Some Factors in the Evaluation of Image Quality: A British View

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INTRODUCTION

The Romans worshipped a number of gods; one of them was Janus. It will be remembered that Janus was a two-headed god with faces looking in opposite directions. Of course, January acquired its name from Janus as, in that context, the god is seen as looking back over the old year and forward into the new.

Perhaps broadcasting engineers have - but hopefully not to worship - a Janus-like situation in television at this time. For much more than a decade, the world's colour television systems have operated on fairly clearly defined, and well-accepted, principles. Within the last year or two, the broadcasting world has suddenly found itself at one of those great watersheds when it has the chance to keep its present practices or to make a significant change. These opportunities do not occur very often.

This paper considers some factors in the evaluation of image quality, both in terms of where the present system has reached and also with one eye on where it is, or may be, going. Inevitably, therefore, it is a mixture of the author's personal views and those of the post which he holds within the Independent Broadcasting Authority (IBA) in the United Kingdom. There, as its Head of Quality Control, he is responsible for overseeing the technical standards which prevail in the independent part of broadcasting in the United Kingdom - a system consisting of seventeen programme companies, with more than sixty studios, providing programmes for the IBA's two television networks and 1,000 transmitters. Accordingly, the author lives very much with the problems of today.

SUBJECTIVE OR OBJECTIVE EVALUATIONS

Now presumably everybody who watches television does so entirely subjectively - i.e. the aural and pictorial images carry all the information which the broadcaster wishes to convey. It would, therefore, be delightful if all evaluations of picture quality could be made purely subjectively. However, it is a well-known fact that even professional broadcasting engineers are rather variable in their assessment of the seriousness of impairments. As a consequence, they resort to objective evaluation techniques; if such evaluations are to be fully meaningful, it is vital that "the objective measurements should always relate to the subjective effect or defect".

THE PRESENT STANDARDS

The IBA networks operate to widely publicised technical standards - set out in its Code of Practice. Essentially, these are analogue-based with a composite coding system for transmission, and with the viewing expected to be on a screen having a diagonal between perhaps 20 and 26 inches, i.e. between one-half and two-thirds of a metre - a small screen therefore. The

United Kingdom broadcasters have established operating tolerances for the studio equipment, the transmission links and the transmitters themselves, all of which are as near transparent as the present balance in broadcasting economics will allow them to be. Table 1 lists the day-to-day operating tolerances for various signal paths in and around a studio centre. Table 2 extends the details of Table 1 by including the distribution network and various transmitter configurations. Until recently, these standards have been sensibly met for some 90% of the broadcasting time. Before considering the 90% concept further, it is important briefly to consider the front end of the system as well - the place where the studio scene is turned, by one means or another, into an electronic signal.

In this journal, it is not necessary to rehearse all the pros and cons of electronic cameras versus film cameras. In objective measurement terms, tolerances exist within the IBA's network for the lens and electronic camera combination. These are illustrated in Table 3.

It is harder to find the equivalent lens and film camera details. However, there is a much more tortuous electronic versus film debate. Suffice it to say that, certainly in the United Kingdom and presumably in North America as well, there is a definite school of directors that prefers "the film look".

ELECTRONIC LOOK VERSUS FILM LOOK

From the purely engineering standpoint, quantifying that statement is a nearly impossible task - but perhaps it is one to which the electronic camera devotees have not paid enough attention. Variations in transfer characteristic, colorimetric performance, picture repetition rate in movement portrayal, and definition are obviously significant factors - though the last is only indirectly related to the electronic camera per se.

(i) Transfer Characteristics

It is notable that, in some recent television camera designs, new variations in transfer characteristics are becoming a reality. These will allow a closer emulation of this apparently desirable film look by allowing a knee in the highlight area. One of the "failings" of electronic cameras is "burnt-out" whites - when the contrast range is too great and highlights have to be clipped in order to expose flesh tones correctly. But why is the highly non-linear transfer characteristic of the film chain deemed to be preferable to the more linear electronic, when both are viewed via a television system - or is that only true for certain types of programme production? Whatever the reason, it has a marked effect on the next point.

