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le esperienze hanno dimostrato che qualsiasi variazione delle condizioni normali di esercizio, come ad esempio oscillazioni di tensione e frequenza della rete, ha per sola conseguenza la impercettibile variazione del numero di linee.

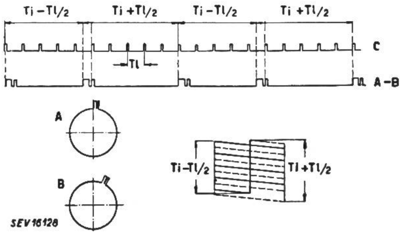

Fig. 8
Impulsi generati secondo lo schema della fig. 7

Rimane quindi escluso l'inconveniente che si ha con gli altri sistemi generatori d'impulsi, consistente nel fatto che in seguito a variazione delle condizioni di esercizio per una qualsiasi delle cause sopra citate viene a variare la distanza di due reticoli in successione così da farli talora sembrare sovrapposti annullando di conseguenza il principale vantaggio dell'interlacciato cioè la possibilità con una stessa banda di frequenza-video di poter raddoppiare la finezza delle immagini.

Inoltre con questo nuovo metodo si potè nuovamente prendere in considerazione la possibilità di un accoppiamento del generatore d'impulsi con la rete di alimentazione. Infatti come detto più sopra, con gli altri metodi secondo i vari «standard» è necessario impiegare un numero dispari di linee mantenendolo il più possibile invariato. Con le variazioni di tensione e frequenza di rete non è facile mantenere nel tempo questa condizione e ne risulta la nota fastidiosa instabilità fra i due reticoli dell'interlacciato. Col nuovo metodo invece si poterono raggiungere risultati soddisfacenti ottenendo, come già accennato, le varie frequenze per la rotazione dei raggi da un'unica frequenza base per moltiplicazione.

Allo scopo partendo dalla frequenza di rete ad esempio di 50 c./s e moltiplicandola secondo la tabella numerica quì accanto, si ottengono due frequenze di 800 c./s e 25 600 c./s. La prima è necessaria per la deviazione circolare del tubo o tubi d'immagine, la seconda per il tubo o tubi di linea. Per ogni moltiplicazione sono stati soddisfacentemente impiegati un tubo diodo-amplificatore, il cui circuito anodico era sintonizzato sulla rispettiva frequenza di moltiplicazione predisponendo però un certo appiattimento delle curve di risonanza onde i segnali di uscita risultassero sempre della stessa ampiezza nei limiti di variazione della frequenza di rete usata quale segnale base. Si sono avute in tal modo 512 linee per ogni reticolo cioè 1024 linee totali e 50 reticoli al secondo con tutti i vantaggi illustrati e proprii al metodo descritto.

Tabella moltiplicatore frequenza di rete per deviatore comune

Frequenza di rete c./s	42	45	50
× 2	84	90	100
× 4	168	180	200
× 8	336	360	400
× 16[1]	672	720	800
× 32	1 344	1 440	1 600
× 64	2 688	2 880	3 200
× 128	5 376	5 760	6 400
× 256[2]	11 752	11 520	12 800
× 512[2]	23 504	23 040	25 600

[1] Presa per deviazione d'immagine.
[2] Presa per deviazione di linea.

L'apparecchiatura così completa venne sottoposta a varie prove proiettando anche il reticolo per una sua migliore osservazione.

In quest'ultima prova venne notato che i dischi dei tubi riga producevano, per leggera imperfezione meccanica dei denti, un reticolo interlacciato bensì fisso ma con le linee leggermente raggruppate per 5 cioè per il numero di denti di ogni disco. Applicando ai tubi dei dischi fresati con precisione anche questo trascurabile inconveniente venne tolto, mentre per successive realizzazioni la facile ovvia possibilità di aumentare la velocità del raggio di riga di cinque volte e quindi di adoperare dischi ad un solo dente era da prendere in considerazione qualora la radicale soppressione di quest'ultima causa disturbante per cattiva costruzione dei tubi fosse richiesta.

Nel caso di un'eventuale estesa applicazione di questo nuovo metodo sono stati inoltre progettati dei tubi RC di minore ingombro provvisti di dente a moltiplicazione elettronica.

L'Autore, mentre ringrazia la Società SAFAR per avergli messo a suo tempo a disposizione i mezzi per la realizzazione di questo nuovo generatore, resta a disposizione dei presenti per ogni ulteriore chiarimento che desiderassero in merito.

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Some Aspects of Television Circuit Technique: Phase Correction and Gamma Correction

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By way of introduction I think I should first devote a few minutes to an explanation of why I have chosen to discuss phase correction and gamma correction out of the wide range of topics coming under the general classification of circuit technique.

It is hardly necessary for me to remind you of the extreme complexity of a complete television system. There are almost innumerable reasons why the reproduced picture will fall short of perfection. The development of an improved television system consists mainly in the removal or reduction of the various distortions, faults, and shortcomings of the system, and this requires the successful solution of a large number of individual technical problems.

