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Cathode Ray Television

A Primer of Some of the Considerations in Tube Use

By M. K. Kunins

THE facility of the use of the cathode ray tube for television purposes compared to mechanical television systems using discs or drums is obvious to those experimenters that have considered the tube for the purpose of television. To newcomers in this field it seems strange that the tube has not been more generally adopted for this purpose since it is free from inertial effects, is readily controlled, and is not cumbersome. Were these the sole considerations, the mechanical systems would indeed have been discarded. However, the cathode ray tube that is available on the market at this date has some very bad shortcomings. Nevertheless these may not be quite as bad as they seem, since the tubes are not especially designed for television purposes. By that is meant that these tubes have been marketed for the oscillograph trade where brilliancy of the image, coupled with large image size, is not as important as in television.

Here we have indicated a bad feature of the contemporary cathode ray tube. The image on the screen is not bright enough for television purposes. This statement should not be misunderstood, since the image is bright enough if a small picture, limited by the size of the tube's screen, is satisfactory. However, practically everybody desires a picture that can be projected on a movie type screen. And when this is done with the cathode ray tube image, it is found that the projected picture is very weak.

Man-Sized Tube

Of course we might construct a cathode ray tube with a screen that is large enough for our desire but that tube would certainly be unwieldy, higher than the normal height of a man, not to mention its exorbitant cost and thousands of volts. We are therefore forced to produce a brighter image upon a small tube to establish the practicability of the cathode ray tube.

Another shortcoming of the modern cathode ray tube is the green fluorescence of the screen material. Quite a few persons remark that everybody is accustomed to see pictures in black and white and so television pictures should also meet this requirement. That there is or is not merit to this argument will not be debated here. At any rate, the best plan is to attempt to satisfy these objectors. And so, these two points need consideration.

It will be noted that rectification of these shortcomings can be attained by the discovery of some substance or combination of substances that when bound together to form the cathode ray tube screen will produce a very brilliant black and white image that is capable of enlargement to a reasonable degree despite reduced illumination. This, of course, is a chemist's problem although some layman may be lucky enough to discover the formula and so found his fortune. Here is indeed a needed discovery that is worth much to the public. And so we await the suitable screen to convert the contemporary cathode ray oscillograph tube to the cathode ray television tube. But that inability of the modern tube need not prevent us from understanding the fundamental considerations involved in the use of such a tube for television purposes.

The Screen Material

Fundamentally, the cathode ray tube is applicable in television because of the electron gun (Fig. 6), which shoots a beam of electrons upon a screen that is composed of some chemical or combination of chemicals that fluoresce under an electronic bombardment and which lose this brilliance about as soon as the electronic influence is removed. The cathode ray tube screens that have been applied to oscillographs are composed of a mixture of calcium tungstate and zinc silicate, bound together by transparent water glass. This combination of electron gun and screen is productive of a good fluorescent spot upon the screen. To afford control of this spot over the expanse of the screen and thus build up a television picture, two sets of coils or plates are also included in the tube whereby either electrostatic or electromagnetic deflection of the beam in both horizontal and vertical directions on the screen is obtained. The fluorescent spot may be caused to move to any point on the screen by applying suitable voltages to the deflecting electrodes. For the sake of uniformity and simplicity, it shall be understood that electrostatic means (two sets of plates at right angles to each other) are used for deflection purposes and the diagrams are shown on that basis although the analysis is the same when electromagnetic deflection means is utilized.

Fig. 1 (next page) indicates, on the top, the screen of a cathode ray tube with the two sets of deflection plates indicated, one set for the "X" axis and one set for the "Y" axis. With no voltages on these plates the fluorescent spot on the screen will assume a position in the center as indicated in that sketch, provided there are no other stray potentials upon the bulb, etc., of the tube.

