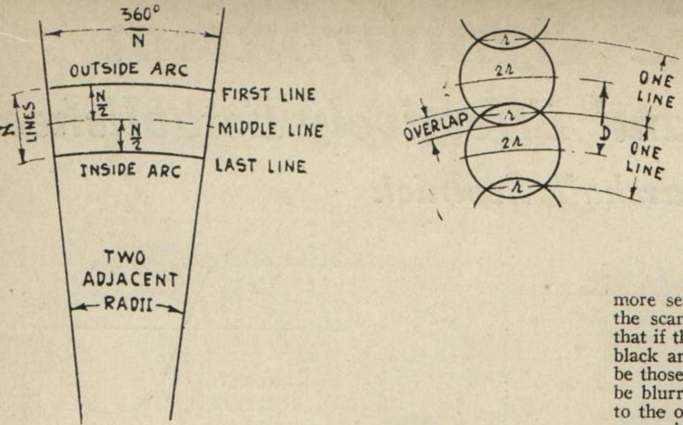

SCAN

By J. E

FIG. 1

This illustrates the method of obtaining the optimum ratio of the hole diameter to the radius of the disc for a 72:60 picture.

THERE is no means at this time of sending all the parts of a picture simultaneously by electrical means. The scene or picture must be broken up into tiny bits and then each bit sent separately. The sending of the various bits must be consecutive and in a definite order. At the receiving end these bits must be assembled in exactly the same order as they were sent, and this must be done synchronously with the sending.

To get a fair idea of the method of breaking up the picture, or of scanning it, as it is called, take a picture and rule equi-spaced lines across it. Then observe each line from left to right through a square aperture the side of which is equal to the width of one band or line. When one line has been scanned in this manner go to the next below and repeat, and so on until all the lines into which the picture was divided have been scanned. Then start at the upper left corner and go through it again. The picture is scanned just as a page in a book is read. If the picture is still, it is the same as if the same page were read over and over again, but if it is moving it is the same as starting a new page as soon as one is finished.

Speed of Scanning

The speed of scanning differs in the various systems. Sometimes a picture is scanned completely once every 1/16th of a second; sometimes faster.

The number of lines into which the picture is divided also differs in different systems. There have been 20, 24, 48, 50, 60, 100, and more lines to a picture. As the art advances the number of lines always increases. At this time 60 lines is "standard" but that only means that most experimenters are now using 60 lines. Soon they will be using twice that number.

In systems using 60 lines, with a speed of one frame, or picture, per 1/16th second, each line is scanned in 1/960 part of a second. Thus the "reading" of the picture is extremely fast.

Definition of Pictures

A large number of lines is necessary in order to get much detail in a picture. The definition of a picture scanned with 120 lines is twice as good as that of a picture scanned with 60 lines, and effectively it is even better than that.

It is customary to draw on the half tone process to estimate the effect of increasing the number of lines. A half tone is made up of a very large number of dots of various sizes. The larger the number of dots per square inch the clearer is the picture, provided the paper is fine enough to take the fine dots. A newspaper picture has 65 to the inch or 4,225 dots to the square inch. Finer half tones, as used in RADIO WORLD, may have 135 dots to the inch, and therefore 18,225 per square inch. The second is greatly superior in detail. Even finer "screens" are used, giving still finer detail, provided coated paper is used.

It is said that a television picture with sixty lines on a one inch square picture is equivalent to a half tone picture having sixty dots per inch, or 3,600 per square inch. This is only approximately true because a television picture is not sent in dots but rather in lines, or bands. The light beam tracing a line does not move jerkily, stopping sixty times in every line for a short interval, as it would have to do if the half tone analogy were to hold, but it moves continuously from one end of the line to the other, and then jumps suddenly to be beginning of the next line.

Advantage of Continuous Motion

On the supposition that the picture is broken up into picture elements in the manner of the half tone, certain requirements of the electrical portion of the television system are imposed if the picture really is to be as good as the half tone. These requirements are much more severe than those actually necessary because of the fact that the scanning in each line is continuous and not jerky. It is true that if the picture consisted of vertical black and white lines, with the black and white space equal, then the electrical requirements would be those demanded on the half tone principle. Such a picture would be blurred, the whites and the blacks changing gradually from one to the other, if the electrical system were not capable of carrying a very wide band of frequencies.

A picture line rarely consists of vertical strips of alternate black and white, but of gentle gradations. It does not require a very high grade electrical circuit to follow such gradations and even with a modest circuit is is possible to reproduce the lines, except in those rare instances where there are sharp contrasts, that is, where black changes into white, or white into black suddenly.