It would hardly be possible, for even the largest of organisations, to carry out active development work on all of these problems simultaneously. What usually happens is that the maximum effort has to be directed to the solution of the major problems, and many of the smaller problems receive very little attention. There are some major problems but there are also very many smaller problems.

A television system usually has a large number of small faults. Many of these faults may appear to be so small that it would hardly be worth while devoting much effort to remove them. However, although the faults, considered individually, may appear small, there are so many of them that their combined effect is quite considerable, and results in the general quality of the picture falling far short of what would otherwise be possible. The best results will be obtained only when all these small faults have been eliminated, but, unfortunately, the removal of these faults, one by one, is a relatively slow and not very exciting occupation and tends to be neglected.

Out of the many little problems which have not received the attention which, I believe, they deserve, I have chosen two for consideration in this paper. My choice of these two particular topics is based on my own experience in the past few years. I have found that the improvements which can be made to a television system by careful attention to phase correction and to gamma correction are quite considerable. The possible improvements are certainly greater than one might be led to believe by the scanty consideration given to these subjects in the available publications on current television technique. These, then, are my excuses, if any are needed, for introducing to you the subjects of phase correction and gamma correction.

Phase Correction

The so-called «steady state» characteristics of a signal transmission channel include the amplitude response and the phase response, both of which are functions of frequency and it has been quite well known from the earliest days of television that for distortionless transmission the amplitude response should be constant and the phase shift should be proportional to frequency. Although both conditions are necessary for distortionless transmission, only the amplitude response has received much attention in practice. It appears to have been assumed that the phase characteristic can be left to take care of itself, indeed I think that some engineers have held the belief that if the amplitude characteristic is flat the phase characteristic will automatically be quite satisfactory. This belief is, of course, quite false. There is a close connection between the amplitude characteristic and the phase characteristic, but the relation between them is, usually, such that the more elaborate the steps taken to improve the amplitude characteristic the greater will be the phase distortion. As this statement forms an essential step in my argument for the use of phase correction I will now emphasize it by reference to a few examples.

My first example is the intervalve coupling of a video frequency amplifier. Fig. 1 shows a number of different coupling circuits together with their frequency characteristics. The horizontal frequency scale is in terms of ωRC where R is the coupling resistance and C is the total shunt capacitance. All the curves are drawn for a two-stage amplifier using the same type of coupling in each stage, and the amplitude response is shown as a percentage of the low frequency response.

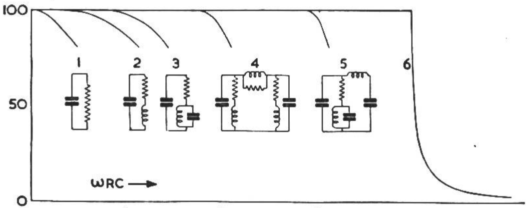

Fig. 1
The Amplitude Response of a Two-Stage Amplifier Using Different Types of Coupling Circuit

If no correction is used the response is as shown in *1*. The simplest form of correction, using an inductance in series with the resistance, is a great improvement, as shown in *2*. A further improvement is obtained by using an additional capacitance across the inductance as in *3*. A great improvement can be obtained by the use of coupling networks which separate the output and input capacitances. A circuit of this type which I used in 1938 is shown in *4*. This circuit has the advantage that it can be used with any ratio of the two capacitances. If, however, the ratio of the capacitances is favourable, and it usually is so, the design of the coupling can be based on low-pass filter theory, as described by H. A. Wheeler in a paper in the Proceedings of the Institute of Radio Engineers of July 1939. A coupling of this type, but with the circuit values modified slightly to give a flat, instead of oscillatory, response curve, is shown in *5*. The theory indicates that the most complicated circuits will approach the limit shown by *6*, but the relatively simple circuit of *5* has already achieved about three quarters of this limit.

If we examine the practical applications of these circuits we find that *2* and *3* are very widely used, but that circuits such as *5* are not at all popular in spite of their great improvement in amplitude response. The reason for this is, almost certainly, the increased phase distortion which occurs with the more efficient couplings. With a simple coupling such as *2* the phase distortion is not serious unless a large number vf stages are used. An efficient circuit such as *5* introduces considerable phase distortion in each stage, and with only three or four stages the distortion becomes large enough to produce intolerable overshoot and ripples after every transient. We conclude that we cannot make full use of the most efficient amplifier couplings unless we can find means for correcting the phase distortion.

So far we have assumed that all the amplifier stages are alike, the amplitude response of each stage being flat. There are other schemes in which the amplitude response of several stages are arranged to differ but to be complementary to each other so that the overall result is a flat response with a relatively sharp cut-off. These schemes produce the same result, that is, the most efficient arrangements produce serious phase distortion and are usable only if steps are taken to correct for the phase distortion.

In the absence of phase correction the design of an amplifier must be a compromise between the conflicting requirements of amplitude response and phase response. Of course it is not always necessary to use the most efficient circuits and many engineers may be prepared to accept the compromise, at least for straightforward amplifiers. There are, however, a number of special cases in which the compromise is not very acceptable.

In the paper already referred to Wheeler described how a valve with negative feedback could operate as a half section filter matched to filters in the input and output circuits. Such an arrangement has a number of useful applications, such as a very low noise input circuit for an amplifier. Very good characteristics can be obtained, but only if steps are taken to correct for the considerable phase distortion which occurs.

