THE PHILOSOPHY OF OUR TV SYSTEM

A Brief Review of the Functions of the Most Important Parts of the TV System, With An Explanation of the Reasoning Behind the Choice of Standards, Types of Transmission, Shape of Synchronizing Pulse, Etc.

by JOHN H. ROE
Supervisor, TV Systems Engineering Group
Engineering Products Department

Introduction

The boom in television has created a need for trained operators which is far in excess of the available facilities for training them. As a result, many stations face the start of regular operating schedules with a staff of inexperienced (in TV, that is) operators who, although they have been briefed in their duties, have only a beginner's knowledge of the overall TV system.

No amount of written description can provide the background which several months of operating experience can give, nor can a story of the system, complete in every detail, be set down in a few pages. However, it is felt that a recapitulation of some of the basic philosophy of the television system will be helpful to many of the beginners in the business, and may prove an incentive to further reading. Therefore an effort will be made to review briefly the functions of some of the important parts of the system and explain the thinking behind them. Detailed discussion of circuits and methods is purposely omitted in order to devote the space to an overall picture of the system. References to other papers covering much of such detail are given in a bibliography.

Limitations

No true appreciation of any system can be realized without some understanding of its basic limitations, and a discussion of the television system should therefore begin by reviewing these. The most serious limitation of a television system, as in the case of an aural system, is "noise." The same phenomena that cause hum, crackle, and hiss in the background of a sound broadcast, cause bar-like shadows, random blotches, and "snow storms" in the background of a television picture. The word, noise, has been carried over from aural terminology into television terminology with the same connotation. In other words, any spurious elements in a television picture are generally called noise. In reading the following discussions, it will be helpful to remember that much of the reasoning behind the methods used in the television system is based on the need to minimize the effects of noise.

Spurious noise components in the signal arise from two general sources, (a) shot noise and thermal agitation in vaccum tubes and other circuit elements, and (b) pickup from associated or remote electrical apparatus. The best means for minimizing noise is to maintain a high signal-to-noise ratio in all parts of the system, but where this is impossible, special circuits are a distinct aid in extending the useful range of operation.

Noise limits, among other things, the ability of the system to resolve fine detail. However, a more direct limitation on the resolving power of the system is the frequency bandwidth available in the transmission system. This limitation has commercial aspects of more significance than the technical aspects because of the limited room available in the radio spectrum. As a result, the decisions of the Federal Communications Commission effectively determine the limits of resolution within the noise-free service area of any station. Through long years of field testing it has been found that a six-megacycle channel will provide adequate resolution and at the same time will yield a reasonable number of channels.

Other factors which limit overall performance are the fineness of scanning apertures,* the degree of accuracy with which tonal gradations are reproduced, and the brightness range of which the reproducing device is capable. However, if it can be assumed that the transmission system between the pickup and reproducing devices is reasonably linear, then the problems arising from these particular limitations are confined largely to the pickup and reproducing devices themselves, and do not affect system considerations to the same extent as limitations described in the preceding paragraphs, and as certain economic factors do.

Economic factors usually limit the degree to which technological development is used to improve the quality of performance. Methods may be known by which some of the physical limitations of the system can be overcome, but sometimes such methods are not used for a long time after their discovery because means for applying them economically are not developed simultaneously. In other words, their use increases the cost of equipment excessively. This is especially true in the case of receiving equipment which must be produced in large quantities at low unit cost. Such methods often do find their way into trans-

---

* The use of the word *aperture* in television probably arose from the use of scanning disks where the light passed through small holes which traversed the projected area of the scene. Small holes traversing closely spaced lines in the area were capable of greater resolution than larger holes traversing more widely spaced lines. Though scanning disks are no longer used, the term aperture is still applied to the scanning device in a general sense. In electronic television, the diameter of the "aperture" is simply the diameter of the scanning beam of electrons in the plane of the scanned image. Similarly the term *aperture correction* is applied to means (usually the use of special circuits) for compensating the picture signal for loss of resolution caused by finite size of the beam and by non-uniform distribution of electrons over the cross-sectional area of the beam.

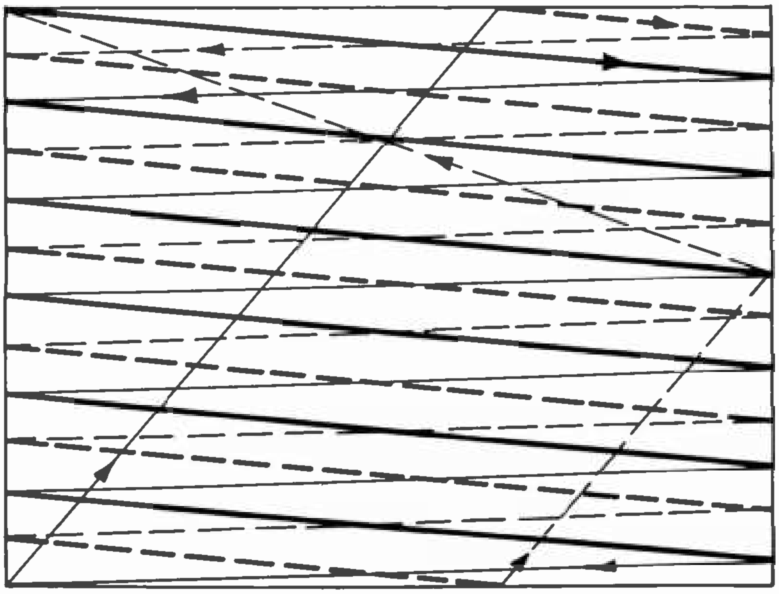


FIG. 1. Odd-line interlaced scanning system with 13 lines. Consecutive fields are indicated by solid and dotted lines, respectively.

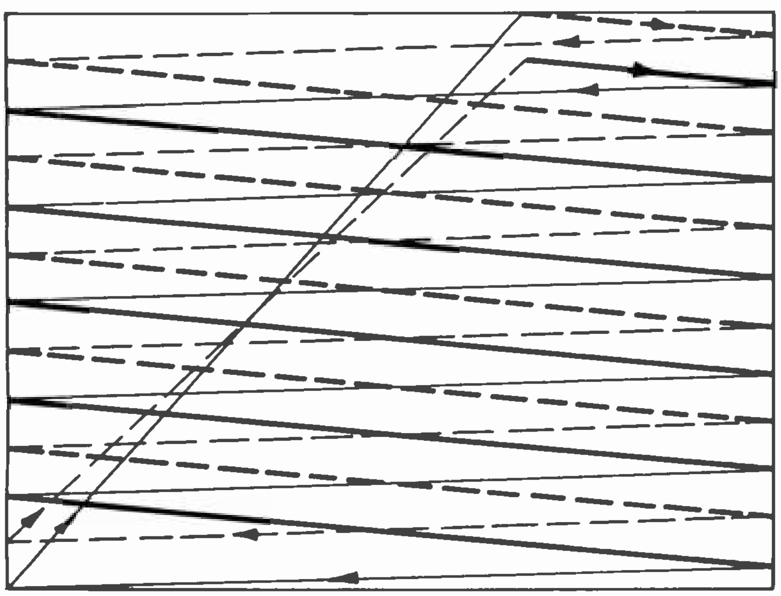


FIG. 2. Even-line interlaced scanning system with 12 lines. Consecutive fields are indicated by solid and dotted lines, respectively.

mitting equipment where low unit cost is not so important and where quality of performance is paramount. Quality is stressed in transmitting equipment to provide reliability and to reduce the need for including in the receivers complicated and expensive corrective circuits. Examples are circuits for automatic correction of scanning linearity, and clamp circuits for accurate re-establishment of black level, or d-c restoration, as it is often called.

Standards

During the decade preceding the entrance of the United States into World War II, Radio Corporation of America carried on an extensive program of research and development in television and the information so derived has been largely responsible for the formulation of the standards governing our present black-and-white system. The earliest work on standards was done through the medium of the Radio Manufacturers' Association. Much more extensive work on standards was carried on later by the National Television System Committee and the Radio Technical Planning Board, the former body being set up to deal exclusively with television standardizing problems and to bring about agreement among the several interested groups on suitable standards for recommendation to the FCC. With the approach of commercial broadcast service, the FCC adopted the recommendations of these bodies as the basis for tentative standards of good operating practice. Activity of the RMA has continued on television and its recommendations have been extended to cover much of the detail of studio and transmitter operation, and of receiver design. While a considerable portion of this material still exists only in the form of recommendations to the FCC, it will undoubtedly constitute the major part of the final standards.

One of the most important standards recommended is the one which describes the wave shape of the picture signal. This standard is outlined in detail in a drawing which is reproduced in Fig. 5. Reference will be made to this drawing from time to time in discussing the system, and an attempt will be made to clarify the reasoning involved in establishing many of the specifications included in it.

Scanning System

The standard system of scanning in television is one in which the scene or image is traversed by the aperture in lines which are essentially horizontal, from left to right and progressively from top to bottom. The aim is to have the aperture move at constant velocity both horizontally and vertically during actual scanning periods because that is a simple type of motion to duplicate in the reproducing aperture and because it provides a uniform light source in the reproducer. At the end of each line the aperture, or scanning beam, moves back to the start of the next line very rapidly. The time occupied by doing this is called the *fly-back* or *retrace* period. In a similar way, the beam moves from the bottom back to the top after the end of each picture scan. Motion during retrace periods need not be linear. The complete traversal of the scene is repeated at a rate high enough to avoid the sensation of flicker. This rate has been set at 60 times per second because most of the power systems in the United States are 60 cycle systems, and synchronization with the power system minimizes the effects of hum and simplifies the problem of synchronizing rotating machinery in the television studio (film projectors) with the scanning.

It has appeared rather recently that the choice of 60 cycles for the vertical scanning frequency was a fortunate one for another reason. The progress of the art has included means for obtaining brightness levels in the reproduced pictures which are appreciably greater than those used in motion picture theatres. It is well known that the threshold of flicker increases as the brightness increases. Thus, 48 or 50 cycle flicker would be noticeable to some observers at modern brightness levels in television receivers. Persistence of vision varies in different people and those whose persistence charactristics are very short are conscious of the 60-cycle flicker in the bright pictures on some present-day receivers. Therefore it appears that a still higher vertical frequency would be desirable if other factors would permit. Needless to say, the interline flicker, mentioned later in connection with interlacing is also less objectionable with the higher scanning rate.

Another important factor affecting flicker is the persistence characteristic of the screen material in the receiver. This can be made long enough to overcome any appearance of flicker even with scanning rates less than 50 cycles per second, but, if carried too far, such long persistence causes ghost-like trailing after moving objects in the scene. Judicious choice of screen persistence is a great aid in reducing flicker.

Obviously the scanning apertures in the pickup and reproducing parts of the system must be in exact synchronism with each other at every instant. To accomplish this, synchronizing information is provided in the form of electrical pulses in the retrace intervals between successive lines and between successive pictures. The retrace intervals are useless in reproducing picture information, hence are kept as short as circuit considerations permit, but are useful places in which to insert the synchronizing pulses. These pulses are generated at the studio in the same equipment that controls the timing of the scanning of the pickup tube, and they become part of the complete composite signal which is radiated to the receiver. Thus scanning operations in both ends of the system are always in step with each other. Synchronizing is discussed in more detail in a later section.