Low Frequencies Required

Very often the low frequencies in the electrical equivalent of the picture are disregarded. They should not be. Indeed, it is just as important to reproduce frequencies below the audible limit as to reproduce those above the audible band. In one of the most elaborately worked out television circuits, the audio amplifier was designed to amplify effectively down to 10 cycles per second, because there was a strong frequency component of this value in the picture. This component was determined by the rate of picture repetition per second. As the speed of the scanning is increased the lowest required frequency will also be increased, but at present, with 15 frames per second, the amplifier should go down at least to 10 cycles per second. This is more important than that the amplification should hold up well at 20,000 cycles per second.

The so-called line in a television picture is not a line at all. It is a band of a certain width, which is determined by the size of the picture from top to bottom and the number of "lines" in the picture. Suppose the picture is four inches from top to bottom and that it is transmitted on a 60-line basis. Then the width of each "line" or band is 4/60 of an inch wide. The length of each line, from left to right, is equal to the width of the picture. This is not necessarily the same as the vertical dimension of the picture. Indeed, standard practice is to make the width of the picture longer than the vertical distance in the ratio of 72 to 60. Therefore, if the picture is 4 inches from top to bottom it is 4.66 inches from left to right.

Production of Lines

The lines are produced in many different ways. In one method a flying spot of intense light scans the object to be transmitted. In this case only a tiny portion of the object is illuminated at a time. This statement is to be taken only in the relative sense, for the entire object may be so well illuminated that it is clearly seen, but the flyng spot is so much more intense than the flood light that as far as the photo-electric cell is concerned everything is dark except the spot. This spot flies over the object in the order stated above, from left to right and from top to bottom, just as the eye moves in reading a book.

In the other method of scanning, the object is illuminated uniformly and this is scanned in the same manner, or a reduced image of the object is scanned. In this case the photo-electric cell "sees" only one spot at a time, as before, but it sees it because everything else is screen from the cell. The spot exposed moves in the manner stated.

The cross section of the beam of light between the scanner and the object is not the same in all instances. The ideal cross section would be a rectangle, longer in the vertical direction than in the direction of motion, and the vertical distance just equal to the width of a scanning band. It is not easy to obtain this ideal shape. Frequently the cross section is square, but it is more often round. The shape of the cross section is not really important in this stage of the art. It has been asserted that the best shape is that of an arrow, with the point forward. At this time about the same results are obtained with all shapes of cross section of the light beam.

Overlap

In all cases it is attempted to scan so that there will be no streaks across the picture. If the spacing of the lines is not accurate there will be streaks, and they are often attributed to dirt on the scanning disc. Inaccurate spacing is more frequently the cause than dirt. Streaks would also result if the width of the scanning beam were wider than the true spacing determined by the size of the picture and the number of lines. However, if the cross section of the beam is circular, arrow-like, or diamond shaped, there should be some overlap if streaks are to be avoided.

NING

Anderson

If the cross section of the beam is circular the distance between the centers of adjacent bands and the radius of the beam should be connected by the relation D=2rsin60°, or D=1.732r, in which D is the distance between lines, or the width of the band, and r is the radius of the cross section of the beam, if the streakiness is to be least.

If the cross section of the scanning beam is square, and if it moves with one corner forward in the middle of the band, then the distance D between centers of adjacent bands and the sides *a* of the square should be related by the equation D=0.707*a* for least streakiness. In both of these cases the assumption is that the bands are accurately spaced.

Blurring and Size of Spot

The larger the spot or the cross section of the scanning beam, the more blurring of the picture there will be. One dimension is determined by the number of lines and the vertical size of the picture. After the line basis has been fixed the vertical dimension of the scanning beam has also been decided. But we are at liberty to choose the dimension in the direction of motion. The smaller this dimension the finer the detail will be. It was for this reason that we stated above that the ideal cross section of the scanning beam should be a rectangle shorter in the direction of motion than in the vertical direction. In this respect the ideal rectangle is a line having no dimension in the line of motion and a length equal to the spacing of the lines. Such a scanning beam would be capable of the greatest possible detail for a fixed distance between the lines. However, an aperture of this shape would not admit any light so that this ideal scanner is not possible. The nearest we can come to it is to make cross section rectangular with a finite width in the direction of motion.

The same problem arises in recording sound on film and reproducing from such a film. The scanning line here is made about one-eighth inch long and 0.001 inch in the direction of motion. Even with a slit so narrow it is not possible to bring out all the detail, that is, the high frequency sounds. It was not practical to make the slit any narrower, for optical as well as for sensitivity reasons, and therefore it was necessary to speed up the film.

Blurring in the sound film results in poor reproduction of the high frequencies. Blurring in a television picture results in actual blurring of the picture, but it is partly due to the elimination of the high frequencies.

Explanation of Blurring

The cause of blurring is evident when we consider the mechanism of scanning. The scanning beam covers a definite area. Within this area the picture is not homogeneous, but different portions of it may have different values of light and shade. The photoelectric cell responds only to the mean value. That is, it blots out all detail within this area. This mean value of the picture varies continuously as the scanning spot moves across the picture and the result is a reproduction of the picture strip. Due to the fact that scanning spot moves continuously, less blurring is caused by the finite dimension of the spot in the direction of motion than is caused by the finite length of the spot in the vertical direction. Improvement must come by making the number of lines per picture larger, and hence the vertical dimension of the scanning spot smaller.