Most of the amplifiers in a television system are required to have level characteristics but it is often desirable to be able to introduce some degree of boosting of the higher frequencies to correct for various losses due, for example, to the finite size of the scanning spot. It would be a simple enough matter to boost the high frequencies to any desired extent but for the fact that this always leads to severe phase distortion. Here again phase correction is required.

So far I have been referring to individual parts of a television system, but I will now turn to a consideration of the system as a whole. It is important to bear in mind that a practical television system, which may include cable links, radio links and scores of amplifier stages, must be designed to work with a strictly limited frequency band, outside which the amplitude response is effectively zero. It is desirable to make the best possible use of the available range of frequencies which suggests that the amplitude response should be fully maintained over a considerable part of the frequency range, with a relatively sharp cut-off. It is instructive to consider the effect of this on the overall transient response, as shown in Fig. 2. Here we have four different amplitude responses with the corresponding transient responses, on the assumption that phase distortion has been completely eliminated. The steepness of the transient response is proportional to the area under the amplitude response curve. The figures indicate the areas as percentages of the rectangular response curve, and they may be regarded as a measure of the extent to which the available band width is being utilized, since the sharpness of the television picture will depend on the steepness of the transient.

The transient responses in the higher efficiency cases show overshoots and ripples. Some television workers appear to consider these objectionable and might express a preference for the 50% case, but I do not share this view. Even with the infinitely sharp cut-off for the 100% case the overshoot is only 9%, and it would be the duration of the ripple, rather than its amplitude, which might prove objectionable. The 75% case shows a well-damped ripple which would hardly ever be noticed and would certainly not be objectionable in a picture and which is certainly a very small price to pay for the improvement in picture definition resulting from the increase of transient steepness compared with the 50% case.

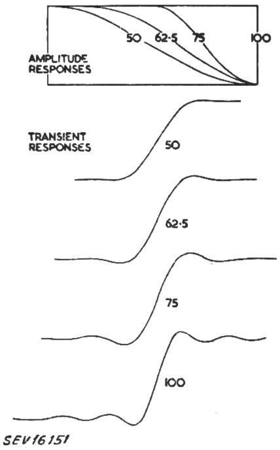

Fig. 2

The Relation Between Amplitude Response and Transient Response

Ripples occur both before and after the main step of the transient. The front ripples cannot occur naturally in a circuit using only minimum-phase-shift-type networks, and represent something which can only occur as a result of the use of phase correctors. These front ripples are, then, a direct indication that it will be necessary to use phase correctors to obtain the desired result.

I will summarize the foregoing argument by saying that a satisfactory method of phase correction would enable us to make better use of available frequency bands and circuit technique and would in many cases enable us to avoid compromises in design which we are forced to accept in the absence of phase correction.

I will now consider the practical means of phase correction which are available. Various methods of phase correction are known and have been described in the literature, but I will confine my attention to the type of phase corrector which I have found most convenient for the majority of television applications.

Fig. 3 shows a typical phase corrector section. It usually consists of two equal coils, coupled with a certain mutual inductance, and two condensers but for purposes of calculation it is convenient to consider the inductances in the form shown in the diagram where L_1 is the total inductance of a centre tapped coil with complete coupling between the two halves and L_2, in series with the centre tap, represents the effect of leakage inductance. It can be shown that if $L_1/C_2 = L_2/C_1 = R^2$ the network has a constant resistance R. Dissipation in the circuit elements can usually be neglected so that all frequencies are freely transmitted. After the constant resistance conditions have been satisfied there remain two free parameters available for control of the phase characteristic, which is given by the formula as shown. This phase shift is added on to the phase shift in the circuit which is to be corrected, and, if the parameters have been suitably chosen, the result is to make the total phase shift much more nearly linear. By using a large number of sections in cascade it is theoretically possible to match any desired characteristic, but for most cases of practical interest it is found that two sections are sufficient. Phase distortion is an odd-power function of frequency, and the four parameters may be used to eliminate powers 3, 5, 7 and 9.

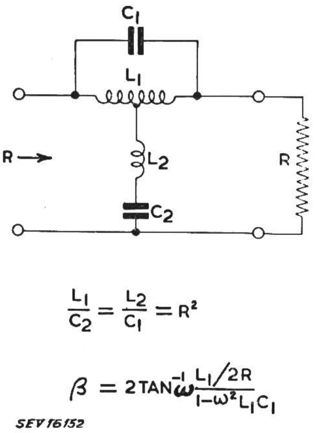

Fig. 3
Simple Phase Corrector

Correctors of this type are entirely practicable in regard to their construction, their application and their performance. They are conveniently designed to match a low resistance such as 100 ohms or 75 ohms, as standardized for coaxial cable connexions, so that there is no difficulty in finding a suitable place to connect them into a television system. There is no difficulty in obtaining, measuring, or adjusting circuit elements of the required magnitudes; the condensers can be of mica or ceramic types and the coils can be simple air core solenoids. Last, but not least, these correctors certainly work very well and produce the desired results.