The number of scanning lines is the principal factor determining the ability of the system to resolve fine detail in the vertical direction. The number of scanning lines is also related to the resolving power in the horizontal direction because it is desirable to have the same resolution in both directions. Thus, as the number of lines increases, the bandwidth of the system must

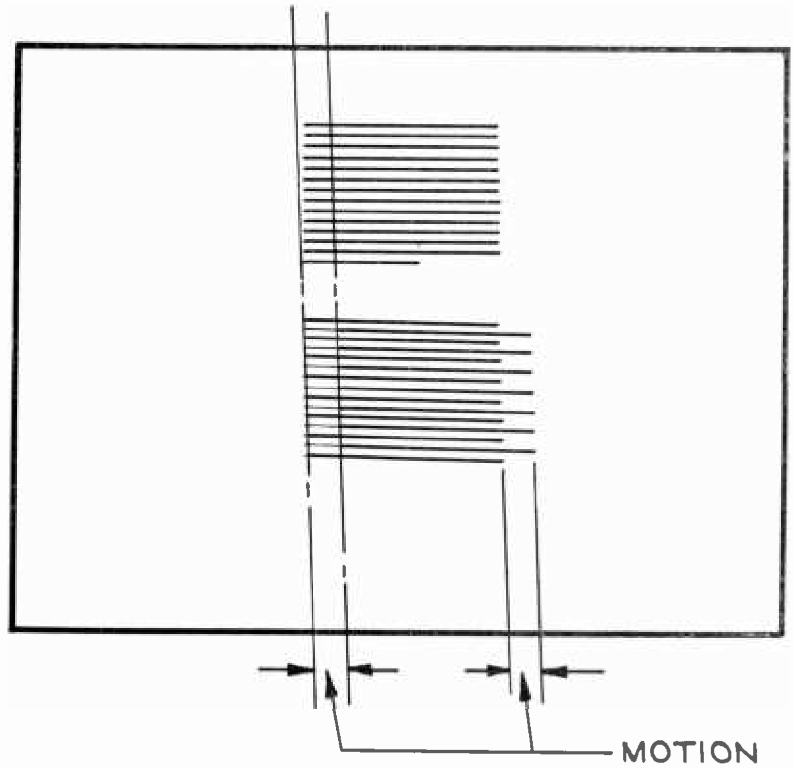


FIG. 3. Effect of horizontal motion of vertical edges in 2-to-1 interlaced system. Upper object stationary. Lower object moving to right.

also increase to accommodate the greater resolution required in the horizontal direction. The present system employs 525 lines, a number arrived at after thorough consideration of the related questions of channel width and resolution by the N.T.S.C. and the R.T.P.B.

One of the most interesting features of the television scanning system is the interlacing of the scanning lines, a scheme which is used to conserve bandwidth without sacrificing freedom from flicker. The sensation of flicker in a television image is related to the frequency of the illumination of the entire scene. It has no relation to the number of scanning lines nor to the frequency of the lines themselves. Therefore a system which causes the entire area of the scene to be illuminated at a higher frequency, even though the same lines are not scanned during successive cycles of illumination, results in greater freedom from flicker. Interlacing does just this by scanning part of the lines, uniformly distributed over the entire picture area, during one vertical scan, and the remaining part or parts during succeeding scans. Thus, without changing the velocity of the scanning beam in the horizontal direction, it is possible to obtain the effect of increased frequency of picture illumination.

In the standard two-to-one interlaced system, alternate lines are scanned consecutively from top to bottom after which the remaining lines, that fall in between those included in the first operation, are likewise scanned consecutively from top to bottom. (See Figs. 1 and 2 which illustrate the principle.) In the 525-line system, each of these groups, called a *field*, consists of 262½ lines. Two consecutive fields constitute a *frame* or complete picture of 525 lines. Each field is completed in 1/60 of a second and each pair of fields, or frame, in 1/30 of a second. The effect on the observer's eye, from the standpoint of flicker, is that of repetition of screen illumination every 1/60 of a second, yet the complete picture is spread out over 1/30 of a second.

The important result of interlacing is a reduction in the bandwidth of the frequencies generated in the picture signal, for a given value of limiting resolution, as compared to the bandwidth produced in a system using sequential scanning. This may be understood as follows: In either system, interlaced or sequential, the vertical scanning frequency must be the same and must be high enough to avoid the sensation of flicker. In the standard television system this frequency is 60 cycles per second. In a sequential system, *all* of the scanning lines must be traversed in the basic vertical scanning period. However, in the two-to-one interlaced system, only *half* of the scanning lines are traversed

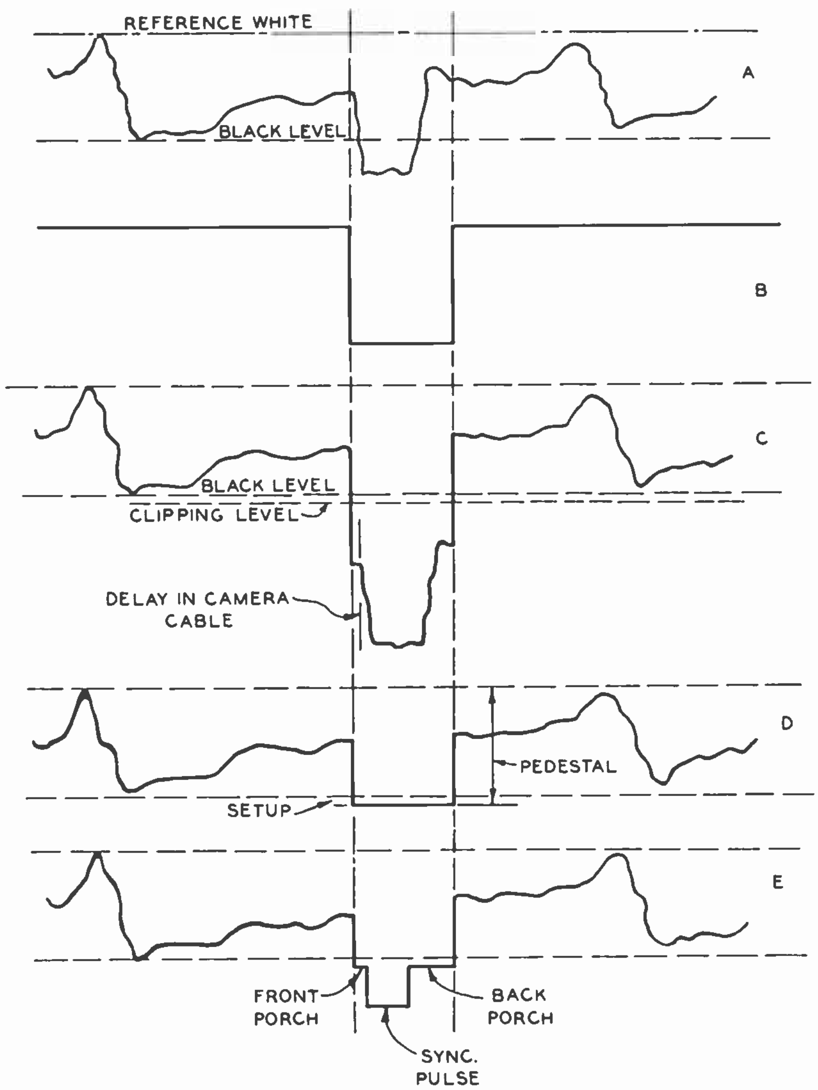


FIG. 4 (at left). Steps in the synthesis of picture signal:
A. Basic camera signal.
B. Kinescope blanking pulse.
C. Camera signal and blanking pulse combined.
D. Combined signal after clipping.
E. Combined signal after addition of sync pulse.

FIG. 5 (opposite page). RMA drawing illustrating approved wave shape of picture line amplifier output signal. This is one of the most important industry standards and is the one which determines the design of many of the components of the TV system.

in the same period. Thus, obviously, the horizontal velocity of motion of the aperture in the interlaced system is only half of the velocity in the sequential system, and likewise the signal frequencies are reduced by the same factor.

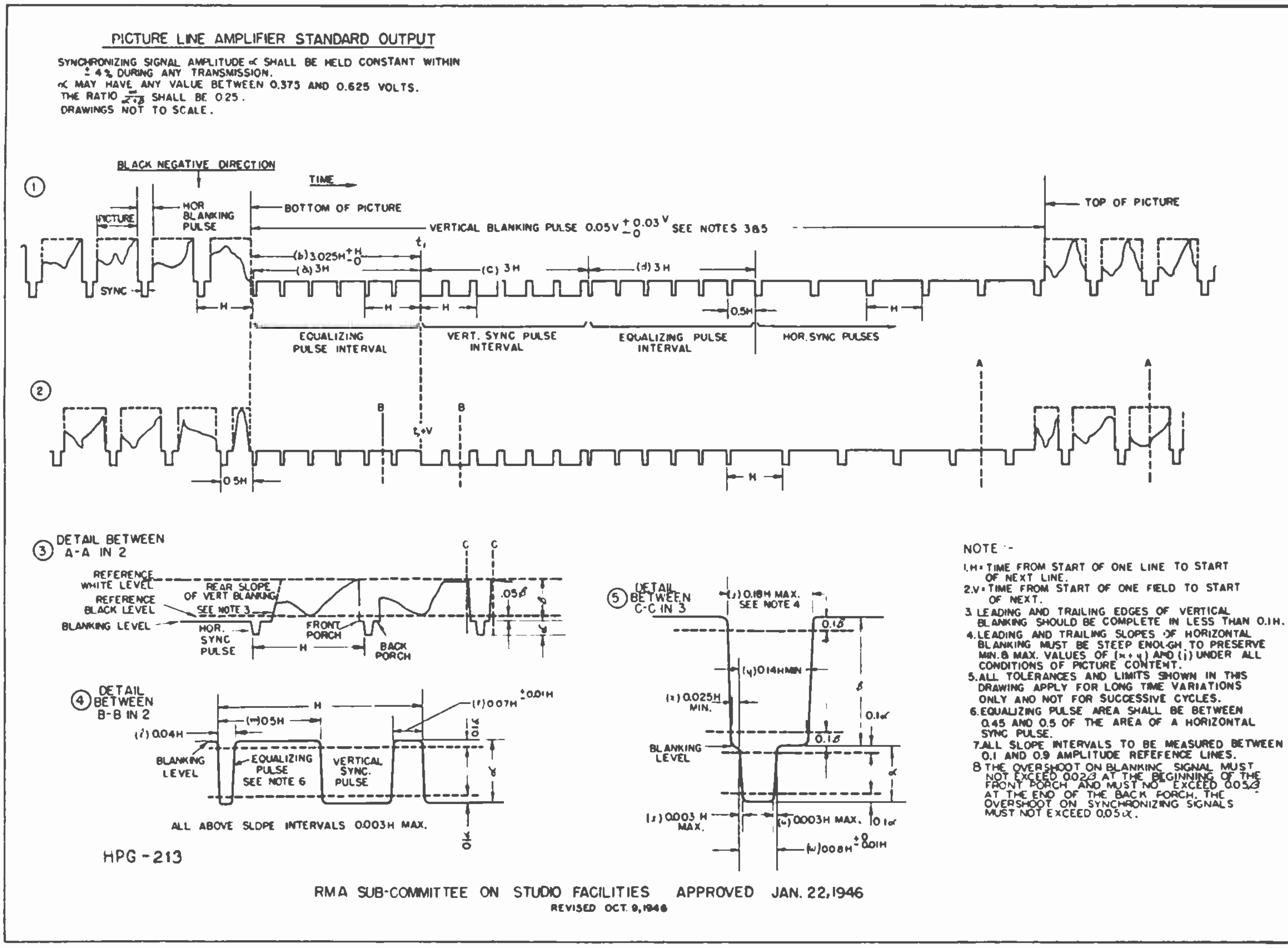
Interlaced scanning has certain inherent faults among which are interline flicker, and horizontal break-up when objects in the scene move in the horizontal direction.