(ii) Colorimetry

Work going on, particularly within the United Kingdom Independent Broadcasting Authority, on an analysis of colorimetric problems is also starting to produce fruit. A spectrophotometric analysis system for cameras and monitors, based on the use of a desk top computer and suitable transducers, etc., has been developed - Figure 1; work is now starting on the equivalent system for film and telecines.

(iii) Movement Portrayal

Perhaps the least contentious difference between the two looks is the effect of picture repetition rate on movement portrayal. There are fundamental differences in the way movements in scenes are portrayed by film and by electronic systems, although the basic picture repetition rate can be the same. Does the staggering of the temporal sampling due to interlace in the electronic picture produce a more pleasing movement portrayal than film?

(iv) Exposure Settings

Considering the whole business of resolution, there is an interesting Janus-like effect again. In general, electronic cameras, working with 30mm tubes and with zoom lenses operating at around f4, have a far greater depth of field than that used and desired by film makers. This appears to be exacerbated by the rather poor "best focus" of a zoom lens compared to a prime lens. As a result, in order to achieve the film resolution look of the precisely sharp main subject of the picture and the quite definitely defocussed surroundings, programme makers are resorting to gauze and gelatine on television camera lenses - which also blurs the main subject as well! - instead of taking the more logical - and humanitarian - course of action - to turn the light level down and force the iris in the lens wider open. Some of the reasons for not doing that are clear. The IBA's regular testing of electronic cameras and lenses shows quite clearly that the zoom lens has, in general, some rather serious failings over parts of the zoom range if the lens is opened up much beyond f4. Shading, vignetting and lack of resolution in the corners become serious problems. It is, of course, even more ironical that this general desire, certainly in entertainment programmes, for a reduced depth of field is actually being made worse with the advent of the lightweight cameras using 17mm tubes. The depth of field has become even greater with these lightweight cameras - which are otherwise so desirable, since they can be made to emulate film cameras in operational convenience terms. That makes the irony yet greater still!

(v) Modulation Transfer Functions

The rather poor "best focus" of a zoom lens compared to a prime lens was mentioned above. This is a factor in the other great difference in resolution performance. It is clear that the modulation transfer function of a lens and electronic camera is different from a lens/film combination. The lack of fine detail in the television system, coupled with the poor vertical resolution due to interlaced scanning, does need compensation. Within the constraints of the system bandwidth, this is partially provided by the correction for scanning spot size. In addition, the use of mid-band horizontal and vertical correction - as a way of allegedly improving the sharpness of the picture - has become an accepted practice. However, one can have too much of a good thing! The "cardboard cut-out" or "bags under the eyes" effects, and magnified skin imperfections, will be familiar to the reader! Too much fine detail correction leads to the well-known problems of "cross-colour" - and that raises the whole subject of luminance bandwidth - to which further reference will be made.

OPERATIONAL CONSIDERATIONS

Some of the effects in engineering terms of the differences between zoom and prime lenses have already been discussed. Because the evaluation of picture quality is, in the end, entirely subjective, and because television is concerned with moving, rather than static, pictures in the main, operational and production factors must count - albeit in a less than easily quantifiable way.

Prime lenses, combined with the tracking of cameras, produce a much greater and realistic sensation of depth in movement than does zooming. Of course, the zoom lens, when considered as a turret with an infinite set of fixed lenses, is another matter.

PRODUCTION REQUIREMENTS VERSUS TECHNICAL QUALITY

It may be just a vogue but there does seem to have been a recent tendency to blame poor technical quality on "producers' requirements". Surely producers do not actually want poor quality. Are not both the engineer and the producer to blame? The engineer shuts himself away in his corner, taking no interest in the artistic requirements, and the producer almost prides himself on knowing nothing about modern technology. Of course, that is an extreme view - but it has more than an element of truth about it. It needs both parties to apply themselves to the optimum solution. Broadcasting engineers have a lot of technology available to them - it is incumbent upon them to take the time to apply it so as to achieve what it is that the producer wants. Likewise, the producer must take the trouble to try and quantify his desires in a way which the engineer can interpret.

On the whole, well aligned television cameras, pointed at well lit scenes (and how important lighting, of whatever style, is to good pictures), are already capable of providing a good start to television pictures. How long will it be before the new television camera is capable of producing pictures very akin to the old favourite, film, but with even more latitude? That sounds like Janus again!