It is rather surprising that these correctors are not more widely used. A number of minor reasons might be suggested, but I think the main reason is the difficulty of computing the required circuit values. The correctors are easy to make and use when the design is known, but it is not easy to calculate the correct circuit elements to suit a given purpose. It is first necessary to determine the distortion which has to be corrected. If sufficient information is available about the circuit the distortion may be calculated, but this procedure is very laborious and subject to the possibility of error and miscalculation. Alternatively the distortion may be measured but to do this with sufficient accuracy requires the use of specialised and expensive apparatus which is not generally available. Even when the phase distortion has been determined it is still a problem to work out the best values for the four parameters of a two-stage corrector. This is a good exercise for the mathematical student, but rather too laborious for the average television engineer.

When I first started using phase correctors I had to work them out the hard way — by calculation. I was very pleased with the results, but I was so impressed by the amount of mathematical labour involved that I decided to seek a more direct method of approach to the problem. The solution which I obtained is simple, but, as far as I am aware, it does not appear to have been suggested before.

The principle of the method is to use a rather elaborate corrector in which the required parameters are adjustable. This corrector is connected temporarily in the circuit and the controls are adjusted until the desired result is obtained, as indicated by impulse and step-function tests. The controls are calibrated, so it is then only necessary to read the settings of the controls to determine the required circuit values to be used in a permanent fixed corrector to give the same results.

The success of the method depends so much on the design of the adjustable corrector that it is desirable to consider this design in some detail. I will now endeavour to explain some of the special requirements, and the manner in which they are met, with the aid of Fig. 4 which shows the general circuit arrangement.

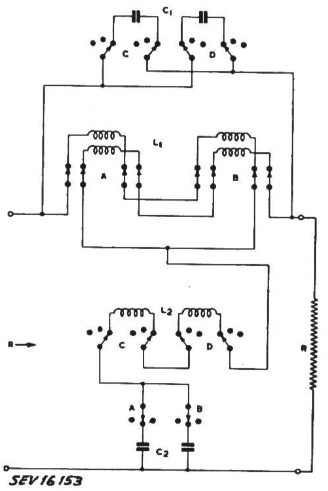

Fig. 4
Adjustable Phase Corrector

The two parameters are each adjustable, in coarse and fine steps, by means of four rotary switches A, B, C and D. In order to maintain the constant resistance condition each switch controls both inductance and capacitance. In order to make the readings of the coarse and fine controls directly additive, the inductances are connected in series and the capacitances in parallel. Each switch has six positions, giving access to five independent coils and condensers of graded values, but, for simplicity, only one coil and one condenser are shown on each switch in the diagram. By means of the coarse and fine controls each parameter can be varied over its total range in thirty equidistant steps. This is adequate for most purposes, though obviously the principle could be extended to give a larger number of steps if desired.

The inductance L_1, controlled by switches A and B, would ideally consist of a centre-tapped coil with 100% coupling between the two halves, but of course it is not possible to attain complete coupling. Each coil is wound with two conductors, side by side, as a single layer solenoid on a former which locates each turn, the dielectric between turns being mainly air, and the two conductors are used as the two halves of the centre-tapped coil. This construction reduces the leakage inductance to a small value, but it also introduces capacitance between the two halves of the coil. One quarter of this capacitance appears as an addition to C_1, while one quarter of the total leakage inductance appears as an addition to L_2. By the correct choice of the relation between conductor spacing and diameter the additional capacitance and inductance can be arranged to satisfy the constant resistance condition. For a 100 ohm or 75 ohm corrector the relation is readily obtained and is found to be quite favourable in other respects. The four halves of the two coils must be connected in series in the order shown in the diagram so that the potential difference between any adjacent conductors in either coil is always exactly half the total potential difference across the complete inductance. This ensures that the capacitance contributions from the A and B coils are directly additive. By attention to these points the total effect of the winding capacitance and leakage inductance amounts only to a small addition to the other parameter which is readily indicated in the calibration table for the corrector.

Apart from these special design features, various precautions necessary in the design and construction are obvious and do not require further comment.

The method of using these correctors is fairly obvious. The system to be corrected must first be adjusted to give the desired amplitude response as any subsequent adjustment of this would alter the phase response. For the transient test it is useful to have available a variety of signals such as a step function and a choice of various widths of narrow impulses, as some phenomena are more clearly shown by one type of signal than by another type. The test signals will usually be generated electrically, but when testing a camera head amplifier it may be more convenient to generate the signals by scanning an optical image of a suitable test pattern. The result is best observed as a waveform on an oscilloscope. In some cases it may be necessary to view the results on a normal picture reproducing tube, but brightness modulation is not as easy to interpret as a waveform observation, so that the waveform observation should be used whenever possible.

Without correction there will be overshoot and ripple following the transient. By adjustment of the controls these effects are greatly reduced, but similar effects will begin to appear before the transient. The criterion of good correction is the symmetry of the effects before and after the transient. It is very easy to adjust a single stage corrector but this does not always give sufficient correction. By using two correctors in cascade it is not only possible to get more correction, it is possible to get more accurate correction since four parameters are available for adjustment. To get the best result which is possible with a two stage corrector requires a certain amount of skill, which is, however, readily acquired with a little practice.