Interline flicker results from the fact adjacent scanning lines are separated in time by 1/60 of a second, and that each line is repeated only at intervals of 1/30 of a second. It is apparent in any part of a scene where some detail of the scene is largely reproduced by a few adjacent scanning lines, and where the contrast in the detail is high. For example, the top edge of a wall which is oriented in the scene so as to be nearly parallel to the scanning lines might be reproduced by only two or three adjacent lines. The 30 cycle flickering of the line segments forming the edge of the wall would be quite noticeable. In the limiting condition, where the wall is exactly parallel to the scanning lines, the edge would be reproduced by only one line repeated at intervals of 1/30 of a second. This is probably the worst possible condition, but one which is encountered rather infrequently. The top and bottom edges of the raster nearly always produce objectionable interline flicker because they are nearly parallel to the scanning lines. Interline flicker, like any other type of flicker, is most objectionable in scenes where the high lights are very bright and the contrast is high. When the brightness and contrast are low, interline flicker becomes negligible.

Break-up exists when an object in the scene moves in the horizontal direction rapidly enough so that the total motion in 1/60 of a second is equal to one or more picture elements. Then vertical edges of the object become jagged lines instead of smooth lines and there is apparent loss in horizontal resolution. This is roughly illustrated in Fig. 3 where two rectangles are shown, the upper one being stationary, and the lower one moving toward the right. The moving rectangle is shown as though it started moving from a position directly below the other. In the moving rectangle, signal is generated, *in both fields,* from the starting position of the left edge because of the storage of information in the pickup tube during the interval between fields. Thus the storage effect causes actual blurring of the trailing edge of a moving object. This is illustrated by the thin extensions of the scanning lines in the second field at the left side. The leading edge of the moving object may have a more definite jagged appearance because the storage effect in the pickup tube cannot fill in the spaces. In non-storage pickup devices, both edges will appear jagged.

The geometrical distortion, illustrated by the tendency for the moving rectangle to become rhombic, is characteristic of any scanning system, whether interlaced or sequential.

Further consideration makes it clear that higher ratios of interlacing would produce these troubles in aggravated form which would be intolerable. Another objection to higher ratios of interlacing is an illusion of crawling of the scanning lines either up



or down, depending on motion of the observer's eyes. The effect is extremely annoying and tends to distract the observer's attention from the scene.

The type of interlacing adopted for commercial television is known as *odd-line* interlacing. The total number of lines is an odd integer. Thus the number of lines in each of two equal fields is a whole number plus a half. In this system, the use of perfectly uniform vertical scanning periods (equal to half the product of the total number of lines and the period of one line) and constant vertical scanning amplitude, results in consecutive fields which are displaced in space with respect to each other by half a line, thus producing interlacing of the lines, as illustrated by the 13-line system in Fig. 1. Specifically, as stated above, the total number of lines in the standard system is 525; the number per field is 262½; the vertical scanning frequency is 60 cycles per second; the number of complete pictures (frames) per second is 30; and the horizontal scanning frequency is 60 × 262½, or 15,750 cycles per second.

Interlacing may also be obtained when the total number of lines is an *even* number, but *even-line* interlacing requires that alternate fields be displaced vertically one half line with respect to each other by the addition of a 30-cycle component to the amplitude of the vertical scanning sawtooth wave (see Fig. 2). This frame frequency component must have a degree of accuracy that is impractical either to attain or maintain. Hence even-line interlacing is not used for commercial television.

One other factor has influenced the choice of the particular number of scanning lines. This is the need for an exact integral relationship between horizontal and vertical scanning frequencies. It has been the practice to attain this relationship by using a series of electronic counting circuits. To secure a high degree of stability, the characteristic count of each circuit was limited to a small integer less than ten. Thus the h/v frequency ratio was required to be related to the combined product of several small integers. In the RCA synchronizing generator equipment, for example, there are four such circuits counting the numbers 7, 5, 5, and 3 respectively. The combined product of these four numbers is 525, the number of lines per frame. The product of 525 and 60 is 31,500 which is the frequency of the master oscillator in the sync. generator. To obtain the correct frequency for the horizontal scanning system, another counter circuit divides the master oscillator frequency by two to yield the required frequency of 15,750 cycles.

Synthesis of the Picture Signal

The basic part of the signal applied to the reproducer is the series of waves and pulses generated during the actual scanning line periods in the pickup or camera tube. No matter what else is done in the equipment intervening between the two ends of the system, this basic part of the signal should be preserved in character with the greatest possible accuracy. However, during the retrace periods, the pickup tube may generate signals which are spurious or which at least do not contain valuable picture information. Furthermore, retrace lines in the reproducing tube itself, especially during vertical retrace, detract from the picture. It is therefore desirable to include in the picture signal, components which will eliminate spurious signals during retrace and the retrace lines themselves in the reproducer. These results may be obtained by adding synthetically some pulses known as blanking pulses.

Blanking pulses are applied to the scanning beams in both the camera tube and the kinescope in the receiver. *Camera blanking* pulses are used only in the pickup device and never appear directly in the final signal radiated to the receiver. They serve to close the scanning aperture in the camera tube during retrace periods. In orthicon tubes, the picture signal during retrace thus goes to reference black or to some level constantly related to reference black. This is a useful result to be discussed later. In iconoscopes, no such constant relationship to black exists during retrace, and the only function of camera blanking is to prevent spurious discharge of the mosaic during the retrace periods.

Kinescope blanking or *picture blanking* pulses are somewhat wider than corresponding camera blanking pulses. They become integral parts of the signal radiated to the receiver.

The function of the kinescope blanking pulses is to suppress the scanning beam in the kinescope (reproducing tube), or in other words, to close the aperture in the receiver during the retrace periods, both horizontal and vertical. They are simple rectangular pulses having time duration slightly longer than the actual retrace periods in order to trim up the edges of the picture and eliminate any ragged appearance. They are produced in the sync generator from the same basic timing circuits that generate the scanning signals; hence they are accurately synchronized with the retrace periods. Typical wave shapes of a basic camera signal and blanking pulses are illustrated in Figs. 4, A and B respectively. Only parts of two scanning line periods are shown, and the pulse in B is therefore a single *horizontal blanking pulse*. The result of adding the signals in A and B is shown in C where it may be seen that the unwanted spurious part of the camera signal has been pushed downward out of the territory of the basic picture signal. This unwanted part may now be clipped off and discarded leaving the signal illustrated in D.

The blanking signal, shown only in part in Fig. 4, B, actually contains pulses for removing visible lines during both horizontal and vertical retrace periods. The horizontal pulses recur at intervals of 1/15,750 of a second and are only a small fraction of a line in duration, but at times corresponding to the bottom of the pictures they are replaced by *vertical blanking pulses* which are just like the horizontal pulses except that they are much longer in duration, approximately 15 scanning lines long, because the vertical retrace is much slower than the horizontal. The period of recurrence of the vertical blanking pulses is 1/60 of a second, of course. Both horizontal and vertical blanking pulses and their approximate relationship are shown in diagrams 1 and 2 of Fig. 5.

The picture signal shown in D of Fig. 4 may be considered as partly natural and partly synthetic. It is important to point out here that the natural part, or basic camera signal, may contain certain noise components arising from the fact that the output of the pickup tube usually is not large compared to the noise threshold of the first picture amplifier stage or some other part of the system such as the scanning beam in an image orthicon. On the other hand, the blanking pulses, or synthetic parts of the signal, are added at a relatively high level part of the system and are therefore noise-free. The importance of noise-free blanking pulses will become apparent in the discussions of other functions which they perform.

Details of horizontal blanking pulse shape are shown in diagram 5 of Fig. 5. That part of the diagram below the point marked Blanking Level is a sync pulse which will be considered later. The overall vertical dimension β is the maximum height of a blanking pulse. Thus the top horizontal line is Reference White Level as indicated in diagram 3. The duration or width of the pulse must be sufficient to cover the horizontal retrace in the most inefficient receiver. Thus the circuit limitations in such receivers set a minimum limit to the horizontal blanking width which was the basis for the RMA specification in Fig. 5. This minimum is indicated by the width near the peak (lower end) of the pulse and is prescribed by the sum of two dimensions $x + y$, the value of which is 16.5% of the horizontal period, H. The impossibility of producing infinitely steep sides on the pulse is recognized in the greater maximum width (18% of H) allowed at the upper end of the pulse and in the obviously sloped sides.

Because of inevitable discrepancies at the extremes of the sides of the pulse, all measurements of pulse widths are made at levels slightly removed from the extremes of the sides. These levels are shown by dotted horizontal lines, in diagram 5 of Fig. 5, spaced 10% of β from top and bottom of the pulse.

Details of the vertical blanking pulses are shown in diagrams 1 and 3 of Fig. 5. The width of the pulses is not limited by circuit considerations, as is the width of horizontal blanking. The limitation here is the requirement of television film projectors of the intermittent type that the scene be projected on the pickup tube only during the vertical blanking period. The maximum period of 8% is ample for the operation of present-day film pickup systems, the criterion being that enough time must be allowed for projection so that there is adequate storage of photoelectric charges on the sensitive surface of the pickup tube. The minimum period of 5% is an indication of expected system improvements in the future when it will be possible to reduce waste of picture transmission time in vertical blanking. The present usefulness of the 5% minimum is to require receiver manufacturers to maintain vertical retrace periods at less than 5% and thus avoid the need for modifying old receivers when improvements are made in the system. The problem of film projectors is discussed in a later section.

The final step in synthesizing the complete composite picture signal which goes to the modulator in the transmitter is to add the synchronizing pulses which are required for triggering the scanning circuits in the receiver. These pulses, like blanking pulses, are essentially rectangular in shape. The blanking pulses serve as bases or pedestals (inverted) for the sync pulses as shown in E of Fig. 4. Here is one of the most important reasons for having noise-free blanking. The synchronizing function in the receiver is a very critical one, and it is important that nothing be allowed to distort the sync pulses either in shape or timing as noise during the blanking intervals would do. The nature of the vertical sync signal is rather complicated and is not illustrated in Fig. 4, but will be discussed later along with other details of synchronizing.

The sync signal is not added individually to the output of each camera, but is added at the studio output so that switching from one camera to another will not cause even momentary interruptions in the flow of synchronizing information to the receivers.

•

(Mr. Roe's article will be continued in the next issue of Broadcast News)

THE PHILOSOPHY OF OUR TV SYSTEM

A Brief Review of the Functions of the Most Important Parts of the TV System, With An Explanation of the Reasoning Behind the Choice of Standards, Type of Transmission, Shape of Synchronizing Pulse, Etc.

by **JOHN H. ROE**
Supervisor
TV Systems Engineering Group
Engineering Products Department

PART II

EDITOR'S NOTE: *The first part of this article appeared in* BROADCAST NEWS *No. 53, February, 1949. The second part is included in this issue. The third, and concluding, part will be published in the next issue of* BROADCAST NEWS, *which should be mailed about June 1. Those desiring to have the whole article in advance may obtain a preprint by writing to the editor.*

The D-C Component of the Picture Signal

The visual and aural senses differ in one important respect which places a requirement on the television transmission system which has no counterpart in the sound transmission system. The response of the ear to sound is actually a response to variations in air pressure. While the ear is very sensitive to rapid variations in pressure, it is completely unconscious of absolute values of air pressure, or of slow variations in pressure, as sound. In other words, there is a definite low limit to the frequency of pressure variations which the ear accepts as sound. Therefore there is no need for a sound transmission system to pass frequencies below the aural limit which is somewhere in the neighborhood of 15 cycles per second. The circuits may be a-c coupled without loss of essential information. Even the best of practical systems have a low frequency cutoff at about 30 cycles, and most others cut off somewhere between 50 and 100 cycles.