Moving the Beam

Now, suppose we apply an alternating sinusoidal voltage upon the X plates of the wave form shown in the second sketch of Fig. 1. Then at the different instances, labelled by the numerals, the spot will be deflected one way or the other from the rest position on a horizontal line depending upon the voltage and the polarity of the potential. Thus, the third sketch should be coupled with the second and it is found that at position 1 on the wave shape of the voltage, the potential is zero which is ineffectual in deflecting the spot so that the spot remains in the unenergized position. However at point 2, the right hand plate of the X plates becomes more positive than the left hand side so that the right-hand one attracts the negatively charged electron beam by an amount that is proportional to its potential difference. We have assumed that in this case this point is half the maximum voltage that will deflect the beam to either end of the screen so that the spot falls at a point that is half way between this maximum position and neutral position. Likewise in position 3, the spot will be deflected all the way to the right. In a similar manner, deflection of the spot to the left of the neutral position occurs during the negative portion of the cycle.

If the frequency of this alternating voltage is on the order of about 10 cycles per second or less, this spot will be clearly seen to move in the fashion indicated by these spots in a straight horizontal line at a speed proportionate to the frequency. Due to the slow speed with which this motion occurs, the individual spot will be readily visible. However, should the frequency of the alternating voltage be increased to 24 cycles per second or more, a defect in the eye known as "persistence of vision" will cause these individual spots to blend into one continuous line indicated in the fourth sketch of Fig. 1. Upon this defect in the eye is the gigantic industry of the motion pictures dependant as well as the new industry of television.

Two Directions

If the sinusoidal voltage shown in the sketch were applied to the Y plates alone, leaving the X plates unenergized in this instance, then a similar action will cause the spot to move in a vertical line as shown in the last two sketches of Fig. 1. The frequency considerations mentioned in connection with the X plates also hold for the Y plates so that it is desirable to have the frequency of the impressed voltage higher than 24 cycles per second if a line is desired rather than a clearly defined moving spot.

However, a moving spot in one straight line is not sufficient to reproduce a television image no matter what its frequency since a line is a one dimensional figure whereas a picture requires motion in two dimensions. Accordingly, we have to impress voltage on both sets of plates simultaneously, in order that a two dimensional picture may be produced. The kind of voltages that we impress on these plates are of extreme importance in order that the picture be most effectively produced so that we shall have to study the effect on the screen of the different types of voltages that might be used.

Suppose this sinusoidal voltage shown in Fig. 1 was applied to both sets of plates of the oscillograph tube. What would the image on the screen look like? If we refer to Fig. 2, it will be noted that the top sketch concerns such a set of conditions. These drawings show the cathode ray tube screen as a heavy circle with four heavy lines that are mutually perpendicular representing the deflector plates.

Within these lines, there is represented the image on the screen that results from the application of the voltage wave shapes depicted on the respective X and Y deflectors.

Frequency Doubled

The first sketch of Fig. 2 concerns the case just mentioned. It will be noted that the image is an inclined straight line. The angle that this line makes with the horizontal will depend upon the ratio between the voltages on the plates. When the voltages are equal, as is the case here, the line is inclined at a 45° angle. Of course, an inclined straight line is just as useless as a vertical or horizontal line obtained from one voltage for television purposes. So this combination of voltages is not to be considered.

Suppose we double the frequency of the voltage on the Y plates, then the image becomes a figure 8 if the X plates are supplied with the original voltage as before. Following this procedure through, of doubling the frequency of the Y voltage, it is seen that it is possible to cover the screen fairly well with the lines. However, it might be preferable to obtain an image that does not zig-zag back and forth in this manner. Also, with the