SIGNAL PROCESSING

That thought leads conveniently to another area of interest - the subsequent processing of signals. Table 2 listed the day-to-day operating tolerances in the United Kingdom television networks. These tolerances are met for some 90% of the time. The use of "special effects" - in the widest sense - has traditionally been regarded as only happening for less than 10% of the time. Times have changed.

The types of technique, previously used solely for those special effects, are now finding their way into circuits used for much greater periods of time.

The spin-off from the computer technology is having its effect on the television industry. Synchronisers, time base correctors, special effects (including electronic scenery) and stills stores, to name but four items, are now coming into regular use. Most of them would not have been sensibly possible before digital processing. Whilst there is undoubtedly an earnest looking forward to the day when the whole signal chain will be digital, there is going to be a long period with those famous digital "islands" in an analogue "sea" and, perhaps later, analogue "islands" in a digital "sea". Broadcasting engineers are spending considerable amounts of time on establishing digital standards for the different parts of the chain - or else on how to construct equipment based on those standards. However, it must not be forgotten that these digital islands each involve a transcoding process from analogue to digital and back again. That in itself requires very careful thought, the need for which is yet further stressed by the fact that the world digital standard is a component and not composite based standard. Broadcasters are therefore facing not only analogue-digital codecs, but composite-component ones as well.

One of the great problems, which is taxing the minds of the engineers in Independent Broadcasting in the United Kingdom, is the increasing use of both forms of transcoding. The present analogue composite standards were chosen on the assumption that there would be one and only one decoder - in the receiver. Since three of those four processing systems mentioned above effectively demand signals in component form - and presumably more and more will as further digital equipment, based on the world digital standard, comes into use - a start is having to be made on assessing the effect of cascaded composite/component coders and decoders. Traditionally, no-one has paid a lot of attention to the bandwidth of the chrominance signal; these successive processes are focussing attention marvellously on this problem.

Within the IBA network, a lot of consideration is being given to how to modify the existing measurement techniques to cope with these new processes. So far, reliance has been placed, certainly for signal path evaluation, on one-dimensional test signals - pulses and bars, staircases, etc. Problems have already been experienced with non-linearity testing of equipment employing PAL delay-line decoders when using the CCIR 1 in 4 staircase - where one line carries the staircase and the next three a pedestal of either 0% or 100% luminance amplitude. Since television signals convey moving information, should the test signals move over the picture area so that any integrating/averaging effects are also taken into account - or will such temporal variations make it too difficult to determine the results?

Janus is back again because the ultimate quality available from a full digital system - operating in its component form - should clearly be better than any of the present analogue systems. After all, the digital standard is such that more than 5.5MHz of luminance and 2.5MHz of chrominance bandwidth are available. Yet, in the process of getting there, the present system is apparently becoming worse and worse. Great care is needed in the engineering considerations if the highly desirable features, which synchronisers, effects units, etc., offer, are not to allow such a poor technical standard to become accepted in the interim, that the motivation to go to the higher quality full digital system is partially or completely eroded. The amazing spread of home VCRs ought to convey a warning to everybody!

A STEP IN THE RIGHT DIRECTION?

A personal thought - on, perhaps, a better compromise path to the all-digital system than allowing the present problems to continue - might be appropriate. Experience of working on the operational side of the IBA's MAC experiments provided a forceful reminder of how good analogue component pictures can be. If the opportunity arises within a studio centre, could not an analogue component studio system be tried - as a stepping stone?

Vision mixers, capable of handling full 5.5MHz component signals, are soon to be available. Television cameras are already capable of that sort of performance. The one weak link in the chain is the video recorder. Although they do not have the full luminance bandwidth, the evidence of the first ½" component recorders suggests that broadcasters could do far worse than to allow such recorders to be used for a limited period - so as to allow a complete component studio system to be tried. The overall advantages in picture quality of operating a studio in component form - albeit analogue - and only coding to composite for final transmission, seem to outweigh - even with the limits of present ½" VTRs - some of the other distortions from which composite signals suffer - cross luminance, cross colour and chrominance noise particularly in FM systems. If such a scheme was tried, the "weak link" of the ½" VTR could be replaced by a full bandwidth analogue component machine when one is available - or, of course, by that elusive pimpernel - the digital VTR. The opportunity is unlikely to arise very rapidly in the United Kingdom because most of the independent studios there have recently re-equipped with composite equipment. However, the future is unknown - and this suggestion could be one safe route to the digital component studio centre.