The eye, on the other hand, is sensitive to absolute intensities of light and to slow variations of intensity. As the frequency of variation increases, the eye rapidly loses its ability to follow the changes and tends to produce a sensation which is an average of the variations. It is this averaging ability that enables the eye to interpret a rapid succession of still pictures as a portrayal of smooth motion. This phenomenon is the basis of both motion picture and television systems.

The important point in the present discussion is that the eye recognizes a slow change in light intensity. The period of the change may be a fraction of a second or it may be a minute, an hour, or a half day in length. A television system must be capable of conveying these slow changes, no matter how long the period, to the receiver. The rapid scanning of the image of the scene in the camera produces a signal containing these slow changes as well as very rapid variations caused by the passage of the scanning beam over small light and dark areas of the image. The slow changes often have periods so long that they may be considered as d-c levels which simply change value occasionally. Hence, the signal is said to contain a *d-c component*. The television system must either pass the entire spectrum, including the d-c component, in each of its stages, or the signal must contain such information that it will be possible to restore the d-c component, which would be lost in an a-c coupled system, when it finally arrives at the reproducer. Because of the well-known difficulties in constructing multistage d-c coupled amplifiers, it is obviously desirable to use an a-c coupled system. It is fortunate that relatively simple means are known for d-c restoration thus making possible the use of an a-c coupled system.

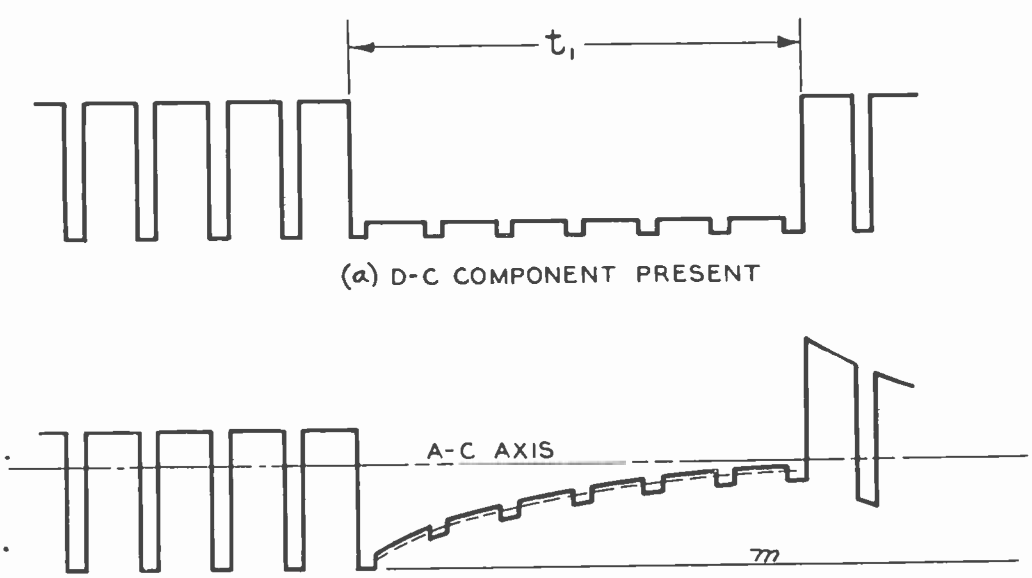


FIG. 6. When a signal containing a d-c component, as in (a), is passed through an a-c coupled system the d-c component is lost, as shown in (b).

Fig. 6(a) illustrates a signal which contains a d-c component in the form of a temporary change in the amplitude of the pulses. The period t_1 embracing the low-amplitude pulses may be of any arbitrary length. The original signal is characterized by the constant level of the negative peaks of all the pulses regardless of amplitude. After passing through an a-c coupled system (in which the time constants of the coupling networks are short compared to the period t_1) the signal becomes distorted approximately as shown in Fig. 6(b). Here the negative pulse peaks no longer fall on a constant level, but the signal tends to adjust itself in a consistent manner about an axis called an a-c axis.

The a-c axis of a wave is a straight line through the wave positioned so that the area enclosed by the wave above the axis is equal to the area enclosed by the wave below the axis. The broken line marked a-c axis in Figure 6(b) is actually the correct axis only for a wave composed of large pulses like the first four at the left. During the transient condition following the first short pulse, the line shown is not the true a-c axis, but represents the operating point of the amplifier in the a-c coupled system. The actual a-c axis of the short pulses (shown by the dotted line) gradually adjusts itself to coincide with the operating point of the amplifier. This adjustment is shown by the exponential rise of the signal during the interval t_1, but it is interrupted before completion by the resumption of the large pulses. Thence a second transient condition takes place leading to a gradual restoration of the signal to its original form.

The departure of the pulse peaks from the original constant level indicated by the line *m*. is called *loss of the d-c component* or loss of "lows". It is interesting to note that this loss causes an increase in the peak-to-peak amplitude of the signal, a condition which is undesirable, especially in high-level amplifiers.

Black Level

An absolute system of measurement must have a fixed standard reference unit or level. This rule applies to the problem of reproducing absolute light intensities. The simplest and most obvious reference for such a system is zero light, or *black level* as it is often called. This is a reference level which can be reproduced arbitrarily at any point in the system. Now if the television signal can be synthesized in such a way that frequent short intervals have some fixed relationship to actual black in the scene, then it becomes possible to restore the d-c component by forcibly drawing the signal to a fixed arbitrary level during these intervals.

D-C Insertion and D-C Restoration

Because the blanking or retrace periods are not useful for transmitting actual picture information, they offer convenient intervals for performing special control functions such as d-c restoration as mentioned in the previous paragraph. If the peaks of the blanking pulses are coincident with black level, or differ from black level by a constant amount, then d-c restoration can be accomplished simply by restoring these peaks to an arbitrary reference level. Thus, in Fig. 6(b), if the peak of each pulse can be restored to the line *m*, then the signal will appear as in (a) and the d-c component will have been restored. Small errors will remain corresponding to the displacements in level between pulses, but these are usually negligible and in any case do not become cumulative. Hence the restoration is essentially complete.

It now becomes apparent that an extremely important step in the synthesis of the television signal is that of making the peaks of the added blanking pulses bear some fixed relationship to actual black level in the scene. It was pointed out previously that the peaks of these pulses are produced by clipping off unwanted portions of the signal as illustrated in Fig. 4, C and D. A second, and most important, function is performed when the clipping is controlled in such a way that the resultant peaks have the required fixed relationship to black level. This process of relating the blanking peaks to actual black level is called *d-c insertion*, or insertion of the d-c component. A subsequent process, later in the system, of bringing these peaks back to an arbitrary reference level is called *d-c restoration*. D-c restoration must be accomplished at the input of the final reproducing device (the kinescope) in order to reproduce the scene faithfully if an a-c amplifier is used. It is desirable to restore the d-c component at other points in the system also, because the process reduces the peak-to-peak excursions of the signal to a minimum by removing increases in amplitude caused by loss of the d-c component. In a similar way, it is possible to remove switching surges, hum, and other spurious signal components which have been introduced by pure addition to the signal. Maintaining minimum excursion of the signal is important, especially at high level points in the system, in order to avoid saturation in amplifiers and consequent distortion of the half tones in the scene. For a specific example, d-c restoration helps to maintain constant sync. amplitude in high-level amplifiers. In other words, it makes possible economies in the power capabilities of amplifiers such as the final stage in the picture transmitter.

Diagram 3 in Fig. 5 illustrates part of a typical picture signal including two horizontal blanking pulses. It may be seen that there is a distinct difference between actual black level and blanking level which is prescribed as 5% of maximum blanking pulse amplitude. This difference is usually called ***setup*** and its magnitude was set as a reasonable compromise between loss of signal amplitude range and the need for a tolerance in operating adjustment. Setup is desirable as an operating tolerance in the initial manual adjustment of the clipper in that part of the system where the d-c is *inserted*. It simply insures that no black peaks in the actual picture signal are clipped off.

The accuracy with which setup is maintained depends on characteristics of the pickup or camera tube. Some types of pickup tubes produce signals during blanked retrace periods which are the same as, or are constantly related to, black level. In systems where such tubes are used, the magnitude of setup may be held constant automatically at whatever value is determined in the initial manual adjustment of the clipper circuit. In general, pickup tubes employing low velocity scanning, such as the image orthicon, provide this kind of basic black level information. The iconoscope is different from orthicons in this respect because the secondary emission resulting from the high velocity scan-

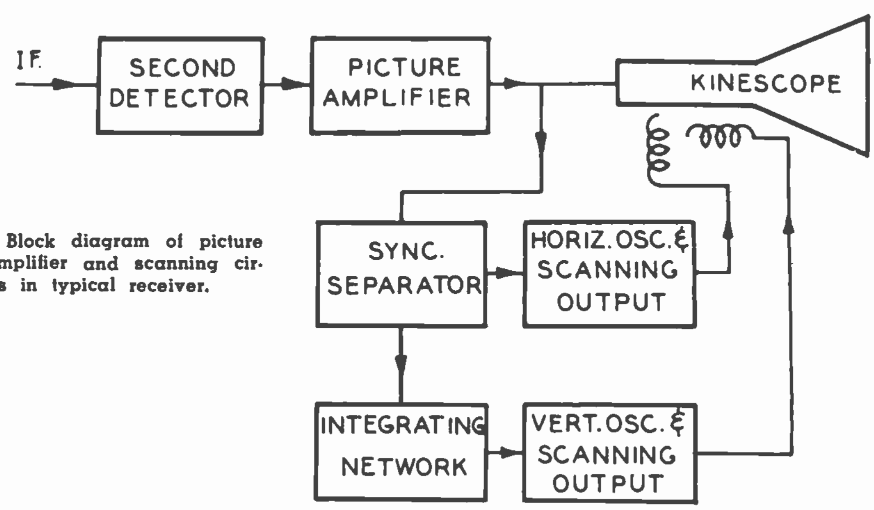


FIG. 7. Block diagram of picture signal amplifier and scanning circuits in typical receiver.

ning, produces a potential distribution on the mosaic in which black level is far from the level existing during the retrace periods when the beam is cut off. In fact the difference between black level and blanking level varies continuously as the scene brightness changes because the potential distribution caused by resettling of the secondaries likewise changes. Automatic maintenance of setup, or pedestal height, cannot therefore be obtained by reference to the signal during blanked retrace periods in the iconoscope, but may be obtained by reference to actual black peaks in the picture signal. Where such reference is not practical, a manual control may be readjusted from time to time to keep the setup at the required value.

Synchronizing

The horizontal and vertical scanning circuits in a receiver are two entirely independent systems both of which require extremely accurate information to keep them in step with the corresponding scanning systems in the camera where the signal originates. Because the duration of sync. pulses may be rather short, they may be added to the picture signal in such a way as to increase the overall amplitude of the final signal without increasing the average transmitted power level very much. Thus, simple amplitude discrimination can be used to separate the synchronizing information from the incoming composite signal in the receiver. It is, however, desirable that a second increase in amplitude should not be used to distinguish between horizontal and vertical sync. One reason for this is that a further increase in signal amplitude would make necessary an increase in the peak power rating of the transmitter or else would unnecessarily restrict the power available for the picture and horizontal sync. portion of the signal.