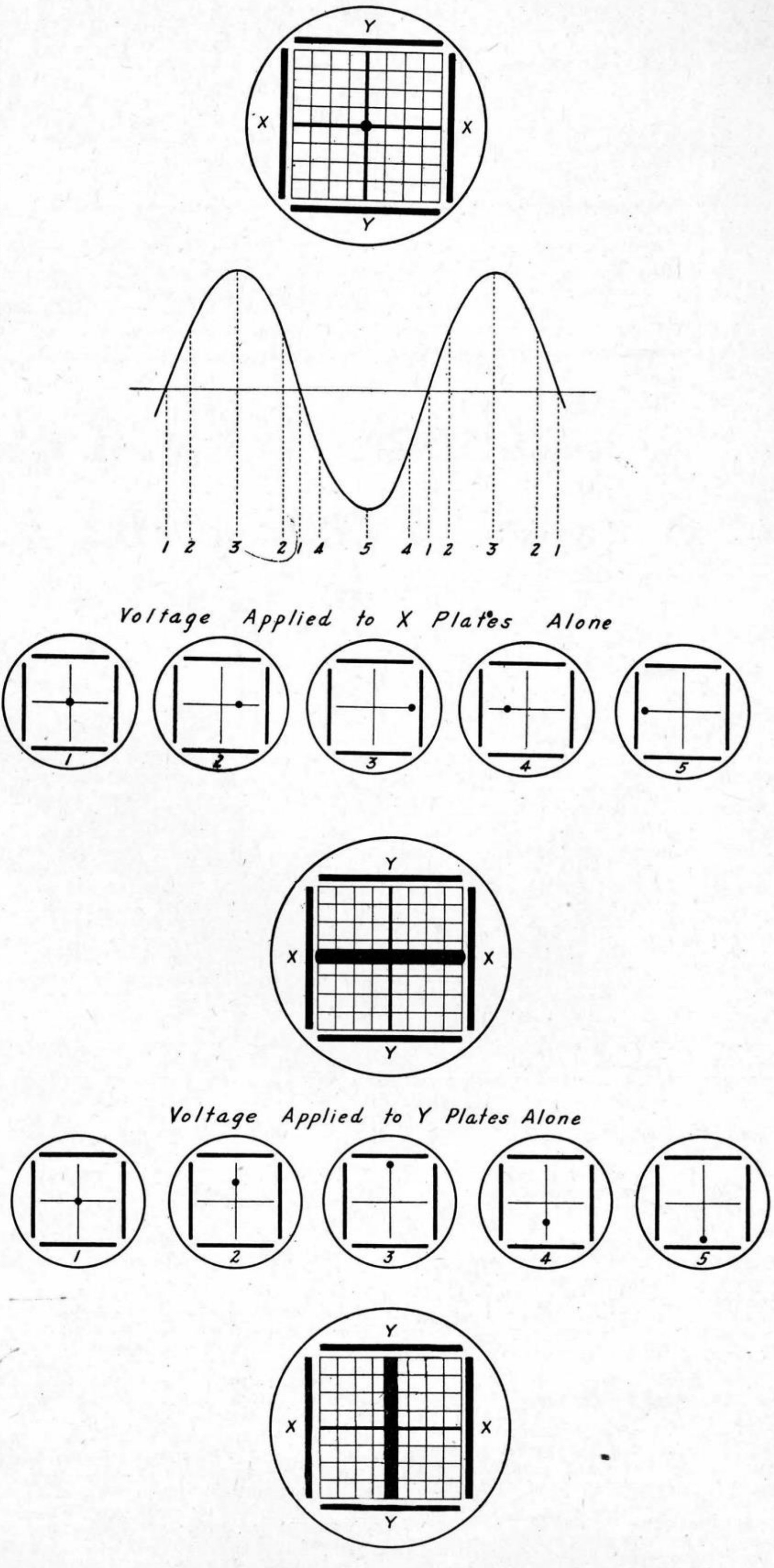

FIG. 1

The application of suitable voltages upon the deflector plates of a cathode ray tube causes the fluorescent spot upon the tube's screen to move in

