frequency differed significantly. These difficulties were sufficiently important for the designers of the 50 fields system to accept that the maximum brightness of the picture could not be, for similar conditions, more than about one-sixth of that of the 60 fields picture. The Ferry-Porter law which connects brightness and flicker is:

$$f_c = F + 12{\cdot}6 \log_{10} B$$

where f_c = critical flicker frequency (in cycles per second) below which perceptible flicker is seen,

F = a constant,

and B = luminance of high-lights, in ft-lamberts.

For typical television viewing conditions, the same reference gives the value of the constant F as 37 which, for 50 fields pictures, gives a maximum highlight for brightness for flicker-free pictures of 10 ft-lamberts, while the equivalent figure for 60 fields pictures is 68 ft-lamberts. Certainly, the former figure has been amply confirmed by experience with 50 fields television, although constant use somewhat dulls the senses and higher brightnesses are commonly used.

Another important characteristic of the television image is the visibility of the scanning structure. Britain is about to make the change from 405 to 625 lines largely because of this feature, and it would seem that the 525 lines system is at a disadvantage in this respect compared with the 625 lines system. However, it is an observed fact that the visibility of the 525 lines and 625 lines scanning structures is about equal, even on a plain raster of constant illumination over the whole area of the picture. It is none too easy to explain why this should be so, but the following is put forward for examination.

Undoubtedly the fundamental cause is the use of interlacing which works according to theory only when there is absolutely no difference between successive fields. As soon as any difference occurs, a component at picture repetition rate is introduced. Even on a plain raster, movements of the observer's eyes, which are occurring continuously, introduce a proportion of the field structure, with half the full number of lines. The observer is made aware of the field structure because of flicker. The Ferry-Porter law shows that awareness of flicker begins at three times the brightness for the 30-cycle component of the 60 fields system as compared with the 25-cycle component of

the 50 fields system. Thus, while neither system is equivalent to a sequential structure of the same number of lines (this is an observed fact), the higher field rate system approaches nearer to this ideal. The argument may be summed up by stating that interlacing works better the faster you do it, and accordingly the 60 fields system gives the appearance of a rather greater proportion on average of the total number of scanning lines than does the 50 fields system. The result is that, subjectively, the fineness of the structure due to the scanning lines appears to be about the same.

The same arguments apply to the ability of the two systems to portray vertical resolution, a point to which reference was made at the beginning of the section. In this case it is rather more obvious that fine detail, which produces a different signal on two successive fields, will generate a pattern at picture repetition rate which will flicker in brightness at that rate. This effect is often called "interline flicker or twinkle", and it sets a limit to the vertical detail which an interlaced system can reproduce, the limit depending on the field repetition rate. Again it is a fact of observation that the 60 fields system has a still "printed on" appearance compared with the restless "busy" 50 fields picture. It is probable that the latter can convey less vertical detail in a satisfactory fashion in spite of the fact that it has more lines.

The situation may be summed up as follows:

In a given bandwidth, the total amount of information which can be transmitted in any prescribed period of time is the same for any television scanning system. The 60 fields system has parameters which make better use of the retentivity feature of human vision, so that interlaced scanning, which depends absolutely on this mechanism, works more effectively. The result is that by comparison with the 50 fields system, the 60 fields system provides pictures of six times the brightness for equal flicker sensations, gives the subjective impression of having as many scanning lines, has less interline flicker effects, probably more vertical resolution, and the same horizontal resolution for the same bandwidth.

THE DIFFICULTY OF ADOPTING THE 525 LINES SYSTEM

Were we free to choose, the only technical difficulty which prevents the adoption of the 525 lines system in countries where the power supply is 50 c/s is the possible production of flicker and picture movements arising at the beat frequency of 10 c/s. This 10 c/s beat is produced in equipment producing or displaying the 60 fields pictures because of residual hum in the power supplies derived from the 50 c/s mains, or in some cases by interference from magnetic and electrostatic fields. The difficulty of coping with this problem should not be underestimated, since flicker at 10 periods per second is several hundred times as visible as that at 50 periods per second, which, we are arguing, is itself obtrusive; in fact at the time at which the 625 lines system was established, a serious study of the possibility of using 60 fields was made and abandoned because of the difficulties encountered with the 10 periods per second beat flicker. However, as always, technology has advanced in the intervening years, and television receivers are now available which perform satisfactorily on a mains frequency differing from that of the field frequency by 10 c/s. A most striking example of this occurs in Japan where the 60 fields system is used while 50% of the power supplies on which they operate are 50 c/s. In addition, the use of transistors in domestic television receivers, which can be expected within the next few years, should further reduce the problem. At the transmitting end, the problem, although severe, is manageable. The additional cost both for the receiver and for the transmitting authorities in using 60 fields pictures in countries having a 50 c/s power supply is quite insignificant in relation to the total cost of the service.