A synchronizing system has therefore been chosen in which both vertical and horizontal pulses have the same amplitude, but different waveshapes. Frequency discrimination may then be used to separate them in the receiver. The shapes of these pulses and their relation to the blanking pulses are illustrated in detail in Fig. 5. Fig. 7 is a functional block diagram showing the steps necessary to utilize the sync. signals.

Diagrams 1 and 2 of Fig. 5 illustrate a typical complete composite picture signal in the neighborhood of the vertical blanking pulse in each of two successive fields. Interlacing of the scanning lines is shown by the time-displacement of the horizontal blanking pulses in one diagram with respect to those in the other diagram. This displacement is one half of the interval of a scanning line (H/2).

All sync. pulses appear below black level in an amplitude region which is sometimes called *blacker-than-black*; hence they can have no effect on the tonal gradation of the picture. Horizontal sync. pulses are (except during the first portion of the vertical blanking interval) simple rectangular pulses such as those appearing at the negative peaks or bases of the horizontal blanking pulses and during the last portion of the vertical blanking pulses. The duration of a horizontal sync. pulse is considerably less than that of the blanking pulse, and the leading edge of the sync. pulse is delayed with respect to the leading edge of blanking, forming a step in the composite pulse which is called the *front porch*. Correspondingly, the step formed by the difference between the trailing edges of sync. and blanking is called the *back porch*. The purpose in forming the front porch is to insure that the horizontal retrace in the receiver (initiated by the sync. pulse) does not start until after the blanking pulse has cut off the scanning beam. It also insures that any discrepancies which may exist in the leading edge of blanking do not affect either the timing or the amplitude of sync.

The choice of the nominal width of horizontal sync. (0.08 H, see diagram 5 in Fig. 5) was influenced by three factors. First, the width should be as great as possible so that the energy content of the pulses will be large compared to the worst type of noise pulses which may be encountered in the transmission process, thus providing maximum immunity to noise. Second, the width should not be greater than is necessary to meet the first condition because average power requirements of the transmitter may thereby be minimized. Modulation of the pcture transmitter is such that sync. pulses represent maximum carrier power; hence it is desirable to keep the duty cycle as small as possible. Third, the horizontal sync. pulses should be kept as narrow as possible so as to maintain a large difference between these pulses and the segments of the vertical sync. pulses described in the following paragraph. Such a large difference makes it easier to separate the vertical sync. from the composite sync. signal. It has also been recognized that the back porch is useful for a special type of clamping for d-c restoration. Hence it should be as wide as possible.

Vertical sync. pulses are also basically rectangular in shape, but are of much greater duration than the horizontal pulses thus providing the necessary means for frequency discrimination to distinguish between them. However, each vertical sync. pulse has six *slots* cut in it which make it appear to be a series of six wide pulses at twice horizontal frequency, i.e., wide compared to horiztontal sync. pulses. The slots contribute nothing to its value as a vertical sync. pulse but do provide means for uninterrupted information to the horizontal scanning circuit.

Before and after each vertical pulse interval are groups of six narrow pulses called *equalizing pulses*. These also are for the purpose of maintaining continuous horizontal sync. information throughout the vertical sync. and blanking interval. The repetition frequency of the equalizing pulses and the slots in the vertical pulses is twice the frequency of the horizontal sync. pulses. This doubling of the frequency does two things. First, it provides an arrangement in which the choice of the proper alternate pulses makes available some kind of a horizontal sync. pulse at the end of each scanning line in either even or odd fields. Second, it makes the vertical sync. interval and both equalizing pulse intervals exactly alike in both even and odd fields. The importance of this latter result will become evident in following paragraphs. It is important to point out that the leading edge (downward stroke) of each horizontal sync. pulse and of each equalizing pulse, and the trailing edge (again the downward stroke) of each slot in the vertical pulses are responsible for triggering the horizontal scanning circuit in the receiver; hence the intervals of H or H/2 apply to these edges.

Perhaps the most difficult problem in synchronizing, and the one in which there is the largest number of failures, is that of maintaining accurate interlacing. Discrepancies in either timing or amplitude of the vertical scanning of alternate fields will cause displacement, in space, of the interlaced field. The result is non-uniform spacing of the scanning lines which reduces the vertical resolution and makes the line structure of the picture visible at normal viewing distance. The effect is usually called *pairing*. The maximum allowable error in line spacing in the kinescope to avoid the appearance of pairing is probably 10% or less. This means that the allowable error in timing of the vertical scanning is less than one part in 5000. This small tolerance explains why so much emphasis is placed on the accuracy of vertical synchronizing.

The presence of a very minute 30-cycle component in the *vertical* scanning in-

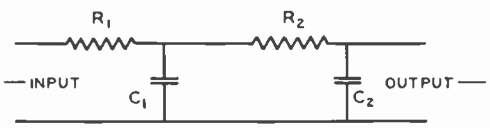


FIG. 8(a). Two-stage integrating network used to separate vertical sync. pulses from the composite picture. Circuit values are as follows:

R_1 = 10,000 ohms	R_2 = 200,000 ohms
C_1 = .012 mfd	C_2 = 150 mmf
T_1 = 120 ms	T_2 = 30 ms

FIG. 8(b)* (right). General action of the integrating circuits in the region of the equalizing pulses and beginning of the vertical sync. pulse. Curves are identified as follows:

Curve acde is Synch. Signal in region of even field pulse

Curve bcde is Synch. Signal in region of odd field pulse

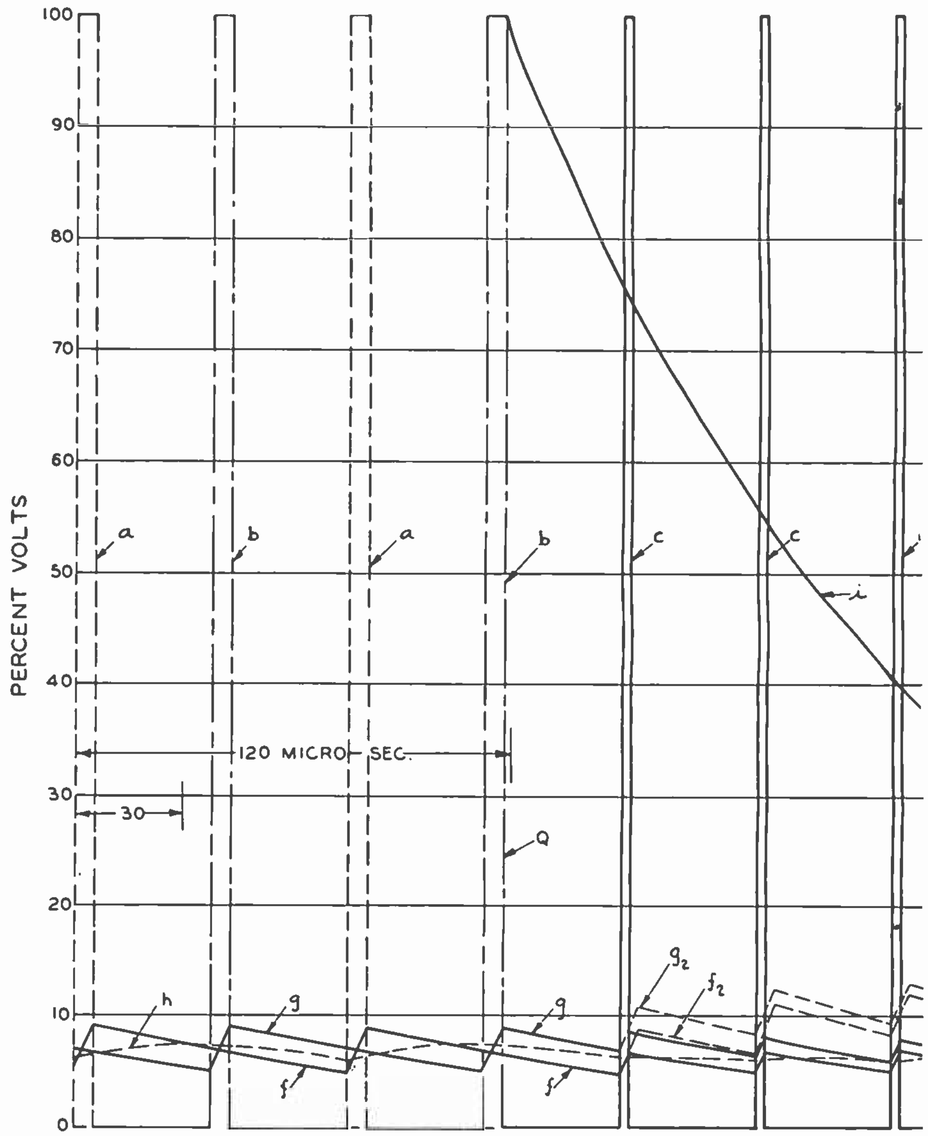
Curve f is curve acde "integrated" by circuit having T = 120 micro-sec.

Curve g is curve bcde "integrated" by circuit having T = 120

Curve h is curve acde "integrated" by two stages, having T_1 = 120 and T_2 = 30

Curve i shows rate at which equalization occurs for T = 120

NOTE: In this diagram the slots in the vertical pulse are shown the same width as the equalizing pulses, whereas they are actually the same width as the horizontal sync pulses (see Fig. 5).