WHAT WILL IT LOOK LIKE ON A BIG SCREEN?

So far, no mention has been made of the differences between evaluations on small screens and on big ones. As was stated at the beginning, the present picture quality evaluations have been based on viewing distances from the screen of between four and six times the picture height. Indeed, within the IBA, critical assessments are made under viewing conditions which conform as closely as possible to the international standard set out in CCIR Recommendation 500. Under those conditions, it does seem that some of the most objectionable impairments with the present system are produced by the moving artifacts due to cross colour, cross luminance and interlace. How much more disturbing will they be on a big screen where the viewing distance is between two and a half and three times the picture height? How will the mind accept larger screen displays of scenes in an environment where the surroundings against which to judge size, etc., can easily be seen? An analogy from the IBA's surround-sound research may be useful. A similar difficulty was experienced with people accepting the realism of the sound image - which was undoubtedly there under certain conditions - when heard in their living rooms. Unlike stereophony which can never produce a sound-filled which envelops the listener, surround-sound can "transform" the living room very effectively into a large reverberant concert hall, with the sound truly enveloping the listener. Yet the mind is always struggling to accept that large concert hall in a much smaller, familiar room. Will the same problem arise with large faces - much larger than life size - looking at us at the much closer viewing distances - or will production techniques change to encompass this? In his vision of the future, aptly called 1984, George Orwell commented "Big Brother is watching you"!!

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TABLE 1

	Direct Path	Worst Path	Studio Path
SIGNAL LEVELS			
(a) Signal Level Adjustment Error	0.7v ±0.2dB	0.7v ±0.2dB	0.7v ±0.2dB
(b) Signal Level Gain Stability	±0.2dB	±0.2dB	±0.2dB
LINEAR WAVEFORM DISTORTION			
(a) 2T Pulse-to-Bar Ratio	½%K	1%K	½%K
(b) 2T Pulse Response	½%K	1%K	½%K
(c) 2T Bar Response	½%K	1%K	½%K
(d) 50Hz Square Wave Response	½%K	1%K	½%K
(e) Chrominance/Luminance Gain Inequality	±3%	±4%	±3%
(f) Chrominance/Luminance Delay Inequality	±20ns	±40ns	±20ns
NON-LINEARITY DISTORTION			
(a) Luminance Line Time Non-Linearity	3%	5%	3%
(b) Differential Phase	±2°	±5°	±2°
(c) Burst/Chroma Phase	±2°	±5°	±2°
(d) Differential Gain	±3%	±5%	±3%
(e) Transient Gain Change, Luminance	2%	5%	±2%
(f) Transient Gain Change, Chrominance	2%	5%	2%
(g) Transient Gain Change, Sync	2%	5%	2%
(h) Chrominance/ Luminance Crosstalk	-	-	-

Cont'd

TABLE 1 Cont'd

	Direct Path	Worst Path	Studio Path
INPUT/OUTPUT IMPEDANCE-RETURN LOSS			
(a) Luminance	-30dB	-30dB	-30dB
(b) Chrominance	-30dB	-30dB	-30dB
(c) Low Frequency	-30dB	-30dB	-30dB
VLF RESPONSE			
(a) First Overshoot	20%	20%	-
(b) Second Overshoot	8%	8%	-
NOISE			
(a) Weighted Luminance (RMS)	-64dB	-58dB	-64dB
(b) Weighted Chrominance (RMS)	-58dB	-52dB	-58dB
(c) Total Low Frequency Random and Periodic (p-p)	-45dB	-45dB	-45dB
(d) Low Frequency Random (p-p)	-52dB	-52dB	-52dB
(e) Interchannel Crosstalk	-55dB	-45dB	-52dB

Table 1
The tolerances shown in this paper are those used within the United Kingdom IBA network for day-to-day operations. The direct path covers the station presentation equipment chain — from the input from the PTT to the output to the transmitter. The worst path covers a typical program compilation chain, including three vision mixers and their ancillary equipments; each of the three mixers and its ancillary equipment has to meet the studio path tolerances. VTR performance is specified separately.