MAKING THE CHANGE TO 60 FIELDS SYSTEMS

The growing public demand to view television pictures in brightly lit surroundings, and particularly in daylight, will inevitably mean that brighter pictures than those at present available will have to be provided. From time to time there have been suggestions that the 50 fields picture could be much brighter by controlling the decay characteristic of the phosphor of the tube on which the pictures are displayed, in such a way that the picture is present during most of the field cycle and is changed to the next picture during a time small in relation to the time of a field. This must be achieved without introducing any appreciable hangover between one picture and the next if the portrayal of movement is not to be blurred. If a picture tube with such characteristics were to become available, it seems more than likely that it would be a great deal more expensive than the simple device at present in use. Since the tubes are used in millions, it seems unlikely that such a solution could be adopted. The alternative is, of course, to change to a 60 fields system, and it seems to be inevitable that the pressure to make such a change will grow continuously. The sooner, therefore, that plans are

made to enable this change to take place at some time in the future, the better.

For countries which have a well-established 50 fields service, the solution is simple but postpones the change for about ten years. All that is required is that receivers placed on the market after a certain date must be capable of receiving both the 50 and 60 fields systems. This is not at all a formidable requirement since both systems use so nearly the same line frequency that the change would be undetectable on the receiver, while to make a field time basis which can be set to run at either 50 or 60 fields is not in the least difficult. The only feature different from that provided by present-day receivers would be the ability of the new receivers to display a 60 fields picture when powered from 50 c/s mains. At an appropriate date when it was considered that the very great majority of the public possessed receivers of the new type, the change from 50 fields to 60 fields could be made overnight. Naturally, such a course of action would not enable direct exchange of programmes to occur between the American and European groups of countries during the period of preparation before the changeover. As now, such exchanges would have to use the process of standards conversion.

Countries about to establish a new television service could adopt a plan which would enable them to take advantage of the better picture quality offered by the 60 fields system, whilst also having the facility of exchanging programmes, without standards conversion, with countries using either the European or American systems. This plan applies with particular force to Great Britain which is about to make the change to a new scanning standard, the intention at the moment being to use the European standard. The plan involves the production of a receiver which is slightly more complicated than that used for the "delayed changeover" to 60 fields television. The receiver, as before, must be capable of producing a satisfactory picture from 60 fields when powered by 50 c/s mains, and must also have a field time base capable of receiving either a 50 fields signal or a 60 fields signal without the viewer having to make any adjustments. If such receivers were available from the start of the new service, the broadcasting authority would be free to transmit either standard at will. For reasons concerned with the existing 405 lines service, we in Britain might wish, at the beginning of the new service, to transmit normally the European system and use that system for international exchanges with "European" countries, but when exchanging programmes with America, either by direct link or through magnetic tape recordings, we would naturally use the American system. The removal of the process of standards conversion from all the pictures sent out for domestic reception would be a gain in quality for which it would be well worth while paying the slightly increased cost of the domestic receiver. In course of time the superior quality of the pictures on the American system would encourage its use as the normal thing, the European system being reserved for such international exchanges as required its use.

So far no mention has been made of colour television, but all the arguments and proposals in favour of 60 fields television and dual-standard receivers apply with equal or greater force to colour television. It would be necessary for a country adopting dual-standard working to choose the same colour sub-carrier frequency for both the 625 and 525 lines systems. The proposed European colour sub-carrier frequency is 4·43 Mc/s, while the 525 lines uses 3·58 Mc/s. In view of the greater bandwidth which is available in those countries using 625 lines—a bandwidth which ensures higher quality for the eventual use of 525 lines than is available in its country of origin, America—it would be undesirable to lower the colour sub-carrier frequency of the 625 lines system to agree with that of the 525 lines system. In this respect, therefore, the present European and American groups would differ in an otherwise ideal situation in which all countries would be able to exchange programmes on identical standards. Although this is to be regretted, the translation of the colour information from one colour sub-carrier to another of different frequency is not difficult and is greatly to be preferred to the daunting and inherently unsatisfactory task of standards conversion of colour pictures.

CONCLUSION

There is no doubt in the writer's mind that 60 fields television offers picture quality superior to 50 fields, and little doubt that developments in the use of television will eventually compel all countries to think in terms of using a 60 fields system in order to provide bright pictures. The plans which have been suggested will allow a changeover to 60 fields in all countries within a period of 10 years, while some countries, notably Great Britain, can begin to benefit almost immediately. At the end of the preparatory period, all countries of the world would be on standards which would allow complete freedom for exchanging programmes without the necessity for standards conversion. The cost of implementing these proposals would be an extremely small fraction of the total investment in television.