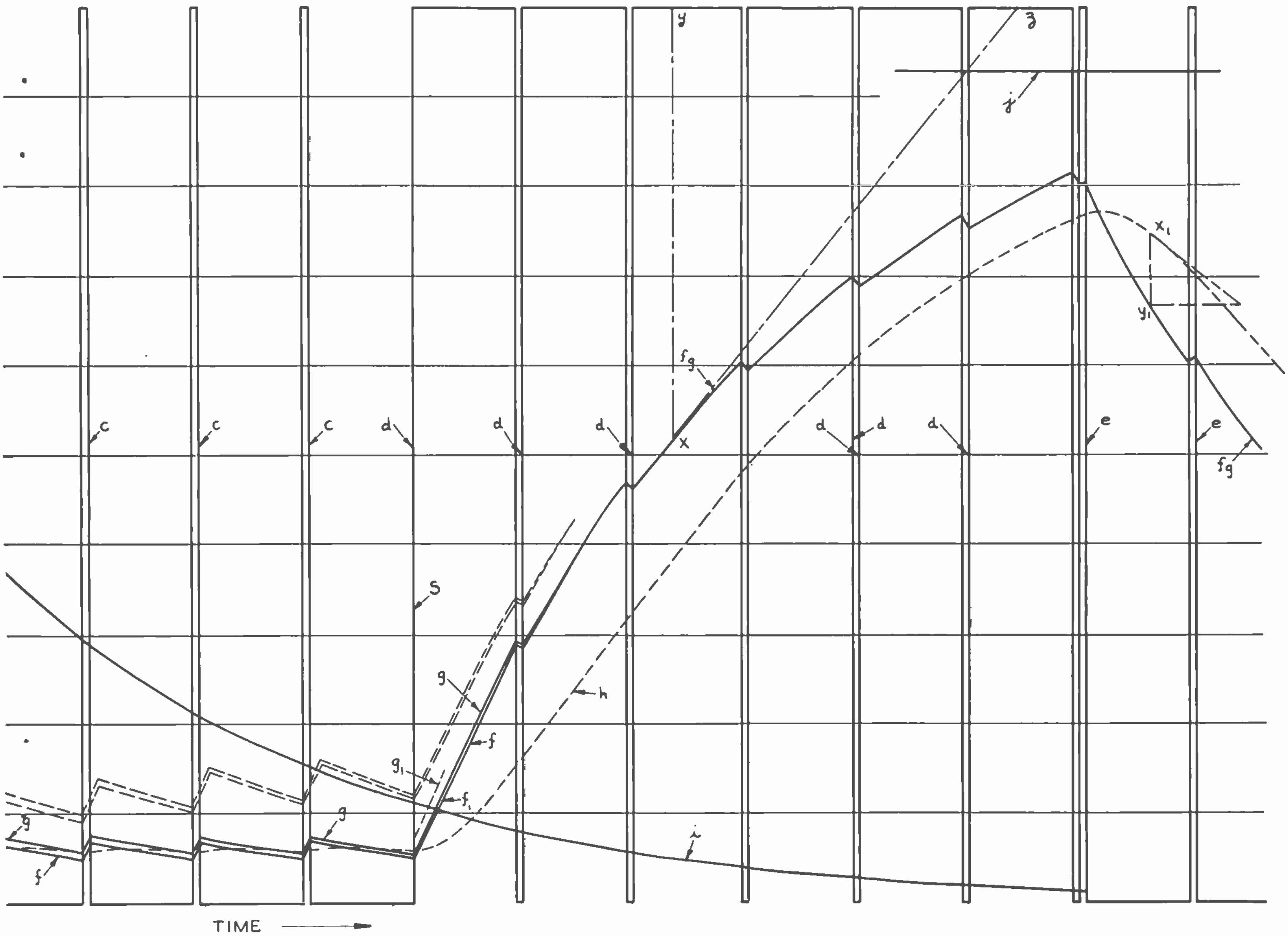


variably causes pairing. The fact that the rasters produced in alternate fields are displaced with respect to each other by half a line means that the *horizontal* sync. signal has an inherent 30 cycle component. It is this situation and the need to prevent any transfer of the 30-cycle component into the vertical deflection which account for the introduction of the double-frequency equalizing pulses before and after the vertical sync. pulses. The vertical sync. pulses are separated from the composite sync. signal, before being applied to the vertical scanning oscillator, by suppressing the horizontal sync. pulses in an integrating network similar to that illustrated in Fig. 8(a).

Most receivers employ integrating networks of three stages instead of the two illustrated. However, the general character of the circuit action is clearly shown by the wave form diagrams in Fig. 8(b). In simple terms, the equalizing pulses before the vertical sync. pulses cause the integrating network to "forget" the difference between alternate fields by the time the vertical sync. pulses begin. This is illustrated by the gradual convergence of curves *f* and *g* during the equalizing pulse interval, as the result of integration in the first stage alone. The effect of further integration in the second stage is shown by curve *h*, which is typical of the pulses applied to the vertical oscillator in a receiver. Thus, the 30-cycle component is effectively eliminated, from the standpoint of accurate timing of the start of vertical retrace, by the addition of the first set of equalizing pulses and the slots in the vertical pulse itself. The second set of equalizing pulses which follow the vertical pulse affect to some extent the impedance of the circuit to which the vertical scanning oscillator is coupled, and thus affect the amplitude of its output; hence these pulses help to provide more nearly constant output of the oscillator. Both sets of equalizing pulses contribute materially to the necessary accuracy of vertical synchronizing.

The width of an equalizing pulse is half the width of a horizontal sync. pulse (see diagram 4 of Fig. 5, and Fig. 8). This width is chosen so that the a-c axis of the sync. signal does not change at the transition from the line-frequency horizontal sync. pulses to the double-frequency equalizing pulses. The curves f_2 and g_2 in Fig. 8 illustrate the undesirable effect of making the equalizing pulses the same width as the horizontal sync. pulses. There is a slight rise in the integrated wave during the equalizing pulse interval which could cause premature triggering of the vertical oscillator in the receiver if the hold control were adjusted near one end of its range.

* Diagram prepared by A. V. Bedford. RCA Laboratories, for presentation to the N.T.S.C.



This rise in the integrated wave results from the change in the a-c axis.

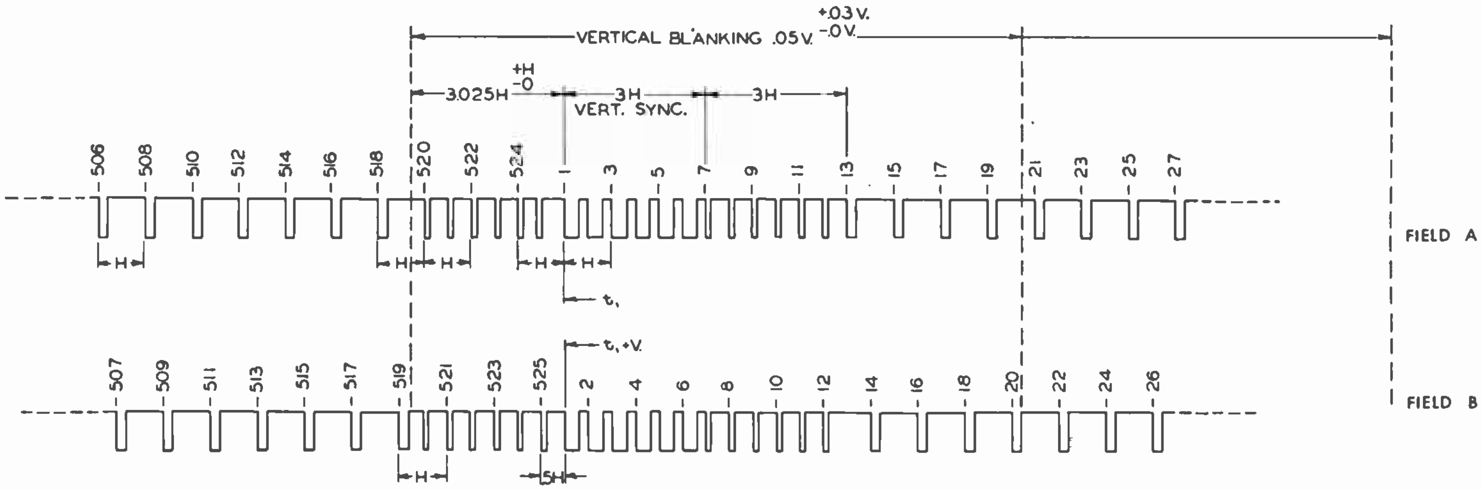
The width of the slots in the vertical sync. pulses is approximately equal to the width of the horizontal sync. pulses. The slots are made as wide as possible so that noise pulses or other discrepancies occurring just prior to the leading edge of a slot (i.e., near the end of the preceding segment of a vertical pulse) do not trigger the horizontal oscillator. Premature triggering can happen if the noise pulse is high enough and if it occurs very close in time to the normal triggering time. Increased time-separaton (a wider slot) reduces likelihood of such premature action. Here again, the requirements of special clamping also are met more easily if the slots are made as wide as possible.

A further important advantage of the RMA system of separating the vertical sync. by means of frequency discrimination is that the integrating network is a potent factor in reducing the effect of noise on vertical synchronizing. Noise signals contain mostly high-frequency components; hence they are almost completely suppressed by the integrating circuit.

Differentiation, or suppression of the low-frequency components, of the sync. signal before it is applied to the horizontal scanning oscillator is done sometimes, but is not necessary, and has not been indicated in Fig. 7.

The methods just described for synchronizing the scanning circuits in a television receiver are complicated by the need for transmitting the complete information over a single channel. In the case of the scanning circuits in the cameras, however, the situation is very different. The cameras and the synchronizing generators are so close to each other that there is no problem in providing as many wire circuits as may be desired. Therefore it is customary to use what are called ***driven*** scanning circuits in cameras and sometimes in picture monitors used with the cameras. Separate pulse signals, called ***driving signals***, are produced in the synchronizing generator for exclusive use in the terminal equipment. Horizontal and vertical driving signals are completely independent of each other in the RCA system and are carried on separate transmission lines to the points of application. The driving signal pulses trigger directly the sawtooth generators which produce the scanning waveforms. This method reduces interlacing errors in the terminal equipment to the errors inherent in the driving signals.

Fig. 9 illustrates a portion of the scanning lines appearing on a kinescope as a result of the application of a television signal composed of RMA sync. and blank-



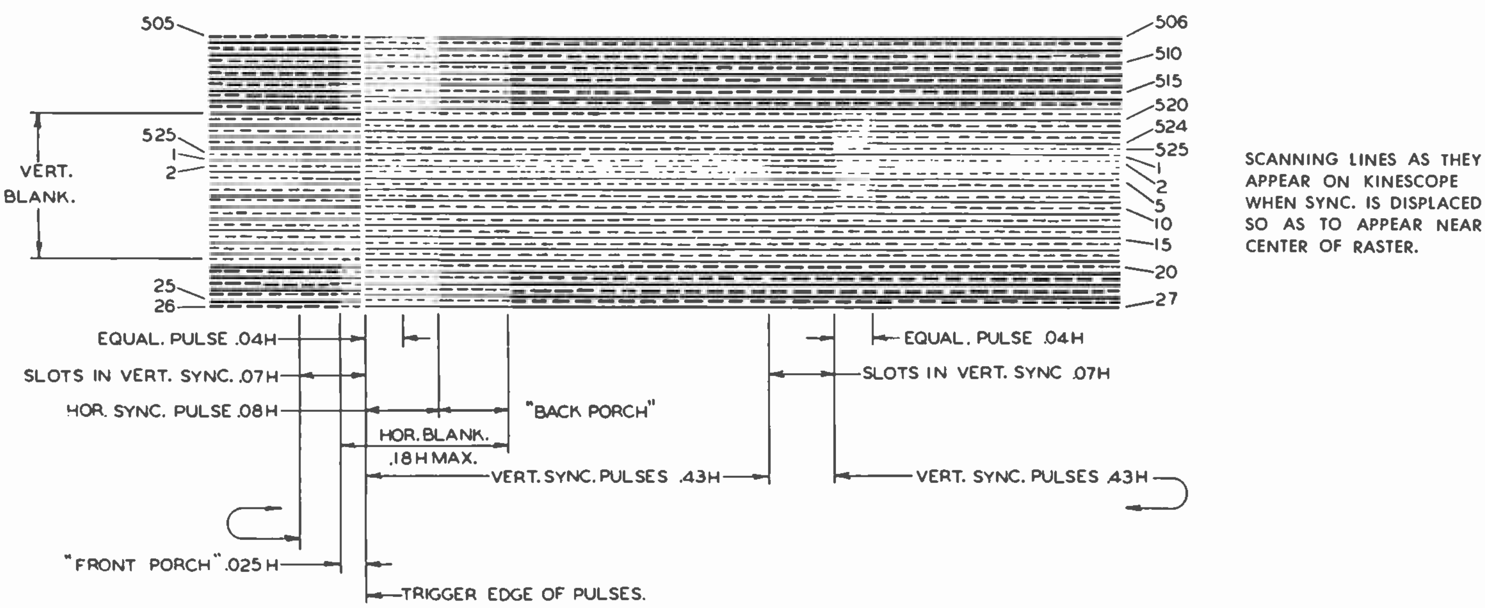


FIG. 9. A portion of the scanning lines appearing on a kinescope as a result of the application of a television signal composed of RMA sync. and blanking pulses. The group of lines shown are those occurring in the neighborhood of the vertical retrace period, including a few before and a few after the vertical blanking pulse.

ing pulses. The group of lines shown are those occurring in the neighborhood of the vertical retrace period including a few before and a few after the vertical blanking pulse. As noted on the diagram, the triggering of the lines has been displaced both vertically and horizontally so that the shadows produced by the sync. and blanking pulses appear near the center of the raster rather than in the normal positions at the edges of the raster. This displacement is brought about simply to clarify the illustration of the effect of the pulses on the raster.