When the desired result has been obtained a note is made of the settings of the controls and then, by means of a simple calibration table, the required values of inductance and capacitance are determined. These values are then used in the construction of a simple fixed corrector which will give the same result.

The adjustable corrector is a relatively expensive piece of equipment but as it is used over and over again the capital expenditure is quickly justified by the results which it makes possible. I have had two of these adjustable correctors in use in our laboratories for about eight months and they have proved extremely useful for determining the phase corrections for all the various amplifiers we have constructed during this period. We have now come to regard phase correction as an entirely practical and normal part of circuit technique. When I first started to introduce phase correction as a practical proposition I met with considerable scepticism from practical minded engineers and it has been a source of satisfaction to me to see this scepticism give way to appreciation as the benefits of phase correction have gradually become apparent in our laboratories.

Gamma Correction

We often refer to a monochromatic picture as a «black and white» picture, but we must recognise the limitations of this description. The picture contains very little of what might be considered as truly black or white, and is, in fact, composed almost entirely of a continuous range of shades or tones. The correct rendering of the relative values of all the various tones plays a very large part in the satisfactory reproduction of a television picture. This applies not only to the broad masses of light and shade which determine the artistic composition of the picture but also, and perhaps with greater force, to the finer details of the picture on which the definition is judged. Very little of the detail in a picture is of the «black and white» kind, most of the important detail covers only a part, in many cases a small part, of the total range of tones. For example, we expect to see details in the highlights, in the middle tones and in the shadows. Faulty tone reproduction can cause many of these details to become invisible, or at least, more difficult to see, and so can cause a loss of apparent definition as serious as the losses caused by the more widely recognised faults such as bad focus, limited frequency characteristics etc. It is not easy, even for a trained observer, to look at a picture and identify the causes of all the loss of picture quality, and the effects caused by incorrect tone reproduction are not always fully appreciated.

A very important factor is the total range of tones which can be reproduced, which can be expressed as the ratio of the brightest to the darkest tone. Modern cathode ray tubes using aluminium-backed screens can easily reproduce a contrast range in excess of 100 to 1, so that in this respect a television picture should be at least as good as a cinema picture if the potentialities of the system are fully exploited. Although the required contrast range is available, good reproduction does not follow automatically — it is usually necessary to introduce various corrections to make the best use of the available range. We do not often see television pictures comparable with cinema pictures, which indicates that there is room for considerable improvement by the use of gamma correction.

The tone reproducing properties of a system my be drawn as a graph relating the output to the input. Since the response of the eye is approximately proportional to the logarithm of the brightness, at least in the range of brightness of interest, logarithmic scales are used for input and output. When the characteristic is plotted in this way the slope of the characteristic is denoted by «gamma», in other words gamma may be defined as the slope of the log output/log input curve. From this definition of gamma it is, of course, possible, by simple mathematics, to derive other expressions for gamma which may be more convenient for particular applications.

If the characteristic is not straight we see from the definition that gamma will vary from point to point along the curve. In particular, if the characteristic is continued sufficiently far in either direction the output must level off to a limiting value so that gamma becomes zero. Whenever gamma becomes too small, detail will be lost in the picture, so that it is desirable to maintain a sufficiently high gamma over the part of the characteristic which is being used. The usual fault is that the gamma is too low in some parts of the characteristic though it may be higher than necessary in other parts. Gamma correction usually requires the introduction into the system of a suitable non-linear device which will make the gamma more uniform over the working range.

The contrast range in the original scene to be transmitted is usually less than the range which can be reproduced, so that the overall gamma can be greater than unity without exceeding the available contrast range on the cathode ray tube screen. A monochrome picture reproduced with unity gamma always appears somewhat lacking in contrast and a higher value of gamma produces a more satisfactory picture, probably because this compensates to some extent for the absence of colour contrasts. When all the conditions have been satisfied for the good definition of detail in all the tones of the picture, the further specification of the most desirable characteristics becomes a matter for artistic considerations of picture composition and lighting effects rather than for mathematical formulation so that it is not usually possible to state precisely what is required. However, the practical problems which arise are usually of a simpler order than this, and it is usually a fairly easy matter to determine the nature, if not the actual magnitude, of the correction which is required.

The gamma characteristics of a system are mainly determined by the terminal equipment, that is, the pick-up devices and the reproducing cathode ray tubes. If we exclude devices with deliberately non-linear characteristics we find that most of the amplifiers, and the transmission system in general, work in a linear manner and do not introduce appreciable gamma changes. Where exceptions occur, such as, for example, the modulation stage of a transmitter, it is obvious that the corrections required should be arranged to restore the transmission system to linearity.

The characteristics of normal cathode ray tubes show a gamma value which usually lies between 2 and 3. The exact value appears to depend on the shapes of the various electrodes, but the influences of the shapes and the reasons are not properly understood. For any particular construction the gamma is usually remarkably constant over the whole of the useful range of operation of the tube.