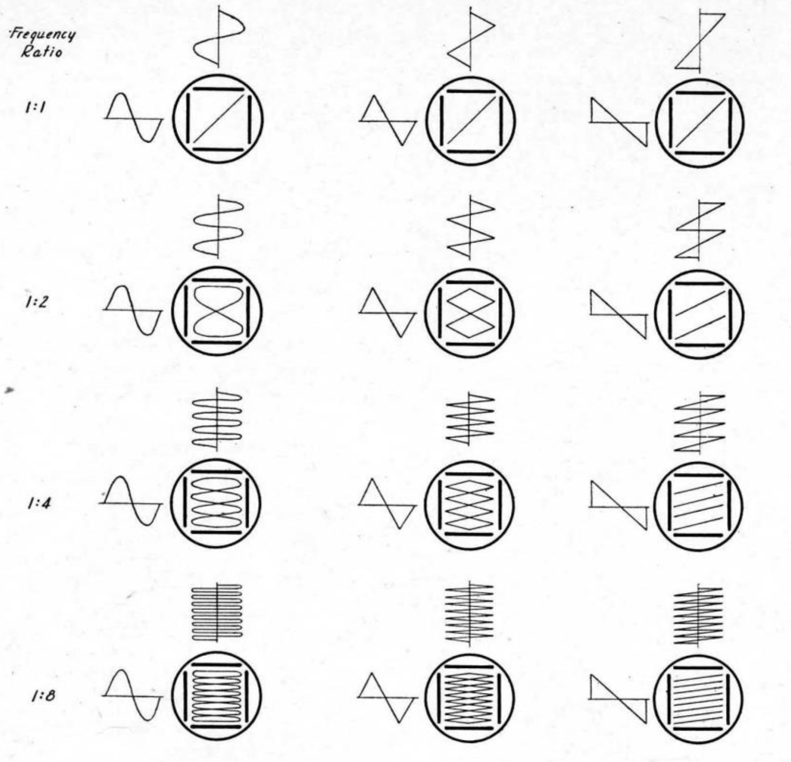

FIG. 2 FIG. 3 FIG. 4

The screen of a cathode ray tube is best scanned by using a saw tooth voltage upon the X deflector plates and a multiple of that voltage's frequency upon the Y deflector plates.

(*Continued from preceding page*)
sinusoidal voltages on the plates, the image brilliance is not uniform since the beam moves slower at the ends and thus affects the screen a longer length of time. This results in an image that is brighter at the ends. So it would be wise to consider a voltage that varies linearly in order to secure an image of uniform brilliance when unmodulated. In this connection we shall consider a "V" shaped saw tooth voltage in Fig. 3.

It will be seen that if the frequency ratio between the two voltages is 1:1, we again get a diagonal line for the image. Obviously, we shall have to consider higher multiple frequencies. Following this procedure through as was done with the sinusoidal voltages it is found that though the brilliancy of the image is uniform as contrasted with the images of Fig. 2, the image is still formed by a zig-zag motion back and forth. This motion is quite complicated and for the purpose of explanation to the beginner is not the best means for producing an understanding of the television process. Fig. 4 concerns itself with a wave that is more easily understood.

Producing an Image

When the frequency ratio with these waves is 1:1, it is seen that we still get an inclined straight line. Obviously, regardless of the characteristics of the wave shape, so long as the frequency ratio is 1:1, the image that appears upon the screen will be an inclined straight line. We therefore have to take recourse to the lowest persistance of vision frequency on the horizontal plates and a multiple thereof on the vertical plates. Studying through Fig. 4, it is seen that the beam is deflected across the screen at a uniform rate which is conducive of an image of uniform brightness. And, the entire area of the screen is swept by the beam progressively. The number of sweeps across the screen is obviously dependant upon the number of times that the frequency of the vertical plate voltage is greater than the frequency of the voltage upon the horizontal plates. Thus, in the last sketch of Fig. 4, where the frequency ratio is 1:8, there appears upon the screen eight lines that are equally spaced and cover the screen completely.

Following this procedure through to higher frequency ratios, say 1:100, it is clear that a greater number of lines that are equally spaced will appear upon the screen. In the instance mentioned, there will be 100 lines that are almost horizontal. It can therefore be readily postulated that the number of lines that appears upon the screen is exactly the same as the frequency of the voltage applied to the vertical plates when the frequency of the horizontal plates voltage has been reduced to one (mathematically speaking).

A little consideration will reveal that the actual frequency of the voltage impressed across the horizontal plates will determine the rapidity with which the beam will traverse the entire screen. In other words, if the frequency of the horizontal voltage is one cycle per second, the beam will take one second to traverse the entire screen. For practical television purposes this frequency is of course useless, since the frequency should at least be the minimum at which the persistence of vision effect in the eye occurs.

Number of Pictures per Second

It has been said that this frequency was about 24 cycles per second, therefore the horizontal timing frequency should be at least 24 cycles per second. This means that the beam will traverse the entire screen 24 times per second. Thus, in order that there be 100 lines on the screen with this 24 cycle frequency on the horizontal plates, the vertical plates require a frequency of 100 times that amount or 2400 cycles per second.