The shadows produced thus are called a *pulse cross*. When expanded vertically so that individual scanning lines become easily apparent, the pulse cross becomes a ready means of checking the performance of the sync. generator. The shadows produced by each different kind of pulses are indicated clearly on the diagram. With linear scanning, the horizontal dimensions of the shadows are measures of time or pulse width, and, because of the expanded scale, they provide a relatively accurate means of measuring pulse width. Furthermore, by counting appropriate lines, the numbers of equalizing pulses, slots, vertical sync. pulses, etc., can be checked easily.

A useful piece of station test equipment can be made by modifying the deflection circuits in a picture monitor to provide the displacement of the lines and the extra large vertical expansion described.

(The third, and concluding, part of Mr. Roe's article will appear in the next issue of Broadcast News)

THE PHILOSOPHY OF OUR TV SYSTEM

A Brief Review of the Functions of the Most Important Parts of the TV System, With An Explanation of the Reasoning Behind the Choice of Standards, Type of Transmission, Shape of Synchronizing Pulse, Etc.

by JOHN H. ROE
Supervisor
TV Systems Engineering Group
Engineering Products Department

PART III

EDITOR'S NOTE: *Previous parts of this article were published in* BROADCAST NEWS, *Vol. 53 and Vol. 54. A reprint of all three parts is also available.*

●

Automatic Frequency Control of Scanning

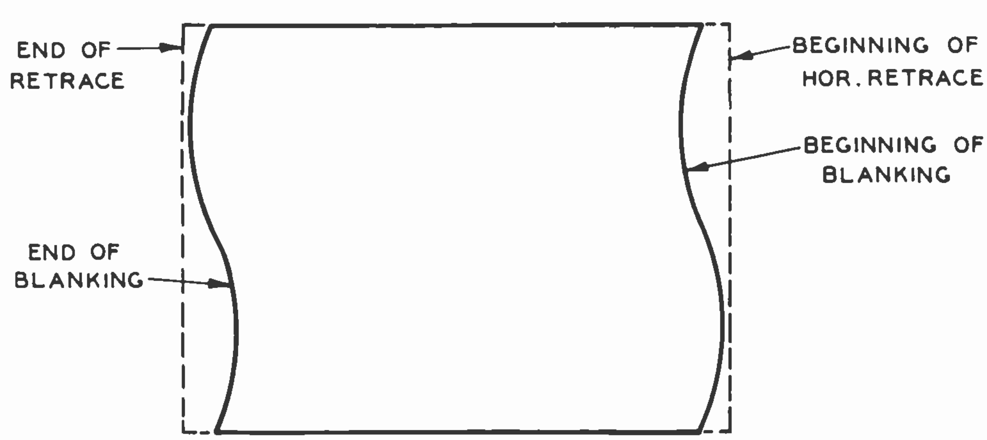
The constant search for means of immunization against the effects of noise has brought about the development of automatic frequency control (afc) of the scanning circuits in television receivers. In triggered circuits, each scanning line (and each field) is initiated individually by a pulse in the incoming signal. Contrastingly in an afc system, scanning generators are governed by stable oscillators which in turn are controlled by voltages obtained from phase comparison of the incoming sync. pulses with the scanning signals themselves. The time-constant of the comparison circuit is usually made long compared to the period of the scanning so that random noise pulses have very little effect on the resulting control voltage, and correspondingly little effect on the scanning frequency. The fact that such afc circuits are keyed circuits provides a further immunization factor by eliminating the possible effect of all noise pulses except those which coincide with the short keying intervals. The use of afc scanning circuits makes possible accurate synchronizing of a receiver under such bad conditions of noise that the masking of the picture by the noise renders it completely unusable. Thus failure to synchronize may be largely eliminated as a limiting factor in picture reception.

Afc may be used with both vertical and horiontal scanning circuits, but so far is being used commercially for horizontal circuits only. One reason for not using afc with the vertical circuits is that the time-constant must be very long to provide a stable control voltage. As a result, the circuit will not recover from an extended interruption of the incoming signal until an intolerably long time has elapsed. The frequency of the oscillator drifts during an interruption, and may not recover for a large number of seconds after the signal returns. During the period of recovery, the raster rolls over continuously at a decreasing rate until control is restored. The time-constant of the horizontal circuit, on the other hand, may be short enough so that recovery takes place in less than one field. Triggered scanning circuits, of course, recover from signal interruptions very rapidly, but they do not have the same high immunity to noise that the afc circuits have.

As a result of the use of afc circuits in receivers, a high degree of frequency stability is required in the horizontal sync. and blanking signals. Frequency modulation of the horizontal pulses is intolerable because it causes the right and left hand edges of the blanked raster in the receiver, as well as vertical lines in the scene, to assume the same shape as the modulating wave. As shown in Fig. 10 the border of the complete raster in the receiver is rectangular, but frequency modulation of the horizontal sync. and blanking will distort the shape of the border produced by blanking. Frequency modulation by a 60-cycle sine wave is illustrated.

Horizontal retrace begins along a straight vertical line regardless of timing and since this retrace is controlled by a stable oscillator in the receiver which is not responsive to short-time changes in sync. timing, the

FIG. 10 (right). Effect of frequency modulation of horizontal sync and blanking on shape of raster in receiver with AFC of horizontal scanning.



presence of variations in sync. timing and of corresponding changes in blanking pulse timing, will show as a displacement of the edges of the blanked raster. The frequency stability of the sync. generator must therefore be at least equal to the stability of the oscillators used in afc receivers. The maximum rate of change of frequency allowable in a sync. generator has been specified by RMA as 0.15% per second. This is a rather strict tolerance as indicated by the fact that it allows a total displacement of only 1/32 of an inch (approx.) in a period of one field in a picture 10 inches wide.

Film Projection

The use of standard sound motion picture film for television program material offers a special problem which arises from the difference in the picture repetition rates used. For reasons explained previously, the rate used for television is 30 frames and 60 fields per second. The standard speed for sound film, both 16mm and 35mm, is 24 frames per second, and since each frame is projected twice, the picture rate is 48 per second. The basic problem of reconciling the frequency difference has been met by using special projectors for television in which alternate frames of the film are projected twice and the remainder are projected three times. In this way, 60 pictures are obtained in place of the usual 48, but the average speed of the film through the projector is unchanged; hence the sound take-off is entirely normal.

Another problem also presents itself in the use of intermittent film projectors for television. The vertical scanning period occupies from 92% to 95% of the total period. If the projected image is to be thrown on the pickup tube during the scanning period at all, it must be for the entire time so that all parts of the area will be subject to the same lighting conditions. Such an arrangement would leave only the vertical retrace period (5% to 8% of the total, or approximately one thousandth of a second) in which to pull down the film to the next frame. 35mm film will not stand up under accelerations produced by sprocket hole pull-down in such a short period; hence some other scheme must be used. The method which has been adopted for use with intermittent projectors makes use of the storage property of certain kinds of pickup tubes, such as the iconoscope. The frame of film is projected with very intense illumination during the vertical blanking period only, while neither the pickup tube nor the receiver is being scanned. Then the light is cut off and the pickup tube is scanned in the absence of any optical image from the film. The signal generated during this scan results from charges stored on the sensitive surface during the preceding flash of light. While the light is cut off during the scan there is ample time to pull the film down before the next flash of light, without exerting destructive forces. The pulses of light may be obtained by chopping the output of a continuous source with a rotating disk, or (with a special type of arc lamp) by pulsing the source itself by electronic means. The storage properties of pickup tubes for this purpose must be sufficiently good so that dissipation of the stored charges is negligible between light pulses. Appreciable dissipation causes loss of contrast at the bottom of the picture.

Another solution to the problem of film projection in television is the use of a continuous projector, a type which produces a stationary image from continuously moving film by means of moving mirrors or lenses. This solution has not been accepted commercially so far because of practical difficulty in making the optical system sufficiently accurate to stop motion of the image completely.

The film problem in England, Europe, and other areas where 50 cycle power systems are standard, and where the television field frequency is also 50 cycles per second, is simpler in one respect, namely that it is not necessary to use the two-three ratio for projection of alternate frames of film. Instead, the film is projected as it is in theaters where each frame is projected twice. No attempt is made to compensate for the difference between the 24 frame taking speed and the 25 frame projection speed. The results are an approximate 4% increase in the apparent speed of motion of objects in the scene (which is probably negligible) and a slight rise in the pitch of all sounds. This latter effect is the more objectionable of the two, though generally it is not noticeable in speech and many other ordinary sounds. The change in pitch is undoubtedly noticeable to the trained musician in the case of musical sounds and must produce an unpleasant mental reaction to the music. However, no easy solution to the problem is known, and the situation is accepted without serious complaint. The other aspects of the film problem are not affected by the use of 50 fields instead of 60.

PROPAGATION METHODS

Modulation

The choice of amplitude modulation for television transmitters was made after comparison of results of a-m and f-m transmissions in field tests in the New York area. The results indicated clearly that f-m is not suitable for use in television broadcast transmitters or in any television radiating system where multipath transmission is encountered. The reason may be understood easily. Multipath transmission in any case means that signals arrive at the receiving antenna from two or more directions, one of which is usually the direct path from transmitter to receiver, and the others indirect paths along which the signal is reflected by objects which are off to the side of the direct path. In the a-m case, a reflected signal, which arrives after the direct signal, produces a single ghost or other repetition of the scene displaced to the right by a distance equivalent to the increase in delay over the longer reflected path. The intensity of the ghost depends on the relative strengths of the two signals. In the f-m case, the delay in the reflected signal can mean that two distinct carrier frequencies arrive at the receiver simultaneously. When this happens, the resulting beat between the two frequencies appears in the picture in the form of a moiré pattern, or multiple repeat after each object. The frequency of the repeats, or spacing of the moiré, is a function of the contrast between adjacent areas in the scene; hence it varies constantly with changes in the scene. The most objectionable moiré is produced by the blanking pulses because they usually represent the largest possible contrast. Where multipath transmission is not present, as in the case of point-to-point relaying systems using highly directive antennas, f-m may be used with excellent results.

American and British standards are at variance in the matter of polarity of transmission. In Great Britain, positive transmission is used. Positive transmission means simply that the carrier is modulated so that an increase in picture brightness brings about an increase in carrier amplitude. In negative transmission, adopted as standard in this country, an increase in picture brightness brings about a decrease in carrier amplitude. Thus sync. peaks represent maximum carrier. The principal points presented in favor of negative transmission are these:

1. An improvement in efficiency is realizable with negative transmission in the case of high level grid modulation. As stated previously, sync. pulses in the negative system represent maximum carrier. Because they are rectangular pulses, any saturation in an amplifier cannot affect their wave shape, but simply reduces their amplitude. Therefore it is possible to utilize the upper

non-linear end of the modulation characteristic for the sync. pulses provided they are pre-emphasized so that the ratio of sync. to picture is correct in the modulated carrier. By using this non-linear part of the modulation characteristic for sync., the entire linear portion of the characteristic is reserved for the picture signal. In the positive system, on the other hand, where the picture whites represent maximum carrier, the non-linear end of the characteristic cannot be used at all without compressing the whites in the picture signal. Furthermore, 25% of the linear characteristic is unavoidably absorbed by the sync. pulses.

2. Noise peaks which produce an increase in carrier will produce white spots, which may bloom (spread to abnormally large size) in the positive system, while they produce black spots in the negative system. Such black noise would normally be less objectionable than the white noise. In other words, the kinescope itself acts as a noise limiter in the negative system.

3. The average carrier power rating of the transmitter for given peak output is less in the negative system than it is in the positive system.