Some television workers have tried to construct tubes with linear characteristics, that is, with unity gamma, but this seems to me to be quite the wrong thing to do. In order to minimise the effect of noise picked up in the transmission link the ideal arrangement would be a transmitter with a logarithmic characteristic and a receiver with an exponential characteristic, but this scheme leads to complications in the receiver. A high-gamma receiver achieves some of the advantages peculiar to the exponential characteristic, and it is a very fortunate circumstance that the simplest and most practical forms of construction for the cathode ray tube produce a gamma value between 2 and 3.

The receivers must be kept as simple as possible, so all necessary corrections should be applied before transmission. The ideal transmitter characteristic is that which gives the best result on the average receiver. In the absence of receiver standardization the receiver may be assumed to have a gamma of 2,5.

The various types of pick up devices which feed the transmitter will have different characteristics so that each will require its own particular type of gamma correction to convert all the signals to the ideal form. For example, the gamma of the iconoscope type of camera falls to very low values in the highlights. Correction for this fault is fairly simple to provide, and results in a great improvement in the quality of the picture. (Incidentally the «tilt and bend» or «shading» errors are much less objectionable when the gamma has been corrected.) The orthicon type of camera, on the other hand, has quite different characteristics. Its gamma is more uniform and is much higher, so that it may be desirable to use a corrector to *reduce* the gamma to produce the best results. The corrections for a film scanner are, again, quite different from the corrections for a direct pick-up camera.

It is obvious that each application of gamma correction calls for individual consideration. It is clearly impossible for me to describe all of them so I will confine my attention to the correction of a film scanner. This particular case is of interest not only because of its importance for good television reproduction of film but also because it is a case in which we can make a clear statement of the objective to be achieved.

The film is designed for optical projection. In the composition of the picture, in the lighting, in the photography and in the processing every care is taken to produce a film which will give a good picture when projected in a cinema. As already stated, the contrast range of a cathode ray tube can be at least as good as in cinema practice. The aim of the television engineer is therefore quite clear, he should aim to reproduce on the receiver screen a picture which, in its tone values, corresponds very closely to what would be obtained by direct optical projection. In other words, the overall gamma of the system must be unity for the whole of the significant range of tone values.

A non-storage type of scanner, such as a flying spot scanner, has a gamma of unity so that it is only necessary to correct for the receiver characteristic. If this has a gamma of 2,5, the corrector should have a gamma of 0,4. The contrast range on the film is in excess of 100 to 1, and for design purposes it is safer to assume a value of 300 to 1. The gamma corrector should therefore accept a signal with a contrast range of 300 to 1 and should operate on it with a gamma of 0,4 so that the contrast range in the output signal is reduced to 10 to 1. This is a clear specification of the required characteristic. An alternative way of expressing the same thing is to say that a signal with a range of 50 decibels has to be compressed uniformly to give an output signal with a range of 20 decibels.

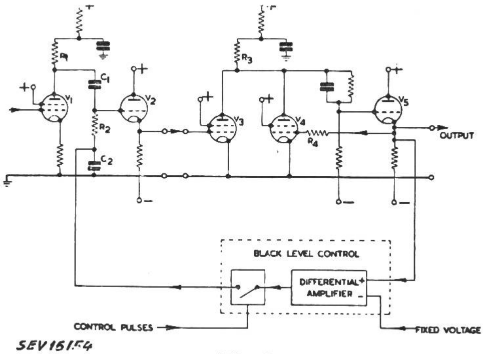

Fig. 5

Gamma Corrector and Black Level Control for Film Scanner

A circuit arrangement for producing this type of characteristic was devised in 1938, and Fig. 5 shows a modern version of it. V_1 is the last amplifying valve in a normal A.C. coupled amplifier. The D.C. component is inserted, by means to be described later, and the signal is transmitted through a cathode follower V_2 to the grid of V_3 which is the first valve of the gamma corrector. The signal on its grid is of negative polarity and the peak amplitude is approximately 5 V. In the anode circuit is a resistance R_3 of a value which would be expected to produce a high amplification, but the amplification is completely changed by the parallel connection of V_4. The grid of V_4 is fed from the common anode circuit through a cathode follower V_5 which serves the double purpose of reducing the shunt capacitance on the anode circuit and of providing a low impedance output point. The signal here is, of course, of positive polarity. Its peak amplitude is, again, approximately 5 V, but its contrast characteristics have been completely changed by the non-linear shunting action of V_4.

The performance of the gamma corrector is mainly determined by the characteristics of V_4 whose anode current should, ideally, follow a 2,5 power law of the grid voltage change. Fortunately such a characteristic can be very closely realized in a high-slope pentode by suitable choice of the D.C. operating conditions. The characteristic of V_4 is good over most of the range, but at high currents the power law of the characteristic falls below 2,5. The resulting effect on the gamma can be corrected by making use of the curvature of the V_3 characteristic. This curvature, again, is not quite right, and a further correction can be obtained by making use of the effect of voltage drop in R_4 due to the onset of grid current in V_4. By adjusting the circuit to take advantage of these effects the straightness of the contrast characteristic can be well maintained up to the point where it bends over fairly sharply to zero gamma, corresponding to input signals large enough to drive V_3 to anode current cut-off.