TABLE 2

Parameter No.	Parameter	Studio Centre Output A	British Telecom Network B	Main Transmitter Output C	Rebroadcast Transmitter Output D	Transposer Output E	A + B + E F
1	Signal/Random Noise, Unweighted (dB)	39	48	46	45	42	37
2	Signal/Noise, Luminance Weighted (dB)	48	56	52	51	48	44
3	Signal/Noise, Chrominance Weighted (dB)	42	52	52	51	48	40
4	Chrominance-Luminance Gain Inequality (%)	±7	+6 -12	±7	±18	±25	±28
5	Chrominance-Luminance Delay Inequality (ns)	±53	±65	±30	±75	±110	±140
6	K Bar (%)	5	3	1	3	4	9
7	K 2T Pulse (%)	5	2	2	3	4	8
8	K 2T Pulse/Bar (%)	5	2	1	3	4	8
9	K 50Hz Square Wave (%)	5	4	1	1	1	8
10	Luminance Non-Linearity (%)	15	14	7	14	20	34
11	Differential Gain (%)	15	10	5	10	15	28
12	Differential Phase (degrees)	15	10	4	10	15	28
13	Chrominance/Luminance Crosstalk (%)		±6	±3	±8	±10	

Table 2
The tolerances shown in this table are estimates of those expected to be met over the designated parts of a typical United Kingdom broadcasting chain for some 90% of the broadcasting time. The results in Column F are derived by addition on a power law basis, according to CCIR Recommendation 451.

TABLE 3

BLACK SHADING	
(a) Inner Zone - luminance	3% Peak-to-peak
(b) Overall (whole field) - luminance	5% Peak-to-peak
(c) Overall - colour separation difference	2% Peak*
* A change of not more than half of the limit may occur in any 10% of the picture width or height	
WHITE SHADING	
(a) Inner zone - luminance	5% Peak-to-peak
(b) Overall (whole field) - luminance	10% Peak-to-peak
(c) Overall - colour separation difference	6% Peak*
* A change of not more than half of the limit may occur in any 10% of the picture width or height	
RESOLUTION	
(a) Centre (0.5-5.0MHz)	$100 \pm 20\%$
(b) Corners (5.0MHz)	40% to 110% (of Centre)
WAVEFORM RESPONSE	
(a) Negative pulse maximum overshoot or pre-shoot	25% of pulse height
(b) Pre-shoot minus overshoot	$0 \pm 10\%$ of pulse height
GEOMETRY	
(a) Inner zone	1% of picture height
(b) Whole field	2% of picture height
REGISTRATION	
(a) Inner zone	0.15% of picture height
(b) Whole Field	0.4% of picture height

Cont'd

TABLE 3 Cont'd

LATENT AND SPURIOUS IMAGES	
(a) Line Scan Ringing	5%
(b) Blemishes, tube spots and other defects	Impairment level 4
STREAKING	
(a) Short-term luminance	1%
(b) Short-term colour separation difference	Less than 1%
(c) Long-term luminance	2%
(d) Long-term colour separation difference	1%
FLARE*	
(a) DC Flare	±2%
(b) AC Flare	±7%
GREYSCALE	
Differential error between any Y, R, G, or B signals in a single studio, OB vehicle or combination of sources used to contribute to single productions	2%
NOISE	
(a) Weighted Luminance (RMS)	-48dB
(b) Weighted Chrominance (RMS)	-43dB
(c) Total Low Frequency Random and Periodic (p-p)	-45dB
(d) Low Frequency Random (p-p)	-52dB
LAG*	
(a) Green channel	7%
(b) Colour separation difference signals	3%

* Target figures not mandatory for the time being

Table 3
The tolerances shown in this table are those used within the United Kingdom IBA network for day-to-day operations. The cameras are set up for the tests in accordance wih the normal operating procedures and are made on the combined lens and camera.

Fig. 1. The picture illustrates the prototype arrangements of the IBA's computer-operated spectrophotometric analysis of cameras equipment.