4. The signal produced in a negative transmission system lends itself to the use of simple a-v-c in receivers because sync. pulse peaks represent constant carrier level. Either peak-sensitive or keyed a-v-c circuits may be used which make use of this constant level as a reference. No such simple reference is available in the positive system.

5. Some receivers use an intercarrier sound system, i.e. a system in which the sound is obtained from the beat between the a-m picture carrier and the f-m sound carrier. This requires that the picture carrier never be driven to zero. In the positive transmission system, this requirement means that the black-reference carrier level must be raised at a further sacrifice of efficiency. In the negative system, only a slight reduction in video modulation amplitude is necessary.

Plate modulation, with its high efficiency and freedom from distortion, is not suitable for television because it is impractical to develop the necessary large amount of power in the modulator in the low impedance required by the broad band. In transmitters where high-level modulation is used the modulating signal is therefore applied to the grid circuit of the final r-f amplifier with consequent economy in the power requirements of the modulator.

Polarization

The question as to which polarization of the carrier waves is better, in the portion of the spectrum used for television, is probably impossible to answer conclusively from a theoretical study alone and was, therefore, investigated experimentally. A paper on this subject by Wickizer describes an investigation carried out at three frequencies, 49.5, 83.5 and 142 mc. around New York City. This investigation indicated preponderantly higher signal strength for horizontal polarization than for vertical. In some cases there was evidence that vertical polarization was preferable within a short radius of the transmitter, but the percentage of the total service area over which this was true was very small. The largest ratio of horizontal/vertical signal strength measured in this study was 9.8 db, the average being a little over 4 db. Thus, though the difference is substantial on the average, it is not great enough to make vertical polarization unusable.

There are other advantages to horizontal polarization among which are the following. Multipath reflections in general are produced by vertical surfaces such as the sides of buildings, cliffs, and groves of trees. Both theoretical and experimental evidence shows that horizontally polarized waves are reflected from such surfaces less than those that are vertically polarized.

Investigation of the character of man-made noise signals has shown that relatively few have appreciable horizontally polarized components. Consequently there is less tendency to pick up noise in horizontal receiving antennas.

The construction of horizontal antennas is somewhat easier, in both transmitting and receiving cases, than the construction of vertical antennas. Horizontal dipoles are simple in construction and are easily balanced with respect to the earth's surface, the roofs of buildings, and supporting structures. Proper balancing of vertical dipoles is more difficult and they are usually abandoned in favor of vertical quarter wave radiators with artificial ground planes which are bulky and often difficult to handle.

The horizontal directivity of horizontal dipoles is a substantial aid in reducing the pickup of interfering signals at a receiving location.

These are probably the most important considerations which led to the adoption of horizontal polarization in this country.

Single Side-Band Transmission

The development of what is usually called single side-band transmission is probably one of the most valuable contributions to the television art, for it has made possible much more efficient use of the available channels, or from another standpoint, it has made possible the use of much smaller channels than would be possible otherwise.

It is well known that amplitude modulation of a wave produces a band of frequencies about the carrier as a center, the boundaries of which are the sum and difference frequencies of the carrier and the maximum frequency of the modulating signal. In the broadcasting of sound by AM it is considered desirable to include both the carrier and the upper and lower side-bands. This requirement makes necessary a total bandwidth equal to twice the highest modulating frequency. For example, for transmission of 10 kc. sound, a bandwidth of 20 kc. would be required.

In television transmission, it has been shown that partial suppression of one side-band does not detract from the quality of the picture in any way, but actually improves the results by making more space available for the other side-band. Side-band suppression is equivalent to moving the carrier toward one side of the transmission channel. In the RMA standards, the carrier is located 1.25 mc. from the low end of a 6 mc. channel, and approximately 4.5 megacycles above the carrier are allowed for the upper side-bands. The remaining part of the channel is allocated to the transmission of the sound. If all of both side-bands were to be transmitted, the channel would have to be increased in width by at least 3 mc., thus making a total channel width of 9 mc. or more. Such an increase in the width of television channels would work a serious hardship by reducing the number of channels available in a field where there is already considerable evidence of scarcity.

Single sideband transmission also permits economy in receiver design by allowing the use of a narrower i-f band. The i-f cutoff may be less abrupt so that phase shift in the upper end of the video frequency band is less severe.

Suppression of the lower side-band is accomplished in the transmitter by either of two means. In the case of high-level modulation, it is done in a filter having the required characteristics located in the antenna transmission line. In transmitters using low-level modulation, it may be done by proper tuning of the linear amplifiers following the modulated amplifier.

References

The preceding discussion is necessarily brief and cannot serve as much more than an outline for further reading. There are many papers dealing more comprehensively with the details and problems associated with the various parts of the television system. References to some of these are included in the following bibliography. Most of the papers referred to also include references to others which, *in toto*, comprise a comprehensive list.

One book deserves special mention as a reference covering much of the engineering background of our television system. It is entitled, "Television Standards and Practice" (McGraw-Hill Publishing Co., 1943), and is essentially an abridged version of the proceedings of the National Television System Committee as edited by Donald G. Fink. It includes a statement of the standards recommended by the Committee to the Federal Communications Commission, discussion of the investigations on which the recommendations were based, and references to pertinent papers.

Acknowledgment

The author wishes to acknowledge the helpful criticisms and suggestions made by G. L. Beers, P. J. Herbst, H. N. Kozanowski, and W. J. Poch.

Bibliography

SYNCHRONIZING AND SCANNING

1. "A Study of Television Image Characteristics," E. W. Engstrom, Proc. IRE, Dec. 1933; Proc. IRE, Apr. 1935.
2. "Scanning Sequence and Repetition Rate of Television Images," R. D. Kell, A. V. Bedford, M. A. Trainer, Proc. IRE, Apr. 1936.
3. "Television Synchronization," E. W. Engstrom and R. S. Holmes, Electronics, Nov. 1938.
4. "Determination of Optimum Number of Lines in a Television System," R. D. Kell, A. V. Bedford, G. L. Fredendall, RCA Review, July 1940.
5. "Postwar Television Standards," A. N. Goldsmith, Televiser (Fall) 1944.
6. A Synchronizing Generator for the RMA Synchronizing Signal, U. S. Patent 2,258,943—A. V. Bedford.
7. "A Precision Television Synchronizing Signal Generator," A. V. Bedford and J. P. Smith, RCA Review, July 1940.
8. "A New Synchronizing and Blanking Signal Generator," E. Schoenfeld, W. Milwitt, W. Brown, RCA Licensee Bulletin LB-678, Aug. 1, 1946.

PICKUP TUBES

9. "Television Pickup Tubes with Cathode Ray Beam Scanning," H. Iams and A. Rose, Proc. IRE, Aug. 1937.
10. "The Image Iconoscope," H. Iams, G. A. Morton, V. K. Zworykin, Proc. IRE, Sept. 1939.
11. "Television Pickup Tubes Using Low Velocity Beam Scanning," A. Rose and H. Iams, Proc. IRE, Sept. 1939.
12. "The Orthicon, A Television Pickup Tube," A. Rose and H. Iams, RCA Review, Oct. 1939.
13. "The Image Orthicon, A Sensitive Television Pickup Tube," A. Rose, P. K. Weimer, H. B. Law, Proc. IRE, July 1946.

THE D-C COMPONENT

14. "DC Picture Transmission, H. N. Kozanowski, BROADCAST NEWS, Aug. 1944.
15. "The Clamp Circuit," C. L. Townsend, Broadcast Engineering Journal, Feb. and March 1945.
16. "New Television Field Pickup Equipment Employing the Image Orthicon," J. H. Roe, Proc. IRE, Dec. 1947.
17. "Television DC Component," K. R. Wendt, RCA Review, March 1948.
18. "How to Use the Television Stabilizing Amplifier," J. H. Roe, BROADCAST NEWS, May 1948.

MOTION PICTURE PROJECTORS FOR TELEVISION

19. "Some Television Problems from the Motion Picture Standpoint," G. L. Beers, E. W. Engstrom, I. G. Maloff, Jour. SMPE, Feb. 1939.
20. "Application of Motion Picture Film to Television," E. W. Engstrom, G. L. Beers, A. V. Bedford, Jour. SMPE, July 1939.
21. "Film Projectors for Television," R. V. Little, Jr., Jour. SMPE, Feb. 1947.

PROPAGATION

22. "Notes on Propagation of Waves Below Ten Meters in Length," B. Trevor and P. S. Carter, Proc. IRE, March 1933.
23. "Television Transmitters Operating at High Power and Ultra-High Frequencies," J. W. Conklin and H. E. Gihring, RCA Review, July 1937.
24. "Mobile Field Strength Recordings of 49.5, 83.5 and 142 Mc. from Empire State Building, New York—Horizontal and Vertical Polarization," G. S. Wickizer, RCA Review, Apr. 1940.
25. "Vertical vs. Horizontal Polarization," G. H. Brown, Electronics, Oct. 1940.
26. "Partial Suppression of One Side-Band in Television Reception," W. J. Poch and D. W. Epstein, RCA Review, Jan. 1937.
27. "Singe Side-Band Filter Theory with Television Applications," J. M. Hollywood, Proc. IRE, July 1939.
28. "A Theoretical Analysis of Single Side-Band Operation of Television Transmitters," L. S. Nergaard, Proc. IRE, Oct. 1939.
29. "Television Detail and Selective Side-Band Transmission," Stanford Goldman, Proc. IRE, Nov. 1939.
30. "Selective Side-Band Transmission in Television," R. D. Kell and G. L. Fredendall, RCA Review, April 1940.
31. "A Vestigial Side-Band Filter For Use With A Television Transmitter," G. H. Brown, RCA Review, Jan. 1941.

RECEIVERS

32. "Television Receivers," E. W. Engstrom and R. S. Holmes, Electronics, April 1938.
33. "Television Receiving and Reproducing Systems," E. W. Engstrom, Jour. App. Phys., July 1939.
34. "Automatic Frequency and Phase Control of Synchronization in Television Receivers," K. R. Wendt and G. L. Fredendall, Proc. IRE, Jan. 1943.
35. "Carrier-difference Reception of Television Sound," R. B. Dome, Electronics, Jan. 1947.
36. "Television Receivers," A. Wright, RCA Review, March 1947.

GENERAL

37. "Television Standards and Practice—N. T. S. C." edited by D. G. Fink, McGraw-Hill Publishing Co., Inc., New York, 1943.
38. "Principles of Television Engineering," D. G. Fink, McGraw-Hill Publishing Co., Inc., New York, 1940.
39. "Television," V. K. Zworykin and G. A. Morton, John Wiley and Sons, New York, 1940.
40. "Cathode-Ray Tube in Television," I. G. Maloff and D. W. Epstein, McGraw-Hill Publishing Co., Inc., New York, 1938.
41. "Television," Vol. I—RCA Institutes Technical Press, N. Y., July 1936.
    Vol. II—RCA Institutes Technical Press, N. Y., Oct. 1937.
    Vol. III—(1938-1941) RCA Review, RCA Laboratories Div., Jan. 1947.
    Vol. IV—(1942-1946) RCA Review, RCA Laboratories Div., Jan. 1947.
42. "Television—A Bibliography of Technical Papers by RCA Authors (1929-1946)", Pamphlet published by RCA Review, Nov. 1946.
43. "Noise in Resistances and Electron Streams," J. R. Pierce, Bell System Tech. Jour., Jan. 1948.

Reprinted from

BROADCAST NEWS, NOS. 53, 54 and 55

RADIO CORPORATION OF AMERICA

Engineering Products Department Camden, N. J.

2J4970

PRINTED IN U.S.A.