At the other end of the scale, for very small signals, a limit is set by the finite resistance of R_3 which does not allow the gain of the amplifier to become infinite for infinitely small signals. However, with practical values of R_3, and with the addition of a small fixed D.C. «lift» or «pedestal» to the output signal, the desired characteristic can be maintained over the specified range of 300 to 1.

If the smallest values of signal are to have any significance, it is obvious that the black level must be stabilised with a degree of accuracy quite beyond the capabilities of any normal method of D.C. restoration, and a special black level control or D.C. restoring circuit has been devised to meet these requirements.

In the intervals between successive line scans the signal level corresponds to black. (In a flying spot scanner this result is obtained quite easily by suppressing the scanning beam.) The black level control is required to ensure that this black interval always occurs at the correct voltage level. The black level control takes a signal from the output of V_5 and compares it, in a differential amplifier, with a fixed reference voltage representing the desired black level. Any difference is amplified and is used to develop a correcting signal across the condenser C_2 in the grid circuit of V_2. The correcting action is required to take place only during those time intervals when it is known that the signal should be at the black level, and control pulses are used to select the required times. This action is shown symbolically in the diagram by a switch, which is closed by each pulse. The voltage across C_2 can be changed only while this switch is closed.

When the switch is closed a loop is formed having a very high negative feedback, so that any error in the black level disappears in the few microseconds required for C_2 to take up its required voltage. The correcting effect does not stop here, however. Even after the switch has opened, C_2 retains its voltage, and correcting current continues to flow through R_2, C_1 and R_1 which results in a further correcting voltage building up across C_1. The time constant R_1C_1 is approximately equal to the time interval between pulses, so that the additional correcting voltage developed across C_1, in this time, is approximately equal to the original correcting voltage across R_1. The result of this action is that the circuit not only corrects the black level line by line, it also puts in the required slope to correct for a rate-of-change of black level. This is a feature which, I believe, has not been achieved before, and it results in a much improved accuracy.

This control circuit was developed in the first place for use with the gamma corrector, but the principle should also have other useful applications. For example, it should be useful for controlling the black level in the modulated output stage of a television transmitter. For this purpose a sample of the transmitter output would be taken, and any error in the observed black level would be used to develop a correcting signal to be applied to an early stage of the modulator. This method should overcome many of the difficulties caused by the impedances of power supplies.

The combination of gamma corrector and black level control works very well in practice and the reproduced picture is very similar to the original. The film used is quite standard, as normally supplied to cinemas, and is not specially processed in any way. Such film contains many sudden changes in brightness from one scene to another, and the total range of contrast is very great. The circuits handle this quite automatically and the best results are obtained without the necessity of any manual adjustments during the running of the film. Engineers with experience of other types of film scanning equipment will appreciate the significance of this result.

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I have tried to explain to you some of the advantages to be gained by phase correction and gamma correction. My arguments and explanations on both subjects have had to be strictly limited by the time available, but I hope I may have succeeded in imparting to you some of my own belief that these subjects are both worthy of more practical attention than they have received in the past.

All my experimental work has been done in the course of my employment with Cinema-Television Ltd., of London. Thanks are due to a number of my colleagues for practical assistance, and to Cinema-Television Ltd. for permission to publish the results and for making possible my visit to this Conference.

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Diskussionsbeitrag

Von *T. Vellat*, Mailand

Die Trennung der Einflüsse von Amplituden- und Phasengang einer Schaltung auf Einschaltvorgänge ist physikalisch nicht gerechtfertigt. Beide Einflüsse nehmen an der Verformung des Eingangsimpulses teil. Allerdings bestehen Zusammenhänge zwischen Amplitudenkurve und Phasengang eines Netzwerkes, so dass man zu einer vorgeschriebenen Dämpfungskurve nicht einen willkürlichen Phasengang wählen kann. Zum Beispiel führt das so oft zitierte Beispiel einer Schaltung mit rechteckiger Durchlasskurve und linearem Phasengang im Durchlassbereich zum Paradoxon, dass der Eingangsimpuls sich am Ausgang der Schaltung noch vor dem Einsetzen des Impulses bemerkbar macht.

Auf den Phasengang einer Schaltung wird man aber nur schliessen können, wenn man die Feinstruktur der Amplitudenkurve in Betracht zieht.

Solange man die Einschwingprobleme mathematisch durch Zerlegung der Impulse in Fouriersche Integrale löste, war es naheliegend den Einfluss des Netzwerkes in Amplituden- und Phaseneinfluss aufzutrennen. Heutzutage, wo man derartige Probleme vermittels Operatorenrechnung (Laplacesche Transformation) löst, ist auch mathematisch kein Grund vorhanden zwischen amplituden- und phasenbedingten Verzerrungen zu unterscheiden.

Das Vorhergesagte gilt für Einschwingvorgänge, also für typische Fernsehprobleme. Unberührt davon wird man für akustische und Frequenzmodulationsprobleme den Dämpfungsverlauf bzw. den Phasengang getrennt heranziehen.