The shape of the cross section of the scanning beam is determined by the shape of the holes in the scanning disc. Circular holes will give circular cross section and rectangular holes will give rectangular cross section and so forth. The number of lines in the picture is determined by the number of holes in the spiral on the scanning disc. The vertical dimension of the picture is determined by the pitch of the spiral, or by the distance between the first and the last holes in the spiral. The length of a scanning line, or the horizontal width of the picture, is determined by the angular separation between adjacent holes on the disc.

Avoiding Curvature of Lines

When a scanning disc is used no line is rectilinear but rather the arc of a circle. There is no objection to this curvature provided that it is exactly the same for both the transmitting and the receiving discs. If dissimilar discs are used the received picture will be distorted. This is true even if the same number of holes is used in both. Of course, if not the same number is used in both no reception is possible.

In order to avoid curvature discs are made comparatively large.

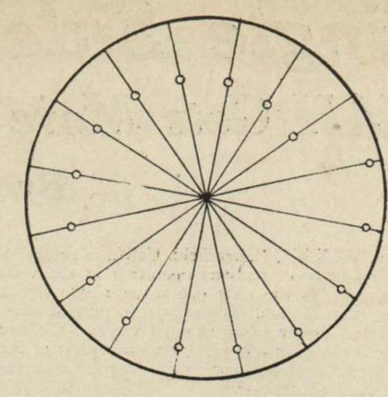

FIG. 2

This illustrates a 16-hole disc of one spiral. Separation between adjacent radii is 22.5 degrees. In this case D should equal 0.01775r.

That is, the total picture area is a very small part of the total area of the disc.

There is another distorting effect when circular discs are used. The outside, or first, hole in the scanner will trace a line with less curvature than the holes nearer the center of the disc. If both discs are the same, proportionally, this does not matter as far as the reproduction of the picture is concerned.

Dimensions of Disc and Pitch of Spiral

Suppose we wish to construct a disc with circular holes with the least streakiness, with a total of N holes in a single spiral, and a dimension ratio of 72 to 60. What should be the pitch of the spiral and the size of the holes? Since all the lines will not be of equal length, for the same angle, we shall consider the middle line as being 72 units. Lines nearer the periphery will be longer and those nearer the center will be shorter.

Since there are 360 degrees in the circle, the angular separation between any two adjacent holes will be 360/N degrees. Let the outside, or first, line be R units from the center. Then the length of the arc will be $2\pi R/N$ units long. The distance from the center to the inside line will be (N—1) D less than R, where D is the distance between two adjacent lines in the same units as R. Therefore the inside arc will be $2\pi[R-(N-1)D]/N$. Taking the mean between the inside and the outside arcs we get $[2R-D(N-1)]\pi/N$. This number should be to 72 as ND is to 60. If we set this proportion down as an equation and solve for D, we obtain the width of the line in terms of the outside radius and the number of lines. We get $D=10R\pi/[6N^2+5\pi(N-1)]$.

To construct the disc we first divide the circle into 360/N equal angles. Then we place the first hole R units from the center on one of the radii. The next hole we place on the next radius a distance D nearer the center, the third on the third radius 2D units nearer the center, and so on.

Numerical Example

Suppose we wish to construct a 60-hole disc. Then N=60 and 360/N becomes 6 degrees. Therefore we draw 60 equi-spaced radii 6 degrees apart on the circles. We place the first hole at R from the center on one of them. If we substitute the value of N=60 in the equation for D and simplify, we have D=R/717. We cannot proceed without knowing the actual value of R. Suppose it is 18 inches, that is, the disc is to be three feet in diameter, measuring only to the outside hole. Then in this case D equals 0.0251 inches. The size of the picture will be 1.81 inches wide and 1.501 inches deep.

Previously we gave the relationship that should exist for least streakiness in the case of circular holes. The relation was D=1.732r, in which r is the radius of the hole. Therefore the radius should be 0.577D. We just found D for a 3-foot disc to be 0.0251 inches, and therefore the radius of the hole should be 0.01448 inch, or the diameter should be 0.029 inch. This should be the diameter of the drill or punch used in making the holes. This is less than 1/32 of an inch.

In the derivation of the formulas above we used the arc as the width of the picture rather than the actual distance. The arc is slightly longer than the chord, but the difference is so small that it can be neglected. Smaller or larger discs can be made in proportion.

The diameter d of the circular holes in the disc can be found directly in terms of N and R by the formula $d=6.05R/(N^2+2.62N-2.62)$. Suppose the value of N is 100 and the radius of the disc is 18 inches, the d=0.0106 inch. In this case there would be 100 radii, 100 holes, and the radii would be spaced 3.6 degrees.