The importance of the number of lines that appears upon the screen is apparent from Fig. 5. Here we have represented an original picture of the first three letters of the alphabet to be televised by three different scanning frequencies. In the first case, the vertical plate frequency is 240 cycles per second to give ten lines on the screen. The second case gives twenty lines upon the screen due to the vertical plate frequency of 480 cycles per second, while the last case gives 40 scanning lines because of the vertical timing frequency of 960 cycles per second. The difference in clarity of the picture reproduction is obvious. It can be seen that the closer these scanning lines are, the more detail that can be obtained in the picture. It is apparent that 10 lines produce an image that is just barely representative of the original whereas the 20 line image is better and the 40 line image still further an improvement.

Another thought that is a corollary of

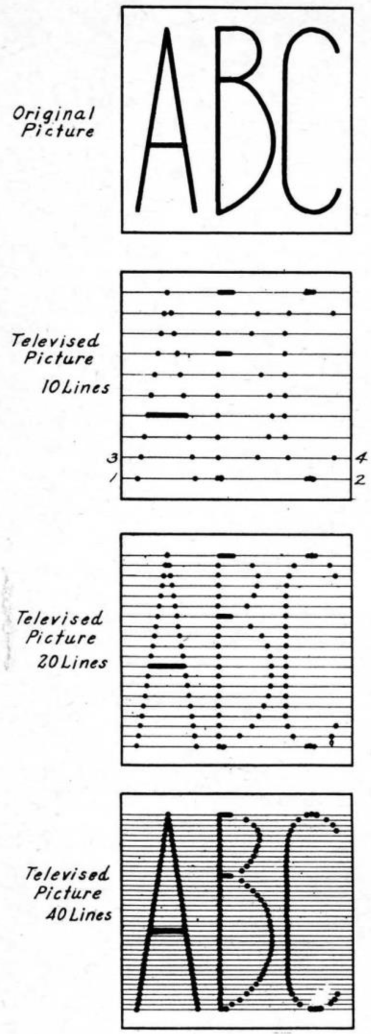

FIG. 5

The original picture in the top sketch is televised by three vertical scanning frequencies so that one gives a picture of ten lines, another gives a picture of twenty lines, a third gives a picture of forty lines. The clarity of each picture is readily contrasted.

this consideration is that the image becomes more concrete the farther the observer is from the image. This consideration of eye resolutions was treated by William Hoyt Peck in the February 16th, 1935, issue of RADIO WORLD. It is the angle that two adjacent television scanning lines form at the eye that will determine the illusion of continuity, or wiping out of the lines. Mr. Peck states that this resolution point occurs when the angle at the eye is 3 minutes.

It is thus seen that the number of lines that will afford picture concreteness is governed by the distance of the observer from the screen and the size of the picture on the screen. Assume that ten lines per inch of vertical screen height gives a satisfactory picture based upon the fact that the observer shall not be closer to the screen than 9 feet, 2 inches.

Introducing Modulation

But, we have jumped ahead of our story. We have not considered how we are to produce these necessary changes in light intensity of the spot on the screen. This is essential if we are to produce a picture rather than a solid area of light that is unintelligible. In other words, we have to modulate the electron beam so that the screen image will contain the modulation of light intensity as existent in the original picture. This is done by impressing the modulated television signal upon one of the elements of the electron gun. This will cause the beam of electrons to vary in intensity in direct proportion with the modulations of the signal.

Thus referring to Fig. 5 again for the case of the 10 line television, we can see that if the spot moves from left to right and progressively upwards in ten equally spaced parallel lines, it will move along line 1 to 2, then practically instantaneously move to 3 so that a return line is not visible upon the screen. When the television transmitter scanned the original picture the intensity of current was a minimum (or maximum according to the system used) until modulated. The lowest scanning line 1-2 will contain dark spots for the points that correspond to the original picture. These dark spots on the receiving system's screen are achieved by impressing the incoming television signal upon any of the grids of the electron gun which will control the beam's intensity at the proper moment with respect to the scanning frequencies, so that a reproduction of the original picture is achieved with the detail determined by the scanning frequencies.