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Contribution to discussion

By *T. H. Bridgewater*, London

In my opinion Mr. Nuttall has rightly stressed the importance of giving attention to phase and amplitude correction. Indeed twenty years ago there was probably more awareness of phase displacement as a factor in television than at the present day, since in the early days the frame repetition frequency of $12^1/_2$c./s made it difficult to reproduce the lower frequencies without any evident distortion.

With a view to clarifying one's concepts I would like to suggest to Mr. Nuttall that there is, philosophically at any rate, no real difference between phase and frequency distortion. Frequency distortion results in the presence of a component at an unwanted frequency or the absence of a wanted one: phase distortion is the appearance of a component where it is unwanted, or the loss of another where it should be.

If this hypothesis can be accepted it seems to me therefore that graphs which may express the phase and frequency characteristics of a particular amplifier are capable of being combined to yield a resultant curve which expresses the over-all effective distortion (or the «goodness» factor). Such an assessment would be far more valuable to operating engineers than the separate curves of phase and frequency whose sum effect cannot readily be visualized. I would be interested to know if Mr. Nuttall can see any practical way of effecting a combination of this sort.

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Wide Band Systems for Television

By *E. Labin*, Nutley, USA

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Introduction

The purpose of this lecture is to consider the bandwidth requirements of various components of television networks and to describe some results obtained in this field. I intend to handle this problem from the point-of-view of a transmission, rather than a television engineer. In transmission, we are interested in reproducing faithfully, at a distance, a message which is not exactly known. The message is generally defined as part of a certain category of signals; such as, television signals, speech signals, etc. The main characteristics of a group of signals of this kind are known only on a statistical basis. The importance of the concept of bandwidth of a given message is due to the experimental fact that messages of a given family have generally the same bandwidth in spite of possible large variations in wave shapes. The usefullness of the bandwidth concept has been often criticized by television engineers who prefer to study signals as time functions. These criticisms are not justified from the point-of-view of the transmission engineers because bandwidth is the most permanent characteristic of a series of messages of the same family.

What are the bandwidths we are likely to meet in television? Present American television standards call for a video bandwidth of 4,5 Mc./s. This is adequate for the screen sizes which are now popular, or which are likely to be used in the average home. It corresponds to a quality comparable to what 16 mm home movie projectors will supply.

Many years will elapse before, in a commercial network, including home receivers, full advantage will be taken of the existing standards. If television pictures shall compare with movie pictures as projected in ordinary theatres in size and quality, a more ambitious standard probably up to 12 Mc./s video will be necessary. If, in addition, color is desired we might arrive at a video standard of 30 Mc./s. The message so defined has to be transmitted from the camera to a distant broadcast transmitter and from there to the home receiver, or eventually to the theatre projector. This represents a complex series of transformations of the message which are outlined in Fig. 1.

We intend to follow the message through this complex network and to indicate how broad a band can now be achieved for the various components. The message at the output of the camera has to be amplified within suitable video amplifiers, from there it has to go either through a coaxial line or through a radio pick-up link to a fixed relay station.

From there, the signal might be transmitted through radio relays, or again through a coaxial line to a distant city. In that distant city, the signal will be restored to its video form, amplified again by video amplifiers and finally applied to an AM transmitter which will broadcast the message. The intermediary coaxial cable links will normally use the video spectrum directly, or the same spectrum translated into another frequency range, but essentially it will be the same bandwidth.

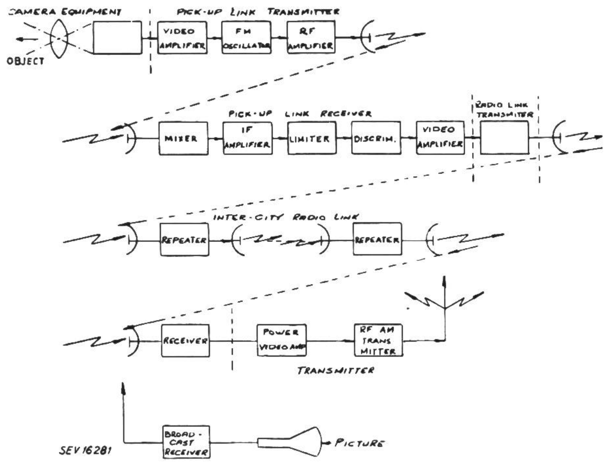

Fig. 1

The radio links will not normally use FM, meaning that the bandwidth at radio frequencies will be at least twice and normally three times the video bandwidth. It might be found useful in the future to transform the video signal before it is applied to the radio link. Such transformation could further increase the bandwidth. All this means that we need various tools; such as, frequency modulated oscillators, RF amplifiers, IF amplifiers, limiters, and discriminators with bandwidths which have to extend, depending upon the video standards referred to above, essentially from 10 to 100 Mc./s. The broadcast transmitters using vestigial side band AM modulation do not have to be that broad, but would still have to operate with a bandwidth of 6 to 60 Mc./s.

I do not intend to determine, on theoretical grounds, what the possible limits might be, but to describe briefly what has been done in our Laboratories in terms of independent components; such as, video amplifiers, IF amplifiers, limiters, discriminators, etc. I would like to stress before I start to show you the results obtained in these various